

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

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## 1 Executive Summary

### 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 5). 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).

### 1.2 Catches

Rougheye/Blackspotted Rockfishes are mainly incidentally caught and retained, and caught mainly by trawl (both bottom and midwater) and non-trawl (largely hook and line gear) in commercial fisheries (Figure 1). The non-trawl removals were dominate until the 1960s were trawl-caught Rougheye/Blackspotted Rockfishes increased. The biggest removals were reported in the 1980s and came from the trawl fishery, but the most recent largest catches come from the at-sea-hake fishery (Table 1). Discards are generally thought to be negligible to low for most fo the time series.

Table 1: Recent landings by fleet, total landings summed across fleets, and the total dead catch including discards.

Year	Trawl	Trawl discard	Non-trawl	Non-trawl discard	Midwater trawl	At-sea-hake	Total Landings	Total Dead (mt)
2015	31	0	47	14	19.26010	21.8019	132.09211	132.09211
2016	31	0	60	13	15.53260	29.6339	148.95011	148.95011
2017	22	0	59	34	2.48250	38.1484	156.01664	156.01664
2018	16	0	47	15	2.57640	161.2370	241.51647	241.51647
2019	22	0	39	31	9.24547	125.3660	226.59244	226.59244
2020	10	0	24	1	28.91830	41.8824	106.07466	106.07466
2021	10	0	21	2	21.39070	37.6155	92.76237	92.76237
2022	12	0	19	3	18.62890	65.4553	117.42518	117.42518
2023	13	0	19	0	26.21650	38.4973	97.62859	97.62859
2024	10	0	10	0	69.14520	29.3232	118.93545	118.93545

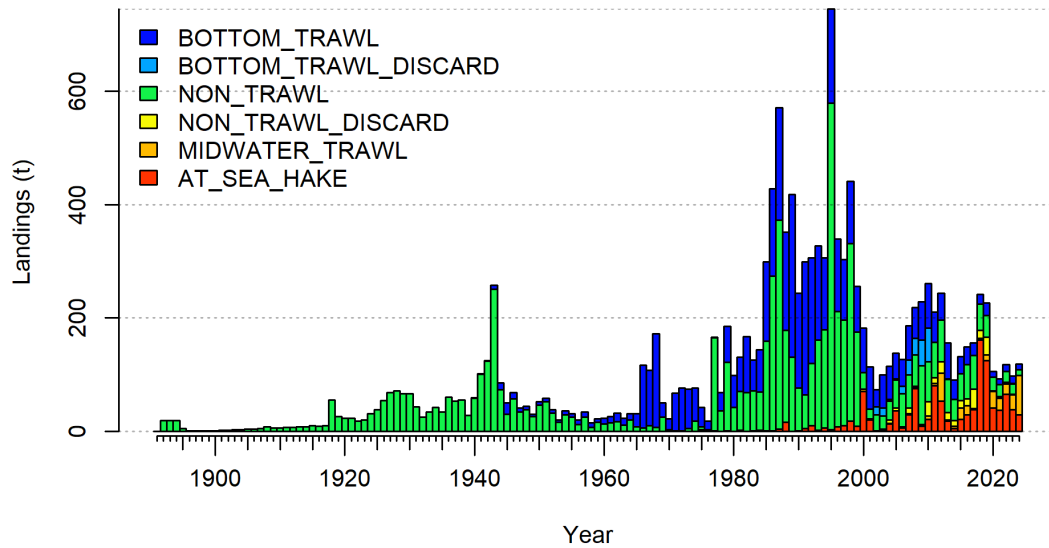


Figure 1: Landings in metric tons (mt) by year for each fleet.

### 1.2.1 Data and Assessments

The only previous stock assessment for Rougheye/Blackspotted Rockfishes for the west coast area was done in 2013. This assessment separates the discard catches from the retained fisheries, maintains the at-sea-hake fishery as its own fishery, and adds a midwater fishery that has emerged in the last 10 years. This stock assessment adds 10+ years of additional length data, and adds several more years of age data (included as conditioned on length data). The same four groundfish abundance surveys (Triennial, Alaska Slope, Northwest Fishery Science Center Slope, and the West Coast Groundfish Bottom Trawl Survey (WCGBTS)) as used in the last stock assessment are used here, with an extension to 2024 to the the WCGBTS. The index standardization of all survey data uses the newer approach of applying spatiotemporal generalized linear mixed models.

### 1.2.2 Stock Output and Dynamics

The model estimates that the population, but increased through the 2000s to mid 2010s (Figure 2, Figure 3). Since 2017 (coincident with the increase in catches), spawning output has been gradually declining, but is still well above the management target of 40% of unfished spawning depletion (Table 2).



Table 2: Estimated recent trend in spawning output and the fraction unfished and the 95 percent confidence intervals.

Year	Spawning output	Lower Interval (mt)	Upper Interval (mt)	Fraction Unfished	Lower Interval	Upper Interval
2015	451,135.00	- 216,852.09	1,119,122.09	0.882	0.648	1.115
2016	450,063.00	- 218,008.36	1,118,134.36	0.880	0.644	1.116
2017	448,779.00	- 219,298.24	1,116,856.24	0.877	0.638	1.116
2018	447,431.00	- 220,620.76	1,115,482.76	0.875	0.633	1.116
2019	445,158.00	- 222,919.24	1,113,235.24	0.870	0.623	1.117
2020	443,261.00	- 225,014.20	1,111,536.20	0.867	0.615	1.118
2021	443,053.00	- 225,727.87	1,111,833.87	0.866	0.613	1.119
2022	443,381.00	- 226,319.09	1,113,081.09	0.867	0.613	1.121
2023	443,867.00	- 227,236.43	1,114,970.43	0.868	0.612	1.123
2024	445,061.00	- 227,963.19	1,118,085.19	0.870	0.614	1.126
2025	446,448.00	- 228,959.51	1,121,855.51	0.873	0.615	1.130

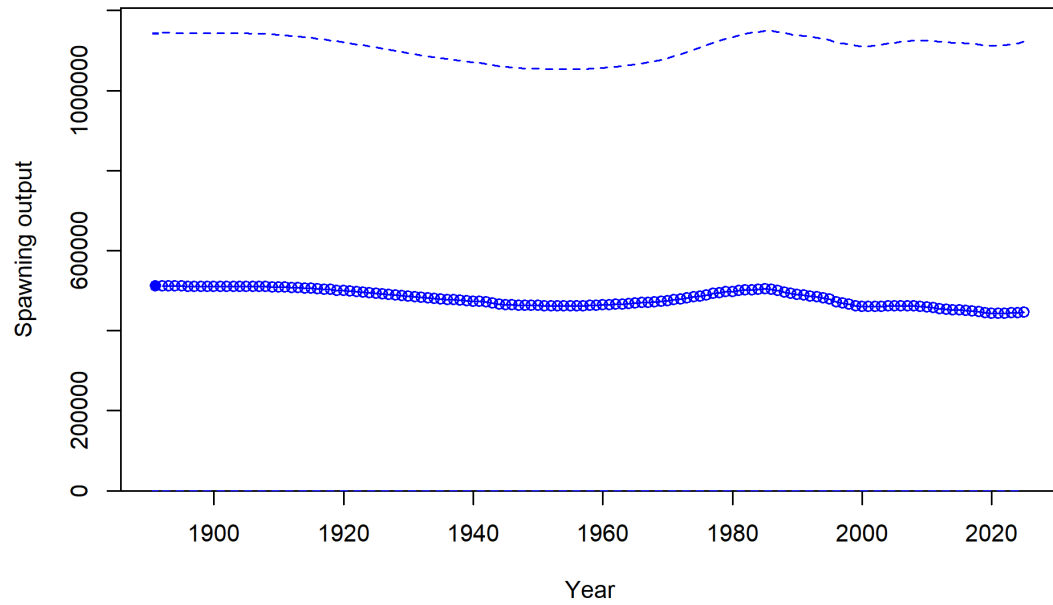


Figure 2: Estimated time series of spawning output (trillions of eggs) for the base model.

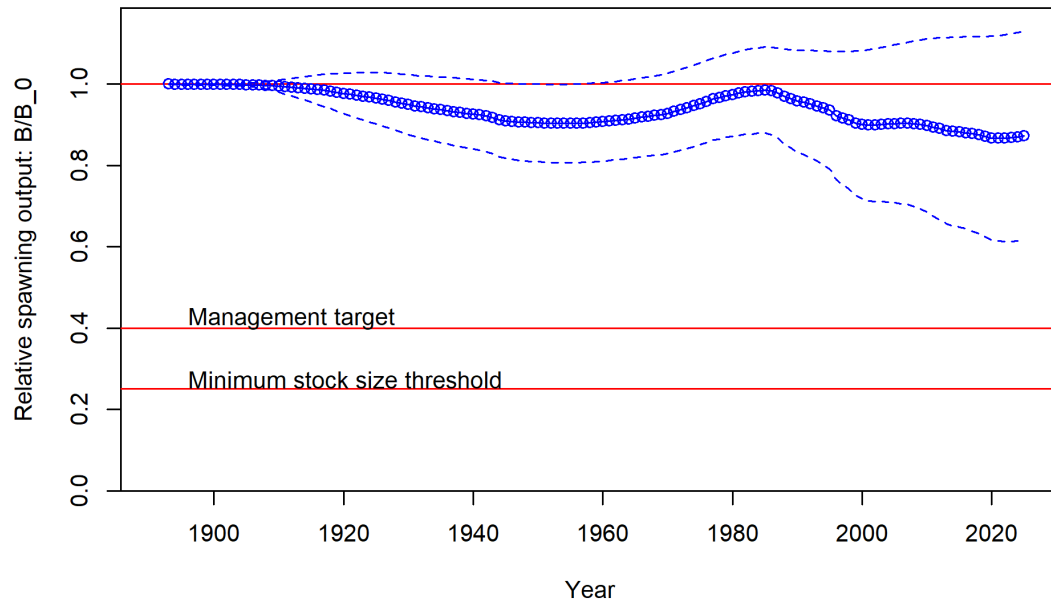


Figure 3: Estimated time series of fraction of unfished spawning output for the base model.

### 1.3 Recruitment

The estimated largest recruitment event throughout the time series was in 2008, which supported an increase in the population leading up to 2017 (Table 3, Figure 4). Recruitment is estimated to be relatively low in the later 2010s, but the model estimates that 2021 and 2023 may support large year classes in the future, with the estimates driven by the new recruitment index for both years.

Table 3: Estimated recent trend in recruitment (1,000s) and recruitment deviations and the 95 percent confidence intervals.

Year	Recruit- ment (1,000s)	Lower Interval (1,000s)	Upper Interval (1,000s)	Recruit- ment Deviations	Lower Interval	Upper Interval
2015	659	173	2,515	-0.445	-1.271	0.382
2016	870	228	3,328	-0.172	-1.012	0.668
2017	2,172	584	8,071	0.738	-0.009	1.484
2018	1,341	354	5,087	0.251	-0.565	1.066
2019	1,197	317	4,517	0.132	-0.678	0.943
2020	846	221	3,242	-0.220	-1.083	0.643
2021	923	236	3,608	-0.138	-1.050	0.774
2022	1,017	254	4,067	-0.046	-1.008	0.916

2023	1,067	266	4,286	-0.003	-0.982	0.975
2024	1,076	268	4,323	0.000	-0.980	0.980
2025	1,076	268	4,324	0.000	-0.980	0.980

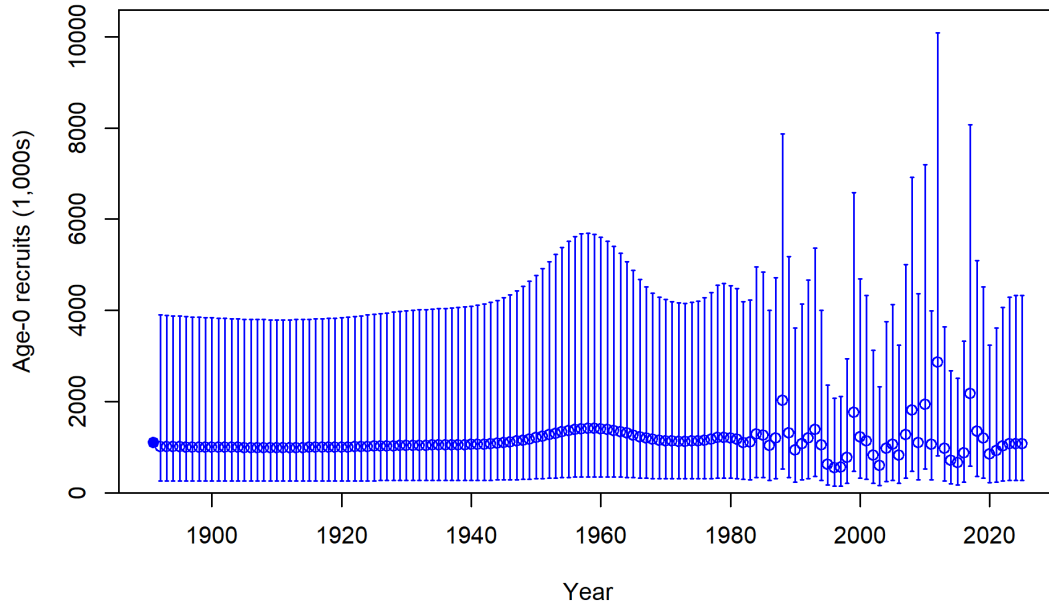


Figure 4: Estimated time series of age-0 recruits for the base model.

#### 1.4 Ecosystem Consideration

The assessment includes a sensitivity model with an oceanographic recruitment index. A number of ecosystem and environmental conditions were compiled by a team of ecosystem scientists at the NWFSC specific to the life history and distribution of northern yellowtail. These conditions included an evaluation of oceanographic conditions impacting recruitment, habitat change, prey availability, predator and competitor abundance, and climate vulnerability.

#### 1.5 Reference Points

A list of estimates of the current state of the population, as well as reference points based on 1) a target unfished spawning output of 40%, 2) a spawning potential ratio of 0.5, and 3) the model estimate of maximum sustainable yield, are all listed in Table 4. SPR, or the spawning potential ratio, is the fraction of expected lifetime reproductive

output under a given fishing intensity divided by unfished expected lifetime reproductive output.

Table 4: Summary of reference points and management quantities, including estimates of the 95 percent confidence intervals. SO is spawning output, SPR is the spawning potential ratio, and MSY is maximum sustainable yield.

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning output	511,528.0	-116,464.1	1,139,520.1
Unfished Age 3+ Biomass (mt)	47,684	-10,835	106,203
Unfished Recruitment (R0)	1,092	-237	2,420
2025 Spawning output	446,448	-228,960	1,121,856
2025 Fraction Unfished	0.873	0.615	1.130
Reference Points Based SO40%	—	—	—
Proxy Spawning output SO40%	204,611	-46,586	455,808
SPR Resulting in SO40%	0.458	0.458	0.458
Exploitation Rate Resulting in SO40%	0.024	0.023	0.025
Yield with SPR Based On SO40% (mt)	553	-119	1,224
Reference Points Based on SPR Proxy for MSY	—	—	—
Proxy Spawning output (SPR50)	228,220	-51,961	508,401
SPR50	0.500	—	—
Exploitation Rate Corresponding to SPR50	0.021	0.021	0.022
Yield with SPR50 at SO SPR (mt)	526	-113	1,165
Reference Points Based on Estimated MSY Values	—	—	—
Spawning output at MSY (SO MSY)	135,603	-31,094	302,300
SPR MSY	0.337	0.334	0.339
Exploitation Rate Corresponding to SPR MSY	0.036	0.035	0.037
MSY (mt)	592	-127	1,311

## 1.6 Management Performance

Although catch increased substantially in 2017, it has still been well below the overfishing limit, allowable biological catch, and annual catch limit (Table 5). Attainment of the OFL has averaged around 50% since the increase in landings, and was even lower in prior years.

Table 5: Recent trend in the overfishing limits (OFL), the acceptable biological catches (ABCs), the annual catch limits (ACLs), and the total dead catch (landings + discards) all in metric tons (mt).

Year	OFL (mt)	ABC (mt)	ACL (mt)	Total dead catch (mt)
2015	NA	NA	NA	132.09211
2016	NA	NA	NA	148.95011
2017	NA	NA	NA	156.01664
2018	NA	NA	NA	241.51647
2019	NA	NA	NA	226.59244
2020	NA	NA	NA	106.07466
2021	NA	NA	NA	92.76237
2022	NA	NA	NA	117.42518
2023	NA	NA	NA	97.62859
2024	NA	NA	NA	118.93545

### 1.7 Evaluation of Scientific Uncertainty

The largest uncertainty in this model is the inability to fit a marked increase in the bottom trawl survey from 2014-2019. This coincides with an increase in catch-per-unit-effort from the midwater trawl fishery (which accounts for the majority of landings). The increase is likely due to the record 2008 year class, but the estimated size of the year class does not lead to a large enough increase to fit the survey index, and it is especially hard to fit the sudden decrease and then flattening of the index, given the estimated natural mortality rate and that catches were relatively stable from 2017-2024. The current assessment estimates that the stock is more depleted than it was in 2017, the time of the last assessment, which is likely the case. The magnitude of that difference is more uncertain.

### 1.8 Harvest Projections and Decision Tables

Projections of the overfishing limit, acceptable biological catch, and annual catch limit, all based on a  $P^*$  of 0.45 and a log-space standard deviation of the overfishing limit of 0.5 are included in Table 6. Assumed catches for 2025 and 2026 for this projection were provided by the Groundfish Management Team, and catches from 2027 onward assume full attainment of the acceptable biological catch.

Table 6: Potential OFLs (mt), ABCs (mt), ACLs (mt), the buffer between the OFL and ABC, estimated spawning output, and fraction unfished with adopted OFLs and ACLs and assumed catch for the first two years of the projection period.

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning output
2025	—	—	968	—	—	—	—	446,448.000
2026	—	—	955	—	—	—	—	438,543.000
2027	—	—	—	942	0.935	880	880	431,142.000
2028	—	—	—	930	0.930	865	865	424,827.000
2029	—	—	—	919	0.926	851	851	418,849.000
2030	—	—	—	908	0.922	837	837	413,148.000
2031	—	—	—	897	0.917	823	823	407,687.000
2032	—	—	—	886	0.913	809	809	402,434.000
2033	—	—	—	876	0.909	796	796	397,334.000
2034	—	—	—	865	0.904	782	782	392,344.000
2035	—	—	—	854	0.900	769	769	387,440.000
2036	—	—	—	843	0.896	756	756	382,597.000

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##/ tbl-pos: H

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#  list(mod_low_B, mod_base_B, mod_high_B),
#  list(mod_low_C, mod_base_C, mod_high_C)
#
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## 1.9 Unresolved Problems and Major Uncertainties

Test G

## 1.10 Research and Data Needs

Test H



## 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 5). 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 6). 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 7). 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, juveniles 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 40° 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 (?) 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 led 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 northern minor slope rockfish complex is provided in Table (?) (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 sources were evaluated within this assessment. Data sources included in the assessment model are summarized in Figure 8. Description of each data source used in the model is provided below.

### 2.1 Fishery-dependent data

Rougheye/Blackspotted Rockfishes are not 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 and shrimp trawl. Recreational catch is inconsequential and not accounted for in this assessment.

Fishery depended data for Rougheye/Blackspotted Rockfishes in this assessment are divided among six fleets, which include:

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

For description and details on fleet structure, please refer to Section ??.

#### 2.1.1 Commercial Fishery Landings

Recent and historical fisheries landings were compiled by state and then combined into the fishing fleets used in the assessment. Time series of landings by fleet and state are reported in Table X. Time series of fisheries catches by fleet are shown in Figure 9.

##### 2.1.1.1 Recent landings

Recent commercial landings of Rougheye/Blackspotted Rockfishes (2000-2024 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 24, 2025.



### 2.1.1.2 Historical Landings

Historical landings of Rougheye/Blackspotted Rockfishes were reconstructed by state, by year (Table X).

The Washington historical landings (1889–2000) of Rougheye/Blackspotted Rockfishes were provided by Washington Department of Fish and Wildlife (WDFW), who recently conducted historical catch reconstruction for rockfish species including Rough-eye/Blackspotted Rockfishes (pers. comm. T. Tsou, WDFW). The three main sources used in this reconstruction included the US Fish Commission Report (UFSC), Washington Bound Volumes, and Washington Statistical Bulletin (SpeciesSumOutput2\_2017.csv-ADD TABLE). The historical species composition was based on the various historical reports and interviews of fishermen and dockside samplers. The 1981 to 2000 landings are provided by WDFW as well (rather than obtained from PacFIN), since those landings are derived by WDFW via a improved method for apportioning out unidentified rockfish (URCK) category in fish tickets to the species level. This improved approach relaxed the borrowing rules for missing data used in the WDFW species allocation algorithm that feeds into PacFIN (pers. comm. T. Tsou, WDFW). 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 (ODFW) in collaboration with NWFSC (Karnowski, Gertseva, and Stephens (2014)). The Oregon landings for the period between 1987 and 1999 were also provided by the ODFW. For that peios, Oregon PacFIN landings were supplemented with the additional estimates of Rougheye/Blackspotted Rockfishes landings reported within unspecified rockfish market categories, (i.e., URCK and POP1; (?)).

The California historical landings were informed by several sources. Landings from the most recent “historical” period (between 1969 and 1980) were obtained from the California Cooperative Survey (CalCOM) database. Earlier landing records (between 1931 and 1968) were informed by the rockfish historical catch reconstruction conducted by the NOAA’s Southwest Fisheries Science Center (Ralston et al. (2010)).

Comparison of Rougheye/Blackspotted Rockfishes historical landings by state and fleet between this and 2013 assessment is provided in Figure 10. The largest differences in this assessment from 2013 model are in Washington landings (Figure 13), 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 11 and Figure 12), with the exception of 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 fleet 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 Rockfishes in the unspecified rockfish market categories (see details above).

The update in historical changes shows only minor differences in model outputs (Figure 16; Figure 17).

#### 2.1.1.3 Bycatch in the foreign POP fishery

Between mid-1960s and mid-1970s, foreign trawl fleets from the former Soviet Union, Japan, Poland, Bulgaria and East Germany targeted aggregations of Pacific ocean perch in the Northeast Pacific Ocean, in the waters off the U.S. West Coast (Love et al., 2002). Rogers (2003) estimated removals of rockfish species caught within this foreign POP fishery, including removals of Rougheye/Blackspotted Rockfishes. In the assessment, Rougheye/Blackspotted Rockfishes bycatch in the foreign POP fishery between 1966 and 1976 as estimated by Rogers (2003) were added to commercial bottom trawl fleet.

#### 2.1.1.4 At-Sea Hake Catches

Rougheye/Blackspotted Rockfishes has long been bycaught in the fishery for the coastal population of Pacific hake, which is almost exclusively conducted with mid-water trawls.

Large-scale harvesting of Pacific hake in the United States began in late-1960s, when factory trawlers from the Soviet Union and other countries began targeting this stock. After the 200-mile U.S. Exclusive Economic Zone was declared in 1977, a Joint-Venture fishery was initiated between United States trawlers and Soviet factory trawlers acting as mother-ships (larger, slower ships for fish processing and storage while at sea). By 1989 the U.S. fleet capacity had grown to a level sufficient to harvest the entire quota, and no further foreign fishing was allowed. The Pacific hake fishery is currently 100% observed by the at-sea hake observer program (A-SHOP) and data on bycatch species, including Rougheye/Blackspotted Rockfishes, is being routinely collected.

Annual amounts of Rougheye/Blackspotted Rockfishes bycatch (retained and discarded) in the Pacific hake fishery were obtained from the North Pacific Database Program (NORPAC). That time series covers the period between 1977 and 2024 and include catches by foreign and domestic fisheries as well as removals during the time of Joint Ventures (JV). Rougheye/Blackspotted Rockfishes catches within the at-sea hake fishery were treated in the model as a separate fleet.

## 2.1.2 Discards

### 2.1.2.1 Historical discard

Historically, little to no discarding was observed for Rougheye/Blackspotted Rockfishes.

The historical discard information comes from Pikitch et al. (1988), and often referred to as the Pikitch study. The Pikitch study was conducted between 1985 and 1987 between 48°42' and 42°60' N. latitude, which is primarily within the Columbia INPFC area (Pikitch et al. 1988). Participation in the study was voluntary and included vessels using bottom, midwater and shrimp trawl gears. Observers of normal fishing operations on commercial vessels collected the data, estimated the total weight of the catch by tow, and recorded the weight of species retained and discarded in the sample.

There are no midwater trawl records of Rougheye/Blackspotted Rockfishes in the Pikitch study, and only few fish records of bottom trawl catches, based on which discard rate (discard weight over total weight) for bottom trawl was just 0.09%. Therefore, no historical discard was assumed in the model.

### 2.1.2.2 Recent Discard

With the introduction of trip limits for rockfish in early 2000, limited discard has been observed for Rougheye/Blackspotted Rockfishes in bottom trawl and non-trawl fisheries.

In 2002, the West Coast Groundfish Observer Program (WCGOP) was implemented on the West Coast of the United States, which began with gathering bycatch and discard information for the limited entry trawl and fixed gear fleets. Observer coverage has expanded to include the California halibut trawl, the nearshore fixed gear and pink shrimp trawl fisheries. Since 2011, trawl fisheries have been managed with catch shares under a system of annual individual fishing quotas (IFQs) for the shoreside sector (i.e., vessels delivering to shoreside processors) and harvest cooperatives for the at-sea hake sectors (catcher-processors who catch and process hake at sea; and Motherships, factory processors that take delivery of hake from catcher vessels at sea). Constant monitoring of catch using observers or electronic monitoring (EM) is required to participate in the trawl catch share fishery.

The discard amounts of Rougheye/Blackspotted Rockfishes for the period between 2002 and 2023 were obtained from WCGOP by year and fleet (bottom trawl, mid-water trawl and non-trawl), for both the catch share and the non-catch share sector. The discarding amounts of Rougheye/Blackspotted Rockfishes within bottom trawl and non-trawl fleets were included in the model as separate fleets.

Mid-water trawl discard was not present in non-catch share sector and was extremely minimal (virtually non-existing) in catch-share sector, with discard amounts averaging to 10kg per year. Therefore, in the model, no discard was assumed for mid-water trawl fleet.

#### 2.1.2.2.1 Bottom Trawl Discard

Bottom trawl discard amounts by year are provided in Table XX. Prior to 2011, before the start of the catch share program, the discard of Rougheye/Blackspotted Rockfishes ranged between 1 metric ton and 60 metric tons, averaging at 23 metric tons a year. After 2011, the discard has been very low, not exceeding 0.5 metric ton a year. No discard data were available for 2024, and we used the average discard amount for 2019 - 2023 period to approximate 2024 discards for bottom trawl discard fleet.

#### 2.1.2.2.2 Non-Trawl Discard

Non-trawl discard amounts by year are provided in Table XX. Non-trawl discard of Rougheye/Blackspotted Rockfishes were made in both catch share and non-catch share sectors. Discard amounts in these sectors were combined by year to represent total discard within the fleet. The discards within this fleet ranged between 0.5 metric ton and 35 metric tons, with 10 metric tons as average per year. No discard data were available for 2024, and the 2023 discard amount was assumed for 2024 for non-trawl discard fleet.

### 2.1.3 Fishery Length and Age Data

Length bins from 10 to 80 cm in 2 cm increments were used to summarize the length frequency of the catches in each year. The first length bin includes all observations less than 10 cm and the last bin includes all fish 80 cm and longer. Age distributions included bins from age 1 to age 100, with the first bin including all fish ages 0 and 1 and the last bin including all fish age 100 and above.

#### 2.1.3.1 Commercial Landings Length and Ages

The fishery length and age data for bottom trawl, non-trawl and midwater trawl fleets, based on samples collected by port samplers, were obtained from the PacFIN Biological Data System (BDS) database and extracted on April 24, 2025. The number of trips and fish sampled for lengths and ages by fleet and year are summarized in Tables XX-XX.

Commercial length-frequency distributions were developed for each fleet and year, for which observations were available (Figure). Females and males distributions were treated separately, to track sex-specific differences. For each fleet, the raw observations were expanded to the trip level, to account for differences in samples sizes relative catch weights among trips (first stage expansion). The expanded length observations were then further expanded to state level, to account for differences in sampling intensity of Rougheye/Blackspotted Rockfishes landings among states combined into a single fleet (second stage expansion). The expansion algorithm can be illustrated with the following equation:

$$N_{b,j,y} = \sum_{s=1}^{s=k} \sum_{t=1}^{t=n} L_{b,j,t} \cdot \left( \frac{LC_t}{SC_t} \right) \cdot \left( \frac{LC_{s,y}}{SC_{s,y}} \right)$$

Where  $N_{b,j,y}$  is the number of lengths in each length bin ( $b$ ) by sex ( $j$ ) and year ( $y$ ) within each fleet.  $L_{b,j,t}$  represents an individual length sample by bin ( $b$ ) and sex ( $j$ ) within an individual fishing trip ( $t$ ). In the first stage expansion,  $L_{b,j,t}$  was multiplied by the ratio of landed catch ( $LC_t$ ) within that trip ( $t$ ) to a portion of catch sampled for lengths ( $SC_t$ ) within the same trip ( $t$ ). In the second stage expansion, the individual length sample ( $L_{b,j,t}$ ) was multiplied by the ratio of landed catch ( $LC_{s,y}$ ) within individual state ( $s$ ) and year ( $y$ ) to catch weights sampled for lengths ( $SC_{s,y}$ ) within the same state ( $s$ ) and year ( $y$ ). As the final step, the expanded length samples from the same size bin and sex were summed across all trips and states (combined into a single fleet) within a single year, to obtain the total number of lengths in each length bin by sex, year and fleet ( $N_{b,j,y}$ ). The same calculations were repeated for each length bin, to develop sex specific length frequencies for each fishing fleet by year.

Age distributions were included in the model as conditional-age-at-length (CAAL) observations. The marginal age-compositions were also included, but only for evaluating the implied fits, while the CAAL data were used in the likelihood. The CAAL data were not expanded and were binned according to length, age, sex, and year.

The filtering and processing of the PacFIN length and age composition data were conducted using the `pacfintools` package in R (Wetzel et al. 2025). The filtering steps included removing samples with missing vital information. Figures XX show the commercial length and age frequencies used in the model for each fleet.

The initial input values for length compositions in this assessment were calculated as a function of the number of trips and number of fish via the Stewart Method (pers.comm. I. Stewart, International Pacific Halibut Commission (IPHC)). The method is based on analysis of the input and model derived effective sample sizes from West Coast groundfish stock assessments. A piece-wise linear regression was used to estimate the increase in effective sample size per sample based on fish-per-sample and the maximum effective sample size for large numbers of individual fish. The resulting equations are:

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

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

The input sample size of CAAL data was set at the number of fish at each length by sex and by year.

#### 2.1.3.1.1 Commercial Discard Lengths

Discard length composition data for both bottom trawl and non-trawl discard fleets were available from WCGOP. Discard length composition data were not sex-specific. Discard raw length observations were expanded to the haul level, to account for differences in catch among hauls.

The initial input values for length compositions were calculated via the Stewart Method (see above).

No age data were available for discarded fish.

#### 2.1.3.1.2 At-sea hake Fishery Length and Age Compositions

The sex-specific length and age data for at-sea hake fleet were collected by the at-sea hake observer program (a-shop) and available through NORPAC database. Input sample sizes for length compositions were based on the number of hauls sampled by year.

Age distributions were included in the model as CAAL observations, binned according to length, age, sex, and year. The input sample size of CAAL data was set at the number of fish at each length by sex and by year.

The marginal age compositions were constructed, but only used in the model for evaluating the implied fits, while the CAAL data were used in the likelihood.

## 2.2 Fishery-independent data

Data from four fishery-independent surveys were used in this assessment:

- AFSC/NWFSC West Coast Triennial (every three years) Shelf survey (1980-2004)
- Alaska Fishery Science Center Slope survey (1997, 1999-2001)
- Northwest Fisheries Science Center Slope Center (1999-2002)

- West Coast Groundfish Bottom Trawl Survey (WCGBTS; 2003-2024)

Information produced by these surveys included indices of relative abundance (all four surveys), length-frequency distributions (Triennial survey and WCGBTS), and age-frequency distributions (WCGBTS).

Only the WCGBTS has new data for this assessment, but new methods were applied to all surveys to develop new indices of abundance. We used geostatistical models of biomass density to fit to survey data using spatial and spatiotemporal GLMMs with TMB or [sdmTMB](#). The method is based on a delta model. Two distributions (gamma and lognormal) were considered for the catch-rate component, but the lognormal error structure was selected for all surveys because it was shown to be able to better account for extreme catch events. Comparing the standardized versions (i.e., Z-scores, which puts all the indices on the same scale for better comparison of trends) shows very similar trends among each model output in the indices, 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, which is consistent with the known challenge of sampling these species with trawl gear. Overall, catches densities are highest in northern Oregon and Washington.

Description of each survey is provided below; information available from each survey and methods used to process the data are also discussed.

## 2.2.1 AFSC/NWFSC West Coast Triennial Shelf Survey

### 2.2.1.1 Survey Description

The triennial survey was first conducted by the AFSC in 1977 and spanned the time frame 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 spatial coverage and timing has changed over the period of survey duration (**Table X, 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 consistent depth range 55–500 meters and surveyed south to 34.5°N. In the final year of the triennial series (2004), the NWFSC conducted the survey and followed very similar protocols as the AFSC, which conducted surveys in all previous years.

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**).

Given the different depths surveyed during 1977, the data from that year were not included in this assessment. Water hauls (**Zimmermann et al. 2003**) and tows located in Canadian waters were also excluded from the analysis of this survey.

#### 2.2.1.2 Abundance Index

Geostatistical models of biomass density were fit to survey data using spatial and spatiotemporal GLMMs with TMB or [sdmTMB](#). The model used a delta model with a lognormal distribution for the catch-rate component.

A logit-link was used for encounter probability and a log-link for positive catch rates. The response variable was catch (mt) with an offset of area ( $\text{km}^2$ ) to account for differences in effort. Fixed effects were estimated for each year. The following additional covariates were included: pass. Vessel-year effects, which have traditionally been included in index standardization for this survey, were not included as the estimated variance for the random effect was close to zero. Vessel-year effects were more prominent when models did not include spatial effects and were included for each unique combination of vessel and year in the data to account for the random selection of commercial vessels used during sampling ([Helser, Punt, and Methot 2004](#); [J. T. Thorson and Ward 2014](#)).

Spatial and 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 because the positive encounters are too sparse to support the dense spatiotemporal structure.

In this assessment, the survey was analyzed as an early series (1980–1992) and a late series (1995–2004) to account for change in spatial coverage and survey timing, as has been done in many other West Coast rockfish assessments. Separate catchability parameters estimated for pre-1995 period and from 1995 forward. Separate selectivity curves were estimated for early and late survey periods.

#### 2.2.1.3 Length Compositions

Length bins from 10 to 80 cm in 2 cm increments were used to summarize the length frequency of the survey catches in each year (Figure XX). Table XX shows the number of lengths taken by the survey.

Length compositions were separated into males and females. These length compositions were expanded to account for difference in catch among tows, with further expansion based upon the stratification by depth and latitude using the `{nwfsSurvey}` package in R (?). The stratification for length data expansions are provided in Table XX.

The input sample sizes for length composition data for all fishery-independent surveys were calculated based on Stewart and Hamel (2014) as Input  $N_y = 2.43 * N_{tow}$  where the 2.43 value was estimated for a group of shelf and slope rockfish species.

There are no Rougheye/Blackspotted Rockfishes age data from the Triennial Survey.

## 2.2.2 AFSC Slope Survey

### 2.2.2.1 Survey Description

The AFSC slope survey was initiated in 1984. The survey methods are described in Lauth (2000). Prior to 1997, the survey was conducted in different latitudinal ranges each year (Table 5). In this assessment, only data from 1997, 1999, 2000 and 2001 were used – these years were consistent in latitudinal range (from 34°30' N. latitude to the U.S.-Canada border) and depth coverage (183-1280 m; 100-700 fm).

### 2.2.2.2 Abundance Index

Geostatistical models of biomass density were fit to survey data using spatial and spatiotemporal GLMMs with TMB or [sdmTMB](#). The model used a delta model with a lognormal distribution for the catch-rate component.

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 (km<sup>2</sup>) 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.



### 2.2.2.3 Length Compositions

Length bins from 10 to 80 cm in 2 cm increments were used to summarize the length frequency of the survey catches in each year (Figure XX). Table XX shows the number of lengths taken by the survey.

Length compositions were separated into males and females. These length compositions were expanded to account for difference in catch among tows, with further expansion based upon the stratification by depth and latitude using the `{nwfsSurvey}` package in R (?). The stratification for length data expansions are provided in Table XX.

The input sample sizes for length composition data for all fishery-independent surveys were calculated based on Stewart and Hamel (2014) as  $\text{Input } N_y = 2.43 * N_{tow}$  where the 2.43 value was estimated for a group of shelf and slope rockfish species.

There are no Rougheye/Blackspotted Rockfishes age data from the AFSC Slope Survey.

## 2.2.3 NWFSC Slope Survey

### 2.2.3.1 Survey Description

The NWFSC slope survey was conducted annually from 1999 to 2002. The survey's design and sampling methods are described in Keller et al.(2007). The surveyed area ranged between 34°50' and 48°07' N. latitude, encompassing the U.S. Vancouver, Columbia, Eureka, Monterey INPFC areas, and a portion of the Conception area, and consistently covered depths from 100 to 700 fm (183-1280 m) (Table XX).

### 2.2.3.2 Abundance Index

Geostatistical models of biomass density were fit to survey data using spatial and spatiotemporal GLMMs with TMB or [sdmTMB](#). The model used a delta model with a lognormal distribution for the catch-rate component.

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.

There are no Rougheye/Blackspotted Rockfishes length and age data from the NWFSC Slope Survey. Given that spatial coverage of NWFSC Slope Survey is the same of AFSC Slope Survey, selectivity of the NWFSC Slope Survey was assumed the same as selectivity of AFSC Slope Survey (mirrored in the model).

## 2.2.4 NWFSC West Coast Groundfish Bottom Trawl Survey

### 2.2.4.1 Survey Description

The West Coast Groundfish Bottom Trawl Survey (WCGBTS) is conducted annually since 2003 (Table XX). The survey's design and sampling methods are most recently described in Bradburn, Keller, and Horness (2011). The survey is based on a random-grid design, covering the coastal waters from a depth of 100 to 700 fm (183-1280 m). This design generally uses four industry-chartered vessels per year assigned to a roughly equal number of randomly selected grid cells and divided into two 'passes' of the coast. Two vessels fish from north to south during each pass between late May to early October. This design therefore incorporates both vessel-to-vessel differences in catchability, as well as variance associated with selecting a relatively small number (approximately 700) of possible cells from a very large set of possible cells spread from the Mexican to the Canadian borders.

### 2.2.4.2 Abundance Index

Geostatistical models of biomass density were fit to survey data using spatial and spatiotemporal GLMMs with TMB or [sdmTMB](#)([Kristensen et al. 2016](#)) via the R package [Species Distribution Models with Template Model Builder \(sdmTMB\)](#) ([Anderson et al. 2022](#)).. The model used a delta model with a lognormal distribution for the catch-rate component.

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 (km<sup>2</sup>) 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.

The data were truncated to depths less than 675 m prior to modeling given that there were zero positive encounters in depths deeper than 675 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 model used a delta model with a lognormal distribution for the catch-rate component. The model used a delta model with a lognormal distribution for the catch-rate component. A logit-link was used for encounter probability and a log-link for positive catch rates. The response variable was catch (mt) with an offset of area ( $\text{km}^2$ ) to account for differences in effort. Fixed effects were estimated for each year. The following additional covariates were included: pass. Vessel-year effects, which have traditionally been included in index standardization for this survey, were not included as the estimated variance for the random effect was close to zero. Vessel-year effects were more prominent when models did not include spatial effects and were included for each unique combination of vessel and year in the data to account for the random selection of commercial vessels used during sampling (Helser, Punt, and Methot 2004; J. T. Thorson and Ward 2014).

Spatial and spatiotemporal variation was included in the encounter probability and the positive catch rate model. Spatial variation was approximated using 500 knots, where more knots led to non-estimable standard errors because the positive encounters are too sparse to support the dense spatiotemporal structure.

The estimated distribution of Rougheye/Blackspotted Rockfishes density for 2004 is shown in Figure ??.

#### 2.2.4.3 Length and Age compositions

Length bins from 10 to 80 cm in 2 cm increments were used to summarize the length frequency of the survey catches in each year (Figure XX). Table XX shows the number of lengths taken by the survey.

Length compositions were separated into males and females. These length compositions were expanded to account for difference in catch among tows, with further expansion based upon the stratification by depth and latitude using the `{nwfsSurvey}` package in R (?). The stratification for length data expansions are provided in Table XX.

The input sample sizes for length composition data were calculated based on Stewart

and Hamel (2014) as Input  $N_y = 2.43 * N_{tow}$  where the 2.43 value was estimated for a group of shelf and slope rockfish species.

Age distributions included bins from age 1 to age 100, with the last bin including all fish of greater age. Table XX shows the number of ages taken by the survey. Age distributions were included in the model as CAAL observations. The marginal age compositions were only used for comparing the implied fits, while the CAAL data were used in the likelihood. The CAAL data were not expanded and were binned according to length, age, sex, and year.

The input sample size of CAAL data was set at the number of fish at each length by sex and by year.

### 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 18 and Figure 19 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 19).

#### 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 (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. Cope and Hamel (2022) ([The Natural Mortality Tool](#)) provide the most up-to-date examination of the relationship between maximum age and natural mortality

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

where  $M$  is natural mortality and  $A_{\max}$  is the assumed maximum age. The prior is defined as a lognormal distribution with mean  $\ln(5.4/A_{\max})$  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 20).

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 21). 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 by 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 22) and 80 (Figure 23) 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 seem 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 Growth (Length-at-Age)

Age and length data are used to estimate important growth parameters. Figure 24 has the currently available age and length data. Female and male sample sizes are very similar. Estimated growth curves are also presented in Figure 24 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 ( $L_\infty$ ) is estimated notably higher from the PacFIN data, though male estimates of  $L_\infty$  are similar across the data sets. The overall externally derived estimates of female and male Rougheye/Blackspotted Rockfishes are

$$\text{Females } L_\infty = 59.03 \text{ cm; } k = 0.07; t_0 = -2.45$$

$$\text{Males } L_\infty = 56.69 \text{ cm; } k = 0.08; t_0 = -2.03$$

The coefficient of variation (CV) of length by age and sex are shown in Figure 25. 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 ( $L_\infty$ ,  $k$ ,  $t_0$ , 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  $L_\infty = 51.43$ ,  $k = 0.06$  and  $t_0 = -3.30$  and  $L_\infty = 54.2$  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. Figure 26 shows which reader assignments are given to each year of ages by data source. 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 27 and Figure 28 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 29).

The resultant sex-specific length-weight relationships are given in Figure 30, 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 30).

### 2.3.5 Maturity

Maturity for the Rougheye/Blackspotted Rockfish complex was estimated using 473 maturity samples collected from 2015 to 2024 on gls{odfw} and gls{wdfw} surveys and the gls{indexwc} in California, Oregon, and Washington waters (M. Head, pers. comm.). The samples included 194 samples genetically assigned as Rougheye Rockfish, 71 samples genetically assigned as Blackspotted Rockfish, and 208 samples with no genetic assignment. The maturity schedule was assumed to be length-based, as in the 2013 benchmark assessment. This assessment used the functional classification of



maturity to describe the maturity schedule, which not only identifies the individuals that are physiologically capable of producing yolk (those that are biologically mature), but also accounts for the occurrence of abortive maturation and skipped spawning, so the functional maturity classification is a more accurate representation of the individuals that may actually spawn in a given year. This is a difference from the 2013 benchmark assessment, which did not explicitly estimate functional maturity, and instead assumed the biological classification of maturity.

Biological maturity and functional maturity observations were fitted in separate models. Biological maturity and functional maturity status observations (0 = immature and 1 = mature) were fitted in a logistic regression model (glm R function, family = binomial, link = "logit"). The estimated model parameters were used to calculate length at 50% maturity (L50%; **Table XXX table Melissa provided**) and maturity ogives (**Fig. XXX figure Melissa provided, the one comparing biological and functional maturity**). The delta method was used to calculate 95% confidence intervals of L50% estimates. The estimated L50% (functional maturity; L50%fxn) was 46.53 cm and the estimated slope of the maturity oogive was 0.25. Sensitivities were run using the estimate of biological maturity and the maturity estimate used in the 2013 benchmark assessment. There was little evidence of skipped spawning, so we did not explore fitting the data with a spline model.

Because there are known life history differences between Rougheye Rockfish and Blackspotted Rockfish, maturity was also estimated for each species, using the samples that were genetically assigned to each species, respectively, using the same methods as above (**Table XXX table Melissa provided and Figure XXX figure Melissa provided, the one comparing overall functional maturity at length and for the two species**). Two sensitivities were run using the functional maturity L50% (and slope) estimated for 1) Rougheye Rockfish and 2) Blackspotted Rockfish (which mature at larger sizes on average than Rougheye Rockfish).

Sensitivities were run using functional age at 50% maturity estimate for the species complex ( $n = 372$ ) and for each species separately. Age at 50% maturity was estimated using the same methods as for length at 50% maturity (**Table XXX table Melissa provided and Figure XXX figure Melissa provided, the one comparing overall functional maturity at age and for the two species**).

### 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  $a = 6.538\text{e-}06$  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 Rough-eye/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.

### 3 Assessment

#### 3.1 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.

#### 3.2 Most Recent STAR Panel Recommendations

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

##### 3.2.1 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.*

### 3.2.2 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.*

### 3.3 Response to SSC Groundfish Subcommittee Recommendations

### 3.4 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.

### 3.5 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 31) and scale (Figure 32) 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 output differences due to the choice of the SS3 version.

### 3.6 Model Structure, Evaluation, and Specification

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

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), while avoiding hard to diagnose issues that come from estimating retention curves.
- 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 33 and Figure 34), regardless of the selectivity form being assumed for the discard fleets. This provides evidence moving to using discard fleets will not induce *a priori* 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 consider logistic and dome-shaped selectivity options during reference model development.

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 (WCG BTS; 2003-2024)

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

### 3.6.2 Model Likelihood Components

There are five primary likelihood components for each assessment model:

1. Fit to length composition samples.
2. Fit to age composition samples (all fit as conditional age-at-length).
3. Fit to survey indices of abundance.
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 an indication that the model has been misspecified, so this likelihood contribution should always be 0.

### 3.6.3 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 risk neutral 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. To achieve the above goals, the model contains uses different data types and sources to estimate reality, but relies on simplifying assumptions when the data are not informative to parameters. A series of investigative model runs were done to achieve the final reference model. Constructing integrated models (i.e., those fitting many data types) takes considerable model exploration using different configurations of the following treatments:

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

Regarding data types, different biological data (i.e., length and/or age composition) 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 fixed life history values (growth fixed to external estimates, natural mortality assume the reference model values) and constant catch over the entire time series, while estimating the selectivity of each fleet. Under this constraint, the lengths suggest a stock status lower than the reference model, while the ages consider the stock is less depleted than supported by the ages (with no ageing error), and more similar to the reference model. Adding ageing error, 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 additional survey variance, and for which survey?
- Logistic or dome-shaped selectivity?
- Estimate or fix selectivity parameters

All growth parameters were estimable and did not change across the large majority of explored model scenarios, so they were estimated in the reference model. Natural mortality ( $M$ ) was not estimable for both sexes. When attempted, both values were estimated at values that caused the scale to approach the higher end of reasonable values, and thus not a risk neutral option. In order to balance model fit and reality, a likelihood profile was conducted on natural mortality for males (females  $M$  being estimated) in order to find the lowest supported (i.e., within 2 negative log likelihood units) by the data male  $M$  value. The profile shows conflicting information in the data, where lengths support higher natural mortality values and ages support lower natural mortality (Figure 35). It is expected that ages would be more informative to natural mortality, which encourages considering just the age component likelihood. Most of the age components are not well informed for natural mortality, though the at-sea-hake fishery sampled age data does seem to be informative. This fishery has a logisitic selectivity, thus obtaining large and old individuals. Using this component likelihood, the value of 0.036 for male  $M$  is the lowest value supported. The reference model this fixes male  $M$  to this value and estimates female  $M$ . Length-at-maturity, fecundity-weight, and length-weight relationship were all fixed, as is the only treatment option in SS3.

For recruitment, steepness ( $h$ ) was not estimable and was fixed to the rockfish prior of 0.72. Recruitment variability was set at 0.5 and checked for consistency with the calculated recruitment variability in the model. Recruitment deviations were estimated as a deviation not constrained to sum to 0, and initially estimated for the full time series. If the full time series was not estimated, the scale and status of the stock increased to unrealistically high levels, so the full time series estimation was retained. Given the



longevity of these species, information on recruitment going deeper into the time series is not unreasonable.

The selectivity of all fisheries and surveys were estimated either as logistic or dome-shaped selectivity. Blocks were also added as described in the data section. In the attempt to fit the biological data, it was found that bottom trawl fisheries, just as the trawl surveys were treated, only fit the data if the selectivity was domed. All fisheries that had final dome-shaped selectivity were given the flexibility to be logistic if it led to a better fit. The midwater, at-sea-hake and the final block of the non-trawl fisheries all required logistic selectivity to fit the data. The use of dome-shaped selectivity for the bottom trawl was a major difference from the previous stock assessment. The choice of selectivity for the bottom trawl survey changed the scale and status of the stock and therefore a major source of sensitivity.

The full list of estimate and fixed parameters are found in Table 12.

The biggest uncertainty was in the treatment of sex-specific  $M$  and the selectivity of the bottom trawl fishery. The combination of these two sources covered the extent of all other sources of uncertainty observed and presented in the “Characterizing uncertainty” section of the document. The parameters uncertainty is different than the uncertainty derived from data treatment, such as ageing error and data-weighting. While these issues cause large uncertainty in stock scale and status estimates, the choice of treatments are based on the common challenge of balancing information content (i.e., what should the data be informing in the stock assessment) in the data within an integrated statistical frameworks. Those explorations are also provided in the “Characterizing uncertainty” section.

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 noted above.

Sensitivity scenarios and likelihood profiles (on  $\ln R_0$ , steepness, and natural mortality) were used to explore uncertainty in the above model specifications and are reported in the “Characterizing uncertainty” section.

### 3.6.4 Data Weighting

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.

The ability to estimate additional variance for indices allows the model to balance model fit to that data while acknowledging that variances may be underestimated in the index standardization. Given the large inputted variances and the limited contrast in the index trends did not require the consideration of further variance estimation. Removal of the index data was explored to demonstrate the limited influence of this data in the model.

### 3.6.5 Model Changes from the Last Assessment

The biggest changes to the 2013 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, which allows for sex-specific estimation of natural mortality and growth.
- Updated and more ageing error matrices
- Allowing the bottom trawl fishery to have some amount of dome-shaped selectivity, consistent with the bottom trawl surveys.

### 3.7 Reference Model Diagnostics and Results

#### 3.7.1 Model Convergence and Acceptability

While there is no definitive measure of model convergence, several measures are routinely applied. These criteria include a low maximum gradient ( $9.46411 \times 10^{-4}$ ), inversion of the Hessian (passed), acceptable fits to data (passed), and reasonable parameter values (passed).

Model efficiency was explored by doing a short run Bayesian analysis using the Random Walk Metropolis with 2,000 draws, keeping all the draws and examining the fast mixing parameters. Those estimated parameters that do not move much from the initial values slow the model down and are recommended to be fixed at the starting value ([Monnahan et al. 2019](#)). No additional parameters were fixed based on this analysis (Figure 36).

An extra effort was given to ensure the model did not rest on a local likelihood minimum. This was done by starting the minimization process from dispersed parameter values away from the maximum likelihood estimates to determine if the approach found a better model fit (i.e., minimum negative log-likelihood value). Starting parameters used a jitter shift value of 0.01 and 0.05. Both jitter scenarios were repeated 100 times with 78 out of 100 (jitter 0.01) and out of 100 (jitter 0.05) runs returned to the reference model likelihood (Figure 37). Out of the combined 200 jitter runs, a better fit, lower negative log-likelihood model was not found in any of the remaining runs. The reference model did not experience convergence issues when provided reasonable starting values. Through the jittering and likelihood profiles, the present reference model represents the best fit to the data given the assumptions.

### 3.8 Base Model Results

#### 3.8.1 Fits to the Data

##### 3.8.1.1 Lengths

3.8.2 Conditional Age at Length and Marginal Ages

3.8.3 Fits to Indices of Abundance

3.9 Reference Model Outputs

3.9.1 Parameter Estimates

3.9.2 Population Trajectory

### 3.10 Characterizing uncertainty

#### 3.10.1 Sensitivity Analyses

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

##### 3.10.1.1 Data treatment sensitivities

Data treatments explored were as follows:

- Treatment of abundance indices
  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 .

##### 3.10.1.2 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.

### 3.10.2 Likelihood Profiles

### 3.10.3 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 relative 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.

#### 3.10.4 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.

## 4 Acknowledgements



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## 6 Tables

Table 7: Landings in metric tons (mt) by year for each fleet.

Year	Total (mt)	Trawl (mt)	Trawl Discard (mt)	Non-trawl (mt)	Non-trawl discard (mt)	Midwater trawl (mt)	At-sea-I
1891	0	0	0	0	0	0	0
1892	19	0	0	19	0	0	0
1893	19	0	0	19	0	0	0
1894	19	0	0	19	0	0	0
1895	5	0	0	5	0	0	0
1896	1	0	0	1	0	0	0
1897	1	0	0	1	0	0	0
1898	1	0	0	1	0	0	0
1899	1	0	0	1	0	0	0
1900	2	0	0	2	0	0	0
1901	2	0	0	2	0	0	0
1902	3	0	0	3	0	0	0
1903	3	0	0	3	0	0	0
1904	4	0	0	4	0	0	0
1905	4	0	0	4	0	0	0
1906	4	0	0	4	0	0	0
1907	5	0	0	5	0	0	0
1908	8	0	0	8	0	0	0
1909	6	0	0	6	0	0	0
1910	6	0	0	6	0	0	0
1911	7	0	0	7	0	0	0
1912	7	0	0	7	0	0	0
1913	8	0	0	8	0	0	0
1914	8	0	0	8	0	0	0
1915	10	0	0	10	0	0	0
1916	9	0	0	9	0	0	0
1917	10	0	0	10	0	0	0
1918	55	0	0	55	0	0	0
1919	26	0	0	26	0	0	0
1920	23	0	0	23	0	0	0
1921	23	0	0	23	0	0	0
1922	18	0	0	18	0	0	0
1923	20	0	0	20	0	0	0
1924	32	0	0	32	0	0	0
1925	38	0	0	38	0	0	0
1926	54	0	0	54	0	0	0
1927	69	0	0	69	0	0	0
1928	72	0	0	72	0	0	0
1929	66	0	0	66	0	0	0
1930	67	0	0	67	0	0	0
1931	44	0	0	44	0	0	0
1932	25	0	0	25	0	0	0
1933	35	0	0	35	0	0	0
1934	42	0	0	42	0	0	0
1935	34	0	0	34	0	0	0
1936	61	0	0	61	0	0	0
1937	53	0	0	53	0	0	0
1938	55	0	0	55	0	0	0
1939	28	0	0	28	0	0	0
1940	60	1	0	59	0	0	0
1941	102	1	0	101	0	0	0

Table 7: Landings in metric tons (mt) by year for each fleet. (*continued*)

Year	Total (mt)	Trawl (mt)	Trawl Discard (mt)	Non-trawl (mt)	Non-trawl discard (mt)	Midwater trawl (mt)	At-sea-I
1942	126	2	0	124	0	0	
1943	258	7	0	251	0	0	
1944	85	11	0	74	0	0	
1945	50	20	0	30	0	0	
1946	69	11	0	58	0	0	
1947	42	7	0	35	0	0	
1948	44	5	0	39	0	0	
1949	31	5	0	26	0	0	
1950	52	6	0	46	0	0	
1951	59	6	0	53	0	0	
1952	38	6	0	32	0	0	
1953	21	5	0	16	0	0	
1954	36	6	0	30	0	0	
1955	32	6	0	26	0	0	
1956	21	8	0	13	0	0	
1957	35	9	0	26	0	0	
1958	15	7	0	8	0	0	
1959	23	7	0	16	0	0	
1960	23	10	0	13	0	0	
1961	26	11	0	15	0	0	
1962	32	14	0	18	0	0	
1963	24	13	0	11	0	0	
1964	31	11	0	20	0	0	
1965	31	23	0	8	0	0	
1966	117	111	0	6	0	0	
1967	108	98	0	10	0	0	
1968	172	165	0	7	0	0	
1969	50	25	0	25	0	0	
1970	23	19	0	4	0	0	
1971	68	67	0	1	0	0	
1972	76	75	0	1	0	0	
1973	75	69	0	6	0	0	
1974	76	58	0	18	0	0	
1975	43	35	0	5	0	0	
1976	19	16	0	2	0	0	
1977	166	1	0	164	0	0	
1978	69	33	0	36	0	0	
1979	185	63	0	121	0	0	
1980	99	56	0	43	0	0	
1981	131	61	0	68	0	0	
1982	167	99	0	68	0	0	
1983	126	55	0	70	0	0	
1984	144	75	0	67	0	0	
1985	298	139	0	158	0	0	
1986	428	154	0	273	0	0	
1987	570	198	0	368	0	0	
1988	351	173	0	162	0	0	
1989	418	287	0	131	0	0	
1990	244	167	0	76	0	0	
1991	299	235	0	59	0	0	
1992	306	186	0	110	0	0	
1993	327	166	0	159	0	0	
1994	306	127	0	173	0	0	
1995	744	165	0	576	0	0	
1996	339	127	0	204	0	0	

Table 7: Landings in metric tons (mt) by year for each fleet. *(continued)*

Year	Total (mt)	Trawl (mt)	Trawl Discard (mt)	Non-trawl (mt)	Non-trawl discard (mt)	Midwater trawl (mt)	At-sea-I
1997	303	107	0	186	0	0	
1998	441	110	0	313	0	0	
1999	256	81	0	166	0	0	
2000	183	79	0	29	0	4	
2001	114	74	0	18	0	1	
2002	74	31	14	27	1	0	
2003	100	58	15	23	2	0	
2004	115	58	3	34	5	1	
2005	137	45	1	50	5	0	
2006	127	48	12	59	1	0	
2007	187	60	27	59	10	2	
2008	219	54	29	56	3	1	
2009	228	67	45	104	1	2	
2010	263	79	60	71	25	6	
2011	210	53	0	63	9	4	
2012	244	47	0	74	20	49	
2013	156	64	0	59	12	3	
2014	91	34	0	37	10	4	
2015	133	31	0	47	14	19	
2016	150	31	0	60	13	16	
2017	155	22	0	59	34	2	
2018	242	16	0	47	15	3	
2019	226	22	0	39	31	9	
2020	106	10	0	24	1	29	
2021	92	10	0	21	2	21	
2022	118	12	0	19	3	19	
2023	96	13	0	19	0	26	
2024	118	10	0	10	0	69	

Table 8: Recent trend in the overfishing limits (OFL), the acceptable biological catches (ABCs), the annual catch limits (ACLs), and the total catch all in metric tons (mt).

Year	OFL (mt)	ABC (mt)	ACL (mt)	Catch (mt)
2015	NA	NA	NA	132
2016	NA	NA	NA	149
2017	NA	NA	NA	156
2018	NA	NA	NA	242
2019	NA	NA	NA	227
2020	NA	NA	NA	106
2021	NA	NA	NA	93
2022	NA	NA	NA	117
2023	NA	NA	NA	98
2024	NA	NA	NA	119



```
#“{r, results = “asis”} ##| label: tbl-area-spex ##| warning: false ##| echo: false
##| tbl-cap: “Adopted coastwide OFL (mt) and ABC (mt) values and the area-based
ACL (mt) north and south of 36 N. latitude by year.” ##| tbl-pos: H
```

```
#area_management_table |> # gt::gt() |> # gt::fmt_number( # columns = c(2:5), #
decimals = 0 # ) |> # gt::tab_options( # table.font.size = 12, # latex.use_longtable =
TRUE # ) |> # gt::as_latex()
```

```
#““
```

Table 9: Specifications and structure of the model.

Section	Configuration
Maximum age	140
Sexes	Females, males
Population bins	4-84 cm by 2 cm bins
Summary biomass (mt) age	3+
Number of areas	1
Number of seasons	1
Number of growth patterns	1
Start year	1892
End year	2024
Data length bins	10-80 cm by 2 cm bins
Data age bins	1-100 by 1 year

Table 10: Estimated parameters in the model.

Type	Count
Natural Mortality (M)	1
M time-variation	0
Growth mean	6
Growth variability	4
Growth time-variation	0
Stock-recruit	1
Stock-recruit variation	0
Rec. dev. time series	133
Rec. dev. initial age	0
Rec. dev. forecast	12
Index	1
Index time-variation	1
Size selectivity	30
Size selectivity time-variation	24
Retention	0
Retention time-variation	0
Age selectivity	0
Age selectivity time-variation	0

Table 11: Likelihood components by source.

Label	Total
TOTAL	7,334.0
Catch	0.0
Equil catch	0.0
Survey	-26.8
Length comp	574.8
Age comp	6,783.5
Recruitment	2.3
InitEQ Regime	0.0
Forecast Recruitment	0.0
Parm priors	0.1
Parm softbounds	0.0
Parm devs	0.0
Crash Pen	0.0

Table 12: Parameter estimates, estimation phase, parameter bounds, estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model.

Label	Value	Phase Bounds	Status	SD	Prior
NatM_uniform_Fem_GP_1	0.0391	1 (0.001, 0.2)	ok	0.000835	lognormal(0.034, 0.310)
L_at_Amin_Fem_GP_1	-3.1	2 (-100, 25)	ok	0.621	none
L_at_Amax_Fem_GP_1	60.1	2 (40, 90)	ok	0.351	none
VonBert_K_Fem_GP_1	0.0786	2 (0.01, 0.15)	ok	0.00179	none
CV_young_Fem_GP_1	0.0513	2 (1e-06, 1)	ok	0.0143	none
CV_old_Fem_GP_1	0.0936	2 (1e-06, 1)	ok	0.00305	none
Wtlen_1_Fem_GP_1	8.78e-06	-3 (-3, 3)	fixed	0	none
Wtlen_2_Fem_GP_1	3.15	-3 (-3, 4)	fixed	0	none
Mat50%_Fem_GP_1	46.5	-3 (1, 60)	fixed	0	none
Mat_slope_Fem_GP_1	-0.254	-3 (-30, 3)	fixed	0	none
Eggs_scalar_Fem_GP_1	6.54e-06	-3 (-3, 3)	fixed	0	none
Eggs_exp_len_Fem_GP_1	4.04	-3 (-3, 5)	fixed	0	none
NatM_uniform_Mal_GP_1	0.036	-2 (0.001, 0.2)	fixed	0	lognormal(0.034, 0.310)
L_at_Amin_Mal_GP_1	-2.68	2 (-100, 25)	ok	1.05	none
L_at_Amax_Mal_GP_1	57.8	2 (40, 90)	ok	0.315	none
VonBert_K_Mal_GP_1	0.0837	2 (0.01, 0.15)	ok	0.00253	none
CV_young_Mal_GP_1	0.0911	2 (1e-06, 1)	ok	0.0197	none
CV_old_Mal_GP_1	0.085	2 (1e-06, 1)	ok	0.00296	none
Wtlen_1_Mal_GP_1	1.18e-05	-3 (-3, 3)	fixed	0	none
Wtlen_2_Mal_GP_1	3.07	-3 (-3, 4)	fixed	0	none
CohortGrowDev	1	-4 (0, 1)	fixed	0	none
FracFemale_GP_1	0.5	-5 (1e-06, 1)	fixed	0	none
SR_LN(R0)	7	1 (1, 15)	ok	0.621	none
SR_BH_steep	0.72	-3 (0.25, 0.99)	fixed	0	beta(0.718, 0.152)
SR_sigmaR	0.5	-4 (0, 2)	fixed	0	none

Label	Value	Phase Bounds	Status	SD	Prior
SR_regime	0	-4 (-5, 5)	fixed	0	none
SR_autocorr	0	-99 (0, 0)	fixed	0	none
Main_RecrDev_1892	-0.0795	1 (-5, 5)	dev	0.481	normal(0.00, 0.50)
Main_RecrDev_1893	-0.0812	1 (-5, 5)	dev	0.48	normal(0.00, 0.50)
Main_RecrDev_1894	-0.0829	1 (-5, 5)	dev	0.48	normal(0.00, 0.50)
Main_RecrDev_1895	-0.0846	1 (-5, 5)	dev	0.48	normal(0.00, 0.50)
Main_RecrDev_1896	-0.0862	1 (-5, 5)	dev	0.479	normal(0.00, 0.50)
Main_RecrDev_1897	-0.0878	1 (-5, 5)	dev	0.479	normal(0.00, 0.50)
Main_RecrDev_1898	-0.0893	1 (-5, 5)	dev	0.479	normal(0.00, 0.50)
Main_RecrDev_1899	-0.0908	1 (-5, 5)	dev	0.478	normal(0.00, 0.50)
Main_RecrDev_1900	-0.0922	1 (-5, 5)	dev	0.478	normal(0.00, 0.50)
Main_RecrDev_1901	-0.0934	1 (-5, 5)	dev	0.478	normal(0.00, 0.50)
Main_RecrDev_1902	-0.0946	1 (-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1903	-0.0957	1 (-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1904	-0.0967	1 (-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1905	-0.0975	1 (-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1906	-0.0982	1 (-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1907	-0.0988	1 (-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1908	-0.0991	1 (-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1909	-0.0993	1 (-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1910	-0.0993	1 (-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1911	-0.0991	1 (-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1912	-0.0986	1 (-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1913	-0.098	1 (-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1914	-0.0971	1 (-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1915	-0.0959	1 (-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1916	-0.0945	1 (-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1917	-0.0927	1 (-5, 5)	dev	0.477	normal(0.00, 0.50)

Label	Value	Phase Bounds	Status	SD	Prior
Main_RecrDev_1918	-0.0907	1 (-5, 5)	dev	0.478	normal(0.00, 0.50)
Main_RecrDev_1919	-0.0884	1 (-5, 5)	dev	0.478	normal(0.00, 0.50)
Main_RecrDev_1920	-0.0857	1 (-5, 5)	dev	0.479	normal(0.00, 0.50)
Main_RecrDev_1921	-0.0828	1 (-5, 5)	dev	0.479	normal(0.00, 0.50)
Main_RecrDev_1922	-0.0796	1 (-5, 5)	dev	0.48	normal(0.00, 0.50)
Main_RecrDev_1923	-0.0761	1 (-5, 5)	dev	0.48	normal(0.00, 0.50)
Main_RecrDev_1924	-0.0725	1 (-5, 5)	dev	0.481	normal(0.00, 0.50)
Main_RecrDev_1925	-0.0687	1 (-5, 5)	dev	0.482	normal(0.00, 0.50)
Main_RecrDev_1926	-0.0649	1 (-5, 5)	dev	0.482	normal(0.00, 0.50)
Main_RecrDev_1927	-0.0611	1 (-5, 5)	dev	0.483	normal(0.00, 0.50)
Main_RecrDev_1928	-0.0574	1 (-5, 5)	dev	0.484	normal(0.00, 0.50)
Main_RecrDev_1929	-0.0539	1 (-5, 5)	dev	0.484	normal(0.00, 0.50)
Main_RecrDev_1930	-0.0506	1 (-5, 5)	dev	0.485	normal(0.00, 0.50)
Main_RecrDev_1931	-0.0477	1 (-5, 5)	dev	0.485	normal(0.00, 0.50)
Main_RecrDev_1932	-0.0452	1 (-5, 5)	dev	0.486	normal(0.00, 0.50)
Main_RecrDev_1933	-0.0431	1 (-5, 5)	dev	0.486	normal(0.00, 0.50)
Main_RecrDev_1934	-0.0412	1 (-5, 5)	dev	0.486	normal(0.00, 0.50)
Main_RecrDev_1935	-0.0395	1 (-5, 5)	dev	0.487	normal(0.00, 0.50)
Main_RecrDev_1936	-0.0378	1 (-5, 5)	dev	0.487	normal(0.00, 0.50)
Main_RecrDev_1937	-0.036	1 (-5, 5)	dev	0.487	normal(0.00, 0.50)
Main_RecrDev_1938	-0.0338	1 (-5, 5)	dev	0.487	normal(0.00, 0.50)
Main_RecrDev_1939	-0.031	1 (-5, 5)	dev	0.488	normal(0.00, 0.50)
Main_RecrDev_1940	-0.0273	1 (-5, 5)	dev	0.489	normal(0.00, 0.50)
Main_RecrDev_1941	-0.0225	1 (-5, 5)	dev	0.49	normal(0.00, 0.50)
Main_RecrDev_1942	-0.0164	1 (-5, 5)	dev	0.491	normal(0.00, 0.50)
Main_RecrDev_1943	-0.00858	1 (-5, 5)	dev	0.493	normal(0.00, 0.50)
Main_RecrDev_1944	0.00111	1 (-5, 5)	dev	0.495	normal(0.00, 0.50)
Main_RecrDev_1945	0.0129	1 (-5, 5)	dev	0.497	normal(0.00, 0.50)

Label	Value	Phase Bounds	Status	SD	Prior
Main_RecrDev_1946	0.0271	1 (-5, 5)	dev	0.501	normal(0.00, 0.50)
Main_RecrDev_1947	0.0436	1 (-5, 5)	dev	0.504	normal(0.00, 0.50)
Main_RecrDev_1948	0.0627	1 (-5, 5)	dev	0.509	normal(0.00, 0.50)
Main_RecrDev_1949	0.0843	1 (-5, 5)	dev	0.514	normal(0.00, 0.50)
Main_RecrDev_1950	0.108	1 (-5, 5)	dev	0.521	normal(0.00, 0.50)
Main_RecrDev_1951	0.134	1 (-5, 5)	dev	0.527	normal(0.00, 0.50)
Main_RecrDev_1952	0.16	1 (-5, 5)	dev	0.535	normal(0.00, 0.50)
Main_RecrDev_1953	0.186	1 (-5, 5)	dev	0.542	normal(0.00, 0.50)
Main_RecrDev_1954	0.211	1 (-5, 5)	dev	0.549	normal(0.00, 0.50)
Main_RecrDev_1955	0.232	1 (-5, 5)	dev	0.556	normal(0.00, 0.50)
Main_RecrDev_1956	0.249	1 (-5, 5)	dev	0.561	normal(0.00, 0.50)
Main_RecrDev_1957	0.259	1 (-5, 5)	dev	0.564	normal(0.00, 0.50)
Main_RecrDev_1958	0.263	1 (-5, 5)	dev	0.566	normal(0.00, 0.50)
Main_RecrDev_1959	0.262	1 (-5, 5)	dev	0.565	normal(0.00, 0.50)
Main_RecrDev_1960	0.257	1 (-5, 5)	dev	0.563	normal(0.00, 0.50)
Main_RecrDev_1961	0.247	1 (-5, 5)	dev	0.559	normal(0.00, 0.50)
Main_RecrDev_1962	0.232	1 (-5, 5)	dev	0.554	normal(0.00, 0.50)
Main_RecrDev_1963	0.212	1 (-5, 5)	dev	0.547	normal(0.00, 0.50)
Main_RecrDev_1964	0.186	1 (-5, 5)	dev	0.539	normal(0.00, 0.50)
Main_RecrDev_1965	0.156	1 (-5, 5)	dev	0.53	normal(0.00, 0.50)
Main_RecrDev_1966	0.125	1 (-5, 5)	dev	0.521	normal(0.00, 0.50)
Main_RecrDev_1967	0.0968	1 (-5, 5)	dev	0.514	normal(0.00, 0.50)
Main_RecrDev_1968	0.0744	1 (-5, 5)	dev	0.507	normal(0.00, 0.50)
Main_RecrDev_1969	0.0591	1 (-5, 5)	dev	0.503	normal(0.00, 0.50)
Main_RecrDev_1970	0.0494	1 (-5, 5)	dev	0.5	normal(0.00, 0.50)
Main_RecrDev_1971	0.042	1 (-5, 5)	dev	0.497	normal(0.00, 0.50)
Main_RecrDev_1972	0.0361	1 (-5, 5)	dev	0.495	normal(0.00, 0.50)
Main_RecrDev_1973	0.0352	1 (-5, 5)	dev	0.493	normal(0.00, 0.50)

Label	Value	Phase Bounds	Status	SD	Prior
Main_RecrDev_1974	0.0403	1 (-5, 5)	dev	0.492	normal(0.00, 0.50)
Main_RecrDev_1975	0.0422	1 (-5, 5)	dev	0.492	normal(0.00, 0.50)
Main_RecrDev_1976	0.0554	1 (-5, 5)	dev	0.492	normal(0.00, 0.50)
Main_RecrDev_1977	0.0757	1 (-5, 5)	dev	0.493	normal(0.00, 0.50)
Main_RecrDev_1978	0.107	1 (-5, 5)	dev	0.495	normal(0.00, 0.50)
Main_RecrDev_1979	0.108	1 (-5, 5)	dev	0.492	normal(0.00, 0.50)
Main_RecrDev_1980	0.098	1 (-5, 5)	dev	0.484	normal(0.00, 0.50)
Main_RecrDev_1981	0.0848	1 (-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1982	0.0217	1 (-5, 5)	dev	0.466	normal(0.00, 0.50)
Main_RecrDev_1983	0.0285	1 (-5, 5)	dev	0.46	normal(0.00, 0.50)
Main_RecrDev_1984	0.181	1 (-5, 5)	dev	0.457	normal(0.00, 0.50)
Main_RecrDev_1985	0.169	1 (-5, 5)	dev	0.436	normal(0.00, 0.50)
Main_RecrDev_1986	-0.0205	1 (-5, 5)	dev	0.438	normal(0.00, 0.50)
Main_RecrDev_1987	0.125	1 (-5, 5)	dev	0.462	normal(0.00, 0.50)
Main_RecrDev_1988	0.657	1 (-5, 5)	dev	0.388	normal(0.00, 0.50)
Main_RecrDev_1989	0.223	1 (-5, 5)	dev	0.439	normal(0.00, 0.50)
Main_RecrDev_1990	-0.113	1 (-5, 5)	dev	0.416	normal(0.00, 0.50)
Main_RecrDev_1991	0.035	1 (-5, 5)	dev	0.394	normal(0.00, 0.50)
Main_RecrDev_1992	0.154	1 (-5, 5)	dev	0.394	normal(0.00, 0.50)
Main_RecrDev_1993	0.305	1 (-5, 5)	dev	0.365	normal(0.00, 0.50)
Main_RecrDev_1994	0.0239	1 (-5, 5)	dev	0.353	normal(0.00, 0.50)
Main_RecrDev_1995	-0.489	1 (-5, 5)	dev	0.351	normal(0.00, 0.50)
Main_RecrDev_1996	-0.617	1 (-5, 5)	dev	0.343	normal(0.00, 0.50)
Main_RecrDev_1997	-0.604	1 (-5, 5)	dev	0.345	normal(0.00, 0.50)
Main_RecrDev_1998	-0.27	1 (-5, 5)	dev	0.35	normal(0.00, 0.50)
Main_RecrDev_1999	0.548	1 (-5, 5)	dev	0.268	normal(0.00, 0.50)
Main_RecrDev_2000	0.187	1 (-5, 5)	dev	0.34	normal(0.00, 0.50)
Main_RecrDev_2001	0.11	1 (-5, 5)	dev	0.316	normal(0.00, 0.50)



Label	Value	Phase Bounds	Status	SD	Prior
Main_RecrDev_2002	-0.218	1 (-5, 5)	dev	0.338	normal(0.00, 0.50)
Main_RecrDev_2003	-0.525	1 (-5, 5)	dev	0.373	normal(0.00, 0.50)
Main_RecrDev_2004	-0.0497	1 (-5, 5)	dev	0.362	normal(0.00, 0.50)
Main_RecrDev_2005	0.0375	1 (-5, 5)	dev	0.37	normal(0.00, 0.50)
Main_RecrDev_2006	-0.213	1 (-5, 5)	dev	0.411	normal(0.00, 0.50)
Main_RecrDev_2007	0.223	1 (-5, 5)	dev	0.391	normal(0.00, 0.50)
Main_RecrDev_2008	0.577	1 (-5, 5)	dev	0.356	normal(0.00, 0.50)
Main_RecrDev_2009	0.0826	1 (-5, 5)	dev	0.427	normal(0.00, 0.50)
Main_RecrDev_2010	0.647	1 (-5, 5)	dev	0.332	normal(0.00, 0.50)
Main_RecrDev_2011	0.0457	1 (-5, 5)	dev	0.383	normal(0.00, 0.50)
Main_RecrDev_2012	1.04	1 (-5, 5)	dev	0.273	normal(0.00, 0.50)
Main_RecrDev_2013	-0.0412	1 (-5, 5)	dev	0.371	normal(0.00, 0.50)
Main_RecrDev_2014	-0.364	1 (-5, 5)	dev	0.397	normal(0.00, 0.50)
Main_RecrDev_2015	-0.445	1 (-5, 5)	dev	0.422	normal(0.00, 0.50)
Main_RecrDev_2016	-0.172	1 (-5, 5)	dev	0.429	normal(0.00, 0.50)
Main_RecrDev_2017	0.738	1 (-5, 5)	dev	0.381	normal(0.00, 0.50)
Main_RecrDev_2018	0.251	1 (-5, 5)	dev	0.416	normal(0.00, 0.50)
Main_RecrDev_2019	0.132	1 (-5, 5)	dev	0.413	normal(0.00, 0.50)
Main_RecrDev_2020	-0.22	1 (-5, 5)	dev	0.44	normal(0.00, 0.50)
Main_RecrDev_2021	-0.138	1 (-5, 5)	dev	0.465	normal(0.00, 0.50)
Main_RecrDev_2022	-0.0461	1 (-5, 5)	dev	0.491	normal(0.00, 0.50)
Main_RecrDev_2023	-0.00314	1 (-5, 5)	dev	0.499	normal(0.00, 0.50)
Late_RecrDev_2024	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2025	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2026	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2027	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2028	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2029	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)

Label	Value	Phase Bounds	Status	SD	Prior
ForeRecr_2030	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2031	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2032	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2033	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2034	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2035	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2036	0	5 (-5, 5)	dev	0.5	normal(0.00, 0.50)
LnQ_base_TRIENNIAL(7)	-1.49	1 (-10, 2)	ok	0.743	none
LnQ_base_AK_SLOPE(8)	-3.11	-1 (-15, 15)	fixed	0	none
LnQ_base_NW_SLOPE(9)	-2.04	-1 (-15, 15)	fixed	0	none
LnQ_base_WCGBTS(10)	-2.61	-1 (-15, 15)	fixed	0	none
LnQ_base_TRIENNIAL(7)_BLK3repl_-1892	-2.27	1 (-10, 2)	ok	0.77	none
Size_DbIN_peak_BOTTOM_TRAWL(1)	49.3	3 (15, 79)	ok	1.02	none
Size_DbIN_top_logit_BOTTOM_TRAWL(1)	-11.5	-4 (-15, 20)	fixed	0	none
Size_DbIN_ascend_se_BOTTOM_TRAWL(1)	4.57	3 (-15, 12)	ok	0.207	none
Size_DbIN_descend_se_BOTTOM_TRAWL(1)	2.95	4 (-15, 20)	ok	0.694	none
Size_DbIN_start_logit_BOTTOM_TRAWL(1)	-999	-3 (-1000, 20)	fixed	0	none
Size_DbIN_end_logit_BOTTOM_TRAWL(1)	-0.639	4 (-15, 20)	ok	0.344	none
Size_DbIN_peak_BOTTOM_TRAWL_DISCARD(2)	25.3	3 (15, 79)	ok	5.37	none
Size_DbIN_top_logit_BOTTOM_TRAWL_DISCARD(2)	-15	-4 (-15, 20)	fixed	0	none
Size_DbIN_ascend_se_BOTTOM_TRAWL_DISCARD(2)	4.89	3 (-15, 12)	ok	2.42	none

Label	Value	Phase Bounds	Status	SD	Prior
Size_DbIN_descend_se_BOTTOM_- TRAWL_DISCARD(2)	3.84	4 (-15, 20)	ok	1.49	none
Size_DbIN_start_logit_BOTTOM_- TRAWL_DISCARD(2)	-15	-3 (-15, 20)	fixed	0	none
Size_DbIN_end_logit_BOTTOM_- TRAWL_DISCARD(2)	-3.82	4 (-15, 20)	ok	1.31	none
Size_DbIN_peak_NON_TRAWL(3)	50.3	3 (15, 70)	ok	1.25	none
Size_DbIN_top_logit_NON_TRAWL(3)	-15	-4 (-15, 20)	fixed	0	none
Size_DbIN_ascend_se_NON_- TRAWL(3)	3.86	3 (-15, 12)	ok	0.296	none
Size_DbIN_descend_se_NON_- TRAWL(3)	20	-4 (-15, 20)	fixed	0	none
Size_DbIN_start_logit_NON_TRAWL(3)	-999	-3 (-1000, 20)	fixed	0	none
Size_DbIN_end_logit_NON_TRAWL(3)	4.6	-4 (-15, 20)	fixed	0	none
Size_DbIN_peak_NON_TRAWL_- DISCARD(4)	49.9	3 (15, 70)	ok	1.5	none
Size_DbIN_top_logit_NON_TRAWL_- DISCARD(4)	-15	-4 (-15, 20)	fixed	0	none
Size_DbIN_ascend_se_NON_TRAWL_- DISCARD(4)	3.75	3 (-15, 12)	ok	0.439	none
Size_DbIN_descend_se_NON_- TRAWL_DISCARD(4)	2.66	4 (-15, 20)	ok	0.95	none
Size_DbIN_start_logit_NON_TRAWL_- DISCARD(4)	-999	-3 (-1000, 20)	fixed	0	none
Size_DbIN_end_logit_NON_TRAWL_- DISCARD(4)	-0.192	4 (-15, 20)	ok	0.419	none
Size_DbIN_peak_MIDWATER_- TRAWL(5)	52.2	3 (15, 79)	ok	2.31	none
Size_DbIN_top_logit_MIDWATER_- TRAWL(5)	-15	-4 (-15, 20)	fixed	0	none
Size_DbIN_ascend_se_MIDWATER_- TRAWL(5)	4.57	3 (-15, 12)	ok	0.384	none

Label	Value	Phase Bounds	Status	SD	Prior
Size_DbIN_descend_se_MIDWATER_- TRAWL(5)	20	-4 (-15, 20)	fixed	0	none
Size_DbIN_start_logit_MIDWATER_- TRAWL(5)	-999	-3 (-1000, 20)	fixed	0	none
Size_DbIN_end_logit_MIDWATER_- TRAWL(5)	-999	-4 (-1000, 20)	fixed	0	none
Size_DbIN_peak_AT_SEA_HAKE(6)	49.7	3 (15, 70)	ok	1.41	none
Size_DbIN_top_logit_AT_SEA_HAKE(6)	-15	-4 (-15, 20)	fixed	0	none
Size_DbIN_ascend_se_AT_SEA_- HAKE(6)	3.59	3 (-15, 12)	ok	0.419	none
Size_DbIN_descend_se_AT_SEA_- HAKE(6)	20	-4 (-15, 20)	fixed	0	none
Size_DbIN_start_logit_AT_SEA_- HAKE(6)	-999	-2 (-1000, 20)	fixed	0	none
Size_DbIN_end_logit_AT_SEA_- HAKE(6)	-999	-4 (-1000, 20)	fixed	0	none
Size_DbIN_peak_TRIENNIAL(7)	21.8	3 (13, 50)	ok	1.94	none
Size_DbIN_top_logit_TRIENNIAL(7)	-8.6	-4 (-15, 20)	fixed	0	none
Size_DbIN_ascend_se_TRIENNIAL(7)	3.52	3 (-15, 12)	ok	0.587	none
Size_DbIN_descend_se_TRIENNIAL(7)	3.95	4 (-15, 20)	ok	0.553	none
Size_DbIN_start_logit_TRIENNIAL(7)	-999	-2 (-1000, 20)	fixed	0	none
Size_DbIN_end_logit_TRIENNIAL(7)	-2.58	4 (-15, 20)	ok	0.321	none
Size_DbIN_peak_AK_SLOPE(8)	37.3	3 (13, 50)	ok	2.38	none
Size_DbIN_top_logit_AK_SLOPE(8)	-15	-4 (-15, 20)	fixed	0	none
Size_DbIN_ascend_se_AK_SLOPE(8)	4.94	3 (-15, 12)	ok	0.425	none
Size_DbIN_descend_se_AK_SLOPE(8)	4.63	4 (-15, 20)	ok	0.381	none
Size_DbIN_start_logit_AK_SLOPE(8)	-999	-2 (-1000, 20)	fixed	0	none
Size_DbIN_end_logit_AK_SLOPE(8)	-10.5	4 (-15, 20)	ok	64.7	none
Size_DbIN_peak_WCGBTS(10)	21.1	3 (13, 50)	ok	3.76	none
Size_DbIN_top_logit_WCGBTS(10)	-15	-4 (-15, 20)	fixed	0	none

Label	Value	Phase Bounds	Status	SD	Prior
Size_DbIN_ascend_se_WCGBTS(10)	3.39	3 (-15, 12)	ok	1.08	none
Size_DbIN_descend_se_WCGBTS(10)	4.65	4 (-15, 20)	ok	1.05	none
Size_DbIN_start_logit_WCGBTS(10)	-999	-2 (-1000, 20)	fixed	0	none
Size_DbIN_end_logit_WCGBTS(10)	-0.834	4 (-15, 20)	ok	0.31	none
Size_DbIN_peak_BOTTOM_- TRAWL(1)_BLK4repl_1892	44.7	3 (15, 70)	ok	2.95	none
Size_DbIN_peak_BOTTOM_- TRAWL(1)_BLK4repl_2002	47.6	3 (15, 70)	ok	1.07	none
Size_DbIN_ascend_se_BOTTOM_- TRAWL(1)_BLK4repl_1892	5.03	3 (-15, 12)	ok	0.51	none
Size_DbIN_ascend_se_BOTTOM_- TRAWL(1)_BLK4repl_2002	4.1	3 (-15, 12)	ok	0.306	none
Size_DbIN_descend_se_BOTTOM_- TRAWL(1)_BLK4repl_1892	2.65	4 (-15, 20)	ok	1.7	none
Size_DbIN_descend_se_BOTTOM_- TRAWL(1)_BLK4repl_2002	2.75	4 (-15, 20)	ok	0.751	none
Size_DbIN_end_logit_BOTTOM_- TRAWL(1)_BLK4repl_1892	-1.59	4 (-15, 20)	ok	0.585	none
Size_DbIN_end_logit_BOTTOM_- TRAWL(1)_BLK4repl_2002	-0.934	4 (-15, 20)	ok	0.324	none
Size_DbIN_peak_BOTTOM_TRAWL_- DISCARD(2)_BLK1repl_1892	47.7	3 (15, 79)	ok	2.49	none
Size_DbIN_ascend_se_BOTTOM_- TRAWL_DISCARD(2)_BLK1repl_1892	6.32	3 (-15, 12)	ok	0.627	none
Size_DbIN_descend_se_BOTTOM_- TRAWL_DISCARD(2)_BLK1repl_1892	3.01	4 (-15, 20)	ok	1.19	none
Size_DbIN_end_logit_BOTTOM_- TRAWL_DISCARD(2)_BLK1repl_1892	-1.7	4 (-15, 20)	ok	0.77	none
Size_DbIN_peak_NON_TRAWL(3)_- BLK2repl_1892	46.8	3 (15, 70)	ok	0.484	none
Size_DbIN_peak_NON_TRAWL(3)_- BLK2repl_2011	49.5	3 (15, 70)	ok	0.556	none

Label	Value	Phase Bounds	Status	SD	Prior
Size_DbIN_ascend_se_NON_- TRAWL(3)_BLK2repl_1892	3.05	3 (-15, 12)	ok	0.207	none
Size_DbIN_ascend_se_NON_- TRAWL(3)_BLK2repl_2011	3.81	3 (-15, 12)	ok	0.154	none
Size_DbIN_descend_se_NON_- TRAWL(3)_BLK2repl_1892	3.17	4 (-15, 20)	ok	0.242	none
Size_DbIN_descend_se_NON_- TRAWL(3)_BLK2repl_2011	2.32	4 (-15, 20)	ok	0.52	none
Size_DbIN_end_logit_NON_- TRAWL(3)_BLK2repl_1892	-2.29	4 (-15, 20)	ok	0.258	none
Size_DbIN_end_logit_NON_- TRAWL(3)_BLK2repl_2011	-0.626	4 (-15, 20)	ok	0.193	none
Size_DbIN_peak_TRIENNIAL(7)_- BLK3repl_1892	17.4	3 (13, 50)	ok	2.64	none
Size_DbIN_ascend_se_TRIENNIAL(7)_- BLK3repl_1892	2.09	3 (-15, 12)	ok	1.39	none
Size_DbIN_descend_se_- TRIENNIAL(7)_BLK3repl_1892	5.11	4 (-15, 20)	ok	0.636	none
Size_DbIN_end_logit_TRIENNIAL(7)_- BLK3repl_1892	-4.29	4 (-15, 20)	ok	1.69	none

Table 13: Summary of reference points and management quantities, including estimates of the 95 percent confidence intervals. SO is spawning output, SPR is the spawning potential ratio, and MSY is maximum sustainable yield.

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning output	511,528	-116,464	1,139,520
Unfished Age 3+ Biomass (mt)	47,684	-10,835	106,203
Unfished Recruitment (R0)	1,092	-237	2,420
2025 Spawning output	446,448	-228,960	1,121,856
2025 Fraction Unfished	0.873	0.615	1.130
Reference Points Based SO40%	—	—	—
Proxy Spawning output SO40%	204,611	-46,586	455,808
SPR Resulting in SO40%	0.458	0.458	0.458
Exploitation Rate Resulting in SO40%	0.024	0.023	0.025
Yield with SPR Based On SO40% (mt)	553	-119	1,224
Reference Points Based on SPR Proxy for MSY	—	—	—
Proxy Spawning output (SPR50)	228,220	-51,961	508,401
SPR50	0.500	—	—
Exploitation Rate Corresponding to SPR50	0.021	0.021	0.022
Yield with SPR50 at SO SPR (mt)	526	-113	1,165
Reference Points Based on Estimated MSY Values	—	—	—
Spawning output at MSY (SO MSY)	135,603	-31,094	302,300
SPR MSY	0.337	0.334	0.339
Exploitation Rate Corresponding to SPR MSY	0.036	0.035	0.037
MSY (mt)	592	-127	1,311

Table 14: Time series of population estimates from the base model.

Year	Total Biomass (mt)	Spawning output	Total Biomass 3+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	1-SPR	Exploita- tion Rate
1892	47710.3	511528	47683.8	1.000	1008	19	0.018	0.000
1893	47688.4	511316	47662.3	1.000	1006	19	0.018	0.000
1894	47665.5	511100	47641.0	0.999	1005	19	0.018	0.000
1895	47640.9	510881	47616.4	0.999	1003	5	0.005	0.000
1896	47629.4	510818	47605.0	0.999	1001	1	0.001	0.000
1897	47618.5	510798	47594.1	0.999	1000	1	0.001	0.000
1898	47603.1	510779	47578.7	0.999	998	1	0.001	0.000
1899	47583.2	510768	47558.9	0.999	997	1	0.001	0.000
1900	47557.5	510752	47533.2	0.998	995	2	0.002	0.000
1901	47525.6	510728	47501.4	0.998	994	2	0.002	0.000
1902	47487.5	510692	47463.3	0.998	993	3	0.002	0.000
1903	47443.2	510636	47419.1	0.998	992	3	0.003	0.000
1904	47392.9	510549	47368.8	0.998	991	4	0.003	0.000
1905	47336.8	510420	47312.7	0.998	990	4	0.004	0.000
1906	47275.3	510236	47251.2	0.997	989	4	0.004	0.000
1907	47208.6	509985	47184.5	0.997	989	5	0.005	0.000
1908	47137.1	509659	47113.1	0.996	988	8	0.007	0.000
1909	47058.5	509226	47034.5	0.995	988	6	0.006	0.000
1910	46978.9	508740	46954.8	0.995	988	6	0.006	0.000
1911	46895.8	508174	46871.8	0.993	988	7	0.006	0.000
1912	46809.7	507533	46785.7	0.992	988	7	0.007	0.000
1913	46721.0	506820	46697.0	0.991	989	8	0.007	0.000
1914	46630.2	506041	46606.1	0.989	990	8	0.008	0.000
1915	46537.6	505204	46513.5	0.988	991	10	0.010	0.000
1916	46441.8	504294	46417.7	0.986	992	9	0.009	0.000
1917	46346.8	503356	46322.7	0.984	993	10	0.010	0.000
1918	46251.2	502376	46227.1	0.982	995	55	0.052	0.001
1919	46105.0	500860	46080.8	0.979	997	26	0.025	0.001
1920	45992.8	499640	45968.6	0.977	1000	23	0.023	0.001
1921	45884.7	498430	45860.5	0.974	1002	23	0.022	0.001
1922	45778.8	497212	45754.4	0.972	1005	18	0.018	0.000
1923	45680.4	496043	45656.0	0.970	1008	20	0.020	0.000
1924	45581.8	494847	45557.3	0.967	1012	32	0.031	0.001
1925	45472.8	493525	45448.2	0.965	1015	38	0.037	0.001
1926	45359.8	492139	45335.2	0.962	1019	54	0.052	0.001
1927	45231.8	490579	45207.0	0.959	1023	69	0.066	0.002
1928	45091.2	488867	45066.4	0.956	1026	72	0.069	0.002
1929	44951.7	487136	44926.8	0.952	1029	66	0.064	0.001
1930	44823.3	485487	44798.3	0.949	1032	67	0.065	0.001
1931	44698.9	483854	44673.8	0.946	1035	44	0.043	0.001
1932	44605.7	482510	44580.5	0.943	1037	25	0.025	0.001
1933	44538.7	481412	44513.5	0.941	1039	35	0.035	0.001
1934	44465.7	480251	44440.5	0.939	1041	42	0.042	0.001
1935	44389.7	479052	44364.4	0.937	1042	34	0.034	0.001
1936	44328.0	477993	44302.7	0.934	1044	61	0.060	0.001
1937	44241.5	476688	44216.2	0.932	1046	53	0.052	0.001
1938	44169.0	475518	44143.6	0.930	1048	56	0.055	0.001
1939	44099.2	474378	44073.8	0.927	1050	28	0.029	0.001
1940	44064.8	473593	44039.3	0.926	1054	59	0.058	0.001
1941	44000.9	472531	43975.4	0.924	1059	102	0.097	0.002
1942	43894.9	471062	43869.2	0.921	1065	125	0.119	0.003
1943	43767.8	469383	43742.0	0.918	1073	257	0.227	0.006



Table 14: Time series of population estimates from the base model. *(continued)*

Year	Total Biomass (mt)	Spawning output	Total Biomass 3+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	1-SPR	Exploita- tion Rate
1944	43499.0	466305	43473.1	0.912	1083	85	0.085	0.002
1945	43429.2	465158	43403.0	0.909	1095	50	0.053	0.001
1946	43404.5	464473	43378.1	0.908	1111	69	0.070	0.002
1947	43364.5	463640	43337.7	0.906	1129	41	0.042	0.001
1948	43361.6	463172	43334.4	0.905	1151	44	0.045	0.001
1949	43362.1	462740	43334.5	0.905	1176	31	0.031	0.001
1950	43384.9	462522	43356.7	0.904	1204	53	0.053	0.001
1951	43391.3	462134	43362.5	0.903	1235	59	0.059	0.001
1952	43400.0	461742	43370.5	0.903	1268	38	0.039	0.001
1953	43441.9	461634	43411.6	0.902	1302	20	0.021	0.000
1954	43514.7	461780	43483.6	0.903	1334	36	0.037	0.001
1955	43583.1	461826	43551.2	0.903	1363	32	0.032	0.001
1956	43670.3	461985	43637.6	0.903	1385	20	0.022	0.000
1957	43785.7	462341	43752.4	0.904	1400	35	0.035	0.001
1958	43902.2	462624	43868.4	0.904	1406	15	0.016	0.000
1959	44058.5	463204	44024.4	0.906	1405	22	0.023	0.001
1960	44224.9	463800	44190.7	0.907	1397	23	0.024	0.001
1961	44409.2	464503	44375.1	0.908	1383	26	0.027	0.001
1962	44608.4	465298	44574.5	0.910	1363	32	0.033	0.001
1963	44818.7	466176	44785.2	0.911	1337	23	0.024	0.001
1964	45054.4	467299	45021.4	0.914	1303	32	0.032	0.001
1965	45294.7	468507	45262.5	0.916	1265	31	0.032	0.001
1966	45547.5	469929	45516.1	0.919	1227	117	0.116	0.003
1967	45714.7	470768	45684.2	0.920	1192	108	0.107	0.002
1968	45895.2	471865	45865.6	0.922	1166	172	0.164	0.004
1969	46006.2	472569	45977.4	0.924	1149	51	0.049	0.001
1970	46246.6	474525	46218.3	0.928	1138	22	0.023	0.000
1971	46513.6	476975	46485.7	0.932	1130	68	0.067	0.001
1972	46724.0	479218	46696.4	0.937	1124	76	0.074	0.002
1973	46914.4	481540	46886.9	0.941	1124	75	0.072	0.002
1974	47093.3	483996	47066.0	0.946	1130	77	0.072	0.002
1975	47256.3	486512	47228.9	0.951	1133	43	0.041	0.001
1976	47442.0	489405	47414.5	0.957	1149	19	0.018	0.000
1977	47638.8	492556	47611.1	0.963	1173	166	0.133	0.003
1978	47658.5	494114	47630.4	0.966	1211	69	0.062	0.001
1979	47771.8	496651	47743.1	0.971	1212	185	0.154	0.004
1980	47744.7	497881	47715.3	0.973	1198	99	0.089	0.002
1981	47801.3	499849	47771.9	0.977	1178	131	0.115	0.003
1982	47811.7	501292	47782.8	0.980	1101	167	0.147	0.003
1983	47773.4	502190	47745.2	0.982	1104	126	0.111	0.003
1984	47771.3	503246	47744.2	0.984	1280	144	0.128	0.003
1985	47742.0	503918	47714.1	0.985	1260	299	0.245	0.006
1986	47534.8	502769	47504.2	0.983	1038	428	0.326	0.009
1987	47179.9	499980	47150.4	0.977	1194	571	0.409	0.012
1988	46663.5	495414	46636.0	0.968	2024	351	0.289	0.008
1989	46393.2	492987	46360.1	0.964	1304	418	0.345	0.009
1990	46055.3	489838	46011.1	0.958	928	244	0.223	0.005
1991	45918.1	488302	45888.5	0.955	1071	299	0.269	0.007
1992	45729.3	486176	45705.6	0.950	1199	306	0.269	0.007
1993	45538.8	483831	45511.7	0.946	1389	327	0.283	0.007
1994	45329.9	481189	45300.1	0.941	1044	306	0.265	0.007
1995	45151.2	478692	45120.2	0.936	625	745	0.507	0.017
1996	44488.3	471416	44465.7	0.922	549	339	0.292	0.008

Table 14: Time series of population estimates from the base model. (*continued*)

Year	Total Biomass (mt)	Spawning output	Total Biomass 3+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	1-SPR	Exploita- tion Rate
1997	44277.0	468496	44262.3	0.916	555	303	0.266	0.007
1998	44097.3	466017	44083.5	0.911	775	441	0.355	0.010
1999	43751.9	462148	43735.5	0.903	1756	256	0.231	0.006
2000	43593.5	460403	43569.3	0.900	1223	183	0.164	0.004
2001	43514.6	459593	43475.4	0.898	1132	114	0.112	0.003
2002	43495.6	459785	43466.9	0.899	816	74	0.072	0.002
2003	43510.9	460514	43485.7	0.900	600	99	0.093	0.002
2004	43492.6	461110	43473.5	0.901	965	115	0.103	0.003
2005	43449.1	461588	43432.1	0.902	1054	138	0.119	0.003
2006	43373.1	461805	43349.4	0.903	820	127	0.115	0.003
2007	43295.8	462089	43270.9	0.903	1268	187	0.162	0.004
2008	43148.6	461547	43125.0	0.902	1807	218	0.183	0.005
2009	42967.1	460402	42934.0	0.900	1102	228	0.202	0.005
2010	42771.1	458973	42730.3	0.897	1938	261	0.226	0.006
2011	42551.9	456941	42521.2	0.893	1061	210	0.168	0.005
2012	42420.8	455176	42376.4	0.890	2857	244	0.192	0.006
2013	42280.4	452941	42246.2	0.885	977	156	0.134	0.004
2014	42263.9	451689	42206.6	0.883	711	91	0.082	0.002
2015	42349.8	451135	42327.8	0.882	659	132	0.114	0.003
2016	42423.6	450063	42406.3	0.880	870	149	0.127	0.004
2017	42501.9	448779	42482.6	0.877	2172	156	0.133	0.004
2018	42587.4	447431	42559.4	0.875	1341	242	0.188	0.006
2019	42610.8	445158	42563.4	0.870	1197	227	0.180	0.005
2020	42665.5	443261	42634.3	0.867	846	106	0.090	0.002
2021	42856.7	443053	42829.7	0.866	923	93	0.079	0.002
2022	43067.5	443381	43046.3	0.867	1017	117	0.098	0.003
2023	43255.0	443867	43231.9	0.868	1067	98	0.083	0.002
2024	43457.8	445061	43432.8	0.870	1076	119	0.098	0.003
2025	43632.5	446448	43606.5	0.873	1076	968	0.500	0.022
2026	42972.8	438543	42946.6	0.857	1074	955	0.500	0.022
2027	42327.7	431142	42301.5	0.843	1072	880	0.481	0.021
2028	41755.2	424827	41729.1	0.831	1070	865	0.480	0.021
2029	41196.9	418849	41170.8	0.819	1069	851	0.478	0.021
2030	40651.4	413148	40625.4	0.808	1067	837	0.477	0.021
2031	40118.8	407687	40092.8	0.797	1065	823	0.476	0.021
2032	39600.2	402434	39574.2	0.787	1064	809	0.474	0.020
2033	39095.0	397334	39069.1	0.777	1062	796	0.473	0.020
2034	38604.0	392344	38578.1	0.767	1060	782	0.472	0.020
2035	38128.4	387440	38102.6	0.757	1059	769	0.470	0.020
2036	37668.2	382597	37642.5	0.748	1057	756	0.469	0.020

```
#“{r, results = “asis”} ##| label: tbl-projections ##| warning: false ##| echo: false
##| eval: !expr eval_tables ##| tbl-cap: !expr if(eval_tables) projections_cap ##|
tbl-pos: H
```

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#projections_table |> # gt::gt() |> # gt::fmt_number( # columns = c(2:5, 7:9), #
decimals = 0 # ) |> # gt::fmt_number( # columns = c(6, 10), # decimals = 3 # ) |>
# gt::tab_options( # table.font.size = 12, # latex.use_longtable = TRUE # ) |> #
gt::sub_missing( # columns = tidyselect::everything(), # missing_text = “—” # ) |>
# gt::cols_align( # align = “center” # ) |> # gt::cols_width( # tidyselect::everything()
~ px(75) # ) |> # gt::as_latex()
```

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## 7 Figures

## 7.1 Introduction

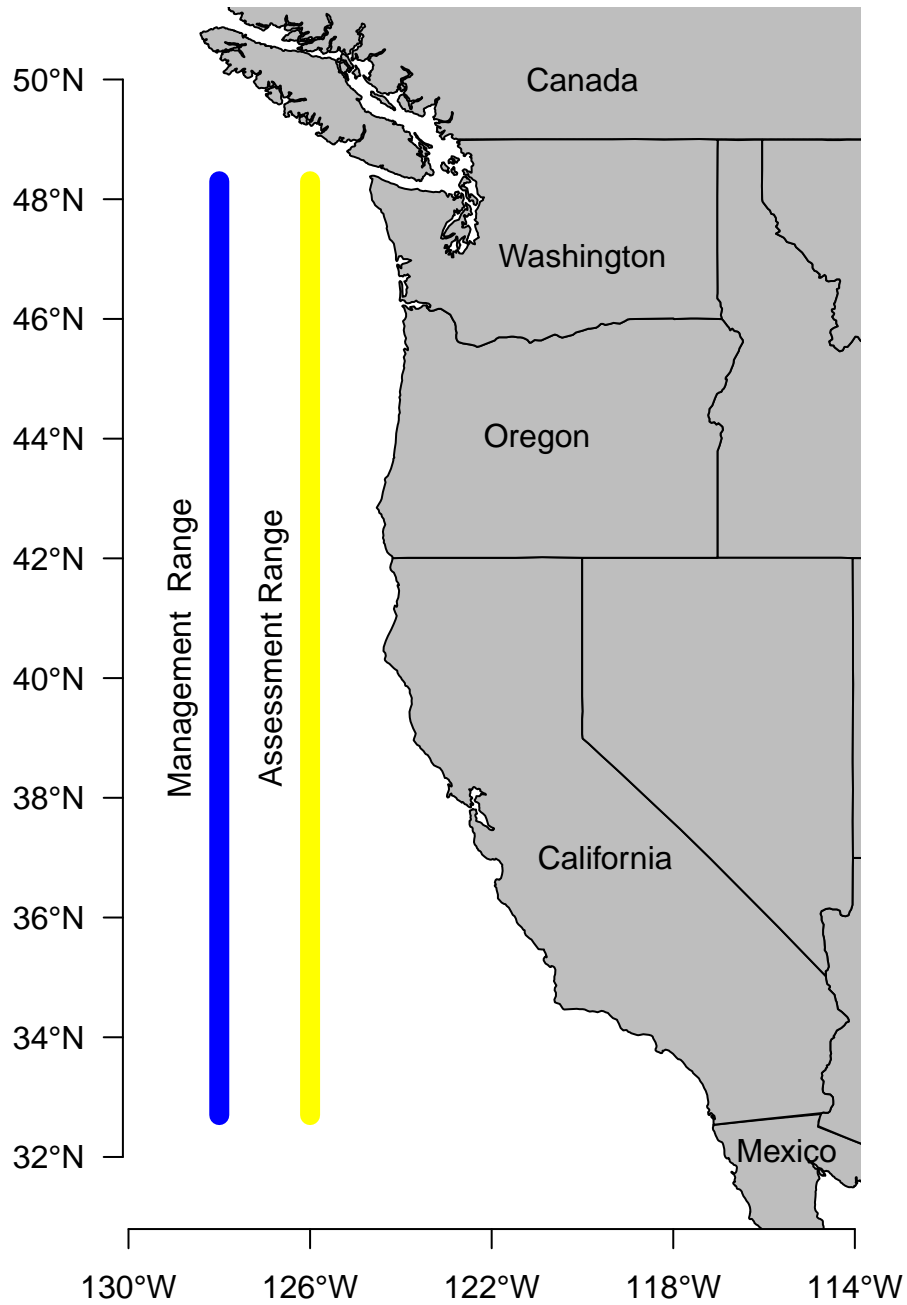


Figure 5: Map of the assessment area.

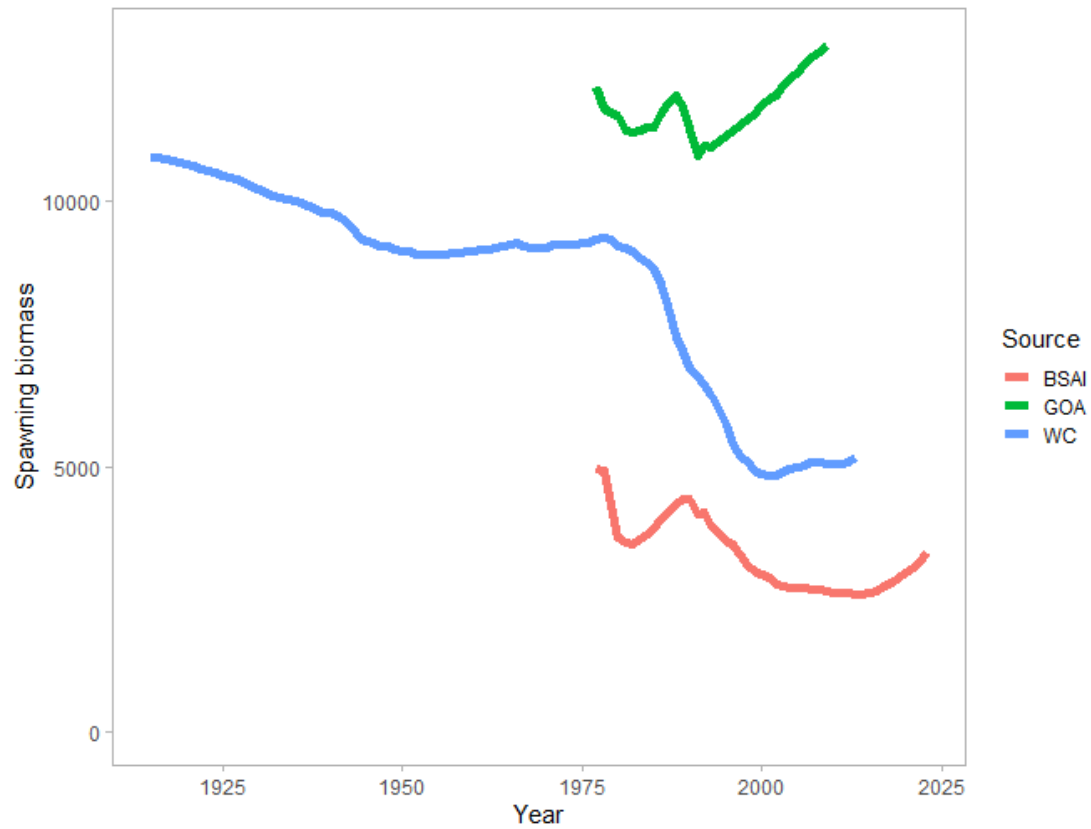


Figure 6: Estimates of spawning biomass (current spawning output/unfished spawning output) for the Rougheye/Blackspotted rockfish complex from the two most recent Alaska (Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA)) and the 2013 U.S. west coast stock assessment.

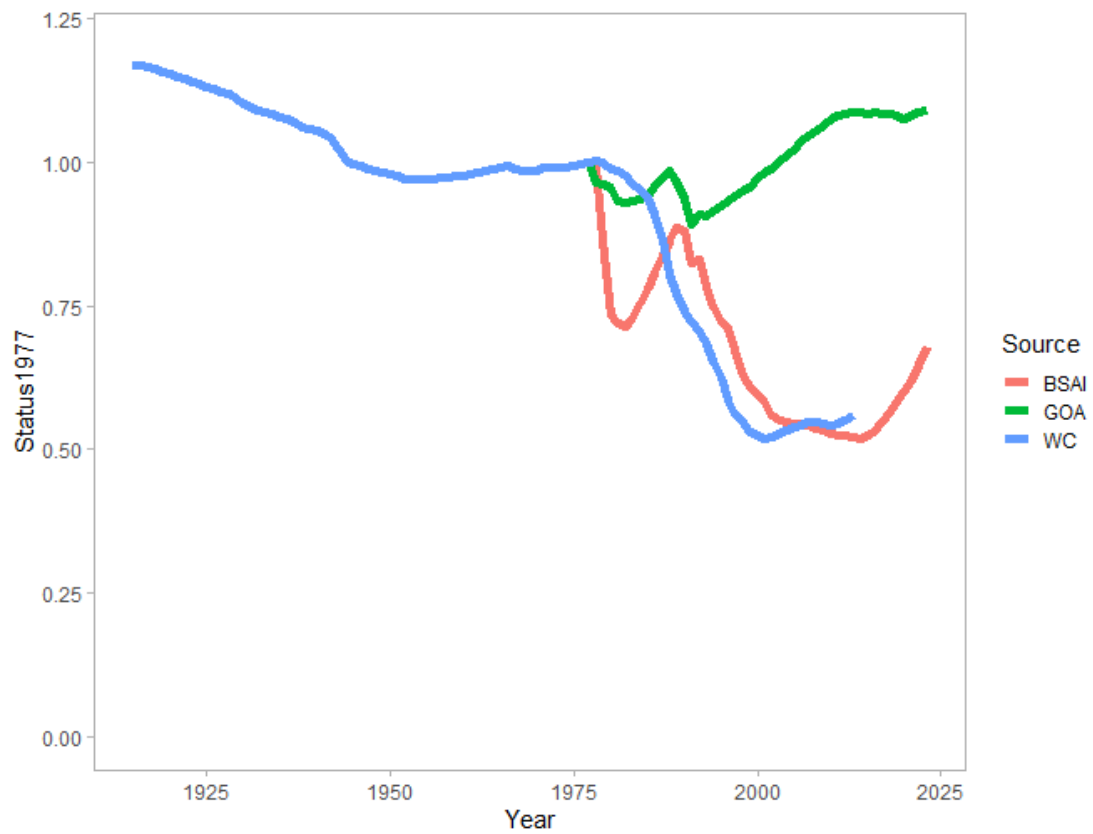


Figure 7: Estimates of relative stock size (current spawning output/unfished spawning output) relative to 1977 (the common year in all stock assessments compared) for the Rougheye/Blackspotted rockfish complex from the two most recent Alaska (Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA)) and the 2013 U.S. west coast stock assessment.

## 7.2 Data

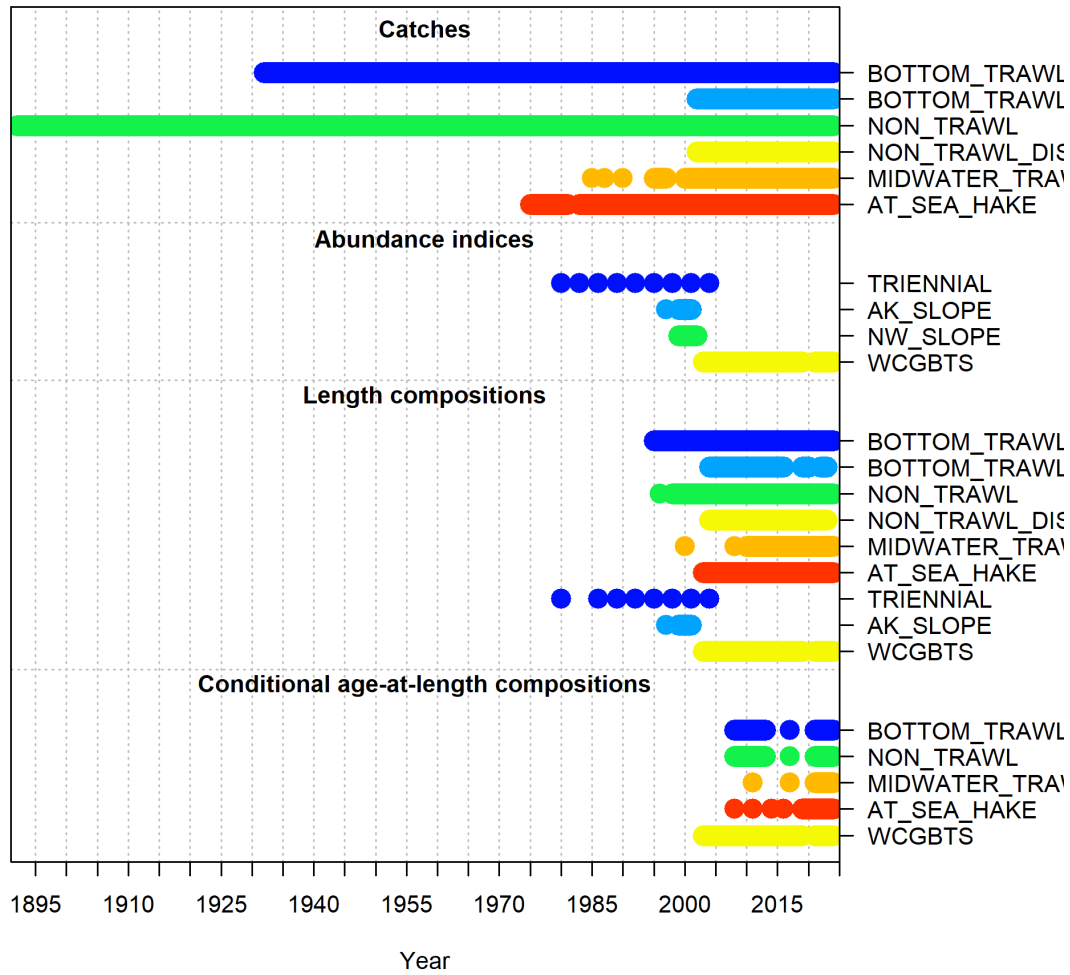


Figure 8: Data used in the base model.

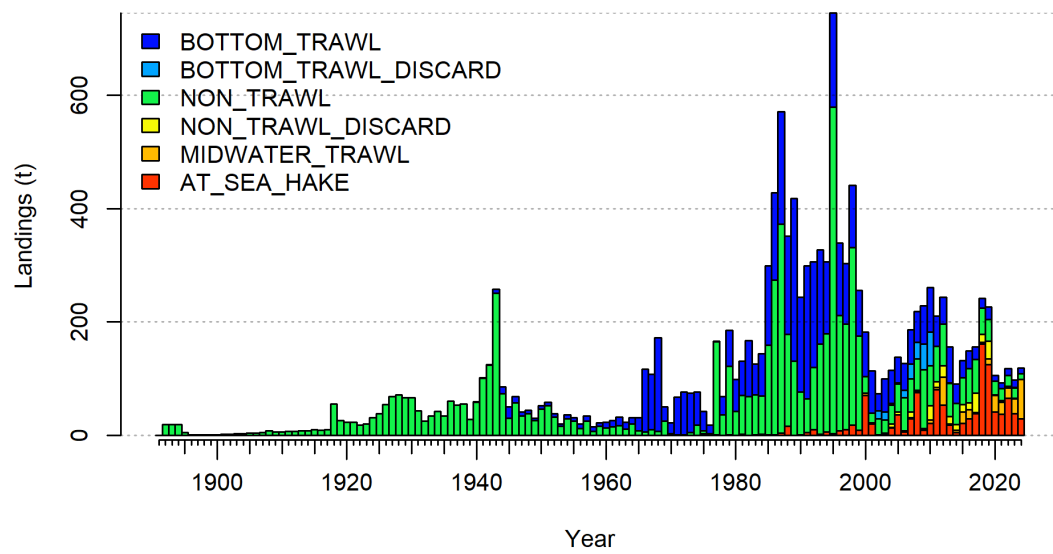


Figure 9: Landings by fleet.



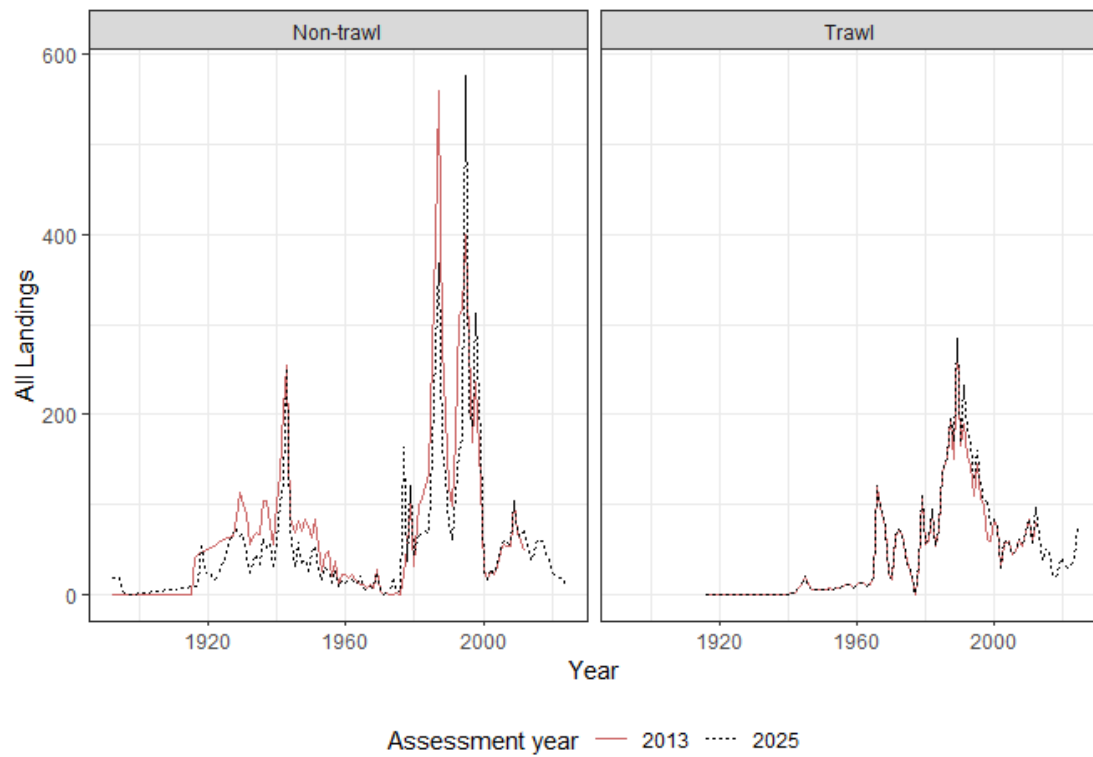


Figure 10: Landings across all states for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

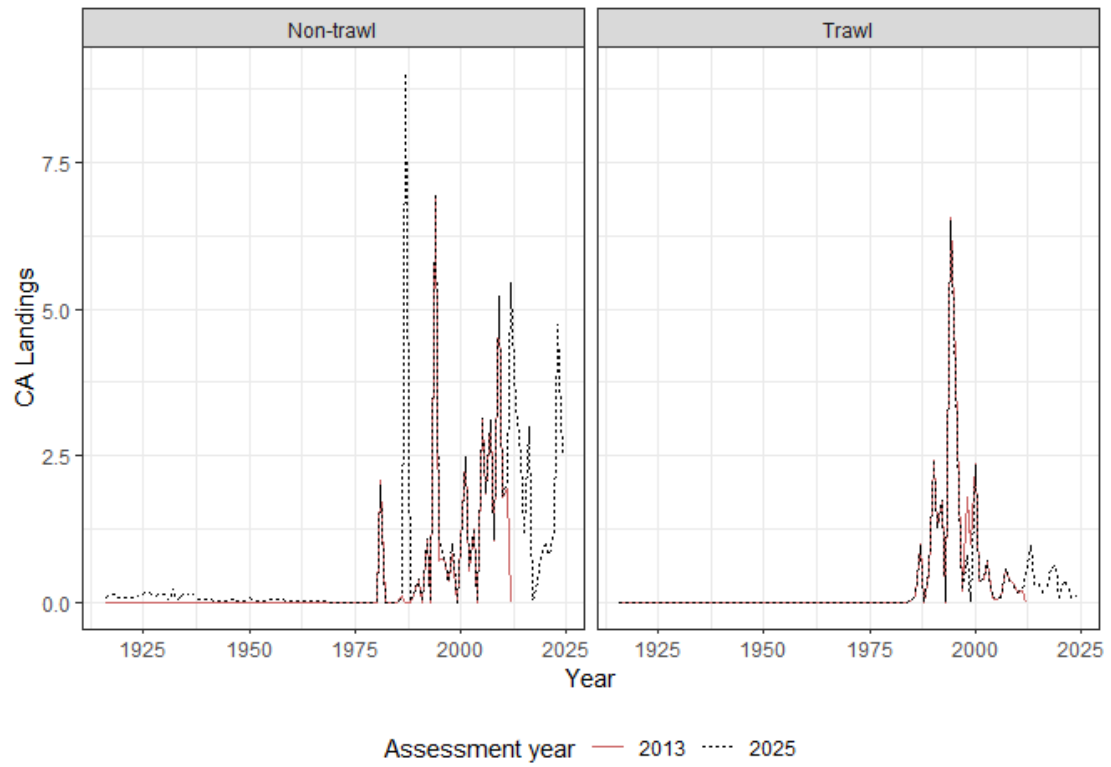


Figure 11: California state landings for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

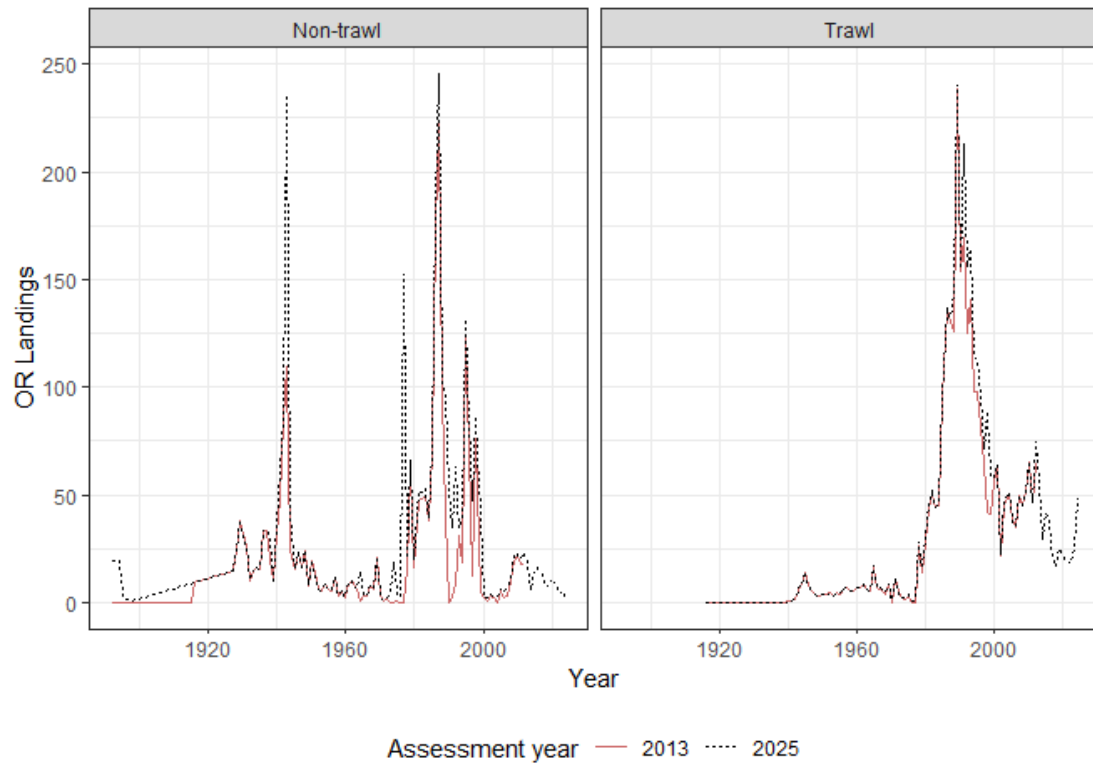


Figure 12: Oregon state landings for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

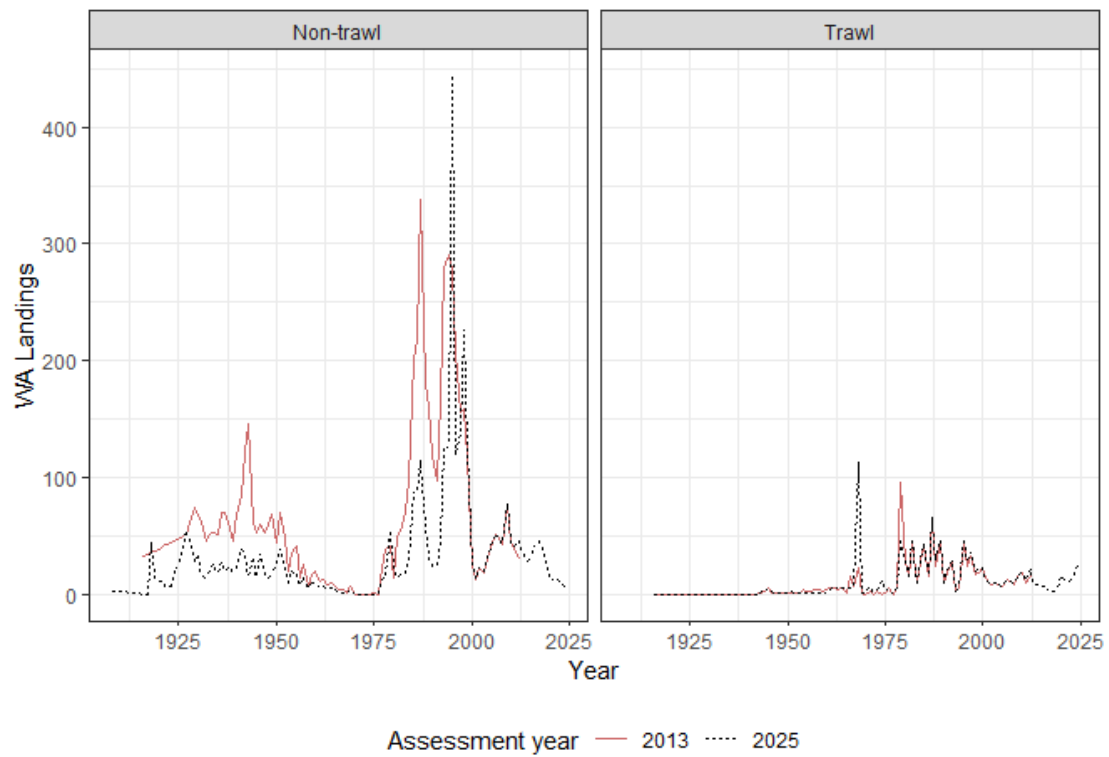


Figure 13: WA. Washington state landings for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

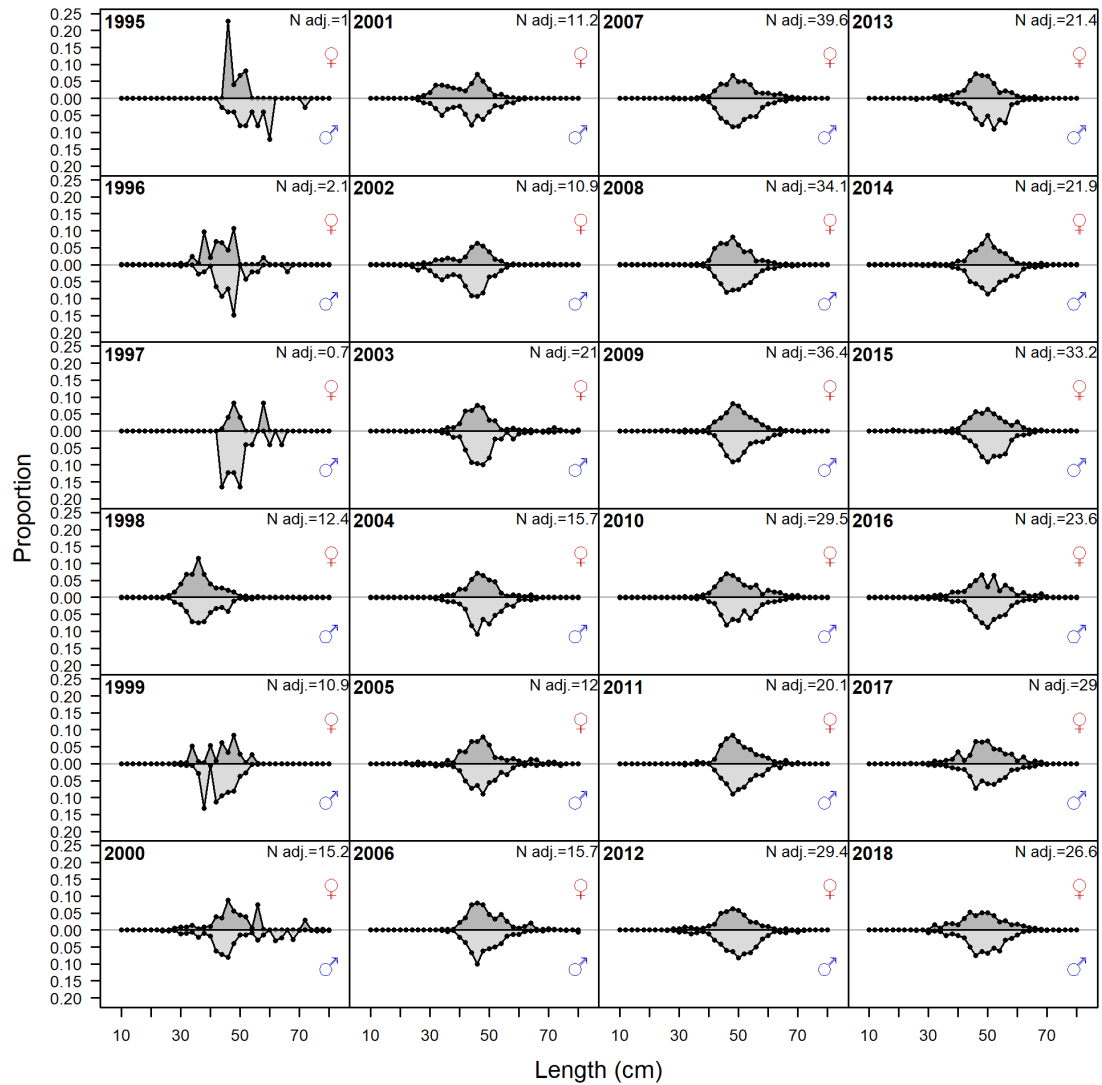


Figure 14: Length composition data for bottom trawl fleet.

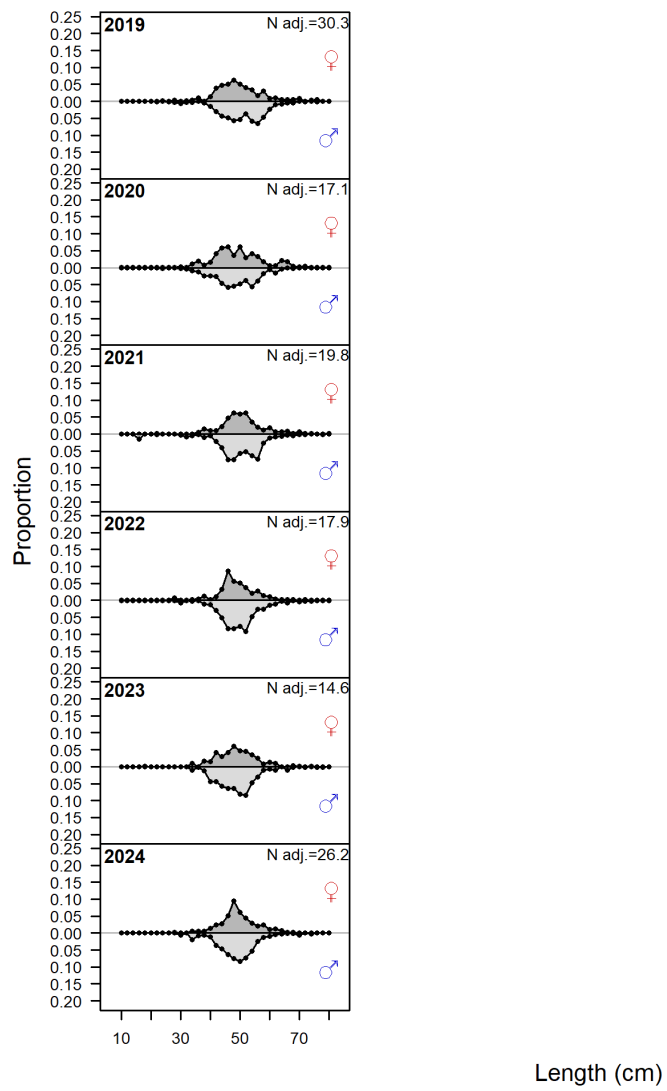


Figure 15: Length composition data for bottom trawl fleet, continued.

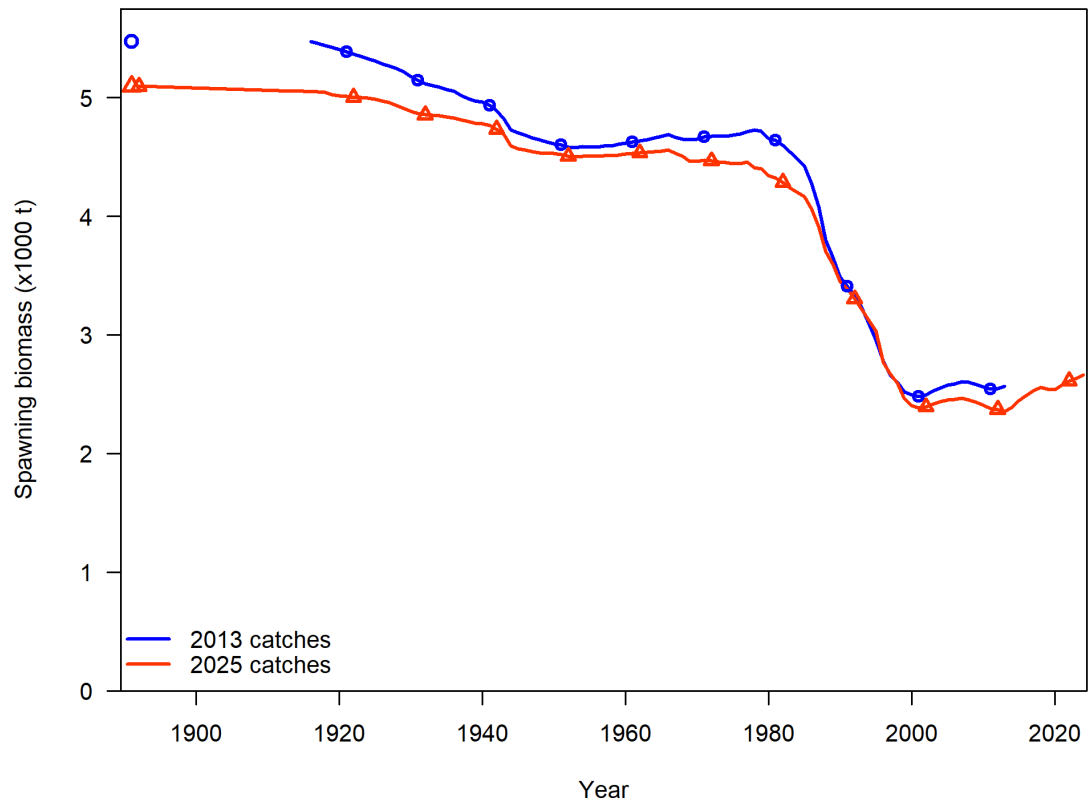


Figure 16: Comparison of spawning output using updated catches vs using catches from the 2013 Rougheye/Blackspotted Rockfishes assessment.

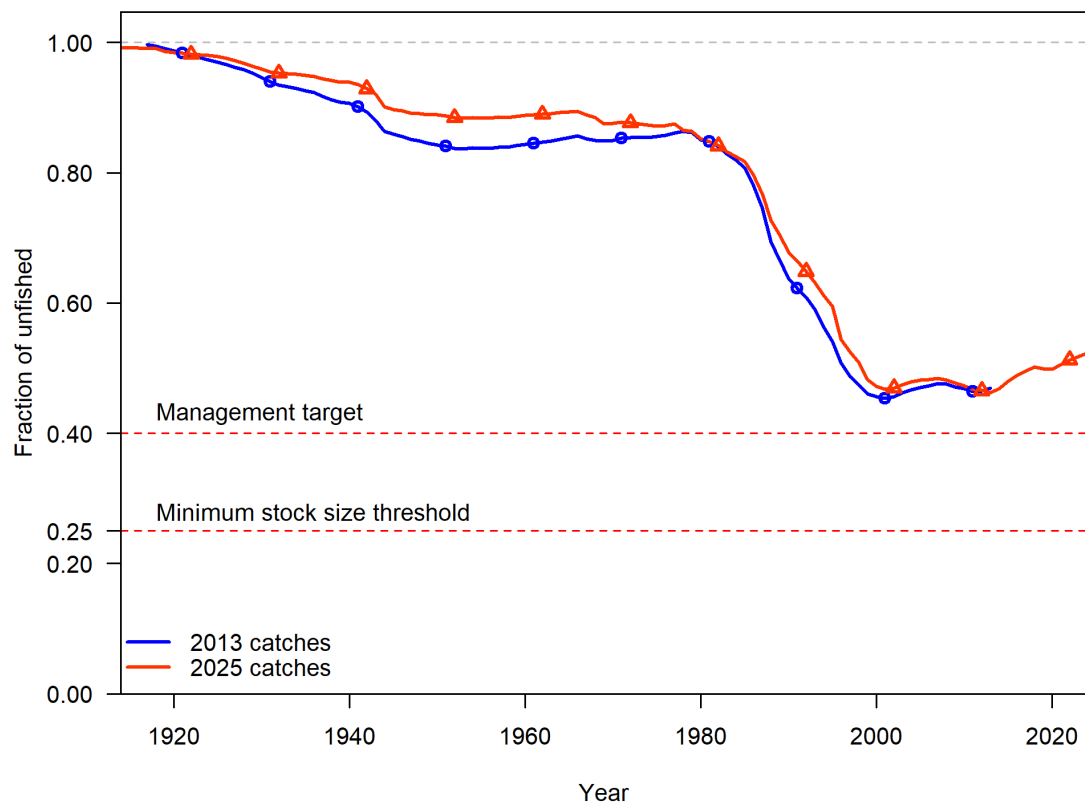


Figure 17: Comparison of relative spawning output using updated catches vs using catches from the 2013 Rougheye/Blackspotted Rockfishes assessment.



## 7.3 Biology

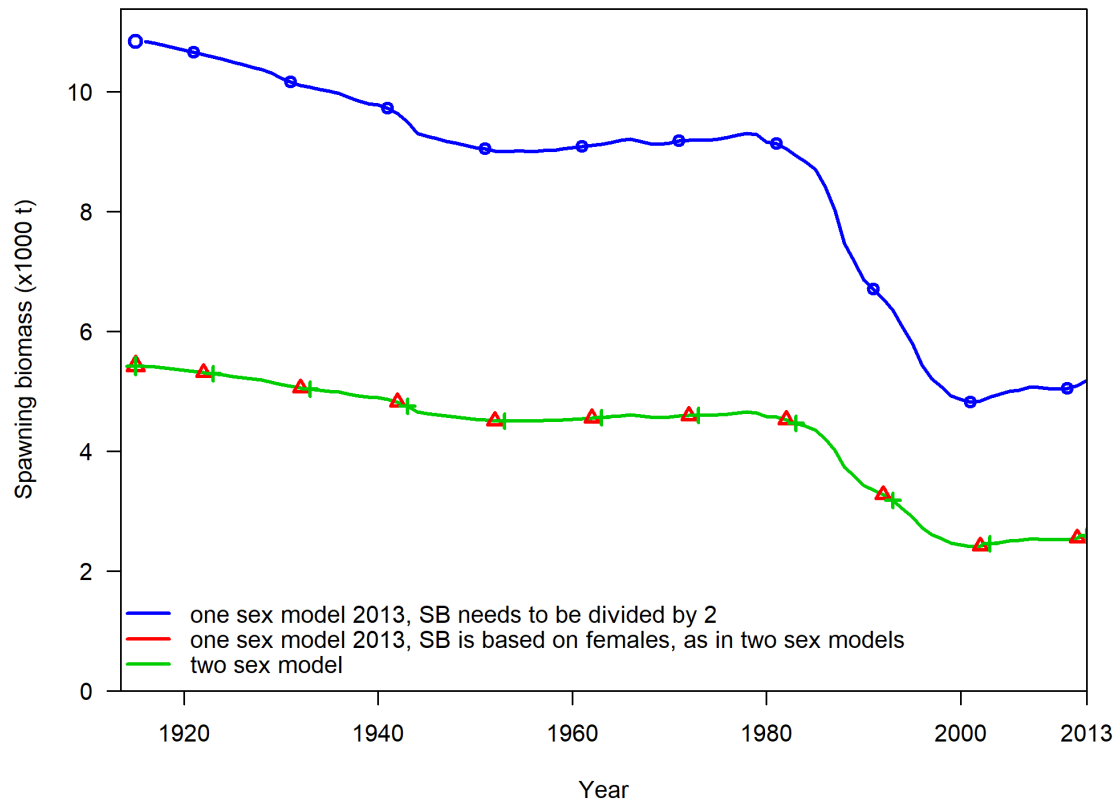


Figure 18: Comparison of spawning output using the 1 sex and 2 sexes set to equal values models based on the 2013 Rougheye/Blackspotted Rockfishes assessment data. The 1 sex model has double the biomass because it includes both females and males.

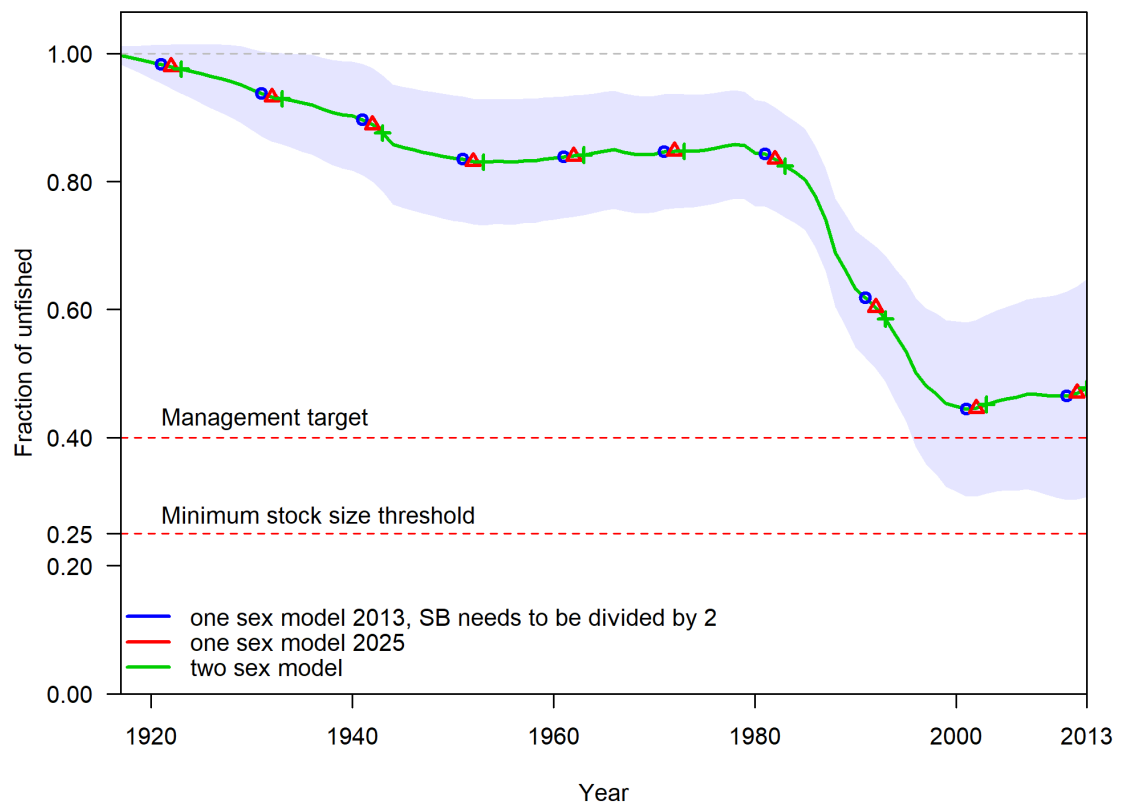


Figure 19: Comparison of spawning output using the 1 sex and 2 sexes set to equal values models based on the 2013 Rougheye/Blackspotted Rockfishes assessment data.

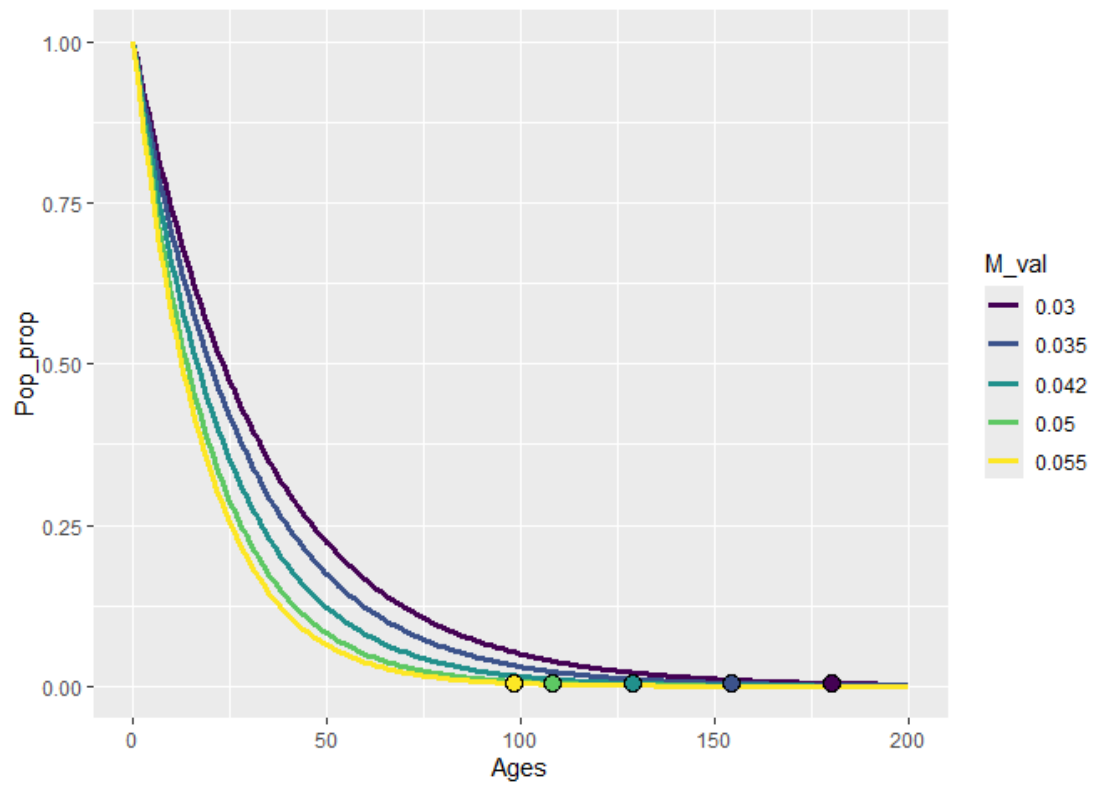


Figure 20: Natural mortality curves by age in years for values of natural mortality used in various Rougheye/Blackspotted Rockfish stock assessments. Dots indicate the range of assumed maximum ages using the equation from Hamel and Cope 2022.

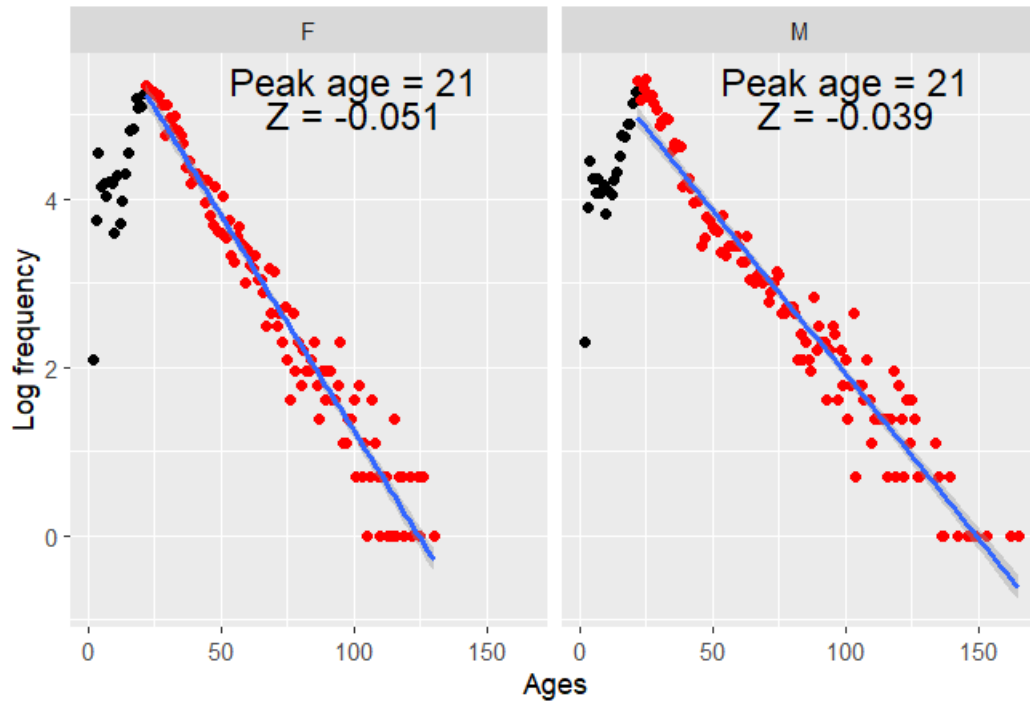


Figure 21: Catch curve (log abundance by age) analysis on aggregated ages over all age sources by sex (black points). The peak selected age was 21 for both sexes, so the linear model was run from age 21 until the oldest age (red points). The slope of the linear model is equal to the estimate of an aggregate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

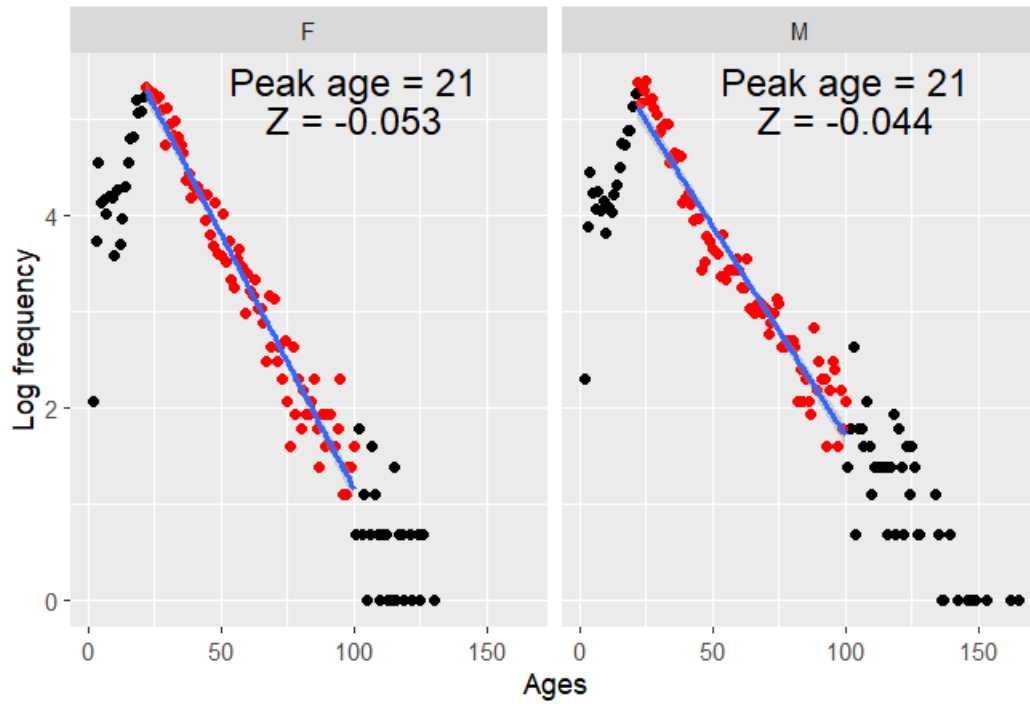


Figure 22: Catch curve (log abundance by age) analysis on aggregated ages over all age sources by sex (black points). The peak selected age was 21 for both sexes with a max age of 100, so the linear model was run from age 21 until age 100 (red points). The slope of the linear model is equal to the estimate of an aggregate total mortality ( $Z$ ).

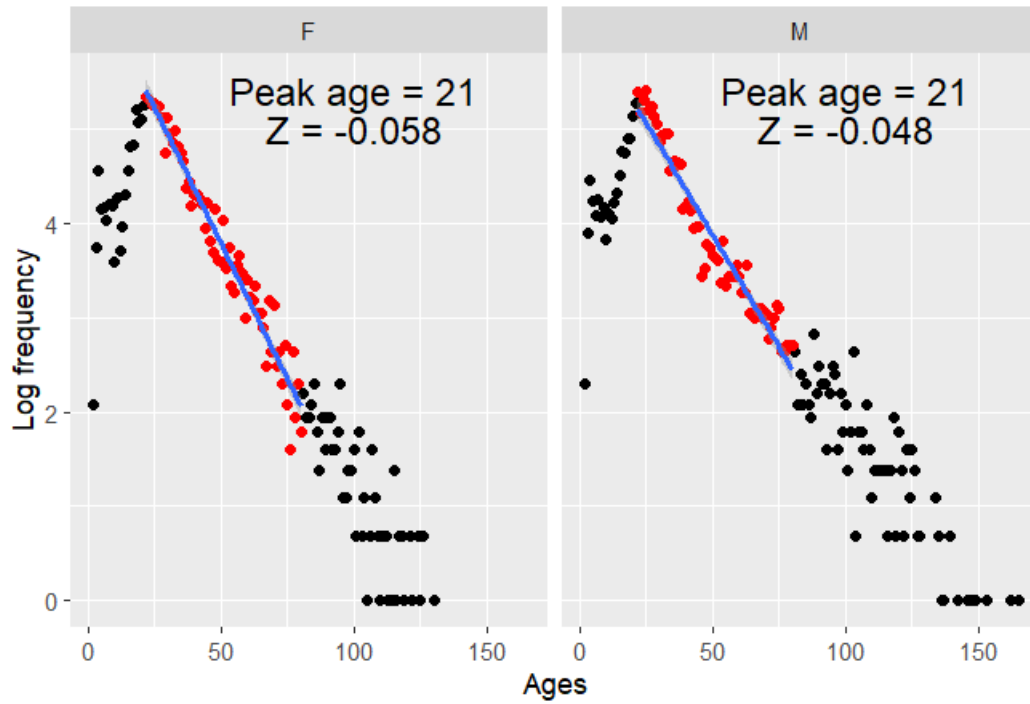


Figure 23: Catch curve (log abundance by age) analysis on aggregated ages over all age sources by sex (black points). The peak selected age was 21 for both sexes with a max age of 80, so the linear model was run from age 21 until age 80 (red points). The slope of the linear model is equal to the estimate of an aggregate total mortality ( $Z$ ).

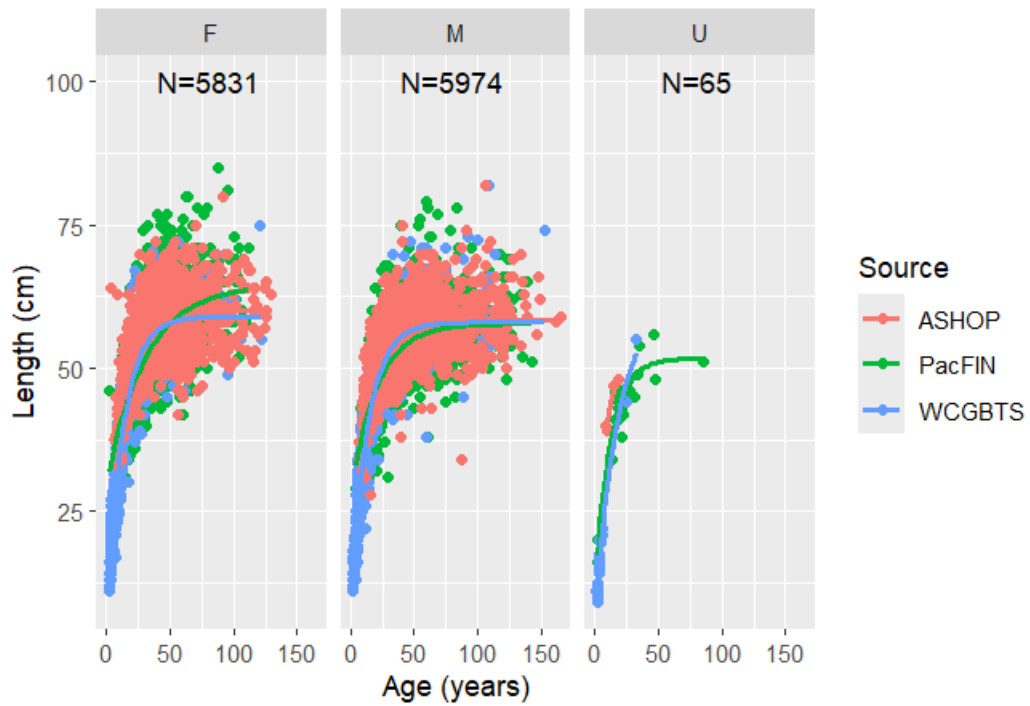


Figure 24: Age and length data, with fitted von Bertalanffy growth curves, by sex and data source for the Rougheye/Blackspotted rockfish complex. Sample sizes (N) are also provided.

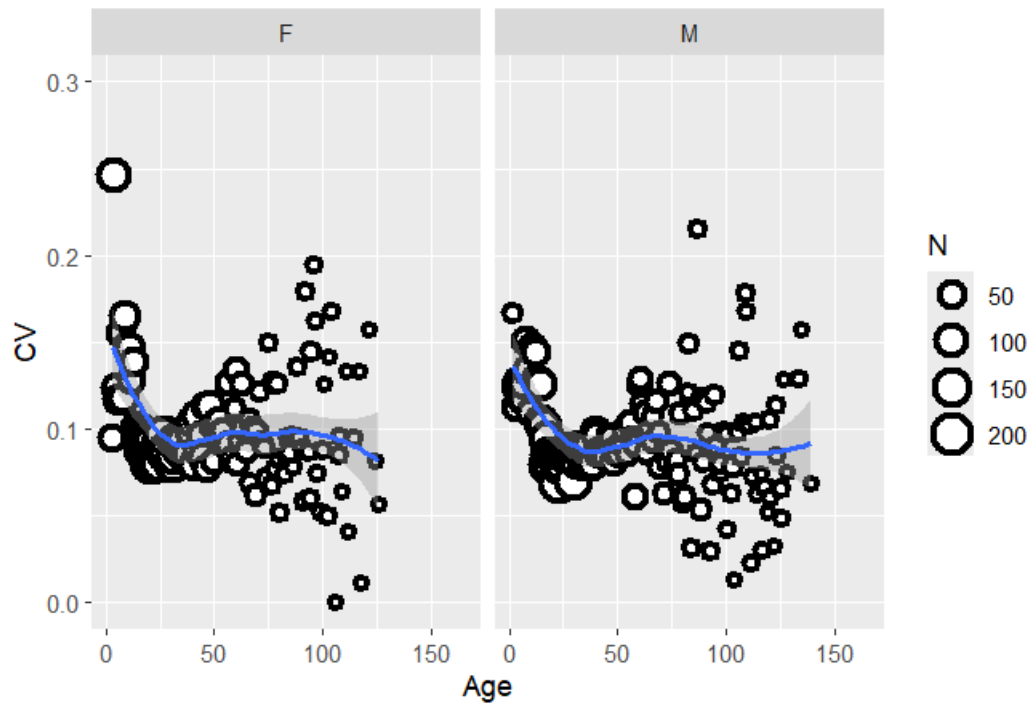


Figure 25: Coefficient of variation by age and sex for all sources of Rougheye/Blackspotted rockfishes ages. Sample sizes (N) are also indicated by size of the point. The line is a smoothed loess (polynomial) line that gives a moving average of CV by age and sex.



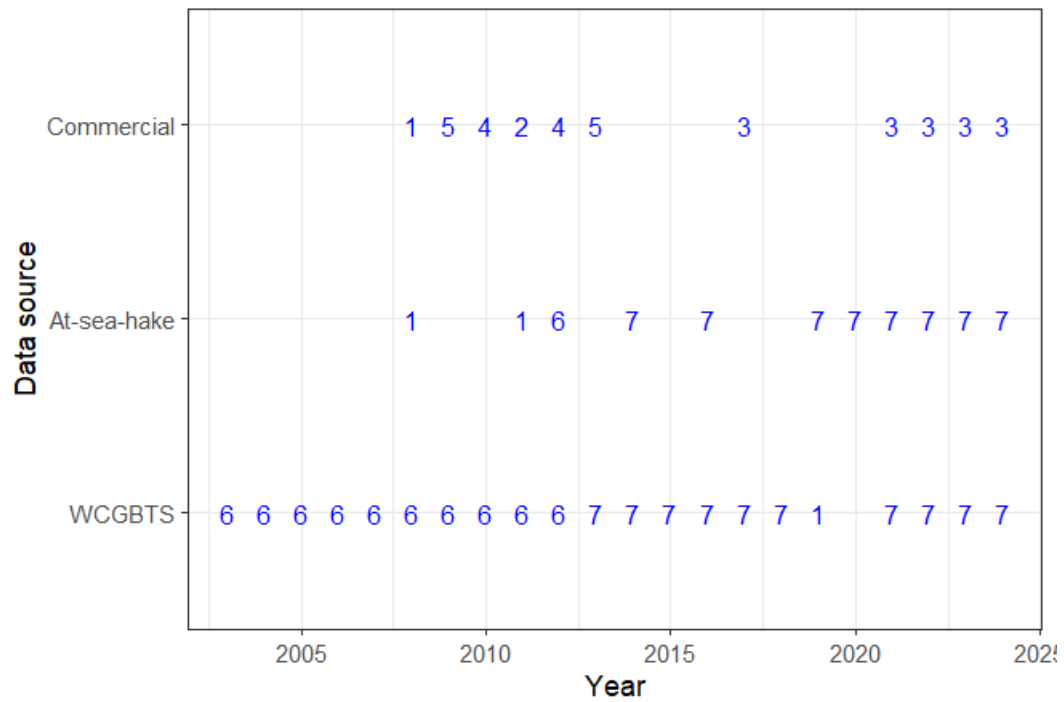


Figure 26: Ageing error matrix assignments by year and data source. The number indicates which ageing error matrix was used for conditional ages within those years and data sources. 'Commercial' is a combination of all commercial fleets.

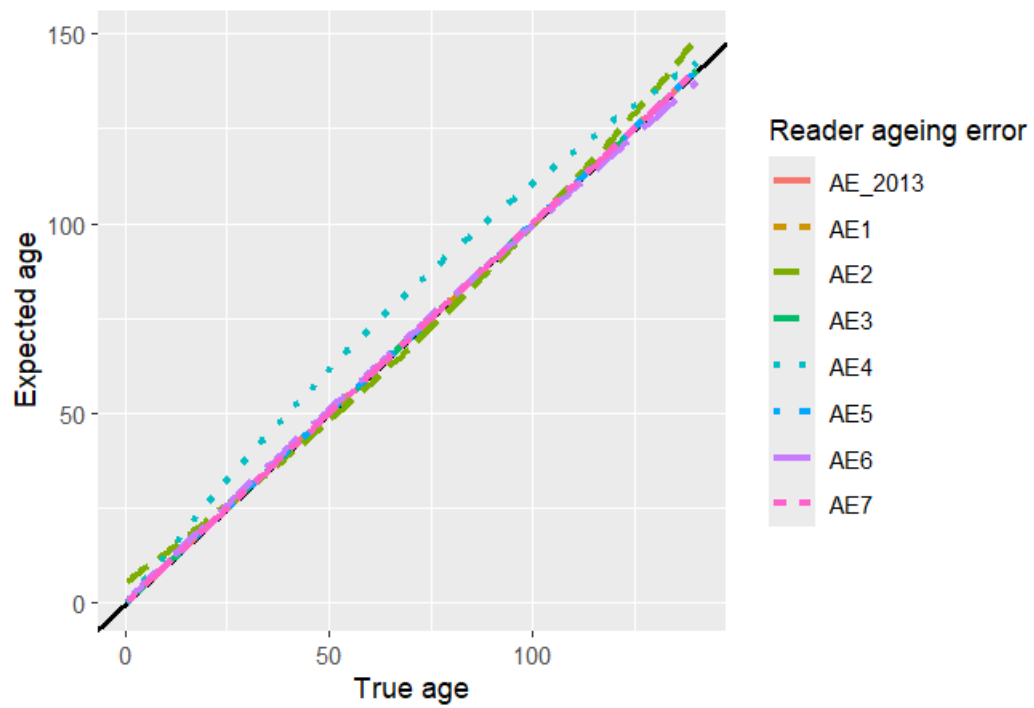


Figure 27: Estimated bias used for each of the seven ageing error matrices.

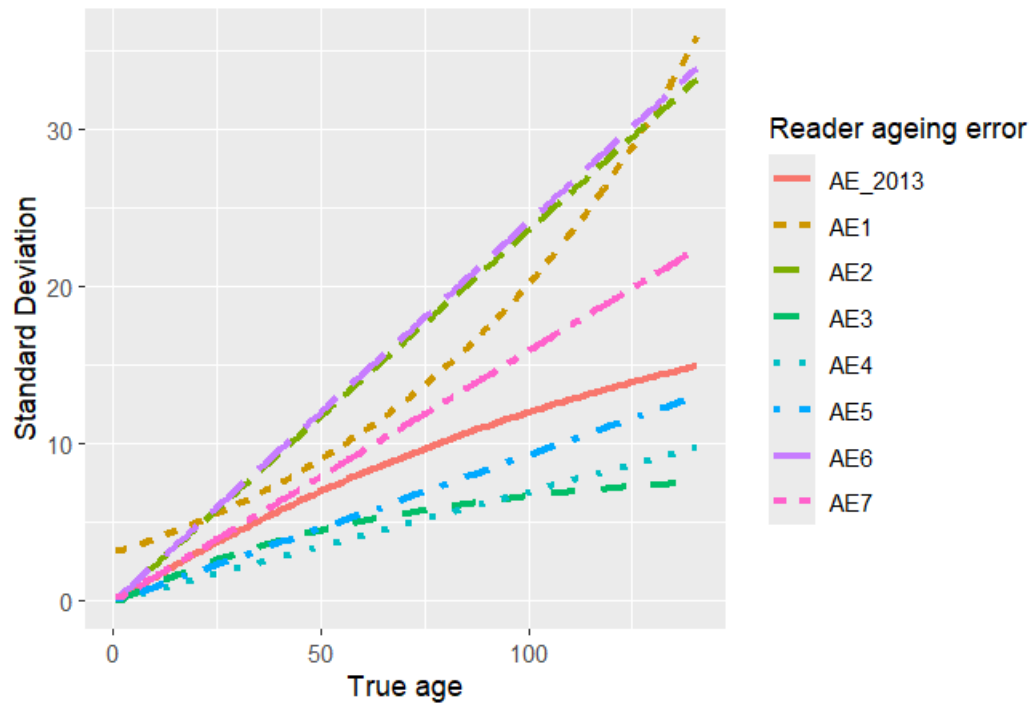


Figure 28: Estimated imprecision (as a standard deviation) used for each of the seven ageing error matrices.

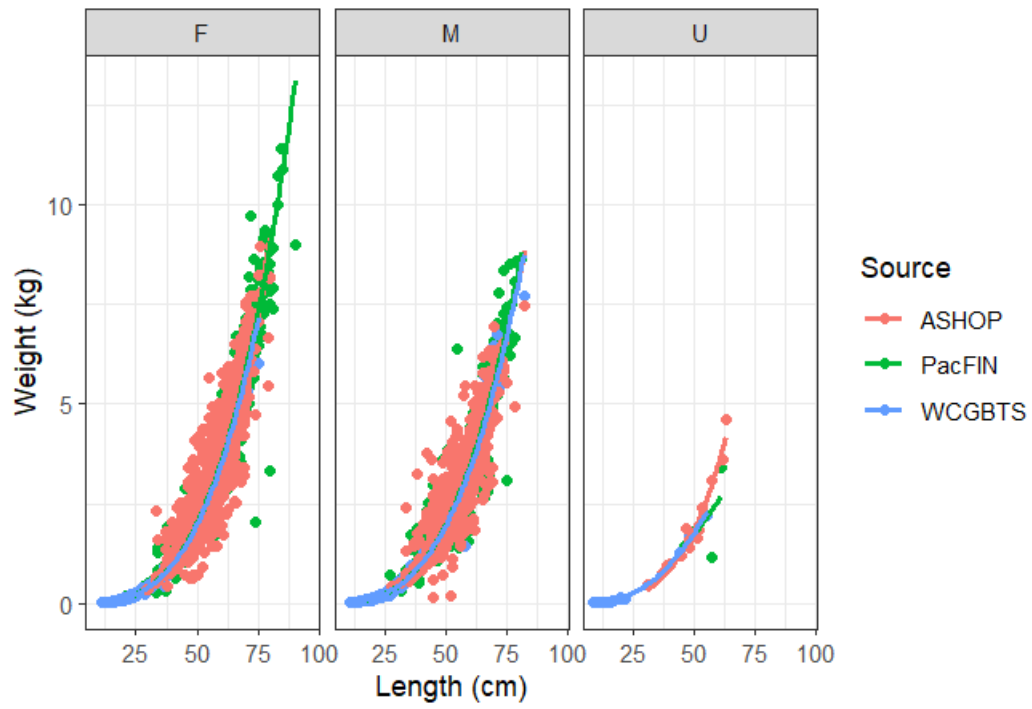


Figure 29: Length and weight samples by sex and data source. Lines are the power function fits by data source.

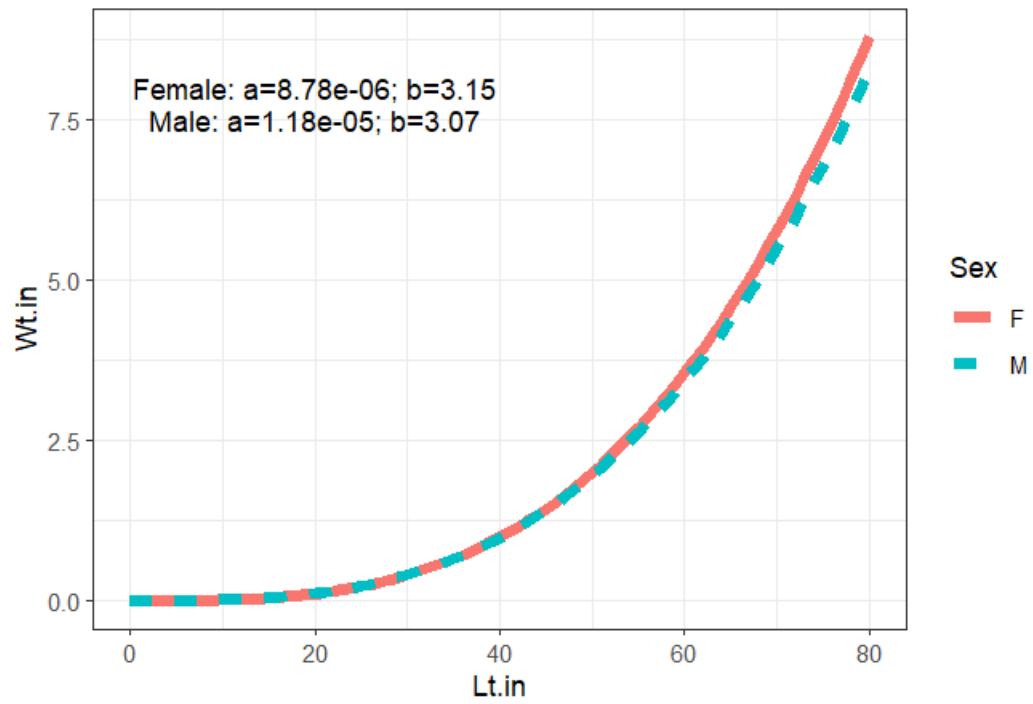


Figure 30: Realized length and weight relationships for female and male Rough-eye/Blackspotted Rockfishes.

## 7.4 Model Bridging

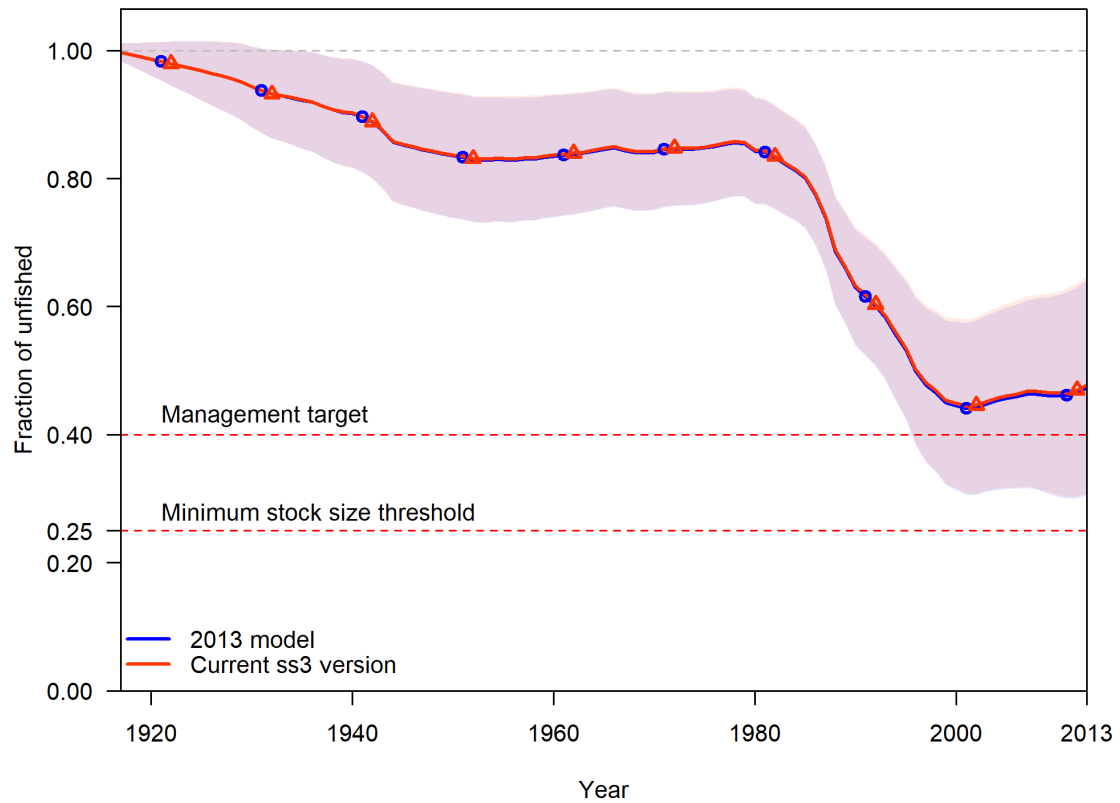


Figure 31: Estimates of relative stock size (current spawning output/unfished spawning output) for the Rougheye/Blackspotted rockfish complex in U.S. west coast waters from the 2013 assessment, and compared to the using the same data in the newest version of SS3 (3.30.22.1).

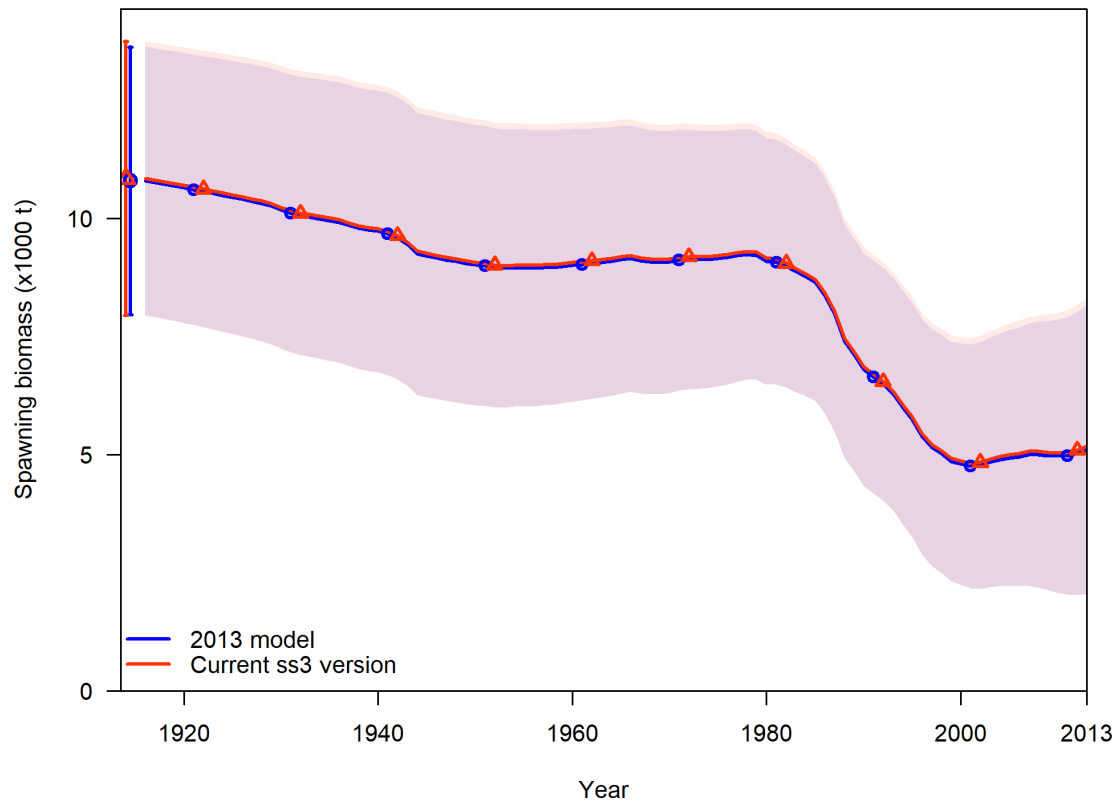


Figure 32: Estimates of spawning output for the Rougheye/Blackspotted rockfish complex in U.S. west coast waters from the 2013 assessment, and compared to the same data in the newest version of SS3 (3.30.22.1). Shading denotes 95% confidence intervals. Shading denotes 95% confidence intervals.

## 7.5 Model Specification

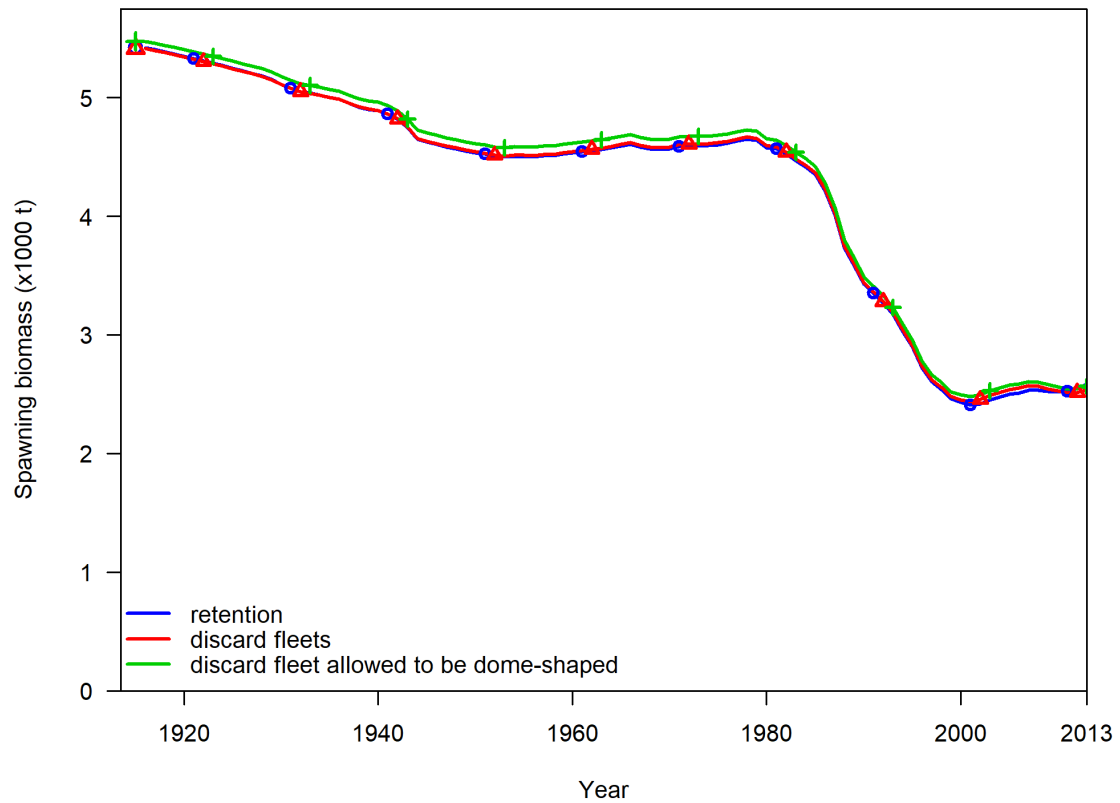


Figure 33: Comparison of spawning output using retention curves or discard fleets using the 2013 Rougheye/Blackspotted Rockfishes assessment.





Figure 34: Comparison of relative spawning output using retention curves or discard fleets using the 2013 Rougheye/Blackspotted Rockfishes assessment.

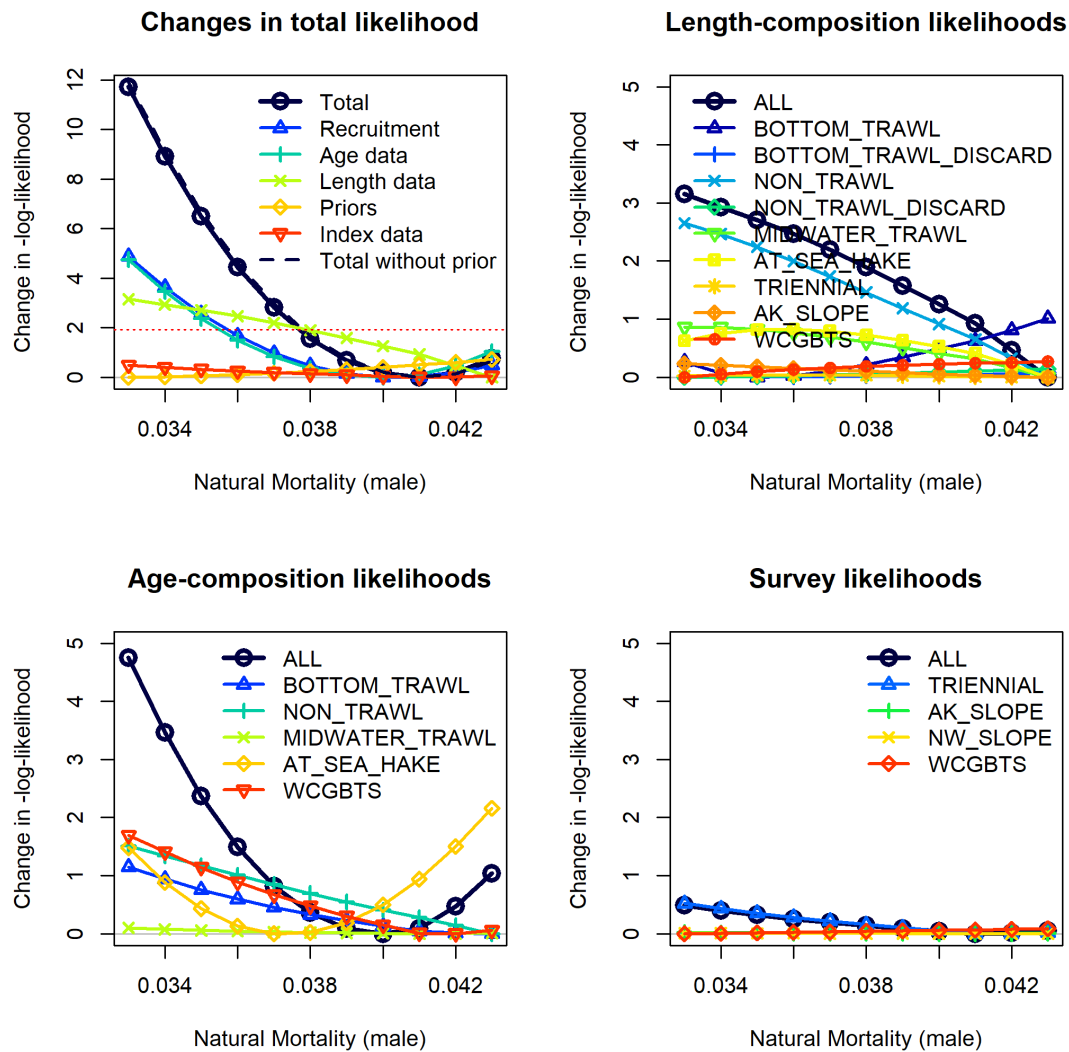


Figure 35: Likelihood profile and component likelihoods used to establish a fixed value for male natural mortality.

## 7.6 Time-series

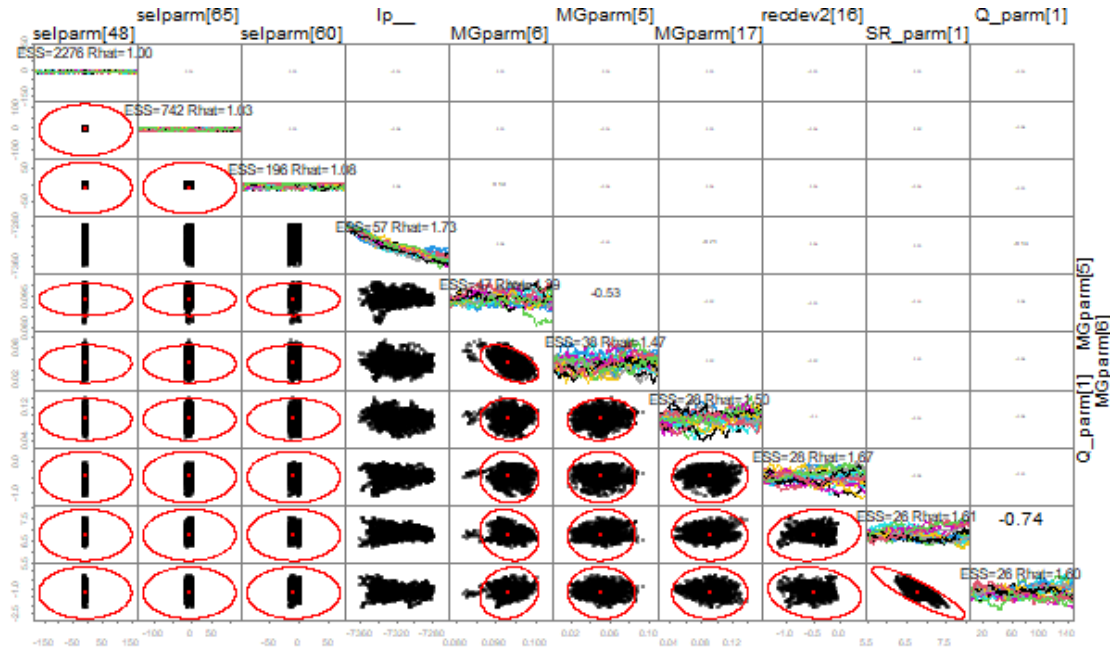


Figure 36: Pairs plots of the fastest mixing parameters from running 2000 posterior draws (keeping every draw) using the random walk Metropolis algorithm. Parameters that show little to no movement are recommended to be fixed to improve model speed and efficiency.

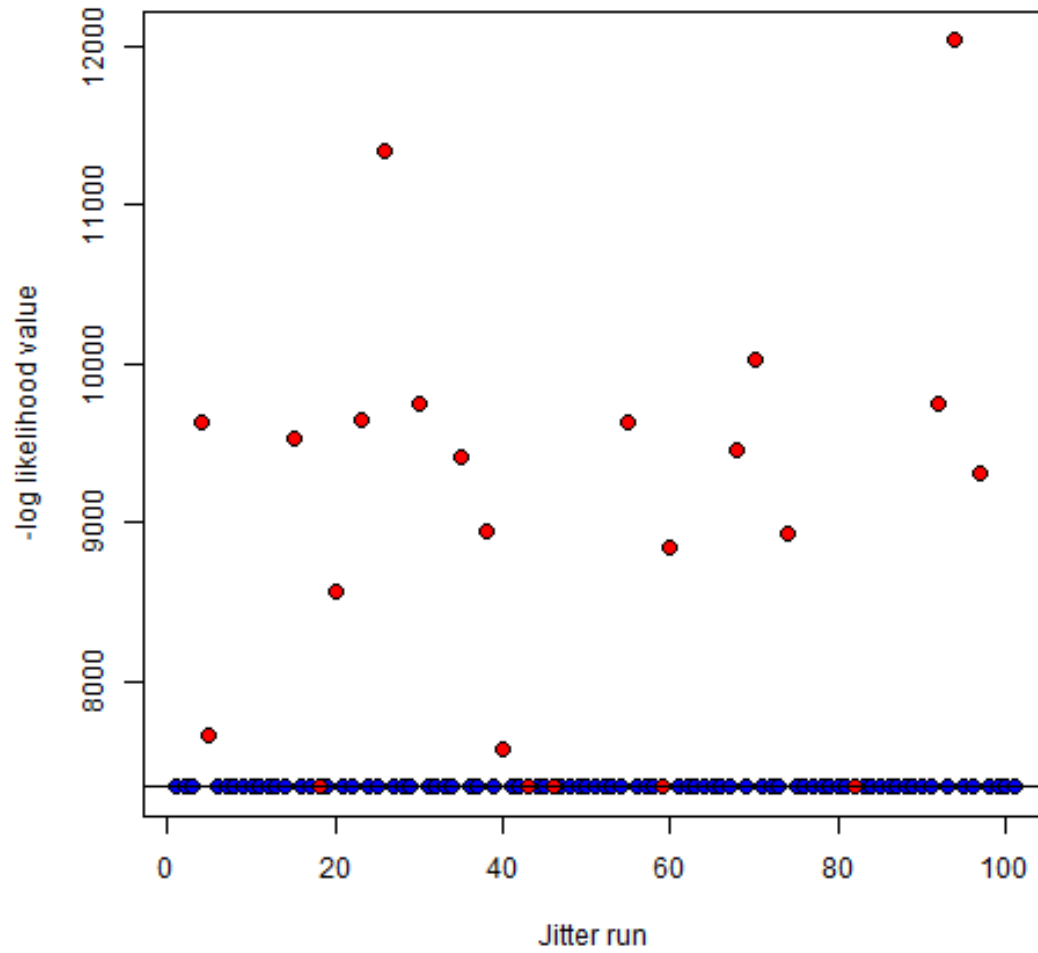


Figure 37: Jitter runs (using a value of 0.01) for the reference model, with jitter run number on the x-axis and -log likelihood value on the y-axis. Blue dot are models that match the likelihood value of the reference model, while red dots deviate from the reference model. All red dots are above the blue dots, indicating no better fit to the reference model was found.

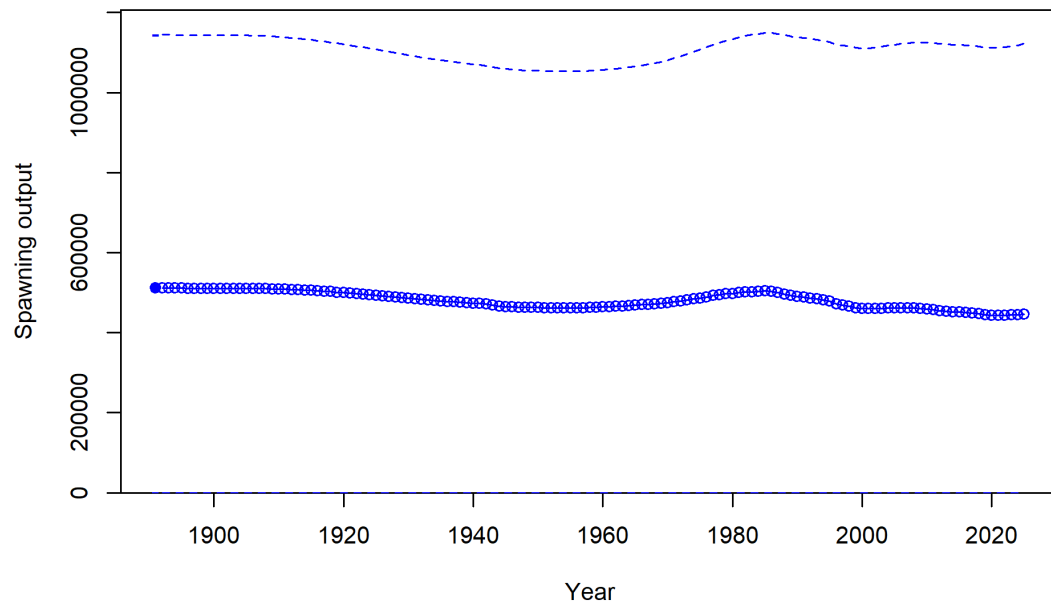


Figure 38: Estimated time series of spawning output for the base model.

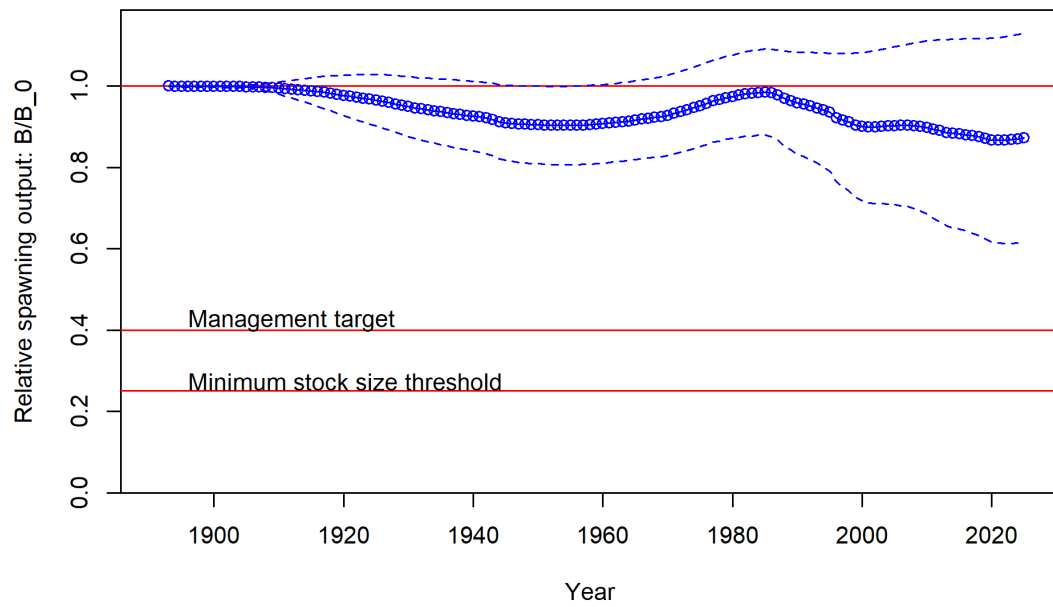


Figure 39: Estimated time series of fraction of unfished spawning output for the base model.

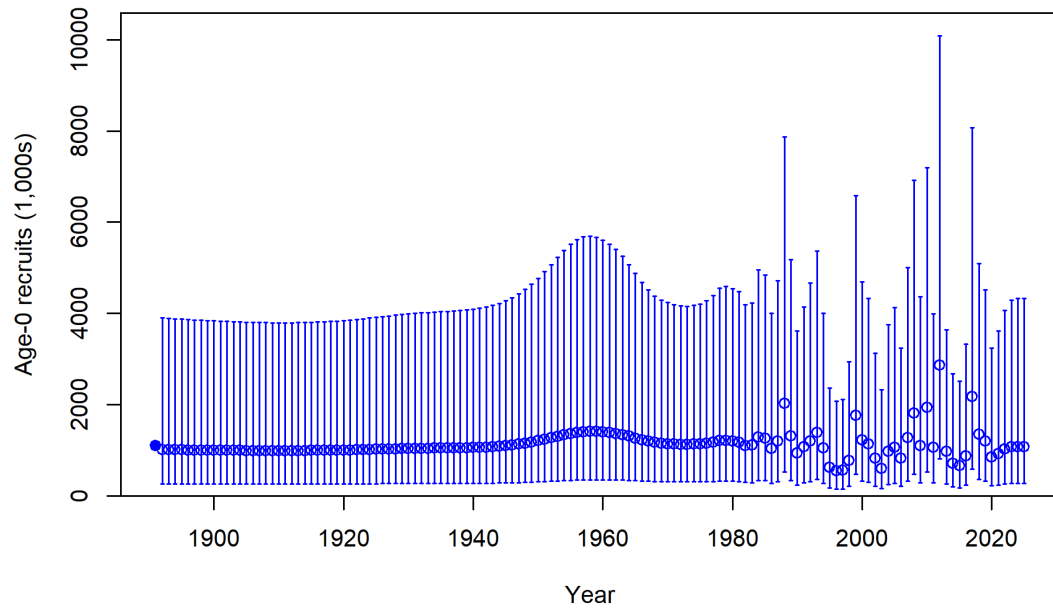


Figure 40: Estimated time series of age-0 recruits for the base model.

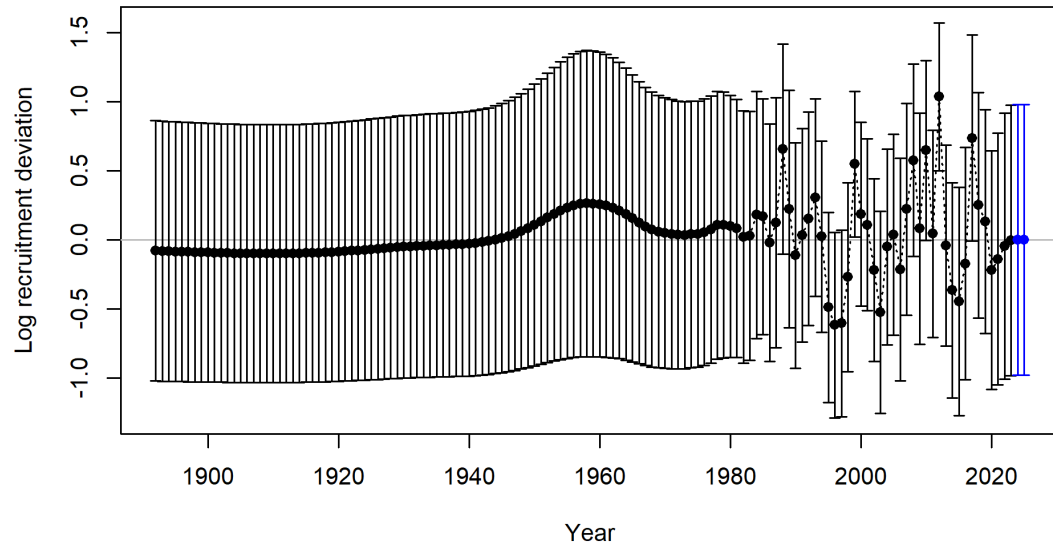


Figure 41: Estimated time series of recruitment deviations for the base model.



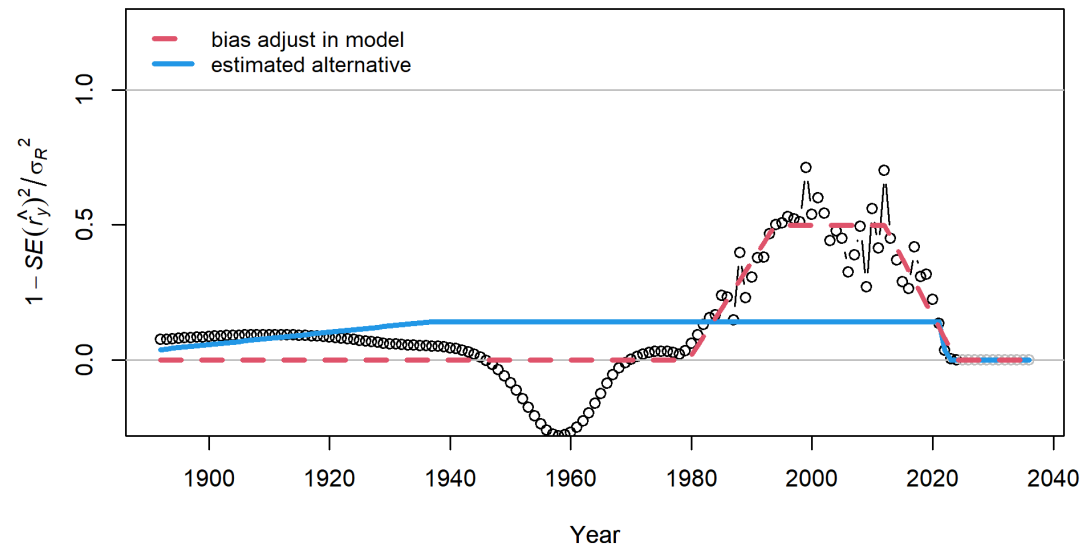


Figure 42: Bias adjustment applied to the recruitment deviations (red line). Points are transformed variances relative to the assumed variance of recruitment.

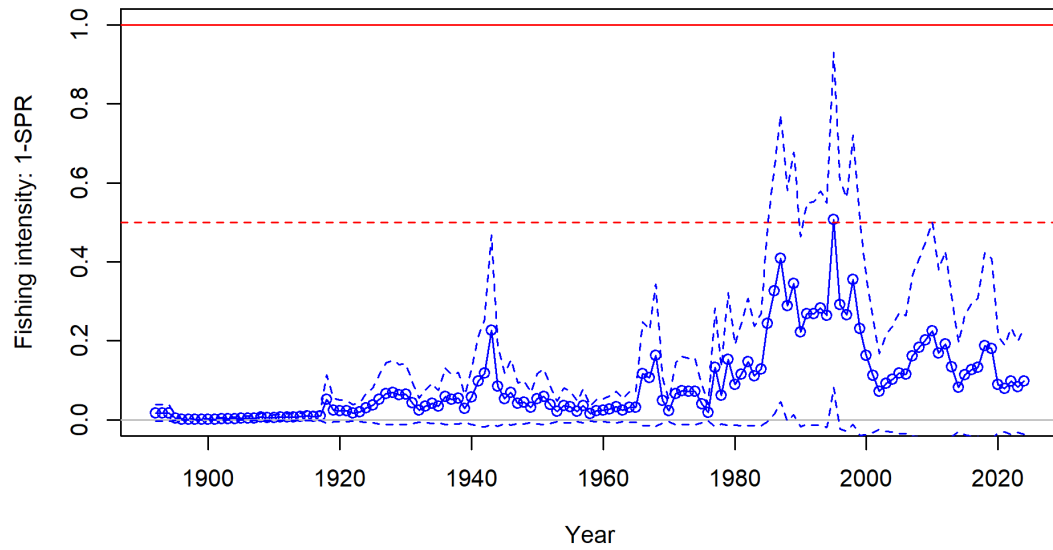


Figure 43: Estimated time series of fishing intensity for the base model.

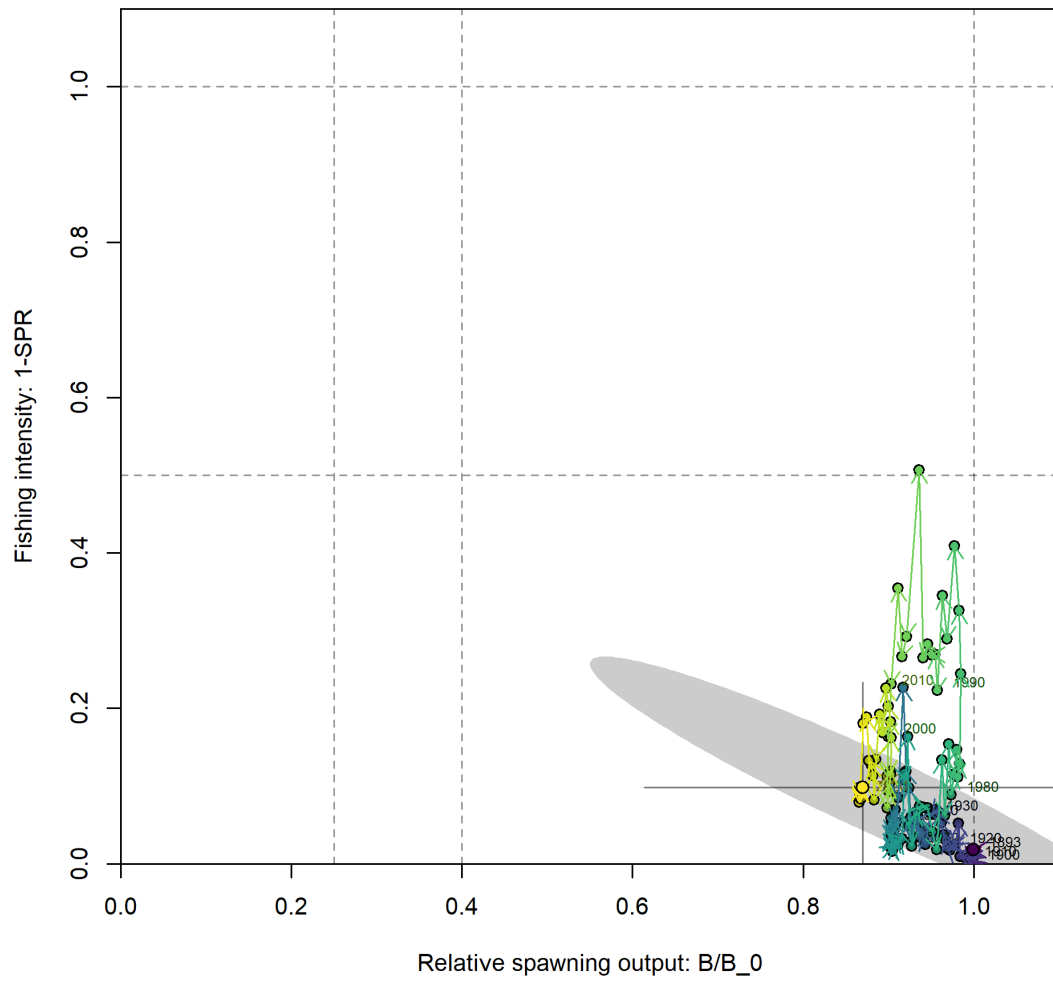


Figure 44: Phase plot of fishing intensity versus fraction unfished for the base model.

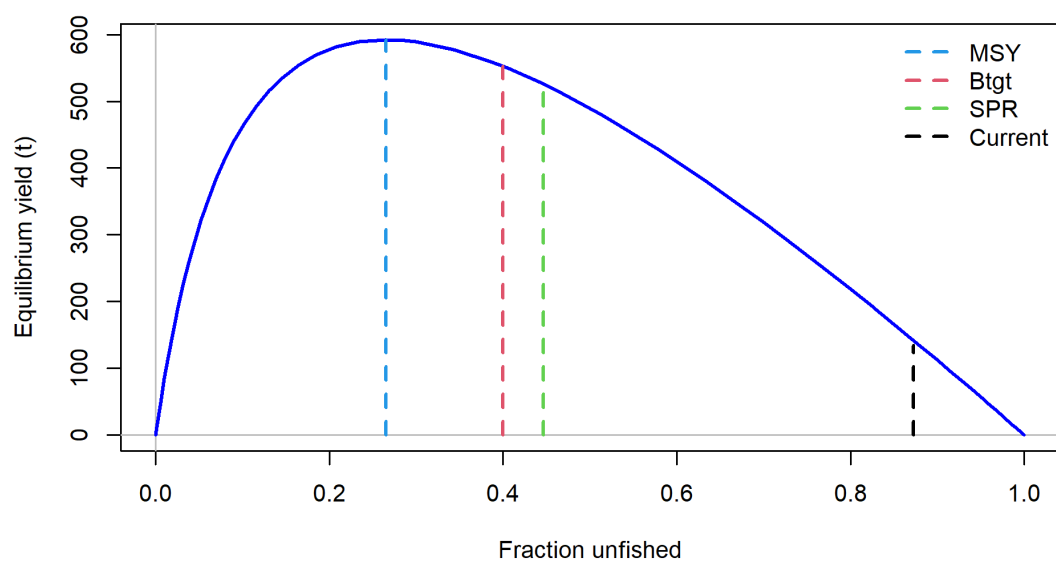


Figure 45: Estimated yield curve with reference points for the base model.

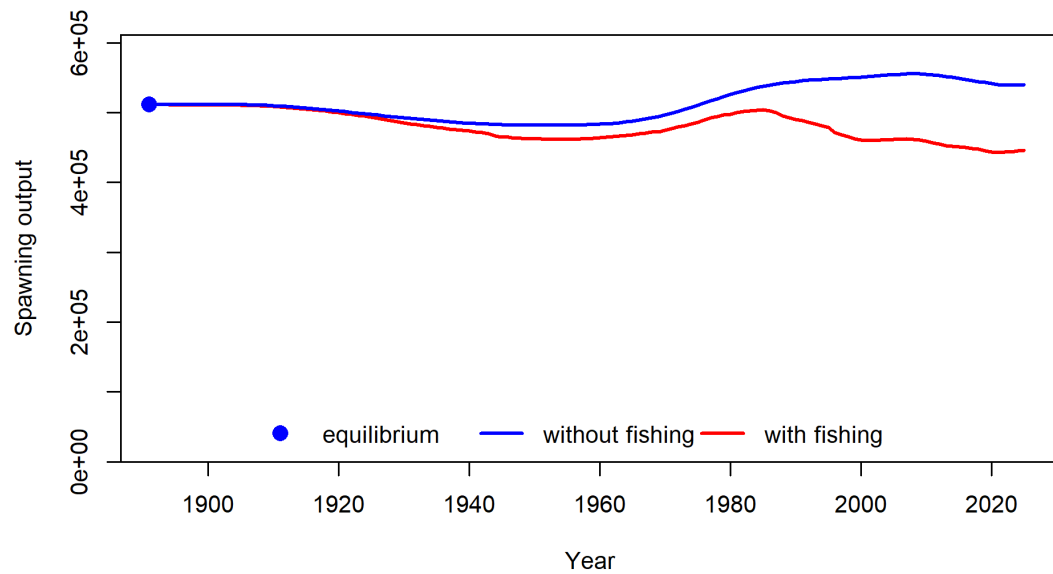


Figure 46: Dynamic B0 plot. The lower line shows the time series of estimated spawning output in the presence of fishing mortality. The upper line shows the time series that could occur under the same dynamics (including deviations in recruitment), but without fishing. The point at the left represents the unfished equilibrium.

## 7.7 Sensitivity Analyses and Retrospectives

## 7.8 Likelihood Profiles

## 7.9 Reference Points and Forecasts



## 8 Notes

## 9 Appendices