14. Assessment of Blackspotted and Rougheye Rockfish stock complex in the Bering Sea/Aleutian Islands

by

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Executive Summary

Fish previously referred to as rougheye rockfish are now recognized as consisting of two species, rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*Sebastes melanostictus*) (Orr and Hawkins 2008). Bering Sea/Aleutian Islands blackspotted/rougheye rockfish is assessed with an age-structured model for the Aleutian Islands portion of the stock, and a non-age-structured model for the eastern Bering Sea portion of the stock. The last full assessment for BSAI blackspotted/rougheye rockfish was presented to the Plan Team in 2020. The following changes were made to blackspotted/rougheye assessment relative to the November 2020 SAFE:

Summary of Changes in Assessment Inputs

Changes in the input data

1) Catch data was updated through 2021, and total catch for 2022 was projected.
2) The 2022 AI survey biomass estimate and length composition were included in the assessment.
3) The 2013 and 2019 AI fishery length compositions were replaced by the age compositions, and the 2020 and 2021 AI fishery age compositions were included in the model.
4) The input multinomial sample sizes for the age and length composition data were reweighted using the Francis iterative reweighting procedure.

Changes in the assessment methodology

1) There were no changes in the methodology for the recommended model.
2) To stabilize the estimate of $B_{40\%}$, we recommend replacing the unusually large estimate of the 2010 year class with the estimate for the nest largest year class.

Summary of Results

The recommended model estimates a very large 2010 year class of 21.25 million with a large coefficient of variation of 0.58. This is over 6 times larger than the estimated 2002 largest – the 2002 year class estimated at 3.43 million. Because the estimate of $B_{40\%}$ is a function of mean recruitment from the post-1977 year classes, this year class increases the estimate of $B_{40\%}$ by 32% relative to the 2020 estimate and hence changes the relative status of the stock using these proxies from the FMP.

The retrospective stability of year class strengths has improved with the adoption of Francis weighting of the composition data, but large year classes can still be uncertain and show instability. For example, retrospective analyses showed that the 2002 year class estimate was large (7.6 million fish) with reduced data from some retrospective peels, but in subsequent years the estimate dropped substantially to 2.6 million fish. Additionally, the 2010 year class has yet to contribute substantially to the fishery catch and spawning stock biomass (SSB; only 3.5% of the fish 12 years old in 2022 are mature, and the fishery selectivity is 26%). For this reason, the estimated large 2010 year class results in a small change in the SSB despite that large change in $B_{40\%}$. Relative to the 2020 assessment, the stock with the estimated 2010 year class more depleted and the F_{abc} lowered because the SSB is further below that value of $B_{40\%}$. Despite the SSB being to the estimate in the 2020 assessment. The ratio of B_{2023}/ $B_{40\%}$ from the 2022 assessment and projection model is 0.74, whereas the ratio of B_{2023}/ $B_{40\%}$ from the 2020 assessment and projection model was 0.98. However, the estimates of B_{2022} and B_{2023} from the 2020 and 2022 assessments were more stable (3,468 t and 3,472 t, respectively). The recommended 2023 ABC for the AI portion of the stock from the 2022 assessment is 394 t, a 13% decline from the 2022 ABC for the AI portion of the stock.

Methods to address the impact that uncertainty in recruitment strength and estimated numbers-at-age have on reference points and recommended ABCs and OFLs are lacking. The reduction in the ABC of 13% is based primarily on the effect that an estimate of a large and uncertain year class has on $B_{40\%}$ and F_{abc}. However, the time series of survey biomass estimates does not indicate a decline since the 2020 assessment, and we could reasonably expect that the recommended 2023 ABC would be relatively similar to the 2022 ABC.

Finally, we considered recommended ABCs from stock projections that set the value of the 2010 year class to a value considered more likely. Note that this was done only for the calculation of average recruitment, and the estimated 2022 numbers at age used to initialize the harvest projection were not altered. It is common to not use estimates of recent year classes when computing average recruitment, and we continue to use a procedure (recommended by the Plan Team) that considers stock longevity and the age of the year class relative to the level of selection in the AI trawl survey when selecting the year classes for calculation of mean recruitment. For this assessment, we considered setting the 2010 year class with a value equal to the 2002 year class (the estimated next largest year class), which produces a recruitment of 3.43 million. There is historical precedent for this type of adjustment in the management projections; for example, in the 2017 sablefish assessment the unusually large estimate of the 2017 year class was set equal to the next largest year class for the purpose of obtaining an author-adjusted reduction in ABC. For the blackspotted/rougheye assessment, this adjustment would result in a 2023 ABC of 533, approximately 18% larger than the 2022 ABC of 453 t, which is approximately the same magnitude of change as the projected ABC from the unadjusted method (but in the other direction). The following table summarizes the effect on reference points, stock status, and ABCs for both adjusted and unadjusted values for the 2010 year class:

	2020 assessment and projection	2022 assessment: Unadjusted 2010 YC used for $B_{40\%}$	2022 assessment: Adjusted 2010 YC used for $B_{40\%}$
$B_{40\%}$	3,524		
$B_{40\%}$ (2022 assessment)		4,662	3,493
Percent change in $B_{40\%}$, 2020 to 2022		32.29%	-0.88%
2022 SSB	3,468		
2023 SSB		3,472	3,471
2024 SSB		3,651	3,642
$B_{2022}/B_{40\%}$	0.98		
$B_{2023}/B_{40\%}$		0.74	0.99
$B_{2024}/B_{40\%}$		0.78	1.04
2022 Total Biomass	17,774		
2023 Total Biomass		23,883	23,856
2024 Total Biomass		24,481	23,374
2022 Fabc	0.033		
2023 Fabc		0.025	0.034
2024 Fabc		0.026	0.034
2022 maximum ABC	453		
2023 maximum ABC		395	533
(percent change 2022 to 2023)		-12.80%	17.66%
2024 maximum ABC		453	584
(percent change 2023 to 2024)		14.68%	9.57%

Given the options considered, we recommend using that adjusted projection to set the maximum ABC. We note that the 2010 year class is estimated to compose a large portion of the stock. Adjusting the 2010 year class stabilizes the $B_{40\%}$ reference point estimate. Using the estimate of this year class in the projections as part of the stock (as age 13 and 14 year olds in the next two years) increases the ABC considerably. We accept that as the "best estimate" for maximum permissible ABC but recommend an ABC consistent with the survey trend and the uncertainty in the current estimates of the 2010 year class. Given the unusually large and uncertain estimate of the 2010 year class, the relatively limited number of times this year class has been observed in our data, and the history of retrospective downweighting of strong year classes (i.e., the 2002 year class), it seems prudent to stabilize the ABCs until more information on the magnitude of the 2010 year-class can be confirmed. The AI survey biomass time series is relatively stable (although with high uncertainty and variability), and recommend not increasing the ABC recommendation until more unequivocal evidence is seem for stock increases. This general approach was also followed in recent sablefish assessments, which also reduced the recommended ABC from the maximum until estimation of unusually large and uncertain year classes could be better informed with more data.

Our recommended ABC for the AI portion of the stock is 467 t, which was obtained from the 2021 projection for 2023. This is a slight increase from the value of 453 t for the AI portion of the stock for 2022, and a 12% decline from the maximum ABC.

A summary of the 2023 and 2024 recommended ABCs (from the AI model) relative to the values specified for 2022 (based on the accepted 2020 AI model) are shown below.

Quantity	As estimated or *specified* last year for:		As estimated or *recommended* this year for:	
	2022	2023	2023*	2024*
M (natural mortality rate)	0.049	0.049	0.050	0.050
Tier	3b	3a	3b	3a
Projected total (age 3+) biomass (t)	17,774	17,862	23,856	24,374
Female spawning biomass (t)				
Projected	3,468	3,568	3,471	3,642
$B_{100\%}$	8,811	8,811	8,733	8,733
$B_{40\%}$	3,524	3,524	3,493	3,493
$B_{35\%}$	3,083	3,083	3,056	3,056
F_{OFL}	0.039	0.039	0.040	0.040
$maxF_{ABC}$	0.033	0.033	0.034	0.034
F_{ABC}	0.033	0.033	0.030	0.030
OFL (t)	531	548	626	686
maxABC (t)	453	467	533	584
ABC (t)	453	467	467	512
Status	As determined *last* year for:		As determined *this* year for:	
	2020	2021	2021	2022
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 harvests of 433 t and 471 t in 2023 and 2024, respectively.

The population size and harvest levels for the EBS portion of the population were obtained by applying Tier 5 methods to recent survey biomass estimates. A random effects model was used to fit a random walk smoother to the survey biomass data from the EBS portion of the stock. A summary of the 2023-2024 recommended ABC’s for the EBS portion of the population is shown below.

Quantity	As estimated or *recommended* last year for: 2022	2023	As estimated or *recommended* this year for: 2023	2024
M (natural mortality rate)	0.049	0.049	0.050	0.050
Tier	5	5	5	5
Biomass (t)	1,371	1,371	1544	1544
F_{OFL}	0.049	0.049	0.050	0.050
$maxF_{ABC}$	0.037	0.037	0.037	0.037
F_{ABC}	0.037	0.037	0.037	0.037
OFL (t)	67	67	77	77
maxABC (t)	50	50	58	58
ABC (t)	50	50	58	58
Status	As determined *this* year 2020	2021	As determined *this* year for: 2021	2022
Overfishing	No	No	No	n/a

The overall BSAI ABC and OFL are shown below.

Quantity/Status	As estimated or *specified* last year for: 2022	2023	As estimated or *recommended* this year for: 2023	2024
OFL (t)	598	615	703	763
ABC (t)	503	517	525	570

The BSAI blackspotted/rougheye stock complex was not subjected to overfishing in 2021. Based on the age-structured model for the AI portion of the stock, BSAI blackspotted/rougheye rockfish is not overfished nor approaching an overfished condition.

Area Apportionment

The ABC for BSAI blackspotted/rougheye is currently apportioned among two areas: the western and central Aleutian Islands, and eastern Aleutian Islands and eastern Bering Sea. A random effects model was used to smooth the time series of subarea survey biomass and obtain the proportions. Additionally, the smoothed biomass estimated for the EBS slope was adjusted to account for differences in estimated catchability and selectivity between the AI and EBS trawl surveys. The following table gives the projected OFLs and apportioned ABCs for 2023 and 2024 and the recent OFLs, ABCs, TACs, and catches.

Area/subarea	Year	Total Biomass (t)[1]	OFL	ABC	TAC	Catch[2]
BSAI	2021	19,003	576	482	482	515
	2022	19,145	598	503	503	339
	2023	25,400	703	525	n/a	n/a
	2024	25,918	763	570	n/a	n/a
Western/Central Aleutian Islands	2021			169	169	319
	2022			177	177	218
	2023			166	n/a	n/a
	2024			182	n/a	n/a
Eastern AI/Eastern Bering Sea	2021			313	313	196
	2022			326	326	121
	2023			359	n/a	n/a
	2024			388	n/a	n/a

[1] The total biomass from AI age-structured model, and survey biomass estimates from EBS.
[2] BSAI catch as of September 25, 2022.

Apportionment within the WAI/CAI area

In recent years, the WAI/CAI has been partitioned into "maximum subarea species catch" for the WAI and CAI areas. A random effects model was used to smooth the time series of subarea survey biomass and obtain proportions used for this partitioning, and the 2023 and 2024 MSSC values are shown below.

Year	WAI MSSC	CAI MSSC
2023	61	105
2024	67	115

Responses to SSC and Plan Team Comments on Assessments in General

(SSC, June 2021) The SSC developed *Preliminary Guidance and SSC Recommendations* regarding the use of risk tables, with 9 specific comments/recommendations.

Authors' response: We have attempted to follow this guidance when updating the risk table in this assessment.

(Joint Plan Team, September 2022) The Teams recommended that stock assessment authors transition from the ADMB random-effects survey smoother to this package which implements the same model with several improvements.

The *rema* package was used to estimate the smoothed survey biomass time series, which were used in the calculations of apportionments.

(SSC, October 2022) *Several assessment updates noted potential impacts of the recent lack of the EBS slope survey on abundance and size/ age composition data. The SSC acknowledges that these challenges result from ongoing survey resource limitations and that the 2018 SSC Sub-Committee on Trawl Survey Options and Priorities ranked the slope survey as the lowest priority. The SSC recommends that* *assessment authors continue to highlight instances where the lack of these data may degrade stock assessment performance.*

The BSAI blackspotted-rougheye stock assessment applies Tier 5 methods of smoothing survey biomass estimates from the EBS slope survey (and the southern Bering Sea portion of the Al trawl survey) to obtain ABC recommendation of the portion of the stock in the EBS management subarea. The lack of recent EBS slope survey biomass estimates causes uncertainty in these procedures. The likelihood that the EBS slope survey is unlikely to be resumed in future motivates exploration of alternative data sources. One possibility is the EBS portion of the AFSC longline survey, which will be explored in future assessments.

Responses to SSC and Plan Team Comments Specific to this Assessment

(SSC, December 2020) *The SSC supports the BSAI GPT recommendation that the authors explore the distribution of the survey samples to evaluate trends by depth, to help determine risk considerations and potentially help inform the industry on how to reduce incidental catch.*

● *Similarly, the SSC recommends an exploration of the spatial footprint of the AI survey and incidental catch fisheries with an eye towards potential mismatches due to untrawlable habitat that might provide context for interpreting conflicting survey abundance and fishery size/ age composition. We note that a graduate research project investigating the survey – fishery alignment along with recent changes in Atka mackerel and POP fishing behavior is underway at Alaska Pacific University. In addition, the SSC pointed out that a NMFS – University – Industry cooperative effort entitled "The Science-Industry Rockfish Research Collaboration in Alaska" being led by Dr. Madison Hall is currently underway. While this effort is primarily focused on GOA rockfish, it may provide important analytical tools and insights for application to the BSAI BS/RE complex.*

● *The SSC supports the BSAI GPT suggestion to explore other survey data (e.g. NMFS and IPHC long-line or ADF&G survey data) to augment abundance and size/ age composition information. We note that a new graduate research project looking at combining data from different surveys and gears is underway at the College of Fisheries and Ocean Sciences at the University of Alaska Fairbanks.*

● *The SSC notes that the values of M used in the AI assessment are very high, especially for a long-lived species, and requests that the authors fully explore the ranges and interactions of catchability and M in the AI assessment model.*

● *The SSC requests an update on work (e.g. genetics) to further refine BS/RE stock structure in the AI.*

● *Given the information regarding shifts in fishing effort to shallower areas provided in public testimony, the SSC requests that the authors investigate the effects of fleet behavior on apparent size/ age compositions, and to what extent this may be influencing fishery selectivity.*

(BSAI Plan Team, September, 2021) *For blackspotted rockfish, the Team made the following recommendations:*

● *The costs and benefits of a tagging study should be evaluated by the AFSC.*

● *The costs and benefits of an IBM specific to answering the questions surrounding blackspotted rockfish larval dispersion and potential stock replenishment rates in the Aleutian Islands should be evaluated by the AFSC.*

● *Except for the genetic study, which has now been completed, the other items on the SSC's list from December 2020 should be pursued, including the convening of another workshop on spatial management, which should address both BSAI blackspotted rockfish in particular and spatial management issues in general. One objective of such a workshop should be the consideration and development of alternative management tools for dealing with stocks or portions of stocks with rankings of "strong concern" due to their prevalence as bycatch.*

(SSC, October, 2021) *The SSC concurs with the BSAI GPT recommendation to evaluate the cost and benefits of these additional studies and suggests that the tagging study has a higher priority than the larval study.*

A paper that addressed the issues above that directly involve the stock assessment was presented at the September, 2022, BSAI Plan Team meeting, and included as Appendix 14A to this assessment. An update on genetic information was presented at the September 2021 BSAI Plan Team meeting. Comments on cost-benefit analysis of large-scale field studies and development of IBMs were directed to the Alaska Fisheries Science Center.

Brief summaries of responses to the remaining topics are shown below; for further details, see Appendix 14A.

Distribution of the survey samples to evaluate trends by depth

For all Aleutian Island survey subareas, the largest amount of samples occurs in the 100 – 200 m depth zone, with the relative amount of sampling in the 200 – 300 m depth zone being largest in the EAI and smallest in the SBS. The overall number of stations sampled has increased over time relative to the 1991 and 1994 surveys. In most subareas, the 300 – 500 m depth zone contains the largest amount of estimated biomass, although the biomass in the 200 – 300m depth zone in the north CAI subarea has been large in some years.

Exploration of the spatial footprint of the AI survey and incidental catch fisheries

Plots of the fishery and survey sampling effort by 0.5° longitudinal bins, for the WAI, CAI, and EAI are shown in Appendix 14A. As expected, the survey hauls are roughly evenly distributed throughout this sampling area, whereas some areas have a concentration of fishery hauls. It is unclear what effect, if any, these differences in spatial footprints would have on the survey biomass estimates, as we would not expect the distribution of survey samples to mimic the distribution of fishery effort.

The SIRICA (Science- Industry Rockfish Research Collaboration in Alaska) project being led by Madison Hall is focused on the GOA, and involves conducting standardized trawls using fishing vessels to augment the GOA survey tows. Field work is underway, and planned to continue through 2025. The objective of the study is to demonstrate the utility of a cooperative data collection program, from which an index of rockfish abundance in untrawlable grounds could be obtained. Another relevant study is the thesis project of Cara Hesselbach (Alaska Pacific University), who is examining the spatial and temporal overlap of survey and fishery observations of blackspotted and rougheye rockfish in the Aleutian Islands. Although this study is ongoing, one notable finding is recognition of consistency between the fishery and survey composition data (i.e., each showing a shift to smaller fish in recent years), and this will be shown later in this assessment.

Exploration other survey data (e.g. NMFS and IPHC long-line or ADF&G survey data)

We examined the survey biomass estimates from the 3 surveys identified in the SSC comment: 1) NMFS longline survey; IPHC longline survey; and 3) ADF&G trawl survey data. In the case of rockfish in the Aleutian Islands, none of the potential additional surveys (beyond the AFSC trawl survey) covers the entire range of the Aleutian Islands area defined for the stock, and there is biological and oceanographic data to suggest that the habitats and system structure differs between Aleutian Islands subareas. If surveys that cover a portion of the Aleutian Islands reflect different signals in the underlying population, then trends in one subarea would not be expected to correspond to trends in other areas. We do not recommend including these surveys in the assessment, and the BSAI Plan Team agreed with this conclusion at the September 2022 meeting.

Natural mortality

The rationale for the scale of the prior distribution was presented in the 2020 BSAI blackspotted-rougheye assessment, and is repeated again in Appendix 14A. Additionally, the estimate of natural mortality in this assessment is consistent with those in assessments on British Columbia and the U.S. West Coast.

Temporal changes in depth of fishery effort, and potential influences on age and size compositions

The mean depths of the fishery and survey have shifted to shallower waters, and both the survey and fishery are catching smaller fish in recent years. “Fishery” is defined here as tows in which blackspotted-rougheye are caught. Blackspotted-rougheye rockfish are caught in tows targeting other species (i.e., POP), and tows from these fisheries which did not catch blackspotted rockfish were not considered because they do not affect the blackspotted-rouheye stock assessment. The of shallower depths and smaller sizes in the fishery was consistent with information presented by fishing industry representatives at the Sept 2022 BSAI Plan Team meeting.

The reduction in fish size cannot be attributed solely to changes in fishery behavior and selectivity, as the AI trawl survey is also catching smaller fish recently. A model run with time-varying selectivity is considered in this assessment, and did not show substantially different selectivity in recent years relative to the existing model with time-invariant selectivity.

(BSAI Plan Team, September 2022) *Finally, the author provided comparisons to the value of M in other North American BS/RE stocks in response to SSC comments about M being “very high”. The Team supported these justifications, and further noted that it may be worth examining the much-lower value of M used in the GOA BS/RE stock assessment.*

(SSC, October 2022) *The SSC concurs with the BSAI GPT’s recommendations for no model changes at this time and for further examination of natural mortality values.*

We note that the reference to the BSAI GPT’s recommendation of “*further examination of natural mortality rates*” referred to the GOA rougheye-blackspotted assessment, and we are willing to work with the authors of that assessment to coordinate our approaches.

(SSC, October 2022) *The SSC acknowledged the changes in the IPHC longline survey sampling design in 2020 but noted that the survey was highly correlated with the bottom trawl survey prior to 2020. Given the retrospective bias in the current model and its difficulty in assessing the scale of the stock, the SSC recommends the author explore use of the pre-2020 data in the assessment with emphasis on sampling in untrawlable habitats. It may also be possible to continue use of the time series of IPHC data after 2019 if model-based estimates are used.*

The historical pre-2020 IPHC longline survey will be considered in future assessments.

Introduction

Rougheye rockfish (*Sebastes aleutianus*) have historically been managed within various stock complexes in the Bering Sea/Aleutian Islands (BSAI) region. For example, from 1991 to 2000, rougheye rockfish in the eastern Bering Sea (EBS) area were managed under the "other red rockfish" species complex, which consisted of shortraker (*Sebastes borealis*), rougheye (*S. aleutianus*), sharpchin (*S. zacentrus*), and northern rockfish (*S. polyspinis*), whereas in the Aleutian Islands (AI) area during this time rougheye rockfish were managed within the rougheye/shortraker complex. In 2001, the other red rockfish complex in the EBS was split into two groups, rougheye/shortraker and sharpchin/northern, matching the complexes used in the Aleutian Islands. Additionally, separate TACs were established for the EBS and AI management areas, but the overfishing level (OFL) pertained to the entire BSAI area. By 2004, rougheye, shortraker, and northern rockfish were managed with species-specific OFLs applied to the BSAI management area.

Species composition within the two-species complex

Fish historically referred to as "rougheye" rockfish are now recognized as consisting of two separate species (Orr and Hawkins 2008), with rougheye rockfish retaining the name *Sebastes aleutianus* and resurrection of a new species, blackspotted rockfish (*S. melanostictus*). Both species are distributed widely throughout the north Pacific. *S. aleutianus* is distributed from the eastern AI near Unalaska Island along the continental slope to southern Oregon, while *S. melanostictus* is distributed along the continental slope from Japan to California (Orr and Hawkins 2008), and *S. melanostictus* is distributed in the Western and Central Aleutian Islands, where *S. aleutianus* is not found.

Several studies (Hawkins et al. 2005; Gharrett et al. 2005; Orr and Hawkins 2008) have used genetic and morphometric analyses to document the scarcity of rougheye rockfish west of the eastern AI and the occurrence of blackspotted rockfish throughout the BSAI area, thus establishing differences in species composition between areas in the BSAI. Hawkins et al. (2005) conducted allozyme analyses on collections obtained from bottom trawl and longline survey samples from a variety of locations in the north Pacific. Two "types" of rougheye were recognized by Hawkins et al. (2005), *S. aleutianus* and *S.* sp. cf. *aleutianus*, with the Aleutian Islands composed almost entirely of *S.* sp.cf. *aleutianus*. The genetic basis for distinct species was also established by Gharrett et al. (2005), who applied mitochondrial DNA and microsatellite analyses to longline and trawl survey samples. "Type II" rougheye (corresponding to *S. aleutianus* of Hawkins et al. 2005) were absent from the western AI and western BS collections, and were rare elsewhere in the BSAI area. In contrast, "type I" rougheye (corresponding to *S.* sp.cf. *aleutianus* of Hawkins et al. 2005) extended throughout the range sampled (Figure 14.1). The distributions observed in Hawkins et al 2005 and Gharrett et al. 2005 were corroborated with microsatellite and mitochondrial analyses applied to samples obtained from the north Pacific (Gharrett et al. 2007). The description of the two rougheye species is established by application of morphometric and meristic analyses by Orr and Hawkins (2008) to catalogued samples, with genetic analysis used to verify the morphometric and meristic patterns. The range of *S. aleutianus* (corresponding to *S. aleutianus* of Hawkins et al 2005 and "type II" rougheye from Gharrett et al. 2005), was found to extend westward to the eastern Aleutian Islands near Unalaska Island, whereas the range of *S. melanostictus* (corresponding to *S.* sp.*cf. aleutianus* of Hawkins et al. 2005 and "type I" rougheye from Gharrett et al. 2005) extended throughout the BSAI area (Figure 14.2). Finally, additional genetic testing on samples collected in the 2012 AI survey corroborates these findings (Dr. Anthony Gharrett, University of Alaska, pers. comm.). Of 105 total samples, identified in the field as either rougheye or blackspotted rockfish, 4 of 80 (5%) samples in the EAI and CAI were genetically identified as rougheye rockfish, and most rougheye rockfish that were sampled were obtained from the southern Bering Sea area:

	Genetic Identification			
Area	Rougheye	Blackspotted	Hybrid	Sum
SBS	11	3	1	15
EAI	3	22		25
CAI	1	64		65
Sum	15	89	1	105

This distribution pattern has also been observed in recent AI trawl surveys, where rougheye rockfish are rarely found in the central and western AI. Identification to species within the blackspotted/rougheye complex was initiated in the 2006 AI survey and the 2008 EBS slope survey. These data show the complex is composed nearly entirely of blackspotted rockfish in the AI management area (ranging between 95% and 99% by weight in the 2006 – 2012 surveys), with a higher proportion of rougheye rockfish in the southern Bering Sea (SBS) and EBS slope. Field identification of these species can be difficult in areas where both species are abundant, such as the Gulf of Alaska, but blackspotted rockfish in the AI have been observed to have more clearly identifiable characteristics than blackspotted rockfish in other areas (Jay Orr, AFSC, pers. comm.). Errors in species identification may be particularly problematic in the Gulf of Alaska (GOA), where a field test in the 2009 GOA trawl survey reported high misidentification rates. However, the distribution pattern in the AI survey biomass estimates is consistent with information obtained from the previously cited genetic and morphometric analyses, which did not rely on field identification. Data for the two species are combined in the assessment, as species-specific catch records do not exist and identification by species has occurred in the AI trawl survey only since 2006.

Information on stock structure

A stock structure evaluation report was included in the 2010 assessment, and evaluated species distributions within the blackspotted/rougheye complex, genetic data, and size at age data (Appendix A in Spencer and Rooper 2010). The patterns of spatial variation in species composition noted above for this two-species complex were considered in this evaluation because differences in species composition could imply different levels of productivity across spatial areas. Tests for genetic homogeneity indicated that genetic differences occurred between samples of blackspotted rockfish grouped into four areas within the BSAI. A significant isolation by distance (IBD) pattern was also estimated in the 2010 analysis, although this was based upon a relatively small sample size. The BSAI Plan Team concluded in 2010 that spatial structure exists within the BSAI for blackspotted and rougheye rockfish, and recommended the BSAI ABC be partitioned into an ABC for the western and central Aleutian Islands, with a separate ABC for the remainder of the BSAI area.

Additional information was presented to the BSAI Plan Team in 2010, 2012, and 2013 indicating disproportionate harvesting within the three subareas within the AI, and identifying several attributes regarding spatial patterns in abundance, mean size, proportion of survey tows with no blackpotted/rougheye catch, exploitation rates, and distribution of harvest.

The relative small number of samples available for the genetic analysis conducted in 2010 motivated the collection and analysis of additional samples since 2010. The most recent genetic analysis does not indicate a statistically significant pattern of isolation by distance at the $\alpha = 0.05$ level (P=0.11). However, stock structure remains a concern. Disproportionately high harvest rates (see Appendix 14B of this assessment) and reduced abundance occur in the western AI. The reduced abundance of western Aleutian Islands stock of blackspotted rockfish does not appear to have been replaced by fish from the central Aleutian Islands, consistent with a lack of movement in rockfish in general. Rockfish typically exhibit strong spatial genetic structure and further work is underway to examine the spatial stock structure of blackspotted rockfish across the Aleutian archipelago using next generation sequencing techniques.

Fishery

Historical Background

Catches of rougheye rockfish have been reported in a variety of species groups in the foreign and domestic Alaskan fisheries. Foreign catch records did not identify rougheye rockfish by species, but reported catches in categories such as "other species" (1977, 1978), "POP complex" (1979-1985, 1989), and "rockfish without POP" (1986-1988).

Rougheye rockfish have also been managed in multiple species groups since 1991 in the domestic fishery as part of the "other red rockfish" or "shortraker/rougheye" complexes. In 1991, the "other red rockfish" species group was used in both the EBS and AI, but beginning in 1992 rougheye rockfish in the AI were managed in the "rougheye/shortraker" species group. Prior to 2001, rougheye rockfish were managed with separate ABCs and TACs for the AI and EBS, and from 2001-2003 rougheye rockfish were managed as a single stock in the BSAI area with a single OFL and ABC, but separate TACs for the EBS and AI subareas. From 2005-2010, rougheye rockfish were managed with BSAI-wide OFLs, ABCs, and TACs, and beginning in 2011 the BSAI ABC and TAC has been divided between the western and central AI, and the eastern AI and the EBS area. The OFLs, ABCs, TACS, and catches by management complex from 1977-2003 are shown in Table 14.1, and those from 2004 to present are shown in Table 14.2.

Since 2003, the catch accounting system (CAS) has reported catch of rougheye by species and area. From 1991-2002, 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 rougheye catch for each area (i.e., the EBS and each of the three AI areas) and gear type from 1994-2002. For 1991-1993, the Regional Office blend catch data for the AI 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 PACFIN records. Catches of rougheye since 1977 by the EBS and AI subareas are shown in Table 14.3. Catches were relatively high during the late 1970s, declined during the late 1980s as the foreign fishery was reduced, increased in the early 1990s and mid-1990s, and declined in the late-1990s.

The catches by area from 1994-2022 have been relatively evenly distributed throughout the three AI subareas, with 31%, 30%, and 31% in the WAI, CAI, and EAI, respectively, and the remaining 8% in the EBS management area (Table 14.4). However, biomass estimates from the AI survey indicate that a relatively small portion of the AI stock (averaging approximately 9% from 1994-2022) occurs in WAI. Information on spatial exploitation rates is updated in Appendix 14B. The domestic fishery observer data indicates that the percentage of BSAI catch in the eastern AI averaged 71% from 1992 to 1995, with the western AI averaging 7% (Figure 14.3). The proportion of the annual harvest in the western Aleutian Islands increased to an average of 63% during 2004 – 2006, and has declined since 2007 to an average of 30%. Temporal variability has occurred in AI subareas in which blackspotted/rougheye rockfish are captured, and in the depths of capture (Figure 14.3). The proportion captured at depths greater than 300 m has also varied, ranging between 4% to 16% in the Aleutian Islands during 1999 - 2003 to between 21% to 42% from 2009 – 2014, but decreasing to between 5% to 15% from 2015-2021.

Catch by species from BSAI trips targeting rockfish from 2011 to 2021 indicate that the largest non-rockfish species caught are Atka mackerel, walleye pollock (*Gadus chalcogrammus*), Pacific cod (*G. microcephalus*), arrowtooth flounder (*Atheresthes stomas*), and Kamchatka flounder (*A. evermanni*) (Table 14.5). Blackspotted and rougheye rockfish are primarily caught in rockfish trips targeting rockfish, Atka mackerel, and Pacific cod (Table 14.6). Catch of prohibited species is low in trips targeting rockfish, with the catch of most prohibited species groups averaging less than 80 t or 6000 individuals from 2011-2021 (Table 14.7). Catch of non-FMP species by in BSAI trips targeting rockfish are largest for giant grenadier (*Albatrossia pectoralis*), miscellaneous fish, and unidentified sponge (Table 14.8).

Non-commercial catches are shown in Appendix 14C.

Discards

Estimates of discarding by species complex are shown in Table 14.9. Estimates of discarding of the other red rockfish complex in the EBS were generally above 56% from 1993 to 2000, with the exception of 1993 and 1995 when discard rates were less than 21%. The variation in discard rates may reflect different species composition of the other red rockfish catch. Discard rates of the EBS RE/SR complex from 2001 to 2003 were at or below 52%, and discard rates of the AI RE/SR complex from 1993-2003 were below 41%. In general, the discard rates of the EBS RE/SR (2001-2003) are less than the discard rates of the EBS other red rockfish (1993-2000), likely reflecting the relatively higher value of rougheye and shortraker rockfishes over other members of the complex. From 2004 to 2022, discard rates of rougheye in the AI and EBS averaged 23% and 37%, respectively. Discarding has increased recently in the Aleutian Islands, with the rates for 2017 and 2019-2022 each above 29%; in contrast, the AI discarding rate was at or below 20% each year from 2005 to 2015.

Bycatch Rates across Areas and Target Fisheries

Bycatch rates of blackspotted and rougheye rockfish across various fisheries and BSAI subareas are shown in Table 14.10. The rates were computed from hauls sampled for species composition in the Groundfish observer program, and a target fishery was assigned based on the dominant species (in weight) in the haul catch. Target hauls for POP were defined as those in which rockfish, as a group, were the dominant species group and also POP was the dominant rockfish species. Bycatch rates are defined as the catch weight of blackspotted and rougheye rockfish as a percent of the catch weight of the target species. In the western AI, blackspotted and rougheye rockfish are caught primarily in the POP fishery, and the bycatch rates here declined from 2.5% in 2004 to 0.4% in 2007, increased to 1.5% in 2010, declined to 0.34% in 2016, and have since increased to 2.0% in 2020 before declining to 1.1% in 2022 (using data through Sep 25, 202). The unusually large bycatch rate for in the WAI Atka mackerel fishery in 2013 was based on one tow. Bycatch rates in the POP fishery in the central Aleutians have also increased recently, from 0.7% in 2017 to above 2.4% from 2019 – 2021. Bycatch rates in the Pacific cod fishery in the central Aleutian Islands increased from 0.3% in 2009 to above 3.4% from 2020-2022. In the eastern Aleutian Islands, the bottom trawl pollock fishery had relatively high bycatch rates from 2013-2015 (between 1.0 and 1.3%), but the rates since 2018 have been below 1.0%. The large rate for this fishery in 2012 was based on only 6 tows. Finally, bycatch rates in the Eastern Bering Sea have been small relative to other areas, typically not exceeding 1%.

The higher catch rates in the WAI from 2019-2022 are also revealed in cumulative distribution plots of bycatch rates in tows from A80 vessels targeting POP from 2012-2022 (Figure 14.4). In 2016 and 2017, 62% and 64%, respectively, of these tows had no catch of blackspotted/rougheye rockfish, and 80% of the tows had bycatch rates of ≤ 0.4% and 0.3%, respectively. In contrast, from 2019-2022 the percentage of tows without bycatch ranged between 32% and 39%, and the bycatch rates at the 80% percentile ranged between 1.3% and 2.1%.

Spatial Management

Examination of stock structure information in 2010 resulted in the BSAI ABC being subdivided in subarea ABCs for the WAI/CAI and EAI/EBS areas beginning in 2011. Concern over the disproportionately large harvest rates in the WAI has not led to harvest specifications specifically for this region. Instead, a “maximum subarea species catch” (MSSC) level was developed for the WAI to help guide the fishing fleet in voluntary efforts reduce harvest in this area. The MSSC is computed in an identical manner as subarea ABC, and is the only stock managed by the NPFMC in which an MSSC is used in lieu of a subarea ABC. The Plan Team and SSC have requested monitoring of WAI relative to the MSSC (Joint Plan Team, September, 2016).

The WAI MSSCs and catches are shown below (2022 catch through Sep 25):

Year	MSSC	Catch	Catch/MSSC
2015	46	70	1.51
2016	58	40	0.69
2017	29	35	1.21
2018	35	67	1.91
2019	37	104	2.81
2020	48	168	3.50
2021	31	120	3.89
2022	32	98	3.08

The WAI catch has exceeded the MSSC in each year except 2016, and degree of “overage” has increased in recent years such that catches are approximately 3 times larger than the MSSC from 2019 - 2022. Additionally, at the larger spatial scale, the WAI/CAI catches have exceeded the WAI/CAI ABC each year since 2019, and have on average been 53% larger than the WAI/CAI annual ABCs (Table 14.2).

Data

The following table summarizes the data available for the blackspotted/rougheye rockfish assessment model:

Component	Years
Fishery catch	1977-2022
Fishery age composition	2004-2005, 2007-2009, 2011, 2013, 2015, 2017, 2019-2021
Fishery size composition	1979, 1990, 1992-1993, 2003, 2010, 2012, 2014, 2016, 2018
AI Survey age composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018
AI Survey length composition	2022
AI Survey biomass estimates	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2018, 2022

Fishery data

The catch data used in the assessment model are the estimates of single species catch described above and shown in Table 14.3.

Prior to 1999, the fishery data is characterized by inconsistent sampling of lengths (Table 14.11) and ages (Table 14.12), as many fish were measured in some years whereas other years had no data. In 1979, 1990, 1992, and 1993, over 1,000 fish were measured in the AI and the size compositions were used in the assessment model. In the domestic fishery, changes in observer sampling protocol went into effect in 1999, increasing the number of fish and hauls from which rougheye rockfish age and length data are collected, increasing the utility for stock assessment modeling. The fishery length composition data used in the model is shown in Table 14.13.

The fishery age composition data indicates relatively moderate cohorts from the early 1970s to early 1980s, but some of the more recent cohorts from the mid-1990s appear inconsistently in the data (Table 14.14, Figure 14.5). For example, the 1997 cohort appears relatively strong as 12 year olds in the 2009 age composition and 14 year olds in the 2011 age composition, but was not observed in previous samples. Similarly, the 1996 cohort appears strong in the 2008 fishery age composition, is not observed in the 2009 age composition, and appears weak in the 2011 age composition. The 1998 year class appears relatively strong in both the 2009 and 2011 fishery age compositions. Beginning in 2013, the fishery began to catch increased proportion of young fish (i.e., less than 20 years). The 2015 and 2017 fishery age compositions show reduced proportions of fish at ages > 20 years. This pattern has been especially pronounced from 2019 to 2021, when fish less than 15 years comprised a relatively large portion of the catch. In 2019, a mode in the age distribution occurs for ages 9 – 11.

Survey data

Biomass estimates for other red rockfish were produced from the cooperative U.S.-Japan trawl survey from 1979-1985 on the EBS slope, and from 1980-1986 in the AI. U.S trawl surveys on the EBS slope were conducted by the National Marine Fisheries Service (NMFS) in 1988, 1991, and biennially beginning in 2002. NMFS trawl surveys in the AI were conducted in 1991, 1994, 1997, and biennially beginning in 2000. The EBS slope surveys in 2006, 2014, and 2018, and the AI trawl survey in 2008 were canceled due to lack of funding or vessels. Both the AI and EBS trawl surveys were canceled in 2020 due to the COVID-19 pandemic, and the EBS slope survey is unlikely to be conducted again. Differences in vessels and gear design exist between the 1980-1986 cooperative surveys and the U.S. domestic surveys conducted since 1991. For example, the Japanese nets used in the 1980, 1983, and 1986 cooperative surveys varied between years and included large roller gear (Ronholt et al. 1994), in contrast to the poly-nor'eastern nets used in the current surveys (von Szalay et al. 2017), and similar variations in gear between surveys occurred in the cooperative EBS surveys. The cooperative surveys from the 1980s are not used in this assessment.

The AI surveys from 1991 to 2022 indicated higher abundances in the central and eastern Aleutians than in the western AI and southern Bering Sea area (Table 14.15). However, unusually low CPUE levels occurred in the WAI during the 2012 survey, which reduced the biomass estimate for this area to 335 t from an average of 1,075 t in the 2000-2010 surveys. The 2022 survey biomass of 1,793 t in the western AI was nearly 3 times the value of 632 t in the 2018 survey. The 2022 estimate for the EAI increased to 10.834 t from the estimate of 6,535 t in the 2018 survey, although the coefficient of variation was very large at 0.71. The overall biomass estimate increased from 9,843 t in the 2018 survey to 15,680 t in the 2022 survey, although CVs for the 2018 and 2022 surveys (0.46 and 0.50, respectively) were larger than in previous years. The 2016 – 2022 surveys showed similar spatial patterns of survey CPUE (Figure 14.6), with the largest percentage increases occurring in the WAI and SBS areas with relatively low biomass.

Length compositions from the survey indicate the reduction in the abundance of larger fish in several of the AI survey subareas until the 2022 survey (Figures 14.7 - 14.10), when increased abundances were observed. In the western AI, the decline in the biomass estimate in the 2012-2018 surveys can be attributed to a reduced number of fish across most size classes, with the exception of fish from 30 – 40 cm in 2014. In the 2016 and 2018 surveys the relative abundance in these size classes was reduced from previous years. The 2022 survey in the WAI showed increased abundances but relatively small fish, with 73% of the abundance ≤ 35 cm, the largest proportion in this size group within the time series. In the CAI, the abundance of fish greater than 35 cm is reduced in the 2010-2018 surveys relative to the 1991-2006 surveys, with the exception of the 2012 survey (Figure 14.8). In the 2022 survey, proportion in the CAI greater than 25 cm increased to 0.67, which is the largest value since the 2012 survey (0.90). The increase in survey biomass from 2016 to 2022 in EAI results from a larger number of fish in the 25- 40 cm range, whereas much of the length composition in the 2006-2012 surveys was between 35 and 50 cm (Figure 14.9).

The mean size in the western AI was 34 cm in the 2022 survey, similar to values observed in between 2006 and 2018 (32 cm - 37 cm) (Figure 14.11). However, these recent mean sizes in the western AI are lower than those observed in earlier years, when the mean size in the 1991-2002 surveys ranged from 39 cm to 45 cm. The mean sizes in the central and eastern AI decreased sharply in the 2014 survey to 34 cm and 33 cm, respectively. The mean size in the central AI and eastern AI increased to 37 cm and 35 cm, respectively, and there has been an overall decline in mean size in all AI survey subareas since 1991. The time series of mean age data corroborate the time series of mean size, and indicate that the mean age has declined the most in the WAI. The mean age in the WAI from the 1994 – 2002 surveys averaged 33 years, whereas the mean ages in the 2012 - 2018 surveys averaged 17 years.

The spatial pattern in the percentage of survey tows which did not catch blackspotted/rougheye rockfish was similar between 2000 – 2018 (Figure 14.12), with the WAI and EAI having the highest percentage of survey tows with no catch. In the 1991-1994 surveys, the WAI had the lowest percentage of tows without blackspotted/rougheye rockfish among the subareas, whereas from 2000 -2016 the WAI had the highest percentage (or tied for the highest percentage) of tows without blackspotted/rougheye rockfish. In the 2022 survey, the percentage of tows with no catch declined across all areas.

The survey biomass estimates of blackspotted and rougheye rockfish from the 2002-2012 EBS slope surveys have ranged between 553 t (2002) and 1,613 t (2012), with CVs between 0.16 and 0.50. EBS survey CPUE from the 2016, 2012, and 2016 surveys are shown in Figure 14.13. The 2016 slope survey estimate of 458 t is inconsistent with the increasing estimates from 2002-2012, and may be due to inadequate sampling. In the 2016 survey, equipment failure resulted in only 53 of the 75 planned stations being completed in the Bering Canyon subarea of the survey, which is the southernmost portion of the survey. Maps of survey CPUE from 2010-2016 indicate that this area typically has a large portion of the blackspotted and rougheye rockfish biomass.

A random effects smoothing model was applied to the time series of subarea biomass levels from the AI and EBS surveys (Figure 14.14). The increases in the 2022 survey biomass estimates resulted in the smoothed biomass estimate increasing in most areas, and the smooth estimate for the WAI fits very closely to the 2022 point estimate of survey biomass. These smoothed estimates are used for subarea partitioning of the ABC, and the estimation of subarea exploitation rates shown in Appendix 14B.

Biological Data

The AI survey provides data on age and length composition of the population, growth rates, and length-weight relationships. The number of lengths measured and otoliths sampled are shown in Tables 14.16 and 14.17, along with the number of hauls producing these data. The survey data produce reasonable sample sizes of lengths and otoliths throughout the survey area. The maximum age observed in the survey samples was 134 years (observed in the 2016 survey).

The AI survey age composition data in years prior to 2014 indicate a relatively even distribution across a broad range of ages (i.e., ages 20 to 40) (Table 14.18, Figure 14.15). Prior to 2006, fish less than 10 years old have been uncommon in the surveys; however, the 2006 and 2010 surveys indicate potentially strong 1998 and 1999 year classes. The 2014, 2016, and 2018 AI surveys show reduced proportions of fish > 20 years old.

The survey otoliths were read with the break and burn method, and are considered unbiased (Chilton and Beamish 1982); however, the potential for aging error exists. In previous assessments, information on aging error was obtained from multiple independent readings on GOA otoliths collected in 1990, 1999, and 2003 (Shotwell et al. 2007), with a procedure that estimates the percent agreement between readers. In this assessment, the ageing error estimation methodology described by Punt et al. (2008) was applied to BSAI data (described below in the *Parameters Estimated Outside the Assessment Model* Section).

The survey age data indicates a decline in the numerical abundance of older fish, consistent with the decline in larger fish noted above. The estimated number of blackspotted/rougheye rockfish, binned by groups comprising 5 age classes, are shown in Figure 14.16. The percentage decline of survey abundance of 5 sets of age groups older than 21 years (i.e., ages 21-25, 26-30, 31-35, 36-40, and 40+) ranged between 52% (for ages 40+) and 87% (for ages 21-25) from the 2012 survey to the 2014 survey. The survey abundance of these age groups in the 2016 and 2018 AI surveys were similar to those in the 2014 survey. Coincident with the declines of older fish in the survey are increases in younger fish, particularly for ages 11-15 and 16-20, although note that comparisons across these younger age groups is complicated due to unequal survey selectivity. For each of the ages from 3-5, very low or zero values of abundance were observed in surveys from 1991-2000, with relatively high values observed on the 2014-2018 surveys.

The AI survey otolith data were used to estimate size at age and von Bertalanffy growth parameters. Unbiased estimates of mean length at age were generated from multiplying the survey length composition by the age-length key in order to produce a matrix of estimated population numbers by age and length, from which an unbiased average length for each age could be determined. Preliminary analyses did not reveal any patterns by year and subarea within the AI survey areas, so the mean length at age from each survey year from 1991 to 2018 was used to fit the growth curve. The estimated von Bertalanffy parameters are as follows, and were used to create a conversion matrix and a weight-at-age vector:

L_{inf} (cm)	K	t_0 (years)
51.53	0.06	-3.40

A conversion matrix was created to convert modeled number at age into modeled number at length bin, and consists of the proportion of each age that is expected in each length bin. This matrix was created by fitting a polynomial model to the observed CV in length at each age (the estimated length at age was obtained for each survey from 1991-2018 by multiplying the estimated survey length distribution by the age-length key), 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 conversion matrix decrease curvilinearly from 0.22 at age 3 to 0.05 at age 45.

A length-weight relationship of the form $W = aL^b$ was fit from the survey data, and produced estimates of $a = 6.54 \times 10^{-6}$ and $b = 3.24$. This relationship was used in combination with the von Bertalanffy growth curve to obtain the estimated weight at age vector of the population (Table 14.19).

Analytic Approach

Model structure

The assessment model for rougheye rockfish is similar to that currently used for other BSAI rockfish, which was used as a template for the current model. The assessment model is a single sex model with one fishing fleet and one fishery-independent survey biomass index. Age and length composition data used, and the range of age and length bins are 3 to 45+ years, and 12- 50+ cm, respectively, with the final bins being plus groups.

The total numbers of age 3 fish from 1977 to year *T*-3 are modeled with a lognormal distribution

$$N_{t,3} = e^{(\mu_R + \nu_t)}$$

where estimated parameters are μ_r (the log-scale mean recruitment) and ν_t (time-variant deviation in log recruitment, assumed to be normally distributed on a log scale with a standard deviation of σ_r), and *T* is the terminal year of the analysis (defined as 2022). Little information exists to estimate recruitment in the most recent years due to the relatively late age of recruitment to both the fishery and survey, and recruitment for 2020-2022 are set at the expected mean recruitment (based upon the log-scale mean, and the value of σ_r).

Population size in numbers at age *a* in year *t* was modeled as

$$N_{t,a} = N_{t-1,a-1} e^{-Z_{t-1,a-1}} \qquad 3 \le a < A, \quad 1977 < t \le T$$

where *Z* is the sum of the instantaneous fishing mortality rate ($F_{t,a}$) and the natural mortality rate (*M*), and *A* is 45+ age bin. The numbers at age in the plus group consist of fish of age *A* and older, and are estimated as

$$N_{t,A} = N_{t-1,A-1} e^{-Z_{t-1,A-1}} + N_{t-1,A} e^{-Z_{t-1,A}}$$

The numbers at age in the first year are estimated as

$$N_{a,1} = R_0 e^{-M(a-3)+\gamma_a} \qquad a > 3$$

where R_0 is the mean number of age 3 recruits prior to the start year of the model, and γ_a is an age-dependent deviation assumed to be normally distributed with mean of zero and a standard deviation equal to σ_r, the recruitment standard deviation. Estimation of the vector of age-dependent deviations from average recruitment allows estimation of year class strength for the cohorts that contribute to the initial numbers at age.

The fishing mortality rate for a specific age and year ($F_{t,a}$) is modeled as the product of a fishery age-specific selectivity ($s^f_{a,t}$) that increases asymptotically with age and a year-specific fully-selected fishing mortality rate *f*. The fully selected mortality rate is modeled as the product of log-scale mean instantaneous fishing morality rate μ_f and a year-specific deviation ε_t (estimated as parameters); thus $F_{t,a}$ is

$$F_{t,a} = s^f_{a,t} f_t = s^f_{a,t} e^{(\mu_f + \varepsilon_t)}$$

Fishery selectivity was estimated with a logistic curve

$$S_{f,a} = \frac{1}{1 + e^{-\phi_a (a - a_{50\%})}}$$

where ϕ_a and $a_{50\%}$ are the slope parameter and the age at 50% selectivity, respectively.

The mean number at age for each year was computed as

$$\overline{N}_{t,a} = N_{t,a} * (1 - e^{-Z_{t,a}}) / Z_{t,a}$$

The catch at age ($C_{t,a}$) were calculated by the multiplying the mean numbers at age by instantaneous fishing mortality rate:

$$C_{t,a} = \overline{N}_{t,a} F_{t,a}$$

and the catch biomass at age was computed as the product of catch at age and weight at age (W_a).

The predicted fishery length composition data were calculated by multiplying the mean numbers at age by an age-length conversion matrix, which gives the expected proportion of each age (rows) in each length group (columns):

$$\hat{p}_{f,t,l} = Q_{a \to l} \frac{C_{t,a}}{\sum_a C_{t,a}}$$

where Q is the age to length conversion matrix. A similar equation is used to compute the predicted survey length composition:

$$\hat{p}_{s,t,l} = Q_{a \to l} \frac{\overline{N}_{t,a} s^{twl}_a}{\sum_a \overline{N}_{t,a} s^{twl}_a}$$

where s^{twl}_a is the survey selectivity. The mean number of fish at age available to the survey is multiplied by the aging error matrix to produce the observed survey age compositions:

$$\hat{p}_{s,t,a} = E_{a \to a'} \frac{\bar{N}_{t,a} s_a^{twl}}{\sum_a \bar{N}_{t,a} s_a^{twl}}$$

where *E* is the ageing error matrix. The observed fishery age compositions are produced in a similar manner:

$$\hat{p}_{f,t,a} = E_{a \to a'} \frac{C_{t,a}}{\sum_a C_{t,a}}$$

The predicted survey biomass for the AI trawl survey biomass $\hat{B}_{AI,t}^{twl}$ was computed as

$$\hat{B}_{AI,t}^{twl} = q_{AI}^{twl} \sum_a \left(\bar{N}_{t,a} s_a^{twl} W_a \right)$$

where q^{twl} is the AI trawl survey catchability. Selectivity for the AI trawl survey was modeled with a logistic function.

To facilitate parameter estimation, a lognormal prior distribution were used for the natural mortality rate *M*. The mean of the prior distribution was updated based on research by Then et al. (2015). Three natural mortality models developed by Then et al (2015) based on maximum age (t_{max}) were considered, which Then et al. (2015) recommend as the preferred methodology. The observed maximum age t_{max} for BSAI blackspotted/rougheye rockfish is 134 years, and estimates of natural mortality for each model were obtained from values of t_{max} ± 25 years are shown below and ranged from 0.033 to 0.067 and averaged 0.045, which was used as the mean of the prior distribution. This value also corresponds to the center of a range considered (0.035 – 0.055) for British Columbia rougheye/blackspotted (DFO, 2020).

A lognormal prior distribution was also used for q_{AI} with a mean of 1.0 and a CV of 0.05. The standard deviation of log recruits, σ_r, was fixed at 0.75.

The proportion mature at age was estimated within the assessment model based on 237 aged blackspotted rockfish collected in the Gulf of Alaska from 2009-2012 by Christina Conrath (NOAA-Fisheries, AFSC, pers. comm.). Parameters of the logistic equation were estimated by maximizing the bionomial 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 each age by the 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.

Individual years of age and length composition data are iteratively reweighted, with the multinomial sample size $N_{j,y}$ for data type *j* and year *y* is computed as

$$N_{j,y} = w_j \tilde{N}_{j,y},$$

where $\tilde{N}_{j,y}$ is the original "first stage" sample size (set to number of hauls with fish measured or aged), and w_j is a weight for data type *j*. The weights are a function of the fit to the age and length composition data, and iterated in successive model runs until they converge. Note that this method preserves the relative weighting between years within a given data type.

The weights are the variance of standardized residuals between the means of observed and predicted ages (or lengths) (i.e., one residual is computed for each year within a data type). This is method TA1.8 in Francis (2011) and often referred to as the "Francis method".

Description of Alternative Models

In this assessment, we consider the accepted model from 2020 and an alternative model (model 22). The alternative model was motivated by the observation that the fishing fleet has been actively moving to shallower grounds in recent years in an effort to avoid bycatch of blackspotted and rougheye rockfish. Model 22 models fishing selectivity with a bicubic spline to allow time-varying selectivity, with 5 age nodes and 5 year nodes (identical to the BSAI POP assessment model). Relative to the POP model, the constraints on the variation and smoothness in selectivity across years (i.e., the first and second differences, respectively) were relaxed (i.e., the weights for these terms were reduced from 800 to 100) in order to explore more flexibility in fitting time-varying selectivity patterns.

The models are summarized in the table below:

Model	Differences from accepted 2020 model
Model 20 (2022)	Updated catch and age/length composition data, and include 2022 survey biomass estimate. Iteratively reweight the composition data with the Francis method.
Model 22	Updated catch and age/length composition data, and include 2022 survey biomass estimate. Model fishery selectivity with a cubic spline, using 5 age nodes and 5 year nodes and setting the parameters controlling variability for temporal variability and smoothness to 100. Iteratively reweight the composition data with the Francis method.

Because each of the models considered iteratively re-estimate the Francis weights for the age and length composition data, standard model selection criteria such as AIC do not apply. The root mean squared error (RMSE) was used to evaluate the relative size of residuals within data types across the different models:

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

where y and $\hat{y}$ are the observed and estimated values, respectively, of a series length n.

Parameters Estimated Outside the Assessment Model

The parameters estimated independently from the assessment model include the ageing error matrix, the age-length conversion matrix, and individual weight at age. The derivation of the age-length conversion matrix and the weight at age vector are described above.

The Punt et al. (2008) methodology for ageing error estimation was applied, which requires a set of fish with age readings from multiple readers for each fish, and 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). The Punt et al. (2008) methodology was applied to 2341 double readings of blackspotted/rougheye rockfish from the BSAI sampled during 1986 – 2017. The CVs in read ages than was estimated for the 2018 model, with the CV from the Punt et al. (2008) methodology estimated at 0.121.

Parameters Estimated Inside the Assessment Model

Parameter estimation is facilitated by comparing the model output to several observed quantities, such as the age and length composition of the survey and fishery catch, the survey biomass, and the catch biomass. The general approach is to assume that deviations between model estimates and observed quantities are attributable to observation error and can be described with statistical distributions. Each data component provides a contribution to a total log-likelihood function, and parameter values that minimize the negative log-likelihood (*NLL*) are selected.

A recruitment deviation penalty was modeled as

$$NLL_r = \lambda_1 \left[\sum_{t=1}^{n} \frac{\left(\nu_t + \sigma_r^2/2\right)^2}{2\sigma_r^2} + n \ln(\sigma_r) \right],$$

where n is the number of years where recruitment is estimated. The adjustment of adding $\sigma_r^2/2$ to the deviation was made in order to produce deviations from the mean, rather than the median, recruitment. If σ_r is fixed, the term $n \ln(\sigma_r)$ adds a constant value to the negative log-likelihood. A penalty for the recruitment of cohorts represented in the first year (excluding age 3, which is included in the recruitment negative log-likelihood) of the model is treated in a similar manner:

$$NLL_{init\_naa} = \lambda_1 \left[\sum_{a=4}^{A} \frac{\left(\gamma_a + \sigma_r^2/2\right)^2}{2\sigma_r^2} + (A-3) \ln(\sigma_r) \right].$$

The negative log-likelihoods of the fishery and survey age and length compositions were modeled with a multinomial distribution. The log of the multinomial function (excluding constant terms) for the fishery length composition data, with the addition of a term that scales the likelihood, is

$$NLL_{composition} = -n_{f,t,l} \sum_{t,l} \left(p_{f,t,l} \ln \hat{p}_{f,t,l} + p_{f,t,l} \ln p_{f,t,l}\right) ,$$

where n is the number of hauls that produced the data, and $p_{f,t,l.}$ and $\hat{p}_{f,t,l}$ are the observed and estimated proportion at length in the fishery by year and length. The negative log-likelihood for the age and length proportions in the survey, $p_{s,t,a}$ and $p_{s,t,l}$, respectively, follow similar equations.

The negative log-likelihood of the survey biomass was modeled with a lognormal distribution:

$$NLL_{AI\ survey} = \lambda_2 \sum_t \left(\ln B_{AI,t}^{twl} - \ln \hat{B}_{AI,t}^{twl}\right)^2 / 2cv_t^2 ,$$

where $B_{AI,t}^{twl}$ is the observed survey biomass at time t, cv_t is the coefficient of variation of the survey biomass in year t, and λ_2 is a weighting factor. The negative log-likelihood of the catch biomass was modeled with a lognormal distribution:

$$NLL_{catch} = \lambda_3 \sum_t \left(\ln C_t - \ln \hat{C}_t\right)^2$$

where C_t and $\hat{C}_t$ are the observed and predicted catch. The "observed" catch for 2022 is obtained by estimating the Oct-Dec catch (based on the remaining TAC available after October, and the average proportion in recent years of the remaining TAC caught from Oct-Dec) and adding this to the observed catch through October. Because the catch biomass is generally thought to be observed with higher precision than other variables, λ_3 is given a very high weight so as to fit the catch biomass nearly exactly.

The overall negative log-likelihood function (excluding the maturity component) is

$$\lambda_1 \sum_{t=1}^{n} \frac{\left(\nu_t + \frac{\sigma_r^2}{2}\right)^2}{2\sigma_r^2} + n \ln(\sigma_r) +$$

$$\lambda_1 \sum_{a=4}^{A} \frac{\left(\gamma_a + \frac{\sigma_r^2}{2}\right)^2}{2\sigma_r^2} + (A-3) \ln(\sigma_r) +$$

$$\lambda_2 \sum_{t} \left(\ln B_{AI,t}^{twl} - \ln \hat{B}_{AI,t}^{twl}\right)^2 / 2cv_t^2 +$$

$$-n_{f,t,l} \sum_{t,l} \left(p_{f,t,l} \ln \hat{p}_{f,t,l} + p_{f,t,l} \ln p_{f,t,l}\right) +$$

$$-n_{f,t,a} \sum_{t,l} \left(p_{f,t,a} \ln \hat{p}_{f,t,a} + p_{f,t,a} \ln p_{f,t,a}\right) +$$

$$-n_{s,t,a} \sum_{t,l} \left(p_{s,t,a} \ln \hat{p}_{s,t,a} + p_{s,t,a} \ln p_{s,t,a}\right) +$$

$$\lambda_3 \sum_{t} \left(\ln C_t - \ln \hat{C}_t\right)^2$$

For the model runs in this year's assessment, λ_1, λ_2, and λ_3 were assigned weights of 1,1, and 50, reflecting the strong emphasis on fitting the catch data.

The negative log-likelihood function was minimized by varying the following parameters (for the models for the AI area, with fishery selectivity modeled with a time-invariant logistic curve):

Parameter type	***Number***
1) fishing mortality mean	1
2) fishing mortality deviations	46
3) recruitment mean	1
4) recruitment deviations	43
5) historic recruitment	1
6) first year recruitment deviations	42
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	142

Results

Model Evaluation

The conflict between composition data and the AI survey biomass is indicated by the RMSE values for these components across the data weighting procedures. Estimated RMSE values and negative log-likelihoods are shown in Table 14.20, and estimated key parameters and management quantities are shown in Table 14.21. Model 22 had a lower RMSE value for the fishery length composition (as expected with more flexibility in fishery selectivity) and the 2022 AI survey age composition, but higher RMSE values for age compositions for the fishery and AI survey, and the survey biomass. The iterative reweighting procedure resulted in much larger stage 2 weights for fishery length composition data in Model 22 (Figure 14.17), and the differences in likelihoods between the two models reflect this difference in the weighting of the sample sizes for this composition data rather than improvement in the model fits.

Both models estimated the 2010 year class to be very large at 21.3 million in model 20 and 23.4 million in model 22. These estimates are approximately an order of magnitude larger that the next largest estimate of recruitment. The flexibility of model 22 to allow to time-varying fishery selectivity has not resulted in attribution of the recent observations of the 2010 year class to changes in fishery selectivity rather than recruitment strength. In both models, the uncertainty of the 2010 year class estimate is very large (0.58 for model 20 and 0.63 for model 22), resulting from the limited number of times this year class has been observed and its low selectivity in previous years of sampling.

The time-varying fishery selectivity curve in Model 22 is largely asymptotic without strong dome-shaped patterns. The estimated selection varies over time, with higher selection at younger ages in recent years (Figure 14.18). The average selection at short time intervals is shown in the lower panel of Figure 14.18, and the selectivity since 2012 is similar to that estimated with the time-invariant selectivity in Model 20 (2022). The recent years of fishery composition data has higher stage 1 data weights (i.e., larger number of hauls with observations), so these years are weighted more strongly in fitting the selectivity curve.

Examination of estimated composition data indicates that both models did not estimate the recent age composition data that contains information on relatively strong recent recruitment strength. Beginning with the 2006 AI survey, Model 22 has larger residuals than Model 20 (2022) for fish below approximately 25 years in the AI survey age compositions, and the relatively strong proportions of young fish observed since the 2014 survey are poorly fit by each model (Figure 14.19). A relatively similar pattern of each model not fitting well to proportions of young fish are seen in the fishery age composition data (Figure 14.20). The lower RMSE of Model 22 for the fishery length composition data appears to result from fits to data in the early 1990s, with fits to recent fishery length compositions being more similar between the models.

Both models fit the trend in the AI survey biomass poorly, particularly the estimated biomasses in 2000, 2004, and 2012 (Figure 14.21). However, Model 22 provides a worse fit for most years, with an estimated steeper decline in biomass prior to 2003 and an estimated steeper increase in survey biomass since 2003.

The retrospective patterns between the two models were similar, with Mohn's rho for SSB of 0.28 and 0.35 for Model 20 (2022) and Model 22, respectively (Figure 14.22). For each model, the 2022 survey biomass estimate did not have an especially strong influence on the model, as estimated increases in biomass occurred without this data point (which additionally had a large coefficient of variation). Each model also indicates large uncertainty in the 2002 year class, with respective estimates increasing to 7.6 million and 16.3 million in peels of Model 20 (2022) and Model 22, respectively, before being lowered to much smaller estimates based on current data (Figure 14.23).

The issues present in the 2018 and 2020 assessments (i.e., estimated large year classes based on limited data, a rapidly increasing population based on strong year classes of young fish not completely observed in the composition data, and a poor residual pattern in the fit to the survey biomass estimates) are still present in Model 22. Modeling time-varying fishery selectivity has not had a substantial influence he overall results, in part because the observation of recent strong year classes are also observed in survey data and thus cannot attributed solely to recent changes in fishery selectivity. The use of the Francis data-weighting procedure beginning in the 2020 assessment was motivated, in part, by placing more emphasis on the AI survey biomass estimates relative to the composition data, but Model 22 fits the survey biomass estimates worse than Model 20 (2022) and also has a worse retrospective pattern. We recommend Mode1 20 (2022) for these reasons, and the results reported in this assessment were obtained from this model for the AI subarea, and a Tier 5 approach for the EBS subarea. Estimated values of model parameters and their standard deviations are shown in Table 14.22.

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 all blackspotted/rougheye rockfish age 3 and older. Recruitment is defined as the number of age 3 blackspotted/rougheye rockfish.

Biomass Trends

The estimated AI survey biomass decreased during the 1990s and early 2000s to 7,442 t in 2007 has increased to 12,839 t in 2022 (Figure 14.24). The total and spawning biomass also show a decline in the late 1970s, increases throughout the 1980s, and a decline during most of the 1990s. Since 2005, the spawning biomass has increased from 2,715 t to 3,335 t in 2022, and the total biomass has increased from 10,692 t to 23,221 t over this period (Figure 14.25). The more rapid recent increase of total biomass relative to spawning stock biomass reveals that much of this increase can be attributed to relatively recent year classes that have not fully matured. The time series of estimated total biomass, spawner biomass, and recruitment, and their estimated CVs (from the Hessian approximation) are shown in Table 14.23, and the estimated numbers at age are shown in Table 14.24.

Age/size compositions

The model fits to the fishery age and size compositions are shown in Figure 14.20 and Figure 14.26 and the model fit to the AI survey age composition data are shown in Figure 14.19. The 2009 fishery age composition shows strong year class strengths for the 1998 and 1999 year classes. In the 2015 and 2017 composition data these year classes appear less distinct compared to neighboring year classes, as the 2000

– 2003 year classes also appear relatively strong (Figure 14.20). The recent young year classes observed in the 2019 to 2021 fishery age compositions are not well fit by the model.

The 2010 and 2012 fishery length composition data indicate that higher proportions of relatively small rougheye (i.e., 33-36 cm in 2010, 35-40 cm in 2012) are caught by the fishery. These lengths correspond approximately to 13-16 year old fish in 2010, 15-22 year old fish in 2012, and the 1990-1997 year classes. Because these year classes are not consistently observed in other age and length compositions, the model does not produce a strong fit to these fishery length composition data. The 2014, 2016, and 2018 fishery length composition data showed a broader range of sizes (although generally smaller fish than observed in the 1990s) and had better model fits.

The 2010, 2014, and 2018 AI survey age composition data also indicates relatively strong 1998 and 1999 year classes, but either or both of these year classes appeared less strong in the 2012 and 2016 AI survey age composition data (Figure 14.19). The 2014 - 2018 survey age composition also showed relatively high proportions for ages < 17, although this is influenced by the absence of older fish. In general, the model does not track cohort strengths between years with a high degree of precision, in part because them data show some inconsistencies and the Francis weights deemphasizes the composition data. The fit the 2022 AI survey length composition is shown in Figure 14.27; the models underestimates the amount of fish between about 25 cm and 40 cm, and overestimates the amount of fish > 40 cm.

The CVs of 5% for the priors on survey catchability and natural mortality constrained these parameters to values of 1.04 and 0.050, respectively, slight increases from the prior distribution means of 1.0 and 0.045, respectively.

The estimated age at 50% selection for the AI trawl survey was 16.2, very similar to the value of 16.9 in the 2020 assessment (Figure 14.28). The fishery selectivity reached 50% at age 13.5, also nearly identical to the value of 13.4 in the 2020 assessment.

Maturity

The estimated proportion mature based on Gulf of Alaska sampling by Dr. Christina Conrath (Figure 14.29, Table 14.19) has an estimated age at 50% of 24.5. The samples from Dr. Conrath show several ages of older fish (≥ 30) with unusually low observed proportion mature is < 50%. For most of these ages the sample sizes are small, and these outliers were not used to fit the maturity ogive.

Fishing Mortality and Stock Status

The estimates of instantaneous fishing mortality rate are shown in Figure 14.30. Very high rates of fishing mortality are required in 1978 and 1979 to account for the high catches during these years, followed by rapid decreases in the early 1980s. Fishing mortality rates began to increase during the late 1980s, and were high for several years between the late 1980s and mid-1990s. With the exception of 2001, fishing mortality rates began to decline from late 1990s to the mid-2000s. Recently, fishing mortality rates have increased from 0.011 in 2016 to 0.037 in 2020, and declined to 0.021 in 2022.

The stock status, relative to $B_{40\%}$, depends on a set of year classes used to compute average recruitment. The recommendation from the Plan Team work group on recruitment is to identify a critical age as the sum of $0.05/M$ (rounded to the nearest integer) and the age at which fish are 10% selected in the AI survey, and estimated mean recruitment would be based on cohorts which exceeded this age in the final model year. For AI blackspotted/rougheye rockfish, this procedure results in a critical age of 11, and would use recruitments from year classes 1977 – 2011.

As mentioned in the Executive Summary of this assessment, the large 2010 year class of 21.25 million was replaced by a value equal to the 2002 year class (the next largest) for the purpose of computing reference points and determining stock status. The $B_{40\%}$ resulting from the mean recruitment (with the adjustment for the 2010 year class) is 3,493 t, and the ratio of spawning stock biomass in 2022 to $B_{40\%}$ is 0.95 (Table 14.21). A plot of fishing mortality rates and spawning stock biomass in reference to the ABC and OFL harvest control rules (Figure 14.31) shows stock status relative to $B_{35\%}$.

Recruitment

Recruitment strengths by year class, with credibility bounds from the MCMC integration, are shown in Figure 14.32. Other than the unusually large 2010 year class, the use of Francis weights generally results in reduced interannual variability in estimated recruitment, although the 1998 and 2002 year classes are estimated as relatively strong.

The plot of recruitment against spawning stock biomass is shown in Figure 14.33.

Harvest Recommendations

Amendment 56 reference points for AI blackspotted/rougheye rockfish

The reference fishing mortality rate for blackspotted/rougheye 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 $F_{0.40}$, $F_{0.35}$, and $SPR_{0.40}$ were obtained from a spawner-per-recruit analysis. Based on the information presented above, estimated recruitment from the 1977-2011 year classes were used to estimate equilibrium recruitment for future. The average recruitment from these year classes estimated in this assessment is assumed to represent a reliable estimate of equilibrium recruitment. An estimate of $B_{0.40}$ is calculated as the product of $SPR_{0.40}$ * equilibrium recruits, and this quantity is 3,493 t. The year 2023 spawning stock biomass is estimated as 3,471 t.

Amendment 56 reference points for EBS blackspotted/rougheye rockfish

The age-structured model pertains to the AI management area, and management reference points for the EBS management area were obtained from applying Tier 5 methods to the survey data in the EBS management area. Tier 5 reference points specify $F_{abc} = 0.75*M$ and $F_{ofl} = M$, and current estimates of M for blackspotted/rougheye rockfish obtained from the AI age structured model (0.050) were used, resulting in F_{abc} and F_{ofl} levels of 0.037 and 0.050 respectively. The ABC and OFL levels for the EBS blackspotted/rougheye rockfish were obtained by multiplying the F_{abc} and F_{ofl} values by estimated biomass. The random effects model was used to smooth the survey biomass time series and obtain estimates of current biomass.

Application of the random effects model results in a biomass estimate of 1,544 t for the EBS subarea, and was obtained by summing the estimates of biomass obtained from the EBS slope and the southern Bering Sea (SBS) area sampled by the AI trawl survey. Application of the F_{abc} and F_{ofl} values above to this biomass estimate yields the EBS OFL and ABC values to 77 t and 58 t, respectively. Summing the EBS ABC and OFL values with those obtained from the age-structured model for the AI portion of the population results in an overall BSAI maximum ABC and OFL of 591 t and 703 t, respectively.

Specification of OFL and maximum permissible ABC for AI blackspotted/rougheye rockfish

Since reliable estimates of the 2023 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B<B_{0.40}$ (3,471 t < 3,493 t), blackspotted/rougheye rockfish reference fishing mortality is defined in Tier 3b. For this tier, the maximum permissible F_{ABC} and F_{OFL} are reduced from $F_{0.40}$ and $F_{0.35}$, respectively. The 2023 values of

F_{abc} and F_{OFL} are 0.034 and 0.040, respectively. The 2023 maximum ABC and OFL for the AI blackspotted/rougheye resulting from these rates are 533 t and 626 t, respectively. A summary of these values is below.

2023 SSB estimate (B)	=	3,471 t
$B_{0.40}$	=	3,493 t
$F_{0.40}$	=	0.034
F_{ABC}	=	0.034
$F_{0.35}$	=	0.040
F_{OFL}	=	0.040

Projections

Age-structured population projections are not possible for the EBS portion of the blackspotted/rougheye rockfish, and were conducted only for the AI blackspotted/rougheye rockfish. 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 2022 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2023 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2022. 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 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 will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2023, are as follow ("*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}, where this fraction is equal to the ratio of the F_{ABC} value for 2023 recommended in the assessment to the *max* F_{ABC} for 2023. (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.)

Scenario 3: In all future years, F is set equal to the 2017-2021 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 4: 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 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 follow (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; 1) above its MSY level in 2022 or; 2) above ½ of its MSY level in 2022 and above its MSY level in 2032 under this scenario, then the stock is not overfished.)

Scenario 7: In 2023 and 2024, *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 2034 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, and projections of the mean harvest and spawning stock biomass for the remaining six scenarios are shown in Table 14.25.

Risk Table and ABC recommendation

Overview

The following template is used to complete the risk table:

	Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
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: Substantially increased concerns	Substantially increased assessment uncertainty/ unresolved issues.	Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or	Some indicators showing adverse signals relevant to the stock but the pattern is not consistent across all indicators.	Some indicators showing adverse signals but the pattern is not

		recruitment pattern is atypical.		consistent across all indicators
Level 3: 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 4: 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

The AI assessment model shows a relatively poor fit to the AI survey biomass estimates, with the large estimates in years 2000, 2002, and 2012, and the low estimate in 2014, not well fit by the model. A strong retrospective bias exists, with a Mohn's rho for the recommended model of 0.28, and the positive retrospective bias indicates the potential for overharvesting. The Mohn's rho exceeds the rule of thumb guideline of 0.20 for long-lived stocks proposed by Hurtado-Ferro at al. (2015), who also propose that model misspecification may be an underlying cause of retrospective patterns.

For this assessment, the model is not able explain the decline in abundance of older fish, as the proportions ages ≥ 20 are overestimated by model for recent years of both the fishery and survey age compositions. Some key parameters and population process are tightly constrained in the model (i.e., natural mortality and survey catchability), which limit the capacity of the model to explain the recent decline in older fish. The use of strong prior for key parameters such as natural mortality and survey catchability understates the level of uncertainty in the assessment. The population process that has the most flexibility in the model to explain the decline in older fish is recruitment, even if the actual mechanisms are something other than recruitment. This potential aliasing also contributes to the assessment uncertainty. The unusually large uncertainty in the 2010 year class is further evidence of problematic assessment performance.

Given these considerations, we rank the assessment considerations for the recommended Model 20 (2022) as a 3 *(Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias*).

Population dynamics considerations

In addition to the decline of older fish mentioned above, the number of younger fish observed in the AI survey has increased. These two factors combine to result in a population comprised primarily of young fish, with the 65% of estimated 2022 abundance from the recommended model 20 (2022) comprised of ages with less than 20% survey selectivity. The estimated age at 50% maturity is 24 years, indicating that a young population of blackspotted rockfish would have limited reproductive capacity. The recruitment estimates from recommended model 20 (2022) indicates an usual pattern of large recruitment in recent years, with the estimate of 21.2 million for the 2010 year class exceeding the next highest recruitment value (the 2002 year class) by a factor of 6.2.

Rockfish generally show relatively strong spatial structure with limited dispersal distances. BSAI blackspotted/rougheye rockfish were one of the first stocks to be analyzed for stock structure, and are the only Alaska stock which has a ranking of "strong concern" regarding stock structure. This designation was applied due, in part, to high catch levels in the 1990s in the WAI followed by sharp declines in WAI beginning in 2000, and disproportionately large catches in the WAI (the area with the lowest survey biomass). Current harvest specifications apply an ABC to the combined WAI/CAI spatial area, which has not been effective in limiting catch in the WAI and reducing disproportionate harvesting. The catches in the WAI have exceeded reference MSSC catch levels in every year except one, and overages have increased over time such the current WAI catch is ~ 3 times the MSSC values. The existing spatial management measures are also generally inconsistent with the smaller spatial structure of Pacific rockfish. The catch is occurring as bycatch from other target fisheries, and the large catches in the WAI in recent years appear to be comprised of relatively young fish. The continued pattern of disproportionate harvesting could increase the levels of depletion and loss of fishery yield from current levels. If recent recruitment has actually increased, the large harvest of young fish in the WAI may limit their potential to rebuild the stock in this area. Overall, we rank the assessment considerations as a 2 (*Substantially increased concern; stock trends unusual*)

Environmental/ecosystem considerations

Environment: The average bottom temperature from the Aleutian Islands bottom trawl survey (AIBTS, (165°W – 172°E, 30-500 m) was ~4.4◦C, similar to 2018 and cooler than the highest observed in 2016 but still above the long term mean, as have the last four surveys (2014 onwards). Mid-depth (100-300m) and water column temperature (surface to bottom) from the longline survey (164°W to 180°W) and bottom trawl survey, respectively show a similar pattern, with warmer temperatures throughout the water column starting 2014. Surface temperature both from the AIBTS, as well as satellite, show an increasing trend in temperatures, during both summer and winter with 2022 being one of the warmest years in summer throughout the Aleutians and in wintertime for the western and central Aleutians. . Peak sea surface temperature varies between 11-12°C based on satellite data. Most of 2022 through August has been under some level of heatwave in the central and western Aleutians at times reaching a severe intensity. The extent, duration and intensity of the marine heatwaves was lower in the eastern Aleutians (Bond et al, 2022).

Rougheye and blackspotted rockfish are typically found in the Aleutians at temperatures between 2.9–5.1°C, in the eastern Bering Sea, while only between 3.9–4.2 in the Aleutian Islands. Their corresponding depth range is from 120–150m in the EBS and 200–450 m in the Aleutian Islands. However, rougheye rockfish depth distribution has become shallower over time in the AI bottom trawl survey (Laman, 2022a); no analogous data are available for darkspotted rockfish. The warming trend in bottom water temperature observed in the bottom trawl survey data, as well as the mid-depth warmer temperatures from the longline survey, indicate that both rougheye and blackspotted rockfish are still potentially at risk of thermal stress. In general, higher ambient temperatures incur bioenergetic costs for ectothermic fish such that, all else being equal, consumption must increase to maintain fish condition. Likewise, although being viviparous provide some level of protection to adverse environmental conditions, the planktonic larvae which are released are vulnerable to high sea surface temperatures aka – marine heatwaves which can be more intense during the summer in the Aleutian Islands. Thus, the persistent higher temperatures may be considered a negative indicator for rougheye and blackspotted rockfish. Increased bioenergetic demands may be mitigated by their generalist diet.

Prey: Based on stomachs of rougheye rockfish sampled during the AI bottom trawl survey, rougheye rockfish feed on a variety of fish including myctophids and other deepfish and roundfish, shrimps and squids; no consistent prey item dominates their diet. As rougheye rockfish do not rely on copepods or euphausiids in general, they do not compete with Pacfic Ocean perch for prey. However, euphausiids have been observed in stomachs collected from the South Bering Sea section of the bottom trawl survey.

Competitors and predators: Rougheye rockfish share prey items with shortraker rockfish and shortspine thornyheads which also consume general fish, myctophids and shrimp (shortraker rockfish) as well as squid and shrimps (shortspine thornyheads). There are no recorded fish predators of rougheye rockfish in the Aleutian Islands. Biomass estimates based on the bottom trawl survey data show large sculpins increased compared to 2022, and shrimp increased towards the eastern Aleutians. The indicator most relevant to reflecting habitat disturbance is the estimated area disturbed by trawls from the fishing effects model (Olson, 2021). Trends in potential habitat disturbance are relevant for adult rougheye as they can be found on soft substrates, where shrimp is abundant, and in areas with frequent boulders and steep slopes, which are generally not targeted by bottom trawlers. The fishing effects model has not indicated large changes in habitat disturbance trends, and has remained below 3% for the Aleutian Islands (EAI, CAI and WAI) since 2009, so we assume that the level of habitat disturbance for rougheye has been stable. Some habitat forming species might be more impacted as the relative CPUE of sponges and hydrocorals form the bottom trawl survey show slight decreases (Laman, 2022b), coinciding with a decrease in bycatch of structural epifauna in the fishery (Whitehouse, 2022). Rooper et al (2019) concluded the removal of deep coral and sponges is likely to reduce the overall density of rockfishes.

Taken together, we rank the environmental/ecosystem considerations as a 1 (*Normal; No apparent environmental/ecosystem concerns*) aside from the recent stretch of increased temperatures.

Fishery performance
Catches of blackspotted/rougheye are currently obtained as bycatch in other fisheries. Bycatch rates have increased in recent years, indicating that these target fisheries may be finding it more difficult to avoid catch (Table 14.10).

Additionally, the spatial pattern of catch per unit effort (CPUE) differs from the spatial pattern in the survey biomass estimates (Figure 14.34). CPUE was computed from hauls sampled for species composition in the Groundfish observer program, and a target fishery was assigned based on the dominant species (in weight) in the haul catch. Target hauls for POP were defined as those in which rockfish, as a group, were the dominant species group and also POP was the dominant rockfish species. CPUE was defined as the average tons of blackspotted rockfish caught per hour fished in tows targeting POP, and shown in Figure 14.34 for the WAI, CAI, and EAI areas. If CPUE is interpreted as a rough index of biomass, particularly in cases where the fish are not targeted and caught relatively randomly, then the rank order of CPUE among spatial areas should roughly correspond to the rank of biomass. From 2004 to 2011, CPUE was similar among the three areas despite lower survey biomass in the WAI. Similarly, since 2014 the CPUE has been higher in the WAI than the EAI, whereas the survey biomass shows higher biomass in the EAI. Since 2017, the CPUE in both the CAI and WAI has increased.

For a target fishery, evaluation of fishery performance would focus on the efficiency with which the harvest quota is obtained, and whether any potential inefficiencies are cause for concern. However, for a bycatch fishery the goal is avoidance of the bycatch stock; thus, concerns over fishery performance can be evaluated with respect to how easily the target fishery can avoid bycatch stocks (and any temporal/spatial pattern in this ability to avoid bycatch). An example of a concern listed above for this category is fishery CPUE showing a contrasting pattern from the stock biomass, and this is exhibited spatially for this stock. Additionally, the consistent pattern of the WAI catches exceeding the MSSC is a cause for concern, and these “overages” have increased over time such that recent catches are about 2 – 3 times the MSSC. These overages also apply to the WAI/CAI subarea ABC, which has was exceeded each year since 2019.

For these reasons, we rank the fishery performance as a 2 (*Substantially increased concerns*).

Summary and ABC recommendation

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance considerations*
Level 3: Major concern	Level 2: Substantially increased concerns	Level 1: no increased concerns	Level 2: substantially increased concerns

The level 3 and level 2 rankings above are consistent with previous years, and would be expected to produce a reduction in the recommended ABC. In this assessment, an unusually large and uncertain estimate of the 2010 year class resulted in a large change in the estimate of $B_{40\%}$ and stock status, and would lead to reduction in the maximum ABC despite the lack of evidence that the stock abundance has declined. Conversely, setting the 2010 year class to a more likely value for the purpose of computing mean recruitment has the positive effect of stabilizing $B_{40\%}$, but would result in the substantially increased maximum ABC. Because 2010 year class contributes a large portion of the estimated stock, the large uncertainly associated with this year class increases the uncertainty in current stock size, and increased harvest would the risk of exceeding the OFL. We accept use of the estimated 2010 year class as the “best estimate” for forward projections and computing maximum permissible ABC, but recommend an ABC consistent with the survey trend and the uncertainty in the current estimates of the 2010 year class. Given the unusually large and uncertain estimate of the 2010 year class, the relatively limited number of times this year class has been observed in our data, and the history of retrospective downweighting of strong year classes (i.e., the 2002 year class), it seems prudent to stabilize the ABCs until more information on the magnitude of the 2010 year-class can be confirmed. Our recommended ABC for the AI portion of the stock is 467 t, which was obtained from the 2021 projection for 2023. This is a slight increase from the value of 453 t for the AI portion of the stock for 2022, and a 12% decline from the maximum ABC.

Area Allocation of ABC

The BSAI blackspotted/rougheye ABC is currently allocated with a subarea ABC for the western AI-central AI area, and a separate subarea ABC for the eastern AI-eastern Bering Sea area. In recent years the subarea ABC for the western and central Aleutians Islands has partitioned into “maximum subarea species catch” in order to guide voluntary efforts from the fishing fleet to reduce harvest in the WAI.

A random effects model is used to smooth subarea survey biomass estimates to obtain the proportions of biomass across the spatial areas, which is used to allocate the ABC across areas.

			Area		
	WAI	CAI	EAI	SBS	EBS slope
Smoothed biomass	1,671	2,887	8,282	534	1,010
percentage (within AI subarea)	13.0%	22.5%	64.5%		

The apportioned ABCs and MSSCs for 2023 and 2024 are:

			Area		
	WAI	CAI	WAI/CAI	EAI/EBS	Total
Year	MSSC	MSSC	ABC	ABC	ABC
2023	61	105	166	359	525
2024	67	115	182	388	570

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 2023, it does not provide the best estimate of OFL for 2024, because the mean 2024 catch under Scenario 6 is predicated on the 2023 catch being equal to the 2022 OFL, whereas the actual 2023 catch will likely be less than the 2023 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL. Catches for 2023 and 2024 were obtained by fishing at $F = 0.027$.

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 (2021) is 515 t. This is less than the 2021 BSAI OFL of 576 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. In this assessment, determination of whether the stock is overfished is complicated in that the age-structured model is applied only to the AI portion of the population; thus an estimate of MSST is only available for this portion of the population. Because current management regulations use a single OFL for the BSAI area, a meaningful measure of MSST and overfished status would need to reflect the entire BSAI population. However, the AI portion of the population composes the majority of the BSAI blackspotted/rougheye rockfish, and evaluation of its population size relative the MSST computed for the AI provides a useful index of stock condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the AI portion of the stock currently overfished? This depends on the estimated spawning biomass in 2022:

a. If spawning biomass for 2022 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2022 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2022 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 14.25). If the mean spawning biomass for 2032 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

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

a. If the mean spawning biomass for 2024 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2024 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2024 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2034. If the mean spawning biomass for 2034 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 AI portion of the stock blackspotted/rougheye rockfish stock is neither overfished nor approaching an overfished condition. With regard whether the stock is currently below overfished, the estimated stock size in 2022 is 3,335 t and exceeds the $B_{35\%}$ value of 3,056 t. With regard to whether the stock is likely to be overfished in the future, the expected stock size in 2034 of 3,616 t exceeds the $B_{35\%}$ value.

Based on the recommended model for the AI portion of the stock, the F that would have produced an AI catch for 2021 equal to the AI portion of the 2021 OFL is 0.038.

Ecosystem Considerations

Ecosystem Effects on the stock

1) Prey availability/abundance trends

The largest components of the blackspotted/rougheye rockfish diet is pandalid and hippolytid shrimp (Yang 1993, 1996, Yang and Nelson 2000). Analysis of specimens in the Aleutian Islands surveys in 1991 and 1994 indicated the diet of large blackspotted/rougheye rockfish had proportionally more fish (e.g., myctophids) than small blackspotted/rougheye, whereas smaller blackspotted/rougheye consumed proportionally more shrimp. The availability and abundance trends of these prey species are unknown.

2) Predator population trends

Blackspotted/rougheye 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 also prey upon northern rockfish as well. The population trends of these predators can be found in separate chapters within this SAFE document.

3) Changes in habitat quality

Adults are demersal and generally occur at depths between 300 m and 500 m. Submersible work in southeast Alaska indicates that blackspotted/rougheye rockfish were associated with habitats containing frequent boulders, steep slopes (more than 20°) and sand-mud substrates (Krieger and Ito 1999). Krieger and Wing (2002) found that large rockfish had a strong association with *Primnoa* spp. coral growing on boulders, and it is likely than many of these large rockfish were blackspotted/rougheye rockfish.

There has been little information identifying how rockfish habitat quality has changed over time, but recent EFH reviews have not indicated effects greater than “minimal and temporary”.

Fishery Effects on the ecosystem

Blackspotted/rougheye rockfish are not subject to a target fishery in the BSAI management area. As previously discussed, much of the blackspotted/rougheye catch occurs in the POP fishery in the western and central Aleutians Islands, and in the POP, arrowtooth flounder, pollock, and Pacific cod fisheries in the eastern Aleutian Islands and eastern Bering Sea area. The ecosystem effects of the fisheries for these stocks can be found in their chapters in in this SAFE document.

Harvesting of blackspotted/rougheye rockfish is not likely to diminish the amount of blackspotted/rougheye 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, relatively high exploitation rates have occurred in the 1990s and it is not known what the effect of harvesting is on the maturity at age.

Data Gaps and Research Priorities

Little information is known regarding most aspects of the biology of blackspotted and rougheye rockfish, particularly in the AI. Distinguishing blackspotted rockfish from rougheye rockfish in the field is a pressing issue, particularly along the EBS slope where both species are found. Further studies to examine the distribution and movement of early life-history stages are needed. Given the results of recent genetic work, further information on the population structure associated with distinctive oceanographic features such as AI passes is needed. Finally, given the relatively unusual reproductive biology of rockfish and its importance in establishing management reference points, data on reproductive capacity should be collected on a periodic basis.

References

Bond , N. 2019. Sea surface temperature and sea level pressure anomalies. In Ecosystem status report 2019: Eastern Bering Sea, pp. 36-39. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501.

Bond, N., S. Batten, W. Cheng, M. Callahan, C. Ladd, E. Laman, E. Lemagie, C. Mordy, O'Leary, C., C. Ostle, N. Pelland., K. Sewicke, P. Stabeno., R. Thoman (authors listed alphabetically after 1st author). 2022. Biophysical Environment Synthesis. In Ortiz, I. and S. Zador, 2022. Ecosystem Status Report 2022: Aleutian Islands, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Chilton, D. E., and R. J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60, 102 p.

DFO. 2020. Rougheye/Blackspotted Rockfish (Sebastes aleutianus/melanostictus) Stock Assessment for British Columbia in 2020. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/047.

Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. Can . J. Fish. Aquat. Sci. 54:284-300.

Gharrett, A.J., A.P. Matala, E.L. Peterson, A.K. Gray, Z. Li, and J. Heifetz. 2005. Two genetically distinct forms of rougheye rockfish are different species. Trans. Am. Fish. Soc. 132:242-260.

Gharrett, A.J., A.P. Matala, E.L. Peterson, A.K. Gray, Z. Li, and J. Heifetz. 2007. Distribution and population genetic structure of sibling rougheye rockfish species. Pages 121-140 *In* J. Heifetz, J. DiCosimo, A.J. Gharrett, M.S. Love, V.M. O'Connell, and R.D. Stanley (eds.) 2007. Biology, assessment, and management of North Pacific rockfishes. Alaska Sea Grant College Publication AK-SG-07-01, University of Alaska Fairbanks.

Guttormsen, M., R. Narita, J. Gharrett, G. Tromble, and J. Berger. 1992. Summary of observer sampling of domestic groundfish fisheries in the northeast Pacific ocean and eastern Bering Sea, 1990. NOAA Tech. Memo NMFS-AFSC-5. 281 pp.

Hawkins, S.L., J. Heifetz, C.M. Kondzela, J.E. Pohl, R. L. Wilmot, O. N. Katugin, and V.N. Tuponogov. 2005. Genetic variation of rougheye rockfish (*Sebates aleutianus*) and shortraker rockfish inferred from allozymes. Fish. Bull. 103:524-535.

Hurtado-Ferro, F., Szuwalski, C.S., Valero, J.L., Anderson, S.C., Cunningham, C.J., Johnson, K.F., Licandeo, R., McGilliard, C.R., Monnahan, C.C., Muradian, M.L. and Ono, K. 2015. Looking in the rear-view mirror: bias and retrospective patterns in integrated, age-structured stock assessment models. ICES Journal of Marine Science, 72(1), pp.99-110.

Krieger, K.J., and D.H. Ito. 1999. Distribution and abundance of shortraker rockfish, Sebastes borealis, and rougheye rockfish, S. aleutianus, determined from a manned submersible. Fish. Bull. 97: 264-272.

Krieger, K.J., and B.L. Wing. 2002. Megafauna associations with deepwater corals (Primnoa spp.) in the GOA. Hydrobiologia 471: 83-90.

Laman, E. 2022a. Rockfish distribution in the Aleutian Islands. In Ortiz, I. and S. Zador, 2022. Ecosystem Status Report 2022: Aleutian Islands, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Laman, E. 2022b. Habitat Areas of particular concern Biota in the Aleutian Islands. In Ortiz, I. and S. Zador, 2022. Ecosystem Status Report 2022: Aleutian Islands, Stock Assessment and Fishery

Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Major, R.L. and H.H. Shippen. 1970. Synopsis of biological data on Pacific ocean perch, Sebastodes alutus. United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 1970.

McAllister, M.K. and J.N. Ianelli. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. Can . J. Fish. Aquat. Sci. 54:284-300.

McDermott, S.F. 1994. Reproductive biology of rougheye and shortraker rockfish, Sebastes aleutianus and Sebastes borealis. Masters thesis. University of Washington, Seattle 76 pp

Olson, J. 2021. Area disturbed by trawl fishing in Alaska. In Ortiz, I. and S. Zador, 2021. Ecosystem Status Report 2021: Aleutian Islands, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Orr, J.W. and S. Hawkins. 2008. Species of the rougheye rockfish complex: resurrection of Sebastes melanostictus (Matsubara, 1934) and a redescription of Sebastes aleutianus (Jordan and Evermann, 1898) (Teleostei: Scorpaeniformes). Fish. Bull. 106(2):111-134

Perry, R.I. and S.J. Smith. 1994. Identifying habitat associations of marine fishes using survey data: an application to the northwest Atlantic. Can J. Fish. Aquat. Sci. 51:589-602.

Punt, Andre E., D.C. Smith, K. Krusic-Golub, and S. Robertson. 2008. Quantifying age-reading error for use in fisheries stock assessments, with application to species in Australia's southern and eastern scalefish and shark fishery. Canadian Journal of Fisheries and Aquatic Sciences 65(9):1991-2005.

Ronholt, L.L., K. Teshima, and D.W. Kessler. 1994. The groundfish resources of the Aleutian Islands region and southern Bering Sea 1980, 1983, and 1986. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-31, 351 pp.

Rooper, C. P. Goddard, and R. Wilson. 2019. Are fish associations with corals and sponges morethan an affinity to structure? Evidence in two widely divergent ecosystems. Can. J. Fish. Aquat. Sci. 76: 2184-2198. doi.org/10.1139/cjfas-2018-0264

Shotwell, S.K., D. Hanselman, and D.M. Clausen. 2007. Gulf of Alaska Rougheye Rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, pp. 675-734. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501.

Spencer, P.D. 2008. Density-independent and density-dependent factors affecting temporal changes in spatial distributions of eastern Bering Sea flatfish. Fish. Oceanogr. 17:396-410.

Spencer, P.D., and C.N. Rooper. 2010. Assessment of the blackspotted and rougheye rockfish complex in the eastern Bering Sea and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region as projected for 2011, pp. 1127-1194. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501

Then, A.Y., J.M. Hoenig, N.G. Hall, D.A. Hewitt. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES J. of Mar. Sci. 72(1); 82-92.

Von Szalay, P.G., N.W. Raring, C.N. Rooper, and E.A. Laman. 2017. Data report: 2016 Aleutian Islands Bottom Trawl Survey. NOAA Tech. Memo. NMFS-AFSC-349, 161 p.

Whitehouse, A. 2022. Time trends in on-targe species catch. In Ortiz, I. and S. Zador, 2022. Ecosystem Status Report 2022: Aleutian Islands, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Yang, M-S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-22, 150 p.

Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-AFSC-60, 105 p.

Yang, M.S. and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. NOAA Tech. Memo. NMFS-AFSC-112. 174 p.

Tables

Table 14.1. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the species groups used to manage blackspotted and rougheye rockfish in the Aleutian Islands and eastern Bering Sea from 1977 to 2003. The "other red rockfish" group includes shortraker rockfish, rougheye rockfish, northern rockfish, and sharpchin rockfish. The "POP complex" includes the other red rockfish species plus POP.

	BSAI					AI					EBS				
Year	Management Group	OFL	ABC (t)	TAC (t)	Catch (t)	Management Group	OFL (t)	ABC	TAC	Catch	Management Group	OFL	ABC	TAC	Catch
1977						Other species				155	Other species				2
1978						Other species				2423	Other species				99
1979						Other species				3077	Other species				477
1980						Other species				660	Other species				160
1981						Other species				595	Other species				283
1982						POP complex				189	POP complex				124
1983						POP complex				58	POP complex				53
1984						POP complex				35	POP complex				79
1985						POP complex				10	POP complex				18
1986						Other rockfish			5800	21	Other rockfish			825	52
1987						Other rockfish			1430	79	Other rockfish			450	99
1988						Other rockfish		1100	1100	75	Other rockfish		400	400	111
1989						POP Complex		16600	6000	381	POP Complex		6000	5000	204
1990						POP Complex		16600	6000	1619	POP Complex		6300	6300	369
1991						Other red rockfish		4685	4685	137	Other red rockfish		1670	1670	106
1992						RE/SR	1220	1220	1220	1181	Other red rockfish	1400	1400	1400	77
1993						RE/SR	1220	1220	1100	924	Other red rockfish	1400	1400	1200	146
1994						RE/SR	1220	1220	1220	749	Other red rockfish	1400	1400	1400	22
1995						RE/SR	1220	1220	1098	395	Other red rockfish	1400	1400	1260	28
1996						RE/SR	1250	1250	1125	816	Other red rockfish	1400	1400	1260	34
1997						RE/SR	1250	938	938	954	Other red rockfish	1400	1050	1050	15
1998						RE/SR	1290	965	965	526	Other red rockfish	356	267	267	16
1999						RE/SR	1290	965	965	385	Other red rockfish	356	267	267	9
2000						RE/SR	1180	885	885	280	Other red rockfish	259	194	194	26
2001	RE/SR	1369	1028	1028	565	RE/SR			912	550	RE/SR			116	15
2002	RE/SR	1369	1028	1028	284	RE/SR			912	273	RE/SR			116	12
2003	RE/SR	1289	967	967	191	RE/SR			830	174	RE/SR			137	17

Table 14.2. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the species groups used to manage blackspotted and rougheye rockfish in the Aleutian Islands and eastern Bering Sea from 2004 to 2022. Catch data is through September 25, 2022, from NMFS Alaska Regional Office. The “rougheye” management group includes both blackspotted rockfish and rougheye rockfish.

	BSAI						WAI/CAI					EAI/EBS			
Year	Management Group	OFL	ABC (t)	TAC (t)	Catch (t)	Management Group	OFL	ABC	TAC	Catch	Management Group	OFL	ABC	TAC	Catch
2004	Rougheye	259	195	195	208										
2005	Rougheye	298	223	223	90										
2006	Rougheye	299	224	224	203										
2007	Rougheye	269	202	202	168										
2008	Rougheye	269	202	202	193										
2009	Rougheye	660	539	539	197										
2010	Rougheye	669	547	547	228										
2011	Rougheye	549	454	454	170	Rougheye		220	220	77	Rougheye		234	234	92
2012	Rougheye	576	475	475	201	Rougheye		244	244	130	Rougheye		231	231	71
2013	Rougheye	462	378	378	337	Rougheye		209	209	152	Rougheye		169	169	185
2014	Rougheye	505	416	416	208	Rougheye		239	239	101	Rougheye		177	177	108
2015	Rougheye	560	453	349	196	Rougheye		304	200	125	Rougheye		149	149	71
2016	Rougheye	693	561	300	164	Rougheye		382	200	89	Rougheye		179	100	75
2017	Rougheye	612	501	225	234	Rougheye		195	125	153	Rougheye		306	100	81
2018	Rougheye	749	613	225	250	Rougheye		239	150	180	Rougheye		374	75	70
2019	Rougheye	676	555	279	405	Rougheye		204	204	311	Rougheye		351	75	94
2020	Rougheye	861	708	349	531	Rougheye		264	264	380	Rougheye		444	85	151
2021	Rougheye	576	482	482	515	Rougheye		169	169	319	Rougheye		313	313	196
2022	Rougheye	598	503	503	339	Rougheye		177	177	218	Rougheye		326	326	121

Table 14.3. Catch of blackspotted and rougheye rockfish (t) in the BSAI area.

	Eastern Bering Sea			Aleutian Islands			BSAI
Year	Foreign	JV	Domestic	Foreign	JV	Domestic	Total
1977	2	0		155	0		157
1978	99	0		2,423	0		2,522
1979	477	0		3,077	0		3,553
1980	160	0		660	0		820
1981	283	0		595	0		878
1982	124	0		189	0		312
1983	53	0		56	2		111
1984	79	0		31	4		114
1985	18	0		1	9		27
1986	3	1	48	0	2	19	74
1987	1	2	96	0	3	76	179
1988	0	1	110	0	5	70	185
1989	0	2	202	0	0	381	585
1990			369			1,619	1,988
1991			106			137	243
1992			77			1,181	1,258
1993			146			924	1,070
1994			22			749	770
1995			28			395	423
1996			34			816	850
1997			15			954	969
1998			16			526	542
1999			9			385	394
2000			26			280	307
2001			15			550	565
2002			12			273	284
2003			17			174	191
2004			23			185	208
2005			12			78	90
2006			7			197	203
2007			10			157	168
2008			22			171	193
2009			13			184	197
2010			27			201	228
2011			38			131	170
2012			19			182	201
2013			34			303	337
2014			29			179	208
2015			37			159	196
2016			43			121	164
2017			43			191	234
2018			19			232	250
2019			60			345	405
2020			54			477	531
2021			103			412	515
2022			52			287	339

*Catch data through September 25, 2022, from NMFS Alaska Regional Office.

Table 14.4. Area-specific catches (t) of blackspotted and rougheye rockfish (t) in the BSAI area, obtained from the North Pacific Groundfish Observer Program, NMFS Alaska Regional Office. BSAI subareas are the western Aleutians Islands (WAI), central Aleutian Islands (CAI), and eastern Aleutian Islands (EAI), and eastern Bering Sea (EBS).

Year	WAI	CAI	EAI	EBS	Total
1994	49	197	503	22	770
1995	43	100	252	28	423
1996	446	184	186	34	850
1997	513	138	303	15	969
1998	109	232	185	16	542
1999	88	161	136	9	394
2000	103	139	39	26	307
2001	128	133	289	15	565
2002	96	63	114	12	284
2003	66	58	51	17	191
2004	112	64	10	23	208
2005	43	24	11	12	90
2006	109	45	43	7	203
2007	43	42	72	10	168
2008	58	67	47	22	193
2009	67	81	37	13	197
2010	85	42	74	27	228
2011	46	31	54	38	170
2012	65	65	52	19	201
2013	84	68	151	34	337
2014	57	44	79	29	208
2015	70	56	34	37	196
2016	40	50	32	43	164
2017	35	118	38	43	234
2018	67	113	52	19	250
2019	104	208	34	60	405
2020	168	212	97	54	531
2021	120	198	93	103	515
2022*	98	119	70	52	339

* Estimated removals through September 25, 2022.

Table 14.5. 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 11/15/2022.

Species Group Name	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Average
Pacific Ocean Perch	18315	18671	25492	26071	23420	19589	20422	21091	27651	25802	23637	19347	22459
Atka Mackerel	1804	1447	2967	2175	5490	5255	5365	5513	8734	8527	6846	5390	4960
Northern Rockfish	1104	587	1253	864	2863	1338	1476	1768	4527	3512	2193	3050	2045
Pollock	536	667	1380	1104	947	875	1424	1524	2254	1995	2248	2332	1440
Pacific Cod	342	273	587	361	731	625	813	637	1217	975	899	572	669
Arrowtooth Flounder	512	483	1114	698	630	363	359	257	465	579	672	602	561
BSAI Kamchatka Flounder	355	245	1169	642	565	463	427	322	518	714	549	267	520
Other Rockfish	223	125	191	168	171	129	163	198	342	405	284	307	225
Sablefish	19	18	53	20	11	14	143	147	286	370	475	613	181
BSAI Skate and GOA Skate,	104	97	232	164	171	139	144	165	294	282	216	111	177
Rougheye Rockfish	90	104	162	113	92	70	65	116	246	288	248	152	146
BSAI Shortraker Rockfish	234	247	197	54	63	38	36	116	121	146	224	127	134
Sculpin	122	100	129	96	127	88	135	106	199	188			129
BSAI Other Flatfish	66	147	52	67	41	16	52	88	157	141	161	208	100
Flathead Sole	59	28	42	39	52	41	53	67	119	89	125	134	71
Greenland Turbot	29	20	59	42	34	28	37	53	119	165	115	75	65
Squid	37	33	60	56	66	26	31	50					45
Rock Sole	12	22	29	21	38	15	32	36	67	61	49	49	36
Shark	5	1	2		2	2		2	2	4	2	6	3
Octopus	4	4	2	3	1	1	3	3	4	2	2	3	3
Yellowfin Sole	1	1	4	0	1	1	0	4	1	1	5	0	2
BSAI Alaska Plaice								1		0			0

Table 14.6. Catch (t) of BSAI blackspotted and rougheye rockfish by trip target fishery. "Conf" indicates confidential records with less than three vessels or processors. Source: Alaska Regional Office, via AKFIN 11/15/2022.

Fishery	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Average
Rockfish	90	104	162	113	92	70	65	116	246	288	247	152	145
Atka Mackerel	17	22	29	35	33	35	38	79	76	98	144	124	61
Pacific Cod	12	39	24	10	36	12	78	35	29	69	43	20	34
Kamchatka Flounder - BSAI	18	22	41	11	22	25	9	6	5	35	42	40	23
Arrowtooth Flounder	23	7	60	23	9	9	1	2	1	11	17	4	14
Halibut	6	3	10	9	3	6	26	7	9	7	4	2	8
Pollock - midwater	0	1	0	2	0	2	7	2	8	4	0	0	2
Greenland Turbot - BSAI	0	1			0		1	2	7	5	2	2	2
Flathead Sole	0								9		7	6	5
Sablefish	2	0	5	2		0		0		0	2	2	2
Pollock - bottom	0	0	0	1	0	1	3	1	4	2		2	1
Other Flatfish - BSAI						1	2		3		5	1	2

Table 14.7. 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 11/15/2022.

Species Group Name	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	Average
Bairdi Tanner Crab	0.70	7.66	0.25	0.62	0.84	0.10	0.07	0.05	0.10	0.61	0.10	0.43	0.96
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chinook Salmon	0.18	0.39	0.17	1.04	0.27	0.58	0.21	0.79	0.26	1.54	0.28	0.36	0.51
Golden (Brown) King Crab	3.25	3.30	3.66	6.30	4.95	3.02	5.29	5.59	7.67	15.22	7.72	5.68	5.97
Halibut	67.07	81.93	59.64	86.00	44.16	51.18	24.98	76.95	89.89	140.40	94.02	120.79	78.08
Herring	2.12	0.01	0.00	1.34	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.29
Non-Chinook Salmon	0.91	0.77	0.41	1.28	0.76	0.12	0.19	0.27	0.33	0.00	0.08	0.00	0.43
Opilio Tanner (Snow) Crab	0.14	2.31	0.10	0.71	14.54	0.07	0.02	0.00	0.00	0.07	0.01	0.17	1.51
Red King Crab	0.00	0.21	0.06	0.33	0.48	0.63	0.06	0.10	0.13	0.41	0.12	0.14	0.22

Table 14.8. Bycatch (t) of non-FMP species by BSAI trip targeting rockfish. “Conf” indicates confidential records with less than three vessels or processors. Source: Alaska Regional Office, via AKFIN 11/15/2022.

Species Group Name	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011
Benthic urochordata	0.39	0.46	6.08	12.16	2.88	0.32	0.18	1.50	2.82	0.27	2.08	4.41
Birds - Auklets					Conf							
Birds - Black-footed Albatross	Conf											
Birds - Gull												
Birds - Laysan Albatross					Conf							
Birds - Northern Fulmar	Conf				Conf			Conf				
Birds - Shearwaters		Conf			Conf	Conf						
Birds - Storm Petrels		Conf			Conf							
Bivalves	0.07	0.17	0.03	0.15	0.05	0.02	0.05	0.14	0.03	0.09	0.02	0.02
Brittle star unidentified	1.06	3.27	6.08	3.21	5.02	0.14	0.12	1.61	0.17	0.22	0.17	0.39
Capelin										Conf		
Corals Bryozoans - Corals Bryozoans Unid	5.27	5.23	9.25	23.56	5.89	26.61	11.15	46.45	32.65	27.44	20.52	40.67
Corals Bryozoans - Red Tree Coral									Conf	0.41	Conf	Conf
Eelpouts	19.26	3.17	3.57	2.46	1.75	4.56	1.33	1.77	2.84	11.00	1.88	12.03
Giant Grenadier	240.85	321.44	181.68	95.36	121.74	29.33	108.63	69.95	161.34	286.15	42.02	288.00
Greenlings	2.44	0.46	0.79	0.67	Conf	Conf					Conf	Conf
Grenadier - Pacific Grenadier												Conf
Grenadier - Rattail Grenadier Unidentified	3.25	Conf		23.44	Conf			Conf	Conf	Conf	5.79	14.75
Gunnels										Conf		
Hermit crab unidentified	0.15	0.08	0.04	0.10	0.04	0.01	0.02	0.09	0.03	0.06	0.01	Conf
Invertebrate unidentified	0.32	8.62	1.69	4.86	0.16	0.13	1.86	Conf	0.34	128.04	55.21	1.36
Lanternfishes (myctophidae)	0.07	0.14	Conf	0.11	0.03	Conf	Conf	0.05	0.11	0.06	Conf	0.01
Misc crabs	5.11	0.35	0.30	1.00	0.28	0.24	0.40	0.24	0.30	0.70	0.20	0.22
Misc crustaceans	0.23	0.15	0.18	0.18	0.22	0.38	0.11	0.20	0.23	0.11	0.04	0.20
Misc deep fish	Conf	0.01	Conf	Conf	Conf		Conf	Conf	0.01	0.01		
Misc fish	49.93	55.68	78.92	104.32	74.95	107.35	58.93	61.48	43.00	67.48	55.44	66.46
Misc inverts (worms etc)	0.01	0.01	0.03	0.00	Conf		Conf	Conf	Conf	Conf	Conf	Conf
Other osmerids		0.01	Conf	Conf	Conf							Conf
Pacific Hake												Conf
Pacific Sand lance			Conf									
Pandalid shrimp	0.53	0.38	0.16	0.14	0.32	0.10	0.15	0.40	0.26	0.45	0.19	0.44
Polychaete unidentified	0.01	0.00	Conf	0.03	0.02		Conf		Conf			0.01
Saffron Cod					Conf							
Sculpin	139.34	96.57										
Scypho jellies	2.42	15.23	3.43	11.50	1.23	0.39	0.52	0.73	0.46	8.14	0.11	0.75
Sea anemone unidentified	2.46	4.41	0.36	1.22	0.49	0.25	0.19	0.29	0.22	0.78	0.36	1.59
Sea pens whips	0.04	0.15	0.20	0.14	0.46	Conf	0.06	0.07	0.14	0.11	0.01	0.02
Sea star	12.55	12.45	16.01	32.69	45.25	4.27	3.29	9.13	5.90	9.25	5.17	6.48
Smelt (Family Osmeridae)	Conf											
Snails	0.80	0.76	0.79	0.80	0.81	0.31	0.13	0.51	0.42	0.68	0.24	0.38
Sponge unidentified	51.26	72.86	92.48	96.75	77.81	71.48	48.31	149.37	127.84	211.09	51.04	67.87
Squid	78.86	75.80	56.42	23.41								
State-managed Rockfish	0.68	0.46	1.13	0.34	0.36	Conf	0.62	0.49	Conf	Conf		Conf
Stichaeidae			Conf		Conf		Conf	Conf	0.02			Conf
urchins dollars cucumbers	3.92	1.05	0.69	2.64	2.10	1.14	0.37	1.55	0.93	2.34	0.94	1.64

Table 14.9. Estimated retained (t), discarded (t), and percent discarded of other red rockfish (ORR), shortraker/rougheye (SR/RE), and blackspotted/rougheye rockfish from the eastern Bering Sea (EBS) and Aleutian Islands (AI) regions.

		AI				EBS				
Year	Species Group	Retained	Discarded	Total	Percent Discarded	Species Group	Retained	Discarded	Total	Percent Discarded
1993	RE/SR	737	403	1139	35%	Other red rockfish	367	97	464	21%
1994	RE/SR	701	224	925	24%	Other red rockfish	29	100	129	78%
1995	RE/SR	456	103	558	18%	Other red rockfish	274	70	344	20%
1996	RE/SR	751	208	959	22%	Other red rockfish	58	149	207	72%
1997	RE/SR	733	310	1043	30%	Other red rockfish	44	174	218	80%
1998	RE/SR	447	238	685	35%	Other red rockfish	38	59	97	61%
1999	RE/SR	319	195	514	38%	Other red rockfish	75	163	238	68%
2000	RE/SR	285	196	480	41%	Other red rockfish	111	141	253	56%
2001	RE/SR	476	246	722	34%	RE/SR	27	16	43	38%
2002	RE/SR	333	146	478	30%	RE/SR	50	54	105	52%
2003	RE/SR	197	84	281	30%	RE/SR	62	54	116	47%
2004	Rougheye	83	102	185	55%	Rougheye	15	8	23	36%
2005	Rougheye	72	6	78	8%	Rougheye	3	8	12	70%
2006	Rougheye	167	30	197	15%	Rougheye	5	2	7	30%
2007	Rougheye	127	30	157	19%	Rougheye	7	3	10	29%
2008	Rougheye	137	35	171	20%	Rougheye	12	10	22	46%
2009	Rougheye	155	30	184	16%	Rougheye	10	3	13	23%
2010	Rougheye	174	27	201	13%	Rougheye	18	9	27	34%
2011	Rougheye	115	16	131	12%	Rougheye	30	8	38	22%
2012	Rougheye	158	24	182	13%	Rougheye	14	5	19	25%
2013	Rougheye	243	60	303	20%	Rougheye	21	13	34	39%
2014	Rougheye	158	21	179	12%	Rougheye	17	12	29	40%
2015	Rougheye	135	24	159	15%	Rougheye	23	15	37	39%
2016	Rougheye	106	15	121	13%	Rougheye	34	9	43	21%
2017	Rougheye	109	82	191	43%	Rougheye	23	20	43	46%
2018	Rougheye	193	39	232	17%	Rougheye	10	9	19	47%
2019	Rougheye	244	101	345	29%	Rougheye	32	28	60	47%
2020	Rougheye	319	158	477	33%	Rougheye	42	12	54	23%
2021	Rougheye	250	161	412	39%	Rougheye	59	44	103	42%
2022*	Rougheye	186	102	287	35%	Rougheye	31	21	52	40%

* Estimated removals through September 25, 2022.

Table 14.10. Bycatch rates (t blackspotted/rougheye rockfish per ton of target species) by fishery and area, calculated from hauls sampled for species composition by fishery observers.

	WAI	WAI	WAI	CAI	CAI	CAI	CAI	EAI	EAI	EAI	EAI	EAI	EBS	EBS	EBS	EBS	EBS	EBS
Year	POP	Atka mackerel	Pacific cod	POP	Atka mackerel	Pacific cod	Other species	POP	Atka mackerel	AR/KM	Bottom pollock	Other species	POP	Other species	Bottom pollock	Pacific cod	pelagic pollock	AR/KM
2004	2.53%	0.11%	0.01%	1.49%	0.01%	0.01%	0.01%	0.14%	0.00%	0.15%	0.03%	0.00%	0.69%	0.00%	0.04%	0.00%	0.00%	0.20%
2005	1.15%	0.02%	0.00%	1.39%	0.02%	0.05%	0.00%	0.00%	0.00%	0.07%	0.00%	0.00%	0.22%	0.00%	0.03%	0.00%	0.00%	0.15%
2006	1.63%	0.03%	0.00%	0.82%	0.01%	0.00%	0.00%	0.94%	0.01%	0.22%	0.00%	0.00%	0.17%	0.00%	0.02%	0.00%	0.00%	0.16%
2007	0.42%	0.06%	0.00%	0.71%	0.01%	0.02%	0.00%	1.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.08%
2008	0.59%	0.03%	0.10%	0.86%	0.01%	1.24%	0.14%	0.76%	0.00%	0.46%	0.01%	0.53%	0.08%	0.13%	0.03%	0.09%	0.00%	0.20%
2009	1.24%	0.07%	0.47%	1.78%	0.04%	0.26%	0.40%	0.44%	0.00%	0.20%	0.00%	0.19%	0.20%	0.03%	0.04%	0.01%	0.00%	0.22%
2010	1.48%	0.05%	0.26%	0.73%	0.02%	0.48%	0.13%	1.00%	0.00%	0.53%	0.94%	0.20%	0.36%	0.05%	0.15%	0.06%	0.00%	0.49%
2011	0.65%	0.24%		0.54%	0.02%	1.65%	1.05%	0.25%	0.01%	0.87%	0.83%	0.43%	0.19%	0.11%	0.08%	0.16%	0.00%	0.29%
2012	1.04%	0.53%	2.59%	0.80%	0.03%	3.72%	0.69%	0.37%	0.01%	0.72%	4.67%	0.27%	0.25%	0.03%	0.01%	0.03%	0.01%	0.05%
2013	1.07%	10.14%	0.58%	0.76%	0.01%	1.59%	1.49%	0.63%	0.05%	1.24%	1.25%	1.46%	0.07%	1.77%	0.15%	0.18%	0.00%	0.76%
2014	0.76%		0.00%	0.59%	0.00%	1.33%	0.06%	0.40%	0.01%	0.93%	1.04%	0.94%	0.09%	0.29%	0.07%	0.08%	0.00%	0.19%
2015	0.83%	0.10%	1.30%	0.68%	0.01%	1.11%	1.55%	0.31%	0.01%	0.60%	1.35%	1.03%	0.01%	0.32%	0.08%	0.08%	0.00%	0.37%
2016	0.34%	0.09%	0.40%	0.70%	0.02%	0.34%	0.89%	0.23%	0.01%	0.66%	0.32%	1.17%	0.03%	0.22%	0.05%	0.07%	0.00%	0.36%
2017	0.40%	0.12%	0.30%	0.69%	0.04%	4.10%	18.71%	0.34%	0.01%	1.46%	1.87%	1.72%	0.04%	0.20%	0.04%	0.09%	0.00%	0.21%
2018	0.73%	0.14%	0.24%	1.42%	0.03%	1.76%	9.47%	0.39%	0.04%	0.50%	0.11%	3.09%	0.14%	1.45%	0.03%	0.26%	0.00%	0.05%
2019	1.15%	0.26%	1.09%	2.77%	0.06%	1.03%	2.14%	0.25%	0.04%	0.49%	0.84%	2.08%	0.14%	0.51%	0.05%	0.17%	0.00%	0.35%
2020	2.05%	0.21%	1.27%	2.63%	0.09%	3.61%	1.21%	0.93%	0.02%	0.78%	0.29%	2.46%	0.40%	0.50%	0.01%	0.09%	0.00%	0.53%
2021	1.68%	0.24%	0.34%	2.95%	0.07%	3.38%	3.29%	1.01%	0.06%	0.83%	0.90%	0.77%	1.46%	0.90%	0.02%	0.15%	0.00%	0.64%
2022	1.11%	0.11%	0.00%	2.44%	0.13%	3.60%	2.56%	0.84%	0.19%	0.56%	0.59%	0.33%	0.55%	0.23%	0.04%	0.05%	0.00%	0.46%

Table 14.11. Samples sizes of blackspotted/rougheye lengths from fishery sampling in the eastern Bering Sea (EBS), Aleutian Islands (AI), and the eastern Bering Sea and Aleutian Islands combined (BSAI), with the number of hauls from which these data were collected, from 1977-2022.

	EBS		AI		BSAI	
Year	Lengths	Hauls	Lengths	Hauls	Lengths	Hauls
1977						
1978			54	6	54	6
1979	2340	132	4406	93	6746	225
1980						
1981						
1982						
1983			33	1	33	1
1984						
1985						
1986						
1987						
1988						
1989						
1990	800	29	1161	20	1961	49
1991	95	16	49	1	144	17
1992	61	1	1182	67	1243	68
1993	2	2	1046	39	1048	41
1994			27	1	27	1
1995	42	3			42	3
1996	14	3			14	3
1997						
1998						
1999	4	2	53	4	57	6
2000	4	1	160	21	164	22
2001	10	1	277	42	287	43
2002			336	49	336	49
2003	76	18	832	100	908	118
2004	215	41	1265	242	1480	283
2005	71	39	314	94	385	133
2006	61	16	266	56	327	72
2007	104	40	716	160	820	200
2008	38	20	371	105	409	125
2009	16	10	1002	211	1018	221
2010	103	46	1904	375	2007	421
2011	157	81	692	170	849	251
2012	81	48	923	164	1004	212
2013	209	81	1504	276	1713	357
2014	153	93	748	213	901	306
2015	312	151	1546	287	1858	438
2016	115	57	488	130	603	187
2017	74	32	2007	426	2081	458
2018	159	34	1308	331	1467	365
2019	519	260	1352	267	1871	527
2020	354	205	2089	610	2443	815
2021	457	203	3008	765	3465	968
2022	65	36	914	297	979	333

Table 14.12. Samples sizes of blackspotted/rougheye otoliths from fishery sampling in the eastern Bering Sea (EBS), Aleutian Islands (AI), and the eastern Bering Sea and Aleutian Islands combined (BSAI), with the number of hauls from which these data were collected, from 1977-2022.

	Otoliths Sampled			Otoliths Read			Hauls (Otoliths Read)		
Year	EBS	AI	BSAI	EBS	AI	BSAI	EBS	AI	BSAI
1977									
1978									
1979	440	383	823	14	38	52	6	4	10
1980									
1981									
1982									
1983									
1984									
1985									
1986									
1987									
1988									
1989									
1990	54	0	54						
1991									
1992	0	50	50						
1993									
1994									
1995									
1996									
1997									
1998									
1999	4	4	8						
2000	2	24	26						
2001	2	76	78						
2002		67	67						
2003	19	120	139						
2004	14	147	161	14	146	160	11	90	101
2005	37	100	137	35	97	132	23	65	88
2006	5	83	88		82	82		47	47
2007	14	138	152	14	134	148	10	83	93
2008	17	125	142	17	121	138	13	74	87
2009	13	138	151	6	138	144	6	90	96
2010	24	172	196						
2011	22	153	175	19	152	171	12	85	97
2012	26	109	135						
2013	44	254	298	41	252	293	33	160	193
2014	51	242	293						
2015	70	206	276	69	206	275	47	126	173
2016	17	118	135						
2017	18	260	278	18	258	276	12	156	168
2018	38	332	370						
2019	346	342	688	332	341	673	184	201	385
2020	245	805	1050	82	264	346	67	224	291
2021	257	997	1254	122	489	611	98	397	495
2022	22	410	432						

Table 14.13. Fishery length compositions used in the model, from the NORPAC foreign and domestic Observer databases.

	Year									
Length (cm)	1979	1990	1992	1993	2003	2010	2012	2014	2016	2018
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000
15	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.003
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.004
17	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.006	0.001
18	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.009	0.004
19	0.002	0.000	0.000	0.000	0.000	0.000	0.004	0.001	0.006	0.005
20	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.003	0.004
21	0.002	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.009	0.011
22	0.004	0.000	0.000	0.000	0.000	0.000	0.002	0.008	0.012	0.011
23	0.004	0.000	0.000	0.001	0.000	0.002	0.006	0.016	0.006	0.013
24	0.007	0.002	0.000	0.001	0.000	0.001	0.015	0.012	0.010	0.015
25	0.011	0.000	0.000	0.002	0.000	0.004	0.002	0.016	0.021	0.011
26	0.010	0.000	0.000	0.001	0.000	0.004	0.014	0.020	0.006	0.018
27	0.014	0.000	0.000	0.009	0.000	0.010	0.028	0.014	0.011	0.020
28	0.018	0.001	0.004	0.007	0.000	0.015	0.018	0.023	0.019	0.016
29	0.020	0.002	0.002	0.002	0.002	0.026	0.012	0.032	0.028	0.015
30	0.026	0.002	0.004	0.009	0.001	0.033	0.024	0.027	0.019	0.018
31	0.033	0.010	0.002	0.016	0.000	0.045	0.026	0.043	0.038	0.021
32	0.037	0.023	0.007	0.012	0.004	0.056	0.033	0.033	0.030	0.030
33	0.045	0.014	0.011	0.018	0.008	0.069	0.049	0.035	0.046	0.029
34	0.048	0.016	0.021	0.013	0.014	0.070	0.047	0.044	0.031	0.040
35	0.055	0.007	0.019	0.023	0.015	0.078	0.074	0.041	0.069	0.053
36	0.055	0.048	0.028	0.016	0.022	0.065	0.076	0.047	0.065	0.042
37	0.059	0.029	0.020	0.027	0.029	0.054	0.065	0.063	0.046	0.055
38	0.053	0.027	0.022	0.040	0.059	0.032	0.059	0.047	0.062	0.050
39	0.056	0.044	0.057	0.034	0.060	0.042	0.051	0.053	0.062	0.053
40	0.055	0.043	0.066	0.037	0.052	0.031	0.056	0.049	0.044	0.066
41	0.050	0.059	0.094	0.042	0.083	0.031	0.031	0.045	0.068	0.064
42	0.046	0.079	0.106	0.064	0.059	0.022	0.030	0.027	0.046	0.049
43	0.053	0.051	0.107	0.059	0.095	0.031	0.031	0.041	0.051	0.061
44	0.046	0.090	0.104	0.093	0.083	0.028	0.021	0.036	0.024	0.042
45	0.037	0.067	0.060	0.107	0.072	0.025	0.033	0.035	0.017	0.037
46	0.029	0.099	0.085	0.094	0.064	0.021	0.024	0.031	0.027	0.041
47	0.028	0.073	0.058	0.092	0.052	0.025	0.017	0.023	0.014	0.020
48	0.020	0.090	0.034	0.071	0.036	0.026	0.015	0.024	0.006	0.020
49	0.014	0.049	0.016	0.029	0.036	0.023	0.017	0.020	0.003	0.009
50+	0.057	0.076	0.071	0.082	0.155	0.130	0.115	0.085	0.075	0.048

Table 14.14. Fishery age compositions used in the model, from the NORPAC domestic Observer database.

	Year											
Age	2004	2005	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	0.001	0.000	0.000
4	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.005	0.004	0.004	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.006	0.025	0.033
6	0.000	0.000	0.000	0.007	0.000	0.005	0.003	0.000	0.000	0.010	0.027	0.033
7	0.000	0.000	0.004	0.000	0.000	0.005	0.001	0.000	0.006	0.025	0.030	0.034
8	0.000	0.000	0.000	0.004	0.019	0.016	0.004	0.000	0.006	0.031	0.056	0.048
9	0.003	0.000	0.013	0.052	0.056	0.021	0.000	0.010	0.012	0.068	0.109	0.074
10	0.000	0.000	0.003	0.014	0.179	0.015	0.030	0.008	0.006	0.028	0.036	0.085
11	0.001	0.000	0.000	0.008	0.174	0.031	0.041	0.008	0.018	0.046	0.027	0.066
12	0.000	0.005	0.011	0.140	0.055	0.028	0.062	0.058	0.013	0.068	0.053	0.042
13	0.000	0.000	0.007	0.021	0.010	0.076	0.101	0.083	0.018	0.043	0.068	0.050
14	0.000	0.000	0.000	0.028	0.000	0.031	0.191	0.127	0.072	0.073	0.076	0.054
15	0.000	0.009	0.000	0.022	0.022	0.009	0.092	0.063	0.155	0.076	0.072	0.072
16	0.012	0.003	0.000	0.000	0.000	0.007	0.069	0.140	0.110	0.089	0.049	0.074
17	0.000	0.007	0.010	0.004	0.005	0.000	0.030	0.125	0.109	0.100	0.058	0.063
18	0.013	0.006	0.000	0.007	0.004	0.000	0.005	0.088	0.124	0.106	0.049	0.038
19	0.011	0.018	0.006	0.000	0.018	0.027	0.015	0.044	0.113	0.058	0.059	0.034
20	0.021	0.048	0.008	0.006	0.010	0.023	0.004	0.028	0.071	0.046	0.044	0.050
21	0.038	0.025	0.012	0.032	0.010	0.000	0.035	0.018	0.037	0.019	0.020	0.028
22	0.034	0.051	0.000	0.026	0.017	0.000	0.023	0.009	0.029	0.009	0.035	0.016
23	0.072	0.051	0.039	0.056	0.029	0.039	0.026	0.000	0.021	0.007	0.007	0.020
24	0.065	0.029	0.027	0.000	0.024	0.038	0.018	0.014	0.007	0.005	0.008	0.012
25	0.044	0.159	0.102	0.019	0.042	0.038	0.035	0.007	0.004	0.000	0.018	0.006
26	0.052	0.056	0.025	0.060	0.020	0.027	0.032	0.008	0.006	0.007	0.008	0.011
27	0.050	0.070	0.063	0.022	0.055	0.037	0.011	0.013	0.000	0.000	0.008	0.005
28	0.062	0.028	0.079	0.021	0.029	0.047	0.030	0.020	0.000	0.007	0.006	0.006
29	0.055	0.016	0.054	0.040	0.031	0.035	0.009	0.013	0.005	0.003	0.004	0.003
30	0.069	0.052	0.046	0.027	0.034	0.028	0.009	0.007	0.006	0.004	0.003	0.006
31	0.012	0.014	0.054	0.028	0.038	0.039	0.007	0.015	0.000	0.007	0.003	0.008
32	0.027	0.012	0.033	0.042	0.033	0.014	0.014	0.003	0.006	0.001	0.004	0.002
33	0.022	0.027	0.010	0.081	0.005	0.018	0.011	0.007	0.006	0.000	0.004	0.001
34	0.017	0.023	0.034	0.021	0.013	0.057	0.018	0.011	0.000	0.010	0.000	0.002
35	0.050	0.000	0.056	0.016	0.007	0.022	0.010	0.000	0.002	0.000	0.009	0.001
36	0.010	0.000	0.008	0.000	0.006	0.012	0.003	0.000	0.006	0.005	0.001	0.003
37	0.037	0.022	0.007	0.009	0.000	0.029	0.001	0.000	0.006	0.004	0.000	0.001
38	0.004	0.016	0.032	0.028	0.009	0.031	0.007	0.005	0.001	0.000	0.001	0.003
39	0.000	0.016	0.016	0.017	0.006	0.005	0.000	0.008	0.000	0.002	0.003	0.000
40	0.006	0.009	0.007	0.019	0.005	0.033	0.007	0.000	0.000	0.002	0.001	0.003
41	0.024	0.018	0.008	0.012	0.003	0.032	0.005	0.000	0.000	0.000	0.000	0.000
42	0.050	0.055	0.017	0.020	0.000	0.017	0.002	0.011	0.000	0.003	0.001	0.001
43	0.016	0.000	0.018	0.023	0.000	0.013	0.005	0.000	0.000	0.002	0.000	0.001
44	0.020	0.005	0.015	0.000	0.000	0.007	0.000	0.002	0.003	0.001	0.001	0.000
45+	0.104	0.153	0.173	0.071	0.033	0.087	0.032	0.048	0.015	0.023	0.014	0.009

Table 14.15. Estimated biomass (t) of blackspotted/rougheye rockfish from the EBS slope survey and AI trawl survey (by management area), with the coefficient of variation (CV) shown in parentheses.

	Aleutian Islands Survey					
Year	Western	Central	Eastern	southern BS	Total AI survey	EBS slope survey
1980						
1983						
1986						
1991	3,037 (0.42)	2,380 (0.41)	5,221 (0.90)	676 (0.12)	11,314 (0.44)	
1994	2,908 (0.43)	3,470 (0.21)	7,037 (0.49)	1,208 (0.49)	14,623 (0.26)	
1997	3,373 (0.50)	4,607 (0.22)	2,925 (0.50)	561 (0.66)	11,466 (0.21)	
2000	661 (0.29)	9,333 (0.33)	4,224 (0.24)	1,054 (0.26)	15,271 (0.21)	
2002	1,390 (0.69)	3,934 (0.26)	3,099 (0.36)	1,251 (0.48)	9,674 (0.20)	553 (0.20)
2004	1,185 (0.54)	7,681 (0.37)	5,520 (0.44)	654 (0.31)	15,039 (0.25)	646 (0.16)
2006	519 (0.29)	4,959 (0.38)	2,803 (0.32)	1,224 (0.33)	9,506 (0.23)	
2008						829 (0.24)
2010	1,601 (0.44)	2,238 (0.24)	4,702 (0.44)	221 (0.28)	8,762 (0.26)	999 (0.25)
2012	335 (0.38)	8,268 (0.55)	3,798 (0.36)	405 (0.27)	12,807 (0.37)	1,594 (0.51)
2014	589 (0.28)	2,878 (0.27)	958 (0.30)	311 (0.20)	4,736 (0.18)	
2016	501 (0.34)	2,803 (0.35)	6,165 (0.37)	600 (0.35)	10,069 (0.25)	458 (0.27)
2018	632 (0.34)	2,438 (0.36)	6,535 (0.68)	328 (0.27)	9,843 (0.46)	
2022	1,793 (0.19)	3,053 (0.37)	10,834 (0.71)	643 (0.35)	15,680 (0.50)	

Table 14.16. Samples sizes of blackspotted/rougheye lengths from the Aleutian Island trawl survey, with the number of hauls from which these data were collected, from 1991-2022.

	Aleutian Islands		Eastern Bering Sea	
Year	Lengths	Hauls	Lengths	Hauls
1991	1060	35		
1994	2375	104		
1997	1817	121		
2000	1673	119		
2002	1288	98	119	30
2004	1522	117	225	49
2006	1260	109		
2008			213	43
2010	986	78	267	43
2012	1356	105	230	37
2014	1035	99		
2016	1574	105	162	21
2018	1209	104		
2022	2159	136		

Table 14.17. Number of sample and read otoliths of blackspotted/rougheye otoliths from the Aleutian Island and EBS slope trawl surveys, with the number of hauls from which these data were collected, from 1991-2022.

	Aleutian Islands survey			Eastern Bering Sea slope		
Year	Sampled	Read	Hauls	Sampled	Read	Hauls
1991	480	476	29			
1994	729	486	68			
1997	866	578	92			
2000	492	490	87			
2002	473	451	81	104	104	27
2004	475	472	97	217	216	48
2006	459	459	89			
2008				206	206	40
2010	491	482	76	262	130	36
2012	560	557	99	162	161	36
2014	441	441	82			
2016	329	323	97	150	150	21
2018	314	314	96			
2022	652					

Table 14.18. AI survey age compositions used in the model.

	Year											
Age	1991	1994	1997	2000	2002	2004	2006	2010	2012	2014	2016	2018
3	0.000	0.000	0.000	0.000	0.005	0.002	0.002	0.002	0.000	0.007	0.003	0.000
4	0.001	0.000	0.000	0.000	0.011	0.011	0.004	0.009	0.000	0.012	0.007	0.006
5	0.001	0.000	0.000	0.000	0.001	0.008	0.008	0.005	0.005	0.022	0.015	0.002
6	0.001	0.000	0.000	0.000	0.001	0.014	0.012	0.004	0.013	0.023	0.025	0.010
7	0.003	0.000	0.000	0.000	0.000	0.007	0.021	0.018	0.009	0.027	0.009	0.024
8	0.010	0.000	0.002	0.001	0.002	0.003	0.026	0.039	0.013	0.027	0.038	0.072
9	0.010	0.001	0.004	0.001	0.000	0.001	0.008	0.028	0.021	0.024	0.027	0.036
10	0.019	0.001	0.006	0.000	0.000	0.001	0.002	0.032	0.028	0.020	0.011	0.018
11	0.019	0.006	0.008	0.001	0.000	0.005	0.005	0.058	0.022	0.073	0.065	0.032
12	0.010	0.010	0.001	0.001	0.001	0.001	0.000	0.051	0.031	0.076	0.045	0.046
13	0.002	0.015	0.007	0.008	0.000	0.003	0.000	0.025	0.048	0.096	0.131	0.036
14	0.034	0.014	0.027	0.009	0.002	0.005	0.000	0.015	0.031	0.050	0.077	0.071
15	0.014	0.034	0.018	0.008	0.017	0.000	0.000	0.010	0.018	0.077	0.081	0.114
16	0.014	0.022	0.021	0.017	0.011	0.006	0.004	0.011	0.007	0.086	0.109	0.093
17	0.005	0.039	0.020	0.016	0.009	0.019	0.008	0.005	0.027	0.050	0.092	0.076
18	0.009	0.029	0.020	0.013	0.022	0.009	0.007	0.001	0.017	0.015	0.039	0.096
19	0.016	0.025	0.029	0.024	0.027	0.017	0.007	0.018	0.002	0.023	0.007	0.060
20	0.041	0.032	0.047	0.030	0.038	0.027	0.018	0.002	0.020	0.005	0.032	0.069
21	0.021	0.048	0.053	0.028	0.037	0.027	0.045	0.010	0.021	0.004	0.012	0.031
22	0.031	0.010	0.029	0.013	0.051	0.056	0.029	0.023	0.020	0.007	0.011	0.014
23	0.039	0.023	0.012	0.039	0.041	0.025	0.047	0.032	0.018	0.005	0.002	0.009
24	0.037	0.031	0.027	0.057	0.048	0.059	0.038	0.011	0.043	0.006	0.003	0.006
25	0.032	0.026	0.034	0.049	0.025	0.045	0.048	0.028	0.030	0.009	0.018	0.002
26	0.053	0.043	0.047	0.038	0.040	0.047	0.041	0.059	0.017	0.016	0.011	0.000
27	0.062	0.018	0.051	0.048	0.032	0.048	0.036	0.040	0.034	0.008	0.013	0.000
28	0.054	0.021	0.047	0.028	0.030	0.056	0.021	0.071	0.038	0.019	0.014	0.010
29	0.085	0.021	0.032	0.033	0.028	0.048	0.033	0.040	0.046	0.007	0.007	0.000
30	0.070	0.039	0.039	0.069	0.041	0.036	0.036	0.042	0.087	0.018	0.007	0.000
31	0.045	0.059	0.037	0.044	0.038	0.035	0.037	0.012	0.056	0.013	0.001	0.005
32	0.050	0.074	0.035	0.055	0.059	0.035	0.028	0.026	0.041	0.015	0.005	0.000
33	0.047	0.034	0.057	0.042	0.031	0.031	0.035	0.031	0.034	0.014	0.015	0.011
34	0.037	0.054	0.038	0.016	0.051	0.048	0.032	0.020	0.008	0.018	0.006	0.001
35	0.038	0.033	0.039	0.039	0.030	0.039	0.030	0.020	0.008	0.013	0.011	0.003
36	0.033	0.062	0.044	0.021	0.024	0.016	0.026	0.028	0.035	0.009	0.000	0.001
37	0.011	0.035	0.024	0.026	0.023	0.030	0.066	0.010	0.016	0.005	0.000	0.008
38	0.017	0.025	0.018	0.020	0.030	0.022	0.022	0.001	0.019	0.011	0.006	0.004
39	0.007	0.030	0.032	0.032	0.018	0.011	0.024	0.012	0.013	0.006	0.012	0.009
40	0.004	0.012	0.013	0.038	0.015	0.011	0.020	0.014	0.005	0.009	0.006	0.000
41	0.002	0.021	0.010	0.016	0.036	0.018	0.025	0.020	0.010	0.010	0.000	0.002
42	0.006	0.008	0.023	0.022	0.028	0.018	0.034	0.007	0.017	0.010	0.003	0.001
43	0.003	0.024	0.008	0.013	0.018	0.005	0.013	0.011	0.006	0.006	0.001	0.003
44	0.000	0.008	0.009	0.018	0.015	0.009	0.020	0.006	0.005	0.005	0.000	0.003
45+	0.005	0.016	0.029	0.065	0.067	0.085	0.080	0.093	0.061	0.046	0.024	0.018

Table 14.19. Predicted weight and proportion mature at age for BSAI rougheye rockfish.

Age	Predicted weight (g)	Proportion mature
3	55	0.003
4	81	0.004
5	112	0.006
6	147	0.007
7	188	0.010
8	232	0.013
9	280	0.016
10	331	0.021
11	384	0.027
12	440	0.035
13	497	0.046
14	556	0.059
15	615	0.075
16	675	0.095
17	735	0.121
18	795	0.152
19	854	0.189
20	913	0.232
21	970	0.283
22	1,027	0.339
23	1,082	0.400
24	1,137	0.465
25	1,189	0.531
26	1,240	0.596
27	1,290	0.657
28	1,338	0.714
29	1,384	0.765
30	1,429	0.809
31	1,472	0.846
32	1,513	0.878
33	1,553	0.903
34	1,591	0.924
35	1,627	0.940
36	1,662	0.954
37	1,695	0.964
38	1,727	0.972
39	1,757	0.978
40	1,786	0.983
41	1,814	0.987
42	1,840	0.990
43	1,865	0.992
44	1,888	0.994
45+	2,007	0.998

Table 14.20. Negative log likelihoods, effective sample sizes, and root mean squared errors, for the evaluated models for BSAI blackspotted/rougheye rockfish.

	20 (2022)	22
Negative log-likelihood		
Data components		
AI survey biomass	13.40	18.59
Catch biomass	0.00	0.00
Fishery ages	30.16	31.61
Fishery lengths	85.95	257.99
AI survey ages	47.39	37.30
AI survey lengths	6.02	4.29
Maturity	1.39	1.39
Priors and penalties		
Recruitment	-4.15	5.33
Prior on survey q	0.36	0.57
Prior on M	2.30	3.26
Total negative log-likelihood	188.68	384.86
Parameters	142	165
Effective sample size		
Fishery ages	45	42
Fishery lengths	168	256
AI survey ages	70	79
AI survey lengths	63	51
Root mean square error		
AI survey biomass	0.343	0.394
Recruitment	0.730	0.746
Fishery ages	0.022	0.024
Fishery lengths	0.016	0.014
AI survey ages	0.017	0.018
AI survey lengths	0.016	0.014

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Table 14.21. Key parameter estimates and management quantities for the evaluated models for the AI portion of BSAI blackspotted/rougheye. Model 20 (2022) uses time-invariant fishery selectivity, whereas model 22 uses time-varying fishery selectivity modeled with a bicubic spline.

	20 (2022)	22
Key parameters and management quantities		
AI Survey catchability	1.04	1.05
CV	0.05	0.05
2022 total biomass (t)	23,221	24,752
CV	0.23	0.26
2022 Spawning stock biomass (t)	3,335	3,901
CV	0.53	0.51
2010 year class (millions)	21.25	23.39
CV	0.58	0.63
$F_{40\%}$	0.034	0.038
$SB_{40\%}$ (t)	3,493	3,535
$SB_{2022}/SB_{40\%}$	0.95	1.10
2023 max ABC (AI portion)	533	510

Table 14.22. Estimated parameter values and standard deviations from the age-structure model applied to AI blackspotted/rougheye rockfish.

Parameter	Estimate	Standard Deviation	Parameter	Estimate	Standard Deviation	Parameter	Estimate	Standard Deviation
sel_aslope_fish	0.69	0.09	fmort_dev	0.16	0.14	mean_log	0.36	0.15
sel_a50_fish	13.50	0.57	fmort_dev	0.44	0.15	log_rinit	0.34	0.11
sel_aslope_ai_srv	0.33	0.05	fmort_dev	0.24	0.16	fydev	-0.04	0.70
sel_a50_ai_srv	16.18	1.24	fmort_dev	-0.13	0.17	fydev	0.02	0.72
M	0.05	0.00	rec_dev	-0.10	0.68	fydev	0.09	0.75
log_avg_fmort	-3.74	0.09	rec_dev	-0.14	0.67	fydev	0.14	0.77
fmort_dev	-0.92	0.13	rec_dev	-0.18	0.66	fydev	0.20	0.80
fmort_dev	1.87	0.13	rec_dev	-0.22	0.65	fydev	0.25	0.82
fmort_dev	2.25	0.13	rec_dev	-0.23	0.65	fydev	0.30	0.85
fmort_dev	0.81	0.13	rec_dev	-0.21	0.65	fydev	0.35	0.88
fmort_dev	0.72	0.13	rec_dev	-0.17	0.65	fydev	0.39	0.91
fmort_dev	-0.43	0.13	rec_dev	-0.16	0.65	fydev	0.48	0.97
fmort_dev	-1.64	0.12	rec_dev	-0.20	0.64	fydev	0.48	0.98
fmort_dev	-2.17	0.12	rec_dev	-0.32	0.62	fydev	0.53	1.02
fmort_dev	-3.45	0.12	rec_dev	-0.47	0.59	fydev	0.43	0.95
fmort_dev	-2.73	0.12	rec_dev	-0.62	0.57	fydev	0.37	0.91
fmort_dev	-1.43	0.12	rec_dev	-0.75	0.55	fydev	0.27	0.85
fmort_dev	-1.50	0.12	rec_dev	-0.87	0.53	fydev	0.25	0.84
fmort_dev	0.12	0.11	rec_dev	-0.95	0.52	fydev	0.15	0.80
fmort_dev	1.61	0.11	rec_dev	-0.99	0.52	fydev	0.20	0.82
fmort_dev	-0.80	0.11	rec_dev	-0.98	0.52	fydev	0.11	0.78
fmort_dev	1.38	0.11	rec_dev	-0.91	0.53	fydev	0.05	0.75
fmort_dev	1.20	0.11	rec_dev	-0.80	0.54	fydev	-0.01	0.73
fmort_dev	1.04	0.11	rec_dev	-0.65	0.56	fydev	-0.05	0.72
fmort_dev	0.44	0.11	rec_dev	-0.47	0.59	fydev	-0.09	0.71
fmort_dev	1.20	0.10	rec_dev	-0.25	0.62	fydev	-0.11	0.70
fmort_dev	1.43	0.10	rec_dev	-0.05	0.67	fydev	-0.12	0.70
fmort_dev	0.89	0.10	rec_dev	0.19	0.75	fydev	-0.14	0.69
fmort_dev	0.61	0.10	rec_dev	0.58	0.81	fydev	-0.16	0.69
fmort_dev	0.32	0.10	rec_dev	0.50	0.86	fydev	-0.17	0.68
fmort_dev	1.04	0.10	rec_dev	0.48	0.86	fydev	-0.18	0.68
fmort_dev	0.38	0.10	rec_dev	0.51	0.94	fydev	-0.19	0.68
fmort_dev	-0.06	0.10	rec_dev	0.87	0.97	fydev	-0.20	0.67
fmort_dev	0.02	0.11	rec_dev	0.50	0.93	fydev	-0.21	0.67
fmort_dev	-0.84	0.11	rec_dev	0.30	0.82	fydev	-0.22	0.67
fmort_dev	0.09	0.11	rec_dev	0.35	0.83	fydev	-0.22	0.67
fmort_dev	-0.13	0.11	rec_dev	0.53	0.86	fydev	-0.23	0.67
fmort_dev	-0.05	0.11	rec_dev	0.48	0.88	fydev	-0.22	0.67
fmort_dev	0.01	0.11	rec_dev	0.35	0.86	fydev	-0.22	0.67
fmort_dev	0.07	0.11	rec_dev	0.21	0.83	fydev	-0.22	0.67
fmort_dev	-0.39	0.11	rec_dev	2.69	0.56	fydev	-0.22	0.67
fmort_dev	-0.11	0.11	rec_dev	0.33	0.90	fydev	-0.21	0.67
fmort_dev	0.36	0.12	rec_dev	0.46	0.92	fydev	-0.21	0.67
fmort_dev	-0.22	0.12	rec_dev	0.45	0.89	fydev	-1.38	0.47
fmort_dev	-0.40	0.12	rec_dev	0.42	0.87	q_srv[1]	1.04	0.05
fmort_dev	-0.74	0.13	rec_dev	0.33	0.83	mat_beta:	-6.47	5.49
fmort_dev	-0.34	0.13	rec_dev	0.18	0.78	mat_beta:	0.26	0.23
fmort_dev	-0.19	0.14						

Table 14.23. Estimated time series of AI blackspotted/rougheye total biomass (t), spawner biomass (t), and recruitment (thousands), and their CVs (from the Hessian approximation).

	Total Biomass (ages 3+)				Spawner Biomass (ages 3+)				Recruitment (age 3)			
	Assessment Year				Assessment Year				Assessment Year			
	2022		2020		2022		2020		2022		2020	
Year or Year Class	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
1977	20,807	0.068	20,954	0.073	4,974	0.334	5,393	0.310	1,158	0.656	1,283	0.722
1978	21,060	0.065	21,173	0.070	4,968	0.334	5,357	0.308	1,144	0.651	1,286	0.719
1979	18,971	0.070	19,067	0.075	4,360	0.339	4,684	0.312	1,164	0.650	1,324	0.722
1980	16,206	0.078	16,299	0.084	3,716	0.347	3,977	0.319	1,210	0.652	1,380	0.726
1981	15,902	0.077	16,001	0.083	3,653	0.350	3,885	0.322	1,227	0.649	1,379	0.718
1982	15,652	0.077	15,767	0.082	3,626	0.352	3,831	0.324	1,178	0.637	1,280	0.696
1983	15,805	0.074	15,944	0.080	3,708	0.353	3,891	0.325	1,040	0.617	1,103	0.663
1984	16,079	0.072	16,248	0.076	3,827	0.354	3,990	0.326	896	0.596	935	0.631
1985	16,359	0.069	16,563	0.073	3,958	0.353	4,101	0.326	773	0.575	799	0.604
1986	16,642	0.066	16,885	0.070	4,099	0.352	4,223	0.326	677	0.557	694	0.582
1987	16,890	0.064	17,175	0.068	4,240	0.349	4,346	0.326	604	0.545	614	0.567
1988	17,051	0.062	17,380	0.066	4,368	0.346	4,457	0.325	554	0.538	557	0.556
1989	17,185	0.060	17,559	0.064	4,482	0.342	4,557	0.324	533	0.536	526	0.552
1990	16,979	0.060	17,398	0.064	4,444	0.337	4,510	0.323	539	0.539	520	0.553
1991	15,495	0.064	15,960	0.068	4,154	0.333	4,215	0.322	576	0.547	539	0.559
1992	15,497	0.063	16,003	0.067	4,181	0.327	4,241	0.319	645	0.561	585	0.570
1993	14,419	0.067	14,964	0.071	3,932	0.321	4,000	0.317	749	0.580	658	0.586
1994	13,592	0.070	14,171	0.075	3,748	0.315	3,825	0.314	902	0.604	777	0.610
1995	12,935	0.073	13,542	0.078	3,618	0.308	3,707	0.311	1,124	0.636	969	0.644
1996	12,634	0.075	13,262	0.080	3,551	0.302	3,654	0.306	1,369	0.679	1,243	0.701
1997	11,907	0.079	12,550	0.084	3,351	0.296	3,473	0.303	1,739	0.757	1,740	0.831
1998	11,054	0.085	11,702	0.091	3,128	0.292	3,271	0.301	2,571	0.814	2,909	0.896
1999	10,663	0.089	11,310	0.095	3,024	0.288	3,183	0.298	2,362	0.879	2,253	0.999
2000	10,452	0.093	11,098	0.098	2,959	0.284	3,135	0.295	2,335	0.882	2,139	0.960
2001	10,419	0.096	11,080	0.102	2,903	0.281	3,096	0.293	2,385	0.961	2,225	1.101
2002	10,141	0.102	10,798	0.108	2,782	0.279	2,991	0.291	3,435	0.974	4,258	1.095
2003	10,194	0.106	10,838	0.112	2,742	0.277	2,966	0.289	2,360	0.951	2,126	1.057
2004	10,397	0.109	11,024	0.115	2,728	0.276	2,965	0.287	1,937	0.839	1,813	0.885
2005	10,692	0.113	11,353	0.120	2,715	0.274	2,965	0.284	2,047	0.847	1,869	0.873
2006	11,105	0.115	11,760	0.124	2,726	0.272	2,986	0.281	2,432	0.883	2,013	0.895
2007	11,417	0.120	12,069	0.128	2,703	0.271	2,973	0.278	2,330	0.898	1,976	0.904
2008	11,809	0.124	12,453	0.133	2,692	0.271	2,969	0.275	2,040	0.888	1,999	0.926
2009	12,239	0.128	12,860	0.138	2,677	0.272	2,959	0.273	1,773	0.863	2,109	0.951
2010	12,686	0.133	13,278	0.144	2,662	0.275	2,946	0.273	21,247	0.584	2,185	0.941
2011	13,127	0.137	13,702	0.149	2,650	0.282	2,935	0.275	1,994	0.930	1,706	0.849
2012	13,645	0.141	14,225	0.153	2,661	0.292	2,948	0.281	2,277	0.944	1,439	0.799
2013	15,189	0.156	14,718	0.158	2,665	0.307	2,950	0.291	2,244	0.915	1,353	0.779
2014	15,982	0.166	15,075	0.164	2,656	0.328	2,937	0.307	2,199	0.899	1,317	0.776
2015	16,968	0.175	15,543	0.168	2,692	0.352	2,969	0.326	1,992	0.862		
2016	17,998	0.183	16,023	0.172	2,751	0.379	3,022	0.348	1,725	0.813		
2017	19,112	0.190	16,518	0.175	2,834	0.407	3,097	0.371				
2018	20,132	0.198	16,963	0.179	2,922	0.435	3,177	0.395				
2019	21,089	0.206	17,339	0.183	3,019	0.461	3,261	0.417				
2020	21,908	0.214	17,584	0.188	3,111	0.486	3,337	0.437				
2021	22,547	0.222	17,632		3,203	0.509	3,372					
2022	23,221	0.229			3,335	0.527						
2023	23,883				3,472							
Mean recruitment of post-1976 year classes									2,037		1,470	

Table 14.24. Estimated numbers at age for BSAI blackspotted/rougheye rockfish (millions).

	Age																			
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1977	1.31	1.29	1.30	1.32	1.33	1.34	1.34	1.33	1.33	1.32	1.37	1.31	1.31	1.13	1.01	0.87	0.81	0.70	0.70	0.61
1978	1.24	1.24	1.22	1.24	1.25	1.27	1.27	1.27	1.27	1.27	1.25	1.30	1.24	1.24	1.07	0.95	0.82	0.77	0.66	0.66
1979	1.20	1.18	1.18	1.16	1.17	1.19	1.20	1.20	1.19	1.18	1.16	1.12	1.13	1.05	1.03	0.88	0.78	0.67	0.63	0.54
1980	1.16	1.14	1.13	1.12	1.11	1.11	1.13	1.13	1.12	1.10	1.06	1.00	0.93	0.91	0.83	0.80	0.68	0.60	0.51	0.48
1981	1.14	1.10	1.08	1.07	1.07	1.05	1.06	1.07	1.07	1.06	1.03	0.98	0.92	0.85	0.83	0.75	0.72	0.61	0.54	0.46
1982	1.16	1.09	1.05	1.03	1.02	1.02	1.00	1.00	1.01	1.01	1.00	0.96	0.91	0.85	0.78	0.75	0.68	0.66	0.55	0.49
1983	1.21	1.11	1.04	1.00	0.98	0.97	0.97	0.95	0.95	0.96	0.96	0.94	0.90	0.85	0.80	0.73	0.71	0.64	0.61	0.52
1984	1.23	1.15	1.05	0.98	0.95	0.93	0.92	0.92	0.90	0.91	0.91	0.91	0.89	0.86	0.81	0.75	0.69	0.67	0.60	0.58
1985	1.18	1.17	1.09	1.00	0.94	0.90	0.88	0.88	0.87	0.86	0.86	0.87	0.86	0.85	0.81	0.77	0.72	0.66	0.63	0.57
1986	1.04	1.12	1.11	1.04	0.95	0.89	0.86	0.84	0.83	0.83	0.82	0.82	0.83	0.82	0.81	0.77	0.73	0.68	0.62	0.60
1987	0.90	0.99	1.07	1.06	0.99	0.91	0.85	0.82	0.80	0.79	0.79	0.78	0.78	0.78	0.78	0.77	0.73	0.69	0.65	0.59
1988	0.77	0.85	0.94	1.01	1.00	0.94	0.86	0.81	0.78	0.76	0.75	0.75	0.74	0.74	0.74	0.74	0.72	0.69	0.66	0.61
1989	0.68	0.74	0.81	0.89	0.96	0.96	0.90	0.82	0.77	0.74	0.72	0.71	0.71	0.70	0.70	0.70	0.70	0.69	0.66	0.62
1990	0.60	0.64	0.70	0.77	0.85	0.92	0.91	0.85	0.78	0.73	0.70	0.68	0.67	0.66	0.65	0.65	0.65	0.65	0.64	0.61
1991	0.55	0.57	0.61	0.67	0.73	0.81	0.87	0.86	0.80	0.73	0.67	0.63	0.60	0.58	0.57	0.55	0.55	0.55	0.55	0.54
1992	0.53	0.53	0.55	0.58	0.63	0.70	0.77	0.83	0.82	0.76	0.69	0.63	0.60	0.57	0.55	0.54	0.52	0.52	0.52	0.52
1993	0.54	0.51	0.50	0.52	0.55	0.60	0.66	0.73	0.78	0.77	0.71	0.63	0.57	0.53	0.50	0.48	0.47	0.45	0.45	0.45
1994	0.58	0.51	0.48	0.48	0.49	0.53	0.57	0.63	0.69	0.73	0.71	0.65	0.57	0.51	0.47	0.44	0.42	0.41	0.40	0.40
1995	0.65	0.55	0.49	0.46	0.45	0.47	0.50	0.54	0.59	0.65	0.69	0.66	0.60	0.52	0.46	0.42	0.40	0.38	0.37	0.35
1996	0.75	0.61	0.52	0.46	0.44	0.43	0.45	0.47	0.51	0.56	0.61	0.64	0.61	0.55	0.48	0.42	0.39	0.36	0.35	0.34
1997	0.90	0.71	0.58	0.50	0.44	0.41	0.41	0.42	0.45	0.48	0.52	0.56	0.58	0.55	0.49	0.42	0.37	0.34	0.32	0.30
1998	1.12	0.86	0.68	0.56	0.47	0.42	0.39	0.39	0.40	0.42	0.45	0.48	0.50	0.52	0.48	0.43	0.37	0.32	0.29	0.28
1999	1.37	1.07	0.82	0.64	0.53	0.45	0.40	0.37	0.37	0.38	0.39	0.42	0.44	0.46	0.47	0.44	0.38	0.33	0.29	0.26
2000	1.74	1.30	1.02	0.78	0.61	0.50	0.43	0.38	0.35	0.35	0.35	0.37	0.39	0.40	0.42	0.43	0.40	0.35	0.30	0.26
2001	2.57	1.65	1.24	0.97	0.74	0.58	0.48	0.40	0.36	0.33	0.33	0.33	0.34	0.36	0.37	0.39	0.39	0.37	0.32	0.28
2002	2.36	2.45	1.57	1.18	0.92	0.70	0.55	0.45	0.38	0.34	0.31	0.30	0.30	0.31	0.32	0.33	0.35	0.35	0.33	0.29
2003	2.33	2.25	2.33	1.50	1.12	0.87	0.67	0.53	0.43	0.36	0.32	0.29	0.28	0.28	0.29	0.30	0.31	0.32	0.32	0.30
2004	2.39	2.22	2.14	2.21	1.42	1.07	0.83	0.63	0.50	0.41	0.34	0.30	0.28	0.26	0.26	0.27	0.28	0.29	0.30	0.30
2005	3.43	2.27	2.11	2.03	2.10	1.35	1.01	0.79	0.60	0.47	0.38	0.32	0.28	0.26	0.25	0.24	0.25	0.26	0.27	0.28
2006	2.36	3.27	2.16	2.01	1.93	2.00	1.29	0.96	0.75	0.57	0.45	0.36	0.30	0.27	0.24	0.23	0.23	0.23	0.24	0.25
2007	1.94	2.24	3.11	2.05	1.91	1.84	1.90	1.22	0.91	0.71	0.54	0.42	0.34	0.28	0.25	0.23	0.22	0.21	0.22	0.22
2008	2.05	1.84	2.14	2.96	1.95	1.82	1.75	1.81	1.16	0.87	0.67	0.51	0.40	0.32	0.27	0.23	0.21	0.20	0.20	0.20
2009	2.43	1.95	1.75	2.03	2.81	1.86	1.73	1.66	1.72	1.10	0.82	0.63	0.48	0.37	0.30	0.25	0.21	0.20	0.19	0.19
2010	2.33	2.31	1.85	1.67	1.93	2.67	1.76	1.64	1.58	1.63	1.04	0.77	0.59	0.45	0.35	0.28	0.23	0.20	0.18	0.17
2011	2.04	2.22	2.20	1.76	1.59	1.84	2.54	1.68	1.56	1.49	1.54	0.98	0.72	0.56	0.42	0.32	0.26	0.21	0.19	0.17
2012	1.77	1.94	2.11	2.09	1.68	1.51	1.75	2.42	1.59	1.48	1.41	1.45	0.92	0.68	0.52	0.39	0.30	0.24	0.20	0.17
2013	21.25	1.69	1.85	2.00	1.99	1.59	1.43	1.66	2.29	1.51	1.40	1.33	1.36	0.86	0.64	0.49	0.36	0.28	0.22	0.19
2014	1.99	20.21	1.60	1.76	1.91	1.89	1.51	1.36	1.57	2.17	1.42	1.31	1.24	1.27	0.80	0.59	0.45	0.33	0.26	0.21
2015	2.28	1.90	19.22	1.53	1.67	1.81	1.80	1.44	1.29	1.49	2.05	1.34	1.23	1.17	1.19	0.75	0.55	0.42	0.31	0.24
2016	2.24	2.17	1.80	18.28	1.45	1.59	1.72	1.71	1.37	1.23	1.41	1.94	1.27	1.16	1.10	1.11	0.70	0.51	0.39	0.29
2017	2.20	2.13	2.06	1.72	17.39	1.38	1.51	1.64	1.63	1.30	1.16	1.34	1.83	1.19	1.09	1.03	1.05	0.66	0.48	0.37
2018	1.99	2.09	2.03	1.96	1.63	16.54	1.31	1.44	1.56	1.54	1.23	1.10	1.26	1.72	1.12	1.02	0.97	0.98	0.62	0.45
2019	1.72	1.89	1.99	1.93	1.86	1.55	15.72	1.25	1.36	1.48	1.46	1.16	1.03	1.18	1.61	1.05	0.96	0.90	0.91	0.57
2020	1.90	1.64	1.80	1.89	1.84	1.77	1.48	14.94	1.18	1.29	1.39	1.37	1.09	0.96	1.10	1.50	0.97	0.88	0.83	0.84
2021	1.90	1.81	1.56	1.71	1.80	1.75	1.68	1.40	14.17	1.12	1.22	1.31	1.28	1.01	0.89	1.01	1.37	0.89	0.81	0.76
2022	1.90	1.81	1.72	1.48	1.63	1.71	1.66	1.60	1.33	13.41	1.06	1.14	1.22	1.19	0.93	0.82	0.93	1.27	0.82	0.75

Table 14.24 (continued). Estimated numbers at age for BSAI blackspotted/rougheye rockfish (millions).

	Age																						
Year	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45+
1977	0.54	0.49	0.44	0.41	0.38	0.36	0.33	0.31	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.19	0.19	0.18	0.17	0.16	0.15	0.15	0.89
1978	0.57	0.51	0.46	0.42	0.38	0.36	0.34	0.31	0.29	0.28	0.26	0.24	0.23	0.22	0.20	0.19	0.18	0.18	0.17	0.16	0.15	0.14	0.97
1979	0.54	0.47	0.42	0.37	0.34	0.31	0.29	0.27	0.26	0.24	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.91
1980	0.41	0.41	0.36	0.32	0.28	0.26	0.24	0.22	0.21	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.79
1981	0.43	0.37	0.37	0.32	0.29	0.26	0.23	0.21	0.20	0.19	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.80
1982	0.42	0.39	0.34	0.33	0.29	0.26	0.23	0.21	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.81
1983	0.46	0.39	0.36	0.31	0.31	0.27	0.24	0.22	0.20	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.84
1984	0.49	0.43	0.37	0.35	0.30	0.30	0.26	0.23	0.21	0.19	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.88
1985	0.55	0.47	0.41	0.35	0.33	0.28	0.28	0.24	0.22	0.20	0.18	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.91
1986	0.54	0.52	0.44	0.39	0.34	0.31	0.27	0.27	0.23	0.21	0.19	0.17	0.16	0.14	0.14	0.13	0.12	0.11	0.10	0.10	0.09	0.09	0.95
1987	0.57	0.52	0.50	0.42	0.37	0.32	0.30	0.25	0.25	0.22	0.20	0.18	0.16	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.99
1988	0.56	0.54	0.49	0.47	0.40	0.35	0.30	0.28	0.24	0.24	0.21	0.19	0.17	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.09	0.09	1.02
1989	0.58	0.53	0.51	0.46	0.45	0.38	0.33	0.29	0.26	0.23	0.23	0.20	0.18	0.16	0.14	0.13	0.12	0.12	0.11	0.10	0.09	0.09	1.05
1990	0.58	0.54	0.49	0.48	0.43	0.41	0.35	0.31	0.26	0.24	0.21	0.21	0.18	0.16	0.15	0.13	0.12	0.11	0.11	0.10	0.09	0.09	1.05
1991	0.51	0.49	0.45	0.41	0.40	0.36	0.35	0.29	0.26	0.22	0.21	0.18	0.18	0.15	0.14	0.12	0.11	0.10	0.10	0.09	0.08	0.08	0.96
1992	0.51	0.48	0.46	0.43	0.39	0.38	0.34	0.33	0.28	0.24	0.21	0.19	0.17	0.17	0.15	0.13	0.12	0.11	0.10	0.09	0.09	0.08	0.98
1993	0.45	0.44	0.42	0.40	0.37	0.34	0.33	0.30	0.28	0.24	0.21	0.18	0.17	0.15	0.14	0.13	0.11	0.10	0.09	0.08	0.08	0.07	0.92
1994	0.40	0.39	0.38	0.37	0.35	0.32	0.30	0.29	0.26	0.25	0.21	0.19	0.16	0.15	0.13	0.13	0.11	0.10	0.09	0.08	0.07	0.07	0.87
1995	0.35	0.35	0.35	0.34	0.33	0.31	0.29	0.26	0.26	0.23	0.22	0.19	0.17	0.14	0.13	0.11	0.11	0.10	0.09	0.08	0.07	0.07	0.84
1996	0.32	0.32	0.32	0.32	0.31	0.30	0.28	0.26	0.24	0.23	0.21	0.20	0.17	0.15	0.13	0.12	0.10	0.10	0.09	0.08	0.07	0.07	0.83
1997	0.30	0.29	0.28	0.28	0.28	0.28	0.26	0.25	0.23	0.21	0.21	0.19	0.18	0.15	0.13	0.11	0.11	0.09	0.09	0.08	0.07	0.06	0.79
1998	0.26	0.25	0.25	0.24	0.24	0.24	0.24	0.23	0.22	0.20	0.18	0.18	0.16	0.15	0.13	0.12	0.10	0.09	0.08	0.08	0.07	0.06	0.73
1999	0.25	0.24	0.23	0.22	0.22	0.22	0.22	0.21	0.20	0.19	0.18	0.16	0.16	0.14	0.14	0.12	0.10	0.09	0.08	0.07	0.07	0.06	0.71
2000	0.24	0.23	0.21	0.21	0.20	0.20	0.20	0.20	0.19	0.19	0.18	0.16	0.15	0.15	0.13	0.13	0.11	0.09	0.08	0.08	0.06	0.06	0.70
2001	0.24	0.22	0.21	0.20	0.19	0.19	0.18	0.18	0.18	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.10	0.09	0.07	0.07	0.06	0.71
2002	0.25	0.22	0.20	0.18	0.18	0.17	0.16	0.16	0.16	0.16	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.09	0.08	0.07	0.06	0.68
2003	0.26	0.23	0.20	0.18	0.17	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.10	0.08	0.07	0.06	0.68
2004	0.28	0.25	0.21	0.19	0.17	0.16	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.07	0.07	0.69
2005	0.28	0.26	0.23	0.20	0.17	0.16	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.07	0.70
2006	0.26	0.26	0.24	0.21	0.18	0.16	0.15	0.14	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.08	0.73
2007	0.23	0.24	0.24	0.23	0.20	0.17	0.15	0.14	0.13	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.09	0.09	0.08	0.07	0.75
2008	0.21	0.22	0.22	0.23	0.21	0.19	0.16	0.14	0.13	0.12	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.08	0.08	0.77
2009	0.19	0.19	0.20	0.21	0.21	0.20	0.17	0.15	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.08	0.07	0.78
2010	0.17	0.18	0.18	0.19	0.19	0.20	0.18	0.16	0.14	0.12	0.11	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.07	0.80
2011	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.17	0.15	0.13	0.11	0.10	0.10	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.81
2012	0.16	0.15	0.15	0.15	0.16	0.16	0.17	0.17	0.16	0.14	0.12	0.10	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.83
2013	0.16	0.15	0.14	0.14	0.14	0.15	0.15	0.16	0.16	0.15	0.13	0.11	0.10	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.84
2014	0.17	0.15	0.14	0.13	0.13	0.13	0.13	0.14	0.14	0.15	0.14	0.12	0.10	0.09	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.84
2015	0.19	0.16	0.14	0.13	0.12	0.12	0.12	0.12	0.13	0.13	0.14	0.13	0.11	0.10	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.84
2016	0.23	0.18	0.15	0.13	0.12	0.11	0.11	0.11	0.12	0.12	0.13	0.13	0.12	0.10	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.85
2017	0.28	0.21	0.17	0.14	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.11	0.10	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.86
2018	0.34	0.26	0.20	0.16	0.13	0.11	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.10	0.09	0.08	0.07	0.06	0.06	0.06	0.05	0.85
2019	0.42	0.32	0.24	0.19	0.15	0.12	0.11	0.10	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.09	0.07	0.06	0.06	0.05	0.05	0.85
2020	0.53	0.39	0.30	0.22	0.17	0.14	0.11	0.10	0.09	0.09	0.08	0.09	0.09	0.09	0.10	0.10	0.09	0.08	0.07	0.06	0.05	0.05	0.83
2021	0.77	0.49	0.36	0.27	0.20	0.16	0.13	0.10	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.08	0.07	0.06	0.05	0.05	0.81
2022	0.71	0.71	0.45	0.33	0.25	0.19	0.15	0.12	0.10	0.08	0.08	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.07	0.06	0.05	0.79

Table 14.25. Projections of blackspotted/rougheye rockfish spawning biomass (t), catch (t), and fishing mortality rate for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 3,493 t and 3,056 t, respectively.

Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2022	305	305	305	305	305	305	305
2023	533	533	414	150	0	626	533
2024	581	581	451	165	0	679	581
2025	621	621	485	180	0	722	729
2026	652	652	512	193	0	754	761
2027	672	672	531	203	0	774	781
2028	684	684	544	211	0	784	791
2029	690	690	552	217	0	786	793
2030	691	691	557	222	0	784	790
2031	689	689	559	225	0	778	784
2032	685	685	559	228	0	770	775
2033	679	679	557	231	0	760	765
2034	671	671	554	232	0	748	753
2035	662	662	549	233	0	735	739
Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2022	3,335	3,335	3,335	3,335	3,335	3,335	3,335
2023	3,467	3,467	3,471	3,481	3,486	3,464	3,467
2024	3,616	3,616	3,647	3,715	3,754	3,592	3,616
2025	3,778	3,778	3,839	3,973	4,050	3,732	3,774
2026	3,952	3,952	4,045	4,252	4,374	3,882	3,925
2027	4,136	4,136	4,265	4,553	4,724	4,040	4,084
2028	4,329	4,329	4,496	4,875	5,102	4,205	4,250
2029	4,529	4,529	4,738	5,216	5,506	4,375	4,421
2030	4,734	4,734	4,988	5,575	5,935	4,549	4,596
2031	4,941	4,941	5,242	5,948	6,385	4,722	4,769
2032	5,146	5,146	5,498	6,331	6,854	4,892	4,939
2033	5,342	5,342	5,747	6,715	7,330	5,053	5,100
2034	5,526	5,526	5,985	7,096	7,809	5,200	5,246
2035	5,687	5,687	6,201	7,458	8,275	5,324	5,371
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2022	0.021	0.021	0.021	0.021	0.021	0.021	0.021
2023	0.034	0.034	0.026	0.009	0	0.040	0.034
2024	0.034	0.034	0.026	0.009	0	0.040	0.034
2025	0.034	0.034	0.026	0.009	0	0.040	0.040
2026	0.034	0.034	0.026	0.009	0	0.040	0.040
2027	0.034	0.034	0.026	0.009	0	0.040	0.040
2028	0.034	0.034	0.026	0.009	0	0.040	0.040
2029	0.034	0.034	0.026	0.009	0	0.040	0.040
2030	0.034	0.034	0.026	0.009	0	0.040	0.040
2031	0.034	0.034	0.026	0.009	0	0.040	0.040
2032	0.034	0.034	0.026	0.009	0	0.040	0.040
2033	0.034	0.034	0.026	0.009	0	0.040	0.040
2034	0.034	0.034	0.026	0.009	0	0.040	0.040
2035	0.034	0.034	0.026	0.009	0	0.040	0.040

Figures

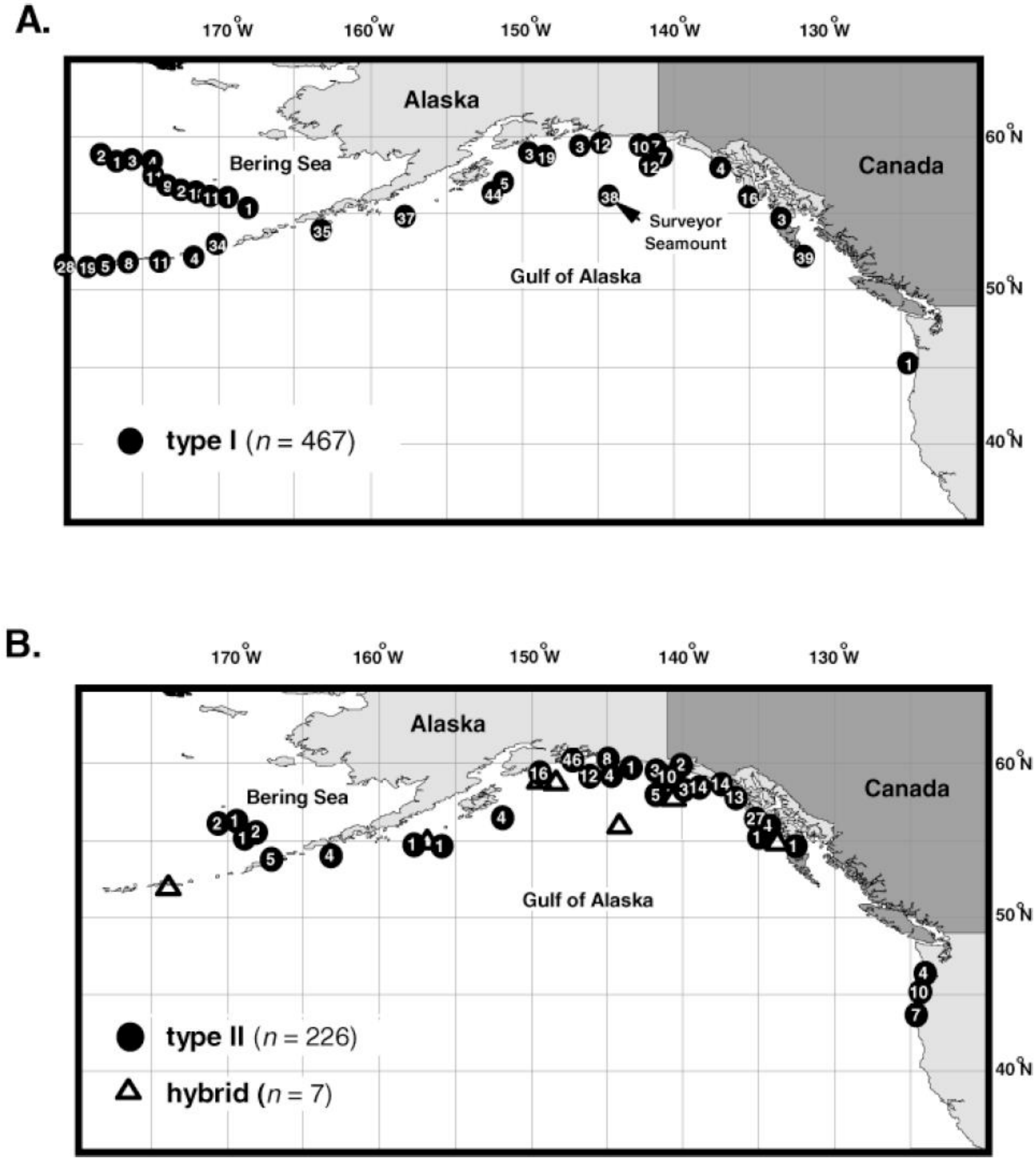


Figure 14.1. Distribution type I (i.e., blackspotted rockfish, *S. melanostictus*) and type II (i.e., rougheye rockfish, *S. aleutianus*) fish previously thought to be a single species of rougheye rockfish, based mtDNA and microsatellite genetic analyses. From Gharrett et al. (2005).

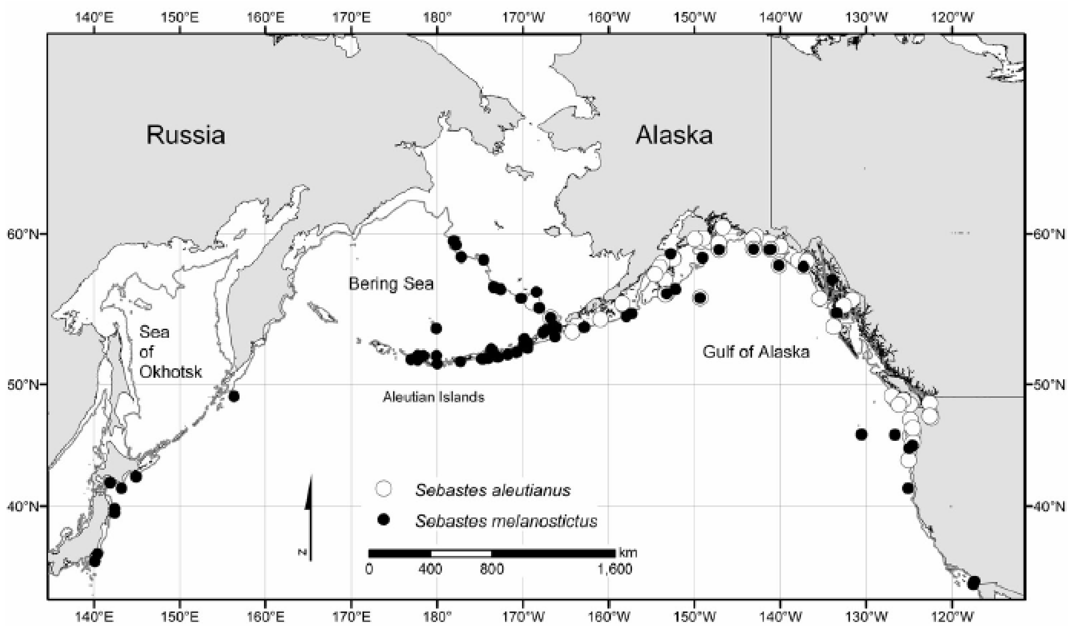


Figure 14.2. Distribution blackspotted rockfish (*S. melanostictus*) and rougheye rockfish (*S. aleutianus*) based upon genetic, morphometric, and meristic analyses. From Orr and Hawkins (2008).

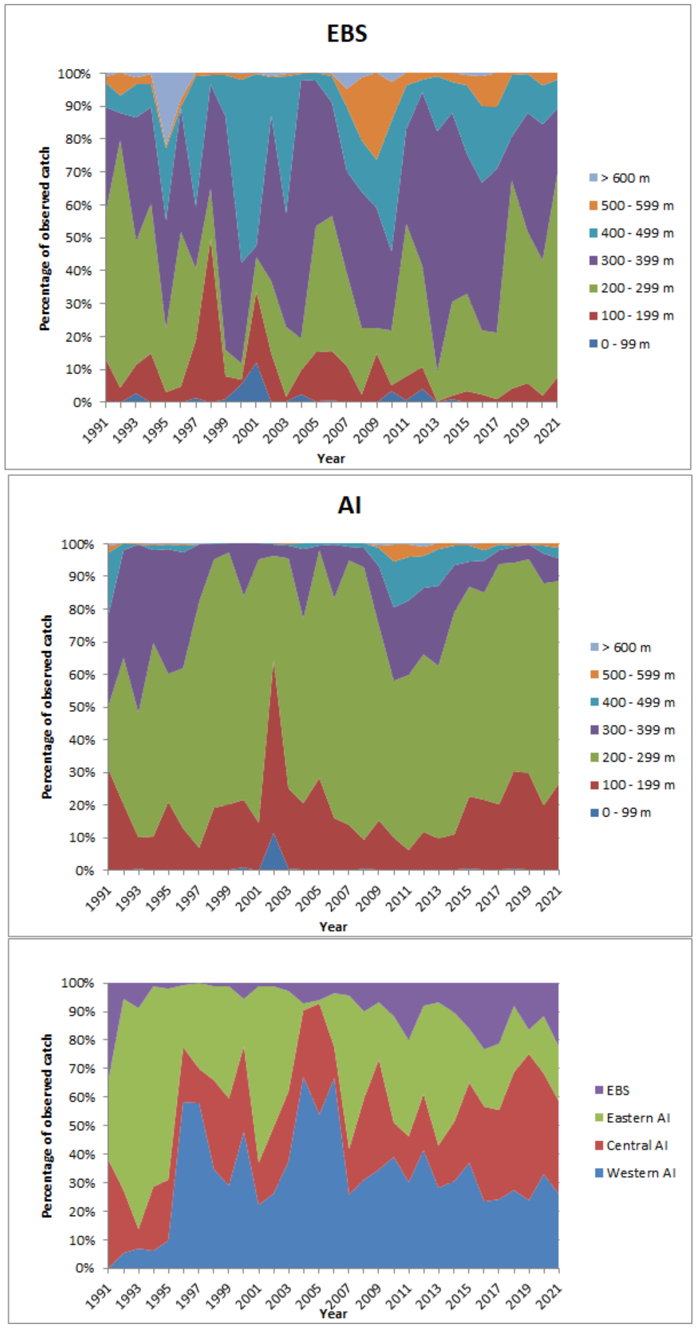


Figure 14.3. Distribution of observed BSAI blackspotted/rougheye rockfish catch (from North Pacific Groundfish Observer Program) by depth zone for the AI (top panel) and EBS (middle panel), and by BSAI subarea (bottom panel) from 1991 to 2021.

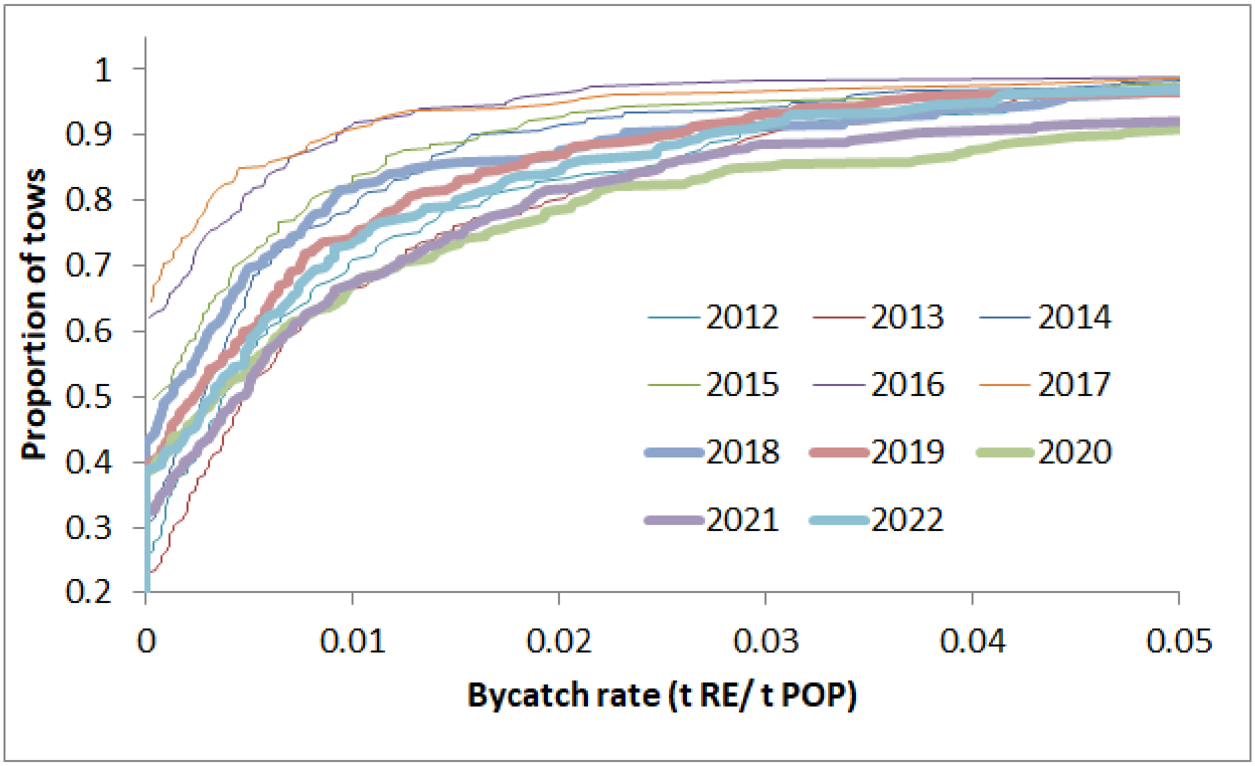


Figure 14.4. Cumulative distribution plots of rougheye blackspotted bycatch rates for tows by A80 vessels targeting Pacific ocean perch in the WAI.

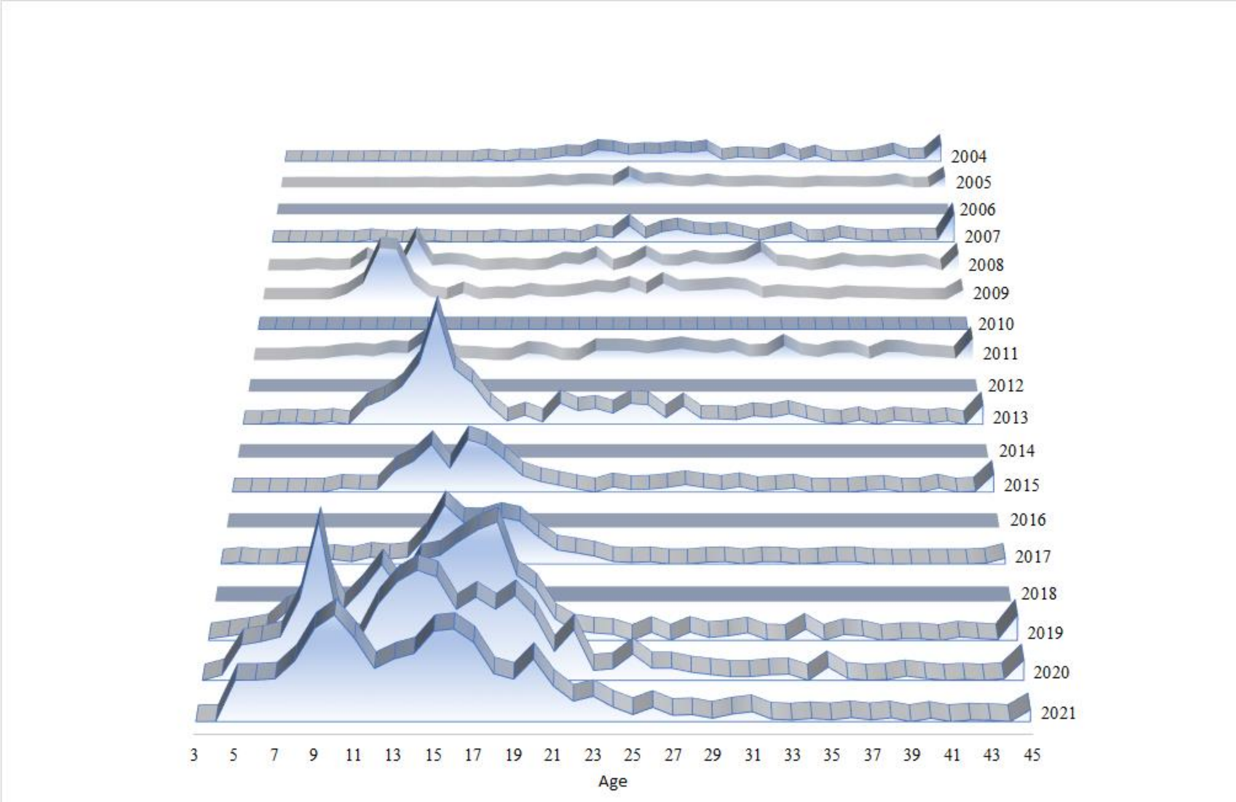


Figure 14.5. Fishery age composition data for the BSAI, scaled to the extrapolated number of fish caught from Observer sampling.

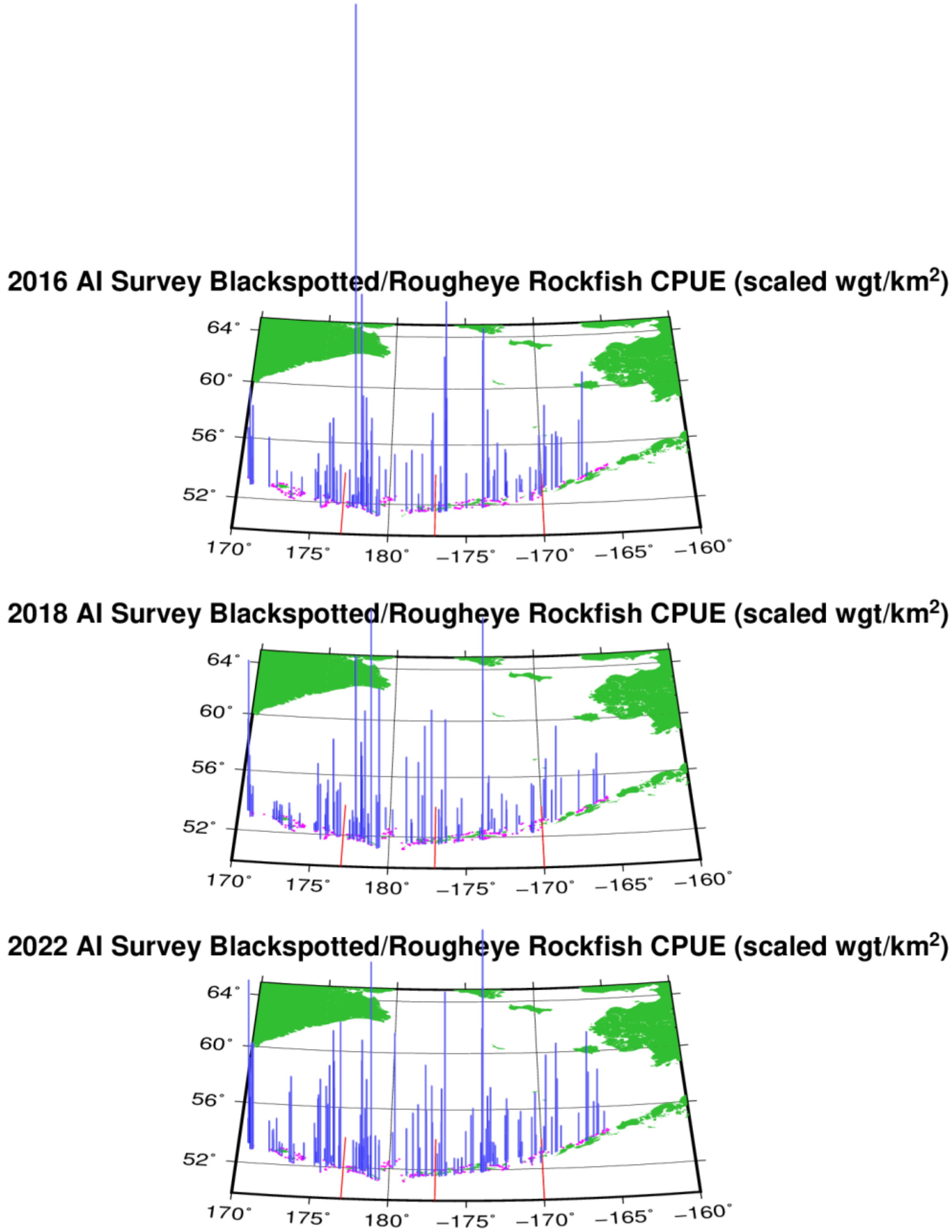


Figure 14.6. Scaled Aleutian Islands (AI) survey combined blackspotted and rougheye rockfish CPUE (kg/km^2) from 2016-2022; the symbol × denotes tows with no catch. The red lines indicate boundaries between the western Aleutian Islands (WAI), central Aleutian Islands (CAI), eastern Aleutian Islands (EAI), and eastern Bering Sea (EBS) areas.

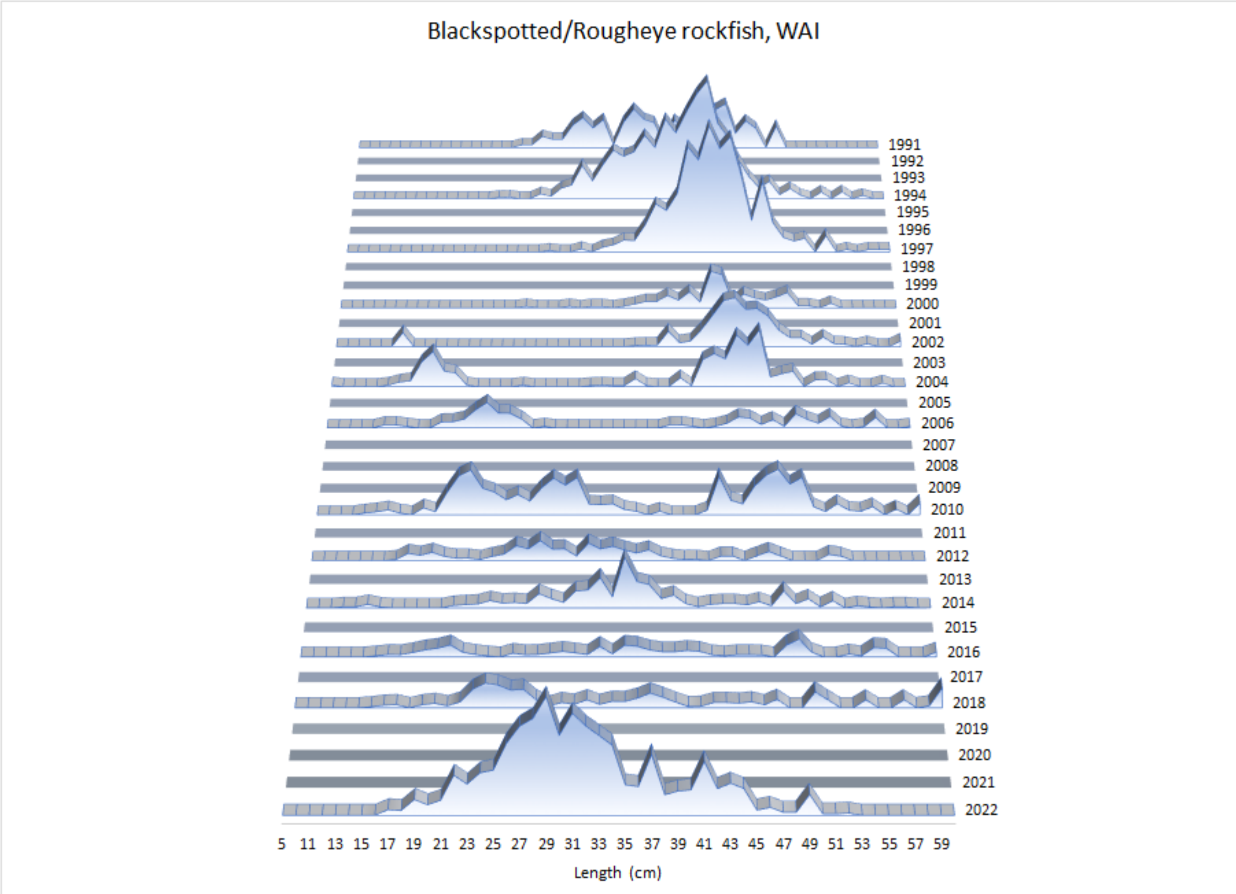


Figure 14.7. Estimated abundance by length for blackspotted/rougheye rockfish in the western Aleutian Islands subarea, from the 1991-2022 AI surveys.

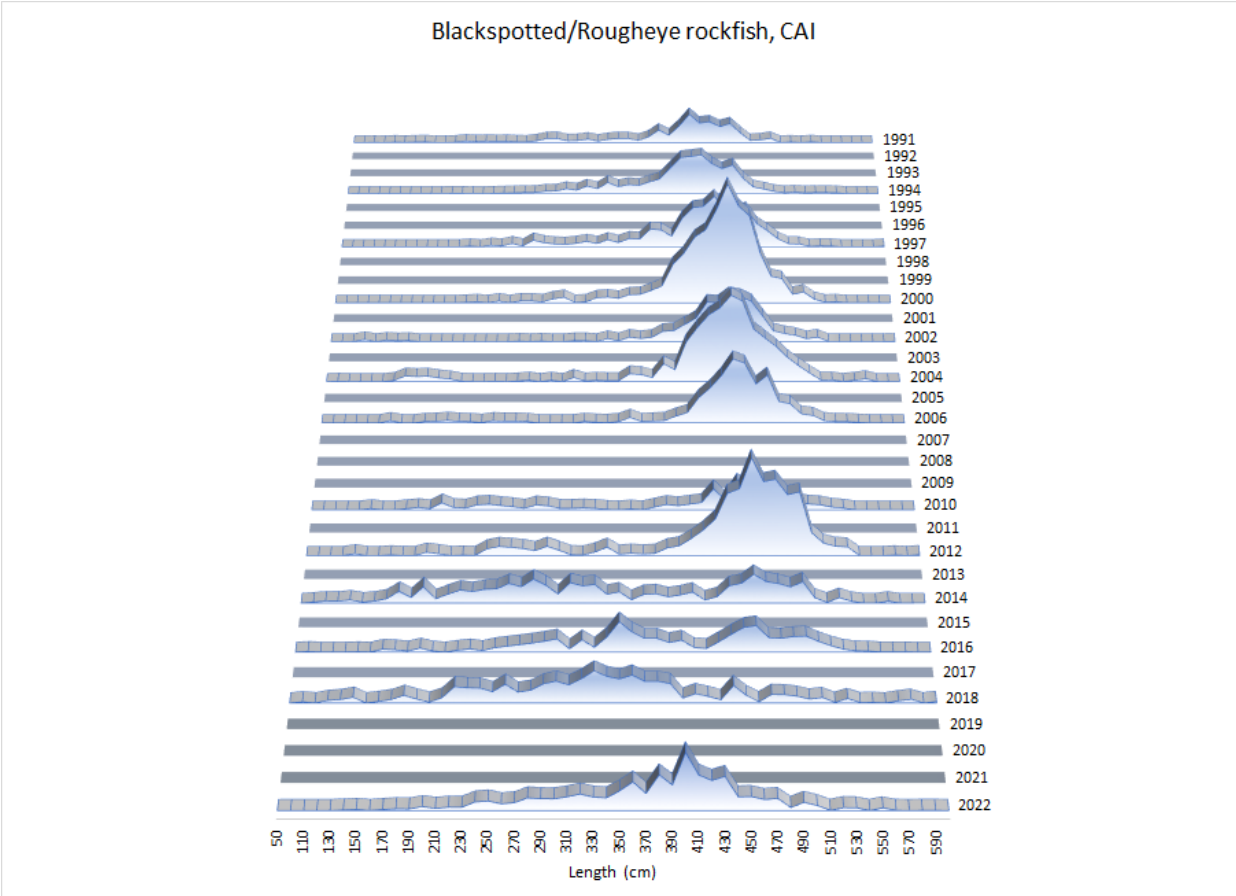


Figure 14.8. Estimated abundance by length for blackspotted/rougheye rockfish in the central Aleutian Islands subarea, from the 1991-2022 AI surveys

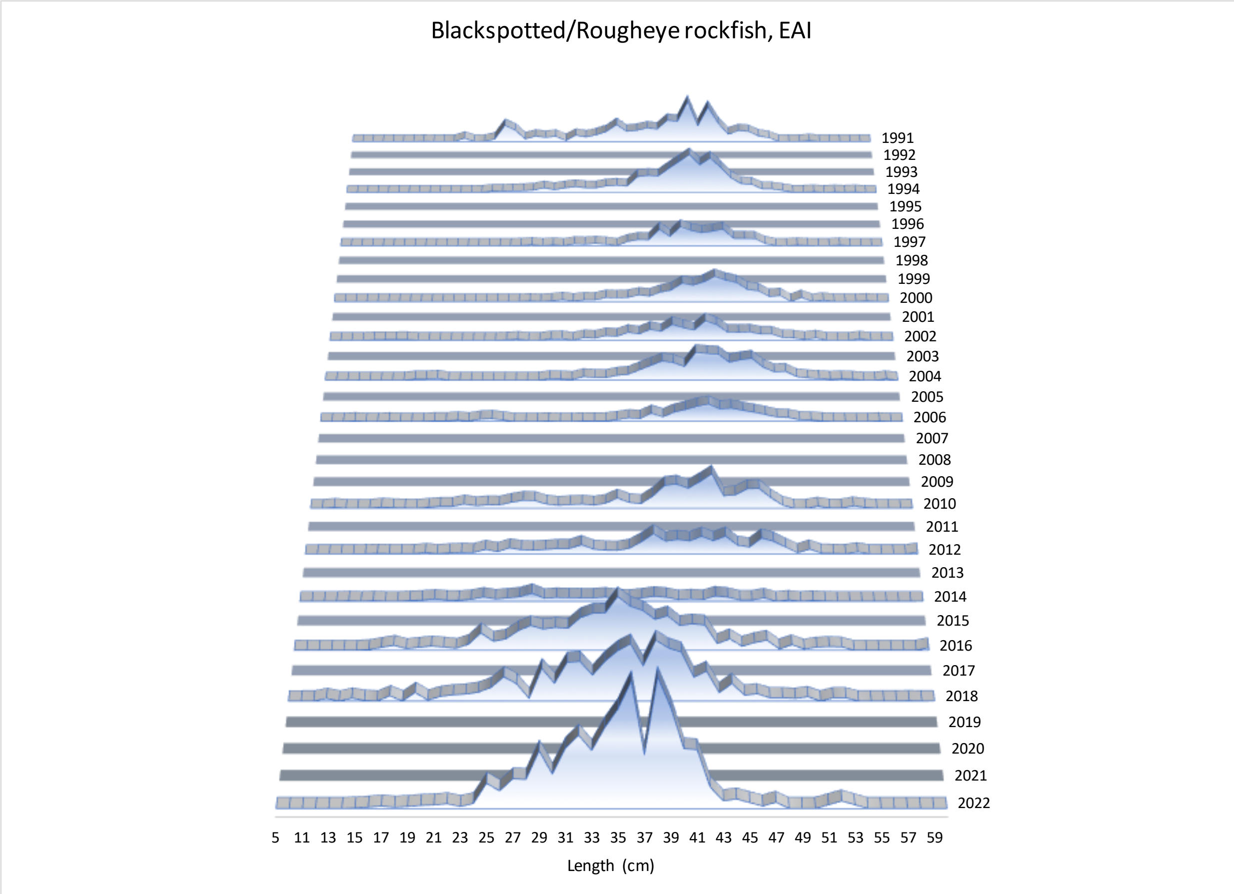


Figure 14.9. Estimated abundance by length for blackspotted/rougheye rockfish in the eastern Aleutian Islands subarea, from the 1991-2022 AI surveys.

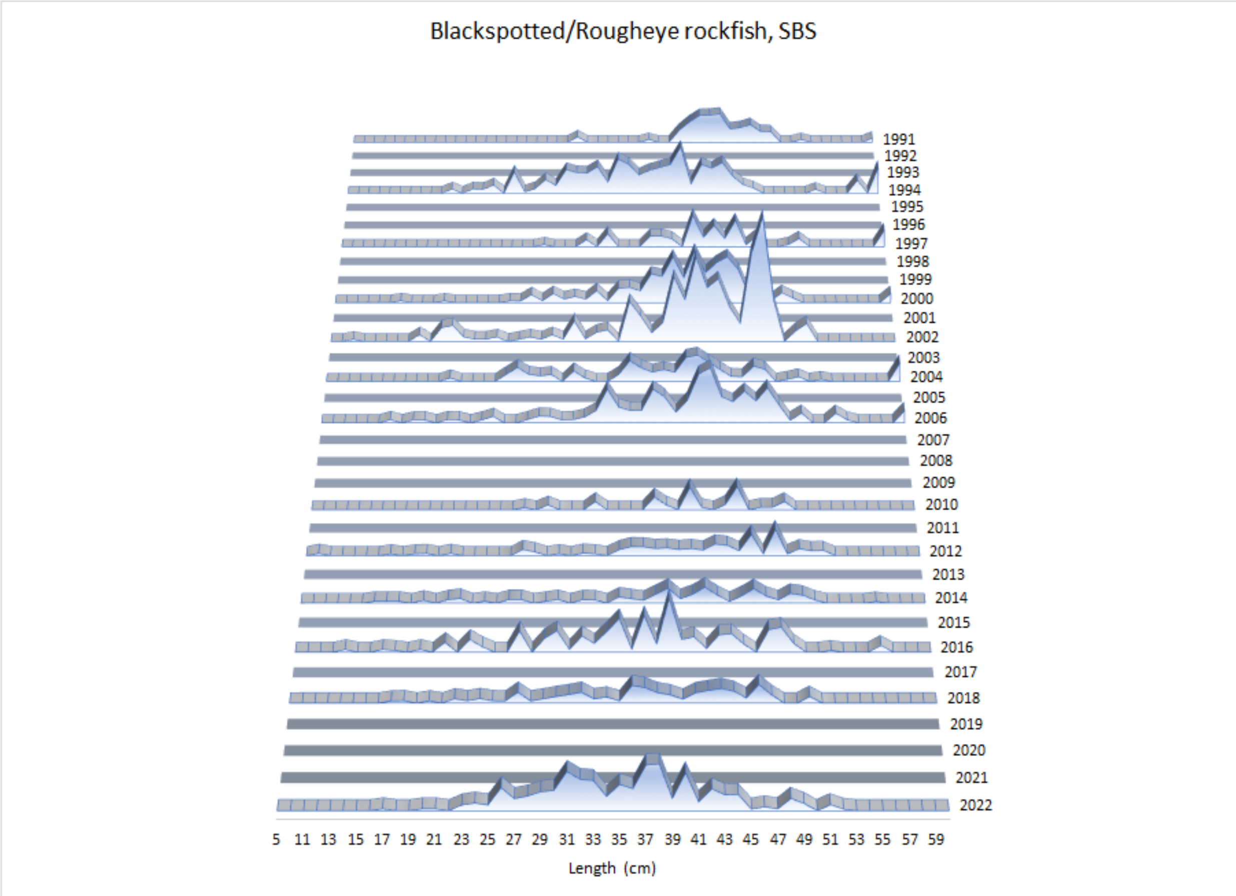


Figure 14.10. Estimated abundance by length for blackspotted/rougheye rockfish in the southern Bering Sea, from the 1991-2022 AI surveys.

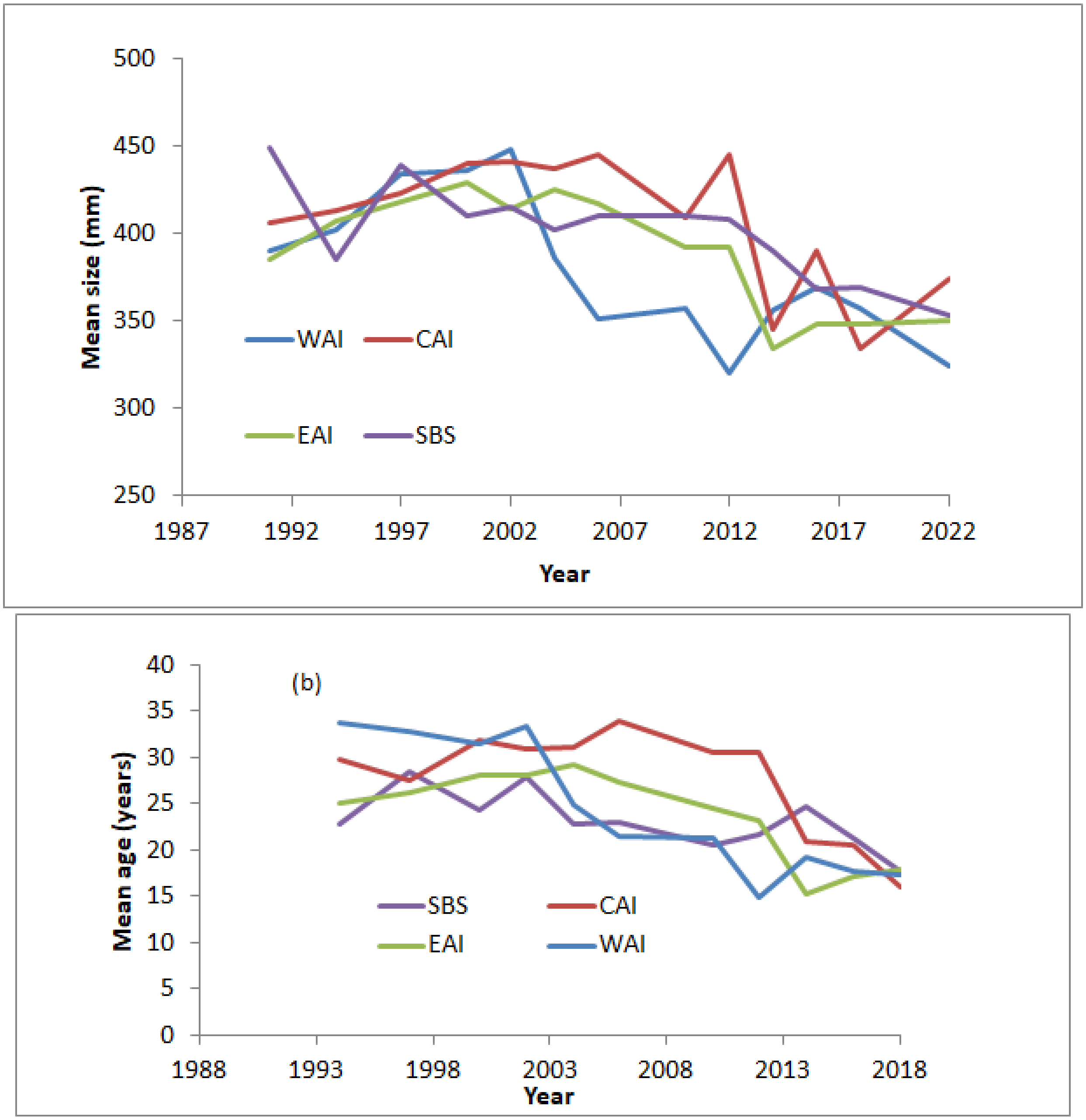


Figure 14.11. Mean size (a) and age (b) of blackspotted/rougheye rockfish from the 1991-2022 AI trawl surveys by subarea.

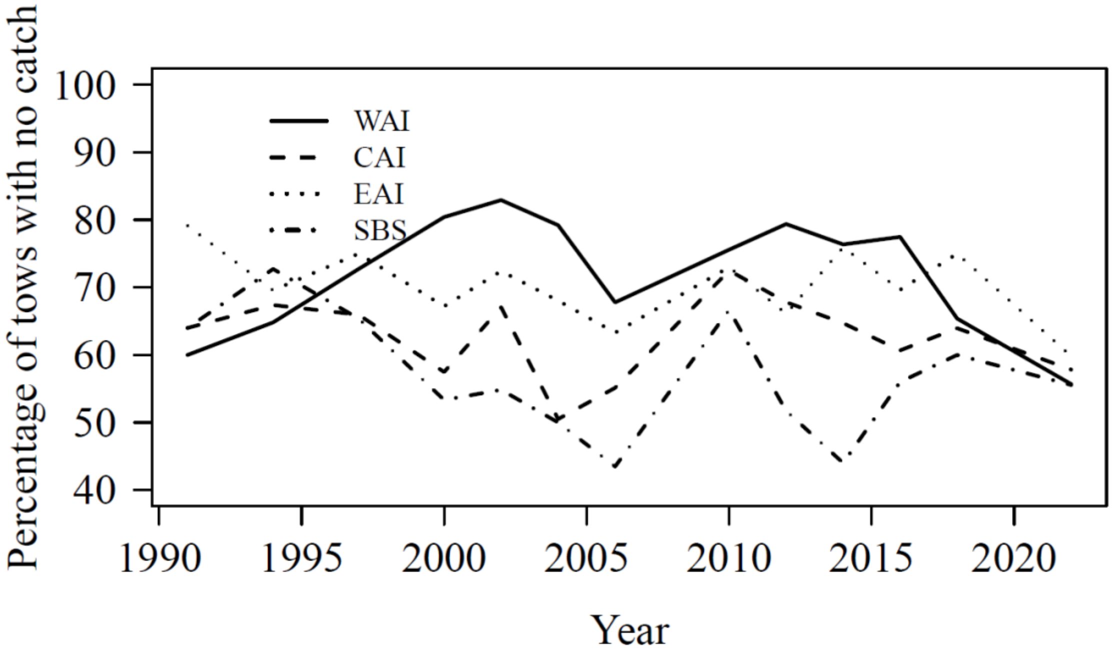


Figure 14.12. Percentage of survey tows with no catch of blackspotted/rougheye rockfish from the 1991-2022 AI trawl surveys by subarea.

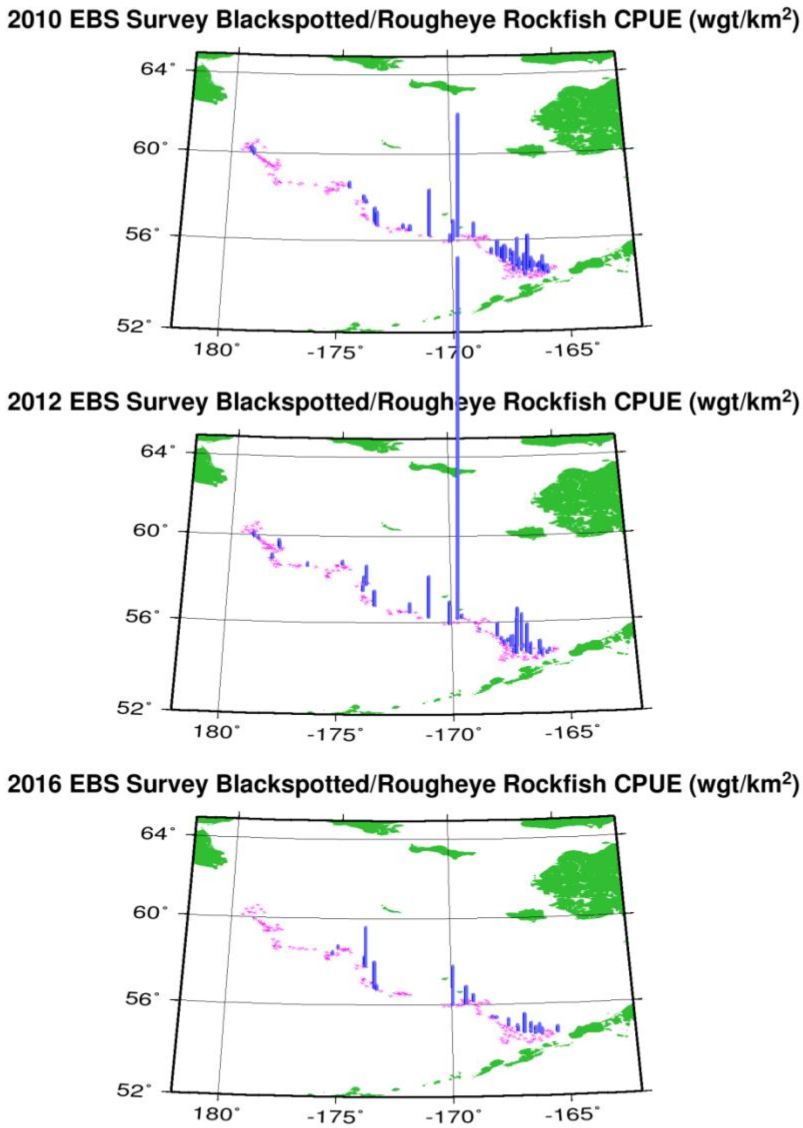


Figure 14.13. Scaled EBS survey combined blackspotted and rougheye rockfish CPUE (kg/km^2) from 2010-2016; the symbol × denotes tows with no catch.

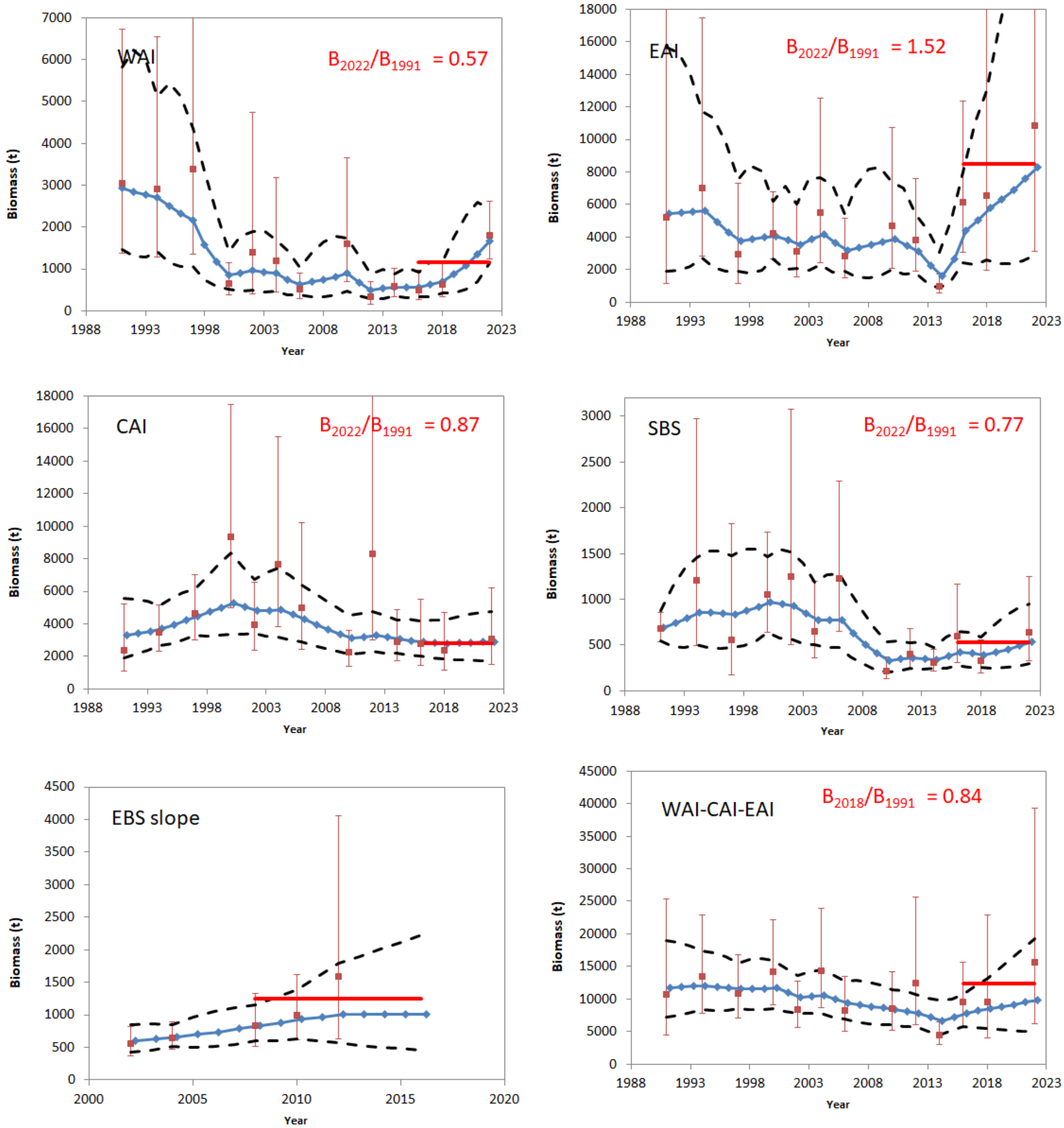


Figure 14.14. Time series of AI and EBS slope trawl survey biomass by subarea, with the fits from a random effects model to smooth the time series. The ratio of the biomass estimate in 2022 to that in 1991 indicates relatibve change over this time period. The horizontal red lines show the estimate from a weighted average of the three most recent surveys.

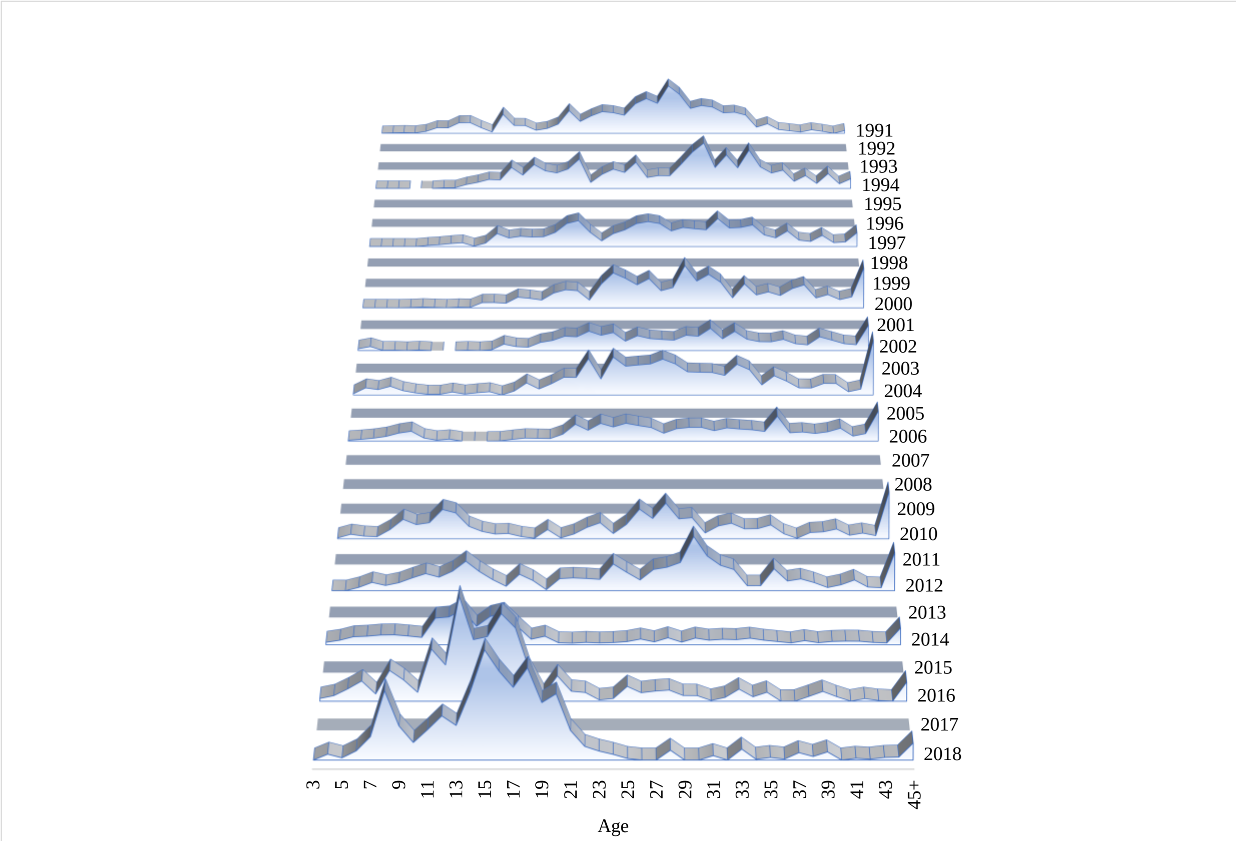
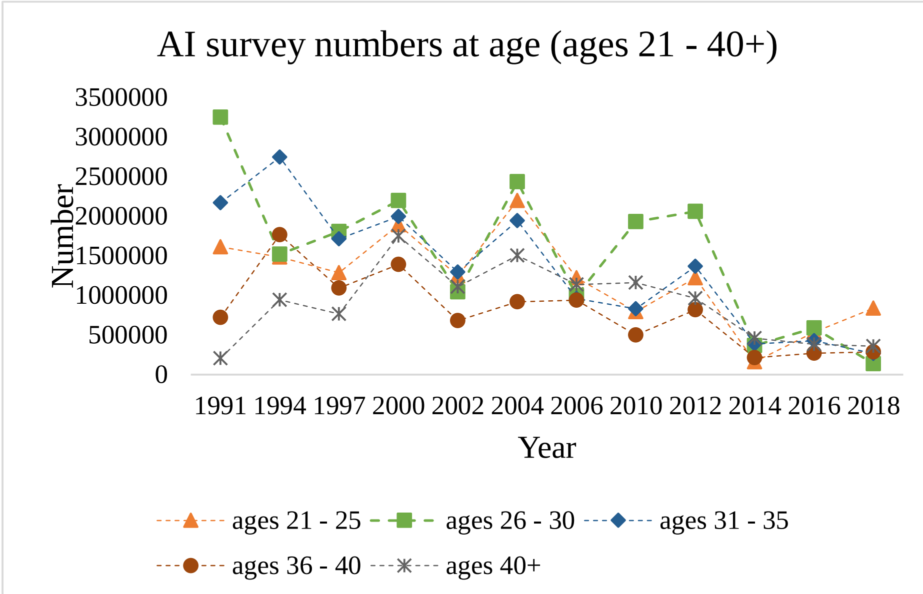


Figure 14.15. Estimated abundance by age from the Aleutian Islands trawl survey, 1991-2018.



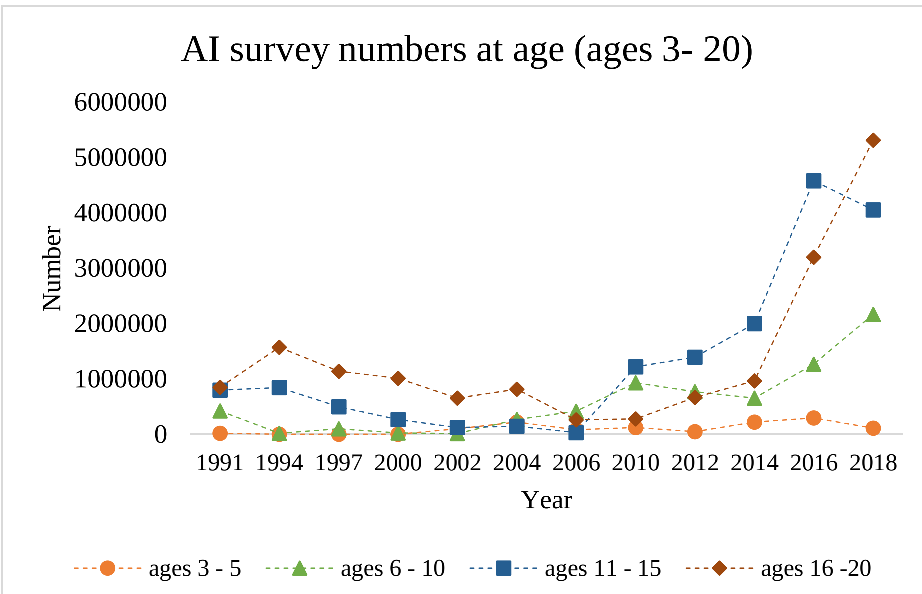


Figure 14.16. Estimated abundance, by age groups, from the AI trawl survey, 1991-2018.

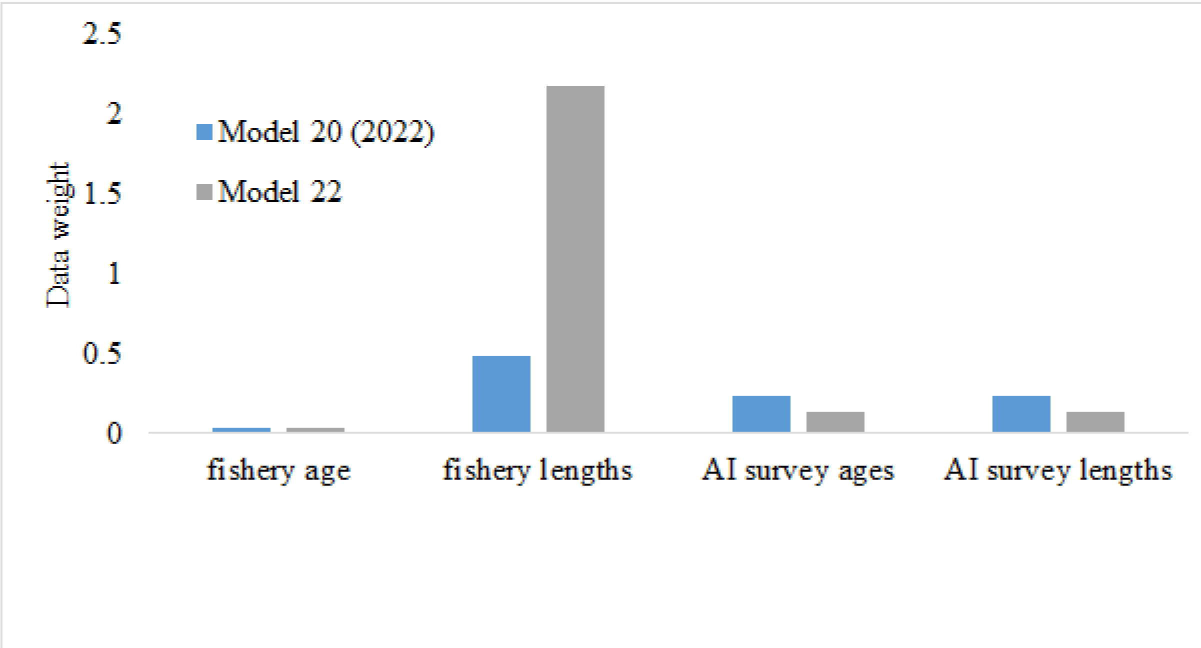


Figure 14.17. Estimated stage 2 composition data weights for Model 20 (2022) and Model 22.

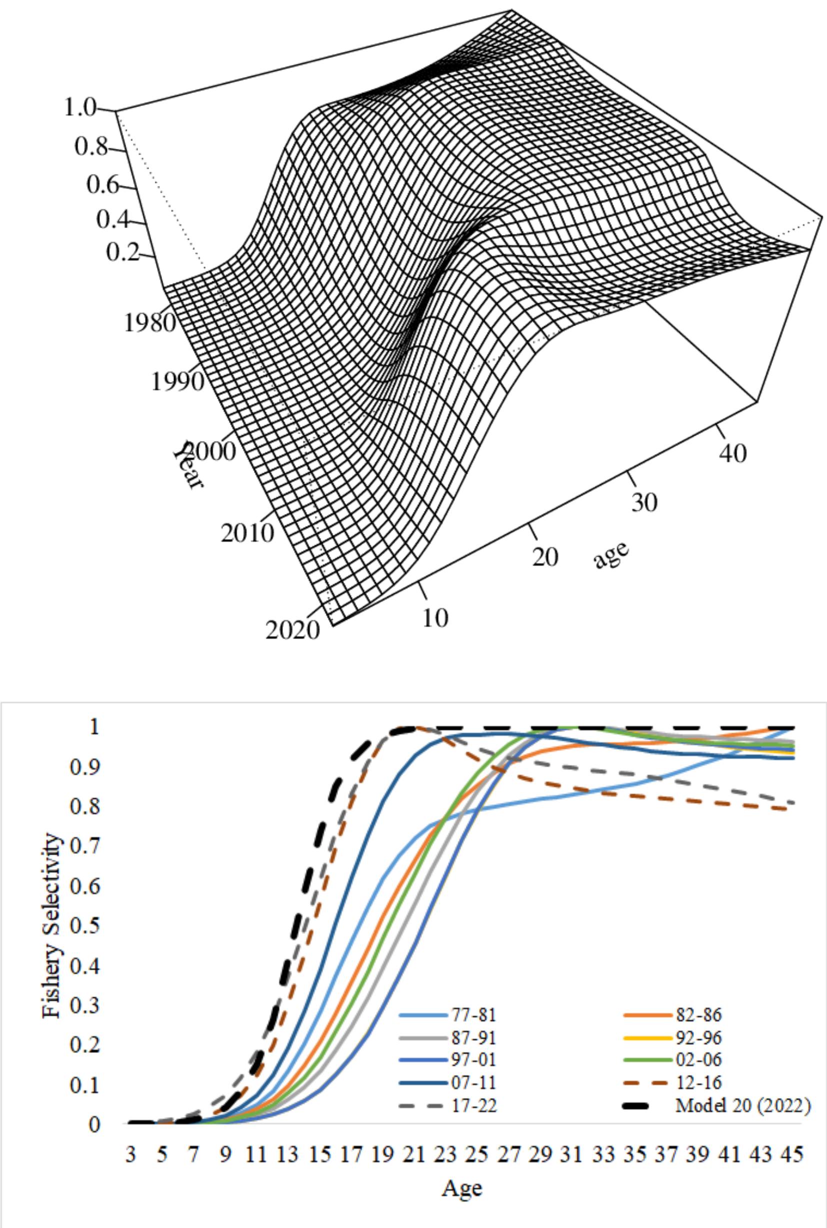


Figure 14.18. Estimated fishery selectivity by age and year for Model 22 (top panel). The average selectivity across shorter time blocks are shown in the bottom panel, with the two most recent time blocks in dashed lines. The time-invariant selectivity from Model 20 (2022) is shown with the thick black dashed line.

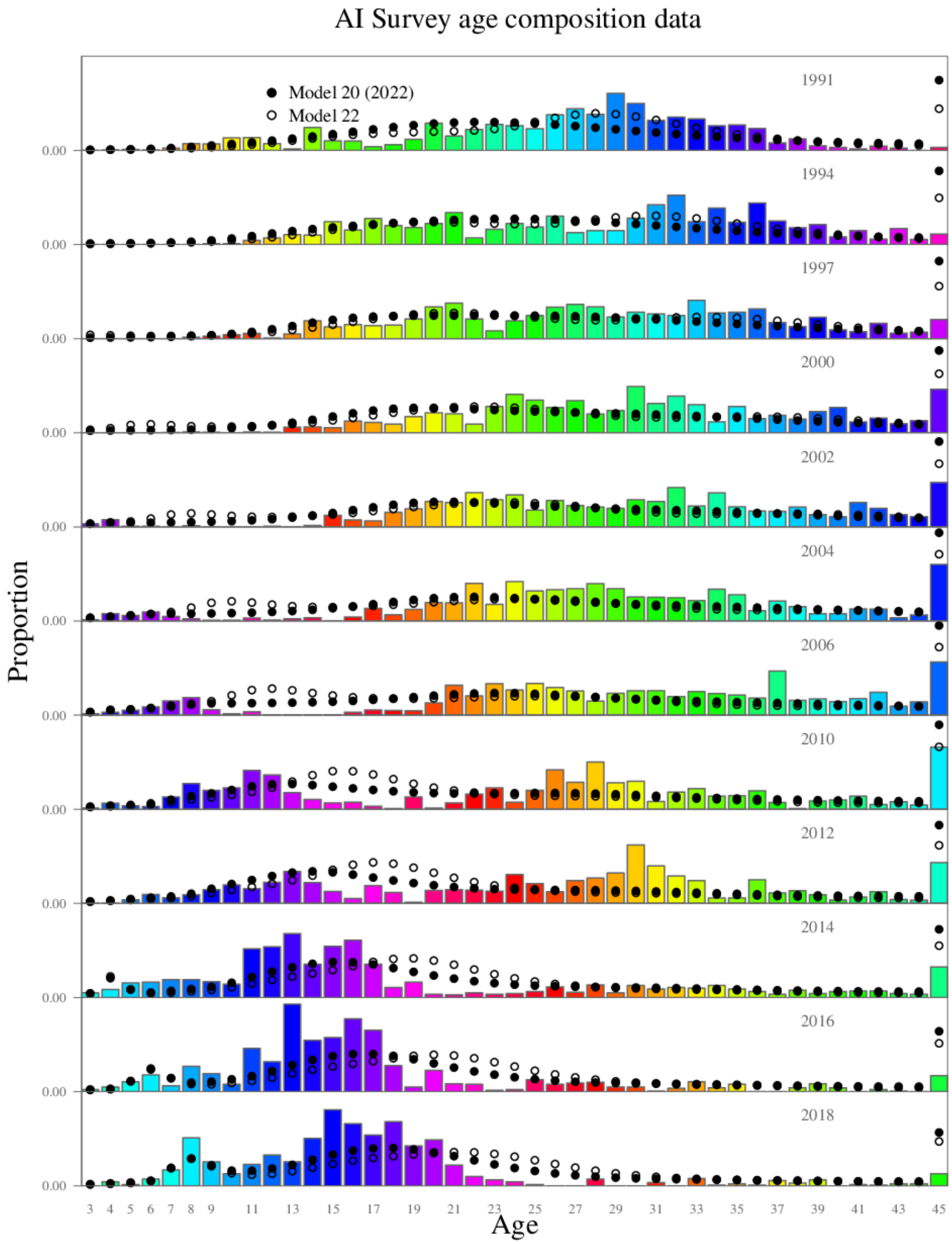


Figure 14.19. Estimated survey age compositions from model 20 (2022) and Model 22.

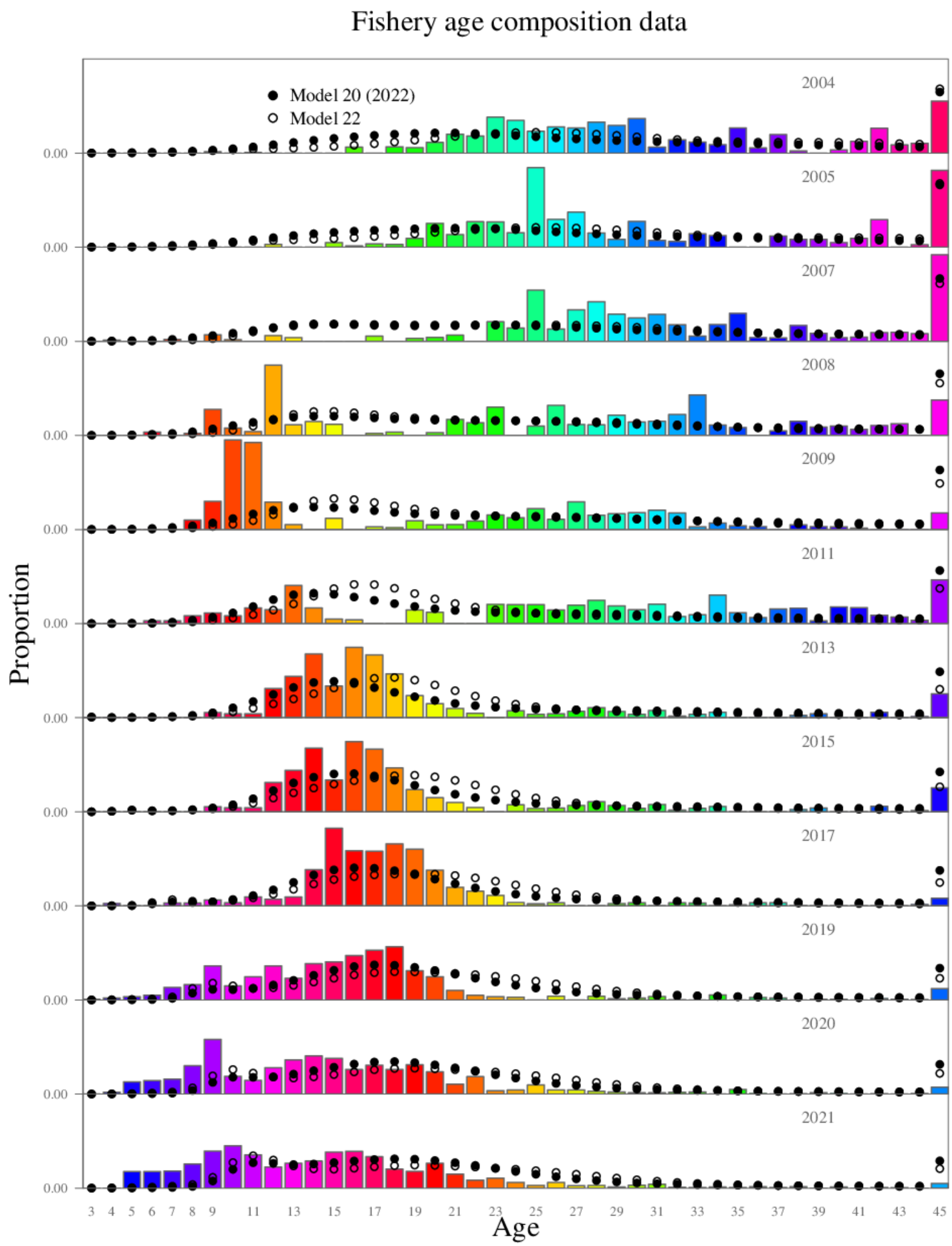


Figure 14.20. Estimated fishery age compositions from model 20 (2022) and Model 22.

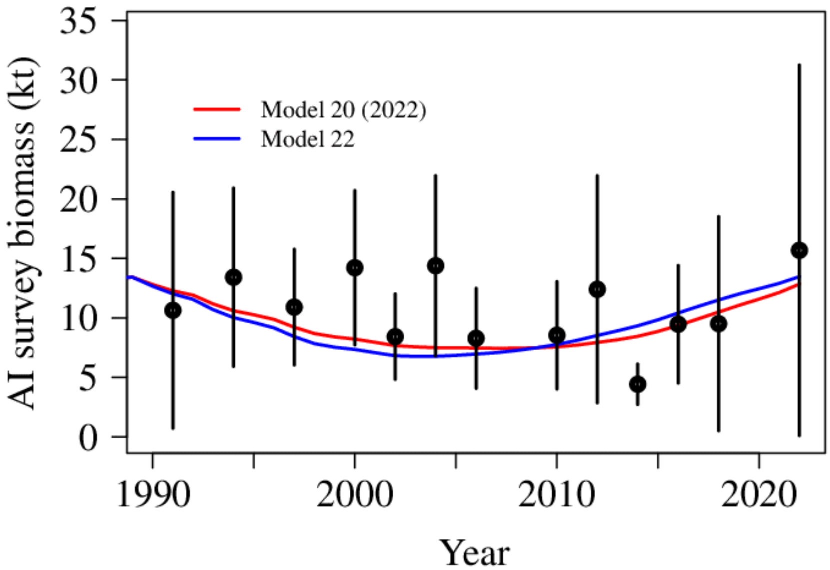


Figure 14.21. Estimated AI survey biomass across the models considered in this assessment.

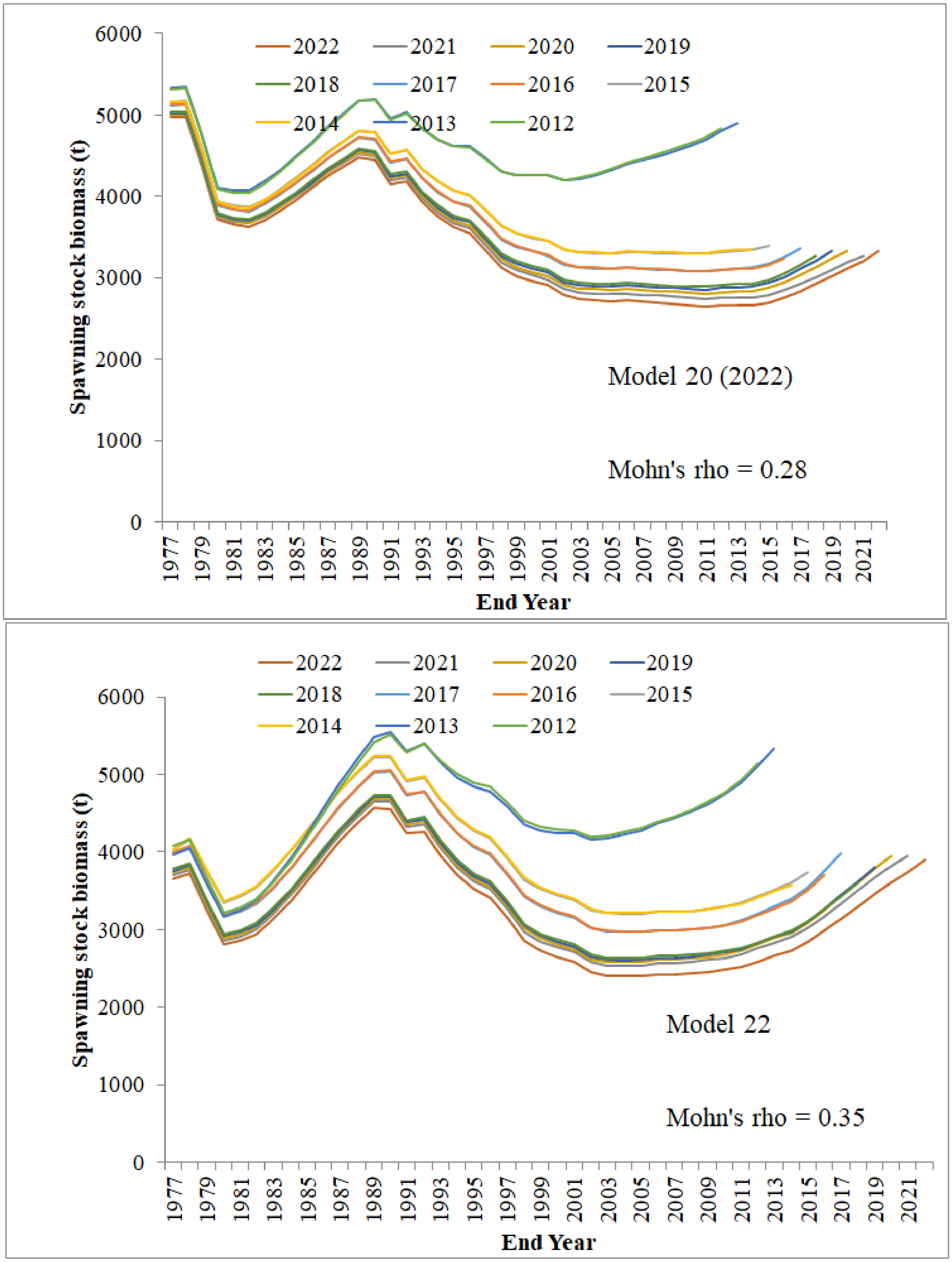


Figure 14.22. Retrospective estimate of spawning stock biomass from model 20 (2022) and Model 22.

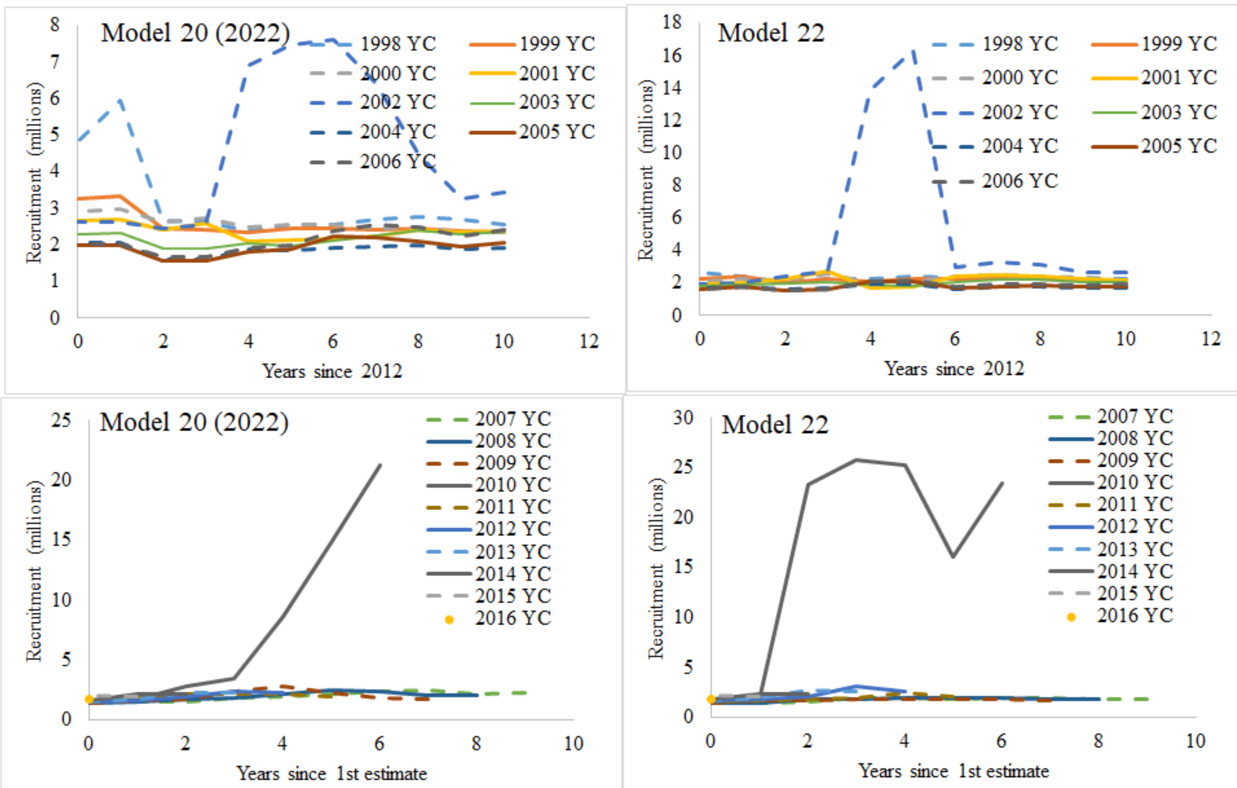


Figure 14.23. Retrospective estimates of recruitment for the 1998 – 2016 year classes, as a function of the years since either the first estimate or 2012 (whichever is later), for model 20 (2022) and model 22.

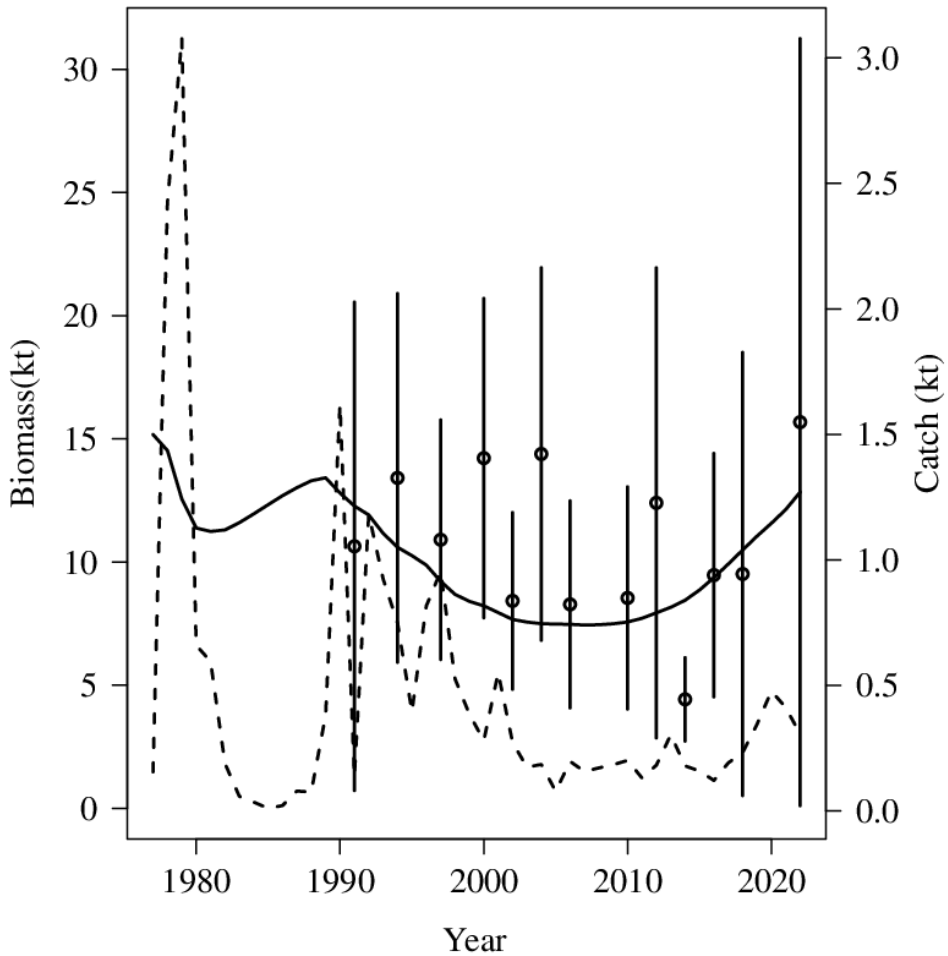


Figure 14.24. Observed Aleutian Islands (AI) survey biomass for blackspotted/rougheye rockfish (data points, +/- 2 standard deviations), predicted survey biomass (solid line), and harvest (dashed line).

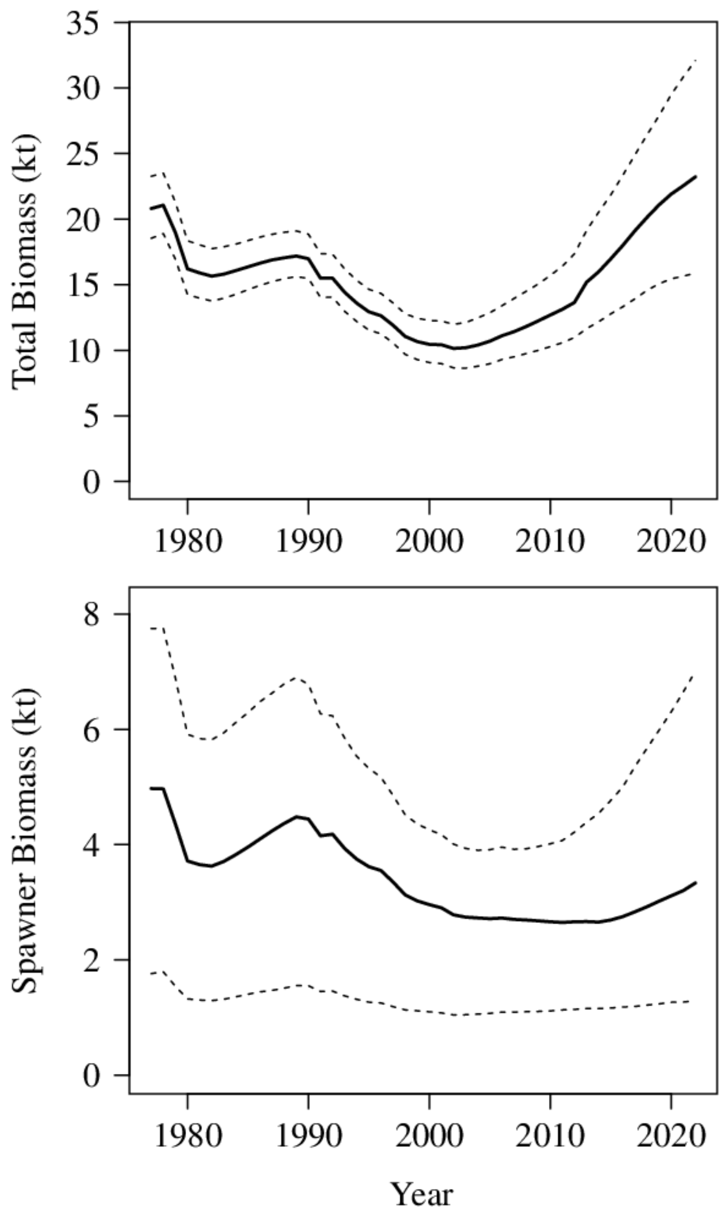


Figure 14.25. Total (top panel) and spawner (bottom panel) biomass for BSAI blackspotted/rougheye rockfish, with 95% confidence intervals from MCMC integration.

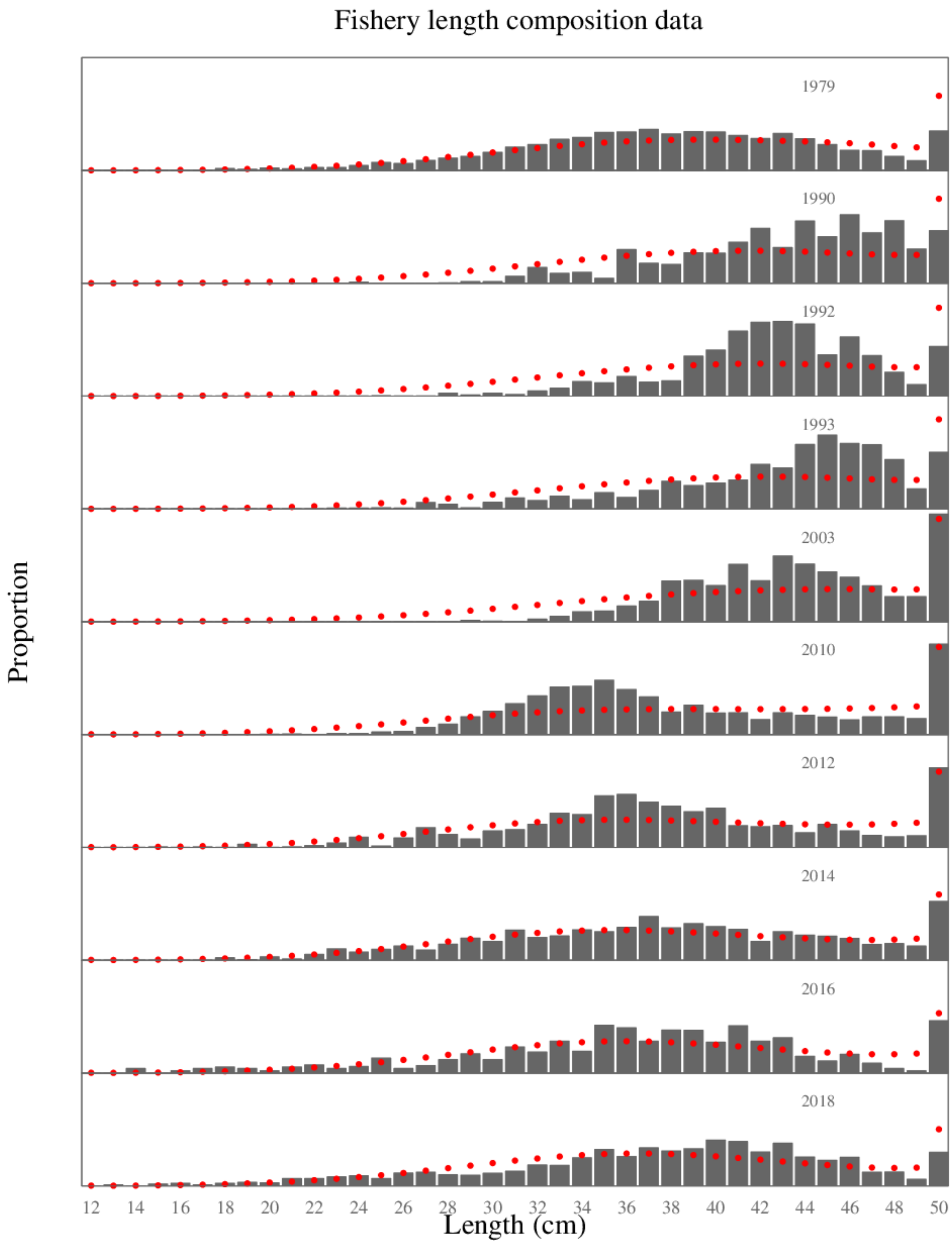


Figure 14.26. Model fits (dots) to the fishery length composition data (columns) for AI blackspotted/rougheye rockfish, 1979-2018.

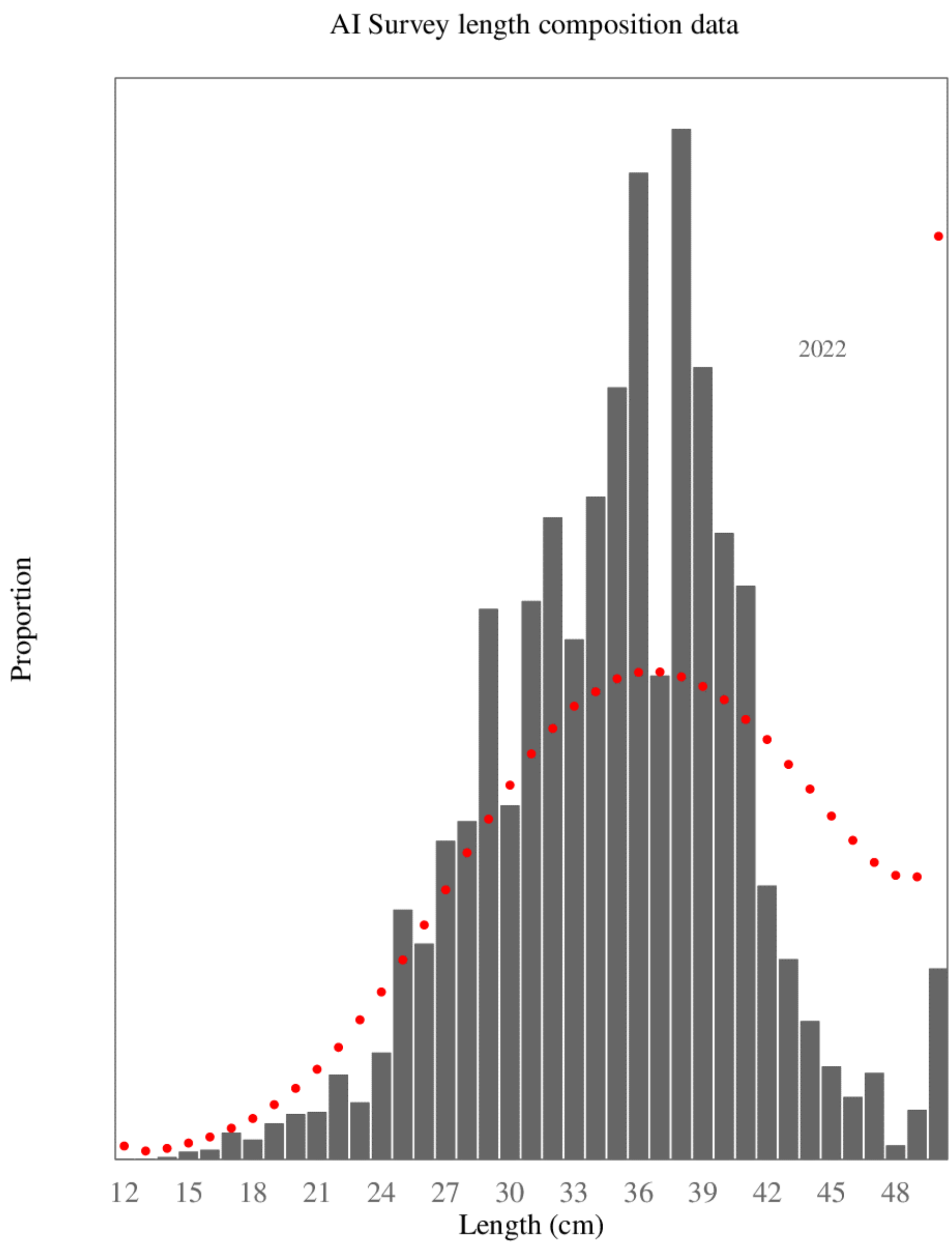


Figure 14.27. Fit of the model to the 2022 AI survey length composition.

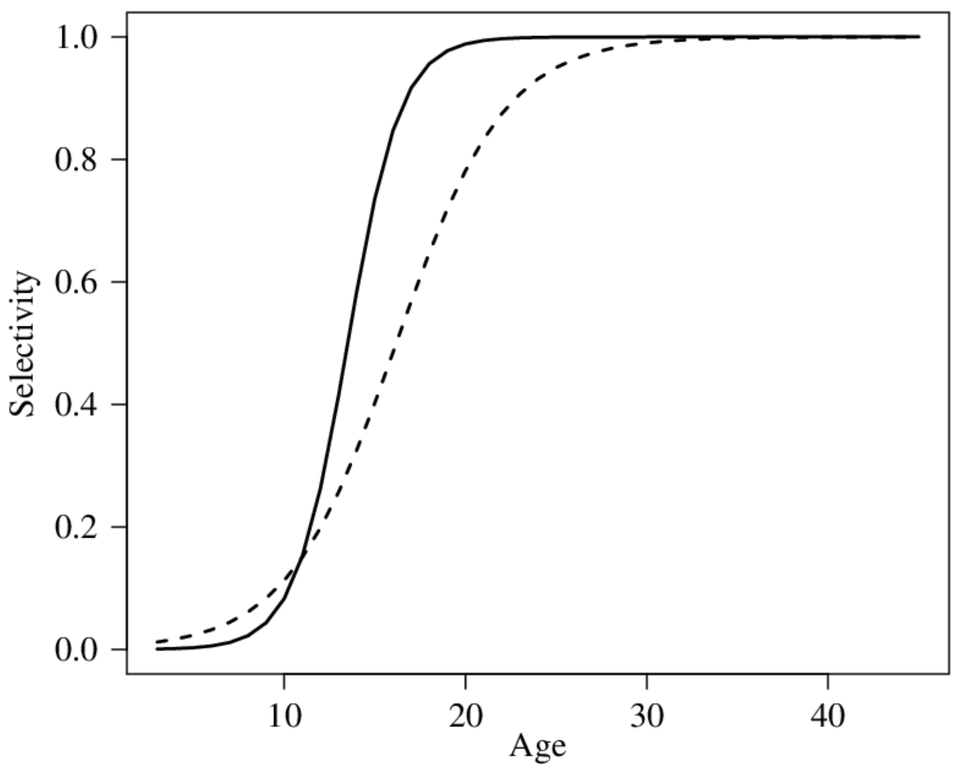


Figure 14.28. Estimated fishery (solid line) and AI survey (black dashed line) selectivity curves by age for blackspotted/rougheye rockfish.

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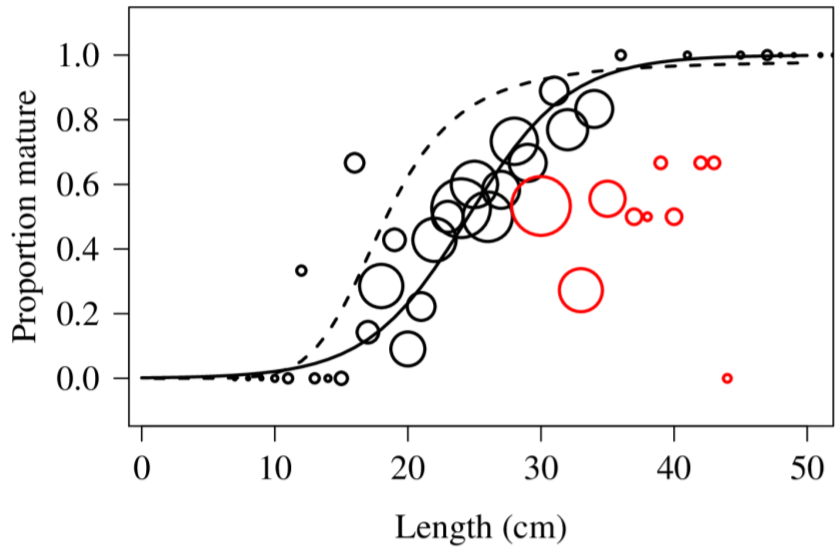

Figure 14.29. Observed and estimated proportion mature at age from data collected in the GOA from Dr. Christina Conrath (black circles and solid line, respectively). Symbol size is scaled by the number of observations. Red data point represent outliers which had unusually low proportion mature for old fish, and were not used for model estimation. For reference, the maturity ogive used in the 2018 assessment is shown as the dashed line.

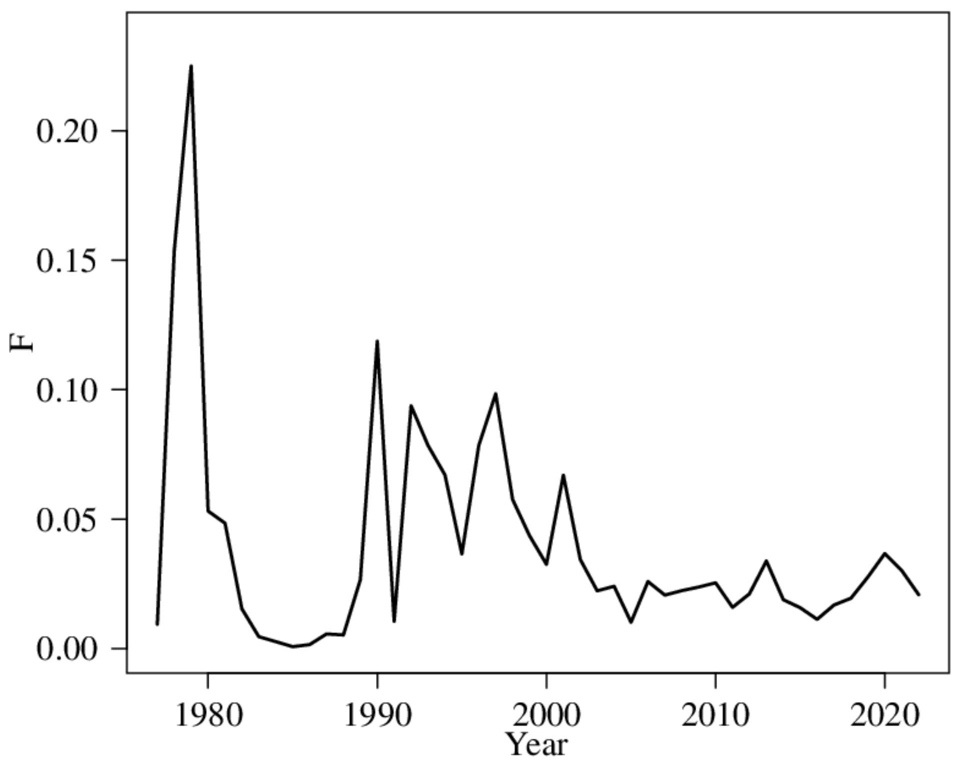

Figure 14.30. Estimated fully selected fishing mortality for blackspotted/rougheye rockfish.

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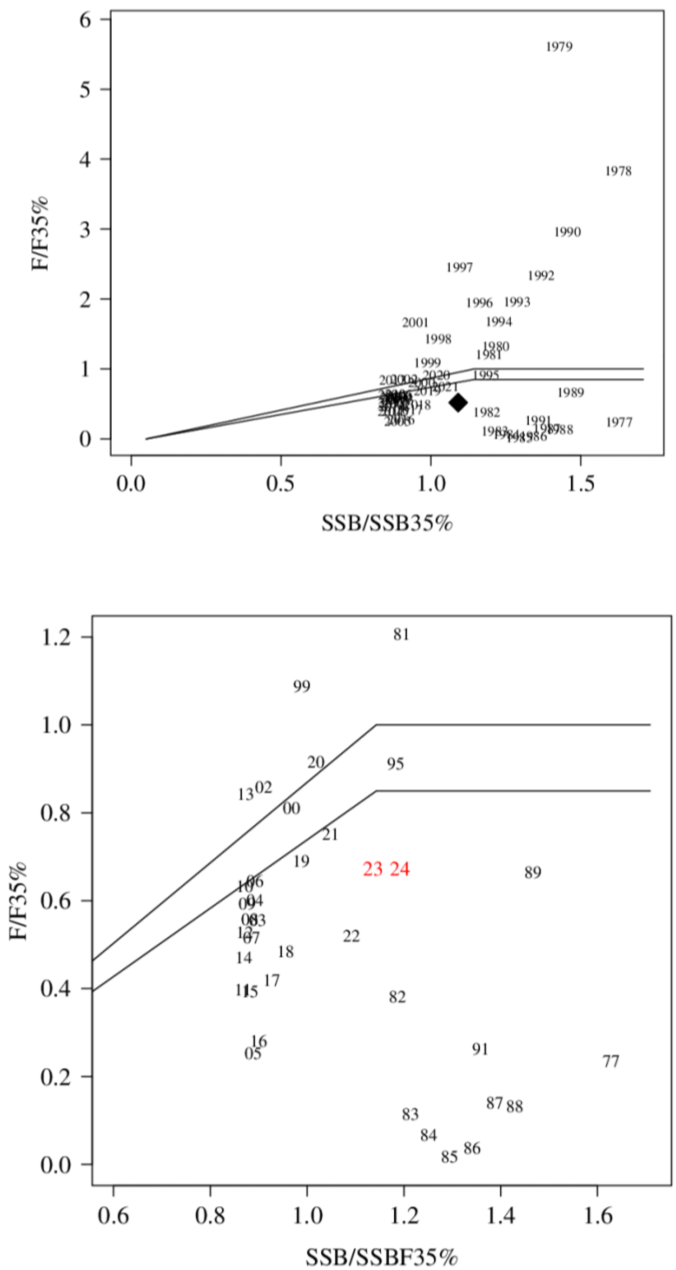

Figure 14.31. (Top panel) Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvest control rules, with 2022 shown as the diamond symbol. The bottom panel shows the projected stock status and *F* for 2023 and 2024.

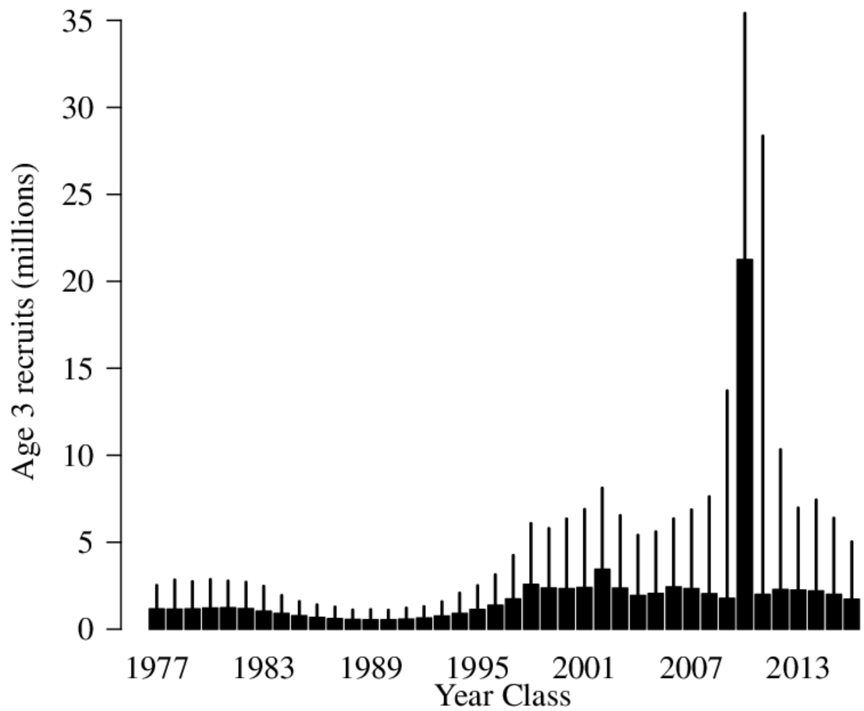

Figure 14.32. Estimated recruitment (age 3) of blackspotted/rougheye rockfish, with 95% CI. limits obtained from MCMC integration.

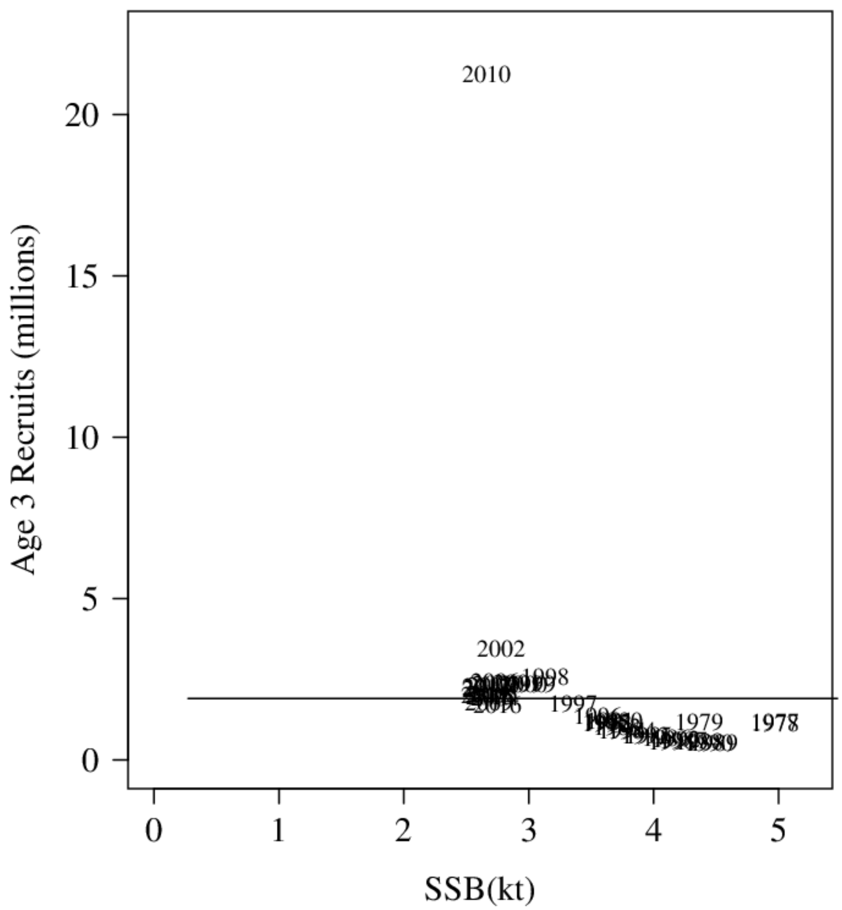

Figure 14.33. Scatterplot of blackspotted/rougheye rockfish spawner-recruit data; label is year class. Horizontal line is median recruitment.

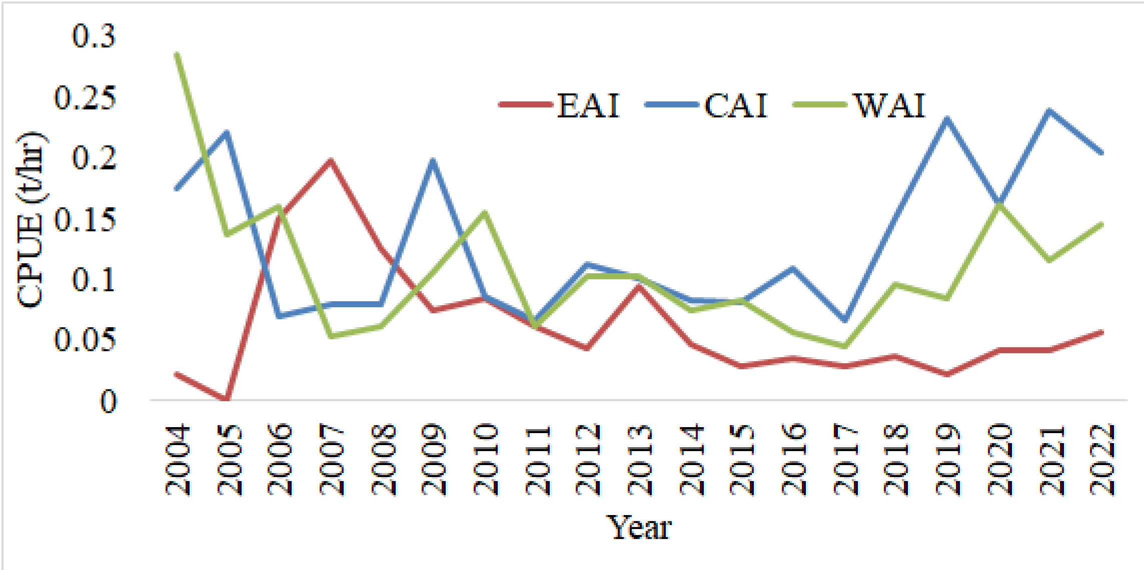

Figure 14.34. Bycatch of blackspotted/rougheye rockfish (t/hr) in tows targeting POP by AI subarea, from tows sampled for species composition in the North Pacific Groundfish Observer Program.

Appendix 14A. Update on Plan Team and SSC requests for the BSAI Blackspotted/rougheye stock assessment

Introduction

In the December, 2020 meeting of the Statistical and Scientific Committee of the North Pacific Fisheries Management Council, the following requests were made regarding the BSAI blackspotted and rougheye stock assessment:

● *The SSC supports the BSAI GPT recommendation that the authors explore the distribution of the survey samples to evaluate trends by depth, to help determine risk considerations and potentially help inform the industry on how to reduce incidental catch.*

● *Similarly, the SSC recommends an exploration of the spatial footprint of the AI survey and incidental catch fisheries with an eye towards potential mismatches due to untrawlable habitat that might provide context for interpreting conflicting survey abundance and fishery size/ age composition. We note that a graduate research project investigating the survey – fishery alignment along with recent changes in Atka mackerel and POP fishing behavior is underway at Alaska Pacific University. In addition, the SSC pointed out that a NMFS – University – Industry cooperative effort entitled "The Science-Industry Rockfish Research Collaboration in Alaska" being led by Dr. Madison Hall is currently underway. While this effort is primarily focused on GOA rockfish, it may provide important analytical tools and insights for application to the BSAI BS/RE complex.*

● *The SSC supports the BSAI GPT suggestion to explore other survey data (e.g. NMFS and IPHC long-line or ADF&G survey data) to augment abundance and size/ age composition information. We note that a new graduate research project looking at combining data from different surveys and gears is underway at the College of Fisheries and Ocean Sciences at the University of Alaska Fairbanks.*

● *The SSC notes that the values of M used in the AI assessment are very high, especially for a long-lived species, and requests that the authors fully explore the ranges and interactions of catchability and M in the AI assessment model.*

● *The SSC requests an update on work (e.g. genetics) to further refine BS/RE stock structure in the AI.*

● *Given the information regarding shifts in fishing effort to shallower areas provided in public testimony, the SSC requests that the authors investigate the effects of fleet behavior on apparent size/ age compositions, and to what extent this may be influencing fishery selectivity*

● *The JGPT proposed a Council workshop in 2021 to evaluate both the fishing mortality rates by gear associated with different apportionment schemes as well as the management and socio-economic considerations of alternatives. The SSC concurs with the JGPT's note that the area apportionment approach currently used for the BSAI BS/RE complex should be included in the Spatial Management Workshop proposed for 2021.*

The purpose of this report is to address the items above that concern the BSAI blackspotted/rougheye stock assessment and its input data, and present potential options for the 2022 assessment.

1) The distribution of the survey samples to evaluate trends by depth

The sample sizes of the AFSC Aleutian Islands survey hauls is shown in Table 14A.1. Samples between the western Aleutian Islands (WAI), central Aleutian Islands (CAI), and eastern Aleutian Islands (EAI) are relatively evenly distributed, with smaller sample sizes in the southern Bering Sea area (SBS). For all subareas, the largest amount of samples occurs in the 100 – 200 m depth zone, with the relative amount of sampling in the 200 – 300 m depth zone being largest in the EAI and smallest in the SBS. The overall number of stations sampled has increased over time relative to the 1991 and 1994 surveys.

Survey biomass trends by depth and survey subarea are shown in Figure 14A.1, and for the CAI and EAI subareas the trends shown separately for strata north and south of the Aleutian Islands chain. In most subareas, the 300 – 500 m depth zone contains the largest amount of estimated biomass, although the biomass in the 200 – 300m depth zone in the north CAI subarea has been large in some years. In the WAI, biomass in depth zones > 200 m decreased from the 1997 survey to the 2000 survey, whereas biomass in these depth zones in the north CAI increased between these survey years. Biomass in the north CAI subarea and the WAI were at low levels in the 2018 survey relative to previous years, whereas biomass in the deep strata in the south EAI subarea was at a relatively high level.

2) An exploration of the spatial footprint of the AI survey and incidental catch fisheries

The spatial overlap between the fishing grounds for blackspotted/rougheye rockfish and the survey trawls was first presented to the BSAI Plan Team in 2013, focusing on the WAI subarea. Figure 14A.2 is a map from the 2013 presentation to the BSAI Plan Team showing survey sampling grids in a portion of the WAI, with untrawlable grids in red and successfully trawled grids in green. The 3 ellipses near 175° indicate areas where fishery trawling effort and blackspotted catch have occurred, but are unsampled by the trawl survey. Confidentiality restrictions prevent presentations of individual fishery tows, but an update of the data indicates that these spatial overlap patterns between the fishery and the survey have also continued since 2013.

Due to the multispecies objectives of the AFSC trawl survey, and the emphasis on representative sampling from all trawlable habitats in the survey area, we would not expect the distribution of survey hauls and CPUE to closely match fishery effort and catch for any species. However, plots of the relative proportion of fishery and survey hauls by longitudinal bins can reveal differences in patterns of spatial effort. The relative proportion of number of survey hauls, by 0.5° longitudinal bins, for the WAI, CAI, and EAI are shown in Figure 14A.3, along with the relation proportion of the number of fishery hauls which had a positive catch of blackspotted/rougheye rockfish. As expected, the survey hauls are roughly evenly distributed throughout this sampling area. The fishery hauls have been concentrated in various locations, and the strength of these concentrations can vary between years. The shaded red bar corresponds to 174.5°- 176°, roughly the area shown in Figure 14A.2, and indicates a low area of survey effort but often a high area of fishery effort (particularly in years 1996-1998, 2001 – 2007, and 2015 – 2021). A similar plot (Figure 14A.4) indicates that the relative portion of fishery catch from this area typically exceeds the relative proportion of survey CPUE.

This particular area of 174.5°- 176° was chosen as an illustrative example, as there are other areas where the fishery and survey distributions of catch and sampling effort do not match each other (i.e., the EAI east of -173°). Finally, it is unclear what effect, if any, these differences in spatial footprints would have on the survey biomass estimates. In any area-swept trawl survey, the density from the areas sampled by the trawl are applied to the areas unsampled by the trawl. If the densities from the sampled and unsampled areas are similar, then the effect on the survey indices would be minimal.

The SIRICA (Science- Industry Rockfish Research Collaboration in Alaska) project being led by Madison Hall is focused on the GOA, and involves conducting standardized trawls using fishing vessels to augment the GOA survey tows. The study will use two types of tows: experimental tows conducted in untrawlable habitats (to further obtain information about density), and calibration tows in trawlable habitat (to estimate relative fishing power between the fishery and survey tows). Field work is underway, and planned to continue through 2025. The objective of the study is to demonstrate the utility of a cooperative data collection program, from which an index of rockfish abundance in untrawlable grounds could be obtained.

Another relevant study is the thesis project of Cara Hesselbach (Alaska Pacific University), who is examining the spatial and temporal overlap of survey and fishery observations of blackspotted and rougheye rockfish in the Aleutian Islands. Some of this work will involve descriptive measures of overlap (similar to what is presented in this update), but will also extend to development of species distribution models. Although this study is ongoing, one notable finding is recognition of consistency between the fishery and survey composition data (i.e., each showing a shift to smaller fish in recent years), and this will be shown later in this document.

3) Exploration other survey data (e.g. NMFS and IPHC long-line or ADF&G survey data)

We examined the survey biomass estimates from the 3 surveys identified in the SSC comment: 1) NMFS longline survey; IPHC longline survey; and 3) ADF&G trawl survey data. Inclusion of multiple indices of abundance can be useful to fill in missing gaps with respect to temporal coverage or sampling of age and length categories. Implicit in the inclusion of multiple survey indices of abundance is that each abundance is representative of a single underlying population, and any differences between the surveys can be attributed to the sampling characteristics (i.e., catchability and selectivity) (Conn 2010). The use of multiple surveys that each cover a portion of the distribution of the stock complicates interpretation, as any differences between indices could represent either differences in sampling characteristics (i.e., the proportion of the stock sampled by the survey could vary between regional subareas), or local differences in abundance trends (Peterson et al. 2021). Hilborn and Walters (1992) recommend that representative surveys cover the entire range of stock, as multiple surveys that each cover subareas of the stock may not necessarily be measuring the same signals (Maunder and Piner 2017). Conn (2010) developed a method for analyzing multiple “noisy” indices of abundance, but recommends screening the individual indices of abundance to ensure that the sampling is spatially balanced.

In the case of rockfish in the Aleutian Islands, none of the potential additional surveys (beyond the AFSC trawl survey) covers the entire range of the Aleutian Islands area defined for the stock, and there is biological and oceanographic data to suggest that the habitats and system structure differs between Aleutian Islands subareas. I begin by discussing the nature of these additional surveys, followed by discussion of the differences between subareas

NMFS longline survey

The AFSC longline survey samples a portion of the Aleutian Islands in even years. Prior to 1996 the survey was conducted cooperatively with Japanese vessels, whereas in 1996 and later the survey was conducted solely by AFSC. Sampling occurs east of 180° longitude in the “NE” and “SE” longline survey strata (Figure 14A.5; from Echave et al. 2013). Although no sampling occurs west of 180° longitude, the Relative Population Number (RPN) estimates for this area (i.e., the NW and SW strata) are produced based on ratios between the east and west Aleutians based on data from the Japanese longline surveys (which ended in 1994).

The correlation between the RPN values in the NE and SE areas is small (R^2 = 0.001); Figure 14A.6). The combined RPNs in the NE and SE longline areas can also be compared to the trawl survey estimates of abundance and biomass in the EAI and the eastern portion of the CAI (strata 32x and 42x). These correlations are also small, with R^2 values for 0.003 for trawl abundance and 0.05 for trawl numbers (Figure 14A.7). Finally, the CVs for the RPN index are consistently larger than those for either the trawl survey index of biomass or abundance (Figure 14A.8).

IPHC longline survey
The IPHC longline survey samples that entire Aleutian Islands area defined as the stock area in the assessment for most of the time series, with the IPHC AI subarea roughly corresponding to the WAI-CAI-EAI subarea of the AFSC trawl survey. IPHC RPN estimates are available beginning in 1998; however, beginning in 2021 the sampling design for this survey was substantially changed, with no sampling in the WAI.

The correlation between the IPHC survey RPN estimates for the AI subarea are generally consistent with the AFSC trawl survey abundance and biomass estimates (R^2 values of 0.71 and 0.44, respectively; Figure 14A.9). However, the data used for these correlations begins in 2000 and includes only years with estimates for each survey, and does not include a period in the late 1990s when the IPHC estimates declined sharply while the AFSC trawl estimates were more stable (Figure 14A.9). Finally, the CV estimates of the IPHC RPN values are generally larger than those of the AFSC trawl survey estimates of either biomass or abundance (Figure 14A.10).

ADFG trawl survey

The ADFG trawl survey extends as far west as Makushin Bay, and the Aleutian Islands stations for this survey correspond to the southern Bering Sea portion of the AI trawl survey. The survey time series begins in 1988, but in recent years the sampling in the AI has been limited to Akutan, Unalaska, and Makushin Bays. Given the limited geographic coverage of this survey, no further analyses were considered.

Spatial complexity within the Aleutian Islands

As mentioned above, differences in survey estimates of abundance or biomass between spatial subareas can be attributed to either sampling characteristics or underlying population characteristics. Comparing the correspondence between subarea estimates within a survey would presumably control for some of the sampling characteristics, and there was little correlation in the RPNs between the Aleutian Islands NE and SE areas of the AFSC longline survey (Figure 14A.6). Similarly, there is relatively little correspondence in the subarea biomass estimates from the AFSC trawl survey (Figure 14A.11), and the two areas with the strongest correlations (WAI and CAI) showed a negative correlation (i.e., in the 1990s the WAI was high and the CAI biomass was low, whereas the two years with the largest CAI abundance showed small estimated biomass in the WAI).

Given the oceanographic and biological complexity within the Aleutian Islands, it is not surprising that there is variation in trends between regions even within a single survey. The Aleutian Islands Ecosystem status reports recognizes three ecoregions (Ortiz and Zador, 2021), with the WAI subarea are from the trawl survey corresponding to the Western ecoregion, the CAI and EAI subareas from the trawl survey corresponding to the Central ecoregion, and the southern Bering Sea subarea from the trawl survey included in the Eastern ecoregion. These ecoregions were defined in 2011 by a team of ecosystem experts based on the ecological characteristics and oceanography; for example, the western ecoregion is distinct from the central ecoregion with respect to the northward flow of the Alaska Stream through deep passes (Ortiz and Zador 2021).

Given the differences in these ecological regions within the Aleutians, it is likely that underlying population trends differ between AI subareas, and that the spatial patterns cannot be attributed solely to variations in sampling characteristics (i.e., catchability). If surveys that cover a portion of the Aleutian Islands reflect different signals in the underlying population, then trends in one subarea would not be expected to correspond to trends in other areas.

Within AFSC, a team of scientists has been documenting the methodology of the AFSC and IPHC longline surveys, and providing RPN indices for various species. The advice of members of this team was not to use the IPHC longline survey due to the changes in the sampling design that started in 2021. Whereas the IPHC longline survey only recently had a spatial coverage issue in the Aleutian Islands, the AFSC longline survey has never sampled the WAI area. Given the rationale for the not including the IPHC survey, it appears that a stronger argument exists for also not including the AFSC longline survey in the assessment due to a mismatch in the spatial extent of the survey and stock area.

4) Natural mortality estimates

Natural mortality has been the subject of several comments from the BSAI Plan Team and SSC in recent years, as well as a focus of assessment model updates. A brief summary of this history is shown below.

BSAI Plan Team, November 2018 -- *For the next assessment, the Team recommends . . . examining larger bounds on M and investigating a profile of M and its subsequent impacts on model results.*

SSC, December 2018 – *The SSC also supports the PT recommendations for . . . examining larger bounds on M, applying a more rigorous prior on M, and investigating the profile of M.*

September 2020 Plan Team *The Team agrees with the author's recommendation to pursue the following three elements for the November 2020 assessment:*

1. Updating either the natural mortality point estimate or prior distribution using recent literature,

2. updating the ageing error matrix with likelihood-based estimates, and

3. using the Francis method for weighting composition data

SSC, October 2020 - *The PT recommended the updated model use the Then et al. (2015) literature value of M=0.045 as either a mean on the prior distribution for M or as a fixed M. The SSC concurs with the PT recommendation for the December assessment.*

The 2020 stock assessment set the mean of the prior distribution for natural mortality to 0.045, based on research by Then et al. (2015), as was recommended by both the Plan Team and SSC. The estimated *M* was 0.049. Additionally, a profile on the natural mortality parameter was presented.

SSC, December 2020 -- *The SSC notes that the values of M used in the AI assessment are very high, especially for a long-lived species, and requests that the authors fully explore the ranges and interactions of catchability and M in the AI assessment model.*

The methodology for obtaining the prior distribution of M was documented in the 2020 BSAI blackspotted-rougheye rockfish stock assessment (Spencer et al. 2020), and is based on three natural models developed by Then et al. (2015) based on maximum age, which Then et al. (2015) recommend as the preferred methodology. The observed maximum age t_{max} for BSAI blackspotted/rougheye rockfish is

134, and estimates of natural mortality for each model were obtained from values of t_{max} ± 25 years are shown below and ranged from 0.033 to 0.067:

		Maximum Age		
Method	Model	109	134	159
$Then_{1parm}$	$M = a/t_{max}$	0.047	0.038	0.032
$Then_{lm}$	$\log(M) = a + b * \log(t_{\max})$	0.049	0.040	0.033
$Then_{nls}$	$M = at_{max}^{b}$	0.067	0.055	0.047

The average from this table is 0.045, which is larger than the currently estimated value for Gulf of Alaska blackspotted/rougheye rockfish (0.034; Sullivan et al. 2021). However, a mean of the prior of 0.045, and an estimated parameter of 0.049 is consistent with other north Pacific stocks of blackspotted and rougheye rockfish. For example, a range of 0.035 – 0.055 was analyzed for British Columbia blackspotted and rougheye rockfish (DFO, 2020). Natural mortality was an estimated parameter in the stock assessment of rougheye and blackspotted rockfish along the ES west coast (Hicks et al. 2014). Despite using a prior distribution with a median of 0.034, the estimated natural mortality was 0.042, with a 95% confidence limit of 0.035 – 0.049.

The estimated natural mortality for Gulf of Alaska blackspotted and rougheye rockfish is lower than estimated values for the BSAI, British Columbia, and the US west coast, and is lower than estimates obtained from the more recent analyses of Then et al. (2015). The most recent assessment for GOA rougheye and blackspotted rockfish noted these differences, and stated that the authors plan to revisit natural mortality in future assessments (Sullivan et al. 2021).

5) Temporal changes in depth of fishery effort, and potential influences on age and size compositions

The mean depths of fishery trawl hauls, by AI subarea and year, are shown in Figure 14A.12, with red dashed lines the unweighted mean depths of all observed hauls that caught any blackspotted and rougheye rockfish, and the mean depths weighted by the extrapolated number caught in the haul shown in the solid red line. In the WAI, the unweighted mean depths increased from 155 m in 2002 to 270 m in 2013, and declined to 186 m in 2022. The weighted mean depth (i.e., the depths reflecting the locations where fish are captured by the trawl fishery) follows a similar trend, although not declining as rapidly in recent years as the unweighted mean depth. The pattern in the EAI is similar but with more temporal change, where the unweighted mean depths increased from 181 m in 2004 to 418 m in 2010 before declining to 192 m in 2022, and in recent years the unweighted and weighted mean depths are very similar. In the CAI, both the weighted and unweighted mean depths are have been relatively stable since the early 1990s.

It is useful to also compare the fishery mean depths to those from the trawl survey, as this would give an indication of the characteristics of the population. As expected, the unweighted mean depths in the survey are generally flat over time, and any changes in the unweighted mean depths is likely attributable to changes in allocation of survey tows between depth strata. However, in both the WAI and CAI, the weighted mean depth (in this case, weighted by numerical CPUE) has shown more temporal variability than the unweighted mean depth, and has decreased over time. In the WAI, the weighted mean survey depth of blackspotted and rougheye rockfish has decreased from 277 m in 1997 to 207 m in 2018, and in the CAI the weighted mean depth has decreased from 337 m in 2006 to 226 m in 2018. In the EAI, the weighted mean depth has decreased from 336 m in 2004 to 246 m in 2014, and increased to 292 m in 2018.

In summary, the mean depths of the fishery and the survey have each shown decreases over time. Shifting of fishery effort to shallower depths could contribute to the fishery pattern but would not explain the pattern in the survey mean depths. The decreases in the survey mean depths could be explained by changes in the age/size structure (i.e., age/size groups that occur at shallower depths have increased their relative proportion in the population over time).

Similarly, any change in the fishery length distributions over time could either reflect changes in selectivity that result from changes in fishing behavior, or changes in the underlying population. Comparisons between the fishery and survey size compositions can help disentangle these factors, and are shown in Figure 14A.13 by area for different time periods. Each of the time periods shows the combined size composition for multiple years of survey populations and fishery catch for relatively short time blocks. In general, the fishery and survey populations correspond relatively closely to each other, with only a few exceptions (i.e., CAI from 2010 – 2012, WAI from 2004 – 2006). Both the survey and fishery length compositions have shifted to smaller sizes over time. Using the WAI as an illustrative example, from 2000 – 2002 the proportion of fish exceeding 40 cm was 86% in the survey ad 82% in the trawl fishery, and from 2016 – 2018 these proportions decreased to 34% in the survey and 29% in the trawl fishery. Thus, while the depth of fishery effort has varied somewhat over time, the length compositions in the fishery has largely tracked the length compositions in the trawl survey.

Summary, and recommendations for November 2022 assessment

A team of scientists within AFSC that has reviewed the IPHC longline survey and produced RPN estimates for groundfish stocks do not recommend use of the IPHC survey RPN estimates, largely because the changes in sampling effort in 2021 resulted in the much of the western Aleutian Islands being unsampled (Jane Sullivan., AFSC, pers. comm.). Whereas the IPHC longline survey only recently had a reduction in spatial coverage, the AFSC longline survey has never sampled the WAI area; thus, a stronger argument exists for also not including the AFSC longline survey in the assessment due to a mismatch in the spatial extent of the survey and stock area. None of the additional candidate surveys covers the entire Aleutian Islands, and the observed differences in trends between subareas (both within a given survey, and between separate survey series) could reflect some combination of both sampling characteristics (i.e. catchability and selectivity) and underlying differences in population signals. The ecological differences between Aleutian Islands subareas recognized in the Aleutian Islands ecosystem report (Ortiz and Zador 2021) reflects potential habitat differences that would be expected to affect subarea productivity and population dynamics. Finally, both the AFSC and IPHC longline surveys have higher CVs for the RPNs than the CVs for the abundance or biomass estimates from the AFSC trawl survey.

Length compositions between the trawl fishery and the AI survey are largely consistent with each other, indicating that recent increases in the proportion of small fish is not primarily a function of changes in the depths of fishery effort. Given this observation, it is unclear what effect modeling time-varying fishery selectivity would have on the model results, although this could be explored for the November 2022 assessment.

References

Conn, P.B. 2010. Hierarchical analysis of multiple noisy abundance indices. Can. J. Fish. Aquat. Sci. 67: 108–120.

DFO. 2020. Rougheye/Blackspotted Rockfish (Sebastes aleutianus/melanostictus) Stock Assessment for British Columbia in 2020. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/047.

Echave, K., Rodgveller, C. and Shotwell, S.K. 2013. Calculation of the geographic area sizes used to create population indices for the Alaska Fisheries Science Center longline survey. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-253, 93 pp.

Hicks, A.C, Wetzel, C., and Harms, J. 2014. The status of rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*) as a complex along the U.S. West Coast in 2013. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.

Hilborn, R. and Walters, C.J. 1992. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall, London.

Maunder, M.N. and Piner, K.R. 2017. Dealing with data conflicts in statistical inference of population assessment models that integrate information from multiple diverse data sets. Fisheries Research 192 (2017) 16–27.

Ortiz, I. and Zador, S. 2021. Ecosystem Status Report 2021: Aleutian Islands, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, Alaska 99501.

Peterson, C.D., Courtney, D.L., Cortes, E., and Latour, R.J. 2021. Reconciling conflicting survey indices of abundance prior to stock assessment. ICES Journal of Marine Science, 78(9), 3101–3120.

Spencer, P.D., J.N. Ianelli, and W.A. Palsson. 2020. Assessment of the blackspotted and rougheye rockfish complex in the eastern Bering Sea and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501

Sullivan, J.Y., Shotwell, S.K., Hanselman, D.H., Hulson, P.-J. F., Williams, B.C., Yasumiishi, E.M., and Ferriss, B.E. 2021. Assessment of the Rougheye and Blackspotted Rockfish stock complex in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501

Then, A.Y., Hoenig, J.M., Hall, N.G., and Hewitt, D.A. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science, 72(1), 82–92.

Table 14A.1. Number of the AFSC Aleutian Islands trawl survey hauls, by year, subarea, and depth

	WAI					CAI					EAI					EAI					AI Survey
Year	0 - 100 m	100 - 200 m	200 - 300 m	300 - 500 m	WAI total	0 - 100 m	100 - 200 m	200 - 300 m	300 - 500 m	WAI total	0 - 100 m	100 - 200 m	200 - 300 m	300 - 500 m	WAI total	0 - 100 m	100 - 200 m	200 - 300 m	300 - 500 m	WAI total	total
1991	6	31	10	9	56	16	44	20	11	91	14	66	28	21	129	30	19	2	4	55	331
1994	15	33	12	9	69	22	49	24	19	114	18	62	30	23	133	31	26	4	3	64	380
1997	15	50	22	10	97	26	53	30	22	131	21	61	42	28	152	31	17	6	3	57	437
2000	16	57	30	10	113	23	39	28	20	110	13	46	55	24	138	28	17	8	5	58	419
2002	25	51	18	13	107	29	45	23	17	114	16	47	43	27	133	30	16	7	9	62	416
2004	23	62	25	14	124	31	48	30	21	130	15	42	33	22	112	33	8	4	8	53	419
2006	22	47	23	21	113	32	35	21	22	110	12	31	28	23	94	21	12	4	8	45	362
2010	32	55	22	9	118	48	47	21	12	128	21	55	33	12	121	27	14	5	5	51	418
2012	23	57	31	9	120	26	42	32	14	114	14	59	47	13	133	26	16	8	5	55	422
2014	24	70	33	7	134	25	43	32	10	110	15	55	44	9	123	19	12	9	4	44	411
2016	24	75	30	6	135	25	49	30	10	114	15	58	45	9	127	18	13	8	4	43	419
2018	25	73	25	6	129	34	52	24	10	120	18	61	39	8	126	20	14	7	4	45	420

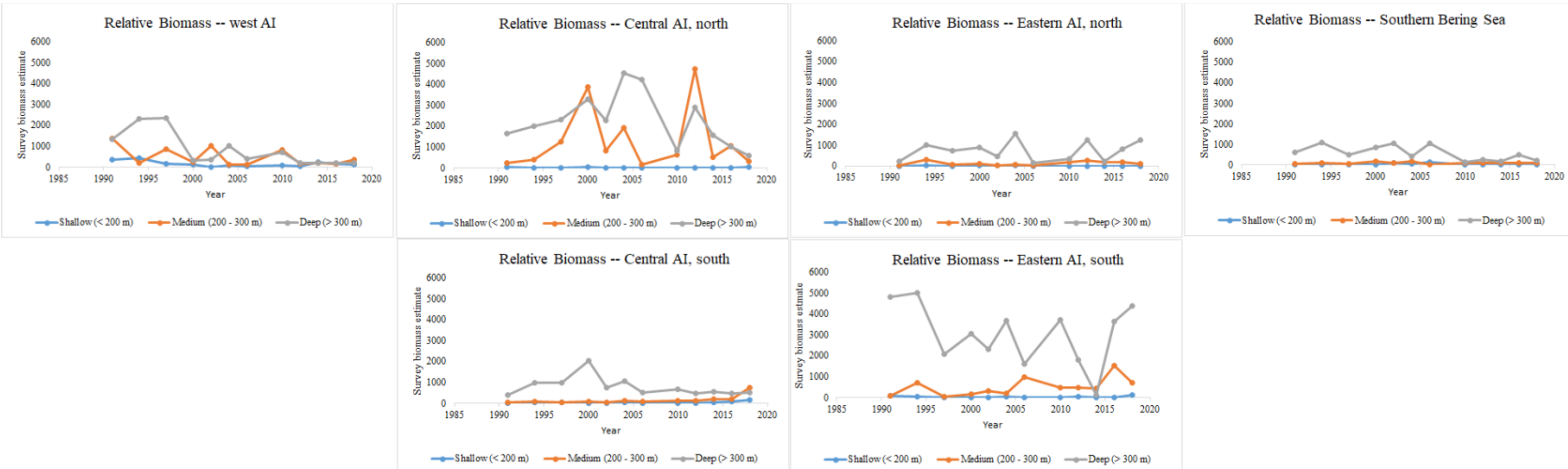

Figure 14A.1. Estimated biomass from the AFSC Aleutian Islands trawl survey, by year, depth, and subarea

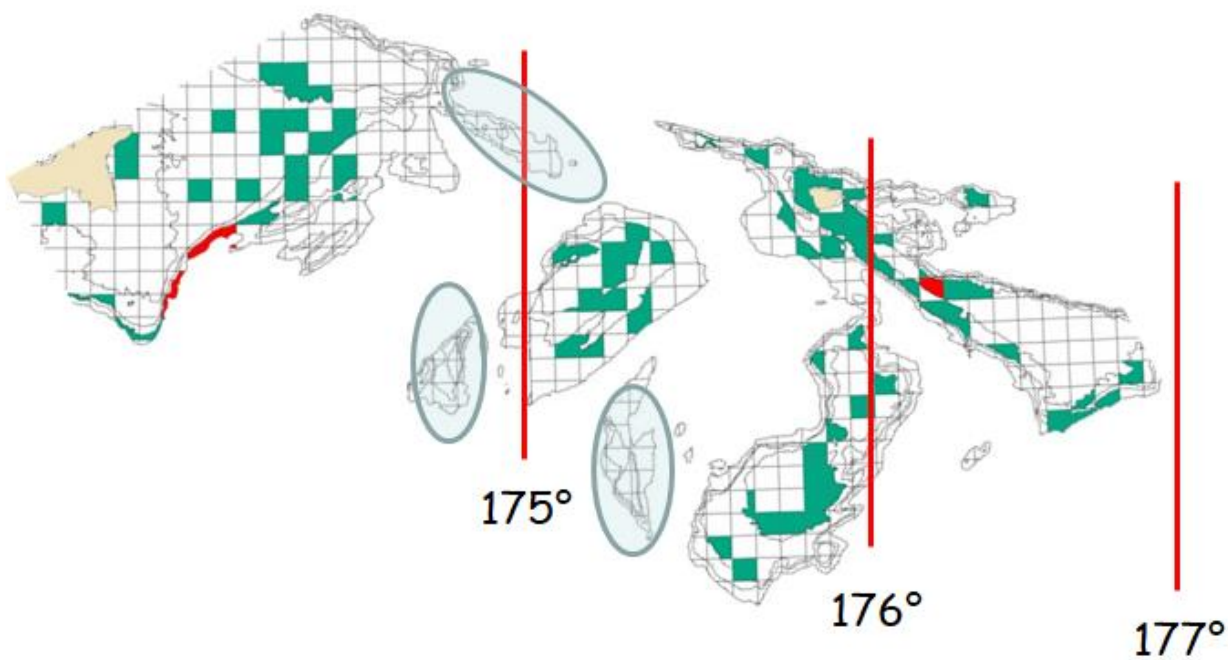

Figure 14A.2. Aleutian Island trawl survey sampling cells in the WAI subarea. Green cells indicate sampling cells that have been successfully trawled, and red cells indicate untrawlable cells. The 3 ellipses indicate areas without survey sampling that commonly has fishing effort.

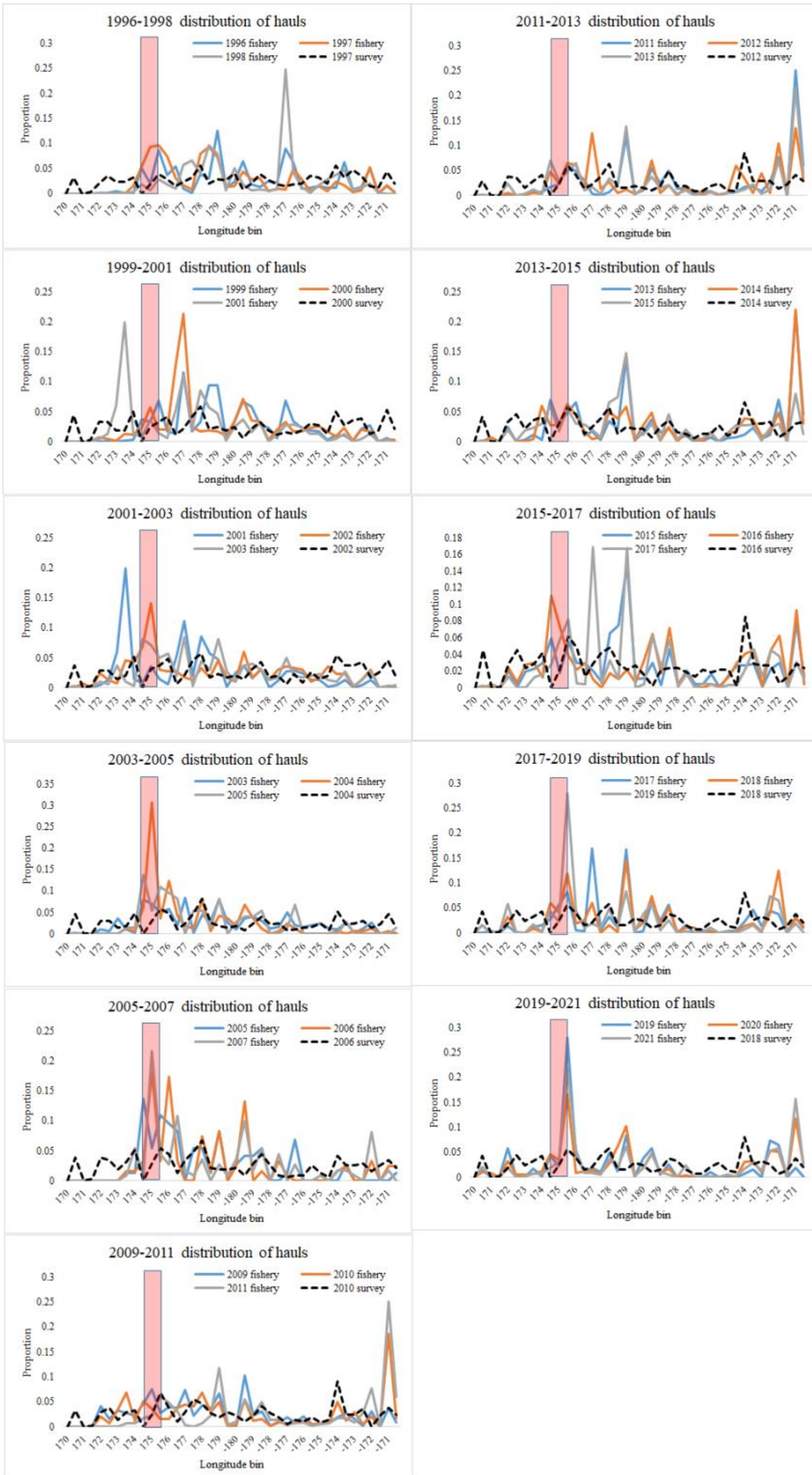

Figure 14A.3. Proportion of Aleutian Islands fishery and survey hauls by 0.5° longitude bins. The red region spans 174.5° - 176° longitude, corresponding to the area shown in Figure 2.

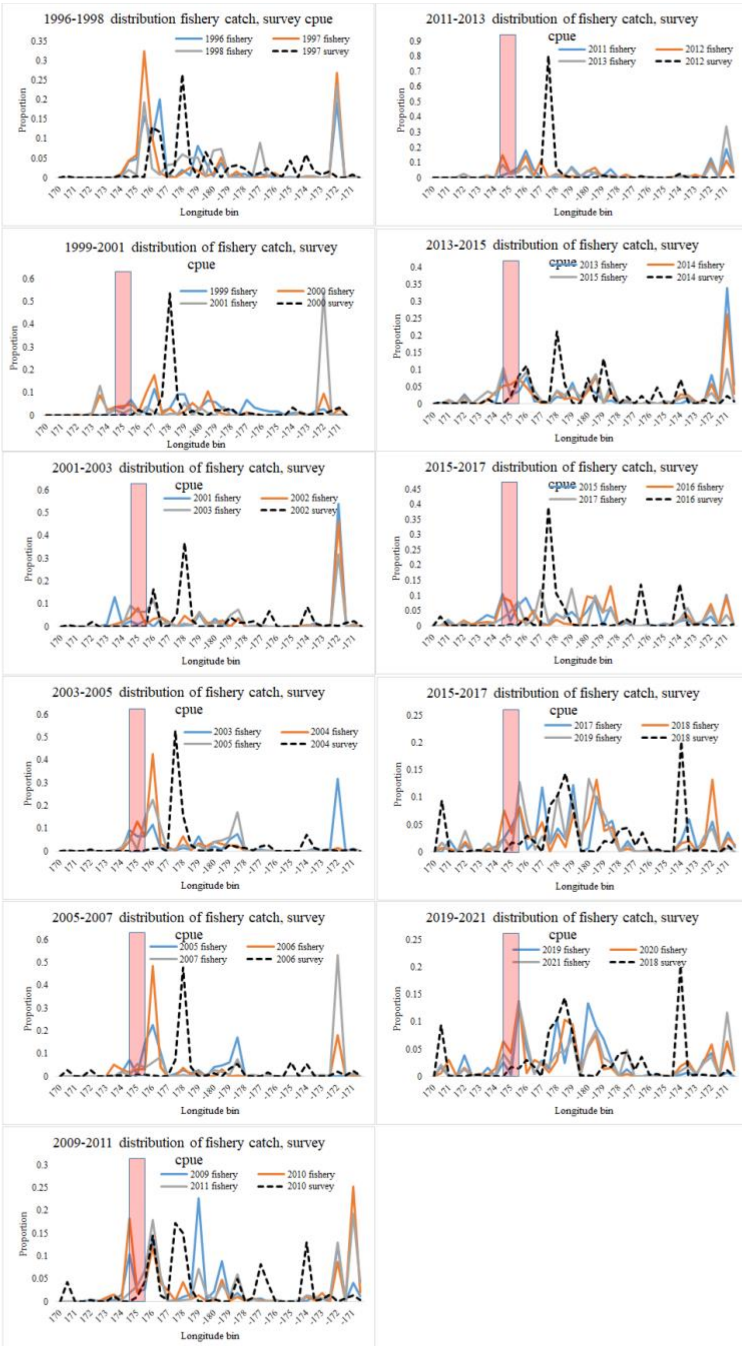

Figure 14A.4. Proportion of Aleutian Islands fishery catch and survey CPUE by 0.5° longitude bins. The red region spans 174.5° - 176° longitude, corresponding to the area shown in Figure 2.

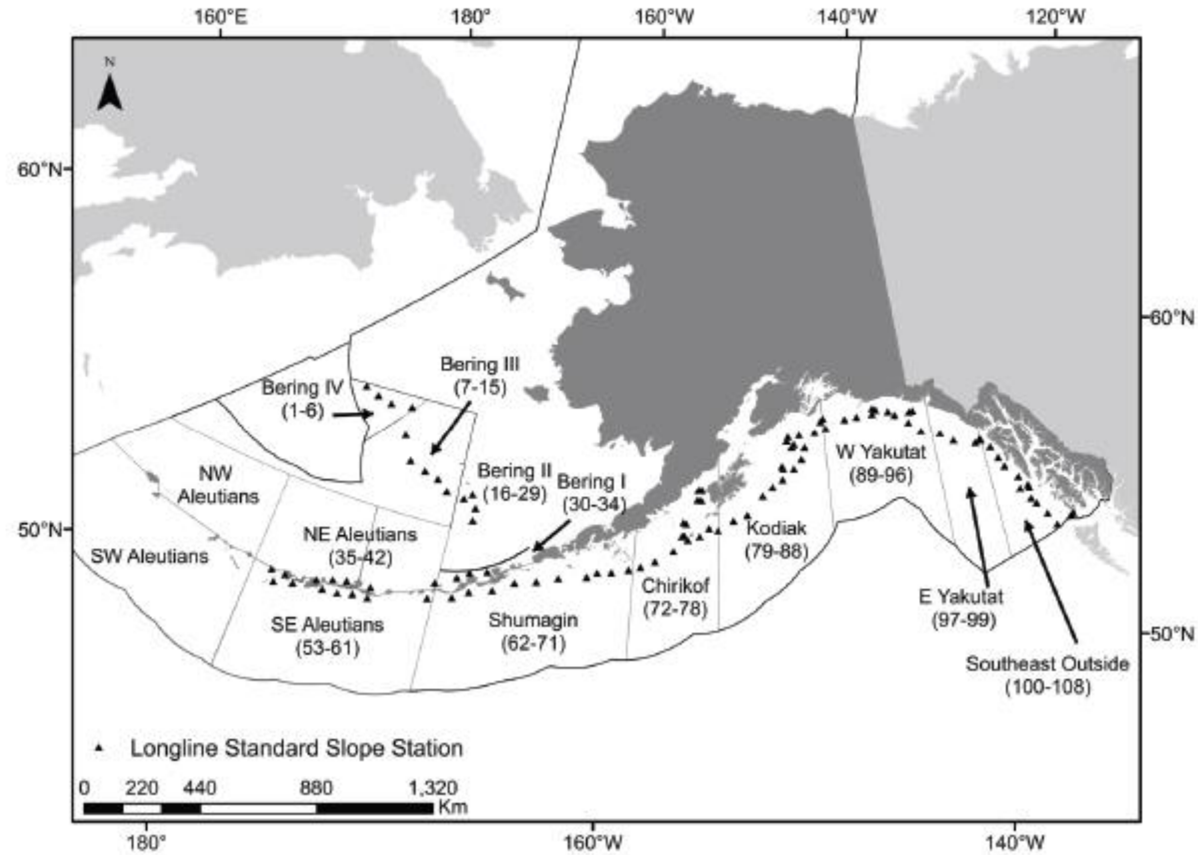

Figure 14A.5. Sampling locations of the AFSC Longline Survey (from Echave et al. 2013).

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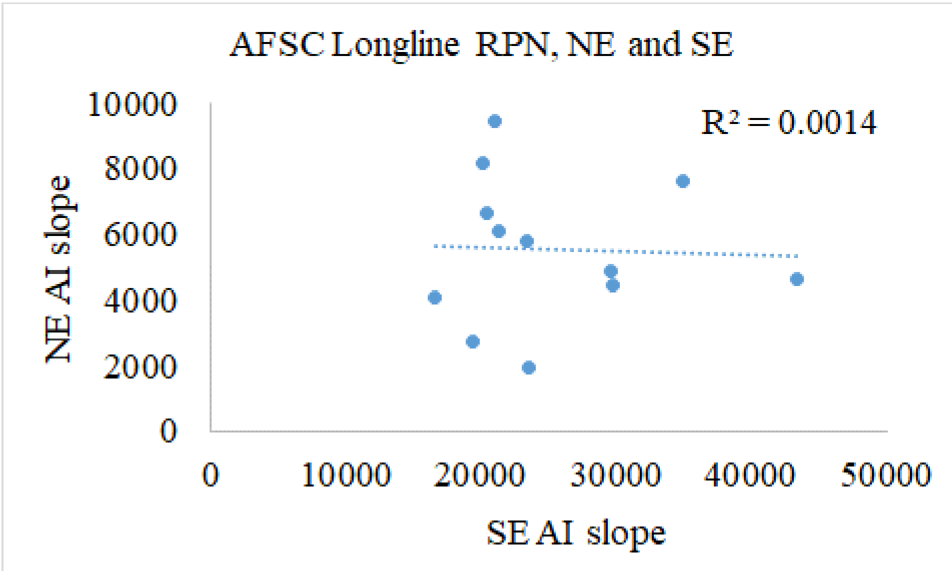

Figure 14A.6. Correlation between AFSC longline survey RPN estimates from the NE and SE regions.

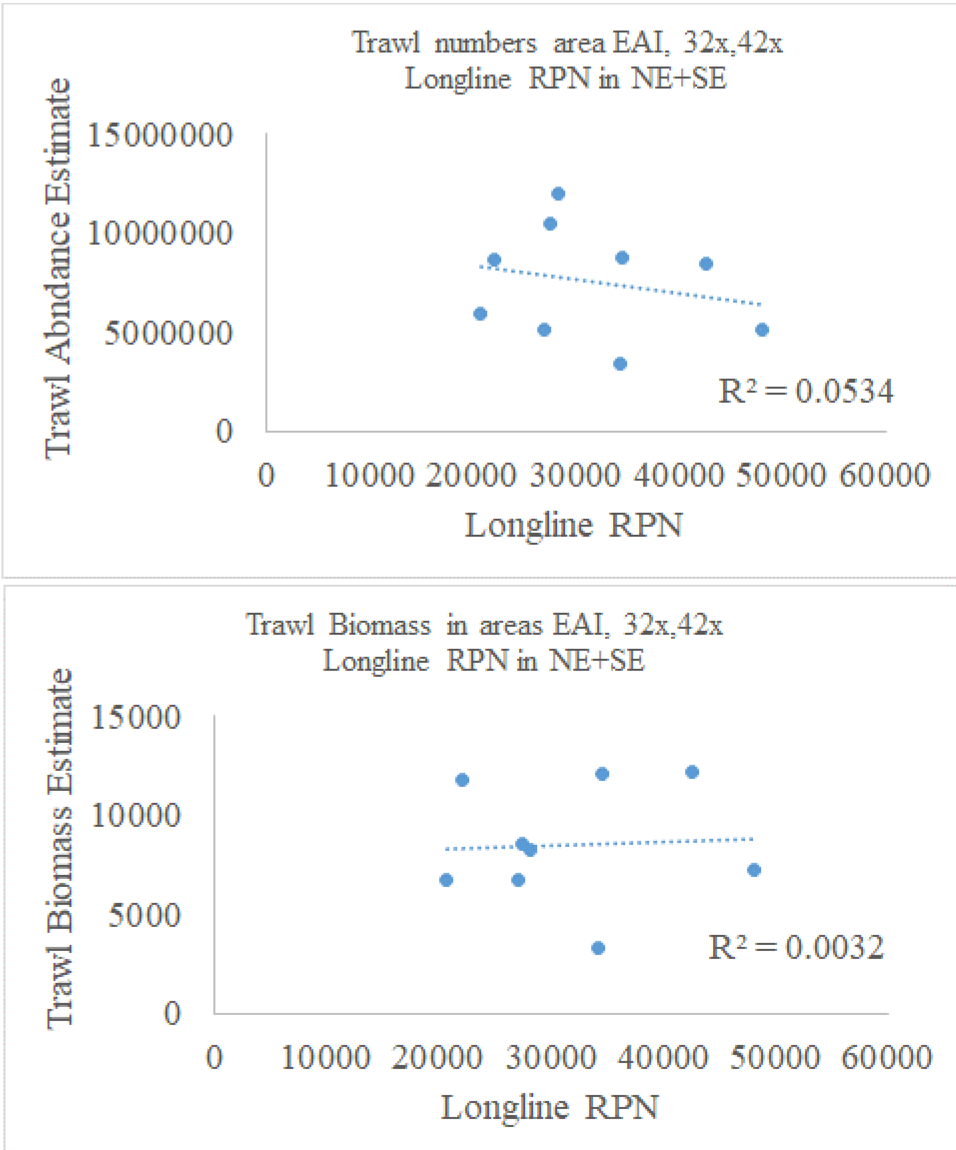

Figure 14A.7. Correlation between AFSC longline survey RPN estimates from the combined NE and SE regions, and AFSC trawl survey estimates from the EAI and strata 32x and 42x (i.e., the eastern portion the CAI area).

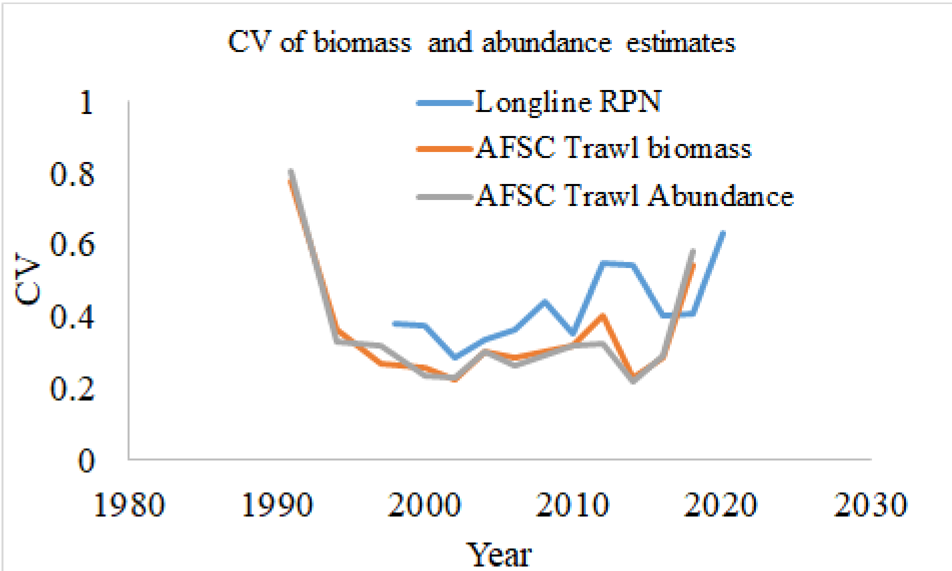

Figure 14A.8) CVs of biomass and abundance estimates from the AFSC longline and trawl surveys (for the EAI and eastern portion of the CAI).

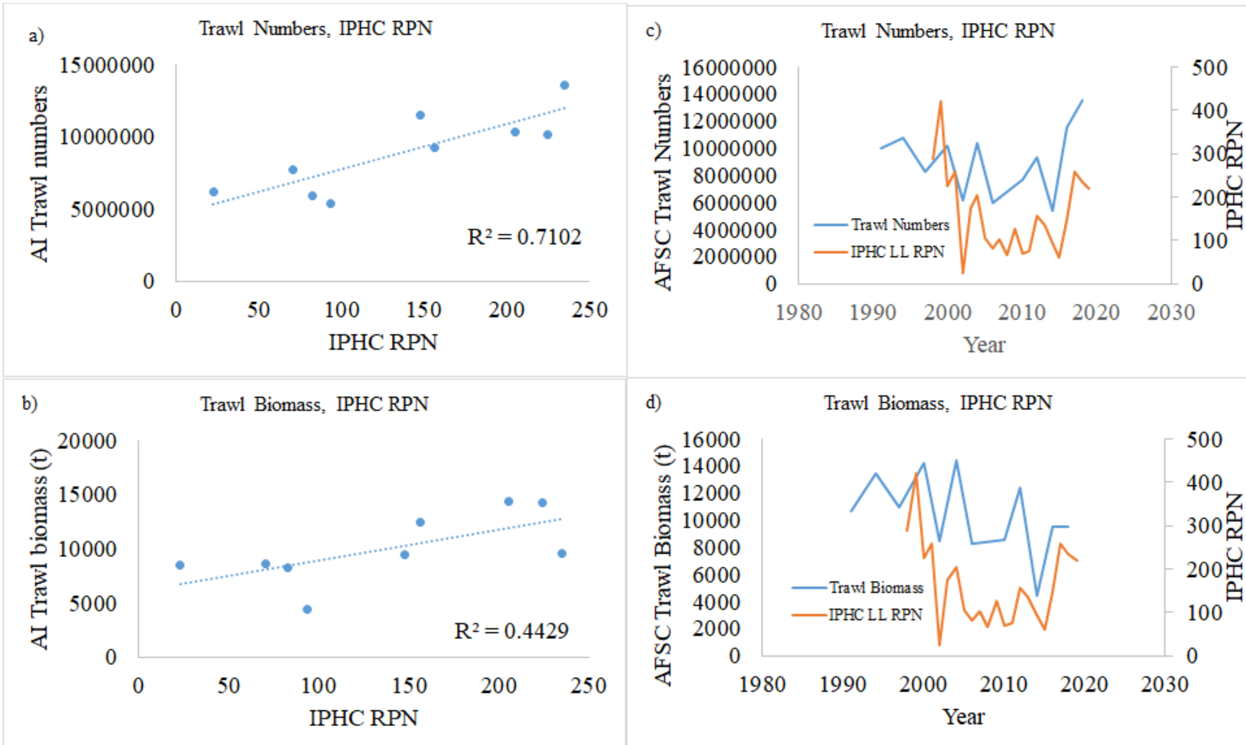

Figure 14A.9). Correlation between IPHC longline survey RPN estimates and AFSC trawl survey estimates from the Aleutian Islands (areas WAI, CAI, and EAI).

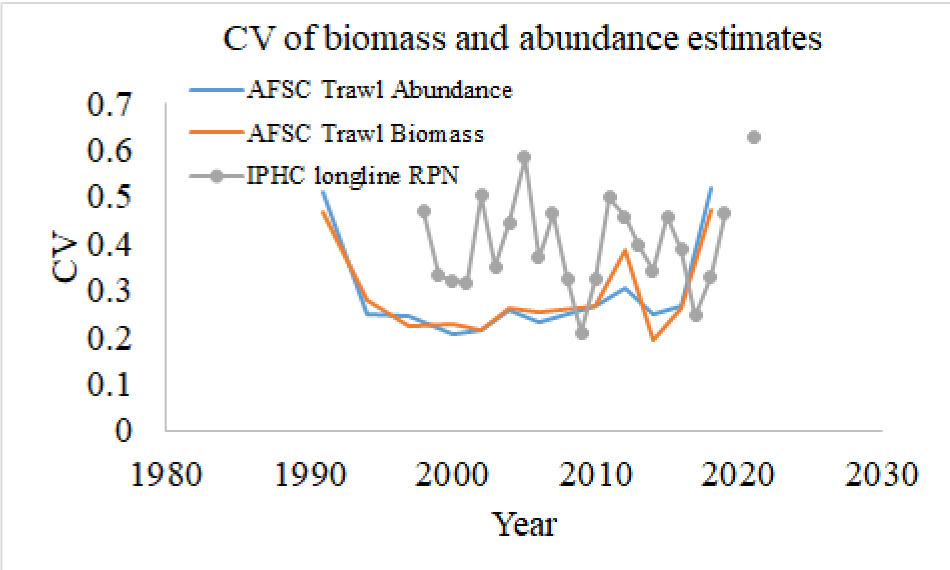

Figure 14A.10) CVs of biomass and abundance estimates from the IPHC longline and AFSC trawl surveys (areas WAI, CAI, and EAI).

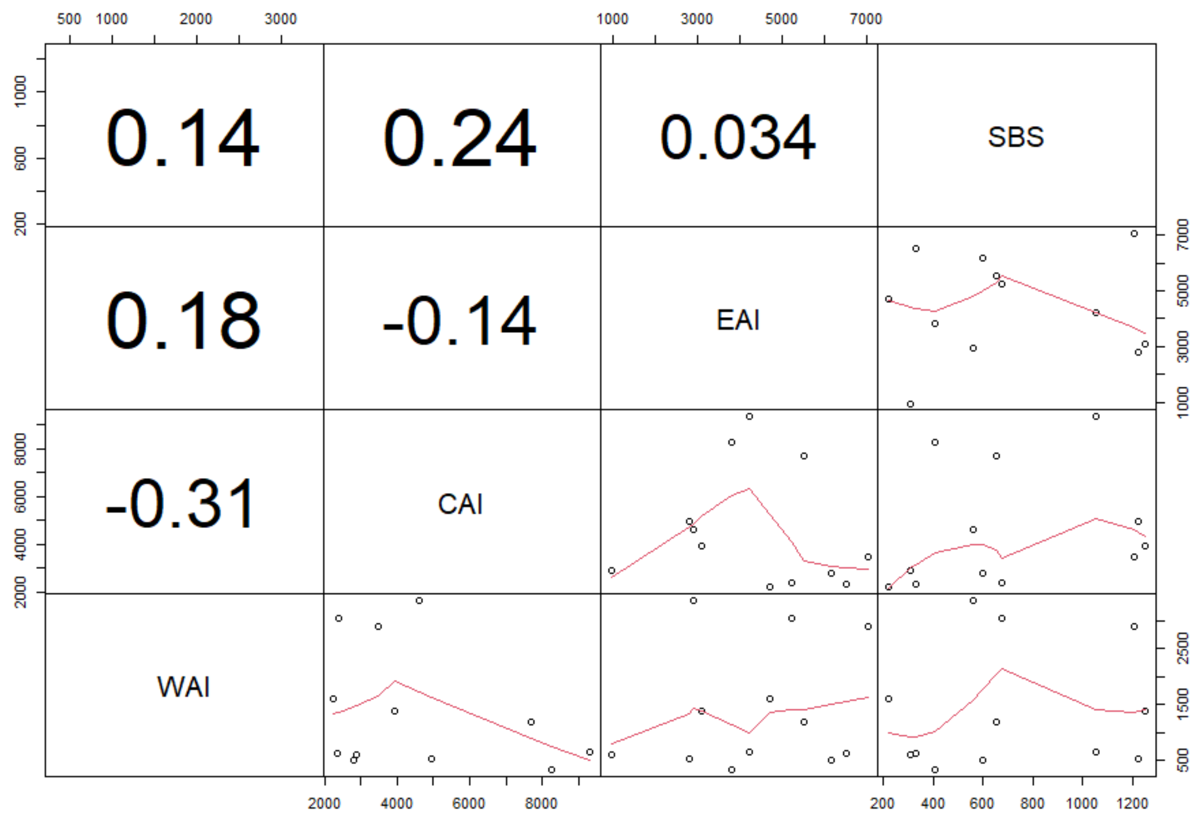

Figure 14A.11. Correlations (upper diagonal) and scatterplots (lower diagonal) of subarea biomass estimates from the AFSC trawl survey (1991 – 2018)

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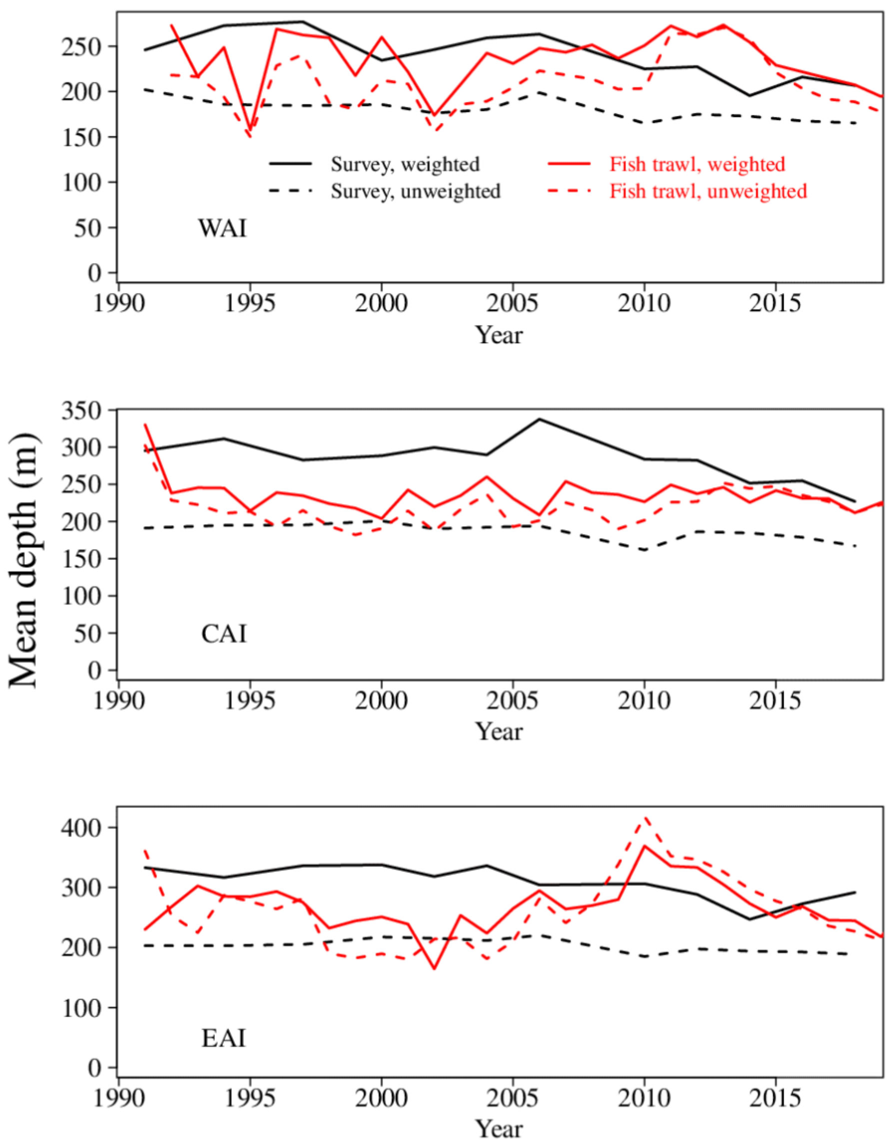

Figure 14A.12. Mean depth for fishery and survey tows by year and subarea in the Aleutian Islands. The fishery unweighted time series corresponds to all trawls capturing blackspotted rockfish or rougheye rockfish, whereas fishery weighted time series weights tows by the extrapolated number in the haul. The survey unweighted time series uses all survey hauls, whereas the survey weighted time series weight tows by the numerical CPUE.

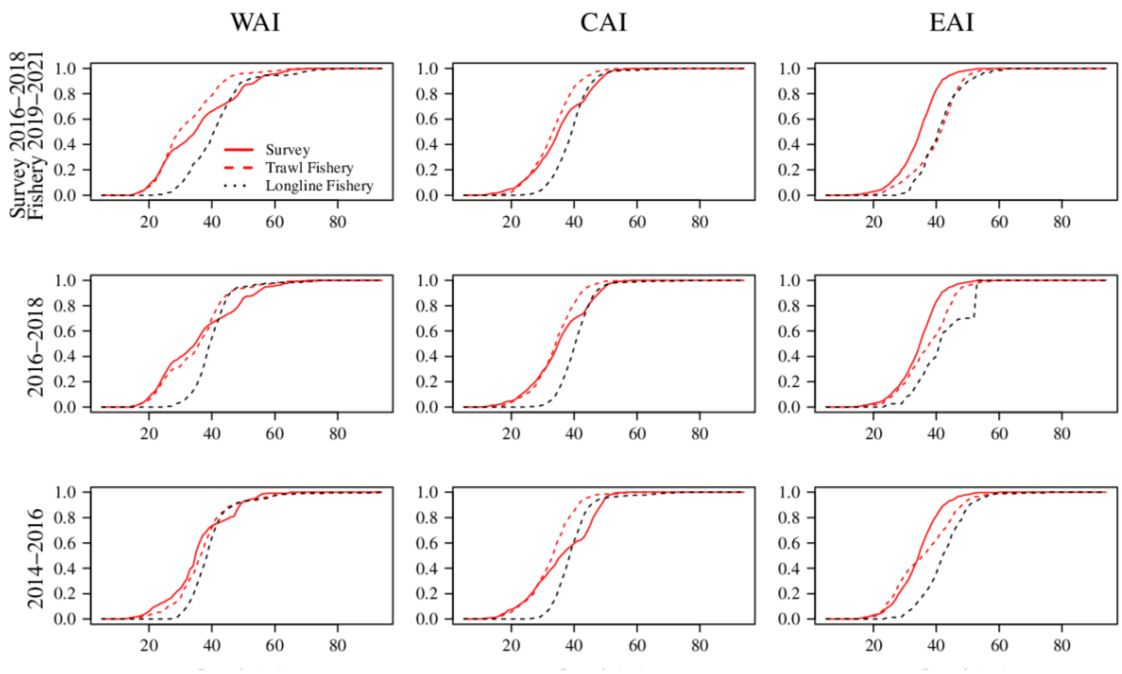

Figure 14A.13) Length compositions (shown as cumulative distributions) from the fishery and AFSC trawl survey, by area and time periods.

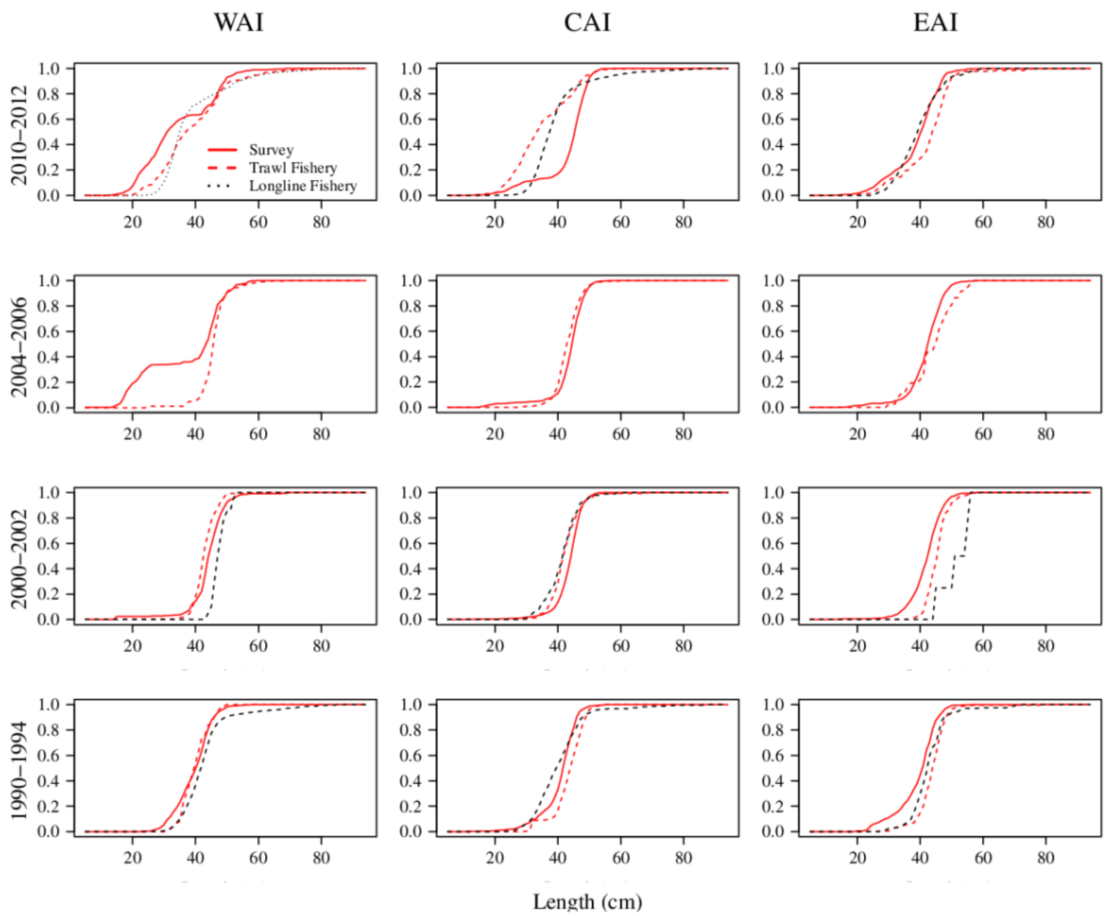

Figure 14A.13, continued).

Appendix 14B. Area-specific exploitation rates

Area-specific exploitation rates are defined here as the yearly catch within a subarea divided by an estimate of the subarea biomass at the beginning of the year. Area-specific exploitation rates are generated to assess whether subarea harvest is disproportionate to biomass, which could result in reductions of subarea biomass for stocks with spatial structure.

For each year from 2004 through 2022, the biomass for the subareas was obtained by partitioning the estimated total AI biomass (ages 3+) at the beginning of the year (obtained from 2022 AI blackspotted/rougheye age structured model). The biomass estimates from the 2022 AI age structured model are assumed to be the best available information on the time series of total biomass for the AI area, and this method can be considered a "retrospective" look at past exploitation rates. The distribution of biomass across the AI subareas was obtained by fitting a random walk smoother (with changes in biomass modeled as random effects) to the time series of biomass within each subarea, and computing the relative spatial distribution of the smoothed results. The smoothed biomass estimates for the SBS area and the EBS slope survey were used as the best available biomass estimates for the EBS area. Catches through September 25, 2022, were obtained from the Catch Accounting System database.

To evaluate the potential impact upon the population, exploitation rates were compared to two reference levels: 1) 0.75 times the estimated rate of natural mortality (M), which is the fishing mortality F_{abc} that produces the allowable biological catch for Tier 5 stocks; and 2) 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, and thus may be seen as more appropriate for Tier 3 stocks because harvest recommendations are based upon this age-structured information. Blackspotted/rougheye rockfish were assessed as a Tier 5 stock prior to 2009, and as a Tier 3 stock since 2009.

The exploitation rate in the WAI has been above $U_{F40\%}$ for each year since 2004. Exploitation rates in the WAI from 2014 to 2017 have declined from generally higher levels from 2004-2013 (Figure 14B.1). However, the WAI exploitation rate in 2020 increased to 0.09, the largest observed since 2006 and approximately 4.2 times $U_{F40\%}$ reference value of 0.021, before declining in 2021 and 2022. The exploitation rates for the CAI and EBS have also been increasing and were above $U_{F40\%}$ from 2019 - 2021. It is important to note that in recent years, blackspotted/rougheye rockfish have been managed as Tier 3b stock and the F values used for management were lower than $F_{40\%}$.

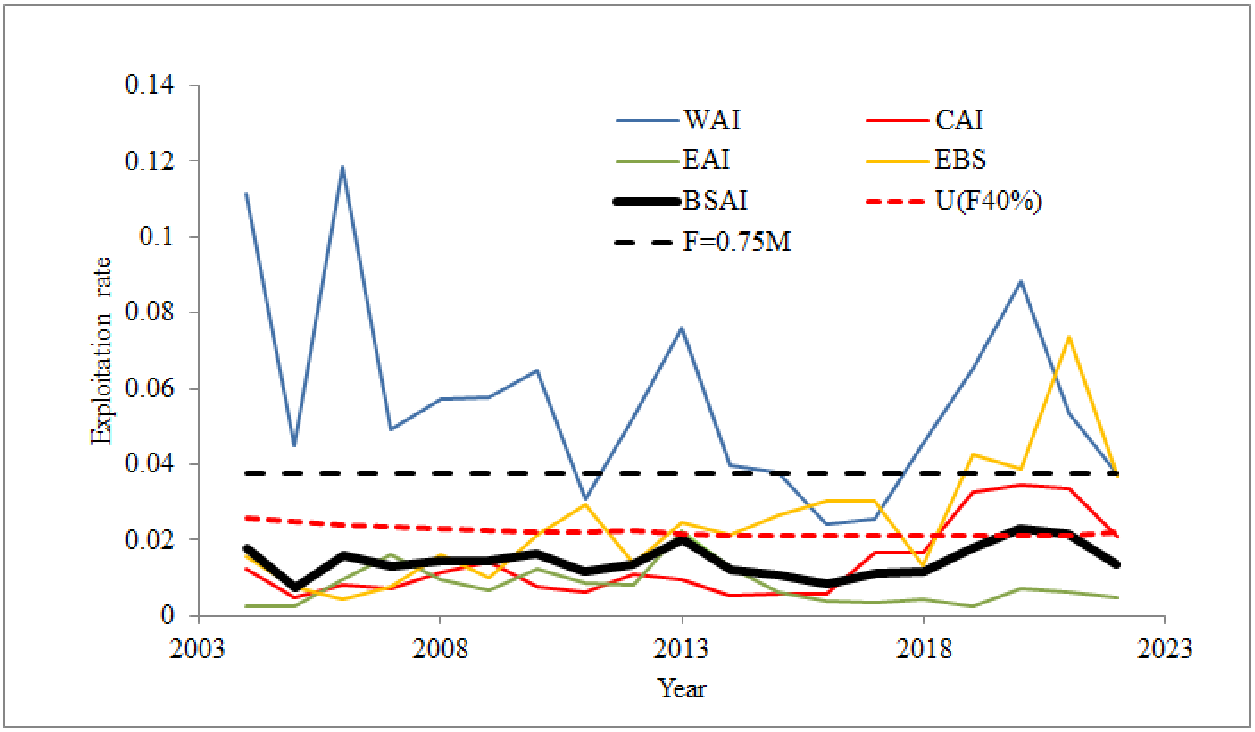

Figure 14B.1. Exploitation rates within BSAI subareas for blackspotted/rougheye rockfish, with reference exploitation rates of 0.75*M and $U_{F40\%}$.

Appendix 14C. 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 14C.1). In these datasets, blackspotted /rougheye rockfish are often reported as rougheye rockfish. 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 blackspotted/rougheye rockfish, these estimates can be compared to the trawl research removals reported in previous assessments. BSAI blackspotted/rougheye 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 blackspotted/rougheye rockfish. The annual amount of blackspotted/rougheye rockfish captured in research longline gear not exceeded 1.01 t. Total removals ranged between 2010 and 2021 ranged between 0.149 t and 1.08 t, which were less than 0.25% of the ABC in these years.

Appendix Table 14C.1. Removals of BSAI blackspotted/rougheye rockfish (t) from activities other than groundfish fishing. Trawl and longline include research survey and occasional short-term projects. "Other" is recreational, personal use, and subsistence harvest.

Year	Source	Trawl	Longline	Other
1977	NMFS-AFSC survey databases	0.000		
1978		0.002		
1979		0.468		
1980		6.844		
1981		1.086		
1982		0.963		
1983		9.780		
1984		0.000		
1985		3.719		
1986		24.241		
1987		0.006		
1988		0.200		
1989		0.001		
1990		0.018		
1991		1.994		
1992		0.014		
1993		0.000		
1994		2.769		
1995		0.003		
1996		0.001		
1997		2.596		
1998		0.000		
1999		0.010		
2000		3.343		
2001		0.001		
2002		2.276		
2003		0.011		
2004		3.499		
2005		0.001		
2006		1.976		
2007		0.001		
2008		0.205		
2009		0.006		
2010	AKFIN database	0.133	0.424	
2011		0.005	0.154	
2012		0.132	0.300	
2013		0.000	0.299	
2014		0.032	0.508	
2015		0.000	0.216	
2016		0.048	0.334	
2017		0.000	1.080	
2018		0.018	0.623	
2019		0.000	1.009	
2020		0.000	0.149	
2021		0.000	0.175	