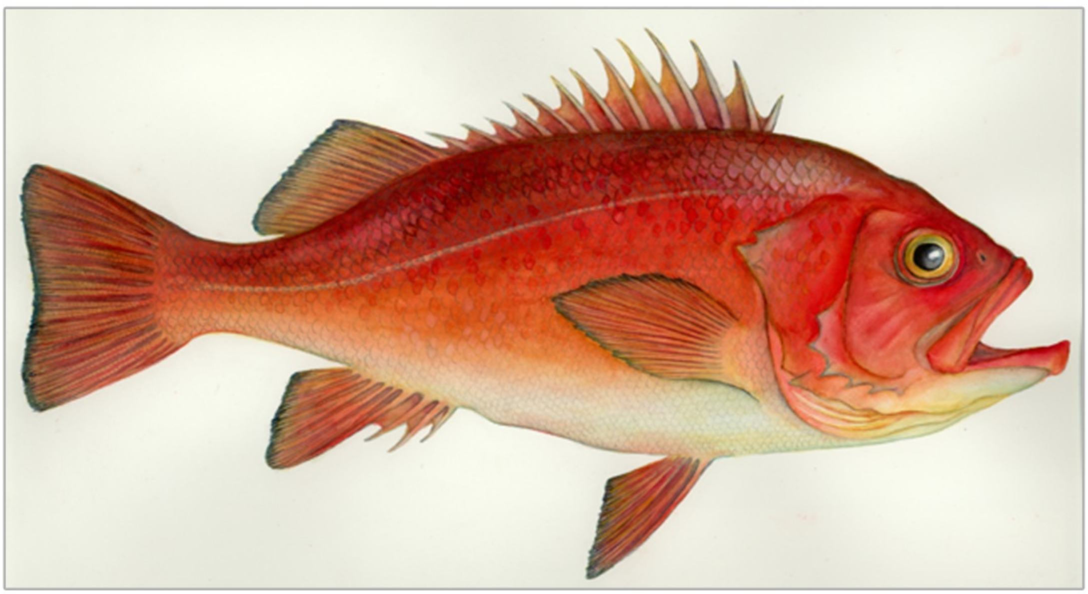
COSEWIC
Assessment and Status Report

on the

Yelloweye Rockfish
Sebastes ruberrimus

Pacific Ocean outside waters population
Pacific Ocean inside waters population

in Canada



THREATENED
2020

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2020. COSEWIC assessment and status report on the Yelloweye Rockfish *Sebastes ruberrimus*, Pacific Ocean outside waters population and Pacific Ocean inside waters population in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xvi + 72 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

Previous report(s):

COSEWIC. 2008. COSEWIC assessment and status report on the Yelloweye Rockfish *Sebastes ruberrimus*, Pacific Ocean inside waters population and Pacific Ocean outside waters population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 75 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Production note:
COSEWIC would like to acknowledge Chris Neufeld and Stacey Hrushowy for writing the status report on Yelloweye Rockfish, *Sebastes ruberrimus*, Pacific Ocean outside waters population and Pacific Ocean inside waters population. The report was overseen and edited by Alan Sinclair and Ross Claytor, Co-chairs of the COSEWIC Marine Fishes Specialist Subcommittee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Sébaste aux yeux jaunes (*Sebastes ruberrimus*), population des eaux extérieures de l'océan Pacifique et population des eaux intérieures de l'océan Pacifique, au Canada.

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Yelloweye Rockfish — Cover illustration: Brenda G. Gillespie, courtesy of the Department of Fisheries and Oceans Canada.

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COSEWIC
Assessment Summary

Assessment Summary – November 2020

Common name
Yelloweye Rockfish - Pacific Ocean outside waters population

Scientific name
Sebastes ruberrimus

Status
Threatened

Reason for designation
This marine fish is an important component of most nearshore rocky reef waters on the Pacific coast of British Columbia, outside the Strait of Georgia. This population is important to the commercial and recreational fisheries, and it is culturally significant for Aboriginal communities. New analyses since the last assessment determined that the population has declined dramatically over the last 100 years and indicate the conservation risk is greater than previously assessed. Due to its relatively slow growth, late age of maturity, and territorial behaviour, this population is slow to recover once depleted. However, the population is not regarded to be in imminent danger of extinction because survey data indicates the population has been stable for 20 years (0.5 generation) and current exploitation levels are considered sustainable. Ongoing threats from pervasive ecosystem modifications and climate change remain.

Occurrence
Pacific Ocean, British Columbia

Status history
Designated Special Concern in November 2008. Status re-examined and designated Threatened in November 2020.

Assessment Summary – November 2020

Common name
Yelloweye Rockfish- Pacific Ocean inside waters population

Scientific name
Sebastes ruberrimus

Status
Threatened

Reason for designation
This marine fish is an important component of near shore rocky reef waters within the Strait of Georgia on the west coast of British Columbia. This population is important to commercial and recreational fisheries, and it is culturally significant for Aboriginal communities. New analyses since the last assessment determined that the population has declined dramatically over the last 100 years and indicate the conservation risk is greater than previously assessed. Due to its relatively slow growth, late age of maturity, and territorial behaviour, this population is slow to recover once depleted. However, the population is not in imminent danger of extinction because survey data indicate the population has been stable for 20 years (0.5 generation), population abundance is near sustainable levels, and long-term projections are stable. Ongoing threats from pervasive ecosystem modifications and climate change remain.

Occurrence
Pacific Ocean, British Columbia

Status history
Designated Special Concern in November 2008. Status re-examined and designated Threatened in November 2020.

COSEWIC
Executive Summary

Yelloweye Rockfish
Sebastes ruberrimus

Wildlife Species Description and Significance

Yelloweye Rockfish, *Sebastes ruberrimus,* Cramer 1895, is one of approximately 112 described species in the genus *Sebastes* worldwide and one of approximately 90 species of rockfish found in the North Pacific. Yelloweye Rockfish is one of the largest rockfish, reaching a maximum recorded length of 91 cm and 11.3 kg.

Distribution

Yelloweye Rockfish is found from the Gulf of Alaska to Northern Baja California, Mexico, but is less abundant in the southern part of their range. It is present in all British Columbia coastal waters.

This report retains the two designatable units (DUs) for Yelloweye Rockfish identified in previous reports as Inside Waters and Outside Waters. This recommendation is based on genetic population structure coinciding with geographically distinct regions. The Pacific Ocean Inside Waters DU includes the Strait of Georgia, Johnstone Strait and Queen Charlotte Strait. The Pacific Ocean Outside Waters DU includes all other coastal British Columbia waters. New genetic evidence was used to change the southern boundary between the Inside and Outside Waters DU.

The US National Marine Fisheries Service recognizes that the Inshore Yelloweye Rockfish population in Washington State (Puget Sound/Georgia Basin Distinct Population Segment) and the Canadian Pacific Inside Water DU are part of the same population.

Habitat

Yelloweye Rockfish has been observed from dive surveys, submersibles, and captured in research surveys in depths from 1 m to 693 m. Juveniles and subadults are usually found between 40 – 100 m. Adults generally occur at depths less than 270 m. They prefer substrates that are hard, complex and with some vertical relief, such as broken rock, rock reefs, ridges, overhangs, crevices, caves, and cobble and boulder fields.

Biology

Female Yelloweye Rockfish produce between 1.2 and 2.7 million eggs annually and supply nutrients to the developing embryos and give birth to live young. Mating takes place from September to April, becoming progressively later as one moves further south in the species' range. Females may store the sperm for weeks or months prior to fertilization, and young are born after a typical gestation period of several months. A prolonged pelagic larval phase may last for up to two months, after which settlement occurs in benthic habitats. Yelloweye Rockfish are solitary benthic dwellers with small home ranges. It is not known whether they form mating aggregations.

Maximum age recorded is 121 years for females and 115 years for males. Estimates of natural mortality based on these ages were 0.045 (females) and 0.040 (males). Age at maturity was estimated using an updated method for generation time using these natural mortality estimates. The generation times estimated using only female characteristics were 39 years for the Outside Waters DU and 41 years for the Inside Waters DU. Previous generation time estimates used a lower estimate of natural mortality (0.02) determined from catch curve analysis. Hence, the current generation time estimates are lower than the 70 years for the Outside Waters DU and 66 years for the Inside Waters DU in previous reports.

Population Sizes and Trends

Biomass of the Outside Waters DU declined by 69 – 72% from 1918- 2018 (~ 2.5 generations). Inside Waters DU biomass declined by 68 - 88% from 1918 to 2019 (~ 2.5 generations). However, survey data for both DUs indicates these populations have been stable for 20 years (~0.5 generation).

Threats and Limiting Factors

Fishing above sustainable levels is the principal known threat to the Yelloweye Rockfish populations in British Columbia. How the population biomass increases or decreases as fishing mortality changes is a measure of the impact of fishing as a threat to the population. These responses to change in fishing mortality are important when considering designation status. The Threat Calculator impact assessments were completed before the updated assessments. Inside and Outside DUs each experienced dramatic declines in response to increased fishing pressure during the 1990s. However, modelling estimates completed after the Threats Calculator suggest that exploitation levels are currently considered sustainable.

Nevertheless, climate change and unfavourable ocean conditions leading to direct or indirect effects on recruitment are ongoing threats that remain. Variability and uncertainty in recruitment lead to variation in cohort strength, affecting population structure and trajectory.

Protection, Status and Ranks

Yelloweye Rockfish do not have any International Union for Conservation of Nature (IUCN) status designations. The U.S. Puget Sound Georgia Basin population of Yelloweye Rockfish that abuts the Canadian Inside Waters DU is listed as threatened under the U.S. *Endangered Species Act* (ESA). Under the ESA legislation, 414 $miles^2$ of critical habitat in US waters adjacent to the Canadian Inside Waters DU has been protected from fishing. According to the US National Marine Fisheries Service, Yelloweye Rockfish in the outer Pacific waters of Washington, Oregon, and California is overfished. In Canada, both the Inside and Outside Waters DUs of Yelloweye Rockfish were designated Special Concern by COSEWIC in 2008 and have been listed as Special Concern under Schedule 1 of the *Species at Risk Act* (SARA) since 2011. Habitat protection for Yelloweye Rockfish occurs via a number of measures currently in place: Marine Protected Areas, Sponge Reef Closures, National Parks fishing closures, and restriction of bottom trawl fishing areas.

TECHNICAL SUMMARY (Pacific Ocean outside waters population)

Sebastes ruberrimus

Yelloweye Rockfish (Pacific Ocean outside waters population)

Sébaste aux yeux jaunes (Population des eaux extérieures de l'océan Pacifique)

Range of occurrence in Canada (province/territory/ocean): Pacific Ocean, British Columbia

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	39 years, based on female life-history (calculated as: age at 50% maturity + 1/Natural Mortality) = 16.4 + 1/0.045
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No. Modelling estimates of mature biomass predict stable numbers in the future.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	NA. Modelling estimates of mature biomass are expected to be stable into the future.
[inferred percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Yes. Modelling estimates of mature biomass are available for 1918-2018 and indicate an overall ~2.5 generational decline for the outside waters DU ranged from 69 to 72%.
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	NA. Modelling estimates of mature biomass are expected to be stable into the future.
Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Modelling estimates of mature biomass are expected to be stable into the future, but 3 generation decline rates would be suspected to be negative over a time period including both the past and the future.
Are the causes of the decline a.clearly reversible and b.understood and c. ceased?	a. Yes, fishing is reversible b. Yes, fishing is understood c. No, fishing has not yet been determined to have ceased as a cause of decline Ongoing threats from pervasive ecosystem modifications and climate change remain and are not clearly reversible, understood, nor ceased.
Are there extreme fluctuations in number of mature individuals?	No.

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	262,877 km² (Within Canadian Jurisdiction)
Index of area of occupancy (IAO) (Always report 2x2 grid value).	40,620 km²

Is the population “severely fragmented” i.e. is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. NA b. NA
Number of “locations”* (use plausible range to reflect uncertainty if appropriate)	Does not apply.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	No.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	NA
Is there an [observed, inferred, or projected] decline in number of “locations”*?	NA
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	No.
Are there extreme fluctuations in number of subpopulations?	NA
Are there extreme fluctuations in number of “locations”*?	NA
Are there extreme fluctuations in extent of occurrence?	No.
Are there extreme fluctuations in index of area of occupancy?	No.

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
None	
Total	> 2 million mature individuals

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not done.

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes. Completed before the most recent rebuilding potential assessment was complete 5.4. Fishing and Harvesting Aquatic Resources (Medium impact, 3 -21% biomass reduction for the next 3 generations from this threat acting in the next 10 years. Modelling estimates completed after the Threats Calculator suggest that mature biomass is stable, while surveys indicate a slight decline or stable population. However, 3 generation decline rates are suspected to remain negative for an uncertain period of time. 9. Pollution (Negligible) 10. Geological events (Negligible) 11. Climate change and severe weather (Unknown). Climate change and unfavourable ocean conditions leading to direct or indirect effects on recruitment are ongoing threats that remain. Variability and uncertainty in recruitment lead to variation in cohort strength, affecting population structure and trajectory. What additional limiting factors are relevant? Yelloweye Rockfish is among the largest, longest-lived, latest-maturing of rockfish species. Populations with these attributes have long recovery times even after fishing impacts have ceased.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Alaska population is healthy. The California, Oregon, and Washington outer coast populations are overfished.
Is immigration known or possible?	Possible (larval drift).
Would immigrants be adapted to survive in Canada?	Probably.
Is there sufficient habitat for immigrants in Canada?	Yes.
Are conditions deteriorating in Canada?[+]	No.
Are conditions for the source population deteriorating?[+]	No.
Is the Canadian population considered to be a sink?[+]	No.
Is rescue from outside populations likely?	Yes, but very slow.

Data Sensitive Species

Is this a data sensitive species? No.

Status History

COSEWIC: Designated Special Concern in November 2008. Status re-examined and designated Threatened in November 2020.

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** Meets criteria for Endangered, A2bd+4bd, but designated Threatened, A2bd+4bd, because the species is not at risk of imminent extirpation.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Reasons for designation:
This marine fish is an important component of most nearshore rocky reef waters on the Pacific coast of British Columbia, outside the Strait of Georgia. This population is important to the commercial and recreational fisheries, and it is culturally significant for Aboriginal communities. New analyses since the last assessment determined that the population has declined dramatically over the last 100 years and indicate the conservation risk is greater than previously assessed. Due to its relatively slow growth, late age of maturity, and territorial behaviour, this population is slow to recover once depleted. However, the population is not regarded to be in imminent danger of extinction because survey data indicates the population has been stable for 20 years (0.5 generation) and current exploitation levels are considered sustainable. Ongoing threats from pervasive ecosystem modifications and climate change remain.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals):
Meets Endangered, A2bd+4bd, but was assessed as Threatened. The decline was based on an index appropriate to the taxon (b) and levels of exploitation (d) were the main cause of the decline. Recent analysis indicated declines were between 69% and 72% over the last 100 years (2.5 generations). The species is slow to recover after depletion. These decline rates and slow recovery would be consistent with an Endangered status, but the population is above fishery management target levels and survey data indicates a stable trend for the past 20 years (0.5 generation) indicating the population is not in imminent danger of extinction.

Criterion B (Small Distribution Range and Decline or Fluctuation):
Not applicable. EOO and IAO exceed thresholds.

Criterion C (Small and Declining Number of Mature Individuals):
Not applicable. Number of mature individuals exceeds criteria.

Criterion D (Very Small or Restricted Population):
Not applicable. Number of mature individuals exceeds the criteria. Does not meet Threatened, D2.

Criterion E (Quantitative Analysis):
Not applicable. Not done.

TECHNICAL SUMMARY (Pacific Ocean inside waters population)

Sebastes ruberrimus

Yelloweye Rockfish (Pacific Ocean inside waters population)

Sébaste aux yeux jaunes (Population des eaux intérieures de l'océan Pacifique)

Range of occurrence in Canada (province/territory/ocean): Pacific Ocean, British Columbia

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	41 years based on female life-history (calculated as: age at 50% maturity + 1/Natural Mortality) = 18.7 + 1/0.045
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No. Modelling estimates of mature biomass predict stable numbers in the future.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	NA. Modelling estimates of mature biomass predict stable numbers in the future.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Yes, Modelling estimates for the inside waters DU mature biomass declined by 68 - 88% from 1918 to 2019 (~ 2.5 generations).
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Modelling estimates of mature biomass are expected to be stable into the future.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Yes, modelling estimates of mature biomass are expected to be stable into the future, but 3 generation decline rates would be suspected to be negative over a time period including both the past and the future.
Are the causes of the decline a. clearly reversible and b. understood, and c. ceased?	a. Yes, fishing is reversible b. Yes, fishing is understood c. No, fishing has not yet been determined to have ceased as a cause of decline. Ongoing threats from pervasive ecosystem modifications and climate change remain and are not clearly reversible, understood, nor ceased.
Are there extreme fluctuations in number of mature individuals?	No.

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	27,183 km² (Within Canadian Jurisdiction)
Index of area of occupancy (IAO) (Always report 2x2 grid value).	2,628 km²

Is the population “severely fragmented” i.e. is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No. b. No.
Number of “locations”* (use plausible range to reflect uncertainty if appropriate)	NA
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	No.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	NA
Is there an [observed, inferred, or projected] decline in number of “locations”*?	NA
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	No.
Are there extreme fluctuations in number of subpopulations?	NA
Are there extreme fluctuations in number of “locations”*?	NA
Are there extreme fluctuations in extent of occurrence?	No.
Are there extreme fluctuations in index of area of occupancy?	No.

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
None	
Total	> 250,000 mature individuals

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not done.

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes. Completed before the most recent rebuilding potential assessment was completed. 5.4 Fishing and Harvesting Aquatic Resources. Fishing (Medium impact, 3 -21% biomass reduction for the next 3 generations from this threat acting in the next 10 years. Modelling estimates completed after the Threats Calculator suggest that mature biomass is stable, while surveys indicate a slight decline or stable population. However, 3 generation decline rates are suspected to remain negative for an uncertain period of time. 9. Pollution (Negligible) 10. Geological events (Negligible) 11. Climate change and severe weather (Unknown). Climate change and unfavourable ocean conditions leading to direct or indirect effects on recruitment are ongoing threats that remain. Variability and uncertainty in recruitment lead to variation in cohort strength, affecting population structure and trajectory. What additional limiting factors are relevant? Yelloweye Rockfish is among the largest, longest-lived, latest-maturing of rockfish species. Populations with these attributes have long recovery times even after fishing impacts have ceased.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	No
Is immigration known or possible?	Possible (larval drift).
Would immigrants be adapted to survive in Canada?	Probably.
Is there sufficient habitat for immigrants in Canada?	Yes.
Are conditions deteriorating in Canada?[+]	No.
Are conditions for the source population deteriorating?[+]	No.
Is the Canadian population considered to be a sink?[+]	No.
Is rescue from outside populations likely?	No. The US National Marine Fisheries Service recognizes that the Inshore Yelloweye Rockfish population in Washington State (Puget Sound/ Georgia Basin) includes the entire range of the Canadian Pacific inside waters DU. The Puget Sound/Georgia Basin Distinct Population Segment is threatened.

Data Sensitive Species

Is this a data sensitive species? No.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Status History

COSEWIC: Designated Special Concern in November 2008. Status re-examined and designated Threatened in November 2020.

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Threatened	Meets criteria for Endangered, A2bd+4bd, but designated Threatened, A2bd+4bd, because the species is not at risk of imminent extirpation.
Reasons for designation: This marine fish is an important component of near shore rocky reef waters within the Strait of Georgia on the west coast of British Columbia. This population is important to commercial and recreational fisheries, and it is culturally significant for Aboriginal communities. New analyses since the last assessment determined that the population has declined dramatically over the last 100 years and indicate the conservation risk is greater than previously assessed. Due to its relatively slow growth, late age of maturity, and territorial behaviour, this population is slow to recover once depleted. However, the population is not in imminent danger of extinction because survey data indicate the population has been stable for 20 years (0.5 generation), population abundance is near sustainable levels, and long-term projections are stable. Ongoing threats from pervasive ecosystem modifications and climate change remain.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered, A2bd+4bd, but was assessed as Threatened. The decline was based on an index appropriate to the taxon (b) and levels of exploitation (d) were the main cause of the decline. Recent population modelling indicated that declines greater than 70% have occurred with a probability of 43 – 99% and that declines greater than 50% have occurred with a probability of 86 – 99% over the last 100 years (2.5 generations). These declines would be consistent with an Endangered status, but survey data indicates that the population has been stable for 20 years (0.5 generation), modelling indicates that the population is near fishery management target levels, and projection analysis indicates that the population is not in imminent danger of extinction. Decline rates indicate the risk is greater than the previously assessed Special Concern.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. EOO and IAO exceed thresholds.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Number of mature individuals exceeds criteria.
Criterion D (Very Small or Restricted Population): Not applicable. Number of mature individuals exceeds the criteria. Does not meet Threatened, D2.
Criterion E (Quantitative Analysis): Not applicable. Not done.

PREFACE

Yelloweye Rockfish was first assessed in 2008 and a status of Special Concern was determined by COSEWIC for the two identified Inside Waters and Outside Waters designatable units (COSEWIC 2008). This Special Concern recommendation was based on life history characteristics (e.g., late maturity) that make the species slower to recover from depressed numbers combined with the likelihood of continued harvest in commercial, Aboriginal, and recreational fisheries. Since then, Fisheries and Oceans Canada (DFO) stock assessments that incorporated catch reconstructions, fisheries catch data, and research survey data to construct stock biomass estimates dating back to 1918 were conducted for the Outside Waters DU (Yamanaka *et al.* 2018) and the Inside Waters DU (Yamanaka *et al.* 2011).

These assessment results were summarized together with additional updates provided by DFO in 2019 (Keppel and Olsen 2019). Additional evidence from long-line surveys, since 2000, covering a subset of the Outside Waters DU on the central coast of B.C. and surveys of Aboriginal anglers, covering fishing since 1950, provided information on changes over time in average size and average age. Fisheries management changes with respect to quotas and bycatch have been initiated since the last assessments with the objective of reducing fishing mortality on Yelloweye Rockfish stocks.

Additional genetic analyses conducted by Siegle *et al.* (2013) and Andrews *et al.* (2018) support the Inside Waters and Outside Waters DU structure. A change in the southern boundary between the Inside Waters and Outside Waters DUs is made based on a U.S. assessment of Yelloweye Rockfish (Drake *et al.* 2010; Andrews *et al.* 2018).

A draft COSEWIC Status report was prepared based on these findings and was scheduled for presentation in November 2019.

In October 2019, DFO requested that COSEWIC delay the presentation of these results because an updated assessment of stock status for the purpose of developing a rebuilding plan was in progress. The updated data and analyses would be reviewed during the winter and spring of 2020. COSEWIC agreed to delay the presentation of the November 2019 report until November 2020. This report incorporates the findings from the rebuilding plan assessments undertaken by DFO in February 2020 for the Outside Waters DU (Cox *et al.* 2020; DFO 2020a) and June of 2020 for the Inside Waters DU (DFO 2020b).

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2020)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
Service canadien de la faune
Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Yelloweye Rockfish
Sebastes ruberrimus

in Canada

2020

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Yelloweye Rockfish *Sebastes ruberrimus,* Cramer 1895, is one of approximately 112 described species in the genus *Sebastes* worldwide and one of approximately 90 species of rockfish found in the North Pacific (Hyde and Vetter 2007; Magnuson-Ford *et al.* 2009). Yelloweye Rockfish are referred to by many names including Red Snapper, Red Rock Cod, Rasphead Rockfish, Red Rockfish, Red Cod, Goldeneye Rockfish, and Turkey Red Rockfish (Lamb and Edgell 2010), and by First Nations, for example glowuksum on Gilford Island (Broughton Archipelago) (COSEWIC 2008) and sgang on the southwest coast of Haida Gwaii (Jones 1999).

Morphological Description

Yelloweye Rockfish is one of the largest rockfish, reaching a maximum recorded length of 91 cm and 11.3 kg (Love *et al.* 2002). They are easily identified by their bright orange to red colouration and bright yellow eyes. Adults usually have a light to white stripe on their lateral line, while subadults often have a second shorter stripe below the lateral line (Cover, Figure 1). Juveniles are more dark red in colouration than the adults and have two distinct light stripes, one on the lateral line and a shorter one below the lateral line (Mecklenburg *et al.* 2002) (Figure 1). Yelloweye Rockfish has 13 dorsal spines and the fins may have black tips (Kramer and O'Connell 1995). Yelloweye Rockfish can be confused with Canary (*Sebastes pinniger*) and Vermilion Rockfishes (*Sebastes miniatus*) because all have similar body shapes and adult colouration. However, only Yelloweye Rockfish have a bright yellow eye (Love *et al.* 2002).

Figure 1. Photographs of Yelloweye Rockfish taken from a submersible, subadult (left panel) and juvenile (right panel). Photo credit K. L. Yamanaka.

Population Spatial Structure and Variability

Nine neutral microsatellite loci examined from commercial fishery and research survey samples collected between 1998 and 2007 form the baseline data for examining the genetic population structure of Yelloweye Rockfish (Table 1). Based on F_{ST} cluster and dendrogram analyses, differences in heterozygosity, and allelic richness it was concluded that Yelloweye Rockfish consisted of two distinct populations, one within the Strait of Georgia (Inside Waters) and one outside the Strait of Georgia (Outside Waters) (Yamanaka *et al*. 2006; COSEWIC 2008). Subsequent analyses using these samples (Siegle *et al*. 2013) supplemented by additional fishery and survey samples (Andrews *et al*. 2018) have supported the genetic differences between these two populations (Tables 1, 2, 3). In addition, Andrews *et al*. (2018) identified a separate population in Hood Canal, Washington (Table 3).

Table 1. List of sample localities used to examine the genetic differentiation among the Yelloweye Rockfish from various geographic areas. F_{ST} values represent comparisons between individuals collected near San Francisco, California, as a reference outside group, and the indicated sample location. Samples are grouped by locality with respect to southern (proposed DU) and northern boundaries. References are listed in order of analyses completed for each sample. References are: Y 2006 = Yamanaka *et al.* 2006, S 2013 = Siegle *et al.* (2013), and A 2018 = Andrews *et al.* (2018). Outside Water DU versus Inside Water DU distinctions using A 2018 were made using pairwise F_{ST} values, see Table 3. HE is the expected heterozygosity expressed as a percentage.

Location	Date	Samples	HE	DU	Reference	F_{ST}
Southern boundary samples						
Juan de Fuca Strait	2000	1	-	Outside	C 2008	
Juan de Fuca Strait	2014	19		Outside	A 2018	0.005-0.015
L.W. Vancouver Island	2005 - 2008	7	74.0	Outside	C 2008	
Outer WA coast	2009 - 2015	22		Outside	A 2018	-0.008-0.005
San Juan Islands	2014 - 2015	28		Inside	A 2018	0.015-0.045
Central Puget Sound	2015	4		Inside	A 2018	0.015-0.035
Northern boundary samples						
Gordon Channel	2006	26	75.0	Outside	C 2008	
Gordon Channel	2007	37	71.0	Outside	C 2008	
Gordon Channel	2009	5		Outside	A 2018	-0.008-0.005
George Passage	2006	6	58.0	Inside	C 2008	
George Passage	2007	14	68.0	Inside	C 2008	

Location	Date	Samples	HE	DU	Reference	F_{ST}
Clearly within indicated DU samples						
U Johnstone Strait	2007	19	62.0	Inside	C 2008	
U Johnstone Strait	2006	27	63.0	Inside	C 2008	
U Johnstone Strait	2010	5		Inside	A 2018	0.025-0035
Thurlow Islands	2007	11	63.0	Inside	C 2008	
L. Bute Inlet*/ QC Strait / Discovery passage / Strait of Georgia	2004	35 23 123	67.0 63.1	Inside	C 2008 Y 2006 S 2013	
L. Bute Inlet	2006	29	62.0	Inside	C 2008	
L. Bute Inlet	2007	19	63.0	Inside	C 2008	
Desolation Sound	2005	89	62.0	Inside	C 2008	
Desolation Sound	2013	5			A 2018	0.025-0.035
Mitlenatch Island	2005	9	62.0	Inside	C 2008	
Mitlenatch Island	2006	28	68.0	Inside	C 2008	
Mitlenatch Island	2013	5			A 2018	0.025-0.035
Malaspina Strait	2005	24	64.0	Inside	C 2008	
Hower Sound	2005	3	65.0	Inside	C 2008	
W. Texada Island	2005	66	62.0	Inside	C 2008	
Gabriola Island* Georgia Strait	2000	57 57	63.0 62.7	Inside	C 2008 Y 2006	
Gabriola Island* Georgia Strait	2005	90 47	64.0 62.7	Inside	C 2008 Y 2006	
Saltspring Island	2000 - 2007	7	67.0	Inside	C 2008	
Saltspring Island	2013	3		Inside	A 2018	0.015-0.025
S.E. Alaska	1998 - 2000	88 85	71.9 72.2	Outside	Y 2006 S 2013	
Bowie Seamount	1998 - 2000	848 779	72.6 72.6	Outside	Y 2006 S 2013	
Tasu	1998 - 2000	264 231	74.2 74.1	Outside	Y 2006 S 2013	
Barber Point	1998 - 2000	402 345	72.8 72.8	Outside	Y 2006 S 2013	
Cape St. James	1998 - 2000	369 327	72.3 72.3	Outside	Y 2006 S 2013	
B.C. Central Coast Calvert Island	2006	91 87	72.6 72.5	Outside	Y 2006 S 2013	
N. W. Vancouver Island	2008	1		Outside	A 2018	-0.008-0.005
N. W. Vancouver Island	2012	4		Outside	A 2018	-0.008-0.005

Location	Date	Samples	HE	DU	Reference	F_{ST}
Triangle	1998 - 2000	221 187	72.6 72.8	Outside	Y 2006 S 2013	
Topknot	1998 - 2000	224 167	72.3 72.8	Outside	Y 2006 S 2013	
Brooks Bay	1998 - 2000	73 50	72.8 73.1	Outside	Y 2006 S 2013	
Esperanza	1998 - 2000	46 46	73.0 73.0	Outside	Y 2006 S 2013	
Washington	2006	82 81	70.7 72.8	Outside	Y 2006 S 2013	
Oregon	2006	87 75	72.2 71.4	Outside	Y 2006 S 2013	
Hood Canal samples						
Hood Canal	2014	16		Hood Canal	A 2018	

* L Bute Inlet, Gabriola Island were 127 in Y 2006 but 182 in C 2008

There were no unique alleles found in the Inside Waters designatable unit (DU) samples. All alleles found in the Inside Waters DU samples were also found in the Outside Waters DU samples (COSEWIC 2008). The reduced heterozygosity and number of alleles in the Inside Waters DU samples indicated they were drawn from a population with a smaller effective population size than all other samples. These observations are consistent with the hypothesis that loss of rare alleles accounts for the differentiation between the Inside Waters and Outside Waters populations (Yamanaka *et al.* 2006).

Questions arising from the COSEWIC (2008) genetic interpretation concerned the southern boundary between the two populations, the mechanism creating barriers to dispersal between the populations, and the stability of the genetic differentiation.

An F_{ST} comparison analysis separating samples into those born before 1980 from those born after 1980 supported the temporal stability in the genetic differences between the two populations (Table 2, Siegle *et al*. 2013).

Table 2. Pairwise F_{ST} values and allelic richness from indicated references. The Outside column for the three FST rows represents Outside Waters DU vs Outside Waters DU sample comparisons. The Inside column for the three FST rows represents Inside Waters DU vs. Outside Waters DU sample comparisons.

	Outside	Inside	Reference
Allelic richness	10.7 – 11.7	8.0	Y 2006
Allelic richness	10.54 – 11.77	8.0	S 2013
FST – All	0.001	0.016	S 2013
FST before 1980	0.0003	0.0203	S 2013
FST after 1980	0.0041	0.0204	S 2013

The Inside Waters DU is associated primarily with the Strait of Georgia DFO Marine Ecoregion, while the outside waters population is associated with the Southern Shelf and Northern Shelf Marine Ecoregions (DFO 2009, Figure 2). The Strait of Georgia is bordered by shallow depths in the north and south, is bounded by strong tidal fronts to the north and south and has appreciable freshwater influence from the Fraser River. The Strait of Juan de Fuca is a transition zone between the Strait of Georgia and the Southern Shelf separating the Inside Waters DU and Outside Waters DU in the south (Powles *et al.* 2004).

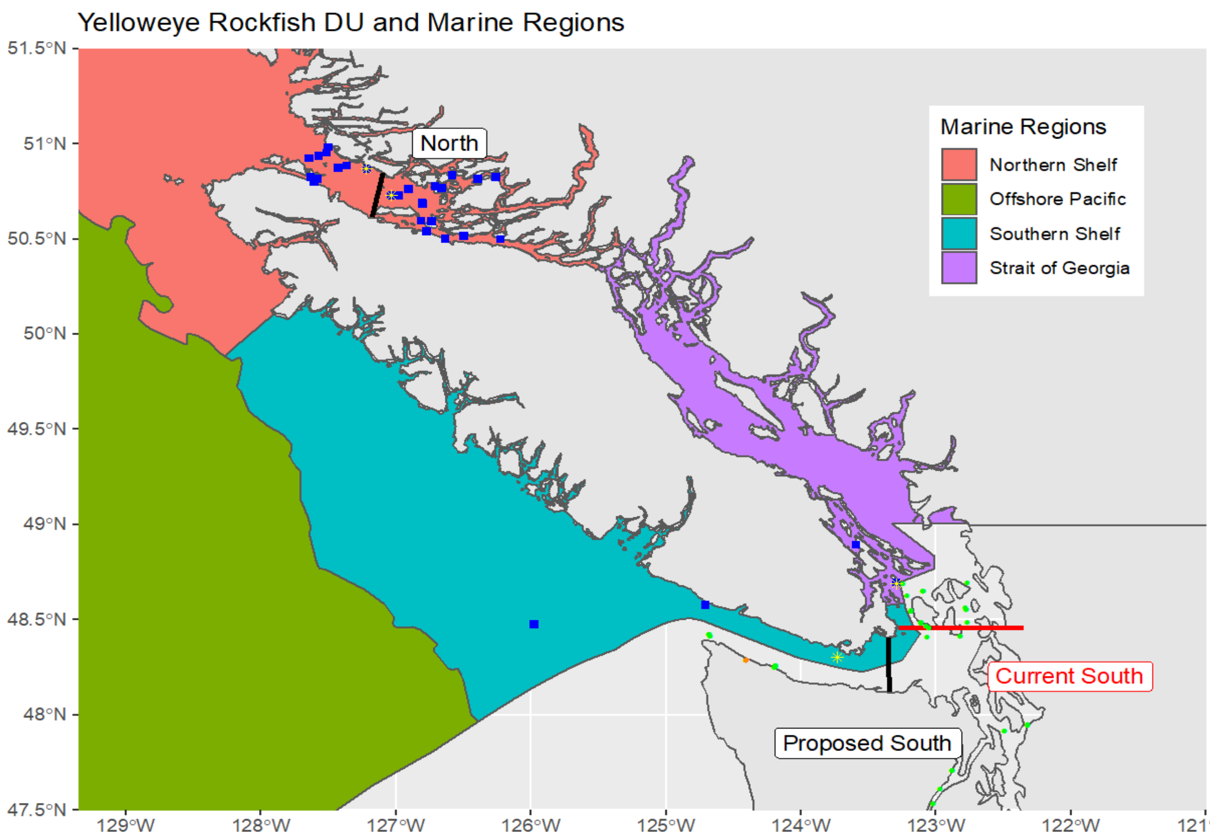

Figure 2. Localities of genetic samples with respect to DFO Marine Regions, northern DU boundary, current southern DU boundary (COSEWIC 2008) and proposed southern DU boundary. Orange dot is the Sekiu River. Northern Shelf, Offshore Pacific, and Southern Shelf are associated with Outside waters DU. Strait of Georgia is associated with the Inside Waters DU. Blue points represent samples by Yamanaka *et al.* (2006) reanalyzed by Siegle *et al.* (2013) that reinforce the separation of the two DUs. Green points represent recent samples analyzed by Andrews *et al.* (2018) used to recommend the southern boundary of the DUs be moved to the region of the Victoria Sill. Stars to the left and right of the boundaries indicate the furthest east of samples belonging to the Outside Waters DU and the furthest west of samples belonging to the Inside Waters DU used to define the original DU boundaries in 2008 (COSEWIC 2008). Source for Marine Region shapefiles: Living Oceans (2019).

Physical oceanographic patterns acting as barriers to larval dispersal were collated by Drake *et al*. (2010) for a U.S. status review of five rockfish species including Yelloweye Rockfish. These patterns were discussed by Siegle *et al*. (2013) and by Andrews *et al.* (2018) to explain the stability and creation of the genetic distinctiveness between the inside and outside populations.

Pairwise F_{ST} comparisons incorporating 121 new samples by Andrews *et al.* (2018) differentiated a third Hood Canal, Washington cluster, distinct from the Inside and Outside populations (Table 3).

Table 3. Pairwise F_{ST} values between regions for Yelloweye Rockfish from Andrews *et al.* (2018). Confidence intervals were created using bootstrapping, p-values test the hypothesis that pairwise F_{ST} is significantly different from 0.

Comparison	F_{ST}	95% CI	P value
Outside Waters DU vs. Hood Canal HC	0.0276	0.0264 – 0.0289	<0.001
Outside Waters DU vs. Inside Waters DU excluding HC	0.0191	0.0184 – 0.0198	<0.001
Inside waters excluding HC vs. Hood Canal	0.0128	0.0120 – 0.0137	<0.001

Designatable Units

Discreteness and Significance

This report retains the two designatable units (DUs) for Yelloweye Rockfish identified as Inside Waters and Outside Waters in COSEWIC (2008). A new southern boundary between the two DUs is delineated (discussed below).

The two identified populations are considered to meet the COSEWIC discreteness criteria for designatable units by evidence of genetic distinctness, natural disjunctions in the species' range combined with territorial behaviour, and occupation of differing geographic regions as explained below.

1. The temporal stability of the genetic distinctiveness between the two populations has been supported by analyses since the last assessment (COSEWIC 2008; Siegle *et al*. 2013; Andrews *et al.* 2018). The inside population has significantly lower genetic diversity compared to the outside population. Yelloweye Rockfish in each population, born before and after 1980, exhibit the same genetic distinctions (Siegle *et al*. 2013). The observed genetic differentiation between the inside and outside population is relatively large for a marine fish, particularly one with an extended pelagic larval phase (Tables 1,2,3). Unique microsatellite alleles were not found in the Inside Waters DU. However, unique microsatellite alleles are rarely observed in marine fish populations (COSEWIC 2008).

2. A natural disjunction occurs between the inside and outside populations because of the unique physical, chemical, and biological oceanographic characteristics of the Strait of Georgia (Inside Waters DU) versus the neighbouring northern and southern outer shelfs (Outside Waters DU). At the southern boundary between the two populations, the Victoria Sill creates a natural barrier that promotes larval retention. Juvenile and adult territoriality also promote genetic differences between the populations (Drake *et al*. 2010).

3. The Inside Waters DU primarily consists of the Strait of Georgia marine ecoregion and the Outside Waters DU is composed of the Southern Shelf, Northern Shelf, and Offshore Pacific Ecozones defined by Fisheries and Oceans Canada (DFO 2009, Figure 2). Hence, the two populations occupy different eco-geographic regions. A rationale for moving the current southern boundary southwestward from that proposed in COSEWIC (2008) is discussed below. This proposed move would not change the primary association of each DU with the Marine Ecoregions.

The two identified populations are considered to meet the COSEWIC significance criteria for designatable units based on the persistence of genetic differences in a setting unique to the species such that it is likely to have given rise to local adaptations as described below.

1. Distinct eco-geographic environments occur within these population boundaries (Powles *et al.* 2004; Drake *et al*. 2010). Thus, the temporal genetic stability observed makes it reasonable to expect that these distinct environmental selective regimes have produced local adaptations.

2. Juvenile and adult territoriality in promoting genetic differences between the populations (Drake *et al*. 2010) also contribute to the likelihood that local adaptations have developed within these DUs.

The rockfishes (*Sebastes* spp.) of the Pacific Ocean are a well-known example of adaptive radiation. It is the most species rich genus in the Pacific Ocean, with over 100 described species (Kendall 2000). Multiple studies (Johns and Avise 1988; Li *et al.* 2006; Rocha-Olivares *et al.* 1999; Seeb 1986) have demonstrated the monophyletic nature of the genus, with low levels of genetic divergence between species, indicating rapid radiation within the genus from a period beginning 3.6-18 million years ago (Johns and Avise 1998; Rocha-Olivares 1998). The number of species supports the adaptive capacity for speciation within the genus. In addition, many rockfish species occupy nearshore coastal habitats and are sympatric along most parts of the Pacific coast, supporting the conclusion that adaptive heritable traits have evolved on fine environmental and ecological scales (Love *et al*. 2002).

Thus, the two populations meet the discreteness and significance criteria for Inside Waters and Outside Waters designatable units.

DU boundaries

With respect to the northern boundary there is no new information to suggest a change in boundary. Hence it is appropriate to maintain the established northern boundary. This boundary was established by noting that the most westerly George Passage (grouped with the inside population) sampled location was 50.728° N and 127.033° W and the most easterly Gordon Channel (grouped with the outside population) sampled location was 50.869° N and 127.215° W. Thus, the northern boundary between the Inside and Outside Waters DUs between these locations is a straight line, and connecting the western shores of Numas and Malcolm Islands within Queen Charlotte Strait remains appropriate (Table 4, Figures 2, 3, 4).

Table 4. Geographic coordinates for Yelloweye Rockfish DU boundaries.

Boundary	Point No.	Lat. (DD.dd)	Long. (DD.dd)
Northern	1	50.613021	-127.173083
Northern	2	50.845951	-127.092040
Southern (Old)	1	48.452786	-123.266523
Southern (Old)	2	48.457374	-123.162103
Southern (Proposed)	1	48.403010	-123.348964
Southern (Proposed)	2	48.264482	-123.344355

Andrews *et al.* (2018) sampled 28 Yelloweye Rockfish from the San Juan Islands and four from Central Puget Sound (Table 1). These samples were more southerly and genetically similar to the previously sampled Inside Waters DU suggesting that a shift of the southern boundary to the southwest should be considered.

The Victoria Sill which bisects the Strait of Juan de Fuca and runs from east of Port Angeles north to Victoria is an important oceanographic feature in this area. Patterns of circulation created by the Sill create discontinuities in temperature, salinity, nitrogen, primary productivity, and organic carbon. A U.S. status review concluded that the Victoria Sill has the potential to restrict larval dispersal and was thought to be the most likely southwestern boundary between inside and outside waters populations (Drake *et al*. 2010). A more conservative boundary, the Sekiu River (48.288111 and -124.394556), was also considered (Figure 2). Juvenile and adult territoriality also promote genetic differences between the populations (Drake *et al*. 2010).

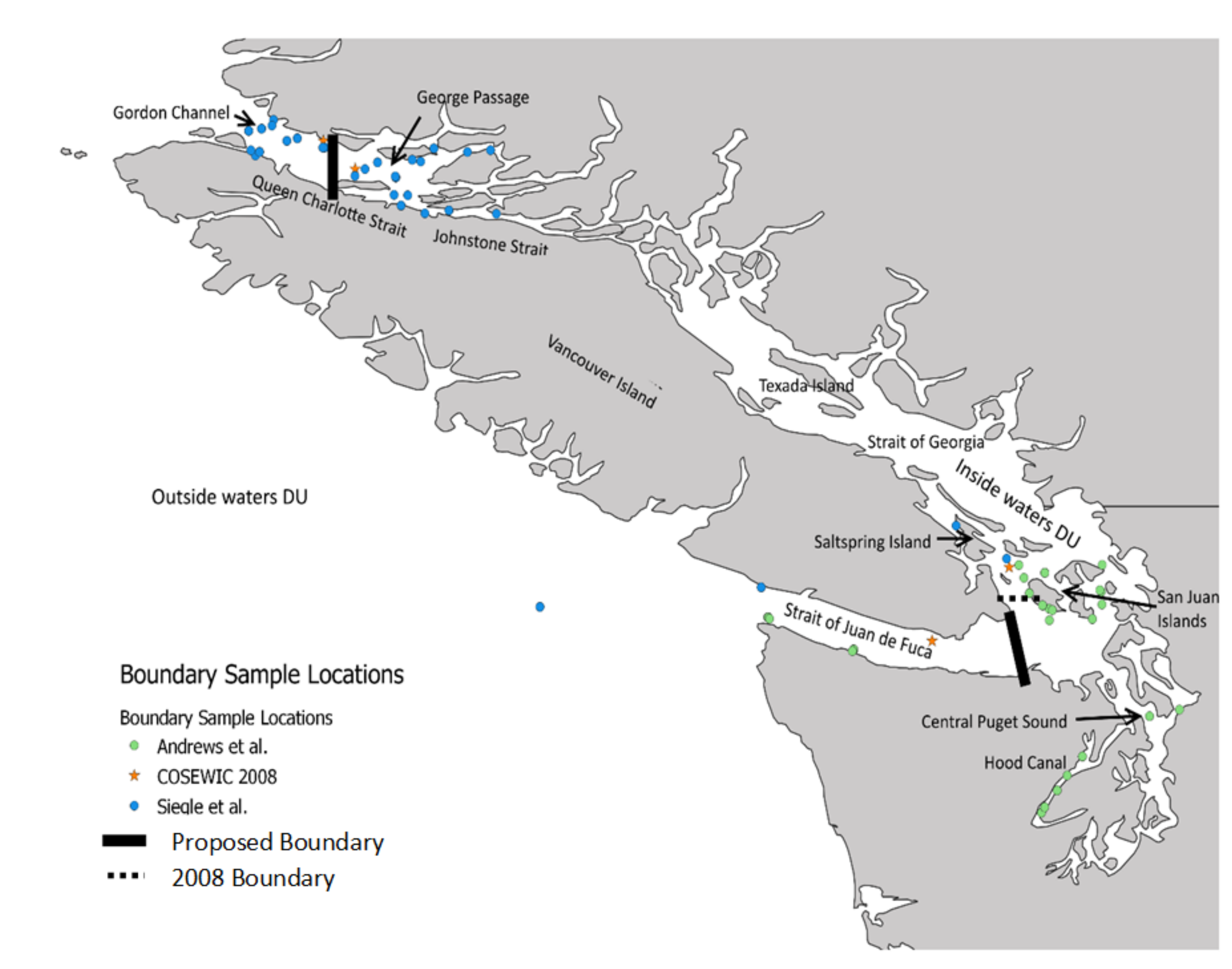

Figure 3. Localities of Yelloweye Rockfish sample collections used to define the borders of the Inside and Outside Waters DUs. Blue points represent samples by Yamanaka *et al.* (2006) reanalyzed by Siegle *et al.* (2013) that reinforce the separation of the two DUs. Green points represent recent samples analyzed by Andrews *et al.* (2018) used to recommend the southern boundary of the DUs be moved to the region of the Victoria Sill. Stars to the left and right of the boundaries indicate the furthest east of samples belonging to the Outside Waters DU and the furthest west of samples belonging to the Inside Waters DU used to define the original DU boundaries in 2008 (COSEWIC 2008). Note: previous 2008 southern DU boundary shown with dotted line.

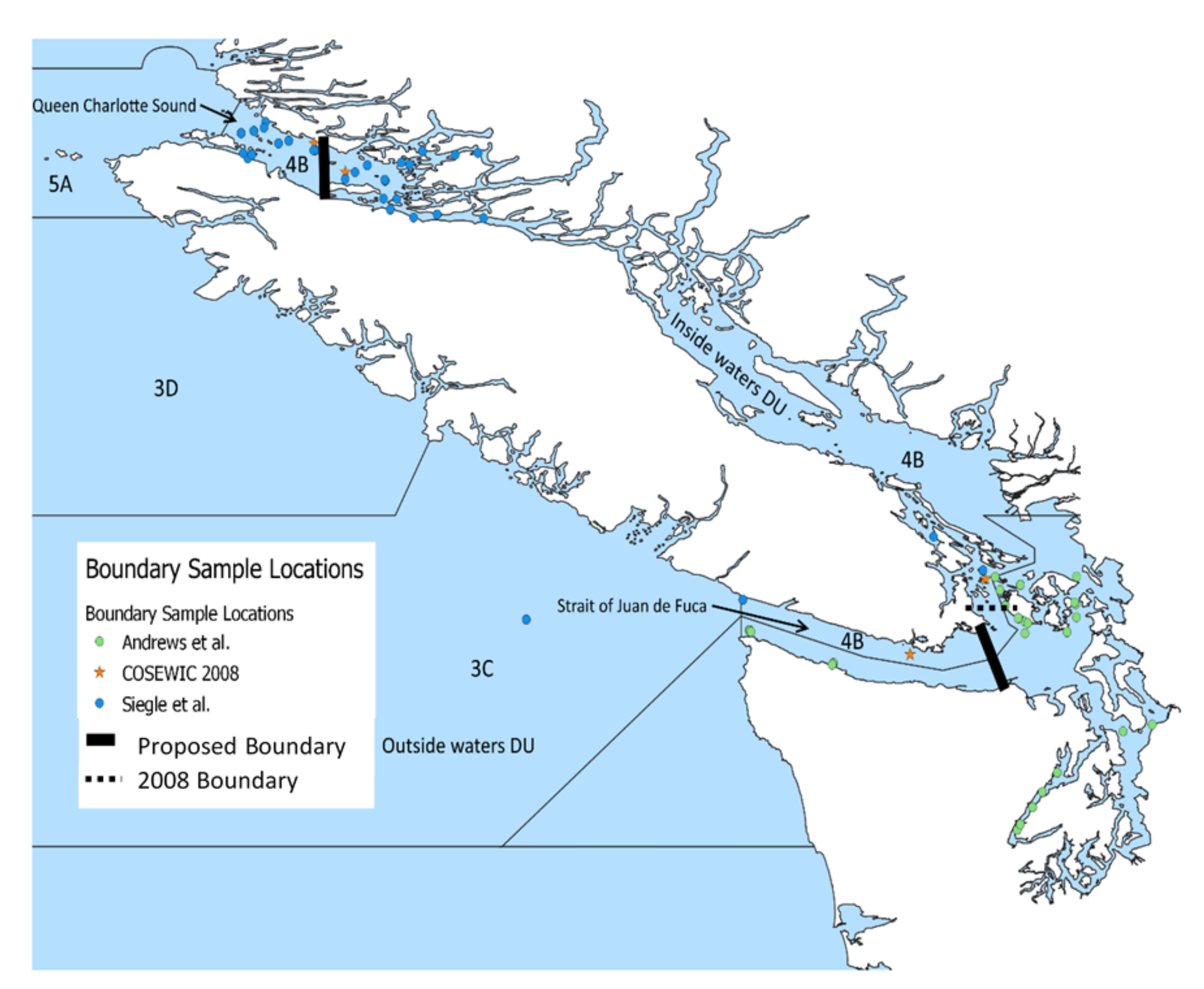

Figure 4. Inside and Outside Waters DUs with respect to current Pacific Fisheries Management Areas (PFMAs). The Inside Waters DU roughly corresponds to PFMA 4B, while the Outside Waters DU encompasses all other areas in coastal B.C., including small areas of PFMA 4B in Queen Charlotte Sound and the Strait of Juan de Fuca. Note: previous 2008 southern DU boundary shown with dotted line.

These northern and Victoria Sill boundaries are defined in areas where mixing of Yelloweye Rockfish associated with each DU occurs. This mixing introduces a source of uncertainty in DU border definition. For example, three of 19 individuals sampled west of the proposed Victoria Sill border in the Strait of Juan de Fuca and two sampled from the 22 northern Washington coast samples were genetically characterized as Inside Waters DU fish. A sample in the San Juan Islands area, east of the Victoria Sill border, was characterized genetically as an Outside Waters DU (COSEWIC 2008; Andrews *et al.* 2013). Similar mixing, but with fewer occurrences than in the south, was observed at the northern border (COSEWIC 2008; Andrews *et al.* 2013). The southern and northern boundaries proposed in COSEWIC 2008 was a straight line between the most easterly Outside Waters DU sample and the most westerly Inside Waters DU sample in these areas (Figures 2, 3). Given that it is not possible to define a mutually exclusive boundary based on genetic sampling sites, DU boundaries associated with oceanographic features, like the Victoria

Sill, that differentiate chemical and biological oceanographic characteristics and circulation patterns between the DUs, are likely to be more stable than those based strictly on genetic sample site distribution.

Maintaining the northern boundary from COSEWIC (2008) and adopting the new southwestern boundary at the Victoria Sill do not change the primary associations with the DFO Marine Ecoregions nor the Pacific Fisheries Management Areas. The Inside Waters DU is associated almost entirely with Area 4B and the Outside Waters DU is associated with Areas 3CD, 5A-E, and a relatively small portion of 4B (Figures 2, 3, 4).

An important aspect of these DUs with respect to the rescue effects is that the Inside Waters DU includes Yelloweye Rockfish associated with Puget Sound in the state of Washington and does not include any Yelloweye Rockfish outside Canada in the north. The Outside Waters DU includes Yelloweye Rockfish along the coasts of Alaska, Washington, Oregon, and California (Andrews *et al*. 2018).

The US National Marine Fisheries Service recognizes that the Inshore Yelloweye Rockfish population in Washington State (Puget Sound/Georgia Basin Distinct Population Segment) and the Canadian Pacific Inside Water DU are part of the same population.

Special Significance

The ecological role of Yelloweye Rockfish is not known, but given their longevity, late maturity, large size, and piscivorous habit, they are likely an important component of the near shore rocky reef ecosystems. Aside from their ecological significance, they are an important component in commercial, Aboriginal, and recreational fishing sectors where they are targeted directly, and are caught as bycatch when targeting other species such as Lingcod (*Ophiodon elongatus*) and Pacific Halibut (*Hippoglossus stenolepis*).

Yelloweye Rockfish is also culturally significant to local First Nations. Legends of the Kwicksutaineuk-ah-kwaw-ah-mish First Nation situated on Gilford Island (Broughton Archipelago) involve an “underwater world” comprised of a variety of animals, one of which is “glowuksum” or Yelloweye Rockfish (COSEWIC 2008, Figure 5). *Sgang Gwaii* on the southwest coast of Haida Gwaii directly translates as “Yelloweye Island” from “sgang” the Haida word for Yelloweye Rockfish (Jones 1999). The island is well known by the Haida for the biomass of Yelloweye; it was said that Yelloweye could be taken in any type of weather. The Ninstints site on the island of *Sgang Gwaii* was the main village of the Kunghit Haida and is now a United Nations World Heritage Site.

Figure 5. Photograph of a painting by artist Alan James depicting ‘glowuksum’ or Yelloweye Rockfish as part of the “underwater world” legends of the Kwicksutaineuk-ah-kwaw-ah-mish First Nation. Painting located on Gilford Island, B.C. Photo credit: S. Wallace.

Yelloweye Rockfish are also important to the Maa-nulth First Nations. They are part of the larger Nuu-chah-nulth people, who have lived along the west coast of Vancouver Island for over 10,000 years (Toquaht Nation 2020).

DISTRIBUTION

Global Range

Yelloweye Rockfish is found from the Gulf of Alaska to Northern Baja California, Mexico (Figure 6), but is less abundant in the southern part of their range (Love *et al.* 2002; Stewart *et al.* 2009). No information exists on changes to the global distribution of Yelloweye Rockfish since the initial COSEWIC assessment (2008).

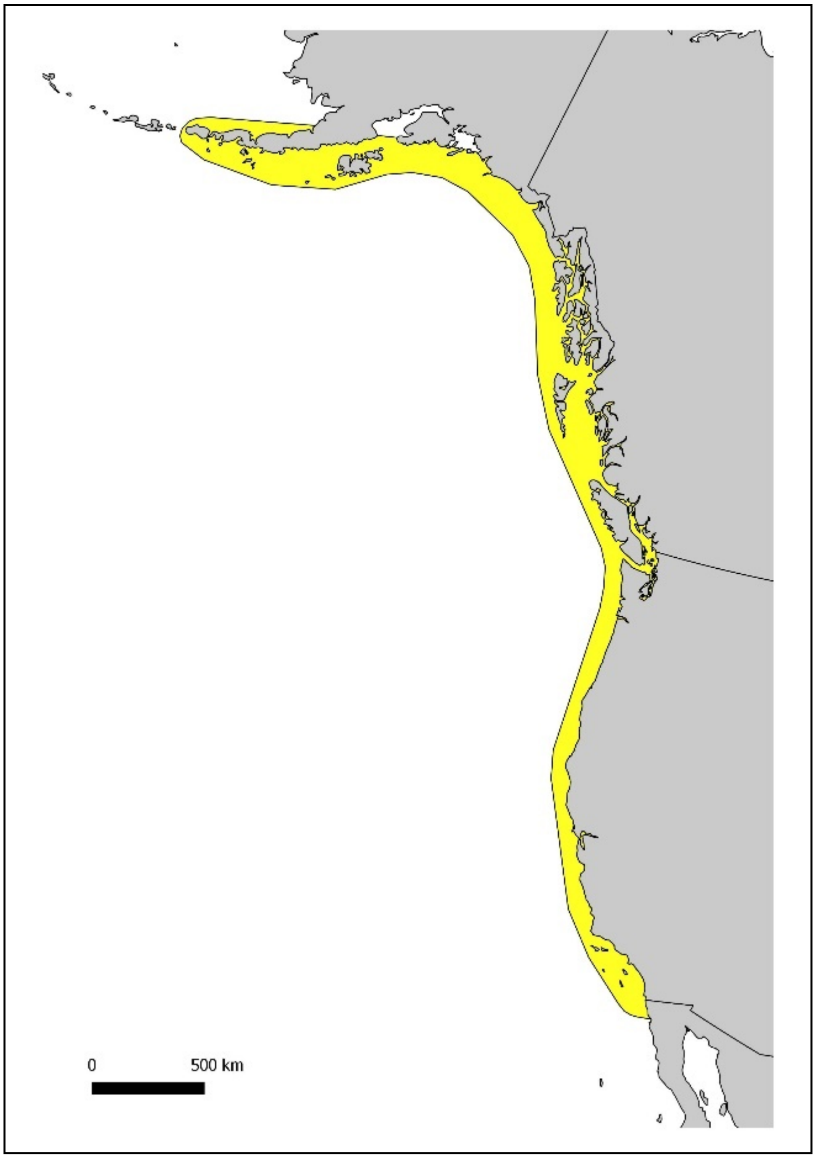

Figure 6. Global distribution of Yelloweye Rockfish (in yellow) (COSEWIC 2008 based on figure from Love *et al*. 2002).

Canadian Range

Yelloweye Rockfish is found widely in most parts of the Canadian Pacific Ocean (Figure 7) based on commercial catch records and fishery-independent research surveys (Tables 5-7). Approximately one third of the coastal habitat for this species is in Canadian waters (Figure 7). No reliable information exists to determine possible changes in the Canadian range since the initial assessment (COSEWIC 2008).

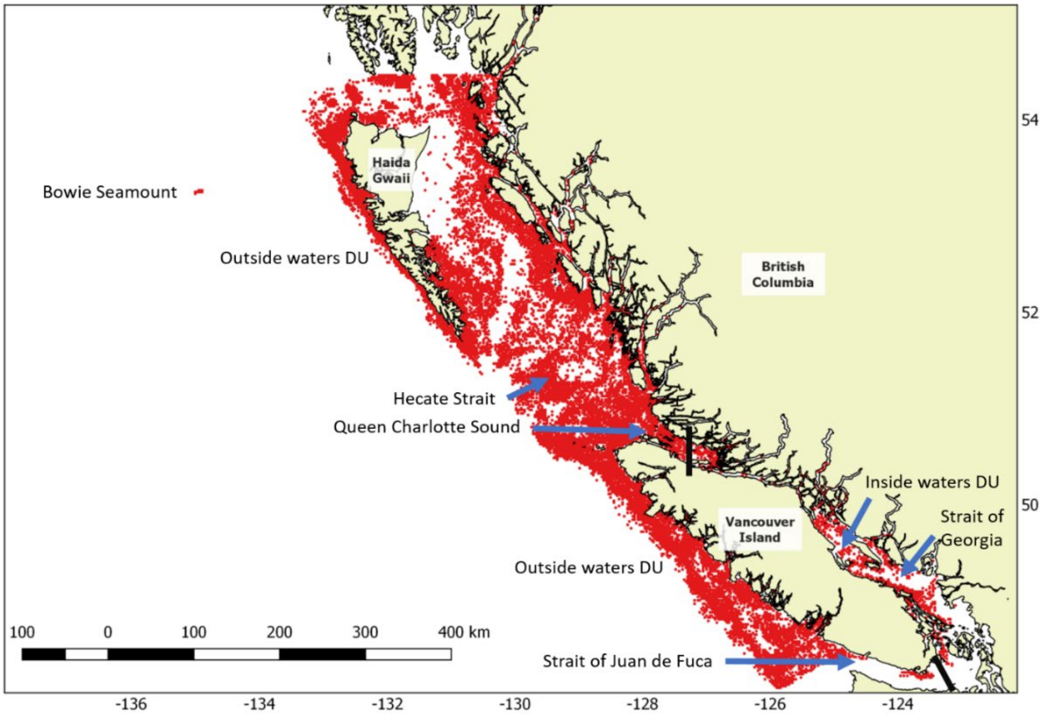

Figure 7. Yelloweye Rockfish distribution in Canadian waters. Red points represent occurrence on a 4 km^2 cell-size grid. Absence of occurrence is not corrected for effort. Data from commercial groundfish fisheries (all gear types; 1982-2017) and research survey data sources (1963-2017). Black lines represent DU Boundaries. (Figure from Keppel and Olsen 2019.)

Table 5. Minimum and maximum survey depths and minimum and maximum depths at which Yelloweye Rockfish (YE) were captured in research surveys (from Keppel and Olsen 2019).

Survey	Min Survey Depth	Min YE Depth	Max Survey Depth	Max YE Depth
Research Surveys Hecate Strait Multispecies Assemblage Survey	18	32	232	137
Hecate Strait Pacific Cod Monitoring Survey	22	46	168	141
Hecate Strait Synoptic Survey	19	34	385	208
Queen Charlotte Sound Synoptic Survey	42	45	626	276
West Coast Vancouver Island Synoptic Survey	41	54	988	329
West Coast Haida Gwaii Synoptic Survey	157	157	1329	263
Strait of Georgia Synoptic Survey	59	110	395	224
Queen Charlotte Sound Shrimp Survey	35	124	231	212

Survey	Min Survey Depth	Min YE Depth	Max Survey Depth	Max YE Depth
West Coast Vancouver Island Shrimp Survey	81	99	165	162
Lingcod Young of Year Trawl Survey	12	61	97	78
IPHC Longline Survey	27	31	464	346
HBLL (PHMA) Rockfish Longline Survey - Outside North	22	22	262	258
HBLL (PHMA) Rockfish Longline Survey - Outside South	20	27	260	252
Inshore Rockfish Longline Survey (North)	20	20	140	121
Inshore Rockfish Longline Survey (South)	35	35	105	105
Strait of Georgia Dogfish Longline Survey	5	37	348	275
1995 QC Sound Rockfish Survey	143	152	296	196
1996 West Coast VI Rockfish Survey (single survey series)	150	165	787	196
Jig Surveys	4	6	91	81
Sablefish Inlet Standardized	302	435	832	693
Sablefish Offshore Standardized	161	161	1397	379
Sablefish Stratified Random	140	140	1463	384
Remotely operated vehicle video surveys	3	10	343	294

Table 6. Details of modern surveys available and used in Inside Waters DU stock assessment. Data from Keppel and Olsen (2019). YE: Yelloweye Rockfish.

Survey	First Year	Last Year	Years	Years w/ YE	Sets	Sets w/ YE	Gear type	Used in Stock Assessment	Bias or rationale if not used in Assessment
IRF Longline Survey (North)	2003	2016	8	8	426	221	Longline	Y	Max survey depth 100 m.
IRF Longline Survey (South)	2005	2015	5	5	289	135	Longline	Y	Max survey depth 100 m.
Strait of Georgia Dogfish Longline Survey	1986	2014	6	6	312	87	Longline	Y	Focused on Dogfish fishing areas.
Strait of Georgia Bottom Trawl Survey	2012	2015	2	2	93	10	Ground-fish bottom trawl	N	Only conducted in two years – not a long enough time series.
Jig Survey	1984	2004	9	8	1630	196	Longline	N	Inconsistent target species, gear type and areas or depths surveyed .

Table 7. Details of modern surveys available and used in recent DFO Yelloweye Rockfish Outside Waters DU stock assessment. Data from Keppel and Olsen (2019). YE: Yelloweye Rockfish.

Survey	First Year	Last Year	Years	Years w/ YE	Sets	Sets w/ YE	Gear type	Used in Stock Assessment	Bias or rationale if not used in Assessment
Queen Charlotte Sound Synoptic Survey	2003	2015	8	8	1908	233	Groundfish bottom trawl	Y	Preferred YE rocky bottom habitat more difficult to trawl without damaging gear.
West Coast Vancouver Island Synoptic Survey	2004	2016	7	7	985	128	Groundfish bottom trawl	Y	Preferred YE rocky bottom habitat more difficult to trawl without damaging gear.
Hecate Strait Synoptic Survey	2005	2015	6	6	1000	30	Groundfish bottom trawl	Y	Preferred YE rocky bottom habitat more difficult to trawl without damaging gear.
West Coast Haida Gwaii Synoptic Survey	2006	2016	7	6	764	20	Groundfish bottom trawl	N	Encountered few YE.
West Coast Vancouver Island Shrimp Survey	1975	2016	40	22	3120	31	Shrimp trawl	N	Encountered few YE; depth strata not designed for YE.
Queen Charlotte Sound Shrimp Survey	1998	2016	17	12	1169	33	Shrimp trawl	Y	Depth strata not designed for YE.
IPHC Longline Survey	2003	2016	12	12	2035	775	Longline	Y	Some lines have more skates (= longer set) which may end up in different habitat with potentially different catch. Aimed at and timed for catching Halibut.
HBLL (PHMA) - Outside North	2006	2015	5	5	951	692	Longline	Y	Initially designed for YE and Quillback Rockfish in their preferred habitat.
HBLL (PHMA) - Outside South	2007	2016	5	5	920	549	Longline	Y	Initially designed for YE and Quillback Rockfish in their preferred habitat.
Hecate Strait Multispecies Assemblage Survey	1984	2003	11	8	1110	21	Groundfish bottom trawl	N	Encountered few YE.
Sablefish Inlet Standardized	1995	2015	21	2	418	2	Trap	N	Not designed to capture YE; too deep for YE and wrong gear type. Encountered few YE.
Sablefish Offshore Standardized	1990	2010	21	3	1040	8	Trap	N	Not designed to capture YE; too deep for YE and wrong gear type. Encountered few YE.
Sablefish Stratified Random	2003	2016	14	14	1256	85	Trap	N	Not designed to capture YE; too deep for YE and wrong gear type.
Yelloweye Rockfish Charter Longline Survey	1997	2003	4	4	16222	5303	Longline	N	Designed to determine if differences could be detected between specific sites with different fishing histories.

Survey	First Year	Last Year	Years	Years w/ YE	Sets	Sets w/ YE	Gear type	Used in Stock Assessment	Bias or rationale if not used in Assessment
Goose Island Gully Survey	1967	1995	9	7	460	21	Groundfish bottom trawl	N	Encountered few YE.
West Coast Vancouver Island Thornyhead Survey	2001	2003	3	0	198	0	Groundfish bottom trawl	N	Encountered no YE.

Extent of Occurrence and Area of Occupancy

The data for estimating extent of occurrence (EOO) and index of area of occupancy (IAO) for Yelloweye Rockfish included capture records held by DFO from all fishery sectors (1982 – present) and from all fishery-independent research surveys including visual surveys (1963 – present) (Keppel and Olsen 2019).

The method for estimating EOO and IAO included land in order to be consistent with COSEWIC (2020) and International Union for Conservation of Nature (IUCN) (IUCN Standards and Petitions Subcommittee 2017) criteria guidelines. Hence, it differs from IAO and EOO estimates from Keppel and Olsen (2019) which excluded land.

Using these approaches, the extent of occurrence (EOO) for the Inside Waters DU was 27,183 km², with an index of area of occupancy (IAO) of 2,628 km² (Figure 8). The EOO for the Outside Waters DU was 262,877 km² with an IAO of 40,620 km² (Figure 9).

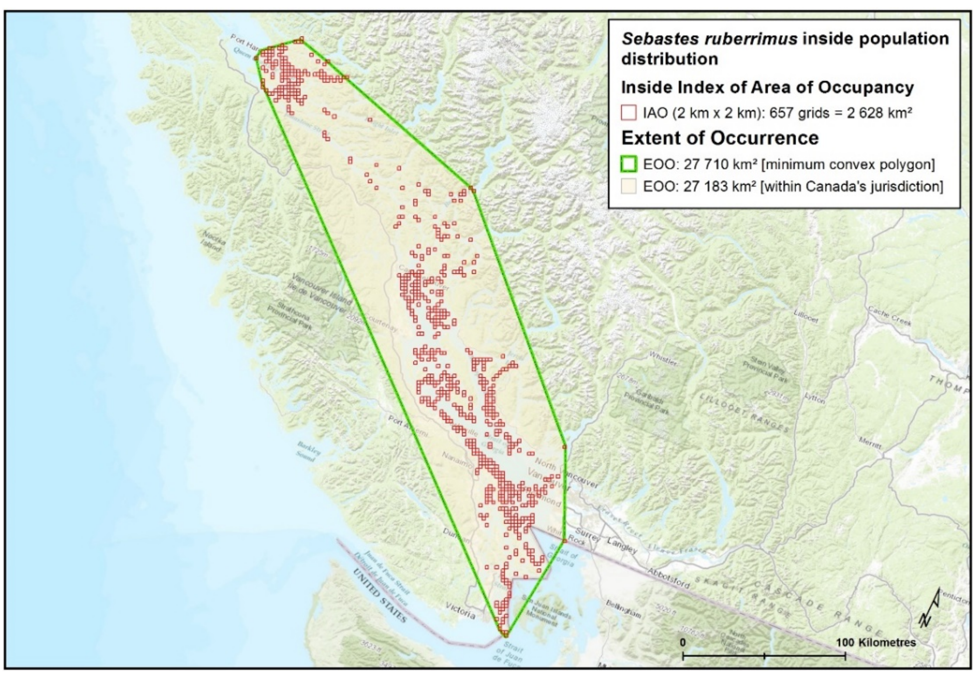

Figure 8. Estimated extent of occurrence (EOO) and index of area of occupancy (IAO) for the Inside Waters Yelloweye Rockfish DU.

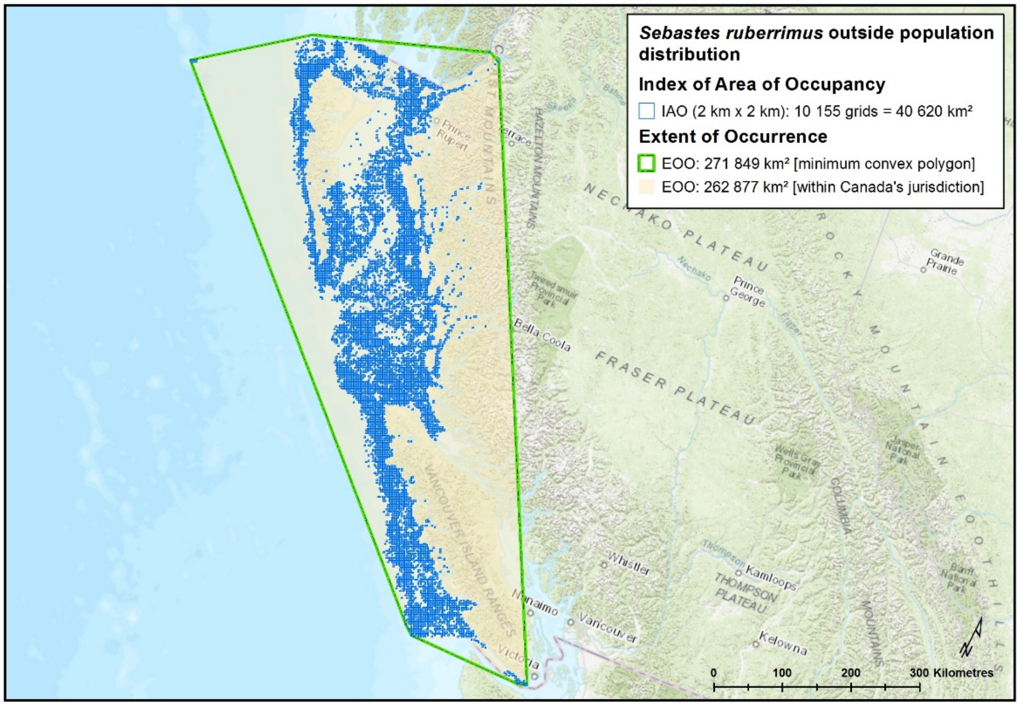

Figure 9. Estimated extent of occurrence (EOO) and index of area of occupancy (IAO) for the Outside Waters Yelloweye Rockfish DU.

Search Effort

A comprehensive summary of the search effort used to describe the distribution and habitat preferences of this species is listed in appendices found in Keppel and Olsen (2019).

HABITAT

Habitat Requirements

Most information on the habitat type preference of Yelloweye Rockfish has come from direct *in situ* observations from submersibles, dive surveys, and other research surveys. Yelloweye Rockfish are habitat specialists, exhibiting a solitary, demersal existence over substrates that are hard, complex, and have some vertical relief, such as broken rock, rock reefs, ridges, overhangs, crevices, caves, cobble, and boulder fields (Richards 1986; O'Connell and Carlile 1993; Murie *et al.* 1994; Yoklavich *et al.* 2000; Love *et al.* 2002). Submersible surveys conducted in B.C. (in 1984, 2000, 2003, 2005, 2009-11) have observed Yelloweye Rockfish at various localities coastwide (Richards 1986; Murie *et al.* 1994; Yamanaka 2005; Haggarty *et al.* 2016b; Yamanaka unpubl. data). Subadult and adult Yelloweye Rockfish (>20 cm fork length) have been observed from submersibles in B.C. hovering near or settled upon rock ridges or outcrops and occupying crevices in rock substrates or boulders patches (Yamanaka *et al.* 2006). Recent dive surveys conducted by the Central Coast Indigenous Resource provide some additional preference information for depths shallower than 35 m, although no statistics are associated with these preferences.

Depth preferences for Yelloweye Rockfish may vary with age, where younger individuals are often associated with shallower substrates (Richards 1986; O'Connell and Carlile 1993). Haggarty *et al.* (2016b) observed juvenile and subadult Yelloweye across a wide range of depths (from 10-180 m, with the majority of individuals occurring between 40-100 m). Research surveys have caught Yelloweye Rockfish across a much wider range of depths from 6 to 693 m, with most captures occurring shallower than 270m. Jig surveys target more structurally complex habitat and found Yelloweye in much shallower water than the other surveys, which were restricted to less complex habitat (Table 5; Keppel and Olsen 2019).

Temperatures where Yelloweye were observed during a submersible survey (Yamanaka *et al.* 2006) ranged from 8.1 to 12.1^{o}C and salinity from 28.2 to 35 ppt. However, those surveys were conducted for only a few years, over a very small study area and a limited range of habitats in B.C. As such these data likely capture a subset of the overall preference and/or physiological tolerance of the species.

Habitat Trends

There are no data on habitat trends for Yelloweye Rockfish.

BIOLOGY

Much of the information in this section comes from Yamanaka *et al.* (2006) with additional information from Keppel and Olsen (2019).

Life Cycle and Reproduction

Female Yelloweye Rockfish produce between 1.2 and 2.7 million eggs annually (Love *et al.* 2002). Although other rockfishes display courtship behaviours, this is undocumented for Yelloweye Rockfish. Mating takes place from September to April, becoming progressively later as one moves further south in the species' range. Females may store the sperm for weeks or months prior to fertilization (Wyllie-Echeverria 1987). Young are born after a typical gestation period of several months. Females can mate with several males and store sperm for several weeks prior to fertilization. Rockfishes are matrotrophically viviparous, supplying nutrients to the developing embryos late in their development (Boehlert and Yoklavich 1984; Yoklavich and Boehlert 1991).The gestation period is generally between one to two months for rockfishes (Love *et al.* 2002). It is not known if they form mating aggregations.

The duration of the pelagic larval phase of Yelloweye Rockfish is unknown but *Sebastes*, in general, have a pelagic larval period lasting for one to two months (Love *et al.* 2002). Larvae and juveniles occur in the upper mixed layer (<300 m) and are dispersed by physical transport processes (Loeb *et al.* 1995; Kokita and Omori 1999). In the pelagic environment, the small (3-7 mm) larvae develop into pelagic juveniles (20 to 70 mm) prior to settling in benthic habitats (Bjorkstedt *et al.* 2002). *Sebastes* larvae are opportunistic feeders known to feed initially on copepod nauplii and invertebrate eggs, moving onto larger prey such as copepodites, adult copepods, and euphausiids as they grow (Moser and Boehlert 1991). Settlement occurs when the pelagic juveniles reach 3 to 9 cm (Love *et al.* 2002). Benthic juveniles continue to feed on crustaceans but shift to larger prey moving from planktonic to benthic invertebrate species then on to fish (Love *et al.* 1991).

Yelloweye Rockfish is long-lived, having been aged to a maximum of 121 (females) and 115 years (males) in the Outside Waters DU (Keppel and Olsen 2019). The oldest ages observed for the Inside Waters DU was 98 years for females and 90 years for males. However, because of the smaller data set for the Inside Waters DU compared to Outside Waters DUs it was decided to use the Outside Waters DU maximum ages for estimation of M (natural mortality) (Keppel pers. comm. 2019).

Aging records were extracted from the GFBio database for Yelloweye Rockfish samples collected during commercial fishing and research surveys (Keppel and Olsen 2019). Yelloweye Rockfish ages at maturity are shown in Table 8. Research surveys likely provide more reliable estimates than commercial samples because of their larger sample sizes, adherence to a sampling design, and greater range of habitats and depths surveyed (Keppel and Olsen 2019).

Table 8. Estimates of natural mortality (M) and age at 50% maturity from research surveys and commercial sampling used to estimate generation time for Yelloweye Rockfish in each DU. The oldest observed female age in the Outside Waters DU was used for both DUs (Keppel and Olsen 2019). Female age-at-maturity from research sampling in each DU was used to estimate generation time (bold).

	Max Age (years)	M	Age at maturity Sample method	Generation time
Inside				
Female	98	0.055	14.2 (Commercial) 18.7 (Research)	32 37
Male	90	0.060	14.2 (Commercial) 21.3 (Research)	31 38
Age used	121 (Outside)	0.045	14.2 (Commercial) 18.7 (Research) 14.2 (Commercial) 21.3 (Research)	37 **41** 37 44
Outside				
Female	121	0.045	16.2 (Commercial) 16.4 (Research)	39 **39**

	Max Age (years)	M	Age at maturity Sample method	Generation time
Male	115	0.047	15.2 (Commercial) 21.2 (Research)	37 42

Generation time – historical and current methods

Yelloweye Rockfish have a relatively low natural mortality (M) and the method used to calculate M has changed over time. Natural mortality was estimated as 0.02 for both DUs using catch curve analysis in 2006 (Yamanaka *et al.* 2006) and was later used in COSEWIC (2008). This method estimated generation times of 66 years for the Outside Waters DU and 70 years for the Inside Waters DU. Subsequent work estimated Outside Waters DU generation time as ~42 years and Inside Waters DU generation time as ~40 years (Keppel and Olsen 2019) using Hoenig's method (described below) as described in Yamanaka *et al.* (2018). This report uses an additional refinement of the methodology as described below to estimate generation time.

Hoenig's formula (Hoenig 1983) is (where A_{max} is defined as mximun age):

$$M = {}^{4.22}/_{{A_{max}}^{0.982}}$$

An updated formula using Then *et al*. (2015) suggested a higher natural mortality rate of 0.061 (female, maximum age 121) and 0.063 (male, maximum age 115).

The Then *et al.* (2015) formula is below:

$$M = 4.899/A_{max}^{0.916}$$

Subsequently, analyses in Gertseva and Cope (2017) indicated that the formula described by Hamel (2015) and provided below was most appropriate. Hamel (2015) applied a meta-analysis of the longevity data provided by Then *et al.* (2015). The motivation for the re-analysis was that Then *et al.* (2015) did not consistently apply the log-transformation to their data. Gertseva and Cope (2017), summarizing the conclusions of Hamel (2015), state: "One would expect substantial heteroscedasticity in both the observation and process error associated with the observed relationship of M to A_{max} in real space. It is thus reasonable to fit all models under a log transformation, but this was not done in Then *et al.* (2015). … by fitting the one-parameter A_{max} model under a log-log transformation (such that the slope is forced to be -1 in the transformed space (as in Hamel 2015), resulting in the following point estimate for M."

$$M = 5.4/\ A_{max}$$

As a result of these considerations, the Hamel (2015) formula presented by Gertseva and Cope (2017) and provided below was used to estimate M as input into the generation time estimation equation (Table 8).

$$M = 5.4 / A_{max}$$

Generation time is then estimated as:

$$G = A_{mat} + {}^{1}/_{M}$$

where G is generation time, A_{mat} is age at 50% maturity and M is natural mortality. Age at first reproduction is usually used but it is often approximated by the age at which 50% of the females mature.

Generation times in this report are based on the maximum female age (regardless of DU origin) observed by all sampling methods and age of 50% female maturity based on research survey estimates (Table 8).

For this report the generation time based on the Hamel (2015) method was used. This produced an Outside Waters DU generation time of 39 years (A_{mat} + 1/Natural Mortality) = 16.4 + 1/0.045 and an Inside Waters DU generation time of 41 years (A_{mat} + 1/Natural Mortality) = 18.7+ 1/0.045.

Generation time – sources of uncertainty

The following sources of uncertainty are inherent in all approaches that use M, age at maturity, and maximum age to estimate generation time. Uncertainty in M results from the observed maximum age, method used to estimate maximum age, and choice of model used to describe the relationship between M and maximum age. For example, Gertseva and Cope (2017) report a value of 137 as the maximum age in the samples but use 90% of the maximum age (123) as the input into the Hamel (2015) formula. As Gertseva and Cope (2017) point out the standard error assumed in Hamel's (2015) model is 0.438 which has not been applied here. In addition, there is uncertainty in estimates of age at 50% maturity which have not been incorporated. Because of the relatively long generation time, with respect to length of observed data, reporting the uncertainty around generation time is not likely to alter conclusions regarding expected increases or declines over 2 or 3 generations and point estimates only have been provided.

An additional source of uncertainty with respect to status designation is that these estimates depend on data collected during the exploitation phase of the Yelloweye Rockfish DUs. COSEWIC and IUCN guidelines indicate that pre-exploitation generation time, likely to be longer than the exploitation generation time, should be used to reduce the likelihood of incorrectly lowering the threat category. This concern is important if higher biomass is excluded from the decline estimates because of the shorter generation time. The current data time period is 100 years and the current generation time, 40 years, covers ~2.5 generations. Even if the pre-exploitation generation time were longer than 40 years, there is no data that would be excluded from the current decline estimate and lower the threat category. However, it may affect designation conclusions once the current data period exceeds 120 years (based on the 40-year generation time).

Physiology and Adaptability

Rockfish populations are characterized by highly variable recruitment where prolonged periods of poor recruitment may result in natural population declines. Unfavourable oceanic conditions are a likely cause for poor recruitment, but little is known about specific environmental factors which contribute to recruitment of Yelloweye Rockfish in B.C. Recruitment for other inshore rockfish species in B.C. varies widely in space and in time, differing by more than an order of magnitude between years and locations as observed in a recent study conducted on Vancouver Island (Markel *et al.* 2017). In the same study, recruitment seemed to be related to variation in physical factors such as sea surface temperature, tidal velocity, and fetch, but the strength of these relationships differed through time, and by species (Markel *et al.* 2017). In California, similar links have been made between rockfish recruitment and oceanographic conditions such as upwelling and strong onshore drift (Yoklavich *et al.* 1996). Haggarty *et al.* (2017) found that the abundance of adult age classes is related to factors such as larval settlement into suitable habitat and early mortality. Recruitment variation coupled with the long generation time and late age at maturity of Yelloweye Rockfish will likely make this species slow to recover from population declines and unlikely to adapt quickly to changing environmental conditions.

Dispersal and Migration

Rockfish are known to disperse passively with ocean currents during their extended pelagic larval stage and this may affect recruitment. *Sebastes* larvae were found to concentrate over the continental shelf and slope west of Haida Gwaii, up to 300 nautical miles from shore (LeBrasseur 1970). From the composition of otolith microstructure, there is evidence that dispersal may be less than 120 km for Black Rockfish (*Sebastes melanops*) (Miller and Shanks 2004). However, the actual dispersal distance for Yelloweye Rockfish is unknown.

Interspecific Interactions

Sperm Whales (*Physeter macrocephalus*) and Killer Whales (*Orcinus orca*) are known to consume adult Yelloweye Rockfish; Harbour Seals (*Phoca vitulina*) and Steller Sea Lions (*Eumetopias jubatus*) are also known to consume rockfishes, some of which may be Yelloweye Rockfish (Olesiuk *et al.* 1990; Ford and Ellis 2006; Lance *et al.* 2012). Juvenile Yelloweye Rockfish are preyed upon by Chinook Salmon (*Oncorhynchus tshawytscha*), rockfishes, Lingcod (*Ophlodon elongatus*) and marine birds (Mills *et al.* 2007).

Yelloweye Rockfish is an aggressive piscivore that feeds on other rockfishes (they are known to be cannibalistic), Pacific Herring (*Clupea pallasi*), juvenile Cod (Gadidae), Sand Lance (*Ammodytes hexapterus*), flatfishes (Pleuronectiformes), Opal Squid (*Loligo opalescens*), shrimps (*Caridea* spp., *Pandalus* spp.), and crabs (*Acantholithodes hispidus, Cancer oregonensis*) (Steiner 1979; Rosenthal *et al.* 1988; Love *et al.* 2002).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

DFO Yelloweye Rockfish Population Modelling and Assessment Approach

In 2014 a DFO population assessment concluded that Outside Waters Yelloweye Rockfish DU biomass was below the Limit Reference Point (LRP) (Yamanaka *et al*. 2018). In 2010 a DFO population assessment concluded that Inside Waters Yelloweye Rockfish DU biomass was below the DFO Precautionary Approach (PA) (DFO 2006) Limit Reference Point (LRP) (Yamanaka *et al.* 2011). The default LRP definition is 40% of B_{msy}, where B_{msy} is the mature biomass level that corresponds to the maximum yield (catch) over time, and LRP is the level below which productivity is sufficiently impaired to cause serious harm to the resource (DFO 2009). DFO policy requires a rebuilding plan to be put in place when a stock is determined to be below the LRP. The proposed options for the Outside Waters and Inside Waters DU rebuilding plans were developed using a Management Strategy Evaluation (MSE) approach. A key element of this approach is to create population trend models that encompass the range of uncertainties concerning past life-history parameters, such as natural mortality (M) and exploitation to determine the historical population trajectories. These models are referred to as operating models (OMs). These OMs provide the biomass estimates used to determine the Yelloweye Rockfish DU declines. An age-structured modelling approach was used to generate these OMs compared to the surplus production approach used by Yamanaka *et al.* (2018) and Yamanaka *et al*. (2011). Management Procedures (MPs) consisting of various monitoring data methods, assessment methods, and harvest control rules encompassed uncertainties in future population trajectories. The performance of the MPs is assessed relative to stock reference points, estimated by the OMs, relative to management objectives. The assessment methods to evaluate future trends included a catch-at-age model, a surplus production model, and a survey index model. That the MSE approach encompasses the uncertainties in model parameters and tests performance of MPs makes it more robust to uncertainties and preferable to the previous population assessment methods.

The MP subsequently adopted will be important to COSEWIC to consider in the future when evaluating threats from fishing and the likelihood of future population declines. Adoption of a particular MP will occur after additional consultation with fishery managers, First Nations, and fishery stakeholders. The DFO rebuilding policy includes a provision for a three-year review cycle.

Use of mature biomass

Mature biomass rather than mature numbers has been used to estimate declines for these Yelloweye Rockfish DUs. Exploitation is expected to reduce body size and for the Outside Waters DU there is some evidence (see below) that this expected effect has occurred. The designation context is described in IUCN 4.3.3 (IUCN 2017) and quoted here. “Fishes In many taxa of marine fish, reproductive potential is commonly closely related to body size. Since exploitation usually reduces the mean age and size of individuals, assessing declines in numbers of mature individuals may under-estimate the severity of the decline. When evaluating population decline, this factor should be kept in mind. One possible method is to estimate decline in the biomass of mature individuals rather than the number of such individuals when applying Criterion A, where biomass is ‘an index of abundance appropriate to the taxon’.”

Outside Waters DU

DFO Yelloweye Rockfish Outside DU Assessment Approach

The Outside OMs consisted of a two-area (North and South), age-structured operating model in which the areas were assumed to be independent and closed populations, but with identical population dynamics. Current life-history understanding is consistent with the independent and closed population assumptions with respect to these areas because movement rates are extremely low once fish settle to rocky bottom habitats (Drake *et al*. 2010, DFO 2020a).

The Outside population was also divided into North and South segments in order to capture uncertainties in differing hypothesized abundance and exploitation history in these two areas. A total of four OMs, out of 24 OM scenarios tested, were used to describe the range in past and future population trends and uncertainty in each area. The OMs tested were:

1. OM1 (Base) estimated historical trends from 1918 to 2018 and used the upper bound of reconstructed commercial and recreational catch series (see below) and the base prior mean for natural mortality (M) of 0.0345/yr. This model was considered the most plausible based on statistical data fits and biologically plausible assumptions and is referred to as the base OM.

2. OM2 estimated trends from 1960 to 2018 and used the lower bound of reconstructed commercial and recreational catch series (see below) and the same M as OM1.

3. OM3 estimated trends from 1960 to 2018 and used the upper bound of reconstructed commercial and recreational catch series (see below)) and the base prior mean for natural mortality (M) of 0.03/yr.

4. OM4 estimated trends from 1918 to 2018. It used the lower bound of reconstructed commercial and recreational catch series (see below)) and the same M as OM1.

Values and uncertainty distributions for M used in this analysis were chosen to encompass the uncertainty associated with M used in fishery assessments from the most Northern Yelloweye Rockfish stocks in Alaska to the most southern in Washington and California (Cox *et al*. 2020). Generation times were those used in this report.

The OM1 model was given 50% of the weight and OMs 2 – 4 were each given 16.7% of the weight to assess the overall population trends from 1960 to 2018 (DFO 2020a). OM1 and OM4 were combined (OM14) with OM1 receiving 76% of the weight and OM4 with 24% of the rate for estimating overall population trends from 1918 to 2018 (Cox *et al*. 2020).

The biomass trajectories from the North and South areas were added together, using the above percentages, to determine the entire Outside Waters DU trends for each of the four OMs.

Outside Waters DU Catch – Historical data input

Because early catch records do not provide landings of individual rockfish species, biomass estimates from 1918 to the mid-1980s rely on extracting estimated Yelloweye Rockfish catch from aggregate rockfish landings. This catch reconstruction was done by using ratios of Yelloweye Rockfish in modern catches to calculate historical Yelloweye Rockfish catch. A variety of assumptions are applied to permit these reconstructions. While each assumption has uncertainty attached to it, these are the best estimates obtainable given the data provided. A complete description of the methods used in this catch reconstruction are described in Haigh and Yamanaka (2011). Biomass and catch updates for result presentations have been provided by DFO (Haggerty pers. comm. 2020).

Outside Waters DU Surveys – data input

Hook and line surveys providing model input data were:

1. The Pacific Halibut Management Association (PHMA) surveys in the North, South, and Queen Charlotte Sound areas between 2006 and 2018. However, these surveys were not run every year nor always in the same years in each area (Figure 10).

2. The International Pacific Halibut Commission (IPHC) conducted fixed-grid surveys in the North and South Areas between 1998 and 2018. They have been conducted annually in the North and South areas since 1998. However, they have only been done consistently in each area since 2002 (Figure 10). Additional updates to data used in the earlier stock assessments have been provided by DFO (Haggerty pers. comm. 2020).

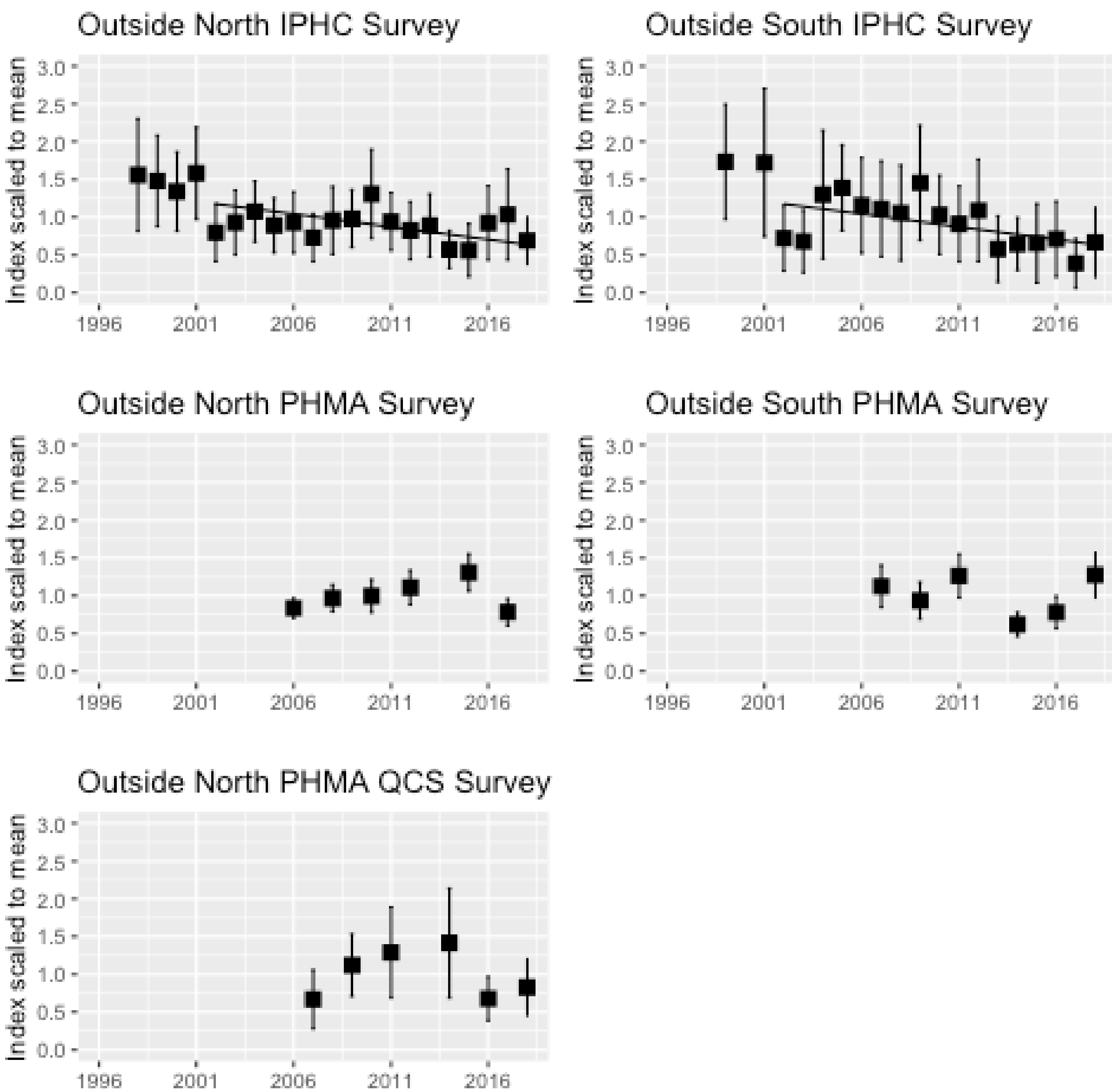

Figure 10. Survey indices for Outside Waters Yelloweye Rockfish DU in various areas with 95% confidence intervals (vertical lines). PHMA are the Pacific Halibut Management Association surveys, where QCS indicates Queen Charlotte Sound, and IPHC are the International Pacific Halibut Commission surveys. Regression analysis trends indicate declining trends in main survey indices (IPHC) since 2002 for the Outside Waters DU. P-value for the North IPHC survey is 0.31 and for the South IPHC survey is 0.02. The year 2002 was chosen to investigate trends because it is the year when surveys were done annually in both areas, it is after major management changes (DFO 2020a), and fishing mortality (F) has been consistently below the F defining overfishing (F_{msy} F at maximum sustainable yield) (Figure 12).

Outside Waters DU Changes in size and age structure

Data from the IPHC Longline Surveys (2003-2015) and the PHMA Longline Surveys (2006-2015) of the Central Coast of B.C. documented a 7% decline in mean fork length and a 10-15% decrease in mean age of Yelloweye Rockfish captured over 10-13 years for the Outside Waters DU (McGreer and Frid 2017).

This trend of decreasing size on the central B.C. coast (Outside Waters DU) extends back further than research survey data. A recent study in the same region compared size change of Yelloweye Rockfish caught by Aboriginal anglers over their lifetimes from the 1950s to present (Eckert *et al.* 2017). Results from research surveys and these semi-structured interviews with 42 Aboriginal participants were similar for overlapping time periods, and this study estimated the median historical length caught (during the period of 1950–1989) was 84 cm while the median modern reported length (during the period of 2000-2015) was 46 cm (Table 9).

Table 9. Reported change by Aboriginal fishers in average fork length (FL) of Yelloweye Rockfish in relation to decade. Respondents (N = 42). A significant difference exists between FL in the 2010s and all previous decades (Eckert *et al.* 2017).

Decade	Average FL (cm)	Lower 95% CI	Upper 95% CI
1950s	85	60	110
1960s	80	55	105
1970s	87.5	62.5	115
1980s	93.75	68.75	120
2010s	46	20	68

These decreases in size coincided with improvements in technology that allowed participants to fish deeper and farther from their communities (19/42 participants had changed fishing methods over time) (Eckert *et al.* 2017). Most respondents (41/42 individuals) also described a decrease in the amount of Yelloweye Rockfish and other rockfish species, with most participants identifying that the largest recognizable decline occurred between 1980 and 2005 (Eckert *et al.* 2017).

Outside Waters DU Biomass and Abundance

Total mature biomass using the four OMs ranged from about 4,500t to 12,500t. Assuming a mean individual weight of 2 kg (Keppel and Olsen 2019), this would translate to > 2 million mature individuals for the Outside Waters DU.

Outside Waters DU Fluctuations and Trends

The Outside Waters DUs of Yelloweye Rockfish have experienced declining biomass trends over time. Population declines from 1918 to 2018 (about 2.5 generations) ranged from 69 – 72% for OM1 and OM4 separately and combined (OM14). Population declines over all OMs separately and combined ranged from 52 – 73% from 1960 to 2018 (about 1.5 generations). Population declines over all OMs separately and combined ranged from 38 – 68% from 1985 to 2018 (about 4/5 generation) (Figure 11).

These dates correspond to dates chosen for the OMs and major changes in fishery exploitation (Figure 12).

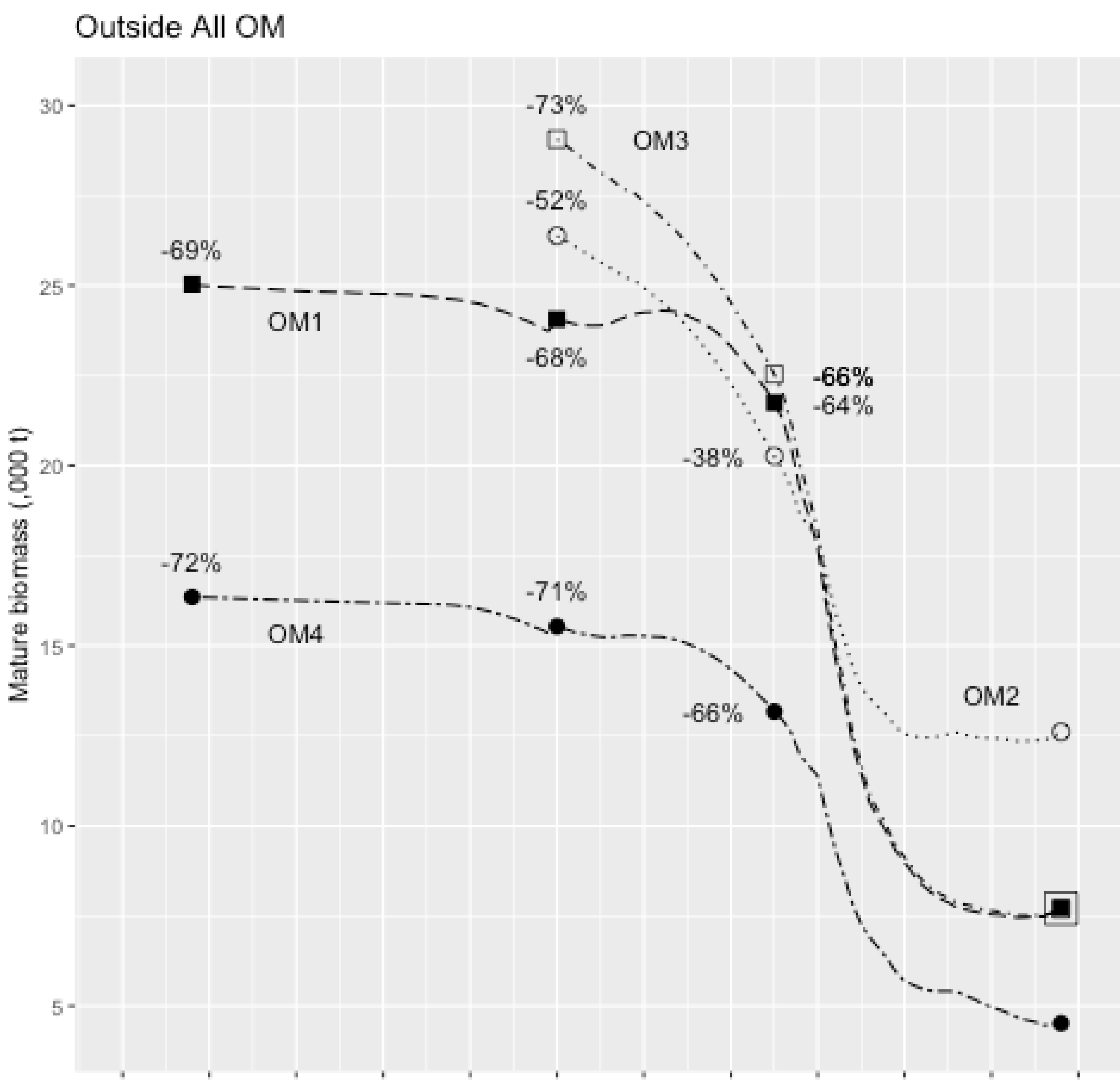

Figure 11. Decline rates from 1918 to 2018 for OM1 and OM4 and from 1960 and 1985 to 2018 for each OM. OM1 and OM4 combined declines (not shown) were 70% for 1918 to 2018, 68% for 1960, and 65% for 1985 to 2018. OM1,2,3,4 combined declines (not shown) were 66% for 1960 and 60% for 1985 to 2018.

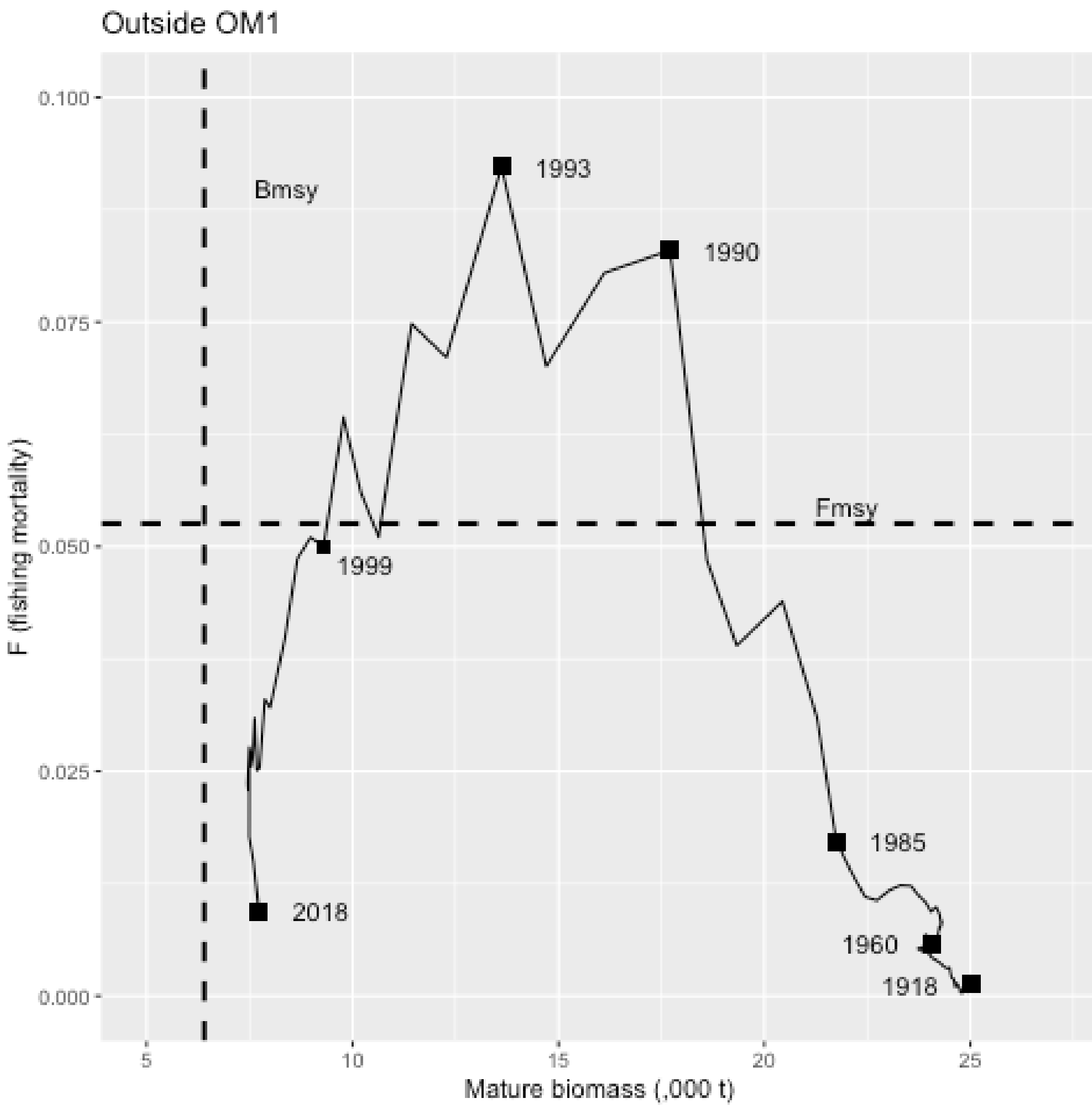

Figure 12. Relationship between F (fishing mortality) and Mature Biomass from 1918 to 2018 as estimated using OM1. F_{msy} and B_{msy} for OM1 are indicated by dashed lines. Key years for management or assessment changes and peaks in F are indicated.

Outside Waters DU sources of uncertainty

While the strength of the MSE approach is that the OMs are designed to cover the range in population dynamics and biomass trends, there are some uncertainties to consider with respect to COSEWIC designations.

Model structure and population trend – assessment differences

The model used in the 2014 assessment was based on a Surplus Production method (Yamanaka *et al*. 2018) and the current assessment used an age-structured approach (Cox *et al.* 2020). The surplus production model from the 2014 assessment predicted greater declines in biomass (83%) from 1920 (27,692 t) to 2014 (4722 t) (Yamanaka *et al.* 2018) than the current assessment (Cox *et al.* 2020). The Surplus Production model estimated higher biomass at the beginning of the time series and lower biomass (below LRP) at the end of the time series than the OM1 model in the current assessment (above LRP).

Parameter uncertainties (Cox *et al*. 2020)

1. The time span for survey and age-composition data is less than a generation. This limited amount of data increases the importance of including scenarios that cover the uncertainty range for important parameters such as M, that influence biomass estimates.

2. IPHC and PHMA Surveys over-estimate the 65+ ages and under-estimate the observed decline in the southern area.

3. The IPHC Surveys are designed for halibut and their accuracy with respect to Outside Waters Yelloweye Rockfish DU trends have not been examined using alternative modelling approaches.

4. Apparent positive bias for young ages in the estimated growth curves could lead to over-estimates of exploitation biomass and under-estimation of F.

5. Insufficient aging data creates uncertainty in selectivity functions in the fishery models.

6. Lack of monitoring within Marine Protected Areas did not permit an evaluation regarding their influence on population abundance and trends.

7. The population has been fished consistently below F_{msy} since 1999 with no appreciable biomass increase to 2018 (Figure 12).

Outside Waters DU commentary on COSEWIC criteria

The main survey (IPHC) shows declines or no trends between 2002-2018 (Figure 10). Mature biomass declines over the past 2.5 generations are consistently estimated to be > 50% by all OMs (Figure 11). All biomass estimates are currently above LRP (Figure 12). Reductions in F to levels below F_{msy} began in 1999. However, all OMs and observed indices indicate mature biomass has not increased since then (for example see OM1 in Figure 12). The rebuilding policy includes provision for a three-year review cycle and reassessment if evidence for exceptional circumstances occurs.

Inside Waters DU

DFO Inside Waters DU Yelloweye Rockfish DU Assessment Approach

An age-structured Stock Reduction Analysis (SRA) (DFO 2020b) modelling approach was used to generate 6 OMs (four reference set and two robustness set OMs) to estimate past population trajectories. This model structure differs from the surplus production approach used in Yamanaka *et al.* (2011) which did not consider age-structure. Management Procedures (MPs) consisting of various monitoring data methods, assessment methods, and harvest control rules encompassed uncertainties in future population trajectories. The performance of the MPs is assessed relative to DFO Precautionary Approach reference points (DFO 2006) and management objectives. Future population trends used the SRA model, parameters determined from the historical SRA population trend model, and variation in key future parameters as described below.

The MP subsequently adopted is important to COSEWIC for evaluating threats from fishing and future population declines. Adoption of a particular MP will occur after additional consultation with fishery managers, First Nations, and fishery stakeholders. The DFO rebuilding policy includes a provision for a three-year review cycle to manage uncertainty and exceptional circumstances that result in unanticipated future population trajectories.

Six OMs were used to describe the range in past and future population trends and uncertainty in each area. Each OM estimated historical trends from 1918 to 2019.

1. OM1 (Base) was the standard against which the effects of parameter changes were assessed.

2. OM2 (Low catch) tested sensitivity to the assumption of large unreported catch for 1986 – 2005 as only the reported catch. Instead of doubling the nominal catch data as OM1, the nominal catch as reports was used as model catch input.

3. OM3 (Episodic recruitment) tested the effect of occasional and very large recruitment events.

4. OM4 (Estimate Hard-Bottom Long Line (HBLL) selectivity) tested the effect of using the SRA model to estimate fishery selectivities from the very small age-composition data sets.

5. OMA (Low M) tested the effect of an M about half the size of the other scenarios (lognormal with mean 0.025, and standard deviation 0.2).

6. OMB (High HBLL CV) tested the effect that future HBLL indices are less precise than the base scenario.

The OMs tested consisted of four identified as reference OM scenarios OM1 - 4 and two robustness set OMs encompassing additional sources of uncertainty OMA and OMB. Reference OMs include the most important uncertainties and robustness OMs explore a wider range of uncertainties and represent alternative hypotheses on population parameters compared to reference OMs (DFO 2020b).

Initial OM parameter distributions are explained in Appendix D of Haggarty *et al*. (2020) and represent values used in the 2010 assessment (Yamanaka *et al.* 2011). M was sampled from a lognormal distribution with mean 0.045, and standard deviation 0.2. All models were considered equally plausible. For all OM scenarios the reconstructed catch up to 1985 and the nominal catch from 1986 onwards was doubled as was done in Yamanaka *et al.* (2011). Changes in these are noted where applicable. OMs 1, 3, and 6 used the same parameters for past population trajectories. However, the changes noted below were used for future population trajectories. Hence, results for OMs 1, 3, and 6 were combined for past decline analyses.

Inside Waters DU Catch – Historical data input

Because early catch records do not provide landings of individual rockfish species, biomass estimates from 1918 to the mid-1980s rely heavily on extracting estimated Yelloweye catch from aggregate rockfish landings. This catch reconstruction was done by using ratios of Yelloweye Rockfish in modern catches to calculate historical Yelloweye catch. A complete description of the methods used in this catch reconstruction are described in Haigh and Yamanaka (2011). Additional updates to data used in the earlier stock assessments have been provided by DFO (Haggerty pers. comm. 2020).

Inside Waters DU Survey and Catch-rate indices

Longline surveys providing input data for model fits were:

1. Historical commercial catch-per-unit-effort (CPUE) provided an index of abundance from 1986 to 2005. The index is declining during this period (Figure 13) and provided a good model fit biomass trends during this time. All model outputs indicated that the mature biomass increase began in 2002 (Figure 14).

2. The survey data with the most consistent timing and the source for survey biological data is the inshore rockfish hard bottom longline survey (HBLL) survey (Appendix B Haggarty *et al.* 2020). It has been providing annual abundance indices and biological data since 2003 with the exceptions of 2006 and 2017 (Figure 14). This survey indicates a decline since 2004, p-value = 0.24 (Figure 14).

3. A survey directed to dogfish provides a third abundance index. This survey has been conducted sporadically starting in 1986 (Haggarty *et al.* 2020) and has increased since 2004 with a p-value of 0.15 (Figure 14). Changes in fishing operations and hook type occurred in 2004. Additional updates to data used in the earlier stock assessments have been provided by DFO (Haggerty pers. comm. 2020).

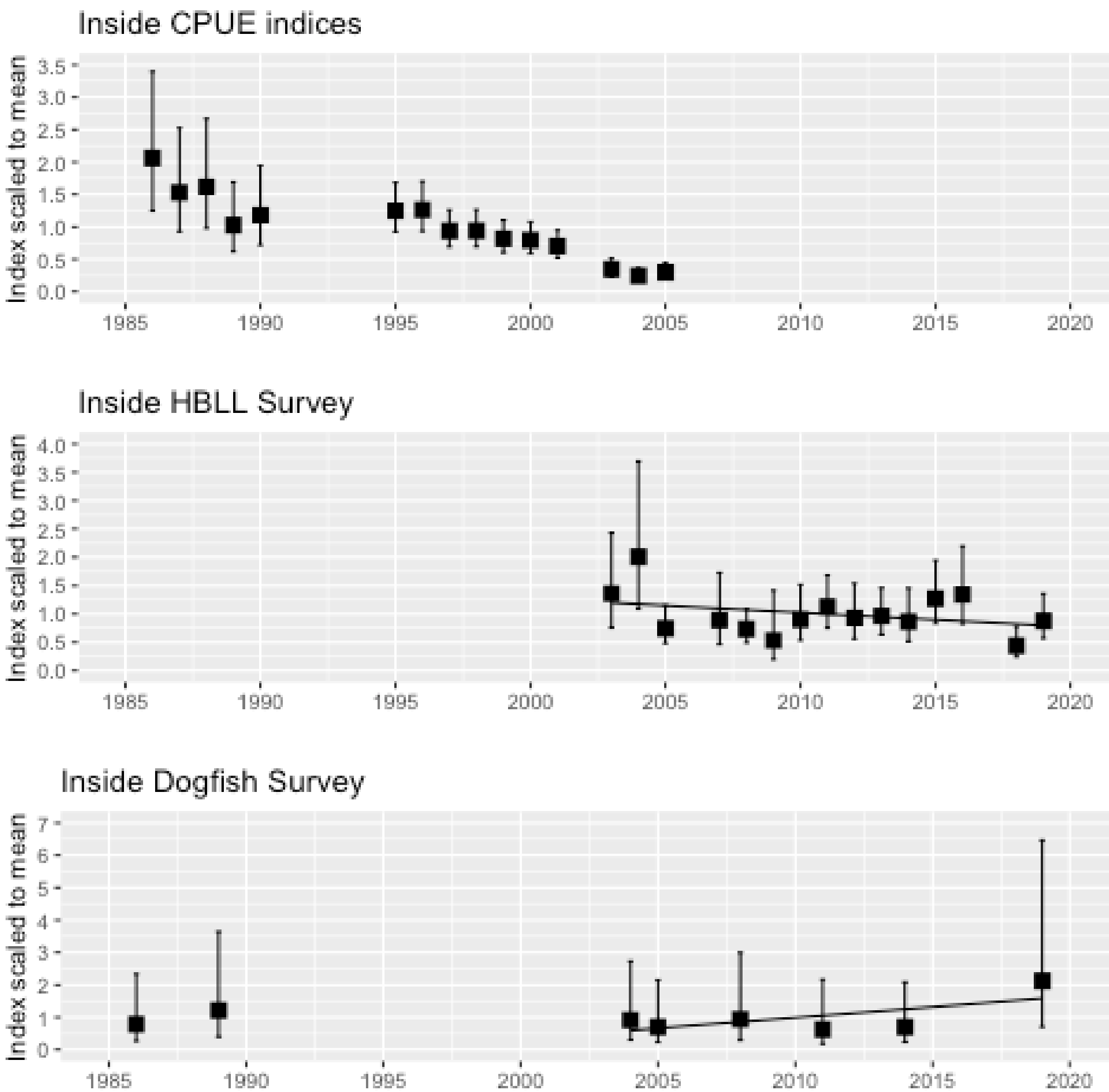

Figure 13. Survey indices for Inside Waters Yelloweye Rockfish DU with 95% confidence intervals (vertical lines). Regression analysis trends indicate declining trends for the Hard-Bottom Long Line (HBLL) survey since 2002. P-value for the HBLL survey was 0.24. Indices for the Dogfish survey in 1985 and 1989 are scaled separately from indices for 2004 – 2019. This distinction was made because of a change in hook type in 2004 (Haggarty *et al.* 2020). The dogfish survey has an increasing trend since 2004 with a p-value of 0.15.

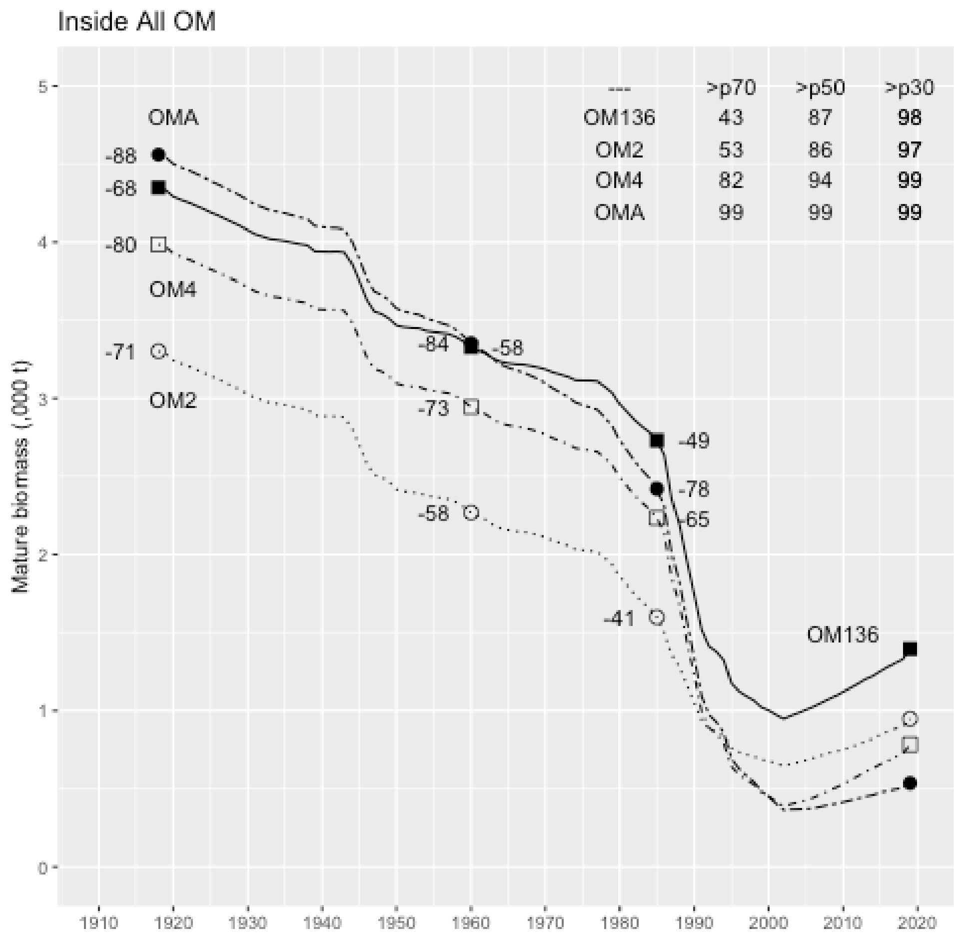

Figure 14. Decline rates from 1918 to 2019 for OMs 136 (OM 1, 3, 6 were the same for historical trends), OM2, OM4 and OMA from 1918,1960 and 1985 to 2019. The table in the upper right-hand portion of figure indicates the probability that the declines from 1918 to 2019 exceed 70%, 50%, and 30% for each OM indicated. The decline rates for all OMs combined were 77% from 1918, 69% from 1960, and 59% from 1985 to 2019 (not shown).

Inside Waters DU Biomass and Abundance

Total mature biomass using the four OMs ranged from about 500 t to 4500 t. Assuming a mean individual weight of 2 kg (Keppel and Olsen 2019), this would translate to > 250,000 mature individuals for the Inside Waters DU.

Inside Waters DU Fluctuations and Trends

The Yelloweye Rockfish Inside Waters DU has experienced declining mature biomass trends over time. Population declines from 1918 to 2019 (about 2.5 generations) ranged from 71 - 88% for OM136 and 77% for all OMs combined. Population declines for all OMs ranged from 58 – 84% from 1960 to 2019 (about 1.5 generations) and were 69% for all OMs combined. Population declines for all OMs ranged from 41 – 78% from 1985 to 2019 (about 4/5 generation) and were 59% for all OMs combined. Probability that population declines for these OMs separately exceeded 70% ranged from 0.43 to 0.99, that they exceeded 50% ranged from 0.87 to 0.99, and that they exceeded 30% ranged from 0.97 to 0.99 (Figure 14). These dates correspond to dates chosen for the OMs and major changes in fishery exploitation (Figure 15).

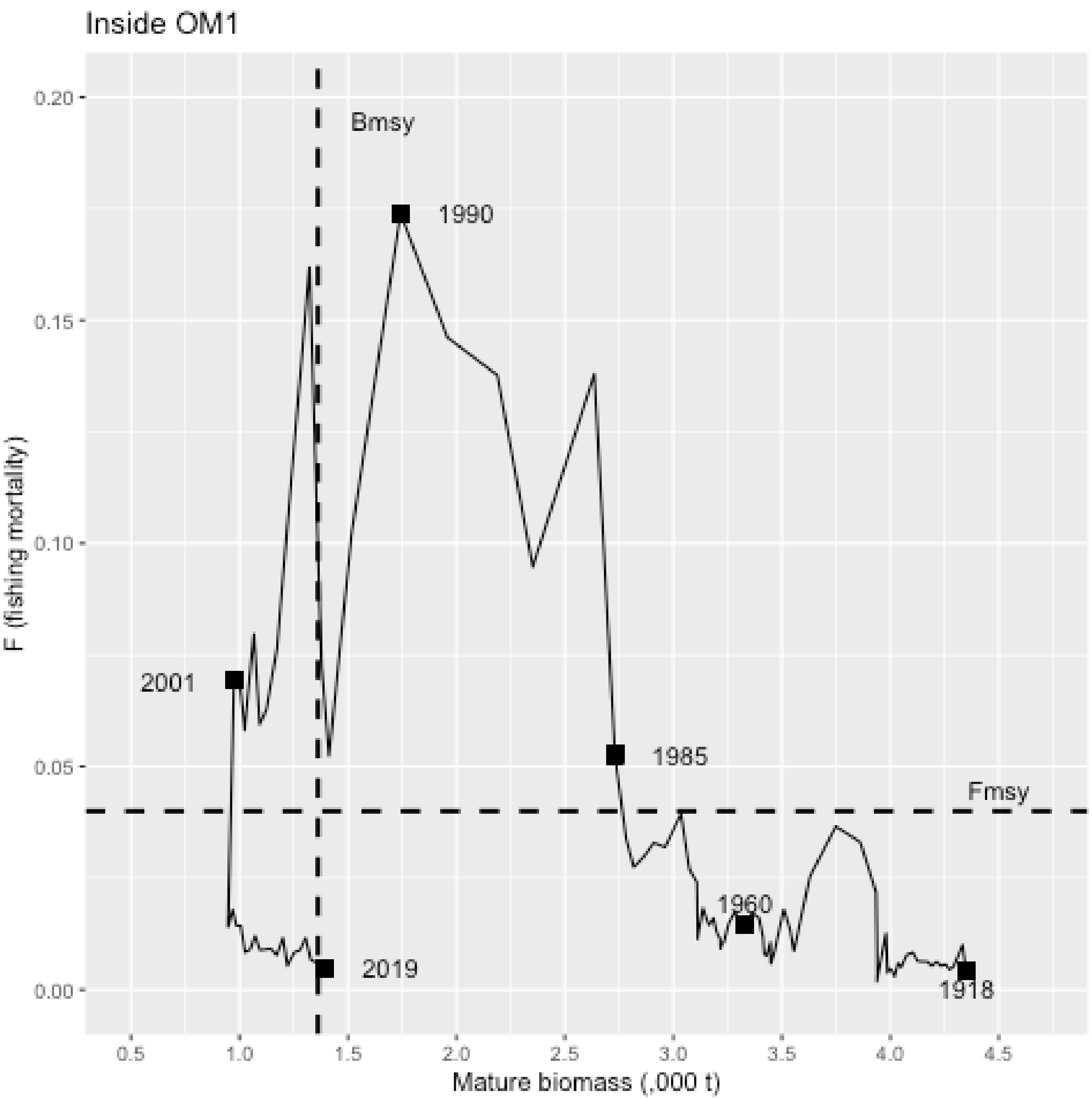

Figure 15. Relationship between F (fishing mortality) and Mature Biomass from 1918 to 2019 as estimated using OM1 for the Inside DU. F_{msy} and B_{msy} for OM1 are indicated by dashed lines. Key years for management or assessment changes and peaks in F are indicated.

Probability that the population, using each of the MPs examined, will on average, throughout the 100-year projection time-period, remain 2% or 5% above the LRP was 0.99 (DFO 2020b). This type of analysis was only done for the Inside Waters DU.

Inside Waters DU sources of uncertainty

While the strength of the MSE approach is that the OMs are designed to cover the range in population dynamics and biomass trends, there are some uncertainties to consider with respect to COSEWIC designations.

Model structure and population trends

The model used in the 2010 assessment was based on a Surplus Production method (Yamanaka *et al.* 2011) and the current assessment used an age-structured approach (Haggarty *et al.* 2020). The surplus production model from the 2010 assessment predicted greater declines in mature biomass (89%) from 1920 (6685 tonnes) to 2009 (761 tonnes) (Yamanaka *et al.* 2018) than the current assessment (Haggarty *et al.* 2020). The Surplus Production model estimated higher biomass at the beginning of the time series and lower biomass (below LRP) at the end of the time series than the OM1 model in the current assessment (above LRP).

Parameter assumptions

Uncertainty with respect to catch assumptions between 1985 and 2005 can be assessed by comparing OM1 and OM2 results. The population declines and probabilities of declines exceeding critical values were similar between these OMs (Figure 14) indicating minimal effect of catch level uncertainty in this time period on decline rates. However, uncertainty with respect to selectivity (OM4) produced higher probabilities of greater than 70% decline than OM1 and OM2, indicating that uncertainty in selectivity is an important parameter to reduce (Figure 14). Uncertainty in M had the greatest effect on probabilities that declines exceeded 70% (Figure 14). In spite of these uncertainties, the probability of declines exceeding 70% exceed 50% for all OMs except OM1. Probabilities of declines exceeding 50% and 30% are greater than 80% for all OMs.

Time span, fishing pressure responses, and contrast in data

The time span for survey and age-composition data is less than a generation and there is little contrast in the data. This limited time span increases the potential for uncertainty in key parameters and emphasizes the importance of including scenarios that capture these uncertainties (Haggarty *et al.* 2020).

This lack of contrast in the data confounds the result that mature biomass since 2002 is increasing. While there is evidence that increasing fishing mortality (F) causes decline in biomass (compare 1985 – 2005 CPUE in Figure 14 with F and biomass trends in Figure 15), there is no observed data to support the increase in biomass with the decline in F in recent years (Figure 13).

Protection

Lack of monitoring within Marine Protected Areas did not permit an evaluation regarding their influence on population abundance and trends (Haggarty *et al.* 2020 section 8.2).

Inside DU Uncertainty commentary on COSEWIC criteria

Current declines over the past 100 years (~2.5 generations) of > 50% are consistently estimated by all OMs.

All OMs indicate an increase in biomass since 2002 and are above estimated LRP levels (Figure 15,16). F is estimated to have been below F_{msy} since 2000, and similar to those from the early portion of the time-series (Figure 15) but the HBLL survey index has not increased since 2002 (Figure 13). The rebuilding policy includes provision for a three-year review cycle and reassessment if evidence for exceptional circumstances occurs.

Rescue Effect – Outside Waters and Inside Waters DUs

Repopulation of the Yelloweye Rockfish Outside Waters DU would be slow through the dispersal of larvae from adults living outside of Canada. Nevertheless, rescue is possible because there are no obvious physical barriers to dispersal in the outer coast marine environment; Yelloweye Rockfish exist on the outer coasts both to the north and south of British Columbia, and genetic evidence supports a high likelihood of at least some movement between outer coast regions (Andrews *et al.* 2018). Currently, the Alaska population is assessed as Healthy (Alaska Department of Fish and Game 2018) while the outer coast population in Washington, Oregon, and California is considered Overfished (Wallace 2001; Wallace *et al.* 2006; Stewart *et al.* 2009).

Repopulation of the Yelloweye Rockfish Inside Waters DU through the dispersal of larvae from adults living outside of Canada is possible given the absence of dispersal barriers between Yelloweye inhabiting the inside waters of Canada and the contiguous waters of the Salish Sea and Puget Sound in the U.S. (Andrews *et al.* 2018). Based on new genetic evidence, the US National Marine Fisheries Service recently changed the legally recognized boundaries of the inshore Yelloweye Rockfish population in Washington State (The Puget Sound / Georgia Basin Distinct Population Segment (DPS)) to now include the entire range of the Canadian Inside Water DU described above (NOAA 2017). However, because the Puget Sound / Georgia Basin DPS is listed as Threatened in the U.S., repopulation of the Canadian Inside Waters DU, from the U.S. portion of this DU would be unlikely.

THREATS AND LIMITING FACTORS

Threat impacts were assessed following the IUCN-CMP (International Union for Conservation of Nature – Conservation Measures Partnership) unified threats classification system, based on the lexicon for biodiversity conservation of Salafsky *et al.* (2008). The threat calculator assessment was done prior to the DFO Yelloweye Rockfish reassessments in 2020 (DFO 2020a,b). Life-history characteristics relevant to threat considerations are in Appendix 1.

The overall threat impact in each of the Outside Inside and Waters DUs was Medium impact. The threat with the highest impact (Medium) in each DU was from current fishing exploitation rates. All other threats were either Negligible, Unknown, or not relevant to these DUs (Appendices 2, 3). A medium impact estimates a 3 -21% biomass reduction for the next 3 generations from these exploitation rates acting in the next 10 years.

Fishery Harvest Data Sources and Regulations Common to Both DUs

Yelloweye Rockfish are caught primarily by demersal hook and line gear in Aboriginal, recreational, and commercial (directed and bycatch) fisheries coastwide (Yamanaka *et al.* 2006). Fishing has had a longer history in the Inside Waters DU between Vancouver Island and the mainland, where human population has grown rapidly over the past century, than in Outside Waters DU. The entire Inside Waters DU can be easily reached by recreational anglers, while large areas of the Outside Waters DU are only accessible to the larger-vessel commercial fishers.

Yelloweye Rockfish was harvested in commercial fisheries as far back as the early 20th century according to recent catch reconstructions, although there are uncertainties in the estimates to the mid-1980s (details in Haigh and Yamanaka 2011).

Estimates from the mid-1980s to 1996 may include uncertainty due to improper identification of Yelloweye in at-sea logs. In contrast, there is high confidence in identification of Yelloweye Rockfish and other rockfish in catches since 1996 when 100% fisheries observer coverage was initiated. However, the trawl fishery in the inside waters is classified as Option B, which do not have observers (Keppel and Olsen 2019).

The most recent commercial catches of Yelloweye Rockfish are taken in the directed commercial Pacific Halibut and rockfish fisheries. Incidental bycatch occurs in other directed commercial fisheries, such as those for Spiny Dogfish (*Squalus acanthias*), lingcod and salmon and to a lesser extent in groundfish and shrimp trawl fisheries and prawn and Sablefish (*Anoplopoma fimbria*) trap fisheries. Trawl gear types, because of their use either off the substrate (mid-water) or over smooth substrates (bottom trawl) do not typically intercept Yelloweye Rockfish.

Rebuilding Plans have been developed under the Integrated Fisheries Management Plan (IFMP) for each DU with the primary objective of rebuilding the population out of the ‘critical zone’ (Biomass > 0.4 Biomass at maximum sustainable yield), within a certain timeframe (DFO 2018a). These rebuilding plans will be reconsidered based on science input from the updated assessments (DFO 2020a,b).

Commercial fisheries are managed via measures set out in the Groundfish Integrated Fisheries Management Plan (IFMP) (DFO 2018a). Measures to improve commercial catch monitoring are: 100% at-sea monitoring for the entire groundfish fishery, eliminating unreported catch of rockfish throughout the commercial groundfish fishery. To complement 100% observer coverage earlier introduced on trawl vessels, 100% video monitoring is now in place for the commercial groundfish hook and line fisheries, which include the directed Pacific Halibut, Spiny Dogfish and rockfish fisheries. Catches in all fleets are constrained by an annual quota and vessel-specific quotas (Keppel and Olsen 2019).

Measures to improve recreational catch information come from a variety of sources including creel surveys, lodge reports, and online surveys (Keppel and Olsen 2019). Some uncertainty in Yelloweye Rockfish identification exists in creel surveys, especially for data before 2000. Since then, training in identification of rockfish species has been provided to surveyors so the creel surveys and lodge reports are now more reliable. Recreational harvest is generally reported in pieces (i.e. numbers of individuals) but has been converted to weight here by multiplying number of pieces by 2 kg as an average weight estimate per fish (Keppel and Olsen 2019).

Management changes included in rebuilding plans to reduce recreational catch initially included constraining groundfish catches in the recreational fishery by a “bag limit” of total rockfish catch as well as Yelloweye Rockfish-specific limits, both of which vary by area. In 2016, recreational daily Yelloweye Rockfish catch limits were reduced from three to two per person in the north (Haida Gwaii, North Coast, and Central Coast) and from two to one in the South Coast. In 2017 recreational limits of all rockfish combined were reduced from five to three in the north and from three to two in the South Coast region (DFO 2018a). Improved reporting and avoiding Yelloweye bycatch by the salmon troll fishery were promoted (DFO 2018a).

Threats: Outside Waters DU

<u>Threat 5: Biological Resource Use (Medium impact)</u>

5.4: Fishing and harvesting resources (Medium impact)

Total harvest for the Outside Waters DU, as reconstructed by Yamanaka *at al.* (2018), suggests a current annual harvest from bycatch, commercial, Aboriginal, and recreational harvest of under 300 tonnes from a peak of nearly 2000 tonnes in the early 1990s. Current overall Yelloweye Rockfish catches are only a fraction of their former size (Figures 16, 17). However, exploitation rates since 1999 are lower than F_{msy} and similar to those from 1918 to 1989. Exploitation rates between 1990 and 1998 were above F_{msy} (Figure 12).

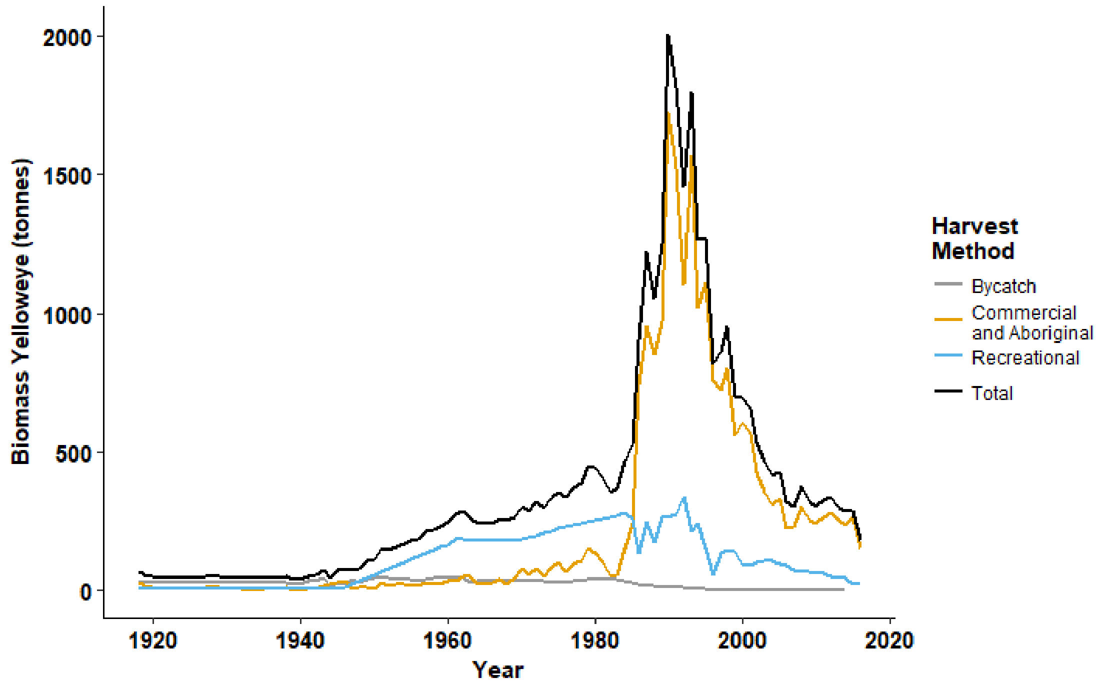

Figure 16. Reconstructed catches for salmon troll bycatch, commercial hook and line and trawl (including Aboriginal) fisheries and imputed recreational catches for the Outside Waters Yelloweye Rockfish DU from 1918-2016 (Yamanaka *et al.* 2018, Table A 12). Data for 2015-2016 lacks Aboriginal fisheries information and includes only raw estimates of the recreational catch based on creel survey data and lodge logbooks (Keppel and Olsen 2019).

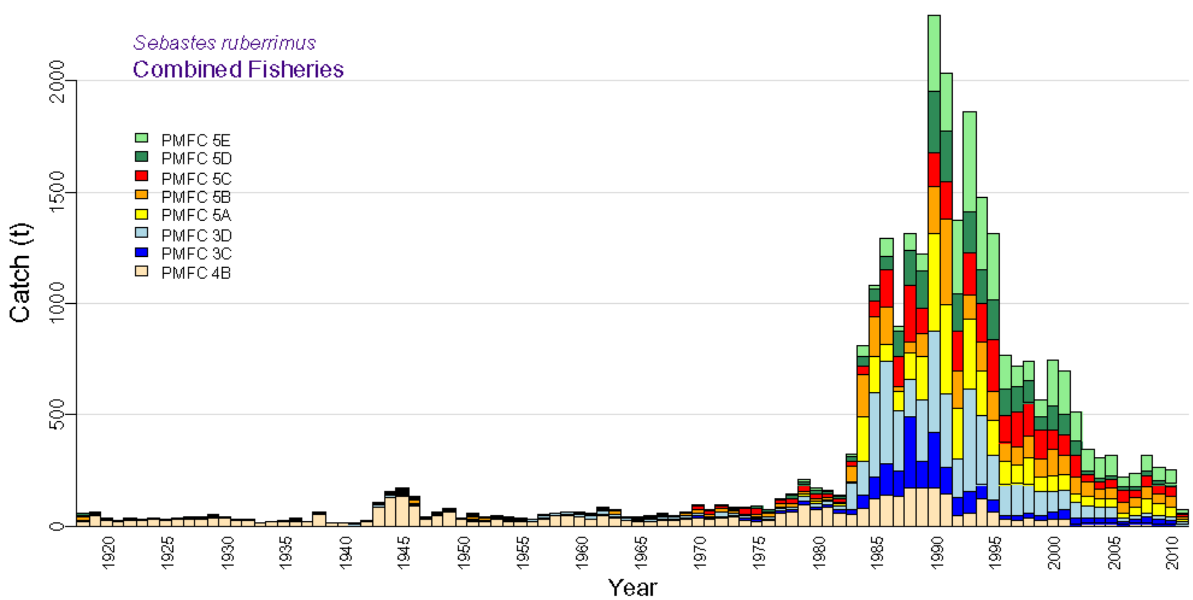

Figure 17. Reconstructed total (landed and discarded) catches for Outside Waters Yelloweye Rockfish DU from all fisheries combined. Catch coded by Pacific Marine Fisheries Commission (PMFC) catch areas along the B.C. Coast (from Haigh and Yamanaka 2011).

Fishery rebuilding plans – Outside

Quotas for the Outside Waters Yelloweye DU were reduced by 75% in 2002. In 2016, a Rebuilding Plan for these Yelloweye Rockfish was implemented as part of the IFMP with an aim to achieve rebuilding throughout the Outside Waters DU and increase biomass out of the critical zone within 15 years, with a 57% probability of success.

Since 2018, no recreational retention of Yelloweye Rockfish has been permitted in the Outside Waters DU as per the Yelloweye Rockfish Rebuilding Plan (DFO 2018a). However, non-retention does not necessarily equate to a lack of mortality because rockfish released at the surface are assumed to have a 100% mortality rate due to the effects of barotrauma.

Threats – Inside Waters DU

Threat 5: Biological Resource Use (Medium impact)

5.4: Fishing and harvesting resources (Medium impact)

Current total annual harvest in the Inside Waters DU (commercial, bycatch, recreational and Aboriginal) is now less than 10 tonnes, having decreased from a peak of just over 200 tonnes in the late 1940s (Figures 18, 19). However, because of reduced biomass, exploitation rates from 1918 to 1984 and 2002 – 2019 are lower than F_{msy} and below those between 1985 – 2001 (Figure 15).

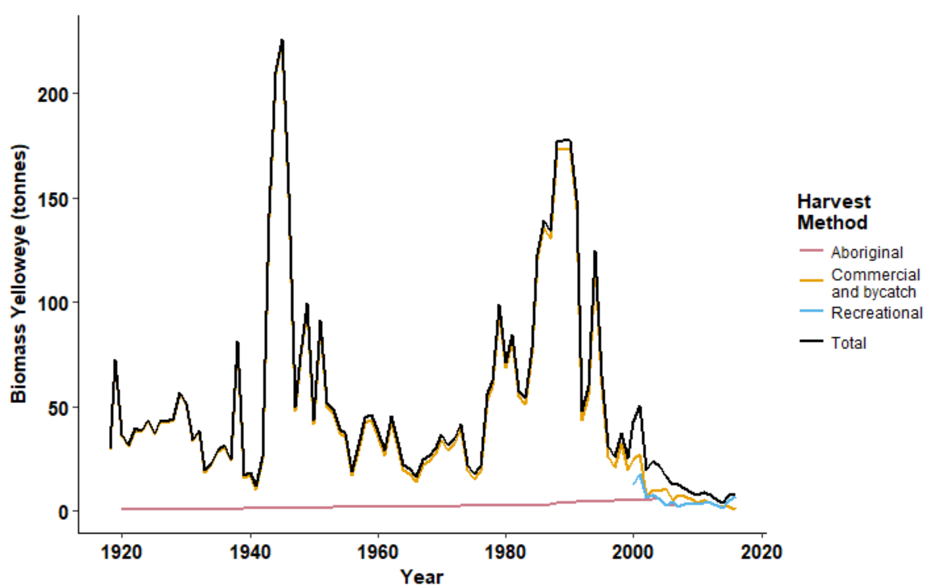

Figure 18. Reconstructed Aboriginal, commercial (including bycatch) and recreational catches for Inside Waters Yelloweye Rockfish DU from 1918-2016. Fishery data sources: 1918 – 1950 Canadian Bureau of Statistic, 1951 – 1981 B.C. Commercial Catch Statistics: Pacific Region, 1982 – 1995 Pacific Region Sales slips, 1996 – 2005 Dockside Monitoring Program, 2006 – 2014 Fisheries Operations System (FOS). Survey catches and dual fishing Aboriginal food, social and ceremonial (FSC) catches are included in FOS landings.

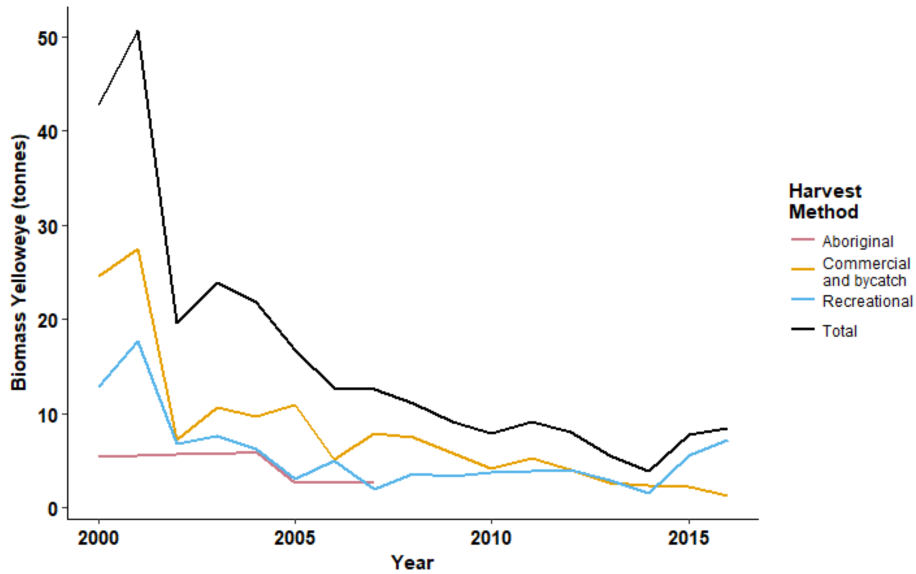

Figure 19. Reconstructed recent (since 2000) Aboriginal, commercial and recreational catches for Inside Waters Yelloweye Rockfish DU from 2000-2016. Fishery data sources: 1918 – 1950 Canadian Bureau of Statistic, 1951 – 1981 B.C. Commercial Catch Statistics: Pacific Region, 1982 – 1995 Pacific Region Sales slips, 1996 – 2005 Dockside Monitoring Program, 2006 – 2014 Fisheries Operations System (FOS). Survey catches and dual fishing Aboriginal food, social and ceremonial (FSC) catches are included in FOS landings.

Fishery rebuilding plans – Inside

In 2002, the implementation of the Inshore Rockfish Conservation Strategy led to large decreases in commercial catch quotas. Quotas for Inside Waters DU Yelloweye (as approximated by PFMA area 4B) were reduced by 75% in 2002. These quotas have remained relatively stable since 2002.

Marine Protected Areas, in this case also called Rockfish Conservation Areas (RCAs), currently protect approximately 28% of the Inside Waters DU (see **Habitat Protection and Ownership** below). However, while commercial compliance is likely very high, a recent study suggests that compliance among recreational fishers is quite low. After establishment, no change in fishing effort was observed in 83% in these RCAs, and an increase in fishing effort was observed in five RCAs (Haggarty *et al.* 2016a). This may be due to a lack of awareness of the RCAs among recreational fishers; however, awareness may improve as boundaries are added to maps and software devices used by fishers.

Remaining Threats: Both DUs

<u>Negligible</u>

Threat 9: Pollution (Negligible impact)

9.1 Domestic and urban wastewater and 9.2 Industrial and military effluents (Negligible impact)

There is a possible overflow issue from Vancouver sewage; the effects are unknown but are likely small. It is likely a certain portion of the habitat is not exposed to such overflow.

9.3 Agricultural and forestry effluents (Negligible impact)

Possible concerns with log booms shedding woody debris onto habitat.

Threat 10. Geological Events (Negligible impact)

10.2 Earthquakes or Tsunamis

Evidence from the Alaska earthquake and the Port Alberni tsunami suggests Yelloweye Rockfish could be affected by tsunamis. Adults would be the most vulnerable to this threat.

Threat 7: Natural system modifications (Unknown impact)

7.3: Other ecosystem modifications (Unknown impact)

Significant sources of uncertainty in Yelloweye Rockfish recruitment are climate change including unfavourable ocean conditions leading to direct or indirect effects on recruitment. There is very little direct or indirect knowledge of how oceanic conditions affect Yelloweye through food web interactions. Variable and high uncertainty in recruitment would lead to variation in cohort strength, affecting population structure and trajectory.

Threat 8: Invasive and other problematic species and genes (Unknown impact)

8.1 Invasive non-native/alien species/ diseases

No known predictions related to ballast water.

8.2 Problematic native species/ diseases

No clear indication that a change in pinniped, salmon, or orca populations would negatively affect Yelloweye Rockfish.

Threat 11: Climate change and severe weather (Unknown impact)

Unfavourable oceanic conditions driven by climate change could be a mitigating factor contributing to dispersal to locations preventing successful recruitment, but current data are unavailable to address this speculation.

11.3 Temperature extremes (*Unknown impact)*

Larvae and adults may be affected by changes. High temperature could also lead to hypoxia-induced mortality. Not much is known directly for Yelloweye.

11.4 Storms and flooding (Unknown impact)

Limiting Factors

Yelloweye Rockfish is among the largest, longest-lived, latest-maturing of rockfish species (Love *et al.* 2002), with low natural mortality (estimated at 0.045; Table 8). Populations with these attributes have long recovery times even after fishing impacts have ceased (Yamanaka *et al.* 2011, 2017). The slow recovery for Yelloweye Rockfish is exemplified by results of recent surveys inside and immediately outside recently established Rockfish Conservation Areas (RCAs) in B.C. (Haggarty *et al.* 2016b). This study observed mostly juvenile and subadult Yelloweye Rockfish (< 50 cm) inside or outside these RCAs 3-7 years after their establishment, suggesting that the establishment of no-take zones will likely not yield benefits for breeding populations of Yelloweye Rockfish for several years. There have been no studies assessing the impact of these areas on population recovery since Haggarty *et al.* (2016b).

Number of Locations

The term 'location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. Fishing can be expected to rapidly affect all individuals if it exceeds defined sustainable exploitation rates (overfishing) but is otherwise unlikely. For Yelloweye Rockfish, exploitation rate is currently estimated to be below overfishing levels. Hence, it is unlikely that fishing can be expected to rapidly affect all individuals in the case of Yelloweye Rockfish. As a result, the concept of locations does not apply for the Yelloweye Inside and Outside DUs.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

The U.S. population of Yelloweye Rockfish that abuts the Canadian Inside Waters DU (known as the Puget Sound / Georgia Basin Distinct Population Segment, or PS/GB DPS) is listed as Threatened under the US *Endangered Species Act* (NOAA 2010). Furthermore, the US National Marine Fisheries Service recently changed the legally recognized boundaries of the PS/GB DPS to now include the entire range of the Canadian Pacific Inside Waters DU (NOAA 2017). Under the U.S. *Endangered Species Act* legislation, 414 $miles^2$ of critical habitat in the U.S. portion of the PS/GB DPS has been protected (NOAA 2017). In Canada, both the Inside and Outside Waters DUs of Yelloweye Rockfish were designated Special Concern by COSEWIC in 2008 and have been listed as Special Concern under SARA (Schedule 1) since 2011.

Non-Legal Status and Ranks

Habitat protection for Yelloweye Rockfish occurs via a number of Marine Protected Areas currently in place: Rockfish Conservation Areas (RCAs), Sponge Reef Closures, National Marine Conservation Areas (NMCAs), and restriction of bottom trawl fishing areas (Figure 20). A more detailed description of these closures than what follows (with additional small-scale maps) is available in Keppel and Olsen (2019).

RCAs currently protect approximately 28% of the Inside Waters DU and 20% of the Outside Waters DU rockfish habitat (Yamanaka and Logan 2010; Siegle *et al.* 2103) (Figure 20). Whether RCAs function effectively to bolster the Yelloweye Rockfish populations will require ongoing long-term monitoring due to the life history traits of this species coupled with the apparent intermittent good recruitment.

Another avenue of protection comes from Glass Sponge Reef Closures in Hecate and Queen Charlotte Straits (Outside DU) (Figure 20) and an MPA created on the Bowie Seamount. The Glass Sponge Reefs Closures (Inside Waters DU) were first closed to the groundfish trawl fishery in 2002 and were expanded in size and gear restrictions in 2006/2007, and designated as a 2,410 km^2 Marine Protected Area (MPA) in February 2017 (Keppel and Olsen 2019). This MPA is now closed to all commercial bottom contact fishing activities including hook and line for groundfish.

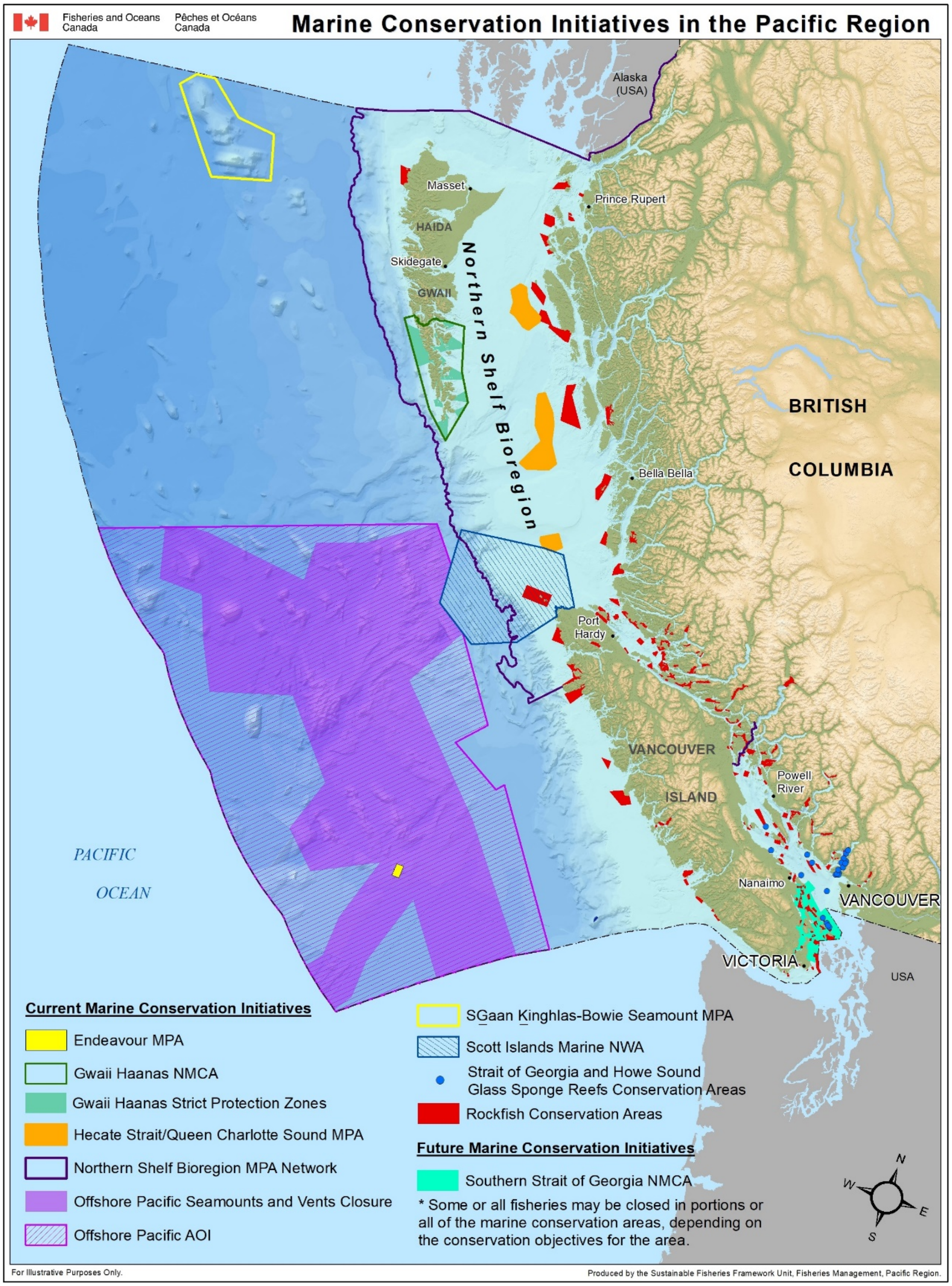

Figure 20. Areas designated as closed to all or some fishing in B.C. waters. (Map provided by Faith Yu (pers. comm. 2020.)

Additional sponge reef closures were implemented in the Strait of Georgia and Howe Sound in 2015 (Inside DU) (Figure 20). They prohibit all commercial and recreational bottom contact fishing activities over 27 km^2. First Nation Food, Social and Ceremonial bottom-contact fisheries were also closed in these areas starting in 2016 (Keppel and Olsen 2019).

The SGaan Kinghlas-Bowie Seamount (SKB) MPA (Outside DU), which was designated in 2008, has prohibited all commercial fishing since 2008; the Haida First Nation and Government of Canada increased protection within the SKB MPA by also closing the second zone to all bottom-contact commercial fishing in 2018 (DFO 2018b).

The Gwaii Haanas National Marine Conservation Area Reserve, six zones (Outside DU) that are closed to commercial and recreational fishing also provide some protection (Figure 20) (DFO 2018a).

Finally, bottom trawl fishing areas were restricted in 2012 (Outside DU) to limit habitat disturbance. The area where bottom trawling is allowed is 21% smaller than historically (Keppel and Olsen 2019).

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Chris Neufeld is the Associate Director of Education at the Bamfield Marine Sciences Centre where he has taught undergraduate and graduate courses since 2010 including Coastal Community Ecology and Marine Population Ecology and Dynamics. Before coming to the Bamfield Marine Sciences Centre Chris taught Ecology, Evolution, and Animal Behaviour at Quest University with a focus on student-centred experiential learning. He Holds a Ph.D. in Ecology and Environmental Biology from the University of Alberta and has conducted postdoctoral research at the University of Washington's Friday Harbor Laboratories. Chris has authored 13 peer-reviewed scientific publications on topics such as island biogeography, morphological plasticity, and the ecological impacts of introduced species.

Stacey Hrushowy is a recent M.Sc. graduate from Simon Fraser University and a current teaching assistant with the Bamfield Marine Sciences Centre.

COLLECTIONS EXAMINED

None.

Appendix 1. Important life-history events and stages relevant to threats.

Important life-history events and stages relevant to threats

1. Life-history event: Live birth – nutrients and energy transferred directly to embryo
    a. Typical Timing and (range): gestation: 1 – 2 months, birth April – Sept. peak in May and June
    b. Habitat: Larvae absorb yolk-sac and feed on phytoplankton and zooplankton in the upper 10 – 50 metres of water column
2. Life-history event: Larval development
    a. Typical Timing and (range): 1 – 2 months based on other Sebastes
    b. Habitat: feed on copepod nauplii and invertebrate eggs, moving onto larger prey such as copepodites, adult copepods, and euphausiids phytoplankton and zooplankton in the upper mixed layer (<300 m), dispersed by physical transport processes. Larvae (20 to 70 mm) develop into pelagic juveniles (20 – 70 mm) prior to settling into benthic habitats. Sebastes larvae were found to concentrate over the continental shelf and slope west of Haida Gwaii, up to 300 nautical miles from shore (LeBrasseur 1970). From the composition of otolith microstructure, there is evidence that dispersal may be less than 120 km for Black Rockfish (*Sebastes melanops*) (Miller and Shanks 2004). However, the actual dispersal distance for Yelloweye Rockfish is unknown.
2. Life-history event: Juvenile - Settle on bottom
    a. Typical Timing and (range): 6 – 9 months (3 to 9 cm)
    b. Habitat: feed on crustaceans but shift to larger prey moving from planktonic to benthic invertebrate. Typically, rockfish juveniles settle to nearshore hard bottom habitats at shallower depths than their conspecific adults. The recruitment of rockfish is influenced to a large extent by their success during these pelagic larval-juvenile and benthic settlement phases. Observed juvenile and subadult Yelloweye across a wide range of depths (from 10-180 m, with the majority of individuals occurring between 40-100 m).
3. Maturing and mature adults
    a. Life-history event: Maturing and mature – depth distribution
    b. Typical Timing and (range): Adult life, Age at maturity varies across populations. Recruitment to fishery begins at ages 1 – 3 years.
    c. Habitat: Rockfish move bathymetrically, hence older (larger) rockfish tend to occupy the deeper depths. Within their specific depth range Yelloweye Rockfish exhibit undirected swimming in coastal waters and migrations to predictable locations.

4. Life-history event: Adult - Spawning
    a. Typical Timing and (range): Inside DU A_{50} (males) is 21, (females) is 19. research, Outside A_{50} (males) is 21 and (females) is 16. November and may extend into winter months. Females mate with several males and store sperm prior to fertilization.
    b. Habitat: 10s to 100s metres depth, breed annually but up to 30% skip a year. Batch spawners 5 – 25% of eggs released at a time. Spawning intervals of 2 – 6 days are typical. Greater reproductive success with size-selective mating.

Appendix 2. Threat calculator for Outside waters population.

THREATS ASSESSMENT WORKSHEET				
Species or Ecosystem Scientific Name	*Sebastes ruberrimus* Yelloweye Rockfish: Outside Waters DU 2			
Element ID			**Elcode**	
Date:				
Assessor(s):	Dwayne Lepitzki (Facilitator), Kelly Andrews, Ross Claytor, Ian Fleming, Alejandro Frid, Lea Gelling, Dana Haggarty, Dave Kulka, Bruce Leaman, Lynn Lee, Chris Neufield, Karine Robert, Kevin Romanin, Margaret Treble, Greg Wilson, Jennifer Yakimishyn, Bev McBride (Secretariat)			
References:	Draft calculator for DU1 (inside waters population) prepared by Chris and Ross; 6-month COSEWIC report; telecon 30 Jan 2019; telecon calculator for DU1 then used as template for DU2 (outside waters)			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	1	1
	D	Low	0	0
Calculated Overall Threat Impact:			Medium	Medium
Assigned Overall Threat Impact:			**C = Medium**	
Impact Adjustment Reasons:				
Overall Threat Comments			Revised generation time estimate = 39 years. Yelloweye Rockfish are subject to variable recruitment and cohort size. This variation coupled with the long generation time and late age at maturity of Yelloweye Rockfish will likely make this species slow to recover from population declines and unlikely to adapt quickly to changing environmental conditions. Modeling estimates of mature biomass indicate an overall 100-year (~2.5 generational decline) for the Outside Waters DU ranged from 69 to 72%.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development						
1.1	Housing & urban areas						Not relevant to this DU.
1.2	Commercial & industrial areas						Not Relevant to this DU.
1.3	Tourism & recreation areas						Not Relevant to this DU.
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						Not relevant to this DU.
2.2	Wood & pulp plantations						Not relevant to this DU.
2.3	Livestock farming & ranching						Not relevant to this DU.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.4	Marine & freshwater aquaculture						Not relevant to this DU.
3	Energy production & mining						There are no energy production and mining threats in this DU.
3.1	Oil & gas drilling						There has been a moratorium in place since 1972 and although the previous government in BC committed to continued exploration in its 2010 BC Energy Plan and requested to Canada to lift the federal moratorium and reiterated that the provincial moratorium will be lifted at the same time, this did not occur. As of 2018, the moratorium was still in effect. Shell Canada also gave up its exploration rights off northwest Vancouver Island to protect marine birds in 2018.
3.2	Mining & quarrying						Not relevant to this DU.
3.3	Renewable energy						No proposed tidal energy projects inside DU were identified.
4	Transportation & service corridors						
4.1	Roads & railroads						Not relevant to this DU.
4.2	Utility & service lines						Not relevant to this DU.
4.3	Shipping lanes						Not relevant to this DU.
4.4	Flight paths						Not relevant to this DU.
5	Biological resource use	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						Not relevant to this DU.
5.2	Gathering terrestrial plants						Not relevant to this DU.
5.3	Logging & wood harvesting						Not relevant to this DU.
5.4	Fishing & harvesting aquatic resources	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Population has declined to low levels at current exploitation rates. Numerous management measures have been implemented. The severity agreed-upon by participants is dependent on good recruitment occurring. Recent ROV surveys of Yelloweye habitat by Canadian and US counterparts suggest that recruitment is occurring. Group thought fishing grounds don't cover a majority of the area where fish occur. The group had concerns about the relative lack of monitoring and enforcement that could affect severity.
6	Human intrusions & disturbance						
6.1	Recreational activities						Not relevant to this DU.
6.2	War, civil unrest & military exercises						Not relevant to this DU.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.3	Work & other activities						Not relevant to this DU.
7	Natural system modifications		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
7.1	Fire & fire suppression						Not relevant to this DU.
7.2	Dams & water management/use						Not relevant to this DU.
7.3	Other ecosystem modifications		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Unfavourable oceanic conditions are a likely cause for poor recruitment, but little is known about specific environmental factors which contribute to recruitment. Changes to growth rates may be a result of changes in temperature. In general, we have little knowledge of how prey species will be affected by human changes to ecosystems. We don't know what favourable and unfavourable conditions for recruitment look like. All life stages could be affected.
8	Invasive & other problematic species & genes		Unknown	Unknown	Unknown	Unknown	
8.1	Invasive non-native/alien species/diseases		Unknown	Unknown	Unknown	Unknown	No knowledge or prediction that ballast water would affect Yelloweye Rockfish.
8.2	Problematic native species/diseases		Unknown	Unknown	Unknown	Unknown	No clear indication that a change in pinniped, salmon, or orca populations would negatively affect Yelloweye Rockfish given that orca and chinook are likely to decrease, and pinnipeds are near carrying capacity. Indications are that yelloweye make up a small portion of pinniped diet.
8.3	Introduced genetic material						Not relevant to this DU.
8.4	Problematic species/diseases of unknown origin						Not relevant to this DU.
8.5	Viral/prion-induced diseases						Not relevant to this DU.
8.6	Diseases of unknown cause						Not relevant to this DU.
9	Pollution		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
9.1	Domestic & urban waste water		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Possible overflow issue from Victoria sewage. Effects are unknown but likely small. Likely very large portions of the habitat that are not exposed.
9.2	Industrial & military effluents		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Any effects would be negligible
9.3	Agricultural & forestry effluents		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Possible concerns with log booms shedding woody debris onto Yelloweye habitat affecting juvenile and adult Yelloweye.
9.4	Garbage & solid waste						Microplastics could potentially be present in wastewater. However, not expected to be a threat to Yelloweye Rockfish.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.5	Air-borne pollutants						Not relevant to this DU.
9.6	Excess energy						There is little understanding of how fish are affected by sound but rockfish are noisy and use sound. It will affect behaviour, but threat impact is unknown. Yelloweye are territorial so sound could disrupt territory. Any life stage could be vulnerable.
10	Geological events		Negligible	Pervasive (71-100%)	Negligible (<1%)	Moderate - Low	
10.1	Volcanoes						Not relevant to this DU.
10.2	Earthquakes/tsunamis		Negligible	Pervasive (71-100%)	Negligible (<1%)	Moderate - Low	Evidence from Alaska earthquake and Port Alberni tsunami suggests Yelloweye could be affected by tsunamis. Given there is information, negligible is a better score than unknown. Adults most vulnerable.
10.3	Avalanches/landslides						Not relevant to this DU.
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.1	Habitat shifting & alteration						Mismatches between plankton prey and birth from temperature alteration for larval and settling juveniles. Ocean acidification threat most likely, but impact unknown.
11.2	Droughts						Not relevant to this DU.
11.3	Temperature extremes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Larvae may be affected by changes in temperature (similar to OA). High temperature could also lead to hypoxia-induced mortality of any stage. Not much is known directly for Yelloweye Rockfish. However, most rockfishes go deeper to spawn and larvae are in a more stable thermal environment; effects may be more manifest at post-larval stages.
11.4	Storms & flooding		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Large storm in Ucluelet caused adult rockfish to wash in on shore.
11.5	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).							

Appendix 3. Threat calculator for Inside waters population.

THREATS ASSESSMENT WORKSHEET				
Species or Ecosystem Scientific Name	*Sebastes ruberrimus* Yelloweye Rockfish: Inside Waters DU 1			
Element ID			**Elcode**	
Date:				
Assessor(s):	Dwayne Lepitzki (Facilitator), Kelly Andrews, Ross Claytor, Ian Fleming, Alejandro Frid, Lea Gelling, Dana Haggarty, Dave Kulka, Bruce Leaman, Lynn Lee, Chris Neufield, Karine Robert, Kevin Romanin, Margaret Treble, Greg Wilson, Jennifer Yakimishyn, Bev McBride (Secretariat)			
References:	Draft calculator for DU1 (inside waters population) prepared by Chris and Ross; 6-month COSEWIC report; telecon 30 Jan 2019; telecon calculator for DU1 then used as template for DU2 (outside waters)			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	1	1
	D	Low	0	0
Calculated Overall Threat Impact:			Medium	Medium
Assigned Overall Threat Impact:	**C = Medium**			
Impact Adjustment Reasons:				
Overall Threat Comments	Revised estimate 41 years. Yelloweye Rockfish are subject to variable recruitment and cohort size. This variation coupled with the long generation time and late age at maturity of Yelloweye Rockfish will likely make this species slow to recover from population declines and unlikely to adapt quickly to changing environmental conditions. Inside Waters DU biomass declined by 68 - 88% from 1918 to 2019 (~ 2.5 generations).			

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development						
1.1	Housing & urban areas						Not relevant to this DU.
1.2	Commercial & industrial areas						Not Relevant to this DU.
1.3	Tourism & recreation areas						Not Relevant to this DU.
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						Not relevant to this DU.
2.2	Wood & pulp plantations						Not relevant to this DU.
2.3	Livestock farming & ranching						Not relevant to this DU.
2.4	Marine & freshwater aquaculture						Not relevant to this DU.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3	Energy production & mining						There are no energy production and mining threats in this DU.
3.1	Oil & gas drilling						There has been a moratorium in place since 1972 and although the previous government in BC committed to continued exploration in its 2010 BC Energy Plan and requested to Canada to lift the federal moratorium and reiterated that the provincial moratorium will be lifted at the same time, this did not occur. As of 2018, the moratorium was still in effect. Shell Canada also gave up its exploration rights off northwest Vancouver Island to protect marine birds in 2018.
3.2	Mining & quarrying						Not relevant to this DU.
3.3	Renewable energy						No proposed tidal energy projects inside DU were identified.
4	Transportation & service corridors						
4.1	Roads & railroads						Not relevant to this DU.
4.2	Utility & service lines						There was an impact threat assessment conducted by BC Hydro in 2006. In it was the statement, Within each cable area, three of the existing 1950s era cables will be replaced by three new 230kV cables in 2008, with the remaining four cables replaced in about 2018 by three more cables.
4.3	Shipping lanes						Not relevant to this.
4.4	Flight paths						Not relevant to this DU.
5	Biological resource use	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						Not relevant to this DU.
5.2	Gathering terrestrial plants						Not relevant to this DU.
5.3	Logging & wood harvesting						Not relevant to this DU.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.4	Fishing & harvesting aquatic resources	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Catch quotas implemented 2002, reduced in 2016 with rebuilding plan. Large + moderate = 3-21% reduction. Primarily hook and line fishery, inside greater pressure from trawls than outside. Inside DU soon to have zero retention for Yelloweye Rockfish, with mandatory "rigged and ready" descending device on hand when fishing for other bottom fish. RCA and sponge reef closure cover 28% of habitat. The scope agreed-upon by participants is dependent on good recruitment occurring. Recent ROV surveys of yelloweye habitat by Canadian and US counterparts suggest that recruitment is occurring. Group thought fishing grounds don’t cover a majority of the area where fish occur. The group had concerns about the relative lack of monitoring and enforcement that could affect severity.
6	Human intrusions & disturbance						
6.1	Recreational activities						Not relevant to this DU.
6.2	War, civil unrest & military exercises						Not relevant to this DU.
6.3	Work & other activities						Not relevant to this DU. Any research, fisheries or others, not accounted for under 5.4?
7	Natural system modifications		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
7.1	Fire & fire suppression						Not relevant to this DU.
7.2	Dams & water management/use						Not relevant to this DU.
7.3	Other ecosystem modifications		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Unfavourable oceanic conditions are a likely cause for poor recruitment, but little is known about specific environmental factors which contribute to recruitment. Significant sources of uncertainty in Yelloweye Rockfish recruitment: climate change including unfavourable ocean conditions leading to direct or indirect effects on recruitment. There is very little direct or indirect knowledge of how oceanic conditions affect yelloweye through food web interactions. Variable and high uncertainty in recruitment would lead to variation in cohort strength, affecting population structure and trajectory.
8	Invasive & other problematic species & genes		Unknown	Unknown	Unknown	Unknown	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.1	Invasive non-native/alien species/diseases		Unknown	Unknown	Unknown	Unknown	This effect can occur from ballast dumping. No knowledge or prediction that ballast water would affect Yelloweye Rockfish. Unusual increase in anchovy in Inside Waters DU may affect Yelloweye Rockfish but unknown, and probably positive.
8.2	Problematic native species/diseases		Unknown	Unknown	Unknown	Unknown	No clear indication that a change in pinniped, salmon, or orca populations would negatively affect yelloweye given that orca and chinook are likely to decrease, and pinnipeds are near carrying capacity and indications are that yelloweye make up a small portion of pinniped diet.
8.3	Introduced genetic material						Not relevant to this DU.
8.4	Problematic species/diseases of unknown origin						Not relevant to this DU.
8.5	Viral/prion-induced diseases						Not relevant to this DU.
8.6	Diseases of unknown cause						
9	Pollution		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	
9.1	Domestic & urban waste water		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	Possible overflow issue from Vancouver sewage. Effects are unknown but likely small. Likely certain portions of the habitat that are not exposed.
9.2	Industrial & military effluents		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	Any effects would be negligible
9.3	Agricultural & forestry effluents		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	Possible concerns with log booms shedding woody debris onto Yelloweye Rockfish habitat.
9.4	Garbage & solid waste						Microplastics could potentially be present in wastewater. However, not expected to be a threat to Yelloweye Rockfish.
9.5	Air-borne pollutants						Not relevant to this DU.
9.6	Excess energy						There is little understanding of how fish are affected by sound, but rockfish are noisy and use sound. It will affect behaviour, but threat impact is unknown. Yelloweye are territorial so sound could disrupt territory.
10	Geological events		Negligible	Pervasive (71-100%)	Negligible (<1%)	Moderate - Low	
10.1	Volcanoes						Not relevant to this DU.
10.2	Earthquakes/tsunamis		Negligible	Pervasive (71-100%)	Negligible (<1%)	Moderate - Low	Evidence from Alaska earthquake and Port Alberni tsunami suggests Yelloweye Rockfish could be affected by tsunamis. Given there is information, negligible is a better score than unknown.
10.3	Avalanches/landslides						Not relevant to this DU.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.1	Habitat shifting & alteration						Ocean acidification threat most likely, but impact unknown, and not enough information to score.
11.2	Droughts						Not relevant to this DU.
11.3	Temperature extremes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Larvae may be affected by changes in temperature (similar to OA). High temperature could also lead to hypoxia-induced mortality of any stage. Not much is known directly for Yelloweye. Unlike the Outside DU, this could be more relevant in the Inside DU where the thermal environment is less stable than outside waters.
11.4	Storms & flooding		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Large storm in Ucluelet caused adult rockfish to wash in on shore.
11.5	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008)							