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

by

Paul D. Spencer, James N. Ianelli, and Wayne A. Palsson

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 2018. The following changes were made to blackspotted/rougheye assessment relative to the November 2018 SAFE:

Summary of Changes in Assessment Inputs

Changes in the input data

1) Catch data was updated through 2019, and total catch for 2020 was projected.
2) The 2018 AI survey length composition was replaced by the 2018 survey age composition.
3) The 2018 and 2019 AI fishery length compositions were included in the assessment.
4) The length-at-age, weights-at-age, and age-to-length conversion matrices were updated based on data from the NMFS AI trawl survey beginning in 1991.

Changes in the assessment methodology

1) The weights for the age/length composition data were calculated based on the Francis iterative reweighting procedure (Francis 2011). This method was used in the recommended model for 2018, but was not used in the model accepted by the SSC in 2018.
2) The mean of the prior distribution for natural mortality was increased to 0.045, based on research by Then et al. (2015).
3) The proportion mature at age was estimated within the model from data collected by Dr. Christina Conrath (NOAA-Fisheries, AFSC, pers. comm.).

Summary of Results

The assessment of AI blackspotted/rougheye rockfish indicates a reduction of older fish in the 3 AI surveys from 2014-2018 which is not explained by the models considered. Some increase in the younger fish is also observed in recent AI surveys, although these are for ages with low survey and fishery selectivity. Models that give relatively more emphasis to fitting the age and length compositional data (relative to fitting the AI survey biomass index) result in degraded fits to the AI biomass survey biomass estimates, strong retrospective patterns in estimated spawning stock biomass and recruitment, and large estimates of recruitment for recent year classes with low selectivity (and which can vary substantially between assessments). In contrast, models that give relatively more emphasis to fitting the AI survey biomass index result in improved fits to this index, reduced retrospective bias, and lower estimates of recent year classes that produce a time series of estimated biomass more consistent with the scale and trend of the AI survey biomass estimates. A number of these observations/concerns are described in more detail below.

Drop in abundance of older fish: The number of older fish in the recent AI surveys and fishery catch is less than previous years. 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, and have remained low in the 2016 and 2018 surveys. Prior to 2015, the proportion of fish aged 23 and older in the fishery catch ranged from 42% (2009) to 92% (2007). In 2015 and 2017, these proportions were reduced to 19% and 9%, respectively.

Mismatch in data vs. model total mortality: Cohort-specific mortality rates from the models considered in this assessment are smaller than those estimated directly from survey data (via catch curves), indicating that the model does not have a mechanism for explaining less than expected number of older fish in recent years.

Poor residual pattern: The fit and residual pattern to the AI survey estimate is poor, with the large biomass estimates from 2000, 2002, and 2012 not well fit by the models considered in this assessment.

Mismatch in model versus survey trend: There is an overall decreasing trend in the AI survey biomass trend, yet the 2018 population model (updated with current data) shows a strong increase in recent total biomass (i.e., a factor of 2.75 since 2000).

Changes in magnitude of year-class estimates: The estimate of the 1998 year class has declined from 23.1 million in the 2014 assessment to 7.8 million in the 2018 assessment, indicating an example of the uncertainty in early recruitment estimates.

Population shifts younger: The 2018 model (updated with current data) estimates that the current population is young and consists of a relatively small number of year classes with low survey selectivity, with 70% of the 2020 numerical abundance at or below age 15 (ages which have less than 20% survey selectivity). In this model, the large year class for 2010 comprises 21% of the 2020 total biomass, and the 2010, 2002, and 1999 year classes comprise about 41% of the total 2020 biomass.

Large inter-assessment changes: Because surveys and full assessment do not occur annually, projected population biomass and harvest specifications in off years or non-survey years are not updated with new survey information that may reduce uncertainty of key year class strengths. For example, for the accepted 2018 assessment model, the concentration of the estimated 2018 population into a small number of year classes resulted in a sharp increase in the 2020 ABC and OFL as the estimated population has grown in size and become more available to the fishery. The 2020 maximum ABC for the AI portion of the stock was a 29% increase from the 2019 ABC. This increase is unusual for a long-lived stock, particularly without a definitive increase in survey biomass estimates.

Positive retrospective bias in recruitment estimates: Models with relatively stronger emphasis on fitting the age/length composition data did poorly in retrospective analyses with positive biases for spawning stock biomass.

A data-weighting method to improve fit to survey index: The Francis (2011) data weighting procedure improved the retrospective bias and produce trends in abundance more consistent with the observed trends in survey biomass, and is recommended for this assessment.

The recommended 2021 BSAI ABC of 482 t is a 32% decrease from the 2020 ABC of 708 t. The decrease in ABC results from the change in the method for weighting the compositional data (i.e., the Francis method in the recommended model and the McAllister-Ianelli method in the accepted 2018 model), and the lower estimates of recent biomass with the Francis weighting which is more consistent with the scale and trend of survey biomass estimates. Additionally, as noted above the 2020 ABC (obtained from an off-year assessment with no new data) is itself a substantial increase (29% for the AI portion of the stock) from the 2019 ABC due to projecting forward from a 2018 assessment model that showed a high proportion of the stock at young ages with low survey selectivity (i.e., ages which are not commonly observed in the survey data).

Use of the updated prior distribution for natural mortality (*M*) increased the estimate of *M* to 0.049 (from 0.033 in the 2018 assessment). The effect of this increase on fishing mortality reference points is tempered by an updated age at 50% maturity to 24.5 years (from 18.4 years in the 2018 assessment), based on recent data collected in the Gulf of Alaska.

A summary of the 2021 recommended ABC's (from the AI model) relative to the values specified for 2020 (based on the accepted 2018 AI model) is shown below.

Quantity	As estimated or *specified* last year for:		As estimated or *recommended* this year for:	
	2020	2021	2021*	2022*
M (natural mortality rate)	0.032	0.032	0.049	0.049
Tier	3b	3b	3b	3b
Projected total (age 3+) biomass (t)	49,005	51,451	17,632	17,729
Female spawning biomass (t)				
Projected	10,213	11,551	3,372	3,457
$B_{100\%}$	29,287	29,287	8,811	8,811
$B_{40\%}$	11,715	11,715	3,524	3,524
$B_{35\%}$	10,250	10,250	3,083	3,083
F_{OFL}	0.042	0.047	0.038	0.038
$maxF_{ABC}$	0.034	0.039	0.032	0.033
F_{ABC}	0.034	0.039	0.032	0.033
OFL (t)	817	1046	509	528
maxABC (t)	675	866	432	450
ABC (t)	675	866	432	450
Status	As determined *last* year for:		As determined *this* year for:	
	2018	2019	2019	2020
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on estimated catches of 432 t in 2021, and 438 t used in place of maximum permissible ABC for 2022.

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 2021-2022 recommended ABC's for the EBS portion of the population is shown below.

Quantity	As estimated or *recommended* last year for:		As estimated or *recommended* this year for:	
	2020	2021	2021	2022
M (natural mortality rate)	0.032	0.032	0.049	0.049
Tier	5	5	5	5
Biomass (t)	1371	1371	1371	1371
F_{OFL}	0.032	0.032	0.049	0.049
$maxF_{ABC}$	0.024	0.024	0.037	0.037
F_{ABC}	0.024	0.024	0.037	0.037
OFL (t)	44	44	67	67
maxABC (t)	33	33	50	50
ABC (t)	33	33	50	50
Status	As determined *this* year		As determined *this* year for:	
	2018	2019	2019	2020
Overfishing	No	No	No	n/a

The overall BSAI ABC and OFL are shown below.

Quantity/Status	As estimated or *specified* last year for:		As estimated or *recommended* this year for:	
	2020	2021	2021	2022
OFL (t)	861	1090	576	595
ABC (t)	708	899	482	500

The BSAI blackspotted/rougheye stock complex was not subjected to overfishing in 2019. 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 2021 and 2022 and the recent OFLs, ABCs, TACs, and catches.

Area/subarea	Year	Total Biomass (t)[1]	OFL	ABC	TAC	Catch[2]
BSAI	2019	47,853	676	555	279	391
	2020	50,376	861	708	349	453
	2021	19,003	576	482	n/a	n/a
	2022	19,100	595	500	n/a	n/a
Western/Central Aleutian Islands	2019			204	204	304
	2020			264	264	333
	2021			169	n/a	n/a
	2022			176	n/a	n/a
Eastern AI/Eastern Bering Sea	2019			351	75	88
	2020			444	85	120
	2021			313	n/a	n/a
	2022			324	n/a	n/a

[1] The total biomass from AI age-structured model, and survey biomass estimates from EBS.
[2] BSAI catch as of October 10, 2020.

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 2021 and 2022 MSSC values are shown below.

Year	WAI MSSC	CAI MSSC
2021	31	138
2022	32	144

Responses to SSC and Plan Team Comments on Assessments in General

(SSC, October 2019) *The SSC recommends the authors complete the risk table and note important concerns or issues associated with completing the table.*

We completed the risk table in this assessment.

Responses to SSC and Plan Team Comments Specific to this Assessment

(BSAI Plan Team, November 2018) *For the next assessment, the Team recommends:*

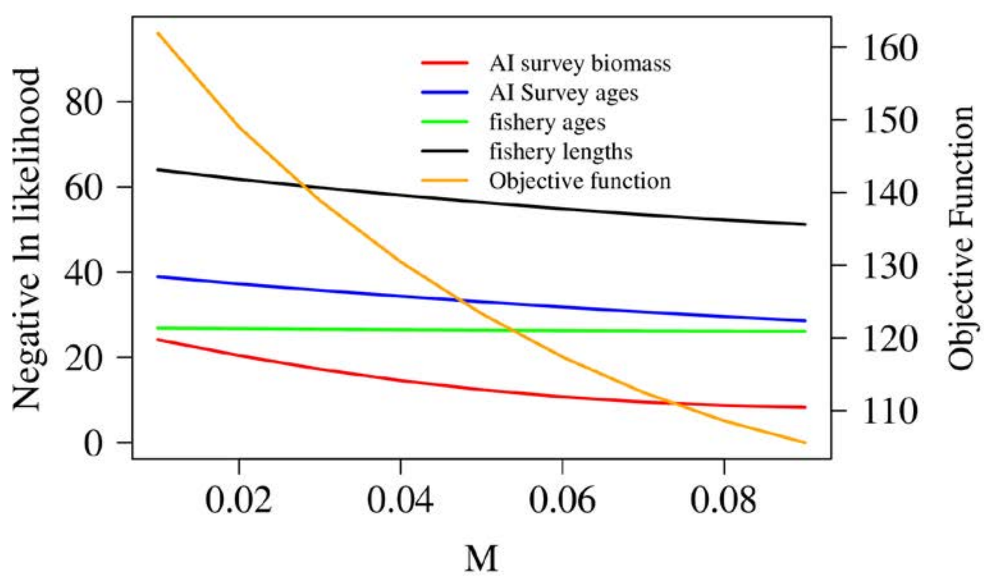
• *updating the age error matrix, as this has helped with the corresponding model in the GOA.*

• *evaluating dome-shaped selectivity for the survey, to better account for the survey's difficulty in sampling large/old fish accurately.*

• *examining larger bounds on M and investigating a profile of M and its subsequent impacts on model results.*

Exploratory analyses were presented to the BSAI Plan Team at their September, 2020, meeting in which the effects of several modeling options were explored, including updating the ageing error matrix, evaluation of dome shaped survey selectivity, and updating the prior distribution for natural mortality based on research by Then et al. (2015). The aging error and natural mortality updates are included in this assessment as recommended modeling changes from the 2018 model. The use of dome-shaped survey selectivity had relatively little effect on model output and produced a sharp knife-edged decline in survey selectivity for the 45+ age group, and was not recommended for inclusion in further models by either the authors, the BSAI Plan Team (September 2020 minutes), or the SSC (October 2020 minutes). The BSAI Plan Team (September 2020 minutes) and the SSC (October 2020 minutes) agreed that the following elements should be pursued for the November 2020 assessment: 1) updated natural mortality estimate; 2) updated ageing error matrix; and 3) use of the Francis method for weighting the compositional data.

A likelihood profile on the natural mortality rate parameter *M* for the recommended model in this assessment is shown below. The objective function decreases with increasing *M* and does not show a clear minimum over a wide range of *M* values. The decrease in the objective function with increasing *M* is due to several data components, including the AI survey biomass estimates, the AI survey age compositions, and the fishery length compositions.



(SSC, December 2018) *A recent paper by Dr. Christina Conrath provides new estimates for maturity-at-age for both rougheye and blackspotted rockfish. The study suggests that the maturity-at-age is older for blackspotted rockfish (than rougheye) and may have an effect on reference points for this assessment. However, it is the understanding of the SSC that these specimens were not genetically ID-ed so there is some uncertainty. The SSC recommends that the authors explore whether these new maturity results should be used in this assessment.*

The data from Dr. Conrath is considered in this assessment, and it is also our understanding that these samples have not been genetically identified and could potentially contain a mixture of blackspotted and rougheye rockfish. However, the maturity information currently in the model predates the identification of blackspotted rockfish as a cryptic species, and also likely contains a mixture of rougheye and blackspotted rockfish. Our recommended model uses the updated information on blackspotted rockfish from Dr. Conrath.

(SSC, December 2018) *The SSC recommends the author bring forward a model without any length data, which may provide more consistent fits to the remaining data than can not be attained by only adjusting weights, along with an updated ageing error matrix to aid in recruitment estimation.*

Models that remove the length compositions are considered in this assessment.

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 14A 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 1994-2020 have been relatively evenly distributed throughout the three AI subareas, with 32%, 29%, and 32% in the WAI, CAI, and EAI, respectively, and the remaining 7% in the EBS management area (Table 14.4). However, biomass estimates from the AI survey indicate that a relatively small portion of the stock (approximately 9%) occurs in WAI. Information on spatial exploitation rates is updated in Appendix 14A. The domestic fishery observer data indicates that the eastern AI accounted for more than 70% of the observed catch from 1992 to 1995, with the western AI accounting for less than 10% (Figure 14.3). The proportion of the harvest in the western Aleutian Islands increased during 2004 – 2006, averaging 66%, and has declined since 2007, averaging 35%. 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 has also varied, ranging between 4% to 20% during 1999 - 2003 to between 22% to 46% from 2009 – 2017, but decreasing to between 8% to 12% from 2018-2019.

Non-commercial catches are shown in Appendix 14B.

Discards

Estimates of discarding by species complex are shown in Table 14.5. 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 2020, discard rates of rougheye in the AI and EBS averaged 19% and 33%, respectively. Discarding has increased recently in the Aleutian Islands, with the rates for 2017, 2019, and 2000 each above 25%; 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 14.6. 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 1.3% in 2020 (using data through Sep 19, 2020). 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 3.0% in 2020. Bycatch rates in the Pacific cod fishery in the central Aleutian Islands increased from 0.35% in 2011 to 3.2% in 2017, and has since decreased to 0% in 2020. In the eastern Aleutian Islands, the bottom trawl pollock fishery had high bycatch rates from 2013-2015 and were above 1%, but the rates from 2016 – 2018 have been variable, ranging from 0.11% to 1.8%. 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, not exceeding 1%.

The higher catch rates in the WAI in from 2018-2020 are also revealed in cumulative distribution plots of bycatch rates in tows from A80 vessels targeting POP from 2011-2020 (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 2018-2020 the percentage of tows without bycatch ranged between 31% and 43%, and the bycatch rates at the 80% percentile ranged between 0.9% and 1.5%.

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 (2020 catch through Oct 17):

Year	WAI MSSC	WAI Catch	Catch/MSSC
2015	46	67	1.46
2016	58	38	0.65
2017	29	34	1.17
2018	35	66	1.89
2019	37	100	2.70
2020	48	155	3.23

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 in 2019 and 2020. Additionally, at the larger spatial scale, the WAI/CAI catches of 304 and 333 t in 2019 and 2020, respectively, have exceeded that WAI/CAI ABC by 49% and 26% (Table 14.2).

Data

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

Component	Years
Fishery catch	1977-2020
Fishery age composition	2004-2005, 2007-2009, 2011, 2015, 2017
Fishery size composition	1979, 1990, 1992-1993, 2003, 2010, 2012-2014, 2016, 2018-2019
AI Survey age composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018
AI Survey biomass estimates	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2018

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 14.7) and ages (Table 14.8), 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 14.9.

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 14.10, 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. The 2015 and 2017 fishery age compositions show reduced proportions of fish at ages > 20 years.

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. 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 2018 indicated higher abundances in the central and eastern Aleutians than in the western AI and southern Bering Sea area (Table 14.11). However, the 2012 survey was characterized by generally lower CPUE levels in the WAI, which reduced the biomass estimate for this area to 335 t from an average of 1,075 t in the 2000-2010 surveys. The 2018 survey biomass of 632 t in the western AI was a 26% increase from the value of 501 t in the 2016 survey. The 2018 survey biomass estimate in the SBS was also low (328 t), a continuation of low estimates from 2010 – 2016 (average of 384 t) and a decrease from 1991 – 2004 (average of 901 t). The 2014 – 2018 surveys show similar spatial patterns of survey CPUE (Figure 14.6), and the largest proportional differences between 2016 and 2018 occurred 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 (Figures 14.7 - 14.10). 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, and the increased WAI biomass estimate in 2018 is attributed to fish between 22 - 28 cm (Figure 14.7). The percentage of the WAI survey size composition less than 35 cm was 55%, in the 2018 survey, an increase from the value of 46% in the 2016 survey. In the CAI, the abundance of fish greater than 40 cm is reduced in the 2010-2018 surveys relative to the 1991-2006 surveys, with the exception of the 2012 survey (Figure 14.8). The increase in 2016 and 2018 survey biomass in the eastern AI 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 36 cm in the 2018 survey, similar to values observed in between 2006 and 2016 (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, and were low in the 2018 survey (33 cm and 35 cm, respectively), with an overall decline in mean size in the central and eastern AI since the 1991 – 2002 surveys. 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 in the 2018 survey is similar to that observed in the 2016 survey (Figure 14.12), with the WAI and EAI having the highest percentage of survey tows with no catch. In the SBS area, the percentage of tows with no catch increased from 44% in 2014 to 60% in 2018. 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 2018, the percentage was higher in the EAI (75%) than in the WAI (65%).

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 similarity in the survey biomass estimates by area between the 2016 and 2018 survey resulted in similar estimates of smoothed biomass between these assessment years. These smoothed estimates are used for subarea partitioning of the ABC, and the estimation of subarea exploitation rates shown in Appendix 14A.

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 14.12 and 14.13, 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 14.14, 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}	K	t_0
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 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 14.15).

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. 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), A is the maximum number of age groups modeled in the population (defined as 45), and T is the terminal year of the analysis (defined as 2020). The numbers at age A are a "pooled" group consisting 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

$$N_a = R_0 e^{-M(a-3)+\gamma_a}$$

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.

The total numbers of age 3 fish from 1977 to 2017 are estimated as parameters in the model, and are modeled with a lognormal distribution

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

where ν_t is a time-variant deviation. 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 2018-2020 are set at the expected mean recruitment (based upon the log-scale mean, and the value of σ_r).

The fishing mortality rate for a specific age and time ($F_{t,a}$) 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 a mean (μ_f) and a year-specific deviation (ε_t), thus $F_{t,a}$ is

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

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 predicted length composition data were calculated by multiplying the mean numbers at age by a conversion matrix, which gives the proportion of each age (rows) in each length group (columns). The age bins range from 3 to 45 and the length bins range from 12 to 50, with the terminal bin being a plus group that includes all older (or larger) fish. The mean number of fish at age available to the survey or fishery is multiplied by the aging error matrix to produce the observed survey or fishery age compositions.

Catch biomass at age was computed as the product of mean numbers at age, instantaneous fishing mortality, and weight at age.

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 W_a is the population weight-at-age, s_a^{twl} is the survey selectivity, and q^{twl} is the 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*. In previous assessments, the mean set to 0.03 and with the coefficient of variation (CV) set to 0.05. In this assessment, 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, 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 currently estimated values in Alaska blackspotted/rougheye assessments (i.e., 0.032 and 0.036 for BSAI and GOA, respectively). The mean of the prior distribution for *M* was increased to 0.045; this value also corresponds to the center of a range considered (0.035 – 0.055) for British Columbia rougheye/blackspotted rockfish (Dr. Paul Starr, Canadian Groundfish Research and Conservation Society, pers. comm.)

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.

Fishery selectivity was estimated with either 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.

In previous assessments, the proportion mature at age was estimated outside the model based on data on Gulf of Alaska rougheye rockfish in McDermott (1994). In this assessment, maturity is 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.). Because the two-species complex in the AI consists nearly entirely of blackspotted rockfish, it is desirable to obtain maturity data from this species. The specimens collected by Dr. Conrath were visually identified to species, and some specimens within this sample may be rougheye rockfish due to the potential for species misidentification. However, the data from McDermott (1994) were collected before recognition that fish historically identified as “rougheye” rockfish also included blackspotted rockfish, so this collection also would contain a mixture of blackspotted and rougheye rockfish. Given these alternative data sets, it is expected that the proportion of blackspotted rockfish in the samples would be larger in the more recent data from Dr. Conrath than in the McDermott (1994) data.

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.

The 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 the square root of number of fish lengthed 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.

Two types of weighting methods are considered. The “McAllister-Ianelli” (McAllister and Ianelli 1997) method computes weights as the harmonic mean of the ratio of effective sample size to first stage sample size (method TA1.1 in Francis (2011). Alternatively, the weights are computed as 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 2018 and 4 alternatives. Each of the alternative models include the following updates: 1) update of the prior distribution for M; 2) updating the ageing error matrix; and 3) updating the estimated proportion mature by age. These updates were requested by the BSAI Plan Team and/or SSC, and were reviewed during the September 2020 Plan Team meeting (with the exception of the maturity data). The four alternative models differ with the respect to the weighting of the composition data, and with respect to the inclusion of the length composition data.

The models are summarized in the table below:

Model	Differences from accepted 2018 model
Model 18.1 (2020)	Updated catch and and/length composition data, transition matrix, and weight-at-age
Model 20	Updated catch and and/length composition data, transition matrix, and weight-at-age. Updated prior distribution for natural mortality, updated ageing error matrix, and updated estimation of proportion mature at age. Iteratively reweight the composition data with the Francis method
Model 20a	Model 20, but iteratively reweight the composition data with the McAllister-Ianelli method.
Model 20b	Model 20, but remove the fishery length composition data
Model 20c	Model 20a, but remove the fishery length composition data

Because the differences between the alternative "models" above pertain to differences in the input 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 include the age 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 requires a set of fish with age reading 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).

This estimation procedure differs from that used to generate the ageing error matrix in the 2018 model, which is not based on fitting data on individual fish but rather fits the percent agreement for each age (and weights each age equally regardless of differences in sample size). Additionally, the data used for the current ageing error matrix was sampled in the Gulf of Alaska, whereas the Punt et al. (2008) methodology was applied to 2341 double readings of blackspotted/rougheye rockfish from the BSAI sampled during 1986 – 2017. The updated ageing error shows higher 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 whereas the CV used in the 2018 assessment estimated at 0.065 (for older ages) (Figure 14.17). Application of the estimation procedure used for the 2018 ageing error matrix to the updated BSAI data (not shown) indicates that the differences in the estimated CV results primarily from changes in the estimation procedure, not the input data.

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 are selected.

The negative log-likelihood of the initial recruitments were modeled with a lognormal distribution

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

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 (σ_r) adds a constant value to the negative log-likelihood. The negative log-likelihood of 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:

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

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

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

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:

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

where obs_biom_t 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:

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

where C_t and $\hat{C}_t$ are the observed and predicted catch. The "observed" catch for 2020 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

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

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

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

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

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

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

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

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 logistic curve):

Parameter type	***Number***
1) fishing mortality mean	1
2) fishing mortality deviations	44
3) recruitment mean	1
4) recruitment deviations	41
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	138

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 14.16, and estimated key parameters and management quantities are shown in Table 14.17. Models with the McAllister-Ianelli weighting procedure (i.e., Models 18.1 (2020), 20a, and 20c) had the largest RMSE values for the AI survey biomass and the lowest RMSE values for each of the composition data types (Table 14.16). In contrast, models with the Francis weighting (i.e., Models 20 and 20b) had the lowest RMSE values (i.e., best fits) to the AI survey biomass and the highest values for each of the composition data types. The fits to the AI survey biomass were relatively similar between models within each of the two reweighing procedures, indicating that removing the fishery length data does not have a substantial effect on model results (Figure 14.18). However, the recent survey biomass estimates are substantially different between the two reweighting procedures. The 3 models that used the McAllister-Ianelli weights all showed a rapid increase in estimated survey biomass (i.e., estimated 2020 biomass is more than double the estimated 2010 biomass), which is inconsistent with the area-swept survey biomass estimates that have shown a gradual decrease since 1990. The models using the Francis weighting show a more gradual increase in survey biomass in recent years, and it more consistent with the recent estimates of survey biomass. None of the models show a good fit to the large survey biomass estimates of 2000, 2002, and 2012, indicating a poor residual pattern.

Examination of estimated composition data from Model 18.1(2020) and Model 20 indicates similar fits for many years, but differences in some recent years. For example, the fits to the fishery age composition data between these two models were generally similar for years ≤ 2011, but in years 2015 and 2017 the use of McAllister-Ianelli weights allowed closer fits to several year classes than the Francis weighting, which produced a more smoothed estimates (Figure 14.19). However, the large estimates of recent year classes result in the large discrepancy in recent modeled biomass noted above, and contributes to a large retrospective bias (discussed below). The observed and estimated average age compositions across years within each data type (weighted by stage 1 sample weights) show general similarity between Model 18.1(2020) and Model 20 (Figure 14.20).

Models with the McAllister-Ianelli weighting resulted in estimates of the 2020 stock consisting largely of young fish which are not commonly seen in the survey data (Figure 14.21). For example, under Model

18.1 (2020), fish ≤ age 15 have survey selectivity of < 20%, but these ages account for 70% of the estimated 2020 abundance of the stock. In contrast, in Model 20 with the Francis weighting the estimated numbers at age in 2020 are spread across a larger number of ages. In this model, fish ≤ age 12 have survey selectivity < 20%, and these ages account for 48% of the stock. The estimation of large recent recruitments results from the greater emphasis on fitting the composition data when using the McAllister-Ianelli weights. The downweighting of the composition data in the Francis model removes the need to sharply increase recruitment in recent years, which is required to overcome low estimated selectivity for these young ages. This general pattern holds across the models considered in this assessment, as seen in the table below:

Model	***Weighting method for compositional data***	$A_{<=20\%}$ **(Age with maximum AI survey selectivity <= 0.2)**	**Selectivity at** $A_{<=20\%}$	**Percentage of estimated 2020 abundance at ages less than or equal to** $A_{<=20\%}$
18.1 (2020)	McAllister-Ianelli	15	0.18	70%
20	Francis	12	0.20	48%
20.a	McAllister-Ianelli	15	0.17	75%
20.b	Francis	10	0.17	39%
20.c	McAllister-Ianelli	15	0.19	71%

None of the models considered was able to account the sharp decline in older fish in recent years, as the difference in the data-weighting procedures largely affects the estimation of more recent year classes. The absence of older/larger fish in recent surveys implies mortality rates that are higher than those estimated in the models considered here. Simple mortality rates were estimated directly from the survey data via catch curves applied to cohorts with fish fully selected to the fishery (i.e., ages > 20) and extending past 2000 indicate total mortality rates between 0.14 and 0.19. In contrast, the mortality rates for these cohorts from model 18.1(2020) model 20 ranged between 0.08 – 0.09 (Figure 14.22).

Models with the McAllister-Ianelli weighting showed the strongest retrospective pattern (Figure 14.23). In Model 18.1 (2020), the retrospective estimates of SSB form two distinct groups, with peels that include the low 2014 survey biomass estimate showing much lower estimated SSB than peels without this data point. Within each of these two sets, the estimated SSB increases rapidly in the end years of the longest peels. In Model 20, with the Francis weighting, the influence of the 2014 survey biomass estimate also results in the formation of two distinct sets of retrospective peels of SSB. However, the difference in SSB between these sets is not as large, and the pattern of SSB increasing rapidly in the end years of the peels is not observed. The Mohn's rho for Model 20 is 0.30, which is reduced from the Mohn's rho of Model 18.1 (2020) of 0.55. The Mohn's rho for the other models follow the pattern of being lower with the Francis weighting:

Model	***Weighting method for compositional data***	**Mohn's rho**
18.1	McAllister-Ianelli	0.55
20	Francis	0.30
20.a	McAllister-Ianelli	0.56
20.b	Francis	0.32
20.c	McAllister-Ianelli	0.47

The retrospective analysis also indicates large uncertainty in recruitment estimates (Figure 14.24). In Model 18.1 (2020), the 2002 year class, currently estimated to be a strong component of the population in this model, increased from an estimated 7.7 million in the 2010 peel to 15.1 in the 2020 peel. Other year classes have declined substantially. The 1998 year class was estimated as strong in the 2010-2013 peels (ranging from 22.8 – 33.7 million), but has since declined to the 6.2 million in the 2020 peel. Similarly, the 2000 year class decreased from 11.3 million in the 2010 peel to 4.0 million in the 2020 peel.

Use of the Francis weighting results in reduced a reduced range of recruitment estimates (Figure 14.24). In Model 20, the 1998 year class shows the same general pattern seen with the McAllister-Ianelli weighting in Model 18.1 (2020), but the peak of the recruitment estimates has been reduced to 10.8 million. The 2002 year class shows a reduced increase over time, from 1.7 million in the 2010 peel to 4.3 million in the 2020 peel.

The variability in recruitment estimates revealed by the retrospective analysis are consistent with the variability observed between actual assessments. For example, in the 2014 assessment the 1998 year class was estimated at 23.1 million, but this has been reduced to 7.8 million in the 2018 assessment.

The most defining feature of the current BSAI blackspotted/rougheye assessment model is the conflict between the age/length composition data and the trend in the survey biomass estimates. The causes for this conflict within the model are unclear, and we hypothesize that two processes might be relevant. First, there has been an increase in the number of observed young fish in the AI survey in recent years. These young ages still comprise a small percentage of the survey age composition, so the estimated survey selectivity is low. In order to account for these observations of these young fish, the recruitment has to be large to overcome the low survey selectivity. Second, the model may be trying to model the decline in older fish via variation in recruitment strength. For any given survey year, an increase in the estimated proportion of young fish would decrease the estimated proportion of older fish.

By definition, data conflicts force a consideration of which data to emphasize in the estimation procedure because the model results are sensitive to data weighting. For BSAI blackspotted/rougheye rockfish, we recommend giving more weight to the survey biomass trends and less weight to the age/length composition data than what was used for the accepted 2018 model. As noted in the 2018 assessment, the use of the McAllister-Ianelli weights produces variability in estimated recruitment strengths between assessments, which is further supported by the strong retrospective patterns observed in this assessment. This also has management implications, as uncertain estimates of year class strength are projected forward and have produced substantial percentage increases in the ABC and OFL since the 2018 assessment. Specifically, the 2020 ABC was a 28% increase from the 2019 ABC, and the estimated 2021 ABC (from Model 18.1 (2020)) is 20% larger than the 2020 maximum ABC. Without a definitive increase in the survey biomass estimates or more reliable estimates of year class strength, these percentage increases in ABC and OFL may not be warranted for a long-lived stock that has exhibited less than expected older fish in recent surveys and fishery catch.

The issues present in the 2018 assessment (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 survey, and a poor residual pattern in the fit to the survey biomass estimates) are still present in the Model 18.1 (2020). The exclusion of fishery length data has relatively little effect on model results, as the primary differences between the models in this assessment resulted from different data weighting procedures. No data-weighting procedure can, in itself, identify the biological and observation processes that lead to data conflicts; however, the Francis data weighting improves the retrospective bias, produces trends in abundance more consistent with the observed trends in survey biomass, and reduces the influence of uncertain estimates of year class strength on assessment results and projected harvest specifications. We recommend Mode1 20 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 14.18.

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 7,863 t in 2007 has increased to 11,042 t in 2020 (Figure 14.25). 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 2,965 t to 3,337 t in 2020, and the total biomass has increased from 11,353 t to 17,584 t over this period (Figure 14.26). 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 14.19, and the estimated numbers at age are shown in Table 14.20.

Age/size compositions

The model fits to the fishery age and size compositions are shown in Figure 14.19 and Figure 14.27 and the model fit to the AI survey composition data are shown in Figures 14.28. The 2009 fishery age composition shows strong year class strengths for the 1998 and 1999 year classes. In the 2015 and 2017 composition data the 1998 and 1998 year classes appear less distinct compared to neighboring year classes, as the 2000 – 2003 year classes also appear relatively strong (Figure 14.19).

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 2013-2014, 2016, and 2018-2019 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. The 2014 - 2018 survey age composition also showed relatively high proportions for ages < 17, although this is influenced by the absence of older fish noted above. 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 CVs of 5% for the priors on survey catchability and natural mortality constrained these parameters to values of 1.03 and 0.049, 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 16.9, a decrease from 20.9 in the 2018 assessment (Figure 14.29). The fishery selectivity reached 50% at age 13, a decrease from a value of 19.2 in the 2018 assessment. The declines in the age at 50% selection in both the AI survey and the fishery reflect the low proportion of older fish in the composition data (particularly the 2014 - 2018 AI surveys and the 2015 and 2017 fishery age compositions), as well as the Francis weighting that reduces the need to estimate large recent year class strengths.

Maturity

The estimated proportion mature based on Gulf of Alaska sampling by Dr. Christina Conrath (Figure 14.30, Table 14.15) has an estimated age at 50% of 24.5. This is an increase over the estimate of 18.4 in the 2018 assessment, with was obtained from data in McDermott (1994). The more recent 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 14.31. 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 0.010 in 2016 to 0.032 in 2020.

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, 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 – 2009. The $B_{40\%}$ resulting from the mean recruitment from these year classes is 3,524 t, and the ratio of spawning stock biomass in 2020 to $B_{40\%}$ is 0.95 (Table 14.17). A plot of fishing mortality rates and spawning stock biomass in reference to the ABC and OFL harvest control rules (Figure 14.32) shows stock status relative to $B_{35\%}$.

Recruitment

Recruitment strengths by year class, with credibility bounds from the MCMC integration, are shown in Figure 14.33. Relative to previous assessments, the use of Francis weights results in less 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 14.34.

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 1977-2009 year classes were used to estimate equilibrium recruitment for future years. 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 3,524 t. The year 2021 spawning stock biomass is estimated as 3,372 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 (0.049) were used, resulting in F_{abc} and F_{ofl} levels of 0.037 and 0.049, 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 1,371 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 67 t and 50 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 ABC and OFL of 482 t and 576 t, respectively.

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

Since reliable estimates of the 2021 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B<B_{0.40}$ (3,372 t < 3,524 t), blackspotted/rougheye rockfish reference fishing mortality is defined in Tier 3b. For this tier, the maximum permissible and F_{ABC} and F_{OFL} are reduced from $F_{0.40}$ and $F_{0.35}$, respectively. The 2021 values of F_{abc} and F_{OFL} are 0.032 and 0.038, respectively. The 2021 ABC and OFL for the AI blackspotted/rougheye resulting from these rates are 432 t and 509 t, respectively. A summary of these values is below.

2021 SSB estimate (B)	=	3,372 t
$B_{0.40}$	=	3,524 t
$F_{0.40}$	=	0.033
F_{ABC}	=	0.032
$F_{0.35}$	=	0.039
F_{OFL}	=	0.038

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 2020 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2021 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2020. 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 2021, 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 2021 recommended in the assessment to the *max* F_{ABC} for 2021. (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 2015-2019 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 2020 or; 2) above ½ of its MSY level in 2020 and above its MSY level in 2028 under this scenario, then the stock is not overfished.)

Scenario 7: In 2021 and 2022, 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 2032 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 14.21.

Risk Table and ABC recommendation

<u>Overview</u>
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 recruitment pattern	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 consistent across all indicators

		is atypical.		
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 data conflict exists, as the estimates of survey and total biomass differ markedly depending on the data-weighting procedures used. This data conflict is indicative of an inability to simultaneously fit multiple data inputs. A strong retrospective bias exists, with a Mohn's rho for the recommended model of 0.30, 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 in recent years Several 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. A likelihood profile indicates limited information in the data to estimate a plausible value for natural mortality. 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.

Given these considerations, we rank the assessment considerations for the recommended Model 20 as a 3 *(Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias*). Note that the evaluation of the assessment considerations would differ among the assessment models considered in this assessment. The model accepted in 2018 corresponds to Model 18.1 (2020) in this assessment, and showed even stronger retrospective patterns, greater discrepancies between the survey biomass time series and model estimates, and more variable estimates of recent year class strengths that are influential for management. For model 18.1 (2020), we would rank the assessment considerations as a 4.

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 48% of estimated 2020 abundance from the recommended model 20 comprised of ages with less than 20% survey selectivity. Recent data indicate that the 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 indicates an usual pattern of large recruitment in recent years, with the estimate of 4.3 million for the 2002 year class exceeding the next highest recruitment value (the 1998 year class) by 46%.

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 comprised on 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*)

<u>Environmental/ecosystem considerations</u>

Due to lack of 2020 surveys and fieldwork, many ecosystem indicators were not measured this year. Thus, much of the ecosystem information available for this year is derived from remote sensing. 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 (Rooper et al., 2018 AI ESR); no analogous data are available for darkspotted rockfish. The National Centers for Environmental Prediction Global Ocean Data Assimilation System (GODAS) temperature anomalies for the 100–250m depth range show that significantly warmer temperatures have remained since 2016; the GODAS estimates are supported by the water column temperatures indicator for the AI (AI ESR Physical factors 2020). In general, higher ambient temperatures incur bioenergetic costs for ectothermic fish such that, all else being equal, consumption must increase to maintain fish condition. 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.

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. 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.

The indicator most relevant to reflecting habitat disturbance is the estimated area disturbed by trawls from the fishing effects model (Olson et al, AI ESR). 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.

Taken together, these indicators suggest no clear concerns for the rougheye/blackspotted rockfish stocks aside from the recent stretch of increased temperatures. However, both the lack of ecological data relevant to the stocks (particularly blackspotted rockfish) as well as lack of data in 2020 limits our assessment of potential recent ecosystem impacts on this stock.

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 14.6).

Additionally, the spatial pattern of catch per unit effort (CPUE) differs from the spatial pattern in the survey biomass estimates (Figure 14.35). 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 14.35 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 in 2019 and 2020.

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

For a target fishery, the level 3 and level 2 rankings above might be expected to produce a reduction in the recommended ABC. For a bycatch fishery, the effect of a reduction in ABC would be, ideally, to motivate changes in fishing practices such that bycatch is further reduced. However, the fishing industry reports that blackspotted/rougheye rockfish have been difficult to avoid in recent years such that the WAI/CAI subarea ABC and the MSSC are being exceeded. This concern is discussed above in the *Fishery performance considerations,* and also highlights that a reduction in ABC, in itself, may not necessarily result in reduced catch. Part of the population dynamics considerations is that the spatial management is not consistent with the spatial structure of the stock, and this would not be addressed by a reduction in the ABC. Finally, since 2015 the TACs have been, on average, 48% smaller than the maximum ABC (Table 14.2); if this pattern were to hold, a reduced ABC would have little effect if the eventual TAC is even lower. For these reasons, we recommend the maximum permissible ABC of 482 t.

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	595	2,691	5,114	361	1,010
percentage (within AI subarea)	7.1%	32.0%	60.9%		

The apportioned ABCs and MSSCs for 2019 and 2020 are:

	Area				
	WAI	CAI	WAI/CAI	EAI/EBS	Total
Year	MSSC	MSSC	ABC	ABC	ABC
2021	31	138	169	313	482
2022	32	144	176	324	500

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 2021, it does not provide the best estimate of OFL for 2022, because the mean 2022 catch under Scenario 6 is predicated on the 2021 catch being equal to the 2020 OFL, whereas the actual 2021 catch will likely be less than the 2021 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL. Catches for 2021 and 2022 were obtained by setting the *F* rate for these years to the estimated *F* rate for 2020.

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 (2019) is 391 t. This is less than the 2019 BSAI OFL of 676 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 2018:

a. If spawning biomass for 2020 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2020 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2020 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 14.18). If the mean spawning biomass for 2030 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 2022 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2022 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2022 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2032. If the mean spawning biomass for 2032 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 expected stock size in the year 2030 of Scenario 6 is 1.28 times its $B_{35\%}$ value of 3,084 t. With regard to whether the stock is likely to be overfished in the future, the expected stock size in 2032 of Scenario 7 is 1.31 times 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 2019 equal to the AI portion of the 2019 OFL is 0.049.

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”.

Warmer temperatures have been recorded in the fall of 2015 and summer of 2016 in the Alaska Peninsula and Aleutian Islands, and temperatures have remained relative to average conditions (Bond, 2019). Warmer temperatures have also been observed in the bottom temperatures from the AI trawl survey (Figure 14.36).

An indication of temperature preferences can be obtained by plotting the catch-weighted cumulative frequency distributions of temperature against the cumulative frequency distributions of temperature available in the EBS survey area (Perry and Smith 1994, Spencer 2008). The quantiles from the two CDF can be plotted against each other (i.e., a Q-Q plot), and plots that deviate from the 1:1 line would indicate that fish occupy habitats with different temperature characteristics than is available in survey area. Multiple years can be summarized by plotting the 10% and 90% percentiles. Blackspotted rockfish and rougheye rockfish occupy cooler water than is available, as the 90th percentiles fall below the 1:1 line (Figure 14.37).

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.

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.

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.

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

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.

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.

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.

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 2020. Catch data is through October 10, 2020, 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	163	Rougheye		220	220	74	Rougheye		234	234	89
2012	Rougheye	576	475	475	191	Rougheye		244	244	124	Rougheye		231	231	67
2013	Rougheye	462	378	378	322	Rougheye		209	209	145	Rougheye		169	169	177
2014	Rougheye	505	416	416	198	Rougheye		239	239	99	Rougheye		177	177	99
2015	Rougheye	560	453	349	180	Rougheye		304	200	117	Rougheye		149	149	63
2016	Rougheye	693	561	300	158	Rougheye		382	200	87	Rougheye		179	100	72
2017	Rougheye	612	501	225	204	Rougheye		195	125	134	Rougheye		306	100	70
2018	Rougheye	749	613	225	238	Rougheye		239	150	173	Rougheye		374	75	66
2019	Rougheye	676	555	279	391	Rougheye		204	204	304	Rougheye		351	75	88
2020	Rougheye	861	708	349	453	Rougheye		264	264	333	Rougheye		444	85	120

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			36			127	163
2012			17			174	191
2013			27			295	322
2014			24			174	198
2015			31			150	180
2016			41			117	158
2017			35			169	204
2018			15			223	238
2019			55			336	391
2020*			33			419	453

*Catch data through October 10, 2020, 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	28	54	36	163
2012	65	58	50	17	191
2013	84	61	150	27	322
2014	57	42	75	24	198
2015	67	50	33	31	180
2016	38	49	31	41	158
2017	34	100	35	35	204
2018	66	107	51	15	238
2019	100	204	33	55	391
2020*	155	178	86	33	453

* Estimated removals through October 10, 2020.

Table 14.5. 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	12	127	10%	Rougheye	29	7	36	20%
2012	Rougheye	154	20	174	12%	Rougheye	13	4	17	21%
2013	Rougheye	243	52	295	18%	Rougheye	20	7	27	25%
2014	Rougheye	158	16	174	9%	Rougheye	17	7	24	30%
2015	Rougheye	134	16	150	11%	Rougheye	22	9	31	29%
2016	Rougheye	106	12	117	10%	Rougheye	34	7	41	17%
2017	Rougheye	106	64	169	38%	Rougheye	23	12	35	35%
2018	Rougheye	190	33	223	15%	Rougheye	9	6	15	38%
2019	Rougheye	241	96	336	28%	Rougheye	31	24	55	44%
2020*	Rougheye	316	103	419	25%	Rougheye	24	10	33	30%

* Estimated removals through October 10, 2020.

Table 14.6. 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%	0.23%
2010	1.48%	0.05%	0.26%	0.73%	0.02%	0.48%	0.14%	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%	0.35%	0.42%	0.25%	0.01%	0.82%	0.83%	0.14%	0.19%	0.06%	0.08%	0.07%	0.00%	0.29%
2012	1.04%	0.53%	0.67%	0.80%	0.03%	0.82%	0.26%	0.37%	0.01%	0.72%	4.67%	0.21%	0.25%	0.02%	0.01%	0.01%	0.01%	0.05%
2013	1.07%	10.14%	0.35%	0.76%	0.01%	1.19%	0.84%	0.63%	0.05%	1.24%	1.25%	0.44%	0.07%	0.78%	0.15%	0.06%	0.00%	0.60%
2014	0.76%		0.00%	0.59%	0.00%	0.80%	0.07%	0.40%	0.01%	0.93%	1.04%	0.55%	0.09%	0.07%	0.07%	0.03%	0.00%	0.19%
2015	0.83%	0.10%	0.96%	0.68%	0.01%	0.54%	0.67%	0.31%	0.01%	0.60%	1.35%	0.33%	0.01%	0.07%	0.08%	0.05%	0.00%	0.37%
2016	0.34%	0.09%	0.27%	0.70%	0.02%	0.16%	0.15%	0.23%	0.01%	0.66%	0.32%	0.17%	0.03%	0.09%	0.05%	0.02%	0.00%	0.36%
2017	0.40%	0.12%	0.16%	0.69%	0.03%	3.21%	3.81%	0.34%	0.01%	1.46%	1.87%	1.12%	0.04%	0.12%	0.04%	0.04%	0.00%	0.21%
2018	0.73%	0.14%	0.19%	1.42%	0.03%	1.30%	7.67%	0.39%	0.04%	0.51%	0.11%	1.25%	0.14%	0.56%	0.03%	0.10%	0.00%	0.06%
2019	1.15%	0.26%	0.55%	2.77%	0.06%	0.78%	2.14%	0.25%	0.04%	0.49%	0.84%	0.70%	0.14%	0.33%	0.05%	0.04%	0.00%	0.35%
2020	1.33%	0.17%	0.00%	2.99%	0.03%	0.00%		1.32%	0.01%	0.80%	0.34%	1.35%	0.11%	0.05%	0.00%	0.02%	0.00%	0.42%

Table 14.7. 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 1977-2020.

	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	162	96	871	303	1033	399

Table 14.8. 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 1977-2020.

	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						
2014	51	242	293						
2015	70	206	276	69	206	275	47	126	173
2016	17	118	135						
2017	18	260	278	18	251	269	12	151	163
2018	38	332	370						
2019	346	342	688						
2020	105	479	584						

Table 14.9. 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	2013	2014	2016	2018	2019
12	0.000	0.000	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	0.000	0.001	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.003	0.001
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.004	0.004
17	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.006	0.001	0.003
18	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.009	0.004	0.001
19	0.002	0.000	0.000	0.000	0.000	0.000	0.005	0.002	0.001	0.006	0.005	0.004
20	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.003	0.004	0.004
21	0.002	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.002	0.009	0.011	0.013
22	0.004	0.000	0.000	0.000	0.000	0.000	0.002	0.004	0.008	0.012	0.011	0.017
23	0.004	0.000	0.000	0.001	0.000	0.002	0.006	0.003	0.016	0.006	0.013	0.016
24	0.007	0.002	0.000	0.001	0.000	0.001	0.016	0.003	0.012	0.010	0.015	0.017
25	0.011	0.000	0.000	0.002	0.000	0.004	0.002	0.007	0.016	0.021	0.011	0.021
26	0.010	0.000	0.000	0.001	0.000	0.004	0.014	0.011	0.020	0.006	0.019	0.018
27	0.014	0.000	0.000	0.009	0.000	0.010	0.030	0.007	0.014	0.011	0.020	0.013
28	0.018	0.001	0.004	0.007	0.000	0.015	0.019	0.023	0.023	0.019	0.016	0.024
29	0.020	0.002	0.002	0.002	0.002	0.026	0.012	0.015	0.032	0.028	0.015	0.020
30	0.026	0.002	0.004	0.009	0.001	0.033	0.024	0.022	0.027	0.019	0.018	0.026
31	0.033	0.010	0.002	0.016	0.000	0.045	0.026	0.019	0.043	0.038	0.021	0.037
32	0.037	0.023	0.007	0.012	0.004	0.056	0.032	0.032	0.033	0.030	0.030	0.030
33	0.045	0.014	0.011	0.018	0.008	0.069	0.049	0.042	0.035	0.046	0.029	0.035
34	0.048	0.016	0.021	0.013	0.014	0.070	0.045	0.039	0.044	0.031	0.040	0.039
35	0.055	0.007	0.019	0.023	0.015	0.078	0.074	0.042	0.041	0.069	0.052	0.037
36	0.055	0.048	0.028	0.016	0.022	0.065	0.076	0.048	0.047	0.065	0.042	0.039
37	0.059	0.029	0.020	0.027	0.029	0.054	0.065	0.047	0.063	0.046	0.055	0.058
38	0.053	0.027	0.022	0.040	0.059	0.032	0.059	0.037	0.047	0.062	0.050	0.047
39	0.056	0.044	0.057	0.034	0.060	0.042	0.048	0.053	0.053	0.061	0.053	0.054
40	0.055	0.043	0.066	0.037	0.052	0.031	0.056	0.057	0.048	0.044	0.066	0.056
41	0.050	0.059	0.094	0.042	0.083	0.031	0.029	0.059	0.045	0.068	0.064	0.051
42	0.046	0.079	0.106	0.064	0.059	0.022	0.029	0.051	0.027	0.046	0.049	0.042
43	0.053	0.051	0.108	0.059	0.095	0.031	0.032	0.053	0.041	0.051	0.062	0.037
44	0.046	0.090	0.104	0.093	0.083	0.028	0.021	0.033	0.036	0.024	0.042	0.036
45	0.037	0.067	0.060	0.107	0.072	0.025	0.034	0.050	0.035	0.017	0.037	0.035
46	0.029	0.099	0.085	0.094	0.064	0.021	0.025	0.055	0.031	0.027	0.041	0.030
47	0.028	0.073	0.058	0.092	0.052	0.025	0.017	0.028	0.023	0.014	0.020	0.027
48	0.020	0.090	0.034	0.071	0.036	0.026	0.016	0.034	0.024	0.006	0.020	0.018
49	0.014	0.049	0.016	0.029	0.036	0.023	0.017	0.025	0.020	0.003	0.009	0.017
50+	0.057	0.076	0.071	0.082	0.155	0.130	0.117	0.095	0.085	0.076	0.048	0.074

Table 14.10. Fishery age compositions used in the model, from the NORPAC domestic Observer database.

	Year							
Age	2004	2005	2007	2008	2009	2011	2015	2017
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.005
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.007	0.000	0.006	0.000	0.000
7	0.000	0.000	0.004	0.000	0.000	0.006	0.000	0.006
8	0.000	0.000	0.000	0.004	0.019	0.016	0.000	0.006
9	0.003	0.000	0.013	0.052	0.056	0.022	0.010	0.012
10	0.000	0.000	0.003	0.014	0.179	0.016	0.008	0.006
11	0.001	0.000	0.000	0.008	0.174	0.031	0.008	0.018
12	0.000	0.005	0.011	0.140	0.055	0.028	0.058	0.013
13	0.000	0.000	0.007	0.021	0.010	0.077	0.083	0.018
14	0.000	0.000	0.000	0.028	0.000	0.031	0.127	0.075
15	0.000	0.009	0.000	0.022	0.022	0.009	0.064	0.153
16	0.012	0.003	0.000	0.000	0.000	0.007	0.140	0.113
17	0.000	0.007	0.010	0.004	0.005	0.000	0.125	0.117
18	0.013	0.006	0.000	0.007	0.004	0.000	0.087	0.124
19	0.011	0.018	0.006	0.000	0.018	0.027	0.044	0.115
20	0.021	0.048	0.008	0.006	0.010	0.022	0.028	0.073
21	0.038	0.025	0.012	0.032	0.010	0.000	0.018	0.035
22	0.034	0.051	0.000	0.026	0.017	0.000	0.009	0.023
23	0.072	0.051	0.039	0.056	0.029	0.038	0.000	0.021
24	0.065	0.029	0.027	0.000	0.024	0.038	0.014	0.007
25	0.044	0.159	0.102	0.019	0.042	0.037	0.007	0.004
26	0.052	0.056	0.025	0.060	0.020	0.027	0.008	0.006
27	0.050	0.070	0.063	0.022	0.055	0.036	0.013	0.000
28	0.062	0.028	0.079	0.021	0.029	0.046	0.020	0.000
29	0.055	0.016	0.054	0.040	0.031	0.035	0.013	0.005
30	0.069	0.052	0.046	0.027	0.034	0.027	0.007	0.007
31	0.012	0.014	0.054	0.028	0.038	0.039	0.015	0.000
32	0.027	0.012	0.033	0.042	0.033	0.014	0.003	0.006
33	0.022	0.027	0.010	0.081	0.005	0.017	0.007	0.000
34	0.017	0.023	0.034	0.021	0.013	0.057	0.011	0.000
35	0.050	0.000	0.056	0.016	0.007	0.022	0.000	0.000
36	0.010	0.000	0.008	0.000	0.006	0.012	0.000	0.006
37	0.037	0.022	0.007	0.009	0.000	0.029	0.000	0.006
38	0.004	0.016	0.032	0.028	0.009	0.031	0.005	0.001
39	0.000	0.016	0.016	0.017	0.006	0.006	0.008	0.000
40	0.006	0.009	0.007	0.019	0.005	0.033	0.000	0.000
41	0.024	0.018	0.008	0.012	0.003	0.033	0.000	0.000
42	0.050	0.055	0.017	0.020	0.000	0.017	0.011	0.000
43	0.016	0.000	0.018	0.023	0.000	0.013	0.000	0.000
44	0.020	0.005	0.015	0.000	0.000	0.007	0.003	0.003
45+	0.104	0.153	0.173	0.071	0.033	0.088	0.048	0.015

Table 14.11. 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)	

Table 14.12. Samples sizes of blackspotted/rougheye lengths from the Aleutian Island trawl survey, with the number of hauls from which these data were collected, from 1991-2018.

	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		

Table 14.13. 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 1991-2018.

	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	304	94			

Table 14.14. 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 14.15. 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 14.16. Negative log likelihoods, effective sample sizes, and root mean squared errors, for the evaluated models for BSAI blackspotted/rougheye rockfish.

	18.1 (2020)	20	20.a	20.b	20.c
Negative log-likelihood					
Data components					
AI survey biomass	23.77	12.66	18.46	10.14	15.65
Catch biomass	0.01	0.00	0.00	0.00	0.00
Fishery ages	120.74	26.41	118.23	27.69	116.81
Fishery lengths	195.94	56.55	194.54	0.00	0.00
AI survey ages	194.11	33.20	197.25	33.69	194.05
Maturity		1.39	1.39	1.39	1.39
Priors and penalties					
Recruitment	47.59	-11.98	34.89	-11.17	41.60
Prior on survey q	1.47	0.17	0.87	0.05	0.60
Prior on M	3.61	1.32	5.05	0.60	4.21
Total negative log-likelihood	593.63	125.48	576.92	68.09	380.43
Parameters	136	138	138	138	138
Effective sample size					
Fishery ages	81	43	65	46	69
Fishery lengths	235	193	262	0	0
AI survey ages	158	68	145	63	149
Root mean square error					
AI survey biomass	0.483	0.337	0.425	0.307	0.393
Recruitment	1.250	0.598	1.193	0.640	1.265
Fishery ages	0.020	0.023	0.020	0.022	0.020
Fishery lengths	0.014	0.016	0.014	0.000	0.000
AI survey ages	0.012	0.018	0.013	0.019	0.012

Table 14.17. Key parameter estimates and management quantities for the evaluated models for BSAI blackspotted/rougheye. Models 18.1(2020), 20a, and 20.c use McAllister-Ianelli weighting of the compositional data, whereas Model 20 and 20.b use Francis weighting.

	18.1 (2020)	20	20.a	20.b	20.c
Key parameters and management quantities					
AI Survey catchability	1.09	1.03	1.07	1.01	1.06
CV	0.05	0.05	0.05	0.05	0.05
2020 total biomass (t)	50,596	17,584	56,821	13,645	49,287
CV	0.19	0.19	0.22	0.20	0.22
2020 Spawning stock biomass (t)	9,339	3,337	5,149	2,927	4,693
CV	0.17	0.43	0.83	0.36	0.81
$SB_{40\%}$ (t)	12,525	3,524	6,080	2,901	6,885
$SB_{2020}/SB_{40\%}$	0.75	0.95	0.85	1.01	0.68
2021 BSAI ABC	849	482	1077	394	821

Table 14.18. 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	0.81	0.20	fmort_dev	-0.46	0.14	log_rinit	0.32	0.12
sel_a50_fish	13.38	0.69	fmort_dev	-0.23	0.15	fydev	0.07	0.74
sel_aslope_ai_srv	0.29	0.05	fmort_dev	0.15	0.16	fydev	0.10	0.75
sel_a50_ai_srv	16.87	1.60	fmort_dev	0.36	0.16	fydev	0.13	0.77
M	0.05	0.00	rec_dev	0.04	0.73	fydev	0.16	0.78
log_avg_fmort	-3.81	0.09	rec_dev	0.02	0.72	fydev	0.19	0.80
fmort_dev	-0.88	0.13	rec_dev	0.01	0.72	fydev	0.22	0.81
fmort_dev	1.91	0.13	rec_dev	-0.01	0.71	fydev	0.25	0.83
fmort_dev	2.30	0.13	rec_dev	0.00	0.71	fydev	0.29	0.85
fmort_dev	0.86	0.13	rec_dev	0.03	0.72	fydev	0.34	0.88
fmort_dev	0.77	0.13	rec_dev	0.07	0.73	fydev	0.37	0.90
fmort_dev	-0.38	0.13	rec_dev	0.07	0.72	fydev	0.35	0.89
fmort_dev	-1.58	0.13	rec_dev	-0.01	0.70	fydev	0.35	0.89
fmort_dev	-2.11	0.12	rec_dev	-0.16	0.66	fydev	0.30	0.86
fmort_dev	-3.39	0.12	rec_dev	-0.32	0.63	fydev	0.24	0.84
fmort_dev	-2.67	0.12	rec_dev	-0.48	0.60	fydev	0.19	0.81
fmort_dev	-1.37	0.12	rec_dev	-0.62	0.57	fydev	0.17	0.80
fmort_dev	-1.44	0.12	rec_dev	-0.74	0.55	fydev	0.10	0.78
fmort_dev	0.17	0.11	rec_dev	-0.84	0.54	fydev	0.11	0.78
fmort_dev	1.66	0.11	rec_dev	-0.90	0.53	fydev	0.05	0.76
fmort_dev	-0.76	0.11	rec_dev	-0.91	0.53	fydev	0.01	0.74
fmort_dev	1.41	0.11	rec_dev	-0.87	0.54	fydev	-0.03	0.73
fmort_dev	1.23	0.11	rec_dev	-0.79	0.55	fydev	-0.06	0.72
fmort_dev	1.06	0.11	rec_dev	-0.67	0.56	fydev	-0.08	0.71
fmort_dev	0.45	0.11	rec_dev	-0.51	0.59	fydev	-0.10	0.70
fmort_dev	1.21	0.10	rec_dev	-0.29	0.62	fydev	-0.11	0.70
fmort_dev	1.42	0.10	rec_dev	-0.04	0.68	fydev	-0.12	0.70
fmort_dev	0.88	0.10	rec_dev	0.30	0.82	fydev	-0.13	0.70
fmort_dev	0.60	0.10	rec_dev	0.81	0.90	fydev	-0.14	0.69
fmort_dev	0.30	0.10	rec_dev	0.56	0.98	fydev	-0.14	0.69
fmort_dev	1.02	0.10	rec_dev	0.51	0.93	fydev	-0.15	0.69
fmort_dev	0.35	0.10	rec_dev	0.55	1.07	fydev	-0.15	0.69
fmort_dev	-0.08	0.11	rec_dev	1.19	1.10	fydev	-0.16	0.69
fmort_dev	-0.01	0.11	rec_dev	0.50	1.03	fydev	-0.16	0.69
fmort_dev	-0.87	0.11	rec_dev	0.34	0.86	fydev	-0.17	0.68
fmort_dev	0.07	0.11	rec_dev	0.37	0.85	fydev	-0.17	0.68
fmort_dev	-0.15	0.11	rec_dev	0.45	0.87	fydev	-0.17	0.69
fmort_dev	-0.07	0.11	rec_dev	0.43	0.88	fydev	-0.16	0.69
fmort_dev	-0.01	0.11	rec_dev	0.44	0.90	fydev	-0.16	0.69
fmort_dev	0.06	0.11	rec_dev	0.49	0.92	fydev	-0.16	0.69
fmort_dev	-0.43	0.12	rec_dev	0.53	0.91	fydev	-0.16	0.69
fmort_dev	-0.16	0.12	rec_dev	0.28	0.82	fydev	-0.15	0.69
fmort_dev	0.32	0.12	rec_dev	0.11	0.76	fydev	-1.18	0.49
fmort_dev	-0.26	0.13	rec_dev	0.05	0.74	q_ai_srv	1.03	0.05
fmort_dev	-0.47	0.13	rec_dev	0.02	0.74	mat_beta1	-6.47	5.49
fmort_dev	-0.78	0.14	mean_log_rec	0.25	0.16	mat_beta2	0.26	0.23

Table 14.19. 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			
	2020		2018		2020		2018		2020		2018	
Year or Year Class	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
1977	20,954	0.073	15,325	0.042	5,393	0.310	4,255	0.063	1,283	0.722	1,017	0.518
1978	21,173	0.070	15,801	0.041	5,357	0.308	4,391	0.058	1,286	0.719	715	0.517
1979	19,067	0.075	13,881	0.044	4,684	0.312	3,712	0.058	1,324	0.722	688	0.505
1980	16,299	0.084	11,235	0.047	3,977	0.319	2,990	0.061	1,380	0.726	837	0.500
1981	16,001	0.083	11,091	0.048	3,885	0.322	3,013	0.061	1,379	0.718	1,006	0.499
1982	15,767	0.082	10,996	0.050	3,831	0.324	3,069	0.060	1,280	0.696	1,080	0.482
1983	15,944	0.080	11,310	0.049	3,891	0.325	3,256	0.058	1,103	0.663	837	0.479
1984	16,248	0.076	11,760	0.049	3,990	0.326	3,485	0.055	935	0.631	541	0.479
1985	16,563	0.073	12,232	0.048	4,101	0.326	3,722	0.053	799	0.604	443	0.466
1986	16,885	0.070	12,716	0.047	4,223	0.326	3,967	0.050	694	0.582	466	0.447
1987	17,175	0.068	13,165	0.047	4,346	0.326	4,201	0.048	614	0.567	455	0.436
1988	17,380	0.066	13,533	0.047	4,457	0.325	4,410	0.047	557	0.556	364	0.448
1989	17,559	0.064	13,886	0.047	4,557	0.324	4,591	0.045	526	0.552	310	0.449
1990	17,398	0.064	13,907	0.048	4,510	0.323	4,563	0.046	520	0.553	297	0.447
1991	15,960	0.068	12,654	0.053	4,215	0.322	4,201	0.049	539	0.559	298	0.448
1992	16,003	0.067	12,866	0.054	4,241	0.319	4,264	0.049	585	0.570	305	0.457
1993	14,964	0.071	11,997	0.058	4,000	0.317	3,972	0.054	658	0.586	341	0.470
1994	14,171	0.075	11,363	0.063	3,825	0.314	3,773	0.058	777	0.610	458	0.489
1995	13,542	0.078	10,882	0.067	3,707	0.311	3,654	0.062	969	0.644	801	0.509
1996	13,262	0.080	10,743	0.070	3,654	0.306	3,624	0.065	1,243	0.701	1,243	0.502
1997	12,550	0.084	10,160	0.076	3,473	0.303	3,428	0.072	1,740	0.831	1,104	0.654
1998	11,702	0.091	9,434	0.084	3,271	0.301	3,207	0.080	2,909	0.896	7,836	0.358
1999	11,310	0.095	9,171	0.089	3,183	0.298	3,141	0.085	2,253	0.999	8,317	0.520
2000	11,098	0.098	9,056	0.094	3,135	0.295	3,127	0.089	2,139	0.960	3,922	0.781
2001	11,080	0.102	9,428	0.100	3,096	0.293	3,119	0.094	2,225	1.101	1,826	0.796
2002	10,798	0.108	9,709	0.111	2,991	0.291	3,022	0.101	4,258	1.095	19,371	0.310
2003	10,838	0.112	10,246	0.117	2,966	0.289	3,024	0.104	2,126	1.057	3,426	1.122
2004	11,024	0.115	10,894	0.122	2,965	0.287	3,053	0.107	1,813	0.885	2,880	1.197
2005	11,353	0.120	12,568	0.134	2,965	0.284	3,077	0.110	1,869	0.873	6,684	0.867
2006	11,760	0.124	13,955	0.139	2,986	0.281	3,127	0.111	2,013	0.895	7,236	0.823
2007	12,069	0.128	15,336	0.145	2,973	0.278	3,135	0.115	1,976	0.904	2,521	1.006
2008	12,453	0.133	17,098	0.153	2,969	0.275	3,163	0.118	1,999	0.926	16,855	0.454
2009	12,860	0.138	19,061	0.159	2,959	0.273	3,201	0.121	2,109	0.951	1,809	0.861
2010	13,278	0.144	20,963	0.163	2,946	0.273	3,270	0.125	2,185	0.941	17,142	0.587
2011	13,702	0.149	23,707	0.171	2,935	0.275	3,398	0.129	1,706	0.849	2,805	1.026
2012	14,225	0.153	26,110	0.175	2,948	0.281	3,630	0.133	1,439	0.799	2,634	0.846
2013	14,718	0.158	29,358	0.181	2,950	0.291	3,953	0.139	1,353	0.779		
2014	15,075	0.164	32,080	0.185	2,937	0.307	4,380	0.146	1,317	0.776		
2015	15,543	0.168	34,984	0.189	2,969	0.326	4,999	0.153				
2016	16,023	0.172	37,944	0.192	3,022	0.348	5,790	0.159				
2017	16,518	0.175	40,887	0.195	3,097	0.371	6,740	0.165				
2018	16,963	0.179	43,711	0.198	3,177	0.395	7,789	0.171				
2019	17,339	0.183	46,482		3,261	0.417	8,965					
2020	17,584	0.188			3,337	0.437						
2021	17,632				3,372							
Mean recruitment of post-1976 year classes									1,470		3,302	

Table 14.20. 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	1.35	1.41	1.38	1.36	1.33	1.31	1.28	1.26	1.24	1.24	1.22	1.15	1.09	0.98	0.89	0.81	0.75	0.67	0.64	0.58
1978	1.32	1.28	1.34	1.31	1.29	1.27	1.25	1.22	1.20	1.18	1.18	1.16	1.09	1.03	0.93	0.84	0.76	0.70	0.63	0.60
1979	1.30	1.26	1.22	1.28	1.25	1.23	1.21	1.18	1.15	1.12	1.08	1.06	1.01	0.92	0.86	0.77	0.69	0.62	0.58	0.52
1980	1.28	1.24	1.20	1.16	1.21	1.19	1.17	1.14	1.11	1.07	1.01	0.94	0.88	0.81	0.72	0.66	0.59	0.53	0.48	0.44
1981	1.29	1.22	1.18	1.14	1.11	1.16	1.13	1.11	1.08	1.05	1.00	0.94	0.87	0.80	0.73	0.65	0.60	0.53	0.48	0.43
1982	1.32	1.23	1.16	1.12	1.09	1.05	1.10	1.08	1.05	1.03	0.99	0.94	0.87	0.79	0.73	0.67	0.59	0.54	0.48	0.43
1983	1.38	1.26	1.17	1.11	1.07	1.03	1.00	1.05	1.02	1.00	0.97	0.94	0.88	0.82	0.75	0.69	0.63	0.56	0.51	0.45
1984	1.38	1.31	1.20	1.11	1.06	1.02	0.98	0.96	1.00	0.97	0.95	0.92	0.89	0.84	0.78	0.71	0.65	0.59	0.53	0.48
1985	1.28	1.31	1.25	1.14	1.06	1.01	0.97	0.94	0.91	0.95	0.93	0.91	0.88	0.84	0.80	0.74	0.67	0.62	0.56	0.50
1986	1.10	1.22	1.25	1.19	1.09	1.01	0.96	0.92	0.89	0.87	0.90	0.88	0.86	0.84	0.80	0.76	0.70	0.64	0.59	0.54
1987	0.93	1.05	1.16	1.19	1.14	1.04	0.96	0.91	0.88	0.85	0.83	0.86	0.84	0.82	0.80	0.76	0.72	0.67	0.61	0.56
1988	0.80	0.89	1.00	1.11	1.13	1.08	0.99	0.91	0.87	0.84	0.81	0.78	0.82	0.80	0.78	0.75	0.72	0.68	0.63	0.58
1989	0.69	0.76	0.85	0.95	1.05	1.08	1.03	0.94	0.87	0.83	0.80	0.77	0.74	0.77	0.76	0.74	0.71	0.69	0.65	0.60
1990	0.61	0.66	0.72	0.81	0.91	1.00	1.03	0.98	0.89	0.83	0.78	0.75	0.72	0.69	0.72	0.70	0.68	0.66	0.64	0.60
1991	0.56	0.59	0.63	0.69	0.77	0.86	0.95	0.98	0.93	0.84	0.76	0.71	0.66	0.63	0.60	0.61	0.60	0.58	0.56	0.54
1992	0.53	0.53	0.56	0.60	0.66	0.73	0.82	0.91	0.93	0.88	0.80	0.73	0.67	0.63	0.59	0.56	0.58	0.56	0.55	0.53
1993	0.52	0.50	0.51	0.53	0.57	0.63	0.70	0.78	0.86	0.87	0.82	0.73	0.65	0.59	0.55	0.52	0.49	0.50	0.49	0.48
1994	0.54	0.50	0.48	0.48	0.51	0.54	0.60	0.66	0.74	0.81	0.82	0.76	0.66	0.59	0.53	0.49	0.46	0.43	0.45	0.43
1995	0.59	0.51	0.47	0.45	0.46	0.48	0.52	0.57	0.63	0.70	0.76	0.76	0.69	0.60	0.53	0.47	0.44	0.41	0.39	0.40
1996	0.66	0.56	0.49	0.45	0.43	0.44	0.46	0.49	0.54	0.60	0.66	0.71	0.71	0.64	0.56	0.49	0.44	0.40	0.38	0.36
1997	0.78	0.63	0.53	0.47	0.43	0.41	0.42	0.44	0.47	0.51	0.56	0.61	0.65	0.63	0.57	0.49	0.43	0.39	0.36	0.33
1998	0.97	0.74	0.60	0.51	0.44	0.41	0.39	0.39	0.41	0.44	0.47	0.51	0.55	0.58	0.56	0.50	0.43	0.37	0.34	0.31
1999	1.24	0.92	0.70	0.57	0.48	0.42	0.39	0.37	0.37	0.39	0.41	0.44	0.47	0.50	0.52	0.50	0.45	0.39	0.34	0.30
2000	1.74	1.18	0.88	0.67	0.54	0.46	0.40	0.37	0.35	0.35	0.37	0.39	0.41	0.43	0.46	0.48	0.46	0.41	0.35	0.31
2001	2.91	1.66	1.13	0.84	0.64	0.52	0.44	0.38	0.35	0.34	0.34	0.35	0.36	0.38	0.40	0.43	0.44	0.43	0.38	0.33
2002	2.25	2.77	1.58	1.07	0.80	0.61	0.49	0.41	0.36	0.33	0.32	0.31	0.32	0.33	0.34	0.36	0.38	0.40	0.38	0.34
2003	2.14	2.15	2.64	1.50	1.02	0.76	0.58	0.47	0.39	0.34	0.31	0.30	0.29	0.29	0.30	0.32	0.33	0.35	0.37	0.35
2004	2.22	2.04	2.04	2.51	1.43	0.97	0.72	0.55	0.44	0.37	0.33	0.30	0.28	0.27	0.28	0.28	0.30	0.31	0.33	0.34
2005	4.26	2.12	1.94	1.95	2.39	1.36	0.93	0.69	0.52	0.42	0.35	0.31	0.28	0.26	0.25	0.26	0.26	0.28	0.29	0.31
2006	2.13	4.06	2.02	1.85	1.85	2.28	1.30	0.88	0.66	0.50	0.40	0.34	0.29	0.26	0.25	0.24	0.24	0.25	0.26	0.27
2007	1.81	2.02	3.86	1.92	1.76	1.76	2.17	1.24	0.84	0.62	0.47	0.38	0.32	0.27	0.24	0.23	0.22	0.23	0.23	0.24
2008	1.87	1.73	1.93	3.68	1.83	1.68	1.68	2.07	1.18	0.80	0.59	0.45	0.36	0.30	0.26	0.23	0.21	0.21	0.21	0.22
2009	2.01	1.78	1.64	1.84	3.50	1.74	1.60	1.60	1.96	1.12	0.76	0.56	0.42	0.33	0.28	0.24	0.21	0.20	0.19	0.20
2010	1.98	1.92	1.70	1.57	1.75	3.34	1.66	1.52	1.52	1.87	1.06	0.71	0.52	0.39	0.31	0.26	0.22	0.20	0.19	0.18
2011	2.00	1.88	1.83	1.61	1.49	1.67	3.18	1.58	1.44	1.44	1.77	1.00	0.67	0.49	0.37	0.29	0.24	0.21	0.19	0.17
2012	2.11	1.90	1.79	1.74	1.54	1.42	1.59	3.02	1.50	1.37	1.37	1.67	0.94	0.63	0.46	0.34	0.27	0.23	0.19	0.17
2013	2.19	2.01	1.81	1.71	1.66	1.46	1.35	1.51	2.88	1.43	1.30	1.30	1.57	0.88	0.59	0.43	0.32	0.25	0.21	0.18
2014	1.71	2.08	1.91	1.73	1.63	1.58	1.39	1.29	1.44	2.73	1.35	1.22	1.21	1.46	0.82	0.55	0.40	0.30	0.24	0.20
2015	1.44	1.62	1.98	1.82	1.64	1.55	1.50	1.33	1.22	1.36	2.59	1.28	1.15	1.14	1.37	0.77	0.51	0.37	0.28	0.22
2016	1.35	1.37	1.55	1.89	1.73	1.57	1.47	1.43	1.26	1.16	1.29	2.45	1.21	1.09	1.07	1.29	0.72	0.48	0.35	0.26
2017	1.32	1.29	1.31	1.47	1.80	1.65	1.49	1.40	1.36	1.20	1.11	1.23	2.32	1.14	1.03	1.01	1.22	0.68	0.45	0.33
2018	1.71	1.25	1.23	1.24	1.40	1.71	1.57	1.42	1.34	1.29	1.14	1.05	1.16	2.19	1.07	0.96	0.95	1.14	0.64	0.43
2019	1.71	1.63	1.19	1.17	1.18	1.34	1.63	1.50	1.35	1.27	1.23	1.08	0.99	1.09	2.05	1.00	0.90	0.89	1.07	0.60
2020	1.71	1.63	1.55	1.14	1.11	1.13	1.27	1.55	1.42	1.28	1.20	1.16	1.01	0.92	1.01	1.90	0.93	0.84	0.82	0.99

Table 14.20 (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	0.52	0.48	0.45	0.41	0.39	0.37	0.34	0.32	0.31	0.29	0.27	0.26	0.25	0.23	0.22	0.21	0.20	0.19	0.18	0.18	0.17	0.16	1.14
1978	0.54	0.50	0.46	0.42	0.39	0.37	0.35	0.32	0.31	0.29	0.27	0.26	0.25	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.17	0.16	1.23
1979	0.49	0.45	0.41	0.37	0.34	0.32	0.30	0.28	0.27	0.25	0.24	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.16	0.15	0.14	0.14	1.14
1980	0.39	0.38	0.34	0.31	0.28	0.26	0.24	0.23	0.22	0.20	0.19	0.18	0.17	0.16	0.15	0.15	0.14	0.13	0.12	0.12	0.11	0.11	0.97
1981	0.40	0.36	0.34	0.31	0.28	0.26	0.24	0.22	0.21	0.20	0.18	0.17	0.16	0.15	0.15	0.14	0.13	0.12	0.12	0.11	0.11	0.10	0.98
1982	0.39	0.36	0.32	0.31	0.28	0.25	0.23	0.22	0.20	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	0.98
1983	0.41	0.37	0.34	0.30	0.29	0.26	0.24	0.22	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.11	0.10	0.10	1.01
1984	0.43	0.39	0.35	0.32	0.29	0.27	0.25	0.23	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	1.05
1985	0.46	0.41	0.37	0.33	0.31	0.27	0.26	0.24	0.21	0.20	0.18	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	1.09
1986	0.48	0.44	0.39	0.35	0.31	0.29	0.26	0.25	0.22	0.20	0.19	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	1.13
1987	0.51	0.45	0.42	0.37	0.33	0.30	0.28	0.25	0.24	0.21	0.19	0.18	0.16	0.15	0.14	0.14	0.13	0.12	0.11	0.11	0.10	0.10	1.16
1988	0.53	0.48	0.43	0.39	0.35	0.31	0.28	0.26	0.23	0.22	0.20	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.10	1.19
1989	0.55	0.50	0.46	0.41	0.37	0.33	0.30	0.27	0.25	0.22	0.21	0.19	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.10	1.22
1990	0.56	0.51	0.47	0.42	0.38	0.35	0.31	0.28	0.25	0.23	0.21	0.20	0.18	0.16	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.09	1.22
1991	0.51	0.47	0.43	0.39	0.36	0.32	0.29	0.26	0.23	0.21	0.20	0.17	0.17	0.15	0.14	0.13	0.12	0.11	0.10	0.10	0.09	0.08	1.12
1992	0.51	0.48	0.44	0.41	0.37	0.34	0.30	0.28	0.25	0.22	0.20	0.18	0.16	0.16	0.14	0.13	0.12	0.11	0.10	0.10	0.09	0.08	1.13
1993	0.46	0.44	0.42	0.39	0.35	0.32	0.29	0.26	0.24	0.21	0.19	0.17	0.16	0.14	0.14	0.12	0.11	0.10	0.10	0.09	0.08	0.08	1.06
1994	0.42	0.41	0.39	0.37	0.34	0.31	0.29	0.26	0.23	0.21	0.19	0.17	0.15	0.14	0.13	0.12	0.11	0.10	0.09	0.08	0.08	0.07	1.00
1995	0.39	0.38	0.36	0.35	0.33	0.30	0.28	0.26	0.23	0.21	0.19	0.17	0.15	0.14	0.13	0.11	0.11	0.10	0.09	0.08	0.08	0.07	0.96
1996	0.37	0.36	0.35	0.33	0.32	0.30	0.28	0.26	0.23	0.21	0.19	0.17	0.15	0.14	0.13	0.12	0.10	0.10	0.09	0.08	0.08	0.07	0.95
1997	0.32	0.32	0.31	0.31	0.30	0.28	0.27	0.25	0.23	0.21	0.19	0.17	0.15	0.14	0.12	0.11	0.10	0.09	0.09	0.08	0.07	0.07	0.90
1998	0.29	0.27	0.28	0.27	0.27	0.26	0.25	0.23	0.22	0.20	0.18	0.16	0.15	0.13	0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.84
1999	0.28	0.26	0.25	0.25	0.25	0.24	0.23	0.22	0.21	0.19	0.18	0.16	0.15	0.13	0.12	0.11	0.10	0.09	0.08	0.07	0.07	0.06	0.82
2000	0.28	0.26	0.24	0.23	0.23	0.23	0.22	0.21	0.20	0.19	0.18	0.16	0.15	0.14	0.12	0.11	0.10	0.09	0.08	0.07	0.07	0.06	0.80
2001	0.29	0.26	0.24	0.22	0.21	0.21	0.21	0.20	0.20	0.19	0.18	0.16	0.15	0.14	0.13	0.11	0.10	0.09	0.08	0.07	0.07	0.06	0.80
2002	0.29	0.26	0.23	0.21	0.20	0.19	0.19	0.19	0.18	0.18	0.17	0.16	0.15	0.13	0.12	0.11	0.10	0.09	0.08	0.07	0.07	0.06	0.77
2003	0.32	0.27	0.24	0.21	0.20	0.18	0.17	0.18	0.17	0.17	0.16	0.16	0.15	0.14	0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.77
2004	0.33	0.30	0.25	0.22	0.20	0.18	0.17	0.16	0.17	0.16	0.16	0.15	0.15	0.14	0.13	0.12	0.11	0.10	0.09	0.08	0.07	0.06	0.77
2005	0.32	0.31	0.27	0.24	0.21	0.18	0.17	0.16	0.15	0.15	0.15	0.15	0.14	0.14	0.13	0.12	0.11	0.10	0.09	0.08	0.07	0.07	0.78
2006	0.29	0.30	0.29	0.26	0.22	0.19	0.17	0.16	0.15	0.14	0.15	0.14	0.14	0.13	0.13	0.12	0.11	0.10	0.09	0.09	0.08	0.07	0.80
2007	0.25	0.27	0.28	0.27	0.24	0.21	0.18	0.16	0.15	0.14	0.13	0.14	0.13	0.13	0.12	0.12	0.11	0.10	0.09	0.09	0.08	0.07	0.81
2008	0.23	0.24	0.25	0.26	0.25	0.23	0.19	0.17	0.15	0.14	0.13	0.12	0.13	0.12	0.12	0.12	0.11	0.10	0.10	0.09	0.08	0.07	0.82
2009	0.20	0.21	0.22	0.23	0.24	0.23	0.21	0.18	0.16	0.14	0.13	0.12	0.11	0.12	0.11	0.11	0.11	0.10	0.10	0.09	0.08	0.08	0.83
2010	0.18	0.19	0.20	0.21	0.22	0.23	0.22	0.20	0.17	0.15	0.13	0.12	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.09	0.08	0.08	0.85
2011	0.17	0.17	0.18	0.18	0.19	0.20	0.21	0.20	0.18	0.16	0.14	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.08	0.08	0.86
2012	0.16	0.16	0.16	0.16	0.17	0.18	0.19	0.20	0.19	0.17	0.15	0.13	0.11	0.11	0.10	0.09	0.10	0.09	0.09	0.09	0.08	0.08	0.88
2013	0.16	0.15	0.15	0.15	0.15	0.16	0.17	0.18	0.19	0.18	0.16	0.14	0.12	0.11	0.10	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.90
2014	0.17	0.15	0.14	0.14	0.14	0.14	0.15	0.16	0.16	0.17	0.17	0.15	0.13	0.11	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.90
2015	0.18	0.16	0.14	0.13	0.13	0.13	0.13	0.14	0.15	0.15	0.16	0.15	0.14	0.12	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.92
2016	0.21	0.17	0.15	0.13	0.12	0.12	0.12	0.13	0.13	0.14	0.15	0.15	0.15	0.13	0.11	0.10	0.09	0.08	0.07	0.07	0.07	0.07	0.93
2017	0.25	0.19	0.16	0.14	0.12	0.12	0.11	0.11	0.12	0.12	0.13	0.14	0.14	0.14	0.12	0.11	0.09	0.08	0.08	0.07	0.07	0.07	0.94
2018	0.31	0.23	0.18	0.15	0.13	0.12	0.11	0.11	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.12	0.10	0.09	0.08	0.07	0.07	0.06	0.95
2019	0.40	0.29	0.22	0.17	0.14	0.12	0.11	0.10	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.11	0.09	0.08	0.07	0.07	0.06	0.95
2020	0.55	0.37	0.27	0.20	0.16	0.13	0.11	0.10	0.10	0.09	0.09	0.10	0.10	0.11	0.11	0.12	0.11	0.10	0.09	0.07	0.07	0.06	0.94

Table 14.21. 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 3,524 t and 3,084 t, respectively.

Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2020	427	427	427	427	427	427	427
2021	432	432	222	126	0	507	432
2022	450	450	228	131	0	522	450
2023	465	465	235	135	0	537	545
2024	469	469	240	139	0	542	547
2025	471	471	245	143	0	542	547
2026	472	472	249	146	0	540	545
2027	471	471	252	149	0	537	542
2028	470	470	255	151	0	533	538
2029	469	469	258	154	0	530	534
2030	468	468	260	156	0	526	530
2031	466	466	262	158	0	523	526
2032	464	464	264	160	0	519	522
2033	462	462	266	161	0	514	517
Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2020	3,337	3,337	3,337	3,337	3,337	3,337	3,337
2021	3,372	3,372	3,381	3,385	3,390	3,369	3,372
2022	3,456	3,456	3,519	3,547	3,585	3,434	3,456
2023	3,547	3,547	3,670	3,725	3,799	3,506	3,544
2024	3,642	3,642	3,832	3,916	4,029	3,580	3,618
2025	3,740	3,740	4,000	4,115	4,271	3,655	3,693
2026	3,836	3,836	4,170	4,320	4,523	3,728	3,767
2027	3,928	3,928	4,340	4,525	4,780	3,796	3,835
2028	4,012	4,012	4,504	4,727	5,037	3,856	3,895
2029	4,087	4,087	4,661	4,924	5,291	3,907	3,946
2030	4,152	4,152	4,809	5,112	5,540	3,948	3,986
2031	4,206	4,206	4,945	5,290	5,780	3,978	4,016
2032	4,248	4,248	5,070	5,457	6,010	3,998	4,035
2033	4,280	4,280	5,182	5,611	6,229	4,009	4,045
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2020	0.032	0.032	0.032	0.032	0.032	0.032	0.032
2021	0.032	0.032	0.016	0.009	0	0.037	0.032
2022	0.033	0.033	0.016	0.009	0	0.038	0.033
2023	0.033	0.033	0.016	0.009	0	0.039	0.039
2024	0.033	0.033	0.016	0.009	0	0.039	0.039
2025	0.033	0.033	0.016	0.009	0	0.039	0.039
2026	0.033	0.033	0.016	0.009	0	0.039	0.039
2027	0.033	0.033	0.016	0.009	0	0.039	0.039
2028	0.033	0.033	0.016	0.009	0	0.039	0.039
2029	0.033	0.033	0.016	0.009	0	0.039	0.039
2030	0.033	0.033	0.016	0.009	0	0.039	0.039
2031	0.033	0.033	0.016	0.009	0	0.039	0.039
2032	0.033	0.033	0.016	0.009	0	0.039	0.039
2033	0.033	0.033	0.016	0.009	0	0.039	0.039

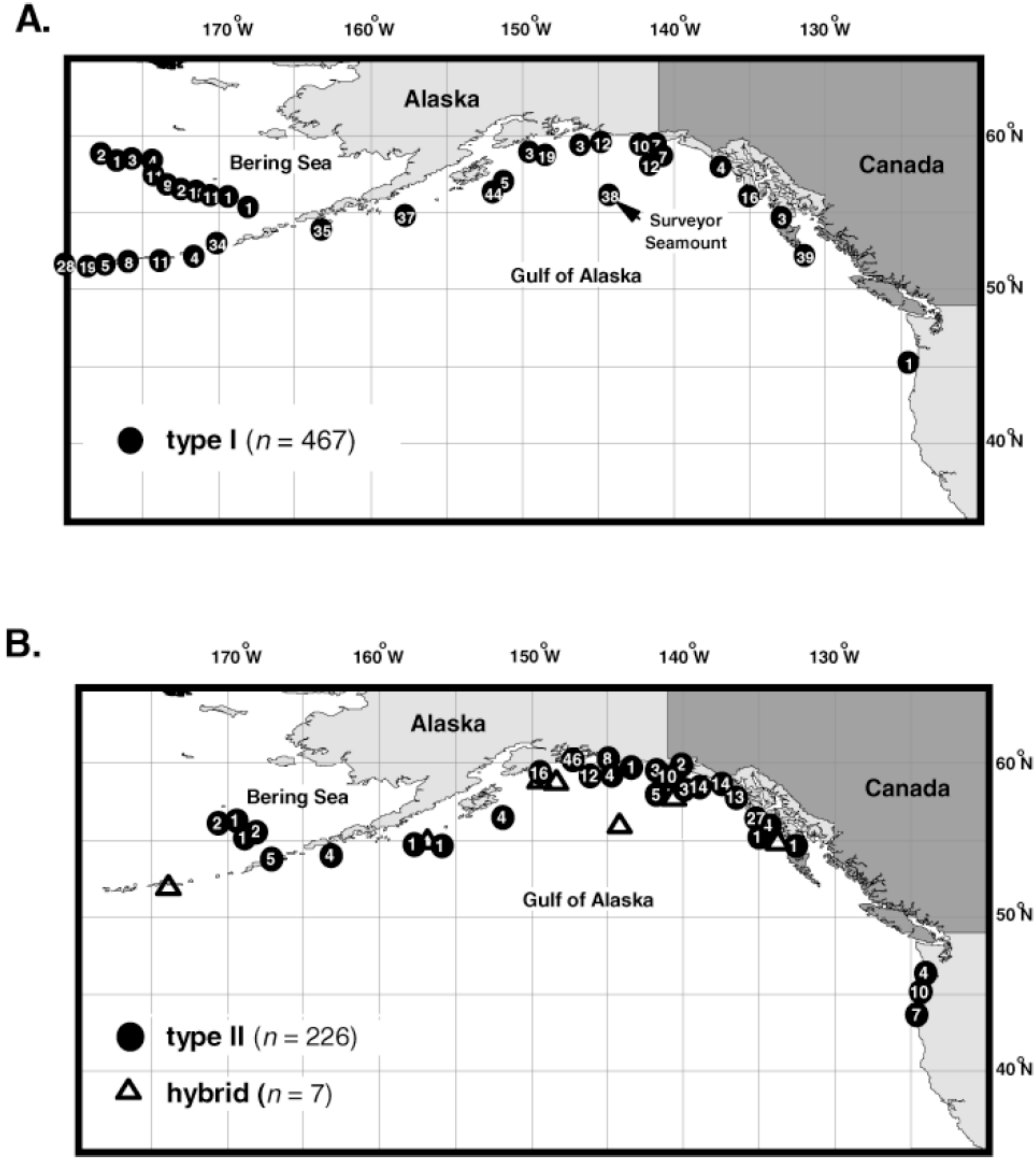


Figure 14.1. Distribution type I (i.e., blackspotted rockfish, *S. melanostictus*) and type II (i.e., rougheye rockfish, *S. aleutianus*) fish previously thought to be a single species of rougheye rockfish, based mtDNA and microsatellite genetic analyses. From Gharrett et al. (2005).

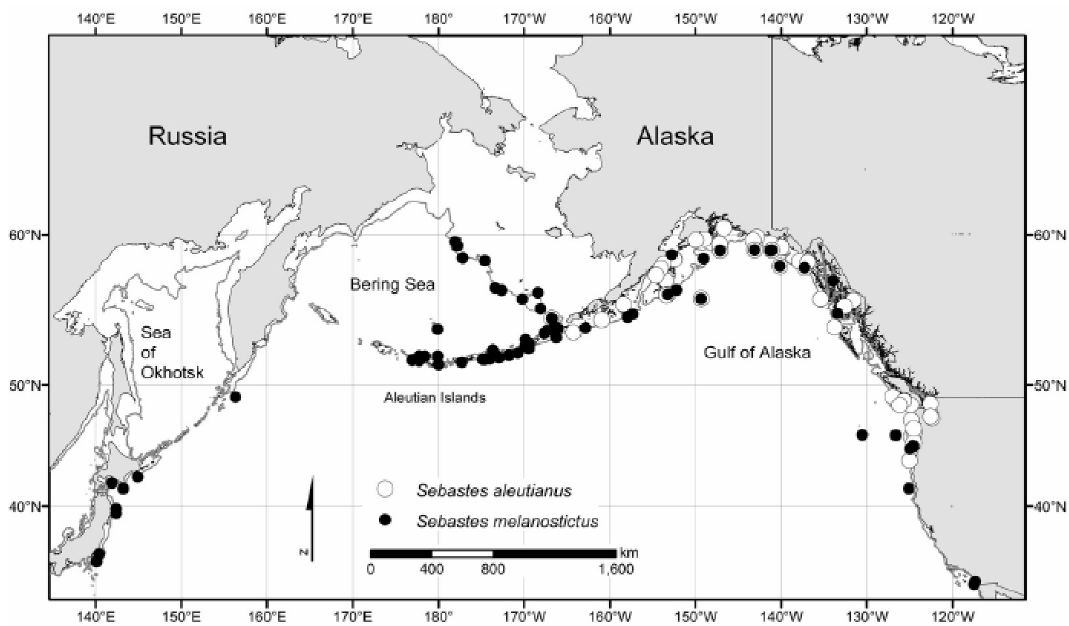
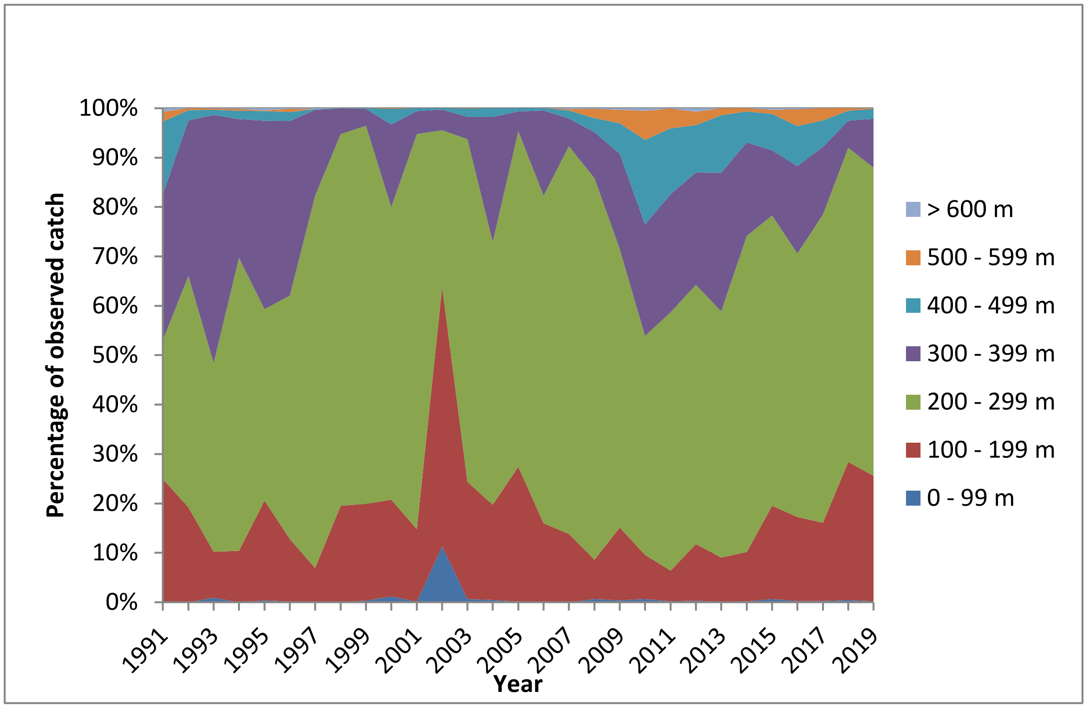


Figure 14.2. Distribution blackspotted rockfish (*S. melanostictus*) and rougheye rockfish (*S. aleutianus*) based upon genetic, morphometric, and meristic analyses. From Orr and Hawkins (2008).



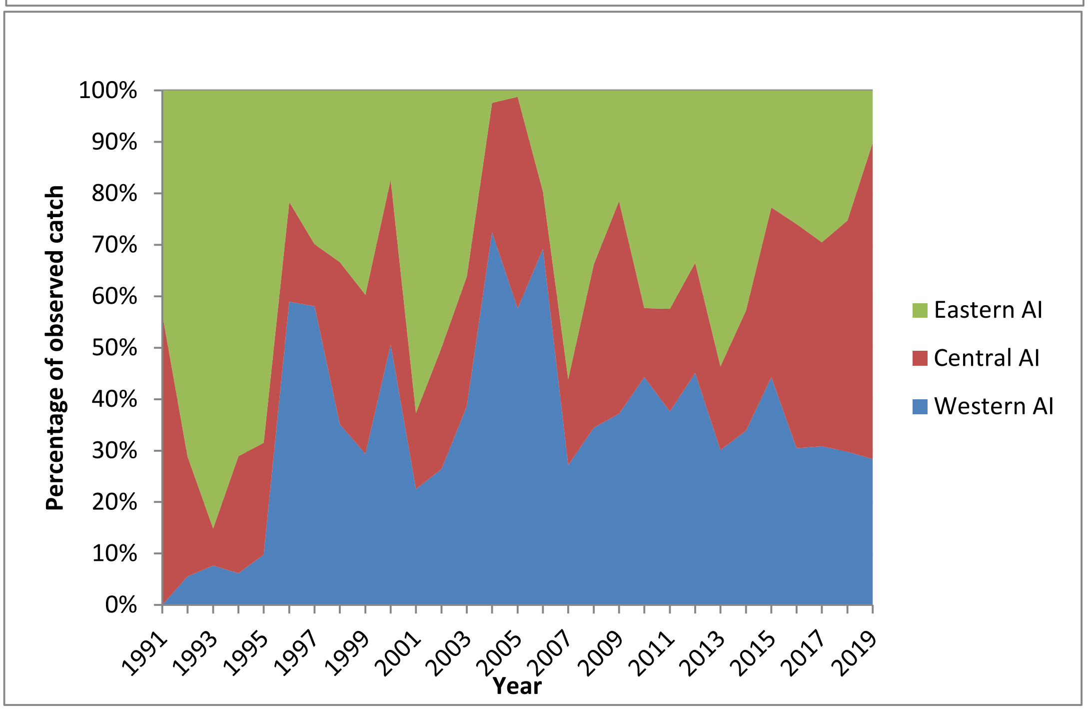


Figure 14.3. Distribution of observed Aleutian Islands (AI) blackspotted/rougheye rockfish catch (from North Pacific Groundfish Observer Program) by depth zone (top panel) and AI subarea (bottom panel) from 1991 to 2019.

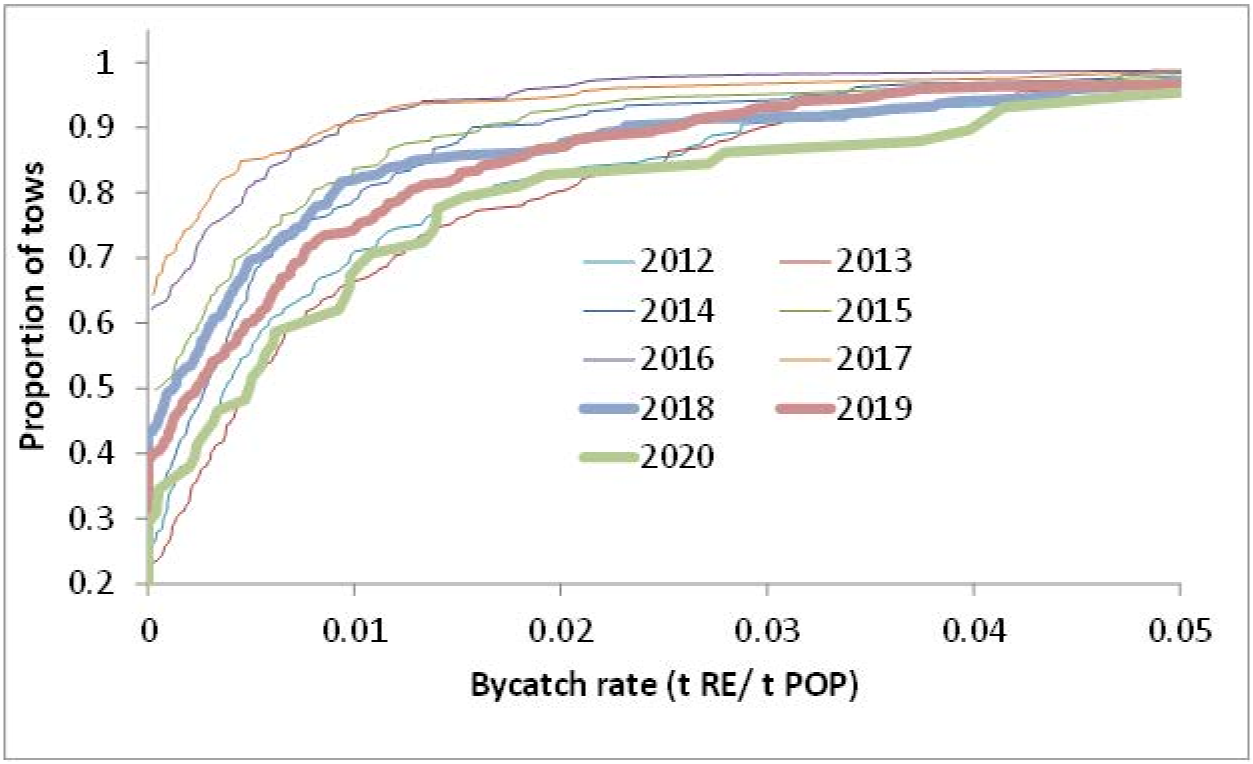


Figure 14.4. Cumulative distribution plots of rougheye blackspotted bycatch rates for tows by A80 vessels targeting Pacific ocean perch in the WAI.

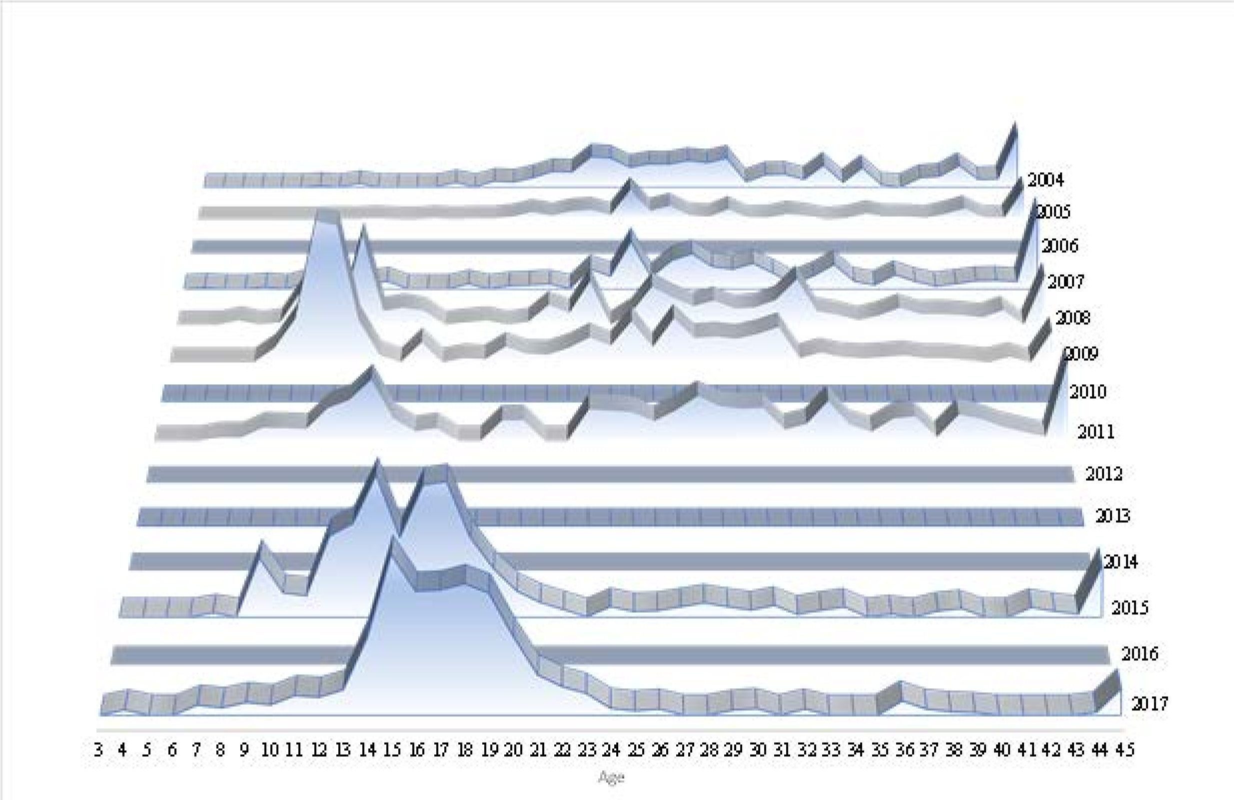


Figure 14.5. Fishery age composition data for the BSAI, scaled to the extrapolated number of fish caught from Observer sampling.

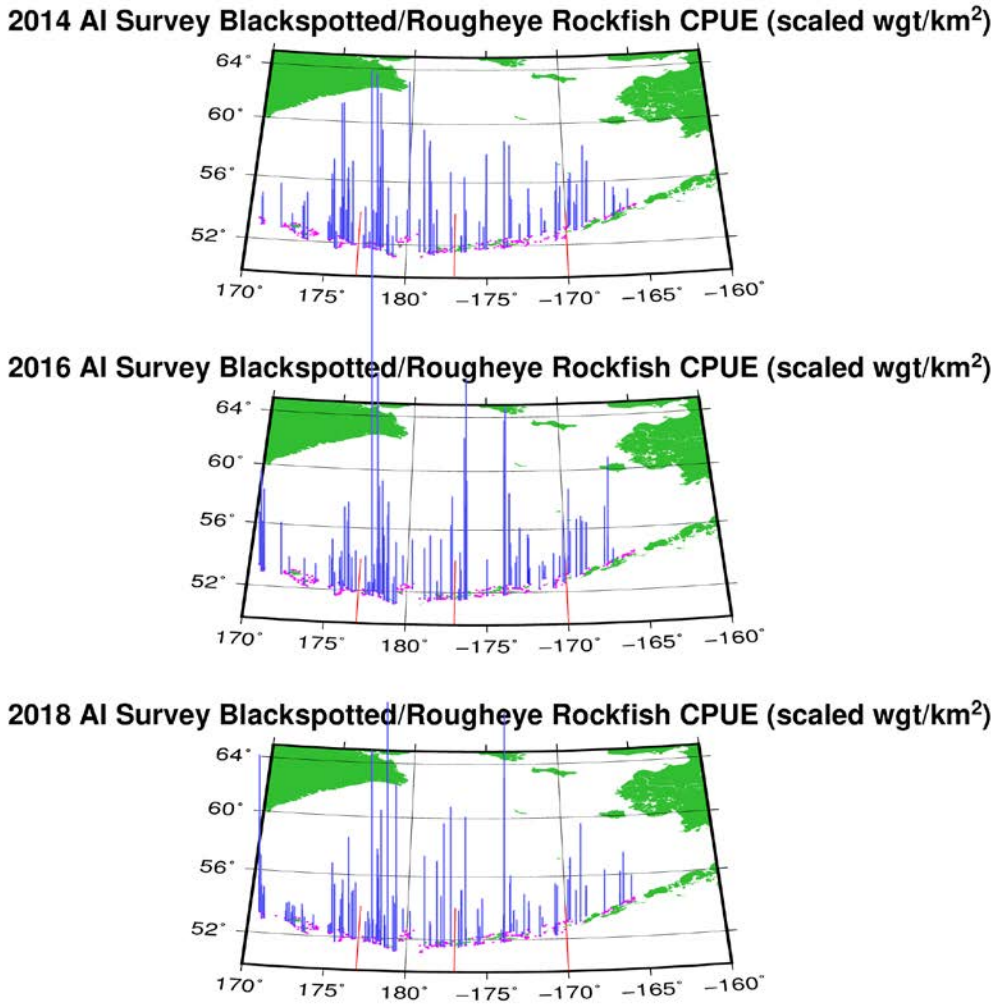


Figure 14.6. Scaled Aleutian Islands (AI) survey combined blackspotted and rougheye rockfish CPUE (kg/km^2) from 2014-2018; the symbol × denotes tows with no catch. The red lines indicate boundaries between the western Aleutian Islands (WAI), central Aleutian Islands (CAI), eastern Aleutian Islands (EAI), and eastern Bering Sea (EBS) areas.

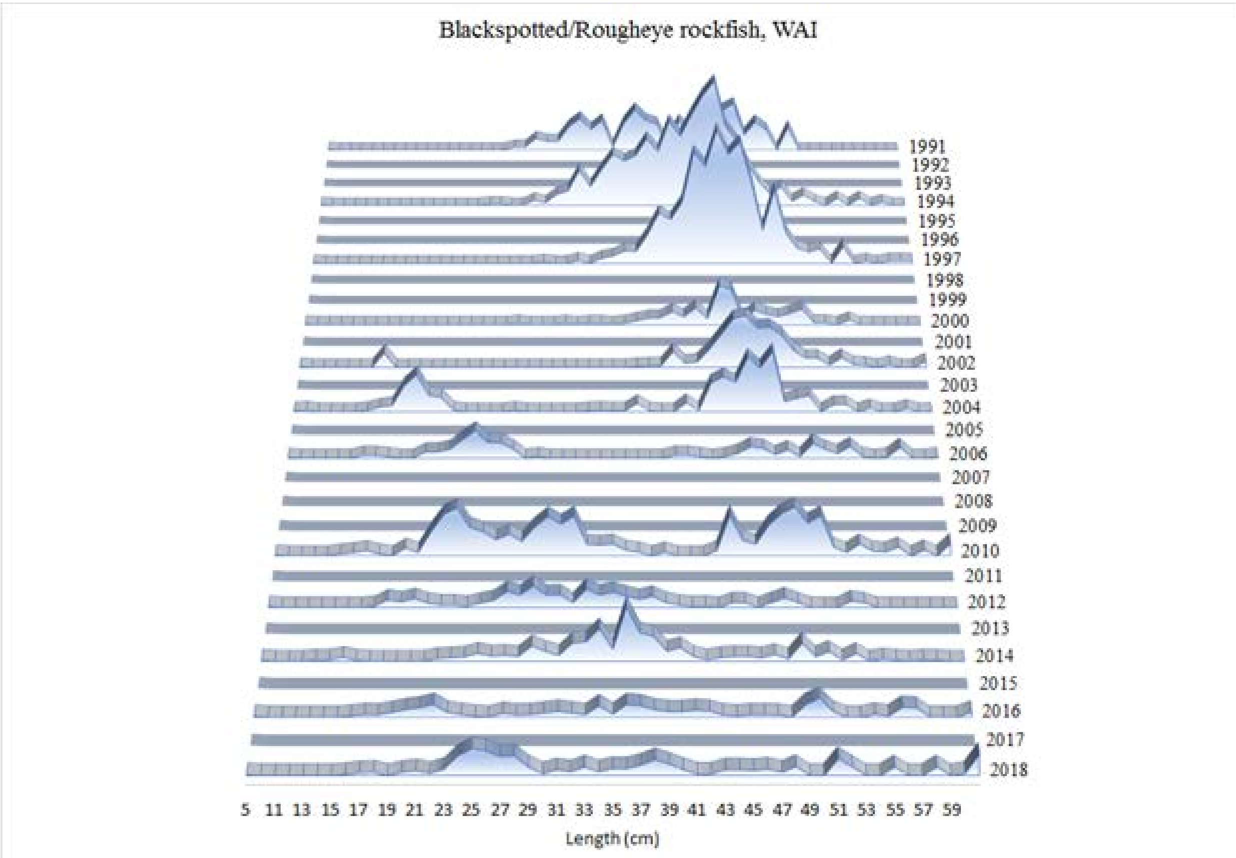


Figure 14.7. Estimated abundance by length for blackspotted/rougheye rockfish in the western Aleutian Islands subarea, from the 1991-2018 AI surveys.

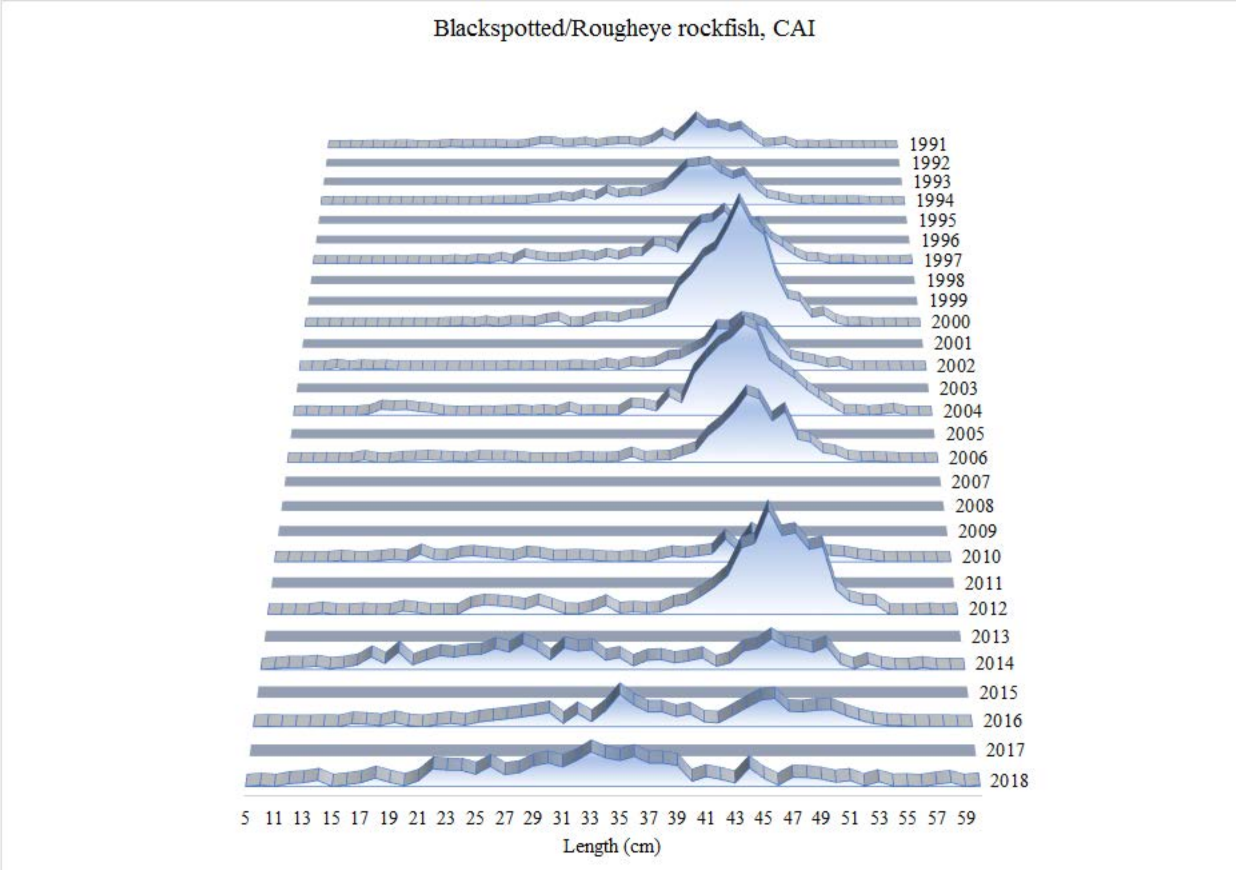


Figure 14.8. Estimated abundance by length for blackspotted/rougheye rockfish in the central Aleutian Islands subarea, from the 1991-2018 AI surveys

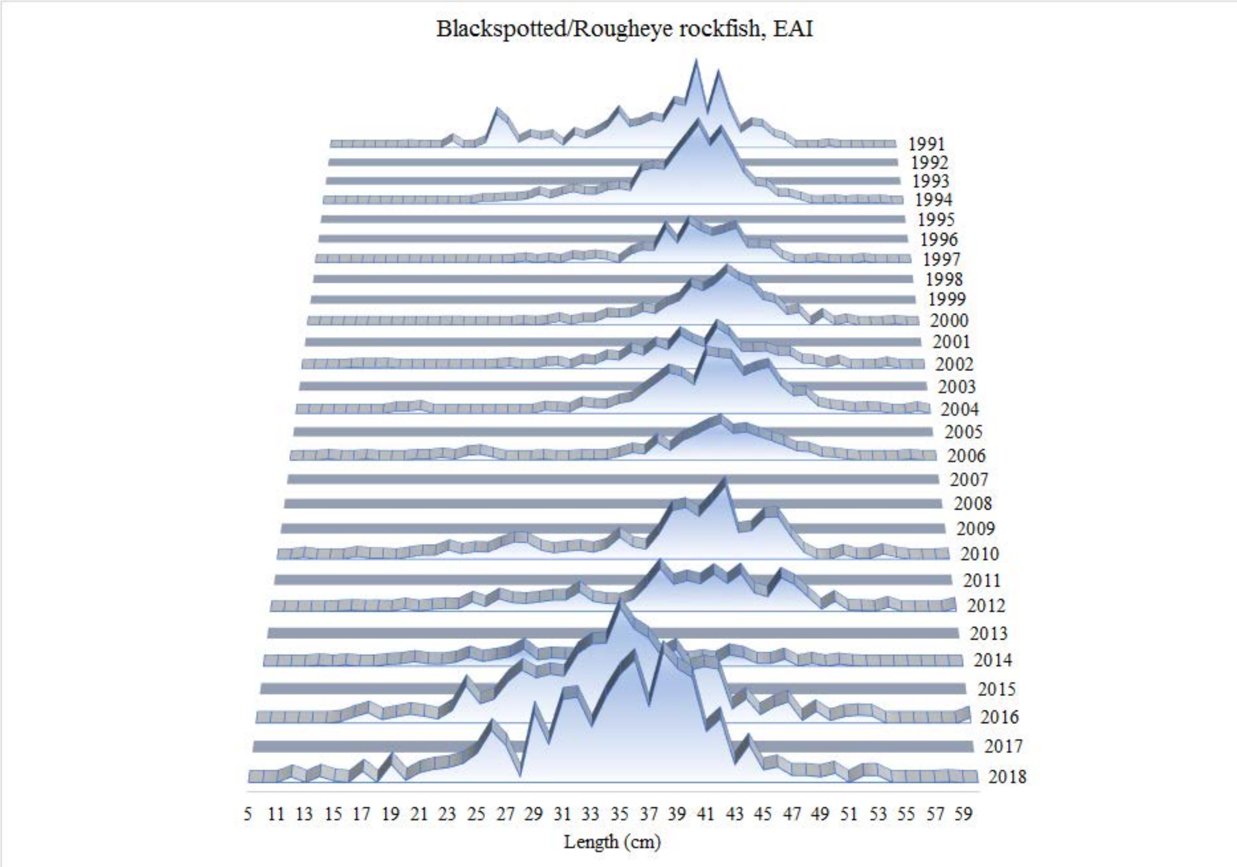


Figure 14.9. Estimated abundance by length for blackspotted/rougheye rockfish in the eastern Aleutian Islands subarea, from the 1991-2018 AI surveys.

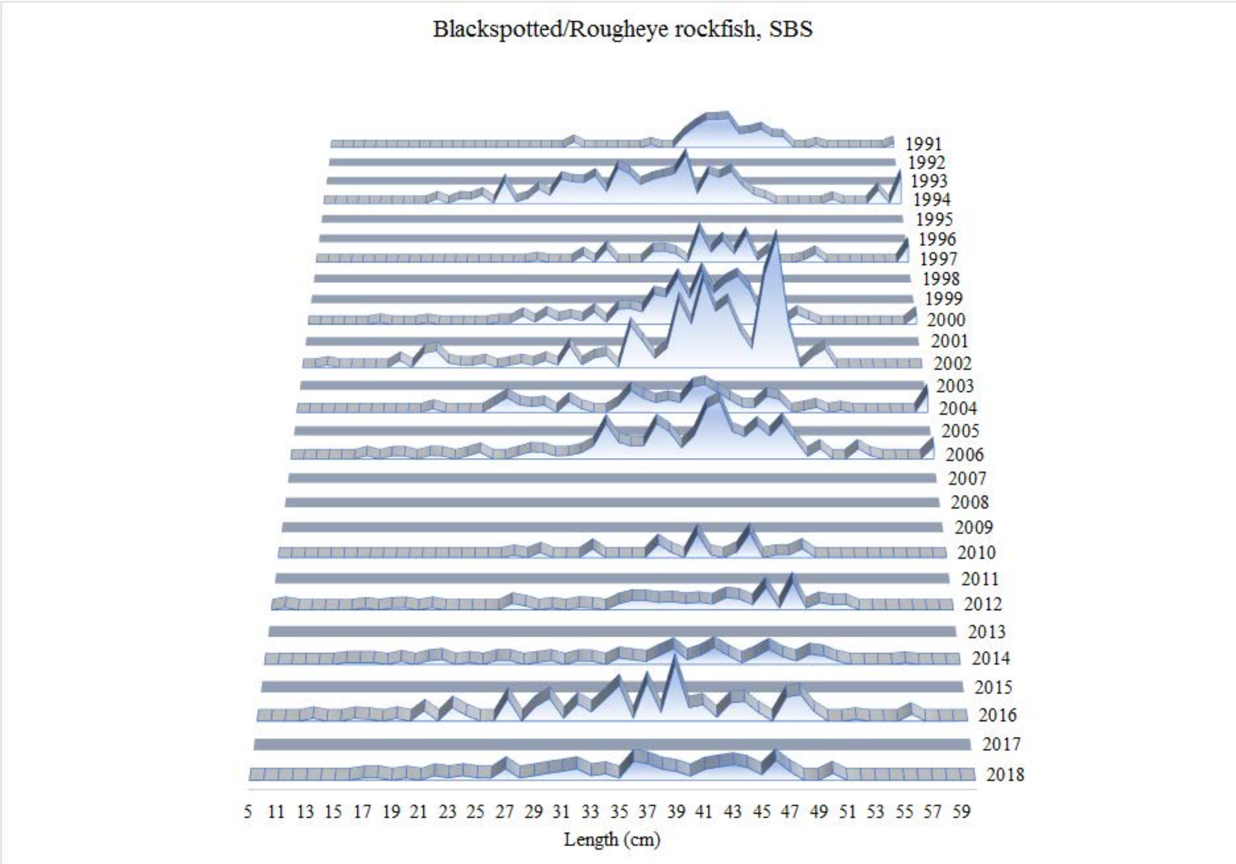


Figure 14.10. Estimated abundance by length for blackspotted/rougheye rockfish in the southern Bering Sea, from the 1991-2018 AI surveys.

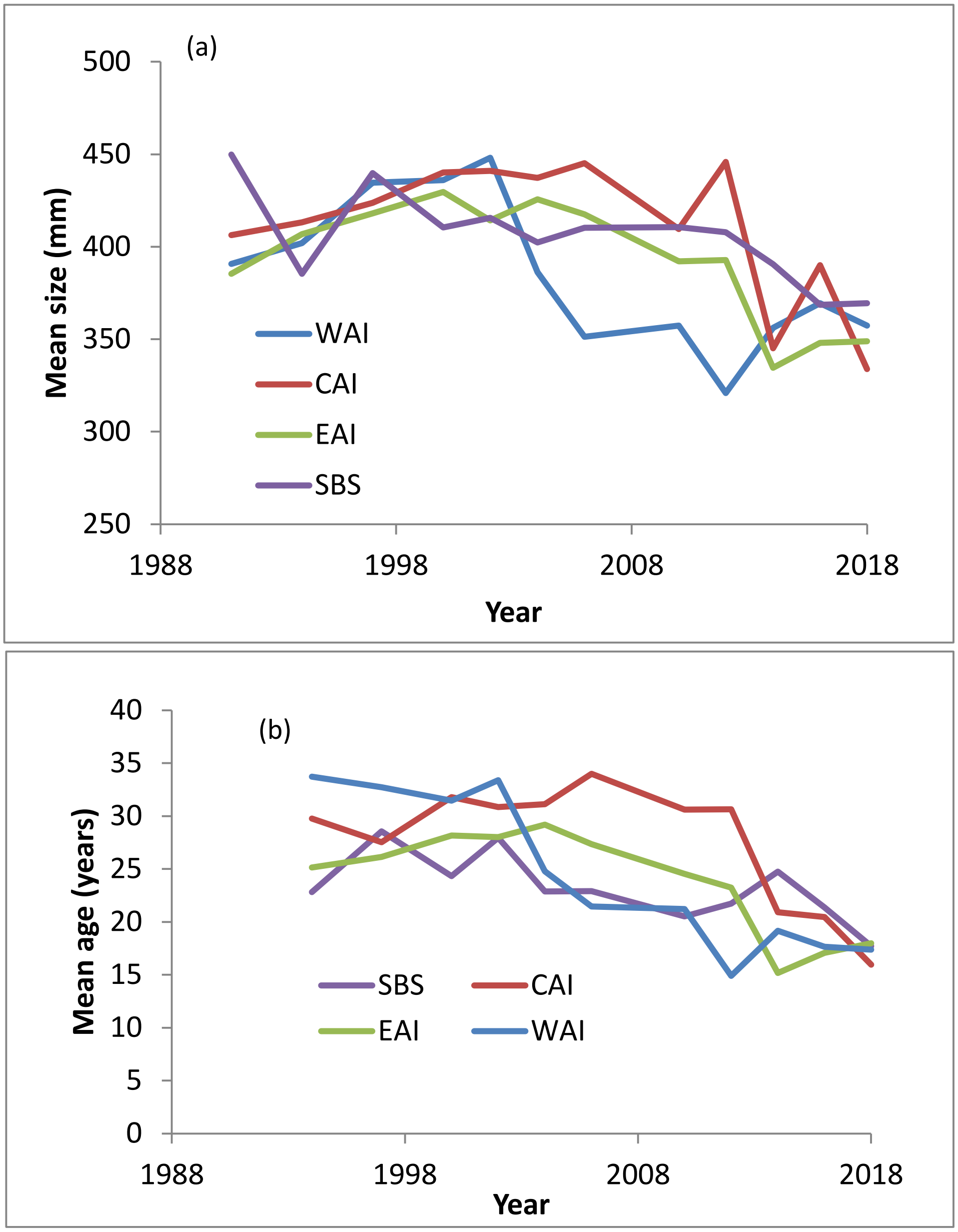


Figure 14.11. Mean size (a) and age (b) of blackspotted/rougheye rockfish from the 1991-2018 AI trawl surveys by subarea.

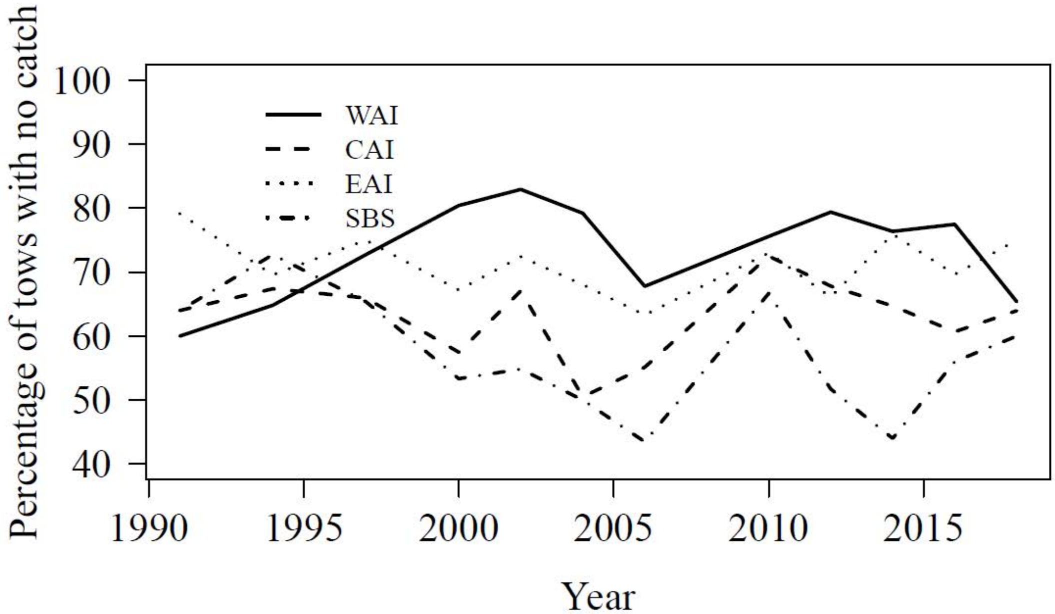


Figure 14.12. Percentage of survey tows with no catch of blackspotted/rougheye rockfish from the 1991-2018 AI trawl surveys by subarea.

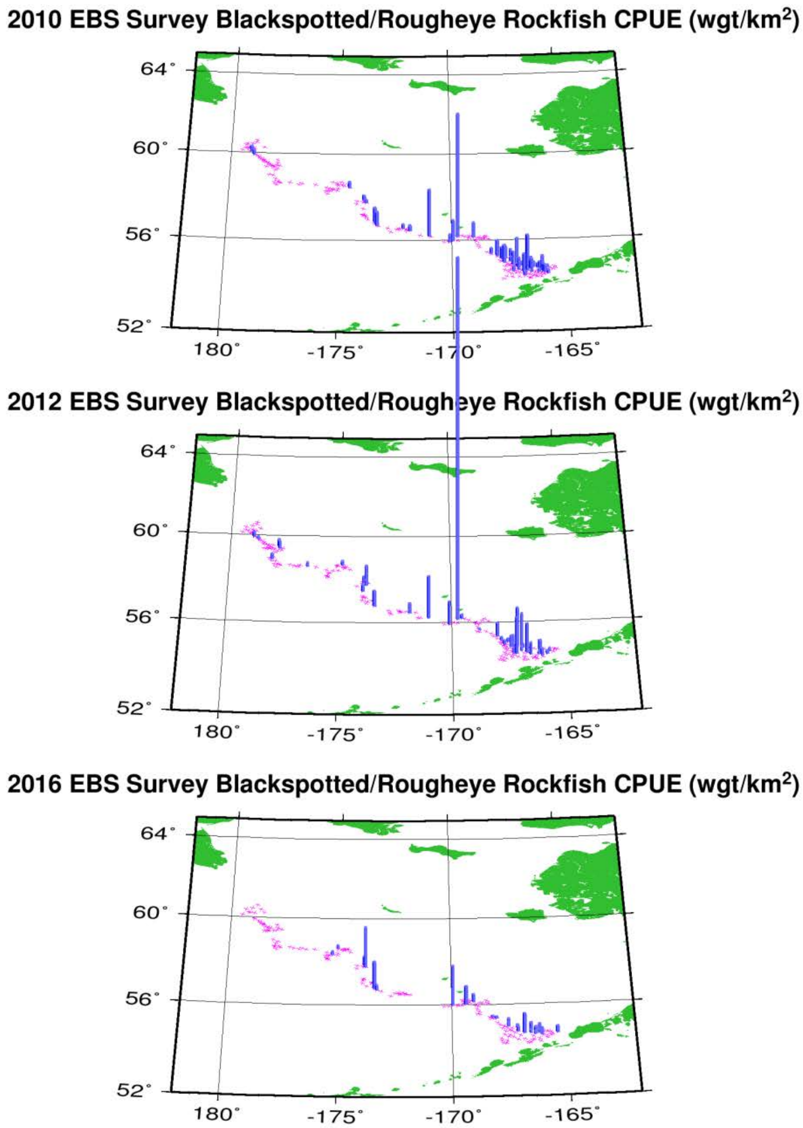


Figure 14.13. Scaled EBS survey combined blackspotted and rougheye rockfish CPUE (kg/km^2) from 2010-2016; the symbol × denotes tows with no catch.

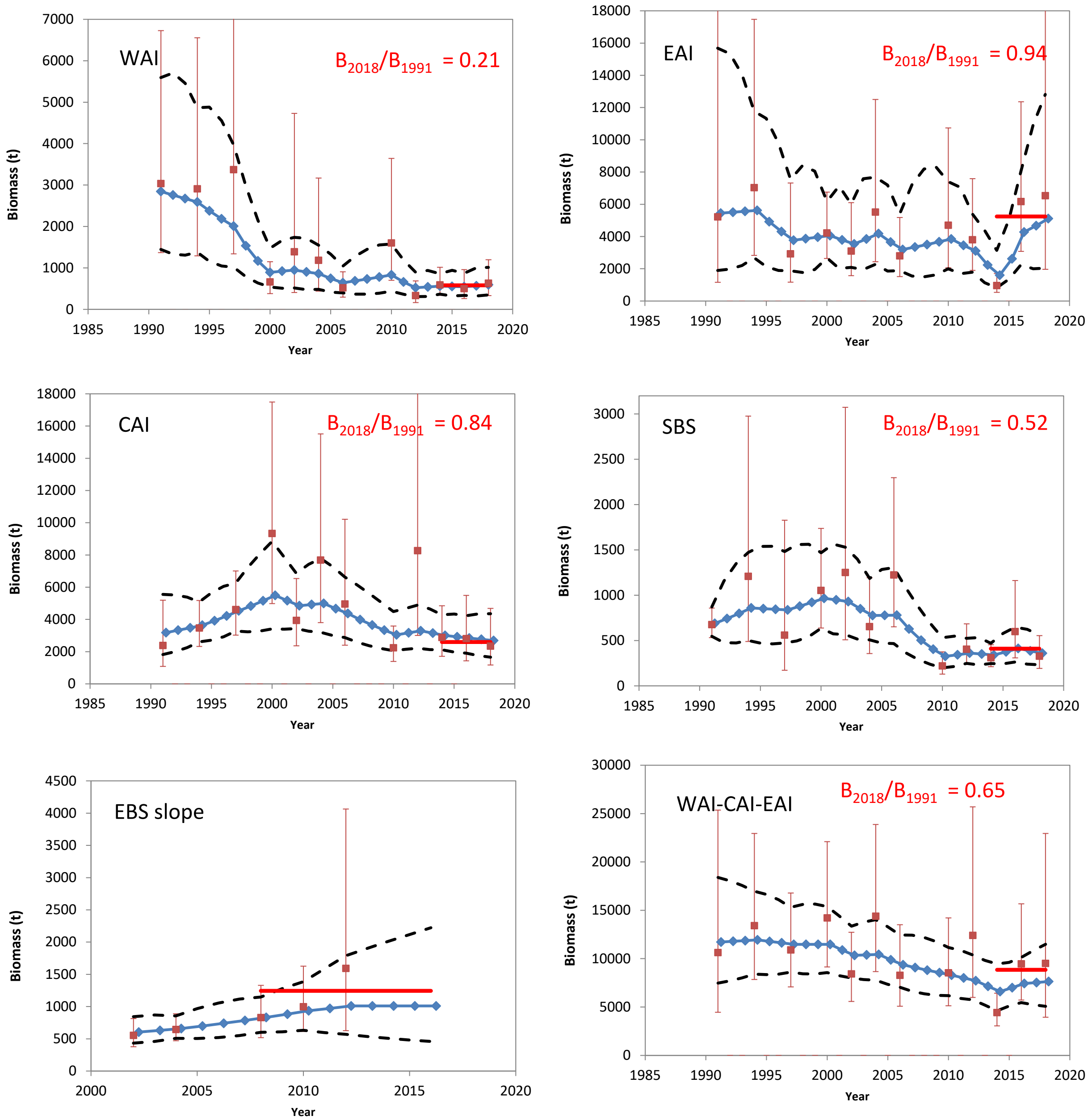


Figure 14.14. Time series of AI and EBS slope trawl survey biomass by subarea, with the fits from a random effects model to smooth the time series. The ratio of the biomass estimate in 2018 to that in 1991 indicates the estimated level of depletion over this time period. The horizontal red lines show the estimate from a weighted average of the three most recent surveys.

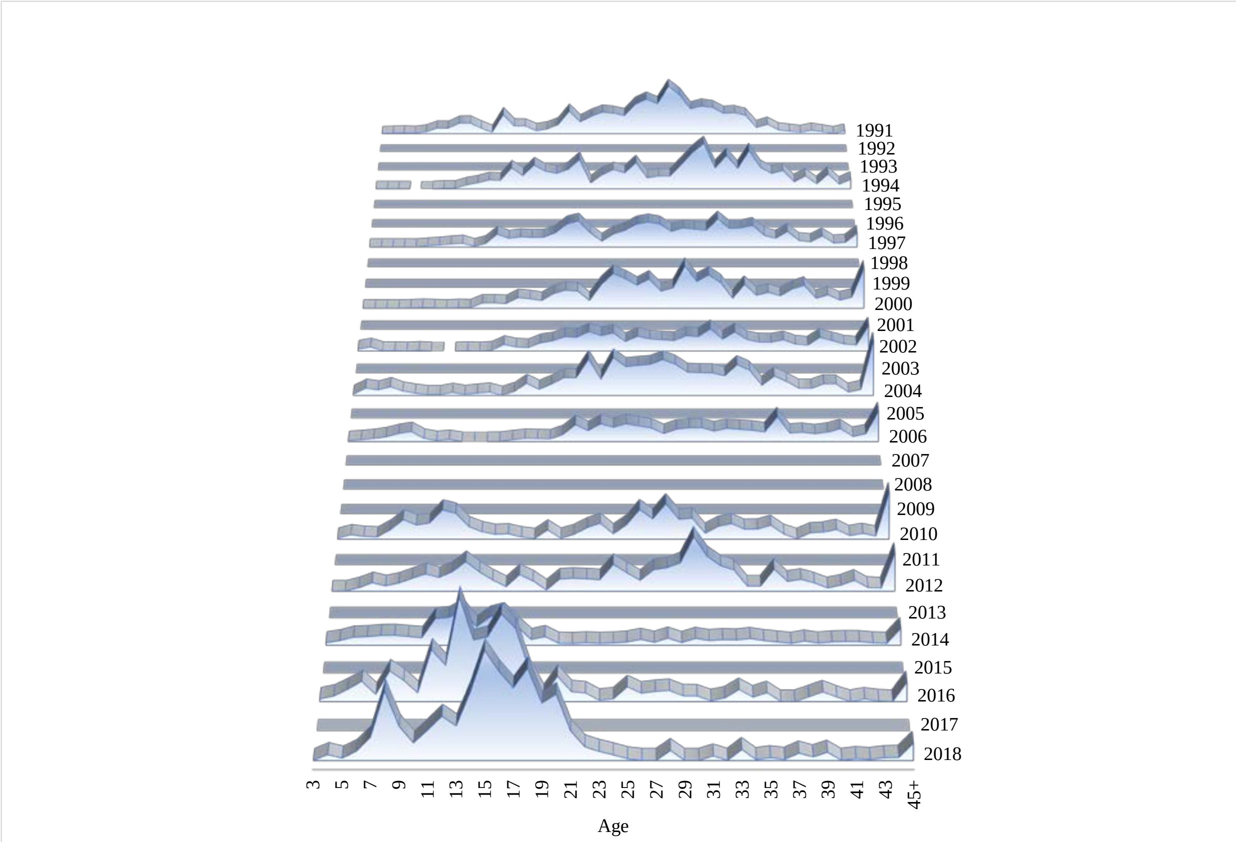
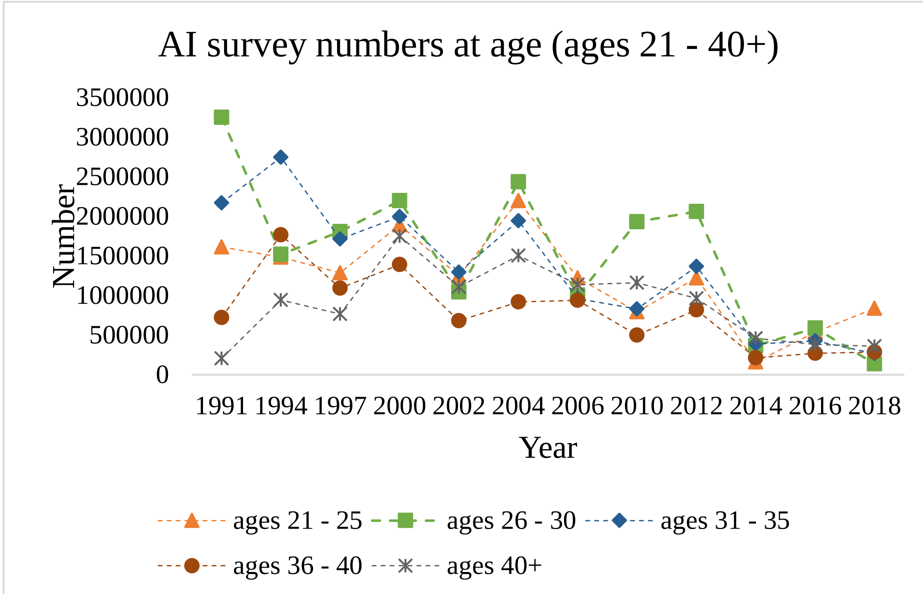


Figure 14.15. Estimated abundance by age from the Aleutian Islands trawl survey, 1991-2018.



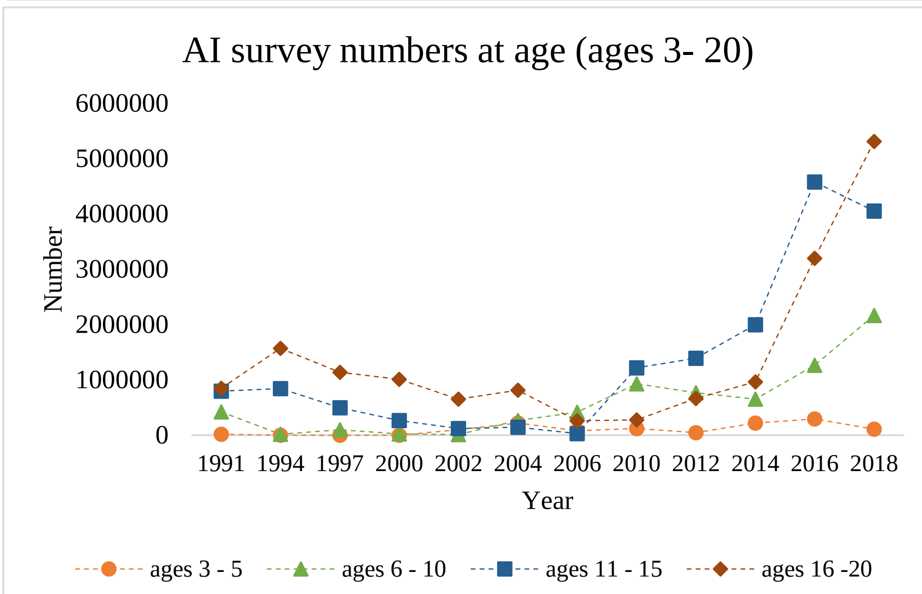


Figure 14.16. Estimated abundance, by age groups, from the AI trawl survey, 1991-2018.

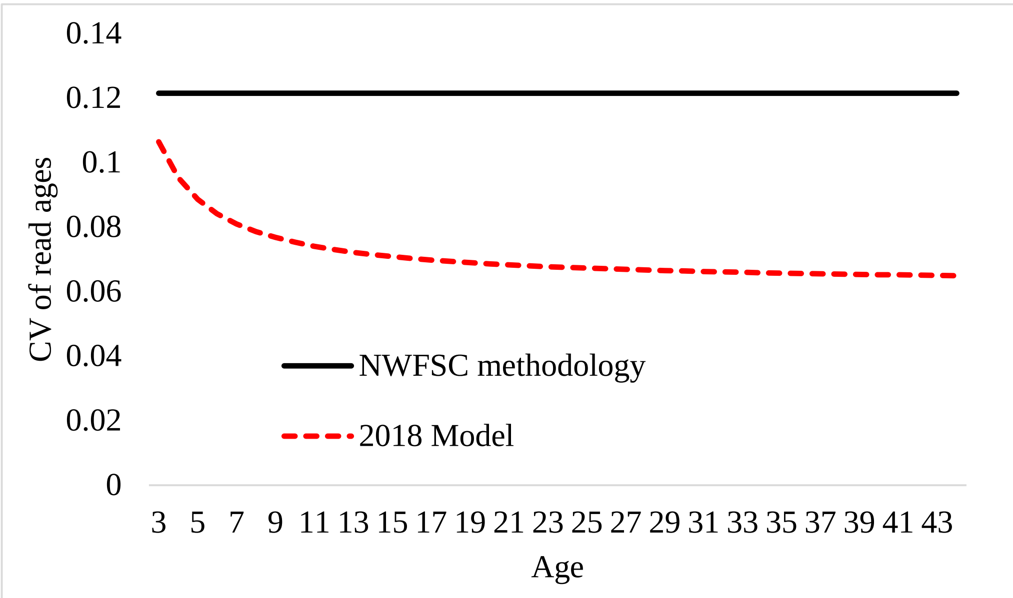


Figure 14.17. The coefficient of variation (CV) in read ages around a true age, estimated from the NWFSC method in Punt et al. (2008) and used this assessment; for comparison, the values used in the 2018 assessment are also shown.

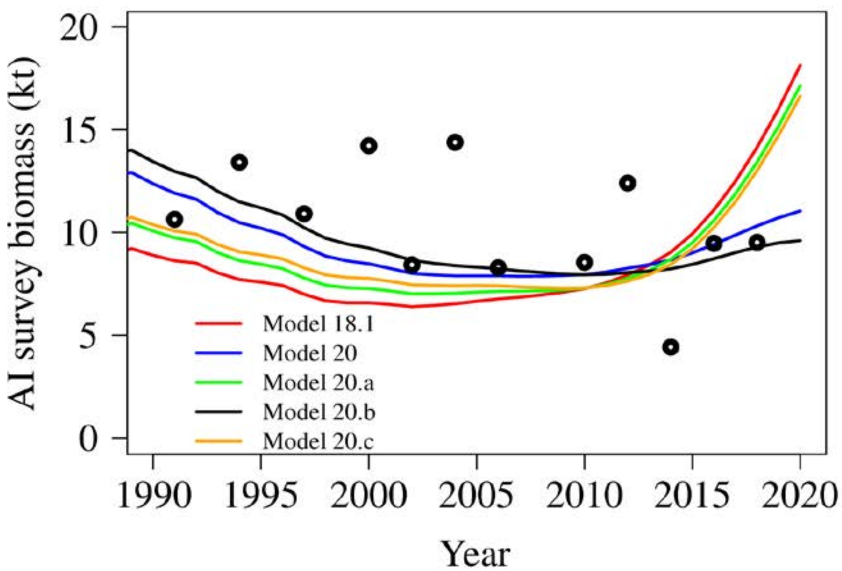


Figure 14.18. Estimated AI survey biomass across the models considered in this assessment.

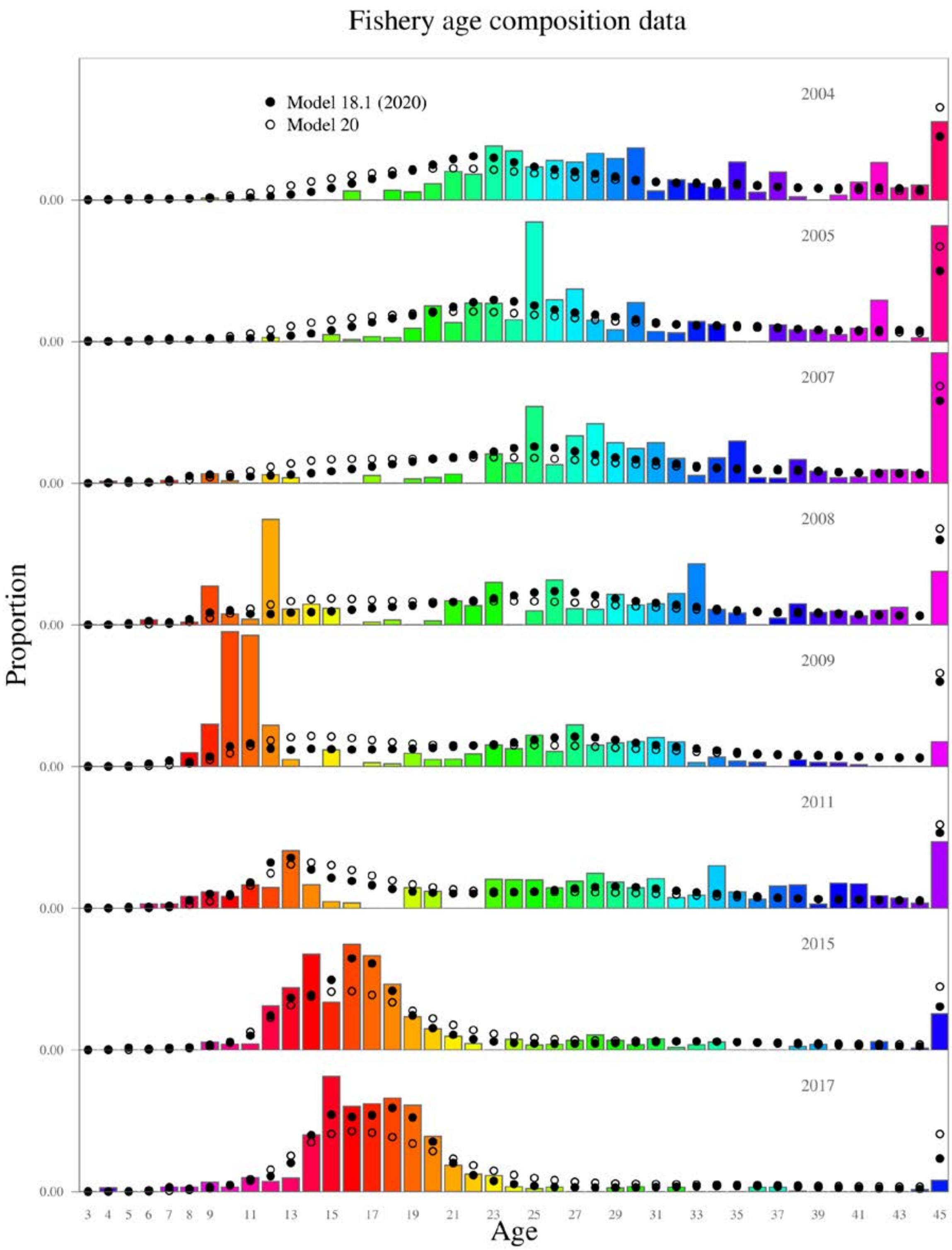


Figure 14.19. Estimated fishery age compositions from model 18.1(2020) and Model 20.

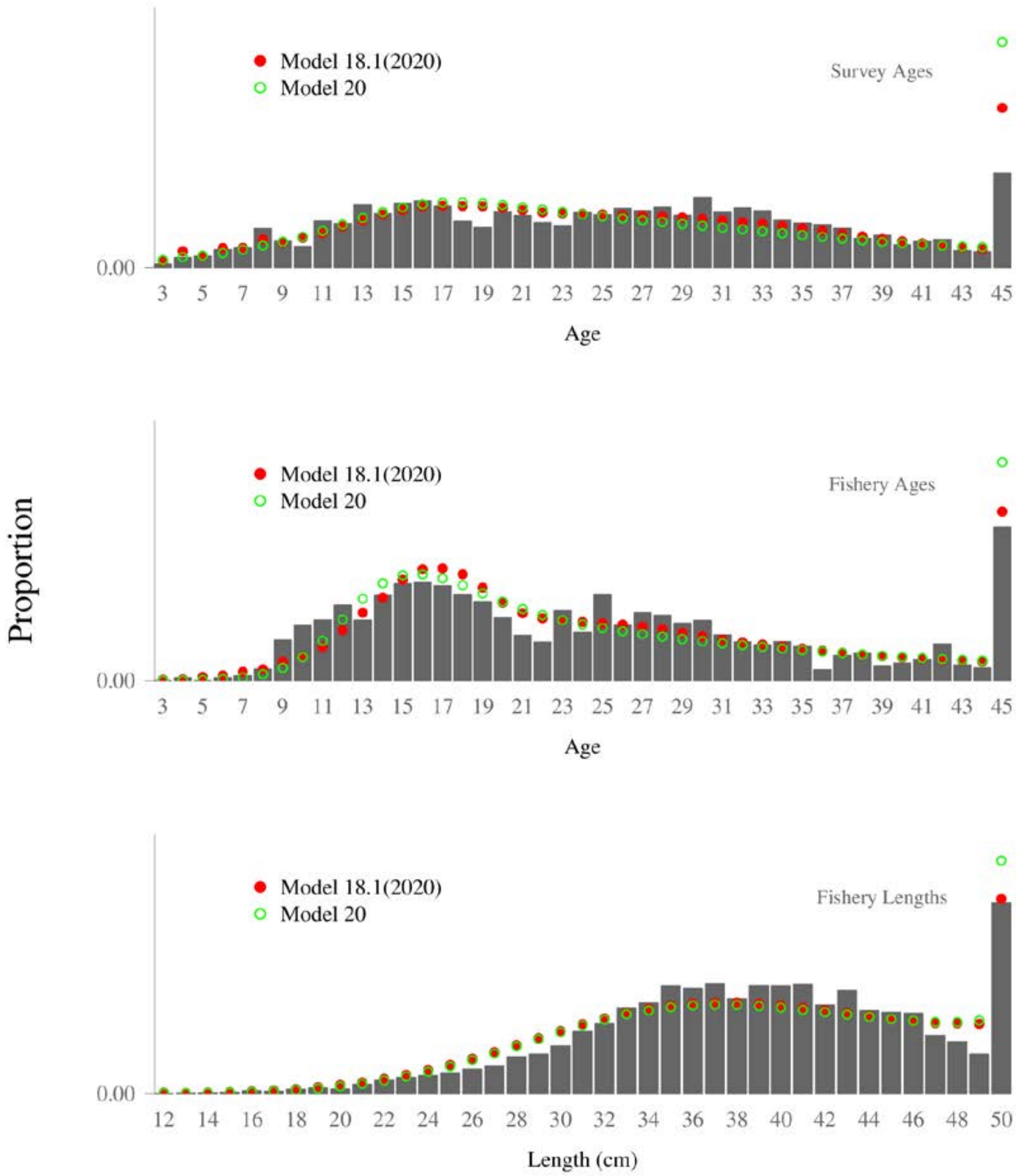


Figure 14.20. Estimated and observed age and length compositions, averaged across years within each data type, from Model 18.1(2020) and Model 20.

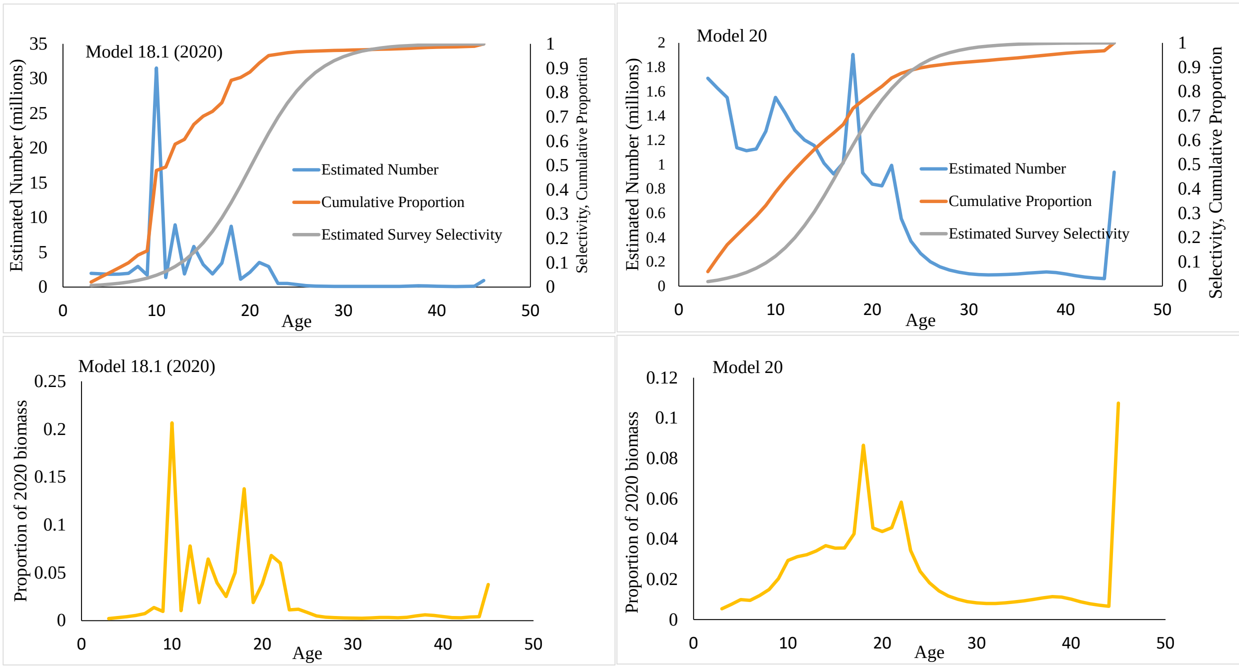


Figure 14.21. The estimated 2020 distribution of abundance and biomass across ages, and estimated survey selectivity, for Model 18.1(2020) and Model 20.

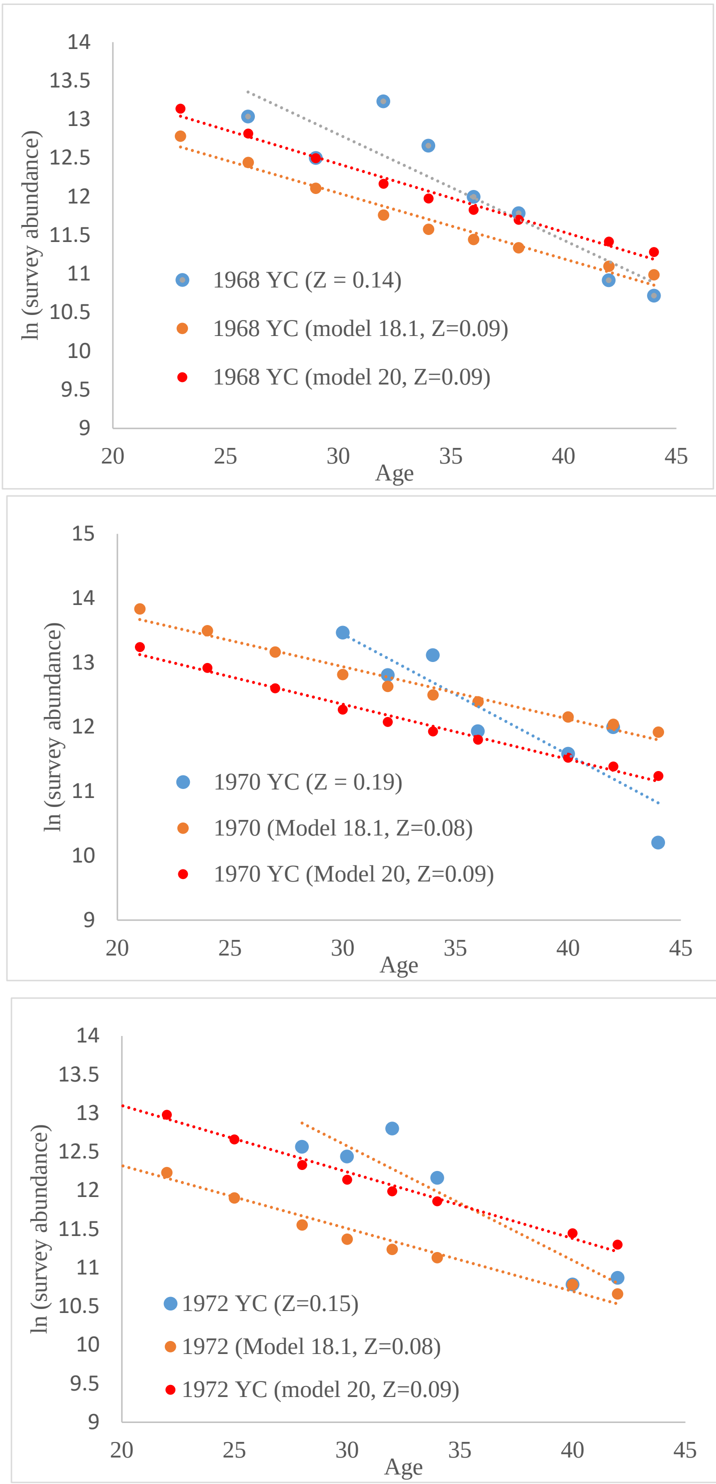
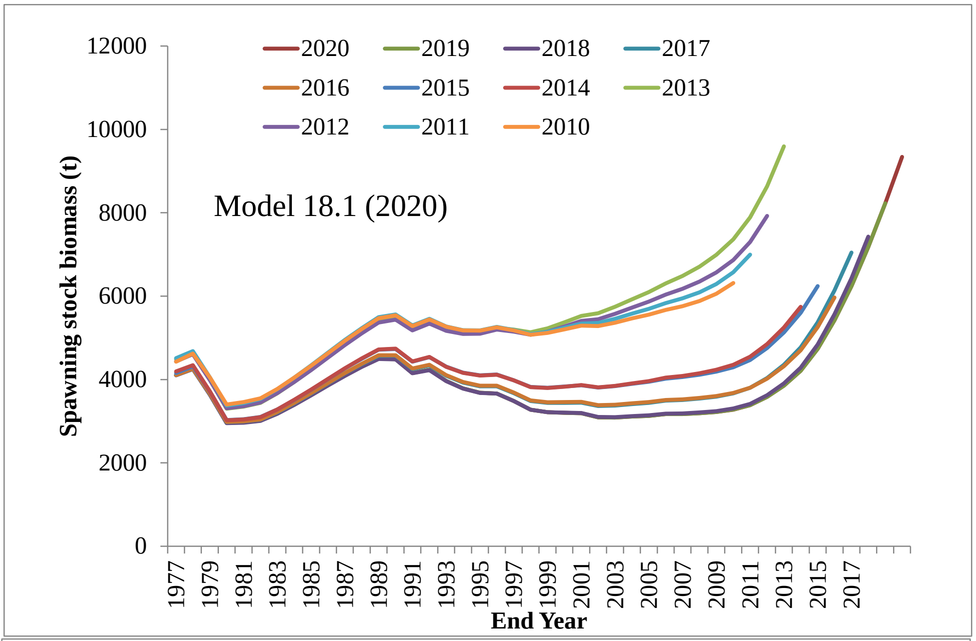


Figure 14.22. Log abundance for selected cohorts of blackspotted/rougheye rockfish from the AI survey (excluding the SBS area) and estimated from model 18.1(2020) and model 20.



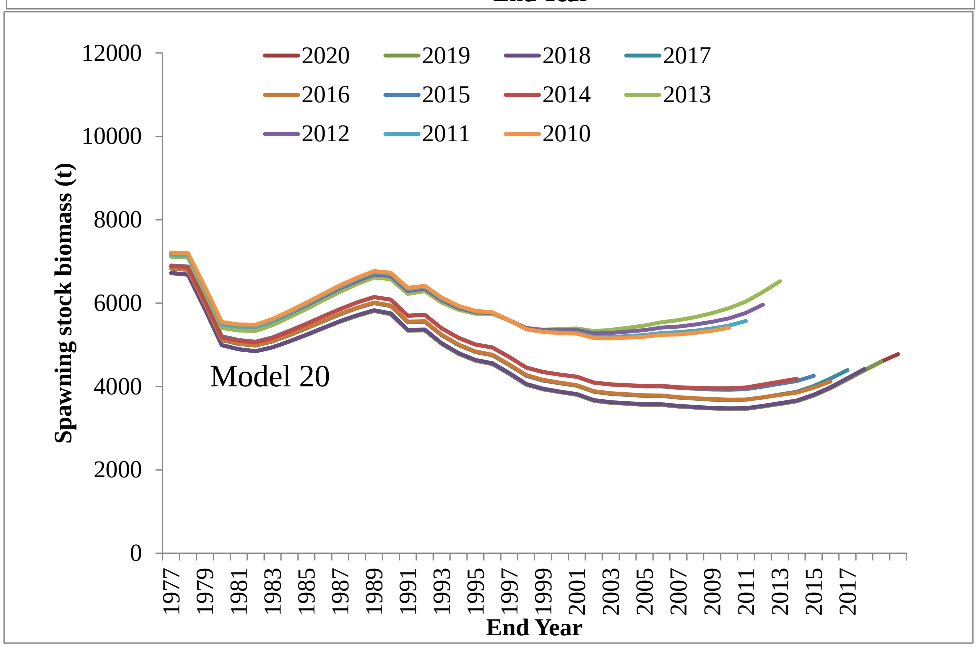


Figure 14.23. Retrospective estimate of spawning stock biomass from for model 18.1(2020) and model 20.

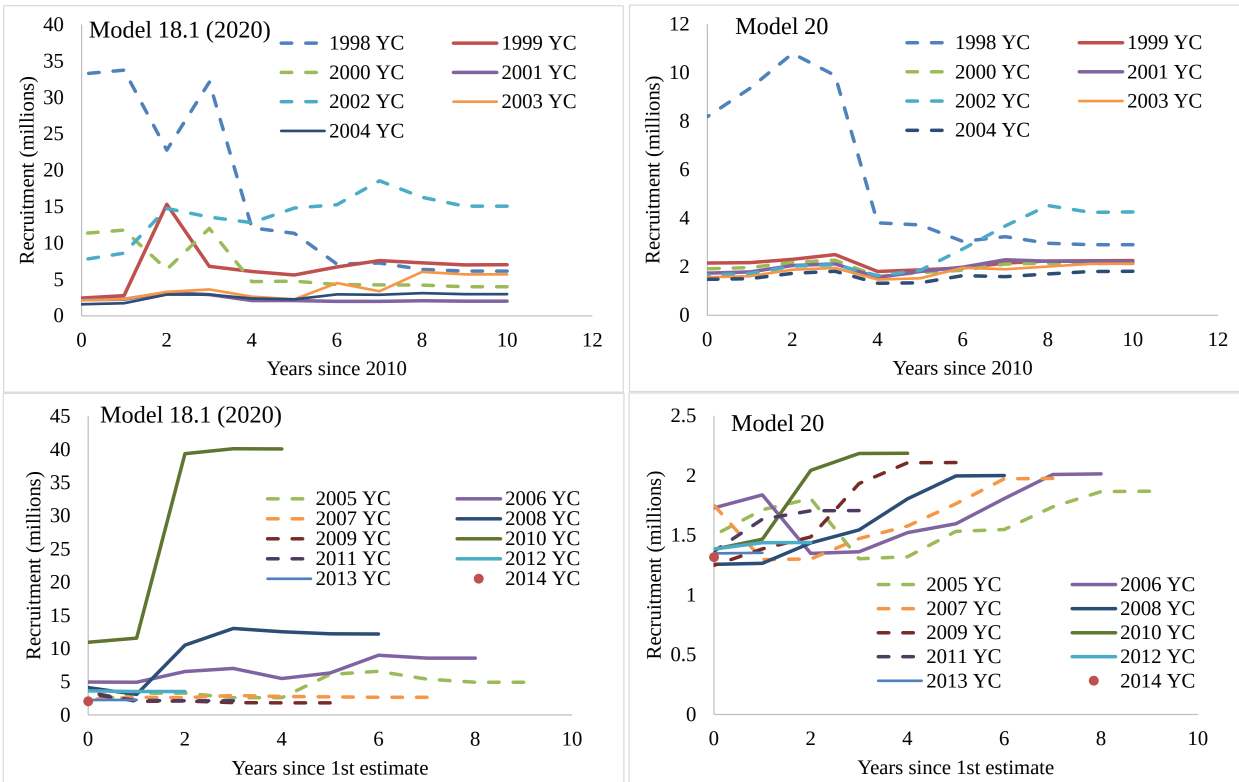


Figure 14.24. Retrospective estimates of recruitment for the 1998 – 2014 year classes, as a function of the years since either the first estimate or 2010 (whichever is later), for model 18.1(2020) and model 20.

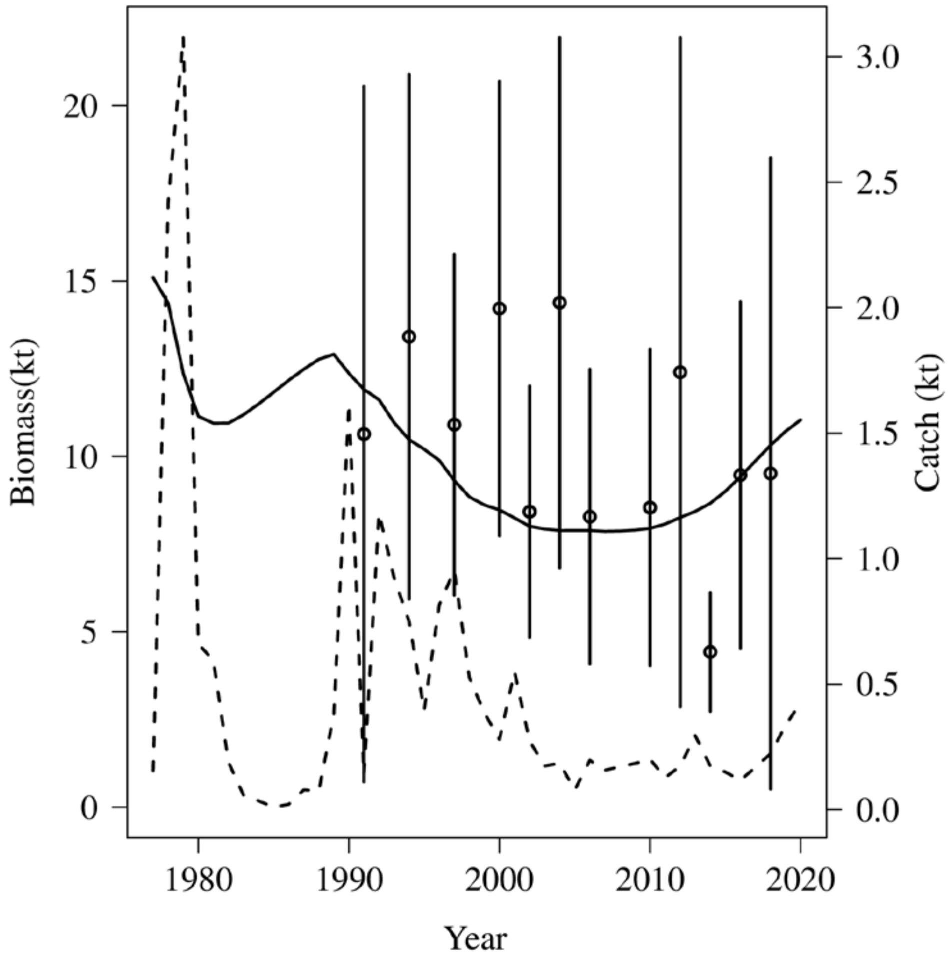


Figure 14.25. Observed Aleutian Islands (AI) survey biomass for blackspotted/rougheye rockfish (data points, +/- 2 standard deviations), predicted survey biomass (solid line), and harvest (dashed line).

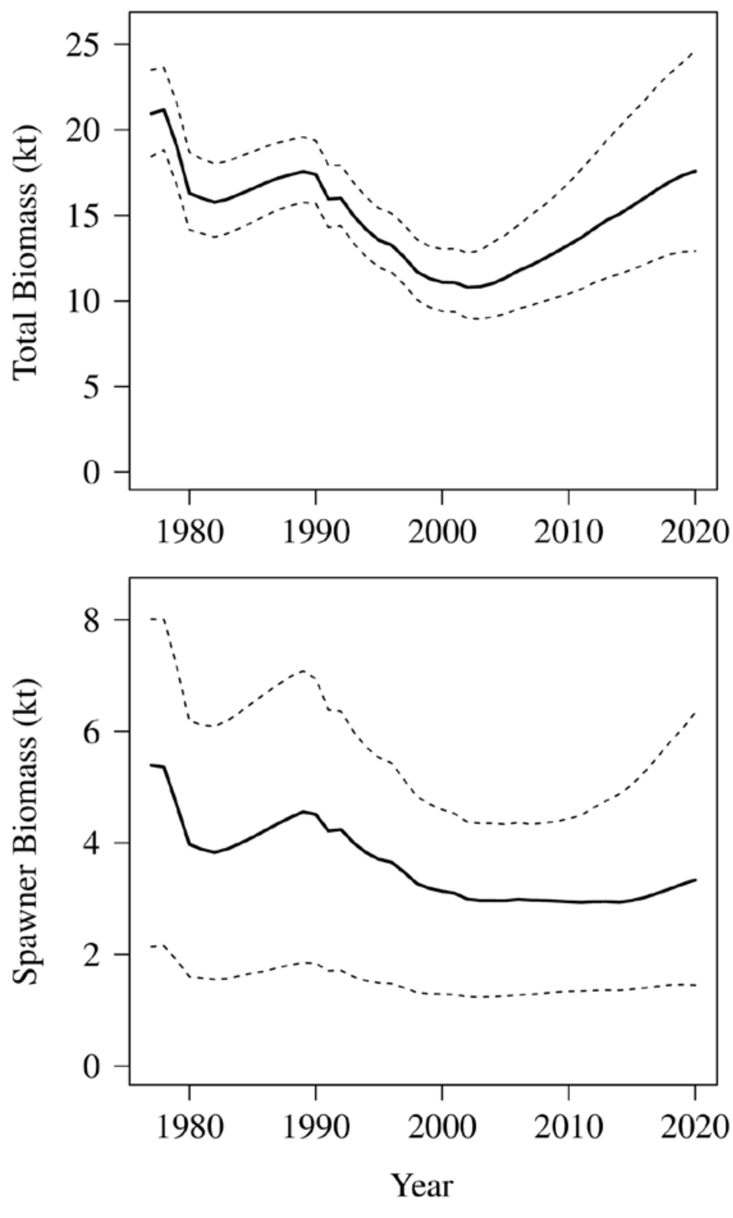


Figure 14.26. Total (top panel) and spawner (bottom panel) biomass for BSAI blackspotted/rougheye rockfish, with 95% confidence intervals from MCMC integration.

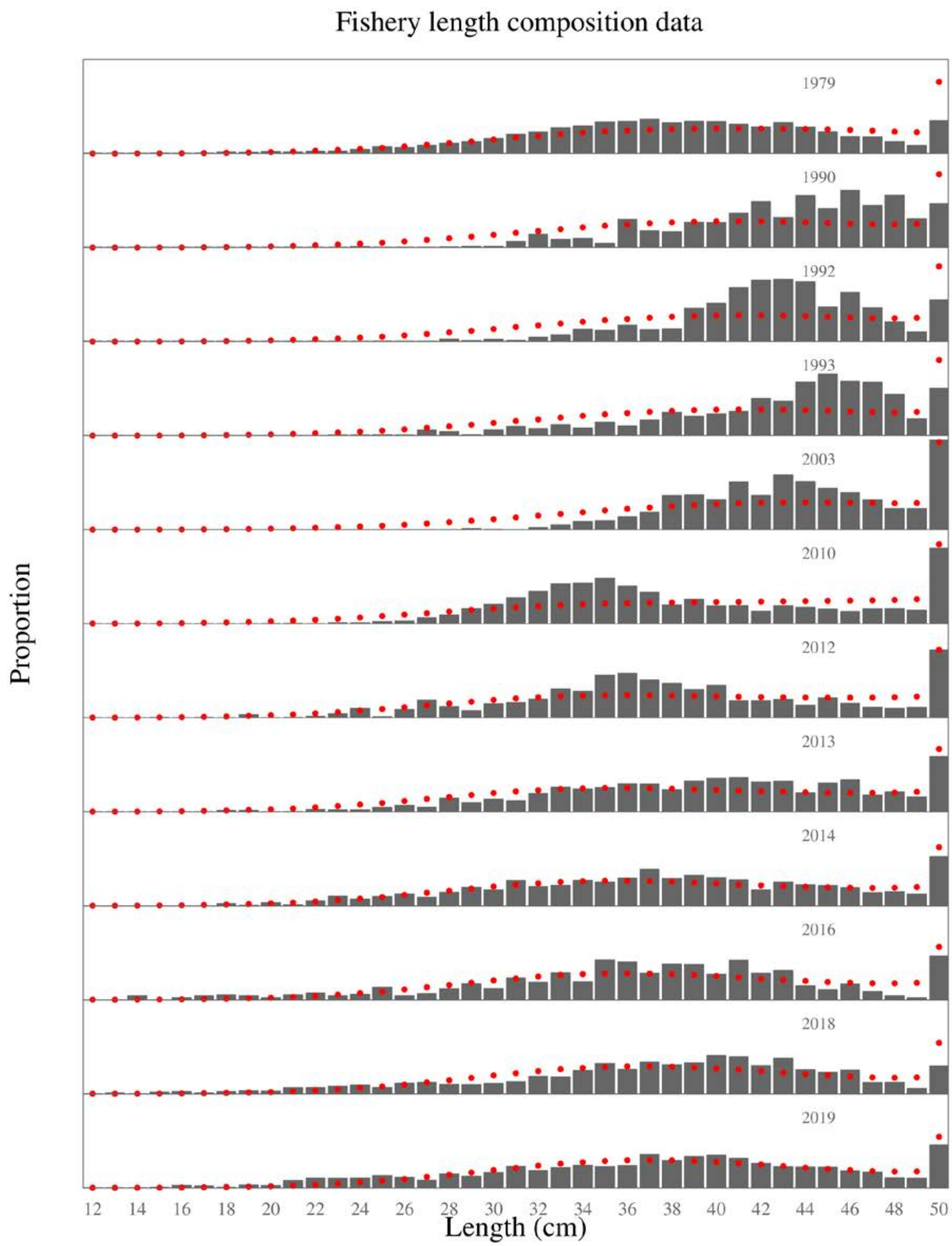


Figure 14.27. Model fits (dots) to the fishery length composition data (columns) for AI blackspotted/rougheye rockfish, 1979-2019.

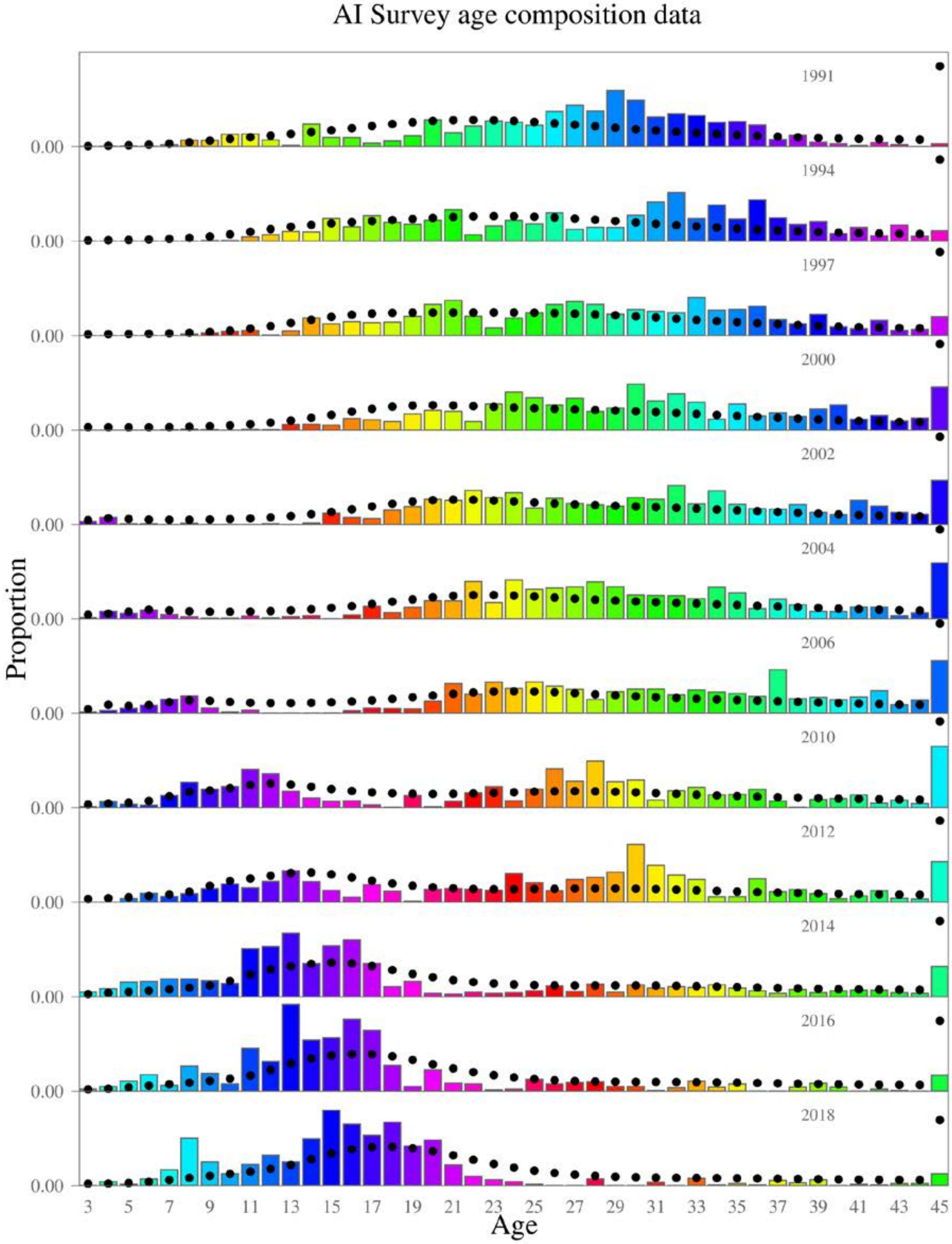


Figure 14.28. Model fits (dots) to the survey age composition data (columns) for Aleutian Islands (AI) blackspotted/rougheye rockfish, 1991-2018. Colors of the bars correspond to cohorts (except for the 45+ group).

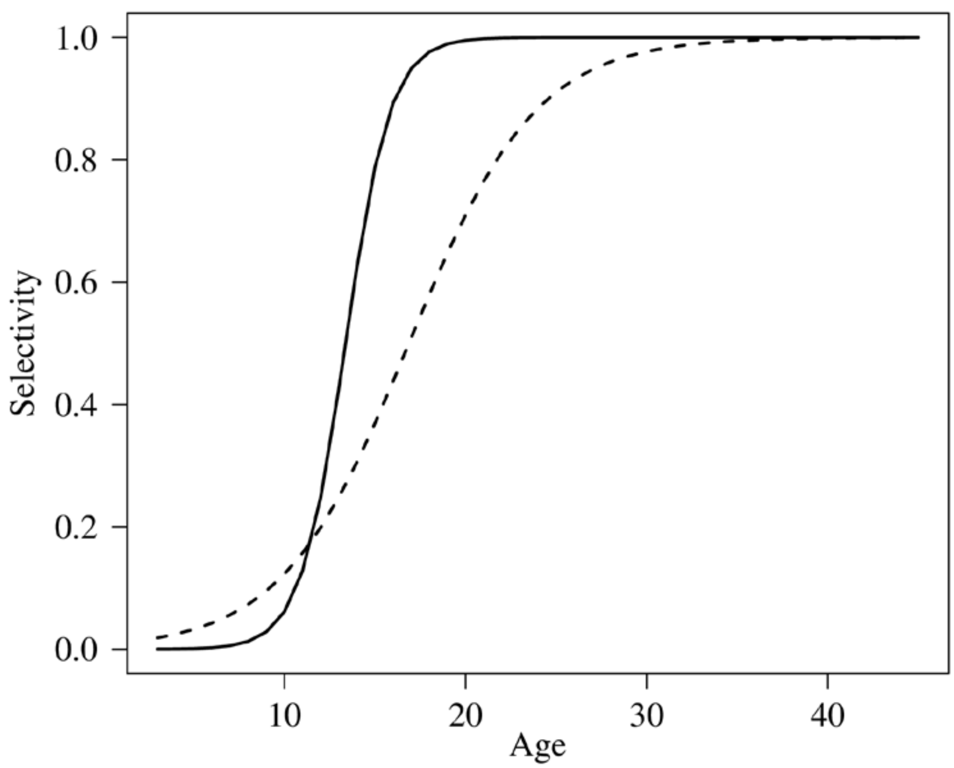


Figure 14.29. Estimated fishery (solid line) and AI survey (black dashed line) selectivity curves by age for blackspotted/rougheye rockfish.

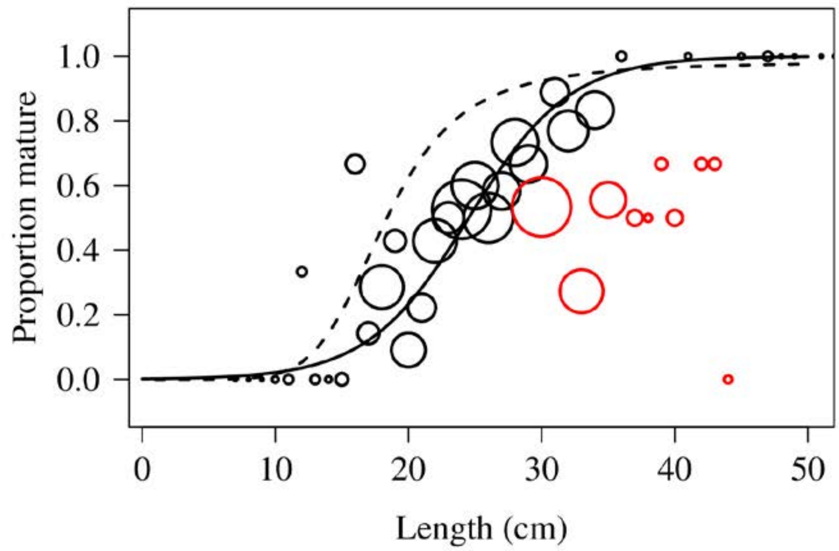


Figure 14.30. Observed and estimated proportion mature at age from data collected in the GAO from Dr. Christina Conrath (black circles and solid line, respectively). Symbol size is scaled by the number of observations. Red data point represent outliers which had unusually low proportion mature for old fish, and were not used for model estimation. For reference, the maturity ogive used in the 2018 assessment is shown as the dashed line.

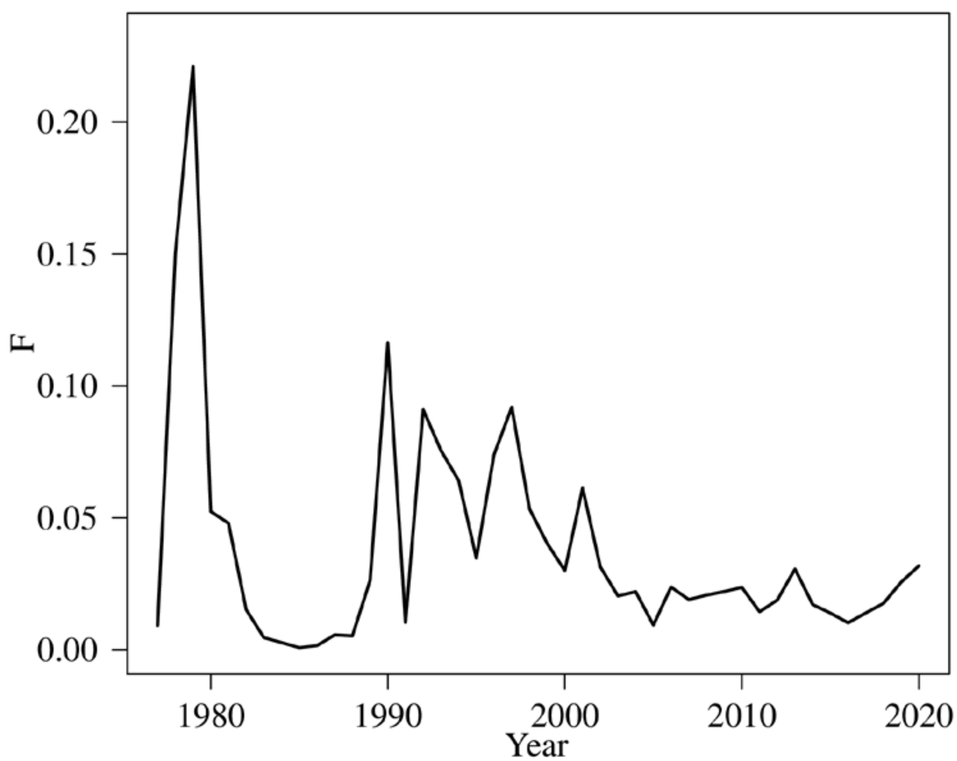


Figure 14.31. Estimated fully selected fishing mortality for blackspotted/rougheye rockfish.

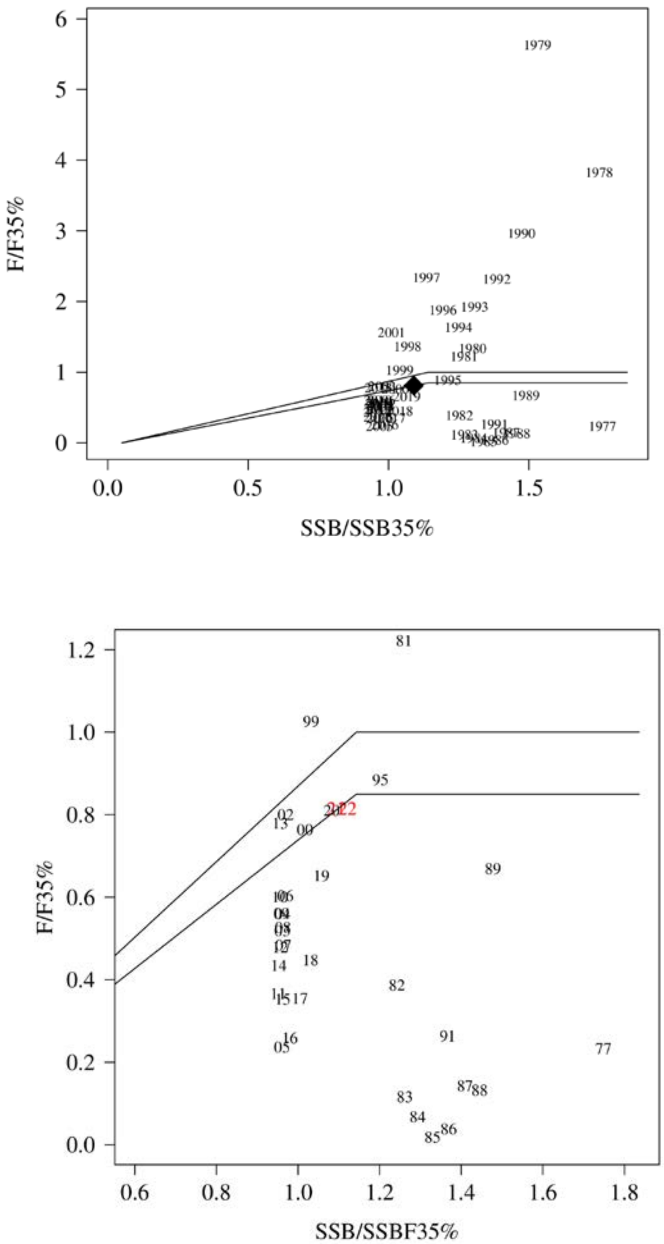


Figure 14.32. (Top panel) Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvest control rules, with 2020 shown as the diamond symbol. The bottom panel shows the projected stock status and *F* for 2021 and 2022.

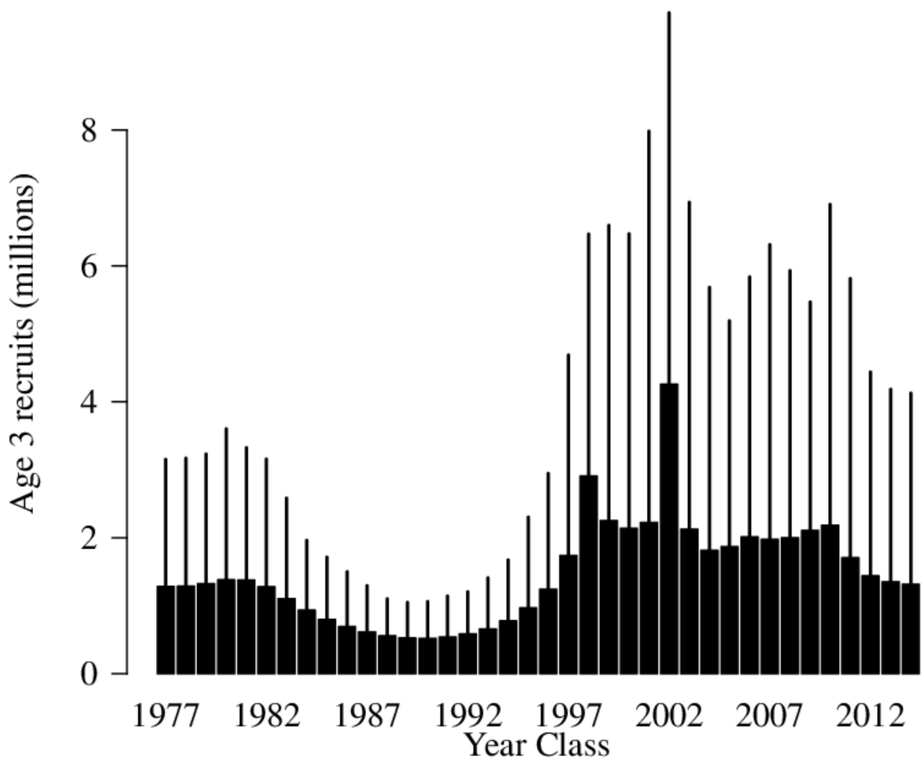


Figure 14.33. Estimated recruitment (age 3) of blackspotted/rougheye rockfish, with 95% CI limits obtained from MCMC integration.

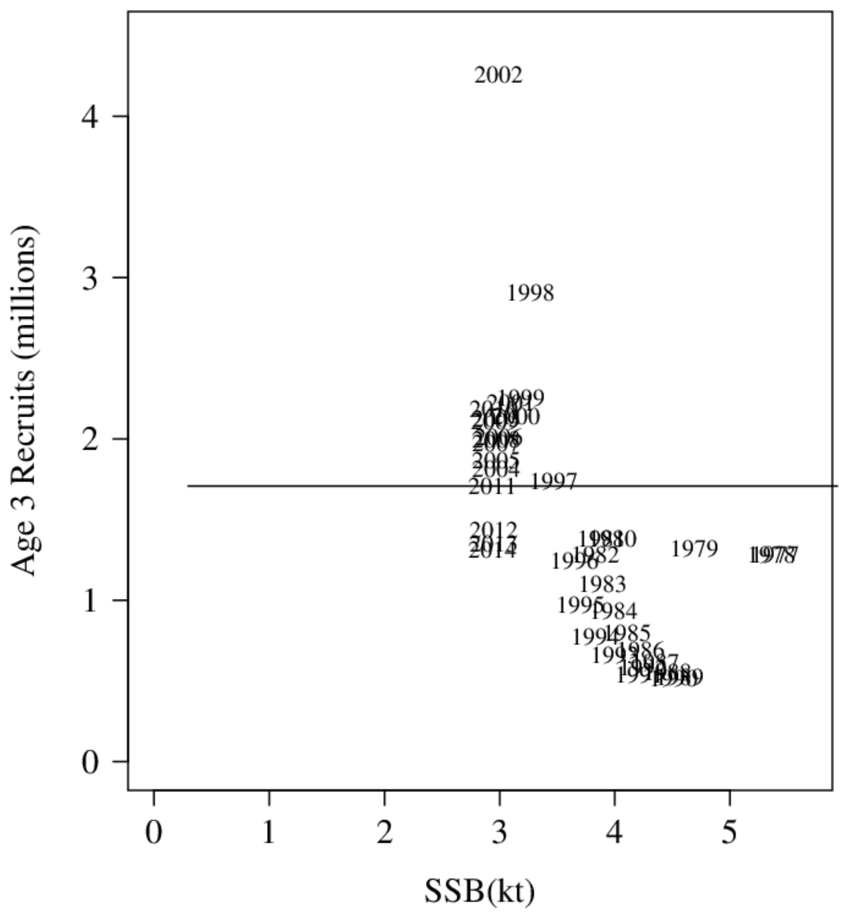


Figure 14.34. Scatterplot of blackspotted/rougheye rockfish spawner-recruit data; label is year class. Horizontal line is median recruitment.

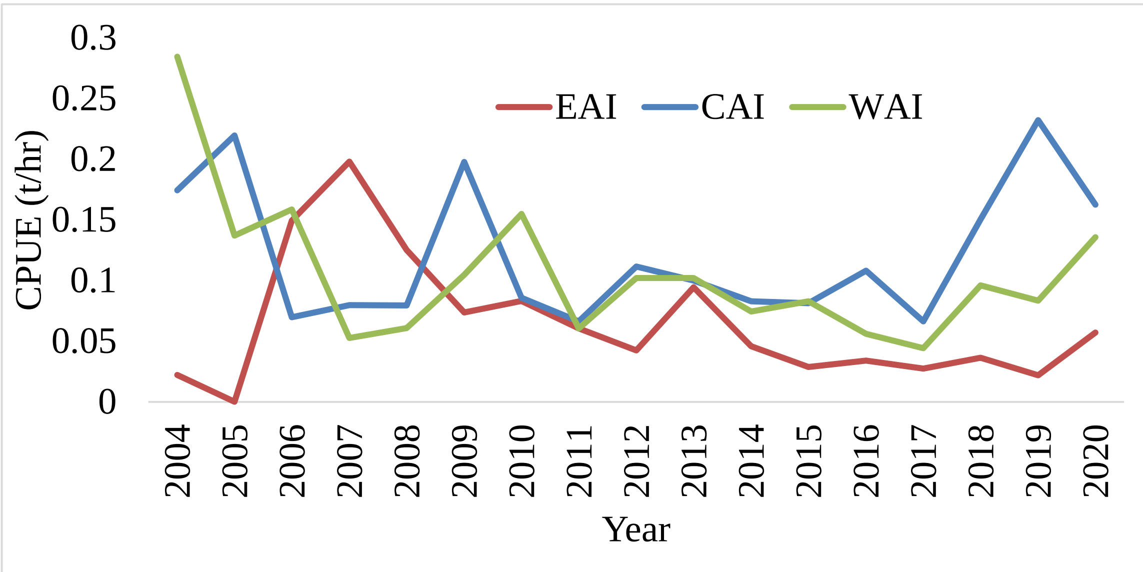


Figure 14.35. Bycatch of blackspotted/rougheye rockfish (t/hr) in tows targeting POP by AI subarea, from tows sampled for species composition in the North Pacific Groundfish Observer Program.

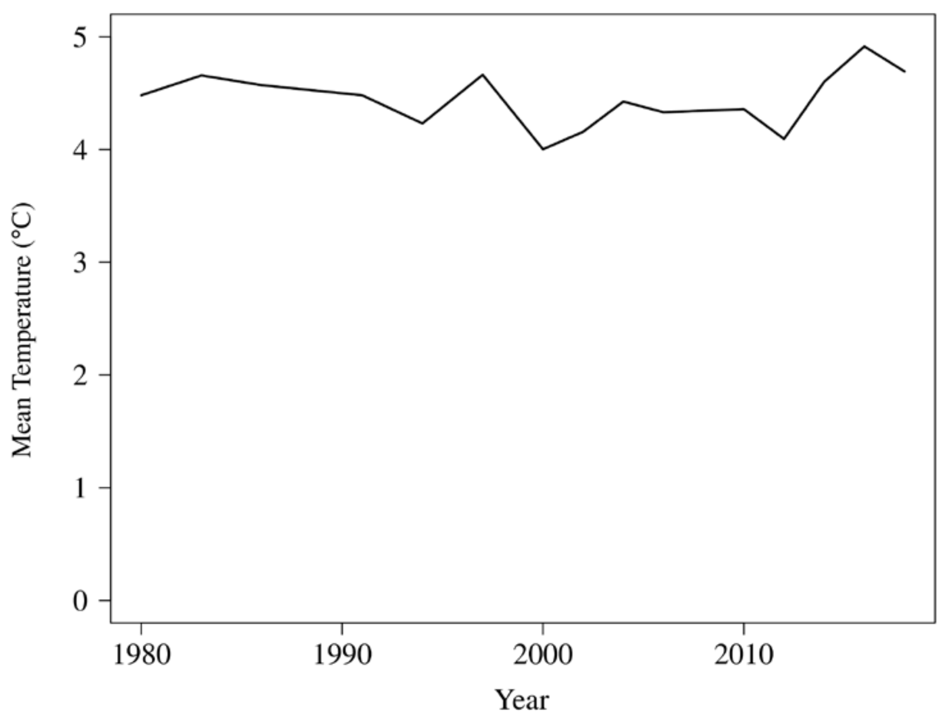


Figure 14.36. Mean temperature at trawl gear from AI bottom trawl surveys, 1980 – 2018.

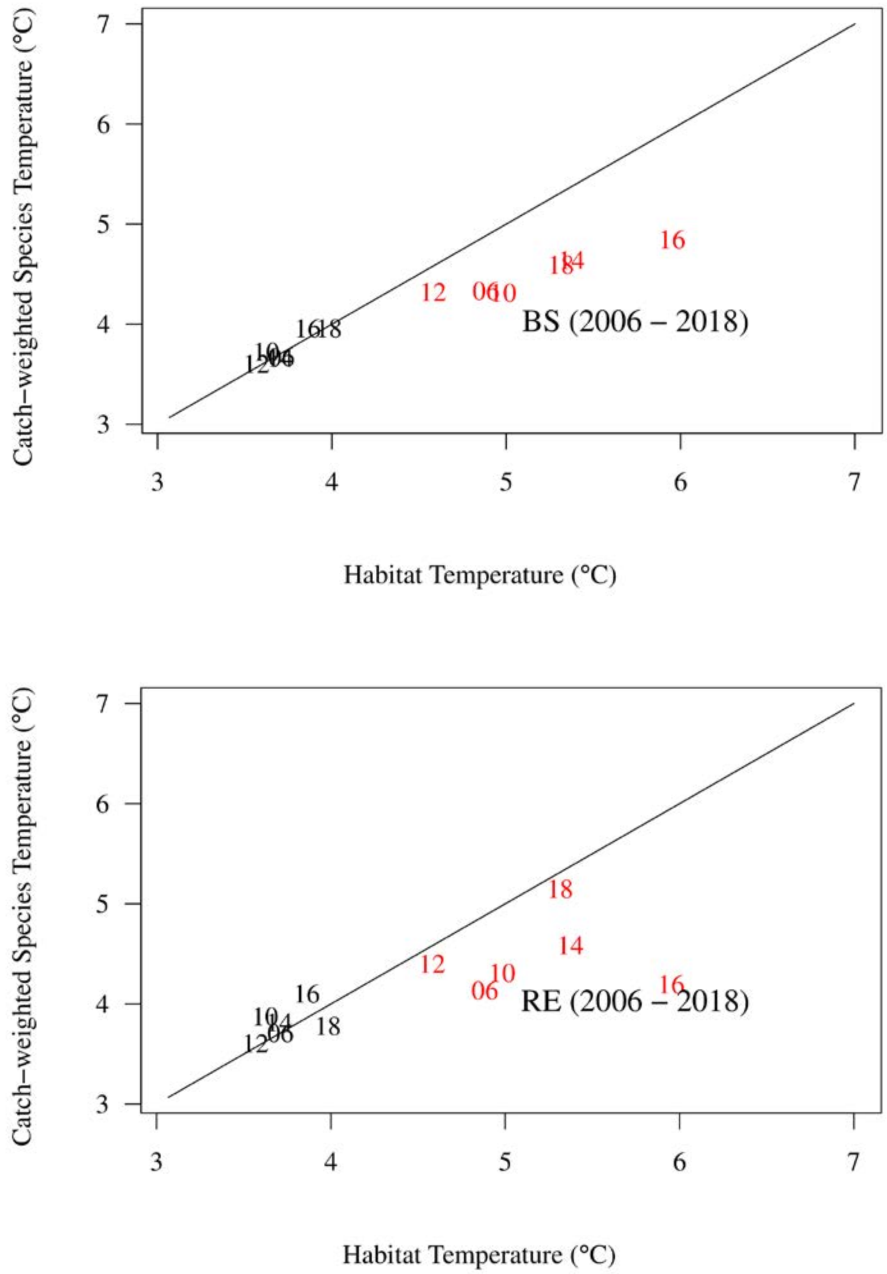


Figure 14.37. Temperatures at 10th (black) and 90th (red) percentiles of distributions of catch-weighted temperature, and overall habitat temperature, from the AI trawl survey (labeled by survey year) for blackspotted rockfish (top panel) and rougheye rockfish (bottom panel).

Appendix 14A. 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 2020, the biomass for the subareas was obtained by partitioning the estimated total AI biomass (ages 3+) at the beginning of the year (obtained from 2020 AI blackspotted/rougheye age structured model). The biomass estimates from the 2020 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 October 10, 2020, 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.

Exploitation rates in the WAI from 2014 to 2020 (to date) have declined from generally higher levels from 2004-2013 (Figure 14A.1). However, the WAI exploitation rate in 2020 increased to 0.13, approximately 4.8 times $U_{F40\%}$ reference value of 0.026, and is the largest observed. The exploitation rates for the CAI have been increasing since 2014, and in 2019 and 2020 have also exceeded $U_{F40\%}$. Exploitation rates in the EBS have occasionally exceeded $U_{F40\%}$, and were also above $U_{F40\%}$ in 2019 and 2020. 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 $F_{40\%}$.

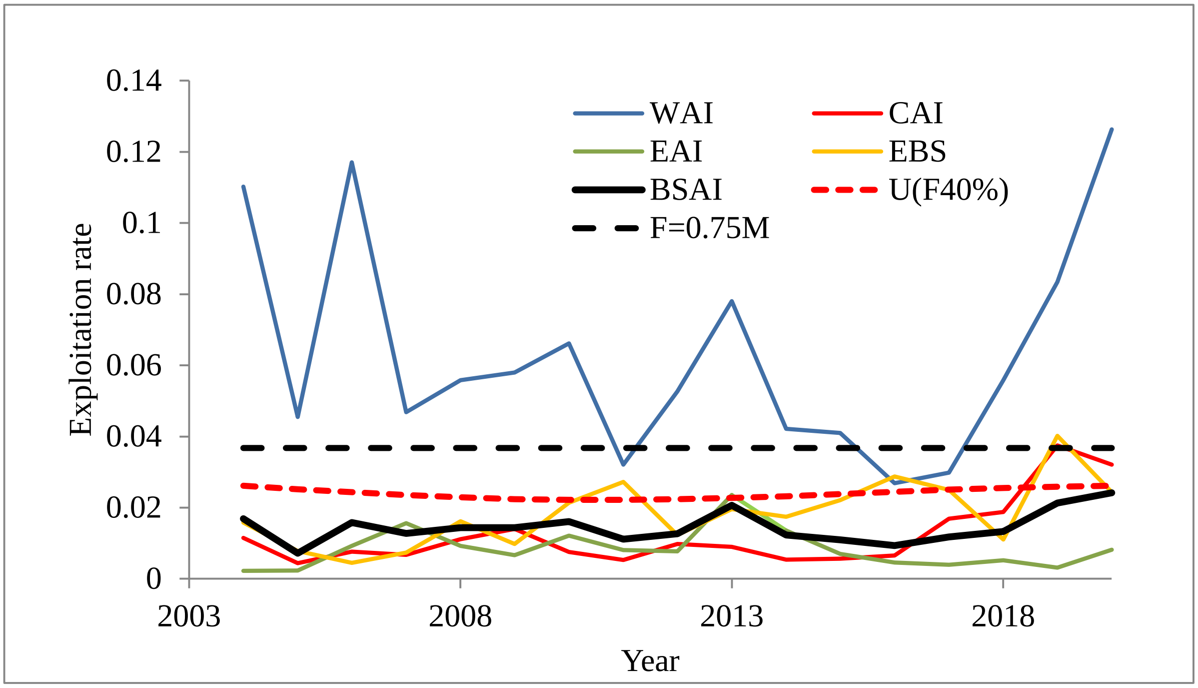


Figure 14A.1. Exploitation rates within BSAI subareas for blackspotted/rougheye rockfish, with reference exploitation rates of 0.75*M and $U_{F40\%}$.

Appendix 14B. 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 14B.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 2019 ranged between 0.216 t and 1.08 t, which were less than 1.0% of the ABC in these years.

Appendix Table 14B.1. Removals of BSAI blackspotted/rougheye rockfish 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
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	0.3
2013			0.299
2014		0.032	0.508
2015			0.216
2016		0.048	0.334
2017			1.08
2018		0.018	0.623
2019		0.000	1.009