

13. Assessment of the Northern Rockfish stock in the Bering Sea/Aleutian Islands

by

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Executive Summary

The last full assessment for northern rockfish was presented to the Plan Team in 2021. The following changes were made to northern rockfish assessment relative to the November 2021 SAFE:

Summary of Changes in Assessment Inputs

Changes in the input data:

- 1) Catch data were updated through 2022, and total catch for 2023 was projected.
- 2) The 2022 Aleutian Island survey age composition, the 2021 fishery age composition data, and the 2022 fishery length composition data were included in the assessment.
- 3) The 2022 Aleutian Island survey biomass estimate was included in the assessment.
- 4) The ageing error matrix was updated.

Changes in the Assessment Methodology

- 1) There were no changes to the assessment methodology.

Summary of Results

BSAI northern rockfish are not overfished or approaching an overfished condition. The recommended 2024 ABC and OFL are 19,274 t and 23,556 t, which are 3% increases from the values specified last year for 2023 of 18,687 t and 22,776 t. The reason for the increase in the harvest level is an increase in the 2022 survey biomass estimate relative to previous survey years.

The Risk Table categories have been altered for 2023, with the category of “substantial concern” being eliminated. Our evaluation of the risks for this assessment is below:

<i>Assessment-related considerations</i>	<i>Population dynamics considerations</i>	<i>Environmental/ecosystem considerations</i>	<i>Fishery Performance considerations</i>	<i>Overall score (highest of the individual scores)</i>
Level 2: Major Concern	Level 2: Major Concern	Level 1: No Concern	Level 1: No Concern	Level 2: Major Concern

The assessment-related concerns relate to the retrospective pattern in the assessment, and the use of strong priors for several key model parameters that cannot be reliably estimated (in effect understating the level of uncertainty in the assessment). A population dynamics concern is that the spatial management of the stock is not consistent with the genetic spatial structure, which could lead to subarea depletion and loss of fishery yield, particularly as the target fishery for northern rockfish is developing.

The concerns identified above are not addressed in the assessment and Tier status for this stock. Issues such as the retrospective pattern and the use of strong prior distributions affect the results of the assessment, but are not mitigated or otherwise addressed within the assessment. These factors are also not addressed by our current Tier system. Additionally, the mismatch between the genetic spatial structure and the spatial management of the stock is not addressed within the assessment or the Tier system, as this issue extends beyond the assessment itself.

Overall, the stock abundance is high and the exploitation rates are low. Given the current stock status, we recommend the full ABC.

A summary of the recommended ABCs and OFLs from this assessment relative to the ABC and OFL specified last year is shown below:

Quantity	As estimated or specified last year for:		As estimated or recommended this year for:	
	2023	2024	2024*	2025*
<i>M</i> (natural mortality rate)	0.054	0.054	0.052	0.052
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)	277,133	273,414	297,189	292,686
Female spawning biomass (t)				
Projected	118,251	115,209	128,229	124,651
<i>B</i> _{100%}	171,768	171,768	187,268	187,268
<i>B</i> _{40%}	68,707	68,707	74,907	74,907
<i>B</i> _{35%}	60,119	60,119	65,544	65,544
<i>F</i> _{OFL}	0.085	0.085	0.086	0.086
<i>maxF</i> _{ABC}	0.069	0.069	0.070	0.070
<i>F</i> _{ABC}	0.069	0.069	0.070	0.070
OFL (t)	22,776	22,105	23,556	22,838
maxABC (t)	18,687	18,135	19,274	18,685
ABC (t)	18,687	18,135	19,274	18,685
Status	As determined last year for: for:		As determined this year	
	2021	2022	2022	2023
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on estimated catches of 8,494 t and 8,234 t used in place of maximum permissible ABC for 2024 and 2025. Fishing and biomass reference points (i.e., $\max F_{abc}$, F_{ofl} , and $B_{x\%}$) are based on estimated average population and fishery sizes-at-age from 2019-2023.

Summaries for the Plan Team

The following table gives the recent biomass estimates, catch, and harvest specifications, and projected biomass, OFL and ABC for 2022-2025.

Year	Biomass (ages 3+) ¹	OFL	ABC	TAC	Catch ²
2022	279,584	23,420	19,217	17,000	7,898
2023	277,133	22,776	18,687	11,000	9,948
2024	297,189	23,556	19,274		
2025	292,686	22,838	18,685		

¹ Total biomass from age-structured projection model.

² Catch as of September 16, 2023.

Responses to SSC and Plan Team Comments on Assessments in General

SSC (June, 2021) *The SSC supports the recommendation of reducing the number of category levels from four to three.*

The number of category levels for the risk table was reduced from 4 to 3 in this assessment.

SSC (October, 2023) *When there are time-varying biological and fishery parameters in the model, the SSC requests that a table be included in the SAFE that documents how reference points are calculated.*

A footnote was added to the Executive Summary table noting that the reference points were based on the recent 5-year averages of population and fishery size at age.

Responses to SSC and Plan Team Comments Specific to this Assessment

SSC (December, 2021) *The SSC suggests the technical description of the model (e.g., equations etc.) be moved to an appendix in this assessment, and the main document should contain a detailed text description of the model structure.*

The text includes a streamlined description of the model, with lists of model equations included as assessment tables.

SSC (December, 2021) *Finally, as the SSC reiterates its request that the aging error matrix be updated with data from the BSAI, as the assessment author did not have time to complete the request this cycle.*

The ageing error matrix has been updated in this assessment.

SSC (December, 2021) *It would also be helpful to confirm the absence of northern rockfish in the EBS survey data, noting the increase in the portion of the AI survey that enters the southern Bering Sea in 2018, following the marine heatwave.*

A table of recent biomass estimates of northern rockfish from the EBS shelf survey is shown below.

Year	Total Hauls	Hauls with Northern Rockfish Catch	Biomass Estimate (t)	CV of Biomass Estimate
2003	376	5	1531	0.79
2004	375	0	0	NA
2005	373	2	62	0.69
2006	376	3	186	0.64
2007	376	1	5853	1.00
2008	375	1	580	1.00
2009	376	2	169	0.84
2010	376	3	1116	0.91
2011	376	5	584	0.61
2012	376	2	223	0.77
2013	376	3	538	0.90
2014	376	2	840	0.98
2015	376	4	465	0.79
2016	376	4	115	0.50
2017	376	4	903	0.71
2018	376	5	47946	0.96
2019	376	4	371	0.70
2021	376	4	2281	0.93
2022	376	10	3213	0.65
2023	376	5	456	0.57

The biomass estimates have not exceed 5,900 t with the exception of 2018, when the estimate was 48,000 t with a CV of 0.96; since 2018, the biomass estimates have not exceeded 3,300 t. Additionally, the number of hauls in which northern rockfish was caught has not exceeded 5 with the exception of 2022 (with 10 hauls). Given the uncertainty in these estimates, the small biomass levels compared to the AI trawl survey, and the limited number of hauls in which northern rockfish were captured, these data were not included in the assessment.

BSAI Plan Team (September, 2023) *The Teams noted the continuing evidence for stock structure and concerns over risks to stock biomass and productivity from disproportionate harvesting. The lack of spatial harvest regulations would not prevent spatially disproportionate harvesting, which has occurred for other BSAI rockfish such as Pacific ocean perch and blackspotted/rougheye rockfish. However, the low rates of harvest for BSAI northern rockfish suggests that this risk has not yet been realized. The Team recommends this information be included in the risk table for the November assessment and that the author and Team continue to monitor this stock for potential spatial concerns.*

SSC (October, 2023) *The SSC supports the BSAI GPT recommendation that the stock structure information be included in the risk table for November and to continue to monitor the stock for potential spatial concerns.*

The information on stock structure and the mismatch between spatial stock structure and spatial management units continues to be included in the Risk Table.

Introduction

Northern rockfish (*Sebastes polyspinis*) inhabit the outer continental shelf and upper slope regions of the North Pacific Ocean and Bering Sea. Northern rockfish in the Bering Sea/Aleutians Islands (BSAI) region were assessed under Tier 5 of Amendment 56 of the NPFMC BSAI Groundfish FMP until 2004. The reading of archived otoliths from the Aleutian Islands (AI) surveys allowed the development of an age-structured model for northern rockfish beginning in 2003. Since 2004, BSAI northern rockfish have been assessed as a Tier 3 species in the BSAI Groundfish FMP.

Information on Stock Structure

A stock structure evaluation was included as an appendix to the 2012 stock assessment (Spencer and Ianelli 2012). A variety of types of data were considered, including genetic data, potential barriers to movement, growth differences, and spatial differences in growth and age and size structure.

Several genetic tests were conducted on northern rockfish samples obtained in the 2004 Aleutian Islands and EBS trawl surveys (Gharrett et al. 2012). A total of 499 samples were collected at six locations ranging from the EBS slope to the western Aleutian Islands, and analyses were applied to 11 microsatellite loci. Information on the spatial population structure was obtained from the spatial analysis of molecular variance (SAMOVA; Dupanloup et al. 2002), which identified sets of collections that showed maximum differentiation. Three groups were identified: 1) the eastern Bering Sea; 2) two collections west of Amchitka Pass; and 3) three collections between Amchitka Pass and Unimak Pass. The genetic data also show a statistically significant pattern of isolation by distance, indicating genetic structure being produced from the dispersal of individuals being smaller than the spatial extent of the sampling locations. A range of expected lifetime dispersal distances were estimated, reflecting different assumptions regarding effective population size and migration rates of spawners, and the estimated lifetime dispersal distances did not exceed 250 km. This estimated dispersal distance is comparable to other *Sebastes* species in the north Pacific, which have ranged from 4 to 40 for near shore species such as grass rockfish (Buonaccorsi et al. 2004), brown rockfish (Buonaccorsi et al. 2005), and vermilion rockfish (Hyde and Vetter 2009), and up to 111 km for deeper species such as POP (Palof et al. 2011) and darkblotched rockfish (Gomez-Uchida and Banks 2005). The demographic implication is that movement of fish from birth to reproduction is at a much smaller scale than the geographic scale of the BSAI area. Finally, it is important to recall that the time unit for the estimated dispersal is not years, but generations, and the generation time for northern rockfish is more than 36 years.

Aleutian Island trawl survey data was used to estimate von Bertalanffy growth curves by areas, and show increasing size at age from the western AI to the eastern AI. The largest difference in the growth curves was in the rate parameter K , which was smallest in the western Aleutians, indicating that fish in this area approached their asymptotic size more slowly than fish in the EAI and SBS. Additionally, size at age in the GOA is larger than that in the AI, indicating an east-west cline in growth (Clausen and Heifetz 2002)

Spatial differences in age compositions, obtained from the AI trawl surveys from 2002, 2004, and 2006, were evaluated by testing for significant differences in mean age between areas. Significant differences were observed in the mean age between subareas for individual years, but a consistent pattern did not emerge across the years.

Finally, any potential physical limitations to movement were considered. Physical barriers are rare in marine environments, but the Aleutian Islands are unique due to the occurrence of deep passes, typically exceeding 500 m, that may limit the movement of marine biota. For example, Logerwell et al. (2005) identify a “biophysical transition zone” occurs at Samalga Pass. Northern rockfish are a demersal species captured during the AI trawl survey at depths between 100 m and 200 m, so adult rockfish traversing the much deeper AI passes would require greater utilization of pelagic habitats or deeper depths than currently observed in the AI trawl surveys. Movement of larvae between areas is likely a function of

ocean currents. On the north side of archipelago, the connection between the east and west Aleutians is limited due to the break associated with Petral Bank and Bowers Ridge, which results in water flowing away from the Aleutian Islands archipelago. On the south side of the Aleutian Islands, the Alaska Stream provides much of the source of the Alaska North Slope Current (ANSC) via flow through Amukta Pass and Amchitka Pass. However, The Alaska Stream separates from the slope west of the Amchitka Pass and forms meanders and eddies, perhaps limiting the connection between the east and west Aleutians.

Fishery

BSAI foreign and joint venture rockfish catch records from 1977 to 1989 are available from foreign “blend” estimates of total catch by management group, and observed catches from the North Pacific Observer Program database. The foreign catch of BSAI rockfish during this time was largely taken by Japanese trawlers, whereas the joint-venture fisheries involved partnerships with the Republic of Korea. Because northern rockfish were taken as bycatch in the BSAI area, historical foreign catch records have not identified northern rockfish catch by species. Instead, northern rockfish catch has been reported in a variety of categories such as “other species” (1977, 1978), “POP complex” (1979-1985, 1989), and “rockfish without POP” (1986-1988).

Rockfish management categories in the domestic fishery since 1991 have also included multiple species. In 1991, the “other red rockfish” species group was used in both the EBS and AI, but beginning in 1992 northern rockfish in the AI were managed in the “northern/sharpchin” species group. Prior to 2001, northern rockfish were managed with separate ABCs and TACs for the AI and EBS, and in 2001 the two areas were combined into a single management unit under the “sharpchin/northern” species complex. In 2002, sharpchin rockfish (*S. zacentrus*) were dropped from the complex because of their sparse catches, leaving a single-species management category of northern rockfish. The OFLs, ABCs, TACS, and catches by management complex from 1977-2000 are shown in Table 1, and catches from 2001 to present are shown in Table 2.

Since 2002, the blend and catch accounting system (CAS) databases have reported catch of northern rockfish by EBS and AI subareas. From 1991-2001, species catches were reconstructed by computing the harvest proportions within management groups from the North Pacific Foreign Observer Program database, and applying these proportions to the estimated total catch obtained from the NOAA Fisheries Alaska Regional Office “blend” database. This reconstruction was conducted by estimating the northern rockfish catch for each area (i.e., the EBS and each of the three AI areas) and gear type from 1994-2001. For 1991-1993, the Regional Office blend catch data for the Aleutian Islands was not reported by AI subarea, and the AI catch was obtained using the observer harvest proportions by gear type for the entire AI area. Similar procedures were used to reconstruct the estimates of catch by species from the 1977-1989 foreign and joint venture fisheries. Estimated domestic catches in 1990 were obtained from Guttormsen et al. 1992. Catches from the domestic fishery prior to the domestic observer program were obtained from the Pacific Fisheries Information (PACFIN) records.

Catches of northern rockfish since 1977 by area are shown in Table 3. Northern rockfish catch prior to 1990 was small relative to more recent years (with the exception of 1977 and 1978). Harvest data from 2004 -2010 indicates that approximately 88% of the BSAI northern rockfish were harvested in the Atka mackerel (*Pleurogrammus monopterygius*) fishery. Prior to 2011, much of the northern rockfish catch occurred in the western and central Aleutian Islands, reflecting the high proportion of Atka mackerel fishing in these areas (Table 4). However, restrictions on Atka mackerel fishing in the western Aleutians from 2011-2014 constrained the northern rockfish harvest in this area, and during these years the average proportion of northern rockfish harvested in the Atka mackerel fishery declined to 54%. Northern rockfish are patchily distributed and are harvested in relatively few areas within the broad management subareas of the Aleutian Islands, with important fishing grounds being Petral Bank, Sturdevant Rock, south of Amchitka I., and Seguam Pass (Dave Clausen, NMFS-AFSC, personal communication).

Although northern rockfish are generally harvested as a bycatch species, targeting of northern rockfish has occurred in recent years. Observer catch records were used to identify the targeted species of tows, based on the dominant species in the catch. Tows targeting northern rockfish are defined as having rockfish be the largest species group in the catch, and northern rockfish being the most abundant rockfish species. The number of tows targeting northern rockfish increased from 46 in 2014 to 113 in 2015, and this targeting resulted in a catch of 7,197 t exceeding the TAC of 3,250 t, although the 2015 catch was below the ABC of 12,488 t (in recent years, the TAC for northern rockfish is usually set much lower than the ABC). The number of tows targeting northern rockfish increased from 60 in 2016 to 290 in 2019, and declined to 232 in 2022. Although these tows comprise a relatively small proportion of the total number of tows in which northern rockfish are caught (Figure 1a), they contribute a large share of the observed catch (Figure 1b). In 2021 and 2022, 33% and 43%, respectively, of the observed northern rockfish catch was obtained in tows targeting northern rockfish, indicating the development of a growing target fishery. The catch of northern rockfish in these tows has generally exceeded 50%, and exceeded 60% in 2013 and 2014 (Figure 1c). Increased targeting of northern rockfish since 2016 has led to increased catches, from 4,536 t in 2016 to 9,948 t in 2023 (through Sept 16), which is the largest on record.

The distribution of the percent northern rockfish in the total catch by haul, for vessels identified as targeting northern rockfish, has ranged between 9% and 99% (Figure 2) from 2019 to 2022. The percent of these target hauls for which the northern rockfish catch exceeded 65% of the total catch ranged between 29% in 2019 to 37% in 2022.

The observer records of catch of northern rockfish in tows targeting northern rockfish was used to compute the catch per unit effort (CPUE) per year, defined as the sum of northern rockfish catch (t) divided by the sum of tow duration (hrs). Northern rockfish fishery CPUE has been relatively stable but shows a slight increase since 2007 (Figure 3a), and years with low catches also had low CPUE values (Figure 3b).

Area-specific exploitation, defined as the yearly catch within a subarea divided by an estimate of the subarea biomass at the beginning of the year, was computed for 2004 to 2023. The subarea biomass was obtained by applying the spatial distributions observed in the survey biomass estimates (after a smoother is applied) to the estimated total biomass from the 2023 recommended assessment model. To provide a reference for evaluating these exploitation rates in the context of our harvest control rule, exploitation rates were compared to the exploitation rate for each year that would result from applying a fishing rate of $F_{40\%}$ to the estimated beginning-year numbers, and this rate is defined as $U_{F40\%}$. The $U_{F40\%}$ rate takes into account maturity, fishing selectivity, size-at-age, and time-varying number at age. Exploitation rates for all subareas are lower than the $U_{F40\%}$ reference, although they increased substantially from 2016 to 2023, particularly in the WAI and CAI (Figure 4).

Temporal variability in northern rockfish catches has occurred in AI subareas. Variability in catches by depth of capture has also been observed, but to a lesser extent (Figure 5). The domestic fishery observer data indicates that the eastern AI accounted for 49% and 63% of the AI harvest in 1990 and 1991, respectively, decreasing to less than 15% of the observed catch from 1997 to 2006 (except 1999 and 2000). In contrast, the proportion of observed catch in the western AI increased from less than 20% from 1991 to 1993 to greater than 40% in most years from 1996-2005, and has decreased to less than 15% from 2011 – 2014 with the closure of the western AI to Atka mackerel fishing in these years. The observed catch of northern rockfish is predominately captured at depths between 100 m and 200 m. The percentage obtained at depths between 200 m and 300 m has been variable, ranging from less than 5% during 2000 – 2007 to between 4% and 14% from 2008 – 2023.

Information on proportion discarded is generally not available for northern rockfish in years where the management categories consist of multi-species complexes. However, because the catches of sharpchin rockfish are generally rare in both the fishery and survey, the discard information available for the “sharpchin/northern” complex can be interpreted as northern rockfish discards. This management category

was used in 2001 in the EBS, and from 1993-2001 in the AI. Prior to 2003 the discard rates were generally above 80%, with the exception of the mid-1990s when some targeting occurred in the Aleutians Islands (Table 5). Discard rates in the AI have declined from 90% in 2003 to < 10% in most years since 2011. In the eastern Bering Sea, discard rates have declined from 75% in 2003 to < 5% in 2010, and have ranged from 12% to 66% from 2012 to 2022.

Catch by species from BSAI trips targeting rockfish from 2016 to 2023 indicate that the largest non-rockfish species caught are Atka mackerel, walleye pollock (*Gadus chalcogrammus*), Pacific cod (*G. macrocephalus*), Kamchatka flounder (*Atheresthes evermanni*), and arrowtooth flounder (*A. stomias*) (Table 6). Northern rockfish are primarily caught in rockfish trips targeting rockfish and Atka mackerel (Table 7). Catch of prohibited species is low in trips targeting rockfish, with the catch of most prohibited species groups averaging less than 5 t or 5000 individuals from 2016-2023 (Table 8). Catch of non-FMP species by in BSAI trips targeting rockfish are largest for giant grenadier (*Albatrossia pectoralis*), sculpins, miscellaneous fish, and unidentified sponge (Table 9).

Non-commercial catch data are shown in Appendix A.

Data

Fishery Data

The fishery data are characterized by inconsistent sampling of lengths and ages (Table 10). In some years, such as 1984 and 1987, over 700 fish lengths were obtained but these data samples came from a limited number of hauls. Additionally, the length data from the foreign fishery tended to originate from predominately one location in each year, and was not consistent between years. For example, the 1977 and 1978 fishery length data were collected from Tahoma Bank in the western Aleutians, whereas samples in 1984 were obtained from Seguam Pass and samples in 1987 were obtained from Petral Bank. In the domestic fishery, changes in observer sampling protocol since 1999 have improved the distribution of hauls from which northern rockfish age and length data are collected.

Length measurements and otoliths read from the EBS and AI management areas were combined to create fishery age/size composition matrices, with the length composition within management subareas weighted by the estimated catch numbers from observed tows (Table 11). The selection of fishery length frequency data for the age-structured assessment model was based on the consistency in sampling location and the number of samples collected. Foreign fishery length compositions from 1977 and 1978 were used in the assessment, in part, because of the consistency in their sampling location with other sampling years, the increased numbers of hauls from which they were obtained, and the absence of other length composition data during this portion of the time series. Domestic fishery length compositions from 1996, 1998-1999, 2010, 2012, 2014, 2016, 2018, and 2022 were used in the assessment, and the length and age data from 2000-2009, 2011, 2013, 2015, 2017, and 2019-2021 were used to estimate the age compositions of the fishery catch (Table 12).

The estimated lengths at age by subarea, across all years, is shown in Figure 6, and indicate a cline from small fish in WAI to larger fish in the EAI and SBS areas. In the 2016 and prior assessments, a “global” age-length key, per year, was used to compute the fishery age compositions by ignoring any spatial differences in size at age and using the aggregate sample of otoliths across subareas (i.e., in effect weighting the spatial subareas by the number of read otoliths instead of the fishery catch). Because of the spatial differences in size at age, the fishery age compositions in the 2019 and subsequent assessments were produced by applying area-specific age-length key to the fishery length composition from each area, and weighting the resulting subarea age compositions by the extrapolated catch number by subarea from the North Pacific Groundfish Observer Program. The subareas considered in the assessment are the three Aleutian Island subareas (western Aleutians (WAI), central Aleutians (CAI), and eastern Aleutians

(EAI)), plus the Bering Sea (BS) area. The age compositions produced by the two methods were generally similar to each other (Spencer and Ianelli 2016), which results from randomized sampling of fishery otoliths in which the distribution of read otoliths being relatively similar to the distribution of fishery catch (Figure 7).

The fishery age composition data indicates the relatively strong cohorts in 1984-1985, and 1995. The 2005 year class initially appeared strong through the 2017 sampling year, but in the 2019 and 2020 samples the 2006 year class appears stronger than the 2005 year class (Figure 8, Table 12).

Survey data

Biomass estimates for other red rockfish were produced from cooperative U.S.-Japan trawl survey from 1979-1985 on the eastern Bering Sea slope, and from 1980-1986 in the Aleutian Islands. U.S. trawl surveys on the eastern Bering Sea slope were conducted by the National Marine Fisheries Service (NMFS) in 1988, 1991, and biennially beginning in 2002 (except 2006 and 2014, when the survey was canceled due to lack of funding). NMFS trawl surveys in the Aleutian Islands were conducted in 1991, 1994, 1997, and biennially beginning in 2000. Differences exist between the 1980-1986 cooperative surveys and the U.S. domestic surveys with regard to the vessels and gear design used (Skip Zenger, National Marine Fisheries Service, personal communication). For example, the Japanese nets used in the 1980, 1983, and 1986 cooperative surveys varied between years and included large roller gear, in contrast to the poly-nor' eastern nets used in the current surveys (Ronholt et al 1994), and similar variations in gear between surveys occurred in the cooperative EBS surveys. In previous assessments, these surveys were included in the assessment to provide some indication of biomass during the 1980s. Given the difficulty of documenting the methodologies for these surveys, and standardizing these surveys with the NMFS surveys, this assessment model is conducted with only the NMFS surveys.

Survey abundance in the western and central Aleutians is generally larger than abundance in the eastern Aleutians and eastern Bering Sea (Table 13), as indicated by a plot of the survey CPUE values by tow (Figure 9). In 2014, the survey abundance in the eastern AI increased sharply to 77,000 t (from an average of 20,000 t from 2006-2012) and has a large coefficient of variation of 0.79, but biomass in this area decreased to 48,000 t in 2016 and 20,000 t in 2018 before increasing to 74,000 t in 2022. Abundance in the western Aleutian Islands also showed a large increase in the 2014 survey (to 346,392 t), but decreased to 123,000 t in the 2022 survey. Areas of particularly high survey abundance are Amchitka Island, Kiska Island, Buldir Island, and Tahoma Bank. The 2022 Aleutian Island survey biomass was 287,000 t, which represents an increase of 25% from the 2018 estimate of 212,472 t. Increases were observed in the WAI, EAI, and southern Bering Sea, but the 2022 biomass estimate in the CAI area decreased from 54,500 t in 2018 to 32,212 t in 2022. The CV for the overall 2022 AI biomass estimate is 0.22. The coefficients of variation (CV) of these biomass estimates by region are generally high, but especially so in the southern Bering Sea portion of the surveyed area (165 W to 170 W), where the CV was less than 0.50 only in the 2000 survey, and was 0.76 for the 2022 survey.

Similar to the fishery data, the size at age data from the AI survey shows a spatial cline with length at age increasing from west to east (Figure 10), and assessments in and prior to 2016 used a global age-length key, per year, that did not account for this pattern. In the 2019 and subsequent assessments, the survey age compositions were produced in a similar manner as the fishery age compositions by applying the area-specific age-length key to the estimated survey length composition from each area, and weighting the resulting subarea survey age compositions by the estimated survey population number. In general, application of the weighted subarea age-length keys produces survey age compositions with relatively fewer young fish and relatively more older fish (Spencer and Ianelli 2016), and this pattern is generally consistent across all survey years. The survey abundance is concentrated in the WAI (Figure 11) which has the smallest size at age; any population-level estimate of size at age and age compositions should reflect that most of the stock is located in an area with smaller size at age. However, the spatial distribution of otoliths has generally not been proportional to the spatial distribution of the population. In

years prior to 2016, length-stratified sampling of otoliths occurred in the AI survey, which resulted in relatively similar numbers of otoliths being sampled across subareas irrespective of the subarea abundance. Beginning in 2016, random sampling of otoliths have occurred in the AI survey, which has resulted in the spatial distribution of otoliths samples more closely corresponding to the spatial distribution of abundance (Figure 12). Application of the global age-length key (i.e., weighing the spatial areas by the otolith sample size rather than abundance) gives disproportionate weight to areas with larger size at age, and fish of a given length would be estimated to have a younger age relative to the age composition obtained from applying the subarea age-length keys.

In the 1991-1997 surveys, a large portion of the age composition was less than 15 years old, reflecting relatively abundant 1984, 1989, and 1994 cohorts, and more recent survey age composition data indicates a relatively strong 2005 year class (Figure 13, Table 14).

The AFSC biennial EBS slope survey was initiated in 2002 and has not been repeated since the 2016 survey, with the 2008 and 2014 surveys canceled to due lack of funding. The EBS slope survey biomass estimates of northern rockfish from the 2002-2016 surveys ranged between 3 t (in 2008, 2012, and 2016) and 42 t (2010), with CVs between 0.38 (2002) and 1.0 (in 2008, 2012, and 2016). Given these low levels of biomass, the slope survey results are not used in this assessment.

Biological Data

The AI survey provides data on age and length composition of the population, growth rates, and length-weight relationships. The number of otoliths read and lengths measured are shown in Table 15, along with the number of hauls producing these data. The number of otoliths read by area is shown in Table 16. The surveys collect reasonable sample sizes of lengths and otoliths from throughout the survey area. The survey otoliths are read with the break and burn method, and are thus considered unbiased (Chilton and Beamish 1982).

As indicated above, the expected length at age differs between the four AI survey subareas (Figure 10). Variability occurs between years but without any apparent direction trend as indicated by the L_{inf} and K parameters (Figure 14). Additionally, the weight-at-length relationship ($W = aL^b$) shows spatial differences, with generally larger values of the exponential parameter b in the WAI and CAI (Figure 15). The estimated survey weight at age curves by AI subarea are shown in Figure 16. A similar pattern across areas is seen in the subareas weights at age in the fishery; additionally, the fishery weights at age are generally larger than those from the AI survey.

In assessments in and prior to 2016, “global” estimates of length and weight at age were computed by ignoring any spatial differences and using the aggregate sample of otoliths across subareas to construct a single age-length key for each year (i.e., in effect weighting the spatial distribution of read otoliths by their sample size instead of the population size). In the 2019 and subsequent assessments, the size at age for the population was obtained from the 1991-2022 AI survey data as an average of each of the 4 subarea weight at age curves shown in Figure 16 (weighted by a smoothed estimate of survey abundance). Years prior to 1991 were set to the weight at values from 1991, whereas the values for 2022 to present were set to the 2022 values. A similar procedure was used for the fishery weights at age from 1990 - 2022, with the subarea curves weighted by the extrapolated catch number by subarea from the North Pacific Groundfish Observer Program. Fishery weights at age prior to 1990 were set to an average of the 1990-1992 values, whereas fishery weights at age in 2023 were set to the 2022 values. An average of the 2016-2022 survey weight at age, and an average of the 2017-2021 fishery weight at age, is shown in Table 17.

Fishery length data are used in the model, and a conversion matrix was created to convert modeled number at ages to modeled number at length bin, and consists of the proportion of each age that is expected in each length bin. The expected size at age for the conversion matrix is an average of the yearly fishery size at age curves from 1990-2020 described above. The conversion matrix was created by fitting a power relationship to the observed standard deviation in length at each age (obtained from the aged fish

in the fishery from 1998-2021), and the predicted relationship was used to produce variation around the predicted size at age from the von Bertalanffy relationship. The resulting CVs of length at age of the transition matrix decrease from 0.11 at age 3 to 0.08 at age 40.

The following table summarizes the data available for the BSAI northern rockfish model:

Component	BSAI
Fishery catch	1977-2023
Fishery age composition	2000-2009, 2011, 2013, 2015, 2017, 2019-2021
Fishery size composition	1977-1978, 1996, 1998-1999, 2010, 2012, 2014, 2016, 2018, 2022
Survey age composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, 2022
Survey biomass estimates	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, 2022

Analytic Approach

Model structure

An age-structured population model, implemented in the software program AD Model Builder, was used to obtain estimates of recruitment, numbers at age, and catch at age. The model is identical to the accepted model for the 2021 assessment, and uses the same ADMB modeling framework since the initial age-structured model for BSAI northern rockfish in 2003. McAllister-Ianelli (McAllister and Ianelli 1997) weighting is used for the composition data, and prior distributions were used for survey catchability, the natural mortality rate M , and the survey selectivity curve. The definitions of model parameters and quantities is shown in Table 18, and equations for population dynamics, estimated quantities, and likelihood components are shown in Tables 19-20.

The root mean squared error (RMSE) was used to evaluate the relative size of residuals within data types:

$$RMSE = \sqrt{\frac{\sum (\ln(y) - \ln(\hat{y}))^2}{n}}$$

Description of Alternative Models

The model used in this assessment is the accepted model from the 2021 assessment, and alternative models are not considered

Parameters Estimated Outside the Assessment Model

The parameters estimated independently include the age error matrix, the age-length conversion matrix, and the individual fishery and population (i.e., AI survey) weights at age. The derivation of the age-length conversion matrix and the weight at age vector are described above.

The ageing error matrix was updated using the Punt et al. (2008) methodology based on maximum likelihood, and requires a set of multiple age readers for each fish. The mean and standard deviation of the

read ages for each reader was estimated based on the likelihood of observing the read age for each fish given the true age. The true ages are unobserved, and maximum likelihood estimates are obtained by integrating across all possible values for the true age. It was assumed that the readers had equal variation in the read ages and were unbiased. Additionally, the coefficient of variation of the read ages was modeled as constant with age (i.e., the standard deviation of increases linearly with age).

This estimation procedure differs from that used to generate the ageing error matrix in the 2021 model, which is not based on fitting data on individual fish but rather fits the percent agreement for each age (and weights each age equally regardless of differences in sample size). Additionally, the data used for the ageing error matrix in the 2021 model was sampled in the Gulf of Alaska from the Gulf of Alaska from 1984-1993, whereas the Punt et al. (2008) methodology was applied to 3213 double readings of northern rockfish from the BSAI sampled during 1980 – 2022. The updated ageing error shows higher CVs in read ages than was estimated for the 2021 model, with the CV from the Punt et al. (2008) methodology estimated at 0.077 for all ages, whereas the CV used in the 2021 assessment was estimated at 0.029 (for age 40) (Figure 17). For older fish, the difference in the ageing error matrices results in approximately 20% less fish being read as the true age with the new matrix, and slight increases in the proportion being assigned ages more than 2-5 years different than the true age (Figure 18).

Parameters Estimated Inside the Assessment Model

Parameters estimated inside the assessment model include the mean and annual deviations for recruitment and fishing mortality, survey catchability, natural mortality, and the parameters associated with the curves for fishery selectivity, survey selectivity, and maturity-at-age.

Prior distributions were used for the survey catchability, the natural mortality rate M , and the survey selectivity curve. A lognormal distribution was used for the natural mortality rate M , with the mean set to 0.06 (the value used in previous assessments, based upon expected relationships between M and longevity identified in Then et al. (2015), with the CV set to 0.15. The standard deviation of log recruits, σ_r , was fixed at 0.75. Similarly, the prior distribution for survey catchability followed a lognormal distribution with a mean of 1.0 and a coefficient of variation (CV) of 0.001, essentially fixing survey catchability at 1.0.

The “observed” catch for 2023 is obtained by estimating the Oct-Dec catch (based on the remaining ABC available after October, and the average proportion in recent years of the remaining ABC caught from Oct-Dec) and adding this to the observed catch through October.

A maturity ogive was fit in the assessment model to samples collected in 2010 ($n=322$; TenBrink and Spencer 2013) and in 2004 by fishery observers ($n=256$). Parameters of the logistic equation were estimated by maximizing the binomial likelihood within the assessment model. The number of fish sampled and number of mature fish by age for each collection were the input data, thus weighting the two collection by sample size. Due to the low number of young fish, high weights were applied to age 3 and 4 fish in order to preclude the logistic equation from predicting a high proportion of mature fish at age 0. The estimated age at 50% maturity is 8.2 years.

The number of estimated parameters is shown below :

Parameter type	Number
1) fishing mortality mean	1
2) fishing mortality deviations	47
3) recruitment mean	1
4) recruitment deviations	44
5) Initial recruitment	1
6) first year recruitment deviations	37
7) biomass survey catchability	1
8) natural mortality rate	1
9) survey selectivity parameters	2
10) fishery selectivity parameters	2
11) maturity parameters	2
Total number of parameters	139

Results

Model Evaluation

The assessment model is unchanged from the accepted 2021 model, and there are no alternative models to evaluate.

The negative log-likelihoods of the data components and prior distributions, and the root mean squared errors, for the 2021 assessment and the 2023 assessment are shown in Table 21. The general pattern in these values are similar to each other between the two assessment years. The fishery and survey age composition likelihoods contribute most of the negative log-likelihood, with larger values in the 2023 assessment due to the increased amount of data. The root mean squared error for recruitment (reflecting the interannual variation) was larger in the 2023 assessment, which results from the updated ageing error matrix.

A series of bridging models were conducted to evaluate the effect of each updated data component on the model output (Figure 19). The 2022 survey biomass estimate had the largest effect of any single model change, and increased the estimated total biomass for 2023 by 6% over the model with only the catch data updated. The combined effect of the updated composition data raised the estimated total biomass for 2023 by an additional 4%. Changes in size at age in recent years (i.e., more of the survey abundance in the southern Bering Sea) further increased the post-2018 biomass estimates. In contrast, the updated ageing error matrix had little effect on estimated total biomass. The data weights were very similar between the 2021 and 2023 assessments (Figure 20).

A list of parameter estimates and their standard deviations from Model 21 from the 2023 assessment is shown in Table 22.

Time series results

In this assessment, spawning biomass is defined as the biomass estimate of mature females age 3 and older. Total biomass is defined as the biomass estimate of northern rockfish age 3 and older. Recruitment is defined as the number of age-3 northern rockfish.

The estimated values for total biomass, spawning biomass, and recruitment, and their CVs (from the Hessian approximation) are shown in Table 23, and the estimated numbers at age are shown in Table 24.

Biomass trends

The estimated survey biomass shows an increasing trend, starting at 91,159 t in 1977 and increasing to a peak of 256,819 t in 2014, and declining to 236,604 t in 2023 (Figure 21). The estimated total biomass shows a similar trend, increasing to a peak value of 343,230 t in 2014, and the estimated spawning biomass increases from 55,180 in 1977 to its highest value of 151,130 in 2015 (Table 23, Figure 22).

Age/size compositions

The model fits to the fishery age and size compositions are shown in Figures 23-24, and the model fit to the survey age composition data is shown in Figure 25. The model fit the fishery and survey age composition data reasonably well (notwithstanding years with low sample sizes). The number of hauls in which otoliths or length measurements has increased in recent years (in part due to the random sampling of otoliths initiated in the AI survey beginning in 2016), which results in the higher weights placed on the recent composition data relative to the earlier years. The plus group in the fishery length composition data (38 cm+) and the fishery age plus group (40+ years) are often overestimated whereas the survey age plus group is often underestimated, reflecting a trade-off in the model.

Fishing and survey selectivity

The estimated survey selectivity curve had an age at 50% selection of 11.3, similar to the estimate of 11.1 in the 2021 assessment. The selectivity slope parameter was 0.28, identical to the value in the 2021 assessment. The fishery selectivity had an age of 50% selection of 9.2, similar to the value of 9.1 obtained from the 2021 assessment (Figure 26).

Fishing mortality

The estimates of fully selected instantaneous fishing mortality rates are shown in Figure 27. A relatively high rate in 1977 is estimated to account for the relatively high catch in this year, followed by very low levels of fishing mortality during the 1980s when catch was small. Fishing mortality rates began to increase during the early 1990s, and declined from the late 1990s to 2014. Fishing mortality rates have increased since 2014, and the 2023 estimate of 0.034 is the largest F in the estimated time series beginning in 1977. A plot of fishing mortality rates and spawning stock biomass in reference to the ABC and OFL harvest control rules indicates that the stock is currently below $F_{35\%}$ and above $B_{40\%}$ (Figure 28).

Recruitment

Recruitment strengths by year class are shown in Figure 29. Relatively strong year classes are observed in 1984-1985, 1989, 1993, 1995-1998, and 2005, reflecting several of the strong year classes observed in the age composition input data (Figures 23 and 25). Most of these estimated strong year classes are larger than their estimates in the 2021 assessment, and years adjacent to the strong year classes are often smaller than estimated in the 2021 assessment (for example, the 1985, 1989, and 2005 year classes). This reflects the influence of the updated aging error matrix; the greater uncertainty in the observed ages allows stronger recruitments which will be distributed to a greater degree to adjacent observed ages. The scatterplot of recruitment against spawning stock biomass is shown in Figure 30, indicating substantial variability in the pattern between recruitment and spawning stock size.

Retrospective analysis

A retrospective analysis was conducted to evaluate the effect of recent data on estimated spawning stock biomass. For the current assessment model, a series of model “peels” were conducted in which the end year of the model was varied from 2023 to 2013, and this was accomplished by sequentially dropping age and length composition data, survey biomass estimates, and catch from the input data files.

The plot of retrospective estimates of spawning biomass is shown in Figure 31. The retrospective estimates show distinct groups that reflect years when survey data are included in the assessment. For example, all the retrospective runs ending in 2018 to 2021 are very similar to each other. The retrospective runs for 2022 and 2023 are also consistent with each other but show larger biomass than the 2018 – 2021 group due to the large 2022 survey biomass estimate. The 2022 and 2018 survey biomass estimates are influential, and exclusion of these data result in a lower group of retrospective SSB estimates for the 2014-2016 peels. Mohn’s rho can be used to evaluate the severity of any retrospective pattern, and compares an estimated quantity (in this case, spawning stock biomass) in the terminal year of each retrospective model run with the estimated quantity in the same year of the model using the full data set. The absence of any retrospective pattern would result in a Mohn’s rho of 0, and would result from either identical estimates in the model runs, or from positive deviations from the reference model being offset by negative deviations. The Mohn’s rho for these retrospective runs was -0.16, similar to the value of -0.18 obtained in the in the 2021 assessment.

Harvest recommendations

Amendment 56 reference points

The reference fishing mortality rate for northern rockfish is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Estimates of $F_{40\%}$, $F_{35\%}$, and $SPR_{40\%}$ were obtained from a spawner-per-recruit analysis. Assuming that the average recruitment from the 1977-2017 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{40\%}$ is calculated as the product of $SPR_{0.40}$ * equilibrium recruits, and this quantity is 74,907 t. The year 2024 spawning stock biomass is estimated as 128,229 t.

Specification of OFL and maximum permissible ABC

Since reliable estimates of the 2022 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B > B_{40\%}$ (128,229 t > 74,907 t), northern rockfish reference fishing mortality is defined in Tier 3a. For this tier, the maximum permissible (MaxPerm) F_{ABC} is defined as $F_{40\%}$ and F_{OFL} is defined as $F_{35\%}$. The values of $F_{40\%}$ and $F_{35\%}$ are 0.070 and 0.086, respectively.

The ABC associated with the $F_{40\%}$ level of 0.070 is 19,274 t.

The estimated catch level for year 2024 associated with the overfishing level of $F_{35\%} = 0.086$ is 23,556 t. A summary of these values is below.

2024 SSB estimate (B)	=	128,229 t
$B_{40\%}$	=	74,907 t
MaxPerm F_{ABC}	=	0.070
$F_{ABC} = F_{40\%}$	=	0.070
$F_{OFL} = F_{35\%}$	=	0.086
ABC	=	19,274 t
OFL	=	23,556 t

Projections

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2023 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2024 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2023. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight at age schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios support the alternative harvest strategies analyzed in the Alaska Groundfish Harvest Specifications Final Environmental Impact Statement. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2024, are as follows (“ $max F_{ABC}$ ” refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to $max F_{ABC}$. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of $max F_{ABC}$. (Rationale: When F_{ABC} is set at a value below $max F_{ABC}$, it is often set at the value recommended in the stock assessment. For this assessment, the fraction used was 1.)

Scenario 3: In all future years, F is set equal to $F_{75\%}$. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 2018-2022 average F . (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC} .)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA’s requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL} . (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above 1) above its MSY level in 2023 or 2) above $\frac{1}{2}$ of its MSY level in 2023 and above its MSY level in 2033 under this scenario, then the stock is not overfished.)

Scenario 7: In 2024 and 2025, F is set equal to $max F_{ABC}$, and in all subsequent years F is set equal to F_{OFL} . (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2035 under this scenario, then the stock is not approaching an overfished condition.)

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment (scenarios one and two), and projections of the mean harvest, spawning stock biomass, and fishing mortality rate for the remaining five scenarios are shown in Table 25.

Risk Table and ABC recommendation

Overview

The risk table categories have been altered for 2023, with the category of “substantial concern” being eliminated. We used the following risk table template:

	<i>Assessment-related considerations</i>	<i>Population dynamics considerations</i>	<i>Environmental/ecosystem considerations</i>	<i>Fishery Performance</i>
Level 1: Normal	Typical to moderately increased uncertainty/minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns
Level 2: Major Concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock)	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types
Level 3: Extreme concern	Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented; More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock; Potential for cascading effects on other ecosystem components	Extreme anomalies in multiple performance indicators that are highly likely to impact the stock

The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. These considerations are stock assessment considerations, population dynamics considerations, environmental/ecosystem considerations, and fishery performance. Examples of the types of concerns that might be relevant include the following:

1. Assessment considerations—data-inputs: biased ages, skipped surveys, lack of fishery-independent trend data; model fits: poor fits to fits to fishery or survey data, inability to simultaneously fit multiple data inputs; model performance: poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds; estimation uncertainty: poorly-estimated but influential year classes; retrospective bias in biomass estimates.
2. Population dynamics considerations—decreasing biomass trend, poor recent recruitment, inability of the stock to rebuild, abrupt increase or decrease in stock abundance.
3. Environmental/ecosystem considerations—adverse trends in environmental/ecosystem indicators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.
4. Fishery performance—fishery CPUE is showing a contrasting pattern from the stock biomass trend, unusual spatial pattern of fishing, changes in the percent of TAC taken, changes in the duration of fishery openings.

Assessment considerations

Several major aspects of the biology of the northern rockfish, and our ability to infer abundance from the AI trawl survey are uncertain, including the natural mortality rate, survey catchability, and survey selectivity. Survey catchability and selectivity are highly constrained by prior distributions, which underestimates the level of uncertainty in the assessment and impedes our ability to estimate the scale of abundance. In addition, the retrospective bias in the assessment is still relatively high and can be attributed to a large biomass estimate from the 2014 AI trawl survey, and differences in the estimated survey selectivity as additional age composition data are included. The Mohn's rho of -0.16 is similar to the Mohn's rho in the 2021 assessment (-0.18). More generally, the retrospective bias indicates that the increase in biomass observed in the data is not consistent with the modeled estimates of survey catchability and mortality. Finally, the 2020 survey was cancelled due to Covid-19, and skipped surveys were identified as one criteria in evaluating assessment considerations for the risk table. We rank the assessment considerations as a 2 (*Major concern with assessment uncertainty, and strong retrospective bias*).

Population dynamics considerations

The trend in survey biomass abundance based on the estimates from the 1994 to 2014 show a rapid increase, resulting from low biomass in the 1994 and 1997 surveys and a high biomass in the 2014 survey. However, reduced biomass estimates from the 2016, 2018, and 2022 surveys are more consistent with the remainder of the time series than the 2014 estimate, and have resulted in a more stable trend in biomass over time. The recruitment of some recent year classes, such as 2005, are estimated to be relatively high.

Northern rockfish show genetic structure within the Aleutian Islands, with the lifetime dispersal distances estimated as not exceeding 250 km (Gharrett et al. 2012). Spatial management of the harvest does not occur within the BSAI, so a population dynamics consideration is that the spatial management of the stock is not consistent with the spatial structure of the stock. This could lead to disproportionate harvest rates within BSAI subareas, with depletion and loss of fishery yield. This risk has not been realized yet as exploitation rates are currently relatively low, and this risk would be lessened if the catches only occurred as bycatch in other target fisheries. However, the recent increased catches and relatively high proportion of catch taken in targeted tows, when combined with the lack of spatial harvest management, increases the risk of disproportionately high subarea harvest rates in the future, which could result in unusual spatial

patterns in stock trends and a potentially limited capacity to rebuild quickly locally depleted areas. Overall, we rank the assessment considerations as a 2 (*Major concern*)

Environmental/Ecosystem considerations

Northern rockfish are mostly found in the top 200 m, at a mean depth of ~165 m in the Aleutian Islands and within temperatures ranging from 2 to 7.7 °C (mean 4.4 °C). In general, higher ambient temperatures incur bioenergetic costs for ectothermic fish such that, all else being equal, consumption must increase to maintain fish condition. Annual mean sea surface temperature in the North Pacific (including all Alaskan waters) had a regime shift to warmer temperatures in 2013-2014 (Xiao and Ren 2023), which is consistent with an increasing trend of bottom temperature observed in the AI trawl survey since 2014. The longline survey data also show a general increase in the eastern AI temperatures throughout the water column beginning in 2014 (Siwicke, 2023). The Extended Reconstructed Sea Surface Temperature (ERSST) dataset (Thoman, 2023) and satellite data (Lemagie and Callahan, 2023) show 2023 to be one of the warmest winters on record. Based on sea surface temperatures (SST), the eastern Aleutian Islands experiencing an increase in extension and intensity of the marine heat wave (MHW) whereas the western Aleutians are currently experiencing a moderate MHW, with one of the warmest fall SST. In 2022, the occupied mean-weighted temperature for northern rockfish was lower than the previous two surveys, although the overall trend over the time series is toward occupying warmer temperatures

Thus, the persistent higher temperatures may be considered a negative indicator for northern rockfish, and combined with higher competition and high biomass of POP, may have jointly contributed to the below average northern rockfish body condition since 2012. Despite remaining below the long-term average, body condition in 2022 did improve compared to that observed in 2018 in all areas except for the western Aleutians. The below-average condition indicates suboptimal foraging conditions are still widespread throughout the Aleutians.

Given that the majority of the biomass of northern rockfish is in the western AI ecoregion, we reviewed indicators from this ecoregion. Reproductive success of planktivorous birds can serve as indirect indicators of prey abundance for northern rockfish, particularly those <30 cm that primarily eat zooplankton. Within the western Aleutians, POP and northern rockfish dominate the pelagic forager guild over Atka mackerel and pollock which were the most abundant in the early 1990s. At Buldir Island (western Aleutian Islands), conditions have changed from above-average reproductive success for all seabirds, to average- to below-average reproductive success for those seabirds with mixed or strictly planktivorous diets (squid, euphausiids, amphipods) and reproductive failure of red kittiwakes (mixed diet). This indicates there is sufficient zooplankton prey but perhaps not as varied and abundant as in the past couple years to support reproduction in the western AI. Piscivorous and cephalopod-eating tufted puffins had above-average reproductive success, indicating that forage fish to support chick-rearing was available this year. For 2023, seabird success suggests potentially lower availability of prey than last year, which overlaps with prey of northern rockfish larger than 20 cm (zooplankton and squid, amphipods).

Based on the availability of prey, temperature trends, and fish condition in 2022 compared to 2018 and the population trend, we consider the level of concern to be 1 (no apparent environmental/ ecosystem concern).

Fishery performance

The growth of the northern rockfish stock since the mid-2000s has led to the development of a target fishery, initially during 2011-2014 when Atka mackerel fishing in the WAI was closed, and more recently since 2016. The CPUE and the number of hauls in which northern rockfish are identified as the target species (based on species composition) have increased from 2021 to 2022. Additionally, the proportion of the harvest obtained in these northern rockfish targeted tows remains generally high, and the catch as a percentage of the ABC has increased since 2014. This indicates that the fishing fleet has not encountered

reduced performance in their ability to target this stock. Inferring conditions of the stock based on fishery indicators is difficult due to the evident change in targeting behavior over time. We rank the fishery performance as a 1 (*No apparent fishery/resource-use performance and/or behavior concerns*).

Summary and ABC recommendation

The assessment-related concerns relate to the retrospective pattern in the assessment, the use of strong priors for some key model parameters that cannot be reliably estimated (in effect understating the level of uncertainty in the assessment), and cancellation of the 2020 survey. A population dynamics concern is that the spatial management of the stock is not consistent with the genetic spatial structure, which could lead to subarea depletion and loss of fishery yield, particularly as the target fishery for northern rockfish is developing; however, this risk has not been realized yet.

The concerns identified above are not addressed in the assessment and Tier status for this stock. Issues such as the retrospective pattern and the use of strong prior distributions affect the results of the assessment, but are not mitigated or otherwise addressed within the assessment. These factors are also not addressed by our current Tier system. Additionally, the mismatch between the genetic spatial structure and the spatial management of the stock is also not addressed within the assessment or the Tier system, as this issue extends beyond the assessment itself. Simply lowering the ABC to a level below the max ABC would not be an effective remedy for a misspecification in the spatial management of the stock.

These assessment-related risk factors are concerning and motivate further continued monitoring of the stock. It is difficult to quantitatively assess the potential for the estimated maximum ABC to exceed the true OFL due to these risk factors. We recommend the maximum permissible ABC 19,274 t for 2024.

Status Determination

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2024, it does not provide the best estimate of OFL for 2025, because the mean 2024 catch under Scenario 6 is predicated on the 2024 catch being equal to the 2024 OFL, whereas the actual 2024 catch will likely be less than the 2024 OFL. Catches for 2024 and 2025 were obtained by setting the F rate for these years to the average of the estimated F rates for 2022 and 2023.

The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official BSAI catch estimate for the most recent complete year (2022) is 7,898 t. This is less than the 2022 BSAI OFL of 23,420 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2023:

- a. If spawning biomass for 2023 is estimated to be below $\frac{1}{2} B_{35\%}$, the stock is below its MSST.
- b. If spawning biomass for 2023 is estimated to be above $B_{35\%}$ the stock is above its MSST.
- c. If spawning biomass for 2023 is estimated to be above $\frac{1}{2} B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 25). If the mean spawning biomass for 2033 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:

- a. If the mean spawning biomass for 2025 is below $\frac{1}{2} B_{35\%}$, the stock is approaching an overfished condition.
- b. If the mean spawning biomass for 2025 is above $B_{35\%}$, the stock is not approaching an overfished condition.
- c. If the mean spawning biomass for 2025 is above $\frac{1}{2} B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2035. If the mean spawning biomass for 2035 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

The results of these two scenarios indicate that the BSAI northern rockfish stock is neither overfished nor approaching an overfished condition. With regard to whether the stock is currently overfished, the estimated 2023 stock size is 2.0 times its $B_{35\%}$ value of 65,544 t. With regard to whether BSAI northern rockfish is likely to be overfished in the future, the expected stock size in 2025 of Scenario 7 is 1.8 times the $B_{35\%}$ value.

Based on the recommended model, the F that would have produced a catch for 2022 equal to the 2022 OFL is 0.079.

Ecosystem Considerations

Ecosystem Effects on the stock

1) Prey availability/abundance trends

Northern rockfish feed primarily upon zooplankton, including calanoid copepods, euphausiids, and chaetognaths. From a sample of 118 Aleutian Island specimens collected in 1994, calanoid copepods, euphausiids, and chaetognaths contributed 84% of the total diet by weight. Small northern rockfish (<30 cm FL) consumed a higher proportion of calanoid copepods than larger northern rockfish, whereas euphausiids were consumed primarily by fish larger than 25 cm. Myctophids and cephalopods were consumed mainly by the largest size group, contributing 11% and 16%, respectively, of the diet for fish > 35 cm. The availability and abundance trends of these prey species are unknown.

2) Predator population trends

Northern rockfish are not commonly observed in field samples of stomach contents. Pacific ocean perch, a rockfish with similar life-history characteristics as northern rockfish, has been found in the stomachs of Pacific halibut and sablefish (Major and Shippen 1970), and it is likely that these species also prey upon northern rockfish as well. The population trends of these predators can be found in separate chapters within this SAFE report.

3) Changes in habitat quality

Little information exists on the habitat use of northern rockfish. Carlson and Straty (1981) and Krieger (1993) used submersibles to observe that other species of rockfish appear to use rugged, shallower habitats during their juvenile stage and move deeper with age. Although these studies did not specifically observe northern rockfish, it is reasonable to suspect a similar ontogenetic shift in habitat. Length frequencies of the Aleutian Islands survey data indicate that small northern rockfish (< 25 cm) are generally found at depths less than 100 m. The mean depths of northern rockfish from recent AI trawl surveys have ranged between 100 and 150 m. There has been little information identifying how rockfish habitat quality has changed over time.

Fishery Effects on the ecosystem

Northern rockfish has historically been a bycatch fishery, with the catches largely occurring in the BSAI Atka mackerel and Pacific ocean perch fisheries. The ecosystem effects of these fisheries can be found in their respective SAFE documents. Targeted fishing for northern rockfish has been increasing in recent years.

Harvesting of northern rockfish is not likely to diminish the amount of northern rockfish available as prey due to the low fishery selectivity for fish less than 20 cm. Although the recent fishing mortality rates have been relatively light, averaging 0.02 over the last five years, it is not known what the effect of harvesting is on the size structure of the population or the maturity at age.

Data Gaps and Research Priorities

Little information is known regarding most aspects of the biology of northern rockfish, particularly in the Aleutian Islands. Recent genetic data suggests that the spatial movement of northern rockfish, per generation, may be much smaller than the BSAI management area. More generally, little is known regarding the reproductive biology, distribution, duration, and habitat requirements of various life-history stages. Given the relatively unusual reproductive biology of rockfish (i.e., maternal effects, and skipped spawning) and its importance in establishing management reference points, data on reproductive capacity should be collected on a periodic basis.

Further research on the functional form of survey selectivity should be investigated, with the aim of achieving estimates of survey selectivity and /or to inform use of a prior distribution. Previous assessments have considered alternative fishery selectivity formulations (i.e., dome-shaped and/or time-varying), and these formulations could be explored for the survey as well. Studies on the distribution of fish in trawlable and untrawlable grounds may help refine our prior distribution of survey catchability.

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Table 1. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the species groups used to manage northern rockfish from 1977 to 2000 in the Aleutian Islands and the eastern Bering Sea. The “other red rockfish” group includes, shortraker rockfish, rougheyeye rockfish, northern rockfish, and sharpchin rockfish. The “POP complex” includes the other red rockfish species plus POP.

Year	Aleutian Islands				Eastern Bering Sea					
	Management Group	OFL (t)	ABC (t)	TAC (t)	Catch (t)	Management Group	OFL (t)	ABC (t)	TAC (t)	Catch (t)
1977	Other species				3264	Other species				5
1978	Other species				3655	Other species				32
1979	POP complex				601	POP complex				46
1980	POP complex				549	POP complex				89
1981	POP complex				111	POP complex				35
1982	POP complex				177	POP complex				71
1983	POP complex				47	POP complex				42
1984	POP complex				196	POP complex				32
1985	POP complex				189	POP complex				6
1986	Other rockfish	n/a	UN	5800	208	Other rockfish	n/a	UN	825	61
1987	Other rockfish	n/a	UN	1430	308	Other rockfish	n/a	UN	450	77
1988	Other rockfish	n/a	1100	1100	493	Other rockfish	n/a	400	400	40
1989	POP complex	n/a	16600	6000	306	POP complex	n/a	6000	5000	78
1990	POP complex	n/a	16600	6000	1235	POP complex	n/a	6300	6300	247
1991	Other red rockfish	0	4685	4685	233	Other red rockfish	0	1670	1670	626
1992	Sharpchin/northern	5670	5670	5670	1548	Other red rockfish	1400	1400	1400	309
1993	Sharpchin/northern	5670	5670	5100	4530	Other red rockfish	1400	1400	1200	859
1994	Sharpchin/northern	5670	5670	5670	4666	Other red rockfish	1400	1400	1400	61
1995	Sharpchin/northern	5670	5670	5103	3858	Other red rockfish	1400	1400	1260	266
1996	Sharpchin/northern	5810	5810	5229	6637	Other red rockfish	1400	1400	1260	87
1997	Sharpchin/northern	5810	4360	4360	1996	Other red rockfish	1400	1050	1050	164
1998	Sharpchin/northern	5640	4230	4230	3746	Other red rockfish	356	267	267	45
1999	Sharpchin/northern	5640	4230	4230	5492	Other red rockfish	356	267	267	157
2000	Sharpchin/northern	6870	5150	5150	5066	Other red rockfish	259	194	194	97

Table 2. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the species groups used to manage northern rockfish from 2001 to present in the eastern Bering Sea and Aleutian Islands.

		Bering Sea and Aleutian Islands			
Management					
Year	Group	OFL (t)	ABC (t)	TAC (t)	Catch (t)
2001	Sharpchin/northern	9020	6764	6764	6488
2002	Northern rockfish	9020	6760	6760	4057
2003	Northern rockfish	9468	7101	6000	4929
2004	Northern rockfish	8140	6880	5000	4684
2005	Northern rockfish	9810	8260	5000	3964
2006	Northern rockfish	10100	8530	4500	3828
2007	Northern rockfish	9750	8190	8190	4016
2008	Northern rockfish	9740	8180	8180	3287
2009	Northern rockfish	8540	7160	7160	3111
2010	Northern rockfish	8640	7240	7240	4332
2011	Northern rockfish	10600	8670	4000	2763
2012	Northern rockfish	10500	8610	4700	2487
2013	Northern rockfish	12200	9850	3000	2037
2014	Northern rockfish	12077	9761	2594	2342
2015	Northern rockfish	15337	12488	3250	7197
2016	Northern rockfish	14689	11960	4500	4536
2017	Northern rockfish	16242	13264	5000	4697
2018	Northern rockfish	15888	12975	6100	5765
2019	Northern rockfish	15507	12664	6500	9092
2020	Northern rockfish	19751	16243	10000	8443
2021	Northern rockfish	18917	15557	13000	6212
2022	Northern rockfish	23420	19217	17000	7898
2023*	Northern rockfish	22776	18687	11000	9948

*Catch data through September 16, 2023, from NMFS Alaska Regional Office.

Table 3. Catch of northern rockfish (t) by fishery and subregion in the BSAI area.

Year	Eastern Bering Sea			Aleutian Islands			Total
	Foreign	Joint Venture	Domestic	Foreign	Joint Venture	Domestic	
1977	5	0		3,264	0		3,270
1978	32	0		3,655	0		3,687
1979	46	0		601	0		647
1980	84	5		549	0		638
1981	35	0		111	0		145
1982	63	8		177	0		248
1983	10	32		47	0		89
1984	26	6		11	185		229
1985	5	1		0	189		195
1986	5	41	15	0	193	15	270
1987	1	45	31	0	248	60	385
1988	0	4	36	0	438	55	534
1989	0	12	66	0	0	306	384
1990			247			1,235	1,481
1991			626			233	859
1992			309			1,548	1,857
1993			859			4,530	5,389
1994			61			4,666	4,727
1995			266			3,858	4,124
1996			87			6,637	6,724
1997			164			1,996	2,161
1998			45			3,746	3,791
1999			157			5,492	5,650
2000			97			5,066	5,162
2001			180			6,309	6,488
2002			114			3,943	4,057
2003			67			4,862	4,929
2004			116			4,567	4,684
2005			112			3,852	3,964
2006			246			3,582	3,828
2007			70			3,946	4,016
2008			22			3,265	3,287
2009			48			3,064	3,111
2010			299			4,032	4,332
2011			197			2,566	2,763
2012			91			2,395	2,487
2013			138			1,900	2,038
2014			147			2,195	2,342
2015			199			6,998	7,197
2016			203			4,333	4,536
2017			225			4,472	4,697
2018			185			5,579	5,764
2019			492			8,601	9,092
2020			307			8,136	8,443
2021			329			5,883	6,212
2022			568			7,330	7,898
2023*			1,001			8,947	9,948

*Catch data through September 16, 2023, from NMFS Alaska Regional Office.

Table 4. Area-specific catches of northern rockfish (t) in the BSAI area, obtained from the NMFS Alaska Regional Office.

Year	WAI	CAI	EAI	EBS	Total
1994	1,572	2,534	560	61	4,727
1995	1,421	1,641	796	266	4,124
1996	3,146	1,978	1,514	87	6,724
1997	1,287	490	219	164	2,161
1998	2,392	916	438	45	3,791
1999	3,185	1,104	1,203	157	5,650
2000	1,516	2,347	1,202	97	5,162
2001	3,725	1,840	743	180	6,488
2002	2,328	1,318	298	114	4,057
2003	2,506	1,994	361	67	4,929
2004	1,926	2,430	211	116	4,684
2005	1,822	1,759	271	112	3,964
2006	1,127	2,149	306	246	3,828
2007	974	1,821	1,151	70	4,016
2008	1,314	1,344	608	22	3,287
2009	1,191	1,315	558	48	3,111
2010	1,988	1,266	778	299	4,332
2011	311	1,351	905	197	2,763
2012	140	1,651	605	91	2,487
2013	115	1,308	478	138	2,038
2014	83	1,111	1,002	147	2,342
2015	3,346	1,600	2,052	199	7,197
2016	1,624	1,728	981	203	4,536
2017	1,776	2,013	683	225	4,697
2018	2,072	2,790	716	185	5,764
2019	5,106	1,763	1,732	492	9,092
2020	4,780	2,614	742	307	8,443
2021	3,457	1,903	523	329	6,212
2022	4,423	1,957	949	568	7,898
2023*	5,424	1,621	1,902	1,001	9,948

* Estimated removals through September 16, 2023.

Table 5. Estimated retained, discarded, and percent discarded sharpchin/northern (SC/NO), and northern rockfish catch in the eastern Bering Sea (EBS) and Aleutian Islands (AI) regions. The catches of the SC/NO group consist nearly entirely of northern rockfish.

Year	Species Group	Aleutian Islands				Eastern Bering Sea				
		Retained	Discarded	Total	Percent Discarded	Species Group	Retained	Discarded	Total	Percent Discarded
1993	SC/NO	317	4218	4535	93.00%	Other red rockfish	367	97	464	20.92%
1994	SC/NO	797	3870	4667	82.92%	Other red rockfish	29	100	129	77.59%
1995	SC/NO	1208	2665	3873	68.82%	Other red rockfish	274	70	344	20.42%
1996	SC/NO	2269	4384	6653	65.89%	Other red rockfish	58	149	207	71.92%
1997	SC/NO	145	1852	1997	92.74%	Other red rockfish	44	174	218	80.02%
1998	SC/NO	458	3288	3747	87.76%	Other red rockfish	38	59	97	61.06%
1999	SC/NO	735	4759	5493	86.63%	Other red rockfish	75	163	238	68.33%
2000	SC/NO	592	4492	5084	88.37%	Other red rockfish	111	140	155	90.22%
2001	SC/NO	403	5906	6309	93.62%	SC/NO	15	164	180	91.11%
2002	Northerns	347	3596	3943	91.19%	Northerns	9	105	114	92.50%
2003	Northerns	465	4397	4862	90.45%	Northerns	17	51	67	75.22%
2004	Northerns	686	3881	4567	84.97%	Northerns	35	82	116	70.23%
2005	Northerns	912	2940	3852	76.32%	Northerns	45	67	112	59.56%
2006	Northerns	965	2617	3582	73.06%	Northerns	109	137	246	55.56%
2007	Northerns	850	3096	3946	78.45%	Northerns	23	46	70	66.46%
2008	Northerns	1523	1742	3265	53.34%	Northerns	8	14	22	64.25%
2009	Northerns	1941	1122	3064	36.63%	Northerns	40	8	48	15.90%
2010	Northerns	3075	957	4032	23.74%	Northerns	284	15	299	4.97%
2011	Northerns	2442	124	2566	4.85%	Northerns	167	30	197	15.23%
2012	Northerns	2015	380	2395	15.88%	Northerns	45	46	91	50.19%
2013	Northerns	1719	181	1900	9.51%	Northerns	104	34	138	24.46%
2014	Northerns	2115	80	2195	3.66%	Northerns	88	59	147	40.20%
2015	Northerns	6619	379	6998	5.41%	Northerns	127	72	199	36.37%
2016	Northerns	4112	222	4333	5.12%	Northerns	134	69	203	33.84%
2017	Northerns	4191	281	4472	6.28%	Northerns	181	44	225	19.58%
2018	Northerns	5181	397	5579	7.12%	Northerns	63	123	185	66.08%
2019	Northerns	8196	405	8601	4.71%	Northerns	407	84	492	17.14%
2020	Northerns	7099	1037	8136	12.74%	Northerns	232	75	307	24.29%
2021	Northerns	5415	468	5883	7.95%	Northerns	234	96	329	29.08%
2022	Northerns	6763	567	7330	7.73%	Northerns	500	68	568	12.01%
2023*	Northerns	8525	422	8947	4.71%	Northerns	913	88	1001	8.76%

* Estimated removals through September 16, 2023.

Table 6. Catch (t) of FMP groundfish species caught in BSAI trips targeting rockfish. “Conf” indicates confidential records with less than three vessels or processors. Source: Alaska Regional Office, via AKFIN 10/19/2023.

Species Group Name	2016	2017	2018	2019	2020	2021	2022	2023	Average
Pacific Ocean Perch	19,589	20,422	21,091	27,651	25,802	23,637	23,415	20,481	22,761
Atka Mackerel	5,255	5,365	5,513	8,734	8,527	6,846	6,173	7,499	6,739
Northern Rockfish	1,338	1,476	1,768	4,527	3,512	2,193	3,133	4,891	2,855
Pollock	875	1,424	1,524	2,254	1,995	2,248	2,779	2,485	1,948
Pacific Cod	625	813	637	1,217	975	899	721	585	809
Arrowtooth Flounder	363	359	257	465	579	672	708	526	491
BSAI Kamchatka Flounder	463	427	322	518	714	549	305	512	476
Sablefish	14	143	147	286	370	475	707	595	342
Other Rockfish	129	163	198	342	405	284	355	339	277
BSAI Skate and GOA Skate, Other	139	144	165	294	282	216	174	133	193
Rougheye Rockfish	70	65	116	246	288	248	219	225	185
Sculpin	88	135	106	199	188				143
BSAI Other Flatfish	16	52	88	157	141	161	248	176	130
BSAI Shortraker Rockfish	38	36	116	121	146	224	152	113	118
Flathead Sole	41	53	67	119	89	125	172	209	109
Greenland Turbot	28	37	53	119	165	115	91	168	97
Rock Sole	15	32	36	67	61	49	59	44	45
Squid	26	31	50						35
Shark	2	Conf	2	2	4	2	6	3	3
Octopus	1	3	3	4	2	2	3	2	2
Yellowfin Sole	1	0	4	1	1	5	0		2
BSAI Alaska Plaice	Conf		1		0	Conf	Conf		0

Table 7. Catch (t) of BSAI northern rockfish by trip target fishery. “Conf” indicates confidential records with less than three vessels or processors. Source: Alaska Regional Office, via AKFIN 10/19/2023.

Target	2016	2017	2018	2019	2020	2021	2022	2023	Average
Atka Mackerel	2941	3071	3865	4361	4681	3858	4502	4841	4015
Rockfish	1338	1476	1768	4527	3512	2193	3133	4891	2855
Pollock - midwater	109	48	70	78	107	72	23	32	67
Pacific Cod	83	67	48	66	63	72	36	25	58
Kamchatka Flounder - BSAI	1	20		15	16	4	167	140	52
Pollock - bottom	45	14	8	37	51	1	23	16	24
Flathead Sole				8					8
Arrowtooth Flounder	18				3	1		1	6
Other Flatfish - BSAI		0							0
Halibut	0		1	0	0		0	0	0

Table 8. Bycatch (t) of PSC species by BSAI trip targeting rockfish, in tons for halibut and herring and 1000s of individuals for crab and salmon. “Source: Alaska Regional Office, via AKFIN 10/19/2023.

Species Group Name	2016	2017	2018	2019	2020	2021	2022	2023	Average
Bairdi Tanner Crab	70.00	100.00	844.05	616.00	251.08	7660.05	704.18	4230.00	1809.42
Blue King Crab	0	0	0	0	0	0	0	103.00	12.88
Chinook Salmon	211.00	577.00	274.00	1036.80	173.06	395.00	208.00	0.00	359.36
Golden (Brown) King Crab	5288.89	3016.00	4950.55	6298.29	3655.84	3300.53	3324.54	2787.72	4077.80
Halibut	24.98	51.18	44.16	86.00	59.64	81.93	73.87	52.58	59.29
Herring	0	0	0	1	0	0	2	0.58	0.51
Non-Chinook Salmon	185.00	124.00	764.00	1281.18	405.80	775.00	949.86	704.00	648.61
Opilio Tanner (Snow) Crab	17.00	73.00	14541.11	714.97	96.72	2313.00	142.00	577.00	2309.35
Red King Crab	58.13	631.00	477.08	327.00	63.23	206.04	0.00	102.00	233.06

Table 10. Samples sizes of otoliths and lengths from fishery sampling, with the number of hauls from which these data were collected, from 1977-2022. Years where either age or length compositions were used in the assessment are shown in bold.

Year	Lengths	Hauls	Otoliths collected	Hauls (read otoliths)	Otoliths read
1977	1202	16	230	11	224
1978	759	11	148	16	148
1979					
1980					
1981					
1982	334	5			
1982					
1984	703	4			
1985	12	9	12	0	0
1986	100	2	100	0	0
1987	976	9	79	0	0
1988					
1989	80	1	80	0	0
1990	403	11			
1991	145	8			
1992					
1993	1809	16			
1994	767	8			
1995	833	14			
1996	4554	68			
1997	1	1			
1998	543	14	30	5	29
1999	917	42	50	0	0
2000	995	69	170	49	169
2001	661	70	136	58	135
2002	889	68	200	60	195
2003	1362	124	318	110	317
2004	842	78	198	69	196
2005	466	47	120	44	118
2006	895	73	231	71	230
2007	843	98	230	90	228
2008	897	127	256	125	255
2009	834	108	247	103	247
2010	1281	148	346		
2011	1596	210	469	200	462
2012	1785	219	506		
2013	2081	268	609	251	596
2014	1542	224	484		
2015	3006	341	869	294	574
2016	2447	311	716		
2017	3924	431	869	308	434
2018	5478	559	1148		
2019	7998	761	1620	804	553
2020	6989	688	1474	591	434
2021	5678	696	1372	680	485
2022	6830	780	1578		

Table 11. Estimated BSAI northern rockfish fishery length compositions.

Length (cm)	Year										
	1977	1978	1996	1998	1999	2010	2012	2014	2016	2018	2022
15	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
17	0.001	0.000	0.000	0.000	0.002	0.000	0.000	0.001	0.000	0.000	0.001
18	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
19	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000
20	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.001	0.000	0.001	0.001
21	0.005	0.000	0.000	0.000	0.002	0.000	0.003	0.002	0.002	0.001	0.001
22	0.034	0.048	0.000	0.000	0.000	0.002	0.005	0.002	0.002	0.001	0.001
23	0.040	0.024	0.002	0.000	0.004	0.000	0.012	0.004	0.001	0.001	0.002
24	0.070	0.109	0.006	0.000	0.001	0.002	0.021	0.005	0.002	0.003	0.004
25	0.095	0.089	0.017	0.000	0.006	0.002	0.021	0.010	0.003	0.005	0.006
26	0.143	0.115	0.046	0.000	0.000	0.005	0.041	0.018	0.006	0.006	0.005
27	0.121	0.108	0.046	0.000	0.018	0.006	0.041	0.039	0.014	0.009	0.011
28	0.125	0.119	0.027	0.012	0.013	0.017	0.055	0.036	0.019	0.020	0.020
29	0.118	0.095	0.068	0.028	0.034	0.041	0.066	0.054	0.047	0.035	0.037
30	0.090	0.071	0.046	0.071	0.052	0.062	0.061	0.054	0.068	0.069	0.064
31	0.060	0.091	0.103	0.083	0.099	0.093	0.087	0.076	0.092	0.108	0.080
32	0.055	0.080	0.107	0.113	0.122	0.132	0.096	0.083	0.113	0.139	0.110
33	0.026	0.025	0.061	0.154	0.134	0.149	0.096	0.071	0.128	0.147	0.126
34	0.010	0.017	0.121	0.142	0.133	0.134	0.083	0.109	0.139	0.125	0.126
35	0.003	0.007	0.151	0.096	0.136	0.115	0.069	0.091	0.109	0.094	0.111
36	0.001	0.002	0.088	0.098	0.098	0.078	0.059	0.086	0.075	0.076	0.098
37	0.000	0.000	0.027	0.058	0.074	0.044	0.043	0.058	0.066	0.054	0.068
38+	0.001	0.000	0.084	0.145	0.069	0.117	0.138	0.198	0.115	0.105	0.129

Table 12. Estimated BSAI northern rockfish fishery age compositions.

Age	Year																
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2011	2013	2015	2017	2019	2020	2021
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.031	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.084	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.001	0.004	0.000
6	0.002	0.000	0.031	0.000	0.003	0.000	0.002	0.000	0.001	0.021	0.018	0.004	0.007	0.003	0.004	0.004	0.007
7	0.047	0.000	0.073	0.016	0.014	0.035	0.001	0.000	0.000	0.014	0.010	0.012	0.007	0.003	0.004	0.011	0.008
8	0.004	0.015	0.005	0.019	0.032	0.004	0.032	0.000	0.003	0.000	0.011	0.059	0.005	0.031	0.014	0.008	0.013
9	0.000	0.000	0.086	0.025	0.043	0.003	0.068	0.049	0.005	0.006	0.031	0.028	0.020	0.008	0.016	0.013	0.023
10	0.041	0.011	0.004	0.069	0.031	0.019	0.093	0.053	0.058	0.016	0.025	0.060	0.085	0.018	0.031	0.022	0.044
11	0.045	0.064	0.014	0.008	0.047	0.041	0.101	0.076	0.066	0.067	0.051	0.048	0.046	0.030	0.022	0.034	0.026
12	0.032	0.017	0.042	0.032	0.005	0.003	0.027	0.096	0.066	0.065	0.031	0.009	0.031	0.105	0.059	0.035	0.043
13	0.045	0.064	0.049	0.045	0.024	0.011	0.045	0.052	0.117	0.060	0.046	0.025	0.037	0.075	0.078	0.062	0.036
14	0.056	0.049	0.029	0.072	0.031	0.014	0.018	0.039	0.030	0.103	0.097	0.014	0.031	0.054	0.042	0.086	0.046
15	0.136	0.060	0.064	0.043	0.054	0.040	0.043	0.039	0.054	0.069	0.095	0.038	0.022	0.045	0.034	0.038	0.053
16	0.068	0.075	0.028	0.046	0.025	0.046	0.016	0.038	0.025	0.071	0.093	0.079	0.028	0.015	0.049	0.043	0.056
17	0.004	0.143	0.073	0.046	0.069	0.070	0.039	0.022	0.026	0.008	0.062	0.089	0.039	0.023	0.030	0.022	0.028
18	0.025	0.043	0.062	0.087	0.058	0.042	0.030	0.028	0.026	0.015	0.034	0.077	0.061	0.022	0.028	0.034	0.030
19	0.028	0.034	0.060	0.087	0.071	0.048	0.017	0.032	0.032	0.007	0.020	0.055	0.058	0.023	0.016	0.042	0.028
20	0.016	0.027	0.025	0.035	0.077	0.102	0.047	0.024	0.028	0.028	0.017	0.026	0.046	0.057	0.044	0.038	0.037
21	0.036	0.000	0.036	0.041	0.045	0.150	0.069	0.030	0.035	0.031	0.025	0.009	0.043	0.058	0.037	0.051	0.044
22	0.032	0.060	0.022	0.038	0.030	0.042	0.070	0.045	0.043	0.016	0.018	0.021	0.032	0.056	0.049	0.027	0.037
23	0.007	0.047	0.001	0.013	0.064	0.058	0.015	0.085	0.044	0.009	0.007	0.024	0.032	0.031	0.048	0.021	0.038
24	0.025	0.006	0.014	0.026	0.010	0.054	0.024	0.025	0.043	0.040	0.009	0.019	0.038	0.024	0.028	0.054	0.035
25	0.021	0.036	0.011	0.020	0.003	0.006	0.034	0.016	0.039	0.038	0.021	0.011	0.026	0.029	0.035	0.031	0.028
26	0.010	0.013	0.009	0.025	0.029	0.035	0.019	0.035	0.013	0.010	0.044	0.008	0.025	0.012	0.033	0.034	0.033
27	0.014	0.021	0.038	0.029	0.008	0.029	0.048	0.025	0.021	0.006	0.025	0.028	0.017	0.026	0.034	0.020	0.017
28	0.009	0.003	0.003	0.035	0.025	0.000	0.005	0.016	0.015	0.018	0.035	0.044	0.026	0.022	0.033	0.024	0.039
29	0.037	0.018	0.020	0.005	0.011	0.026	0.012	0.016	0.012	0.029	0.028	0.029	0.025	0.017	0.016	0.033	0.019
30	0.010	0.010	0.026	0.010	0.026	0.006	0.012	0.007	0.024	0.013	0.011	0.024	0.020	0.016	0.037	0.019	0.030
31	0.017	0.089	0.016	0.023	0.016	0.000	0.018	0.010	0.011	0.014	0.033	0.021	0.021	0.030	0.018	0.016	0.023
32	0.006	0.024	0.028	0.028	0.011	0.000	0.014	0.015	0.011	0.008	0.009	0.004	0.030	0.019	0.009	0.037	0.016
33	0.021	0.006	0.036	0.005	0.038	0.000	0.010	0.005	0.017	0.015	0.005	0.017	0.016	0.012	0.022	0.023	0.013
34	0.007	0.016	0.004	0.013	0.017	0.000	0.004	0.010	0.015	0.008	0.007	0.005	0.016	0.020	0.013	0.008	0.017
35	0.022	0.006	0.011	0.005	0.011	0.032	0.008	0.000	0.048	0.017	0.007	0.013	0.009	0.009	0.013	0.023	0.015
36	0.015	0.009	0.004	0.009	0.012	0.009	0.004	0.018	0.000	0.028	0.011	0.014	0.012	0.016	0.008	0.012	0.012
37	0.008	0.010	0.001	0.000	0.000	0.001	0.009	0.015	0.003	0.006	0.009	0.012	0.011	0.015	0.015	0.015	0.015
38	0.007	0.012	0.004	0.004	0.000	0.000	0.003	0.016	0.003	0.009	0.002	0.005	0.013	0.007	0.009	0.003	0.016
39	0.002	0.000	0.012	0.000	0.004	0.010	0.000	0.008	0.015	0.008	0.005	0.009	0.008	0.000	0.006	0.002	0.002
40+	0.028	0.011	0.052	0.039	0.054	0.064	0.042	0.052	0.051	0.122	0.048	0.056	0.061	0.068	0.066	0.045	0.073

Table 13. Northern rockfish biomass estimates (t) from Aleutian Islands trawl survey, with coefficients of variation shown in parentheses.

Year	Aleutian Islands Survey				Total AI survey
	Western	Central	Eastern	southern BS	
1980	3,024 (0.98)	316 (0.63)	34,170 (0.99)	83 (0.95)	37,593 (0.90)
1983	34,361 (0.21)	9,106 (0.48)	11,765 (0.10)	1,136 (0.57)	56,368 (0.15)
1986	20,691 (0.44)	105,608 (0.44)	4,014 (0.55)	10,092 (0.64)	140,405 (0.34)
1991	144,043 (0.21)	64,119 (0.18)	4,068 (0.52)	582 (0.63)	212,813 (0.15)
1994	65,843 (0.65)	15,832 (0.58)	5,933 (0.54)	855 (0.60)	88,463 (0.50)
1997	65,493 (0.38)	18,363 (0.55)	3,331 (0.58)	204 (0.68)	87,391 (0.31)
2000	142,393 (0.39)	37,949 (0.44)	24,982 (0.70)	49 (0.40)	205,373 (0.29)
2002	136,440 (0.33)	38,819 (0.43)	3,242 (0.42)	290 (0.67)	178,791 (0.27)
2004	146,179 (0.27)	26,913 (0.39)	10,375 (0.37)	5,980 (0.93)	189,446 (0.22)
2006	102,651 (0.29)	70,834 (0.51)	22,982 (0.45)	22,883 (1.00)	219,350 (0.24)
2010	143,953 (0.29)	51,331 (0.40)	21,847 (0.50)	189 (0.52)	217,319 (0.22)
2012	216,325 (0.65)	52,674 (0.40)	15,615 (0.60)	550 (0.73)	285,164 (0.50)
2014	346,392 (0.38)	48,049 (0.44)	76,787 (0.79)	1,668 (0.80)	472,895 (0.31)
2016	124,310 (0.21)	78,869 (0.37)	48,382 (0.52)	1,656 (0.55)	253,217 (0.18)
2018	98,756 (0.24)	54,500 (0.40)	20,096 (0.63)	34,120 (0.70)	212,472 (0.20)
2022	122,692 (0.24)	32,212 (0.46)	73,986 (0.47)	58,425 (0.76)	287,315 (0.23)

Table 14. Estimated age compositions from the Aleutian Islands trawl survey.

Age	Year												
	1991	1994	1997	2000	2002	2004	2006	2010	2012	2014	2016	2018	2022
3	0.000	0.000	0.004	0.009	0.000	0.000	0.005	0.002	0.001	0.000	0.000	0.001	0.000
4	0.000	0.000	0.022	0.027	0.010	0.001	0.011	0.006	0.004	0.000	0.000	0.002	0.001
5	0.014	0.017	0.013	0.030	0.016	0.011	0.007	0.034	0.001	0.003	0.003	0.000	0.000
6	0.035	0.016	0.034	0.017	0.035	0.004	0.011	0.041	0.010	0.004	0.002	0.001	0.027
7	0.128	0.017	0.035	0.029	0.026	0.017	0.009	0.017	0.032	0.003	0.029	0.001	0.015
8	0.052	0.039	0.181	0.007	0.113	0.053	0.010	0.025	0.020	0.010	0.031	0.000	0.027
9	0.021	0.074	0.080	0.010	0.099	0.057	0.053	0.010	0.025	0.048	0.021	0.012	0.018
10	0.090	0.116	0.031	0.053	0.038	0.063	0.066	0.014	0.013	0.042	0.030	0.032	0.009
11	0.036	0.012	0.027	0.105	0.034	0.041	0.074	0.020	0.010	0.019	0.061	0.018	0.017
12	0.035	0.020	0.105	0.032	0.041	0.043	0.043	0.036	0.014	0.028	0.035	0.037	0.064
13	0.061	0.040	0.056	0.035	0.061	0.013	0.031	0.034	0.027	0.017	0.031	0.046	0.015
14	0.053	0.007	0.028	0.048	0.061	0.041	0.035	0.043	0.043	0.022	0.008	0.036	0.034
15	0.027	0.072	0.010	0.050	0.040	0.059	0.027	0.054	0.024	0.010	0.010	0.020	0.029
16	0.032	0.060	0.012	0.054	0.044	0.047	0.035	0.036	0.029	0.019	0.006	0.009	0.024
17	0.017	0.037	0.011	0.017	0.026	0.042	0.041	0.017	0.033	0.024	0.017	0.008	0.050
18	0.034	0.023	0.012	0.002	0.006	0.035	0.015	0.022	0.030	0.038	0.041	0.012	0.043
19	0.024	0.027	0.020	0.021	0.000	0.022	0.024	0.015	0.033	0.058	0.029	0.018	0.026
20	0.028	0.053	0.018	0.016	0.016	0.046	0.033	0.024	0.033	0.033	0.041	0.035	0.016
21	0.022	0.024	0.004	0.039	0.016	0.022	0.029	0.027	0.027	0.054	0.044	0.054	0.015
22	0.035	0.029	0.005	0.020	0.005	0.013	0.030	0.021	0.020	0.046	0.023	0.066	0.020
23	0.034	0.014	0.010	0.019	0.001	0.032	0.009	0.015	0.015	0.015	0.031	0.046	0.048
24	0.043	0.047	0.010	0.011	0.030	0.012	0.022	0.017	0.031	0.036	0.028	0.022	0.041
25	0.034	0.024	0.033	0.008	0.027	0.013	0.015	0.042	0.031	0.043	0.034	0.035	0.051
26	0.022	0.015	0.032	0.031	0.014	0.012	0.017	0.029	0.026	0.036	0.022	0.044	0.037
27	0.005	0.011	0.026	0.035	0.018	0.031	0.019	0.015	0.040	0.021	0.041	0.028	0.022
28	0.010	0.026	0.013	0.021	0.019	0.021	0.017	0.027	0.034	0.025	0.032	0.044	0.017
29	0.017	0.000	0.015	0.018	0.000	0.029	0.018	0.004	0.011	0.024	0.023	0.022	0.021
30	0.016	0.009	0.022	0.047	0.000	0.025	0.028	0.004	0.007	0.020	0.022	0.021	0.038
31	0.013	0.010	0.007	0.047	0.007	0.006	0.030	0.014	0.007	0.016	0.043	0.038	0.024
32	0.000	0.006	0.004	0.002	0.023	0.024	0.026	0.028	0.023	0.015	0.028	0.023	0.018
33	0.010	0.028	0.004	0.006	0.011	0.021	0.012	0.036	0.033	0.023	0.018	0.027	0.041
34	0.000	0.019	0.007	0.008	0.000	0.032	0.027	0.015	0.020	0.018	0.017	0.026	0.011
35	0.004	0.007	0.002	0.011	0.007	0.015	0.018	0.013	0.017	0.031	0.009	0.014	0.014
36	0.000	0.000	0.009	0.018	0.000	0.010	0.022	0.041	0.021	0.010	0.019	0.016	0.020
37	0.000	0.020	0.022	0.019	0.000	0.002	0.018	0.019	0.017	0.008	0.027	0.021	0.017
38	0.008	0.000	0.010	0.016	0.043	0.008	0.005	0.022	0.019	0.025	0.012	0.016	0.008
39	0.007	0.000	0.002	0.007	0.010	0.002	0.025	0.016	0.014	0.016	0.012	0.017	0.008
40+	0.034	0.081	0.063	0.057	0.100	0.074	0.082	0.145	0.204	0.141	0.120	0.132	0.115

Table 15. Sample sizes of otoliths and length measurement from the AI trawl survey, 1991-2022, with the number of hauls from which these data were collected.

Year	Lengths	Otoliths		
		Hauls	read	Hauls
1980	3351	31	473	4
1983	6535	71	625	11
1986	5881	41	565	18
1991	4853	47	456	14
1994	6252	118	409	19
1997	7554	153	652	68
2000	7779	135	725	92
2002	9459	153	259	69
2004	12176	201	515	65
2006	8404	160	535	57
2010	11796	198	538	72
2012	10523	188	576	67
2014	14884	209	550	60
2016	15116	240	576	146
2018	14640	230	588	140
2022	10782	205	647	135

Table 16. Sample sizes of read otoliths by area and year in the Aleutian Islands surveys.

Year	Southern				Total
	Western AI	Central AI	Eastern AI	Bering Sea	
1980	201	92	180		473
1983	268	225	93	39	625
1986	132	293	25	115	565
1991		243	159	54	456
1994	180	61	127	41	409
1997	234	219	199		652
2000	229	275	200	21	725
2002	88	74	66	31	259
2004	193	156	120	46	515
2006	197	148	113	77	535
2010	195	186	139	18	538
2012	206	156	160	54	576
2014	201	147	150	52	550
2016	288	167	106	15	576
2018	289	150	119	30	588
2022	284	191	147	25	647

Table 17. Average of predicted weight (kg, from 2016 – 2022 from AI trawl survey data, and from 2017-2021 from the fishery), and proportion mature at age for BSAI northern rockfish.

Age	Predicted weight (g)		Proportion mature
	AI Survey (2016-2022)	Fishery (2017-2021)	
3	63	123	0.026
4	96	165	0.050
5	133	209	0.096
6	172	252	0.176
7	209	294	0.301
8	246	333	0.464
9	280	369	0.636
10	311	401	0.779
11	340	431	0.876
12	366	457	0.934
13	389	480	0.966
14	410	501	0.983
15	428	519	0.991
16	444	535	0.996
17	458	549	0.998
18	471	561	0.999
19	482	571	0.999
20	492	581	1
21	500	589	1
22	507	596	1
23	514	602	1
24	520	607	1
25	525	612	1
26	529	616	1
27	533	619	1
28	536	622	1
29	539	625	1
30	542	627	1
31	544	629	1
32	546	631	1
33	548	632	1
34	549	633	1
35	551	635	1
36	552	636	1
37	553	636	1
38	554	637	1
39	555	638	1
40	555	638	1

Table 18. Parameters and quantities for the BSAI northern rockfish model, with values where fixed or specified.

Parameter	Description	Value(s)
Y	Year	1977, . . . , 2023
N	Population abundance	
a	Age classes	
a_r	Age of recruitment	3
A	Plus-group age	40
l	Length classes	15, . . . , 38+
$w_{y,a}^p$	Vector of population weight-at-age by year (kg)	
$w_{y,a}^f$	Vector of fishery weight-at-age by year (kg)	
m_a	Vector of maturity-at-age	
μ_r	Average annual recruitment, log-scale	
μ_{init}	Average annual recruitment, log-scale, cohorts in initial year	
μ_f	Average fishing mortality	
ε_y	Annual fishing mortality deviation, log-scale	
τ_y	Annual recruitment deviation	
γ_y	Annual recruitment deviation, cohorts in first year	
σ_R	Recruitment variability	0.75
s_a^f	Vector of selectivity-at-age for fishery	
s_a^f	Vector of selectivity-at-age for survey	
M	Natural mortality	
$F_{y,a}$	Fishing mortality for year y and age class a	
$Z_{y,a}$	Total mortality for year y and age class a	
SB_frac	Spawning month as fraction of year	0.25

Table 18 (continued). Parameters and quantities for the BSAI northern rockfish model, with values where fixed or specified.

Parameter	Description	Value(s)
$T_{a \rightarrow a'}$	Aging error matrix	
$T_{a \rightarrow l}$	Age to length conversion matrix	
q	Trawl survey catchability	
SB_y	Spawning biomass in year y ($=m_a w_a N_{y,a}$)	
M_{prior}	Prior mean for natural mortality	0.06
q_{prior}	Prior mean for trawl survey catchability	1.0
σ_M	Prior log-scale standard deviation for natural mortality	0.15
σ_q	Prior log-scale standard deviation for trawl survey catchability	0.001
σ_s	Prior standard deviation for trawl survey selectivity constraint	0.003
$n_y^{f,a}, n_y^{f,l}, n_y^{t,a}$	First-stage input sample sizes for fishery length and age compositions, and survey age compositions (number of hauls)	
$\lambda_{\hat{p}_a^f}, \lambda_{\hat{p}_l^f}, \lambda_{\hat{p}_a^t}$	Second-stage weights for fishery length and age compositions, and survey age compositions (from McAllister-Ianelli weighting)	
$\lambda_{\hat{c}}$	Weight for catch likelihood	200
$\lambda_{\hat{I}}$	Weight for survey index	1
λ_f	Weight for F fishing mortality deviations	0.1

Table 19. Equations for modeling the population dynamics and observed data for BSAI northern rockfish, see Table 18 for definitions.

Equations describing population dynamics

$N_{y,3} = \begin{cases} e^{\mu_r + \tau_y} & 1977 \leq y \leq 2020 \\ e^{\mu_r + \sigma_r^2 / 2} & 2021 \leq y \leq 2023 \end{cases}$	Number at age of recruitment
$N_{st,y,r,a} = \begin{cases} e^{\mu_{init} - M(a-a_r) + \gamma_{a-a_r+1}} & a_r < a < A \\ \frac{e^{\mu_{init} - M(A-a_r) + \gamma_{A-a_r+1}}}{(1-e^{-M})} & a = A \end{cases}$	Numbers at age, start year
$N_{y,a} = \begin{cases} N_{y-1,a-1} e^{-Z_{y-1,a-1}} & a_r < a < A \\ N_{y-1,a-1} e^{-Z_{y-1,a-1}} + N_{y-1,a} e^{-Z_{y-1,a}} & a = A \end{cases}$	Numbers at age, subsequent years
$s_a^f = \left(1 + e^{-\delta^f(a-a_{50\%}^f)}\right)^{-1}$	Fishery selectivity
$F_{y,a} = s_a^f e^{\mu_f + \epsilon_y}$	Fishing mortality
$Z_{y,a} = Z_{y,a} + M$	Total mortality
$SSB_{y,a} = 0.5 N_{y,a} m_a w_{y,a}^p e^{-SB_{frac} Z_{y,a}}$	Spawning biomass

Equations describing the observed data

$\bar{N}_{y,a} = N_{y,a} (1 - e^{-Z_{y,a}}) / Z_{y,a}$	Mean numbers at age
$\hat{C}_{y,a} = F_{y,a} \bar{N}_{y,a}$	Estimated catch numbers at age
$\hat{Y}_t = \sum_{a=a_r}^A w_a \hat{C}_{y,a}$	Estimated catch biomass
$s_a^t = \left(1 + e^{-\delta^t(a-a_{50\%}^t)}\right)^{-1}$	AI trawl survey selectivity
$\hat{I}_{t,y} = q \sum_{a=a_r}^A w_a s_a^t \bar{N}_{y,a}$	Estimated trawl survey biomass
$\hat{p}_{y,a}^t = T_{a \rightarrow a'} \frac{s_a^t \bar{N}_{y,a}}{\sum_{a=a_r}^A s_a^t \bar{N}_{y,a}}$	Estimated trawl survey age composition
$\hat{p}_{y,l}^f = T_{a \rightarrow l} \frac{\hat{C}_{y,a}}{\sum_{a=a_r}^A \hat{C}_{y,a}}$	Estimated fishery length composition
$\hat{p}_{y,a}^f = T_{a \rightarrow a'} \frac{\hat{C}_{y,a}}{\sum_{a=a_r}^A \hat{C}_{y,a}}$	Estimated fishery age composition
$\hat{m}_a = \left(1 + e^{-\delta^m(a-a_{50\%}^m)}\right)^{-1}$	Estimated maturity at age

Table 20. Equations for likelihood components for the BSAI northern rockfish model, see Tables 18-19 for definitions.

Negative log likelihood, data components

$L_{\hat{c}} = \lambda_{\hat{c}} \sum_Y \ln \left(\frac{Y_y + 0.001}{\hat{Y}_y + 0.001} \right)^2$	Catch likelihood
$L_{\hat{i}} = \lambda_{\hat{i}} \sum_Y \frac{1}{2(\sigma_{I,y}/I_y)} \ln \left(\frac{I_y}{\hat{I}_y} \right)^2$	Trawl survey biomass likelihood
$L_{\hat{p}_a^f} = \lambda_{\hat{p}_a^f} \left(\sum_Y -n_y^{f,a} \sum_{a=a_r}^A (p_{y,a}^f + 0.00001) \ln(\hat{p}_{y,a}^f + 0.00001) \right)$	Fishery age composition likelihood
$L_{\hat{p}_l^f} = \lambda_{\hat{p}_l^f} \left(\sum_Y -n_y^{f,l} \sum_L (p_{y,l}^f + 0.00001) \ln(\hat{p}_{y,l}^f + 0.00001) \right)$	Fishery length composition likelihood
$L_{\hat{p}_a^t} = \lambda_{\hat{p}_a^t} \left(\sum_Y -n_y^{t,a} \sum_{a=a_r}^A (p_{y,a}^t + 0.00001) \ln(\hat{p}_{y,a}^t + 0.00001) \right)$	Trawl survey age composition likelihood
$L_m = \sum_D \sum_{a=a_r}^A -\lambda_{D,a} \ln(\text{Binom}(n_{a,D}, \hat{m}_a))$	Maturity likelihood

Negative log likelihoods, prior distributions and penalties

$L_r = \frac{1}{2\sigma_r^2} \sum_Y (\tau_y + \sigma_r^2/2)^2 + Y \ln \sigma_r$	Recruitment deviations
$L_r = \frac{1}{2\sigma_r^2} \sum_A (\gamma_y)^2 + A \ln \sigma_r$	Recruitment deviations for cohorts in first ye
$L_M = \frac{1}{2\sigma_M^2} (\ln \theta - \ln M_{prior} + \sigma_M^2/2)^2$	Prior distribution for natural mortality
$L_q = \frac{1}{2\sigma_q^2} (\ln \theta - \ln q_{prior} + \sigma_q^2/2)^2$	Prior distribution for survey catchability
$L_f = \lambda_f \sum_Y \epsilon_y^2$	F deviation penalty
$L_s = \frac{1}{2\sigma_s^2} (s_{30}^t - 1)^2$	Survey selectivity constraint

Table 21. Negative log likelihood of model components, root mean squared errors, and estimates and standard deviations of key quantities.

	Model 21 (2021)	Model 21 (2023)
Negative log-likelihood		
<i>Data components</i>		
AI survey biomass	8.43	8.77
Catch biomass	0.00	0.00
Fishery age comp	237.93	257.77
Fishery length comp	75.33	84.10
AI survey age comp	172.67	198.34
Maturity	7.21	7.21
<i>Priors and penalties</i>		
Recruitment	-5.72	-2.91
Prior on survey q	0.00	0.00
Prior on M	0.23	0.35
penalty on survey sel	1.61	1.54
Fishing mortality penalty	5.73	5.91
Total negative log-likelihood	503.42	561.08
Parameters	135	139
Root mean square error		
AI survey biomass	0.375	0.355
Recruitment	0.571	0.622
Fishery age comp	0.015	0.015
Fishery length comp	0.030	0.029
AI survey age comp	0.017	0.016
Estimated key quantities		
<i>M</i>	0.054	0.052
standard deviation	0.005	0.004
CV	0.088	0.085
<i>2023 total biomass</i>		308,010
standard deviation		32,138
CV		0.10

Table 22. Estimated parameter values and standard deviations for Model 21 (2023).

Parameter	Estimate	Standard Deviation	parameter	estimate	Standard Deviation	parameter	estimate	Standard Deviation
sel_aslope_fish	0.7841	0.0632	fmort_dev	0.7467	0.0902	rec_dev	-0.2195	0.4260
sel_a50_fish	9.2416	0.2348	fmort_dev	1.2435	0.0947	rec_dev	-0.2137	0.4592
sel_aslope_srv	0.2802	0.0179	fmort_dev	1.2135	0.0995	rec_dev	-0.1333	0.4794
sel_a50_srv	11.2850	0.5371	fmort_dev	0.9329	0.1043	rec_dev	-0.6850	0.5699
M	0.0523	0.0044	fmort_dev	1.2033	0.1093	mean_log_r	3.8100	0.1014
log_avg_fmort	-4.8491	0.0754	fmort_dev	1.4756	0.1148	log_rinit	3.0662	0.2473
fmort_dev	1.0327	0.1241	rec_dev	-0.0047	0.6366	fydev	0.1371	0.7644
fmort_dev	1.1064	0.1180	rec_dev	-0.1262	0.6410	fydev	0.2967	0.8587
fmort_dev	-0.7029	0.1101	rec_dev	-0.1097	0.6514	fydev	0.3948	0.9770
fmort_dev	-0.7969	0.1032	rec_dev	0.0449	0.6746	fydev	2.1133	0.5131
fmort_dev	-2.3454	0.0983	rec_dev	0.2253	0.6637	fydev	0.2746	0.8804
fmort_dev	-1.8605	0.0942	rec_dev	0.0662	0.6554	fydev	0.1954	0.8080
fmort_dev	-2.9249	0.0901	rec_dev	-0.1197	0.6186	fydev	0.1411	0.7679
fmort_dev	-2.0150	0.0858	rec_dev	-0.2295	0.5737	fydev	0.1112	0.7521
fmort_dev	-2.2083	0.0815	rec_dev	-0.4325	0.5799	fydev	0.1216	0.7563
fmort_dev	-1.9151	0.0775	rec_dev	-0.3189	0.6174	fydev	0.1579	0.7710
fmort_dev	-1.5919	0.0739	rec_dev	0.7904	0.5522	fydev	0.1718	0.7784
fmort_dev	-1.2944	0.0708	rec_dev	1.4376	0.3218	fydev	0.1480	0.7717
fmort_dev	-1.6505	0.0679	rec_dev	-0.2599	0.6317	fydev	0.0818	0.7508
fmort_dev	-0.2930	0.0653	rec_dev	-0.4568	0.5516	fydev	-0.0053	0.7250
fmort_dev	-0.9441	0.0630	rec_dev	-0.1650	0.5578	fydev	-0.0904	0.7013
fmort_dev	-0.1232	0.0607	rec_dev	1.2847	0.1919	fydev	-0.1569	0.6837
fmort_dev	0.9258	0.0590	rec_dev	-0.4090	0.5447	fydev	-0.2018	0.6723
fmort_dev	0.8274	0.0577	rec_dev	-0.5722	0.4508	fydev	-0.2265	0.6663
fmort_dev	0.6343	0.0566	rec_dev	-0.6926	0.5004	fydev	-0.2362	0.6639
fmort_dev	1.1272	0.0553	rec_dev	0.8432	0.2202	fydev	-0.2320	0.6649
fmort_dev	-0.0009	0.0542	rec_dev	0.0231	0.5212	fydev	-0.2255	0.6666
fmort_dev	0.5330	0.0534	rec_dev	1.0273	0.2729	fydev	-0.2172	0.6688
fmort_dev	0.8934	0.0529	rec_dev	1.0188	0.2981	fydev	-0.2078	0.6714
fmort_dev	0.7665	0.0525	rec_dev	0.4811	0.4468	fydev	-0.1997	0.6737
fmort_dev	1.0233	0.0524	rec_dev	0.4075	0.3713	fydev	-0.1922	0.6759
fmort_dev	0.5593	0.0527	rec_dev	-0.6017	0.5112	fydev	-0.1858	0.6778
fmort_dev	0.7221	0.0533	rec_dev	-0.4021	0.4209	fydev	-0.1802	0.6795
fmort_dev	0.6381	0.0542	rec_dev	-0.6009	0.5008	fydev	-0.1737	0.6814
fmort_dev	0.4495	0.0553	rec_dev	0.2402	0.3275	fydev	-0.1669	0.6834
fmort_dev	0.3545	0.0566	rec_dev	0.0834	0.4018	fydev	-0.1602	0.6855
fmort_dev	0.3523	0.0581	rec_dev	-0.1336	0.4788	fydev	-0.1540	0.6874
fmort_dev	0.1810	0.0598	rec_dev	1.1964	0.1737	fydev	-0.1478	0.6893
fmort_dev	0.1215	0.0619	rec_dev	-0.1976	0.5048	fydev	-0.1416	0.6913
fmort_dev	0.4620	0.0643	rec_dev	-0.0965	0.4316	fydev	-0.1357	0.69309
fmort_dev	-0.0517	0.0669	rec_dev	-0.0431	0.4017	fydev	-0.1298	0.6949
fmort_dev	-0.1511	0.0697	rec_dev	0.0916	0.3053	fydev	-0.1243	0.6967
fmort_dev	-0.3599	0.0725	rec_dev	-0.7013	0.4759	fydev	-0.4541	0.6115
fmort_dev	-0.2528	0.0755	rec_dev	-0.1500	0.3189	q_srv	1.0000	0.0010
fmort_dev	0.9493	0.0788	rec_dev	-0.7352	0.4638	mat_beta1	-5.7428	0.6954
fmort_dev	0.4778	0.0825	rec_dev	-0.4515	0.4110	mat_beta2	0.7000	0.0094
fmort_dev	0.5298	0.0862						

Table 23. Estimated time series of northern rockfish total biomass (t, age 3+), spawning biomass (t, age 3+), and recruitment (thousands, age 3).

Year	Total Biomass (ages 3+)				Spawner Biomass (ages 3+)				Recruitment (age 3)				
	Assessment Year		Assessment Year		Assessment Year		Assessment Year		Assessment Year		Assessment Year		
	2023	2021	2023	2021	2023	2021	2023	2021	2023	2021	2023	2021	
	Est.	CV	Est.	CV	Est.	CV	Est.	CV	Est.	CV	Est.	CV	
1977	150,260	0.145	151,640	0.145	55,180	0.168	57,227	0.161		44,940	0.650	61,674	0.480
1978	154,830	0.142	156,490	0.143	58,078	0.167	59,577	0.161		39,799	0.653	46,013	0.562
1979	158,940	0.139	160,760	0.140	61,560	0.161	62,431	0.157		40,461	0.662	41,684	0.531
1980	165,360	0.135	166,870	0.136	65,594	0.152	65,979	0.151		47,224	0.683	41,530	0.536
1981	172,300	0.131	173,620	0.132	69,157	0.144	69,346	0.144		56,560	0.668	56,180	0.467
1982	179,160	0.126	180,600	0.127	72,348	0.137	72,615	0.139		48,240	0.663	53,475	0.443
1983	185,320	0.122	186,240	0.123	75,246	0.132	75,727	0.134		40,059	0.627	32,477	0.561
1984	190,990	0.118	193,660	0.119	78,063	0.127	78,770	0.129		35,893	0.582	69,321	0.332
1985	195,680	0.114	199,470	0.115	80,831	0.123	81,680	0.124		29,298	0.591	38,668	0.487
1986	200,010	0.110	204,510	0.111	83,593	0.118	84,520	0.119		32,823	0.630	32,575	0.533
1987	208,190	0.106	214,150	0.107	86,287	0.114	87,332	0.115		99,525	0.563	119,190	0.257
1988	223,450	0.102	225,180	0.103	88,875	0.110	90,111	0.112		190,110	0.324	118,350	0.274
1989	231,800	0.099	233,410	0.100	91,302	0.106	92,903	0.108		34,819	0.649	48,840	0.474
1990	239,310	0.096	242,000	0.096	93,786	0.104	95,823	0.106		28,595	0.566	57,894	0.347
1991	245,760	0.093	248,810	0.093	96,552	0.104	98,895	0.104		38,285	0.573	45,227	0.411
1992	260,070	0.090	259,530	0.090	100,320	0.104	102,610	0.103		163,160	0.199	113,820	0.199
1993	267,130	0.087	266,290	0.088	104,370	0.104	106,270	0.102		29,994	0.560	44,039	0.380
1994	270,310	0.086	270,150	0.086	107,920	0.102	109,250	0.100		25,477	0.463	48,987	0.310
1995	272,170	0.084	272,470	0.084	111,300	0.098	112,100	0.096		22,587	0.516	32,476	0.429
1996	278,710	0.082	278,040	0.083	114,230	0.094	114,590	0.093		104,930	0.227	94,115	0.194
1997	280,060	0.081	279,010	0.082	116,500	0.092	116,460	0.091		46,209	0.537	44,321	0.362
1998	289,970	0.079	287,720	0.080	119,720	0.089	119,310	0.089		126,130	0.281	119,010	0.188
1999	299,910	0.078	295,010	0.079	121,870	0.086	121,240	0.087		125,060	0.308	97,476	0.226
2000	306,420	0.077	300,500	0.078	123,260	0.085	122,550	0.086		73,049	0.457	78,842	0.248
2001	312,410	0.076	305,020	0.077	124,530	0.086	123,690	0.086		67,865	0.374	62,717	0.254
2002	314,190	0.075	306,180	0.077	126,210	0.087	125,010	0.087		24,737	0.523	30,402	0.377
2003	318,250	0.074	309,920	0.076	129,770	0.089	127,970	0.088		30,204	0.428	37,934	0.277
2004	320,930	0.074	311,940	0.076	133,990	0.089	131,400	0.088		24,756	0.512	21,560	0.403
2005	324,510	0.073	314,540	0.076	138,300	0.086	134,880	0.087		57,409	0.332	51,306	0.236
2006	328,320	0.073	317,910	0.076	142,440	0.083	138,320	0.085		49,079	0.408	52,793	0.251
2007	326,720	0.073	316,250	0.077	143,580	0.079	138,950	0.083		39,505	0.493	47,582	0.293
2008	332,790	0.073	319,230	0.077	144,250	0.078	139,290	0.082		149,370	0.177	111,100	0.171
2009	334,810	0.073	321,230	0.078	144,560	0.077	139,380	0.082		37,056	0.517	55,913	0.269
2010	336,900	0.074	323,200	0.079	144,630	0.078	139,250	0.083		40,996	0.436	49,133	0.264
2011	337,570	0.074	322,850	0.081	144,670	0.079	139,010	0.085		43,248	0.409	31,756	0.332
2012	339,560	0.075	324,060	0.082	145,670	0.081	139,660	0.088		49,482	0.311	46,372	0.245
2013	341,050	0.076	324,630	0.084	147,830	0.083	141,310	0.090		22,393	0.489	17,969	0.413
2014	343,230	0.078	325,040	0.086	150,370	0.084	143,310	0.092		38,864	0.325	23,259	0.360
2015	341,460	0.079	321,960	0.088	151,130	0.085	143,590	0.093		21,646	0.476	17,834	0.460
2016	335,100	0.082	314,450	0.091	150,060	0.086	142,090	0.095		28,746	0.421	27,581	0.438
2017	330,860	0.084	308,400	0.095	149,120	0.088	140,510	0.097		36,252	0.437	29,141	0.529
2018	328,830	0.087	304,580	0.098	148,630	0.090	139,270	0.100		36,464	0.471	31,010	0.563
2019	325,720	0.090	299,120	0.101	146,870	0.093	135,660	0.104		39,519	0.494		
2020	318,910	0.094	291,690	0.105	143,850	0.097	130,750	0.109		22,762	0.589		
2021	314,780	0.098	285,730	0.108	141,160	0.101	125,930	0.114					
2022	313,630	0.101	279,584		139,090	0.105	121,126						
2023	308,010	0.104			132,760	0.111							
2024	297,189				128,229								
Mean recruitment of post-1976 year classes										55,082	54,671		

Table 24. Estimated numbers at age for BSAI northern rockfish (millions).

Year	Age																			
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1977	44.94	23.36	26.00	27.22	144.05	21.74	19.06	17.13	15.78	15.13	14.89	14.33	13.28	11.80	10.26	8.94	7.94	7.21	6.67	6.27
1978	39.80	42.64	22.16	24.66	25.79	136.27	20.51	17.91	16.03	14.72	14.08	13.84	13.31	12.33	10.95	9.53	8.30	7.37	6.69	6.19
1979	40.46	37.76	40.45	21.01	23.36	24.39	128.48	19.25	16.74	14.93	13.67	13.06	12.83	12.34	11.43	10.15	8.83	7.69	6.83	6.20
1980	47.22	38.40	35.84	38.38	19.94	22.16	23.12	121.72	18.23	15.84	14.12	12.93	12.35	12.13	11.66	10.81	9.60	8.35	7.27	6.46
1981	56.56	44.81	36.44	34.00	36.42	18.91	21.01	21.91	115.25	17.25	14.98	13.35	12.23	11.68	11.47	11.03	10.22	9.07	7.89	6.88
1982	48.24	53.68	42.53	34.58	32.27	34.56	17.94	19.93	20.78	109.31	16.36	14.21	12.66	11.59	11.08	10.88	10.46	9.69	8.61	7.48
1983	40.06	45.78	50.94	40.36	32.81	30.62	32.79	17.02	18.90	19.70	103.62	15.51	13.47	12.00	10.99	10.50	10.31	9.92	9.19	8.16
1984	35.89	38.02	43.45	48.34	38.30	31.14	29.05	31.11	16.15	17.93	18.69	98.30	14.71	12.77	11.39	10.42	9.96	9.78	9.41	8.71
1985	29.30	34.06	36.08	41.23	45.87	36.34	29.54	27.56	29.50	15.31	17.00	17.72	93.19	13.95	12.11	10.79	9.88	9.44	9.28	8.92
1986	32.82	27.80	32.33	34.24	39.12	43.53	34.48	28.02	26.14	27.98	14.52	16.12	16.80	88.37	13.22	11.48	10.24	9.37	8.95	8.79
1987	99.52	31.15	26.39	30.68	32.49	37.12	41.30	32.71	26.58	24.78	26.52	13.76	15.28	15.93	83.76	12.53	10.89	9.70	8.88	8.49
1988	190.11	94.45	29.56	25.04	29.11	30.83	35.22	39.16	31.01	25.19	23.49	25.13	13.04	14.48	15.09	79.37	11.88	10.31	9.19	8.42
1989	34.82	180.41	89.63	28.05	23.76	27.62	29.24	33.39	37.11	29.38	23.86	22.24	23.80	12.35	13.71	14.29	75.16	11.25	9.77	8.71
1990	28.60	33.04	171.21	85.06	26.62	22.54	26.20	27.73	31.65	35.18	27.84	22.61	21.08	22.56	11.70	12.99	13.54	71.22	10.66	9.26
1991	38.29	27.14	31.36	162.45	80.69	25.24	21.36	24.80	26.21	29.90	33.21	26.27	21.34	19.89	21.28	11.04	12.26	12.78	67.20	10.06
1992	163.16	36.33	25.75	29.75	154.13	76.54	23.93	20.24	23.49	24.82	28.30	31.43	24.86	20.19	18.82	20.14	10.45	11.60	12.09	63.58
1993	29.99	154.84	34.48	24.43	28.22	146.12	72.50	22.64	19.12	22.17	23.41	26.68	29.62	23.43	19.03	17.74	18.98	9.85	10.93	11.39
1994	25.48	28.46	146.90	32.70	23.15	26.71	137.92	68.19	21.22	17.87	20.67	21.80	24.84	27.57	21.80	17.70	16.50	17.66	9.16	10.17
1995	22.59	24.18	27.00	139.32	30.99	21.92	25.22	129.83	63.97	19.85	16.68	19.28	20.33	23.16	25.70	20.33	16.50	15.38	16.46	8.54
1996	104.93	21.43	22.94	25.61	132.07	29.34	20.71	23.77	122.05	60.00	18.59	15.61	18.04	19.01	21.65	24.03	19.01	15.43	14.38	15.39
1997	46.21	99.56	20.33	21.75	24.26	124.90	27.66	19.44	22.21	113.61	55.71	17.24	14.47	16.71	17.61	20.06	22.26	17.61	14.29	13.32
1998	126.13	43.85	94.47	19.29	20.63	23.00	118.27	26.16	18.36	20.95	107.06	52.48	16.24	13.63	15.74	16.59	18.89	20.96	16.58	13.46
1999	125.06	119.69	41.61	89.61	18.29	19.54	21.75	111.57	24.61	17.24	19.64	100.32	49.16	15.21	12.76	14.74	15.53	17.69	19.63	15.53
2000	73.05	118.67	113.55	39.46	84.92	17.31	18.45	20.46	104.58	23.01	16.08	18.31	93.44	45.78	14.16	11.88	13.72	14.46	16.47	18.28
2001	67.87	69.32	112.59	107.70	37.40	80.40	16.35	17.37	19.21	97.92	21.50	15.02	17.09	87.21	42.72	13.21	11.09	12.80	13.49	15.37
2002	24.74	64.39	65.76	106.77	102.05	35.38	75.84	15.36	16.26	17.91	91.13	19.99	13.95	15.87	80.99	39.67	12.27	10.30	11.89	12.53
2003	30.20	23.47	61.10	62.38	101.22	96.65	33.45	71.53	14.45	15.26	16.79	85.36	18.72	13.06	14.86	75.82	37.14	11.48	9.64	11.13
2004	24.76	28.66	22.27	57.95	59.13	95.83	91.32	31.51	67.18	13.54	14.27	15.69	79.75	17.48	12.20	13.88	70.80	34.68	10.72	9.00
2005	57.41	23.49	27.19	21.12	54.94	55.99	90.58	86.08	29.62	63.00	12.68	13.36	14.68	74.58	16.35	11.41	12.98	66.20	32.43	10.03
2006	49.08	54.48	22.29	25.80	20.03	52.04	52.96	85.48	81.05	27.84	59.14	11.89	12.52	13.76	69.92	15.33	10.69	12.16	62.06	30.40
2007	39.50	46.57	51.69	21.14	24.46	18.98	49.24	50.00	80.54	76.23	26.16	55.53	11.17	11.76	12.92	65.62	14.38	10.04	11.42	58.24
2008	149.37	37.49	44.19	49.04	20.05	23.18	17.95	46.49	47.11	75.76	71.63	24.56	52.13	10.48	11.03	12.12	61.58	13.50	9.42	10.71
2009	37.06	141.75	35.57	41.92	46.50	19.00	21.94	16.97	43.86	44.38	71.29	67.37	23.10	49.01	9.85	10.37	11.40	57.90	12.69	8.86
2010	41.00	35.16	134.50	33.75	39.76	44.08	17.99	20.74	16.01	41.33	41.78	67.09	63.39	21.73	46.11	9.27	9.76	10.72	54.46	11.94
2011	43.25	38.90	33.37	127.59	32.00	37.66	41.69	16.98	19.52	15.04	38.78	39.19	62.90	59.42	20.37	43.22	8.69	9.15	10.05	51.04
2012	49.48	41.04	36.91	31.66	121.02	30.33	35.67	39.43	16.03	18.42	14.18	36.55	36.92	59.26	55.97	19.18	40.71	8.18	8.61	9.47
2013	22.39	46.96	38.94	35.02	30.03	114.74	28.73	33.75	37.26	15.13	17.37	13.37	34.46	34.80	55.86	52.76	18.08	38.37	7.71	8.12
2014	38.86	21.25	44.56	36.95	33.23	28.47	108.72	27.20	31.92	35.20	14.29	16.40	12.62	32.52	32.85	52.73	49.80	17.07	36.22	7.28
2015	21.65	36.88	20.16	42.28	35.05	31.50	26.98	102.90	25.71	30.14	33.23	13.49	15.47	11.91	30.68	30.99	49.73	46.98	16.10	34.16
2016	28.75	20.54	34.99	19.12	40.06	33.17	29.73	25.37	96.38	24.01	28.09	30.93	12.55	14.39	11.08	28.53	28.82	46.25	43.69	14.97
2017	36.25	27.28	19.49	33.19	18.13	37.95	31.37	28.05	23.88	90.55	22.53	26.34	28.99	11.76	13.49	10.38	26.74	27.01	43.34	40.94
2018	36.46	34.40	25.88	18.49	31.47	17.17	35.88	29.59	26.40	22.42	84.92	21.11	24.67	27.16	11.01	12.63	9.72	25.04	25.29	40.59
2019	39.52	34.60	32.64	24.55	17.52	29.79	16.22	33.80	27.78	24.72	20.97	79.33	19.72	23.04	25.35	10.28	11.79	9.07	23.37	23.61
2020	22.76	37.50	32.82	30.94	23.25	16.56	28.06	15.21	31.52	25.80	22.90	19.39	73.31	18.21	21.28	23.41	9.50	10.89	8.38	21.59
2021	59.82	21.60	35.57	31.12	29.31	21.98	15.61	26.32	14.19	29.29	23.91	21.19	17.93	67.78	16.84	19.67	21.64	8.78	10.07	7.75
2022	59.82	56.76	20.49	33.73	29.49	27.73	20.75	14.68	24.66	13.25	27.30	22.27	19.72	16.69	63.07	15.66	18.30	20.13	8.17	9.36
2023	59.82	56.76	53.84	19.43	31.95	27.88	26.13	19.46	13.70	22.92	12.29	25.28	20.60	18.24	15.43	58.31	14.48	16.92	18.62	7.55

Table 24 (continued). Estimated numbers at age for BSAI northern rockfish (millions).

Year	Age																				
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40+	
1977	6.67	6.27	5.98	5.71	5.46	5.23	5.01	4.79	4.57	4.36	4.17	3.98	3.80	3.63	3.47	3.31	3.16	3.02	2.88	2.88	10.39
1978	6.69	6.19	5.82	5.55	5.30	5.07	4.86	4.65	4.44	4.24	4.05	3.87	3.70	3.53	3.37	3.22	3.08	2.94	2.80	2.80	12.32
1979	6.83	6.20	5.74	5.39	5.14	4.91	4.70	4.50	4.31	4.12	3.93	3.75	3.59	3.43	3.27	3.13	2.98	2.85	2.72	2.72	14.02
1980	7.27	6.46	5.86	5.43	5.10	4.86	4.64	4.44	4.26	4.07	3.89	3.72	3.55	3.39	3.24	3.09	2.95	2.82	2.69	2.69	15.82
1981	7.89	6.88	6.11	5.54	5.13	4.82	4.60	4.39	4.20	4.02	3.85	3.68	3.52	3.36	3.21	3.06	2.93	2.79	2.67	2.67	17.51
1982	8.61	7.48	6.52	5.79	5.26	4.87	4.57	4.36	4.16	3.98	3.82	3.65	3.49	3.33	3.18	3.04	2.90	2.78	2.65	2.65	19.14
1983	9.19	8.16	7.09	6.18	5.49	4.98	4.61	4.33	4.13	3.95	3.78	3.62	3.46	3.31	3.16	3.02	2.88	2.75	2.63	2.63	20.65
1984	9.41	8.71	7.74	6.73	5.87	5.21	4.73	4.38	4.11	3.92	3.74	3.58	3.43	3.28	3.14	3.00	2.86	2.73	2.61	2.61	22.08
1985	9.28	8.92	8.26	7.34	6.38	5.56	4.94	4.48	4.15	3.90	3.72	3.55	3.40	3.25	3.11	2.98	2.84	2.71	2.59	2.59	23.41
1986	8.95	8.79	8.46	7.83	6.96	6.05	5.27	4.68	4.25	3.93	3.70	3.52	3.37	3.22	3.08	2.95	2.82	2.70	2.57	2.57	24.66
1987	8.88	8.49	8.34	8.01	7.42	6.59	5.73	5.00	4.44	4.03	3.73	3.50	3.34	3.19	3.05	2.92	2.80	2.67	2.55	2.55	25.81
1988	9.19	8.42	8.04	7.90	7.59	7.03	6.25	5.43	4.74	4.21	3.82	3.53	3.32	3.16	3.02	2.89	2.77	2.65	2.53	2.53	26.88
1989	9.77	8.71	7.97	7.62	7.48	7.19	6.66	5.92	5.15	4.48	3.98	3.61	3.35	3.14	3.00	2.86	2.74	2.62	2.51	2.51	27.85
1990	10.66	9.26	8.25	7.55	7.22	7.09	6.81	6.31	5.61	4.88	4.25	3.77	3.42	3.17	2.98	2.84	2.71	2.60	2.49	2.49	28.77
1991	67.20	10.06	8.73	7.78	7.13	6.81	6.69	6.43	5.96	5.29	4.60	4.01	3.56	3.23	2.99	2.81	2.68	2.56	2.45	2.45	29.49
1992	12.09	63.58	9.51	8.26	7.36	6.74	6.44	6.33	6.08	5.64	5.00	4.35	3.79	3.37	3.06	2.83	2.66	2.53	2.42	2.42	30.22
1993	10.93	11.39	59.92	8.97	7.79	6.94	6.35	6.07	5.96	5.73	5.31	4.72	4.10	3.58	3.17	2.88	2.67	2.51	2.39	2.39	30.76
1994	9.16	10.17	10.60	55.75	8.34	7.24	6.46	5.91	5.65	5.55	5.33	4.94	4.39	3.82	3.33	2.95	2.68	2.48	2.33	2.33	30.84
1995	16.46	8.54	9.48	9.88	51.97	7.78	6.75	6.02	5.51	5.27	5.17	4.97	4.61	4.09	3.56	3.10	2.75	2.50	2.31	2.31	30.92
1996	14.38	15.39	7.98	8.86	9.24	48.59	7.27	6.31	5.63	5.15	4.92	4.84	4.65	4.31	3.83	3.33	2.90	2.57	2.34	2.34	31.08
1997	14.29	13.32	14.26	7.40	8.21	8.56	45.02	6.74	5.85	5.21	4.77	4.56	4.48	4.31	3.99	3.54	3.08	2.69	2.39	2.39	30.95
1998	16.58	13.46	12.55	13.42	6.96	7.73	8.06	42.39	6.34	5.51	4.91	4.49	4.29	4.22	4.06	3.76	3.34	2.90	2.53	2.53	31.39
1999	19.63	15.53	12.60	11.75	12.57	6.52	7.24	7.55	39.69	5.94	5.16	4.60	4.21	4.02	3.95	3.80	3.52	3.12	2.72	2.72	31.77
2000	16.47	18.28	14.45	11.73	10.94	11.70	6.07	6.74	7.03	36.95	5.53	4.80	4.28	3.92	3.74	3.68	3.54	3.28	2.91	2.91	32.10
2001	13.49	15.37	17.06	13.49	10.95	10.21	10.92	5.67	6.29	6.56	34.48	5.16	4.48	3.99	3.66	3.49	3.43	3.30	3.06	3.06	32.67
2002	11.89	12.53	14.27	15.84	12.52	10.17	9.48	10.14	5.26	5.84	6.09	32.02	4.79	4.16	3.71	3.40	3.24	3.19	3.06	3.06	33.18
2003	9.64	11.13	11.73	13.36	14.82	11.72	9.52	8.87	9.49	4.93	5.47	5.70	29.97	4.49	3.90	3.47	3.18	3.04	2.98	2.98	33.92
2004	10.72	9.00	10.39	10.95	12.47	13.84	10.95	8.89	8.29	8.87	4.60	5.11	5.32	27.99	4.19	3.64	3.24	2.97	2.84	2.84	34.47
2005	32.43	10.03	8.42	9.72	10.24	11.66	12.94	10.24	8.31	7.75	8.29	4.30	4.77	4.98	26.17	3.92	3.40	3.03	2.78	2.78	34.88
2006	62.06	30.40	9.40	7.89	9.11	9.60	10.93	12.13	9.60	7.79	7.26	7.77	4.03	4.48	4.67	24.53	3.67	3.19	2.84	2.84	35.30
2007	11.42	58.24	28.53	8.82	7.40	8.55	9.01	10.26	11.39	9.01	7.31	6.82	7.29	3.78	4.20	4.38	23.03	3.45	2.99	2.99	35.79
2008	9.42	10.71	54.66	26.77	8.28	6.95	8.02	8.46	9.63	10.69	8.45	6.86	6.40	6.84	3.55	3.94	4.11	21.61	3.23	3.23	36.40
2009	12.69	8.86	10.07	51.39	25.17	7.78	6.53	7.54	7.95	9.05	10.05	7.95	6.45	6.01	6.43	3.34	3.71	3.86	20.32	20.32	37.26
2010	54.46	11.94	8.33	9.47	48.34	23.68	7.32	6.14	7.10	7.48	8.52	9.45	7.47	6.07	5.66	6.05	3.14	3.49	3.63	3.63	54.16
2011	10.05	51.04	11.19	7.81	8.88	45.31	22.19	6.86	5.76	6.65	7.01	7.98	8.86	7.01	5.69	5.30	5.67	2.94	3.27	3.27	54.17
2012	8.61	9.47	48.08	10.54	7.35	8.37	42.68	20.91	6.46	5.43	6.26	6.60	7.52	8.34	6.60	5.36	4.99	5.34	2.77	2.77	54.11
2013	7.71	8.12	8.92	45.33	9.94	6.93	7.89	40.23	19.71	6.09	5.11	5.91	6.22	7.09	7.87	6.22	5.05	4.71	5.04	5.04	53.62
2014	36.22	7.28	7.66	8.42	42.78	9.38	6.54	7.44	37.97	18.60	5.75	4.83	5.57	5.87	6.69	7.42	5.87	4.77	4.44	4.44	55.36
2015	16.10	34.16	6.87	7.23	7.94	40.35	8.85	6.17	7.02	35.82	17.54	5.43	4.55	5.26	5.54	6.31	7.00	5.54	4.50	4.50	56.41
2016	43.69	14.97	31.77	6.39	6.72	7.39	37.53	8.23	5.74	6.53	33.31	16.32	5.05	4.23	4.89	5.15	5.87	6.51	5.15	5.15	56.64
2017	43.34	40.94	14.03	29.77	5.99	6.30	6.92	35.17	7.71	5.38	6.12	31.22	15.29	4.73	3.97	4.58	4.83	5.50	6.10	6.10	57.91
2018	25.29	40.59	38.34	13.14	27.88	5.60	5.90	6.48	32.93	7.22	5.04	5.73	29.23	14.32	4.43	3.72	4.29	4.52	5.15	5.15	59.94
2019	23.37	23.61	37.89	35.79	12.27	26.03	5.23	5.51	6.05	30.74	6.74	4.70	5.35	27.29	13.37	4.13	3.47	4.01	4.22	4.22	60.76
2020	8.38	21.59	21.80	34.99	33.05	11.33	24.04	4.83	5.09	5.59	28.39	6.22	4.34	4.94	25.20	12.34	3.82	3.20	3.70	3.70	60.02
2021	10.07	7.75	19.95	20.15	32.35	30.55	10.47	22.22	4.47	4.70	5.17	26.24	5.75	4.01	4.57	23.29	11.41	3.53	2.96	2.96	58.89
2022	8.17	9.36	7.21	18.56	18.75	30.09	28.42	9.74	20.67	4.16	4.37	4.81	24.41	5.35	3.73	4.25	21.67	10.61	3.28	3.28	57.54
2023	18.62	7.55	8.66	6.66	17.16	17.33	27.82	26.28	9.01	19.11	3.84	4.04	4.44	22.57	4.95	3.45	3.93	20.04	9.81	9.81	56.24

Table 25. Projections of BSAI northern rockfish catch (t), spawning biomass (t), and fishing mortality rate for each of the several scenarios. The values of B_{40%} and B_{35%} are 74,907 t and 65,544 t, respectively.

Catch	<i>Scenario 1</i>	<i>Scenario 2</i>	<i>Scenario 3</i>	<i>Scenario 4</i>	<i>Scenario 5</i>	<i>Scenario 6</i>	<i>Scenario 7</i>
2023	9,998	9,998	9,998	9,998	9,998	9,998	9,998
2024	19,274	19,274	4,528	6,555	0	23,556	19,274
2025	18,004	18,004	4,448	6,397	0	21,674	18,004
2026	16,912	16,912	4,385	6,265	0	20,068	20,672
2027	16,013	16,013	4,346	6,170	0	18,748	19,286
2028	15,305	15,305	4,332	6,115	0	17,701	18,180
2029	14,754	14,754	4,339	6,093	0	16,880	17,304
2030	14,311	14,311	4,359	6,090	0	16,215	16,590
2031	13,938	13,938	4,384	6,097	0	15,657	15,987
2032	13,616	13,616	4,411	6,109	0	15,177	15,468
2033	13,335	13,335	4,439	6,122	0	14,730	15,005
2034	13,087	13,087	4,466	6,137	0	14,278	14,547
2035	12,862	12,862	4,493	6,151	0	13,857	14,105
2036	12,653	12,653	4,517	6,164	0	13,476	13,699
Sp. Biomass	<i>Scenario 1</i>	<i>Scenario 2</i>	<i>Scenario 3</i>	<i>Scenario 4</i>	<i>Scenario 5</i>	<i>Scenario 6</i>	<i>Scenario 7</i>
2023	132,760	132,760	132,760	132,760	132,760	132,760	132,760
2024	127,029	127,029	128,662	128,441	129,151	126,543	127,029
2025	119,057	119,057	126,724	125,663	129,100	116,851	119,057
2026	112,308	112,308	125,330	123,488	129,501	108,687	111,886
2027	106,800	106,800	124,570	122,003	130,450	102,019	104,873
2028	102,388	102,388	124,388	121,143	131,900	96,662	99,198
2029	98,827	98,827	124,625	120,743	133,706	92,323	94,570
2030	95,861	95,861	125,093	120,610	135,690	88,716	90,701
2031	93,336	93,336	125,690	120,637	137,756	85,661	87,410
2032	91,155	91,155	126,354	120,759	139,842	83,042	84,580
2033	89,260	89,260	127,053	120,945	141,921	80,792	82,139
2034	87,588	87,588	127,747	121,150	143,949	78,852	80,022
2035	86,105	86,105	128,423	121,364	145,916	77,194	78,198
2036	84,785	84,785	129,068	121,572	147,809	75,786	76,639
F	<i>Scenario 1</i>	<i>Scenario 2</i>	<i>Scenario 3</i>	<i>Scenario 4</i>	<i>Scenario 5</i>	<i>Scenario 6</i>	<i>Scenario 7</i>
2023	0.034	0.034	0.034	0.034	0.034	0.034	0.034
2024	0.070	0.070	0.016	0.023	0.000	0.086	0.070
2025	0.070	0.070	0.016	0.023	0.000	0.086	0.070
2026	0.070	0.070	0.016	0.023	0.000	0.086	0.086
2027	0.070	0.070	0.016	0.023	0.000	0.086	0.086
2028	0.070	0.070	0.016	0.023	0.000	0.086	0.086
2029	0.070	0.070	0.016	0.023	0.000	0.086	0.086
2030	0.070	0.070	0.016	0.023	0.000	0.086	0.086
2031	0.070	0.070	0.016	0.023	0.000	0.086	0.086
2032	0.070	0.070	0.016	0.023	0.000	0.086	0.086
2033	0.070	0.070	0.016	0.023	0.000	0.086	0.086
2034	0.070	0.070	0.016	0.023	0.000	0.085	0.085
2035	0.070	0.070	0.016	0.023	0.000	0.084	0.085
2036	0.070	0.070	0.016	0.023	0.000	0.083	0.084

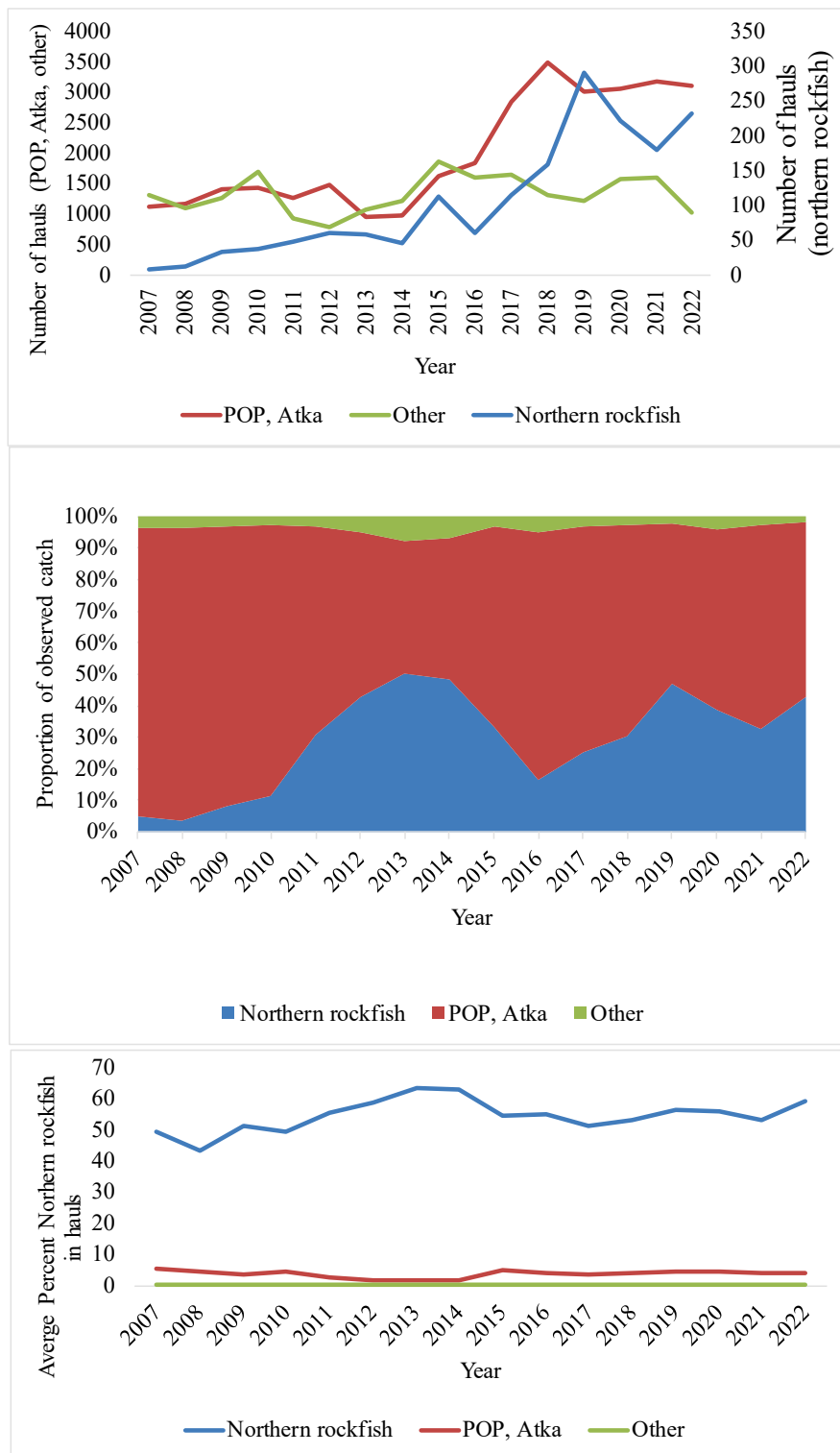


Figure 1. Number of tows, (a), percentage of observed catch (b), and average percent northern rockfish caught (c) in observed hauls from 2007 to 2023 (through August 20) by target fishery. Data are from the North Pacific Groundfish Observer Program.

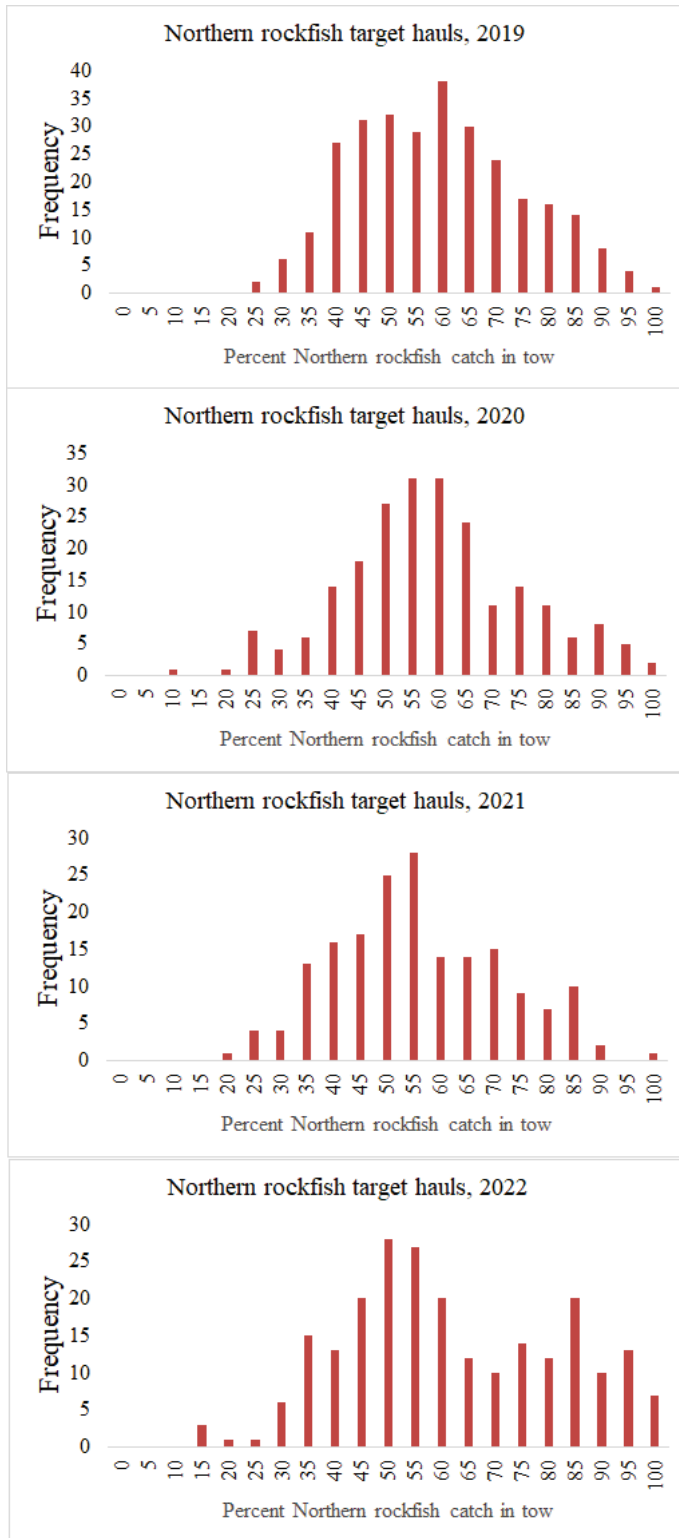


Figure 2. Distribution of the percent northern rockfish in the catch in hauls identified as targeting northern rockfish (based on species composition), from 2018 to 2022. Data are from the North Pacific Groundfish Observer Program.

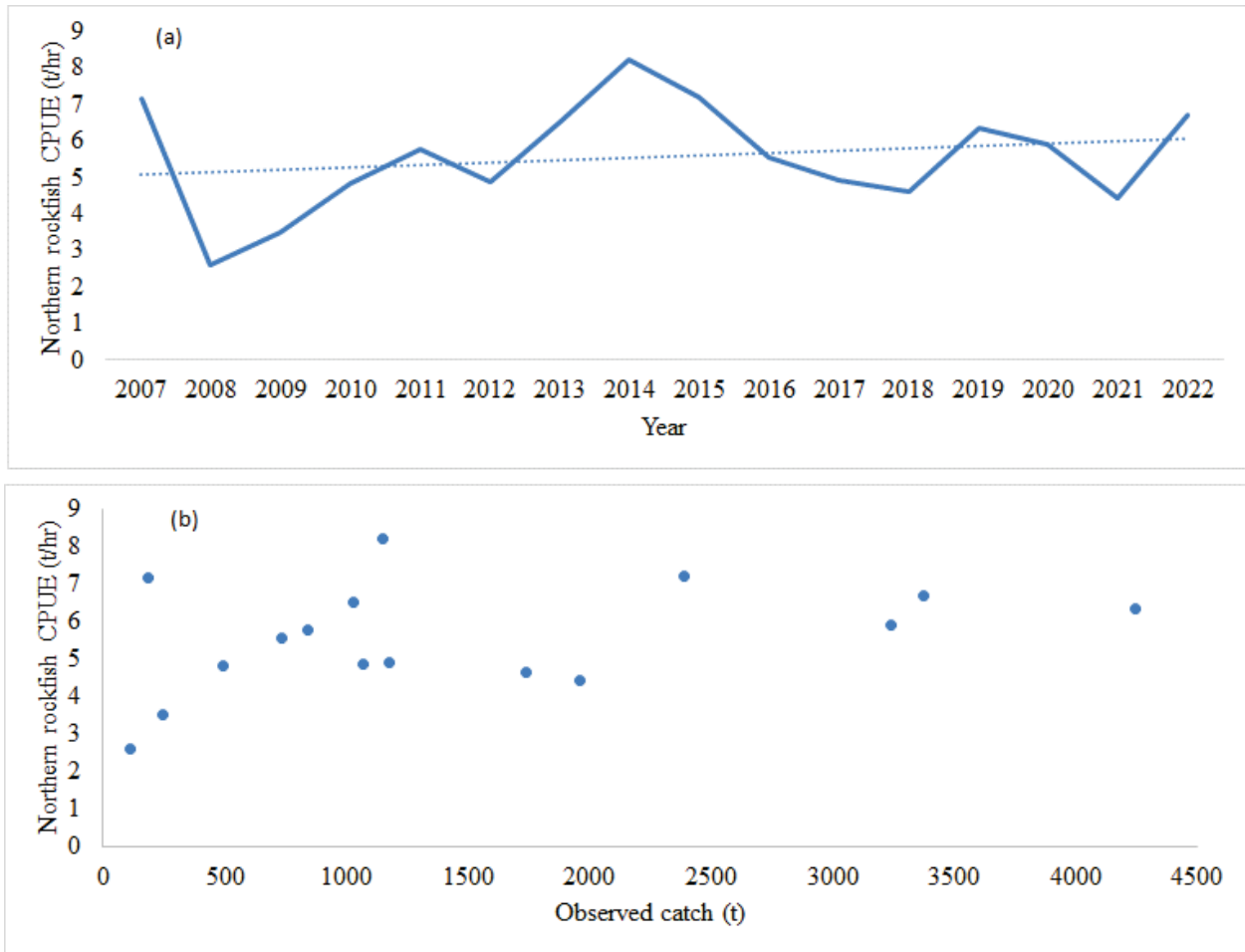


Figure 3. Catch per unit effort of northern rockfish in tows targeting northern rockfish from 2007 to 2022 (a), and plotted against observed catch (b). Data are from the North Pacific Groundfish Observer Program.

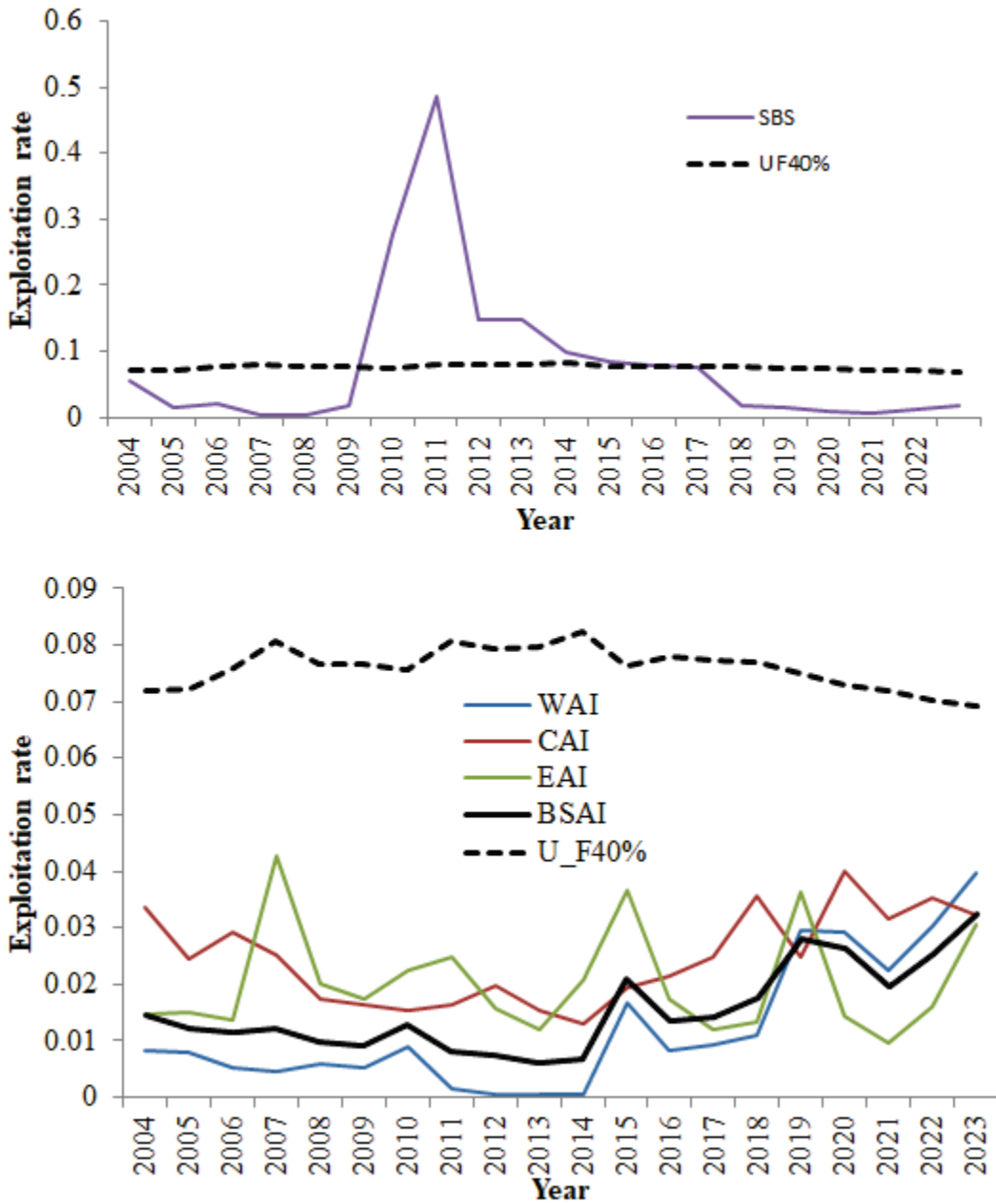


Figure 4. Exploitation rates for northern rockfish. The $U_{F40\%}$ is the exploitation rate for each year that would occur from fishing at $F_{40\%}$, and is a function of the beginning year numbers at age, size at age, and fishing selectivity. The high exploitation rates in the southern Bering Sea (SBS) area result from high variable survey biomass estimates for this area. Exploitation rates for 2023 are preliminary and based on catch through September 26, 2023.

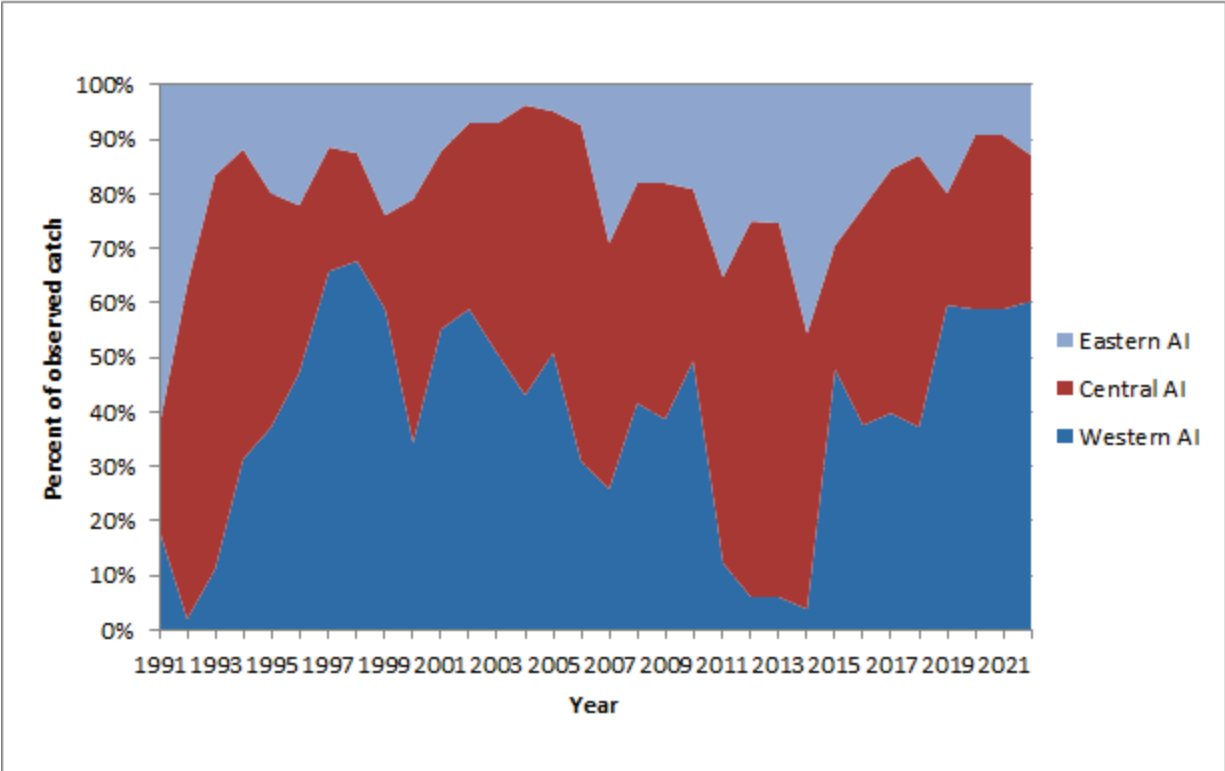
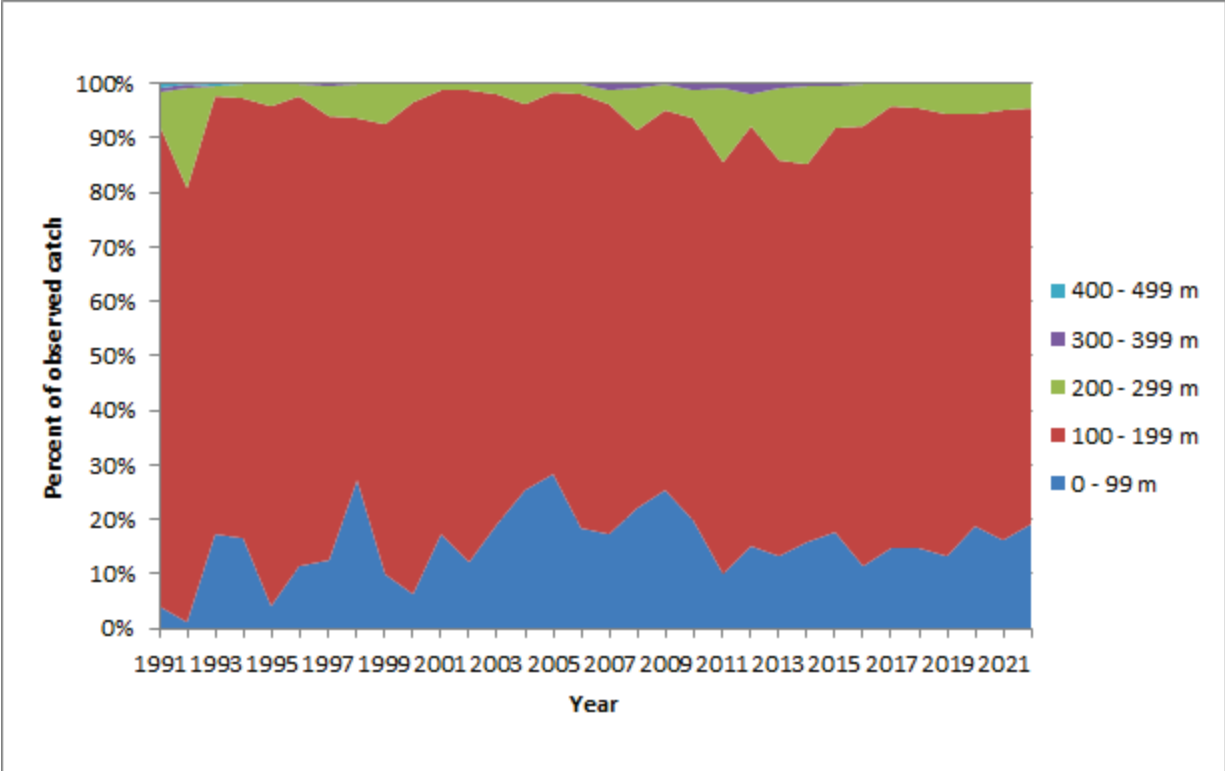


Figure 5. Distribution of observed Aleutian Islands northern rockfish catch (from North Pacific Groundfish Observer Program) by depth zone (top panel) and AI subarea (bottom panel) from 1991 to 2022.

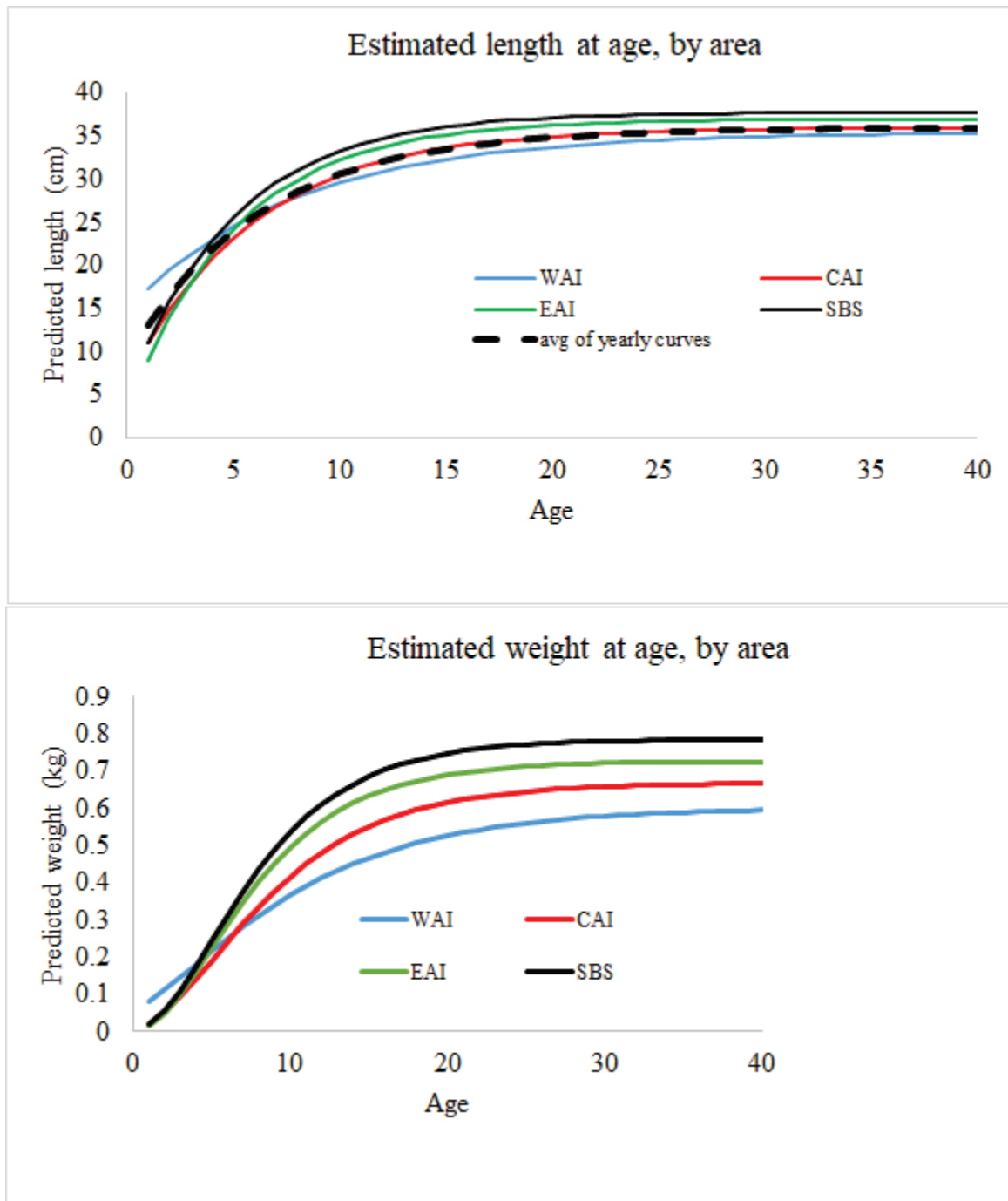


Figure 6. Estimated fishery length and size at age across the AI subareas, from fitted von Bertalanffy curves and length-weight relationships.

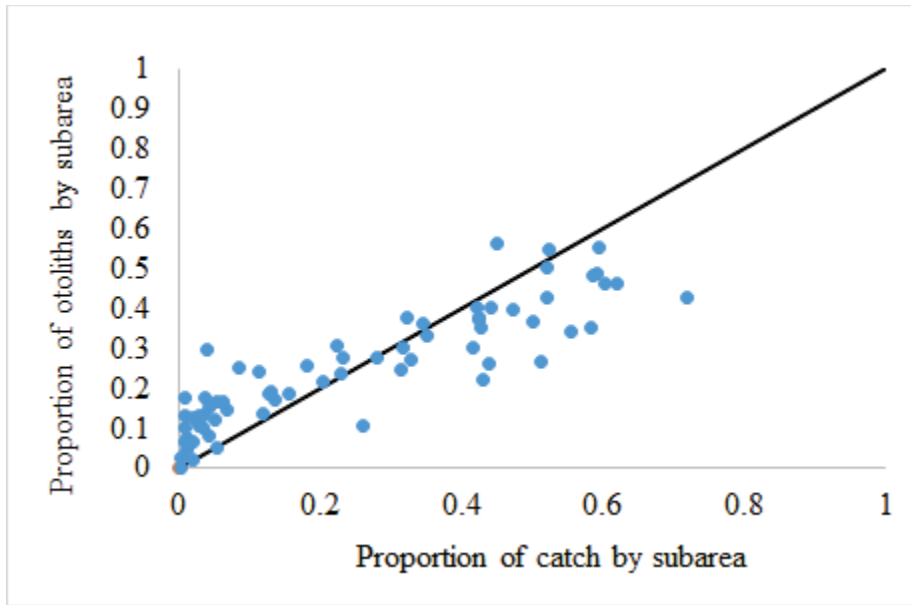


Figure 7. The proportion of the extrapolated fishery catch numbers in AI subarea (i.e., WAI, CAI, EAI, and BS, from North Pacific Groundfish Observer Program) and the proportion of the read otoliths by subarea (from 2000-2021). Random sampling of otoliths from the fishery catch would be expected to generate data near the 1:1 line (in black).

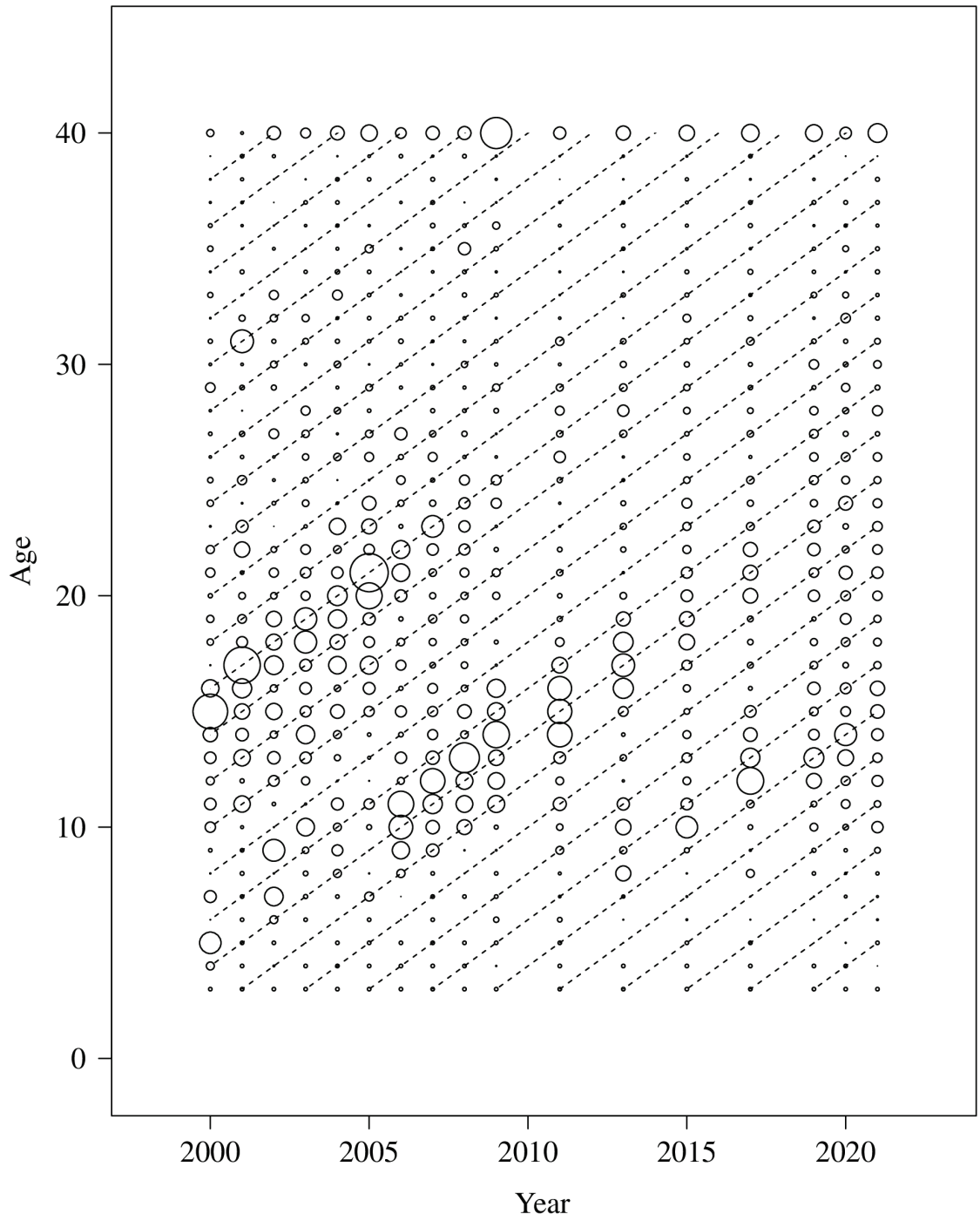
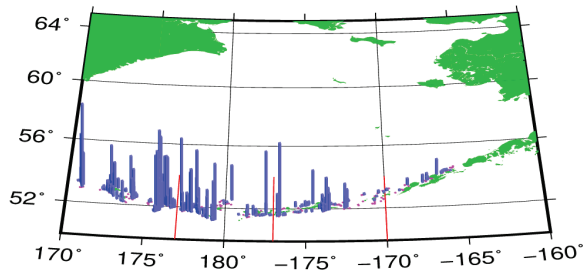
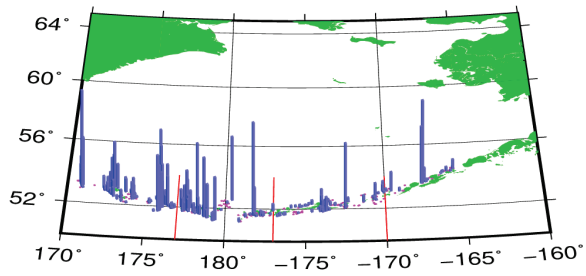


Figure 8. Fishery age composition data for the Aleutian Islands; bubbles are scaled within each year of samples; and dashed lines denote cohorts (beginning at age 3).

2016 AI Survey Northern Rockfish CPUE (scaled wgt/km²)



2018 AI Survey Northern Rockfish CPUE (scaled wgt/km²)



2022 AI Survey Northern Rockfish CPUE (scaled wgt/km²)

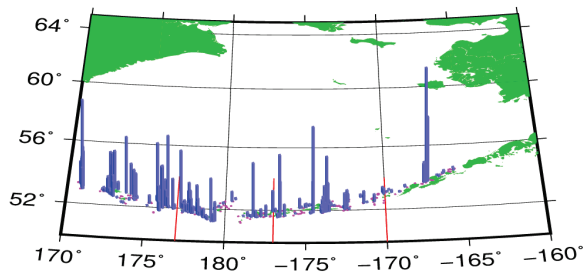


Figure 9. Scaled AI survey northern rockfish CPUE from (square root of kg/km²) from 2016-2022; the red lines indicate boundaries between the WAI, CAI, EAI, and EBS areas.

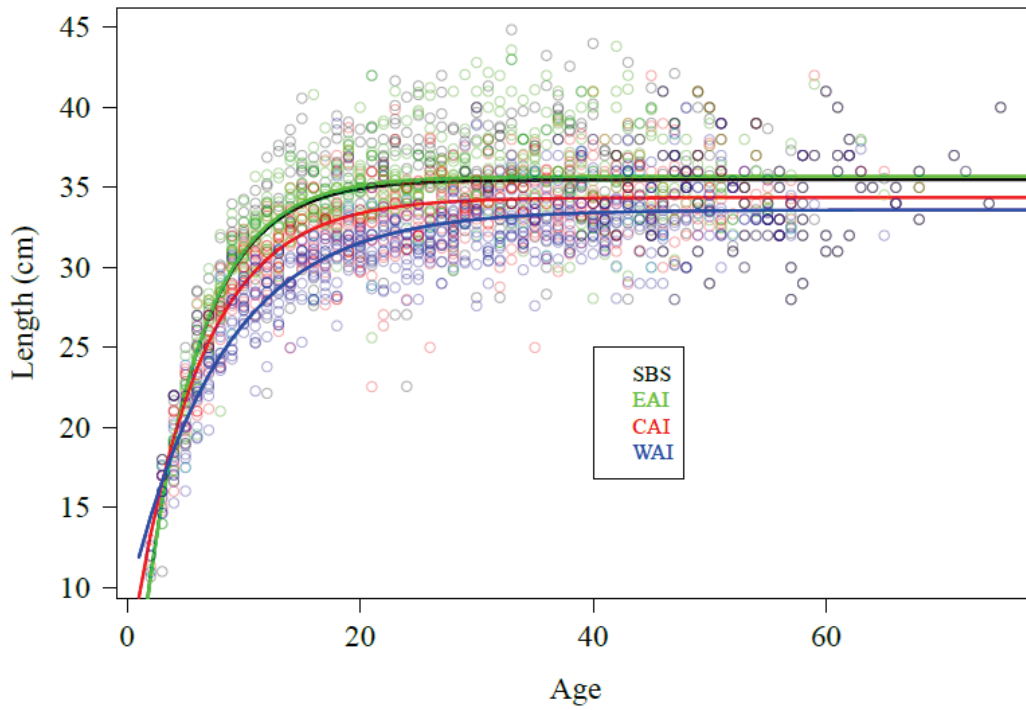


Figure 10. Estimated survey size at age across the AI subareas from fitted von Bertalanffy curves.

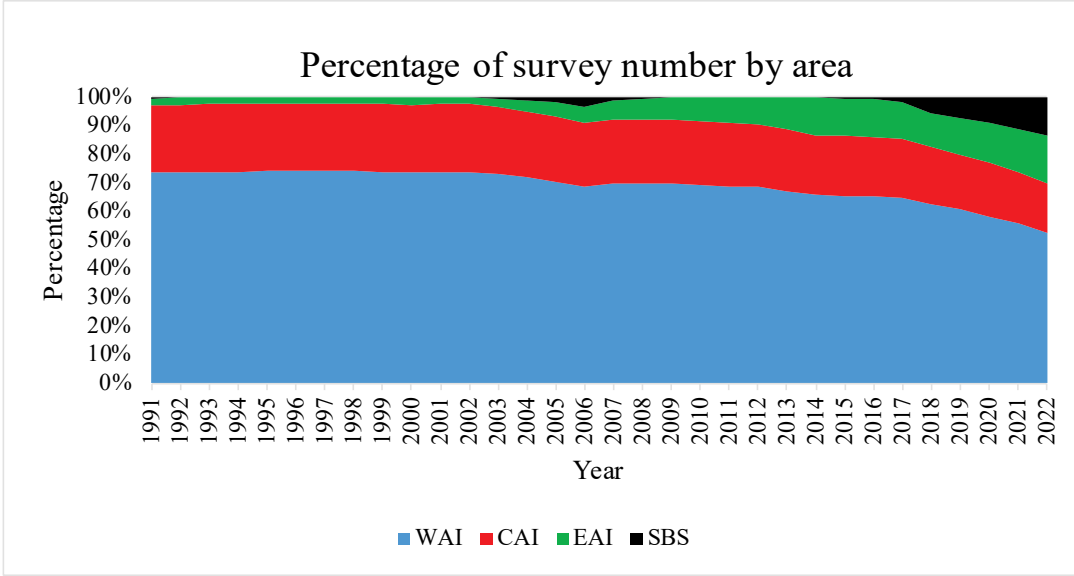


Figure 11. Proportion of northern rockfish survey abundance by area, from a smoother applied to survey estimates from 1991-2022.

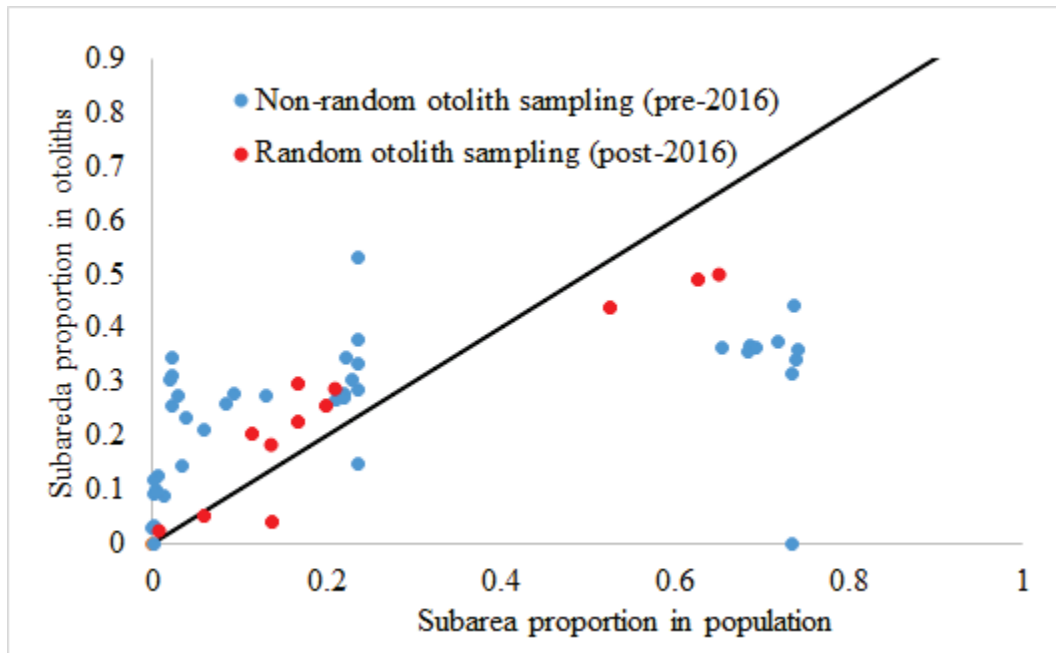


Figure 12. The proportion of the survey population abundance by AI subarea (i.e., WAI, CAI, EAI, and BS) and the proportion of the read otoliths by subarea (from 1991-2022). Random sampling of otoliths occurred since the 2016 survey (shown in red), which would be expected to generate data near the 1:1 line (in black).

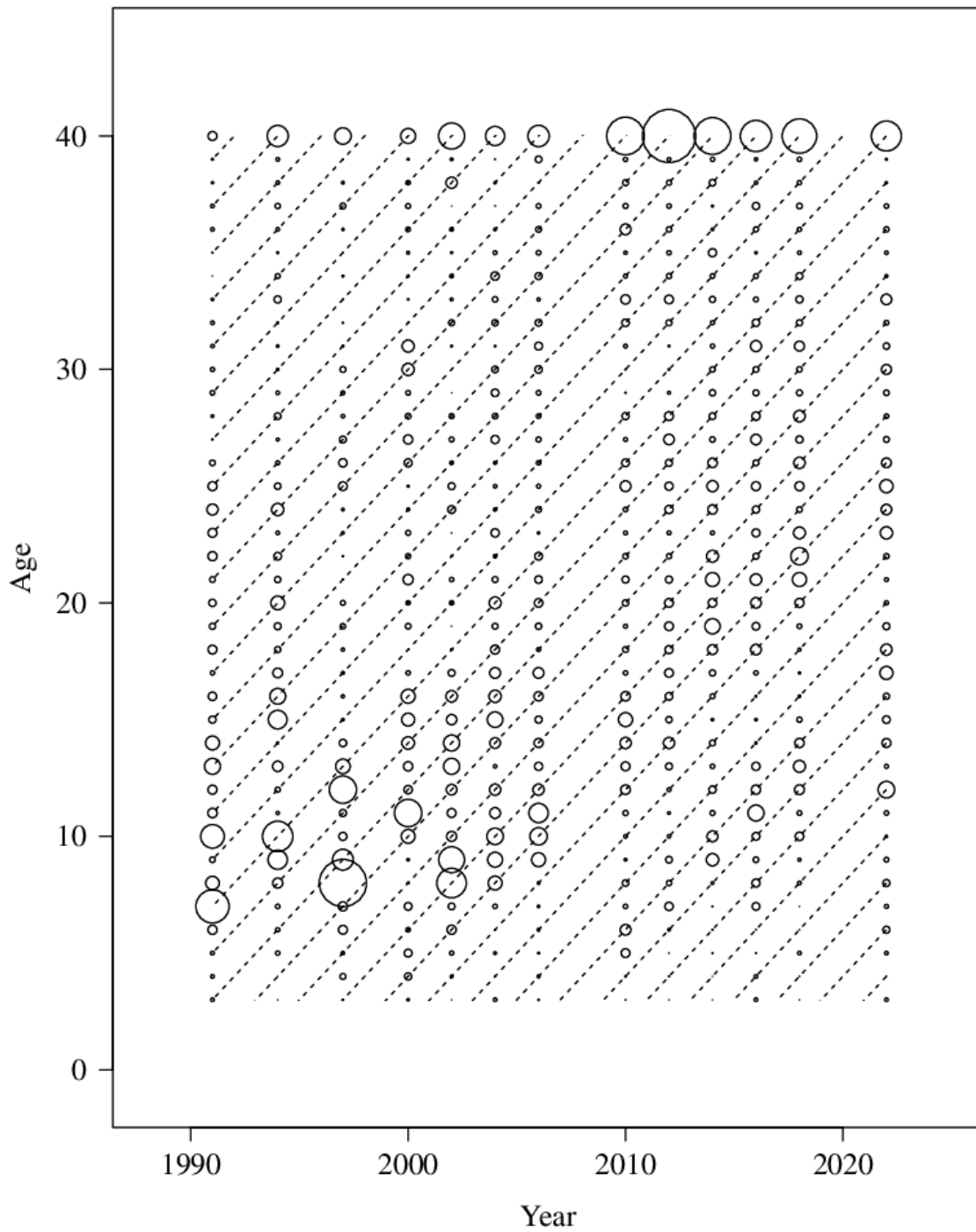


Figure 13. Age composition data from the Aleutian Islands trawl survey; bubbles are scaled within each year of samples; and dashed lines denote cohorts.

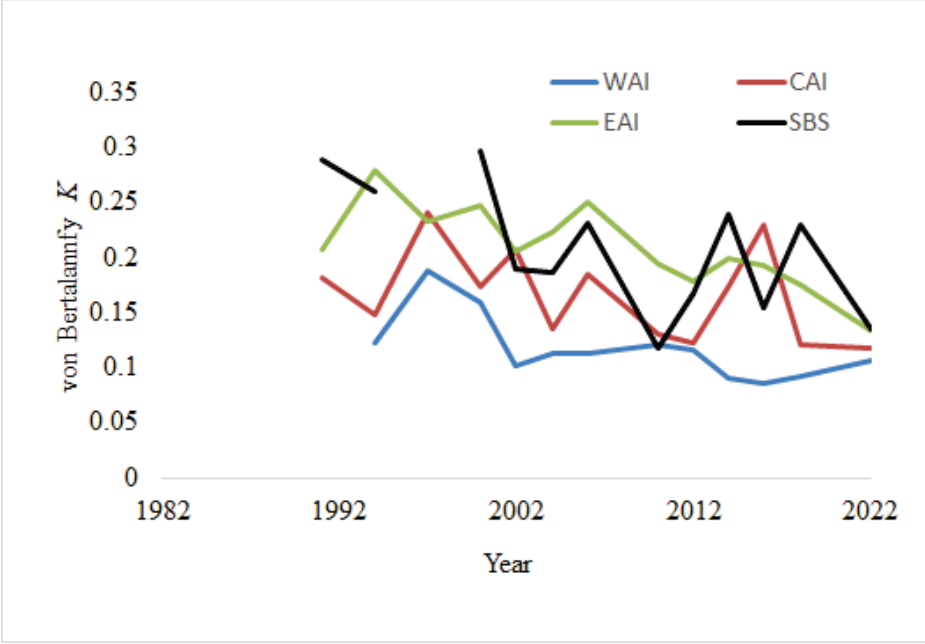
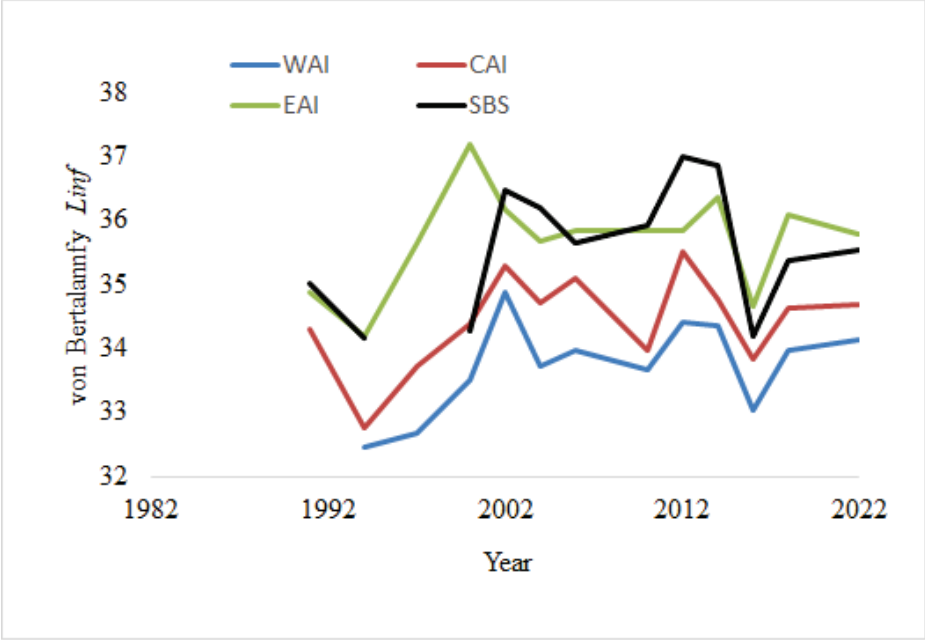


Figure 14. Estimates of von Bertalanffy parameters L_{inf} and K by area and year for the AI trawl survey.

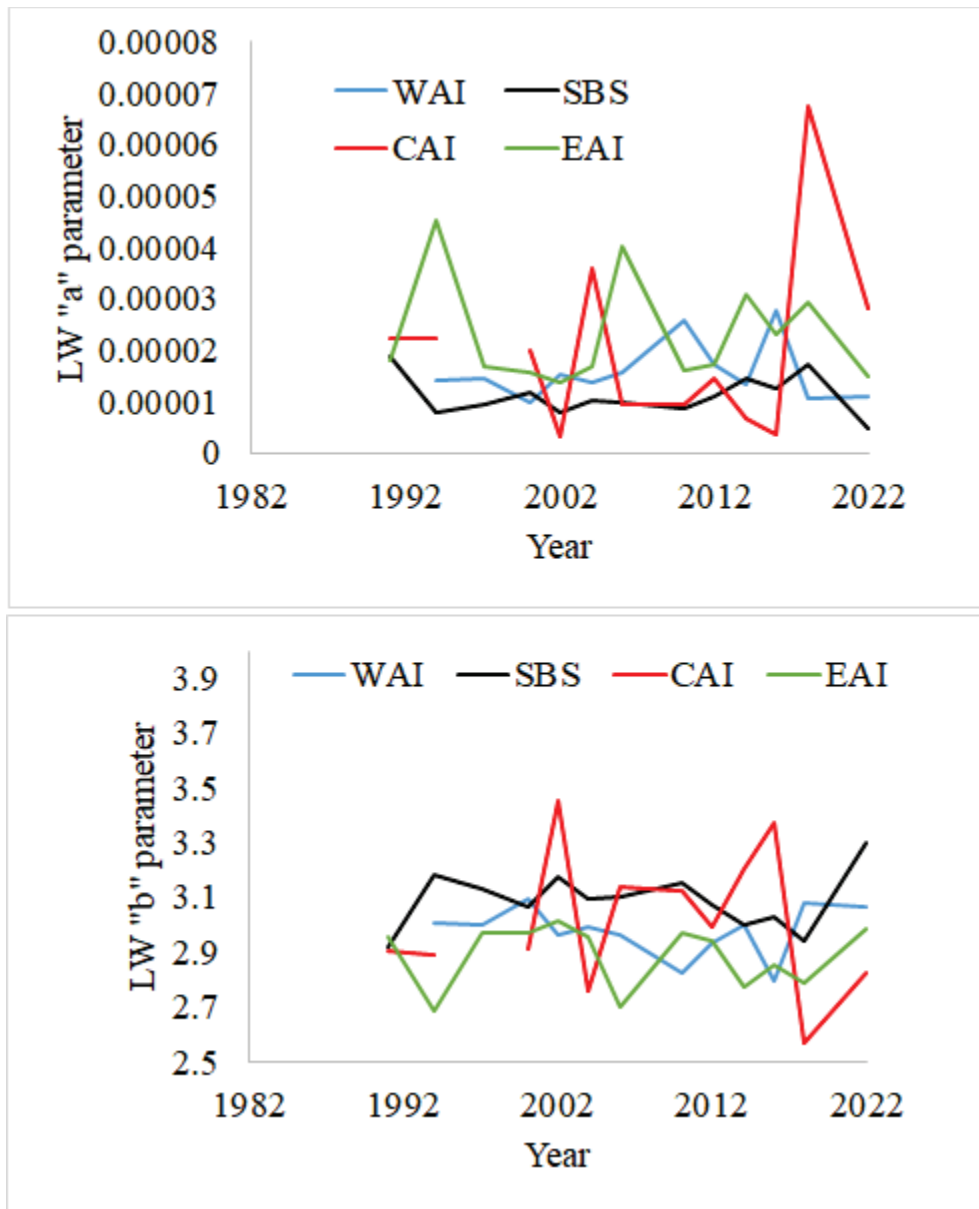


Figure 15. Estimates of the a and b parameters for the weight-length relationship ($W = aL^b$) by year and area for the AI trawl survey.

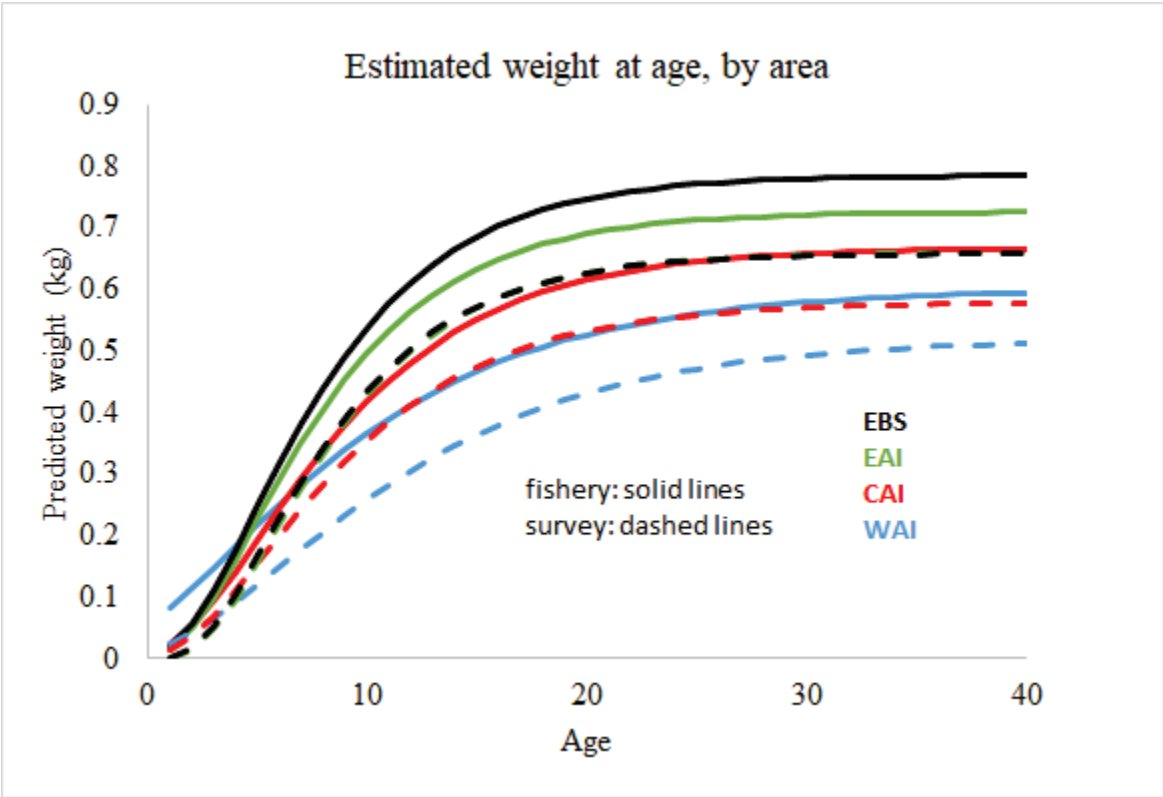


Figure 16. Estimated weights at age by area from the AI trawl survey (dashed lines), combining data across years within each area. The survey size at age for the EAI and EBS are very similar and overlay each other. For comparison, the weight at age in the fishery (solid lines) are also shown.

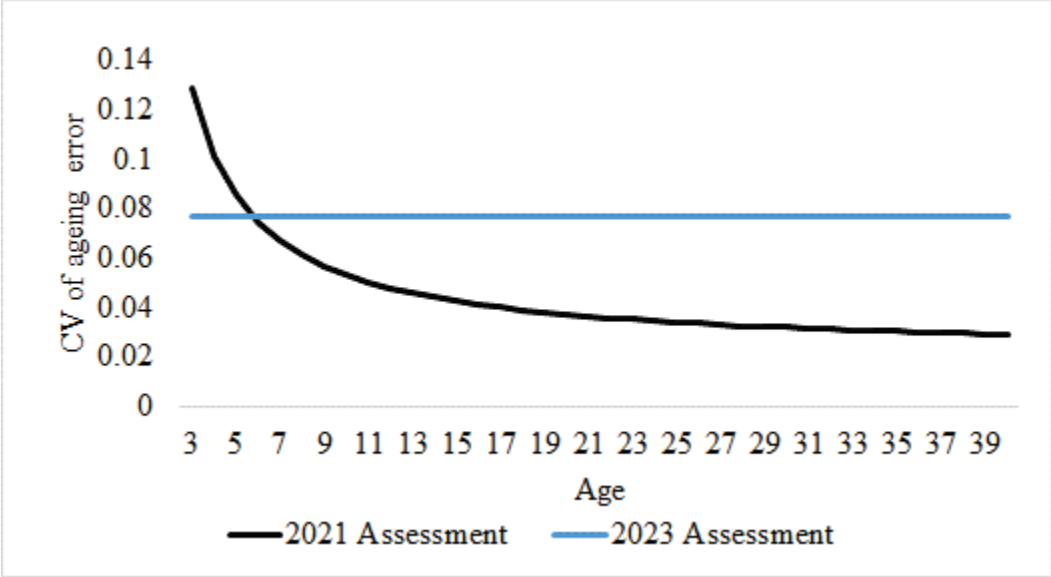


Figure 17. Estimated CV of ageing error in the 2021 and 2023 assessments.

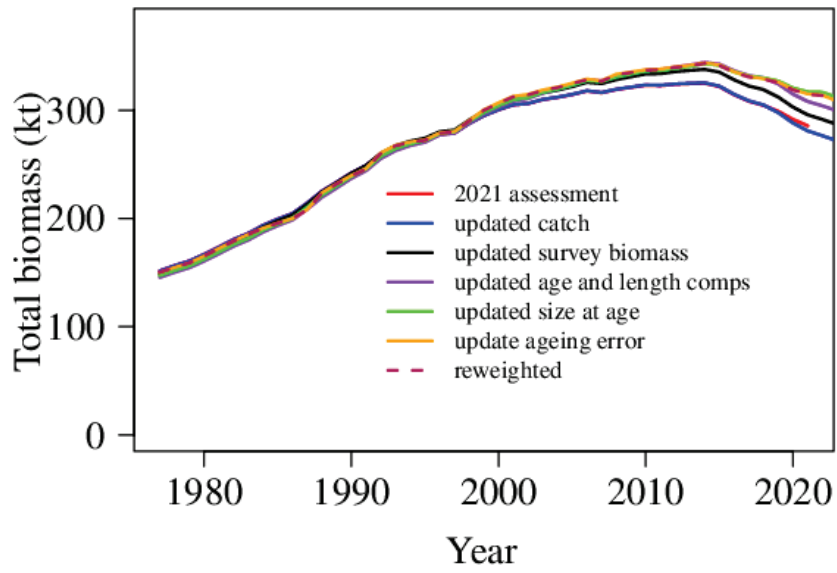


Figure 19. A “bridging” plot showing the sequential effect of updates to the input data on the estimated total biomass, beginning with the final 2021 assessment.

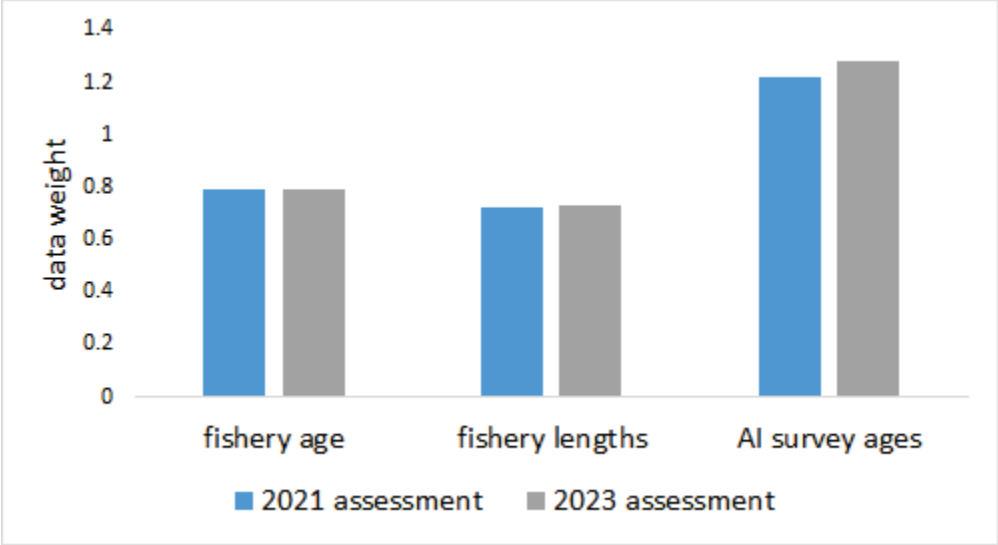


Figure 20. Data weights for the age and length composition data for the 2021 and 2023 assessments.

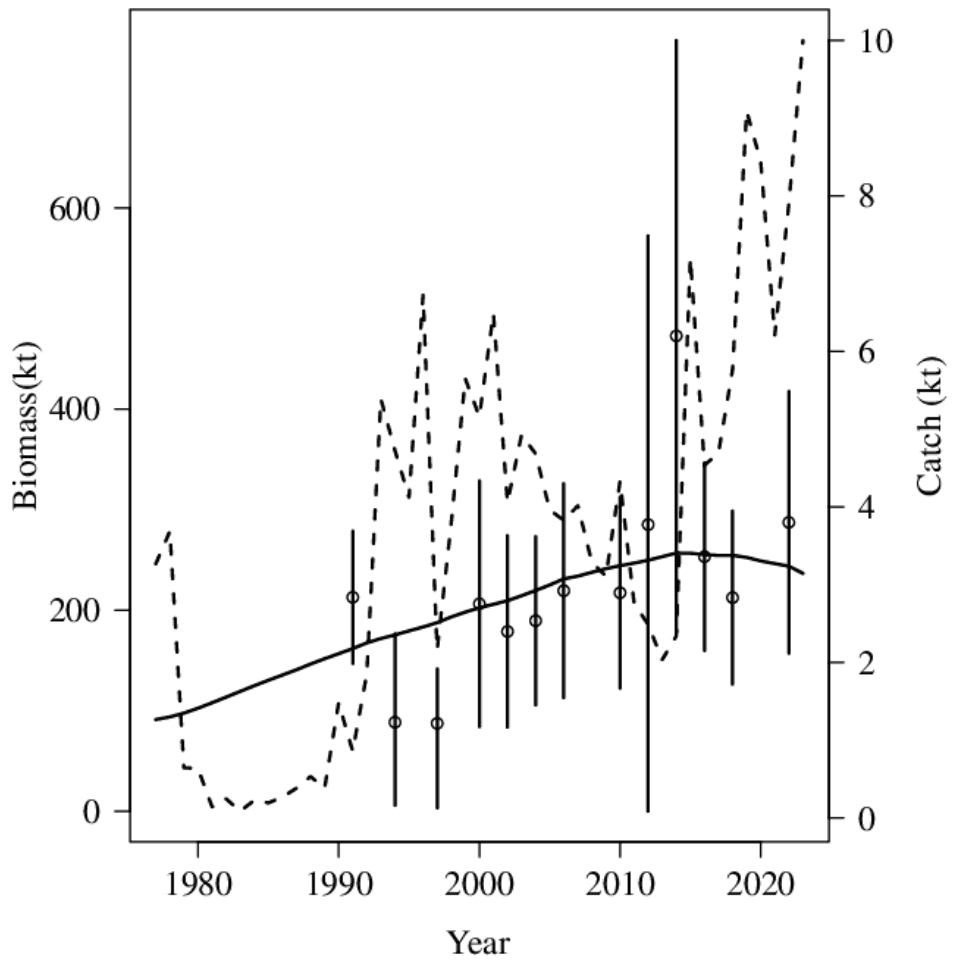


Figure 21. Observed Aleutian Islands survey biomass (data points, ± 2 standard deviations), predicted survey biomass (solid line) and BSAI harvest (dashed line).

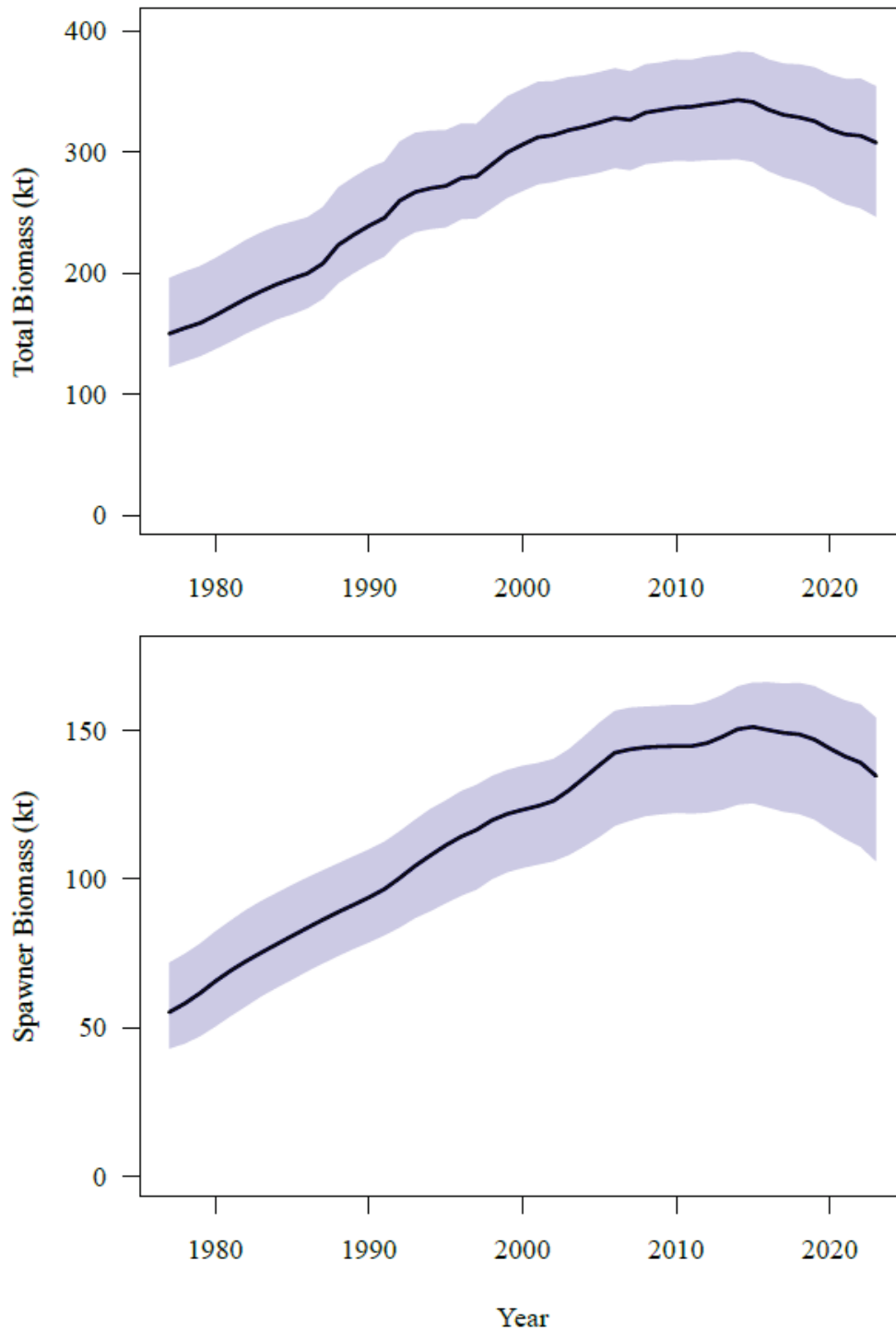


Figure 22. Total and spawning biomass for BSAI northern rockfish with 95% credible intervals from MCMC integration.

Fishery age composition data

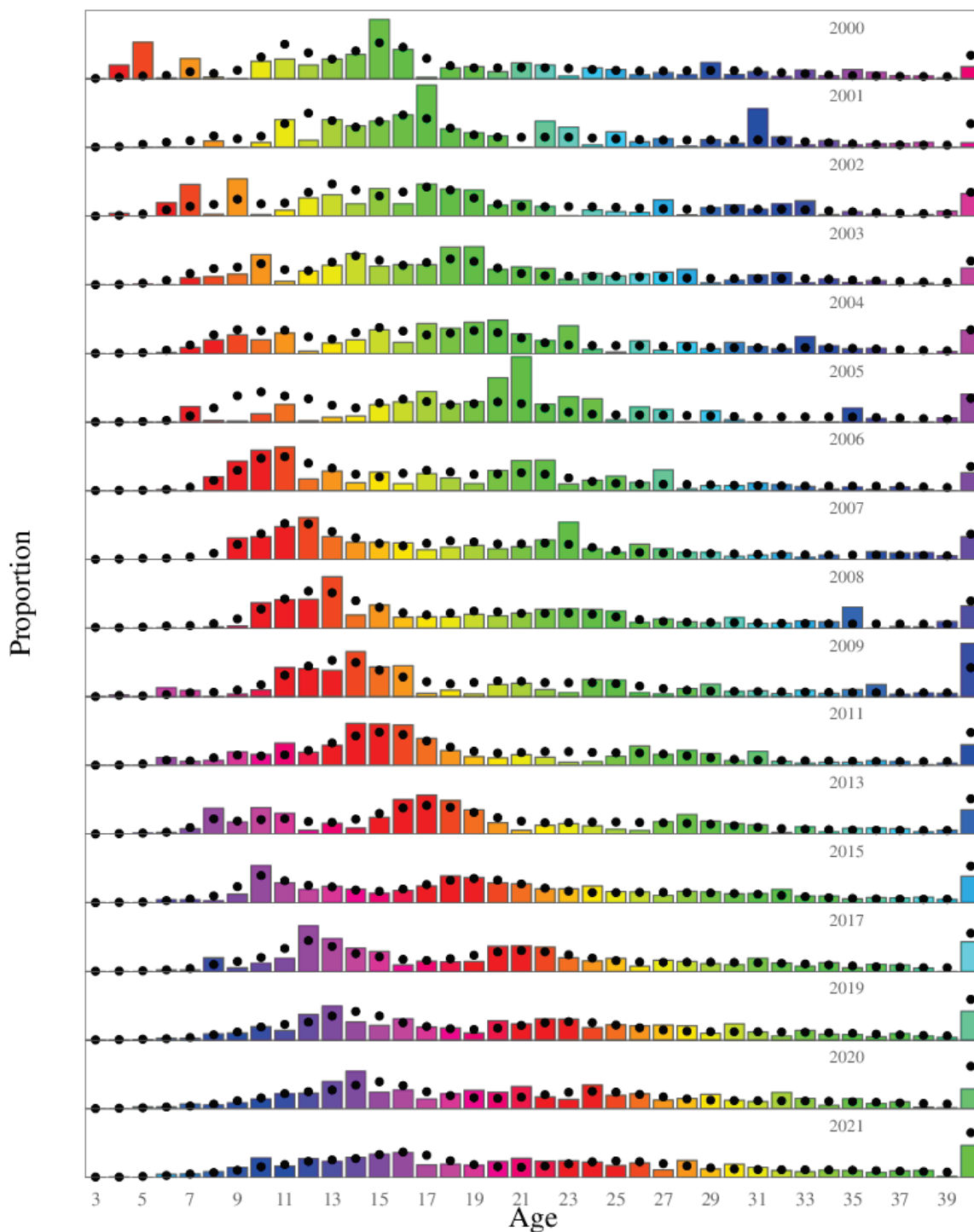


Figure 23. Model fits (dots) to the fishery age composition data (columns) for BSAI northern rockfish. Colors of the bars correspond to cohorts (except for the 40+ group).

Fishery length composition data

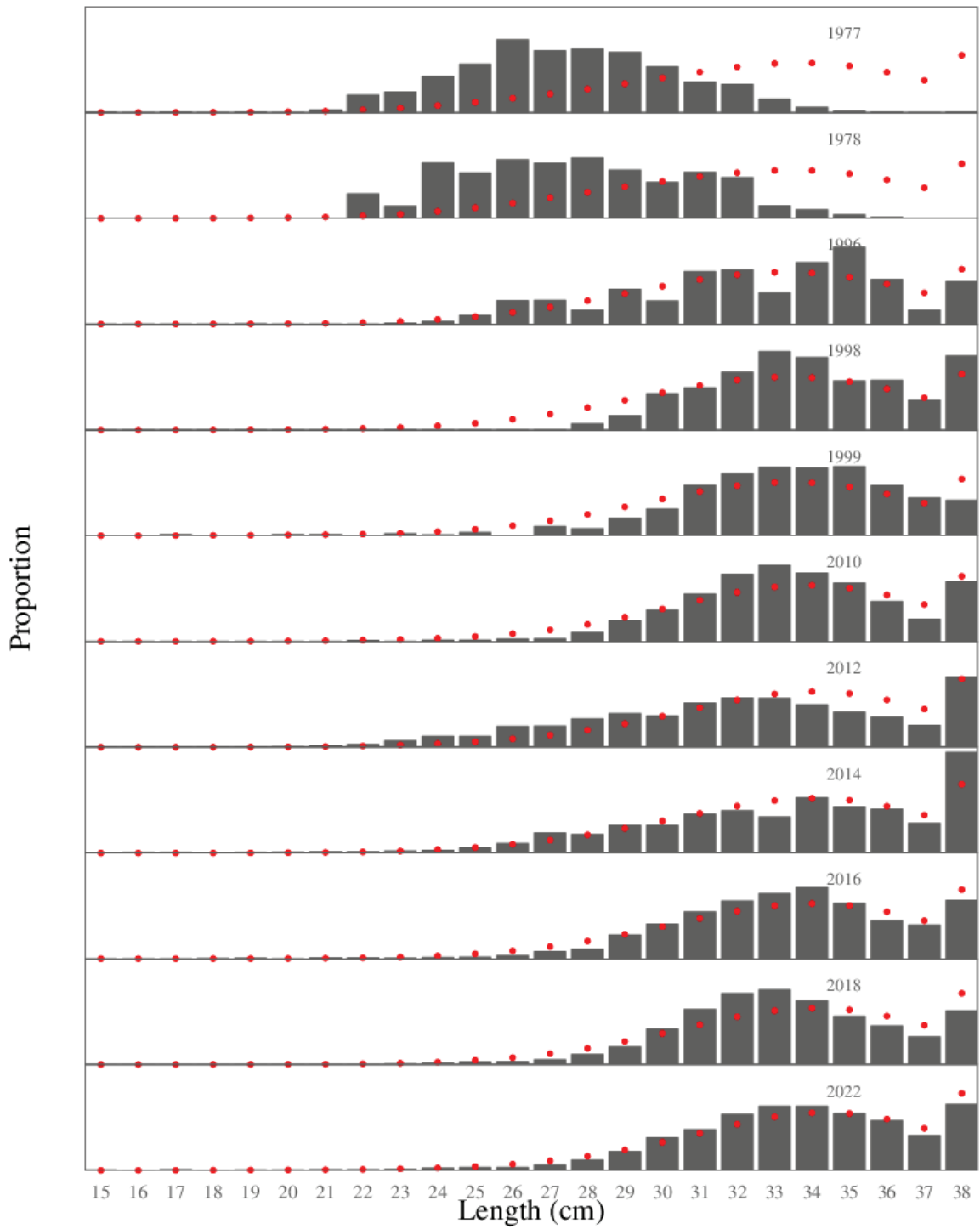


Figure 24. Model fits (dots) to the fishery length composition data (columns) for BSAI northern rockfish.

Survey age composition data

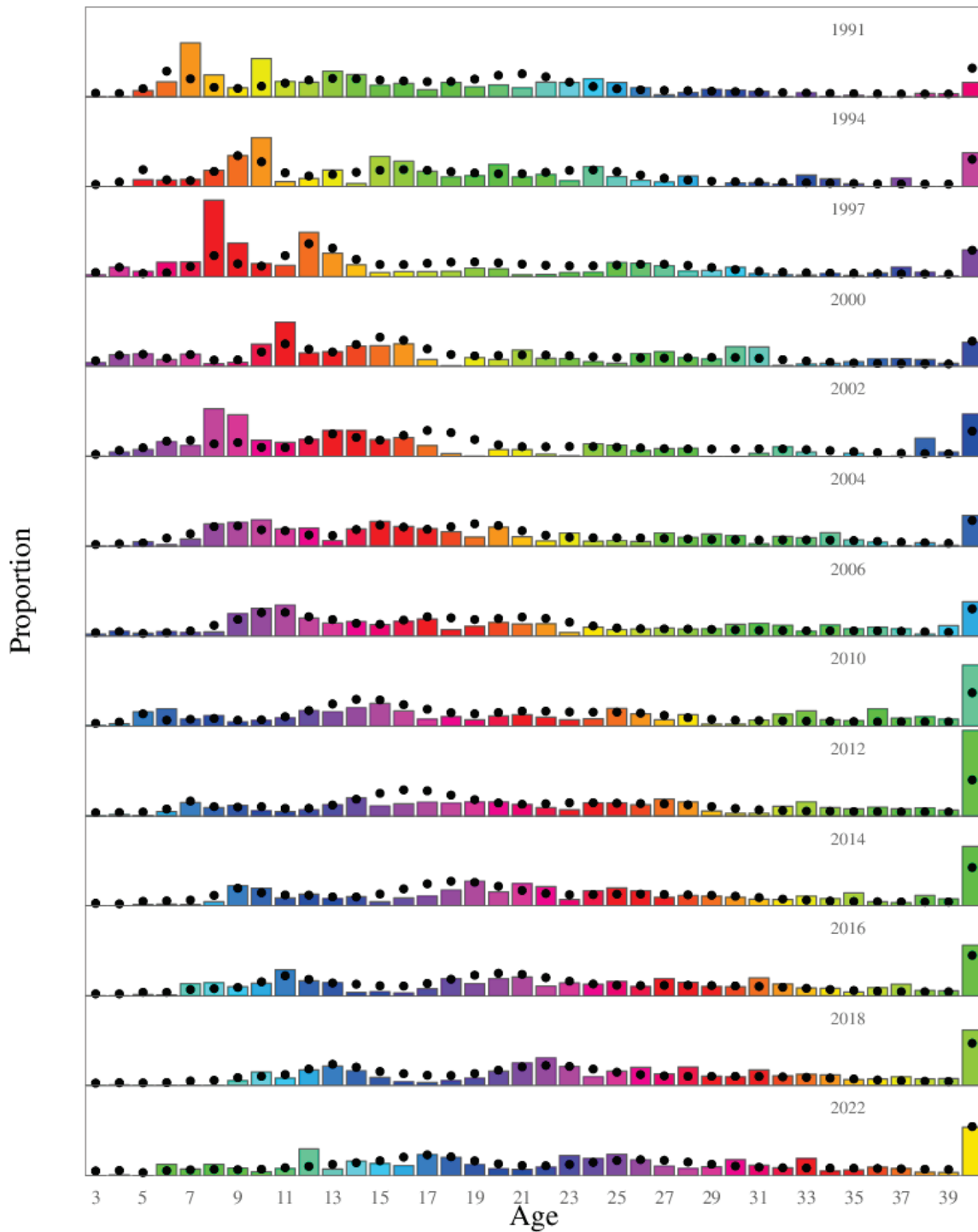


Figure 25. Model fits (dots) to the survey age composition data (columns) for BSAI northern rockfish. Colors of the bars correspond to cohorts (except for the 40+ group).

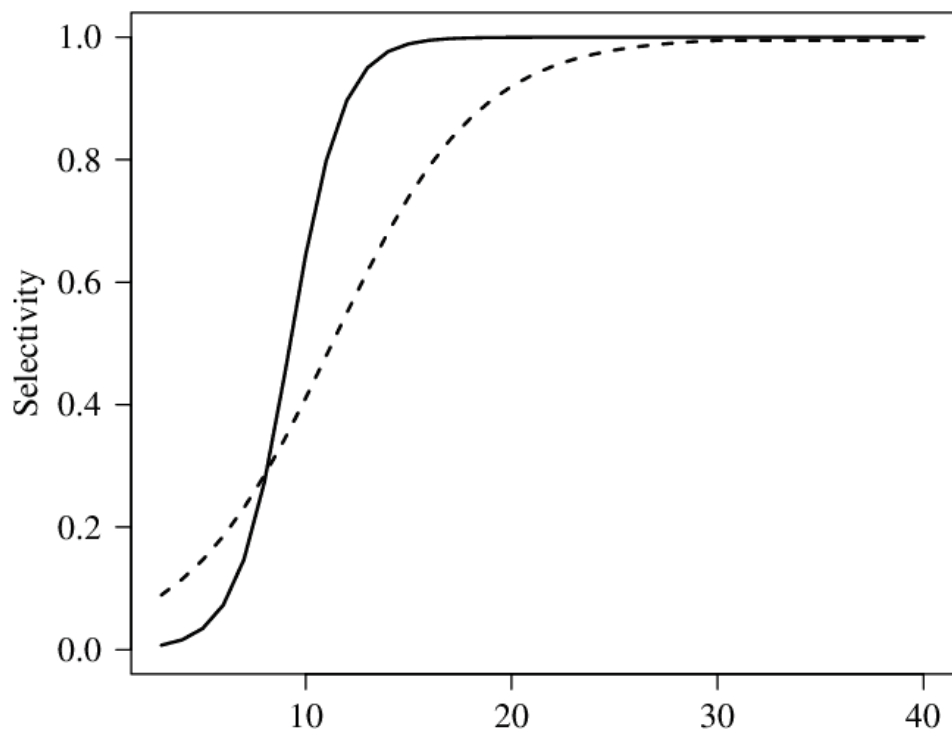


Figure 26. Estimated fishery (solid line) and survey (dashed line) selectivity at age for BSAI northern rockfish.

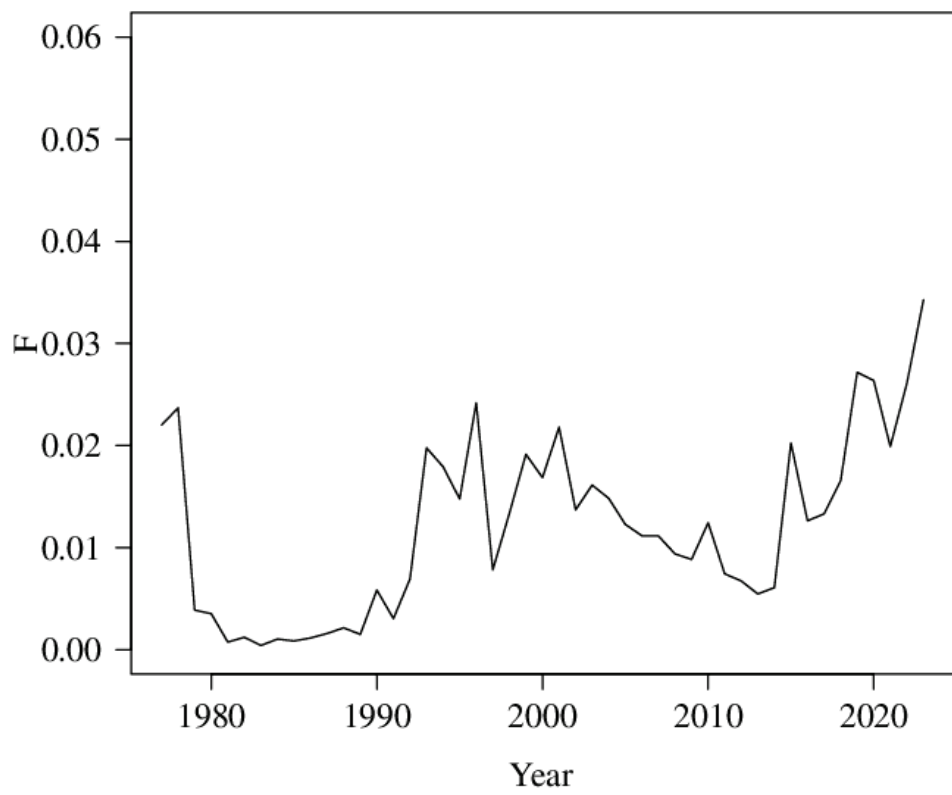


Figure 27. Estimated fully-selected fishing mortality rate for BSAI northern rockfish.

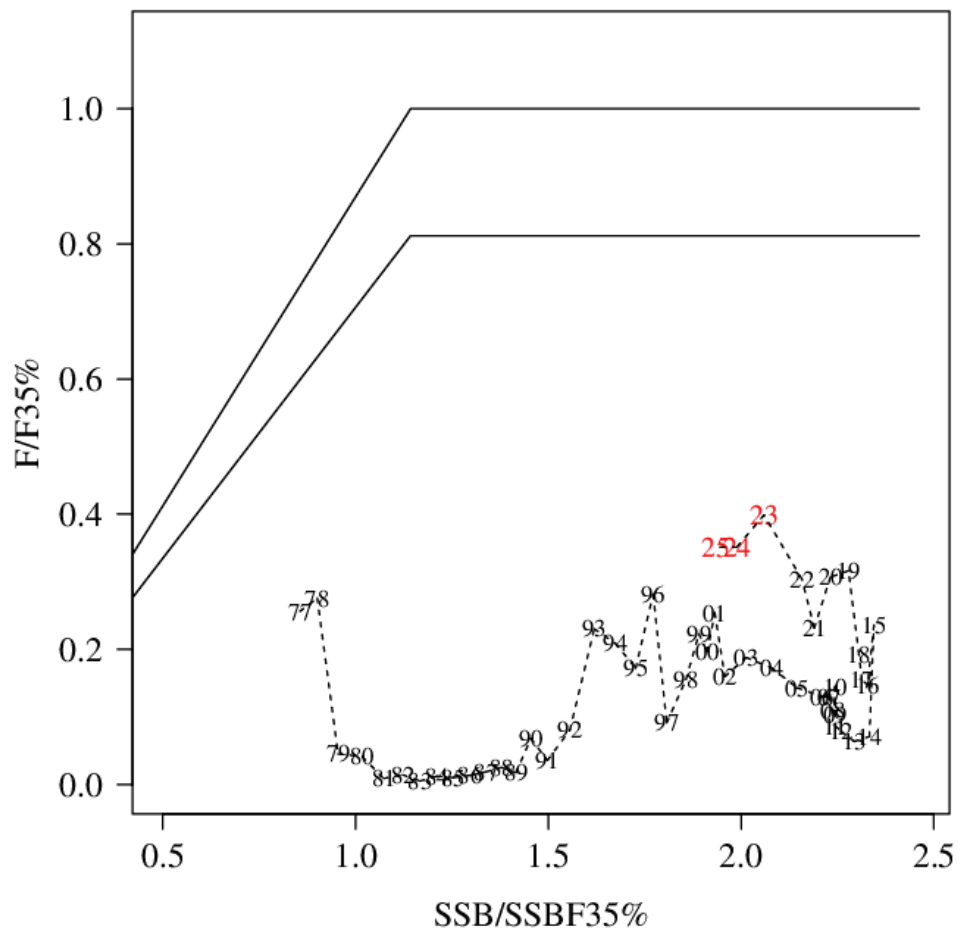


Figure 28. Estimated fishing mortality and SSB from 1977-2025 in reference to OFL (upper line) and ABC (lower line) harvest control rules (values for 2024 and 2025 are based on projections).

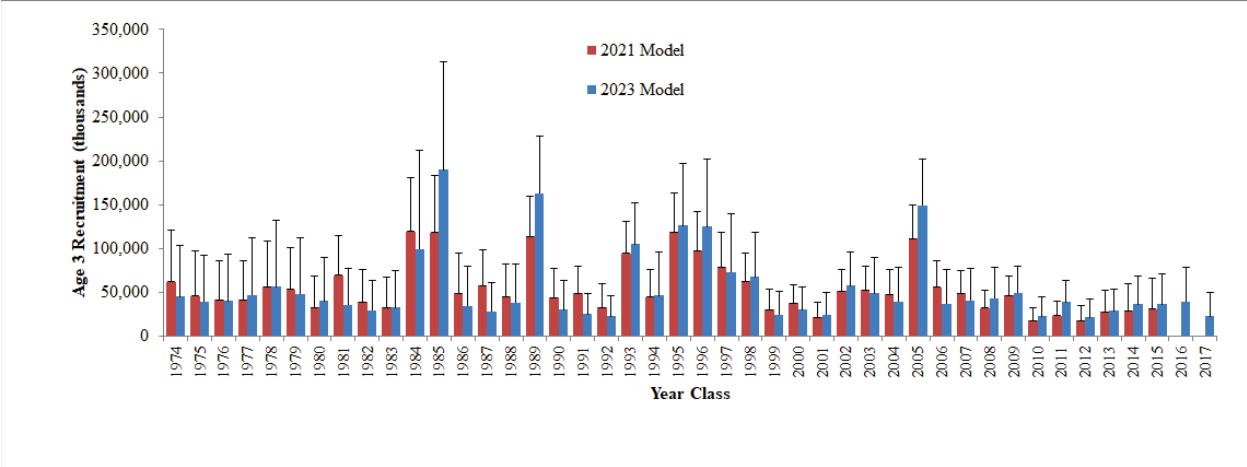


Figure 29. Estimated recruitment (age 3) of BSAI northern rockfish from the 2021 and 2023 assessment models, with 95% CI limits obtained from the Hessian approximation.

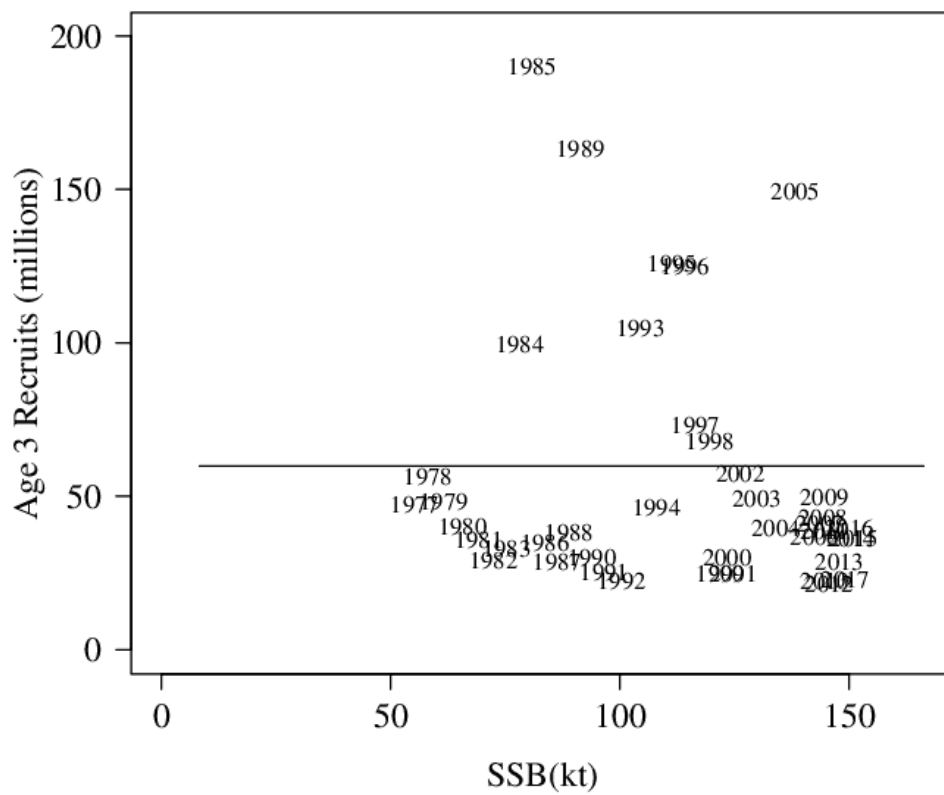


Figure 30. Scatterplot of BSAI northern rockfish spawner-recruit data; labeled values are year classes. The solid line is average recruitment from 1977 to 2017 year classes.

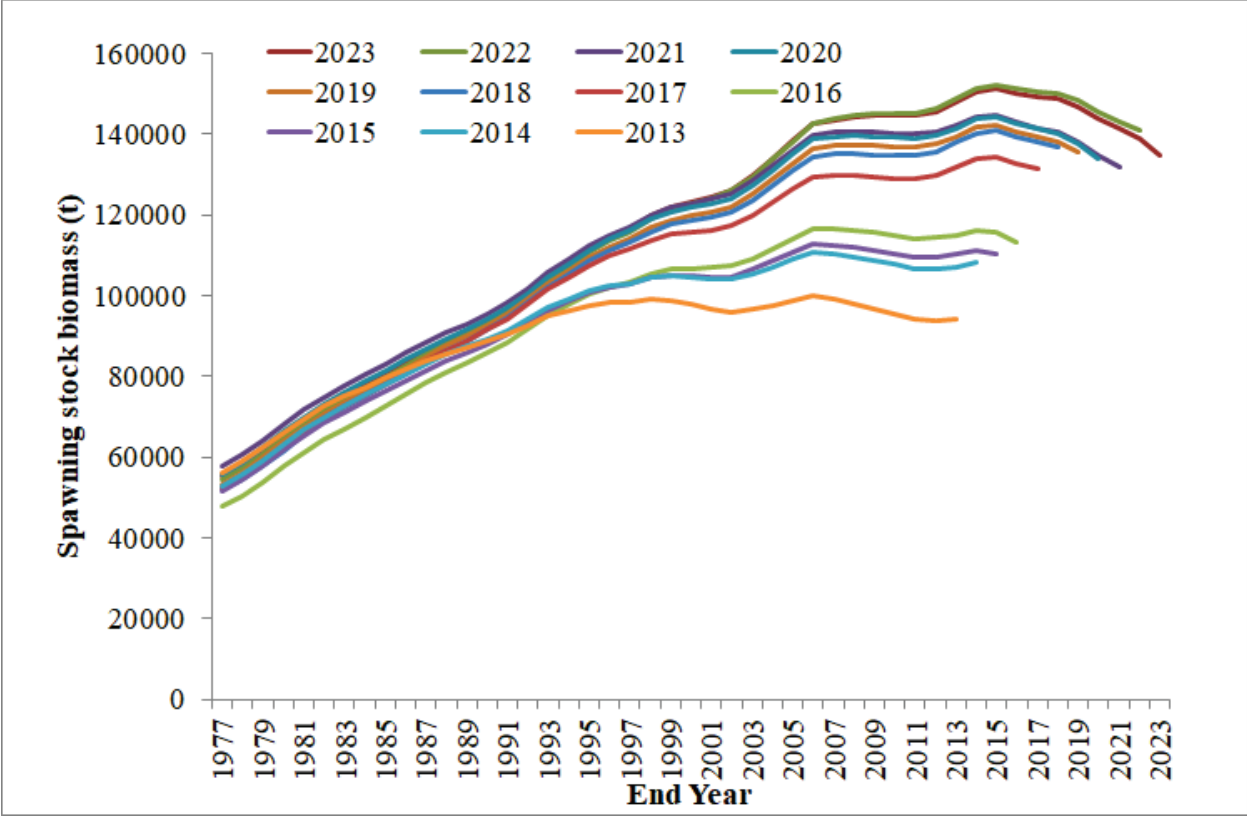


Figure 31. Retrospective estimates of spawning stock biomass for model runs with end years of 2013 to 2023.

Appendix A. Supplemental Catch Data.

In order to comply with the Annual Catch Limit (ACL) requirements, non-commercial removals that do not occur during directed groundfish fishing activities are reported (Table A1). This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For BSAI northern rockfish, these estimates can be compared to the trawl research removals reported in previous assessments. BSAI northern rockfish research removals are small relative to the fishery catch. The majority of removals are taken by the Alaska Fisheries Science Center's (AFSC) biennial bottom trawl survey which is the primary research survey used for assessing the population status of BSAI northern rockfish. The annual amount of northern rockfish captured in research longline gear has not exceeded 0.07 t. Total removals ranged between 0 t and 140 t between 2010 and 2022, which did not exceed 1.6% of the ABC in these years.

Appendix Table A1. Removals of BSAI northern rockfish from activities other than groundfish fishing from 1977-2022. Trawl and longline include research survey and occasional short-term projects.

Year	Source	Trawl	Longline
1977			
1978		0.000	
1979		0.012	
1980		3.576	
1981		0.059	
1982		0.898	
1983		29.285	
1984		0.095	
1985		0.021	
1986		56.895	
1987		0.168	
1988		0.130	
1989		0.062	
1990		0.740	
1991		15.470	
1992		0.077	
1993	NMFS-AFSC	0.001	
1994	survey databases	13.155	
1995		0.015	
1996		0.001	0.034
1997		17.728	
1998		0.252	0.004
1999		0.089	
2000		39.883	0.002
2001		0.038	0.006
2002		36.657	0.011
2003		0.124	0.002
2004		56.763	0.005
2005		0.002	0.002
2006		41.112	0.059
2007		0.172	0.008
2008		0.026	0.008
2009		0.005	0.023
2010		50.354	0.000
2011		140.163	0.014
2012		89.765	0.010
2013		0.014	0.000
2014		69.154	0.000
2015		0.010	0.000
2016	AKFIN database	52.211	0.069
2017		0.043	0.004
2018		49.451	0.000
2019		0.021	0.000
2020		0.000	0.000
2021		0.050	0.041
2022		53.261	0.008