# DRAFT ROCKFISH RECOVERY PLAN

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

Prepared by
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Cover photographs:  Larval rockfish prior to hatching, 63 days, by Mark Tagal.



AR020314

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AR020315

# TABLE OF CONTENTS





AR020316

AR020317

AR020318

# List of Figures





AR020319

## List of Tables





AR020320

## Abbreviations and Acronyms

| | |
|---|---|
| Committee on the Status of Endangered Wildlife in Canada | COSEWIC |
| Department of Defense | DOD |
| Department of Natural Resources, WA | DNR |
| Department of Ecology, WA | Ecology |
| Fisheries and Oceans Canada | DFO |
| Distinct Population Segments | DPS |
| Environmental Protection Agency, US | EPA |
| Environmental Species Act | ESA |
| Fractional lifetime egg production | FLEP |
| Fisheries Conservation Plan | FCP |
| Incidental Take Permit | ITP |
| National Oceanic and Atmospheric Administration | NOAA |
| Northwest Fisheries Science Center | NWFSC |
| Northwest Indian Fisheries Commission | NWIFC |
| Northwest Straits Foundation | NWF |
| Northwest Straits Initiative | NWSI |
| National Marine Fisheries Service | NMFS |
| Marine Resource Committees | MRCs |
| Multibeam Echosounder | MBES |
| Ocean Acidification | OA |
| Polybrominated diphenyl ethers | PBDEs |
| Polychlorinated biphenyls | PCBs |
| Remotely Operated Vehicle | ROV |
| Rockfish Conservation Area | RCA |
| Species at Risk Act (Canada) | SARA |
| Spawning Potential Ratio | SPR |
| United States Fish and Wildlife Service | USFWS |
| Washington Department of Fish and Wildlife | WDFW |
| Young-of-the-Year | YOY |



AR020321

# EXECUTIVE SUMMARY

**Overview—Recovering Listed Rockfish:** Total rockfish abundance in Puget Sound has declined approximately 70 percent in the last 40 years. Yelloweye rockfish (*Sebastes ruberrimus*) and bocaccio (*Sebastes paucispinis*) have declined to an even greater extent (Drake et al. 2010).

This recovery plan outlines actions and research for the conservation and survival of threatened yelloweye rockfish and endangered bocaccio using the best available science per the requirements of the Endangered Species Act (ESA). The recovery plan links management actions to an active research program to fill data gaps and a monitoring program to assess these actions' effectiveness. Research and monitoring results will provide information to refine ongoing actions and prioritize new actions to achieve the plan's goal: to restore the listed species to the point where they no longer require the protections of the ESA.

**Current Species Status:** Yelloweye rockfish and bocaccio occupy the waters of the Pacific coast from California to Alaska. Yelloweye rockfish and bocaccio in the waters of the Puget Sound/Georgia Basin were each determined to be a Distinct Population Segment (DPS) (75 Fed. Reg. 22276). The Puget Sound/Georgia Basin DPS of yelloweye rockfish was listed as "threatened" and bocaccio was listed as "endangered" under the ESA on April 28, 2010 (75 Fed. Reg. 22276). The DPSs include all yelloweye rockfish and bocaccio (listed rockfish) found in waters of Puget Sound, the Strait of Georgia, and the Strait of Juan de Fuca east of Victoria Sill. Critical habitat was designated for all species of listed rockfish in 2014 under section 4(a)(3)(A) of the ESA (79 Fed. Reg. 68041; November 13, 2014). Recent research has found evidence for two populations of yelloweye rockfish within the DPS—one in Hood Canal and one within the rest of the Puget Sound/Georgia Basin.

There is no single reliable historic or contemporary population estimate for yelloweye rockfish or bocaccio within the Puget Sound/Georgia Basin DPS (Drake et al. 2010). Despite this limitation, there is clear evidence that each species' abundance has declined dramatically (Drake et al. 2010). The total rockfish population in the Puget Sound region is estimated to have declined approximately 3 percent per year for the past several decades, corresponding to an approximate 70 percent decline from 1965 to 2007 (Drake et al. 2010). The decline of the yelloweye rockfish and bocaccio is estimated to be greater than the 70 percent observed in the total rockfish during that time period (Drake et al. 2010).

Regulatory measures have been taken by the State of Washington to protect all rockfish over the last several years, including a commercial ban on rockfish fishing in the late 1980s and early 1990s, more recent closures of commercial fisheries with rockfish bycatch (Palsson et al. 2009; WDFW 2010b), a moratorium initiated in 2010 on recreational rockfish catch, and a 120-foot (36.6-m) depth limit while bottom fishing (WDFW 2014). Despite these measures, listed rockfish continue to be at risk from bycatch in some of the areas of the DPSs.

Though historical overfishing has been recognized as the primary cause of the decline of rockfishes in Puget Sound (Palsson et al. 2009; Drake et al. 2010; Williams et al. 2010), there is some uncertainty about the relative impact of some fisheries today, and of the additional remaining threats, which include degraded water quality and habitat, contaminants, derelict fishing gear, and other threats (Palsson et al. 2009; Drake et al. 2010; WDFW 2013).



AR020322

Long lives, slow growth, and late maturity combined with low survival rates of young make it likely that recovery of listed rockfish will take decades, even if all threats are effectively reduced or eliminated.

**Recovery Objectives:** 1) Continue to improve our knowledge of the current and historical population status of yelloweye rockfish and bocaccio and their habitats. This is necessary so that these populations can be characterized on a management unit basis and a detailed program can be developed for implementing recovery actions to most efficiently achieve the delisting criteria. 2) Reduce or eliminate existing threats to listed rockfish from fisheries/anthropogenic mortality. 3) Reduce or eliminate existing threats to listed rockfish habitats and restore important rockfish habitat.

**Recovery Strategy and Program:** The plan is comprehensive to address all of the threats drawing on existing information to prioritize actions. The plan uses an adaptive management approach for conducting the research required to manage and recover listed rockfish and inform implementation of actions to ensure each of the potential threats does not unduly limit recovery.

The plan identifies research to better understand potential impacts from fisheries and other threats, as well as the efficacy of regulations put into place to minimize the effects of threats. The plan calls for research where more information is needed and for action where sufficient information exists to move forward. For example, the plan includes evaluation of fishery regulations and further assessment of the impact of some fisheries, but also suggests beginning the public and scientific process to establish marine reserves or rockfish conservation areas in the San Juan Islands/eastern Strait of Juan de Fuca area in the near term, and considering additional protections after further assessment in other areas over the long term. In these areas we have assessed that high rockfish bycatch remains despite regulations put into place in 2010 or before to limit bycatch. The plan recommends the use of marine reserves or rockfish conservation areas to contribute to the restoration of rockfish population abundance and size and age diversity because their use for rockfish conservation is well-supported in the research. We do not suggest specific sites for these conservation areas, but include biological and sociological parameters to consider during any process to establish them, as well as tribal treaty rights considerations.

The recovery program laid out in the plan includes approximately 45 actions to address the following topics:

- Actions to enable a greater understanding of listed rockfish population abundance and demographics, and habitat associations.
  - Example action: fishery-independent population and spatial surveys (such as Remotely Operated Vehicle (ROV) surveys) in the nearshore and deepwater environments.
- Fisheries management consistent with recovery goals.
  - Example action: establish marine reserves or rockfish conservation areas (areas not subject to potential anthropogenic mortality) where prioritized.
- Protection and restoration of rockfish habitats and the Puget Sound/Georgia Basin ecosystem.
  - Example action: nearshore protection/restoration, with an emphasis on native kelp.
- Development of an education, outreach, and public involvement plan.
  - Example action: improve rockfish species identification by fishermen and documentation of bycatch.



AR020323

- Securing public support for listed rockfish recovery.
  - Example action: work with partners to seek a variety of types of funds to support recovery over a long time frame.

**Recovery Criteria:** To develop objective and measurable biological criteria we used abundance and productivity, spatial structure/connectivity, and diversity concepts outlined in McElhaney et al. (2000). They reflect well-founded conservation biology concepts applicable to a wide variety of species. Fraction of unexploited biomass and fractional lifetime egg production (FLEP) are measurements of proportional change in biomass/egg production for one population between two time periods (O'Farrell and Botsford 2005; Pacific Fishery Management Council 2014). FLEP can be estimated by fish length measurements, quantified by fishery-dependent and fishery-independent survey methods (e.g., ROV surveys) and through documentation of bycatch. FLEP is a proxy for spawning potential ratio (SPR), or the fished state relative to unfished state, and can be determined by comparing recent size distributions to those from the past or from comparing rockfish populations inside and outside of established marine protected areas (MPAs) (Babcock and MacCall 2011). One way to determine the biomass/FLEP would be through non-lethal ROV surveys or other similar methodologies.

We identify three different levels of biomass in association with spatial structure and diversity characteristics that, if any are reached, would likely provide sufficient population biomass and fecundity for down-listing/delisting each species (Tables ES1 to ES4). We also identified threats-based criteria for known threats; examples of these criteria are also shown in Table ES5 below. The downlisting criteria for bocaccio generally require completed research and/or that programs are in place to understand, limit, and mitigate threats, while delisting criteria for both yelloweye rockfish and bocaccio requires that the threats are found to not limit recovery of the listed species.

Table ES1. Yelloweye Rockfish Biological-based Delisting Criteria (non-Hood Canal Population).

| | **Criteria 1: Minimum Biomass/Fraction of Unexploited Biomass** | **Minimum Time at Target** | **Criteria 2: Minimum Spatial Distribution and Size Structure** |
|---|---|---|---|
| Scenario A | 15% (and increasing after first sampling event finds 15%) | 20 years, which is approximately 1/2 of one generation time (no less than four systematic sampling events with 80% probability) | Size class frequency includes multiple size classes of fish documented in identified index survey sites. General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm. |
| Scenario B | 20 to 24% | 10 years (no less than three systematic sampling events with 80% probability) | |
| Scenario C | 25% (and above) | 5 years (no less than two systematic sampling events with 80% probability) | |



AR020324

Table ES2. Yelloweye Rockfish Biological-based Delisting Criteria (Hood Canal Population).

<table>
<tr><th></th><th>Criteria 1:<br>Minimum Biomass/Fraction of Unexploited Biomass</th><th>Minimum Time at Target</th><th>Criteria 2:<br>Minimum Spatial Distribution and Size Structure</th></tr>
<tr><td>Scenario A</td><td>20 to 24%</td><td>10 years (no less than three systematic sampling events with 80% probability)</td><td rowspan="2">Size class frequency includes multiple size classes of fish documented in identified index survey sites. General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm.</td></tr>
<tr><td>Scenario B</td><td>25% (and above)</td><td>5 years (no less than two systematic sampling events with 80% probability)</td></tr>
</table>

Table ES3. Bocaccio Biological-based Downlisting Criteria.

| **Criteria 1: Minimum Biomass/Fraction of Unexploited Biomass** | **Minimum Time at Target** | **Criteria 2: Minimum Spatial Structure and Size and Age Distribution (Diversity)** |
|---|---|---|
| 10% and increasing | 10 years, which is nearly one generation time (no less than three systematic sampling events with 80% probability) | Size class frequency includes multiple size classes of fish documented in identified index survey sites in 4 of 5 management units (one must be Hood Canal or Main Basin). General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm |

Table ES4. Bocaccio Biological-based Delisting Criteria.

| | **Criteria 1: Minimum FLEP Status or Biomass/Fraction of Unexploited Biomass** | **Minimum Time at Target** | **Criteria 2: Spatial Structure and Size and Age Distribution (Diversity)** |
|---|---|---|---|
| Scenario A | 15% (and increasing after first sampling event finds 15%) | 10 years, which is nearly one generation time (no less than three systematic sampling events with 80% probability) | Size class frequency includes multiple size classes of fish in 4 of 5 management units (one must be Hood Canal or Main Basin). General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm. |
| Scenario B | 20% and above | 5 years (no less than two systematic sampling events with 80% probability) | Size class frequency includes multiple size classes of fish in 3 of 5 management units (one must be Hood Canal or Main Basin). General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm. |
| Scenario C | 25% and above | 5 years (no less than two systematic sampling events with 80% probability) | Size class frequency includes multiple size classes of fish in 2 of 5 management units (one must be Hood Canal or Main Basin). General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm. |



AR020325

Table ES5. *Example* Threats-Based Delisting Criteria for Yelloweye Rockfish

| **Listing Factor 1: Destruction, Modification, or Curtailment of Habitat or Range** | |
|---|---|
| Derelict fishing gear | Programs are in place to facilitate and require reporting, preventing, and promptly removing derelict fishing gear (i.e., shrimp pots, fishing nets) that has been demonstrated to result in bycatch or result in harm to yelloweye and yelloweye rockfish habitat. |
| Contaminants/ Bioaccumulants | Contaminant levels in yelloweye rockfish, prey species, or surrogate rockfish populations (i.e., quillback rockfish, *Sebastes maliger*) in the Puget Sound/Georgia Basin indicate a reduction or slowing of accumulation of legacy contaminants, such as PCBs and DDTs. This could include data showing that overall contaminant levels in the population are decreasing or accumulation is slowing, or information that younger fish have a proportionally reduced contaminant load. A decrease in the number of contaminated sites would also indicate a reduction in contaminants in a portion of the habitat of yelloweye rockfish. |
| Nutrients | Management actions and programs are in place to prevent and reduce nutrient inputs. The effects of nutrient inputs (food chain, hypoxia) are found to be not limiting recovery. |
| Invasive species/ Non-native species | Invasive species that can affect habitat (e.g., tunicates, seaweeds, others) are found to be not limiting recovery. Programs are in place to remove or mitigate the effects of invasive species on yelloweye and yelloweye rockfish habitat. |

Table ES5. *Example* Threats-Based Downlisting and Delisting Criteria for Bocaccio.

| **Listing Factor 2: Over-utilization for Commercial, Recreational, Scientific, or Educational Purposes** | | |
|---|---|---|
| | **Downlisting Criteria** | **Delisting Criteria** |
| Bycatch/Catch | Bocaccio are protected from bycatch/catch by fishery regulations and research permitting sufficient to support maintenance and enhancement of abundance, LEP/biomass, spatial structure, and diversity (bycatch/catch can be reliably estimated from empirical data sources). | Bocaccio are protected from bycatch/catch by fishery regulations and research permitting sufficient to support maintenance and enhancement of abundance, LEP/biomass, spatial structure, and diversity (bycatch/catch can be reliably estimated from empirical data sources). Bycatch is mitigated when it occurs (i.e., use of descending devices and safe handling techniques). |

**Coordination, Estimated Date, and Recovery Cost:** Recovery of listed rockfish is a long-term effort that requires cooperation and coordination from organizations and communities around Puget Sound. Many actions that will benefit listed rockfish and their habitats are already underway and involve such cooperation. The plan was developed with involvement and input from a variety of co-managers and stakeholders, including Federal and state agencies, some treaty tribes, and individuals from non-profit groups, and the fishing and academic communities.

At present, it is difficult to project a date for recovery. As we obtain information on present abundance, as well as information to assess the impact on how threats may limit recovery and how the threats can be effectively mitigated, more robust time and expense projections will be developed.

The cost of the approximately 45 actions recommended in this plan for the first 5 years of recovery is about $23,360,000. Assuming that recovery takes one and a half generations (of yelloweye rockfish) or approximately 60 years, the total recovery costs over 60 years would be approximately $82,970,000. The cost of recovery is estimated to decrease substantially after the first 5 to 10 years if the necessary baseline research and management actions are performed. There are numerous parallel efforts underway, independent from listed rockfish recovery, to protect and restore the Puget Sound ecosystem. Examples of such efforts include oil spill prevention measures, contaminated sediment clean-up projects, and



AR020326

restoration of nearshore environments. These efforts will provide benefits to listed rockfish and their habitats and prey base and are thus highlighted in the plan. However, the costs of these actions are not included in the total cost of rockfish recovery because they would occur independent of this plan. Similarly, actions conducted to restore listed rockfish and their habitats will benefit other listed species that utilize the Puget Sound area, such as Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*), and may provide economic benefits. We are unable to quantify the economic benefits of listed rockfish recovery actions, but the benefits to the ecosystem and economy could completely or partially offset the total recovery costs estimated here.



AR020327

# I. BACKGROUND

## A. PURPOSE OF THE RECOVERY PLAN

The Endangered Species Act of 1973 (ESA) requires NOAA's National Marine Fisheries Service (NMFS) to develop recovery plans for marine species listed under the ESA. The purpose of recovery plans is to guide implementation of recovery of the species. Plans address threats to ensure the species are once again self-sustaining components of their ecosystem and no longer require the protections of the ESA.

This recovery plan (plan) is for yelloweye rockfish (*Sebastes ruberrimus*) and bocaccio (*Sebastes paucispinis*) distinct population segments (DPSs) of the Puget Sound/Georgia Basin, hereafter referred to as "listed rockfish." The range of these DPSs includes all the waters of Puget Sound south of the North Strait of Georgia, and the Strait of Juan de Fuca east of Victoria Sill (Figure 1).

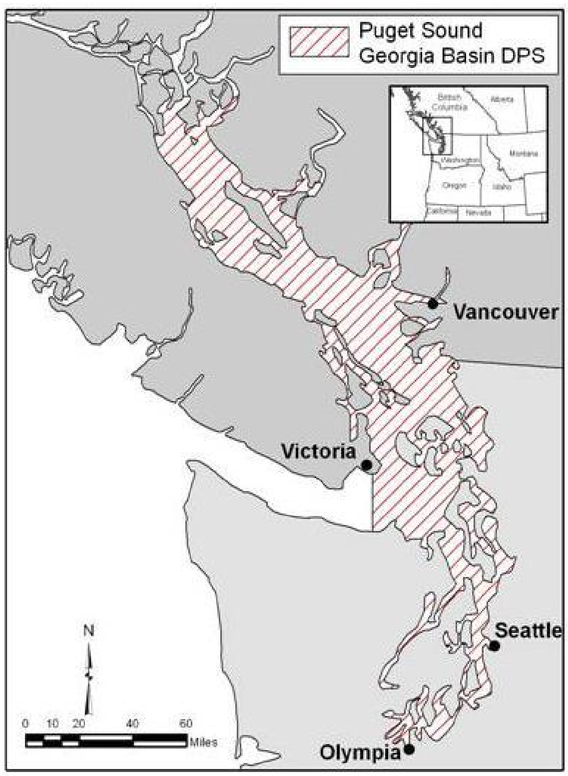


Figure 1. Puget Sound/Georgia Basin.

This recovery plan provides a roadmap for restoring the DPSs of listed rockfish and their habitat to levels that support recovery and allows the species to become viable components of their ecosystems.

Although recovery plans are not regulatory and their implementation is voluntary, they are important tools that help: 1) provide context for regulatory decisions; 2) provide criteria for status reporting and



AR020328

delisting decisions; 3) organize, prioritize, and sequence recovery actions; and 4) organize research, monitoring, adaptation, and evaluation efforts.

NMFS will encourage Federal agencies and non-Federal jurisdictions to take recovery plans under serious consideration as they make the following kinds of decisions and allocate their resources: 1) actions carried out to meet section 7(a)(1) obligations to use their programs in furtherance of the purposes of the ESA and to carry out programs for the conservation of threatened and endangered species; 2) actions that are subject to ESA sections 4(d), 7(a)(2), or 10; 3) revisions of land use and resource management plans; and 4) other natural resource decisions at the state, tribal, and local levels.

### Multispecies Planning Considerations

An analysis of recovery plans indicated that multispecies and ecosystem recovery plans were less likely to result in improving status trends than single species plans (Boersma et al. 2001). This may be for a variety of reasons, such as insufficient funding for multiple species versus single species (Boersma et al. 2001); thus, in cases where the status or recovery needs of rockfish differ, they will be discussed separately in the recovery plan. We use a multispecies plan not only because of taxonomic and geographic similarities between the species but also because they face similar threats and research gaps that need to be addressed for recovery. Funding initiatives will also stress the needs of the two species, as well as the efficiencies gained by combined pursuit of research and recovery actions. Progress toward the individual species' recovery and threat abatement will be monitored (Clark and Wallace 2002) through recovery actions outlined in this document.

### Appendices to Support Implementation

We have developed appendices to assist in recovery implementation for listed rockfish. The appendices provide detailed information regarding a variety of research and recovery actions outlined in this plan, including: 1) education, outreach, and public involvement; 2) fisheries management; 3) barotrauma research and adaptive management; 4) benthic habitat conservation; 5) nearshore habitat and kelp conservation; 6) sediment and water quality; 7) climate change and ocean acidification; and 8) funding opportunities for rockfish conservation.

## B. LEGAL STATUS OF THE SPECIES

Based on information related to rockfish life history, and the environmental and ecological features of Puget Sound and the Georgia Basin, we identified Puget Sound/Georgia Basin DPSs for yelloweye rockfish and bocaccio (Drake et al. 2010). On April 28, 2010, we listed the Puget Sound/Georgia Basin DPSs of yelloweye rockfish and canary rockfish as threatened under the ESA, and bocaccio as endangered (75 Fed. Reg. 22276). We based the decision to list the yelloweye rockfish and canary rockfish DPSs as threatened and the bocaccio DPS as endangered on an evaluation of their status using the best available science and an evaluation of the listing factors that include: 1) present or threatened destruction, modification, or curtailment of habitat or range; 2) over-utilization for commercial, recreational, scientific, or educational purposes; 3) disease and predation; 4) inadequacy of existing



AR020329

regulatory mechanisms; and 5) other natural or human-made factors affecting continued existence. Critical habitat was designated for all three species of rockfish in 2014 under section 4(a)(3)(A) of the ESA (79 Fed. Reg. 68041, November 13, 2014). In 2014 we initiated a cooperative research project to investigate listed rockfish genetics (see sidebar). As a result of the project and subsequent analysis, on July 6, 2016 (81 FR 43979) we proposed to remove canary rockfish from the List of Threatened and Endangered Species under ESA because they were found to not be discrete from coastal populations and no longer met the criteria to be considered a DPS[1]. Hence, this recovery plan only addresses yelloweye rockfish and bocaccio DPSs.

We identified several extinction risk factors common to each DPS (Drake et al. 2010):

- Declining trends in abundance within each DPS contribute significantly to extinction risk.
- Each species has an inherently low growth rate and low productivity and these characteristics are likely exacerbated by the relative paucity of larger, older fish. There is evidence of size truncation for each species, which shifts reproductive output to younger and less productive females.
- These characteristics increase the extinction risk for each species when combined with continued primary threats from fisheries (bycatch), loss of nearshore habitat, chemical contamination, climate change, and areas of low dissolved oxygen. Specifically, some commercial and recreational fisheries can cause direct mortality to rockfish and modify habitats and remove prey species; nearshore habitat degradation and loss can harm rearing habitats used by juveniles for predation refuge and feeding; chemical contamination can harm listed rockfish through accumulation in their food sources or direct exposure to the contaminant; and areas of low dissolved oxygen can alter listed rockfish behavior and habitat use, as well as cause direct mortality to rockfish and their prey.

**ADAPTIVE MANAGEMENT AT WORK**

Since the 2010 listing, NOAA Fisheries and numerous partners have pursued research to enable further understanding of listed rockfish population levels, habitat use, genetics, threats to the species, and other information important to recovery. The genetics project highlights the success of this continual cooperation.

Through a partnership initiated by the Northwest Fisheries Science Center, NOAA Fisheries partnered with recreational fishing guides, anglers, and WDFW to gather biological samples of listed rockfish and conduct a genetics analysis. Most notably, the research showed canary rockfish in the Puget Sound/Georgia Basin are not discrete from canary rockfish of the Pacific Coast. As a result, we proposed to remove canary rockfish from the endangered species list.

Further discussion of genetics and other research is in Section F. Complete genetics results are in our 5-Year Review found on our webpage.

This plan is designed to continue research that will answer important questions about listed rockfish and adapt management to incorporate new findings.

[1] The complete genetics analysis and full report can be found in our 5-Year Review found on our webpage: http://www.westcoast.fisheries.noaa.gov/publications/protected_species/other/rockfish/5.5.2016_5yr_review_report_rockfish.pdf.



AR020330

Based on an evaluation of abundance trends, spatial structure, and diversity as well as the threats listed above, we determined that the Puget Sound/Georgia Basin DPS of bocaccio is at high risk of extinction throughout all of its range and that the Puget Sound/Georgia Basin DPS of yelloweye rockfish is at moderate risk of extinction throughout all of its range (Drake et al. 2010). In 2016 we completed 5-year reviews of the listed species under the ESA and recommended that the status of yelloweye rockfish remain as threatened and that the status of bocaccio remain as endangered (NMFS 2016).

Washington State has listed 13 species of rockfish as “Species of Concern,” including yelloweye rockfish and bocaccio (WDFW 2012b). The Washington Department of Fish and Wildlife (WDFW) created a Plan for Rockfish Recovery in 2011 that included policies, strategies, and actions for all rockfish (WDFW 2011).

In Canada, the yelloweye rockfish population status in inside waters in British Columbia, which extends from east of Vancouver Island down to the U.S. border of Puget Sound, was designated as “special concern” by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2008 (COSEWIC 2008; DFO 2012). The coastal (outside) population of yelloweye rockfish status was also identified as “special concern.” The bocaccio population is recognized as one unit (DFO 2009), including coastal (outside) and inside waters. This population’s status was identified as threatened in 2002 (COSEWIC 2002); COSEWIC re-examined the bocaccio population and identified them as endangered in 2013 (COSEWIC 2013). Yelloweye rockfish inside and outside populations were also designated as “special concern” under the Canadian Species at Risk Act (SARA) in 2011. The bocaccio population is also being considered for listing under the Canadian SARA. Currently, these populations are managed through the Canadian Fisheries Act and Environmental Protection Act. If listed under SARA, they will be given additional protection and the development of a management plan will commence (COSEWIC 2008).

## C. RECOVERY PLANNING COORDINATION

This recovery plan was developed with the involvement and input from various participants. The Rockfish Recovery Team was the primary author of the plan, and other individuals provided invaluable input, review, and feedback. Some of the primary coordinating partnerships are outlined below.

### Rockfish Recovery Team

A review of recovery plans found that plans written by a team comprising non-Federal participants as well as Federal employees were more likely to result in improving status trends of endangered species (Boersma et al. 2001). Therefore, it was determined that members of the academic and fisheries science and management community would be invited to be on the recovery team in addition to Federal employees. The team is composed of experts with backgrounds in genetics, marine ecology, fisheries biology, stock assessment, fisheries management, and other technical knowledge and local expertise needed for recovery planning.



AR020331

**Puget Sound Treaty Tribes and Tribal Trust and Treaty Responsibilities**

In early 2013, NMFS sent a letter to each Puget Sound Treaty Tribe and the Northwest Indian Fisheries Commission (NWIFC) informing them of the recovery planning process. As a result of these letters, NMFS and several treaty tribes had several meetings during summer of 2013 and fall of 2014 to discuss the draft plan. The NWIFC also designated representatives to participate on the Rockfish Recovery Team and the NWIFC and treaty tribes were invited to provide feedback on an early draft recovery plan in 2015.

Puget Sound treaty Indian tribes retain strong spiritual and cultural ties to marine life, based on thousands of years of use for tribal religious/cultural ceremonies, subsistence, and commerce. Many Northwest Indian tribes have treaties reserving their right to fish in usual and accustomed fishing places including areas covered by this recovery plan. These treaty tribes are co-managers of fisheries with the State of Washington. The NMFS Regional Administrator, in testimony before the U.S. Senate Indian Affairs Committee (June 2003), emphasized the importance of this co-manager relationship: "We have repeatedly stressed to the region's leaders, tribal and non-tribal, the importance of our co-management and trust relationship to the tribes."

**Rockfish Workgroup**

Collaboration with and outreach to stakeholders was initiated by NMFS soon after the rockfish ESA listing. It continued through various workgroups, speaking engagements, informal meetings, and phone calls, and by soliciting individual review and comments on draft documents throughout the recovery planning process. These stakeholders include Federal, tribal, and state partners; researchers and academics with rockfish expertise; conservation groups; and recreational angling groups. Specifics of this stakeholder involvement follow.

In June 2011, NMFS, the SeaDoc Society, and WDFW hosted a workshop titled "Rockfish Recovery in the Salish Sea; Research and Management Priorities." This workshop convened scientists, managers, and industry professionals to focus on recent and ongoing research and recovery efforts for rockfish and their habitats in the Salish Sea to enable further collaboration and recovery. The first day of the workshop included sessions detailing recent research on the historical context of rockfish depletion, benthic habitat surveys and abundance estimates, stressors, ecosystem and species interactions, juvenile recruitment, and genetics. The second day of the workshop focused on agency, tribal, and Canadian perspectives on rockfish recovery, and included concurrent sessions designed to list additional research priorities related to reserves and population biology. The proceedings of the workshop were published in Tonnes (2012) (http://www.westcoast.fisheries.noaa.gov/protected_species/rockfish/rockfish_in_puget_sound.html).

After the June 2011 workshop, a group of interested entities (thereafter termed the Rockfish Workgroup) continued to meet regularly and individual members shared rockfish research and discussed research priorities for rockfish conservation in the Salish Sea (the Salish Sea encompasses the Puget Sound/Georgia Basin, but also includes the Strait of Juan de Fuca to Neah Bay). This informal group also received updates on the recovery planning process. The Rockfish Workgroup has included attendees from the Seattle Aquarium, Point Defiance Aquarium, the SeaDoc Society, the Wild Fish Conservancy, the Sierra Club, Puget Sound Anglers, the Coastal Conservation Association, Natural Resource Consultants,



AR020332

the University of Washington, University of Alaska, the Northwest Fisheries Science Center, NMFS, WDFW, U.S. Geological Survey, the Puget Sound Partnership, the Northwest Straits Commission, and the Lummi Indian Nation.

**Canada**

Approximately half of the DPSs' geographic ranges are within Canadian waters. In 2001, the Department of Fisheries and Oceans (DFO) developed an inshore rockfish conservation plan (Yamanaka and Lacko 2001), which continues to be implemented today. In 2011, a retired DFO representative presented and provided a paper entitled "Rockfish Conservation: The British Columbia Experience" at the Salish Sea Rockfish Workshop. Prior to initiating recovery planning, we invited DFO representation on the Recovery Team, which was declined. We also invited representatives from DFO to review the early draft plan in 2015. Two individual rockfish experts from Canada conducted peer review on the plan itself.

**Recreational Fishermen**

In June 2011, NMFS partnered with the University of Washington to conduct a survey of recreational anglers in Puget Sound to inform rockfish recovery planning. The survey was conducted with approximately 500 recreational anglers at the 15 most commonly used boat launches in Puget Sound. The survey was designed to understand angler knowledge of rockfish life history and regulations, current fishing practices, perceptions of threats to rockfish, and preferences for rockfish recovery, as well as relationships between those variables and demographics of the anglers (Sawchuk 2012; Sawchuk et al. 2015). This research was used to inform the Education, Outreach, and Public Involvement Appendix (Appendix I).

Additionally, we have presented research on many occasions to recreational fishing groups. Finally, we have worked cooperatively on projects with fishing guides and fishers, many from the Puget Sound Anglers (PSA). See Section F Conservation Measures and Research.

**Washington Department of Fish and Wildlife**

NMFS and WDFW worked closely during the recovery planning process. Two members of the rockfish recovery team are members of the WDFW Marine Fish Science Unit and are actively involved in rockfish research and management. These members worked closely with NMFS, particularly on the areas of monitoring, research, cooperative research, and fisheries management. WDFW was also given an opportunity to provide feedback on an early draft recovery plan.

**Rockfish Experts**

Several rockfish experts from Alaska, Canada, California, and Washington peer reviewed the draft recovery plan, and their individual input was incorporated as appropriate.

**Public Input**

This draft recovery plan will be provided for public comment, and NMFS will respond to comments and incorporate information as appropriate. Additionally, as the draft plan is released, public meetings will be held to discuss the plan.



AR020333

# II. BIOLOGICAL BACKGROUND

## A. SPECIES DESCRIPTION AND TAXONOMY

Worldwide, there are over 100 species of rockfish (the *Sebastes* or *Sebastolobus)* (Love et al. 2002). Rockfishes make up a significant portion of the marine fish ecosystem within Puget Sound waters, composing at least 28 of an estimated 253 (~11 percent) fish species (Pietsch and Orr 2015). Thirteen species of rockfish are listed as species of concern by the State of Washington (WDFW 2012b).

Yelloweye rockfish (*Sebastes ruberrimus*) and bocaccio (*Sebastes paucispinis*) are members of the family Scorpaenidae and the genus *Sebastes*. Rockfishes are characterized by having spines on their head (at least as juveniles); stiff dorsal fins; spines with venom glands at the base of dorsal, anal and pectoral fins; internal fertilization of eggs; and birth of live larvae (Love at al. 2002).

## B. LIFE HISTORY/ECOLOGY

Rockfish are iteroparous (i.e., have multiple reproductive cycles during their lifetime) and are typically long-lived. Being long-lived allows the adult population to persist through many years of poor reproduction until a good recruitment year occurs (Leaman 1991). As adults, listed rockfish generally inhabit relatively deep waters with steep and complex bathymetry, though they may also occur over less complex habitat or in the water column in association with sheer walls. Their diets are diverse and include many species of marine invertebrates and fish. Successful recruitment occurs only sporadically and may be associated with broad scale environmental conditions (e.g., Tolimieri and Levin 2005). Below, we describe rockfish life history by larval, juvenile, and subadult/adult stages, which reflect distinct habitat use and food sources.

### *Larval Stage Life History, Habitat Use, and Ecosystem Requirements*

Larval rockfish have been documented to occur throughout the major basins of Puget Sound (Greene and Godersky 2012). Larval rockfish are often observed under free-floating algae, seagrass, and detached kelp (Shaffer et al. 1995; Love et al. 2002), and also occupy the full water column (Weis 2004). Larval marine fishes, including rockfishes, have high mortality rates. For instance, in a laboratory setting (without risk of predation), rockfish larvae experienced 70 percent mortality 7 to 12 days after birth (Canino and Francis 1989). Their small size, relative inability to store food within their gut, and slow swimming speeds likely contribute to this high mortality rate by making them vulnerable to predators and starvation. Poor larval survival in most years provides evidence that rockfish populations persist through what has been termed “the storage hypothesis” (Warner and Chesson 1985) where episodic high recruitment success is important in driving population size. Poor larval survival in most years is balanced by the long lives of reproductive adults; thus, when beneficial conditions occur there are new larval cohorts that benefit from them (Drake et al. 2010). Episodic recruitment rates also mean that high fecundity rates do not appear to mitigate risk of extinction or enable more rapid recovery from exploitation (Dulvy et al. 2003). We do not know the relative importance of these factors in the Puget Sound/Georgia Basin.



AR020334

Pelagic larval duration (PLD) is how long larvae may drift before settling to juvenile habitat or adult habitat, and it is an indication of the spatial scales of connectivity and sources for population replenishment. For shelf/slope species of fishes, such as the listed rockfish, PLD in the California Current is greater than 120 days (Shanks and Eckert 2005); for bocaccio PLD is 150 to 170 days (Shanks et al. 2003). Population genetic studies have shown that despite longer PLD, rockfish often exhibit population structure over regional scales (Siegle et al. 2013).

***Juvenile Stage Life History, Habitat Use, and Ecosystem Requirements***

Generally, juvenile rockfish move from the pelagic environment and associate with offshore and/or nearshore benthic environments when they reach about 1.2 to 3.6 inches (3 to 9 cm ) in length and approximately the age of 3 to 6 months (Love et al. 2002). As they grow, juveniles of each species gradually move to areas of high rugosity (roughness) and rocky habitat in deeper waters (Love et al. 1991; Johnson et al. 2003; Love et al. 2002). This movement to deeper water may be driven by environmental conditions that are less favorable for juveniles; over the fall and winter, temperatures decrease, turbulence increases, and submerged aquatic vegetation coverage decreases (Halderson and Richards 1987; Matthews 1989; Love et al. 1991; Carr 1991; Doty et al. 1995).

Areas with floating and submerged kelp (families *Chordeace, Alariaceae, Lessoniacea, Costariaceae,* and *Laminaricea*) support the highest densities of most juvenile rockfish species (Matthews 1989; Halderson and Richards 1987; Carr 1991; Carr and Syms 2006; Hayden-Spear 2006; Springer et al. 2010). Kelp is photosynthetic and requires high ambient light levels and a lack of fine sediment in the water column that can reduce light or that smother the gametophytes (Mumford 2007). There are 23 annual or perennial species of kelp in Puget Sound, two of which have a floating canopy and the rest non-floating stipitate or prostrate canopies (Mumford 2007). When solid substrates occur in lower intertidal and subtidal zones, kelp is often the dominant aquatic flora and forms dense canopies (Mumford 2007). Kelp are attached with a root-like structure, called a holdfast, to solid substrates such as bedrock, large rocks or pebbles, clam shells, or artificial substrates. Kelp grows in areas of high to moderate wave energy or currents to depths as great as 65 feet (20 m) (Mumford 2007; reviewed by Springer et al. 2010; Schiel and Foster 2015; Carr and Reed in press). Most kelp species form blades 3 to 6 feet (1 to 2 m) long, though the one floating variety within the range of the DPSs (*Nereocystis luetkeana*) grows to over 33 feet (10 m) long.

Juvenile yelloweye rockfish are not typically found in intertidal waters (Love et al. 1991; Studebaker et al. 2009). A few juveniles have been documented in shallow nearshore waters (Love et al. 2002; Palsson et al. 2009), but most settle in habitats along the shallow range of adult habitats in areas of complex bathymetry and rocky/boulder habitats and cloud sponges in waters greater than 98 feet (30 m) (Richards 1986; Love et al. 2002; Yamanaka et al. 2006). In British Columbia, juvenile yelloweye rockfish have been observed at a mean depth of 239 feet (73 m), with a minimum depth of 98 feet (30 m) (Yamanaka et al. 2006). Juvenile yelloweye rockfish occur in similar habitats as adults, though in areas with smaller crevices, including cloud sponge formations, crinoid aggregations on top of rocky ridges, and over cobble substrates (Weispfenning 2006; Yamanaka et al. 2006; Banks 2007).

Young-of-the-year juvenile boccacio occur on shallow rocky reefs and nearshore areas (Moser 1967; Anderson 1983; Kendall and Lenarz 1986; Carr 1991; Love et al. 1991; Love et al. 1996; Murphy et al.



AR020335

2000; Love et al. 2002). Young boccacio associate with macroalgae, especially kelps (Laminariales), and sandy areas that support seagrasses. They form aggregations near the bottom in association with drift algae and throughout the water column in association with canopy-forming kelps. It is likely that nearshore habitats used by juvenile bocaccio and other rockfish juveniles offer a beneficial mix of warmer temperatures, food, and refuge from predators (Love et al. 1991). Habitat formed by kelp provides structure for feeding, refuge from predators, and reduced currents that enable energy conservation for juvenile bocaccio.

Juvenile yelloweye rockfish and bocaccio have only been rarely documented in Puget Sound (Palsson et al. 2009). This may be due to a relative lack of studies in Puget Sound that assessed nearshore rockfish assemblages prior to the onset of fisheries removals of adult rockfish. Many small post-settlement rockfish are difficult to identify at the species level (Anderson 1983; Love et al. 2002). Love et al. (1991) describe three reasons that post-settlement habitat is essential for rockfish populations: 1) the successful recruitment of substrate-associated juveniles by larvae dispersed in the pelagic environment is crucial to the survival of local populations; 2) density-dependent regulation of populations may occur at the early juvenile stage, thus the quality and quantity of these habitats could strongly influence subadult and adult abundance (Johnson 2006a, 2006b, 2007); and 3) larval abundance can be a poor predictor of subsequent adult year-class strength, suggesting that post-settlement rearing habitat can strongly influence subsequent population viability.

***Adult Stage Life History, Habitat Use, and Ecosystem Requirements***

Adult yelloweye rockfish remain near the bottom and have relatively small home ranges, while some bocaccio have larger home ranges, move long distances, and spend time suspended in the water column (Demott 1983; Love et al. 2002; Friedwald 2009). Female yelloweye rockfish and bocaccio produce from 1 to 3 million larvae annually, depending upon age and body size. Rockfish are viviparous, meaning the eggs are fertilized internally, the embryonic fish develop within the mother, and the young are released as larvae (Love et al. 2002).

The timing of larval release for each species varies throughout their geographic range. In Puget Sound, there is some evidence that larvae are extruded in early spring to late summer for yelloweye rockfish (Washington et al. 1978) and in British Columbia it occurs between April and September with a peak in May and June (Yamanaka et al. 2006). Along the coast of Washington State, female bocaccio release larvae between January and April (Love et al. 2002).

There have not been historic or contemporary systematic surveys of rockfish populations in all of the basins of Puget Sound (Drake et al. 2010). Fisheries catch data can be used to assist in determining rockfish habitat (Yamanaka and Logan 2010), but the lack of systematic record keeping and unreliable species identification from commercial and recreational fishing in Puget Sound limits the utility of available fishery data (Palsson et al. 2009; Sawchuk 2012; Sawchuk et al. 2015). In addition, spatial information on rockfish fishing areas reflects both fisher behavior and underlying species distributions. Where most historic fisheries data do exist, the precise location of the catch is not documented (e.g., Bargmann 1977). The documented occurrences of yelloweye rockfish and bocaccio are from a wide range of years and with diverse sampling methods such as research trawls, drop cameras, SCUBA, ROVs, and



AR020336

commercial and recreational fishing (Table 1). Most of these documented occurrences are for subadult and adult life stages, with relatively few young-of-the-year fish documented.

Depth is generally the most important determinant in the distribution of many rockfish species of the Pacific Coast (Chen 1971; Williams and Ralston 2002; Anderson and Yoklavich 2007; Young et al. 2010). Adult yelloweye rockfish and bocaccio generally occupy habitats from approximately 90 to 1,394 feet (30 to 425 m) (Orr et al. 2000; Love et al. 2002).

Adult yelloweye rockfish and bocaccio most readily use habitats within and adjacent to areas that are highly rugose. These are benthic habitats with moderate to extreme steepness; complex bathymetry; and/or substrates consisting of fractured bedrock, rock, and boulder-cobble complexes (Yoklavich et al. 2000; Love et al. 2002; Wang 2005; Anderson and Yoklavich 2007) and glass sponges (cloud sponges are a type of glass sponge) (Marliave et al. 2009). Most of the benthic habitats in Puget Sound consist of unconsolidated materials such as mud, sand, clays, cobbles, and boulders (Burns 1985), and despite the relative lack of rock, some of these benthic habitats are moderately to highly rugose. More complex marine habitats are generally used by larger numbers of fish species relative to less complex areas (Anderson and Yoklavich 2007; Young et al. 2010; Pacunski et al. 2013), and thus support food sources for subadult and adult yelloweye rockfish and bocaccio. Biogenic structure (e.g., kelps) also provides refuge from predators and may provide shelter from currents, thus leading to energy conservation (Young et al. 2010).

Though areas near rocky habitats or other complex structure are most readily used by adults of each species, non-rocky benthic habitats are also occupied. In Puget Sound, adult yelloweye rockfish and bocaccio have been documented in areas with non-rocky substrates such as sand, mud, and other unconsolidated sediments (Haw and Buckley 1971; Washington 1977; Miller and Borton 1980; Reum 2006). Surveys from outside the range of the DPSs also have documented each species in relatively less complex habitats, though generally on a less frequent basis than more complex habitats. Yelloweye rockfish have also been documented in areas with mud and mud/cobble habitats in waters off the coasts of Washington (Wang 2005), California (Yoklavich et al. 2000), Oregon (Stein et al. 1992), and British Columbia, Canada (Richards 1986), and have been observed adjacent to large and isolated boulders in areas of flat and muddy bottoms in Alaskan waters (O'Connell and Carlile 1993). Bocaccio also occupy benthic areas with soft-bottomed habitats, particularly those adjacent to structure such as boulders and crevices (Yoklavich et al. 2000; Anderson and Yoklavich 2007). Bocaccio are also known to occupy the water column well off the bottom, making their documentation with traditional bottom sampling methods problematic.



AR020337

Table 1. Summary of listed rockfish habitat use.

| Species | Approximate Size Range | Habitat Associations (e.g., biogenic structure, substrate) | Depth Range |
|---|---|---|---|
| Larval yelloweye rockfish | <1.2 in (3cm) | Water column, free-floating algae, seagrass, detached kelp | Variable |
| Juvenile yelloweye rockfish | 1.2-3.6 in (3-9cm) | Rocky habitat / complex structure, cloud sponges | 98-293 ft (30-73m) |
| Subadult / adult yelloweye rockfish | >3.6 in (9cm+) | Rocky habitat / complex structure, occasionally other (sand, mud, etc.) | 90-1,394 ft (30-425m) |
| Larval bocaccio | <1.2 in (3cm) | Water column, free-floating algae, seagrass, detached kelp | Variable |
| Juvenile bocaccio | 1.2-3.6 in (3-9cm) | Water column, in association with drift algae, seagrasses, and canopy forming kelp | >6 ft (2m), variable |
| Subadult/adult bocaccio | >3.6 in (9cm+) | Water column, rocky habitat / complex structure, occasionally other (sand, mud, etc.) | Variable, 90-1,394 ft (30-425m) |

### *Age and Growth Rates*

Yelloweye rockfish and bocaccio are long-lived, mature slowly, and have sporadic episodes of successful reproduction (Drake et al. 2010). Yelloweye rockfish are one of the longest lived of the rockfishes, with some individuals reaching more than 100 years of age. Yelloweye rockfish reach 50 percent maturity at sizes of 16 to 20 inches (40 to 50 cm) and ages of 15 to 20 years (Rosenthal et al. 1982; Yamanaka and Kronlund 1997). The maximum age of bocaccio is unknown, but may range from 40 to 50 years. Bocaccio are estimated to reach 50 percent maturity at 14 to 20 inches (35 to 50 cm) and become reproductively mature near ages 4 to 6 years (Stanley et al. 2001; Love et al. 2002).

### *Reproduction, Recruitment, and Natural Mortality Rate*

Depending on the size and age of the fish, individual female yelloweye rockfish produce up to 2,700,000 larvae and bocaccio produce up to 2,298,000 larvae annually (Love et al. 2002). Larval rockfish have a low rate of survival in their first year of life and recruitment is erratic and poorly understood in the Puget Sound/Georgia Basin. Larvae of older female rockfish have significantly greater growth rates and starvation tolerance compared to larvae of younger females (Berkeley et al. 2004).

The mean natural mortality rate for rockfish varies by species and environmental conditions. The mean natural mortality rate is 3 percent per year for yelloweye rockfish and 8 percent per year for bocaccio (Table 2) (Gunderson and Vetter 2006; Palsson et al. 2009).



AR020338

Table 2. Characteristics of ESA-listed rockfish species.

| Common Name | Maximum Age (yrs.) | Age at 50% Maturity (yrs.) | Range Natural Mortality Rate (% per year) | Depth range (ft.) (Adults) |
|---|---|---|---|---|
| Yelloweye rockfish | 118+ | 19-22 | 2 to 4.6 percent | 90-1400 |
| Bocaccio | 50 | 4 | 8 | 90-1400 |

Note: Adapted from Orr et al. 2000, Love et al. 2002, Gunderson and Vetter 2006, and Palsson et al. 2009).

### *Diet and Feeding Behavior*

Food sources for yelloweye rockfish and bocaccio occur throughout Puget Sound. However, each of the basins has unique biomass and species compositions of fish and invertebrates that vary temporally and spatially (Rice 2007; Rice et al. 2012). Absolute and relative abundance and species richness of most fish species in the Puget Sound/Georgia Basin increase with latitude (Rice 2007; Rice et al. 2012). Despite these differences, each basin hosts common food sources for yelloweye rockfish and bocaccio as described below.

Larval and juvenile rockfish feed on very small organisms such as zooplankton, particularly copepods, phytoplankton, small crustaceans, invertebrate eggs, krill, and other invertebrates (Moser and Boehlert 1991; Love et al. 1991; Love et al. 2002). Larger juveniles also feed upon small fish (Love et al. 1991). Adult yelloweye rockfish and bocaccio have diverse diets that include many species of fish and invertebrates, including but not limited to crabs (*Crustacea spp.*), various rockfish (*Sebastes spp.*), flatfish (*Pleuronectidae* and *Paralichthyidae spp*), juvenile salmon (*Oncorhynchus spp*), walleye pollock (*Gadus chalcogrammus*), Pacific hake (*Merluccius productus*), Pacific cod (*Gadus macrocephalus*), green sea urchin (*Stongylocentrotus droebachiensis*), lingcod (*Ophiodon elongatus*) eggs, various shrimp species (*Pandalus spp.)*, and surf perch (*Rhacochilus spp.*). Common forage fish that are part of rockfish diets include Pacific herring (*Clupea pallasii*), surf smelt (*Hypomesus pretiosus*), and Pacific sand lance (*Ammodytes hexapterus*) (Washington et al. 1978; Lea et al. 1999; Love et al. 2002; Yamanaka et al. 2006).

### *Natural Predators*

Rockfishes of all sizes are an important food resource for a variety of predators in Puget Sound (Palsson et al. 2009). There is little data regarding specific predators of yelloweye rockfish and bocaccio of the Puget Sound/Georgia Basin, thus we refer to available information regarding predation on *Sebastes* species generally. Rockfish are preyed upon by numerous fish species, birds, and several marine mammals (Mills et al. 2007; Lance et al. 2012; Buzzell et al. 2014). Larvae and juveniles are eaten by birds, salmon, rockfish, lingcod, and other fish species (Mills et al. 2007). Juveniles and adults are eaten by lingcod and some marine mammals (mostly pinnipeds) (Love et al. 2002; Palsson et al. 2009). As with many other marine fish species, as rockfish grow, their potential predators are generally reduced in number because of their larger sizes, physiological development, and behavioral changes (Gislason et al. 2010).



AR020339

It is important to note that the impact of predation on rockfish cannot be determined from the quantity and frequency of rockfish occurrence in predator diets alone. Data on the sizes and quantity of rockfish consumed by predators must be used in combination with models that assess the ecological conditions in which predation has an influence on rockfish population dynamics.

## C. ABUNDANCE, PRODUCTIVITY, CONNECTIVITY, AND DIVERSITY

We summarize our knowledge of each species at the DPS level according to the following demographic viability parameters: abundance and productivity, spatial structure/connectivity, and diversity. These viability criteria are outlined in McElhaney et al. (2000) and reflect concepts that are well founded in conservation biology and are generally applicable to a wide variety of species. These criteria describe demographic conditions that individually and collectively provide strong indicators of extinction risk (Drake et al. 2010). Below we summarize the demographic information applicable to all three DPSs and then present specific demographic information for each DPS. This section also identifies factors influencing demographics and how parameters have changed over time. The term Puget Sound proper refers to the waters east of and including Admiralty Inlet, and North Puget Sound refers to the San Juan/Strait of Juan de Fuca area within the DPSs.

### *Abundance and Productivity*

*Abundance*

There is no single, reliable historical or contemporary abundance estimate for the yelloweye rockfish or bocaccio DPSs in the Puget Sound/Georgia Basin (Drake et al. 2010). Despite this limitation, there is clear evidence that each species' abundance has declined dramatically (Drake et al. 2010). The total rockfish population in the Puget Sound region is estimated to have declined around 3 percent per year for the past several decades, which corresponds to an approximate 70 percent decline from 1965 to 2007 (Drake et al. 2010). Catches of yelloweye rockfish and bocaccio have declined as a proportion of the overall rockfish catch (Figure 2 and Figure 3, from Drake et al. 2010). These patterns are consistent with results of a study that assessed historical trends in rockfish abundance based on local knowledge of resource users and scientists (Beaudreau and Levin 2014). Beaudreau and Levin (2014) reconstructed trends in relative abundance of seven species of rockfish in Puget Sound, including ESA-listed species, since the 1940s from interviews with fishers, divers, and researchers. Trends in abundance indices indicated that all seven species in Puget Sound have been in decline since at least the 1960s. The three ESA-listed species were viewed as relatively lower in abundance across all time periods compared to other rockfishes.

The study shows that expert knowledge may help resolve patterns of abundance for rockfishes. Trends from local knowledge likely reflected true patterns in nature, based on the following: 1) there was a high degree of agreement among respondents about patterns in species abundance, and 2) trends from interview data showed strong concordance with scientific surveys of Puget Sound species for which historical data were available (i.e., harbor seal, *Phoca vitulina*; Pacific herring, *Clupea pallasii*; lingcod, *Ophiodon elongates*) (Beaudreau and Levin 2014). Abundance indices from local knowledge sources could be used in combination with contemporary survey and fishery-dependent data to generate plausible estimates of historical abundance prior to the use of biological surveys (Beaudreau and Levin 2014).

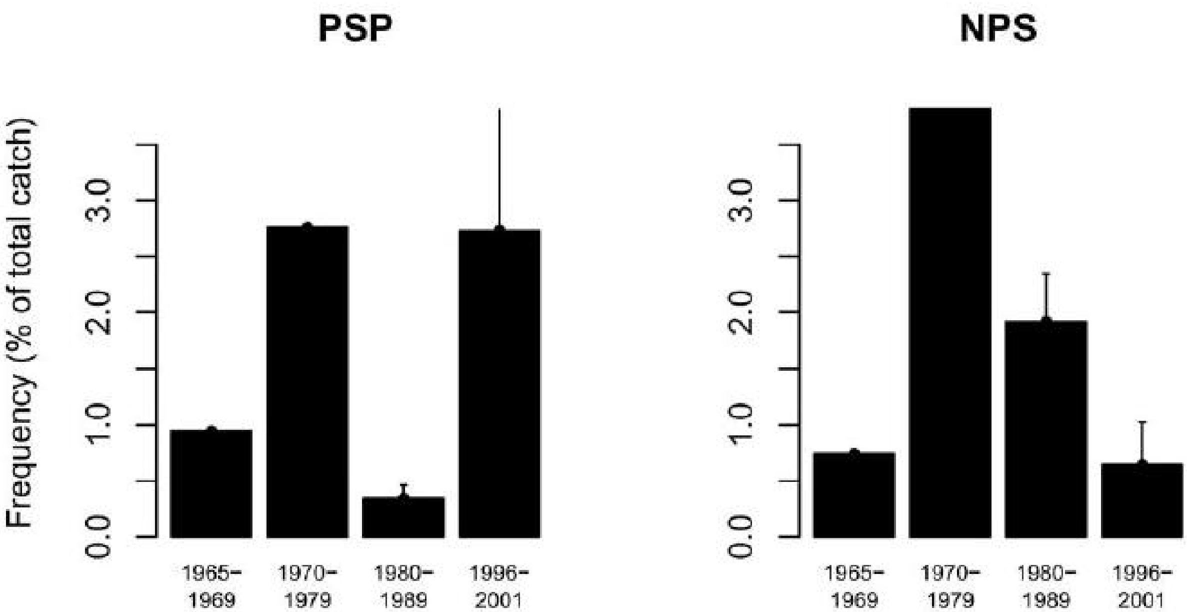


Figure 2. Frequency (% total) for yelloweye rockfish in the recreational catch in Puget Sound proper (PSP) and North Puget Sound (NPS) (Source: Drake et al. (2010).

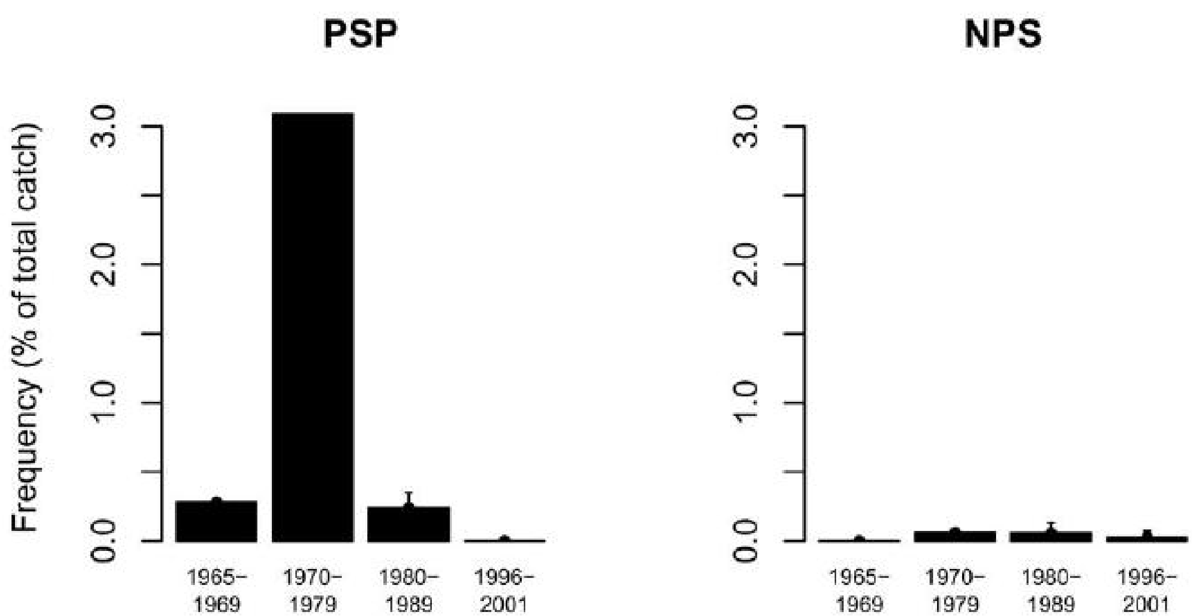


Figure 3. Frequency (% total) for bocaccio in the recreational catch in Puget Sound proper (PSP) and North Puget Sound (NPS) (Source: Drake et al. (2010).

Fishery-independent estimates of abundance come from spatially and temporally limited research trawls, drop camera surveys, and underwater ROV surveys conducted by WDFW. These abundance estimates



AR020341

included in Table 3 should be interpreted in the context of the sampling design and gear. The trawl surveys were conducted on the bottom to assess marine fish abundance for a variety of species. These trawls generally sample over non-rocky substrates where yelloweye rockfish and bocaccio are less likely to occur compared to steep-sloped, rocky habitat (Drake et al. 2010). The drop camera surveys sampled habitats less than 120 feet (36.6 m) deep, which is potential habitat for juveniles, but less likely habitat for adult yelloweye rockfish and bocaccio. Similarly, because juvenile yelloweye rockfish are less dependent on rearing in shallow nearshore environments, the likelihood of documenting them with drop camera surveys in water shallower than 120 feet (36.6 m) is less than for juvenile bocaccio.

The WDFW ROV surveys were conducted exclusively within the rocky habitats of the San Juan Basin in 2008, and represent the best available abundance estimates to date for one basin of the DPS for each species because of their survey area, number of transects, and stratification methods (Pacunski et al. 2013). Rocky habitats have been mapped within the San Juan Basin, which allows a randomized survey of these areas to assess species assemblages and collect data for abundance estimates. WDFW conducted 200 transects and stratified each rocky habitat survey as either “shallower than” or “deeper than” 120 feet (36.6 m). The total area surveyed within each stratum was calculated using the average transect width multiplied by the transect length. The mean density of yelloweye rockfish and bocaccio was calculated by dividing the species counts within each stratum by the area surveyed. Population estimates for each species were calculated by multiplying the species density estimates by the total survey area within each stratum (Pacunski et al. 2013). Because WDFW did not survey non-rocky habitats of the San Juan Basin with the ROV, these estimates do not account for listed rockfish in non-rocky habitat in 2008. WDFW expanded the survey data to estimate total abundance in the San Juan Basin (Table 3). From the bottom trawl and drop camera surveys, WDFW has reported abundance estimates in the North Sound and Puget Sound proper (Table 3).

Table 3. Abundance estimates for yelloweye rockfish and bocaccio.

| **WDFW Survey Method** | **Yelloweye Population Estimate** | | **Percent Standard Error (or Variance)** | |
|---|---|---|---|---|
| | **North Sound** | **Puget Sound proper** | | |
| Bottom Trawl | Not detected | 600 fish | NA | 400 (variance) |
| Drop Camera | Not detected | Not detected | NA | NA |
| Remotely Operated Vehicle | 47,407 fish (San Juan Basin only) | | 29 | |
| **WDFW Survey Method** | **Bocaccio Population Estimate** | | **Percent Standard Error** | |
| | **North Sound** | **Puget Sound proper** | | |
| Bottom Trawl | Not detected | Not detected | NA | NA |
| Drop Camera | Not detected | Not detected | NA | NA |
| Remotely Operated Vehicle | 4,606 fish (San Juan Basin only) | | 100 | |



AR020342

Though the bottom trawl and drop camera surveys did not detect bocaccio in Puget Sound proper, bocaccio were historically caught in recreational fisheries (Palsson et al. 2009; Williams et al. 2010) and have been caught in recent genetic research and ROV surveys in 2015. In past decades, bocaccio were most common within the South Sound and Main Basin (Drake et al. 2010; Williams et al. 2010). The lack of detected bocaccio from these sampling methods in Puget Sound proper is likely due to the following factors: 1) populations are depleted; 2) the general lack of rocky benthic areas in Puget Sound proper may lead to densities of each species that are naturally less than the San Juan Basin; 3) the study design or effort may not have been sufficient to detect each species; and 4) bottom trawls do not effectively sample core rockfish habitats (i.e., high-relief rock). Though bocaccio were likely never a predominant component of the multi-species rockfish abundance within the Puget Sound/Georgia Basin (Drake et al. 2010), their present-day abundance is likely a fraction of their pre-contemporary fishery abundance. Bocaccio abundance may now be very low in much of the Puget Sound/Georgia Basin.

Though yelloweye rockfish were detected in Puget Sound proper with bottom trawl surveys, we do not consider the WDFW estimate of 600 fish to be a complete estimate, for the same reasons given above for bocaccio. Throughout the Puget Sound/Georgia Basin (in U.S. waters), yelloweye rockfish are very likely most abundant within the San Juan Basin. Though there is no reliable population census (ROV or otherwise) within all the Puget Sound/Georgia Basin, the San Juan Basin has the most suitable rocky benthic habitat (Palsson et al. 2009) and historically was the area of greatest numbers of recreational catch (Moulton and Miller 1987; Olander 1991).

*Productivity*

Productivity is the measurement of a population's growth rate through all or a portion of its life cycle. Life history traits of yelloweye rockfish and bocaccio suggest generally low levels of inherent productivity because they are long-lived, mature slowly, and have sporadic episodes of successful reproduction (Tolimieri and Levin 2005).

Yelloweye rockfish productivity is influenced by long generation times that reflect intrinsically low annual reproductive success. Natural mortality rates have been estimated from 2 to 4.6 percent (Wallace 2007; Yamanaka and Kronlund 1997). Productivity may also be particularly impacted by Allee effects, which occur as adults are removed by fishing and the density and proximity of mature fish decreases, though more research is needed to understand the impact of these effects (Hutchings and Reynolds 2004). Adult yelloweye rockfish typically occupy relatively small ranges (Love et al. 2002), and the extent to which they may move to find suitable mates is unknown.

Bocaccio productivity is driven by high fecundity and episodic recruitment events that are largely correlated with environmental conditions (Tolimieri and Levin 2005). Natural annual mortality is approximately 8 percent (Palsson et. al 2009). Tolimieri and Levin (2005) found that the bocaccio population growth rate is around 1.01, indicating a very low intrinsic growth rate for this species. Demographically, this species demonstrates some of the highest recruitment variability among rockfish species, with many years of poor recruitment being the norm (Tolimieri and Levin 2005). Given their severely reduced abundance, Allee effects could be particularly acute for bocaccio, even considering the propensity of some individuals to move long distances and potentially find mates, though the extent of these effects are yet unknown.



AR020343

Overfishing can have dramatic impacts on the size or age structure of rockfish populations, with effects that can influence ongoing productivity. When the size and age of females decline, there are negative impacts to reproductive success. These impacts, termed maternal effects, are evident in a number of traits. Larger and older females of various rockfish species have a higher weight-specific fecundity (number of larvae per unit of female weight) (Bobko and Berkeley 2004; Boehlert et al. 1982; Sogard et al. 2008). A consistent maternal effect in rockfishes relates to the timing of larval release. The timing of larval birth can be crucial in terms of corresponding with favorable oceanographic conditions because most individual fishes release larvae on only 2 days each year (Washington et al. 1978). Several studies of rockfish species have shown that larger or older females release larvae earlier in the season compared to smaller or younger females (Nichol and Pikitch 1994; Sogard et al. 2008). Larger or older females provide more nutrients to larvae by developing a larger oil globule released at parturition, which provides energy to the developing larvae (Berkeley et al. 2004; Fisher et al. 2007), and in black rockfish enhances early growth rates (Berkeley et al. 2004).

Reproductive function as well as other life history stages of rockfish are likely affected by contaminants (Palsson et al. 2009), though the extent of this effect is not known (Drake et al. 2010). Contaminants such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and chlorinated pesticides appear in rockfish collected in urban areas (West and O'Neil 1998; West et al. 2001). While the highest levels of contamination occur in urban areas, toxins can be found in the tissues of fish throughout Puget Sound (West et al. 2001). Although few studies have investigated the effects of toxins on rockfish ecology or physiology, other fish in the Puget Sound region that have been studied do show a substantial impact, including reproductive dysfunction of some sole species (Landahl et al. 1997).

Future climate-induced changes to rockfish habitat could alter their productivity (Drake et al. 2010). Harvey (2005) created a generic bioenergetic model for rockfish, showing that their productivity is highly influenced by climate conditions. For instance, El Niño-like conditions generally lowered growth rates and increased generation time. The negative effect of the warm water conditions associated with El Niño appear to be common across rockfishes (Moser et al. 2000). Recruitment of all species of rockfish appears to be correlated at large scales (Caselle et al. 2010). Field and Ralston (2005) hypothesized that such synchrony was the result of large-scale climate forcing. Exactly how climate influences rockfish in Puget Sound is unknown; however, given the general importance of climate to rockfish recruitment, it is likely that climate strongly influences the dynamics of listed rockfish population viability (Drake et al. 2010).

In summary, though abundance and productivity data for yelloweye rockfish and bocaccio are limited, it is likely that both abundance and productivity have been reduced largely by fishery removals, contaminants, and habitat degradation within the range of both Puget Sound/Georgia Basin DPSs (Drake et al. 2010).

### *Spatial Structure and Connectivity*

Spatial structure consists of both the geographical distribution of individuals in the population and the processes that generate that distribution (McElhaney et al. 2000). A population's spatial structure depends on habitat quality, spatial configuration, and dynamics as well as dispersal characteristics of individuals within the population (McElhaney et al. 2000). Prior to contemporary fishery removals, each of the major basins in the range of the DPSs likely hosted populations of yelloweye rockfish and bocaccio, though



AR020344

their distribution was not uniform throughout the basins of Puget Sound (Moulton and Miller 1987; Washington 1977; Washington et al. 1978; Williams et al. 2010). Wide distribution enables each species to potentially exploit good habitat, which may be naturally limited in portions of Puget Sound, and protect them from potentially negative environmental fluctuations or conditions. These types of fluctuations may include change in prey abundance for various life stages and/or change in environmental conditions that influence the number of annual recruits, such as temperature. Wide spatial distribution also provides a measure of protection from larger scale anthropogenic changes that damage habitat suitability, such as oil spills or hypoxia that can occur within one basin but not necessarily the other basins. Rockfish population resilience may be sensitive to changes in connectivity among various groups of fish (Hamilton 2008). Exchange of water masses that influence larval transport and population connectivity between the basins of Puget Sound is naturally restricted by relatively shallow sills located at Deception Pass, Admiralty Inlet, the Tacoma Narrows, and in Hood Canal (Burns 1985). The Victoria Sill bisects the Strait of Juan de Fuca and runs from east of Port Angeles north to Victoria (Drake et al. 2010). These sills regulate water exchange from one basin to the next, and thus likely moderate the movement of rockfish larvae (Drake et al. 2010). When localized depletion of rockfish occurs, it can reduce resiliency of the entire DPS (Levin 1998; Hilborn et al. 2003; Hamilton 2008). It is likely that natural biogeographic limits to rockfish dispersal (as evidenced by a population of yelloweye rockfish in Hood Canal that is separate from the rest of the Puget Sound/Georgia Basin yelloweye rockfish population, discussed below) and distribution make them particularly susceptible to localized depletion due to fishery harvest.

Yelloweye rockfish spatial structure and connectivity has been reduced by the decline of fish within each basin. This reduction is likely most acute within the basins of Puget Sound proper. The severe decline of fish in these basins may eventually result in a contraction of the DPS' range (Drake et al. 2010). Although yelloweye rockfish are probably most abundant within the San Juan Basin, the likelihood of juvenile recruitment from this basin to the adjacent basins of Puget Sound proper is naturally low because of the generally retentive circulation patterns that occur within each of the major basins of Puget Sound proper. Combined with limited adult movement, yelloweye rockfish DPS viability may be highly influenced by the localized loss of populations within the DPS, which decreases spatial structure and connectivity.

Bocaccio may have been historically limited in their spatial distribution. They were historically most abundant in the Main Basin and South Sound (Drake et al. 2010; Williams et al. 2010) with no known documented occurrences in the San Juan Basin until 2008 (Pacunski et al. 2013). Spatial structure and connectivity in the DPS likely comes from the propensity of some adults and pelagic juveniles to migrate long distances, which could re-establish aggregations of fish in formerly occupied habitat (Drake et al. 2010). The apparent reduction of populations of bocaccio in the Main Basin and South Sound represents a further reduction in the historically limited distribution of bocaccio, and adds significant risk to the viability of the DPS.

In summary, spatial structure and connectivity for each species have been adversely impacted, in large part due to habitat change and past fishery removals (Palsson et al. 2009; Drake et al. 2010).

***Life History Diversity, Demographic and Genetic Structure***

Characteristics of life history diversity for rockfishes include age/size structure, fecundity, timing of larval release, larval condition, age at reproductive maturity, and molecular genetic characteristics. In



AR020345

spatially and temporally varying environments, there are three general reasons why diversity is important for species and population viability: 1) it allows a species to use a wider array of environments; 2) it protects a species against short-term spatial and temporal changes in the environment; and 3) genetic diversity provides the raw material for adaptation to long-term environmental changes. More information is needed to understand factors influencing diversity and how these factors may have changed the populations over time.

*Yelloweye rockfish demographic information*
Data from the 1970s through 2000s indicate that yelloweye rockfish size and age distributions became truncated (Figure 4). Recreationally caught yelloweye rockfish in the 1970s spanned a broad range of sizes. By the 2000s, there was some evidence of fewer older fish in the population (Drake et al. 2010). As a result, the reproductive burden may be shifted to younger and smaller fish. This shift in demographic structure could alter the timing and condition of larval release, which may be mismatched with habitat conditions within the range of the DPS and reduce the viability of offspring (Drake et al. 2010).

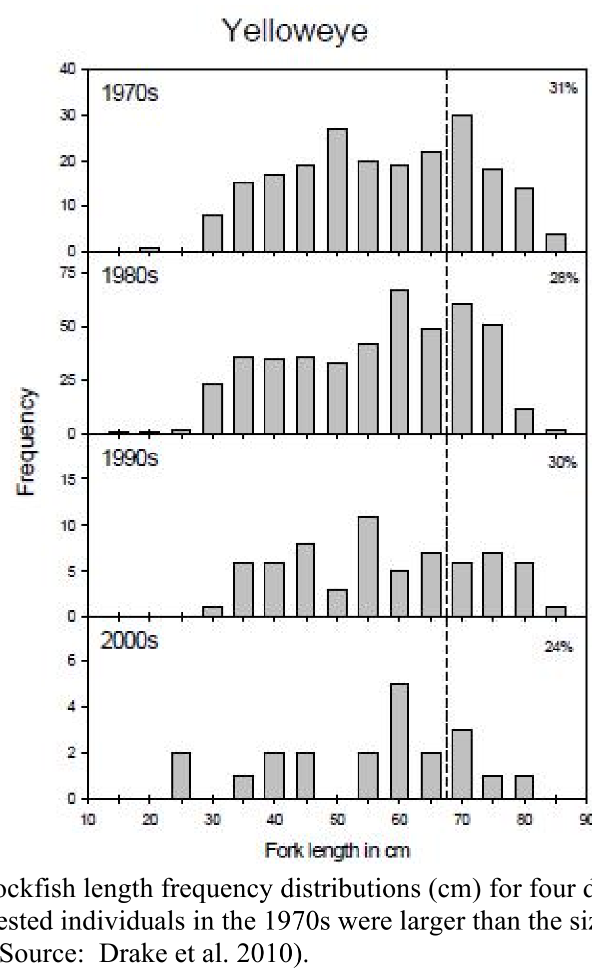


Figure 4. Yelloweye rockfish length frequency distributions (cm) for four decades. Approximately one third of harvested individuals in the 1970s were larger than the size depicted by the vertical dashed line (Source: Drake et al. 2010).



AR020346

WDFW scientists observed a strong rockfish recruitment event in 2006 (Lowry et al. 2013), and there is evidence of improved population size distribution of yelloweye rockfish from data gathered in 2014 and 2015 (Figure 5). Size frequency information was collected during the 2014-2015 cooperative genetics research study (described in Section F and NMFS 2016), which was initiated to gain genetic data to better delineate the population structure for the listed species (Andrews et al. 2015). Yelloweye rockfish show some evidence of recruitment within the last 10 years (Figure 5). Nine yelloweye rockfish were sampled that were less than 15.8 inches (40 cm) in fork length (FL). At 13.8 inches (35 cm) FL, these fish are approximately 7 to 10 years of age (using the von Bertalanffy growth parameters from Love et al. 2002). Thus, the data suggest some recent replenishment of local populations of yelloweye rockfish although the extent is not known. In addition, several observations of young-of-year (YOY) yelloweye rockfish in Puget Sound have been documented by local recreational divers, the Seattle Aquarium, and WDFW (NMFS, unpublished database).

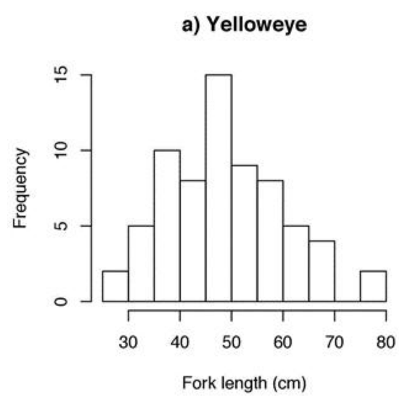


Figure 5. Yelloweye rockfish length frequency distributions (cm) from fish caught in 2014 and 2015 (Andrews et al. 2015).

*Yelloweye rockfish genetic information*

New collection and analysis of yelloweye rockfish tissue samples reveal significant genetic differentiation between the inland (DPS) and coastal samples. These new data are consistent with and further support the existence of a population of Puget Sound/Georgia Basin yelloweye rockfish that is discrete from coastal populations (Ford 2015; NMFS 2016). In addition, yelloweye rockfish from Hood Canal were genetically differentiated from other Puget Sound/Georgia Basin fish (cluster in the upper right of Figure 6), indicating a previously unknown degree of population differentiation within the DPS (Ford 2015; NMFS 2016). Other genetic analysis has found that yelloweye rockfish in the Georgia Basin had the lowest molecular genetic diversity of a collection of samples along the coast (Siegle et al. 2013). Although the

**TWO POPULATIONS OF YELLOWEYE ROCKFISH**

Recent genetic research has found that yelloweye rockfish in Hood Canal are genetically differentiated from other yelloweye rockfish within the DPS – constituting two separate populations of fish within in the Puget Sound/Georgia Basin.

adaptive significance of such microsatellite diversity is unclear, it may suggest low effective population size, increased drift, and thus lower genetic diversity in the Puget Sound/Georgia Basin DPS.

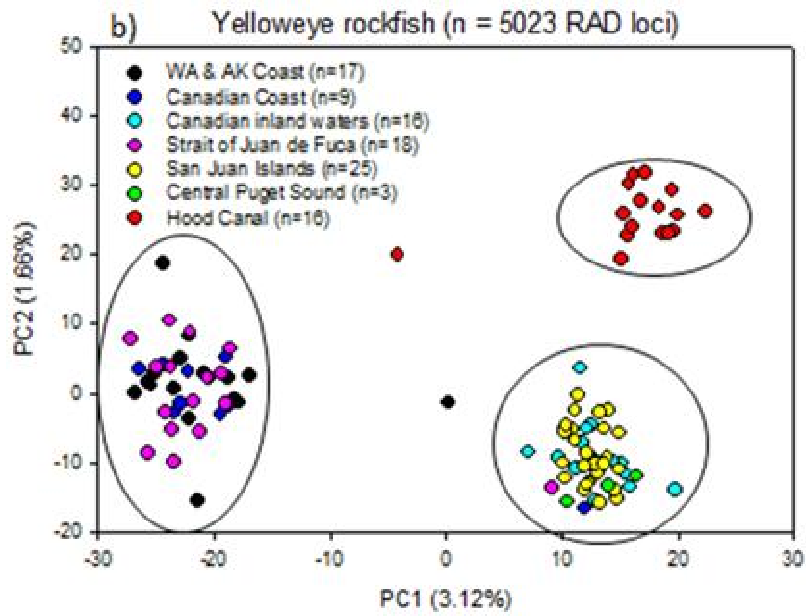


Figure 6. Three distinct clusters of yelloweye rockfish based on a principal components analysis of the genetic variation between individuals a) inside and outside the DPS and b) among specific regions (Andrews et al. 2015).

*Bocaccio demographic information*

Size-frequency distributions for bocaccio in the 1970s indicate a wide range of sizes, with recreationally caught individuals from 9.8 to 33.5 inches (25 to 85 cm) (Figure 7). This broad size distribution suggests a spread of ages, with some successful recruitment over many years. A similar range of sizes is also evident in the 1980s catch data (Palsson et al. 2009; Drake et al. 2010). The temporal trend in size distributions for bocaccio also suggests size truncation of the population, with larger fish becoming less common over time, thereby changing the demographic structure. By the 2000s, no size distribution data for bocaccio were available. The potential loss of diversity in the bocaccio DPS, in combination with their relatively low productivity, may result in a mismatch with habitat conditions and further reduce population viability (Drake et al. 2010).

In summary, although there may have been some recruitment in recent years, size and age structure of both species has likely been adversely impacted by past fishery removals, with the largest individuals removed from the population, thereby altering demographic structure. During the 2014/2015 collection and analysis of yelloweye rockfish tissue that confirmed the DPS and found two populations of yelloweye rockfish within the DPS, scientists also tried to collect bocaccio tissue. Because of their rarity, genetic analysis for bocaccio included only two samples from within the DPS area (Andrews et al. 2015); this is not sufficient information to change the prior status review determination (Ford 2015; NMFS 2016).



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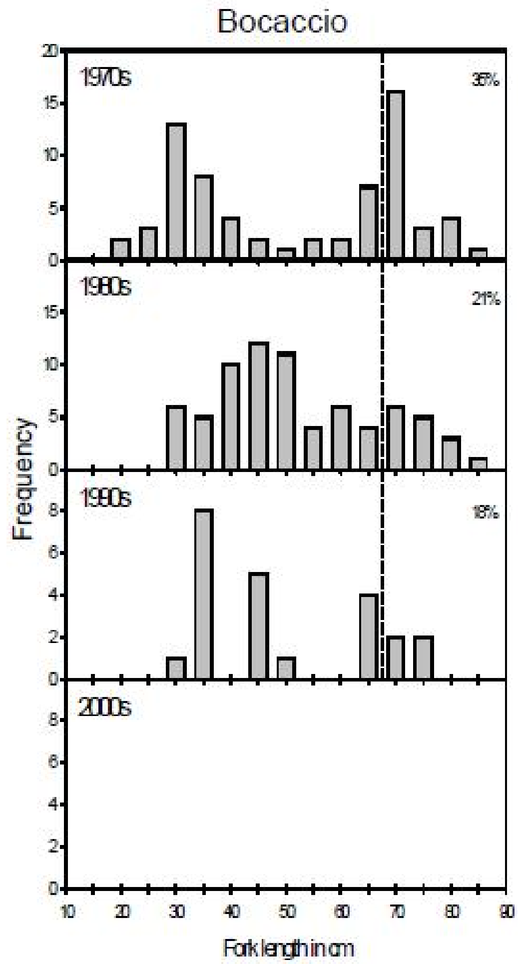


Figure 7. Bocaccio length frequency distributions (cm) for four decades. Approximately one third of harvested individuals in the 1970s were larger than the size depicted by the vertical dashed line (Note: there is no vertical dashed line in the 2000s because no bocaccio were recorded in catch) (Source: Drake et al. 2010).

## D. MANAGEMENT UNITS AND HABITAT CHARACTERISTICS

The yelloweye rockfish DPS and the bocaccio DPS span a range of habitats in the Puget Sound/Georgia Basin that are adjacent to urban hubs, agricultural areas, and remote regions. They also span regions that exhibit different oceanographic conditions. Therefore, we use five geographically based management units (Figure 8) to describe different habitat characteristics to further assist with delisting and downlisting criteria, rank threats by management unit, and identify specific research and recovery actions. This map will be updated to remove the canary rockfish DPS once the proposed rule to delist them is finalized. At that time, the DPS boundary for yelloweye rockfish will also be extended further north into Canada to include Johnstone Strait and Queen Charlotte Channel (NMFS 2016).



AR020349

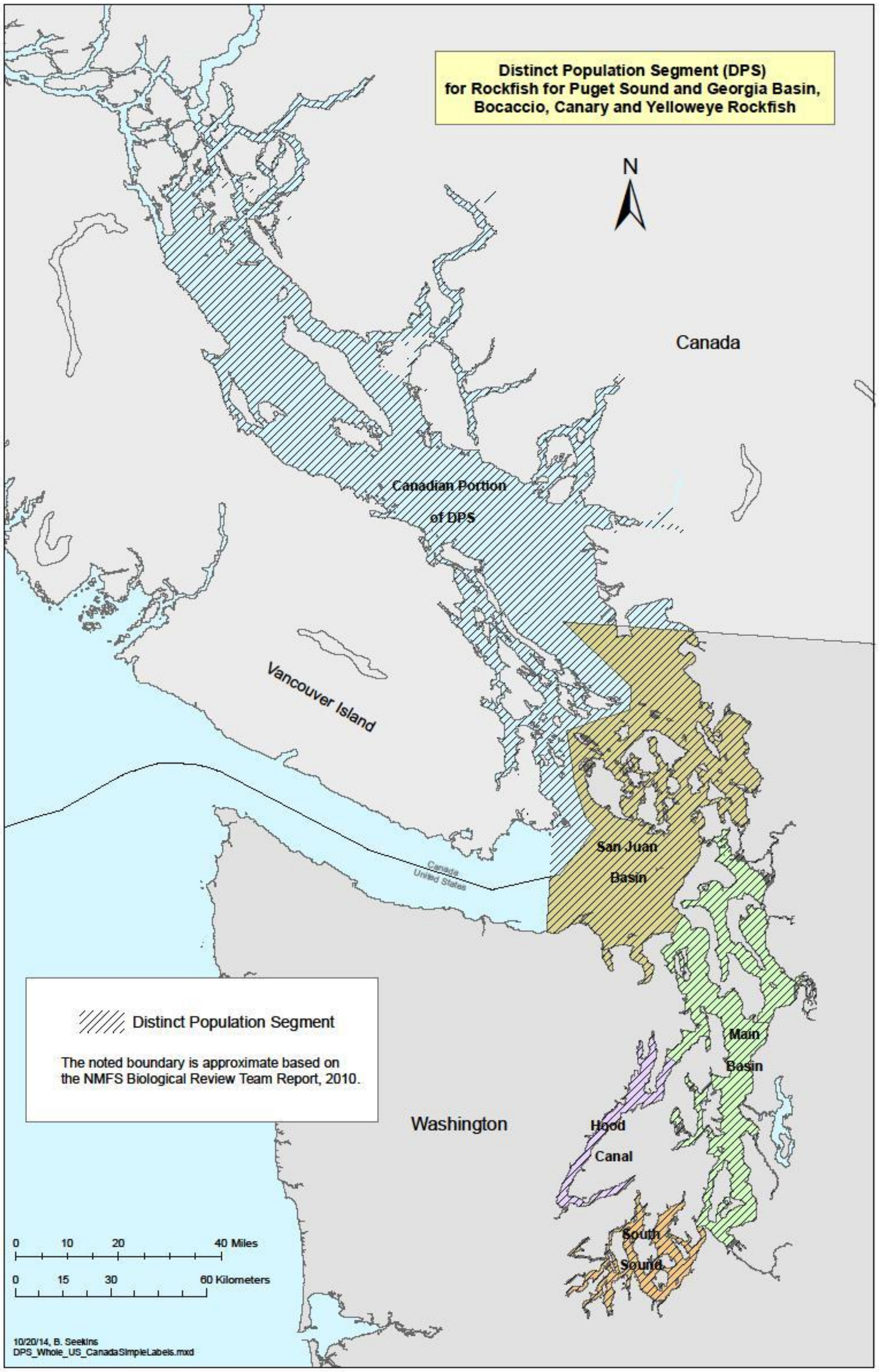


Figure 8. DPSs area and Management Units.



AR020350

***Management Unit and Habitat Descriptions***

The range of the two DPSs includes Puget Sound and Georgia Basin, which make up the southern arm of an inland sea located on the Pacific Coast of North America and connected to the Pacific Ocean by the Strait of Juan de Fuca. Puget Sound can be subdivided into biogeographic basins that encompass contiguous, ecologically unique, and spatially isolated freshwater, estuarine, and marine habitats (Downing 1983; Burns 1985). Puget Sound is a fjord-like estuary covering 2,331.8 square miles (6,039.3 sq. km). Puget Sound is fed by 14 major river systems and consists of a series of interconnected basins separated by prominent sills. Most of the water exchange in Puget Sound proper is through Admiralty Inlet, and the configuration of sills and deep basins results in the partial recirculation of water masses and the retention of contaminants, sediment, and biota (Strickland 1983). Tidal action, freshwater inflow, and ocean currents interact to circulate and exchange salty marine water from the Strait of Juan de Fuca at depth and less dense fresh water from the surrounding watersheds at the surface, producing a net seaward flow of water at the surface (Strickland 1983).

**Role of Listed Rockfish within the Puget Sound Ecosystem**

Listed rockfish are linked to iconic marine species in the regional ecosystem, as well as to the regional culture and economy. These species are two of 28 species of rockfish in Puget Sound which together compose a significant portion (15%) of fish species in the Puget Sound ecosystem (Palsson et al. 2009). Actions outlined in this recovery plan are anticipated to not only benefit these two species but also other rockfish and other species in the ecosystem. In coastal Washington and Oregon where rockfish are more abundant than Puget Sound, juvenile coho salmon and Chinook salmon have been found to consistently eat larval rockfishes in summer months, at which time rockfish are the dominant fishes in their diets (Brodeur et al. 2011). Rockfish are important mid-trophic level species that link upper-level predators, such as lingcod, salmon, seabirds, and marine mammals, with lower trophic level prey, like shrimp, other benthic invertebrates, and forage fish.

Prior to their decline, listed rockfish were important components of recreational and commercial fisheries in Puget Sound (Palsson et al. 2009; Drake et al. 2010; Williams et al. 2010). The loss of the recreational and commercial rockfish fishery, in addition to fewer opportunities for divers to observe rockfish, represent economic and cultural loss along with the aforementioned ecosystem losses, the extent which we do not yet understand.

The sills largely define the boundaries between the biogeographic basins (except where the Whidbey Basin meets the Main Basin) and contribute to relatively fast water currents during portions of the tidal cycle. The sills restrict water exchange, and in combination with bathymetry, freshwater input, and tidal exchange, influence environmental conditions such as the movement and exchange of biota from one region to the next, and water temperatures and water quality (Ebbesmeyer et al. 1984; Burns 1985; Rice 2007). In addition, each basin differs in biological condition; depth profiles and contours; subtidal benthic, intertidal habitats; and shoreline composition and condition (Downing 1983; Ebbesmeyer et al. 1984; Burns 1985; Rice 2007; Drake et al. 2010). Puget Sound has approximately 2,400 miles (3,862 km) of shoreline, ranging from rocky sea cliffs to coastal bluffs and river deltas. Most of the shoreline of Puget Sound proper is composed of erodible gravel, sand, and clay deposited by glaciers more than 15,000 years



AR020351

ago, while much of the San Juan Basin's shoreline is composed of rock and large cobble materials (Downing 1983).

The five Management Units are listed below (Figure 8). The first four are based on the aforementioned conditions. The fifth management unit, which includes the Canadian portion of the Puget Sound/Georgia Basin, is a political boundary because the U.S. does not have authority in Canadian waters.

(1) The San Juan/Strait of Juan de Fuca Basin
(2) Main Basin
(3) South Puget Sound
(4) Hood Canal
(5) The Canadian portion of the Puget Sound/Georgia Basin

*The San Juan/Strait of Juan de Fuca Basin*: This basin is the northwestern boundary of the U.S. portion of the DPSs' ranges. The basin includes Bellingham Bay and is delimited to the north by the Canadian border, to the west by the entrance to the Strait of Juan de Fuca, to the south by the Olympic Peninsula and Admiralty Inlet, and to the east by Whidbey Island and the mainland between Anacortes and Blaine, Washington. The predominant feature of this basin is the Strait of Juan de Fuca, which is 99.4 miles (160 km) long and 13.7 miles (22 km) wide at its western end, to over 24.9 miles (40 km) at its eastern end (Thomson 1994). Drake et al. (2010) considered the western boundary of the DPSs' range as the Victoria Sill because it is hypothesized to control larval dispersal for rockfish (and other biota) of the region.

The San Juan/Strait of Juan de Fuca Basin has the most rocky shoreline and benthic habitats of the U.S. portion of the DPSs. Most of the basin's numerous islands have rocky shorelines and extensive, submerged, aquatic vegetation and floating kelp beds that support juvenile bocaccio settlement to benthic habitats, provide cover from predation, and support rearing. Approximately 93 percent of the rocky benthic habitats of the U.S. portion of the range of all three DPSs are in this basin (Palsson et al. 2009).

Commercial and recreational fisheries occur in the San Juan Basin, as well as scientific research, that may encounter listed rockfish bycatch. The highest concentration of derelict fishing nets in the DPSs' ranges remain here, including many nets in waters deeper than 100 feet (30.5m). This basin has the most kelp in the DPSs' ranges, and because of its commonality, commercial kelp harvest may be proposed for the San Juan Islands area. The Ports of Bellingham and Anacortes are located in this basin, and numerous dredging and dredge disposal projects and nearshore development, such as new docks, piers, and bulkheads, occur in this basin. These development actions have the potential to alter nearshore rearing habitats of bocaccio. Two open-water dredge disposal sites are located in the basin, one in Rosario Strait and the other northwest of Port Townsend. These are termed dispersive sites because they have higher current velocities; thus, dredged material does not accumulate at the disposal site and settles on benthic environments over a broad area (Army Corps of Engineers 2010). Sediment disposal activities in these specific areas may temporarily alter dissolved oxygen levels and alter the ability of juvenile rockfish to seek out prey. There are several areas with contaminated sediments along the eastern portion of this basin, particularly in Bellingham Bay and Guemes Channel near Anacortes.

*The Main Basin*: The Main Basin that hosts both DPSs is delimited to the north by the marine waters east of Whidbey Island at Deception Pass, to the west by a line between Point Wilson near Port Townsend and Partridge Point on Whidbey Island, and to the south by Tacoma Narrows. The Skagit, Snohomish, and



AR020352

Stillaguamish Rivers flow into this northern portion of the basin and contribute the largest influx of freshwater inflow to Puget Sound (Burns 1985). The sill at the border of Admiralty Inlet and the eastern Straits of Juan de Fuca regulates water exchange of Puget Sound (Burns 1985). Water retention is estimated to be 1 month in the southern portion of this basin, and 5.4 month in the northern portion, largely because of the sills at Admiralty Inlet and Deception Pass (Ebbesmeyer et al. 1984).

The nearshore of the Main Basin consists of bluff-backed beaches with unconsolidated materials ranging from mud and sand to mixes of gravels and cobbles (McBride et al. 2006). Some of these nearshore areas support the growth of kelp and support juvenile bocaccio settlement, cover from predation, and rearing. Much of the northern part of this basin is relatively shallow with moderately flat bathymetry near the Skagit, Stillaguamish, and Snohomish River deltas and does not support essential nearshore features such as holdfasts for kelp, and rock and cobble areas for rearing juvenile bocaccio. The southern portion of the basin has more complex bathymetry compared to the north, with deeper waters adjacent to Whidbey Island, southern Camano Island, and off of Mukilteo. Subtidal surface sediments in Admiralty Inlet tend to consist largely of sand and gravel, whereas sediments just south of the inlet and southwest of Whidbey Island are primarily sand. Sediments in the deeper areas of the central portion of the Main Basin generally consist of mud or sandy mud (PSWQA 1987). Benthic areas in this basin with steep and irregular bathymetry and high rugosity support growth, refuge, reproduction, and feeding opportunities.

Possession Point is centrally located within this basin at the southern end of Whidbey Island and has relatively steep eastern, southern, and western edges. It also has some rocky substrates and has relatively consistent aggregations of forage fish (Squire and Smith 1977). There are benthic areas deeper than 98 feet (30 m) along Possession Point, Admiralty Inlet, and the rims of Puget Sound beyond the nearshore that feature sloping bathymetry and areas of high rugosity that support growth, refuge, reproduction, and feeding opportunities for both yelloweye rockfish and bocaccio. The waters in this basin are generally stratified, with surface waters warmer in summer (generally 50° to 55°F [10° to 13°C]) and cooler in winter (generally 45° to 50°F [7° to 10°C]) (Collias et al. 1974).

In Port Susan and Saratoga Passage, salinities of surface waters (27.0 to 29.5 psu) are generally lower than in the southern portion of the basin because of runoff from the major rivers; moreover, after heavy rain these salinities range from 10 to 15 psu. Subsurface temperatures are usually between 46° and 54°F (8° and 12°C). In the deeper portions of the Main Basin, salinities are generally approximately 30 psu in summer and fall, but decrease to approximately 29 psu during the more rainy months.

This basin has consistently higher temperatures and lower salinity relative to the San Juan Basin. Dissolved oxygen levels vary seasonally, with lowest levels of about 5.5 mg/L occurring at depth in summer months, and highest levels of about 7.5 mg/L near the surface. Occasionally, summertime highs reach 13 to 14 mg/L at the surface.

Activities in this basin that may affect listed rockfish and their habitat include bycatch from commercial and recreational fisheries, scientific research, dredging projects and dredge disposal operations, nearshore development projects, and tidal energy projects. Vessel traffic in this basin is common as cargo ships transit to/from the Strait of Juan de Fuca to the Ports of Seattle and Tacoma and other destinations in the Main Basin and South Puget Sound (Bassett et al. 2012). An estimated 23 derelict nets in waters shallower than 100 feet (30.5 m) and one in deeper waters remain in this basin (NRC 2014). Pollution and



AR020353

runoff are also concerns in this basin because of the extensive amounts of impervious surface. Two open-water dredge disposal sites are located in the basin; one located in Elliot Bay and the other in Commencement Bay. These are non-dispersive disposal sites, which are areas where currents are slow enough that dredged material is deposited on the disposal target area rather than dispersing broadly with prevailing currents (Army Corps of Engineers 2010). An estimated 36 percent of the shoreline in this area has been modified by human activities (Drake et al. 2010), and bulkhead/pier repair projects and new docks/piers are proposed regularly in this basin. There are several areas with contaminated sediments in this basin, particularly in Port Gardner, Elliot Bay, Sinclair Inlet, and Commencement Bay.

*South Puget Sound*: This basin includes all waterways south of Tacoma Narrows. This basin is characterized by numerous islands and shallow (generally < 65 feet [20 m]) inlets with extensive shoreline areas. The sill at Tacoma Narrows restricts water exchange between the South Puget Sound and the Main Basin, and water retention is an estimated 1.9 months (Ebbesmeyer et al. 1984). This restricted water exchange influences environmental characteristics of South Puget Sound, such as nutrient levels and dissolved oxygen, and perhaps its biotic communities (Ebbesmeyer et al. 1984; Rice 2007).

A wide assortment of sediments is found in the nearshore and intertidal areas of this basin (Bailey et al. 1998). The most common sediments and the percent of the intertidal area they cover are: mud, 38.3 ± 29.3 percent; sand, 21.7 ± 23.9 percent; mixed fine, 22.9 ± 16.1 percent; and gravel, 11.1 ± 4.9 percent. Subtidal areas have a similar diversity of surface sediments, with shallower areas consisting of mixtures of mud and sand and deeper areas consisting of mud (PSWQA 1987). Some of the nearshore areas of South Puget Sound support the growth of kelp and support juvenile bocaccio settlement, cover from predation, and rearing. The southern inlets of this basin include Oakland Bay, Totten Inlet, Budd Inlet, and Eld Inlet, in addition to the Nisqually River delta.

Sediments in Tacoma Narrows and Dana Passage consist primarily of gravel and sand. With a mean depth of 121 feet (37 m), this basin is the shallowest of the biogeographic basins (Burns 1985), and benthic areas deeper than 98 feet (30 m) occur in portions of the Tacoma Narrows. The rims of South Puget Sound beyond the nearshore have sloping bathymetry and areas of high rugosity that support growth, refuge, reproduction, and feeding opportunities. The major urban areas, and thus more pollution and runoff into South Puget Sound, are found in the western portions of Pierce County. Other urban centers in the southern Puget Sound area include Olympia and Shelton.

The major channels of the southern basin are moderately stratified compared to most other greater Puget Sound basins. Salinities generally range from 27 to 29 psu and, although surface temperatures reach 57° to 59°F (14° to 15°C) in summer, the temperatures of subsurface waters generally range from 50° to 55°F (10° to 13°C) in summer and from 46° to 50°F (8° to 10°C) in winter (Ecology 1999). Dissolved oxygen levels generally range from 6.5 to 9.5 mg/L. Salinity in the inlets tends to be similar to those of the major channels, whereas temperatures and dissolved oxygen levels in the inlets are frequently much higher in summer. Two of the larger inlets, Carr and Case, have surface salinities ranging from 28 to 30 psu in the inlet mouths and main bodies, but lower salinities range from 27 to 28 psu at the heads of the inlets (Collias et al. 1974). Summertime surface waters in Budd, Carr, and Case Inlets commonly have temperatures that range from 59° to 66°F (15° to 19°C) and dissolved oxygen values of 10 to 15 mg/L.



AR020354

Activities in this basin that may affect both yelloweye rockfish and bocaccio and their habitat include bycatch from commercial and recreational fisheries, scientific research, dredging and dredge disposal, nearshore development, pollution and runoff, aquaculture operations, and potential tidal energy projects. An estimated 20 derelict nets in waters shallower than 100 feet (30.5 m) and one in deeper waters remain in this basin (NWSI 2014b). A non-dispersive dredge disposal site is located off Anderson/Ketron Island (Army Corps of Engineers 2010) and is monitored for impacts collaboratively by WDFW and DNR. A potential tidal energy site is located in the Tacoma Narrows area. Important point sources of waste include sewage treatment facilities, and about 5 percent of the nutrients (as inorganic nitrogen) entering greater Puget Sound enter this basin through non-point sources (Embrey and Inkpen 1998). An estimated 34 percent of the shoreline in this area has been modified by human activities (Drake et al. 2010), and bulkhead/pier repair projects and new docks/piers are proposed regularly in this basin. There are several areas with contaminated sediments in this basin (Appendix VI).

*Hood Canal*: Hood Canal branches off the northwest part of the Main Basin near Admiralty Inlet and is the smallest of the greater Puget Sound basins, being 55.92 miles (90 km) long and 0.62 to 1.24 miles (1 to 2 km) wide (Drake et al. 2010). Water retention is estimated at 9.3 months; exchange in Hood Canal is regulated by a 164-foot (50-meter) deep sill near its entrance that limits the transport of deep marine waters in and out of Hood Canal (Ebbesmeyer et al. 1984; Burns 1985).

The major components of this basin consist of the Hood Canal entrance, Dabob Bay, the central basin, and the Great Bend at the southern end. A combination of relatively little freshwater inflow, the sill at Admiralty Inlet, and bathymetry lead to relatively slow currents; thus, water residence time within Hood Canal is the longest of the biogeographic basins, with net surface flow generally northward (Ebbesmeyer et al. 1984). The intertidal and nearshore zone consists mostly of mud (53.4 ± 89.3 percent of the intertidal area), with similar amounts of mixed fine sediment and sand (18.0 ± 18.5 percent and 16.7 ± 13.7 percent, respectively) (Bailey et al. 1998). Some of the nearshore areas of Hood Canal support the growth of kelp and have cobble and gravel substrates intermixed with sand that support juvenile bocaccio settlement, cover from predation, and rearing. Surface sediments in the subtidal areas also consist primarily of mud and cobbles (PSWQA 1987). The shallow areas of the Great Bend, Dabob Bay, Hamma, Quilcene, Duckabush, Dosewallips, Tahuya, and Skokomish River deltas feature relatively muddy habitats that do not support essential nearshore features such as holdfasts for kelp, and rock and cobble areas for rearing juvenile bocaccio. Benthic areas deeper than 98 feet (30 m) occur along the rim of nearly all of Hood Canal, and these areas have sloping and steep bathymetry and areas of high rugosity that support growth, refuge, reproduction, and feeding opportunities.

Portions of Hood Canal are stratified, with marked differences in temperature and dissolved oxygen between the entrance and the Great Bend. Water temperature, salinity, and concentration of dissolved oxygen in Hood Canal are routinely measured by the Washington Department of Ecology (Ecology) at two sites—near the Great Bend and near the entrance. Salinities generally range from 29 to 31 psu and tend to be similar at both sites. In contrast, temperature and dissolved oxygen values are often markedly different between the two sites.

Activities in Hood Canal that could affect yelloweye rockfish and bocaccio include commercial and recreational fisheries, scientific research, nearshore development, non-indigenous species management, and pollution and runoff. An estimated three derelict nets in waters shallower than 100 feet (30.5 m) and



AR020355

two in deeper waters remain in this basin (NRC 2014). The unique bathymetry and low water exchange have led to episodic periods of low dissolved oxygen (Newton et al. 2007), though the relative role of nutrient input from humans in exacerbating these periods of hypoxia is in doubt (Cope and Roberts 2012). Dissolved oxygen levels have decreased to levels that cause behavioral changes and kill rockfish (i.e., below 1.0 mg/L) (Palsson et al. 2008), and beginning in 2004, bottom fishing in Hood Canal became prohibited. An estimated 34 percent of the shoreline in this area has been modified by human activities (Drake et al. 2010), and bulkhead/pier repairs and new docks/piers are regularly proposed in this basin. The non-indigenous tunicate (*Ciona savignyi*) has been documented at 86 percent of sites surveyed in Hood Canal (Drake et al. 2010).

*Canada*: The waters of Canada from the international border in the San Juan Basin northward on the inside of Vancouver Island to near the Campbell River constitute the northern portion of the Puget Sound/Georgia Basin bocaccio DPS range. New evidence has led us to propose that the DPS range for yelloweye rockfish be extend slightly further north into Canadian waters to include Johnstone Strait and Queen Charlotte Channel (NMFS 2016). This extended northerly border for the yelloweye rockfish DPS thus far is the only differentiation in the DPSs ranges, though we will continue to seek further information about both DPSs ranges and provide updates to them if found necessary. This waterway is commonly termed the Strait of Georgia, which is 137.94 miles (222 km) long, 12.43 to 24.85 miles (20 to 40 km) wide and covers approximately of 4,225 square miles (6,800 square km). Depths average 508 feet (155 m), with only 5 percent of the strait estimated to have depths greater than 1,181 feet (360 m) (Wilson et al. 1994).

Major components of this unit include the Fraser River and large networks of islands, such as the Gulf Islands, that result in shallow tidal passes. Water flow and currents in the Strait of Georgia are complex—driven by a large influx of fresh water from the Fraser River, a large tidal range, and prevailing winds. The Fraser River provides regionally significant nutrient and contaminant loadings to the Strait of Georgia. Aside from the Fraser River estuary and nearby shorelines, much of the shorelines in the Strait of Georgia consist of rock and cobble formations, much of which support various species of kelp.

Activities in the inside waters of the Canadian portion of the San Juan Basin northward include First Nations fishing, commercial fishing, and recreational fishing. As of 2006, 100 percent at-sea monitoring standards were put into place for the entire commercial groundfish fishery. This monitoring was intended to eliminate unreported catch of rockfish throughout the commercial groundfish fishery and allow all rockfish to be accounted for within their total allowable catch (TAC). There are also a number of Rockfish Conservation Areas in these waters (Yamanaka et al. 2006; DFO 2015).

Sediment contamination including elevated levels of PAHs, lead, and mercury have been found in various areas of this basin, particularly near the City of Vancouver (Goyette et al. 1988), Howe Sound, and other industrialized areas (Wilson et al. 1994). Other recognized threats in Canada include fisheries (Yamanaka et al. 2006). Oceanographic conditions are a natural limiting factor that may affect successful rockfish recruitment in Canada (Yamanaka et al. 2006), though this effect still requires further regional research.



AR020356

### *Critical Habitat Designation*

Critical habitat was designated for listed rockfish in 2014 under section 4(a)(3)(A) of the ESA (79 Fed. Reg. 68041, November 13, 2014) (Figure 9; Table 4). The specific areas designated for bocaccio total approximately 1,004.50 square miles (1616.59 sq. km) of deep water (> 98.4 feet [30 m]) and nearshore (< 98.4 feet [30 m]) marine habitat in Puget Sound. The specific areas designated for yelloweye rockfish include 414.10 square miles (666.43 sq. km) of deepwater marine habitat in Puget Sound, all of which overlap with areas designated for bocaccio. Section 3(5)(A) of the ESA defines critical habitat as "(i) the specific areas within the geographical area occupied by the species, at the time it is listed . . . on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed . . . upon a determination by the Secretary that such areas are essential for the conservation of the species."

Critical habitat is not designated in areas outside of U.S. jurisdiction; therefore, although waters in Canada are part of the DPSs' ranges for the two species, critical habitat was not designated in that area. We also excluded 13 of the 14 Department of Defense Restricted Areas, Operating Areas, and Danger Zones, and waters adjacent to tribal lands from the critical habitat designation.

On July 6, 2016, along with the proposed rule to remove canary rockfish from the List of Endangered and Threatened species, we proposed to remove the critical habitat designation for canary rockfish (81 FR 43979). Essentially, the total area originally designated would remain in place for yelloweye rockfish and bocaccio (Figure 9). Although the original designation included canary rockfish, the descriptions below are focused on yelloweye and bocaccio.



AR020357

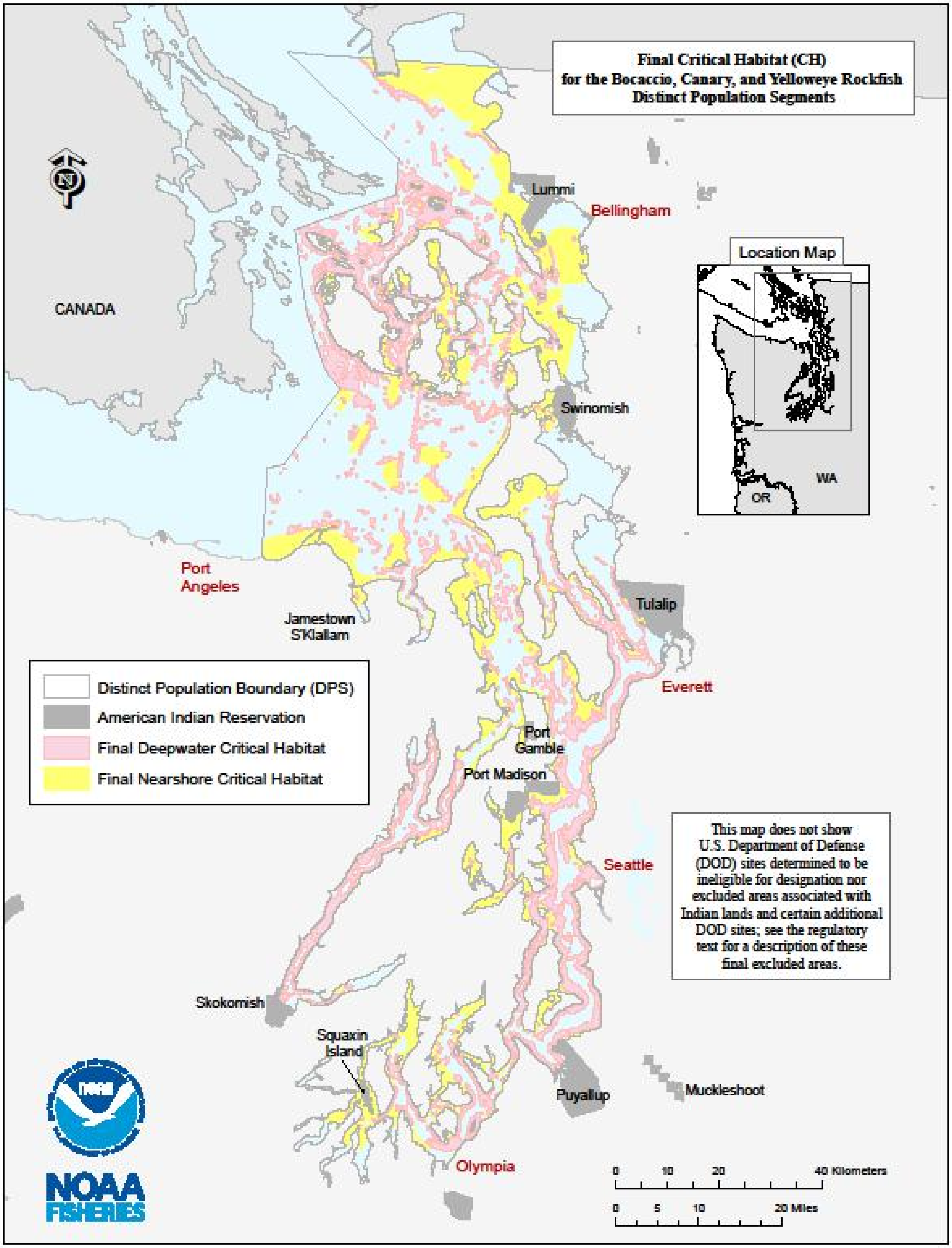


Figure 9. Critical Habitat for yelloweye rockfish and bocaccio.

Physical and Biological Features Essential for Conservation

Based on the best available scientific information regarding natural history and habitat needs, we developed a list of physical and biological features essential to the conservation of adult and juvenile yelloweye rockfish and bocaccio (Table 4), and relevant to determining whether proposed specific areas are consistent with the above regulations and the ESA section (3)(5)(A) definition of "critical habitat." The physical or biological features essential to the conservation of yelloweye rockfish and bocaccio fall into major categories reflecting key life history phases:

*Adult bocaccio, and adult and juvenile yelloweye rockfish:* We designated sites deeper than 98 feet (30 m) that possess (or are adjacent to) areas of complex bathymetry. These features are essential to conservation because they support growth, survival, reproduction, and feeding. Several attributes of these sites affect the quality of the area and are useful in considering the conservation value of the feature, in determining whether the feature may require special management considerations or protection, and in evaluating the effects of a proposed action in a section 7 consultation if the specific area containing the site is designated as critical habitat. These attributes include: 1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities; 2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding; and 3) structure and rugosity to support feeding and predator avoidance.

*Juvenile bocaccio only:* We designated juvenile settlement sites located in the nearshore[2] with substrates such as sand, rock, and/or cobble compositions that also support kelp and eelgrass. These features are essential for conservation because they enable forage opportunities and refuge from predators, and enable behavioral and physiological changes needed for juveniles to occupy deeper adult habitats. Several attributes of these sites affect the quality of the area. They are useful in considering the conservation value of the feature to determine whether the feature may require special management considerations or protection, and in evaluating the effects of a proposed action in a section 7 consultation if the specific area containing the site is designated as critical habitat. These attributes include: 1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding; 2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding; and 3) structure and rugosity (geologic, macroalgae, seagrass) to support predator avoidance.

[2] Most nearshore areas are contiguous with the shoreline from the line of extreme high water out to a depth no greater than 98 feet (30 m) relative to mean lower low water. Several nearshore areas designated as critical habitat are not associated with a beach, but are shallower than 98 feet (30 m) and can support kelp and rearing habitat. They include areas of Hein Bank, Partridge Bank, Coyote Bank, Middle Bank, and several areas north of Orcas Island.



AR020359

Table 4. Physical and biological features and management considerations of subadult and adult habitat for yelloweye rockfish and bocaccio, prior to exclusions[1].

| DPS Basin | Nearshore Square Miles (for juvenile bocaccio only) | Deepwater Square Miles (for adult and juvenile yelloweye rockfish and adult bocaccio) | Physical or Biological Features | |
|---|---|---|---|---|
| San Juan/Strait of Juan de Fuca | 349.4 | 203.6 | Deepwater sites >98 feet (30 m) that support growth, survival, reproduction, and feeding opportunities | Nearshore juvenile rearing sites with sand, rock, cobbles, and/or structure-forming macroalgae (e.g., kelp) to support forage and refuge |
| Whidbey Basin | 52.2 | 32.2 | | |
| Main Basin | 147.4 | 129.2 | | |
| South Puget Sound | 75.3 | 27.1 | | |
| Hood Canal | 20.4 | 46.4 | | |

[1] After exclusions, total nearshore critical habitat includes 590.4 sq. miles (a reduction from 644.7 sq. miles) and deepwater critical habitat includes 414.1 sq. miles (a reduction from 438.5 sq. miles).

## E. FACTORS CONTRIBUTING TO DECLINE AND FEDERAL LISTING

When evaluating a species for protection under the ESA, the Secretary of Commerce must consider whether any one (or more) of five listing factors affect the species. Listing factors deal with those aspects of the species' biology or habitat that affect the level of threat to the species' continued persistence. The ESA requires that each of the factors that contributed to the species' listing be addressed in the recovery actions identified in the recovery plan.

The five listing factors are:

1. Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range
2. Over-utilization for Commercial, Recreational, Scientific, or Educational Purposes
3. Disease and Predation
4. Inadequacy of Existing Regulatory Mechanisms
5. Other Natural or Human-made Factors Affecting Continued Existence

NMFS' listing determinations regarding the rockfish DPSs (75 Fed. Reg. 22276, April 28, 2010, updated 79 Fed. Reg. 20802, April 14, 2014) and additional technical reports (e.g., Palsson et al. 2009; Drake et al. 2010; WDFW 2011) identified the factors of concern for rockfish. In 2016 we completed a 5-year review under the ESA which included a review of the listing factors (NMFS 2016). The review included updated information on threats and actions being implemented to address them and concluded that the collective risk to yelloweye rockfish and bocaccio of the Puget Sound/Georgia Basin's persistence has not changed significantly since the listing determinations in 2010. Below we summarize threats and sources of those threats identified in the listing documents and 5-year review which incorporated updated information available since 2010, noting potential threats that require more research to understand



AR020360

whether they are limiting rockfish recovery. Following the summary addressing all of the threats for listed rockfish throughout their range, there is a threats assessment that is broken down into the four geographically based management units in the United States, and one in Canada. The threats assessment conducted for each unit provides more detailed information on the level of threat from each source.

***Factor 1: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range***

Degradation and/or Loss of Nearshore Habitat

The nearshore provides important habitat for juvenile bocaccio, which most readily use rocky areas with and without kelp, and also use sandy areas and areas that support eelgrass (Moser 1967; Carr 1983; Kendall and Lenarz 1986; Love et al. 1991; Murphy et al. 2000; Love et al. 1991; Love et al. 2002). Macroalgae and eelgrass provide structure for feeding, predation refuge, and buffer against currents to enable energy conservation for juvenile bocaccio (Love et al. 1991).

The human population in the greater Puget Sound region has increased rapidly over the last three decades with approximately 4 million people residing in the Puget Sound region currently. Hutchinson (1988) indicated that overall losses by area of intertidal habitat were 58 percent for greater Puget Sound and 18 percent for the Strait of Georgia since European settlement. Four river deltas (the Duwamish, Lummi, Puyallup, and Samish) have lost more than 92 percent of their intertidal marshes (Simenstad et al. 1982). At least 76 percent of the wetlands around greater Puget Sound have been eliminated, especially in urbanized estuaries. Substantial declines of mudflats and sand flats have also occurred in the deltas of rivers draining to estuaries (Levings and Thom 1994). More recent estimates suggest that more than 80 percent of all tidal wetlands have been converted to human-dominated land uses (Collins and Sheikh 2005). Furthermore, nearly 52 percent of central Puget Sound and about 35 percent of the shorelines of Whidbey Island, Hood Canal, and South Puget Sound have been modified by humans (Nearshore Habitat Program 2001). A third of all Puget Sound shoreline is armored, and in south-central Puget Sound over 60 percent is armored (Simenstad et al. 2011).

The development of nearshore areas likely continues to degrade rearing habitats, such as kelp, and prey resources for rockfish (NMFS 2016), but for the first time (2014) it appeared that more shoreline armoring has been legally removed than installed (Dunagan 2015).

This development and loss of nearshore habitat impairs the productivity of some food sources for rockfish, and alters the quality of nearshore rearing habitats for juvenile bocaccio. For more information and research priorities see Appendix V, Nearshore Habitat and Kelp Conservation.

Degradation and/or Loss of Benthic/Deepwater Habitat

The known and potential threats of deepwater habitat include derelict fishing gear, dredging and sediment disposal, invasive species, artificial reefs (which could act to either augment or threaten habitat), alternative energy structures, and cable laying. Dredging and disposal activities may affect benthic habitats and water quality features; sediment plumes within the water column may disrupt the ability of rockfish to pursue prey, may temporarily reduce dissolved oxygen levels, and may obscure and homogenize depressions used by adult fish (NMFS 2014). The loss of rocky habitats as a result of sedimentation has been documented near the Skagit River delta (Grossman et al. 2007). Dredging often



AR020361

occurs in areas with a variety of contaminated sediments that can be released into the water column by the dredging and disposal process. These contaminants may be taken up by phytoplankton, zooplankton, benthic invertebrates, demersal fish, forage fish, and other fishes (Army Corps of Engineers 2010), which can then be bioaccumulated by long-lived predators such as rockfish. Additionally, Palsson et al. (2009) note that benthic habitat can also be degraded by construction of bridges, sewer lines, and other structures; deployment of cables and pipelines; and by burying from dredge spoils and natural subtidal slope failures.

Benthic habitats have benefited from the removal of thousands of derelict fishing nets, though deepwater derelict nets (NRC 2011) and the continued accumulation of derelict crab and shrimp pots (Antonelis et al. 2011; NRC 2013) change benthic habitats with uncertain impacts to habitat conditions. Some areas with contaminated sediments have been improved (Sanga 2015), yet pollutant loading continues, particularly in the Main Basin and the South Sound. See further details in Appendix IV Benthic Habitat Conservation and in Appendix VI, Sediment and Water Quality.

Invasive / Nonindigenous Species

Invasive or nonindigenous species are an emerging threat to biogenic habitat in Puget Sound. *Sargassum muiticum* is an introduced brown alga now common throughout much of Puget Sound (Drake et al. 2010). The degree to which *S. muiticum* influences native macroalgae, eelgrass, or rockfish is not understood (Drake et al. 2010). However, invasive *S muiticum* has been shown to compete with and impair the re-establishment of giant kelp forests in southern California (Ambrose and Nelson 1982). Several species of nonindigenous tunicates have also been identified in Puget Sound (Cordell et al. 2012). For example, *Ciona savignyo* was initially seen in one location in 2004, but within 2 years spread to 86 percent of sites surveyed in Hood Canal (Drake et al. 2010). The exact impact of invasive tunicates on rockfish or their habitats is unknown, but results in other regions (e.g., Levin et al. 2002) suggest the potential for introduced invertebrates to have widespread impacts on rocky reef fish populations by changing habitat conditions (Drake et al. 2010). For more information and research priorities see Appendix IV, Benthic Habitat Conservation.

Contaminants

Over the last century, human activities have introduced oil and a variety of other toxins into the Georgia Basin at levels that may affect rockfish populations or the prey that support them. The sources of these toxins range from oil and chemical spills, to chronic discharges from point (i.e., sewage) and non-point sources, such as surface water runoff from roads and developed areas. Evidence of decades of contaminant inputs are found in several urban embayments in Puget Sound that have high levels of heavy metals and organic compounds (Palsson et al. 2009), and about 32 percent of the sediments in the Puget Sound region are considered to be moderately or highly contaminated (Puget Sound Action Team 2007). Organisms that live in or eat these sediments are consumed, thus transferring contaminants up the food web to higher level predators like rockfishes and to a wider geographic area (Drake et al. 2010).

Not surprisingly, contaminants such as PCBs, chlorinated pesticides (e.g., DDT), and PBDEs appear in rockfish collected in urban areas (West and O'Neil 1998; West et al. 2001; West et al. 2001b). While the highest levels of contamination occur in urban areas, toxins can be found in the tissues of fish in all



AR020362

regions of Puget Sound (Puget Sound Action Team, 2007). Rockfish collected in rural areas of the San Juan Islands contained high levels of mercury and hydrocarbons (West et al. 2001).

Although few studies have investigated the effects of toxins on rockfish ecology or physiology, other fish in the Puget Sound region that have been studied do show a substantial impact. As an example, in English sole, a demersal fish in Puget Sound that may live in the same depth ranges as rockfishes, reproductive impairment has been documented in individuals from contaminated areas (Landahl et al. 1997). Rockfishes are longer-lived than English sole, and reproductive function of adult rockfish is also likely affected by contaminants (Palsson et al. 2009), and other life history stages may be affected as well (Drake et al. 2010). Some areas with good habitat structure for rockfish are also located in areas that are now subject to high levels of contaminants. This is evidenced by the fact that rockfish were historically captured in great numbers in these areas (Palsson et al. 2009; Puget Sound Action Team 2007; NOAA 2010).

Contaminants may influence growth rates of rockfish. For example, Palsson et al. (2009) describe a case in which male rockfish were found to have lower growth rates than females—an unusual pattern for rockfish because males typically grow faster than females. The explanation may be that male rockfish tend to accumulate PCBs while the female's body burden does not increase with time because they lower their toxin level when they release larvae (West et al. 2001b). Thus, the observed difference in growth rate may result from the higher contaminant concentration in males versus females (Drake et al 2010).

Rockfish rely to some degree on pelagic prey and thus may experience greater exposure to persistent bioaccumulative toxins, or bioaccumulants, across a greater spatial range (not just urban areas) than the discussion above suggests. Prey, such as Pacific herring in Puget Sound, have unusually high body burdens of toxins that can biomagnify in their predators. Long life span and residency in Puget Sound, both characteristics of the listed rockfish species, increase the risk of exposure. In addition, environmental levels of legacy toxins such as PCBs were probably higher in Puget Sound's pelagic species in the 1970s and 1980s, the period when the listed species declined (Drake et al. 2010).

Microplastics are an emerging concern for marine ecosystems. Microplastics come from large plastic trash that has been reduced into smaller particles or they may also come from manufactured plastics such as microbeads in products like facial soap, body wash, and toothpaste. Recent laboratory research experiments have found that European perch larvae exposed to microplastic particles at levels currently present in seas inhibited hatching of fertilized eggs, stunted larval growth, and decreased activity rates and predator-avoidance strategies, thus increasing mortality rates (Lönnstedt and Eklöv 2016). The larvae also preferentially ate microplastic particles instead of plankton. These findings may be of concern for many marine species because microplastic particles often accumulate in shallow coastal areas where developmental stages of many organisms in addition to fish occur (Lönnstedt and Eklöv 2016). For more information and research priorities on all contaminants see Appendix VI, Sediment and Water Quality.

<u>Nutrient Addition and Low Dissolved Oxygen</u>

In addition to chemical contamination, water quality in Puget Sound is influenced by sewage, animal waste, and nutrient input. Portions of Hood Canal have episodic periods of low dissolved oxygen, though the relative role of nutrient input from humans in exacerbating these episodes is in doubt (Cope and



AR020363

Roberts 2012). Typically, rockfish move out of areas with dissolved oxygen less than 2 mg/L; however, when low dissolved oxygen waters were upwelled to the surface in 2003, about 26 percent of the rockfish population was killed (Palsson et al. 2008). In addition to Hood Canal, periods of low dissolved oxygen are becoming more widespread in waters south of Tacoma Narrows (Palsson et al. 2009).

Ecology has been monitoring water quality in the Puget Sound region for several decades. Monitoring includes fecal coliform, nitrogen, ammonium, and dissolved oxygen. In 2005, of the 39 sites sampled, 8 were classified as highest concern, and 10 were classified as high concern. Hood Canal has seen persistent and increasing areas of low dissolved oxygen since the mid-1990s. For more information and research priorities see Appendix VII, Climate Change and Ocean Acidification.

***Listing Factor 2: Over-utilization for Commercial, Recreational, Scientific, or Educational Purposes***

Bycatch and Barotrauma

Historical overfishing played a major role in the declines of rockfish in Puget Sound (Palsson et al. 2009; Williams et al. 2010), and while fishery regulations continue to evolve and are markedly different than they were historically, the ongoing effects of fishing are long-lasting and may constitute an ongoing threat (Drake et al. 2010). Fishing can have dramatic impacts on the size or age structure of rockfish populations, with effects that can influence ongoing productivity because even minor levels of fishing can remove disproportionate numbers of older and larger fish (Drake et al. 2010). Notably, when the size and age of females declines, productivity declines because older and larger females release a higher number of larvae that are more equipped to survive because of a better developed oil globule that protects against the risk of starvation (Berkeley et al. 2004; Sogard et al. 2008). Additionally, in a broad range of species, there is evidence that age or size truncation is associated with increased variability in recruitment (Hsieh et al. 2006). When reproduction is limited to younger ages, the buffering capacity many long-lived species gain by reproducing over a number of years and over variable environmental conditions (Longhurst 2002) is lost and populations more closely follow short-term fluctuations in the environment (Hsieh et al. 2006). Palsson et al. (2009) found in a comparison of density and sizes of rockfish that

**What is Barotrauma?**

All rockfishes possess a closed swim bladder, a gas-filled organ that regulates buoyancy. When rockfish are brought up from deep waters, decreasing pressure allows the gas to expand, which can cause injury and prevent the fish from swimming back down on its own. External symptoms of gas expansion include a swollen and tight belly, stomach protruding into the mouth, and distended and/or bubbles in eyes (see picture below), which may all cause injury or death to the fish. For more information on barotrauma, including research priorities and techniques and tips to properly release rockfish, please refer to Appendix III, Barotrauma Research and Adaptive Management.

Canary rockfish caught in the San Juan Islands area during a genetics research project. This fish has barotrauma. Photo courtesy of Kelly Andrews.

fished areas result in lower abundance and smaller-sized fish than no-take marine protected areas. WDFW considers bycatch of rockfish to be a "high impact stressor" on rockfish populations (Palsson et al. 2009). WDFW estimates the bycatch from recreational fisheries on an annual basis, and has placed a moratorium on retaining rockfish in the Puget Sound and San Juan Islands. WDFW also closed several commercial fisheries that have rockfish bycatch. See Appendix II, Fisheries Management, for more information.

A study of yelloweye rockfishes indicated that when they are caught and released at the surface, the mortality rate is high; however, when they are released with a decompression device, survival may be high (Hochalter and Reed 2011). Other studies of rockfish released at depth indicate good short-term survival of released fish (Parker et al. 2006; Jarvis and Lowe 2008). One recent study found that short term (48 hours) survival for recompressed yelloweye rockfish was good (80 percent or higher) at a variety of depths of capture, while canary rockfish survival dropped to 25 percent at depths greater than 443 feet (135 m) (Hannah et al. 2014).

However, questions about long-term survival probability and effects on productivity and reproduction remain (Schroeder and Love 2002; Jarvis and Lowe 2008; Pribyl et al. 2009; Pribyl et al. 2011). There is some emerging evidence that female yelloweye rockfish can remain reproductively viable after recompression. A recent study conducted in Alaska found that recompressed female yelloweye rockfish remained reproductively viable a year or two after the event (Blain 2014) and one yelloweye rockfish in Hood Canal was observed as gravid several months after barotrauma by WDFW.

It is notable that when rockfish are released at depth using descending devices (recompression), there are many variables that may influence long-term survival, such as angler experience and handling, thermal shock, and depth of capture (Schroeder and Love 2002; Jarvis and Lowe 2008; Pribyl et al. 2009; Pribyl et al. 2011). Cox et al. (2007) found that bycatch mortality reduction measures implemented across a variety of resource users did not perform as well as the reduction measures implemented by managers and scientists (Cox et al. 2007). A recent study of boat-based anglers in Puget Sound revealed that few anglers who incidentally captured rockfish released them at depth (approximately 3 percent), while a small number of anglers attempted to puncture the swim bladder (Sawchuk 2012), which could cause bacterial infections or mortality.

Appendices II, Fisheries Management, and III, Barotrauma Research and Adaptive Management, summarize recommended research and actions to address bycatch and barotrauma.

### *Listing Factor 3: Disease and Predation*

#### Predation

Rockfishes are an important food resource for a variety of predators in Puget Sound (Palsson et al. 2009). There is little data regarding specific predators of yelloweye rockfish and bocaccio of the Puget Sound/Georgia Basin, thus we refer to available information regarding predation on *Sebastes* species generally. Rockfish are preyed upon by numerous fish species, birds, and several marine mammals (Mills et al. 2007; Lance et al. 2012; Buzzell et al. 2014). Larvae and juveniles are eaten by birds, salmon, rockfish, lingcod, and other fish species (Mills et al. 2007). Juveniles and adults are eaten by lingcod and some marine mammals (mostly pinnipeds) (Love et al. 2002; Palsson et al. 2009). As with many other marine fish species, as rockfish grow, their potential predators are generally reduced in number because of their larger sizes, physiological development, and behavioral changes (Gislason et al. 2010).

**How Do Adult Rockfish Deter Predators?**

- Yelloweye rockfish and bocaccio *live in deep waters*, thus reducing the time that diving marine mammals have to find them.
- They also *hide* in rocky, complex habitats, further deterring predation.
- At depth, their orange/tan coloration is a *cryptic black*, providing camouflage.
- Rockfish are deep-bodied and have long *dorsal spines* that inhibit consumption by gape-limited predators.
- Large and old adult fish are *too big* to be eaten by many predators, such as smaller lingcod and sea otters.
- Rockfish have *venom glands* at the base of their fins that sting and may deter predators.

Yelloweye rockfish. Photo courtesy of Florian Granier.

Adult yelloweye rockfish and bocaccio have several physical defenses and behaviors to reduce the likelihood of predators (Roche and Halstead 1972). They occupy deep waters, often near structure such as rock and boulders, where they can seek refuge and thus reduce their vulnerability to predation (Griffiths and Harrod 2007). Like other rockfish species, adults have venom glands at the base of their fins to deter predators. In addition, rockfishes are deep-bodied, with long dorsal spines that may inhibit gape-limited predators. These factors likely influence consumption rates of adult rockfish by some predators, such as pinnipeds. Common pinnipeds within Puget Sound include California sea lions (*Zalophus californianus*) and harbor seals (*Phoca vitulina*). Steller sea lions (*Eumetopias jubatus*), northern fur seals (*Callorhinus ursinus),* and northern elephant seals (*Mirounga angustirostris*) also occur in Puget Sound, but are less abundant than California sea lions and harbor seals.

Patterns of rockfish predation by marine mammals and fishes have been shown to exhibit temporal and spatial variation. In addition, the sizes and ages of rockfish that are vulnerable to predation vary by predator species and size. Rockfish predation by harbor seals, the most abundant pinniped species in Puget Sound and the most common pinniped in the San Juan Islands (Jeffries et al. 2000), varies annually by location and time of the year (Lance and Jeffries 2007). Harbor seal populations have increased from hundreds during the 1970s to more than 10,000 in the late 1990s, a 7- to 10-fold increase in estimated abundance; since the 1990s their population has remained stable (Jeffries et al. 2003). The harbor seal is the only pinniped species that breeds in Washington waters, and is the only pinniped with known haul-out sites in the San Juan Islands (Jeffries et al. 2000). Harbor seals are considered a threat to local fisheries in many areas (Olesiuk et al. 1990; Bjorge et al. 2002) and concerns have arisen about their impact on fisheries in Washington, Oregon, and California, where consumption of fish by California sea lions and harbor seals are estimated to be almost half of what was harvested in commercial fisheries in the late 1990s (NMFS 1997). Rockfish (of all species) occurred in 12 percent of harbor seal diets in the San Juan area in 2006 and 2007, compared to 2.3 percent in 2005 and 2006 (Lance and Jeffries 2007). Most of these rockfish were juveniles. However, in scat collection areas adjacent to marine reserves in the San Juan Islands, rockfishes composed little of harbor seal diets (Lance et al. 2012). Tagged harbor seals apparently do not forage inside marine reserves in the San Juan Islands (Peterson et al. 2012), and during the collection from 2005 to 2008, during all seasons rockfishes were found to be 0.0095 (or 16/1,682 scat samples) of harbor seal diets (Lance et al. 2012). Lance et al. (2012) suggest that the abundance of other species was an important factor in this low predation rate. The harbor seals fed primarily on species that are seasonally and regionally abundant, such as herring (year-round), adult salmon (in summer), and sand lance, anchovy, and juvenile walleye pollock (in winter and spring) (Lance et al. 2012). Recent analysis of harbor seal diets in the San Juan Islands found rockfish exceeding 10 percent of the average diet of all harbor seals combined, with relatively large proportions of black rockfish (*Sebastes melanops*), yellow rockfish (*S. flavidus*), copper rockfish (*S. caurinis*), and Puget Sound rockfish (*S. empaeus*). No listed rockfish were found in seal diets in this study (Bromaghin et al. 2013).

Rockfish were found in 1 percent of seal scats in Hood Canal (London et al. 2002). About 2,000 Steller sea lions occur seasonally in Washington waters, with dozens found in Puget Sound, particularly in the San Juan Islands (Palsson et al. 2009). About 8 percent of the Steller sea lion diet is rockfish (Lance and Jeffries 2007). Though not abundant, their large size and aggregated distribution suggest that their local impact could be nontrivial (Drake et al. 2010). Rockfish have been found as prey of killer whales (*Orcinus orca*) (Ford et al. 1998), but are not known to be a considerable component of the Puget Sound resident killer whales' diet (Palsson et al. 2009; Hanson et al. 2010). A study from the San Juan Islands showed that rockfish were present in 2.7 to 21.9 percent of river otter (*Lontra canadensis*) scat, depending on the sampling location (Buzzell et al. 2014). Juvenile rockfish occurred more frequently in river otter scat than adult rockfish. Rockfish predation by lingcod in the San Juan Islands also varied by season, site, and predator size (Beaudreau and Essington 2007).

Rockfish are a common component of lingcod diets, making up 11 percent of lingcod diet by weight, on average, and occurring in 10.5 percent of sampled lingcod stomachs in Puget Sound (Beaudreau and Essington 2007). Lingcod consumed rockfish ranging from 1.57 to 9.45 inches (4 to 24 cm) in standard length, but most of these were Puget Sound rockfish (*Sebastes emphaeus*), a small-bodied species. Total consumption of rockfishes by lingcod was 5 to 10 times greater in no-take marine reserves compared to nearby fished areas (Beaudreau and Essington 2009).

It is important to note that the impact of predation on rockfish cannot be determined from the quantity and frequency of rockfish occurrence in predator diets alone. Data on the sizes and quantity of rockfish consumed by predators must be used in combination with models that assess the ecological conditions in which predation has an influence on rockfish population dynamics.

Fifteen species of marine birds breed along the Washington coast, seven of which also breed in the San Juan Islands/Puget Sound area (Speich and Wahl 1989). The predominant marine birds in the San Juan Islands are pigeon guillemots (*Cepphus columba*), double-crested cormorants (*Phalacrocorax auritus*), pelagic cormorants (*Phalacrocorax pelagicus*), and members of the western gull and glaucous-winged gull complex (*Larus occidentalis* and *L. glaucescens*) (Speich and Wahl 1989). The first three species are locally abundant. Whether or not these avian predators have an impact on rockfish populations is unknown (Drake et al. 2010).

Disease

Infectious diseases may be a factor in both the decline of threatened or endangered wildlife species and in their recovery (Gaydos et al. 2004). Rockfish are susceptible to diseases and parasites (Love et al. 2002), but their impact on the listed rockfish is not known (Drake et al. 2010). Because rockfish are a long-lived species, diseases that affect fecundity or reproductive success could adversely affect the populations' size and viability (Gaydos et al. 2004). Additionally, small population sizes may make species more susceptible to disease (Gaydos et al. 2004), as may the relatively small home ranges of listed rockfish. Palsson et al. (2009) also suggest that stress associated with poor water quality may exacerbate the incidence and severity of naturally occurring diseases, thereby directly or indirectly decreasing survivorship of the listed rockfish, as has been seen in other fishes (Hershberger et al. 2002).

There are few data on diseases in *Sebastes* species generally, and fewer data on yelloweye rockfish and bocaccio, especially in the Puget Sound/Georgia Basin. Necropsies of 119 Puget Sound rockfishes (*Sebastes emphaeus*) captured by hook and line in four sites around San Juan Island and Shaw Island, Strait of Juan de Fuca/San Juan Basin in 2003 revealed intraerythrocytic blood parasites in approximately 45 percent of sampled fish (van der Straaten et al. 2005). The parasite was found in two distinct forms. Intraerythrocytic blood parasites had previously only been reported as "relatively rare" in fishes of the northeast Pacific Ocean, which may suggest it had previously gone undetected or unstudied, or that they represent an emerging infection (van der Straaten et al. 2005). In the same sites sampled by van der Straaten et al. (2005), 302 Puget Sound rockfishes (*S. emphaeus*) were captured and tested for *Ichthyophonus* infection (Halos et al. 2005). Ichthyophonus was found in approximately 11 percent of the fish tested; this parasite has also been found in canary rockfish, though not in the Puget Sound/Georgia Basin (Halos et al. 2005).

In coastal British Columbia, which is adjacent to but outside the range of the DPSs, a visible infection was identified and described as "black mold" in rockfishes that fishermen had brought to market (Conboy and Speare 2002). Fourteen visibly infected fish of various *Sebastes* species were tested to determine the cause of infection. Researchers found the main cause of infection was the intraepithelial deposition of eggs from a trichuroid nematode (genus *Huffmanela)*, coupled with an inflammatory response (Conboy and Speare 2002). There are several different species of *Huffmanela*, and this is the first documentation of the parasite in rockfish species in the northeast Pacific Ocean (Conboy and Speare 2002). Eight of the 14 rockfish tested also exhibited lymphocytic myocarditis associated with *Ichthyophonus hoferi.* This fungus commonly affects the heart muscle of Pacific herring, which are prey of rockfishes (Conboy and Speare 2002). All of the rockfishes also had low levels of the blood fluke miracidia in their gill pillar channels accompanied by interstitial bronchitis, which has previously been reported in other rockfishes on the Pacific coast of Canada (Conboy and Speare 2002). Finally, in 1995, 42 bocaccio collected by commercial fishermen in northern and southern California waters were found to have *Kudoa miniauriculata,* which in some cases can cause an inflammatory reaction. This parasite was found in over



AR020368

40 percent of the bocaccio tested; there are several other species of *Kudoa* known to be found in other fish species in both the Pacific and Atlantic Oceans off the United States (Whitaker et al. 1996).

***Listing Factor 4: Inadequacy of Existing Regulatory Mechanisms***

Bycatch

Despite increasingly restrictive regulations, rockfish are still incidentally taken in some recreational and commercial fisheries managed by WDFW and the tribes. As detailed under *Listing Factor 2: Over-utilization*, fishing can have dramatic effects on the size or age structure of the population (Drake et al. 2010). The effects can influence ongoing productivity because even minor levels of fishing can remove disproportionate numbers of older and larger fish (Drake et al. 2010), thereby shifting reproduction to younger and smaller-sized fish that produce fewer young that are also less able to survive starvation (Berkeley et al. 2004; Sogard et al. 2008). Many fisheries with rockfish bycatch have been closed (WDFW 2010b), but some fisheries (such as fisheries targeting spot prawn, halibut, and bottom fish) that may affect recovery remain open, and their impact is not well known because of insufficient bycatch data collection and a lack of population information in some areas in which these fisheries occur (see Section F. Conservation Measures, Research, and Monitoring for further discussion). Regulations enacted in 2010 restrict recreational anglers from retaining rockfish within the U.S. portion of the DPSs and anglers are also no longer allowed to fish deeper than 120 feet (36.6 m) for bottom fish (this does not include halibut) (WDFW 2014).

The majority of the existing marine protected areas (MPAs) in the U.S. portion of the DPSs do not encompass rockfish habitat and they were not intended to serve as a regional network for rockfish protection (75 Fed. Reg. 22276, April 28, 2010). The life-history characteristics that make rockfish vulnerable to overfishing also make them good candidates for protection in MPAs (Yoklavich 1998), and rockfish and other species with similar life histories have been key species for protection in networks of MPAs that have been developed in several states and countries, particularly on the west coast of North America in Alaska; British Columbia, Canada; Oregon; California; and Baja California Sur, Mexico. The WDFW has established 25 marine reserves within the DPSs, and 16 host rockfish (Palsson et al. 2009), though most of these reserves are within waters shallower than those typically used by adult yelloweye rockfish or bocaccio (75 Fed. Reg. 22276, April 28, 2010). Because most reserves in Puget Sound were established over several decades with unique and somewhat unrelated ecological goals, and encompass relatively small areas (average of 23 acres), the net effect of existing reserves to listed rockfish abundance, productivity, and spatial structure is probably very small (75 Fed. Reg. 22276, April 28, 2010). Less than 0.1 percent of Puget Sound is protected at the highest level of restriction as either no-take or no-access areas (Van Cleve et al. 2009; Osterberg 2012). Compared to fished areas, studies have found higher fish densities, sizes, or reproductive activity in the assessed WDFW marine reserves (Palsson and Pacunski 1995; Palsson 1997; Eisenhardt 2001; Palsson et al. 2004). WDFW's 2011 Puget Sound Rockfish Conservation Plan also calls for a network of MPAs for recovery (WDFW 2011) but pursuing this management approach has recently been de-emphasized by WDFW (WDFW 2015).

In general, the characteristics of a network of reserves that are relevant to enhancing populations of yelloweye rockfish and bocaccio include sites in each of the major regions of the DPSs, and sites that provide some connectivity to each other for larvae transport (75 Fed. Reg. 22276, April 28, 2010).



AR020369

Finally, the sites would need to be large enough to collectively encompass quality and diverse habitats that facilitate productivity of individual fish and reserve resiliency to outside disturbances and stressors (Sobel and Dahlgren 2004).

Most tribes in the Puget Sound region limit rockfish harvest to subsistence only with no targeted commercial fisheries for rockfish. Perhaps the greatest threat of rockfish bycatch from tribal fisheries occurs in the commercial halibut fishery in the San Juan/Strait of Juan de Fuca area (MCAs 9, 6, and 7).

In 2007, the Canadian government designated approximately 135 rockfish conservation areas (RCAs) that encompass 30 percent of the area of the inside waters of Vancouver Island. These reserves do not allow directed commercial or recreational harvest for any species of rockfish, nor do most allow harvest of marine species that may incidentally catch rockfish (NOAA 2010). These RCAs have been shown thus far to have good compliance within the commercial fishing industry because of the use of boat tracking technology, but they likely have low recreational compliance; therefore, increased education, outreach, and enforcement is recommended (Haggarty 2014).

Appendix II, Fisheries Management, discusses in-depth steps to limit bycatch.

***Listing Factor 5: Other Natural or Human-Made Factors Affecting Continued Existence***

Genetic Changes

*Inbreeding*

Smaller and more isolated populations are more vulnerable to external environmental changes (Keller and Waller 2002) and more prevalent inbreeding, or mating, between closely related individuals (Hoglund 2009), which reduces fitness. There are no known published studies regarding inbreeding in rockfish; thus, we look to other species to understand the potential effects of inbreeding. Small populations may have limited potential for adaptive evolution to environmental disturbances because of reduced genetic diversity (Franklin and Frankham 1998; Willi et al. 2006). The synergistic effects between inbreeding and environmental disturbance can be extensive and have been studied in both laboratory and wild populations. Laboratory reared zebrafish (*Danio rerio*) exposed to chemicals (in this case to the fungicide clotrimazole), for example, exhibited more greatly intensified deleterious effects of inbreeding on key reproductive traits compared to zebrafish that were inbred but not exposed to the chemicals (Bickley et al. 2012). In harbor seal pups, inbreeding as measured by multi-locus heterozygosity of 14,585 RAD loci explained 49 percent of the variance in lungworm infestation (Hoffman et al. 2014). The interaction may cause increased selection for less inbred individuals, which may reduce average individual reproductive success and therefore population productivity (Forcada and Hoffman 2014).

The contribution of inbreeding to extinction risk compared to demographic factors is still unresolved. A study combining a meta-analysis of inbreeding effects in birds and mammals and stochastic population projections applying these estimates concluded that average inbreeding reduced median times to extinction by an average of 37 percent (O'Grady et al. 2006). Other studies found limited genetic contribution to extinction risk (Wootton and Pfister 2013). Nevertheless, the more precautionary principle is to assume such effects, supported by findings that loss of genetic diversity generally precedes population collapse and extinction (Frankham 2005).



AR020370

For listed rockfish specifically, the interaction between inbreeding and a stressful environment may be significant. There have been decades of contaminant inputs in several urban embayments in Puget Sound, which now have high levels of heavy metals and organic compounds (Palsson et al. 2009), and about 32 percent of the sediments in the Puget Sound region are considered to be moderately or highly contaminated (Puget Sound Action Team 2007).

*Hybridization*

Reduced population sizes may induce or increase the rate of hybridization (Currat et al. 2008), which may occur between populations within species or between species. Intraspecific hybridization with coastal conspecifics may lead to the genetic dilution and possible extinction of locally adapted populations. Depending on the genetic differentiation between populations and intrinsic reproductive barriers, hybridization may result in a range of effects, from an increase of fitness because of hybrid vigor, to a reduction in fitness as a result of outbreeding depression (McClelland and Naish 2007). Hybrid vigor is commonly only observed in highly inbred populations (Hedgecock and Davis 2007), though it can lead to the genetic rescue of such populations (Tallmon et al. 2004). More common in marine species is probably outbreeding depression, which reduces fitness in hybrids between locally adapted populations. In Atlantic cod, for example, reproductive barriers among geographically proximate populations appear to be sufficiently strong to prevent backcrossing, even though F1 hybrids between populations were found (Bradbury et al. 2014). Many *Sebastes* species are further along the speciation continuum, and cryptic species were recently found in several *Sebastes* groups (e.g., vermillion rockfish (*S. miniatus*) (Hyde et al. 2008), rougheye rockfish (*S. aleutianus*) (Gharrett et al. 2005), Southern Hemisphere rockfishes (Rocha-Olivares et al. 1999), Atlantic *Sebastes* (Daníelsdóttir et al. 2008). These findings suggest at least the possibility of incipient speciation of listed rockfish. If so, hybridization between Puget Sound/Georgia Basin and coastal populations may result in a potential extinction of the DPS as defined. Such intraspecific hybridization would be difficult to detect other than by genetic approaches, making genetic monitoring of the population essential.

Interspecific hybridization has been described for both Pacific and Atlantic species of *Sebastes,* and may also pose a threat to the integrity and existence of listed rockfish. Extensive hybridization between copper (*S. caurinus*), quillback (*S. maliger*), and brown (*S. auriculatus*) rockfish was found in Puget Sound, possibly because of the very different abundance of those species (Schwenke 2012). Up to 40 percent of sampled fish were hybrids, though no F1 hybrids were found (Schwenke 2012). This suggests weak reproductive barriers, even though the three species have not formed a hybrid swarm and are morphologically easily distinguishable. In Atlantic *Sebastes* species, hybridization appears to be widespread (Roques et al. 2001; Pampoulie and Daníelsdóttir 2008; Artamonova et al. 2013). Although there is no evidence for hybridization in listed rockfish, loss of genetic identity of threatened and endangered rockfish species because of hybridization may become a serious concern if population sizes stay at low levels.

*Hatchery Supplementation*

Although not currently an issue, genetic changes as a result of any future rockfish aquaculture/hatchery practices and trans-basin introductions may alter the genetic structure of wild rockfish stocks (Palsson et al. 2009). However, there is little research on the topic specifically regarding rockfish, making the threat



AR020371

difficult to assess (Palsson et al. 2009). A recent review by NOAA on genetic risks of marine aquaculture and stock enhancements lists three main types of adverse genetic change to wild populations: 1) loss of genetic diversity within populations, 2) loss of diversity among populations, and 3) loss of fitness (Waples et al. 2012). Most of these effects are well known from Pacific salmon (*Oncorhynchus* spp.), where hatchery supplementation has mitigated effects of dam construction, habitat destruction, and exploitation, but has also caused considerable issues with genetic integrity and fitness of endangered populations (Ford 2002; Naish et al. 2008). Because of the high fecundity of marine fishes such as rockfish, such effects of domestication selection and 'swamping' of wild populations are probably more pronounced (Waples et al. 2012). Any supplemental breeding program for listed rockfish should be well-considered and executed with clear goals, balance the extinction risk with the possible adverse genetic changes, and take measures to minimize possible adverse genetic changes or introduction of diseases into wild populations.

<u>Competition</u>

Rockfishes are known to partition their food and habitat resources (Larson 1980; Carr 1991). Harvey et al. (2006) used bioenergetics models to suggest that recovery of coastal populations of bocaccio may be inhibited by more common species of rockfish congeners. In Puget Sound, more abundant species, such as copper and quillback rockfish, may interact with juvenile yelloweye or bocaccio rockfish and share food and habitat resources. Evidence documenting competition among rockfishes in Puget Sound is generally lacking (Drake et al. 2010), and competition among marine fishes is difficult to demonstrate empirically in the wild (Link and Auster 2013).

<u>Release of Propagated Fish</u>

Chinook salmon (*Oncorhynchus tshawytscha)* and coho salmon (*Oncorhynchus kisutch*) consume larval and juvenile rockfish, and also compete for prey with small size classes of rockfish (Buckley 1997); thus, large releases of hatchery salmon have the potential to influence the population dynamics of listed rockfish. Hatchery releases of delayed release (yearling) Chinook salmon and coho salmon into Puget Sound occur, and delayed release of hatchery fishes are more likely to stay in Puget Sound (Palsson et al. 2009), where they could potentially consume rockfishes.

<u>Derelict Fishing Gear</u>

New and existing derelict fishing gear, such as lost fishing nets and shrimp pots, alter benthic habitats and likely kill yelloweye rockfish and bocaccio, and/or their prey (NRC 2008). Lost crab pots are prevalent in Puget Sound and alter habitat, but derelict crab pots have been found to result in very low catch of rockfish (two rockfish found in nearly 3,000 derelict crab pots removed) (K. Antonelis, electronic mail, NRC, December 10, 2013). Commercial gill nets are the majority of derelict nets in Puget Sound (Good et al. 2010). An estimated 16 to 42 gill nets are lost annually in Puget Sound salmon fisheries (NRC 2010). It is estimated that around 12,000 commercial and recreational crab pots are lost, and an estimated 523 to 893 shrimp posts are lost annually in Puget Sound (Antonelis et al. 2011; NRC 2014). Actively fished shrimp pots result in bycatch of juvenile rockfish in the Puget Sound/Georgia Basin (Favro et al. 2010; NRC 2014), and are estimated to result in a low of 253 to a high of 2,809 caught rockfish (of a



AR020372

variety of species) in Puget Sound annually (NRC 2014). Derelict shrimp pots can result in bycatch of juvenile rockfish, but no estimates of annual bycatch have been developed to date (NRC 2014).

Derelict gear may also cause degradation to habitat where it is ensnared through scouring, obstructing, and sediment entrapment (Gilardi et al. 2010; Good et al. 2010; Antonelis 2013). Specifically, fine sediments may be trapped out of the water column, making a layer of soft sediment over rocky areas, changing habitat quality and suitability for benthic organisms (Good et al. 2010). Lost nets can cover habitats used by rockfish for shelter and pursuit of food, rendering the habitat unavailable, and can also reduce the abundance and availability of rockfish prey that include invertebrates and fish (Good et al. 2010).

Copper rockfish (top) in a derelict shrimp pot. Canary rockfish (bottom) in a derelict gill net. Photos courtesy of Natural Resources Consultants.

As of the end of 2013, the Northwest Straits Foundation (NWF), in partnership with the WDFW and volunteers, has removed 4,605 derelict fishing nets (primarily gillnets), 3,173 crab pots, and 47 shrimp pots from Puget Sound over the course of 11 years. There is an estimate of 274 remaining nets in shallower water (< 105 feet [32 m]) and at least 205 are in deeper water (> 105 feet [32 m]) (NWSI 2014b). Appendix IV, Benthic Habitat Conservation, summarizes recommended research and actions to address derelict fishing gear.

Climate Change

Global carbon dioxide ($CO_2$) concentrations have increased from approximately 280 ppm 250 years ago to present levels of approximately 387 ppm, and nearly half of this increase has occurred in the past 3 decades (IPCC 2007). Approximately one-third of the $CO_2$ produced in the last 200 years has been taken up by the oceans (Sabine et al. 2004). The effects of climate change include, but are not limited to, changes in temperature; distribution shifts of species; changes in primary production; changes in biodiversity; declining mid-water oxygen concentrations; changes in upwelling and vertical mixing; sea-level rise; expanding ocean dead zones; an increase in the magnitude, frequency, and duration of harmful algal blooms; erosion; and more severe and frequent inundation from the combined effects of rising sea levels and intensified and more frequent storms (Harley et al. 2006; IPCC 2007; Feely et al. 2008; Fabry et al. 2008; Moore et al. 2008; Brewer and Peltzer 2009; Nicholls and Cazenave 2010; Ainsworth et al. 2011; Feely et al. 2012; Dalton et al. 2013; others).

Climate change can affect the benthic, pelagic, and nearshore environments of rockfish. In November 2015, the Climate Impacts Group at the University of Washington released “State of Knowledge: Climate Change in Puget Sound” (Mauger et al. 2015). The report summarizes how climate change will likely affect the Puget Sound region by altering climate-related factors that shape the local environment. These key factors include temperature, precipitation, heavy rainfall, sea level, and ocean acidification (Mauger



AR020373

et al. 2015). The changes in these factors have implications for changes in freshwater resources, sediment transport, and ecosystems, and consequences for marine waters, coastal and marine ecosystems, water quality, water circulation, species distributions, and timing of biological events (Mauger et al. 2015). It is still unknown to what extent climate change will affect listed rockfish.

Direct studies on the effect of climate variability on rockfish are rare, but all studies performed to date suggest that climate plays an extremely important role in population dynamics. Tolimieri and Levin (2005) examined the effects of climate variability on bocaccio recruitment. They found that the dynamics of bocaccio populations were governed by rare recruitment events, and that these rare events resulted when specific climate conditions (such as various combinations of temperature and upwelling regimes) occurred at different times in their early life history. The coincidence of such climate patterns only occurred 15 percent of the time. Harvey (2005) created a generic bioenergetics model for rockfish, finding that productivity of rockfish is highly influenced by climate conditions, such that El Niño-like conditions generally lowered growth rates and increased generation time. The negative effect of the warm water conditions associated with El Niño appears to be common across rockfishes (Moser et al. 2000). Field and Ralston (2005) noted that recruitment of all species of rockfish appeared to be correlated at large scales and hypothesized that such synchrony was the result of large-scale climate forcing. Exactly how climate influences listed rockfish in the Puget Sound/Georgia Basin is unknown; however, given the general importance of climate to Puget Sound and to rockfish, it is likely that climate strongly influences the dynamics of the listed species (Drake et al. 2010). Appendix VII further outlines climate change effects, local monitoring, and recommended research.

Ocean Acidification

Ocean acidification (OA) is a result of increased atmospheric carbon dioxide. The projected pH decrease is 0.3 to 0.4 for the 21st century, equivalent to an approximately 150 percent increase in $H^+$ and a 50 percent decrease in $CO_3^{2-}$, which is essential for the biology and survival of a wide range of marine organisms (Fabry et al. 2008; Doney et al. 2009). The west coast of the United States is particularly vulnerable to enhanced OA associated with seasonal upwelling because the Pacific Coast's continental shelf is relatively narrow (Feely et al. 2010).

OA will adversely affect calcification, or the precipitation of dissolved ions into solid calcium carbonate structures, for a number or marine organisms, which could alter trophic functions and the distribution and/or availability of prey (Fabry et al. 2008; Feely et al. 2010).

Pteropods (*Euthecosomatous pteropods*), which require $CaCO_3$ to form their shells, may be first among the major groups of planktonic calcifiers to experience reduced calcification (Fabry et al. 2008). Though effects of a reduction in this prey species on rockfish have not been studied, in pink salmon (*Oncorhynchus gorbuscha*) it was found that a 10 percent decrease in pteropod production could lead to a 20 percent decrease in mature body weight (Fabry et al. 2008).

Fertilization rates, early development, and larval size are negatively affected by high $CO_2$ concentrations in a number of groups such as sea urchins, some molluscs, and copepods (Fabry et al. 2008), which are important prey items for larval and juvenile rockfish (Love et al. 1991; Love et al. 2002).



AR020374

In addition to altering the food web, OA can alter the physiology, metabolism, and reproductive biology of fishes. Increased temperature and OA have been linked to impaired immune systems of marine organisms, such as shellfish and fishes, and increased disease frequency (Feely et al. 2012). There have been very few published studies to date on direct effects of OA on rockfish. In other fishes, there is evidence that ocean acidification could have serious consequences on behavior and sensory functions important to recruitment, settlement, prey and predator detection, and overall survival (e.g., Munday et al. 2009; Simpson et al. 2011; Chung et al. 2014). In a laboratory setting, OA did result in changes to juvenile splitnose rockfish (*Sebastes diploproa)* behavior (Hamilton et al. 2014). More research is needed to better understand the effects of OA on rockfish and their ecosystems and to evaluate if this threat is limiting listed rockfish recovery. Appendix VII further details the effects of OA, local monitoring efforts, and suggested research.

<u>Anthropogenic Noise and Vessel Traffic</u>

Little is known about the overall effect of anthropogenic noise levels on fishes (Popper and Hastings 2009). A recent study of coral reef fish larvae found that traffic noise may have a disruptive effect on larvae orientation and settlement (Holles et al. 2013), which are important to finding appropriate habitat to many marine fishes, including rockfishes. Air guns have been shown to significantly depress catch rates of some commercial fish species (Skalski et al. 1992; Engas et al. 1996), and pile driving may also have negative effects on fishes (Popper and Hastings 2009). Catch rates of *Sebastes* species in the commercial hook-and-line fishery along the central California coast (including bocaccio) exposed to a single 1639-$cm^3$ air gun with a source level of 223 dB re 1µPa were found to decline in catch per unit effort (CPUE) by approximately 52 percent compared to control trials (Skalski et al. 1992). Other effects on commercially harvested fish include movement out of preferred habitat, which is a hypothesized explanation for lower catch rates, reduced reproductive performance, and hearing loss, indicating that noise could have fitness consequences (Slabbekoorn et al. 2010).

Regionally, vessel traffic within Admiralty Inlet is high and is increasing (Bassett et al. 2012). Cargo ships, tugs, and passenger vessels all contribute to elevated noise levels (approximately 120 decibels or greater) (Basset et al. 2012) and may affect rockfishes. Noise from Navy training exercises may also affect rockfishes, but no studies have been conducted on possible effects from Northwest Training Range exercises on fish. These exercises can include surface-to-air gunnery and missile exercises; anti-submarine warfare exercises involving tracking aircraft, sonobuoys, and use of surface ship sonar; air-to-surface bombing exercises; and sink exercises.

Few published studies assess mortality from vessel traffic on fishes. Ichthyoplankton, such as larval rockfishes, may be particularly susceptible to mortality because they are unable to swim away from traffic and thus may be harmed by propellers and turbulence (Bickel et al. 2011). One study has shown that although mortality is low, larval loss may be size dependent and smaller larvae will be more susceptible to mortality (Kilgore et al. 2001). Another recent study assessed mortality on copepods, prey of rockfish and many other marine organisms, and suggested that marine food webs may be affected, especially in more enclosed areas (Bickel et al. 2011).



AR020375

***Summary of Threats Assessment***

The Recovery Team assessed current and expected future threats to listed rockfish persistence and recovery within each of the management unit basins. To develop this threats assessment, we evaluated the best available information regarding habitat, fisheries, prey, listed rockfish conditions, and other factors.

Below we summarize the threats for each management unit where sufficient information is available. Where there is not enough information at the management-unit scale, we provide a summary for the whole Puget Sound/Georgia Basin. Due to the complexities of fisheries in the DPSs, we also include a separate assessment based on effort and gear-type below (see also Tables 6-8). Detailed summaries of all of the threats are found below this summary table (Tables 9-13). The risk in Table 5 was calculated by considering the severity of the threat, the level of certainty the listed species are affected, the geographic range of the threat, and the likelihood that the actions outlined in this plan may reduce the threat.

Table 5. Summary of Threats Assessment for Management Units and Puget Sound/Georgia Basin.

| | **Listing Factor** | **Canada** | **San Juan** | **Main Basin** | **South Sound** | **Hood Canal** |
|---|---|---|---|---|---|---|
| Derelict Fishing Gear | E | 1 | 1 | 2 | 4 | 4 |
| Commercial Catch/Bycatch | B, D | 3 | 1 | *3 | 3 | 3 |
| Recreational Catch/Bycatch | B, D | 3 | 1 | 2 | 3 | 4 |
| Nearshore Habitat Disruption | A | 4 | 3 | 1 | 1 | 2 |
| Deepwater Habitat Disruption | A | 3 | 3 | 3 | 3 | 3 |
| Non-native Species Habitat Disruption | E | P | P | P | P | P |
| Hypoxia/Nutrient Addition | E | 4 | 4 | 3 | 2 | 1 |
| Chemical Contamination/Bioaccumulants | A | 3 | 3 | 1 | 1 | 2 |
| Puget Sound/Georgia Basin | | | | | | |
| Marine Mammal Predation | C | 4 | | | | |
| Fish Predation/Hatchery Practices | C, E | 4 | | | | |
| Competition | C | P | | | | |
| Diseases | C | P | | | | |
| Oil Spills | E | 1 | | | | |
| Genetic Changes (Inbreeding/Hybridization) | E | P | | | | |
| Anthropogenic Noise | E | P | | | | |
| Ocean Acidification | E | 1 | | | | |
| Climate Change | E | 1 | | | | |

A = Present or threatened destruction, modification, or curtailment of its habitat or range
B = Over-utilization for commercial, recreational, scientific, or educational purposes
C = Disease or predation
D = Inadequacy of existing regulatory mechanism
E = Other natural or manmade factors affecting its continued existence
1 = High risk
2 = Moderate risk
3 = Low risk
4 = Very Low risk
P = Potential threat. Not enough information to determine if it is a threat at the current time, but could plausibly become a threat in the future.
*Further information required to assess the extent and effects of commercial fisheries in this area and this ranking could change.



AR020376

***Threats Assessment for Fisheries***

Past fishing is very likely a primary cause of the depletion of listed rockfish (Palsson et al. 2009; Drake et al. 2010), yet the threat that fishing creates today and for the next several decades is less certain. To inform management actions recommended in this plan, we assess the relative threat of catch/bycatch for listed rockfish for fisheries within the U.S. portion of the Puget Sound/Georgia Basin, with narratives for fisheries with larger potential to catch listed rockfish. We also provide a narrative for each of the management units based on the known existing fisheries that occur in each area. For many of these fisheries we do not have reliable bycatch numbers or estimates for listed rockfish; thus, we assess the catch risk qualitatively based on the characteristics of effort and gear-type (Table 6).

Table 6. Known fisheries in Puget Sound and their relative risk of rockfish bycatch. This table has been modified from WDFW's incidental take permit from 2012, but also incorporates updated information and known tribal fisheries. "Commercial" may refer to tribal or non-tribal commercial fisheries.

| Type | License Group/ Gear | Potential to Encounter Listed Rockfish | Fishery Access (WDFW) | Comments |
|---|---|---|---|---|
| **MARINE FISH** | | | | |
| **Commercial** | Forage fish lampara net | Low | Open access | This gear type has little or no risk of bycatch. |
| | Forage fish drag seine | None | Open access and limited entry | This gear type has no risk of bycatch. |
| | Herring dip net | None | Limited entry | Fishery closed because of low abundance. |
| | Herring purse seine | Low | Limited entry | Fishery closed because of low abundance. |
| | Halibut longline (tribal fishery only) | High | Limited entry | This gear type has high potential for rockfish bycatch. |
| **SALMON** | | | | |
| **Commercial** | Gill net | Low | Limited entry | These fishing methods target the midwater zone which is likely not occupied by listed rockfish. |
| | Purse seine | Low | Limited entry | |
| | Reef net | Low | Limited entry | Does not fish in deep waters, thus avoiding listed adult rockfish, and mesh size too large for juvenile listed rockfish. |
| | Beach seine | Low | Limited entry | Does not fish in deep waters, thus avoiding listed adult rockfish, and mesh size too large for most juvenile listed rockfish. |
| **SHELLFISH** | | | | |
| **Commercial** | Crab ring net | None | | These gear types have little or no risk of rockfish bycatch. |
| | Clam mechanical harvester | None | | |
| | Burrowing shrimp | None | Open access | |
| | Shrimp trawl | Low | Limited entry | This gear fishes non-rugose habitat, but very limited rockfish bycatch may still occur. |



AR020377

| Type | License Group/ Gear | | Potential to Encounter Listed Rockfish | Fishery Access (WDFW) | Comments |
|---|---|---|---|---|---|
| | Squid | | None | Open access | These gear types have little or no risk of rockfish bycatch. |
| | Dungeness crab pot | | Low (mostly derelict gear) | Limited entry | |
| | Geoduck dive | | None | | |
| | Sea cucumber dive | | None | Limited entry | |
| | Sea urchin dive | | None | Limited entry | |
| **OTHER FIN FISH** | | | | | |
| **Recreational** | Salmon | Hook-and-line | Moderate | Unlimited entry | Risk depends on fishing method (e.g., trolling, jigging, mooching) and proximity to complex habitat. High effort in this fishery. See discussion in *threats* section below. |
| | Halibut | Hook-and-line | High | | Similar habitats are fished. |
| | Halibut | Spear fishing | None | | Divers should be sure of species identification (ID) before shooting (no rockfish of any species can be targeted). |
| | Lingcod | Hook-and-line | High | | Habitats are the same and listed rockfish typically co-occur. 120-foot rule may reduce bycatch risk. |
| | Lingcod | Spear fishing | None | | Divers should be sure of species ID before shooting. |
| | Other bottom fish | Hook-and-line | Moderate | | Risk depends on fishing method, target species, and habitat. 120-foot rule may reduce bycatch risk. |
| | Other bottom fish | Spear fishing | None | | Divers should be sure of species ID before shooting and no rockfish of any species are allowed. |
| | Forage fish | Hook-and-line | None | | This gear type has little or no risk of bycatch. |
| | Forage fish | Dip net | None | | This gear type has little or no risk of bycatch. |
| **SHELLFISH** | | | | | |
| **Recreational** | Crab | Ring and trap | Low | Unlimited entry | This gear type has little or no risk of bycatch. |
| | Crab | Dip net | None | | |
| | Shrimp | Pot | Low to Moderate | | Risk depends on habitat fished; bycatch of juveniles can occur. |
| | Squid | Hook-and-line | None | | Conducted from piers. This gear type has little or no risk of bycatch. |
| | Bivalves | Shovel or tube | None | | Intertidal. This gear type has no risk of bycatch. |

Listed rockfish are caught by some recreational fisheries targeting other species, particularly salmon, bottom fish, and halibut. The WDFW estimates the number of recreational fishing trips as part of their catch estimate calculations. (See Table 7 for annual estimates from 2010-2014.)



AR020378

Table 7. Annual estimated recreational fishing trips in the U.S. portion of the Puget Sound/Georgia Basin; estimates from WDFW from 2010-2014.

| Recreational Fishing Trips with Rockfish Bycatch Potential | San Juan /Strait of Juan de Fuca (annual number of individual fishing trips) | Main Basin | Hood Canal | South Sound |
|---|---|---|---|---|
| Target Species: salmon | 87,395 | 291,469 | 11,208 | 24,587 |
| Target Species: bottom fish | 15,640 | 21,846 | 606 | 6,020 |
| Target Species: halibut | 11,738 | 2,579 | 132 | 0 |
| Target Species: other | 3,098 | 10,475 | 2,219 | 3,247 |
| TOTAL | 117,871 | 326,369 | 14,060 | 33,854 |

Salmon Fisheries and Rockfish Bycatch Risk

The vast majority of recreational fishing trips in the Puget Sound/Georgia Basin target Chinook, coho, pink, chum, and sockeye salmon. Recreational and commercial salmon fishers use diverse equipment, with each gear type having a different risk of incidentally catching yelloweye rockfish and bocaccio. Based on data collected through creel surveys between 1986 and 1999, Palsson (2002) estimated anglers targeting salmon in Puget Sound caught 0.65 groundfish, including 0.05 rockfish per angler trip. The incidental groundfish catch, and likely rockfish catch, varied by marine catch area from a high of 2.09 groundfish per angler trip in Marine Catch Area 5 (Sekiu-Pillar Point), to a low of 0.024 groundfish per angler trip in Marine Catch Area 11 (Tacoma-Vashon) (Palsson 2002; NMFS 2004). The WDFW salmon fishery test boat uses recreational fishing gear, and from 2003 to 2016 has not caught a yelloweye rockfish or a bocaccio (WDFW 2016), yet the net impact from the salmon fishery on listed rockfish may be larger than other fisheries sectors because of the large number of fishing trips (Palsson et al. 2009). Aside from the test boat data, we do not have detailed data sets that explain bycatch for many of these fishing gears and sectors; thus, we conduct a qualitative description of them and highlight data/estimates of bycatch where it is available.

Many recreational salmon anglers use downriggers that consist of cables and weights that deliver fishing gear to specific depths, mostly while trolling artificial lures. A smaller fraction of recreational salmon fishers, often referred to as ‘moochers,’ use 1 to 6 ounces of weight with herring as bait, and free-drift or slowly troll. Some anglers also use weighted artificial lures and free drift while jigging. Salmon and rockfish both consume some similar or identical prey items that include herring, sand lance, and smelt, making them vulnerable to the use of herring as bait and fishing lures imitating these prey items. As a result, anglers targeting salmon occasionally unintentionally hook yelloweye rockfish and bocaccio. Though the frequency of listed rockfish bycatch by recreational salmon anglers is extremely low, the large numbers of angler trips nonetheless results in measurable incidental catches. Most methods of recreational salmon fishing have the potential to encounter listed-rockfish, with the risk increasing the deeper the gear is fished.

The WDFW estimates the annual bycatch of rockfish from anglers targeting salmon, halibut, bottom fish and other marine fishes. There are a number of uncertainties regarding the WDFW recreational fishing bycatch estimates because: 1) they are based on dockside (boat launch) interviews of 10 to 20 percent of



AR020379

fishers, and anglers whose trips originated from a marina are generally not surveyed; 2) since rockfish can no longer be retained by fishermen, the surveys rely upon fishermen being able to recognize and remember rockfish released by species. Recent research has found the identification of rockfish to species is poor; only 5 percent of anglers could identify bocaccio and 31 percent yelloweye rockfish in a study performed throughout the Puget Sound region (Sawchuk et al. 2015); and 3) anglers may under- report the numbers of released fish. A study in Canadian waters compared creel survey reports to actual observer generated information on recreational fishing boats in the Southern Georgia Strait. Substantial differences were documented, with the number of released rockfish observed significantly higher than the number reported by recreational anglers during creel surveys (Deiwert et al. 2005).

These factors could make the actual bycatch of yelloweye rockfish or bocaccio higher or lower than WDFW's estimates. There is additional uncertainty regarding these estimates because WDFW continues to change the methodology to calculate them; thus, we show data from each method to represent a potential range of bycatch for yelloweye rockfish and bocaccio. WDFW has provided bycatch estimates from the 2003 through 2009 time period (WDFW 2011b) and provided updated catch estimates for the 2003 through 2011 time period (WDFW 2014a). The previous (WDFW 2011b) estimates have larger yelloweye and bocaccio bycatch numbers than the new estimates even though they span the same time period from 2003 through 2009 (the new estimates include the years 2010 and 2011). WDFW's estimates of rockfish bycatch from 2014 are similarly small, with the exception of bocaccio. In 2014, WDFW estimated that 132 bocaccio where caught by anglers targeting salmon (all in the San Juan Islands area). The average annual estimated bycatch of yelloweye rockfish from salmon anglers ranges from 4 (WDFW 2014a) to 111 (WDFW 2011b) fish. The average annual estimated bycatch of bocaccio from salmon anglers ranges from 2 (WDFW 2014a) to 132 (WDFW 2011b) fish. Note that it is likely that not all of these fish are killed when they are caught as bycatch (see Appendix III, Barotrauma Research and Adaptive Management).

Most commercial salmon fishers in Puget Sound use purse seines and gill nets (WDFW 2010a). A relatively small number of salmon are harvested within the DPS by reef nets and beach seines. Gill nets and purse seines rarely catch rockfish of any species because of the way they are used. From 1990 to 2008, no rockfish were recorded caught in the purse seine fishery (WDFW 2010a). In 1991, one rockfish (of unknown species) was recorded in the gill net fishery, and no other fish were caught through 2008 (WDFW 2010a). Low encounter rates may be attributed to a variety of factors. For each net type, the mesh size restrictions that target salmon based on size tend to allow juvenile rockfish to pass through. Gill net and purse seine operators also tend to avoid fishing over rockfish habitat, as rocky reef structures can damage their gear. In addition, nets are deployed in the upper portion of the water column away from the deeper water rockfish habitat, thus avoiding interactions with most adult rockfish. In the mid-1990s commercial salmon net closure zones were established in much of Puget Sound for seabird protection. Some of these closed areas overlap with rockfish habitat, reducing the potential for encountering rockfish. Specific areas are: 1) a closure of the waters inside the San Juan Islands, 2) a closure extending 1,500 feet (457.2 m) along the northern shore of Orcas Island, and 3) closure of waters 3 miles from the shore inside the Strait of Juan de Fuca (WDFW 2010b).



AR020380

Bottom Fish Fisheries and Rockfish Bycatch Risk

Recreational anglers targeting bottom fish such as lingcod and cabezon (and to a lesser extent flatfish) use lures and bait that catch yelloweye rockfish and bocaccio. As a result, some anglers targeting bottom fish unintentionally hook listed rockfish. Targeting rockfish and the retention of rockfish of any species is not allowed, nor is fishing in waters deeper than 120 feet (36.6 m) where subadult and adult listed rockfish are most likely to reside. WDFW also has a prohibition on barbed hooks and limits fishing gear to two individual hooks (no treble hooks). In 2012, WDFW estimated that the 120-foot (36.6 m) rule would result in a reduction of bycatch from anglers targeting bottom fish by approximately 75 percent for yelloweye rockfish (WDFW 2012c). We do not have data regarding the compliance levels with the 120-foot (36.6 m) rule, but in 2011 the majority of anglers targeting lingcod and other bottom fish were not aware of the regulation (Sawchuk 2012).

There is a small tribal commercial dogfish fishery. The fishery utilizes gillnets with a seven inch mesh to limit bycatch of other species. The fishery consists of less than 10 fishers, with two to three who regularly fish. It occurs in bays, which generally do not include rockfish habitat and the nets are not deployed deep in the water column, thus decreasing chance of rockfish bycatch.

There is also a tribal commercial flatfish fishery. It is a bottom trawl fishery consisting mainly of one fisher who typically fishes a couple times a year. Tribal scientists observe him because of concerns about crab bycatch and they have not seen any rockfish bycatch. This fishery also occurs in a bay, which is not generally rockfish habitat.

Halibut Fisheries and Rockfish Bycatch Risk

Recreational and commercial fishermen targeting halibut use lures and bait that catch yelloweye rockfish and bocaccio and other rockfish species. Historically, many recreational anglers would simultaneously target halibut and rockfish (Olander 1991), and because of their similar habitat usage, catches of deepwater rockfish during halibut fisheries can be common. For the recreational fishery, WDFW regulations for anglers targeting bottom fish (such as lingcod) do not allow fishing in waters deeper than 120 feet (36.6 m) (where subadult and adult listed rockfish are most likely to reside). This regulation does not apply to anglers targeting halibut. The recreational halibut regulations include a prohibition on barbed hooks and limit fishing gear to two individual hooks (no treble hooks). In recent years, halibut fishing has been restricted to several days annually during the spring in order to apportion the catch among geographic areas and user groups.

The tribal commercial halibut fishery has increased its catch nearly annually in recent years as. In 2009, the tribal commercial fishery had 258 landings and caught 61,443 pounds of halibut. In 2013, the fishery had 550 landings and caught 150,211 pounds of halibut.

In U.S. waters of the Puget Sound/Georgia Basin, gear used in the tribal commercial fisheries include:

- Hook-and-line (rod and reel, no more than two hooks)
- Hand line (no more than two hooks)
- Longline (snap gear only with typically 400 to 800 hooks)
- Bottom troll (no more than six lines)



AR020381

Fish caught on longline gear are typically hooked and suspended near the seafloor for minutes to hours; thus, some fish are likely harmed or killed by predators such as dogfish, sixgill sharks, harbor seals, and sea lions. Yelloweye rockfish are historically a commonly caught rockfish in halibut longline fisheries within the DPS area (Table 7), and have been commonly caught in halibut long-line fisheries in DPS waters of the Georgia Strait (NMFS 2013). Bocaccio are less commonly caught in long-line fisheries (NMFS 2013).

Table 8. Proportion of yelloweye rockfish and bocaccio in the total rockfish catch for past set line fisheries in the North Puget Sound (non-tribal set line fisheries have been closed by WDFW). Table created from data in Palsson et al. 2009.

| | 1970-1987 | 1988 | 1989 | 1990 | 1991-1992 | 1993-2003 |
|---|---|---|---|---|---|---|
| Yelloweye | 28% | 49.8% | 72.5% | 83.4% | 91.9% | 48.8% |
| Bocaccio | 2.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

<u>Spot Prawn Fisheries and Rockfish Bycatch Risk</u>

The spot prawn trap fishery consists of recreational, non-treaty commercial, and treaty commercial/subsistence sectors. The yearly harvest quotas are split evenly between the state recreational and commercial sectors and the treaty fisheries. Seasons and quotas are set using data collected during test fisheries conducted by WDFW and participating treaty tribes. The non-treaty commercial fishery, limited to 18 licenses, takes place from June through September with a weekly harvest cap of 600 pounds (272 kg) per fisher. Typically, used traps in the commercial fishery are truncated cone shaped surrounded by nylon mesh and weighing approximately 5 to 7 pounds (2.3 to 3.2 kg). Entrance rings are 3-inch (7.6-cm) diameter and aligned with the bait cup, usually containing pellet type bait. Strings of 15 to 25 traps are attached to a heavy groundline 29.53 to 98.43 feet (9 to 30 m) apart. Buoyed anchors mark the ends of each string, and soak times range from 2 hours to 48 hours. The treaty fishery has grown in participation in the past decade, with under 200 fishers participating each year, employing similar gear as the non-treaty commercial fleet. The treaty fishery occurs over a relatively short period of time, mostly in April and May, with openings commonly lasting only a few hours (NRC 2012, 2014).

The recreational fishery occurs on specific days in the month of May, and the number of days varies between management regions. The maximum trap limit is two traps per licensed fisher, with no more than four traps per vessel, and daily harvest is limited to 80 individual spot prawn per licensee. The recreational fleet uses similar web mesh trap designs as the commercial fleet, but typically with added weight. More common in the recreational fishery are the square, round, and octagonal shaped, wire mesh traps with two to four entry ramps leading to a bait container, often filled with canned cat food or similar bait. Each trap is fished separately, attached to a single buoy line and buoy. Soak times vary depending on the location and timing of the effort, and the derby style openings usually last 45 minutes to 3 hours (NRC 2012, 2014).

While the limited number of permits allowed prevents growth of the non-treaty commercial fleet, the recreational and treaty spot prawn fleets have increased significantly since the 1990s. Much of the recreational and commercial fishing effort for spot prawn occurs in waters ranging from 196.85 to 393.7



AR020382

feet (60 to 120 m) deep, along relatively steeply sloped and rugose benthic areas of Puget Sound (Martinis 2015), coinciding with juvenile and adult rockfish primary habitats, especially deep water species such as listed rockfish.

Rockfish have been documented as bycatch in active spot prawn fisheries and have been observed in derelict pots. Recent studies from British Columbia have reported rockfish bycatch rates in actively fished prawn traps (Favaro et al 2010, 2012), and the majority of those rockfish were juveniles. While the bycatch rates reported in British Columbia were relatively low, the large amount of fishing effort associated with spot prawn fisheries raised concern about the overall effect this bycatch posed on rockfish populations, especially considering the low survival rate of discarded rockfish following the effects of barotrauma (Favaro et al. 2010). A total of 58 derelict prawn traps have been incidentally removed during derelict net and crab trap removal efforts in Puget Sound. Two of those derelict prawn traps contained a total of eight rockfish (*Sebastes* spp.), two of which were dead. By comparison, only two juvenile rockfish have been found in over 3,900 removed derelict crab traps in Puget Sound (NRC 2012).

***Rockfish Catch Risk Based on Existing Fisheries in Each Management Unit***

The narrative below provides a qualitative bycatch risk for the management units in the U.S. portion of the Puget Sound/Georgia Basin.

<u>San Juan/Strait of Juan de Fuca</u>

We rank this region as having High bycatch risk for the commercial and recreational fishing sectors. This region has the second most salmon fishing trips and bottom fishing trips within the U.S. portion of the DPS, the highest number of recreational halibut trips (Table 7), and a commercial tribal halibut fishery with high risk of rockfish bycatch (Table 6). Of the currently open commercial and recreational fishing sectors, halibut fishing likely has the highest risk of bycatch, and this management unit has the largest number of fishing trips targeting halibut for each sector. The 120-foot (36.6-m) rule for recreational fishermen targeting bottom fish (which does not apply to halibut fishing) reduces risk of bycatch, but the bathymetry of most of the San Juan/Strait of Juan de Fuca is extremely complex, with steep walled pinnacles a very common feature around each island and offshore benthic area. This complex bathymetry makes compliance with the 120-foot (36.6-m) rule challenging as the depth can change rapidly in small horizontal distances, and it makes enforcing the rule difficult because of the uncertainty in assessing from a distance whether a boat is fishing in 120 feet (36.6 m) or more of water. This region also has high numbers of commercial and recreational spot prawn fisheries, but bycatch of rockfish in this region is relatively small compared to other areas (NRC 2012).

<u>Main Basin</u>

We rank this management unit as having Low bycatch risk for commercial fishing and Moderate for recreational fishing sectors. This basin has the most annual recreational salmon fishing trips as well as the most bottom fishing trips and a relatively low number of halibut fishing trips (Table 8). A relatively small amount of recreational halibut fishing occurs mostly in the northwestern portion of this basin (near Mutiny Bay and Port Townsend) and it is not known if commercial/tribal halibut fishing occurs in these areas, and this information is necessary for further assessment. Recreational and commercial shrimp pot fisheries are popular in this basin.



AR020383

Hood Canal

We rank this region as having Low bycatch risk for commercial fishing and Very Low for recreational fishing sectors. Recreational bottom fishing in most areas of Hood Canal have been closed since 2004 because of concerns about hypoxia. There are very few halibut fishing trips in this basin. Recreational salmon fishing occurs in this basin in smaller numbers than other management units, and recreational and commercial shrimping are very popular.

South Sound

We rank this region as having Low bycatch risk for commercial fishing and Low bycatch risk for recreational fishing sectors. Bycatch risk in the South Sound is minimal because of the low amount of bottom fishing trips and no halibut fishing occurring there. Relatively high numbers of recreational salmon fishing trips occur in this basin; thus, the greatest risk of bycatch likely is from this fishing sector.

***Detailed Threats Assessment – Habitat and Other Factors***

Several identified and potential threats and limiting factors may negatively impact rockfish populations. They may cause direct mortality, increased vulnerability to predation or disease, or reduced fitness and productivity (Palsson et al. 2009). The threats are assessed for each management unit, and the results are presented in Tables 9 through 13 according to these criteria: 1) the severity of the treat, 2) the level of certainty that the listed species are affected in the respective Management Unit, 3) the geographic extent of the threat, and 4) the likelihood that the actions outlined in this plan could reduce the threat. The severity of a threat refers to effects it has on the listed species (High- causes direct mortality, loss of productivity, fitness, and other key attributes; Moderate- does not cause decreased fitness or direct mortality and effects a moderate number of other attributes; Low- does not cause decreased fitness or direct mortality and effects a low number of other attributes). The level of certainty that a species is affected refers to the amount of evidence that the threat affects the species in that management unit (High- direct evidence or multiple lines of indirect evidence; Moderate- indirect evidence; Low- little or no evidence). Geographic extent refers to the spatial extent of the threat within the management unit (High- throughout much the basin; Moderate – in a moderate amount of the basin; Low- isolated areas; Very Low – occurs in a negligible amount of the basin). The likelihood of an action reducing a threat refers to the actions outlined in this plan and the likelihood they may reduce the threat (High – action has been proven to decrease threat, Moderate – action is likely to reduce threat, Low – action has small ability to reduce the threat, VL – action may or may not reduce threat). An example of these actions are removal of derelict fishing gear in an area with a lot of derelict gear (High) compared to assessing competition for prey and habitat between rockfish and other fish species like salmon and other groundfish. The criteria may also be rated as Unknown, meaning more information is needed.

**Overall Evaluation of Risk:** The threats criteria described above are combined and assessed to calculate the overall risk of the threats. Criteria include the geographic extent of the threat within the management unit (or DPSs) and the severity of the threat in that same area. 1 = High risk, 2 = Moderate risk, 3 = Low risk, 4 = Very low risk, P = Potential threat, not enough information to determine if it is a threat at the current time, but could plausibly become a threat in the future based on information known at this time.



AR020384

**Listing Factors**: 1) Present or threatened destruction, modification, or curtailment of its habitat or range; 2) over-utilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; 4) inadequacy of existing regulatory mechanisms; 5) other manmade factors affecting its continued existence. The primary listing factors we identified as responsible for decline of the DPSs of rockfishes at the time of listing appear with an (*) in Tables 9 through 13, along with other factors that may have contributed to decline.

**Life Stage Affected**: L = larval; J = juvenile; A = adult

**Historical, Current, Future Effects**: H = historical; C = current; F = future

**High, Moderate, Low, Very Low, Unknown, Potential**: High = H, Moderate = M, Low = L, Very Low = VL, Unknown = U, Potential = P

Tables 9 through 13 are for yelloweye rockfish and bocaccio, and are broken down by management unit. Differences between species are highlighted with a footnote.



AR020385

Table 9. Threats Assessment for Management Unit 1: San Juan/Strait of Juan de Fuca Basin.

| **(San Juan/Strait of Juan de Fuca Basin -- MCAs 6 and 7)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Descriptive Information** | | | | | | **Threat Ranking Information** | | | | | |
| **Listing Factor** | **Threat** | **Source** | **Key Ecological Attributes Affected** | **Life Stage Affected** | **Historical, Current, Future Effect** | **Severity of Threat** | **Level of Certainty Species is Affected** | **Geographic Extent of Threat** | **Recovery Action(s)** | **Likelihood Recovery Action(s) Reduce Threat** | **Overall Ranking** |
| ***Fisheries Interactions*** | | | | | | | | | | | |
| 1, 2, 5 | *Derelict Gear (in nearshore and benthic environments) | Primarily commercial salmon nets, shrimp pots | Mortality, Reproduction, Productivity | J, A | H, C, F | H | H | H | 3.1.1, 3.2.1 | H | 1 |
| 2, 4 | *Fisheries Removals (commercial bycatch) | Primarily bycatch from fisheries targeting halibut and shrimp | Mortality, Reproduction, Productivity, Fitness | J, A | H, C, F | H | H | U | 2.1-2.6 | H | 1 |
| 2, 4 | *Fisheries Removals (recreational bycatch) | Bycatch by anglers targeting salmon, bottom fish and halibut; inadequate enforcement | Mortality, Reproduction, Productivity, Fitness | J, A | H,C, F | H | H | H | 2.1-2.6, 4.1-4.5 | H | 1 |
| ***Habitat*** | | | | | | | | | | | |
| 1, 4 | *Habitat Disruption (**nearshore) | Nearshore development / modification | Productivity | J, A | H, C, F | L | M | L | 3.1, 3.1.2, 3.10, 3.11 | H | 3 |
| 1, 4 | *Habitat Disruption (benthic) | Sediment disposal practices, development | Productivity, Fitness | J, A | H, C, F | H | L | L | 3.2, 3.2.2, 3.2.3, 3.10, 3.11 | M | 3 |
| 1 | *Non-native Species that Alter Habitat (*Sargassum*, tunicates) | Global shipping and fisheries practices, natural disasters | Productivity | J, A | H, C, F | U | U | U | 3.1.3 | U | P |
| 1, 4 | *Hypoxia/ Nutrient Addition | Primarily local point and non-point pollution | Mortality, Productivity | L, J, A | H, C, F | H | L | L | 3.4 | L | 4 |



AR020386

| (San Juan/Strait of Juan de Fuca Basin -- MCAs 6 and 7) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Descriptive Information** | | | | | | **Threat Ranking Information** | | | | | |
| **Listing Factor** | **Threat** | **Source** | **Key Ecological Attributes Affected** | **Life Stage Affected** | **Historical, Current, Future Effect** | **Severity of Threat** | **Level of Certainty Species is Affected** | **Geographic Extent of Threat** | **Recovery Action(s)** | **Likelihood Recovery Action(s) Reduce Threat** | **Overall Ranking** |
| 1, 4 | *Chemical Contamination (bioaccumu-lants) | Primarily local point and non-point pollution | Fitness, Growth, Reproduction, Productivity, Behavior | L, J, A | H, C, F | H | L | L | 3.3, 3.3.1 | H | 3 |

* Primary listing factor as designated by Palsson et al. 2009 and Drake et al. 2010.
** Most directly affects bocaccio.



AR020387

Table 10. Threats Assessment for Management Unit 2: Main Basin and Whidbey Basin.

| **(Main Basin and Whidbey -- MCAs 9, 10, and 11 and 8-1, 8-2)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Descriptive Information** | | | | | | **Threat Ranking Information** | | | | | |
| **Listing Factor** | **Threat** | **Source** | **Key Ecological Attributes Affected** | **Life Stage Affected** | **Historical, Current, Future Effect** | **Severity of Threat** | **Level of Certainty Species is Affected** | **Geographic Extent of Threat** | **Recovery Action(s)** | **Likelihood Recovery Action(s) Reduce Threat** | **Overall Ranking** |
| ***Fisheries Interactions*** | | | | | | | | | | | |
| 1, 2, 5 | *Derelict Gear (in nearshore and benthic environments) | Primarily commercial salmon nets, shrimp pots | Mortality, Reproduction, Productivity | J, A | H, C, F | H | H | L | 3.1.1, 3.2.1 | H | 2 |
| 2, 4 | *Fisheries Removals (commercial bycatch) | Primarily current bycatch from fisheries targeting halibut, shrimp | Mortality, Reproduction, Productivity, Fitness | J, A | H, C, F | H | U | U | 2.1-2.6 | H | ***3 |
| 2, 4 | *Fisheries Removals (recreational bycatch) | Bycatch by anglers targeting salmon, bottom fish, spot prawns and halibut; inadequate enforcement | Mortality, Reproduction, Productivity, Fitness | J, A | H, C, F | H | M | H | 2.1-2.6, 4.1-4.5 | H | 2 |
| ***Habitat*** | | | | | | | | | | | |
| 1, 4 | *Habitat Disruption (**nearshore) | Nearshore development | Productivity | J, A | H, C, F | L | H | H | 3.1, 3.1.2, 3.10, 3.11 | M | 1 |
| 1, 4 | *Habitat Disruption (benthic) | Sediment disposal practices, development | Productivity, Fitness | J, A | H, C, F | H | L | L | 3.2, 3.2.2, 3.2.3, 3.10, 3.11 | M | 3 |
| 1 | *Non-native Species that Alter Habitat, (*Sargassum*, tunicates) | Global shipping and fisheries practices; natural disasters | Productivity | J, A | H, C, F | U | U | U | 3.1.3 | U | P |



AR020388

| (Main Basin and Whidbey -- MCAs 9, 10, and 11 and 8-1, 8-2) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Descriptive Information | | | | | | Threat Ranking Information | | | | | |
| **Listing Factor** | **Threat** | **Source** | **Key Ecological Attributes Affected** | **Life Stage Affected** | **Historical, Current, Future Effect** | **Severity of Threat** | **Level of Certainty Species is Affected** | **Geographic Extent of Threat** | **Recovery Action(s)** | **Likelihood Recovery Action(s) Reduce Threat** | **Overall Ranking** |
| 1, 4 | *Hypoxia/ Nutrient Addition | Primarily local point and non-point pollution | Mortality, Productivity | L, J, A | H, C, F | H | M | L | 3.4 | M | 3 |
| 1, 4 | *Chemical Contamination (bioaccumu-lants) | Primarily local point and non-point pollution | Fitness, Growth, Reproduction, Productivity, Behavior | L, J, A | H, C, F | H | H | H | 3.3, 3.3.1 | H | 1 |

* Primary listing factor as designated by Palsson et al. 2009 and Drake et al. 2010.
** Most directly affects bocaccio.
***Further information required to assess the extent and effects of commercial fisheries in this area and this ranking could change.



AR020389

Table 11. Threats Assessment for Management Unit 3: South Sound.

| **(South South Sound Basin – MCA 13)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Descriptive Information** | | | | | | **Threat Ranking Information** | | | | | |
| **Listing Factor** | **Threat** | **Source** | **Key Ecological Attributes Affected** | **Life Stage Affected** | **Historical, Current, Future Effect** | **Severity of Threat** | **Level of Certainty Species is Affected** | **Geographic Extent of Threat** | **Recovery Action(s)** | **Likelihood Recovery Action(s) Reduce Threat** | **Overall Ranking** |
| ***Fisheries Interactions*** | | | | | | | | | | | |
| 1, 2, 5 | *Derelict Gear (in nearshore and benthic environments) | Primarily commercial salmon nets | Mortality, Reproduction, Productivity | J, A | H | H | L | L | 3.1.1, 3.2.1 | M | 4 |
| 2, 4 | *Fisheries Removals (commercial bycatch) | There are few commercial fisheries remaining here | Mortality, Reproduction, Productivity, Fitness | J, A | H, C, F | H | L | L | 2.1-2.6 | L | 3 |
| 2, 4 | *Fisheries Removals (recreational bycatch) | Bycatch by anglers targeting salmon, bottom fish; inadequate enforcement | Mortality, Reproduction, Productivity, Fitness | J, A | H, C, F | H | L | L | 2.1-2.6, 4.1-4.5 | M | 3 |
| ***Habitat*** | | | | | | | | | | | |
| 1, 4 | *Habitat Disruption (**nearshore) | Nearshore development | Productivity | J, A | H, C, F | L | H | H | 3.1, 3.1.2, 3.10, 3.11 | M | 1 |
| 1, 4 | *Habitat Disruption (benthic) | Sediment disposal practices, development | Productivity, Fitness | J, A | H, C, F | H | L | L | 3.2, 3.2.2, 3.2.3, 3.10, 3.11 | M | 3 |
| 1 | *Non-native Species that Alter Habitat | Global shipping and fisheries practices; natural disasters | Productivity | J, A | H, C, F | U | U | U | 3.1.3 | U | P |
| 1, 4 | *Hypoxia/ Nutrient Addition | Primarily local point and non-point pollution | Mortality, Productivity | L, J, A | H, C, F | H | H | M | 3.4 | M | 2 |
| 1, 4 | *Chemical Contamination (bioaccumulants) | Primarily local point and non-point pollution | Fitness, Growth, Reproduction, Productivity, Behavior | L, J, A | H, C, F | H | H | H | 3.3, 3.3.1 | H | 1 |

* Primary listing factor as designated by Palsson et al. 2009 and Drake et al. 2010.
** Most directly affects bocaccio.



AR020390

Table 12. Threats Assessment for Management Unit 4: Hood Canal Basin.

| **(Hood Canal – MCA 12)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Descriptive Information** | | | | | | **Threat Ranking Information** | | | | | |
| **Listing Factor** | **Threat** | **Source** | **Key Ecological Attributes Affected** | **Life Stage Affected** | **Historical, Current, Future Effect** | **Severity of Threat** | **Level of Certainty Species is Affected** | **Geographic Extent of Threat** | **Recovery Action(s)** | **Likelihood Recovery Action(s) Reduce Threat** | **Overall Ranking** |
| ***Fisheries Interactions*** | | | | | | | | | | | |
| 1, 2, 5 | *Derelict Gear (in nearshore and benthic environments) | Primarily commercial salmon nets, shrimp pots | Mortality, Reproduction, Productivity | J, A | H | H | L | L | 3.1.1, 3.2.1 | H | 4 |
| 2, 4 | *Fisheries Removals (current commercial bycatch) | Primarily bycatch from fisheries targeting spot prawns | Mortality, Reproduction, Productivity, Fitness | J, A | H, C, F | H | L | L | 2.1-2.6 | M | 3 |
| 2, 4 | *Fisheries Removals (current recreational bycatch) | Bycatch by anglers targeting salmon, spot prawns; inadequate enforcement | Mortality, Reproduction, Productivity, Fitness | J, A | H, C, F | H | L | VL | 2.1-2.6, 4.1-4.5 | M | 4 |
| ***Habitat*** | | | | | | | | | | | |
| 1, 4 | *Habitat Disruption (**nearshore) | Nearshore development | Productivity | J, A | H, C, F | L | H | M | 3.1, 3.1.2, 3.10, 3.11 | H | 2 |
| 1, 4 | *Habitat Disruption (benthic) | Sediment disposal practices, development | Productivity, Fitness | J, A | H, C, F | H | L | L | 3.2, 3.2.2, 3.2.3, 3.10, 3.11 | M | 3 |
| 1 | *Non-native Species that Alter Habitat (*Sargassum*, tunicates) | Global shipping and fisheries practices; natural disasters | Productivity | J, A | H, C, F | U | U | U | 3.1.3 | U | P |
| 1, 4 | *Hypoxia/ Nutrient Addition | Primarily natural conditions exacerbated by | Mortality, Productivity | L, J, A | H, C, F | H | H | H | 3.4 | M | 1 |



AR020391

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | local point and non-point pollution | | | | | | | | | |
| 1, 4 | *Chemical Contamination (bioaccumu-lants) | Primarily local point and non-point pollution | Fitness, Growth, Reproduction, Productivity, Behavior | L, J, A | H, C, F | H | M | M | 3.3, 3.3.1 | H | 2 |

* Primary listing factor as designated by Palsson et al. 2009 and Drake et al. 2010.
** Most directly affects bocaccio.



AR020392

Table 13. Threats Assessment for Management Unit 5: Primary Listing Factors in Canada and All Puget Sound/Georgia Basin (Other Factors).

| **Canada** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Descriptive Information** | | | | | | **Threat Ranking Information** | | | | | |
| **Listing Factor** | **Threat** | **Source** | **Key Ecological Attributes Affected** | **Life Stage Affected** | **Historical, Current, Future Effect** | **Severity of Threat** | **Level of Certainty Species is Affected** | **Geographic Extent of Threat** | **Recovery Action(s)** | **Likelihood Recovery Action(s) Reduce Threat** | **Overall Ranking** |
| ***Fisheries Interactions*** | | | | | | | | | | | |
| 1, 2, 5 | *Derelict Gear (in nearshore and benthic environments) | Primarily commercial salmon nets, shrimp pots | Mortality, Reproduction, Productivity | J, A | H, C, F | H | H | H | 3.1.1, 3.2.1 | H | 1 |
| 2, 4 | *Fisheries Removals (commercial catch/bycatch) | Primarily bycatch from fisheries targeting shrimp, salmon, and groundfishes | Mortality, Reproduction, Productivity, Fitness | J, A | H, C, F | H | L | L | 2.1-2.6 | M | 3 |
| 2, 4 | *Fisheries Removals (recreational catch/bycatch) | Primarily bycatch from fisheries targeting bottom fish and salmon | Mortality, Reproduction, Productivity, Fitness | J, A | H, C, F | H | M | U | 2.1-2.6, 4.1-4.5 | M | 3 |
| ***Habitat*** | | | | | | | | | | | |
| 1, 4 | *Habitat Disruption (**nearshore) | Nearshore development | Productivity | J, A | H, C, F | L | L | L | 3.1, 3.1.2, 3.10, 3.11 | M | 4 |
| 1, 4 | *Habitat Disruption (benthic) | Sediment disposal practices, development | Productivity, Fitness | J, A | H, C, F | H | L | L | 3.2, 3.2.2, 3.2.3, 3.10, 3.11 | M | 3 |
| 1 | *Non-native Species that Alter Habitat (*Sargassum*, tunicates) | Global shipping and fisheries practices; natural disasters | Productivity | J, A | H, C, F | U | U | U | 3.1.3 | U | P |
| 1, 4 | *Hypoxia/ Nutrient Addition | Primarily local point and non-point pollution | Mortality, Productivity | L, J, A | H, C, F | H | L | L | 3.4 | M | 4 |
| 1, 4 | *Chemical Contamination (bioaccumu-lants) | Primarily local point and non-point pollution | Fitness, Growth, Reproduction, Productivity, Behavior | L, J, A | H, C, F | H | L | L | 3.3, 3.3.1 | H | 3 |



AR020393

| **Canada** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Descriptive Information** | | | | | | **Threat Ranking Information** | | | | | |
| **Listing Factor** | **Threat** | **Source** | **Key Ecological Attributes Affected** | **Life Stage Affected** | **Historical, Current, Future Effect** | **Severity of Threat** | **Level of Certainty Species is Affected** | **Geographic Extent of Threat** | **Recovery Action(s)** | **Likelihood Recovery Action(s) Reduce Threat** | **Overall Ranking** |
| ***ALL PUGET SOUND/GEORGIA BASIN (US and Canada) Species and Ecosystem Interactions*** | | | | | | | | | | | |
| 3 | Marine Mammal Predation | Pinnipeds, otters | Mortality, Fitness, Productivity | J, A | H, C, F | H | M | L | 3.5.2 | VL | 4 |
| 3 | Fish Predation | Lingcod, rockfish, salmon | Mortality, Fitness, Productivity | L, J, A | H, C, F | H | U | L | 3.5.2 | VL | 4 |
| 5 | Hatchery Practices | Salmon hatcheries | Mortality, Fitness, Productivity | L, J | H, C, F | H | U | L | 3.7 | M | 4 |
| 5 | Competition | Chinook salmon, coho salmon, other rockfish spp., other groundfish spp. | Productivity | L, J, A | H, C, F | L | L | L | 3.5.3 | VL | P |
| 3 | Diseases | Unknown, though we do know of a number of parasites affecting rockfish | Mortality, Productivity, Fitness | U | H, C, F | H | U | U | 3.6 | L | P |
| 5 | Inbreeding | Mating between related individuals in small populations | Fitness, Productivity, Reproduction, Genetic Integrity | L, J, A | U | H | U | U | 1.4, 1.41. | L | P |
| 5 | Hybridization | Low encounter rate of suitable mates in small populations | Fitness, Productivity, Genetic Integrity | L, J, A | U | H | U | U | 1.4, 1.4.1 | L | P |
| 1 | Oil Spills | Global and local shipping and boating | Mortality, Reproduction, Productivity | L, J, A | H, C, F | H | H | H | 3.9 | H | 1 |
| 4, 5 | Ocean Acidification | Global and local carbon dioxide output; local land | Reproduction, Productivity, Behavior, | L, J, A | H, C, F | H | H | H | 3.5, 3.5.1 | M | 1 |

| Canada | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Descriptive Information | | | | | | Threat Ranking Information | | | | | |
| **Listing Factor** | **Threat** | **Source** | **Key Ecological Attributes Affected** | **Life Stage Affected** | **Historical, Current, Future Effect** | **Severity of Threat** | **Level of Certainty Species is Affected** | **Geographic Extent of Threat** | **Recovery Action(s)** | **Likelihood Recovery Action(s) Reduce Threat** | **Overall Ranking** |
| | | use practices; lack of collective action or legislation, natural upwelling | Fitness | | | | | | | | |
| 4, 5 | Climate Change | Global and local carbon dioxide output; lack of collective action or legislation | Likely Reproduction, Productivity, Behavior, Fitness | L, J, A | H, C, F | H | H | H | 3.5, 3.5.1 | L | 1 |
| 5 | Anthropogenic Noise | Construction, shipping, military exercises | Likely Behavior, Productivity | L, J, A | H, C, F | M | L | U | 3.8 | M | P |

* Primary listing factor as designated by Palsson et al. 2009 and Drake et al. 2010.
** Most directly affects bocaccio.



AR020395

## F. CONSERVATION MEASURES, RESEARCH, AND MONITORING

The following section provides an overview of conservation efforts that have been undertaken for yelloweye rockfish and bocaccio of the Puget Sound/Georgia Basin since their listing, and discusses overall efficacy of all efforts and protections. In some cases, these conservation efforts are relatively new and may not have had time to demonstrate their biological benefit. In such cases, provisions for adequate monitoring and funding of conservation efforts are essential to ensure that intended conservation benefits are realized. Further protective action, research, and outreach efforts are, however, still urgently needed to ensure recovery of the ESA-listed DPSs. Many of the primary threats including fisheries bycatch and barotrauma, poor water quality, climate change, ocean acidification, and the loss and/or degradation of nearshore and deep-water habitats, current research and monitoring efforts, and recommended research for these threats are discussed in further detail in the appendices. The appendices are included to provide additional detail for specific topics and aid in implementation.

***Fisheries Management***

Washington State

In 2010, the Washington State Fish and Wildlife Commission formally adopted regulations that ended targeting and retention of rockfish by recreational anglers in Puget Sound and closed fishing for bottom fish in waters deeper than 120 feet (36.6 m) (does not apply to anglers targeting halibut) to reduce bycatch. Additionally, on July 28, 2010, WDFW closed the following non-tribal commercial fisheries in Puget Sound (WDFW 2010):

- the set net fishery
- the set line fishery
- the bottom trawl fishery
- the inactive scallop trawl fishery
- the inactive pelagic trawl fishery
- the inactive bottom fish pot fishery

WDFW also applied for and received a 5-year Incidental Take Permit (ITP) and developed a Fisheries Conservation Plan (FCP) with NOAA (WDFW 2012c). The FCP includes the monitoring and management of two fisheries authorized by the State of Washington to minimize the interactions with listed rockfish. Potential bycatch in the shrimp trawl fishery is monitored by an observer program, and the state also provides estimates of rockfish bycatch in the recreational bottom fish fishery. The ITP was issued in 2012 and runs through 2017.

Canada

The Department of Fisheries and Oceans (DFO) manages fisheries in Area 4(b) of the inside waters of Vancouver Island separately from outside waters. Area 4(b) encompasses all of the Canadian portion of the DPSs' ranges and includes some waters outside of the DPSs' ranges to the west and north. In 2001, DFO began a process to improve inshore[3] rockfish management by: 1) accounting for all catch (landed

[3] Inshore rockfish include yelloweye, black, copper, quillback, China, and tiger rockfish.



AR020396

and released), 2) decreasing fishing mortality, 3) establishing areas closed to activities that result in bycatch, and 4) improving stock assessment and monitoring (Yamanaka and Lacko 2001). DFO adopted a policy to ensure that inshore rockfish are subjected to fisheries mortality equal to or less than half of natural mortality.

In 2007, the DFO formally designated 30 percent of inside rockfish habitat as Rockfish Conservation Areas (RCAs) (Figure 10). The DFO defined and mapped rockfish habitat from commercial fisheries log CPUE density data as well as change in slope bathymetry analysis (Yamanaka and Logan 2010). Within the RCAs, DFO allows some harvest of marine biota.[4] However, these reserves do not allow directed commercial or recreational harvest for any species of rockfish or the harvest of other marine species if that harvest may incidentally catch rockfish. There are anecdotal reports that compliance with the RCAs may be poor and that some may be located in less than optimum areas of rockfish habitat (Haggarty 2014). Systematic monitoring of the RCAs may be lacking as well (Haggarty 2014). Because the RCAs are relatively new, it is uncertain how effective they have been in protecting rockfish populations (Haggarty 2014), but one analysis found that sampled RCAs in Canada had 1.6 times the number of rockfish compared to unprotected areas (Cloutier 2011). Outside the RCAs, recreational fishers generally may keep one rockfish per day from May 1 to Sept. 30. Commercial rockfish catches in Area 4(b) are managed by a quota system (DFO 2011). DFO's 2015 Integrated Groundfish Management Plan calls for a TAC of 110 tonnes (242,508 pounds) of bocaccio from commercial trawling in Area 4(b) (DFO 2015). For yelloweye rockfish, the TAC is 6 tonnes from the commercial hook-and-line fishery and 1 ton for the halibut fishery (DFO 2015). As of 2006, 100 percent at-sea monitoring standards were put in place for the entire groundfish fishery. This monitoring is intended to eliminate unreported catch of rockfish throughout the commercial groundfish fishery and allow all rockfish to be accounted for within their TACs (Yamanaka et al. 2006).

[4] Recreational fishing allowed in RCAs: invertebrates by hand picking or dive, crab by trap, shrimp/prawn by trap, smelt by gillnet. Commercial fishing allowed in RCAs: invertebrates by hand picking or dive; crab and prawn by trap; scallops by trawl; salmon by seine or gillnet; herring by gillnet and seine; spawn-on-kelp sardine by gillnet, seine, and trap; smelt by gillnet; euphausiid (krill) by mid-water trawl; opal squid by seine; groundfish by mid-water trawl. (http://www.pac.dfo-mpo.gc.ca/fm-gp/maps-cartes/rca-acs/permitted-permis-eng.htm)



AR020397

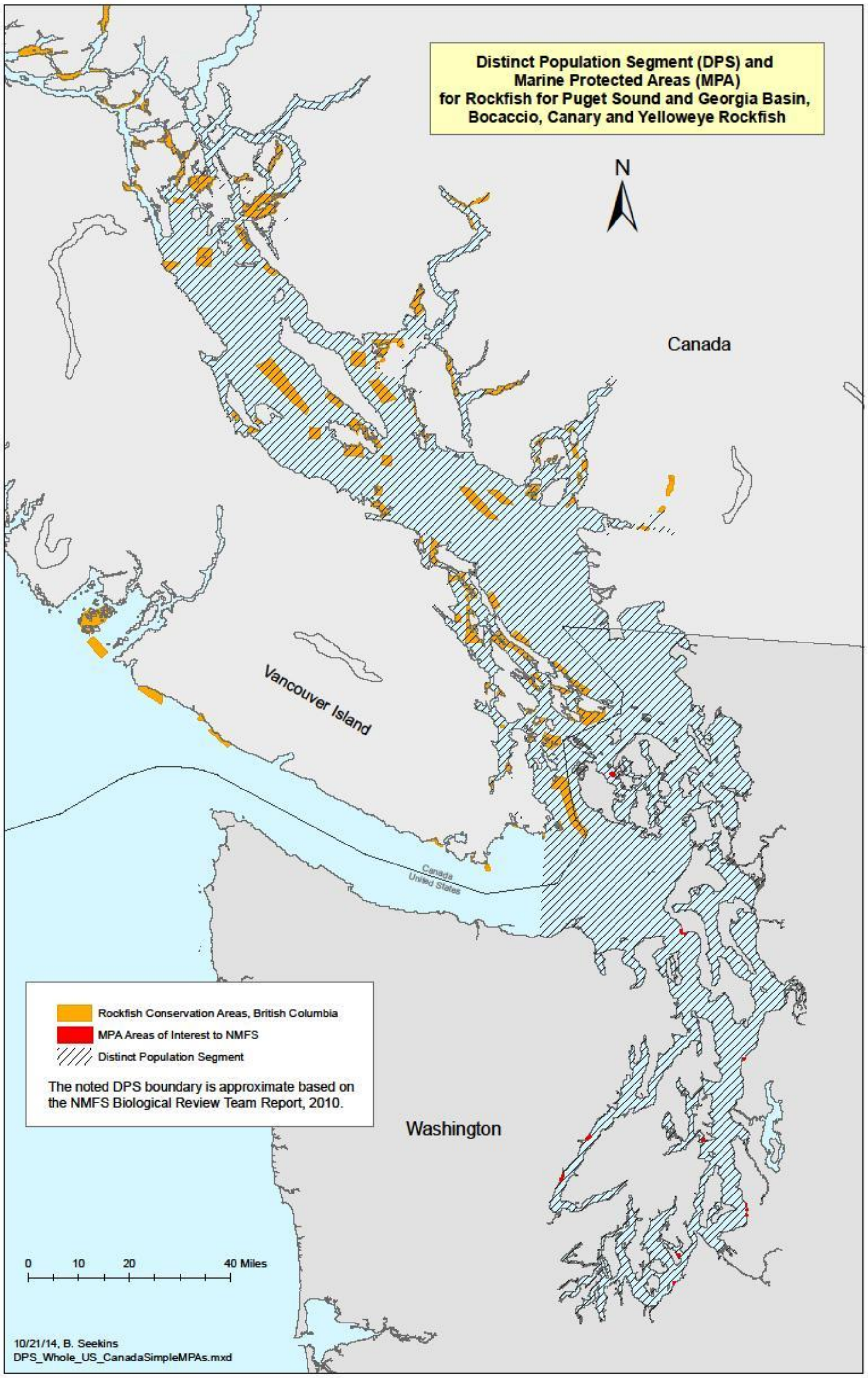


Figure 10. Rockfish Conservation Areas in Canada and reserves that do not allow most fishing.



AR020398

### *Cooperative Research*

In recognition of the knowledge that fishers can bring to the recovery effort, NMFS began an initiative to both further assess bycatch and to involve fishers in research and recovery of rockfish soon after the Federal listing.

Beginning in late 2010, NMFS partnered with the University of Washington to assess recreational anglers' knowledge and perceptions regarding rockfish threats and recovery actions. This project documented angler knowledge of rockfish life history, regulations, and species identification abilities; perceived threats to rockfish; fishing practices; and preferred recovery measures (Sawchuk 2012; Sawchuk et al. 2015). The survey findings have been used to inform the Education, Outreach, and Public Involvement Appendix (I) and guided further angler engagement.

In 2012, NMFS partnered with the Northwest Straits Foundation to commission a study to assess spatial distribution and magnitude of derelict shrimp pots and their potential impacts to rockfish in Puget Sound. The study utilized sidescan sonar surveys, an analysis of the WDFW creel surveys, and an online survey that was made available for shrimp fishers. This study has enabled a foundational knowledge of the potential impact shrimp pots may have on rockfish. In 2013, NMFS partnered with the Northwest Straits Foundation to conduct an assessment of bycatch rates of rockfish in actively fished shrimp pots based on WDFW test fisheries data (NRC 2014).

In 2012, NMFS and the SeaDoc Society sponsored an assessment of cooperative research projects (Browning 2013). The assessment examined several cooperative research projects involving partnerships between fishers and researchers/fishery managers, and it has been used to guide future collaborative efforts.

In 2013 and 2014, NMFS, WDFW, and the SeaDoc Society began two cooperative research projects with recreational fishing guides to assess rockfish bycatch in fisheries targeting lingcod and halibut, and to gain genetic samples of listed rockfish (see inset and below).

**Rockfish Cooperative Research Program**

In 2014 and 2015, NMFS, WDFW, and Puget Sound Anglers and local fishing guides partnered on a cooperative research rockfish genetics project. This project assessed listed rockfish genetics by gathering samples through hook-and-line sampling.

The project has resulted in new genetics information that indicates that Puget Sound/Georgia Basin canary rockfish are not discrete from the coastal population, thus leading to their proposed delisting from the ESA. See the 5 year review posted on our website for details.

In an ongoing project, NMFS, the SeaDoc Society, and local fishing guides are also assessing rockfish bycatch during local lingcod and halibut fisheries.

Each project has provided important information for rockfish recovery efforts.

Captain Jay Field and Kelly Andrews with a yelloweye rockfish caught in the San Juan Islands. Photo courtesy of Kelly Andrews.



AR020399

The cooperative genetics research utilized the experience of recreational fishing guides who had ideas about where to find the rare species of rockfish. Over the course of 74 fishing trips, guides and researchers collected fin clips and length data from listed rockfishes (Andrews et al. 2015). All of the fin clips were analyzed, which resulted in the canary rockfish DPS being recommended for delisting (NMFS 2016). Analyses indicated a lack of genetic differentiation between coastal and Puget Sound/Georgia Basin samples of canary rockfish, as seen in the lack of distinct clusters in the principal components analysis (Figure 11). $F_{ST}$ values, a metric of population differentiation, among groups was not significantly different from zero, and STRUCTURE analysis did not provide evidence supporting population structure. These analyses all suggest there is no evidence of genetic differentiation of canary rockfish across the boundaries of the DPS (Andrews et al. 2015). A full report of this project and the results for all the listed species is found in our 5-year review on our website (NMFS 2016).[5]

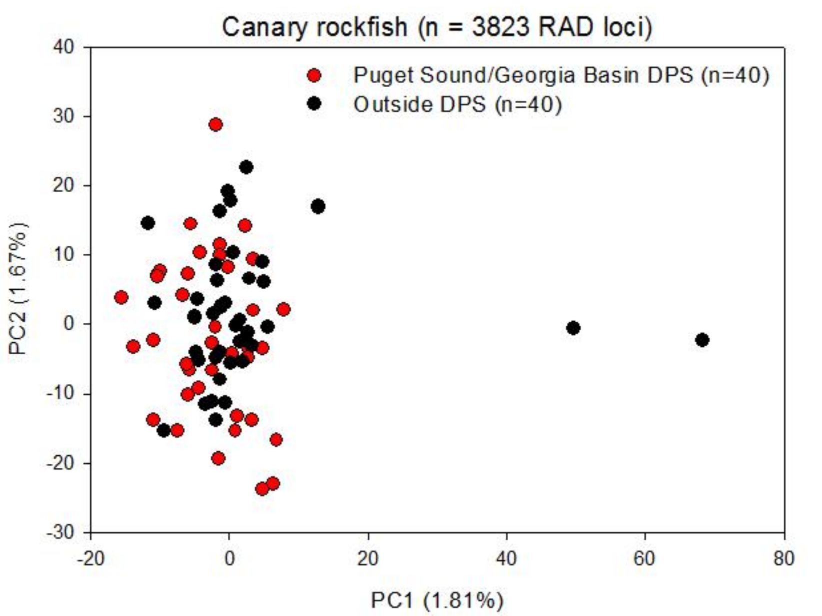


Figure 11. No distinct genetic structure observed in canary rockfish based on a principal components analysis of the genetic variation between individuals inside and outside the DPS (Andrews et al. 2015).

In 2014, NMFS and WDFW began a rockfish habitat-stratified ROV survey in Puget Sound proper. This research enables an assessment of the population while also collecting important habitat information necessary to better characterize rockfish habitat. This cooperative research is key to assessing the status of the population now and into the future. The 2015 survey sampling plan is depicted in Figure 12.

[5] http://www.westcoast.fisheries.noaa.gov/publications/protected_species/other/rockfish/5.5.2016_5yr_review_report_rockfish.pdf



AR020400

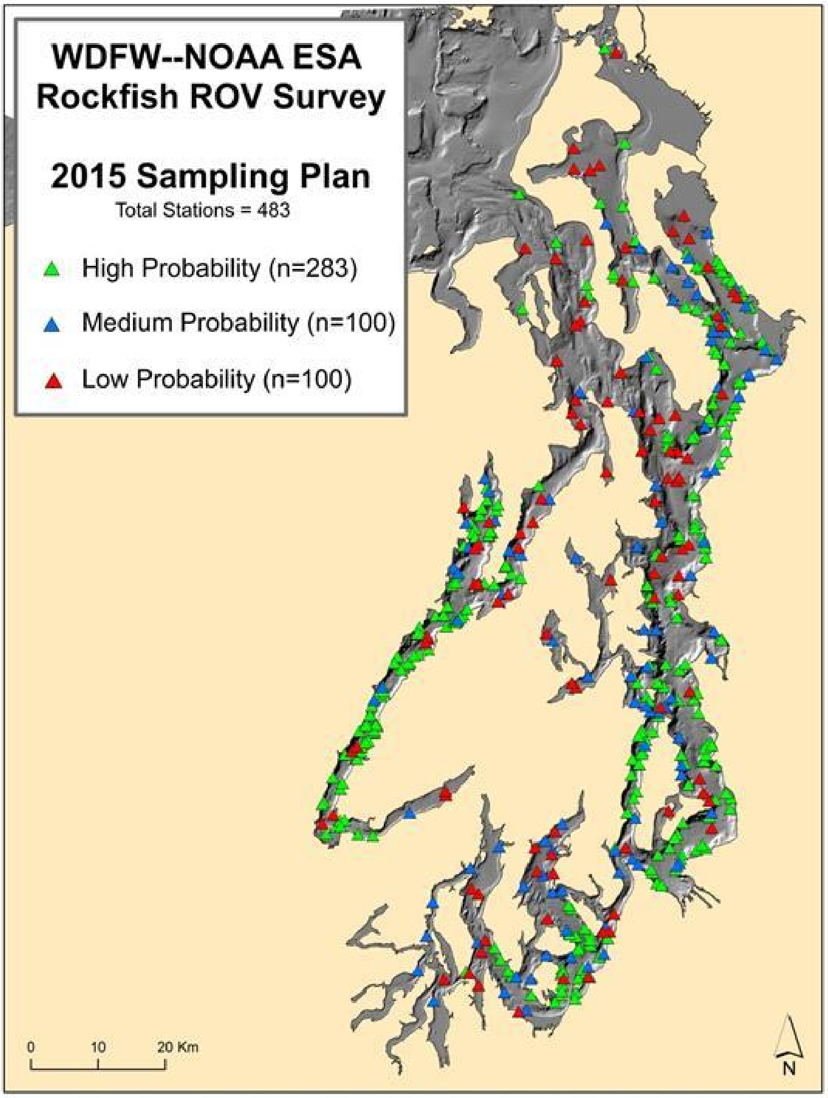


Figure 12. 2015 Rockfish ROV survey target sites.

***Derelict Fishing Gear Removal and Prevention***

*Removal*: Funding from the American Recovery and Reinvestment Act and other Federal funds enabled the Northwest Straits Initiative to remove over 4,500 derelict fishing nets and 140 derelict pots from waters shallower than 100 feet (30.5 m), restoring hundreds of acres of Puget Sound habitat. Conservation efforts directed at removing derelict nets have reduced the threat of mortality and rocky habitat degradation; however, there remain a large number of deepwater nets that still need to be removed.

Most derelict nets have been removed by divers with surface supplied air and supported by a dive vessel that can mechanically lift the nets from the surface onto the boat. All of the derelict nets removed have been from waters 105 feet (32 m) or shallower because of diver safety protocols. Nets that have been found to extend below 105 feet (32 m) are cut off and only the shallow portion of the net is removed.



AR020401

Several hundred derelict nets have been documented in waters deeper than 100 feet (30.5 m) deep (NRC 2010). Removal methodology for deepwater nets has been identified and subsequent testing of deepwater net removal by ROV has occurred recently. In 2013 and 2014, WDFW and NWSI applied for funding to test removal methods and begin removing deepwater derelict gear to benefit listed rockfish under NOAA's Species Recovery Grants to States program. Neither project proposal was funded.

*Research*: NMFS funded a pilot survey using side-scan sonar for derelict fishing nets in waters deeper than 100 feet (30.5 m) off the west coast of San Juan Island, resulting in the documentation of over 50 nets (Figure 13). NMFS was also involved in research to assess possible methods to remove derelict fishing nets at depths great than 98 feet (30 m) and worked with the Northwest Straits Foundation (NSF) and Natural Resources Consultants (NRC) to quantify lost shrimp pots and bycatch of rockfish in actively fished shrimp pots.

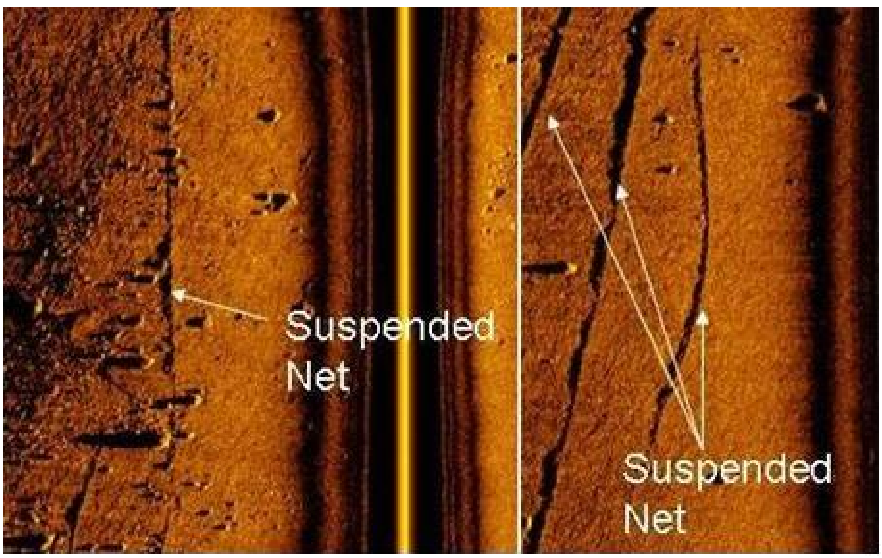


Figure 13. Sidescan sonar images of deepwater derelict nets located on Point Roberts Reef of the San Juan basin. Suspended nets have a larger acoustic shadow than nets flush with the bottom. Image courtesy of Natural Resource Consultants.

Further, NMFS has worked with the NSF and NRC to identify and quantify mortality (including rockfish) in derelict fishing gear (Good et al. 2010). With the help of the NMFS Genetics Program, this group of collaborators identified some rockfish bone samples using molecular markers to quantify and compile a list of affected species.



AR020402

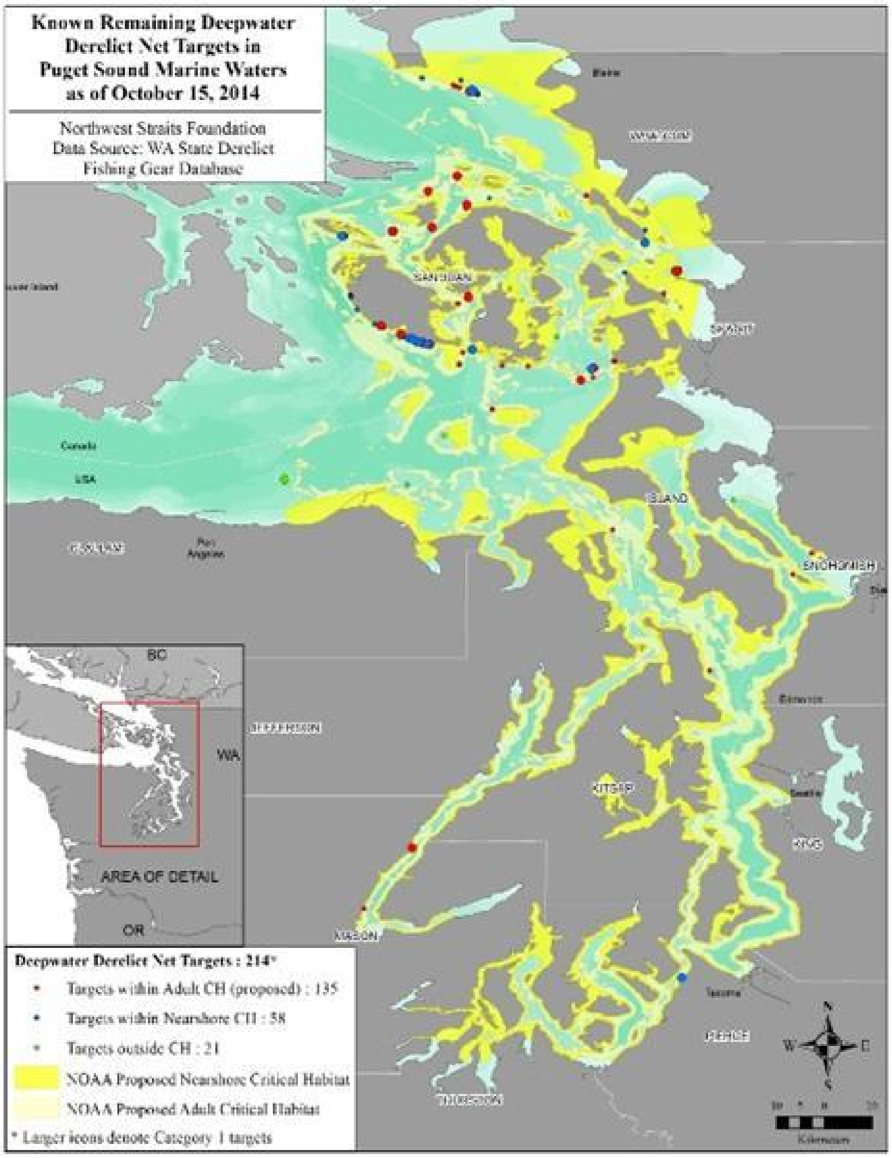


Figure 14. Location of remaining deepwater (>100 feet [30.5 m]) derelict net targets in Puget Sound as of October 2014.

In 2013, NMFS funded a study by the NSF and the NWIFC that utilized ideas and recommendations from commercial fishers and fishing gear experts to assess how to better prevent the loss of nets and encourage the quick retrieval of derelict gillnets from Puget Sound fisheries. They used information from personal interviews, letters, email exchange, and an anonymous online survey (Gibson 2013).

*State Regulations:* On March 29, 2012, the Washington Governor signed into law Senate Bill 5661, making it mandatory for non-tribal commercial fishers to report lost nets to WDFW within 24 hours of loss so that they can be retrieved (Washington State Legislature 2012). In 2013, the Washington State Legislature appropriated 3.5 million dollars to support further removal of shallow water derelict nets, and the vast majority of these nets were removed by summer of 2015. Thus far, a total of 5,660 nets and 3,800 shellfish pots have been removed, improving the habitat conditions of 813 acres (see www.derelictgear.org).

Additionally, WDFW and NSF, assisted by funding from NMFS, have established a reporting, response, and retrieval network that allows online and telephone reporting of derelict nets by members of the public. After a report is received it is evaluated and, if appropriate, a unit is mobilized to locate and remove the gear before it can sink and affect both marine organisms and their habitat.

### *Education and Outreach*

In 2012, the Puget Sound Anglers began outreach to local anglers to better identify rockfish and use rapid-submergence techniques to reduce the effects of barotrauma. This outreach was related to the findings of the NMFS/University of Washington angler study that was introduced at the beginning of the Cooperative Research section (Sawchuk 2012; Sawchuk et al. 2015) WDFW has also produced materials on rockfish bycatch avoidance, identification, handling procedures, and recompression (http://wdfw.wa.gov/fishing/bottomfish/rockfish/mortality.html). Additionally, WDFW has piloted a voluntary recreational fishing logbook program at several ports along the outer coast and in the Strait of Juan de Fuca. This program is now making its way into Puget Sound, starting with some recreational charter boat captains.

In 2003, the Puget Sound Recreational Fisheries Enhancement Fund (PSRFEF) Oversight Committee was created by the legislature to advise WDFW on issues related to improving the recreational fisheries within Puget Sound (http://wdfw.wa.gov/about/advisory/psrfef/). PSRFEF developed program goals (adopted in 2013) to measure progress of improving recreational bottom fish fisheries by utilizing outreach and education to decrease the mortality on rockfish (WDFW 2013). Specific performance measures pertaining to recovering bottom fish include increasing angler identification of rockfish species, increasing the use of descender tools, and decreasing angler encounters (e.g., bycatch) of rockfish.

### *Habitat Mapping*

A Puget Sound benthic habitat mapping team consisting of the United States Geological Survey (USGS), SeaDoc Society/Tombolo Laboratory, the University of Washington, WDFW, NMFS, and others is working to better map and characterize benthic habitat conditions in Puget Sound. The USGS is working on detailed benthic habitat characterizations for most, but not all, of Puget Sound proper. In the San Juan Islands, a cooperative study involving WDFW and the SeaDoc Society/Tombolo Laboratory is using high resolution multibeam bathymetry data, interpreted habitat types informed by geology, and fish occurrence data from visual surveys to develop probabilistic occurrence maps for the listed rockfish and a variety of other benthic organisms. These maps will inform future survey efforts, critical habitat designation, and fishery management actions.

### *Historic Rockfish Abundance Trends and Assemblages*

NMFS partnered with the University of Washington to conduct an analysis of historic rockfish data in Puget Sound and reported in Washington et al. (1977). The analysis calculated the catch per unit of effort of nine species of local rockfish (including listed rockfish), determined depth of capture, and assessed potential habitat associations (Browning 2013).



AR020404

A 7-decade time series of relative abundance was developed for seven species of rockfish in Puget Sound, including the listed rockfish, from interviews with fishers, divers, and researchers (Beaudreau and Levin 2014). Trends in abundance indices indicated that all seven species in Puget Sound have been in decline since at least the 1960s. The listed rockfish were viewed as relatively lower in abundance across all time periods compared to other rockfishes. The study showed that expert knowledge in combination with available scientific data may help resolve patterns of abundance for rockfishes and other data-poor species.

## G. RESEARCH AND MONITORING IN PROGRESS

There are a number of important research projects underway, and are summarized in Table 14.

Table 14. Research projects in progress to address rockfish attributes and inform recovery.

| **Entity** | **Research Type** | **General Rockfish Attribute(s) Research Will Address** | | | | |
|---|---|---|---|---|---|---|
| | | **Abundance** | **Spatial Structure/ Habitat Usage** | **Connectivity** | **Diversity (age/size)** | **Injury / Mortality** |
| WDFW/NMFS | Remotely operated video surveys | ✓ | ✓ | ✓ | ✓ | |
| NMFS/University of Washington | Larval dispersal | | | ✓ | | |
| NMFS/SeaDoc Society/Select Fishing Guides | Bycatch rates in local fisheries | | ✓ | | ✓ | ✓ |
| NMFS/Select Fishing Guides | Bycatch and gear/bait attributes | | | | | ✓ |
| NMFS/Northwest Straits Foundation/NRC | Shrimp pots bycatch rates and derelict gear | | | | ✓ | ✓ |
| NMFS/WDFW/ Sea Doc Society/others | Fine scale habitat associations | | ✓ | | | |
| WDFW | Trawl surveys | | ✓ | | ✓ | |
| NMFS/WDFW | Dive surveys – YOY and kelp restoration | ✓ | ✓ | | ✓ | |
| Puget Sound Restoration Fund/NMFS | Bull kelp life-history | | ✓ | | | |
| WDFW | Evaluation of barotrauma post release (ROV obs.) | | ✓ | | ✓ | ✓ |



AR020405

# III. RECOVERY STRATEGY

This section presents NMFS' recommended strategy for recovering yelloweye rockfish and bocaccio, including the primary focus of the recovery effort and how it addresses the main threats and biological needs of the species. The plan is comprehensive to address all of the threats, draws on existing information to prioritize actions, and identifies research to inform an adaptive approach to develop, prioritize, and implement actions as data gaps are filled. This section provides the rationale for the recommended recovery program, linking information presented in the background section to information provided in the sections on recovery objectives, criteria, and actions.

## A. KEY FACTS AND ASSUMPTIONS

***Population Decline and Life History***—The abundance of yelloweye rockfish and bocaccio within the Puget Sound/Georgia Basin DPSs have each declined, likely as a result of past overharvest and other interacting factors (Palsson et al. 2009; Yamanaka and Logan 2010; Drake et al. 2010). The life history of listed rockfish include long generation times and naturally low productivity. Low productivity is likely exacerbated by past fishery removals that caused size and age truncation, and environmental factors such as contaminants and other habitat degradation. The long time listed rockfish take to become reproductive adults makes them extremely vulnerable to threats that unduly impact adults, including overfishing, and slow to recover once depleted (Drake et al. 2010). The connectivity of larval and juvenile listed rockfish is probably naturally limited between Management Units (particularly within U.S. waters) by relatively shallow sills, and the effects of localized depletions of rockfish are likely exacerbated by these natural hydrologic constrictions (Drake et al. 2010).

***Fisheries***—Under current protective regulations, listed rockfish catch in the U.S. portion of the DPSs' ranges is incidental to other fisheries targeting salmon, bottom fish, halibut, and, to a lesser extent, shrimp (see Section E. Factors Contributing to Decline and Federal Listing, *Threats Assessment for Fisheries*). Identifying and quantifying this bycatch is difficult because of largely inaccurate species identification by recreational anglers (Sawchuk 2012; Sawchuk et al. 2015) and limited frequency of angler surveys, and because of the lack of systematic bycatch tracking in some remaining commercial fisheries.

Recent State of Washington regulations that ended the retention of rockfish and prohibited fishing for bottom fish in waters deeper than 120 feet (36.6 m) have likely reduced bycatch of listed rockfish, though compliance is uncertain because most anglers were found to be unaware of the rule (Sawchuck 2012). In addition, effective enforcement of the 120-foot (36.6-m) rule is challenging because of the large spatial area which it covers, and the rule does not address recreational and commercial fisheries targeting salmon, shrimp, or halibut. Releasing rockfish at-depth with a descending device likely reduces mortality, but a recent survey found that only 3 percent of anglers report releasing rockfish bycatch at-depth within Puget Sound (Sawchuk 2012). There is emerging evidence that long-term survival of yelloweye rockfish and bocaccio released at-depth and with barotrauma is good and in one study female yelloweye rockfish were found to be reproductively viable after recompression (Blain 2014). However, there are many variables that may influence long-term survival of rockfish after recompression, such as angler experience and handling, thermal shock, and depth of capture (Schroeder and Love 2002; Jarvis and Lowe 2008;



AR020406

Pribyl et al. 2009; Pribyl et al. 2011). There is also evidence that bycatch mortality reduction measures implemented across a variety of resource users do not perform as well as the experimental bycatch mortality reduction measures implemented by managers and scientists (Cox et al. 2007).

Recreational and commercial fisheries in the Canadian portion of the DPSs may retain limited numbers of rockfish. Rockfish Conservation Areas (RCAs) were designated in 30 percent of inside Vancouver Island rockfish habitat in 2007, and though commercial compliance with them is high, recreational compliance with them may be low (Haggarty 2014). Cloutier (2011) documented 1.6 times the number of rockfish in RCAs compared to outside unprotected areas; overall, it is likely that the RCAs in Canada are too recently established to determine their overall effectiveness, though compliance is thought to be an issue with their effectiveness thus far (Haggarty 2014). Compared to fished areas, studies have found higher fish densities, sizes, or reproductive activity in the assessed WDFW marine reserves (Palsson and Pacunski 1995; Palsson 1997; Eisenhardt 2001; Palsson et al. 2004). However, because most reserves in Puget Sound were established over several decades with unique and somewhat unrelated ecological goals, and encompass relatively small areas (average of 23 acres), the net effect of existing reserves to listed rockfish abundance, productivity, and spatial structure are probably very small (75 Fed. Reg. 22276, April 28, 2010). The life-history characteristics that make rockfish vulnerable to overfishing also make them good candidates for protection in MPAs (Yoklavich 1998), and rockfish and other species with similar life histories have been key species for protection in networks of MPAs that have been developed in several states and countries, particularly on the west coast of North America in Alaska; British Columbia, Canada; Oregon; California; and Baja California Sur, Mexico.

Therefore, in the areas we have assessed to have remaining high risk of bycatch despite the regulations put into place by WDFW in 2010 to limit bycatch (areas are the San Juan Basin and the eastern Strait of Juan de Fuca (generally east of Port Angeles)) (see Table 15), we recommend beginning the scientific and public process to establish marine protected or rockfish conservation areas to protect listed rockfish. These areas also have the most rockfish habitat. In other areas where further information is needed, we recommend further assessment to determine whether spatial protection or other improved fisheries management protections are needed.

Table 15. Detailed Assessment for Priorities for MPA/RCA Establishment by Management Area.

| **Manage-ment Unit** | **Fisheries w/ Rockfish Bycatch Risk[1]** | **Rec. Trips (Bottom-fish) Rockfish Bycatch Risk[2]** | **Rec. Trips (Halibut) Rockfish Bycatch Risk[2]** | **Rec. Trips (Salmon) Rockfish Bycatch Risk[2]** | **Rec. Trips (Other) Rockfish Bycatch Risk[2]** | **Significant Regulations Affecting Rockfish Bycatch w/ Known High Compliance[3]** | **Spatial Isolation Risk (Genetics + Geography)[4]** | **Rockfish Habitat[5] (sq. mi.)** | **Priority Ranking** |
|---|---|---|---|---|---|---|---|---|---|
| **Canada** | - | - | - | - | - | - | - | - | N/A- RCA network exists |
| **San Juan Is / Strait of Juan de Fuca** | Halibut longline – *High* risk;<br><br>Salmon fisheries – Low risk<br><br>Shrimp fisheries – Low risk | 78,202 *High* risk | 58,688 *High* risk | 436,977 Moderate risk | 15,489 Un-known risk | WDFW closure of most commercial fisheries with rockfish bycatch; no recreational rockfish targeting or retention | Moderate genetic<br><br>Moderate spatial | 533 | High |



AR020407

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Main Basin (includes Whidbey Basin)** | Salmon fisheries – Low risk<br><br>Halibut longline – *More information needed for assessment*<br><br>Shrimp fisheries – Low risk | 109,228 *High* risk | 12,896 Low risk | 1,457,346 Moderate risk | 52,373 Un-known risk | WDFW closure of most commercial fisheries with rockfish bycatch; no recreational rockfish targeting or retention | Moderate genetic<br><br>Moderate spatial | 361 | Medium |
| **South Sound** | NA | 30,102 Low risk | 0 Very Low risk | 122,933 Low risk | 16,237 Un-known risk | WDFW closure of most commercial fisheries with rockfish bycatch; no recreational rockfish targeting or retention | *High* genetic<br><br>*High* spatial | 102.4 | Low |
| **Hood Canal** | Shrimp fisheries – Low risk | 3,028 Low risk | 132 Very Low risk | 56,042 Low risk | 11,097 Un-known risk | Long-term WDFW recreational bottom fish closure; no recreational rockfish targeting or retention | *High* genetic<br><br>*High* spatial | 66.8 | Low |

[1] Risk is rated by considering both risk of bycatch by fishery/fishing type and number of trips/effort for both commercial and recreational fisheries.
[2] Includes 2010-2014 WDFW creel survey trip estimates. Risk is rated by considering both risk of bycatch by fishery and number of trips.
[3] In 2010, WDFW also put into place a no retention regulation and 120 ft. depth restriction while bottom fishing to decrease rockfish bycatch in recreational fisheries (this regulation is difficult to enforce, compliance is unknown, and it does not apply to fishers targeting halibut) and closed several commercial fisheries (see list in Recovery Plan, Section F. and full list of fisheries and bycatch risk in Section E. Table 4).
[4] This column considers listed rockfish decline due to spatial and genetic isolation, which can exacerbate fisheries effects. Hood Canal and South Sound waters also both have long residency times and Hood Canal is subject to episodes of low dissolved oxygen.
[5] Includes nearshore and deepwater critical habitat prior to exclusions, designated in 2014 for each of the listed rockfish under section 4(a)(3)(A) of the ESA (79 Fed. Reg. 68041, November 13, 2014).
Note: recreational shrimp fisheries are not listed in the table. Though we assess this fishery to be low risk further information about the risk of this fishery as well as the effects of the commercial fishery will be integrated into this assessment as it becomes available.

***Habitat Relationships***—The relationship between larval and post-settlement rockfish in the DPSs and their habitats is relatively poorly understood and needs further research. Adult listed rockfish habitat usage in most of Puget Sound proper also needs further research. Marine habitats have been degraded by chemical contamination, derelict fishing gear, dredge disposal, fill, nearshore degradation, poor water quality, and possibly mobile fishing gear such as bottom trawls (Drake et al. 2010; WDFW 2011). The protection and restoration of marine habitats—including structure such as nearshore kelp beds and rocky/complex benthic habitat—is warranted because these areas/features are necessary for listed rockfish recruitment and reproduction (Love et al. 1991; Palsson et al. 2009; Young et al. 2010; Springer et al. 2010).

***Public Involvement***—Education, outreach, and public involvement are essential because support and participation from stakeholders are fundamental to successful conservation (Stankey and Shindler 2006). This support is particularly essential for management that relies largely upon self-regulation and self-



AR020408

reporting by user groups, such as occurs in recreational fisheries (Sawchuk 2012; Sawchuk et al. 2015). In addition, continuing the inclusion of anglers, fishing guides, divers, the PSRFEF Oversight Committee, and others in cooperative research will enable collection of additional information about listed rockfish and their habitats, while helping foster trust and inclusion into recovery plan implementation.

### B. PRIMARY FOCUS AND OBJECTIVES OF RECOVERY EFFORTS

The primary focus and objectives of the recovery effort collectively serve to address the gaps in our knowledge about listed rockfish, and reduce threats so the recovery goals outlined in this plan have the greatest likelihood of being achieved. Additional details of aspects of the recovery effort by primary focus area can be found in the appendices, which are intended to facilitate implementation of actions. The recovery effort for yelloweye rockfish and bocaccio will require a focus on several actions, some of which will be conducted concurrently and some of which will necessarily follow others.

Based on the key facts and assumptions and information regarding biology and threats, the recovery strategy focuses on research to enable a greater understanding of listed rockfish population abundance, distribution, diversity, genetics, demographics, and habitat associations. Better understanding of population characteristics and habitat associations, as well as the extent of some threats, is important to enable management for long-term survival and recovery of such long-lived species.

The recovery strategy calls for fishery management that improves accounting of bycatch and mortality rates consistent with rebuilding each species, expanded use of descending devices to reduce barotrauma, the establishment of Marine Reserves/Rockfish Conservation Areas where potential bycatch remains high, and focused enforcement of fisheries, particularly newly enacted regulations to protect listed rockfish.

The recovery strategy also calls for the protection and restoration of listed rockfish habitat, including key habitats in the nearshore (< 98.4 ft [< 30 m]), and deepwater (> 98.4 ft [> 30 m]) from threats such as derelict fishing gear, construction, hypoxia and contaminants. Restoration actions include the removal of derelict fishing gear, rehabilitation of altered shorelines to improve rearing habitats, and the production of rockfish prey species and clean-up of contaminated sediments. Research on the effects of contaminants, ocean acidification, and other anthropogenic disturbances are important to understand effects to productivity and long-term survival of each species. Systematic surveys of listed rockfish populations will enable observations of population changes over time, adjustment of management actions where warranted, and gauge attainment of the recovery criteria. Finally, this plan includes actions for enhancing public outreach and education, which is vital to garner long-term support for listed rockfish recovery.

## C. INTEGRAL USE OF ADAPTIVE MANAGEMENT

This plan calls for continued improvement of knowledge, checking assumptions, monitoring progress, and adjusting plans and actions prior to and throughout implementation (Figure 15). The process of adaptive management—making decisions, implementing them, learning from the results of implementation, and adjusting decisions as necessary—is recognized as an important management tool (especially in data-poor scenarios) to reduce uncertainty over time. It will also safeguard against inaction and/or misdirection of funding and facilitate integration of the best available science into policy.



AR020409

Research is identified as a focus of the recovery strategy and, as new information is collected, it will inform implementation of the fishery, habitat, outreach, and funding strategies. In the first 5 years, we prioritize using adaptive management to: 1) assess rockfish population abundance, distribution, diversity, genetics, demographics, and habitat associations; 2) better understand the relative risk of the threats to rockfish and abate their impact on recovery where possible; 3) take appropriate fisheries management, habitat research, and protection actions; and 4) conduct a gap analysis to identify additional needed research, monitoring, policies, or funding.


Figure 15. The Adaptive Management Process.



AR020410

# IV. RECOVERY GOAL, OBJECTIVES, AND CRITERIA

## A. RECOVERY GOAL

The goal of this recovery plan is to improve yelloweye rockfish and bocaccio abundance, productivity, and spatial structure in the Puget Sound/Georgia Basin to viable and self-sustaining levels such that: yelloweye rockfish can be removed from the Endangered Species List and bocaccio can be downlisted to threatened status and subsequently removed from the Endangered Species List.

## B. RECOVERY OBJECTIVES

The first objective of the recovery plan is to continue to improve our knowledge of the current and historical status of yelloweye rockfish and bocaccio and their habitats. This will be necessary so that populations can be characterized on a management unit basis and a detailed plan can be adaptively managed to carry out recovery actions in a way that will most efficiently achieve the delisting criteria.

The second objective of the recovery plan is to reduce or eliminate existing threats to listed rockfish from fisheries / anthropogenic mortality.

The third objective of the recovery plan is to reduce or eliminate existing threats to listed rockfish habitats and restore important rockfish habitat.

## C. RECOVERY CRITERIA

In order to determine when recovery objectives have been achieved, we must provide objective, measurable criteria which, when met, would result in a determination that yelloweye rockfish and bocaccio of the Puget Sound Georgia Basin should beremoved from the Endangered Species List. Recovery criteria need to be established for each recovery objective and must provide evidence that the greatest threats have been eliminated or controlled and are unlikely to return if protections provided under the ESA are removed.

There is some uncertainty in our knowledge regarding some anthropogenic and natural factors that could potentially be limiting yelloweye rockfish and bocaccio. The recovery plan and criteria focus on the threats that we know are impacting rockfish and their habitats. It may be possible to recover listed rockfish without addressing additional potential threats with uncertain impacts. If the greatest known threats are addressed and a positive response in population demographics is not observed, then additional threat-based objectives and criteria may need to be developed.

The criteria are organized into two categories:  Biological and Demographic Recovery Criteria, which address abundance, distribution, productivity, and genetic diversity, and Threat-based Recovery Criteria, which address the greatest known threats impeding recovery. The best available information must be used in order to ascertain whether the species has met the recovery criteria and qualifies for delisting or downlisting.



AR020411

***Recovery Criteria—Background***

A decision to list or delist a species focuses on its biological performance and the threats to its continued existence. Our approach to developing objective measurable criteria focuses on two areas: performance of the population over a defined period of time (biological criteria) and the reduction of threats that may have caused the population decline or that limit recovery (threats criteria). In order to propose to downlist/delist a species we conduct a review of both the biological criteria and threats criteria. In practicality, conducting this dual assessment would occur when yelloweye rockfish or bocaccio of the Puget Sound/Georgia Basin are found to be approaching the biological criteria as a result of systematic surveys and other applicable information about the population characteristics.

The following sections provide the basis for the criteria and set out objective, measurable criteria for delisting and downlisting. Under the ESA, we must, to the maximum extent practicable, incorporate in the recovery plan criteria, which when met, would result in a determination that the species be removed from the list. There is one set of biological and threats-based criteria to downlist bocaccio and one set of each criteria to delist bocaccio and yelloweye rockfish, with each species evaluated separately.

Challenges associated with setting the appropriate biological criteria include several data gaps, including a lack of historic (pre-fishery) information regarding population characteristics of listed rockfish. These characteristics include length frequency data, biomass, and abundance within the management units or for the entire DPSs. We identify research to assist in filling these data gaps to enable gauging the recovery over time.

To assess achievement of the biological criteria, information is needed in three areas: 1) quantification of historic (pre-exploitation) and ongoing abundance and productivity through the calculation of biomass/fractional lifetime egg production; 2) evaluation of population spatial structure; and 3) evaluation of the diversity, both in terms of genetics and age classes, of the populations.

<u>Introduction—Assessing Progress in Meeting Biologically-Based Delisting Criteria</u>

We identify listed rockfish population characteristics in terms of biomass, spatial structure, and diversity that would, in combination, contribute to long-term viability and support delisting/downlisting decisions. To inform the biomass targets, we assessed *Sebastes* population recovery off the Pacific Coast (outside the Puget Sound/Georgia Basin) managed under rebuilding plans (Pacific Fishery Management Council 2014). Yelloweye rockfish and bocaccio populations outside of the DPSs' area have each begun to rebuild from levels below 20 percent of initial unfished biomass (Pacific Fishery Management Council 2014). The rebuilding of these populations has demonstrated that biomass levels ranging from 10 percent to 20 percent of initial, unfished biomass imparts sufficient resiliency to maintain and grow population levels (Pacific Fishery Management Council 2014). As such, delisting targets for yelloweye rockfish biomass targets range from 15 percent to 25 percent of initial biomass. The downlisting target for bocaccio is 10 percent of initial, unfished biomass, and 15 percent to 25 percent for delisting.

*Data Sources*: To measure whether the biological-based criteria for listed rockfish are being met, we will need to document the number, size, and location of fish with systematic surveys conducted at least every 5 years at to-be-determined random and/or index sites in each of the management units in the U.S. portion of the DPSs' ranges. We will work with the government of Canada to develop/review complementary



AR020412

surveys in the Canadian portion of the DPS. This information will likely primarily come from fishery-independent information through ROV surveys, but additional observations through other research types or fisheries bycatch reports could provide very useful information.

The biological-based population characteristics are discussed separately below, but nonetheless overlap in terms of gauging population viability. We are able to quantify criteria for abundance and productivity, but spatial structure and diversity characteristics are more qualitative because of the general lack of quantitative benchmarks related to these parameters for these species.

*Abundance/Productivity*: The abundance and productivity of listed rockfish can be measured in several different ways, and additional metrics may be developed or refined in the future. Two related methods are measuring biomass relative to unexploited biomass, and measuring the number of eggs produced over the natural lifespan of a fish, termed Lifetime Egg Production (LEP). Calculating LEP requires size-specific fecundity data for yelloweye rockfish and bocaccio from within the DPSs to estimate the total number of eggs produced by a female over the course of her lifetime (O'Farrell and Botsford 2005). Changes in biomass/LEP through time provide insight into population viability and recovery trajectory. To calculate these changes, we calculate the fractional lifetime egg production (FLEP). FLEP is a measure of the proportional change in egg production for one population between two periods of time (O'Farrell and Botsford 2006). Biomass/FLEP can be estimated by measurement of fish length and can be quantified by fishery-dependent and fishery-independent survey methods (e.g., ROV surveys) that provide reasonably reliable length measures. FLEP is a proxy for spawning potential ratio (SPR) or the fished state relative to unfished state (stock status). More generally, FLEP can be determined by size distributions from the past and from recent measurements:

$$FLEP = \frac{LEP_{recent}}{LEP_{earliest}} \approx \frac{LEP_{present}}{LEP_{unfished}}$$ [6]

The status of biomass and FLEP is one biological criterion for delisting yelloweye rockfish and downlisting/delisting bocaccio in the Puget Sound/Georgia Basin DPSs.

*Measuring Historic Biomass*: As mentioned above, there is limited historical/unfished population data for yelloweye rockfish and bocaccio from within the DPSs' area. In order to overcome this data gap, there are several ways to calculate the "baseline" unfished biomass (or LEP earliest in the equation above). The denominator for the biomass/FLEP calculation can be derived several ways:

- *By unfished population data or protected area population benchmarks*. This method would require assessing unfished populations of yelloweye rockfish and bocaccio to serve as a proxy for historic population attributes. This may require looking at populations from outside the DPSs.
- *LEP derived from prior length data*. Known historical size structure data for listed rockfish is summarized in Drake et al (2010) and Washington et al. (1978). Data summarized in Drake et al. (2010) show the length of each species of fish caught in recreational fisheries over several time periods beginning in the 1970s. Washington et al. (1978) reported length data from research using recreational fishing methods from 1974 to 1977. Use of this data to gauge FLEP would need to

[6] Equation from O'Farrell and Botsford (2005).



AR020413

account for the fact that yelloweye rockfish and bocaccio populations from this time period had already been exploited by fisheries for several decades.

- *Theoretical stable-age distributions derived by a matrix model and fishery selectivity curve.* The theoretical stable-age distribution offers a simplified picture of what the population age structure looked like before fishing. The simple approach assumes individuals recruit and die at a constant rate each year, thus reaching a proportion of individuals per age class that does not change (i.e., stable). It can be calculated by applying a constant mortality rate and allowing the population to exponentially decay over the age distribution, an approach common in life table analysis (Ebert 1999) and/or population matrix models (Caswell 2001). In addition to assuming that natural mortality and recruitment are constant, no fishing mortality is applied. Although rockfish do not recruit at a constant rate, this method would nevertheless provide an estimate. The last assumption can be relaxed by assuming some low level of fishing mortality and fishing selectivity curve, though typically one is most interested in an unfished state, thus fishing mortality (and thus selectivity) is zero.

*Spatial Structure:* Relative presence (and population characteristics) of listed rockfish within each of the management units is a metric to gauge population viability. The first step to gauge the potential change of spatial structure of listed rockfish is to determine the amount of rockfish habitat, and in turn how much of it is occupied. Rockfish habitat has been estimated in Canada (Yamanaka and Logan 2010) and within the rest of the management units in the U.S. via critical habitat designation (79 Fed. Reg. 68041, November 13, 2014). Also, see the details of ongoing habitat mapping projects noted in the cooperative research section above. Habitat valuation will be improved with additional surveys and the development of a habitat suitability model to provide a more sophisticated understanding of listed rockfish habitat.

*Diversity (Demographic Structure):* Length-based measurement is the measurement input for gauging changes in a population's diversity over time (and relates to estimating FLEP/biomass) for delisting/downlisting. The proportion of listed rockfish in each management unit and as an aggregate DPS identified as young-of-the-year, juveniles, and adults is the primary diversity metric for delisting/downlisting. Population viability is enhanced with populations that consist of multiple size and age classes of fish because this allows the species to use a wider array of environments, which protects a species against short-term spatial and temporal changes in the environment.

*Summary of Approach*: For yelloweye rockfish we have separate population target levels for each population (Hood Canal and the rest of the DPS). Each population must reach specified target levels for delisting consideration of the listed DPS. We utilize more conservative population target levels for yelloweye rockfish in Hood Canal because they occupy a spatially isolated environment and have less habitat area available than the rest of the DPS population. For yelloweye rockfish and bocaccio we provide generalized scenarios to gauge population status as part of determining delisting/downlisting criteria for each species (see Tables 15 through 18 below). The scenarios balance overall biological status with spatial distribution and size structure. We identify different levels of biomass and FLEP and time in association with spatial distribution and size structure characteristics that, if any are reached, would provide sufficient population viability for each species (in association with an assessment of the threats-based criteria) for delisting/downlisting.



AR020414

We do not anticipate that any of these scenarios will occur exactly as described over time, but are nonetheless illustrative of population characteristics that interact to impart relative viability.

<u>Introduction—Assessing Progress in Meeting Threats-based Delisting Criteria</u>

The threats criteria are designed to address the five statutory listing factors (see Section E. Factors Contributing to Decline and Federal Listing) described in the ESA listing determination for each species. These same factors must be considered in delisting, with objectives related to each factor included as part of the recovery criteria. Since listed rockfish live in deep waters and are difficult to sample, we may rely on surrogate rockfish species from within the Puget Sound/Georgia Basin in certain sections. The downlisting criteria for bocaccio generally requires completed research and/or that programs are in place to understand, limit, and mitigate threats, while delisting criteria for both yelloweye rockfish and bocaccio requires that the threats are found to not limit recovery of the listed species.

## Yelloweye Rockfish

Table 16. Yelloweye Rockfish Biological-based Delisting Criteria (*non-Hood Canal Population*).

| | **Criteria 1: Minimum Biomass/fraction of Unexploited Biomass** | **Minimum Time at Target** | **Criteria 2: Minimum Spatial Distribution and Size Structure** |
|---|---|---|---|
| Scenario A | 15% (and increasing after first sampling event finds 15%) | 20 years, which is approximately 1/2 of one generation time (no less than four systematic sampling events with 80% probability) | Size class frequency includes multiple size classes of fish documented in identified index survey sites. General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm. |
| Scenario B | 20 to 24% | 10 years (no less than three systematic sampling events with 80% probability) | |
| Scenario C | 25% (and above) | 5 years (no less than two systematic sampling events with 80% probability) | |

Table 17. Yelloweye Rockfish Biological-based Delisting Criteria (*Hood Canal Population*).

| | **Criteria 1: Minimum Biomass/fraction of Unexploited Biomass** | **Minimum Time at Target** | **Criteria 2: Minimum Spatial Distribution and Size Structure** |
|---|---|---|---|
| Scenario A | 20 to 24% | 10 years (no less than three systematic sampling events with 80% probability) | Size class frequency includes multiple size classes of fish documented in identified index survey sites. General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm. |
| Scenario B | 25% (and above) | 5 years (no less than two systematic sampling events with 80% probability) | |



AR020415

**Yelloweye Rockfish Threats-based Delisting Criteria (applicable to both populations)**

Listing Factor 1: Destruction, Modification, or Curtailment of Habitat or Range

A. *Derelict fishing gear (i.e., shrimp pots, fishing nets)*. Programs are in place to facilitate and require reporting, preventing, and promptly removing derelict fishing gear that has been demonstrated to result in bycatch or result in harm to yelloweye and yelloweye rockfish habitat.
B. *Contaminants/Bioaccumulants.* Contaminant levels in yelloweye rockfish, prey species, or surrogate rockfish populations (i.e., quillback rockfish, *Sebastes maliger*) in the Puget Sound/Georgia Basin indicate a reduction or slowing of accumulation of legacy contaminants, such as PCBs and DDTs. This could include data showing that overall contaminant levels in the population are decreasing or accumulation is slowing, or information that younger fish have a proportionally reduced contaminant load. A decrease in the number of contaminated sites would also indicate a reduction in contaminants in a portion of the habitat of yelloweye rockfish.
C. *Nutrients*. Management actions and programs are in place to prevent and reduce nutrient inputs. The effects of nutrient inputs (food chain, hypoxia) are found to be not limiting recovery.
D. *Invasive species/Non-native species*. Invasive species that can affect habitat (e.g., tunicates, seaweeds, others) are found to be not limiting recovery. Programs are in place to remove or mitigate the effects of invasive species on yelloweye and yelloweye rockfish habitat.

Listing Factor 2: Over-utilization for Commercial, Recreational, Scientific, or Educational Purposes.

A. *Bycatch/Catch*. Yelloweye rockfish are protected from bycatch/catch by fishery regulations and research permitting sufficient to support maintenance and enhancement of abundance, LEP/biomass, spatial structure, and diversity (bycatch/catch can be reliably estimated from empirical data sources). Bycatch is mitigated when it occurs (i.e., use of descending devices and safe handling techniques).

Listing Factor 3: Disease/Predation

A. *Disease*. Sufficient knowledge exists to determine that disease and parasites Effects on productivity and survival are found to not limit yelloweye recovery.
B. *Predation*. Monitor for possible predation on yelloweye rockfish that impedes population maintenance and growth. Conclusions are drawn that predation is not limiting recovery of yelloweye rockfish populations.

Listing Factor 4: Inadequate Regulatory Mechanisms

A. *Habitat*. Programs are in place to protect, and restore where necessary, rearing and adult habitats.
B. *Fisheries*. Enforcement adequately controls bycatch and poaching.



AR020416

C. *Contaminants/Bioaccumulants*. Regulations are in place to limit the introduction of harmful contaminants and remove large, known areas of contaminated sediments. There is evidence of decreasing levels of contaminants detected in yelloweye rockfish, prey species, or surrogate rockfish populations (i.e., quillback rockfish, *Sebastes maliger*) in the Puget Sound/Georgia Basin, or evidence that the current level of contaminants are not limiting recovery.

Listing Factor 5: Other Factors Affecting the Species' Continued Existence

A. *Hatchery Releases*. Research has been carried out to determine if/how hatchery-released fish (i.e., salmon) affect yelloweye rockfish recovery; any releases that are determined to be harmful to recovery potential are subsequently controlled or mitigated.
B. *Climate Change and Ocean Acidification*. Research has been undertaken to better understand and adapt to deleterious effects of climate change and ocean acidification. Action has been taken to limit deleterious effects on yelloweye rockfish, or the deleterious effects of climate change and ocean acidification have been slowed or reversed or determined unlikely to limit their recovery.
*C.* *Oil Spills*. Effective oil spill prevention and response plans are in place for the Puget Sound/Georgia Basin (i.e., the Northwest Area Contingency Plan).
*D.* *Genetic Changes.* Research has been conducted to understand the extent of inbreeding and hybridization on the listed species, and neither have been found to be limiting yelloweye rockfish recovery.

### Long-term Monitoring Criteria

A long-term monitoring plan and criteria will be developed as part of any proposal to delist the species. We recommend that potential criteria take into consideration the long generation times of the listed species.



AR020417

**Bocaccio**

Table 18. Bocaccio Biological-based Downlisting Criteria.

| Criteria 1: Minimum Biomass/fraction of Unexploited Biomass | Minimum Time at Target | Criteria 2: Minimum Spatial Structure and Size and Age Distribution (Diversity) |
|---|---|---|
| 10% and increasing | 10 years, which is nearly one generation time (no less than three systematic sampling events with 80% probability) | Size class frequency includes multiple size classes of fish documented in identified index survey sites in 4 of 5 management units (one must be Hood Canal or Main Basin). General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm. |

**Bocaccio Threats-based Downlisting Criteria**

Listing Factor 1: Destruction, Modification, or Curtailment of Habitat or Range

A. *Nearshore habitats*. Nearshore nursery habitats are protected from adverse development and are determined to be of sufficient size and quality to provide adequate food, shelter, and other essential requirements for juvenile bocaccio.
B. *Derelict fishing gear (i.e., shrimp pots, fishing nets)*. Programs are in place to facilitate and require reporting, preventing, and promptly removing derelict fishing gear that has been demonstrated to result in bycatch or result in harm to bocaccio and bocaccio habitat.
C. *Contaminants/Bioaccumulants.* Contaminant levels in bocaccio, prey species, or surrogate rockfish populations (i.e., quillback rockfish, *Sebastes maliger*) in the Puget Sound/Georgia Basin that indicate a reduction or slowing of accumulation of legacy contaminants, such as PCBs and DDTs. This could include data showing that overall contaminant levels in the population are decreasing or accumulation is slowing, or information that younger fish have a proportionally reduced contaminant load. A decrease in the number of contaminated sites would also indicate a reduction in contaminants in a portion of the habitat of bocaccio.
D. *Nutrients*. Management actions and programs are in place to prevent and reduce nutrient inputs.
E. *Invasive species/Non-native species*. Research has been conducted to assess the effects of invasive species on bocaccio and bocaccio habitat (e.g., tunicates, seaweeds, others).

Listing Factor 2: Over-utilization for Commercial, Recreational, Scientific, or Educational Purposes.

A. *Bycatch/Catch*. Bocaccio are protected from bycatch/catch by fishery regulations and research permitting sufficient to support maintenance and enhancement of



AR020418

abundance, LEP/biomass, spatial structure, and diversity (bycatch/catch can be reliably estimated from empirical data sources).

Listing Factor 3: Disease/Predation

A. *Disease*. Research has been conducted to assess the effects of disease and parasites on the productivity and survival of bocaccio.
B. *Predation*. Monitor for possible predation on bocaccio that impedes population maintenance and growth.

Listing Factor 4: Inadequate Regulatory Mechanisms

A. *Habitat*. Programs are in place to protect, and restore where necessary, rearing and adult habitats.
B. *Fisheries*. Enforcement adequately controls bycatch and poaching.
C. *Contaminants/Bioaccumulants*. Regulations are in place to limit the introduction of harmful contaminants and remove large, known areas of contaminated sediments.

Listing Factor 5: Other Factors Affecting the Species' Continued Existence

A. *Hatchery Releases*. Research has been carried out to determine if/how hatchery-released fish (i.e., salmon) affect bocaccio recovery.
B. *Climate change and ocean acidification*. Research has been undertaken to better understand and adapt to deleterious effects of climate change and ocean acidification.
*C. Oil Spills*. Effective oil spill prevention and response plans are in place for the Puget Sound/Georgia Basin (i.e., the Northwest Area Contingency Plan).
*D. Genetic Changes.* Research has been conducted to understand the extent of inbreeding and hybridization on bocaccio.



AR020419

Table 19. Bocaccio Biological-based Delisting Criteria.

| | **Criteria 1: Minimum FLEP Status or Biomass/fraction of Unexploited Biomass** | **Minimum Time at Target** | **Criteria 2: Spatial Structure and Size and Age Distribution (Diversity)** |
|---|---|---|---|
| Scenario A | 15% (and increasing after first sampling event finds 15%) | 10 years, which is nearly one generation time (no less than 3 systematic sampling events with 80% probability) | Size class frequency includes multiple size classes of fish in 4 of 5 management units (one must be Hood Canal or Main Basin). General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm. |
| Scenario B | 20% and above | 5 years (no less than 2 systematic sampling events with 80% probability) | Size class frequency includes multiple size classes of fish in 3 of 5 management units (one must be Hood Canal or Main Basin). General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm. |
| Scenario C | 25% and above | 5 years (no less than 2 systematic sampling events with 80% probability) | Size class frequency includes multiple size classes of fish in 2 of 5 management units (one must be Hood Canal or Main Basin). General size classes include juveniles from 3cm to 20cm, subadults from 20cm to 35cm, and adults 35cm to 90+cm. |

## Bocaccio Threats-Based Delisting Criteria

### Listing Factor 1: Destruction, Modification, or Curtailment of Habitat or Range

A. *Nearshore habitats*. Nearshore nursery habitats are protected from adverse development and are determined to be of sufficient size and quality to provide adequate food, shelter, and other essential requirements for juvenile bocaccio, such that population abundance can increase.

B. *Derelict fishing gear (i.e., shrimp pots, fishing nets)*. Programs are in place to facilitate and require reporting, preventing, and promptly removing derelict fishing gear that has been demonstrated to result in bycatch or result in harm to bocaccio and bocaccio habitat.

C. *Contaminants.* Contaminant levels in bocaccio, prey species, or surrogate rockfish populations (i.e., quillback rockfish, *Sebastes maliger*) in the Puget Sound/Georgia Basin that indicate a reduction or slowing of accumulation of legacy contaminants, such as PCBs and DDTs. This could include data showing that overall contaminant levels in the population are decreasing or accumulation is slowing, or information that younger fish have a proportionally reduced contaminant load. A decrease in the number of contaminated sites would also indicate a reduction in contaminants in a portion of the habitat of bocaccio.



AR020420

D. *Nutrients*. Management actions and programs are in place to prevent and reduce nutrient inputs. The effects of nutrient inputs (food chain, hypoxia) are found to be not limiting recovery.
E. *Invasive species/Non-native species*. Research has been conducted to assess the effects of invasive species on bocaccio and bocaccio habitat (e.g., tunicates, seaweeds, others). Effects are found to not limit recovery or programs are in place to remove or mitigate the effects of invasives on bocaccio and bocaccio habitat.

<u>Listing Factor 2: Over-utilization for Commercial, Recreational, Scientific, or Educational Purposes.</u>

B. *Bycatch/Catch*. Bocaccio are protected from bycatch/catch by fishery regulations and research permitting sufficient to support maintenance and enhancement of abundance, LEP/biomass, spatial structure, and diversity (bycatch/catch can be reliably estimated from empirical data sources). Bycatch is mitigated when it occurs (i.e., use of descending devices and safe handling techniques).

<u>Listing Factor 3: Disease/Predation</u>

A. *Disease*. Research has been conducted to assess the effects of disease and parasites on the productivity and survival of bocaccio. The effects have been determined to not limit recovery of bocaccio.
B. *Predation*. Monitor for possible predation on bocaccio that impedes population maintenance and growth. Conclusions are drawn that predation is not unduly limiting recovery of bocaccio.

<u>Listing Factor 4: Inadequate Regulatory Mechanisms</u>

D. *Habitat*. Programs are in place to protect, and restore where necessary, rearing and adult habitats. Decreased habitat is not found to be limiting bocaccio recovery.
E. *Fisheries*. Enforcement adequately controls bycatch and poaching.
F. *Contaminants/Bioaccumulants*. Regulations are in place to limit the introduction of harmful contaminants and remove large, known areas of contaminated sediments. There is evidence of decreasing levels of contaminants detected in bocaccio, prey species, or surrogate rockfish populations (i.e., quillback rockfish, *Sebastes maliger*) in the Puget Sound/Georgia Basin, or evidence that the current level of contaminants are not limiting recovery.

<u>Listing Factor 5: Other Factors Affecting the Species' Continued Existence</u>

E. *Hatchery Releases*. Research has been carried out to determine if/how hatchery-released fish (i.e., salmon) affect bocaccio recovery; any releases that are determined to be harmful to recovery potential are subsequently controlled or mitigated.
F. *Climate change and ocean acidification*. Research has been undertaken to better understand and adapt to deleterious effects of climate change and ocean acidification. Action has been taken to limit deleterious effects on bocaccio, or the deleterious



AR020421

effects of climate change and ocean acidification have been slowed or reversed or determined unlikely to limit their recovery.

G. *Oil Spills*. Effective oil spill prevention and response plans are in place for the Puget Sound/Georgia Basin (i.e., the Northwest Area Contingency Plan).

H. *Genetic Changes.* Research has been conducted to understand the extent of inbreeding and hybridization on the listed species, and neither have been found to be limiting recovery.

**Long-term Monitoring Criteria**

A long-term monitoring plan and criteria will be developed as part of any proposal to delist the species. We recommend that potential criteria take into consideration the long generation times of the listed species.



AR020422

# V. RECOVERY PROGRAM

We developed a list of specific recovery actions to implement the Recovery Strategy and ensure that yelloweye rockfish and bocaccio reach a spatially and demographically viable state. The recovery actions are intended to increase abundance, support healthy demographic structure and diversity, protect and restore habitat, and sufficiently alleviate the past, current, and potential future threats. Because of the general lack of information regarding listed rockfish abundance and distribution, and regarding some of the threats these species face, the following recovery program provides research and recovery actions to fill key data gaps and address the most significant threats during the first 5 years (Phase I).

Phase I will include:

1. Research to enable a greater understanding of listed rockfish population abundance, distribution, diversity, genetics, demographics, ecology, and habitat associations (some actions are already underway, notably a cooperative research genetics study and ROV surveys).
2. Fisheries management consistent with recovery goals.
3. Protection, restoration, and research of rockfish habitats and the Puget Sound/Georgia Basin ecosystem on which they rely.
4. Implementation of an education, outreach, and public involvement plan public outreach plan (Appendix I).
5. Securing public support and funding for listed rockfish recovery.

Phase II (years 5 through 15) will include:

A continuation of actions 1 through 5 and address lower priority habitat threats.

This recovery plan details an outline and narrative that describes the recovery actions that, once implemented, should achieve the goal of recovering yelloweye rockfish and bocaccio. Specifically, they will provide demographic data needed to assess the populations and address the greatest threats to promote recovery of listed rockfish. These threats were ranked as high, medium, low, or unknown for overall risk in the threats assessment. If these recovery actions are fully implemented and recovery of listed rockfish recovery is not achieved, then it is likely that additional threats that are currently ranked lower may need to be reassessed and addressed in the future (Phase 2). In order to better understand and develop specific recovery actions for the remaining threats, it is imperative to develop and implement a comprehensive long-term research plan. Most actions apply to both yelloweye and bocaccio and we identify where actions apply to the whole DPSs or particular Management Units. Some actions could be conducted in one Management Unit (such as telemetry studies), but nonetheless inform management throughout the DPSs.

An Implementation Schedule follows the recovery action outline and narrative. It provides a summary of the actions, prioritizes them, identifies lead entities and potential partners to carry out the actions, and provides an estimate of rockfish recovery program costs over a 5-year period (Phase I). For the high priority actions, we have developed more detailed appendices to help guide recovery implementation, research, and adaptive management. The recovery actions are identified in the outline and narrative, and



AR020423

detailed information about the threats and opportunities, tools, and research needed are detailed in the appendices.

## A. RECOVERY ACTION OUTLINE

Step-down Outline.

This outline serves to summarize research and recovery actions needed to meet the goals and objectives of the recovery plan.

**Recovery Action 1: Research to enable a greater understanding of listed rockfish population abundance, distribution, diversity, genetics, demographics, ecology, and habitat associations.**

1.1 Fishery-independent surveys of abundance, distribution, and size-structure in the nearshore and deep-water environments, with possible identification of index survey sites in each Management Unit in U.S. waters.

  1.1.1 Surveys every 5 years in each Management Unit to observe changes in population abundance, distribution, diversity, genetics, demographics, and habitat associations, which will inform adaptive management. Identify index survey locations/regions to support delisting/downlisting considerations.

1.2 Improved benthic habitat mapping and rockfish habitat characterization, prioritizing management units of Hood Canal, South Sound, and Main Basin.

  1.2.1 Benthic habitat mapping and rockfish habitat characterization will be used to develop a probabilistic habitat model to assess spatial structure and support recovery actions, and potentially evaluate progress toward achieving delisting or downlisting for the DPSs.

  1.2.2 Supplementary multibeam data collection will be needed to understand habitat characteristics and listed rockfish habitat associations throughout the DPSs. Though this has been done in some areas, further data collection is required.

1.3 Assessment of historical fishing and scientific records and historical "grey literature" for the DPSs.[7]

  1.3.1 Develop statistical methods to integrate these multiple sources of historical data on rockfish size structure and abundance to establish an understanding of baseline abundance and size structure for use in DDL decisions.

1.4 Periodically assess genetic structure in DPSs to inform effective dispersal distances, population size, and variance in reproductive success. Confirm DPS delineation for bocaccio.

  1.4.1 Develop a model to determine genetic thresholds of inbreeding and hybridization within the DPSs.

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[7] These data sets include: 1) trawl logbooks 1953 to current, 2) daily catch and effort by statistical area and gear (1950 to current), 3) WDFW observer data taken from 1980 to 1990 in Puget Sound commercial fisheries for groundfish, and 4) other WDFW recreational fishery data, such as Washington et al. 1978 or analysis of historic Native American middens (R. Barsch).



AR020424

1.5 Annual juvenile (YOY) rockfish surveys in each of the Management Units.

1.6 Larval surveys in each Management Unit.
 1.6.1 Surveys will be used to assist the development of a connectivity model, which could be used to inform fisheries management in the DPSs.

1.7 Assess home range and movement of various life stages of listed rockfish via tagging or other methods.

1.8 Develop population models to evaluate critical life stages dictating rockfish population growth.

1.9 Develop and assess statistical methods for integrating multiple sources of data on rockfish size structure and abundance (i.e., ROV surveys, drop camera surveys, fisheries information, etc.) into informative indices of current trends in rockfish size and abundance.

1.10 Conduct and/or assess comparative studies of rockfish abundance and demographic structure inside and outside established marine reserves/MPAs.

**Recovery Action 2. Fisheries management consistent with recovery goals.**

2.1 Account for all catch and bycatch within the DPSs with statistically valid techniques.
 2.1.1. Further assess fisheries in the DPSs by integrating on-going ROV survey data and additional bycatch risk data.

2.2 Ensure that anthropogenic mortality falls within accepted risk-averse precautionary guidelines at appropriate scales (note that this includes the use of devices to mitigate barotrauma and research of long-term survival).

2.3 Establish marine reserves and/or rockfish conservation areas (areas not subject to potential anthropogenic mortality) in prioritized areas in the U.S. portion of the DPSs.
 2.3.1 Monitoring and adaptive management of established areas to assess and improve their efficacy.

2.4 Conduct further research on bycatch to develop and implement measures to avoid and mitigate barotrauma and other sources of bycatch mortality.

2.5 Assess long-term survival and productivity of recompressed yelloweye rockfish and bocaccio in the wild and take appropriate management actions to improve recompression practices, if appropriate.

2.6 Additional enforcement of fishery regulations with emphasis on reducing listed rockfish mortality.

**Recovery Action 3. Protection, restoration, and research of rockfish habitats and the Puget Sound/Georgia Basin ecosystem on which they rely.**

3.1 Nearshore (< 98.4 feet[30 m]) protection, research, and restoration.
 3.1.1. Continue programs to prevent, report, and remove derelict fishing gear from nearshore environments.



AR020425

3.1.2 Assess potential of native kelp restoration projects and pursue restoration projects if found appropriate.

3.1.3 Assess non-indigenous species (*Sargassum muiticum,* Japanese wireweed, and tunicates, *Ciona savignyo, S. clava*, and *D. vexillum*) to determine if they are degrading or impairing rearing habitats such that they are limiting recovery.

3.2 Protection, research, and restoration of deep-water (> 98.4 feet [30 m]) benthic habitats.

3.2.1 Continue programs to prevent, report, and remove derelict fishing gear from deepwater environments.

3.2.2 Assess sediment disposal practices to determine if they are limiting recovery.

3.2.3 Assess and determine if artificial reefs are needed for listed rockfish recovery.

3.3 Assess the impact of contaminants and bioaccumulants (including emerging contaminants such as microplastics) on listed rockfish survival, health, productivity, and behavior.

3.3.1 Clean up or cap contaminated sediments and reduce contaminant inputs, emphasizing the South Puget Sound and Main Basin.

3.4 Prevent and reduce excessive nutrient input (e.g., from septic systems and other human sources) with emphasis in the South Puget Sound, Main Basin, and Hood Canal.

3.5 Develop ecological models to evaluate critical life stages dictating rockfish population growth, understand the potential impacts of climate change and ocean acidification on rockfish population dynamics, and assess the potential for predation and competition to limit rockfish recovery.

3.5.1 Predict, assess, and manage for habitat changes as related to climate change and ocean acidification and synergistic effects in the DPSs.

3.5.2 Determine conditions under which predation could limit recovery.

3.5.3 Determine the potential for interspecific competition to limit recovery within the DPSs, using field studies, experimentation, and modeling.

3.6 Assess disease to determine if it is limiting recovery of the DPSs.

3.7 Assess the effects of hatchery salmon releases (as warranted) to determine if they are limiting recovery of the listed rockfish species.

3.8 Evaluate effects of anthropogenic noise on listed rockfish behavior and productivity to determine if it is limiting recovery.

3.9 Continue oil spill prevention and response within the DPSs.

3.10 Continue state and Federal review of permitted activities to minimize impacts to rockfish habitats and their prey base.

3.11 Continue to enforce habitat protection laws and regulations; improve as warranted to protect rockfish habitat.



AR020426

**Recovery Action 4. Implement education, outreach, and public involvement plan.**

4.1 Improve rockfish identification and documentation of bycatch by recreational and commercial fishers.

4.2 Encourage rockfish catch avoidance and educate anglers why it is preferred over release at depth; increase use of descending devices to mitigate barotraumas.

4.3 Improve knowledge of rockfish life history and habitat usage, the role rockfish play in the Puget Sound ecosystem, and current efforts to recover rockfish.

4.4 Improve understanding of rockfish fishing regulations.

4.5 Continue the *Cooperative Research Program* and other outreach projects to further cooperative fishing research and fishers' engagement in rockfish recovery.

**Recovery Action 5. Secure public support and funding for listed rockfish recovery.**

5.1 Seek a variety of types of funds, including Federal, state, and private grants over a long time frame.

5.2 Establish collaborative research and cooperative funding agreements among state, Federal, tribal, university, and private entities.

## B. RECOVERY NARRATIVE

This section provides additional context to the research and recovery outlines above. Note that the asterisk (*) corresponds to the highest priority level in the implementation schedule.

**Recovery Action 1. Research to enable a greater understanding of listed rockfish population abundance, distribution, diversity, genetics, demographics, ecology, and habitat associations.** Our understanding of current and historical rockfish abundance, distribution, genetics, demographics, and habitat associations in most management units is currently limited. Understanding of each of these elements is required to address critical information gaps and assess the status of the population, evaluate and refine delisting and downlisting criteria, assist in evaluating proposed federal actions under ESA section 7 jeopardy analyses, and track progress towards attaining recovery goals. Many of these actions will be conducted in partnership with WDFW and other agencies and partners, as appropriate.

**1.1. Fishery-independent surveys of abundance, distribution, and size-structure in the nearshore and deep-water environments, with possible identification of index survey sites in each Management Unit in U.S. waters.*** WDFW and NMFS will design an ROV survey program that focuses on listed rockfish and their habitat, in addition to obtaining information for other ecosystem component species. Observation and surveys of yelloweye rockfish and bocaccio adults are challenging because adults are found in deep waters (normally from 90 to 1,394 feet [30 to 425 m]) occurring in or around complex bathymetry. Analogous population monitoring should be continued in Canadian waters as well (the most recent ROV surveys were



AR020427

conducted in 2010). These surveys are necessary to assess the status of the DPSs, evaluate and refine delisting and downlisting criteria and critical habitat, and conduct section 7 jeopardy analyses.

1.1.1 **Surveys should be conducted every 5 years in each Management Unit to observe changes in population abundance, distribution, diversity, genetics, demographics, and habitat associations, to inform adaptive management and assess the status of the DPSs.*** ROV surveys may be used in combination with dropcam or other surveys.

**1.2. Improved benthic habitat mapping and rockfish habitat characterization, prioritizing management units of Hood Canal, South Sound, and Main Basin.*** Habitat mapping is required to assess the status of the DPSs, provide information needed to conduct efficient ROV surveys, and help develop a probabilistic habitat model.

1.2.1 **Benthic habitat mapping and rockfish habitat characterization will be used to develop a probabilistic habitat model to assess spatial structure and support recovery actions, and potentially evaluate progress toward achieving delisting or downlisting for the DPSs.*** The model will integrate habitat characteristics within the Puget Sound/Georgia Basin and historic and contemporary locations of yelloweye rockfish and bocaccio. It will provide a habitat suitability gradient (or similar metric).

1.2.2 **Supplementary multibeam data collection will be needed to understand habitat and listed rockfish habitat associations throughout the DPSs.*** Though this has been done in some areas, mainly near the San Juan Island archipelago, further data collection is required.

**1.3 Assessment of historical fishing and scientific records and historical "grey literature" for the DPSs.*** Historical abundance and distribution of listed rockfish is poorly understood, and assessing current recovery will be improved by understanding past trends.

**1.3.1 Development of statistical methods for integrating multiple sources of historical data on rockfish size structure and abundance.*** This will enable an understanding of baseline abundance and size structure and will be used for delisting and downlisting criteria.

**1.4 Assess genetic structure in DPSs to confirm the DPS delineations and determine effective dispersal distances, population size, and variance in reproductive success.*** Genetic analysis, particularly of bocaccio, will help define possible metapopulation structure in addition to assessing the boundaries of the DPSs' ranges and potential introgression with fish from outside of the DPS (as applicable). A non-lethal assessment of genetic structure may also be used to determine effective dispersal and population size.

**1.4.1 Develop a model to determine genetic thresholds of inbreeding and hybridization within the DPSs.** This will enable an assessment of the viability of the DPSs.

**1.5 Annual juvenile (YOY) rockfish surveys in each of the Management Units.*** These surveys will be necessary for understanding primary rearing locations, habitat threats, and restoration



AR020428

opportunities. Frequent surveys (e.g., at least every other year) will provide documentation of both episodically successful settlement events and the more common years in which little settlement occurs.

1.6 **Larval surveys in each management unit.** Surveys would help determine larval abundance, dispersal, connectivity, and seasonal and interannual abundance.

1.6.1 Surveys could be used to develop a connectivity model, which would be used to inform fisheries management.

1.7 **Assess home range and movement of various life stages of listed rockfish via tagging or other methods.*** Home range and movement of listed rockfish, particularly bocaccio, is poorly understood within the DPSs. This assessment would aid in the development of the habitat model to assess the population as well as inform fisheries management.

1.8 **Develop population models to evaluate critical life stages dictating rockfish population growth.*** Better understanding of which life stages confer the most benefit to the population will help us better understand what life stages to prioritize in conservation efforts.

1.9 **Develop and assess statistical methods for integrating multiple sources of data on rockfish size structure and abundance into informative indices of current trends in rockfish size and abundance.*** Recent methods to assess rockfish size structure and abundance vary (e.g., ROV surveys, drop camera surveys, fisheries information, etc.). Combining these methods to provide estimates on rockfish size structure and abundance may inform delisting and downlisting criteria, as well as delisting and downlisting decisions.

1.10 **Conduct and/or assess comparative studies of rockfish abundance and demographic structure inside and outside established marine reserves/MPAs.*** Scientifically established, well-enforced marine reserves have been shown to protect structure of reproducing rockfish, increase abundance and diversity, and have beneficial effects that may spill over outside the reserve areas. Few studies in Puget Sound are available to conduct before-after/control-experiment studies or to assess present efficacy and placement of current reserves.

**Recovery Action 2. Fisheries management consistent with recovery goals.** To limit listed rockfish bycatch, current fisheries management, enforcement, and data collection needs to be improved. Available data is insufficient for determining the relative threat of some commercial and recreational fisheries. Many of these actions will be conducted in cooperation with Puget Sound Treaty Tribes, WDFW, and other parties, as appropriate.

2.1 **Account for all catch and bycatch within the DPSs with statistically valid techniques.*** Estimates of listed rockfish bycatch in recreational and some commercial fisheries needs improvement. Within the recreational fishery, studies in the Salish Sea have found that anglers have under-reported their bycatch of rockfish (and other species) and also have difficulty identifying rockfish to species, highlighting the uncertainty in current self-reported bycatch estimates. There are also a number of private boat docks and marinas that are not subject to the creel surveys, bringing into further question the current bycatch estimates. There is also a lack of bycatch data for some fisheries. Quantifying all fisheries bycatch is necessary to understand listed rockfish mortality rates and thus impacts to population abundance, productivity, and spatial structure, and is in keeping with principles of fisheries management outlined in Appendix II, Fisheries Management.

**2.1.1 Further assess fisheries in the DPSs by integrating on-going ROV survey data and additional bycatch risk data.** This action is detailed in Appendix II, Fisheries Management, and can be used to assess whether further management actions (including establishment of marine reserves or conservation areas outside the San Juan Islands/Strait of Juan de Fuca) are needed.

**2.2 Ensure that anthropogenic mortality falls within accepted risk-averse precautionary guidelines at appropriate scales (note that this includes the use of devices to mitigate barotrauma and research of long-term survival).*** This action first requires accurate catch and bycatch estimates. Accurate estimates will enable a determination of whether bycatch mortality of listed rockfish fall within acceptable levels. These guidelines are detailed in Appendix II, Fisheries Management.

**2.3 Establish marine reserves and/or rockfish conservation areas not subject to potential anthropogenic mortality.*** Rockfish Conservation Areas have been established across 30 percent of rockfish habitat in the part of the range of the DPSs that extends into Canada. Establishing analogous areas within the prioritized area (San Juan Islands/eastern Strait of Juan de Fuca, Table 20) in the U.S. portion of the range of the DPSs would help to restore metapopulation structure, overall abundance, and protect and maintain spawning biomass at sustainable levels; support proportionally appropriate size and age structure; buffer for uncertainty regarding fish populations and climate change impacts; habitat changes over time; benefit to other forage fish; and other goals (see Appendix II, Fisheries Management). WDFW put regulations into place in 2010 to help limit rockfish bycatch, however, as identified in the threats assessment (Section E.), the San Juan Islands and the Strait of Juan de Fuca are still at high risk for rockfish bycatch. Thus, while this plan includes continued enforcement and evaluation of fishery regulations, it also suggests beginning the public and scientific process to establish protected areas in the San Juan Islands/eastern Strait of Juan de Fuca in the near term, and considering additional protections after further assessment in other areas over the long term.

Appendix II provides the general biological goals, size and shape attributes, and ecological design considerations for establishing reserves/RCAs, but does not recommend specific sites. Appendix II also discusses tribal guidance and socioeconomic considerations for the establishment of reserves/RCAs.

Table 20. Priority for Marine Reserves/Rockfish Conservation Areas.

| **Management Unit within U.S. portion of the Puget Sound/Georgia Basin** | **RCAs/MPAs priority** | |
|---|---|---|
| | **Yelloweye rockfish** | **Bocaccio*** |
| San Juan Islands/Strait of Juan de Fuca | High Priority | Low Priority |



AR020430

| | | |
|---|---|---|
| Main Basin | Medium Priority | Low Priority |
| Hood Canal | Low Priority | Low Priority |
| South Sound | Low Priority | Low Priority |

* Bocaccio move more as adults than yelloweye rockfish, which have very high site fidelity; therefore, the benefits of RCAs/MPAs to bocaccio may be less than the benefits to yelloweye rockfish.
Priorities were calculated by examining effort (commercial effort and type and recreational fishing trips and type), available rockfish habitat, existing protections to protect rockfish by each management unit, and risk to listed rockfish decline due to spatial and genetic isolation.

**2.3.1 Monitoring and adaptive management of established areas to assess and improve their efficacy.*** Monitoring will provide information needed for adaptive management of these areas and ensure they are effective. Also, sharing long-term monitoring results with the public is anticipated to be important for long-term support of these areas. Appendix II also discusses monitoring and adaptive management of reserves/RCAs.

**2.4 Conduct further research on bycatch to develop and implement measures to avoid incidental catch and mitigate barotrauma and other sources of bycatch mortality.*** Bycatch avoidance is preferred because long-term effects of recompression on listed rockfish are not currently well understood. Education on catch avoidance, safe handling techniques, and the use of descending devices, expanding on existing work by WDFW (http://wdfw.wa.gov/fishing/bottomfish/rockfish/mortality.html), should also occur to mitigate the effects of barotrauma to the greatest extent achievable (also see 4.2). See Appendix III, Barotrauma Research and Adaptive Management.

**2.5 Assess long-term survival and productivity of recompressed yelloweye rockfish and bocaccio in the wild and and take appropriate management actions to improve recompression practices, if appropriate** The total survival, sub-lethal effects, and productivity of recompressed listed rockfish are poorly understood, but there is evidence of internal hemorrhaging, infection, and difficulty returning to neutral bouyancy. As additional information is gathered about long-term effects, management and fisheries actions may be modified. See Appendix III, Barotrauma Research and Adaptive Management.

**2.6 Additional enforcement of fishery regulations with emphasis on reducing listed rockfish mortality.*** Continued and additional enforcement of regulations for recreational and commercial fisheries with risk of listed rockfish catch/bycatch (including derelict gear) is necessary. Research has found that some recreational anglers within the DPS area may under-report their bycatch, have difficulty identifying rockfish to species, and are not familiar with some of the rockfish regulations. Also, after establishment of protected areas (2.3), enforcement will also be required to ensure those areas are effective to help achieve recovery goals.

**Recovery Action 3. Protection, restoration, and research of rockfish habitats and the Puget Sound/Georgia Basin ecosystem on which they rely.** Protection and restoration of rockfish habitats is a priority action and essential for recovery. General principles and the best available science about rockfish habitat use guide immediate actions, and research actions are outlined to address information gaps.



AR020431

**3.1 Nearshore (< 98.4 feet [30 m]) protection, research, and restoration.*** Juvenile bocaccio recruit to kelp, and to a lesser extent eelgrass, in the nearshore. Natural rearing habitats, including existing kelp or eelgrass, or areas that could support kelp (i.e., areas with substrate that could support kelp holdfasts), need to be preserved. See Appendix V, Nearshore Habitat and Kelp Conservation.

**3.1.1 Continue programs to prevent, report, and remove derelict fishing gear from nearshore environments.*** Prevention, reporting, and removal of derelict fishing gear has restored hundreds of acres of rockfish habitat, and the continuation of such programs is important to ensure habitat needed for recovery is available, and to decrease the threat of mortality from lost gear.

**3.1.2 Assess potential of native kelp restoration projects and pursue restoration projects if found appropriate.*** Native kelp, and to a lesser extent, eelgrass, is important for juvenile bocaccio recruitment. As such, research should be conducted into the feasibility of kelp and eelgrass restoration and restoration actions should be taken if found viable.

**3.1.3 Assess non-indigenous species (*Sargassum muiticum,* Japanese wireweed, and tunicates, *Ciona savignyo, S. clava*, and *D. vexillum*) to determine if they are degrading or impairing rearing habitats such that they are limiting recovery.** Research has shown that *S. muiticum* alters macroalgal communities; additionally, it competes with and impairs the reestablishment of giant kelp forests in California. *C. savignyo, S. clava*, and *D. vexillum* have increased in Puget Sound, but their distributions and effects may not have reached full potential. However, the degree to which all of these non-indigenous species affect native macroalgae, eelgrass, or rockfish is not understood, so further assessment is needed.

**3.2 Protection, research, and restoration of deep-water (> 98.4 feet [30 m]) habitats.*** Adult listed rockfish live in deep water, making its protection and restoration a priority. See Appendix IV, Benthic Habitat Conservation.

**3.2.1 Continue programs to prevent, report, and remove derelict fishing gear from deepwater environments.*** As in nearshore environments, preventing, reporting, and removal of derelict fishing gear in deepwater habitat will protect these habitats and decrease the threat of mortality from lost gear. Because many shallow-water nets have already been removed, an emphasis on removal from deepwater environments is appropriate.

**3.2.2 Periodically assess sediment disposal practices to determine if they are limiting recovery.** Periodic assessments of disposal practices will help managers make adjustments, if appropriate.

**3.2.3 Assess and determine if artificial reefs are needed for listed rockfish recovery.** An assessment of the role, function, and necessity of artificial reefs would inform their potential use and efficacy for listed rockfish recovery.

**3.3 Assess the impact of contaminants and bioaccumulants (including emerging contaminants such as microplastics) on listed rockfish survival, health, productivity, and behavior.*** Potential impacts of bioaccumulants on listed rockfish are not well understood, but research thus



AR020432

far indicates they may have significant deleterious effects and additional research is needed. Appendix VI, Sediment and Water Quality, addresses these needs.

**3.3.1 Clean up or cap contaminated sediments and reduce contaminant inputs, emphasizing the South Puget Sound and Main Basin.*** Reducing contaminant input and contaminated sediment restoration or capping is a priority as toxins and contaminants may have a large impact on rockfish productivity and health. Generally, the South Puget Sound and Main Basin contain the most legacy and present contamination. See Appendix VI, Sediment and Water Quality.

**3.4 Prevent and reduce excessive nutrient input (e.g., from septic systems and other human sources) with emphasis in the South Puget Sound, Main Basin, and Hood Canal).*** Anthropogenic input of nutrients may contribute to hypoxia and kill listed rockfish and/or their prey base. Portions of Hood Canal, in particular, have episodic periods of low dissolved oxygen, though the relative role of nutrient input from humans in exacerbating these episodes is in question. In addition to Hood Canal, periods of low dissolved oxygen are becoming more widespread in waters south of Tacoma Narrows. The input of nutrients could particularly threaten nearshore habitats of juvenile bocaccio because it can compromise the growth and recruitment of eelgrass by causing plankton blooms or excess growth of eelgrass epiphytes that collectively reduce light levels. Potential modifications for projects that result in pollution and runoff include changing the outfall location to less sensitive habitats and using enhanced pollutant treatment techniques.

**3.5 Develop ecological models to evaluate critical life stages dictating rockfish population growth, understand the potential impacts of climate change and ocean acidification on rockfish population dynamics, and assess the potential for predation and competition to limit rockfish recovery.*** Climate change may cause increasing surface temperatures, changes to precipitation evaporation, vertical mixing, and other changes to marine ecosystems. Ocean acidification may cause changes in the physiology, behavior, metabolism, and reproductive biology of fish. Ocean acidification could also impact the food web, resulting in unknown changes of food availability to upper-level predators such as rockfish. Improving models would inform further assessment of the relative impacts of threats to listed rockfish, including but not limited to climate change, OA, predation, and competition. Further, developing a better understanding of critical life stages that may influence rockfish population growth will enable managers to better direct resources toward threats that could limit this growth. See Appendix VI, Sediment and Water Quality, and Appendix VII, Climate Change and Ocean Acidification.

**3.5.1 Predict, assess, and manage for habitat changes as related to climate change and ocean acidification and synergistic effects in the DPSs.*** Little is known about the effect climate change and ocean acidification will have on listed rockfish, but recent research indicates that the combined effects of OA, hypoxia, and other factors could cause more severe and more frequent deleterious effects in inland waters than in the open ocean. Research and prediction capabilities are needed to understand and plan to adaptively manage habitats used by listed rockfish in the face of these changes.



AR020433

**3.5.2 Determine conditions under which predation could limit recovery.** Models will also enable understanding of levels of predation under varying conditions, and how or if predation could limit recovery.

**3.5.3 Determine the potential for interspecific competition to limit recovery within the DPSs using field studies, experimentation, and modeling.** Little is understood about interspecific competition within Puget Sound, and various analysis methods would enable understanding of how or if competition could limit recovery.

**3.6 Assess disease to determine if it is limiting recovery of the DPSs.** The effect of disease on rockfish is not well understood, especially on listed rockfish, and further research is needed to determine the extent and severity of disease in rockfish to determine if it may be limiting recovery over time.

**3.7 Assess the effects of hatchery salmon releases (as warranted) to determine if they are limiting recovery of the listed species.** The effects of hatchery salmon on listed rockfish requires further assessment to determine if predation by or competition with hatchery fish may be limiting recovery.

**3.8 Evaluate effects of anthropogenic noise on listed rockfish behavior and productivity to determine if it is limiting recovery**. The effects of anthropogenic noise on listed rockfish in Puget Sound is poorly understood, though research in other marine species indicates it could be significant, especially as vessel traffic and other anthropogenic noise is anticipated to increase in Puget Sound. An assessment of anthropogenic noise would assist in determining if sound affects listed rockfish productivity, habitat use, and behavior and limits recovery.

**3.9 Continue oil spill prevention and response within the DPSs.*** Response and prevention are already conducted in the range of the DPSs; these activities are highlighted here to stress their importance to a healthy ecosystem that supports listed rockfish.

**3.10 Continue state and Federal review of permitted activities to minimize impacts to rockfish habitats and their prey-base.*** Regulatory agencies should continue to assess activities that could affect listed rockfish, their habitat, and their prey-base.

**3.11 Continue to enforce habitat protection laws and regulations; improve as warranted to protect listed rockfish habitat.*** Enforcement of current habitat protections is important to support a healthy ecosystem for rockfish recovery.

**Recovery Action 4. Implement the Outreach and Education Plan.** Outreach and education, particularly directed at commercial and recreational anglers, have been prioritized because individual actions may engender more accurate bycatch estimates, decrease effects of bycatch and barotrauma, and garner support for listed rockfish recovery in general. See Appendix I, Education, Outreach, and Public Involvement, for the detailed Plan.

**4.1 Improve rockfish identification and documentation of bycatch by recreational and commercial fishers.*** Many recreational anglers are unable to reliably identify rockfish to species. Literature produced and distributed by WDFW, the Puget Sound Anglers, and NMFS has improved education, but much remains to be done. Because anglers must self-report bycatch



AR020434

returned at sea, reliable identification is important to valid bycatch estimates. Some fisheries with risk of bycatch may not be well monitored for bycatch, which is needed to assess the risk of bycatch as well as identify actions to decrease the risk, if needed.

**4.2 Encourage rockfish catch avoidance and educate fishers why it is preferred over recompression; increase use of best practices to mitigate barotraumas.*** Catch avoidance is preferred over recompression because of concerns about long-term survival, health, and productivity after recompression; thus, education and outreach to fishers should highlight this priority (2.4). Additionally, when recreational and commercial anglers cannot avoid rockfish bycatch, education and outreach is needed to ensure best practices for handling and rapid recompression using descending devices because there is strong evidence that experience and handling time can affect recompression outcomes. WDFW efforts to this end should be expanded upon (http://wdfw.wa.gov/fishing/bottomfish/rockfish/mortality.html).

**4.3 Improve knowledge of rockfish life history and habitat usage, their role in the ecosystem, and current efforts to recover rockfish.*** Fishers who understand rockfish life history are more likely to support recovery efforts. Further, understanding the roles that rockfish play in the local ecosystem may make rockfish recovery more relevant to commercial fishers, recreational anglers, and other stakeholders. Finally, improving fishers' knowledge of ongoing efforts to recover rockfish will improve understanding of challenges and opportunities to recovery.

**4.4 Improve understanding of rockfish fishing regulations.*** Some recreational fishers are not aware of some of the regulations enacted to protect rockfish. Education and outreach may help fishers' awareness of fishing regulations and the reasons for their existence. Additionally, providing education for commercial fishers about the requirement to report lost derelict gear may engender expedient retrieval of lost gear, as has been demonstrated by a WDFW/NWSF program.

**4.5 Continue the *Cooperative Research Program* and other outreach projects to further cooperative fishing research and fishers' engagement in rockfish recovery.*** Although public support is also a goal of education and outreach, the plan will focus on recreational and commercial fishers and SCUBA divers because they are most likely to come into contact/observe rockfish. Further engagement, such as additional cooperative research as part of the *Cooperative Research Program* or other projects, may engender support for rockfish recovery and conservation as well as provide needed research.

**Recovery Action 5. Secure public support for listed rockfish recovery.** Strong public support is crucial to accomplish the criteria and goals established in this plan. Assessment and monitoring of rockfish, their habitats, and their threats; implementing fishery changes; and implementing an education and outreach program will require considerable funding to achieve this plan's goals and objectives. While some funding programs have supported rockfish recovery (e.g., ESA section 6 grants), current funding is inadequate to implement all of the actions identified in the recovery plan. This plan identifies necessary actions and will help support partners seeking funding opportunities. Below, we identify potential sources for obtaining necessary funding support.

**5.1 Seek a variety of types of funds, including Federal, state, and private grants over a long time frame.*** The rockfish recovery effort has obtained funding primarily from within NMFS through ESA section 6 grants to Washington State and through the Dedicated Rockfish Research



AR020435

Fund created by the Washington State Legislature. Single entities alone cannot support the rockfish recovery effort; typically, the funding scope of one grant program can cover the costs of only a subset of the actions necessary to recover the species. As this recovery program is implemented, there will be an increasing need to secure long-term funding for monitoring the species' status over a time frame that spans several decades. Appendix VIII, Funding Opportunities for Rockfish Conservation, is a partial list of programs and awards that may support rockfish recovery and may be pursued by a variety of organizations.

**5.2 Establish collaborative research and cooperative funding agreements among state, Federal, tribal, university, and private entities.*** Cooperative agreements formed between and within state, Federal, tribal, university and private entities will enable the capacity needed to recover listed rockfish. The effort to pool resources and expertise may also help avoid redundancy in effort and extend the scope of available funds.



AR020436

# VI. IMPLEMENTATION SCHEDULE AND PRELIMINARY COST ESTIMATES

This Implementation Schedule (Table 21) outlines recovery research and actions, priority numbers, and estimated rockfish recovery program costs over a 5-year period. The Implementation Schedule provides projections of which actions may continue beyond year 5, but there is considerable uncertainty regarding how long recovery will take. Currently, we do not have reliable biomass information for listed rockfish. As prioritized information is obtained on present and past biomass, as well as information to assess the impact on how threats may limit recovery and how the threats can be effectively mitigated, more robust time and expense projections will be developed.

The cost of the approximately 45 actions recommended in this plan for the first 5 years of recovery is about $23,360,000. Assuming that recovery takes one and a half generations (of yelloweye rockfish) or approximately 60 years, the total recovery costs over 60 years would be approximately $82,970,000. The annual cost of recovery is estimated to decrease substantially after the first 5 to 10 years, once the necessary baseline research and management actions are performed. There are numerous parallel efforts underway, independent from rockfish recovery, to protect and restore the Puget Sound ecosystem. Such efforts include oil-spill prevention measures, contaminated sediment clean-up projects, and other important projects. These efforts will provide benefits to listed rockfish and their habitats and prey base and are thus highlighted in the plan. However, the cost of these actions will not be included in the total cost of rockfish recovery because they would occur independent of this plan. Similarly, actions conducted to restore listed rockfish and their habitats will benefit other listed species that utilize the Puget Sound area, such as Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*), and may provide economic benefits. We are unable to quantify the economic benefits of listed rockfish recovery actions, but it is likely the benefits to the ecosystem and economy would offset the total recovery costs estimated here.

All recovery actions and descriptions reflect the actions as numbered in the Step-down Outline and Recovery Narrative. Priorities in the Implementation Schedule are assigned as follows:

> Priority 1 – An action that must be taken to prevent extinction or to prevent the listed species from declining irreversibly in the foreseeable future.
>
> Priority 2 – An action that must be taken to prevent significant decline in the listed species population/habitat quality or some other significant negative impact short of extinction.
>
> Priority 3 – All other actions necessary to provide for full recovery of yelloweye rockfish and bocaccio.

Recovery of listed rockfish is a long-term effort that requires cooperation and coordination from a number of agencies, organizations, and communities around Puget Sound. Lead entities and potential partners are listed in the Implementation Schedule. Listing a party in the Implementation Schedule does not require the identified party to implement the action(s) or secure funding for implementing the actions(s), but it does denote which organizations may be appropriate for performing those actions. Abbreviations used appear in the key below. A more detailed breakdown of how cost estimates in the Implementation Schedule (Table 21) were calculated is available upon request.



AR020437

### Key to Implementation Table Abbreviations

| | |
|---|---|
| *Department of Defense* | *DOD* |
| *Department of Natural Resources, WA* | *DNR* |
| *Department of Ecology, WA* | *ECY* |
| *Fisheries and Oceans Canada* | *DFO* |
| *Environmental Protection Agency, US* | *EPA* |
| *Northwest Fisheries Science Center* | *NWFSC* |
| *Northwest Straits Foundation* | *NWF* |
| *Northwest Straits Initiative* | *NWSI* |
| *National Marine Fisheries Service* | *NMFS* |
| *Marine Resource Committees* | *MRCs* |
| *The Nature Conservancy* | *TNC* |
| *United States Army Corps of Engineers* | *USACOE* |
| *United States Geological Survey* | *USGS* |
| *Washington Department of Fish and Wildlife* | *WDFW* |

Table 21. Implementation Schedule for Research and Recovery Actions.

**Implementation Schedule**

**Yelloweye Rockfish and Bocaccio Research and Recovery Actions**

***(action is for both species unless otherwise indicated in the comments section)***

**Labor Costs Source: 2012 American Fisheries Society Salary Survey of Fishery Professionals (Table 2, Public Agencies, WA State, average labor costs for Levels 1-5) and consultation with applicable agencies**

**Operation Costs Sources: Funded NWFSC proposals, IE Economic Report prepared for the Plan, Section 6 Funding Proposals from WDFW and DNR, WDFW and other agency or non-profit consultation, and other applicable sources**

| Action # | Action Description | Priority # | Action Duration | *Lead Entities and Potential Partners | Estimated Fiscal Year Costs (2016 US$) | | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | FY1 | FY2 | FY3 | FY4 | FY5 | |
| ***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 deepwater) | 1 | FY1 and every 5 years through recovery | *WDFW, *NMFS, PS Treaty Tribes, Seattle Aquarium, DFO | 500,114 | | | | 500,114 | Required to assess population abundance, distribution, and recovery. |
| 1.1.1 | Regular ROV survey monitoring to observe changes in population abundance, | 1 | Every 5 years through recovery | *WDFW, *NMFS, PS Treaty Tribes, Seattle Aquarium, DFO | | | | | | Required to indicate when some delisting/ downlisting criteria are met. Cost included in action 1.1. |



AR020438

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| | distribution, diversity, genetics, demographics, and habitat associations | | | | | | | | | |
| 1.2 | Benthic habitat mapping and rockfish habitat characterization | 1 | FY1 and 2 | *WDFW, *NMFS, NWFSC, USGS, TNC, SeaDoc Society, DFO, DNR, Academia | 77,500 | 77,500 | | | | Action required to assess population habitat use and management. |
| 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 | FY3 | *WDFW, *NMFS, NWFSC, USGS, TNC, SeaDoc Society, DFO, DNR, Academia | | | 51,667 | | | Model will aid fishery management and meta- population assessment. |
| 1.2.2 | Supplemental multibeam bathymetry data collection | 2 | FY4 and beyond | *WDFW, *NMFS, NWFSC, USGS, TNC, SeaDoc Society, DFO, DNR, Academia | | | | 410,128 | | This is not needed throughout the DPS, but is needed in many areas. |
| 1.3 | Assessment of historical fishing and scientific records and grey literature | 1 | FY1 and 2 | *WDFW, *NMFS, *NWFSC, DFO, Academia | 84,843 | 84,843 | | | | Required to inform recovery targets and delisting/downlisting. |
| 1.3.1 | Development of method to integrate multiple types of historical data to establish an understanding of baseline abundance and size structure | 1 | FY2 | *WDFW, *NMFS, *NWFSC, DFO, Academia | | 38,750 | | | | Required for delisting and downlisting calculations to understand present populations relative to historical. |
| 1.4 | Assess genetic structure in DPSs, effective dispersal distances, and population size | 1 | FY1 and 2 | *NMFS, *NWFSC, *WDFW, DFO, Seattle Aquarium, Academia | 155,822 | 155,822 | | | | Required to understand DPSs' boundaries and potential meta-population structure. |
| 1.4.1 | Develop a model to determine genetic thresholds of inbreeding and hybridization within the DPSs | 1 | FY3 | *NMFS, *NWFSC, *WDFW, DFO, Academia | | | 32,292 | | | Needed for the delisitng and downlisting criteria to assess the status of populations. |



AR020439

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| 1.5 | Annual YOY surveys in each of the management units | 1 | FY1, 3, and 5 and every 5 years after | *WDFW, *NMFS, NWFSC, REEF, SeaDoc Society, Seattle Aquarium, PS Treaty Tribes, NWSI, DNR, Academia | 257,128 | | 257,128 | | 257,128 | Necessary for understanding primary rearing locations, habitat threats, and restoration opportunities. |
| 1.6 | Larval surveys in each management unit | 2 | FY2, 3, and 4 and approxi-mately every 10 years after | *NMFS, *WDFW, PS Treaty Tribes, DFO, USACOE, Academia | | 66,261 | 66,261 | 66,261 | | Needed to understand larval abundance, dispersal, conditions associated with recruitment and connectivity. |
| 1.6.1 | Research output of action 1.6 will be used to develop a connectivity model, which would be utilized to inform fisheries management. | 2 | Complete in FY3, 4, and 5 and every 10 to 15 years after | *WDFW, *NWFSC, *NMFS, Academia | | | 80,048 | 80,048 | 80,048 | Needed to inform fishery management, meta-population assessment, habitat restoration, and possible reserve siting. |
| 1.7 | Assess home range and movement of various life-stages of ESA-listed rockfish | 2 | FY3 and 5 | *WDFW, *NWFSC, *NMFS, Academia | | | 48,894 | | 48,894 | Assessments inform the habitat model as well as fisheries management actions. |
| 1.8 | Develop population models to evaluate critical life stages dictating rockfish population growth | 2 | FY2 | *WDFW, *NWFSC, *NMFS, Academia | | 51,667 | | | | Model will help guide adaptive management and prioritize actions. |
| 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 | FY2 | *WDFW, *NWFSC, *NMFS, Academia | | 95,314 | | | | Essential for use of data sources from various methods and times of collection, to assess the listed populations' status. |



AR020440

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|---|---|---|---|---|---|---|---|---|---|---|
| 1.1O | 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 | FY2 and 3 | *WDFW, *NWFSC, *NMFS, Seattle Aquarium, REEF, SeaDoc Society, Wild Fish Conservancy, Academia, DFO | | 113,128 | 113,128 | | | Robust baseline data enable assessments of the efficacy of past and future sites and aid in adaptive management actions. |
| ***2. Fisheries management consistent with recovery goals*** | | | | | | | | | | |
| 2.1 | Account for all catch and bycatch with statistically valid techniques | 1 | Annually through recovery | *WDFW, *PS Treaty Tribes, *DFO, *NMFS | 157,500 | 157,500 | 157,500 | 157,500 | 157,500 | Further investment will inform management decisions. See Appendix II. |
| 2.1.1 | Further assess fisheries by integrating ROV survey data and additional bycatch risk data | 1 | FY 1-5 and FY 5-15, and every 10 years through recovery | *WDFW, *PS Treaty Tribes, *DFO, *NMFS | 77,500 | 77,500 | | | | Further assessment will inform management decisions. See Appendix II. |
| 2.2 | Ensure that anthropogenic mortality falls within accepted risk-adverse precautionary guidelines at appropriate scales | 1 | Annually through recovery | *NMFS, *WDFW, *PS Treaty Tribes, *DFO | 38,750 | 38,750 | 38,750 | 38,750 | 38,750 | Needed to ensure the DPSs are managed in accordance with best available science. Appendix II. |
| 2.3 | Establish areas not subject to potential anthropogenic mortality (marine protected areas [MPAs] or rockfish conservation areas [RCAs] in priority areas) | 1,2,3 (see table 20) | FY1-5 until estab-lished | *WDFW, *NMFS, *PS Treaty Tribes, *NWIFC, other interested parties | 885,556 | 885,556 | 885,556 | 885,556 | 885,556 | Action will limit anthropogenic mortality. Cost estimates derived from IE Economics report. Appendix II. |
| 2.3.1 | Monitoring and adaptive management of MPAs/RCAs | 1 | FY5 and every 5 years after | *WDFW, *NMFS, *PS Treaty Tribes, *NWIFC, other interested parties | | | | | 293,128 | Need for adaptive management of MPAs/RCAs. Appendix II. |



AR020441

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|---|---|---|---|---|---|---|---|---|---|---|
| 2.4 | Implement measures to avoid and mitigate barotrauma; conduct further research on both avoidance and mitigation | 1 | FY1-5 and every 10 years after | *NMFS, *WDFW, *PS Treaty Tribes, NWFSC, Academia, SeaDoc Society, recreational and/or commercial fishers, Aquaria | 147,012 | 147,012 | 147,012 | 147,012 | 147,012 | Limits bycatch mortality. Appendix III. |
| 2.5 | Assess long-term survival and productivity of recompressed yelloweye rockfish and bocaccio in the wild and take appropriate management actions | 1 | FY1-FY5 and every 10 years after | *NMFS, *WDFW, *PS Treaty Tribes, NWFSC, Academia, SeaDoc Society, recreational and/or commercial fishers, Aquaria | 111,384 | 111,384 | 111,384 | 111,384 | 111,384 | Action will inform adaptive management. Appendix III. |
| 2.6 | Additional enforcement of fishery regulations | 1 | Annually through recovery | *WDFW, *PS Treaty Tribes, *NWIFC, *NMFS | 137,012 | 137,012 | 137,012 | 137,012 | 137,012 | Needed to enforce regulations to protect listed rockfish. Estimates from WDFW. Appendix II. |
| | ***3. Protection, restoration, and research of rockfish habitats and the Puget Sound/Georgia Basin ecosystem*** | | | | | | | | | |
| 3.1 | Nearshore (< 30 m) protection/ restoration | 1 | FY1-5 and beyond | *WDFW, *NMFS, *NWSF, NWS Commission, DNR, MRCs, Academia, Fishers | | | | | | See Appendix V (most applicable to bocaccio). Costs detailed in action 3.1.1, 3.1.2, and 3.1.3. |
| 3.1.1 | Continue to prevent, report, and remove derelict fishing gear from nearshore environments | 1 | Removals 1x every 5 years | *WDFW, *NMFS, *NWSF, NWS Commission, DNR, MRCs, Academia, Fishers | | | | | 86,423 | Removals completed in much of Puget Sound, important to preserve habitat. See Appendix V. |
| 3.1.2 | Assess potential of native kelp (and possibly eelgrass) restoration projects through mapping projects and begin kelp restoration R&D plantings | 1 | FY1-5 and at least every 10 years after | *WDFW, *DNR, *NMFS, PS Restoration Fund, NWS Commission, NWSI, MRCs, Academia | 743,125 | 743,125 | 743,125 | 743,125 | 743,125 | This is important for bocaccio recruitment and rockfish prey. See Appendix V. |

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| 3.1.3 | Assess non-indigenous species to determine if they are degrading or impairing rearing habitats | 3 | FY5 and every 10 years after | *WDFW, *DNR, *NMFS, Sea Doc Society, MRCs, REEF, Academia | | | | | 180,942 | Needed to assess how invasives may affect recovery. Appendix IV and V (overlap between nearshore and deepwater in this action). |
| 3.2 | Protect and restore deepwater (> 30 m) benthic habitat | 1 | FY1-5 and beyond | *WDFW, *NMFS, *NWSF, MRCs, Local Fishers and Fisher Groups | | | | | | See Appendix IV. Cost details included in action 3.2.1, 3.2.2, and 3.2.3. |
| 3.2.1 | Continue programs to prevent, report, and remove derelict fishing gear from deepwater environments | 1 | Removals annually for first 5 years, then every 10 years after | *WDFW, *NMFS, *NWSF, MRCs, Local Fishers and Fisher Groups | 1,130,705 | 1,130,705 | 1,130,705 | 1,130,705 | 1,130,705 | Needed to preserve habitat and decrease bycatch. Appendix IV. |
| 3.2.2 | Periodic assessments of sediment disposal practices to determine if they are limiting recovery | 3 | FY4 and every 5-10 years after | *NMFS, *USACOE, *EPA, ECY | | | | 127,043 | | Needed for adaptive management. Appendix VI. |
| 3.2.3 | Assess if artificial reefs are needed for listed rockfish recovery | 3 | FY5 | *WDFW, *NMFS, NWFSC, Academia, Interested Angling Organizations | | | | | 60,177 | May enhance habitat. Appendix IV. |
| 3.3 | Assess impact of bio-accumulants and other contaminants on listed rockfish survival, health, productivity, and behavior | 1 | FY1-FY5 and every 5 years after | *NMFS, *WDFW, *ECY, *EPA, NWFSC, Academia | 128,564 | 128,564 | 128,564 | 128,564 | 128,564 | Will engender refining actions to reduce contaminant threats. See Appendix VI. |
| 3.3.1 | Clean up (or cap) contaminated sediments, reduce contaminant inputs | 1 | Annually through recovery | *ECY, *WDFW, *NMFS, *USACOE, *EPA | | | | | | Action is being carried out; continuation of action is needed. |
| 3.4 | Prevent and reduce nutrient input | 1 | Annually through recovery | *ECY, *NMFS, *WDFW, Local and State Jurisdictions, Residents | | | | | | Action is being carried out; continuation of action is needed. |



AR020443

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| 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 | FY2-5 and beyond | *NWFSC, *NMFS, *WDFW, ECY, DNR, Academia | | | | | | Cost for model inaction 1.8, will be built on in actions 3.5.1, 3.5.2, and 3.5.3. (Costs included in those actions.) |
| 3.5.1 | Predict, assess, and manage for habitat changes as related to climate change, OA, and synergistic effects in the DPSs | 1 | FY3,4, and 5 and every 5 years after | *NWFSC, *NMFS, *WDFW, ECY, DNR, Academia | | | 95,314 | 95,314 | 95,314 | Needed to plan and adaptively manage habitats used by listed rockfish. Appendix VII. |
| 3.5.2 | Determine conditions under which predation could limit recovery | 2 | FY3 and every 5 years after | *NWFSC, *NMFS, *WDFW, Sea Doc Society, Academia | | | 166,942 | | 166,942 | Needed for adaptive management. |
| 3.5.3 | Determine the potential for interspecific competition to limit recovery within in the DPSs using field studies | 3 | FY4 and every 10 years after | *NWFSC, *NMFS, *WDFW, SeaDoc Society, Academia | | | | 154,942 | | Needed for adaptive management. |
| 3.6 | Assess disease to determine if it is limiting recovery | 2 | FY1 and 5 and every 5 years after | *NWFSC, *NMFS, Academia, SeaDoc Society, Aquaria | 38,750 | | | | 38,750 | Needed for adaptive management. |
| 3.7 | Assess effects of hatchery salmon releases to determine if they are limiting recovery | 2 | FY2,3 and 4 and every 10 years after | *WDFW, *NMFS, *NWFSC, PS Treaty Tribes | | 185,128 | 185,128 | 185,128 | | Needed for adaptive management. |
| 3.8 | Evaluate effects of anthropogenic noise on ESA-listed rockfish behavior and productivity to determine if it is limiting recovery | 3 | FY3, 4, and 5 and every 10 years after | *WDFW, *NMFS, NWFSC, Academia | | | 159,295 | 159,295 | 159,295 | Needed for adaptive management. |



AR020444

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| 3.9 | Continue oil spill prevention and response | 2 | Through - out recovery | *ECY, *EPA, *NMFS | 0 | 0 | 0 | 0 | 0 | Action is being carried out; continuation of action is needed. |
| 3.1O | Continue state and Federal review of permitted activities to minimize impacts to rockfish habitats and their prey base | 1 | Through - out recovery | *NMFS, *WDFW, *ECY, *DNR, *Army Corps of Engineers, *EPA, *DFO | 0 | 0 | 0 | 0 | 0 | Action is being carried out; continuation of action is needed. |
| 3.11 | Continue to enforce habitat protection laws and regulations; improve as warranted to protect listed rockfish habitat | 1 | Through - out recovery | *NMFS, *WDFW, *ECY, *DNR, *Army Corps of Engineers, *EPA, *DFO | 0 | 0 | 0 | 0 | 0 | Action is being carried out; continuation of action is needed. |
| ***4. Implement Education and Outreach Plan*** | | | | | | | | | | |
| 4.1 | Improve rockfish identification and documentation of bycatch | 1 | FY1-5 and annually after | *WDFW, *NMFS, *PS Treaty Tribes, NWIFC, Seattle Aquarium, NWSI, MRCs, Recreational and Commercial Fishers | 59,447 | 59,447 | 59,447 | 59,447 | 59,447 | More accurate bycatch estimates will inform management. Appendix I and II. |
| 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 | 1 | FY1-5 and every 10 years after | *WDFW, *NMFS, *PS Treaty Tribes, NWIFC, NWSI, MRCs, Recreational and Commercial Fishers | 39,447 | 39,447 | 39,447 | 39,447 | 39,447 | Anticipated to help limit mortality. Appendix I. |
| 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 | FY1-5 and annually after | *WDFW, *NMFS, *PS Treaty Tribes, NWSI, MRCs, Recreational and Commercial Fishers | 12,224 | 12,224 | 12,224 | 12,224 | 12,224 | Action needed to make listed rockfish relevant to stakeholders. Appendix I. |
| 4.4 | Improve understanding of rockfish fishing regulations | 1 | FY1-5 and annually after | *WDFW, *PS Treaty Tribes, *NMFS | 12,224 | 12,224 | 12,224 | 12,224 | 12,224 | Action needed to decrease rockfish bycatch. Appendix I. |

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| 4.5 | Formalize the Innovative Fishing Initiative to further cooperative fishing research and angler engagement in rockfish recovery | 1 | FY1-5 and every other year through recovery | *NMFS, *WDFW, *NWFSC, PS Treaty Tribes, SeaDoc Society, Recreational and Commercial Fishers | 39,375 | 39,375 | 39,375 | 39,375 | 39,375 | Will garner support for recovery and form cooperative methods to collect trusted data in a cost-effective manner. Appendix I. |
| ***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 | Through-out recovery | All | | | | | | Insufficient funding limits recovery. Costs included in current operating costs. |
| 5.2 | Establish cooperative funding agreements among state, Federal, and private entities to avoid redundancy and extend the scope of available funds | 1 | Through-out recovery | All | | | | | | Insufficient funding limits recovery. Costs included in current operating costs. |
| **TOTAL Cost (First 5 Years)** | | | | | | | | | | |
| **$23,364,349** | | | | | | | | | | |



AR020446

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AR020467

## APPENDIX I: EDUCATION, OUTREACH, AND PUBLIC INVOLVEMENT

## APPENDIX II: FISHERIES MANAGEMENT

## APPENDIX III: BAROTRAUMA RESEARCH AND ADAPTIVE MANAGEMENT

## APPENDIX IV: BENTHIC HABITAT CONSERVATION

## APPENDIX V: NEARSHORE HABITAT AND KELP CONSERVATION

## APPENDIX VI: SEDIMENT AND WATER QUALITY

## APPENDIX VII: CLIMATE CHANGE AND OCEAN ACIDIFICATION

## APPENDIX VIII: FUNDING OPPORTUNITIES FOR ROCKFISH CONSERVATION



AR020468