Status of the Rougheye and Blackspotted Rockfishes stock off the U.S. West Coast in 2025

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quiet = TRUE) #cat(a, sep = '\n') #
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0.1 Executive Summary

0.1.1 Stock Description

This document presents the stock assessment for the Rougheye (*Sebastes aleutianus*) and Blackspotted (*Sebastes melanostictus*) Rockfishes, two species that form one management complex. Despite some identification advances and Rougheye and Blackspotted rockfishes are clearly genetically distinct species, data historically and contemporaneously remain available mostly for the Rougheye/Blackspotted Rockfish complex, not consistently at the species level. While we treat these species as one assessed stock complex, we recognize and are mindful of the above species distinctions as we conduct our analyses. This report is for the year 2025 in state and federal waters from California to Washington State, excluding consideration of the Puget Sound and Salish Sea (Figure 1). It seeks to use available catch, biological compositions in the for of lengths and ages, and potential indices of abundance and is the first assessment since the 2013 stock assessment (Hicks, Wetzel, and Harms 2013).

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1 Introduction

This document presents the stock assessment for the Rougheye (*Sebastes aleutianus*) and Blackspotted (*Sebastes melanostictus*) rockfishes, two species that form one management complex. This report is for the year 2025 in state and federal waters from California to Washington State, excluding consideration of the Puget Sound and Salish Sea (Figure 1). It seeks to use available catch, biological compositions in the for of lengths and ages, and potential indices of abundance and is the first assessment since the 2013 stock assessment (Hicks, Wetzel, and Harms 2013).

1.1 Stock Structure

There are at least two questions to think about when considering stock structure for Rougheye and Blackspotted rockfishes when doing a stock assessment.

1. Rougheye and Blackspotted rockfishes are two different species– can we separate them as two stocks and conduct separate assessments? Rougheye rockfish were first described in 1811 as *Perca variabilis* by German zoologist Peter Simon Pallas (Jordan and Evermann 1898), and assigned to various taxa at least 15 times since (Love, Yoklavich, and Thorsteinson 2002). Some descriptions noted both light and dark color morphs, which, along with possible confusion with several morphologically similar co-occurring species (e.g., *S. borealis* and *S. melanostomus*) have contributed to the persistent ambiguity in formal descriptions of Rougheye Rockfish (Orr and Hawkins 2008). The first genetic studies conducted in the late 1960s and early 1970s (Tsuyuki et al. 1968; Tsuyuki and Westrheim 1970) observed diversity suggestive of two genetic types within specimens identified as Rougheye Rockfish. Allozyme studies conducted over the next two decades (Seeb 1986; S. Hawkins, Heifetz, and Pohl 1997; S. L. Hawkins et al. 2005) provided additional evidence suggesting two separate genetic types within field-identified Rougheye Rockfish. Genetic variation between the two types, supported by both nuclear and mitochondrial DNA, was determined to be sufficiently conclusive to separate two species: "Type I" and "Type II" Rougheye Rockfish (Anthony J. Gharrett et al. 2005). Meristic and morphometric comparisons of the two species suggested certain characters such as gill raker counts and length, snout length, anal base length, and pectoral fin base were significantly different, and in combination could reliably, though not definitively, distinguish between the species(A. J. Gharrett et al. 2006). The two separate species were formally re-described by Orr and Hawkins (2008) with the Type II group retaining *S. aleutianus* and the common name Rougheye Rockfish. Blackspotted rockfish was proposed as the common name for the Type I group along with the scientific name of *S. melanostictus*, re-establishing nomenclature from one of the species complex's earlier descriptions (Matsubara 1934).

These two species remain difficult to consistently differentiate visually in the catch, thus are still commonly reported and treated as a species complex. Otolith morphometrics (e.g., shape, size, weight) have shown some promise in possibly identifying these species in Alaskan waters (97.3% Blackspotted and 86.2% of Rougheye rockfishes were accurately identified) and possibly using older otoliths to break out historical information by species (Harris, Hutchinson, and Wildes 2019). Frey et al. (in prep.) provided insight into the ability of the Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey biologists to identify the two species, with 90% of genetically identified Rougheye rockfish being correctly identified in the field. When mis-identifications occurred, it was usually a Blackspotted rockfish being mis-identified as a Rougheye rockfish. There were few mis-identifications when a fish was identified as a Blackspotted rockfish. While this is promising for potential future species-specific data coming from the survey, it does not alleviate the historical problem of separating fishery data into the two species. Frey et al. (in prep.) therefore also considered whether ecological factors like depth or latitude could help separate samples by species. They found that both species occur within the range of this assessment's considered areas (California to Washington), and heavily spatially overlap. Interestingly, there seem to be relative hot spots for these species where one species is more common than the other, and in general, Rougheye rockfish seems to be more common than Blackspotted rockfish (however, Blackspotted rockfish may be the more common of the two in parts of Alaska; Anthony J. Gharrett et al. (2005); S. L. Hawkins et al. (2005); Orr and Hawkins (2008)). Overall, there seems to be little ability to separate current or historical fishery data reliably in order to separate these two species into two stocks, so we will maintain a species complex approach, though given absolute presence off the U.S. West coast, this may be considered more of a Rougheye than Blackspotted stock assessment. We also note that throughout the range of these stocks, all current assessments to this point have maintained a species complex approach.

Despite some identification advances and Rougheye and Blackspotted rockfishes are clearly genetically distinct species, data historically and contemporaneously remain available only for the Rougheye/Blackspotted Rockfish complex, not at the species level. While we treat these species as one assessed stock complex, we recognize and are mindful of the above species distinctions as we conduct our analyses.

2. Both species range into Canada and Alaska– are they one stock? While genetics studies have focused mostly on identification of the two species, little is known about the population structure of either species. This assessment and the 2013 assessment (Hicks, Wetzel, and Harms 2013) represent the most southerly range of these species. Comparing the absolute abundance of the 2013 assessment to the most current estimates of the Alaskan stocks, the absolute number in this southerly range is much smaller than in the Gulf of Alaska (GOA), but higher than in the Bering Sea/Aleutian Island (BSAI) stock (Figure 2). The two smaller stocks have similar trend of decline and stabilization, whereas the higher biomass GOA stock looks to have not dropped at all over the time period considered (Figure 3). We

assume here that the west coast stocks of Rougheye/Blackspotted rockfishes are distinct management units from those in Alaska.

1.2 Life History

Rougheye and Blackspotted Rockfishes range from northern California up to and throughout Alaska and into Japan (Anthony J. Gharrett et al. 2005; S. L. Hawkins et al. 2005; Orr and Hawkins 2008). Both are long-lived (>100 years), with Rougheye Rockfish having the distinction of the oldest ever aged *Sebastes* species at 205 years old. They both greatly overlap in latitude and depth (shallower than 100 m to at least 439 m), and are generally considered slope rockfish, with an ontogenetic shift from shallower to deeper, and adults commonly found at 360 m (around 200 fathoms). Rougheye seems to be proportionally more abundant when survey samples are genetically identified, and Blackspotted Rockfish tend to be found, on average, deeper than Rougheye Rockfish (S. L. Hawkins et al. 2005; Orr and Hawkins 2008).

Rougheye/Blackspotted Rockfishes are often associated with structure, such as hard, rocky bottoms and steep habitats. They are rarely found on the deep flats. They can be found alone or in aggregations (Love, Yoklavich, and Thorsteinson 2002), with aggregations often differentiated by age. Younger fish may school and are often found in shallower waters on the shelf, junveiles and subadults can be found together, and larger fish may form larger aggregations in the Pacific Northwest during the autumn and winter. These two species may also hybridize on occasion (Love 2011). These species are closely related to Shortraker Rockfish (*S. borealis*) and are sometimes difficult to distinguish from Shortraker Rockfish without looking at the gill rakers. One major distinguishing feature of Rougheye Rockfish are the 2–10 spines along the lower rim of their eyes, hence the common name "rougheye".

Like all *Sebastes* species, Rougheye and Blackspotted Rockfishes give birth to live young. Larvae released has been documented between February and June and extrusion lengths are between 4.5-5.3 mm (Love, Yoklavich, and Thorsteinson 2002). There are no studies on the fecundity of rougheye rockfish on the west coast of the U.S.

A wide range of prey items make up the diet of rougheye rockfish. Crangid and pandalid shrimps make up the majority of their diets, and larger individuals, greater than 30 cm, feeding upon other fishes (Love 2011). They are also known to feed upon gammarid amphipods; mysids, crabs, polychaetes, and octopuses (Love, Yoklavich, and Thorsteinson 2002; Love 2011).

1.3 Ecosystem considerations

1.4 Historical and Current Fishery Information

Rougheye/Blackspotted Rockfishes are not often targeted by a specific fishery, but are desirable and marketable, thus are typically retained when captured. They are often captured in bottom trawl, mid-water trawl, and longline fisheries. Small numbers have been observed in pot, shrimp, and recreational fisheries.

After many attempts to start trawl fisheries off the west coast of the United States in the late 1800's, the availability of the otter trawl and the diesel engine in the mid-1920's helped the trawl fisheries expand (Douglas and Division 1998). The trawl fisheries really became established during World War II when demand increased for shark livers and bottomfish. A mink food fishery also developed during World War II (Jones and Harry 1961), and post-war catches for rockfishes, including Rougheye/Blackspotted Rockfishes, increased (Niska 1976). Foreign fleets began fishing for rockfish in the mid 1960's until the EEZ was implemented in 1977 (J. B. Rogers 2003). Since 1977, landings of rockfish were high until management restrictions were implemented in 2000. Longline catches of rougheye rockfish are present from the turn of the century and continue in recent years, targeting sablefish and halibut. The catches by state for the trawl and hook & line fleets as well as for the Pacific whiting at-sea fleet are shown in ******.

A long-term directed fishery has not occurred for rougheye rockfish and historical discarding practices are not well known. Rougheye rockfish inhabit deeper water as adults, which were fished less often historically. More detailed information of the fisheries by state is given in Section ******* where the reconstructed landings are discussed.

1.5 Management History and Performance

Rougheye/Blackspotted Rockfishes has been a small component of groundfish fisheries and catches of Rougheye/Blackspotted Rockfishes have been governed by restrictions on assemblages of species, of which these species are a member. However, the distribution of fishing effort in areas where Rougheye/Blackspotted Rockfishes might be encountered has also been affected by catch restrictions on co-occurring, rebuilding species, as well as associated area closures instituted to promote rebuilding. The first imposed landings limits on a coastwide Sebastes complex (Rougheye/Blackspotted Rockfishes being one of the 50 rockfishes in the complex) were instituted in 1983. Ongoing concern that shelf and slope rockfishes may be undergoing overfishing led the attempt by J. S. Rogers et al. (1996) to describe the status of most rockfishes contained in the Sebastes complex. Rougheye/Blackspotted Rockfishes information content was low, and using the Triennial survey to calculate an average biomass and assuming that fishing mortality equals natural mortality provided estimates of exploitation rates that indicated the stock was undergoing very high exploitation rates in both management areas. The dividing line between the northern and southern management areas was shifted to 40º 10’ N latitude in 1999 and the Sebastes complex was subsequently divided into nearshore, shelf, and slope complexes in 2000. Rougheye/Blackspotted Rockfishes has been managed under trip limits for the minor slope rockfish complex in both north and south management areas since this time.

Table (**management-summary?**) summarizes major management changes since 2000. Some important changes include the implementation of Rockfish Conservation Areas (RCA’s) in 2002, the beginning of trawl rationalization in 2011, and the lifting of the RCAs beginning in 2020 with the removal of the trawl RCA in Oregon and California and loosening restrictions in the non-trawl RCAs in 2023 and 2024.

Though managed as part of a complex, OFL contributions for Rougheye/Blackspotted Rockfishes were calculated using DB-SRA in 2010 for the 2011-2012 management cycle. This lead to the observation that recent catches had frequently exceeded the OFL contribution estimated using data-poor, catch-only methods provided a strong indication that a more thorough evaluation of Rougheye/Blackspotted Rockfishes stock status and sustainable harvest levels be undertaken, using all available data. A full assessment of Rougheye/Blackspotted Rockfishes was undertaken in 2013 and indicated the stock complex was above management target levels (Hicks, Wetzel, and Harms (2013)). Recent management performance for Rougheye/Blackspotted Rockfishes as a part of the nothern minor slope rockfish complex is provided in Table (**managment-performance?**) (ALI IS STILL CREATING THIS TABLE - WILL ADD TEXT FOR IT LATER).

1.6 Fisheries off Canada and Alaska

Rougheye Rockfish are distributed throughout Canada and Alaska and are commonly caught in trawl and hook & line fisheries. Alaska conducts assessments biennially for the Rougheye/Blackspotted complex, and two have been recently done: one for the Bering Sea and Aluetian Islands (Spencer, Ianelli, and Laman 2003) and the other for the Gulf of Alaska (Sullivan et al. 2023). Canada completed an assessment in 2020 (Starr and Haigh 2020). The fisheries and assessments for each country are described below.

Rougheye rockfish have been managed as a bycatch only species in Alaska since 1991 with catches ranging between 130 and 2,418 mt and peaking in the late 1980s and early 1990s (Sullivan et al. 2023). Generally, about 55-75% of the catch are trawl-caught and 30-45% from hook-and-line (mainly, longline) fisheries. Since 2017 the move to pot gear in the sablefish fishery has decreased the longline catches. Discards since 2013 have ranged from 11.6% (in 2023) and 45% (in 2018). The Rougheye/Blackspotted complex catch levels generally are between 20% and 60% of the Total Allowable Catch since the 2005 when the complex began to be managed separately. The most recent age-structured integrated stock assessments of this complex in the Bering Sea and Aluetian Islands (Spencer, Ianelli, and Laman 2003) and for the Gulf of Alaska (Sullivan et al. 2023) do not indicate either overfishing or the stocks being overfished.

Canada identified two species of rougheye rockfish (Type I and Type II) in 2007 and designated both species of special concern, which means that they may become threatened or endangered because of a combination of biological characteristics and identified threats (Report 2007). This designation was given because biomass estimates are uncertain and no strong trends are observed, there is evidence of truncation of the age distribution and overall mortality has doubled, it is a long-lived, low-fecundity Sebastes species, which is susceptible to population collapse and slow recovery, and because the difficulty in separating the two species may result in potential impacts on one of the species going unnoticed. Subsequently, the species were identified as rougheye rockfish and blackspotted rockfish and a management plan was created in 2012 with a goal of sustaining the populations of rougheye and blackspotted rockfishes (Canada 2012). Five high priority and seven low priority actions have been identified to address the threats to the populations and support the management goal.

The first Canadian stock assessment for these species, using a integrated catch-at-age model, was conducted in 2022 to estimated stock status of two Rougheye/Blackspotted (REBS) rockfishes management units (REBS north and REBS south) a the beginning of 2021. The REBS north stock was in the healthy zone in the reference model. The REBS south stock was likely in the healthy zone, but with an elevated possibility of being in the cautious zone.

2 Data

Data from a wide range of programs were available for possible inclusion in the current assessment model. Descriptions of each data source included in the model (Figure 4) and sources that were explored but not included in the base model are provided below. Data that were excluded from the base model were excluded only after being explicitly explored during the development of this stock assessment and found to be inappropriate for use or had not changed since their past exploration for previous Rougheye/Blackspotted stock assessments when they were not used.

2.1 Fishery-dependent data

Fishery depended data for Rougheye/Blackspotted complex in this assessment are divided among six fleets, which include: * Fleet 1: Commercial bottom trawl fishery * Fleet 2: Commercial non-trawl gear (mainly the long-line fishery) fishery * Fleet 3: Dead discard bottom trawl fleet * Fleet 4: Dead discard non-trawl fleet * Fleet 5: Contemporary mid-water fishery * Fleet 6: Bycatch within the at-sea hake fishery

There are no recreational landings of this complex on the West coast.

2.1.1 Landings

2.1.1.1 Recent landings

Recent commercial landings of rougheye rockfish (2000-2024 for Washington, 1987–2022 for Oregon and 1981–2022 for California,) were obtained from PacFIN, a regional fisheries database that manages fishery-dependent information in cooperation with West Coast state agencies and National Marine Fisheries Service (NMFS). Catch data were extracted from PacFIN on April 21, 2015, by state and then combined into the fishing fleets used in the assessment. Time series of recent landings by fleet and state are reported in Table X and shown in Figures X to X.

2.1.1.2 Historical Landings

Historical landings of Rougheye/Blackspotted rockfish were reconstructed by state, by year.

The Washington historical landings (1889–2000) were provided by Washington Department of Fish and Wildlife (WDFW), who recently conducted historical catch reconstruction for rockfish special including rougheye rockfish (pers. comm. T. Tsou, WDFW). The three main sources used in this reconstruction (SpeciesSumOutput2_2017.csv- ADD TABLE) are from the US Fish Commission Report (UFSC), Washington Bound Volumes, and Washington Statistical Bulletin. The historical species composition is based on the various historical reports and interviews of old-time fishermen and dockside samplers. The 1981 to 2000 landings are different from PacFIN records due to a revised approach for apportioning out more unidentified rockfish ("URCK") in fish tickets to the species level. This revised approach relaxed the borrowing rules for missing data currently used in the WDFW species allocation algorithm (Tsou at al., 2015 - CAN'T FIND IN BIB). New Washington historical landings represent improvement to the assessment.

The Oregon historical landings (1896–1986) were obtained from Oregon historical catch reconstruction, conducted by Oregon Department of Fish and Wildlife in collaboration with NWFSC (Karnowski, Gertseva, and Stephens (2014)). The Oregon PacFIN landings for the period between 1987 and 1999 were supplemented with the additional estimates of Rougheye/Blackspotted rockfish landings reported within unspecified rockfish market categories, provided by the ODFW (i.e., URCK and POP1; (**ODFW_URCK_POP_-recon?**)).

The California historical landings were informed by several sources. Landings from the most recent "historical" period (between 1969 and 1980) were available from the CalCOM database for the California Cooperative Survey (CalCOM) database. Earlier landing records (between 1931 and 1968) were reconstructed by the Southwest Fisheries Science Center (Ralston et al. (2010)).

Comparison of Rougheye/Blackspotted rockfish historical landings by state and fleet between this and 2013 assessment is provided in Figure 5.

The largest differences in this assessment from 2013 model are in Washington landings (Figure 8), with newly estimated landings being generally lower than those used in previous assessment. The new WDFW catch reconstruction completed by WDFW is considered an improvement.

Historical California and Oregon landings did not change substantially (Figure 6 and Figure 7), with the exception of the magnitude of hte catch in a few years. Discrepancies in California and Oregon non-trawl landings between the 2013 and 2025 assessments are caused by the fact that non-trawl fleet in 2013 assessment was limited to only fixed gear, when in 2025 assessment non-trawl includes all non-trawl gear groups. Slight discrepancies in Oregon trawl landings between 1987 and 1999, are from adding previously non-reported landings of Rougheye/Blackspotted in the unspecified rockfish market categories (see details above).

Comparing the update historical data with that used in the 2013 stock assessment shows only minor differences (Figure 9; Figure 10).

2.1.1.3 Recent Landings

ADD FLEET STRUCTURE

Recent commercial landings of rougheye rockfish (2001-2024 for Washington, 1987–2024 for Oregon and 1981–2024 for California,) were obtained from PacFIN, a regional fisheries database that manages fishery-dependent information in cooperation with West Coast state agencies and National Marine Fisheries Service (NMFS). Catch data were extracted from PacFIN on April 21, 2025, by state and then combined into the fishing fleets used in the assessment. Time series of recent landings by fleet and state are reported in Table X and shown in Figures X to X. (ADD THESE TABLE/FIGURES)

2.1.1.4 At-Sea Hake Landings

NOTE - Ali added heading but I'm guessing Vlada should write?

2.1.2 Discards

2.1.2.1 Trawl

NOTE - Ali removed the fleet subheadings under this but add back if needed!

2.1.3 Biological data

2.1.3.1 Length and Age Sample Sizes

2.1.3.1.1 Multinomial Sample Sizes

Initial input values for the multinomial samples sizes determine the relative weights applied in fitting the annual composition data within the set of observations for each fishing fleet in the model. The initial input values in this assessment were based on the following equation developed by I. Stewart and S. Miller (NWFSC), and presented at the 2006 Stock Assessment Data and Modeling workshop. The input sample sizes for all commercial data were calculated based on a combination of trips and fish sampled:

$$\text{Input effN} = N_{\text{trips}} + 0.138 * N_{\text{fish}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is} < 44$$

$$\text{Input effN} = 7.06 * N_{\text{trips}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is} \geq 44$$

2.2 Fishery-independent data

2.2.1 Abundance indices

Given Rougheye/Blackspotted are associated with deep, structured habitats, it can be difficult to survey them with trawl gear. Four general fishery-independent bottom trawl surveys were used in the 2013 assessment, and are again included in this assessment:

- Triennial (every three years) survey (1980-2004)
- Alaska Fishery Science Center Slope survey (1997-2001)

- Northwest Fisheries Science Center Slope Center (1999-2001)
- West Coast Groundfish Bottom Trawl Survey (WCGBTS; 2003-2024)

Only the WCGBTS has new data for this assessment, but new methods (spatial and spatiotemporal GLMMs with TMB or sdmTMB) to develop an index of abundance were applied to all surveys to update all indices. Two distributions (gamma and lognormal) were considered, as was the case in 2013 model when a non-spatial generalized linear mixed model was used to develop indices of abundance.

Comparing the standardized versions (i.e., Z-scores, which puts all the indices on the same scale for better comparison of trends) of the indices shows very similar trends among each model output, suggesting little difference in choice of model type. The variance in the indices is generally high (0.3-0.5), suggesting the information content in these indices is low. This is not a surprise given the challenge of sampling these species with trawl gear. Overall, catches densities are highest in northern Oregon and Washington.

2.2.1.1 NWFSC West Coast Groundfish Bottom Trawl Survey

The data were truncated to depths less than 875 m prior to modelling given that there were zero positive encounters in depths deeper than 875 m. The prediction grid was also truncated to only include available survey locations in depths between 55-875 m to limit extrapolating beyond the data and edge effects.

The response variable in the model was catch (mt) with an offset of area (km2) to account for differences in effort. Fixed effects were estimated for each year. The following additional covariate was included: pass.

Spatial variation, but not spatiotemporal variation, was included in the encounter probability and the positive catch rate model. Spatial variation was approximated using 200 knots, where more knots led to non-estimable standard errors.

2.2.1.2 NWFSC Slope Survey

2.2.1.3 AFSC Slope Survey

2.2.1.4 AFSC/NWFSC West Coast Triennial Shelf Survey

The triennial survey was first conducted by the AFSC in 1977 and spanned the timeframe from 1977– 2004. The survey's design and sampling methods are most recently described in **Weinberg et al. (2002)**. Its basic design was a series of equally-spaced transects from which searches for tows in a specific depth range were initiated **(Figure X)**. The survey design has changed slightly over the period of time **(Table X, Figure X)**. In general, all of the surveys were conducted in the mid-summer through early fall: the 1977 survey was conducted from early July through late September; the surveys from

1980 through 1989 ran from mid-July to late September; the 1992 survey spanned from mid-July through early October; the 1995 survey was conducted from early June to late August; the 1998 survey ran from early June through early August; and the 2001 and 2004 surveys were conducted in May-July **(Figure X)**.

Haul depths ranged from 91–457 m during the 1977 survey with no hauls shallower than 91 m. The surveys in 1980, 1983, and 1986 covered the West Coast south to 36.8°N latitude and a depth range of 55–366 meters. The surveys in 1989 and 1992 covered the same depth range but extended the southern range to 34.5°N (near Point Conception). From 1995 through 2004, the surveys covered the depth range 55–500 meters and surveyed south to 34.5°N. In the final year of the triennial series (2004), the NWFSC's Fishery Resource and Monitoring division (FRAM) conducted the survey and followed very similar protocols as the AFSC.

2.2.2 Biological data

2.2.2.1 NWFSC West Coast Groundfish Bottom Trawl Survey

2.2.2.2 NWFSC Slope Survey

2.2.2.3 AFSC Slope Survey

2.2.2.4 AFSC/NWFSC West Coast Triennial Shelf Survey

2.3 Biological Parameters

The major biological inputs to the models are natural mortality, age and growth parameters, weight-length, maturity and stock-recruitment parameters. The following sections outline the treatment of each section. One change from the previous assessment is moving to a two sex from the one-sex specification from 2013. The 2013 stock assessment one-sex specification was based on the observation that the biology of females and males was very similar, thus justifying the simplifying assumption of one sex. The following sections below demonstrates that females and males do generally have similar growth, though there are differences, but may have different natural mortality values. The current assessment will use a two sex configuration that allows for flexibility to set female and male parameters either equal (i.e., functionally equivalent to a one sex model) and or sex-specific. Figure 11 and Figure 12 show that using a two sex configuration with the same life history parameters for females and males is equivalent to the one sex model. Note that the one sex model sums up both female and male biomass, thus why it is twice the size as the two sex female-only spawning output (Figure 12).

2.3.1 Natural Mortality

Natural mortality is a highly influential parameter in age-structured stock assessments. It defines the rate of natural death by age, and thus establishes a stable age-structure and expectation of longevity, and interacts with growth and reproduction to determine stock productivity. It is a very difficult parameter to directly measure, thus empirical relationships based on life history parameters are often used to indirectly determine its value or build prior distributions in belief of what it is in the event we do attempt to estimate it in the model (Jason M. Cope and Hamel (2022); Hamel and Cope (2022); Maunder et al. (2023)). If length and age data are available, it may be possible to estimate it in the model.

An estimate of maximum age tends to be the most reliable life history parameter related to natural mortality to inform its estimation. Jason M. Cope and Hamel (2022) (The Natural Mortality Tool) provide the most up-to-date examination of the relationship between maximum age and natural mortality

$$M = \frac{5.4}{A_{\text{max}}}$$

where M is natural mortality and A_{max} is the assumed maximum age. The prior is defined as a lognormal distribution with mean $ln(5.4/A_{\text{max}})$ and standard error = 0.31. This is the equation typically used to estimate a natural mortality point estimate, but is underpinned by the choice of the value of A_{max}. This equation assumes that the proportion of the stable population at this maximum age is 0.4517%. If we take humans as an example, the longest lived human is 122 years. This is not the maximum age, but the oldest ever recorded age. The maximum age that corresponds to 0.4517% of the population is around 100 years. For Rougheye/Blackspotted, the oldest ever aged individual is 205 years with unknown ageing error. We did not consider this as a realistic maximum age.

The 2013 U.S. west coast stock assessment used a prior built around a mean of 0.034 (corresponding to a maximum age of 163), but estimated natural mortality at 0.042 (maximum age between 128-129 years; Figure M). The 2023 Gulf of Alaska assessment built a prior conditional on a estimate of natural mortality from their 5 oldest aged individuals that ranged from 126-135 years. This resulted in a mean value of 0.042, similar to the 2013 U.S. west coast stock assessment. The 2023 Bering Sea/Aleutian Islands assessment used M = 0.05 (assumed longevity of 108), and the recent Canadian assessments considered a range of M values from 0.03 to 0.055 (assumed maximum ages of 180 to 98 years; Figure 13).

We attempt to estimate natural mortality, as was done in the 2013 U.S. West coast assessment. Examining the available age data, the oldest 10 individuals range from 139 to 165 and were all males. For females, the 10 oldest individuals range from 130 to 121 years. If those oldest ages were used in the Hamel and Cope (2022) longevity estimator, these ages would correspond to a range of natural mortality values of 0.033 to

0.039 for males, which include the mean of the prior used in the 2013 assessment. For females, it corresponds to natural mortality values of 0.039 to 0.045. All these assume that the sampled population has enough of an age structure still available for sampling, as opposed to having some level of age truncation from the theoretical unfished stable age distribution.

Related to this issue of possible age truncation, applying a catch curve analysis (taking the log of the abundance of numbers of samples in available age classes) on the aggregated ages across all age sources by sex, the total mortality (Natural + Fishing mortality= Total mortality) is 0.046 for females and 0.035 for males, which may indicate the natural mortality could be lower than that used in the 2013 assessment, but within the range of values considered in other areas (Figure 14). This also indicates the possibility of estimating sex-specific natural mortality, as natural mortality may differ by sex. The two sex model allows for this type of model specification exploration. Further exploration was done my truncating the upper ages considered, with the assumption that the older ages may also not be sampled fully (i.e., dome-shaped selectivity). We considered both 100 (Figure 15) and 80 (Figure 16) as upper age cut-offs. The less older individuals included, the higher the estimate of total mortality, and this a higher natural mortality. But we can see a general overestimate of how many older individuals are expected using these higher Z values, thus dome-shapeness does not see to explain the sampling of these older individuals.

One challenge to estimating natural mortality within the model is the interaction of estimating dome-shaped selectivity with estimating natural mortality. If all fleets assume some level of dome-shaped selectivity, it is difficult to determine if the unseen larger, older individuals are due to natural death or fishing mortality. Typically, at least one major fleet needs to achieve full selectivity for the larger, older individuals. The 2013 assessment suggested some dome-shaped selectivity in the two major fleets, thus any natural mortality estimates are evaluated depending on the forms of fleet selectivity.

2.3.2 Age and Growth Relationship

Age and length data are used to estimate important growth parameters. Figure 17 has the currently available age and length data. Female and male sample sizes are very similar. Estimated growth curves are also presented in Figure 17 and the parameters are provided in Table AL_1. The West Coast Groundfish Bottom Trawl Survey clearly and importantly samples the smallest, youngest individuals compared to the other two data sources. This allows for a better estimate of the age at size 0 (t_0) and growth coefficient (k). The female asymptotic size (L_∞) is estimated notably higher from the PacFIN data, though male estimates of Linf are similar across the data sets. The overall externally derived estimates of female and male Rougheye/Blackspotted Rockfishes are

$$\text{Females } L_\infty = 58.81 \text{ cm}; k = 0.08; t_0 = \text{-1.19}$$

$$\text{Males } L_\infty = 57.13 \text{ cm}; k = 0.09; t_0 = \text{-1.26}$$

The coefficient of variation (CV) of length by age and sex are shown in Figure 18. This is a measure of the variation in length for a given age class. Sample sizes are highest from the youngest ages up to around 70 (females) to 80 (males) years. The smoothed line shows the average response, and indicates similar CVs values for females and males, with the highest at the youngest ages, but generally 0.1. The amount and range of age samples, along with repeated length samples within an age class, allows growth parameters (L_∞, k, t_0, and CVs at age) to be estimated in the model. Ages are conditioned on lengths in the model in order to estimate growth within the model. We also explore sensitivity in growth values by pre-specifying growth to different values.

We note that the growth values being estimated in our data are notably different than those used in Alaska. For instance, the growth parameters for the BSAI stock is L_∞ = 51.43, k = 0.06 and t_0 = -3.30 and L_∞ = 54.2 cm, k = 0.07, t_0= -1.5 for the GOA population (both sexes combined). These growth parameters shows a larger size and faster growth of the West Coast stock complex versus those in Alaska, though the West Coast stock complex is more similar to the GOA complex.

2.3.3 Ageing Bias and Precision

Counting ages from ageing structures in long-lived, temperate fishes is challenging. Ages derived from these structures can be hard to reproduce within and between readers (i.e., imprecision), and may not contain the true age (i.e., bias). Stock assessment outputs can be affected by bias and imprecision in ageing, thus it is important to quantify and integrate this source of variability when fitting age data in assessments. In Stock Synthesis 3, this is done by including ageing error matrices that include the mean age (row 1) and standard deviation in age (row 2). Ageing bias is implemented when the inputted mean age deviates from the expected middle age for any given age bin (e.g., 1.75 inputted versus 1.5 being the true age for the age 1 bin); ageing imprecision is given as the standard deviation for each age bin.

There are eight primary readers that provided the available ages, two of which often split the ageing duties. Table X shows which reader assignments are given to each year of ages. Reader 7 is the mix of two readers that shared reading duties within years.

Estimation of ageing error matrices used the approach of -Punt et al. (2008) in two different forms: one developed in AD Model Builder (nwfscAgeingError (J. T. Thorson, Stewart, and Punt 2012)) and one adapted to Template Model Builder framework (TMB). The ageing error matrix offers a way to calculate both bias and imprecision in age reads. Reader 1 is always considered unbiased, but may be imprecise. Bias relative to the primary reader is given for the second reader. There were three age readers that were assumed to be unbiased. In those cases, 12 model configurations based on different assumptions of imprecision (constant CV, curvilinear standard deviation, or curvilinear CV, along with an option to either share or independently estimate imprecision between readers) were considered. For the other four age readers that could be biased and/or imprecise, thirty-six total model configurations were explored that included the above imprecision models as well as an exploration of the functional form of bias (e.g., no bias, constant coefficient of variation, or non-linear bias) in the second reader.

Model selection criteria included AIC corrected for small sample size (AICc), which converges to AIC when sample sizes are large, and Bayesian Information Criterion (BIC). Both ADMB and TMB were run using an (ageing error shiny app). Model selection was then compared between ADMB and TMB, which did not always agree, so model selection criteria was added across the two modeling approaches to get an overall model selection criteria. Ageing error matrices were also inspected for behavior in the best supported models to make sure outrageously large precision or bias was not chosen (effectively rendering the ages worthless, which is not an assumption of the quality of the ages). Figure 19 and Figure 20 show the bias and imprecision assumptions applied for each ageing error (AE) matrix.

2.3.4 Length-Weight Relationship

Female and male length-weight relationships were determined using data from the PacFIN database, West Coast Groundfish Bottom Trawl Survey, and ASHOP samples. Samples size by sex were: female (N=13839), males (13625), and unknown sex (53). Each of the data sources estimated very similar length-weight relationships (Figure 21).

The resultant sex-specific length-weight relationships are given in Figure 22, with the following individual values:

- Females: W = 0.000008L^3.15
- Males: W = 0.000012L^3.07

These values are very similar to the previous assessment that used a combine sex value of a=0.0000096 and b=3.12000 (Figure 22).

2.3.5 Maturity

An updated maturity analysis for the Rougheye/Blackspotted rockfish complex with additional samples to estimate the length at which 50% of females in the population are mature (L50) is completed. Biological maturity identifies females that are physiologically capable of spawning. Functional maturity identifies females that are physiologically capable of spawning and will likely spawn in a given year. The most recent L50 estimate (not yet updated) of biological maturity is 43.84 cm and the most recent L50 estimate (not yet updated) of functional maturity is 48.44 cm.

2.3.6 Fecundity

The 2013 U.S. west coast stock assessment assumed that fecundity was proportional to weight. Dick et al. (2017) provided a study on rockfishes showing that rockfishes routinely have a non-proportional relationship of fecundity to weight, with larger individuals producing more eggs than expected only by weight. Neither Rougheye or Blackspotted rockfishes have a species- of subfamily-specific estimate for this relationship, so this stock assessment uses the unobserved Genus Sebastes values of a = 6.538e-06 and b = 4.043 using the F=aL^b relationship.

2.3.7 Stock-Recruitment Function and Compensation

The Beverton-Holt stock recruit relationship is assumed, as it was in the 2013 assessment, to describe the relationship between spawning biomass and recruitment. The steepness parameter may be considered for estimation, but it is notoriously difficult to estimate in assessment models. The 2013 stock assessment used the previous rockfish steepness mean value of 0.77, but this has subsequently been updated to 0.72, to a value that represents a stock with somewhat lower recruitment compensation. Natural variation in recruitment (i.e., not deterministically taken from the stock-recruit curve) is apparent in the length and age data (as notable length or age classes growing/ageing over time), so deviations in recruitment are estimated.

2.3.8 Sex Ratio

No information on the sex ratio at birth was available so it was assumed to be 50:50.

2.4 Environmental and ecosystem data

This stock assessment does not explicitly incorporate trophic interactions, habitat factors or environmental factors into the assessment model. More predation, diet and habitat work, and mechanistic linkages to environmental conditions would be needed to incorporate these elements into the stock assessment and should remain a priority. McClure et al. (2023) report the climate vulnerability for several west coast groundfishes, including Rougheye/Blackspotted Rockfishes. Rougheye/Blackspotted Rockfishes demonstrated both high biological sensitivity and high climate exposure risk, to give it an overall high vulnerability score to climate change. This result should also be considered with the fact that, like many rockfishes, periods of low productivity is not unusual to Rougheye/Blackspotted Rockfishes and their extended longevity (though admittedly this seems shorter than previously believed and should be reconsidered) has historically allowed them to wait for advantageous productivity periods. Stressors such as habitat degradation and climate change could bring significant challenges to population sustainability. Regardless, no environmental or ecosystem data are directly incorporated into the stock assessment model.

2.5 Assessment

2.5.1 History of Modeling Approaches

A previous Category 3 stock assessment was conducted for the U.S. Pacific Coast stock of Rougheye Rockfish (not including Blackspotted) in 2010 by Dick and MacCall (2010) using depletion-based stock reduction analysis (DB-SRA). That model estimated the population had greater than a 50% probability of exceeding the estimated proxy overfishing level in 2010 if the harvest remained at the observed levels. DB-SRA estimated a proxy OFL for rougheye rockfish of 78.7 mt with a 95% confidence interval between 4.7-587 metric tons.

A 2013 benchmark stock assessment (Hicks, Wetzel, and Harms 2013) updated the modeling framework to the integrated statistical catch-at-age model Stock Synthesis 3, which is different from the delay-difference model with an assumed stock status prior in 2010 used in the DB-SRA analysis. The 2013 assessment used a substantially updated catch history, indices of abundance, and biological compositions (lengths and ages). The natural mortality value was also updated to be higher than that used in the DB-SRA model. The stock assessment was accepted for management as a Category 2 stock assessment.

2.5.2 Most Recent STAR Panel Recommendations

There were several recommendations from the 2013 STAR panel, broken into two categories

2.5.2.1 General recommendations

1. Investigate data-weighting options. *This has been an ongoing research topic in stock assessments since this panel, and several options are no available for consideration.*
2. A workshop for constructing abundance indices from survey GLMMs. *This is another topic that has developed greatly since this time. Our use of spatio-temporal models are described in the data section on abundance indices.*
3. Continue collection of ages. *This had been done, and this assessment benefits from several more years of age data.*
4. Exploring historical catches. *This again has been an ongoing topic and addressed for many of our groundfishes. We use the latest estimates in this assessment.*
5. SSC guidance on decision tables. *Decision table discussion evolve after every stock assessment cycle, and we are using the latest approaches to decision tables in this assessment.*
6. Investigate fishery-independent slope surveys, such as submersibles. *These surveys are not currently available for slope species.*

2.5.2.2 Stock-specific recommendations

1. Collecting additional age data. *This has been done and included in this stock assessment.*
2. Collecting genetic material to explore distinguishing Rougheye and Blackspotted Rockfishes. *This work has been done as was presented earlier in the document when discussing stock structure decisions.*
3. The cause of the re-occurring decrease in sizes around 40cm. $$$$$$$$$$$$$$$$
4. Additional maturity and fecundity studies. *While no fecundity studies are available, updated maturity is presented in the maturity section of the document.*
5. Age validation. *While no age validation study has been completed, the agers are confident what annuli represent a year's worth of growth. Multiple ages are available and ageing error is characterized in this stock assessment.*
6. Understanding stock structure. *Discussed in the stock structure section of this document.*
7. Connectivity of stocks across the species ranges. *This is also discussed in the stock structure section of the document.*

2.5.3 Response to SSC Groundfish Subcommittee Recommendations

2.6 Current Modelling Platform

Stock Synthesis version 3.30.23.1 was used as the statistical catch-at-age modelling framework. This framework allows the integration of a variety of data types and model specifications. The Stock Assessment Continuum tool (https://github.com/shcaba/SS-DL-tool) was used also used to explore model efficiency, likelihood profiling, retrospective analyses, and plotting sensitivities. The companion R package r4ss (version 1.51.0) along with R version 4.4.3 were used to investigate and plot model fits.

2.6.1 Bridging the Assessment Model from Stock Synthesis 3.24 (2013) to 3.30 (2025)

More than 10 years have passed from the last assessment and in that time, the model and the Stock Synthesis 3 (SS3) modelling framework has undergone many changes. While the specific changes in the model can be found in the model change log, here we simply update the model from the older 3.24O version to the newer 3.30.22.1 version. We want to ensure that any update to the newest SS3 model software is not a cause of any changes in model outputs when we hold all data and model specifications to be exactly the same as in 2013. We therefore transferred all the older data and model specifications to the newest version of SS3 and compared the outputs. The status (Figure 23) and scale (Figure 24) of both models are exactly the same, as are the estimates of within model uncertainty. This allows us to conclude that we can move forward using the latest version of SS3 without concern of inheriting any model difference due solely to the choice of the SS3 version.

2.7 Model Structure, Evaluation, and Specification

2.7.1 Fleet and Survey Designations

The model is structured to track several fleets and include data from several surveys. Defining fleets is largely based on differing fleet selectivity (i.e., how the fishery captures fish by length and/or age). In the stock assessment model, selectivity translates into how the removals are taken via length and/or age out of the population. Currently, the following fleet structure is being used to model commercial fishery removals as there is no record of a recreational fishery for this stock complex:

- Fleet 1: Commercial trawl fishery
- Fleet 2: Commercial fixed gear (mainly the long-line fishery) fishery
- Fleet 3: At-sea hake fishery
- Fleet 4: Contemporary mid-water fishery
- Fleet 5: Dead discard trawl
- Fleet 6: Dead discard non-trawl

In 2013 assessment, fisheries removals were split among three fleets –trawl, hook-and-line and at-sea hake fishery bycatch. For the first two fleets (trawl and hook-and-line), removals were divided between landings and discards, with selectivity and retention curves estimated within the model.

For this assessment, we plan to treat discards in trawl and non-trawl fisheries as separate fleets from landings fleets. This approach provides several advantages, including:

- With separate discard fleets, we can easily track relative amounts of landings and discards within a fishery (they are not being combined into the total catch).
- This approach provides more flexibility to explore different selectivity assumptions for both landed and discarded fish –dome-shaped vs asymptotic, mirroring one to the other, etc.
- We can easily compare how similar (or different) selection curves for retained and discarded fish (easier than in case of selectivity and retention curves estimated within a single fleet).
- The biological data for landings and discards are collected independently (port sampling vs on-board observers), using different sampling approaches. Treating landings and discards as separate fleets in the model allows us to weight these data separately as well, to balance the representation of samples.

The change in treating discards as separate fleets does not impact model results (Figure 25 and Figure 26), regardless of the selectivity form being assumed for the discard fleets. This provides evidence moving to using discard fleets will not induce *a prior* differences in the model outputs, but it will offer more modelling flexibility.

We use length-based selectivity curves for all fleets for the current stock assessment model (as was done in the 2013 assessment), as there is no reason to believe significant age-based selectivity is occurring. We will consider logistic and dome-shaped selectivity options.

As reported in the data section, the following surveys are included in the model:

- Survey 1: Triennial (every three years) survey (1980-2004)

- Survey 2: Alaska Fishery Science Center Slope survey (1997-2001)
- Survey 3: Northwest Fisheries Science Center Slope Center (1999-2001)
- Survey 4: West Coast Groundfish Bottom Trawl Survey (WCGBTS; 2003-2024)

The specifications of the assessment are listed in Table **??**.

2.8 Model Likelihood Components

There are five primary likelihood components for each assessment model:

1. Fit to survey indices of abundance.
2. Fit to length composition samples.
3. Fit to age composition samples (all fit as conditional age-at-length).
4. Penalties on recruitment deviations (specified differently for each model).
5. Prior distribution penalties

In addition, there is a catch component to the likelihood, but catches are essentially fit without error. Additionally, there is a crash penalty that is invoked if true catches would cause the stock to go extinct. The penalty would alter catches to avoid extinction, but any presence of a crash penalty is used as in indication that the model has been mispecified, so this likelihood contribution should always be 0.

2.9 Reference Model Exploration, Key Assumptions and Specification

The reference model for Rougheye/Blackspotted Rockfishes was developed to balance parsimony and realism, and the goal was to estimate a spawning output trajectory and relative stock status for the stocks of Rougheye/Blackspotted Rockfishes in state and federal waters off the U.S. west coast. The model contains many assumptions to achieve parsimony and uses different data types and sources to estimate reality. A series of investigative model runs were done to achieve the final base model. Constructing integrated models (i.e., those fitting many data types) takes considerable model exploration using different configurations of the following treatments:

- Data types
- Parameter treatments: which parameter can, cannot and do not need to be estimated
- Phasing of parameter estimation
- Data weighting
- Exploration of local minima vs global minimum (see Model Convergence and Acceptability section below)

The different biological data with and without the catch time series (and no additional data weighting) were first included to obtain an understanding of the signal of stock status coming from the data (Figure XXXXXX). The length and age only models assume a constant catch over the entire time series, while estimating the selectivity of each fleet. Under this constraint, the lengths suggest a stock a bit lower than the reference model, while the ages consider the stock is extremely depleted. Putting the two data sources together produce an intermediate stock status in the lower precautionary zone. Adding the catch time series substantially changes the stock status trajectory, with length or age only model above the reference stocks status. Combining the two came out just under the reference model. Only one model includes recruitment deviations, and demonstrates more dynamics behavior similar to that seen when biological compositions are unweighted (see Model Specification Sensitivities section).

Stock scale was comparable once removal history was included, and demonstrates a large sensitivity to the scale of the stock given the data with no additional weighting included (Figure).

Numerous exploratory models that included all data types and a variety of model specifications were subsequently explored and too numerous to fully report. In summary, the estimation of which life history parameters to estimate and fix was liberally explored.

The following is a list of things that were explored, typically in combination with one another

- Estimate or fix M
- Estimate or fix any of the three growth parameter for each sex
- Estimate or fix the stock-recruit relationship
- Estimate or assume constant recruitment. If estimating recruitment, for what years?
- Estimate or fix survey catchability for each survey
- Estimate additional survey variance for which survey
- Estimate or fix selectivity parameters
- Logistic or dome-shaped selectivity?

After much consideration, it was determined that some parameters were inestimable (M, L_{min} for both sexes), some did not move much for initial values and could be fixed (e.g., CV at length values, some selectivity parameters), and others could be estimated (e.g., L_∞, k, lnR_0). Estimation of L_min returned very high estimates of L_∞ for both sexes, thus the L_{min} value for both females and males was fixed to the external estimates. No priors were used on any of the estimated parameters except female L_∞ which used a normal prior and a standard deviation set a bit higher from the external fit to the growth curve (0.2). Length-at-maturity, fecundity-weight, and length-weight relationship, steepness (h) and recruitment variance were all fixed.

The selectivity of all fisheries were estimated as logistic even if dome-shaped selectivity was an option (and starting values begin at a strong dome-shaped position). Constant selectivity was assumed for the whole time period as there was no reason to suggest otherwise, and is consistent with the previous stock assessment treatment.

The full list of estimate and fixed parameters are found in Table }.

The biggest uncertainty was in the treatment of sex-specific M, as estimation came in very low for both sexes versus observed ages in the population and the treatment in the last assessment. This parameter affects both scale and status, and thus is a valuable parameter to consider for characterizing model specification error and defining states of nature. Both likelihood profiles and sensitivities explore the influence of this parameter on derived model outputs.

General attributes of the reference model are that indices of abundance are assumed to have lognormal measurement errors. Length compositions and conditional age at length samples are all assumed to follow a multinomial sampling distribution, where the sample size is fixed at the input sample size calculated during compositional example, and where this input sample size is subsequently reweighted to account for additional sources of overdispersion (see below). Recruitment deviations were also estimated are assumed to follow a lognormal distribution, where the standard deviation of this distribution is tuned as explained below.

Sensitivity scenarios and likelihood profiles (on lnR_0, steepness, and natural mortality) were used to explore uncertainty in the above model specifications and are reported below.

2.9.1 Data Weighting

The reference model allowed for the estimation of additional variance on all surveys. The ability to add variance to indices allows the model to balance model fit to that data while acknowledging that variances may be underestimated in the index standardization. A sensitivity was run with no extra variance estimated, as well as removal of the index data were explored.

Initial sample sizes for the length and conditional age-at-length compositions were also considered for additional data-weighting. The method of Francis (2011), specifically equation TA1.8, was used to re-weight the length and conditional age-at-length composition data against other inputs and likelihood components. The Francis method treats mean length and age as indices, with effective sample size defining the variance around the mean. If the variability around the mean does not encompass model predictions, the data should be down-weighted until predictions fit within the intervals. This method accounts for correlation in the data (i.e., the multinomial distribution), but can be sensitive to years that are outliers, as the amount of down-weighting is applied to all years within a data source, and are not year-specific. Sensitivities were performed examining different data-weighting treatments: 1) the Dirichlet-Multinomial approach (James T. Thorson et al. 2017), 2) the McAllister-Ianelli Harmonic Mean approach (McAllister and Ianelli 1997), or 3) no additional data-weighting.

2.9.2 Model Changes from the Last Assessment

Besides the additional of eight years of data and some changes in the estimation of some parameters, the biggest changes to the 2015 assessment are:

- Change in the removal history, particularly updates to historical data and new catches since 2013.
- Adding discard fleets instead of using retention curves.
- Using spatio-temporal approaches (sdmTMB) to define indices of abundance versus the former GLMM approach.
- Adding more biological compositions, mainly in years since 2013, but also some historical ages.
- Specifying a two sex instead of one sex model.

2.9.3 Reference Model Diagnostics and Results

2.9.3.1 Model Convergence and Acceptability

2.9.4 Base Model Results

2.9.4.1 Fits to the Data

2.9.4.1.1 Lengths

2.9.4.2 Conditional Age at Length and Marginal Ages

2.9.4.3 Fits to Indices of Abundance

2.9.5 Reference Model Outputs

2.9.5.1 Parameter Estimates

2.9.5.2 Population Trajectory

2.10 Characterizing uncertainty

2.10.1 Sensitivity Analyses

Sensitivity analyses were conducted to evaluate model sensitivity to alternative data treatment and model specifications.

2.10.1.1 Data treatment sensitivities

Data treatments explored were as follows:

- Treatment of abundance indiecs 1. 2015 dockside survey

  2. 2015 dockside survey, no extra variance estimated
  3. No extra variance on private boat index

  - Data weighting

  11. No data-weighting
  12. Dirichlet data-weighting
  13. McAllister-Ianelli data weighting

- Other

  14. 2015 removal history

Likelihood values and estimates of key parameters and derived quantities from each sensitivity are available in Table . Derived quantities relative to the reference model are provided in Figure . Time series of spawning output and relative spawning output are shown in Figures and .

2.10.1.2 Model Specification Sensitivities

Model specifications looked at the estimation of individual and combinations of life history parameters, the estimation of recruitment, and the treatment of fecundity and selectivity. All scenarios match the reference model specifications in all other aspects unless otherwise stated.

- Life history estimation
  - Natural mortality (M)
    1. Estimate M
    2. Lorenzen age varying M
    3. Use Oregon 2023 assessment sex-specific M values (females = 0.19; males = 0.17)
    4. Maintain sex ratio in age and length data (sex option 3) and estimate M

- Growth parameters
  6. Fix all growth parameters to external values
  7. Fix all growth parameters to external values, estimate M
  8. Estimate L_min
  9. Fix $t_0 = 0$
  10. Estimate CV_{young} and CV_{old}
- Reproductive Biology
  10. Use biological maturity ogive
  11. Use functional maturity ogive
  12. Fecundity proportional to weight
- Recruitment estimation
  13. No recruitment estimation
  14. Estimate recruitment for all years in the model

Other

Likelihood values and estimates of key parameters and derived quantities from each sensitivity are available in Table . Derived quantities relative to the reference model are provided in Figure . Time series of spawning output and relative spawning output are shown in Figures and . None of the sensitivities indicated an overfished stock.

2.10.2 Likelihood Profiles

2.10.3 Retrospective Analysis

A five-year retrospective analysis was conducted by running the model and sequentially removing one year of data up through minus 5 years. Retrospective spawning output (Figure) and relatives stock status (Figure) estimates show a generally consistent pattern in population scale and trend, within the error of the reference model. All models show the population increasing. This results in a stock status in the precautionary zone over the 5 year consideration. The Mohn's rho evaluation of the degree of retrospective pattern in given in Table and shown in Figure . The relative error in the data peels are below significant levels.

2.10.4 Unresolved Problems and Major Uncertainties

There are no major unresolved problems in the stock assessment, but there are many sources of uncertainty. Natural mortality remains a large source of uncertainty. The estimation of growth also required fixing certain parameters, leading to an underestimation of uncertainty in the model. The stock-recruit relationship is assumed to be a Beverton-Holt relationship with a fixed steepness of 0.72. Large uncertainty was shown if the nature of this relationship varies either deterministically or over time. The full time series of recruitment deviations were not informed, which creates some historical and contemporary uncertainty. Likewise, all life history values are assumed constant, so any time-varying issues that are directional could create more uncertainty.

3 Management

3.1 Reference Points

Reference points were based on the rockfish FMSY proxy ($SPR_{50\%}$), target relative biomass (40%), and estimated selectivity and catch for each fleet (Table **??**). The Rougheye/Blackspotted Rockfishes population in Washington at the start of 2023 is estimated to be just above the target biomass, and fishing intensity during 2022 is estimated to be just below the fishing intensity target (Figure **??**). The yield values are lower than the previous assessment for similar reference points due to updated life history estimates and estimates of the total scale of the population, despite the overall stock status being a bit higher. The proxy MSY values of management quantities are by definition more conservative compared to the estimated MSY and MSY relative to 40% of unfished spawning output because of the assumed steepness value. Sustainable total yield, removals, using the proxy $SPR_{50\%}$ is 471 mt. The spawning output equivalent to 40% of the unfished spawning output ($SO_{40\%}$) calculated using the SPR target ($SPR_{50\%}$) was 7,828 billions of eggs.

Recent removals since 2017 have been at or below the point estimate of potential long-term yields calculated using an $SPR_{50\%}$ reference point (Figure **??**), leading to a population that has continued to increase over recent years with the assistance of above average recruitment between 2003-2014, despite below average recruitment starting in 2015. The equilibrium estimates of yield relative to biomass based on a steepness value fixed at are provided in Figure **??**, where vertical dashed lines indicate the estimate of fraction unfished at the start of 2027 (current) and the estimated management targets calculated based on the relative target biomass (B target), the SPR target, and the maximum sustainable yield (MSY).

The 2023 spawning biomass relative to unfished equilibrium spawning biomass, based on the 2022 fishing year, is 80.5397%, above the management target of 40% of unfished spawning output. The relative biomass and the ratio of the estimated SPR to the management target ($SPR_{50\%}$) across all model years are shown in Figure **??** where warmer colors (red) represent early years and colder colors (blue) represent recent years. There have been periods where the stock status has decreased below the target and limit relative biomass, and fishing intensity has been higher than the target fishing intensity based on $SPR_{50\%}$.

3.2 Management performance

Rougheye/Blackspotted Rockfishes removals have been below the equivalent Annual Catch Limit (ACL) over the recent decade (Table **??**). The ACL declined in 2017 relative to earlier years based on the 2015 assessment of Rougheye/Blackspotted Rockfishes (J. M. Cope et al. 2016). In the last ten years, catches peaked in 2016 at 369 mt. Since then catches have declined to a recent low of 130 mt in 2020 with the catches in the final two model years remaining low with 197 mt in 2021 and 166 mt in 2022. The OFL has not been exceeded in any year over the past 10 years.

3.3 Harvest Projections and Decision Tables

The Rougheye/Blackspotted Rockfishes assessment is being considered as a category 1 assessment with a $P^* = 0.45$, $\sigma = 0.50$, and a time-varying buffer applied to set the ABC below the OFL. These multipliers are also combined with the rockfish MSY proxy of SPR_{50} and the 40-10 harvest control rule to calculate OFLs and ACLs. A twelve-year (2023-2034) projection of the reference model using these specifications along with input removals for 2023 and 2024 provided by the Groundfish Management Team (Katie Pierson, ODFW, pers. comm.) is provided in Table **??**.

Uncertainty in management quantities for the reference model was characterized by exploring various model specifications in a decision table, with the desire for states of nature to represent uncertainty in both scale and relative stock status Initial explorations considering alternative specifications of natural mortality. This was based on using the estimated M scenario as a low state of nature and applying the sex-specific M values from the 2023 Oregon model as the high state of nature. These produced wide states of nature (Figure **??** and Figure **??**). Discussion with the STAR panel led to defining two other states of nature based on the reference model uncertainty in ending spawning output. Low and high states of nature were determined by applying an initial recruitment (lnR_0) value that lead to current spawning output values equivalent to the 12.5% and 87.5% percentile values from the current spawning output distribution (Figure **??** and Figure **??**) that are not as widely spread as the initial states of nature, but are constructed from the current model specifications. The resultant decision table (Table **??**) was built around the initial lnR_0 states of nature approach. The catch rows assume P* values of 0.45 and 0.4, then a constant catch using the yield at FSPR=0.5.

3.4 Evaluation of Scientific Uncertainty

#The model-estimated uncertainty around the 2027 spawning biomass was $\sigma = 100$ and the uncertainty around the OFL was $\sigma =$ NA. This is likely underestimate of overall uncertainty because of the necessity to fix some life history parameters such as natural mortality and steepness, as well as a lack of explicit incorporation of model structural uncertainty. The alternative states of nature used to bracket uncertainty in the decision table assist with encapsulating model structure uncertainty.

3.5 Research and Data Needs

This section briefly highlights progress on research and data needs identified in the most recent (2015) Rougheye/Blackspotted Rockfishes assessment, and then provides recommendations for future research.

Research and data needs identified in the last assessment (italics) are listed here followed by a brief response for each.

3.6 Acknowledgements

3.7 References

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3.8 Tables

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if (file.exists(table_dir)) { # Load in rda files created by: # r4ss::table_exec_summary # r4ss::table_pars # r4ss::table_parcounts

all_files <- list.files(table_dir) all_rda_files <- all_files[grep(".rda", all_files)] for (a in 1:length(all_rda_files)) { load(file.path(table_dir, all_rda_files[a])) }

catches_es_table <- catches_es$tablecatches_{e}s_{c}ap < -catches_{e}s$cap rm(catches_es)

ssb_es_table <- ssb_es$tablessb_{e}s_{c}ap < -ssb_{e}s$cap rm(ssb_es)

spr_es_table <- spr_es$tablespr_{e}s_{c}ap < -spr_{e}s$cap rm(spr_es)

recr_es_table <- recr_es$tablerecr_{e}s_{c}ap < -recr_{e}s$cap rm(recr_es)

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recent_management_table <- recent_management$tablerecent_{m}anagement_{c}ap < -recent_{m}anagement$cap rm(recent_management)

projections_table <- projections$tableprojections_{c}ap < -projections$cap rm(projections)

compweight_table <- table_compweight$tablecompweight_{c}ap < -table_{c}ompweight$cap rm(table_compweight)

config_table <- table_config$tableconfig_{c}ap < -table_{c}onfig$cap rm(table_config)

parcount_table <- table_parcounts$tableparcount_{c}ap < -table_{p}arcounts$cap rm(table_parcounts)

par_table <- table_pars$tablepar_{c}ap < -table_{p}ars$cap rm(table_pars)

time_series_table <- time_series$tabletime_{s}eries_{c}ap < -time_{s}eries$cap rm(time_series)

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3.9 Figures

3.9.1 Introduction

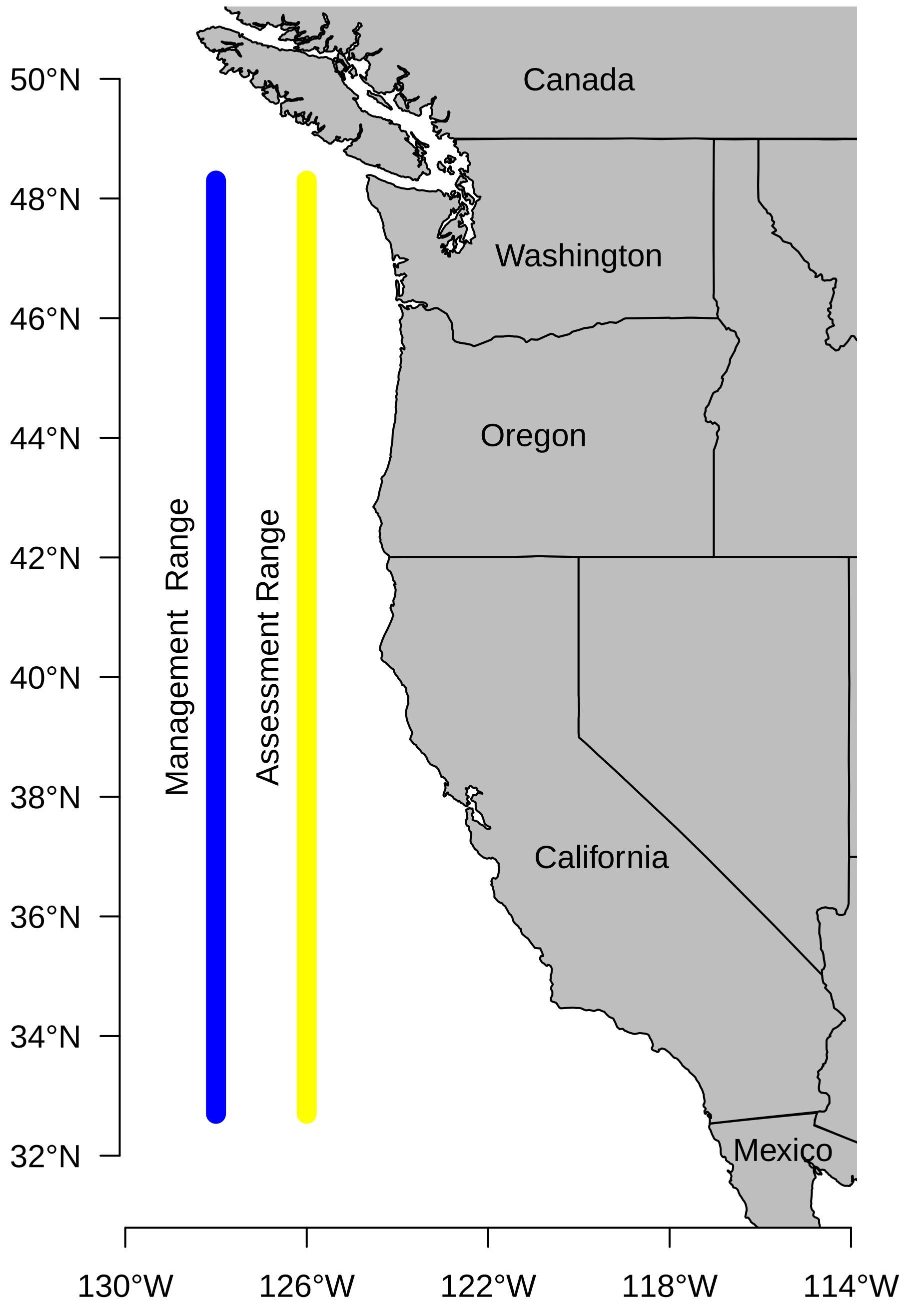

Figure 1: Map of the assessment area.

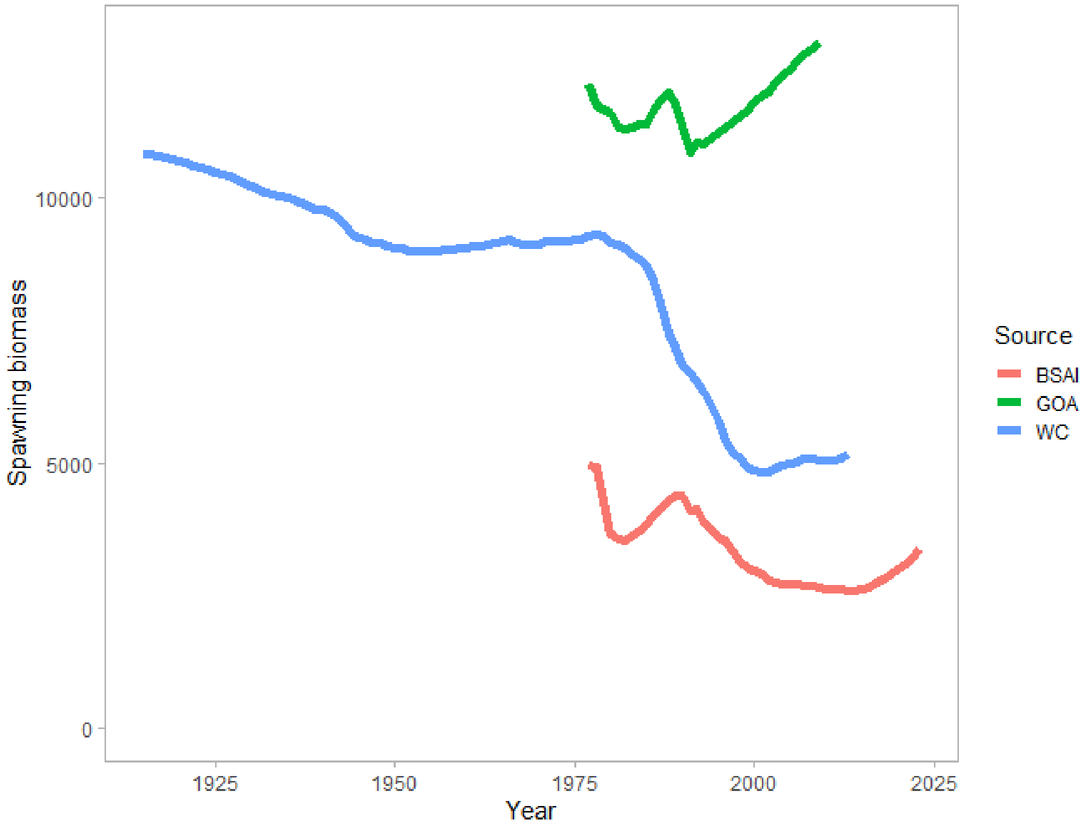

Figure 2: Estimates of spawning biomass (current spawning output/unfished spawning output) for the Rougheye/Blackspotted rockfish complex from the two most recent Alaska (Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA)) and the 2013 U.S. west coast stock assessment.

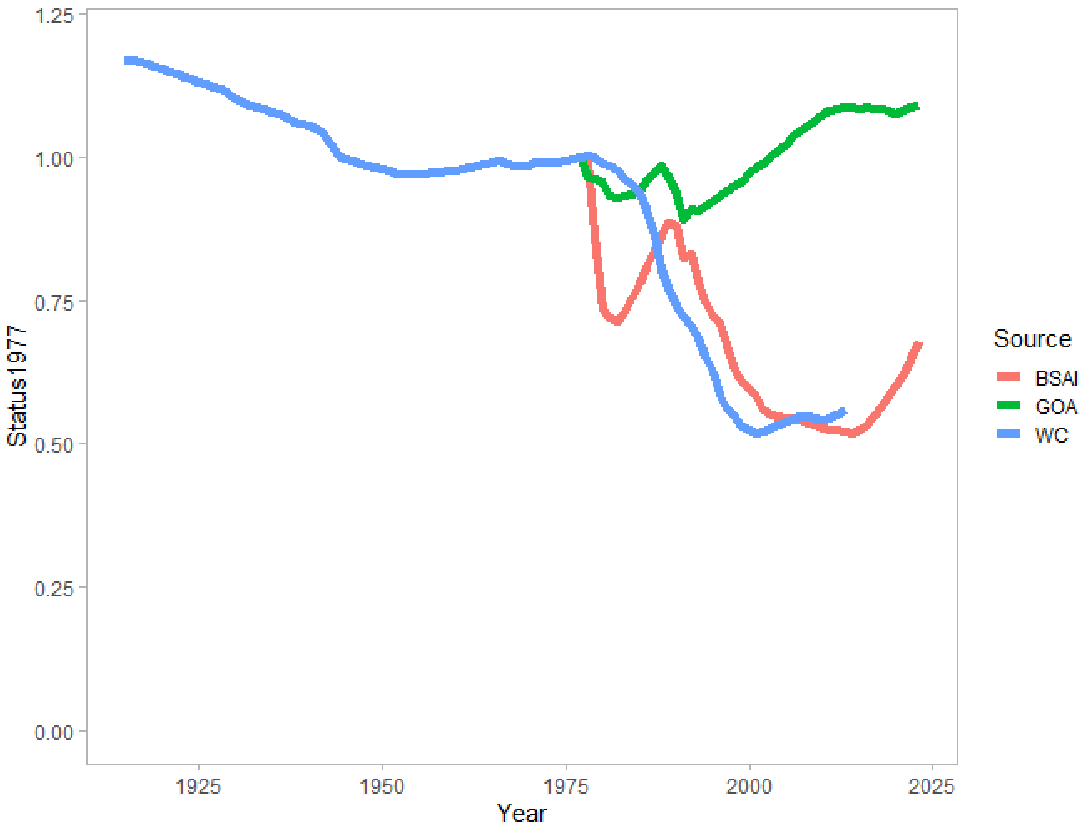

Figure 3: Estimates of relative stock size (current spawning output/unfished spawning output) relative to 1977 (the common year in all stock assessments compared) for the Rougheye/Blackspotted rockfish complex from the two most recent Alaska (Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA)) and the 2013 U.S. west coast stock assessment.

3.9.2 Data

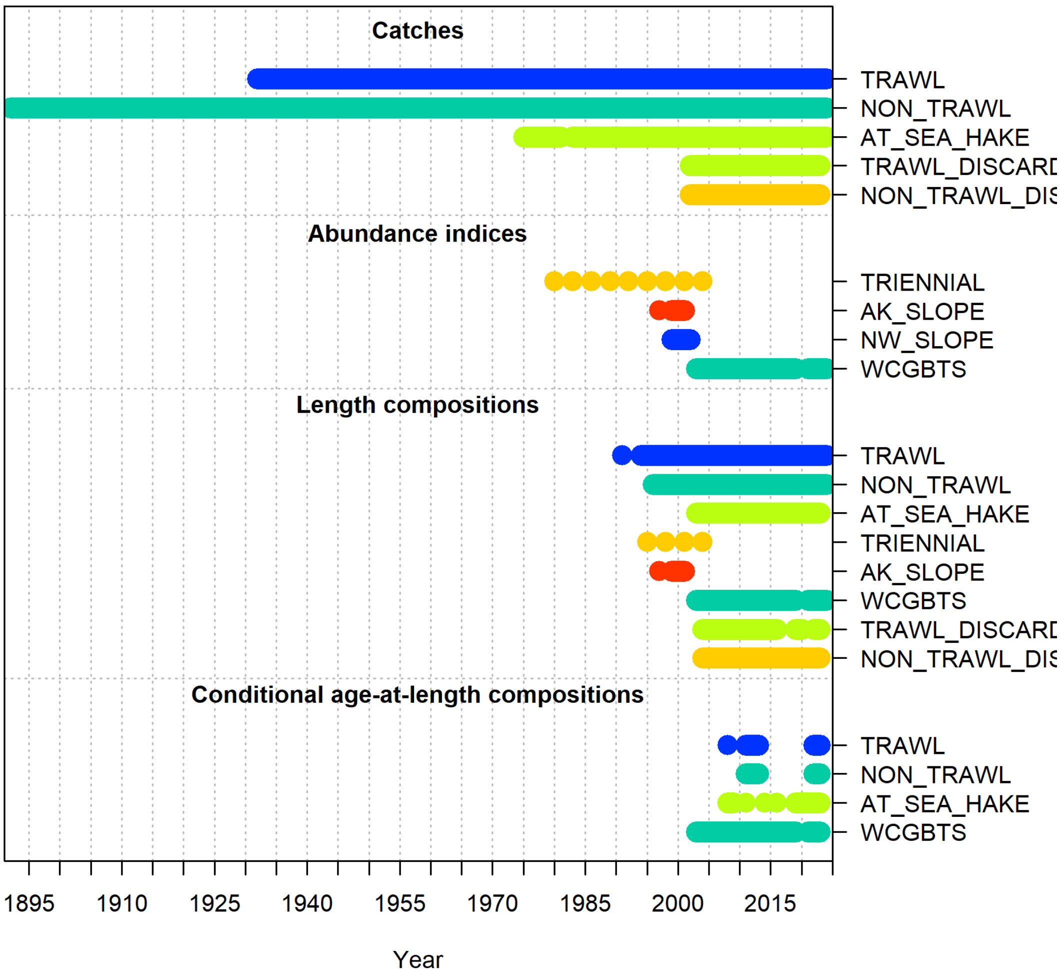

Figure 4: Data used in the base model.

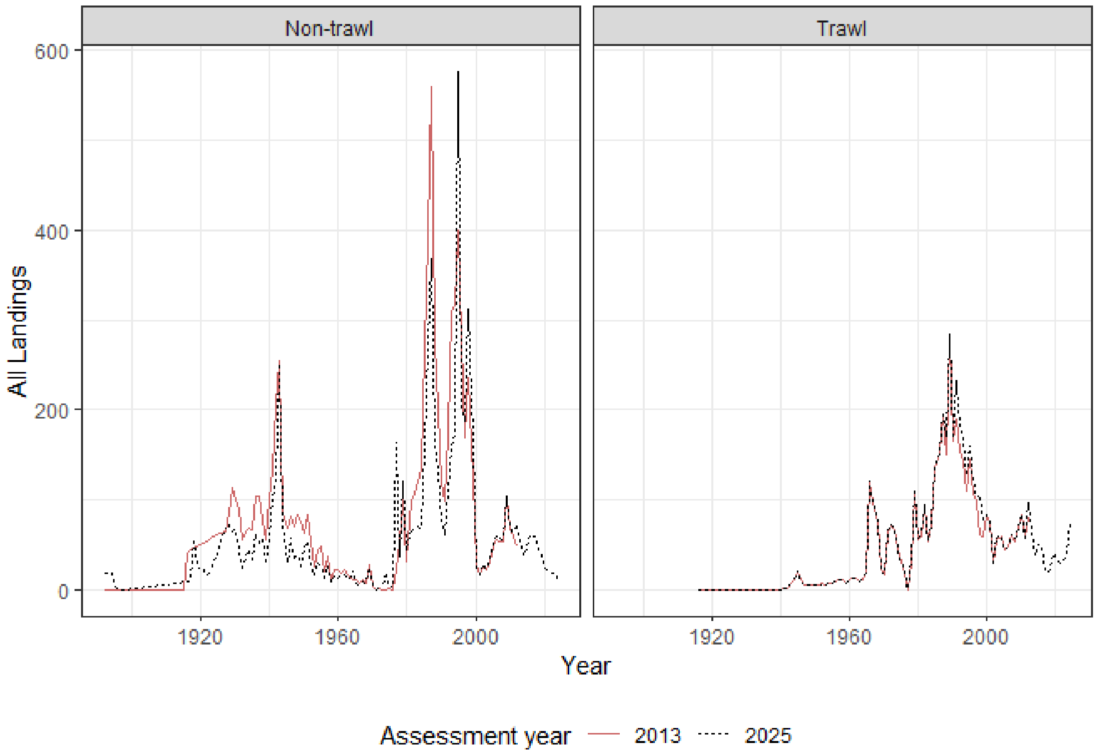

Figure 5: Landings across all states for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

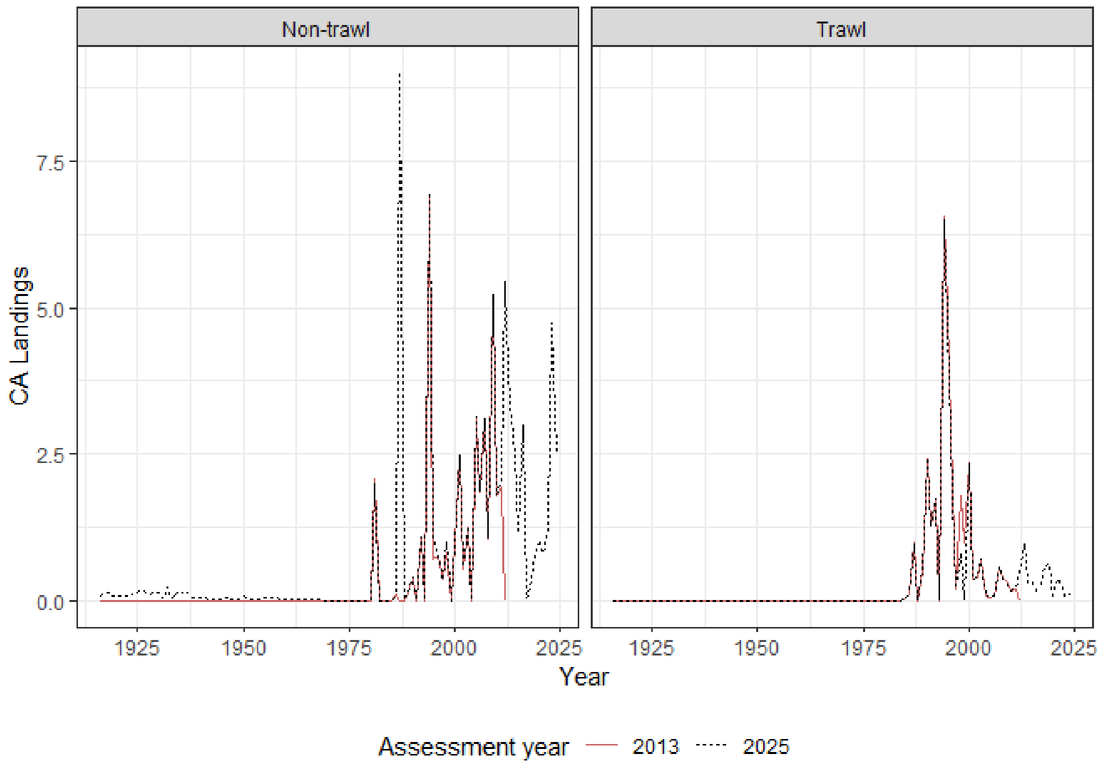

Figure 6: California state landings for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

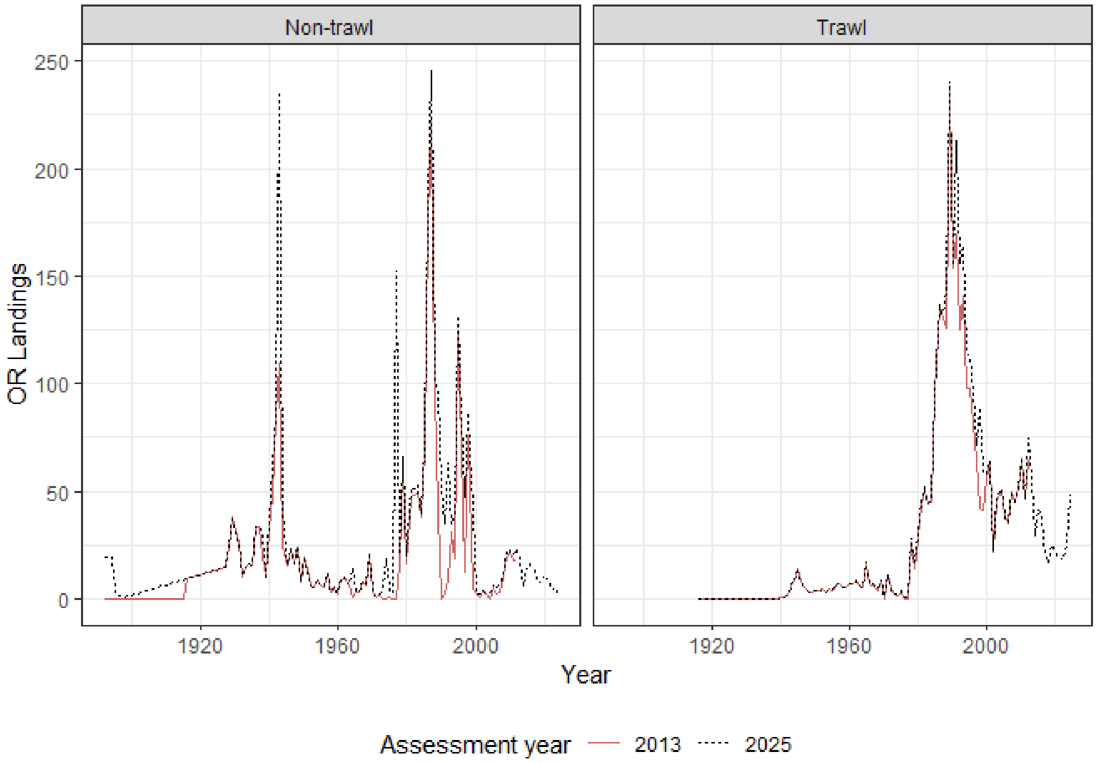

Figure 7: Oregon state landings for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

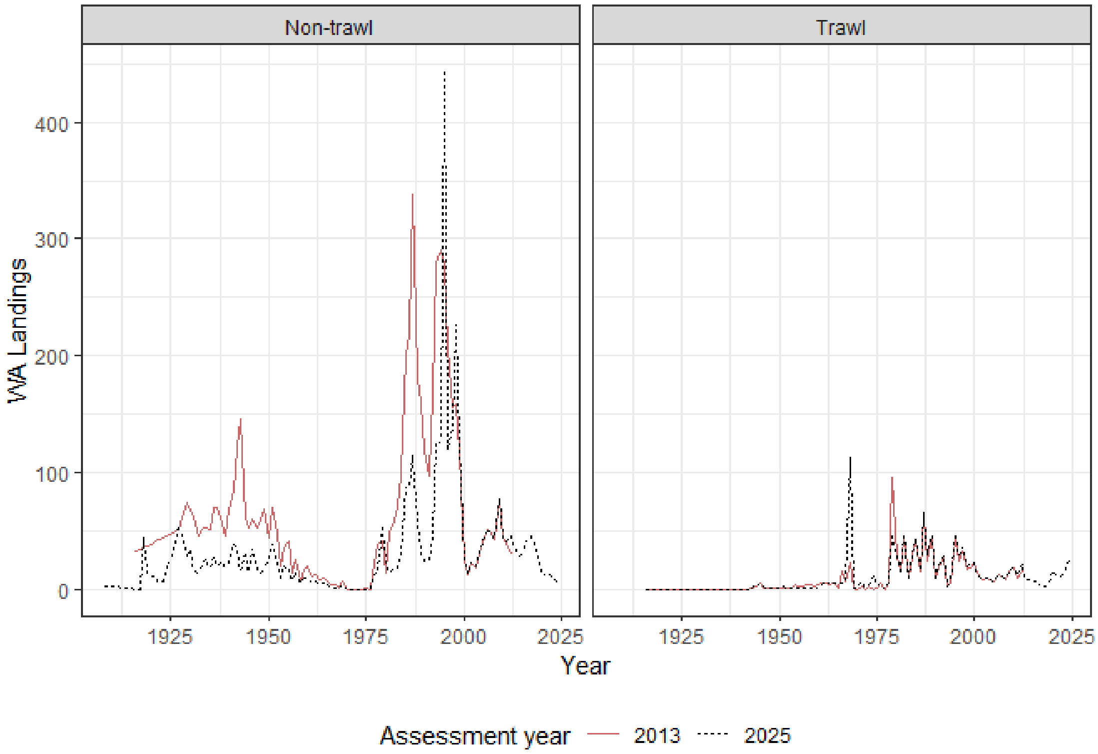

Figure 8: WA. Washington state landings for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

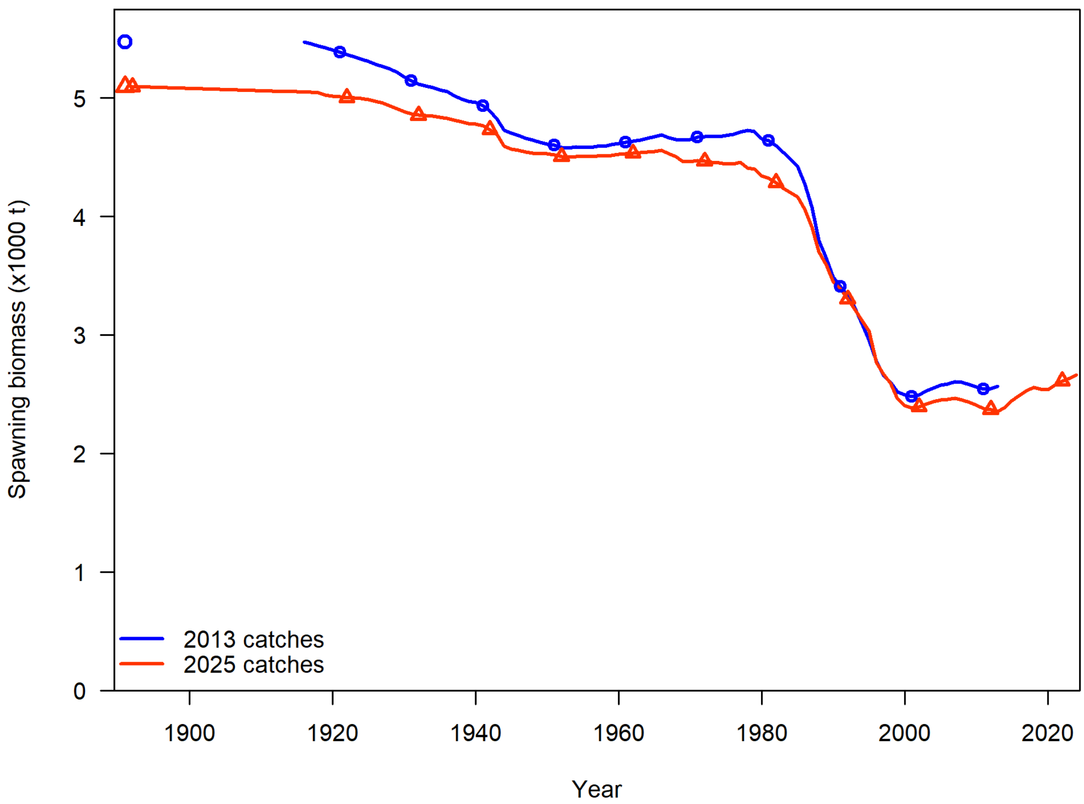

Figure 9: Comparison of spawning output using updated catches vs using catches from the 2013 Rougheye/Blackspotted Rockfishes assessment.

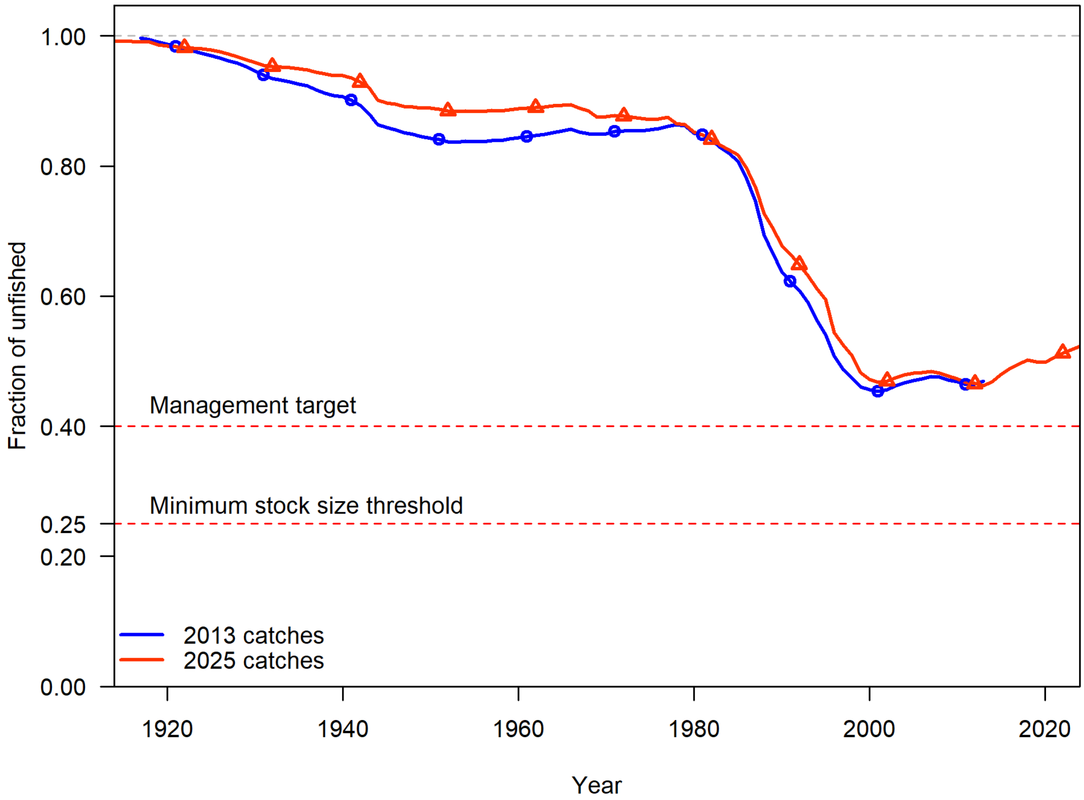

Figure 10: Comparison of relative spawning output using updated catches vs using catches from the 2013 Rougheye/Blackspotted Rockfishes assessment.

3.9.3 Biology

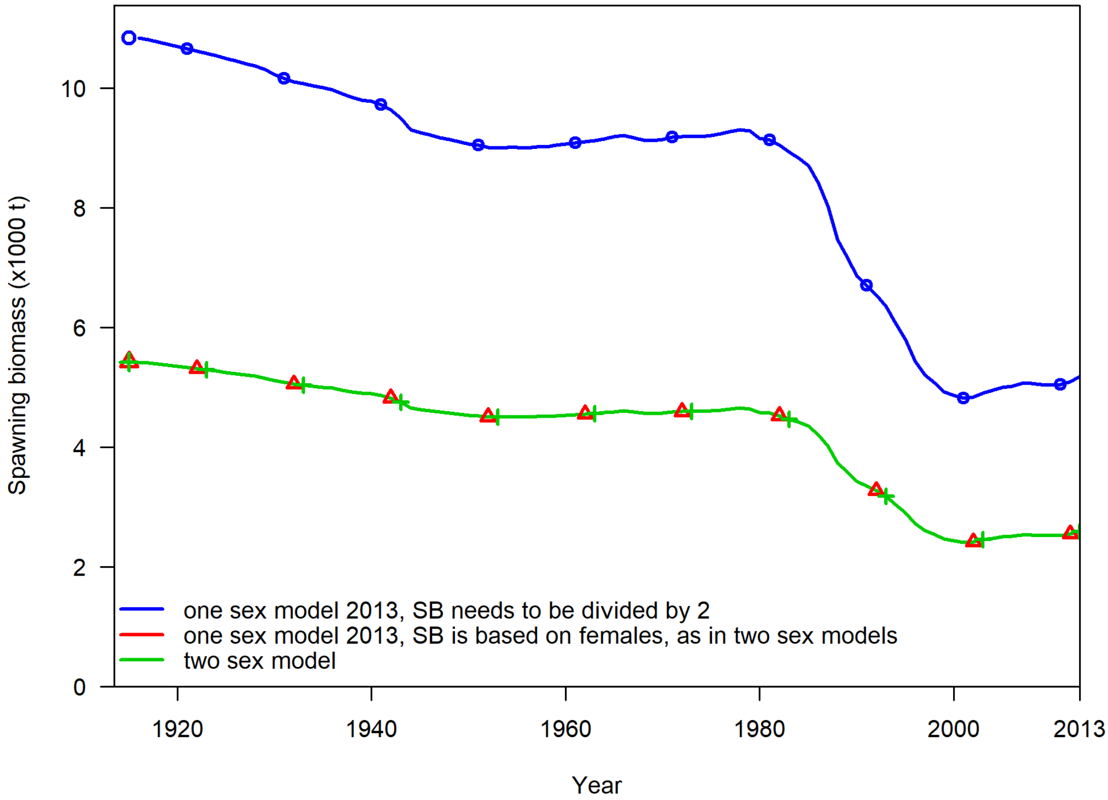

Figure 11: Comparison of spawning output using the 1 sex and 2 sexes set to equal values models based on the 2013 Rougheye/Blackspotted Rockfishes assessment data. The 1 sex model has double the biomass because it includes both females and males.

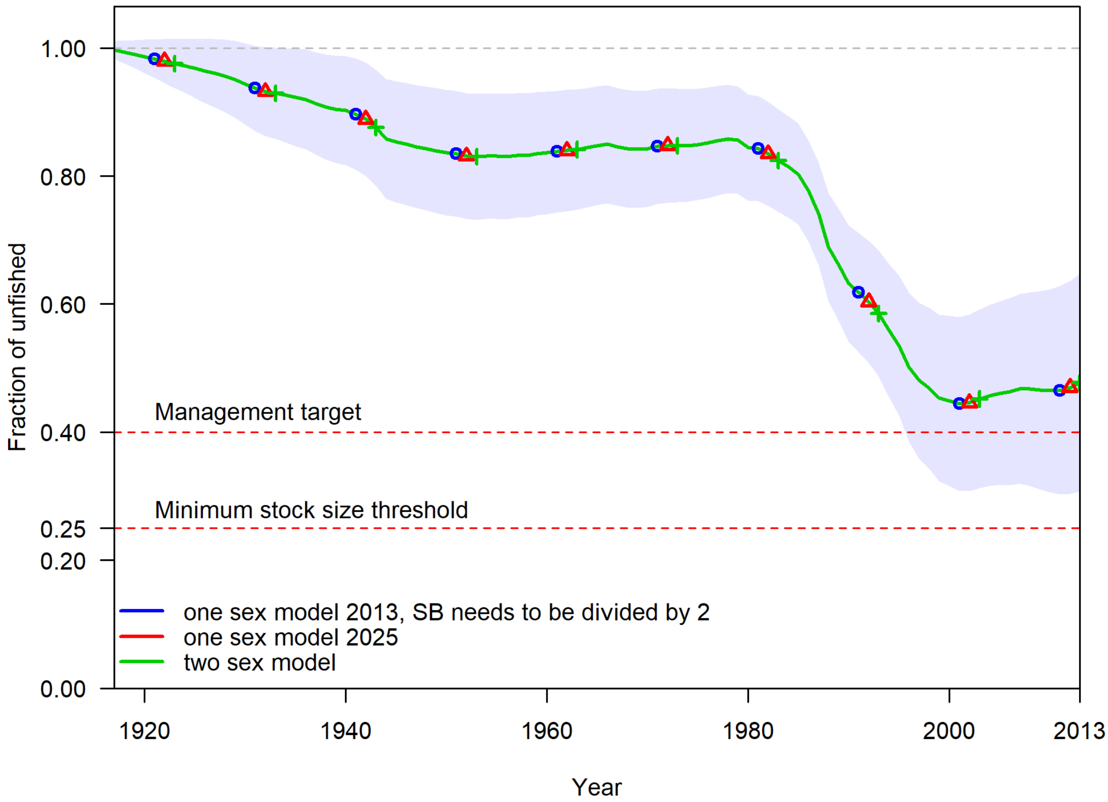

Figure 12: Comparison of spawning output using the 1 sex and 2 sexes set to equal values models based on the 2013 Rougheye/Blackspotted Rockfishes assessment data.

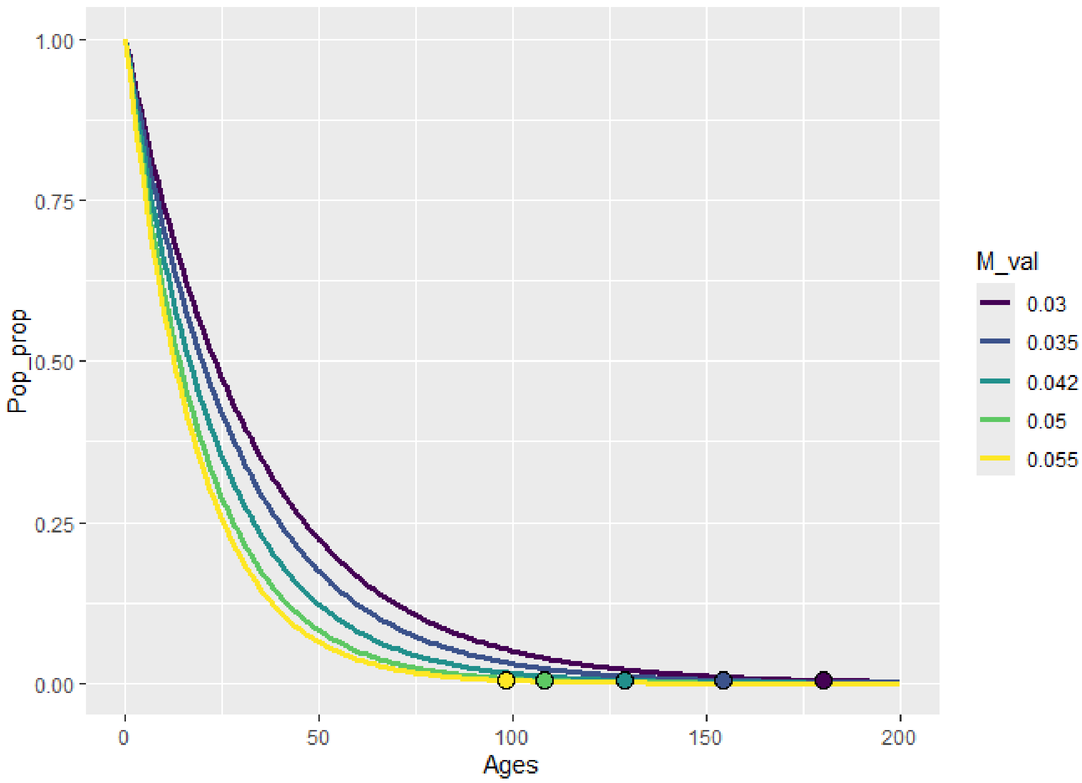

Figure 13: Natural mortality curves by age in years for values of natural mortality used in various Rougheye/Blackspotted Rockfish stock assessments. Dots indicate the range of assumed maximum ages using the equation from Hamel and Cope 2022.

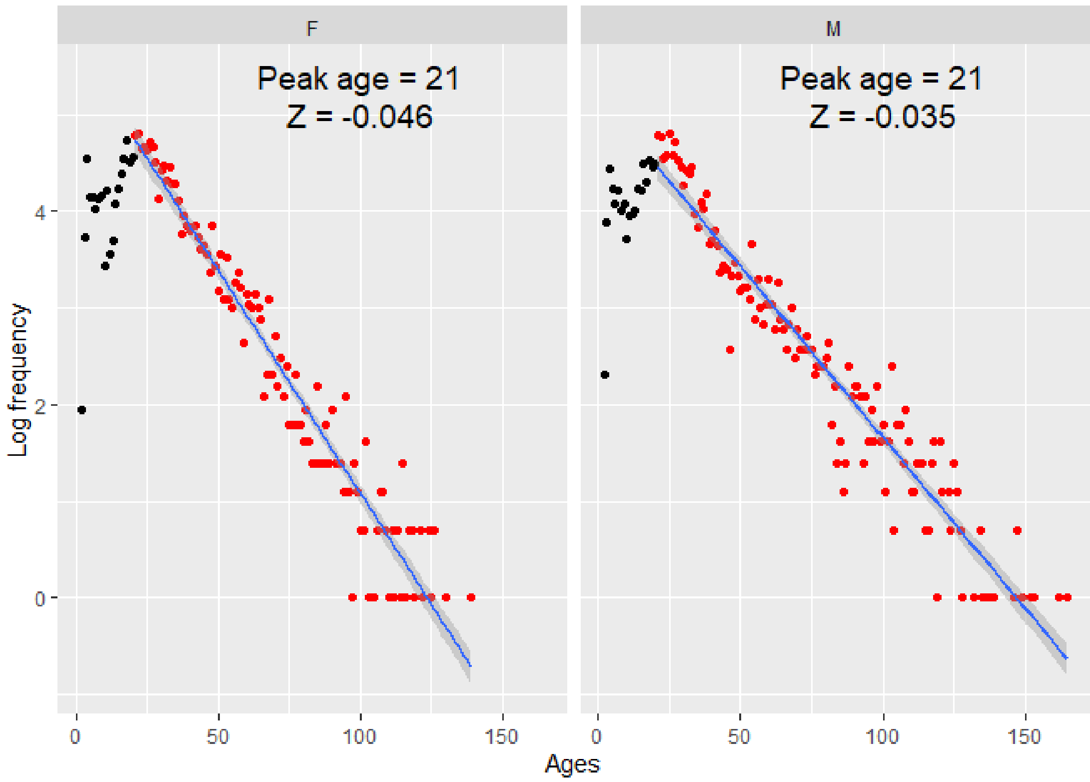

Figure 14: Catch curve (log abundance by age) analysis on aggregated ages over all age sources by sex (black points). The peak selected age was 21 for both sexes, so the linear model was run from age 21 until the oldest age (red points). The slope of the linear model is equal to the estimate of an aggregate total mortality (Z).

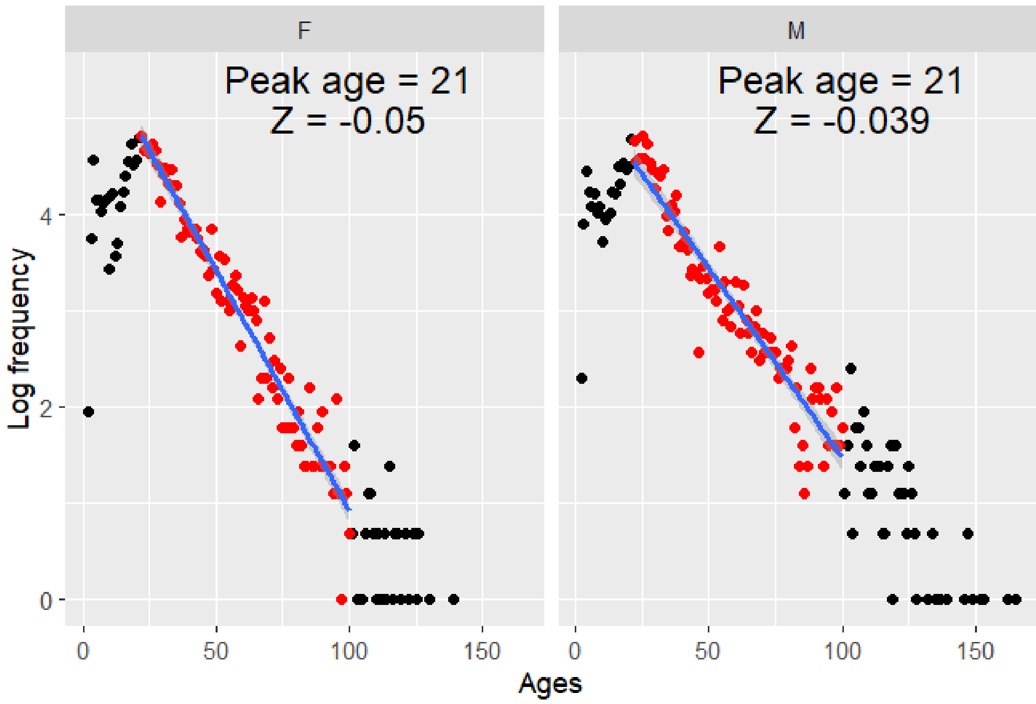

Figure 15: Catch curve (log abundance by age) analysis on aggregated ages over all age sources by sex (black points). The peak selected age was 21 for both sexes with a max age of 100, so the linear model was run from age 21 until age 100 (red points). The slope of the linear model is equal to the estimate of an aggregate total mortality (Z).

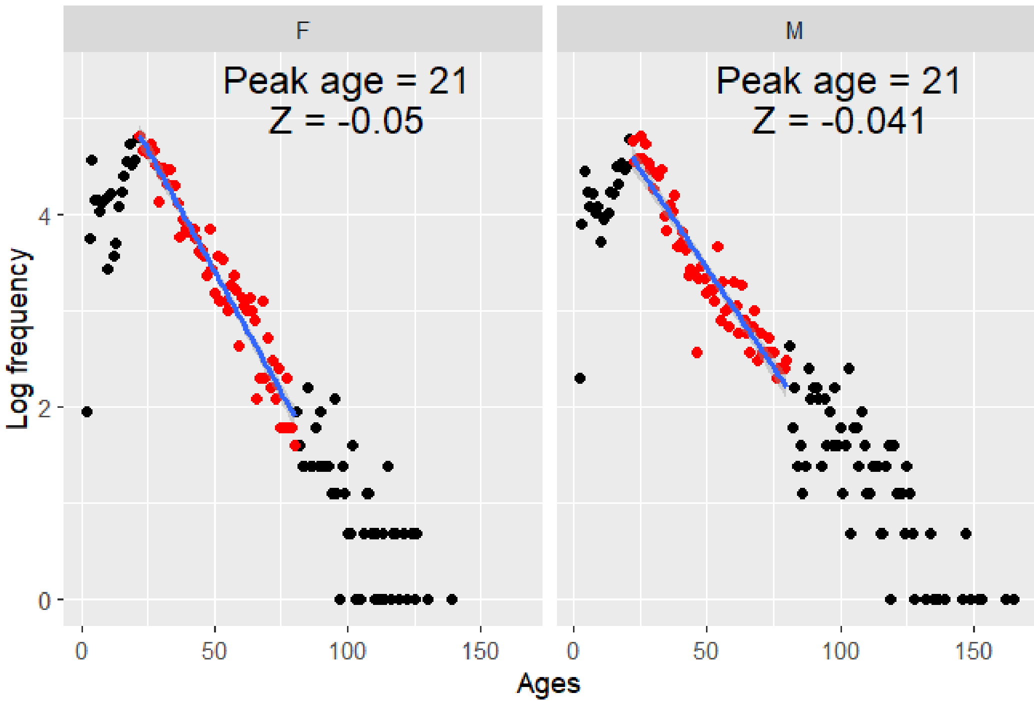

Figure 16: Catch curve (log abundance by age) analysis on aggregated ages over all age sources by sex (black points). The peak selected age was 21 for both sexes with a max age of 80, so the linear model was run from age 21 until age 80 (red points). The slope of the linear model is equal to the estimate of an aggregate total mortality (Z).

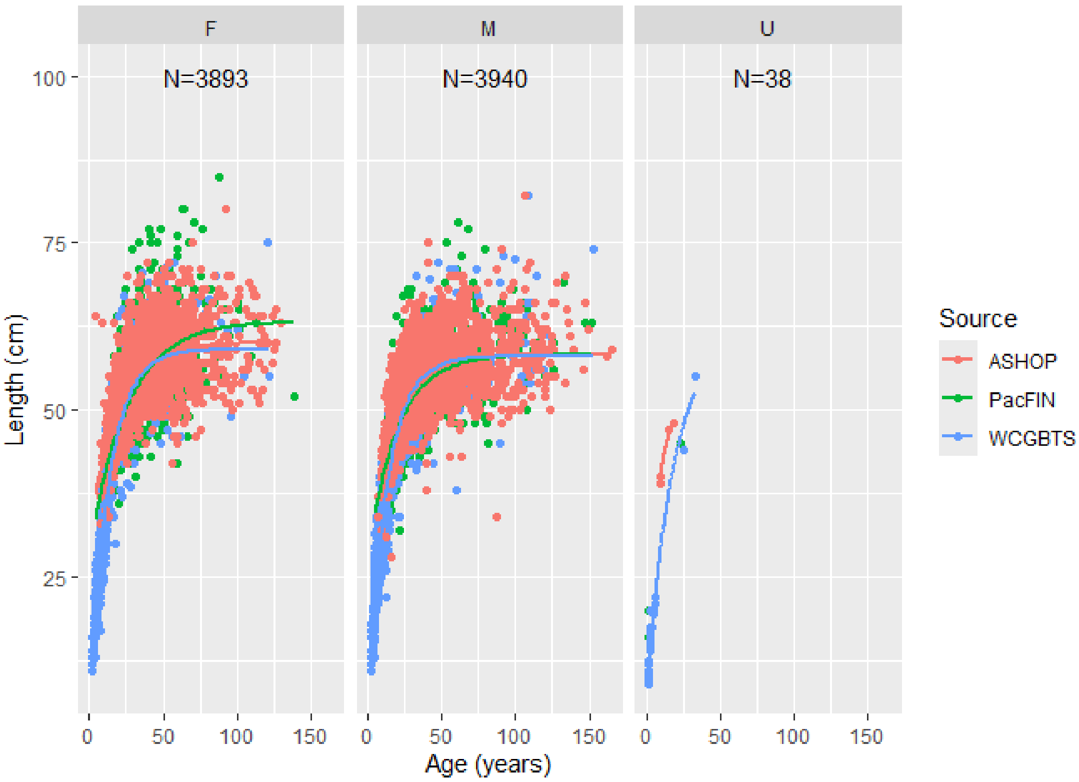

Figure 17: Age and length data, with fitted von Bertalanffy growth curves, by sex and data source for the Rougheye/Blackspotted rockfish complex. Sample sizes (N) are also provided.

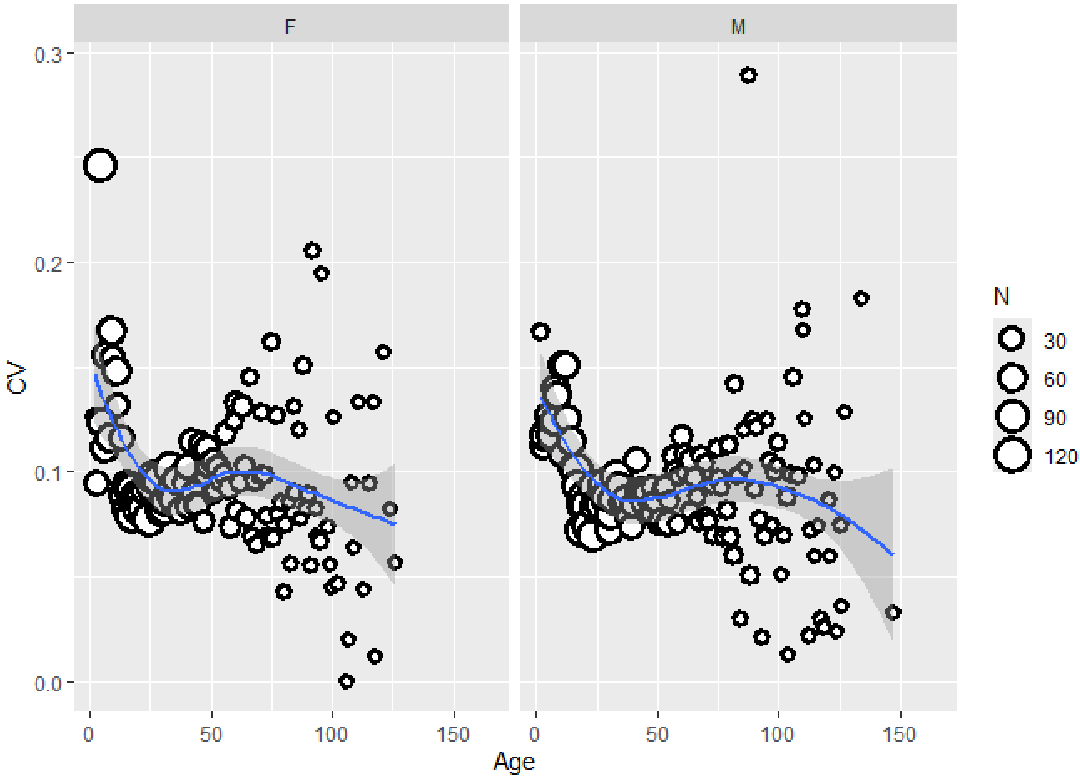

Figure 18: Coefficient of variation by age and sex for all sources of Rougheye/Blackspotted rockfishes ages. Sample sizes (N) are also indicated by size of the point. The line is a smoothed loess (polynomial) line that gives a moving average of CV by age and sex.

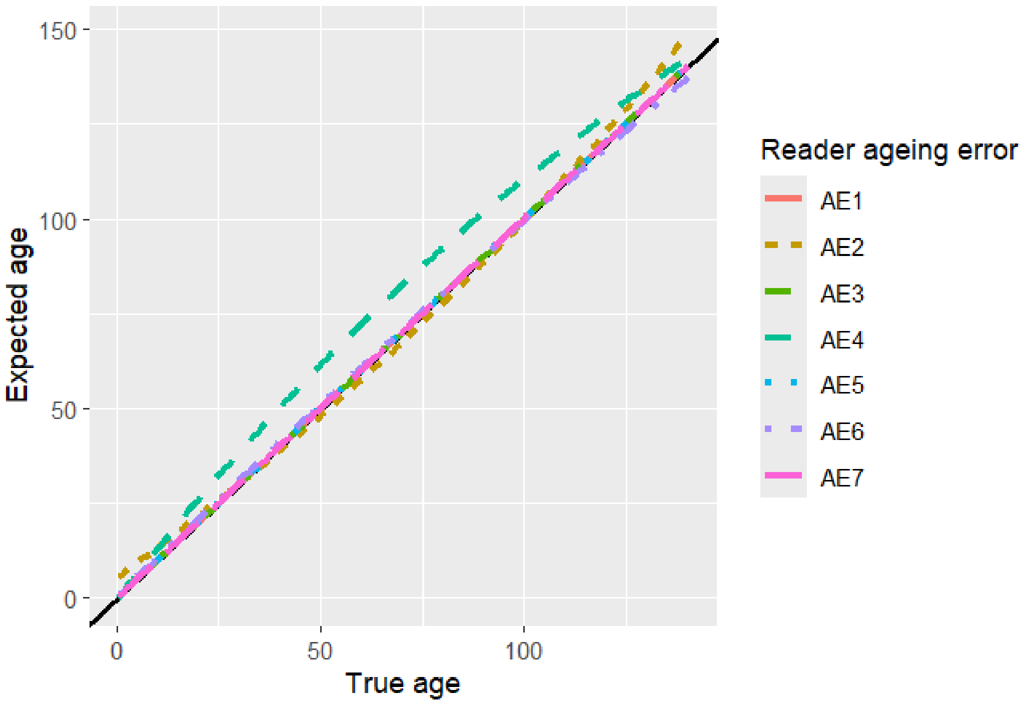

Figure 19: Estimated bias used for each of the seven ageing error matrices.

3.9.4 Model Bridging

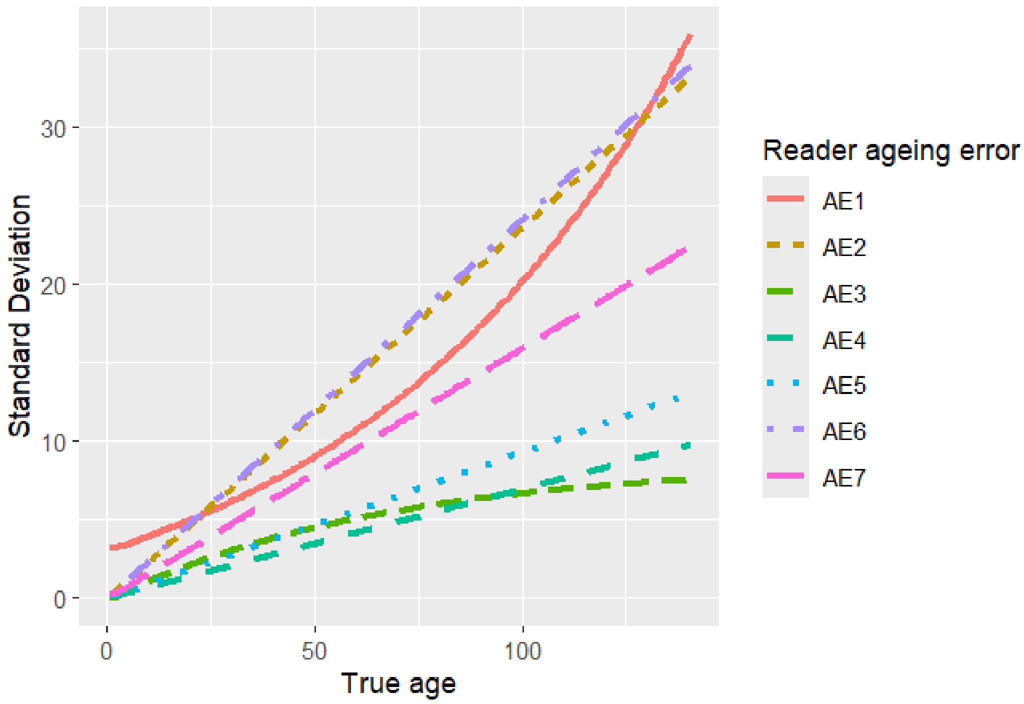

Figure 20: Estimated imprecision (as a standard deviation) used for each of the seven ageing error matrices.

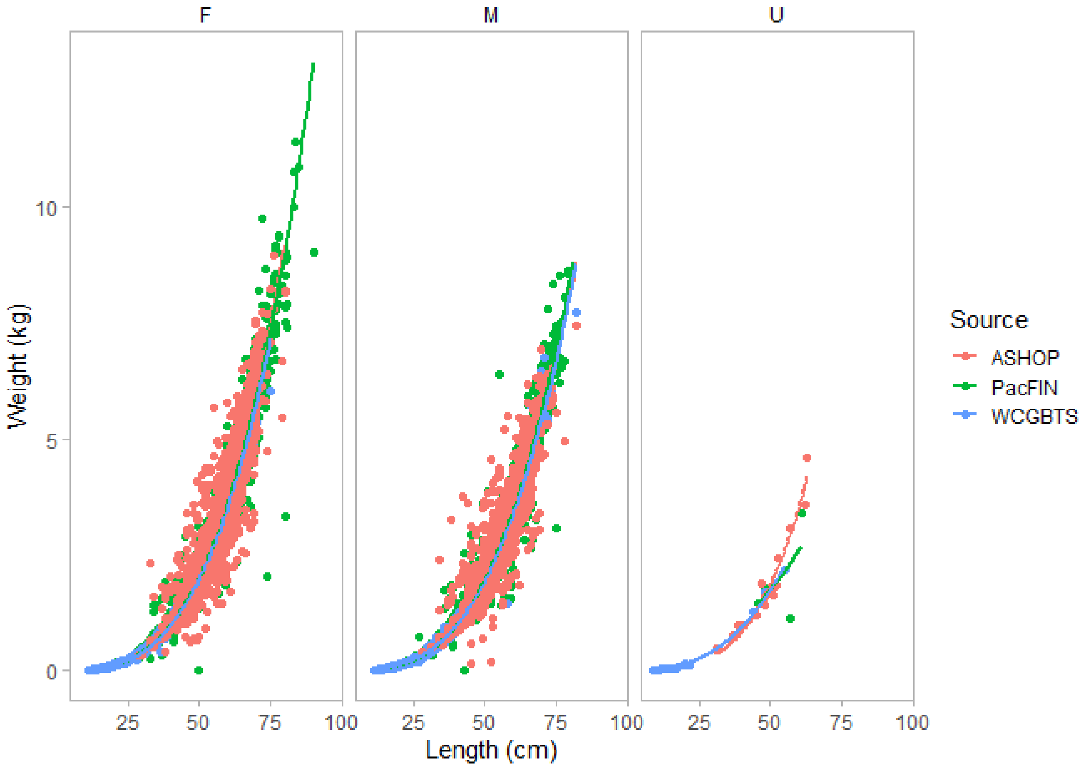

Figure 21: Length and weight samples by sex and data source. Lines are the power function fits by data source.

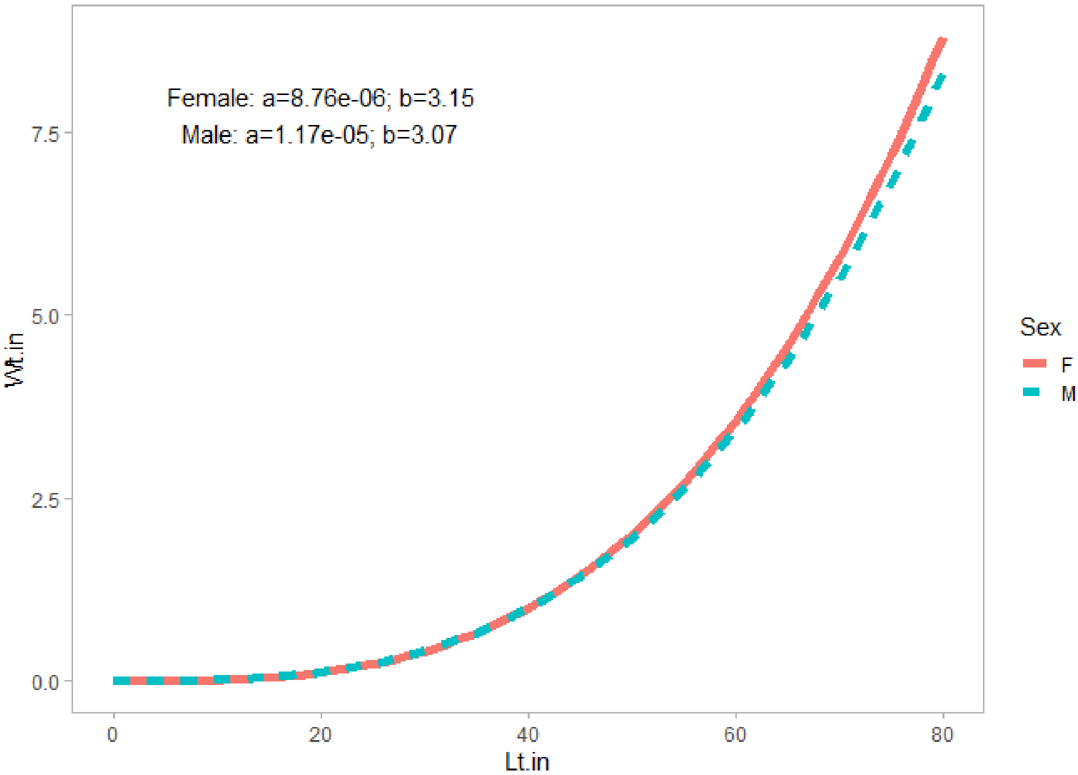

Figure 22: Realized length and weight relationships for female and male Rougheye/Blackspotted Rockfishes.

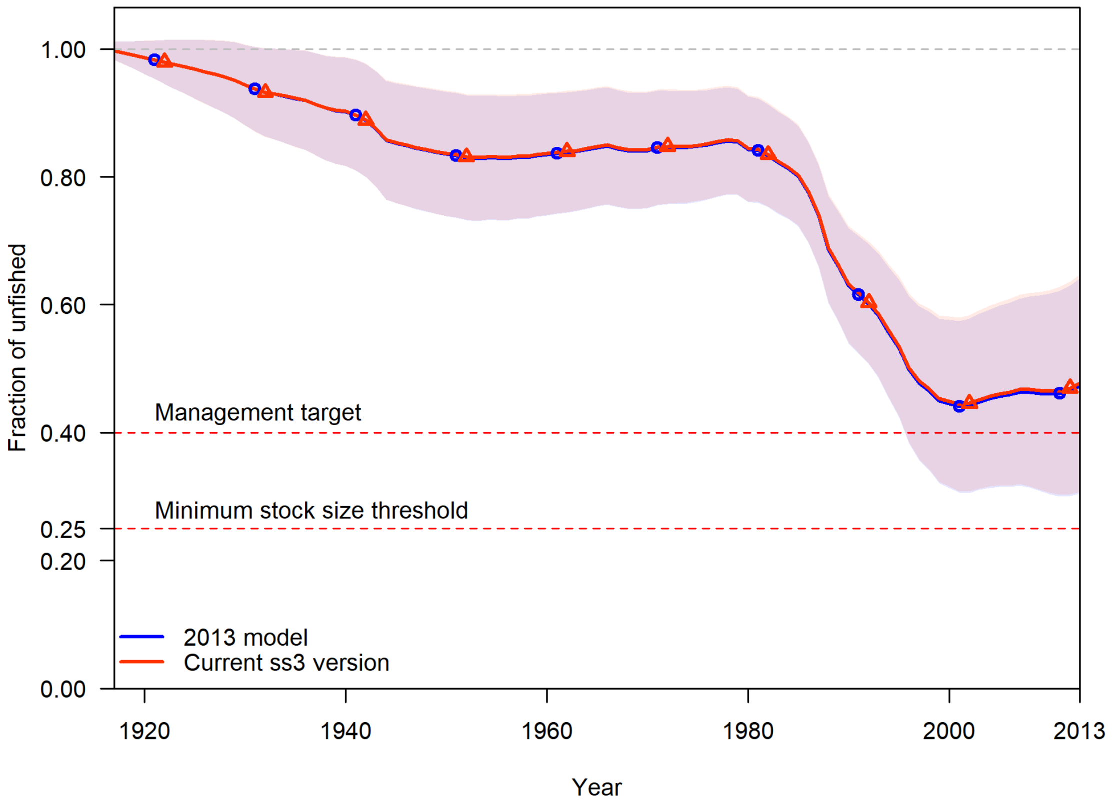

Figure 23: Estimates of relative stock size (current spawning output/unfished spawning output) for the Rougheye/Blackspotted rockfish complex in U.S. west coast waters from the 2013 assessment, and compared to the using the same data in the newest version of SS3 (3.30.22.1).

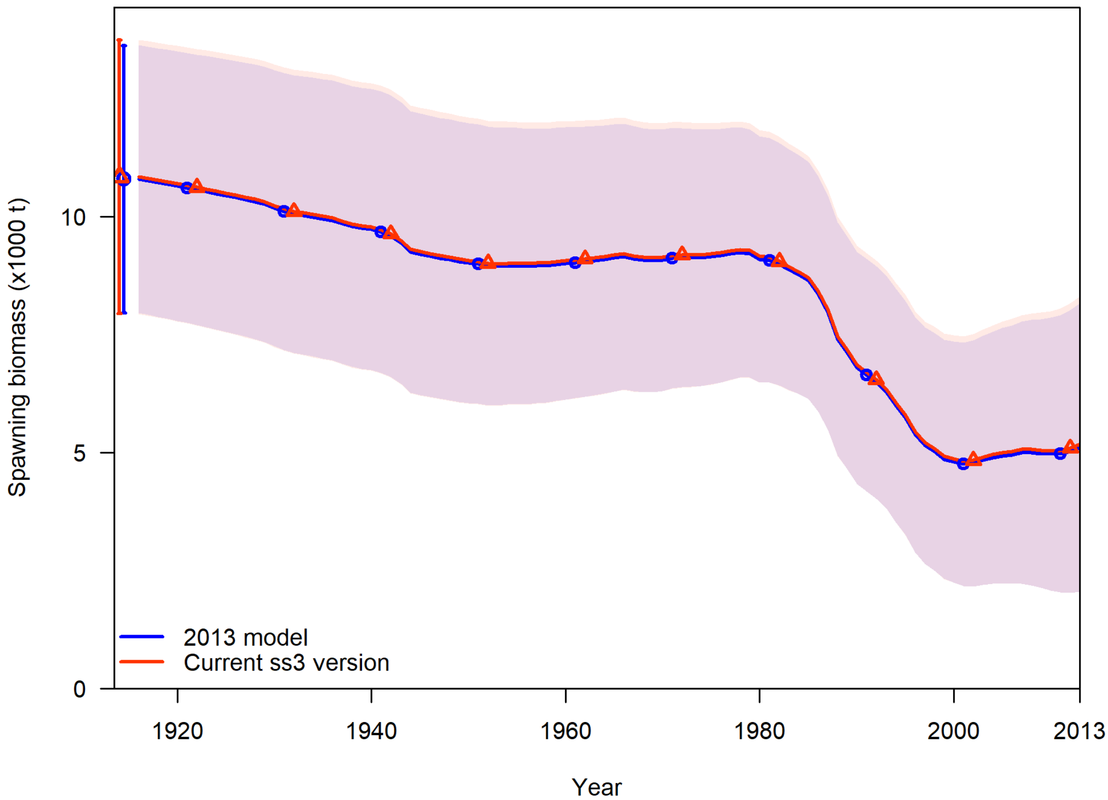

Figure 24: Estimates of spawning output for the Rougheye/Blackspotted rockfish complex in U.S. west coast waters from the 2013 assessment, and compared to the same data in the newest version of SS3 (3.30.22.1). Shading denotes 95% confidence intervals. Shading denotes 95% confidence intervals.

3.9.5 Model Specification

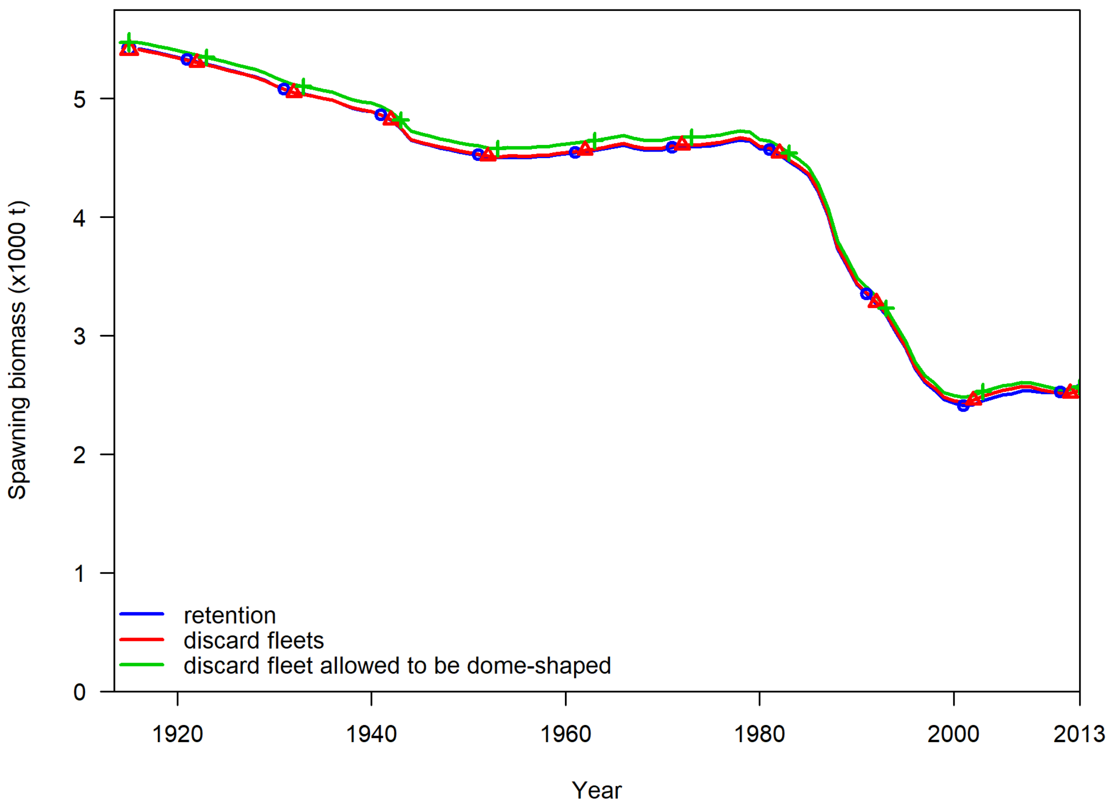

Figure 25: Comparison of spawning output using retention curves or discard fleets using the 2013 Rougheye/Blackspotted Rockfishes assessment.

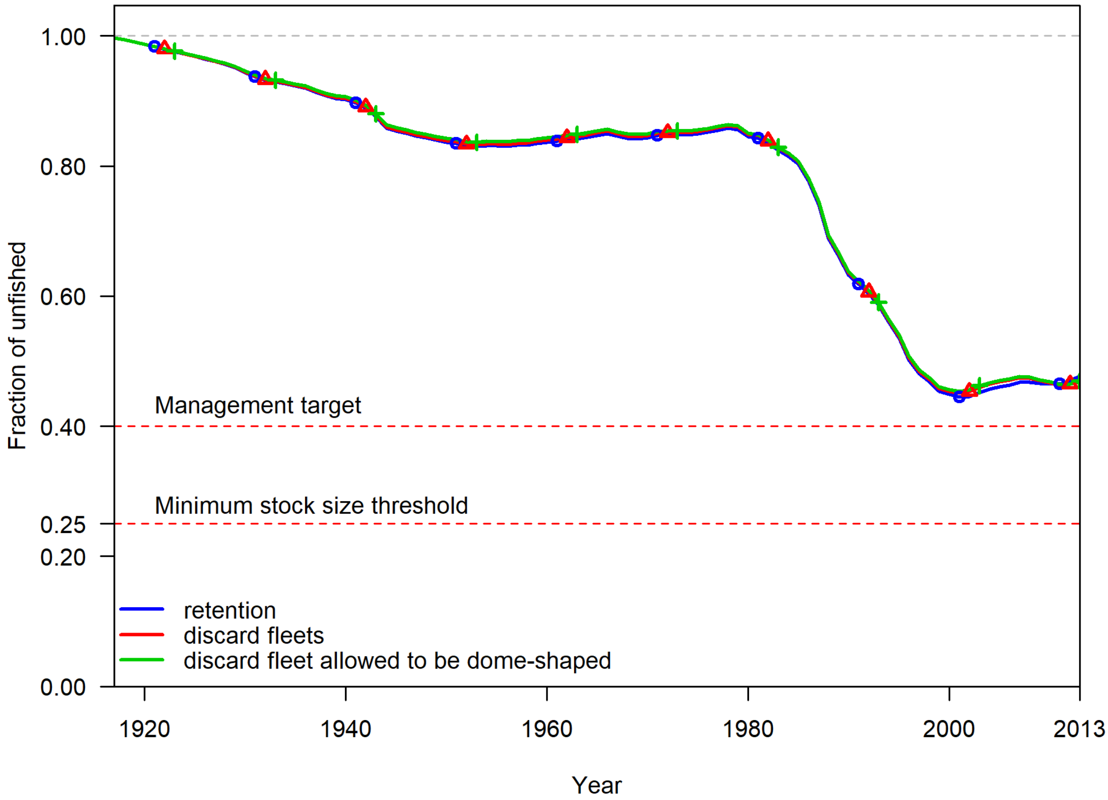

Figure 26: Comparison of relative spawning output using retention curves or discard fleets using the 2013 Rougheye/Blackspotted Rockfishes assessment.

3.9.6 Time-series

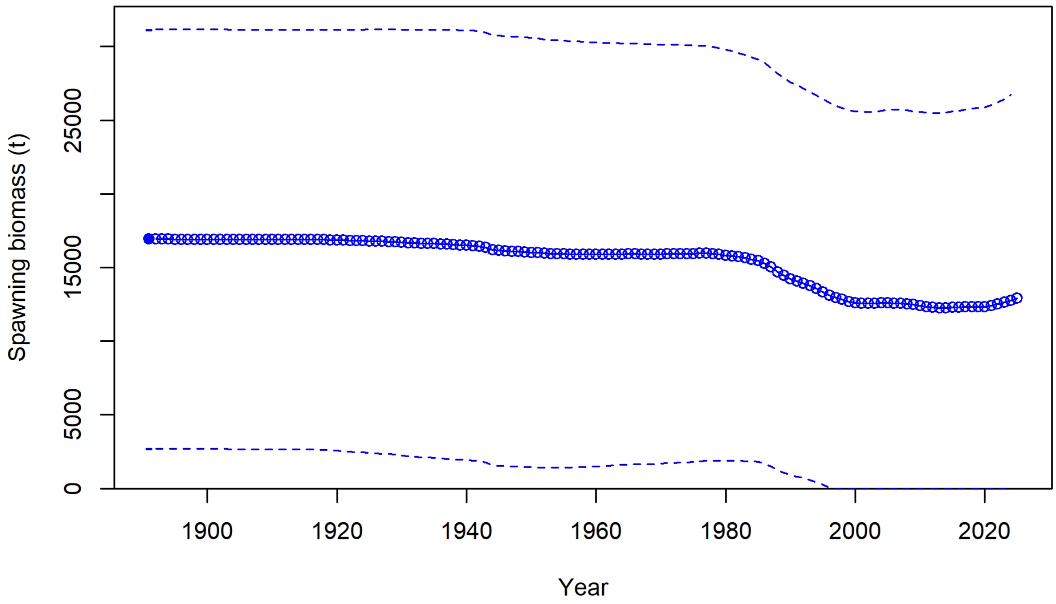

Figure 27: Estimated time series of spawning biomass for the base model.

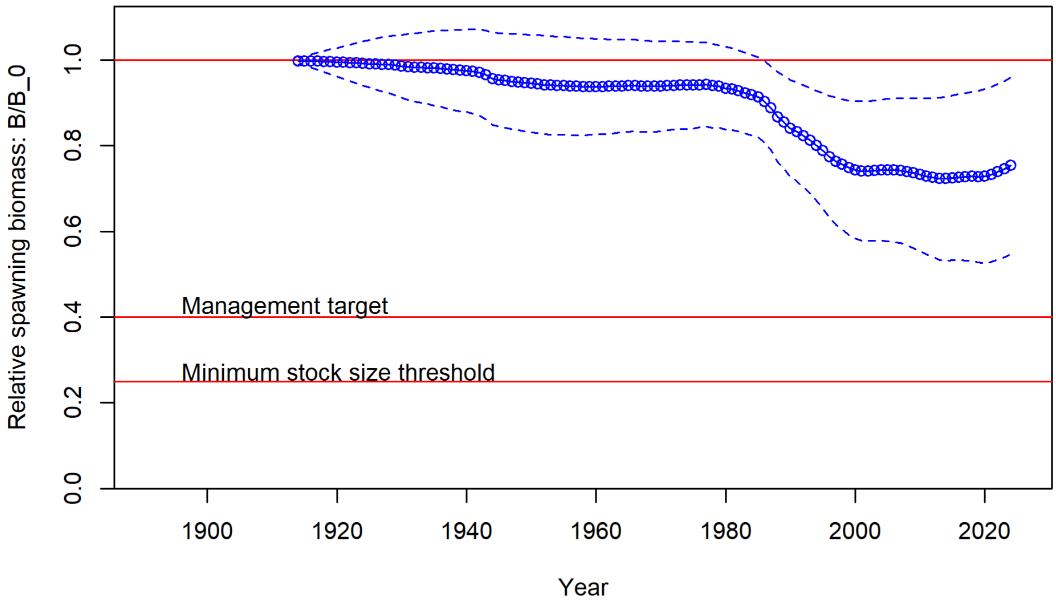

Figure 28: Estimated time series of fraction of unfished spawning biomass for the base model.

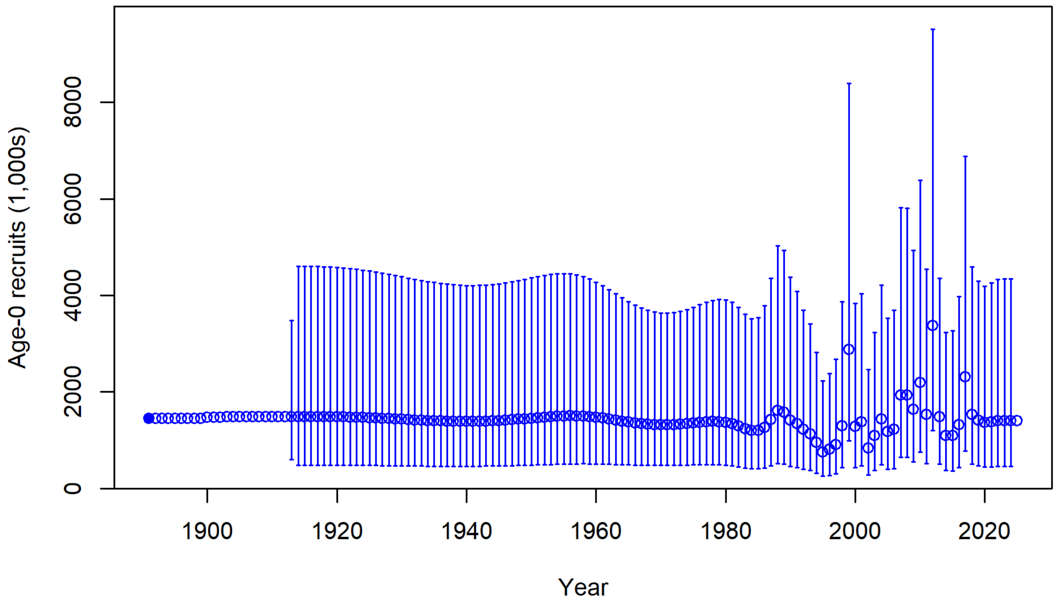

Figure 29: Estimated time series of age-0 recruits for the base model.

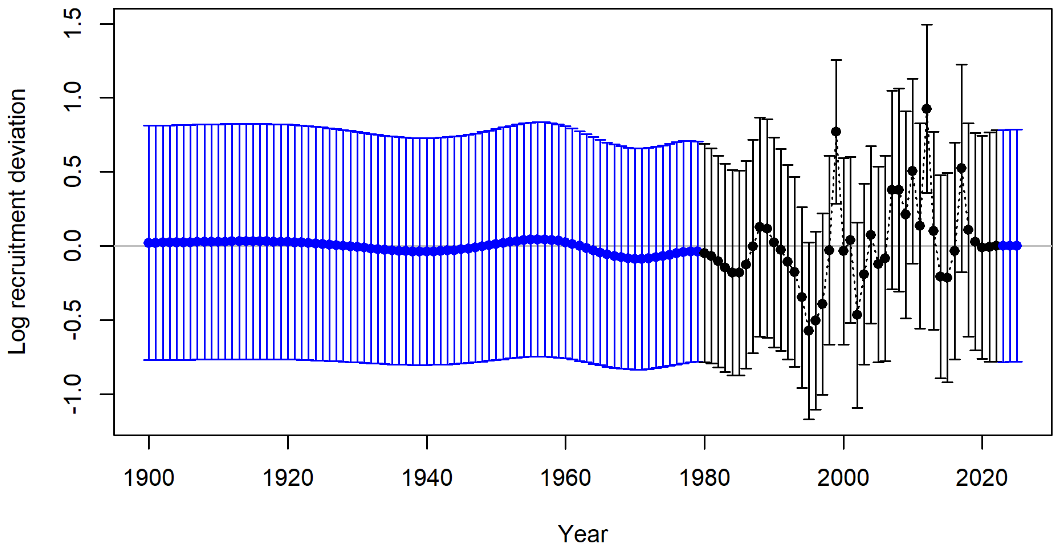

Figure 30: Estimated time series of recruitment deviations for the base model.

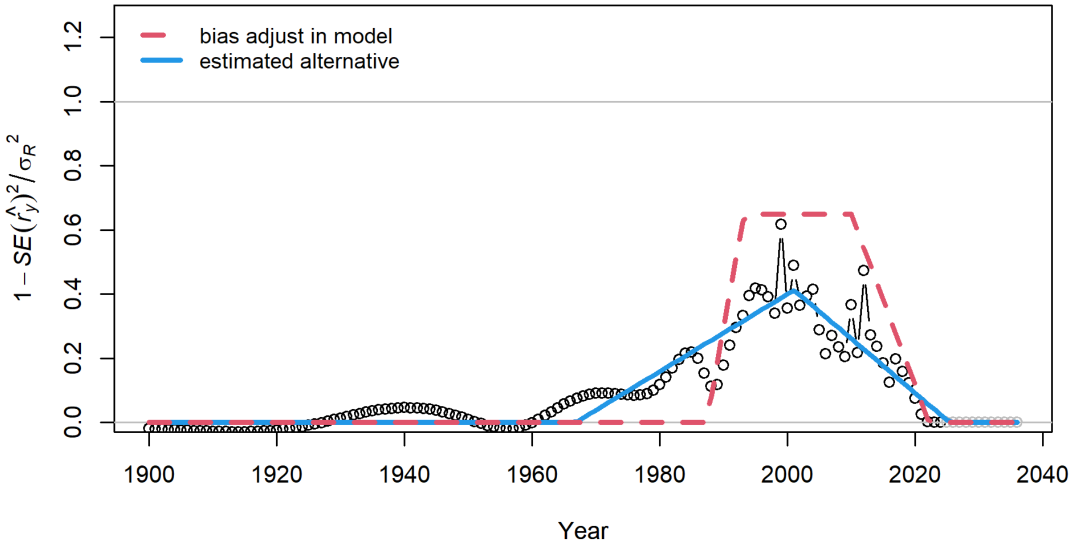

Figure 31: Bias adjustment applied to the recruitment deviations (red line). Points are transformed variances relative to the assumed variance of recruitment.

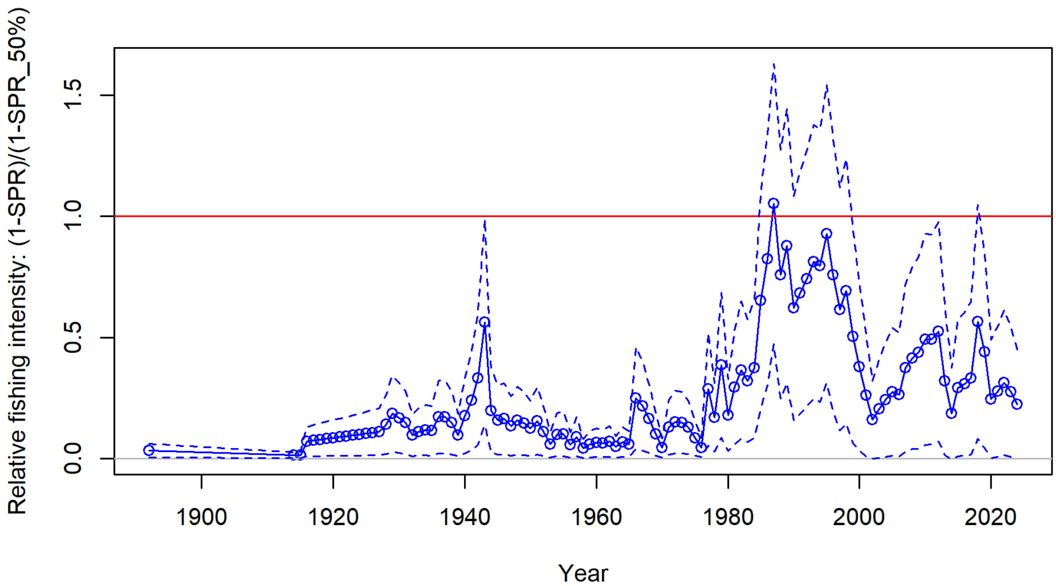

Figure 32: Estimated time series of fishing intensity for the base model.

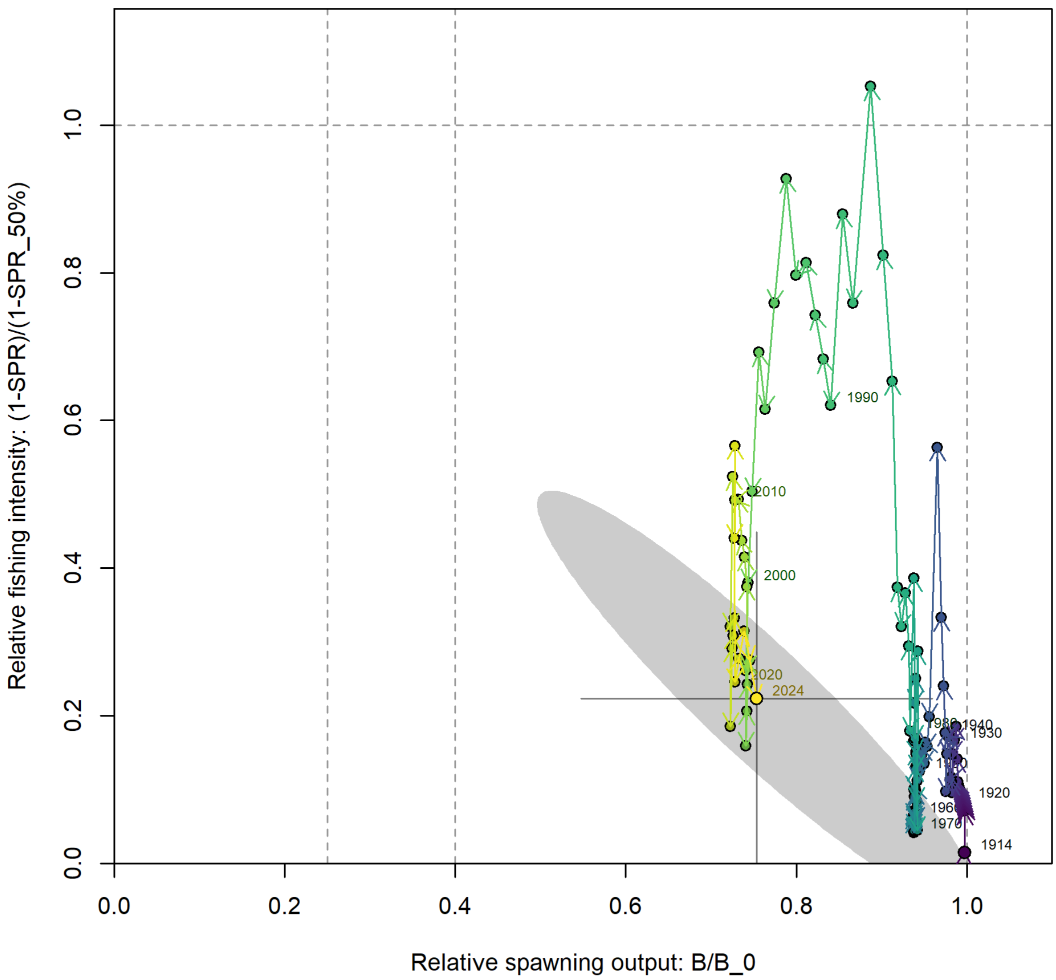

Figure 33: Phase plot of fishing intensity versus fraction unfished for the base model.

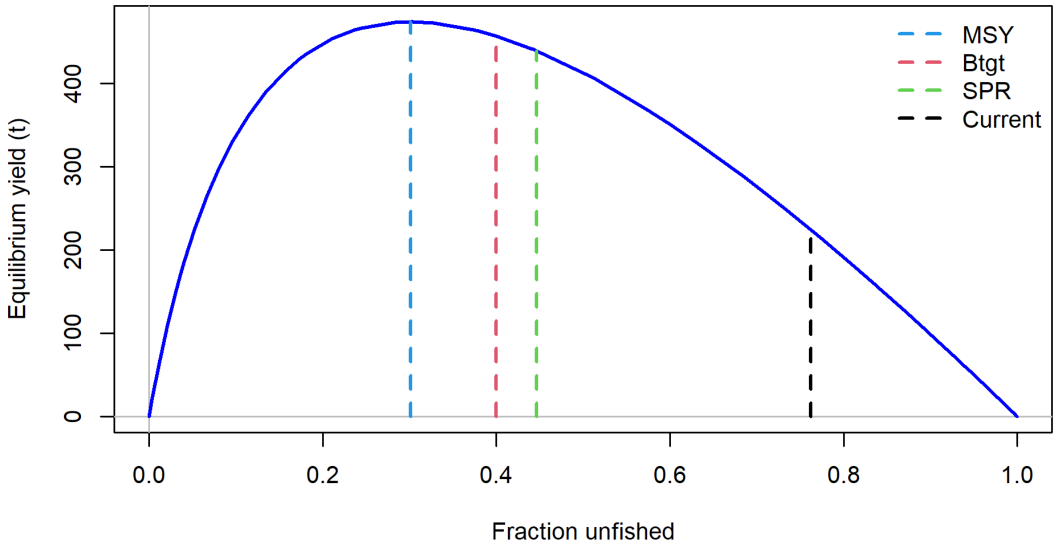

Figure 34: Estimated yield curve with reference points for the base model.

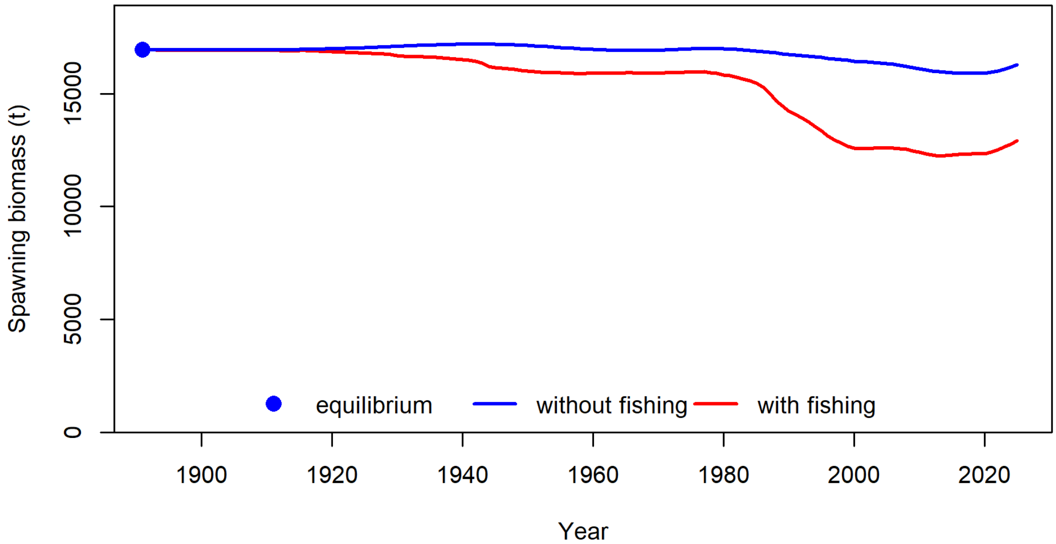

Figure 35: Dynamic B0 plot. The lower line shows the time series of estimated spawning output in the presence of fishing mortality. The upper line shows the time series that could occur under the same dynamics (including deviations in recruitment), but without fishing. The point at the left represents the unfished equilibrium.

3.10 Sensitivity Analyses and Retrospectives

3.11 Likelihood Profiles

3.12 Reference Points and Forecasts

3.13 Notes

3.14 Appendices