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

by

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Executive Summary

Fish previously referred to as rougheye rockfish are now recognized as consisting of two species, rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*Sebastes melanostictus*) (Orr and Hawkins 2008. The current information on these two species is not sufficient to support species-specific assessments, so they are combined as a complex in one assessment. The 2016 assessment applied an age-structured model applied to the BSAI area, using data from both the EBS slope survey and AI survey. In the 2018 assessment, we recommend applying an age-structured model which has been applied to the Aleutian Islands (AI) portion of the population, with the eastern Bering Sea (EBS) portion of the population assessed with Tier 5 methods applied to survey biomass estimates. This methodology had been used from 2008 – 2015. This recommendation is based on the spatial distributions of the two components species (i.e., the AI subarea contains relatively little rougheye rockfish, whereas the EBS area contains a mix of both species), differences in survey biomass trends (biomass in the EBS appears to be increasing, whereas biomass in the AI appears to be decreasing), and uncertainties regarding the relative abundance from the two areas from the survey data. Additionally, the age and length composition data was downweighted by using Francis weights, which produced estimates of stock size more consistent with the biomass estimates from AI survey.

The last full assessment for blackspotted and rougheye rockfish was presented to the Plan Team in 2016. The following changes were made relative to the November 2016 SAFE:

Summary of Changes in Assessment Inputs

Changes in the input data

1) Catch data was updated through 2017, and total catch for 2018 was projected.
2) The AI survey age/length composition data, and survey biomass estimates, were recomputed to only the AI management area (excluding the southern Bering Sea area).
3) The fishery age/length compositional data was recomputed to exclude the data in the EBS management area.
4) The 2018 AI survey biomass estimate and length composition were included in the assessment.
5) The 2016 AI survey age composition was included in the assessment.
6) The 2015 and 2017 AI fishery age compositions were included in the assessment.
7) The 2016 AI fishery length compositions were included in the assessment.
8) 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 from the Francis iterative reweighting procedure (Francis 2011), whereas the 2016 assessment used the McAllister-Ianelli iterative reweighting method.
2) An age-structured model is proposed for the only the AI area as a whole (with the EBS portion of the stock assessed with Tier 5 methods), whereas in the 2016 assessment and age structured model was applied to the BSAI area.

3) In the recommended model, a two-parameter logistic curve was used for fishery selectivity rather than the four-parameter double logistic curve used in the 2016 assessment. Preliminary runs with the recommended model indicated that the descending slope was estimated at 0, essentially fitting a 2-parameter logistic curve. Nearly identical results were obtained with either a logistic or double logistic curve, but use of the 2-parameter logistic curve improved model stability and estimated parameter variances due to removing parameters that had little effect on model results.

Summary of Results

The 2014 and 2016 assessments were characterized by poor fits to the time series of AI survey biomass that estimated an increasing stock since 2000 whereas the survey biomass estimates have been decreasing. The composition data indicated high proportions of younger and smaller fish, which the model attributed to increased recruitment. The inconsistency between the AI survey time series and the estimated biomass was attributed to the population consisting of year classes not fully selected by the survey.

The 2018 AI survey biomass of 9,843 t was very similar to the 2016 survey biomass estimate of 10,069 t, and not indicative of the sharp increase expected for a stock with exceptionally strong year classes that would be more moving into ages with higher survey selectivity. The 2016 survey age composition, the 2018 survey length composition, and the 2015 and 2017 fishery age composition also show a relatively high proportions of younger and smaller fish. Examination of the AI survey abundance estimates by age indicates that the high proportion of young fish is caused partially by increases in recruitment, but also by higher than anticipated decreases in abundance for older (i.e., > 20 years) fish. Catch curves applied to the 1968, 1970, and 1972 cohorts indicated total mortality rates between 0.13 and 0.16, which cannot be explained given the scale of fishery catch and traditional assumptions regarding survey catchability and natural mortality.

Use of the Francis reweighting procedure downweights the composition data, and avoids the interpretation that the recent composition data is attributable to exceptionally strong year classes. While this does not explain the source of the higher than expected mortality for older fish (which will likely require additional data), it does produce biomass estimates on a similar scale to the AI survey data. The 1997 year class remains relatively strong, but its recruitment estimate decreased from 9.5 million to 2.4 million between the 2016 and 2018 assessments. The estimated total 2018 total biomass for 2018 was 15,362 t, relatively similar in scale to the 2018 AI survey estimate of 9,515 t.

The additional composition data indicating lower proportion of older/larger fish resulted in higher estimated fishery and survey selectivity at younger ages. The estimated age at 50% selection for the AI trawl survey was 16.2, a decrease from 20.6 in the 2016 assessment. The fishery selectivity reached 50% at age 13, reduced from the value of 23 in the 2016 assessment.

BSAI blackspotted/rougheye rockfish remain a Tier 3b stock, and its estimated stock status is at $B_{33\%}$.

The survey biomass in the western AI remains low, although the survey biomass estimate for the area increased from 501 t in 2016 to 632 t in 2018. Mean size is also remains low in this area, although in the 2016 and 2018 surveys the mean size was relatively low across all AI survey subareas. In both the 2016 and 2018 surveys the biomass estimate in the eastern AI increased from a very low value in 2014, and the 2016 and 2018 estimates are now relatively consistent with other high estimates in the time series.

A summary of the 2018 recommended ABC's (from the AI model) relative to the 2017 recommendations (from the BSAI model) is shown below.

Quantity	As estimated or *specified* last year for:		As estimated or *recommended* this year for:	
	2018	2019	2019*	2020*
M (natural mortality rate)	0.033	0.033	0.032	0.032
Tier	3b	3a	3b	3b
Projected total (age 3+) biomass (t)	37,453	39,169	15,647	16,002
Female spawning biomass (t)				
Projected	8,208	9,163	4,736	4,962
$B_{100\%}$	20,777	20,777	13,767	13,767
$B_{40\%}$	8,311	8,311	5,507	5,507
$B_{35\%}$	7,272	7,272	4,818	4,818
F_{OFL}	0.054	0.055	0.029	0.030
$maxF_{ABC}$	0.044	0.045	0.024	0.025
F_{ABC}	0.044	0.045	0.024	0.025
OFL (t)	749	829	373	404
maxABC (t)	613	678	314	341
ABC (t)	613	678	314	341
Status	As determined *last* year for:		As determined *this* year for:	
	2016	2017	2017	2018
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 213 t and 220 t used in place of maximum permissible ABC for 2019 and 2020.

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 2018 recommended ABC's for the EBS portion of the population is shown below.

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

The overall BSAI ABC and OFL are shown below.

Quantity/Status	As estimated or *specified* last year for: 2018	2019	As estimated or *recommended* this year for: 2019	2020
OFL (t)	749	829	417	448
ABC (t)	613	678	347	374

The BSAI blackspotted/rougheye stock complex was not subjected to overfishing in 2017. 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 2019 and 2020 and the recent OFLs, ABCs, TACs, and catches.

Area/subarea	Year	Total Biomass (t)[1]	OFL	ABC	TAC	Catch[2]
BSAI	2017	35,669	612	501	225	205
	2018	37,453	749	613	225	215
	2019	17,017	417	346	n/a	n/a
	2020	17,373	448	374	n/a	n/a
Western/Central Aleutian Islands	2017			306	100	134
	2018			374	75	168
	2019			123	n/a	n/a
	2020			133	n/a	n/a
Eastern AI/Eastern Bering Sea	2017			195	125	71
	2018			239	150	47
	2019			224	n/a	n/a
	2020			241	n/a	n/a

[1] For 2017-2018, the total biomass from a BSAI age-structured model. For 2019-2020, the total biomass from AI age-structured model, and survey biomass estimates from EBS.
[2] BSAI catch as of October 6, 2018.

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 2019 and 2020 MSSC values are shown below.

	WAI MSSC	CAI MSSC
2019 MSSCs	22	101
2020 MSSCs	24	109

Responses to SSC and Plan Team Comments on Assessments in General

Comments from the October 2017 SSC meeting

SSC1: "The SSC recommends that, for those sets of environmental and fisheries observations that support the inference of an impending severe decline in stock biomass, the issue of concern be brought to the SSC, with an integrated analysis of the indices in future stock assessment cycles. To be of greatest value, to the extent possible, this information should be presented at the October Council meeting so that there is sufficient time for the Plan Teams and industry to react to the possible reduction in fishing opportunity."

To facilitate a coordinated response to this request, the co-chairs and coordinators of the BSAI and GOA Groundfish Plan Teams, with concurrence from stock assessment program leadership at the AFSC, have suggested that authors address it by using the previous year's Ecosystem Status Report (ESR) as follows:

"No later than the summer of each year, the lead author of each assessment should review the previous year's ESR and determine whether any factor or set of factors described in that ESR implies an impending severe decline in stock/complex biomass, where "severe decline" means a decline of at least 20% (or any alternative value that may be established by the SSC), and where biomass is measured as spawning biomass for Tiers 1-3 and survey biomass as smoothed by the standard Tier 5 random effects model for Tiers 4-5. If an author determines that an impending severe decline is likely and if that decline was not anticipated in the most recent stock assessment, he or she should summarize that evidence in a document that will be reviewed by the respective Team in September of that year and by the SSC in October of that year, including a description of at least one plausible mechanism linking the factor or set of factors to an impending severe decline in biomass, and also including an estimate or range of estimates regarding likely impacts on ABC. In the event that new survey or relevant ESR data become available after the document is produced but prior to the October Council meeting of that year, the document should be amended to include those data prior to its review by the SSC, and the degree to which they corroborate or refute the predicted severe decline should be noted, with the estimate or range of estimates regarding likely impacts on ABC modified in light of the new data as necessary."

This suggestion was followed, and results are addressed in the "Ecosystem considerations" section. Although the recommended model shows a decline of greater than 20% in spawning biomass relative to the 2016 assessment, this difference in results between assessment years stems from differences in weighting the age composition data rather than substantial changes in input data.

SSC2: "The SSC also recommends explicit consideration and documentation of ecosystem and stock assessment status for each stock ... during the December Council meeting to aid in identifying stocks of concern."

This recommendation was subsequently clarified, at some length, in the minutes of the December 2017 SSC meeting and then re-clarified in the minutes of the June 2018 SSC meeting. In the interest of efficiency, the clarification from the December 2017 minutes is not included here. The relevant portion of the clarification from the June 2018 minutes reads as follows:

"This request was recently clarified by the SSC by replacing the terms 'ecosystem status' and 'stock assessment status' with 'Ecosystem Status Report information' and 'Stock Assessment Information,' where the potential determinations for each will consist of 'Okay' and 'Not Okay,' and by issuing the following guidance:

- *The SSC clarifies that 'stock assessment status' is a fundamental requirement of the SAFEs and is not really very useful to this exercise, because virtually all stocks are never overfished nor is overfishing occurring.*

- *Rather the SSC suggests that recent trends in recruitment and stock abundance could indicate warning signs well before a critical official status determination is reached. It may also be useful to consider some sort of ratio of how close a stock is to a limit or target reference point (e.g., B/B35). Thus, additional results for the stock assessments will need to be considered to make the 'Okay' or 'Not Okay' determinations.*

- *The SSC retracts its previous request for development of an ecosystem status for each stock/complex. Instead, while considering ecosystem status report information, it may be useful to attempt to develop thresholds for action concerning broad-scale ecosystem changes that are likely to impact multiple stocks/complexes.*

- *Implementation of these stock and ecosystem determinations will be an iterative process and will require a dialogue between the stock assessment authors, Plan Teams, ecosystem modelers, ESR editors, and the SSC."*

The iterative process described in the final bullet above is scheduled to begin at this year's September meeting of the Joint BSAI and GOA Plan Teams. We will revisit this recommendation when the criteria for these determinations are finalized.

Comments from the December 2017 SSC meeting

SSC3: "The SSC reminds authors of the need to balance the desire to improve model fit with increased risk of model misspecification." This recommendation was subsequently clarified in the minutes of the June 2018 SSC meeting as follows: *"In the absence of strict objective guidelines, the SSC recommends that thorough documentation of model evaluation and the logical basis for changes in model complexity be provided in all cases."*

The differences between the "models" considered in this assessment pertain to the spatial area to which the age-structured model is applied, not differences in complexity of the age-structured model. One minor exception to this was that in Model 18.2, a two-parameter logistic curve was used for fishery selectivity rather than the four-parameter double logistic curve used in previous assessments. Model 18.2 downweights the age and length composition data, and preliminary runs indicated that the descending slope was estimated at 0, essentially fitting a 2-parameter logistic curve. Nearly identical results were obtained with either a logistic or double logistic curve, but use of the 2-parameter logistic curve improved the estimates of parameter variances due to removing parameters that had little effect on model results.

SSC4: "Report a consistent metric (or set of metrics) to describe fish condition among assessments and ecosystem documents where possible." Fish condition is not reported in this assessment, and will be considered for future assessments.

SSC5: "Projections ... clearly illustrate the lack of uncertainty propagation in the 'proj' program used by assessment authors. The SSC encourages authors to investigate alternative methods for projection that incorporate uncertainty in model parameters in addition to recruitment deviations. Further, the SSC noted that projections made on the basis of fishing mortality rates (Fs) only will tend to underestimate the uncertainty (and perhaps introduce bias if the population distribution is skewed). Instead, a two-stage approach that first includes a projection using F to find the catch associated with that F and then a second projection using that fixed catch may produce differing results that may warrant consideration."

Following a consensus recommendation from the co-chairs and coordinators of the BSAI and GOA Groundfish Plan Teams, stock assessment program leadership at the AFSC has agreed to take the following steps:

1. Notify assessment authors that, for the purpose of the standard projection scenarios, the previous requirements for use of the standard Tier 3 projection model and measurement of spawning biomass at the time of peak spawning no longer apply, thereby enabling authors to use Stock Synthesis (SS) or other software to make the projections.

2. Task one or more individuals with modifying the current standard projection code so as to accommodate this request for non-SS Tier 3 assessments, with the understanding that it may not be possible to accomplish this in time for use in the 2018 assessments.

3. Task the authors of Tier 1 assessments with modifying their projection code so as to accommodate this request for Tier 1 assessments, with the understanding that it may not be possible to accomplish this in time for use in the 2018 assessments.

This recommendation will be revisited when the set of individuals tasked with modifying the projection code completes this task. Additionally, for some rockfish stocks there may be a period of several years in which rockfish are partially selected to either a fishery or survey, so incorporating the uncertainties in the recruitment strengths is also of interest for the projection model.

Comments from the October 2018 SSC meeting

SSC6: "Stock assessment authors are encouraged to work with ESR analysts to identify a small subset of indicators prior to analysis, and preferably based on mechanistic hypotheses."

Prior to the next full assessment for BSAI blackspotted/rougheye rockfish, we will work with ESR analysts for assess whether a small set of informative indicators can be identified.

SSC7: "The SSC supports the PT recommendation to make the use of model-based survey estimates at the individual author's discretion for 2018."

The minutes of the September, 2017, Joint Plan Team contained several research recommendations for model-based survey estimates, and plans to create an AFSC workgroup to address these recommendations are developing. Several of these recommendations can be addressed by developing a detailed simulation framework that incorporates the catchability and availability for Alaska surveys. Model-based survey estimates will be considered as these Plan Team research recommendations are addressed.

SSC8: "It would be helpful for the Plan Teams and other authors of Tiers 5 and 6 stocks to explore the increasing number of methods available for data-limited situations."

Alternative data-limited assessment methods will be explored in future assessments, which may pertain the blackspotted/rougheye rockfish in the EBS area.

SSC9: "The SSC also noted that, in order to save resources, authors should not conduct additional assessments beyond the prioritized schedule unless they specifically trigger one or more of the criteria identified."

In future off-years for blackspotted/rougheye rockfish, the criteria identified for triggering a full assessment will be evaluated.

SSC10: "The general approach to accounting for costs and benefits of this [stock] prioritization during the initial four years seems to be a reasonable response to the SSCs request. However, specific benefits (e.g., 'additional' analyses completed) may be difficult to assign unambiguously to reduced assessment frequency. The SSC recognizes these challenges in light of its previous requests."

The frequency of BSAI rockfish age-structured stock assessments has not been reduced, but the scheduling has changed such that no more than 2 full age-structured assessments are conducted within a single year (reduced from 3 full age-structure assessments in a single year). For this year's assessment, this allowed time to more fully evaluated the age and length composition data, which substantially (in our view) improved our understanding of the stock dynamics (despite the mechanisms for these dynamics remaining elusive).

Responses to SSC and Plan Team Comments Specific to this Assessment

JPT1 (November, 2016): The Team recommends that, in the next assessment, the author explore the interplay of catchabilities with availabilities in the incorporation of the slope survey into the model. The

Team also recommends that the author revisit whether a single age-structured Bering Sea/Aleutian Islands model is the most appropriate approach.

SSC11 (December, 2016): Although the use of a single model for the whole area (AI and BS) was recommended this year by the SSC, it may not represent the best approach. The SSC recommends that this choice be reevaluated, with particular investigation into which aspects of adding the EBS data, and how treatment of these data in a combined analysis, are most influencing the model results.

The issue of whether the age-structured model should be applied to the BSAI area, or only the AI subarea, was revisited in this assessment. We recommend an age-structured model for the AI area, based on the spatial distribution of species within the two-species blackspotted/rougheye rockfish stock complex (i.e., rougheye rockfish are not commonly observed in the AI subarea), and the confounding of different survey designs/gear with spatial areas (i.e., the EBS slope survey and AI trawl survey). The dominant issue in either the BSAI or AI-only models was poor fits to the declining AI survey biomass time series, which reflects mortalities on older fish that are higher than previously estimated. Adding data from the EBS area does not improve this issue, but does incorporate data from a separate species (rougheye rockfish) to a model otherwise applied to blackspotted rockfish in the AI subarea.

SSC12 (December, 2016):The SSC noted the very large retrospective pattern observed in this assessment and recommends continued investigation to try to reduce or at least better understand this problem.

Downweighting the age and length composition data improved our understanding of the retrospective pattern, which is still large but can be attributed to an unusually low survey biomass estimate for 2014.

BSAIPT1 (November, 2017): Because of the high uncertainty in recruitment, the Team recommends that the author consider updating the ageing error matrix, as it is currently based on the GOA and may be contributing to the uncertainty about recruitment.

The aging error matrix was not updated in this assessment, and will be considered for future assessment. The downweighting of the age and length composition data resulted in less interannual variability in estimated recruitment, and in the variances of these estimates.

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, where *S. melanostictus* is distributed along the continental slope from Japan to California (Orr and Hawkins 2008).

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 corroborate these findings (Tony 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 due to the limitations of using genetic data to infer spatial structure on temporal scales of interest to fisheries management, and because of the pattern of disproportionately high harvest rates and reduced abundance in the western AI.

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 1994-2018 have been relatively evenly distributed throughout the three AI subareas, with 32%, 28%, and 34% in the WAI, CAI, and EAI, respectively, and the remaining 6% 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 7%) 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 50% 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 36%. 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 increased recently, ranging from 3% to 20% during 1999 - 2003 to 21% to 46% from 2009 – 2017, but declined to 11% in 2018.

Non-commercial catches are shown in Appendix 14B.

An Economic Performance Report (EPR) for BSAI rockfish is included at Appendix 14C, and contains information on the value and per-unit price of BSAI rockfish. Pacific ocean perch and northern rockfish contribute over 90% of the value of BSAI rockfish, with species such as rougheye rockfish, blackspotted rockfish, and shortraker rockfish being caught in much smaller quantities.

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 2018, discard rates of rougheye in the AI and EBS averaged 18% and 34%, respectively.

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 0.43% in 2007, increased to 1.5% in 2010, declined to 0.34% in 2016, and increased to 0.8% in 2018 (using data through Oct 6, 2018). The unusually large bycatch rate for in the Atka mackerel fishery in 2013 was based on one tow. Bycatches rates in the POP fishery in the central Aleutians show a similar scale and trend as those in the western Aleutian Islands, with an increase to 1.25% in 2018 from 0.69% in 2016. Bycatch rates in the Pacific cod fishery in the central Aleutian Islands increased from 0.35% in 2011 to 1.19% in 2013, and has since decreased to 0.16% in 2016 and increased to 1.27% in 2018. In the eastern Aleutian Islands, the bottom trawl pollock fishery had the high bycatch rates from 2013-2015 and were above 1%, but the rates from 2016 – 2018 have been variable, ranging from 0.14% to 0.32%. 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 2018 are also revealed in cumulative distribution plots of bycatch rates in tows from A80 vessels targeting POP from 2011-2018 (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 2018, the percentage of tows without bycatch was reduced to 42%, and the bycatch rates at the 80% percentile increased to 0.9%.

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. Further concern regarding high exploitation rates in the WAI has resulted in the assessment including a "maximum subarea species catch" (MSSC) level for the WAI to help guide the fishing fleet in voluntary efforts reduce harvest in this area. Although the North Pacific Fishery Management Council (NPFMC) has not adopted harvest specifications specifically for the WAI, the MSSC is computed in an identical manner as the subarea ABCs, and the SSC has requested monitoring of WAI relative to the MSSC (Joint Plan Team, September, 2016). The WAI MSSCs and catches are shown below:

Year	WAI MSSC	WAI Catch	Catch/MSSC
2015	46	67	1.46
2016	58	38	0.65
2017	29	34	1.17
2018	35	65	1.86

In 2016 the catch was below the MSSC, whereas catch exceeded MSSC by a relatively small proportion in 2017 and larger proportions in 2015 and 2018.

Data

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 1000 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 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 (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 were 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. 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 the 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 14.9). 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 is a 26% increase from the value of 501 t in the 2016 survey. The 2018 survey biomass estimate in 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%, an increase from the value of 46% in the 2014 survey, and this value has ranged between 26% and 73% in surveys from 2014 to 2012. 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 - 2016 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 biennial EBS slope survey was initiated in 2002. The most recent slope survey prior to 2002 (excluding some experimental tows in 2000 to evaluate survey gear) was in 1991. The 2006, 2014 and 2018 surveys were canceled due to lack of funding and/or contracting issues. 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 14.10 and 14.11, 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 121 years.

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) (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 and 2016 AI surveys show numbers of fish > 20 years.

The age compositions from the EBS slope surveys also show relatively strong recent recruitments, but for different year classes than in the AI survey. For example, the 1998 year class appears relatively weak in the 2012, 2010, and 2008 age compositions, whereas the 2004 year class appears strong in the 2012 age composition (Figure 14.16).

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. Information on aging error was obtained from multiple independent readings on GOA otoliths collected in 1990, 1999, and 2003 (Shotwell et al. 2007). These data were used to estimate the error in age reading based on the percent agreement between the readers. A fitted relationship describing the standard deviation in age was used to produce the aging error matrix.

The AI survey otolith data are 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 2016 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
51.07	0.06	-3.27

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 (obtained for each survey from 1991-2016 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 0.21 at age 3 to 0.11 at age 45.

A length-weight relationship of the form $W = aL^b$ was fit from the survey data, and produced estimates of $a = 6.51 \times 10^{-6}$ 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 14.12).

The following table summarizes the data available for the blackspotted/rougheye rockfish assessment models (assuming application to only the AI subarea):

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

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 2018). 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-dependant deviations from average recruitment allows estimation of year class strength.

The total numbers of age 3 fish from 1977 to 2015 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 2016-2018 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

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

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

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

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, prior distributions were used for the survey catchability and the natural mortality rate M. A lognormal distribution was also used for the natural mortality rate M, with the mean set to 0.03 and with the coefficient of variation (CV) set to 0.05. The prior distribution for q_{AI} followed a lognormal distribution 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 double logistic curve

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

for models 16.5 and 18.1, or a logistic curve (model 18.2) in which the second term in the product is removed and the ϕ_d and $d_{50\%}$ parameters are eliminated.

In the 2016 assessment, an age-structured was developed for the BSAI area, and incorporated the AI and EBS trawl surveys, whereas the data and analytical approach described above pertain to model applied to the AI subarea. The "models" evaluated in this assessment pertain to the expansion of the model area to the BSAI and inclusion of the EBS slope survey data, and alternative methodologies for weighting the composition data (rather than structural changes in the modelling equations). In these reweighting methods, the multinomial sample size $N_{j,y}$ for data type j and year y is computed as

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

where $\widetilde{N}_{j,y}$ 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.

The model considered are:

Model 16.5) The 2016 BSAI model with data updated through 2018, and updated weights for the age composition data. The weighting of the age and length composition data was computed as the harmonic mean of the ratio of effective sample size to first stage sample size (method TA1.1 in Francis (2011), which was developed by McAllister and Ianelli (1997) and often referred to as the "McAllister-Ianelli method".

Model 18.1) An AI model, with McAllister-Ianelli weights of the composition data. (Note: given that the species percentage of blackspotted in the AI surveys from 2006-2012 has ranged from 95%-99%, this model is essentially an assessment of AI blackspotted rockfish).

Model 18.2) An AI model where the composition weighting is computed as the variance of a standardized residual 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". Preliminary runs indicated that the descending slope of the double logistic fishery selectivity curve was estimated at 0, essentially fitting a 2-parameter logistic curve. Nearly identical results were obtained with either a logistic or double logistic curve, but use of the 2-parameter logistic curve improved the estimates of parameter variances due to removing parameters that had little effect on model results.

Because the differences between the "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, individual weight at age, and the proportion mature females at age. The derivation of the age error matrix, the age-length conversion matrix, and the weight at age vector are described above. The proportion of females mature at age (Table 14.12) was obtained from data on Gulf of Alaska rougheye rockfish in McDermott (1994).

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

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

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:

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

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

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

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, $p_{surv,t,a}$ and $p_{surv,t,l}$, respectively, follow similar equations.

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

$$\lambda_2 \sum_t (\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2cv_t^2$$

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:

$$\lambda_3 \sum_t (\ln(obs\_cat_t) - \ln(pred\_cat_t))^2$$

where obs_cat_t and $pred\_cat_t$ are the observed and predicted catch. The "observed" catch for 2018 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 catch component) is

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

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

$$\lambda_2\sum_t\left(\ln(obs\_biom_t)-\ln(pred\_biom_t)\right)^2/2cv_t^2+$$

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

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

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

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

$$\lambda_3\sum_t\left(\ln(obs\_cat_t)-\ln(pred\_cat_t)\right)^2$$

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	42
3) recruitment mean	1
4) recruitment deviations	39
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
Total number of parameters	132

Results

Model Evaluation

Evaluation of the models for BSAI blackspotted and rougheye rockfish is focused on two questions: 1) Is the rougheye complex un the EBS sufficiently similar in their dynamics and species composition to the rougheye in the AI to warrant a single BSAI model?; and 2) Is the age-structured model fit to various data components (particularly the AI survey biomass time series) adequate, or should a Tier 5 methodology be adopted? Note that the differences between the "models" considered here pertain to differences in the amount and weighting of input data, and standard model selection criteria such as AIC do not apply.

Rougheye rockfish are not commonly found in the Aleutian Islands management area, and an age-structured model for this area would thus be applied to blackspotted rockfish and cleanly avoid problems of applying an age-structured model to a two-species stock complex. Combining two species into a single assessment model could degrade model fits to the combined dataset, particularly if recruitment strengths and/or biological parameters differ between the species. The time series of blackspotted and rougheye rockfish from the eastern Bering Sea survey shows an increasing trend (although with large uncertainty in the most recent estimate), whereas the time series of biomass estimated from the AI survey shows a decreasing trend.

Plausible estimates of survey catchability were not obtained with either a BSAI or AI model, and prior distributions have been used to constrain estimates of this parameter. Because neither the AI survey or the EBS slope survey covers the entire habitat in the BSAI where blackspotted and rougheye rockfish are found, the prior distributions for survey catchability will need to reflect that not all of the BSAI population is available to be surveyed. Adjustments to the prior distributions of survey catchability can result in meaningful changes in stock abundance. However, the available information on the distribution of biomass across the AI and EBS areas is not unequivocal and results in uncertainty in using the nominal survey biomass estimates to compute availability. For example, differences between the nominal survey biomass estimates between the AI and EBS areas could result from differences in actual biomass, or differences between catchability and selectivity between the surveys. Restricting the model to only the AI avoids this issue, as the area covered by the survey is consistent with the area covered by the assessment.

The models using the McAllister-Ianelli data weighting (models 16.5 and 18.1) did not fit the AI survey biomass time series well (Figure 14.17), with survey biomass being underestimated during most of the time series and estimated survey biomass increasing since 2000 whereas the observed survey biomass estimates since 2000 have shown a declining trend. This declining trend can be understood by examining the AI survey biomass numbers at age in their original units (i.e., not scaled to the proportions within a year). The estimated numbers at age from the AI survey indicates that fish >= 21 years have been declining in abundance since about 2005, with particularly sharp declines coming in the 2014 and 2016 surveys (Figure 14.18). Younger fish have increased somewhat in abundance, particularly ages 11 – 20 in recent years. Catch curves applied to cohorts where fish are fully selected to the fishery (i.e., ages ≥ 20) and extending past 2000 indicate total mortality rates between 0.13 and 0.16 (Figure 14.19), greatly exceeding estimates of total mortality based on the longevity of the stock and assuming survey catchability of approximately 1.0. The current assessment model (models a6.5 and 18.1) cannot account for declines in older fish given traditional assumptions of natural mortality and survey catchability, but can account for the proportional age composition data with increases in recent recruitment (Figure 14.20). This results in estimates of a population composed of very large recent year classes that is rapidly increasing, with the current estimated total biomass at an all-time maximum (Figure 14.21), with many fish not being selected by the survey. This is in contrast to the declining trend observed in the AI survey biomass estimates. Examination of the survey numbers at age in their original units reveals that there is not a conflict between the time series of biomass estimates and the composition data, as it is the decline of older fish that is causing the decline in the biomass estimates. Rather, the conflict arises from the models inability to account for the apparent "additional" mortality beyond the mortality obtained from standard assumptions regarding natural mortality and survey catchability.

Using the Francis weighting (model 18.2) downweights the composition data (Figure 14.22), resulting in higher RMSE values (i.e., degraded fits) of each of the composition data types and lower RMSE values (i.e., improved fits) to the AI survey biomass time series (Table 14.13). This downweighting of the composition data removes the need to sharply increase recruitment (Figure 14.20) (although some increase in recruitment is observed in recent years) which results in a lower rate of recent increase in total biomass that is more consistent with scale of the survey biomass estimates.

Model 18.2 still underestimates the survey biomass for several years, and it is useful to consider a Tier 5 approach in which the composition data are removed completely. The current biomass estimate from a Tier 5 model for the AI management area is 7,633 t, whereas the current biomass estimate from Model 18.2 is 15,273 t (Table 14.14), with the lower biomass from the Tier 5 method resulting from a better fit to the declining survey biomass time series. This results in a corresponding difference in the 2019 ABC for the AI area, which was 314 for model 18.2 and 183 for a Tier 5 model. Although Model 18.2 downweights the composition data, it can be considered as using the best available information for the assessment relative to a Tier 5 model.

Finally, if an age-structured model is adopted for AI area, there remains a question of what model to apply to the EBS subarea. Both catches and survey biomass estimates for region are of a lower scale than in the AI subarea, and the existence of both the southern Bering Sea portion of the AI survey and the EBS slope survey still poses a challenge on how to interpret these two survey time series with respect to estimates of availability. The number of fishery otoliths sampled and read from the EBS is not adequate to support estimation of fishery selectivity (although recent changes in observer sampling procedures should increase sample sizes in future years). For these reasons, it is recommended that the EBS area be assessed with the Tier 5 method.

In summary, we conclude that combining the EBS and AI data into a single BSAI model does not improve our understanding of the stock dynamics; additionally, given the lack of rougheye rockfish in the AI management area, an AI model largely avoids the complications resulting from applying age-structured model to a mixed stock complex. While none of the models considered here adequately explains the decline in older fish, Model 18.2 downweights the composition data and produces biomass estimates more consistent with the survey data. Finally, Model 18.2 is recommended over a Tier 5 approach for the AI subarea because it makes use of the best available information; examination of age and length composition data in future years may reveal additional knowledge of stock dynamics that would not be revealed from a Tier 5 approach. The results reported in this assessment were obtained from model 18.2 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 14.15.

A retrospective analysis was conducted to evaluate the effect of recent data on estimated spawning stock biomass. For the current assessment model, a series of model runs were conducted in which the end year of the model was varied from 2018 to 2008, and this was accomplished by sequentially dropping age and length composition data, the survey biomass estimates, and the catch from the input data files.

The plot of retrospective estimates of spawning biomass is shown in Figure 14.23. The retrospective runs from 2017 to 2014 are very similar to the model results with data through 2018, as all of these runs include the low AI survey biomass estimate in 2014. Similarly, the retrospective runs from 2013 to 2008 are relatively similar to each other, as these runs do not include the low biomass estimate in 2014. Mohn’s rho for the period of 2018 – 2014 is 0.09, and -0.01 from 2013 – 2008 (using the retrospective run from 2013 as a basis of comparison). However, combining the retrospective runs from 2008- 2008 produces a Mohn’s rho of 0.42.

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 7,750 t in 2003 has increased to 10,833 t in 2018 (Figure 14.24). The total and spawning biomass also show a decline in the late 1970s, increases throughout the 1980s, and a decline during most of the 1990s. Since 2004, the spawning biomass has increased from 3,492 t to 4,558 t in 2018, and the total biomass has increased from 9,942 t to 15,362 t over this period (Figure 14.25). The more rapid recent increase of total biomass relative to spawning stock biomass reveals that much of this increase can be attributed to relatively recent year classes that have not fully matured. The time series of estimated total biomass, spawner biomass, and recruitment, and their estimated CVs (from the Hessian approximation) are shown in Table 14.16, and the estimated numbers age are shown in Table 14.17.

Age/size compositions

The model fits to the fishery age and size compositions are shown in Figures 14.26-14.27 and the model fits to the AI survey composition data are shown in Figures 14.28-14.29. The 2009 fishery age composition shows strong year class strengths for the 1998 and 1999 year classes, whereas in the 2015 and 2017 fishery age composition data the 2000 – 2003 year classes also appear relatively strong.

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 and 2016 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 and 2014 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 and 2016 survey age composition also show relatively high proportions for ages < 17, although this is influenced by the absence of older fish noted above. The 2018 survey length composition shows relatively high proportions of fish form 30 – 40 cm, which correspond to ages 12- 22. 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 0.032, respectively, a slight increase from the prior distribution means of 1.0 and 0.03, respectively.

The estimated age at 50% selection for the AI trawl survey was 16.2, a decrease from 20.6 in the 2016 assessment (Figure 14.30). The fishery selectivity reached 50% at age 13, reduced from the value of 23 in the 2016 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 and 2016 AI surveys and the 2015 and 2017 fishery age compositions.

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 in late 1990s.

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 BSAI blackspotted/rougheye rockfish, this procedure results in a critical age of 11, and would use recruitments from year classes 1977 – 2007. The B40% resulting from the mean recruitment from these year classes is 5,507 t, and the ratio of spawning stock biomass in 2018 to B40% is 0.82 (Table 14.14). 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 1998-1999 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 1977-2007 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 5,507 t. The year 2019 spawning stock biomass is estimated as 4,736 t.

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

Since reliable estimates of the 2019 spawning biomass (*B*), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B<B_{0.40}$ (4,736 t < 5,507 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 2019 values of F_{abc} and F_{OFL} are 0.024 and 0.029, respectively. The 2019 ABC and OFL for the AI blackspotted/rougheye resulting from these rates are 314 t and 372 t, respectively. A summary of these values is below.

2019 SSB estimate (B)	=	4,736 t
$B_{0.40}$	=	5,507 t
$F_{0.40}$	=	0.028
F_{ABC}	=	0.024
$F_{0.35}$	=	0.034
F_{OFL}	=	0.029

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 (0.032) were used, resulting in F_{abc} and F_{ofl} levels of 0.024 and 0.032, 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 44 t and 33 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 347 t and 417 t, respectively.

ABC recommendation

We recommend the maximum permissible ABC of 347 t.

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 2018 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2019 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2018. 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 2019, 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 2019 recommended in the assessment to the *max* F_{ABC} for 2019. (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 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2013-2017 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as 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 2018 or; 2) above ½ of its MSY level in 2018 and above its MSY level in 2028 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2019 and 2020, 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 2030 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 14.18.

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 2019, it does not provide the best estimate of OFL for 2020, because the mean 2020 catch under Scenario 6 is predicated on the 2019 catch being equal to the 2018

OFL, whereas the actual 2019 catch will likely be less than the 2019 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL. Catches for 2019 and 2020 were obtained by setting the *F* rate for these years to the estimated *F* rate for 2018.

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 (2017) is 205 t. This is less than the 2017 BSAI OFL of 612 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 2018 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2018 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2018 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 2028 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 2020 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2020 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2020 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2030. If the mean spawning biomass for 2030 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 2028 of Scenario 6 is 1.17 times its $B_{35\%}$ value of 4,818 t. With regard to whether the stock is likely to be overfished in the future, the expected stock size in 2030 of Scenario 7 is 1.18 times the $B_{35\%}$ value.

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
	MSSC	MSSC	ABC	ABC	ABC
2019 ABCs-MSSCs	22	101	123	224	347
2020 ABCs-MSSCs	24	109	133	241	374

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.

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 the Bering Sea shelf experienced much warmer winter and spring temperatures (Bond, 2016). Warmer temperatures have also been observed in the bottom temperatures from the AI trawl survey (Figure 14.35).

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 90^{th} percentiles fall below the 1:1 line (Figure 14.36).

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.

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Tables

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

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

Table 14.2. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the species groups used to manage blackspotted and rougheye rockfish in the Aleutian Islands and eastern Bering Sea from 2004 to 2018. Catch data is through October 6, 2018, 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 (t)	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	230										
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	321	Rougheye		209	209	145	Rougheye		169	169	176
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	159	Rougheye		382	200	87	Rougheye		179	100	72
2017	Rougheye	612	501	225	205	Rougheye		195	125	134	Rougheye		306	100	71
2018	Rougheye	749	613	225	215	Rougheye		239	150	168	Rougheye		374	75	47

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			11			157	168
2008			22			171	193
2009			13			184	197
2010			30			200	230
2011			36			127	163
2012			17			174	191
2013			26			195	321
2014			24			174	198
2015			31			149	180
2016			41			118	159
2017			36			169	205
2018*			10			205	215

*Catch data through October 10, 2016, 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	11	168
2008	58	67	47	22	193
2009	67	81	37	13	197
2010	85	42	74	30	230
2011	46	28	54	36	163
2012	65	58	50	17	191
2013	84	61	150	27	321
2014	57	42	75	24	198
2015	67	50	33	31	180
2016	38	49	31	41	159
2017	34	100	35	36	205
2018*	65	103	37	10	215

* Estimated removals through October 6, 2018.

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	8	3	11	28%
2008	Rougheye	137	35	171	20%	Rougheye	12	10	22	46%
2009	Rougheye	154	30	184	16%	Rougheye	10	3	13	23%
2010	Rougheye	174	27	201	13%	Rougheye	18	12	30	40%
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	19	7	26	27%
2014	Rougheye	158	16	174	9%	Rougheye	17	7	24	30%
2015	Rougheye	134	16	150	11%	Rougheye	22	9	31	29%
2016	Rougheye	105	12	117	10%	Rougheye	33	8	41	19%
2017	Rougheye	105	64	169	38%	Rougheye	22	13	35	38%
2018*	Rougheye	177	28	205	14%	Rougheye	5	5	10	50%

* Estimated removals through October 6, 2018.

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.

Western Aleutian Islands

	Fishery		
Year	Atka mack	POP	Pacific cod
2004	0.11%	2.53%	0.01%
2005	0.02%	1.15%	0.00%
2006	0.03%	1.63%	0.00%
2007	0.06%	0.42%	0.00%
2008	0.03%	0.59%	0.10%
2009	0.07%	1.24%	0.47%
2010	0.05%	1.48%	0.26%
2011	0.24%	0.65%	
2012	0.53%	1.04%	0.67%
2013	10.14%	1.07%	0.35%
2014		0.76%	0.00%
2015	0.10%	0.83%	0.96%
2016	0.09%	0.34%	0.27%
2017	0.12%	0.40%	0.16%
2018	0.14%	0.80%	0.03%

Central Aleutian Islands

	Fishery			
Year	Pacific coc	POP	Atka mack	Other species
2004	0.01%	1.49%	0.01%	0.01%
2005	0.05%	1.39%	0.02%	0.00%
2006	0.00%	0.82%	0.01%	0.00%
2007	0.02%	0.71%	0.01%	0.00%
2008	1.24%	0.86%	0.01%	0.86%
2009	0.26%	1.78%	0.04%	0.40%
2010	0.48%	0.73%	0.02%	0.14%
2011	0.35%	0.54%	0.02%	0.42%
2012	0.82%	0.80%	0.03%	0.26%
2013	1.19%	0.76%	0.01%	0.84%
2014	0.80%	0.59%	0.00%	0.07%
2015	0.54%	0.68%	0.01%	0.67%
2016	0.16%	0.70%	0.02%	0.15%
2017	3.21%	0.69%	0.03%	3.81%
2018	1.27%	1.25%	0.02%	0.05%

Eastern Aleutian Islands

	Fishery				
Year	POP	AR/KM	Bottom po	Atka mack	Other species
2004	0.14%	0.15%	0.03%	0.00%	0.00%
2005	0.00%	0.07%	0.00%	0.00%	0.00%
2006	0.94%	0.22%	0.00%	0.01%	0.00%
2007	1.21%	0.00%	0.00%	0.00%	0.00%
2008	0.76%	0.46%	0.01%	0.00%	0.53%
2009	0.44%	0.20%	0.00%	0.00%	0.19%
2010	1.00%	0.53%	0.94%	0.00%	0.20%
2011	0.25%	0.82%	0.83%	0.01%	0.14%
2012	0.37%	0.72%	4.67%	0.01%	0.21%
2013	0.63%	1.24%	1.25%	0.05%	0.44%
2014	0.40%	0.93%	1.04%	0.01%	0.55%
2015	0.31%	0.60%	1.35%	0.01%	0.33%
2016	0.23%	0.66%	0.32%	0.01%	0.17%
2017	0.34%	1.46%	1.87%	0.01%	1.12%
2018	0.50%	0.57%	0.14%	0.05%	1.70%

Eastern Bering Sea

	Fishery					
Year	POP	Other spec	Bottom po	Pacific coc	pelagic pol	AR/KM
2004	0.69%	0.00%	0.04%	0.00%	0.00%	0.20%
2005	0.22%	0.00%	0.03%	0.00%	0.00%	0.15%
2006	0.17%	0.00%	0.02%	0.00%	0.00%	0.16%
2007	0.00%	0.00%	0.01%	0.00%	0.00%	0.08%
2008	0.08%	0.13%	0.03%	0.09%	0.00%	0.20%
2009	0.20%	0.03%	0.04%	0.01%	0.00%	0.23%
2010	0.36%	0.05%	0.15%	0.06%	0.00%	0.49%
2011	0.19%	0.06%	0.08%	0.07%	0.00%	0.29%
2012	0.25%	0.02%	0.01%	0.01%	0.01%	0.05%
2013	0.07%	0.80%	0.15%	0.06%	0.00%	0.60%
2014	0.09%	0.07%	0.07%	0.03%	0.00%	0.19%
2015	0.01%	0.07%	0.08%	0.05%	0.00%	0.37%
2016	0.03%	0.09%	0.05%	0.02%	0.00%	0.36%
2017	0.04%	0.12%	0.04%	0.04%	0.00%	0.21%
2018	0.58%	0.23%	0.04%	0.04%	0.00%	0.04%

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 1977-2018.

	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	17	9	455	120	472	129

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 1977-2018.

	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	3	165	168						

Table 14.9. 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 14.10. 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 14.11. 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					

Table 14.12. Predicted weight and proportion mature at age for BSAI rougheye rockfish.

Age	Predicted weight (g)	Proportion mature
3	55	0
4	81	0
5	112	0
6	148	0.001
7	188	0.001
8	233	0.003
9	281	0.008
10	333	0.015
11	387	0.03
12	443	0.053
13	500	0.09
14	559	0.141
15	618	0.209
16	678	0.29
17	738	0.378
18	797	0.467
19	856	0.551
20	914	0.625
21	971	0.689
22	1,027	0.742
23	1,081	0.785
24	1,134	0.82
25	1,186	0.847
26	1,236	0.87
27	1,284	0.888
28	1,331	0.902
29	1,376	0.914
30	1,419	0.924
31	1,460	0.932
32	1,500	0.939
33	1,538	0.944
34	1,575	0.949
35	1,609	0.953
36	1,643	0.956
37	1,674	0.959
38	1,705	0.962
39	1,733	0.964
40	1,761	0.966
41	1,787	0.968
42	1,811	0.969
43	1,835	0.97
44	1,857	0.971
45+	1,966	0.977

Table 14.13. Negative log likelihoods, effective sample sizes, and root mean squared errors, for the evaluated models for BSAI blackspotted/rougheye rockfish (Model 16.5) and AI blackspotted/rougheye rockfish (Models 18.1 and 18.2). The 2016 results for BSAI blackspotted/rougheye rockfish are shown to compare changes since the last assessment.

	2016 Assessment	Model 16.5	Model 18.1	Model 18.2
Negative log-likelihood				
Data components				
AI survey biomass	25.00	26.71	25.95	14.51
EBS survey biomass	4.87	2.02		
Catch biomass	0.01	0.01	0.01	0.00
Fishery ages	85.72	119.58	118.06	21.89
Fishery lengths	139.51	150.65	149.49	42.55
AI survey ages	176.80	180.12	182.30	32.45
AI survey lengths	13.50	19.06	14.75	4.38
EBS survey ages	69.87	73.68		
Priors and penalties				
Recruitment	25.18	35.00	41.83	-10.30
Prior on survey q	2.03	2.53	1.97	0.20
Prior on M	2.31	2.88	2.60	0.57
Total negative log-likelihood	549.43	616.97	543.48	112.01
Parameters	133	137	134	132
Effective sample size				
Fishery ages	69	75	75	46
Fishery lengths	208	284	156	122
AI survey ages	278	241	195	66
AI survey lengths	130	129	93	45
EBS survey ages	53	58		
Root mean square error				
AI survey biomass	0.473	0.479	0.506	0.356
Recruitment	1.010	1.132	1.200	0.533
EBS survey biomass	0.457	0.213		
Fishery ages	0.019	0.018	0.019	0.022
Fishery lengths	0.015	0.015	0.016	0.018
AI survey ages	0.009	0.010	0.011	0.018
AI survey lengths	0.014	0.014	0.016	0.023
EBS survey ages	0.022	0.018		

Table 14.14. Key parameter estimates and management quantities for the evaluated models for BSAI blackspotted/rougheye rockfish (Model 16.5) and AI blackspotted/rougheye rockfish (Models 18.1 and 18.2). The 2016 results for BSAI blackspotted/rougheye rockfish are shown to compare changes since the last assessment.

	2016 Assessment	Model 16.5	Model 18.1	Model 18.2
Key parameters and management quantities				
EBS Survey catchability	0.76	0.77		
CV	0.15	0.15		
AI Survey catchability	1.10	1.12	1.10	1.03
CV	0.05	0.05	0.05	0.05
2018 total biomass (t)		40,563	43,711	15,273
CV		0.17	0.20	0.17
2018 Spawning stock biomass (t)		7,306	7,789	4,513
CV		0.15	0.17	0.16
SB40% (t)	10,728	11,058	11,715	5,507
SB_2018/SB40%		0.66	0.66	0.82
2019 ABC		481	522	314

Table 14.15. 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_forfish	0.80	0.21	fmort_dev	-0.54	0.13	log_rinit	-0.21	0.08
sel_a50_forfish	13.08	0.80	fmort_dev	-0.85	0.14	fydev	0.07	0.72
sel_aslope_srv3	0.28	0.05	fmort_dev	-0.53	0.15	fydev	0.12	0.74
sel_a50_srv3	16.20	1.59	fmort_dev	-0.38	0.15	fydev	0.22	0.78
M	0.03	0.00	rec_dev	0.08	0.72	fydev	0.31	0.81
log_avg_fmort	-3.74	0.09	rec_dev	0.14	0.73	fydev	0.32	0.82
fmort_dev	-0.79	0.13	rec_dev	0.20	0.74	fydev	0.28	0.81
fmort_dev	2.01	0.12	rec_dev	0.17	0.73	fydev	0.24	0.81
fmort_dev	2.42	0.12	rec_dev	0.06	0.71	fydev	0.27	0.83
fmort_dev	0.99	0.12	rec_dev	0.03	0.69	fydev	0.34	0.87
fmort_dev	0.90	0.12	rec_dev	0.07	0.69	fydev	0.45	0.93
fmort_dev	-0.25	0.12	rec_dev	0.11	0.69	fydev	0.53	0.99
fmort_dev	-1.46	0.12	rec_dev	0.05	0.67	fydev	0.55	1.01
fmort_dev	-2.00	0.12	rec_dev	-0.12	0.64	fydev	0.49	0.97
fmort_dev	-3.29	0.12	rec_dev	-0.34	0.60	fydev	0.39	0.90
fmort_dev	-2.59	0.12	rec_dev	-0.51	0.58	fydev	0.29	0.85
fmort_dev	-1.30	0.11	rec_dev	-0.61	0.56	fydev	0.20	0.81
fmort_dev	-1.39	0.11	rec_dev	-0.71	0.54	fydev	0.12	0.77
fmort_dev	0.22	0.11	rec_dev	-0.81	0.53	fydev	0.05	0.75
fmort_dev	1.70	0.11	rec_dev	-0.88	0.53	fydev	-0.01	0.73
fmort_dev	-0.72	0.11	rec_dev	-0.89	0.53	fydev	-0.07	0.71
fmort_dev	1.44	0.11	rec_dev	-0.87	0.53	fydev	-0.11	0.70
fmort_dev	1.26	0.10	rec_dev	-0.81	0.54	fydev	-0.14	0.69
fmort_dev	1.09	0.10	rec_dev	-0.71	0.55	fydev	-0.17	0.68
fmort_dev	0.47	0.10	rec_dev	-0.54	0.57	fydev	-0.19	0.68
fmort_dev	1.22	0.10	rec_dev	-0.31	0.61	fydev	-0.21	0.67
fmort_dev	1.44	0.10	rec_dev	-0.09	0.65	fydev	-0.22	0.67
fmort_dev	0.90	0.10	rec_dev	0.14	0.76	fydev	-0.22	0.67
fmort_dev	0.61	0.10	rec_dev	1.10	0.83	fydev	-0.23	0.67
fmort_dev	0.31	0.10	rec_dev	0.89	1.07	fydev	-0.23	0.67
fmort_dev	1.02	0.10	rec_dev	0.51	0.89	fydev	-0.23	0.67
fmort_dev	0.34	0.10	rec_dev	0.45	0.91	fydev	-0.22	0.67
fmort_dev	-0.10	0.11	rec_dev	1.31	0.79	fydev	-0.22	0.67
fmort_dev	-0.03	0.11	rec_dev	0.50	0.94	fydev	-0.22	0.67
fmort_dev	-0.90	0.11	rec_dev	0.27	0.79	fydev	-0.22	0.67
fmort_dev	0.03	0.11	rec_dev	0.33	0.78	fydev	-0.21	0.67
fmort_dev	-0.20	0.11	rec_dev	0.35	0.79	fydev	-0.21	0.67
fmort_dev	-0.12	0.11	rec_dev	0.32	0.79	fydev	-0.21	0.67
fmort_dev	-0.07	0.11	rec_dev	0.36	0.80	fydev	-0.21	0.67
fmort_dev	0.00	0.11	rec_dev	0.24	0.79	fydev	-0.20	0.67
fmort_dev	-0.50	0.12	rec_dev	0.27	0.78	fydev	-0.20	0.67
fmort_dev	-0.24	0.12	rec_dev	0.16	0.76	fydev	-0.20	0.68
fmort_dev	0.25	0.12	rec_dev	0.08	0.75	fydev	-0.88	0.54
fmort_dev	-0.34	0.13	mean_log_rec	-0.22	0.16	q_srv3	1.03	0.05

Table 14.16. 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			
	2018		2016		2018		2016		2018		2016	
Year	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
1977	17,139	0.060	18,454	0.040	5,666	0.090	5,182	0.054	872	0.740	695	0.515
1978	17,519	0.057	18,984	0.039	5,696	0.087	5,365	0.050	925	0.743	872	0.544
1979	15,561	0.062	17,053	0.041	4,925	0.094	4,662	0.050	981	0.741	1,593	0.457
1980	12,901	0.070	13,986	0.043	4,095	0.105	3,821	0.052	950	0.729	1,220	0.519
1981	12,692	0.071	13,741	0.045	4,025	0.106	3,828	0.051	858	0.709	718	0.520
1982	12,542	0.070	13,412	0.046	4,001	0.105	3,833	0.051	827	0.695	686	0.504
1983	12,803	0.068	13,657	0.047	4,119	0.101	4,020	0.050	866	0.695	906	0.510
1984	13,199	0.065	14,124	0.046	4,286	0.096	4,264	0.048	896	0.690	1,331	0.496
1985	13,616	0.063	14,606	0.046	4,468	0.091	4,508	0.046	847	0.671	1,540	0.470
1986	14,048	0.060	15,145	0.046	4,664	0.087	4,773	0.045	714	0.639	1,034	0.487
1987	14,459	0.058	15,601	0.046	4,858	0.082	5,007	0.044	574	0.608	583	0.484
1988	14,793	0.056	15,924	0.046	5,035	0.078	5,195	0.043	484	0.583	471	0.469
1989	15,114	0.055	16,226	0.047	5,194	0.074	5,342	0.043	436	0.566	566	0.436
1990	15,101	0.055	16,099	0.048	5,161	0.072	5,228	0.044	398	0.554	556	0.420
1991	13,810	0.059	14,519	0.053	4,810	0.074	4,743	0.048	360	0.548	379	0.444
1992	13,991	0.059	14,672	0.054	4,864	0.072	4,779	0.049	335	0.545	310	0.444
1993	13,091	0.062	13,772	0.059	4,581	0.074	4,467	0.053	329	0.546	339	0.437
1994	12,427	0.066	13,039	0.063	4,382	0.076	4,237	0.058	337	0.551	394	0.432
1995	11,917	0.069	12,588	0.067	4,256	0.078	4,132	0.062	359	0.562	412	0.446
1996	11,752	0.071	12,476	0.070	4,213	0.078	4,117	0.065	397	0.576	489	0.459
1997	11,145	0.076	11,937	0.075	4,011	0.082	3,940	0.070	467	0.597	868	0.425
1998	10,387	0.083	11,297	0.082	3,780	0.087	3,746	0.078	592	0.627	1,342	0.413
1999	10,067	0.087	11,124	0.087	3,694	0.090	3,709	0.082	739	0.667	1,570	0.393
2000	9,900	0.090	11,093	0.091	3,654	0.093	3,724	0.086	926	0.783	1,141	0.546
2001	9,928	0.094	11,765	0.097	3,622	0.095	3,739	0.090	2,429	0.830	9,506	0.216
2002	9,696	0.100	11,998	0.105	3,506	0.100	3,666	0.095	1,968	1.092	4,102	0.476
2003	9,755	0.104	12,704	0.110	3,485	0.102	3,692	0.099	1,337	0.908	4,949	0.382
2004	9,942	0.107	13,418	0.113	3,491	0.104	3,740	0.101	1,268	0.937	1,823	0.671
2005	10,240	0.112	14,928	0.120	3,496	0.106	3,781	0.103	2,976	0.805	12,288	0.247
2006	10,627	0.115	16,172	0.123	3,526	0.107	3,853	0.105	1,328	0.972	2,510	0.730
2007	10,912	0.120	17,612	0.128	3,515	0.110	3,886	0.108	1,056	0.821	5,534	0.395
2008	11,269	0.125	18,967	0.131	3,518	0.112	3,939	0.110	1,117	0.809	1,724	0.722
2009	11,637	0.130	20,677	0.136	3,520	0.115	4,005	0.113	1,140	0.821	6,257	0.441
2010	12,013	0.135	22,287	0.139	3,528	0.117	4,105	0.116	1,110	0.825	2,912	0.799
2011	12,390	0.141	24,112	0.143	3,552	0.121	4,264	0.120	1,154	0.834	5,264	0.794
2012	12,853	0.145	26,175	0.147	3,621	0.123	4,516	0.123	1,025	0.818	6,235	0.753
2013	13,278	0.150	28,218	0.149	3,697	0.127	4,853	0.127	1,057	0.811	4,576	0.922
2014	13,577	0.156	30,000	0.153	3,774	0.132	5,266	0.132	947	0.792		
2015	13,997	0.161	31,919	0.155	3,922	0.137	5,841	0.136	868	0.786		
2016	14,450	0.165	33,846	0.157	4,111	0.142	6,543	0.140				
2017	14,935	0.169	35,699		4,333	0.147	7,305					
2018	15,273	0.173			4,513	0.154						
2019	15,647				4,736							
Mean recruitment of post-1976 year classes									930		2,486	

Table 14.17. 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	0.87	0.85	0.86	0.92	0.97	0.95	0.89	0.83	0.82	0.86	0.92	0.97	0.96	0.88	0.77	0.67	0.60	0.53	0.48	0.44
1978	0.92	0.84	0.82	0.84	0.89	0.94	0.92	0.86	0.80	0.80	0.83	0.89	0.94	0.92	0.84	0.74	0.64	0.57	0.51	0.46
1979	0.98	0.90	0.82	0.79	0.81	0.86	0.91	0.89	0.82	0.76	0.73	0.74	0.77	0.78	0.76	0.69	0.60	0.52	0.47	0.42
1980	0.95	0.95	0.87	0.79	0.77	0.78	0.83	0.88	0.84	0.76	0.68	0.62	0.60	0.60	0.60	0.57	0.51	0.45	0.39	0.35
1981	0.86	0.92	0.92	0.84	0.77	0.74	0.76	0.81	0.84	0.81	0.72	0.64	0.58	0.55	0.54	0.54	0.52	0.47	0.41	0.35
1982	0.83	0.83	0.89	0.89	0.81	0.74	0.72	0.73	0.78	0.81	0.77	0.68	0.59	0.53	0.50	0.50	0.50	0.47	0.43	0.37
1983	0.87	0.80	0.81	0.86	0.86	0.79	0.72	0.70	0.71	0.75	0.78	0.74	0.65	0.57	0.51	0.48	0.47	0.47	0.45	0.41
1984	0.90	0.84	0.78	0.78	0.84	0.84	0.76	0.70	0.67	0.69	0.73	0.75	0.72	0.63	0.55	0.49	0.46	0.46	0.46	0.43
1985	0.85	0.87	0.81	0.75	0.76	0.81	0.81	0.74	0.68	0.65	0.66	0.70	0.73	0.69	0.61	0.53	0.47	0.45	0.44	0.44
1986	0.71	0.82	0.84	0.79	0.73	0.73	0.79	0.79	0.72	0.65	0.63	0.64	0.68	0.71	0.67	0.59	0.51	0.46	0.43	0.43
1987	0.57	0.69	0.80	0.82	0.76	0.71	0.71	0.76	0.76	0.70	0.63	0.61	0.62	0.66	0.68	0.65	0.57	0.49	0.44	0.42
1988	0.48	0.56	0.67	0.77	0.79	0.74	0.68	0.69	0.74	0.74	0.67	0.61	0.59	0.60	0.63	0.66	0.62	0.55	0.47	0.43
1989	0.44	0.47	0.54	0.65	0.75	0.77	0.72	0.66	0.67	0.71	0.71	0.65	0.59	0.57	0.58	0.61	0.63	0.60	0.53	0.46
1990	0.40	0.42	0.45	0.52	0.63	0.72	0.74	0.69	0.64	0.64	0.69	0.68	0.62	0.56	0.54	0.54	0.58	0.60	0.56	0.50
1991	0.36	0.39	0.41	0.44	0.51	0.61	0.70	0.71	0.67	0.61	0.60	0.62	0.60	0.54	0.48	0.46	0.46	0.49	0.51	0.48
1992	0.34	0.35	0.37	0.40	0.43	0.49	0.59	0.68	0.69	0.64	0.59	0.58	0.60	0.58	0.51	0.46	0.44	0.44	0.47	0.49
1993	0.33	0.32	0.34	0.36	0.38	0.41	0.47	0.57	0.65	0.66	0.60	0.54	0.52	0.53	0.51	0.45	0.40	0.39	0.39	0.41
1994	0.34	0.32	0.31	0.33	0.35	0.37	0.40	0.46	0.55	0.62	0.62	0.56	0.50	0.47	0.48	0.46	0.40	0.36	0.34	0.35
1995	0.36	0.33	0.31	0.30	0.32	0.34	0.36	0.39	0.44	0.53	0.59	0.58	0.52	0.45	0.43	0.44	0.41	0.37	0.33	0.31
1996	0.40	0.35	0.32	0.30	0.30	0.31	0.33	0.35	0.37	0.42	0.50	0.56	0.55	0.49	0.42	0.40	0.41	0.39	0.34	0.30
1997	0.47	0.38	0.34	0.31	0.29	0.29	0.30	0.32	0.34	0.36	0.40	0.47	0.52	0.50	0.44	0.38	0.36	0.36	0.35	0.30
1998	0.59	0.45	0.37	0.33	0.30	0.28	0.28	0.29	0.31	0.32	0.34	0.37	0.42	0.46	0.44	0.39	0.33	0.31	0.32	0.30
1999	0.74	0.57	0.44	0.36	0.32	0.29	0.27	0.27	0.28	0.29	0.30	0.32	0.35	0.39	0.42	0.41	0.35	0.31	0.29	0.29
2000	0.93	0.72	0.56	0.42	0.35	0.31	0.28	0.26	0.26	0.27	0.28	0.29	0.30	0.32	0.37	0.39	0.38	0.33	0.28	0.27
2001	2.43	0.90	0.69	0.54	0.41	0.34	0.30	0.27	0.25	0.25	0.26	0.27	0.27	0.28	0.30	0.34	0.37	0.35	0.31	0.27
2002	1.97	2.35	0.87	0.67	0.52	0.40	0.33	0.29	0.26	0.24	0.24	0.24	0.25	0.25	0.26	0.28	0.31	0.33	0.32	0.28
2003	1.34	1.91	2.28	0.84	0.65	0.50	0.39	0.32	0.28	0.25	0.23	0.23	0.23	0.23	0.24	0.24	0.26	0.29	0.31	0.30
2004	1.27	1.29	1.85	2.21	0.82	0.63	0.49	0.37	0.31	0.27	0.24	0.22	0.22	0.22	0.22	0.22	0.23	0.25	0.28	0.30
2005	2.98	1.23	1.25	1.79	2.14	0.79	0.61	0.47	0.36	0.30	0.26	0.23	0.21	0.20	0.21	0.21	0.21	0.22	0.23	0.26
2006	1.33	2.88	1.19	1.22	1.73	2.07	0.77	0.59	0.46	0.35	0.29	0.25	0.22	0.21	0.20	0.20	0.20	0.20	0.21	0.22
2007	1.06	1.29	2.79	1.15	1.18	1.68	2.01	0.74	0.57	0.44	0.34	0.27	0.24	0.21	0.19	0.19	0.19	0.19	0.19	0.20
2008	1.12	1.02	1.25	2.71	1.12	1.14	1.63	1.94	0.72	0.55	0.43	0.32	0.26	0.23	0.20	0.19	0.18	0.18	0.18	0.18
2009	1.14	1.08	0.99	1.21	2.62	1.08	1.10	1.58	1.88	0.69	0.53	0.41	0.31	0.25	0.21	0.19	0.18	0.17	0.17	0.17
2010	1.11	1.10	1.05	0.96	1.17	2.54	1.05	1.07	1.52	1.82	0.67	0.51	0.39	0.29	0.24	0.20	0.18	0.17	0.16	0.16
2011	1.15	1.08	1.07	1.02	0.93	1.13	2.46	1.01	1.03	1.47	1.75	0.64	0.49	0.37	0.28	0.22	0.19	0.17	0.16	0.15
2012	1.03	1.12	1.04	1.04	0.98	0.90	1.10	2.38	0.98	1.00	1.42	1.68	0.61	0.47	0.35	0.27	0.21	0.18	0.16	0.15
2013	1.06	0.99	1.08	1.01	1.00	0.95	0.87	1.06	2.30	0.95	0.96	1.36	1.61	0.58	0.44	0.34	0.25	0.20	0.17	0.16
2014	0.95	1.02	0.96	1.05	0.98	0.97	0.92	0.84	1.03	2.22	0.91	0.92	1.29	1.52	0.55	0.42	0.32	0.24	0.19	0.16
2015	0.87	0.92	0.99	0.93	1.02	0.95	0.94	0.89	0.82	0.99	2.14	0.88	0.88	1.24	1.45	0.53	0.40	0.30	0.23	0.18
2016	1.07	0.84	0.89	0.96	0.90	0.98	0.92	0.91	0.87	0.79	0.96	2.06	0.84	0.84	1.18	1.39	0.50	0.38	0.29	0.22
2017	1.07	1.03	0.81	0.86	0.93	0.88	0.95	0.89	0.88	0.84	0.76	0.92	1.98	0.81	0.81	1.13	1.33	0.48	0.36	0.28
2018	1.07	1.03	1.00	0.79	0.83	0.90	0.85	0.92	0.86	0.85	0.81	0.73	0.89	1.90	0.77	0.77	1.08	1.27	0.46	0.35

Table 14.17 (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	0.40	0.37	0.35	0.33	0.31	0.30	0.29	0.28	0.27	0.26	0.25	0.24	0.24	0.23	0.22	0.22	0.21	0.20	0.20	0.19	0.19	0.18	0.78
1978	0.42	0.39	0.36	0.34	0.32	0.30	0.29	0.27	0.26	0.26	0.25	0.24	0.23	0.23	0.22	0.21	0.21	0.20	0.20	0.19	0.18	0.18	0.92
1979	0.38	0.34	0.31	0.29	0.27	0.26	0.24	0.23	0.22	0.21	0.21	0.20	0.20	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.89
1980	0.31	0.28	0.25	0.23	0.22	0.20	0.19	0.18	0.17	0.17	0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13	0.12	0.12	0.11	0.77
1981	0.31	0.28	0.25	0.23	0.21	0.20	0.18	0.17	0.17	0.16	0.15	0.15	0.14	0.14	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.81
1982	0.32	0.29	0.26	0.23	0.21	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.84
1983	0.35	0.31	0.27	0.24	0.22	0.20	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.13	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.10	0.89
1984	0.39	0.34	0.30	0.26	0.24	0.21	0.19	0.18	0.16	0.15	0.15	0.14	0.13	0.13	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.10	0.95
1985	0.42	0.38	0.33	0.29	0.25	0.23	0.21	0.19	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.10	1.02
1986	0.43	0.41	0.37	0.32	0.28	0.25	0.22	0.20	0.18	0.17	0.15	0.14	0.14	0.13	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.10	1.08
1987	0.41	0.41	0.39	0.35	0.31	0.27	0.24	0.21	0.19	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.10	1.14
1988	0.40	0.40	0.40	0.38	0.34	0.30	0.26	0.23	0.20	0.18	0.17	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.11	0.10	0.10	0.10	1.19
1989	0.41	0.39	0.38	0.38	0.36	0.33	0.28	0.25	0.22	0.20	0.18	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.11	0.10	0.10	0.10	1.24
1990	0.43	0.39	0.37	0.36	0.36	0.34	0.31	0.27	0.23	0.21	0.19	0.17	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.09	1.25
1991	0.42	0.37	0.33	0.31	0.31	0.31	0.29	0.26	0.23	0.20	0.18	0.16	0.14	0.13	0.12	0.11	0.10	0.10	0.09	0.09	0.08	0.08	1.15
1992	0.46	0.40	0.35	0.32	0.30	0.29	0.29	0.28	0.25	0.22	0.19	0.17	0.15	0.14	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.08	1.18
1993	0.43	0.40	0.35	0.31	0.28	0.26	0.26	0.26	0.24	0.22	0.19	0.17	0.15	0.13	0.12	0.11	0.10	0.09	0.09	0.08	0.08	0.07	1.10
1994	0.37	0.38	0.36	0.32	0.27	0.25	0.23	0.23	0.23	0.22	0.20	0.17	0.15	0.13	0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.07	1.05
1995	0.31	0.33	0.34	0.32	0.29	0.25	0.22	0.21	0.21	0.21	0.20	0.18	0.15	0.13	0.12	0.11	0.10	0.09	0.08	0.07	0.07	0.07	1.01
1996	0.29	0.29	0.31	0.32	0.30	0.27	0.23	0.21	0.20	0.19	0.19	0.18	0.17	0.14	0.13	0.11	0.10	0.09	0.08	0.08	0.07	0.07	1.00
1997	0.27	0.26	0.26	0.28	0.29	0.27	0.24	0.21	0.19	0.18	0.17	0.17	0.16	0.15	0.13	0.11	0.10	0.09	0.08	0.07	0.07	0.06	0.95
1998	0.27	0.24	0.23	0.23	0.24	0.25	0.24	0.21	0.18	0.16	0.15	0.15	0.15	0.14	0.13	0.11	0.10	0.09	0.08	0.07	0.06	0.06	0.89
1999	0.28	0.24	0.22	0.21	0.21	0.22	0.23	0.22	0.19	0.17	0.15	0.14	0.14	0.14	0.13	0.12	0.10	0.09	0.08	0.07	0.06	0.06	0.87
2000	0.27	0.26	0.23	0.20	0.19	0.19	0.21	0.21	0.20	0.18	0.15	0.14	0.13	0.13	0.13	0.12	0.11	0.10	0.08	0.07	0.07	0.06	0.86
2001	0.25	0.25	0.24	0.21	0.19	0.18	0.18	0.19	0.20	0.19	0.17	0.14	0.13	0.12	0.12	0.12	0.11	0.10	0.09	0.08	0.07	0.06	0.86
2002	0.24	0.23	0.23	0.22	0.19	0.17	0.16	0.17	0.17	0.18	0.17	0.15	0.13	0.12	0.11	0.11	0.11	0.10	0.09	0.08	0.07	0.06	0.84
2003	0.26	0.23	0.21	0.22	0.21	0.18	0.16	0.15	0.16	0.16	0.17	0.16	0.14	0.12	0.11	0.10	0.10	0.10	0.10	0.09	0.08	0.07	0.85
2004	0.28	0.25	0.21	0.20	0.20	0.19	0.17	0.15	0.15	0.15	0.16	0.16	0.15	0.13	0.12	0.10	0.10	0.10	0.10	0.09	0.08	0.07	0.87
2005	0.28	0.27	0.24	0.20	0.19	0.19	0.18	0.16	0.14	0.14	0.14	0.15	0.15	0.14	0.13	0.11	0.10	0.09	0.09	0.09	0.09	0.08	0.89
2006	0.25	0.27	0.26	0.23	0.20	0.18	0.19	0.18	0.16	0.14	0.13	0.13	0.14	0.15	0.14	0.12	0.11	0.09	0.09	0.09	0.09	0.08	0.93
2007	0.21	0.24	0.26	0.24	0.21	0.18	0.17	0.18	0.17	0.15	0.13	0.13	0.13	0.13	0.14	0.13	0.12	0.10	0.09	0.08	0.08	0.08	0.96
2008	0.19	0.20	0.23	0.24	0.23	0.20	0.18	0.17	0.17	0.16	0.14	0.12	0.12	0.12	0.13	0.13	0.12	0.11	0.09	0.09	0.08	0.08	0.99
2009	0.17	0.18	0.19	0.21	0.23	0.22	0.19	0.17	0.16	0.16	0.15	0.13	0.12	0.11	0.11	0.12	0.12	0.12	0.10	0.09	0.08	0.08	1.01
2010	0.16	0.16	0.17	0.18	0.20	0.22	0.21	0.18	0.16	0.15	0.15	0.14	0.13	0.11	0.11	0.11	0.11	0.12	0.11	0.10	0.09	0.08	1.03
2011	0.15	0.15	0.16	0.16	0.17	0.19	0.21	0.20	0.17	0.15	0.14	0.14	0.14	0.12	0.11	0.10	0.10	0.11	0.11	0.11	0.09	0.08	1.05
2012	0.14	0.14	0.15	0.15	0.15	0.16	0.18	0.20	0.19	0.17	0.14	0.13	0.14	0.13	0.11	0.10	0.10	0.10	0.10	0.11	0.10	0.09	1.08
2013	0.14	0.14	0.14	0.14	0.14	0.14	0.16	0.17	0.19	0.18	0.16	0.14	0.13	0.13	0.12	0.11	0.10	0.09	0.09	0.10	0.10	0.10	1.11
2014	0.15	0.13	0.13	0.13	0.13	0.13	0.14	0.15	0.16	0.18	0.17	0.15	0.13	0.12	0.12	0.12	0.10	0.09	0.09	0.09	0.09	0.10	1.13
2015	0.16	0.14	0.13	0.12	0.12	0.13	0.13	0.13	0.14	0.16	0.17	0.16	0.14	0.12	0.11	0.12	0.11	0.10	0.09	0.08	0.08	0.09	1.17
2016	0.17	0.15	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.15	0.16	0.15	0.13	0.12	0.11	0.11	0.11	0.09	0.08	0.08	0.08	1.20
2017	0.21	0.17	0.14	0.13	0.12	0.11	0.11	0.12	0.12	0.12	0.13	0.14	0.15	0.15	0.13	0.11	0.10	0.11	0.10	0.09	0.08	0.08	1.23
2018	0.26	0.20	0.16	0.14	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.14	0.15	0.14	0.12	0.11	0.10	0.10	0.10	0.08	0.08	1.25

Table 14.18. 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 5,507 t and 4,818 t, respectively.

Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2018	206	206	206	206	206	206	206
2019	314	314	158	221	0	373	314
2020	335	335	173	228	0	394	335
2021	354	354	187	234	0	413	421
2022	372	372	201	240	0	430	437
2023	387	387	209	246	0	444	451
2024	400	400	213	250	0	455	462
2025	403	403	218	255	0	464	470
2026	406	406	222	259	0	469	472
2027	409	409	226	263	0	470	472
2028	411	411	230	267	0	470	473
2029	413	413	233	271	0	470	473
2030	414	414	236	274	0	470	473
2031	415	415	239	277	0	469	472
Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2018	4,513	4,513	4,513	4,513	4,513	4,513	4,513
2019	4,730	4,730	4,739	4,735	4,749	4,726	4,730
2020	4,916	4,916	4,985	4,958	5,055	4,890	4,916
2021	5,091	5,091	5,226	5,177	5,367	5,042	5,087
2022	5,250	5,250	5,456	5,387	5,677	5,176	5,221
2023	5,391	5,391	5,673	5,586	5,982	5,291	5,335
2024	5,514	5,514	5,878	5,773	6,282	5,388	5,430
2025	5,619	5,619	6,069	5,946	6,573	5,467	5,507
2026	5,710	5,710	6,248	6,107	6,856	5,529	5,568
2027	5,788	5,788	6,414	6,254	7,128	5,578	5,616
2028	5,854	5,854	6,569	6,390	7,391	5,615	5,652
2029	5,909	5,909	6,711	6,514	7,644	5,642	5,677
2030	5,955	5,955	6,843	6,628	7,887	5,660	5,695
2031	5,993	5,993	6,965	6,732	8,122	5,671	5,705
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2018	0.016	0.016	0.016	0.016	0.016	0.016	0.016
2019	0.024	0.024	0.012	0.017	0	0.029	0.024
2020	0.025	0.025	0.013	0.017	0	0.030	0.025
2021	0.026	0.026	0.013	0.017	0	0.031	0.031
2022	0.027	0.027	0.014	0.017	0	0.032	0.032
2023	0.028	0.028	0.014	0.017	0	0.033	0.033
2024	0.028	0.028	0.014	0.017	0	0.033	0.033
2025	0.028	0.028	0.014	0.017	0	0.034	0.034
2026	0.028	0.028	0.014	0.017	0	0.034	0.034
2027	0.028	0.028	0.014	0.017	0	0.034	0.034
2028	0.028	0.028	0.014	0.017	0	0.034	0.034
2029	0.028	0.028	0.014	0.017	0	0.034	0.034
2030	0.028	0.028	0.014	0.017	0	0.034	0.034
2031	0.028	0.028	0.014	0.017	0	0.034	0.034

Figures

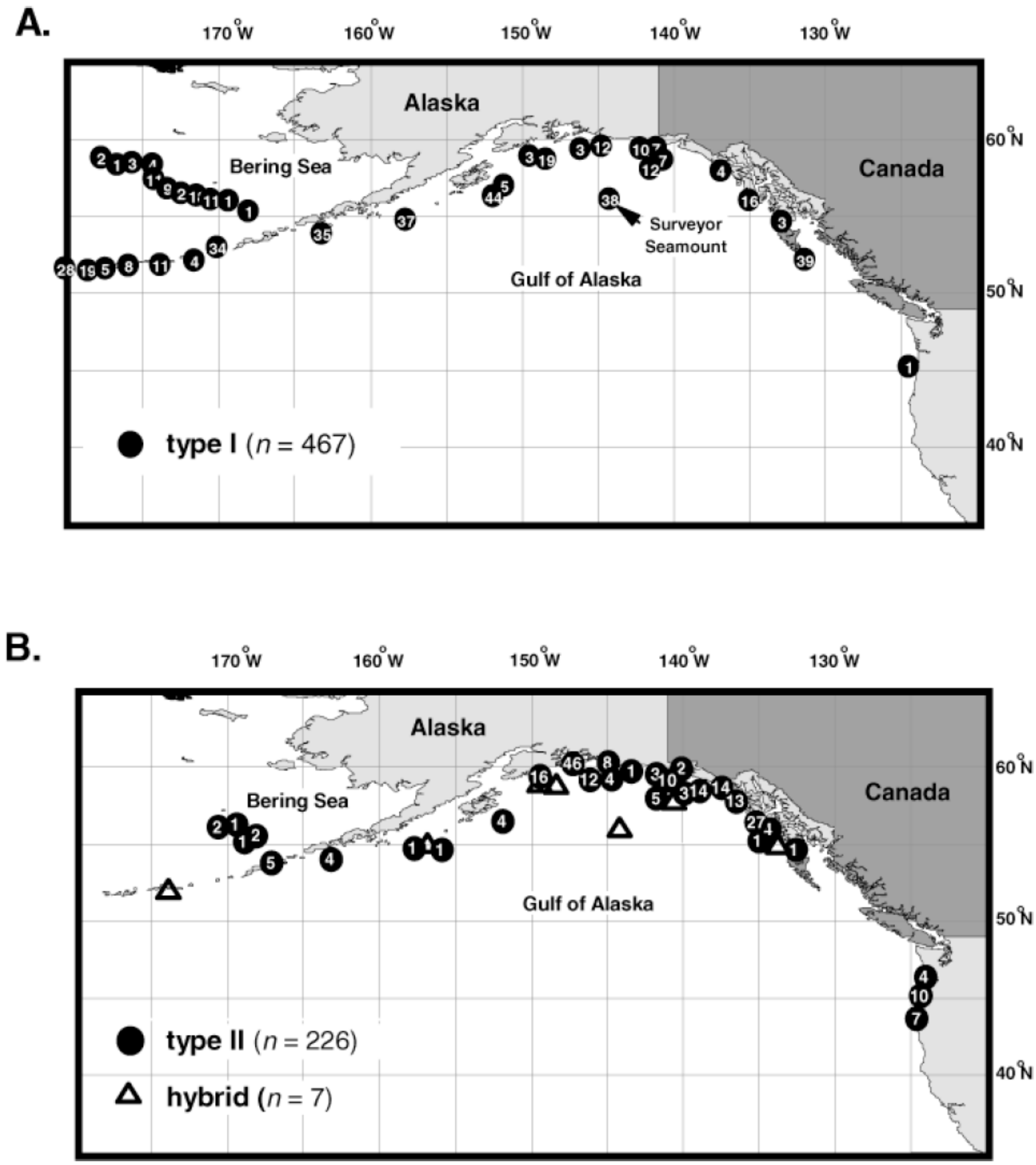


Figure 14.1. Distribution type I (i.e., blackspotted rockfish, *S. melanostictus*) and type II (i.e., rougheye rockfish, *S. aleutianus*) fish previously thought to be a single species of rougheye rockfish, based mtDNA and microsatellite genetic analyses. From Gharrett et al. (2005).

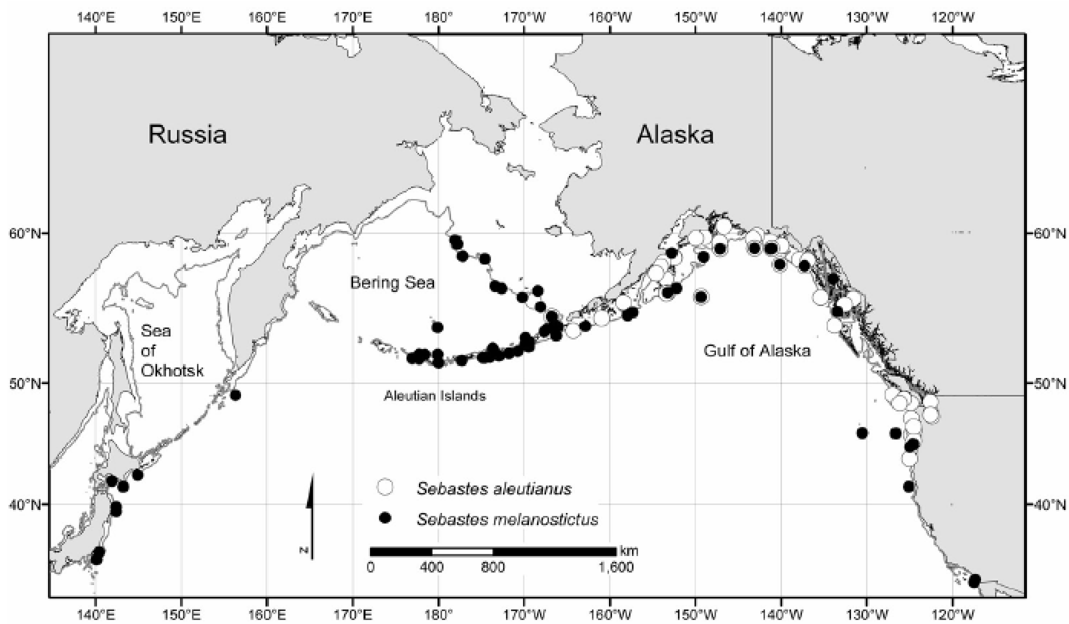
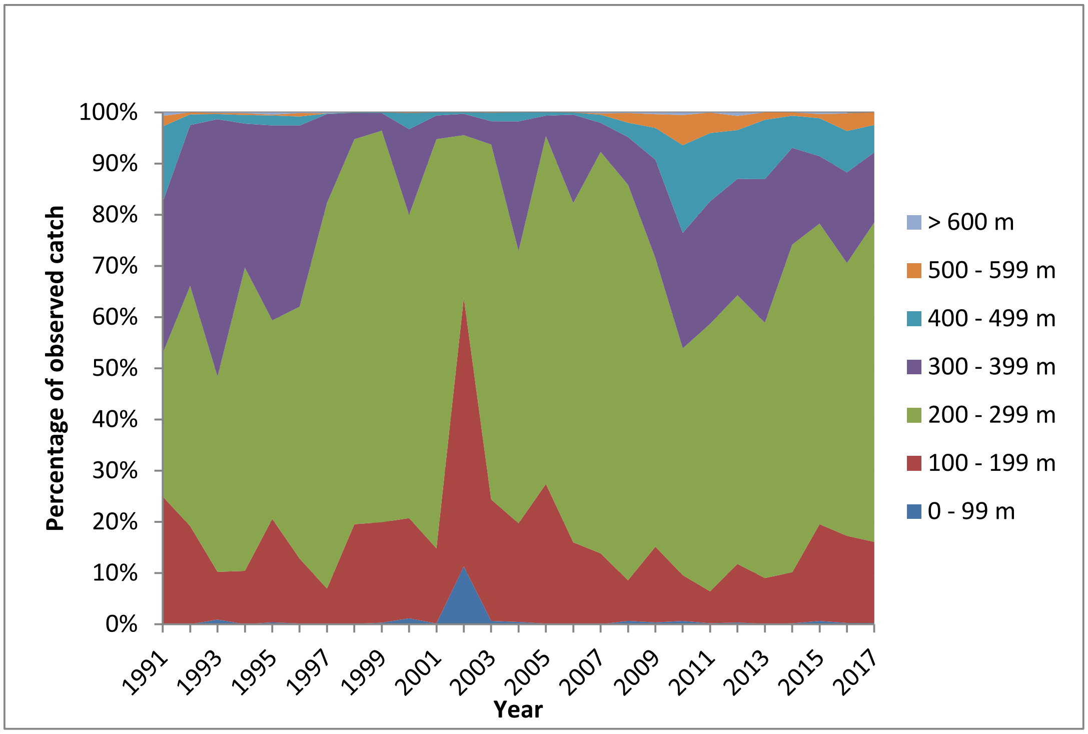


Figure 14.2. Distribution blackspotted rockfish (*S. melanostictus*) and rougheye rockfish (*S. aleutianus*) based upon genetic, morphometric, and meristic analyses. From Orr and Hawkins (2008).



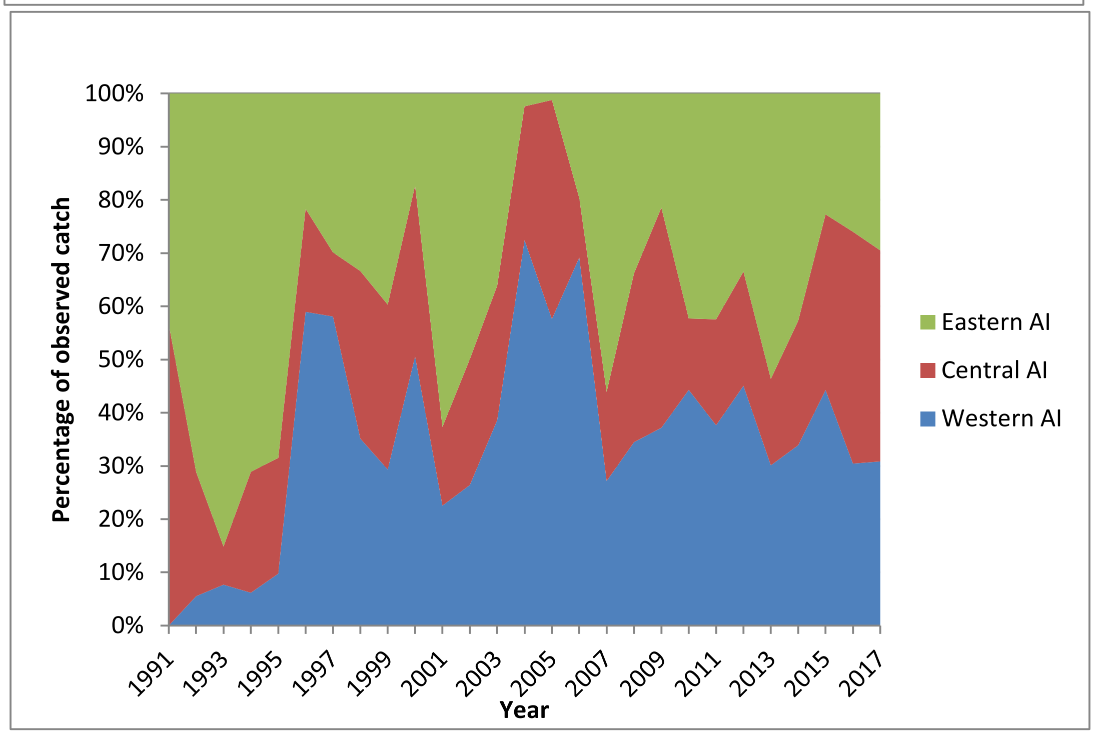


Figure 14.3. Distribution of observed Aleutian Islands (AI) blackspotted/rougheye rockfish catch (from North Pacific Groundfish Observer Program) by depth zone (top panel) and AI subarea (bottom panel) from 1991 to 2017.

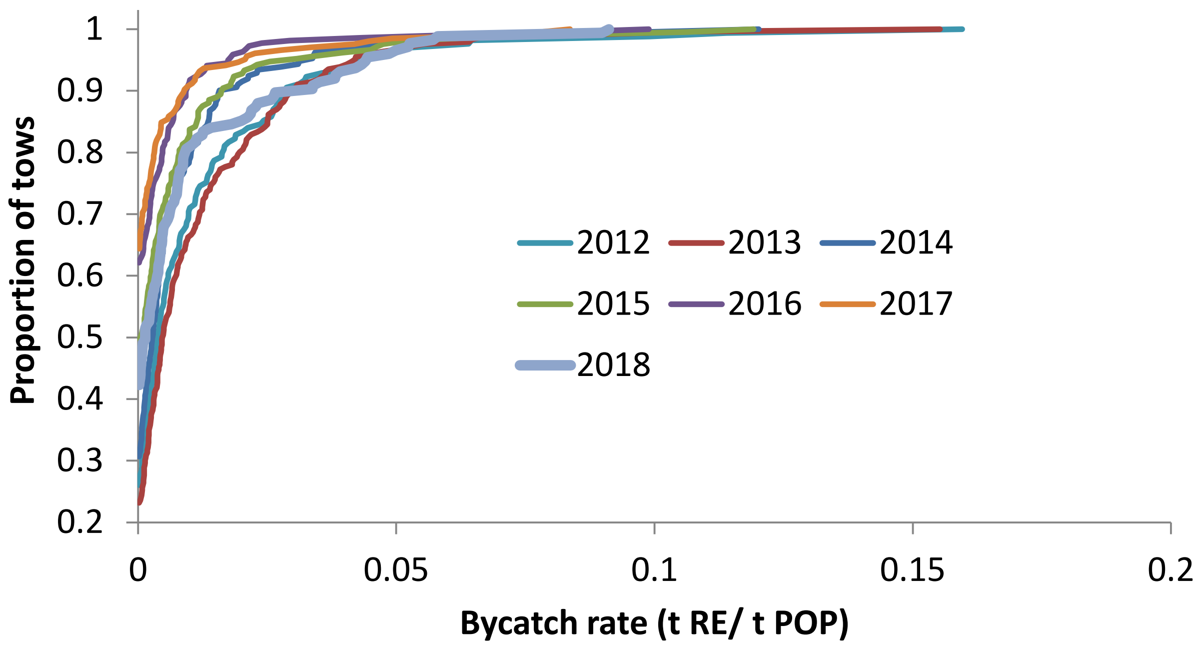


Figure 14.4. Cumulative distribution plots of rougheye blackspotted bycatch rates for tows by A80 vessels targeting Pacific ocean perch in the WAI.

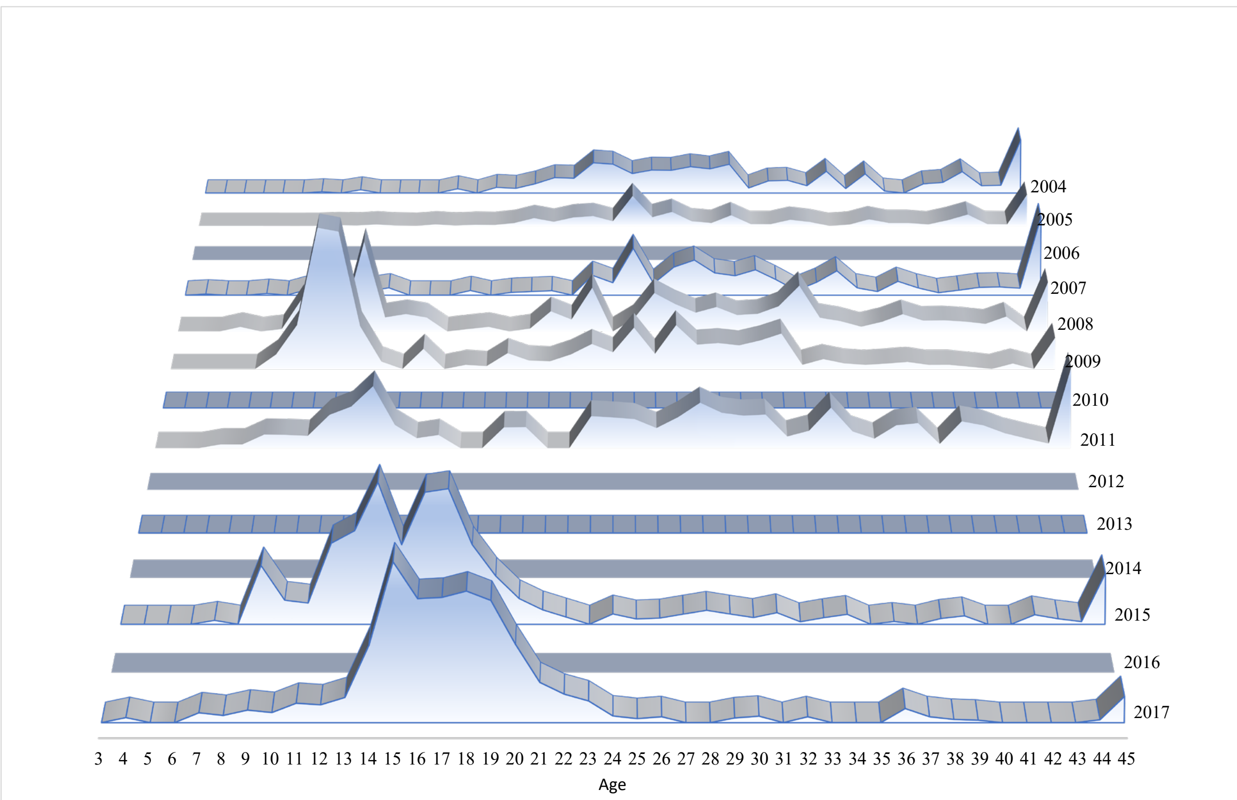


Figure 14.5. Fishery age composition data for the BSAI, scaled to the extrapolated number of fish caught from Observer sampling.

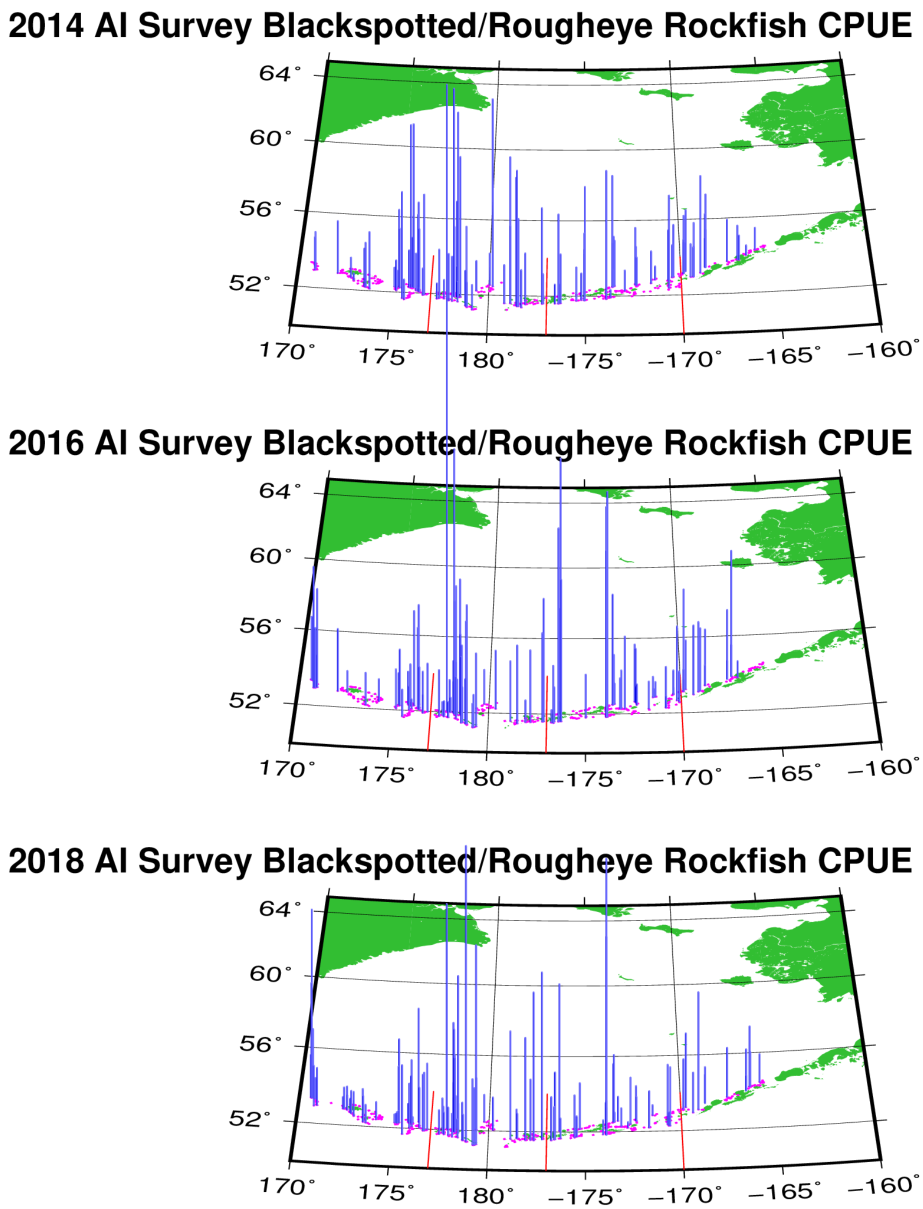


Figure 14.6. Scaled Aleutian Islands (AI) survey combined blackspotted and rougheye rockfish CPUE (kg/km^2) from 1991-2018; the symbol × denotes tows with no catch. The red lines indicate boundaries between the western Aleutian Islands (WAI), central Aleutian Islands (CAI), eastern Aleutian Islands (EAI), and eastern Bering Sea (EBS) areas.

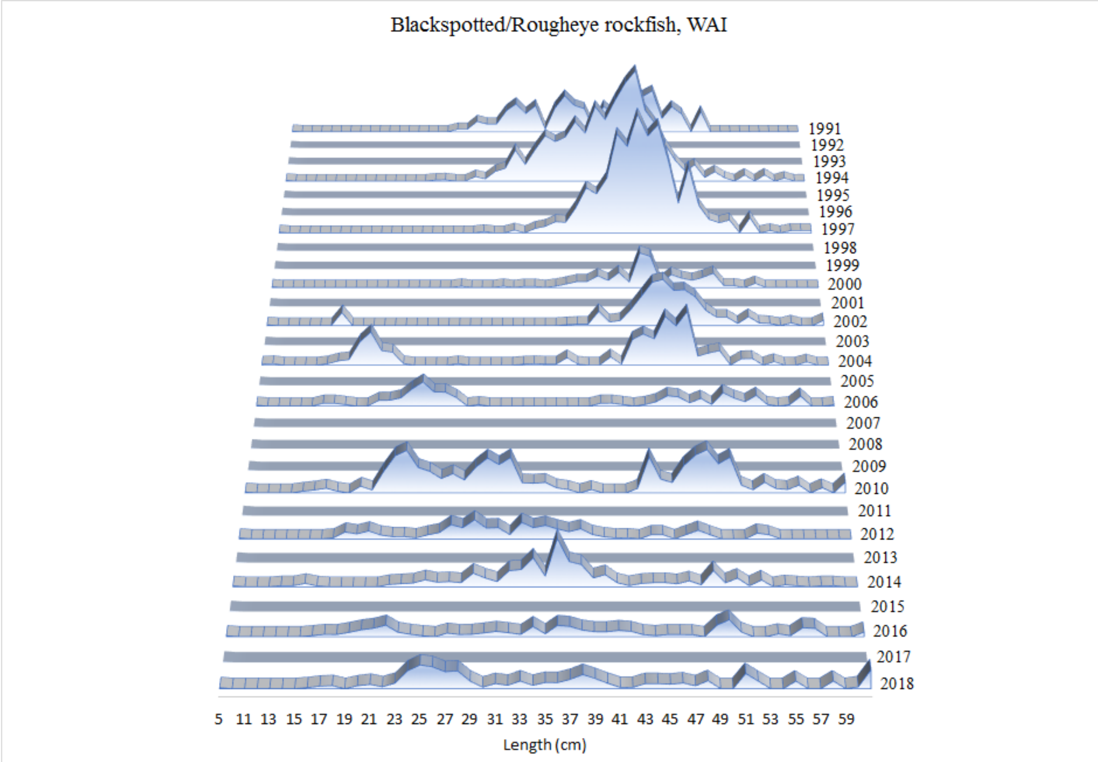


Figure 14.7. Size compositions of blackspotted/rougheye rockfish in the western Aleutian Islands subarea, from the 1991-2018 AI surveys.

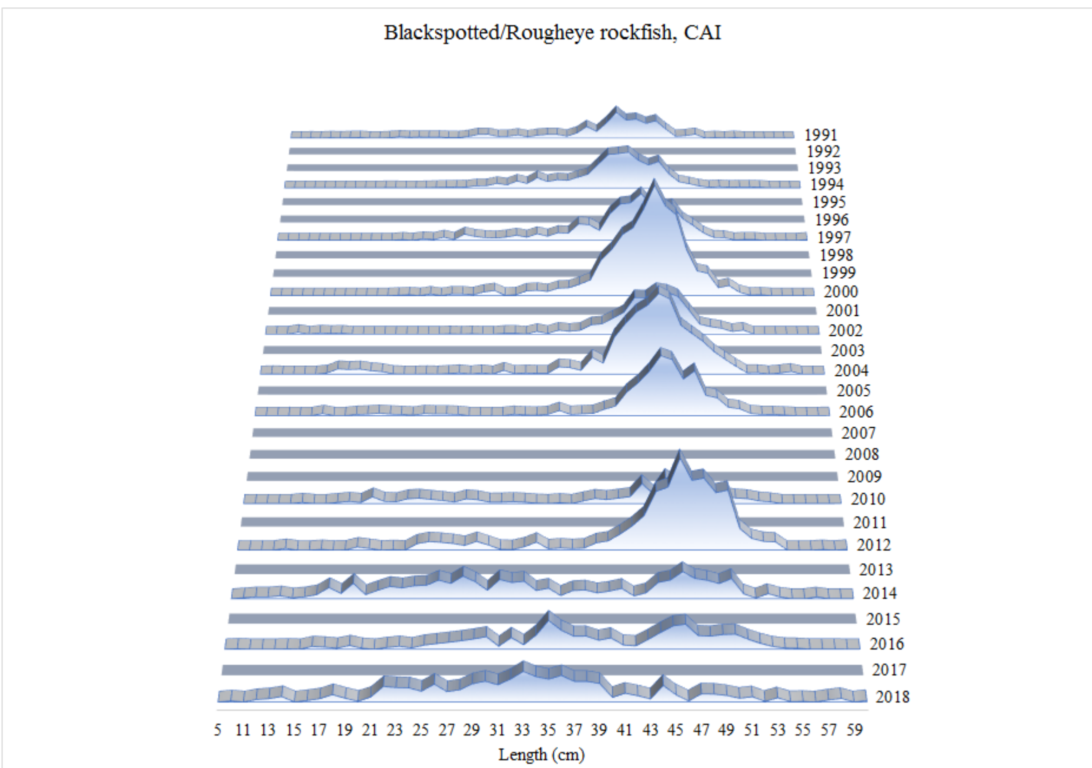


Figure 14.8. Size compositions of blackspotted/rougheye rockfish in the central Aleutian Islands subarea, from the 1991-2018 AI surveys.

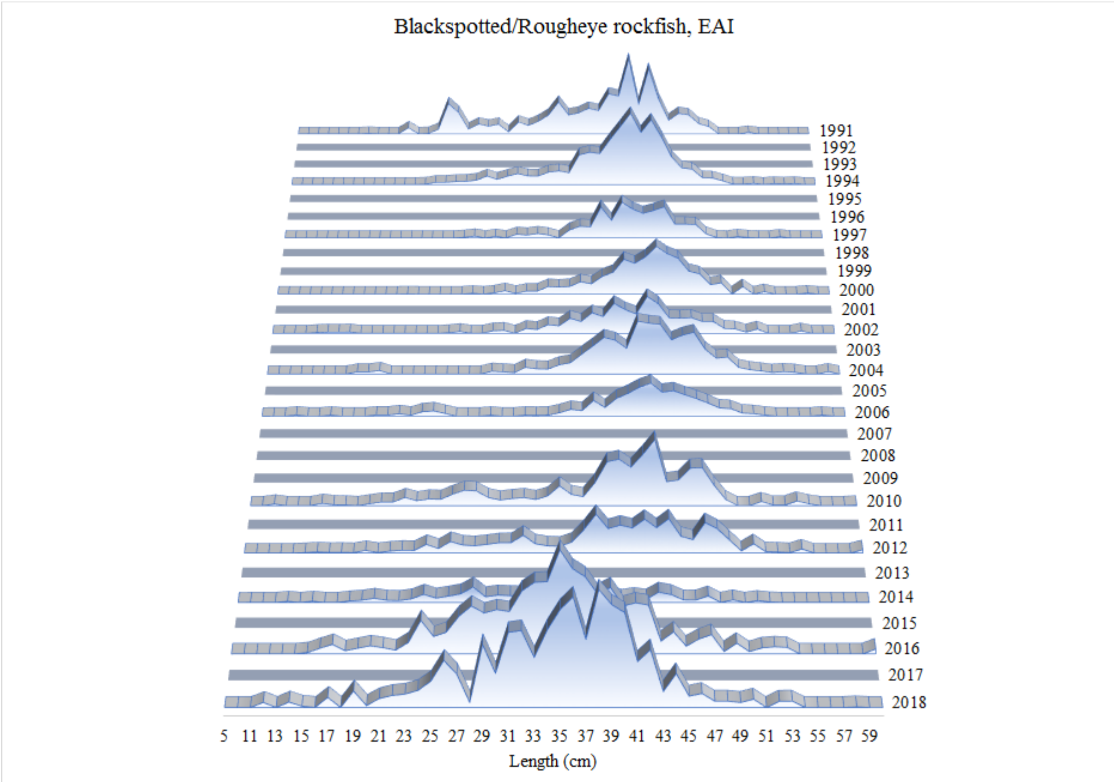


Figure 14.9. Size compositions of blackspotted/rougheye rockfish in the eastern Aleutian Islands subarea, from the 1991-2018 AI surveys.

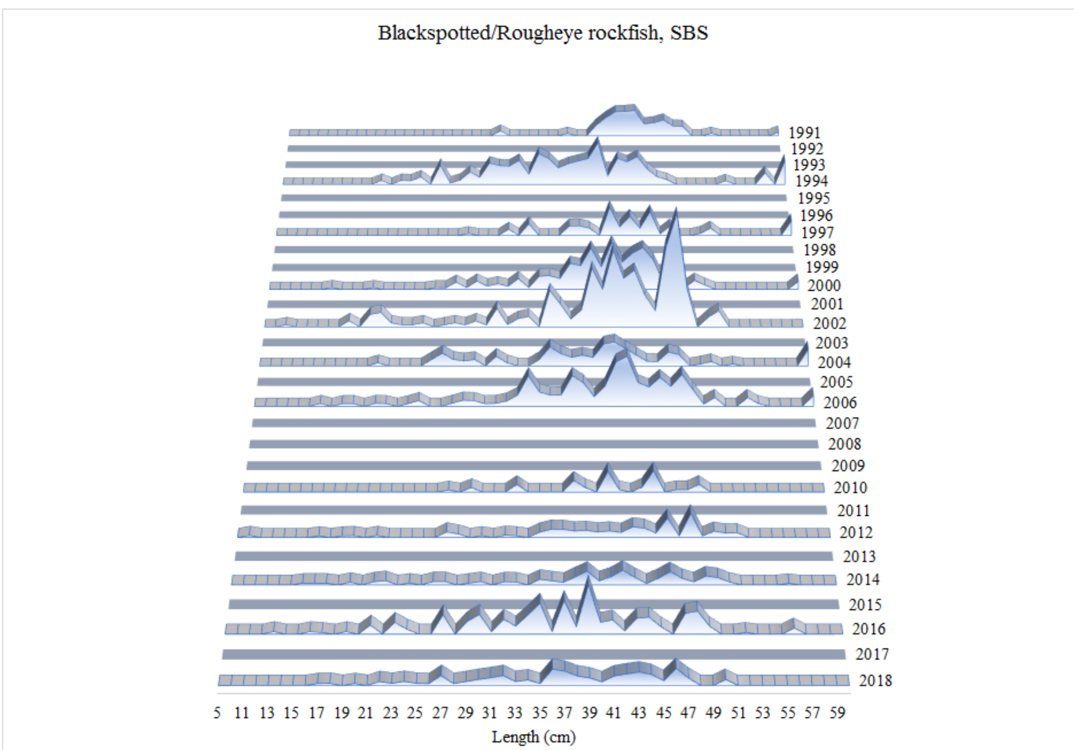


Figure 14.10. Size compositions of blackspotted/rougheye rockfish in the southern Bering Sea, from the 1991-2018 AI surveys.

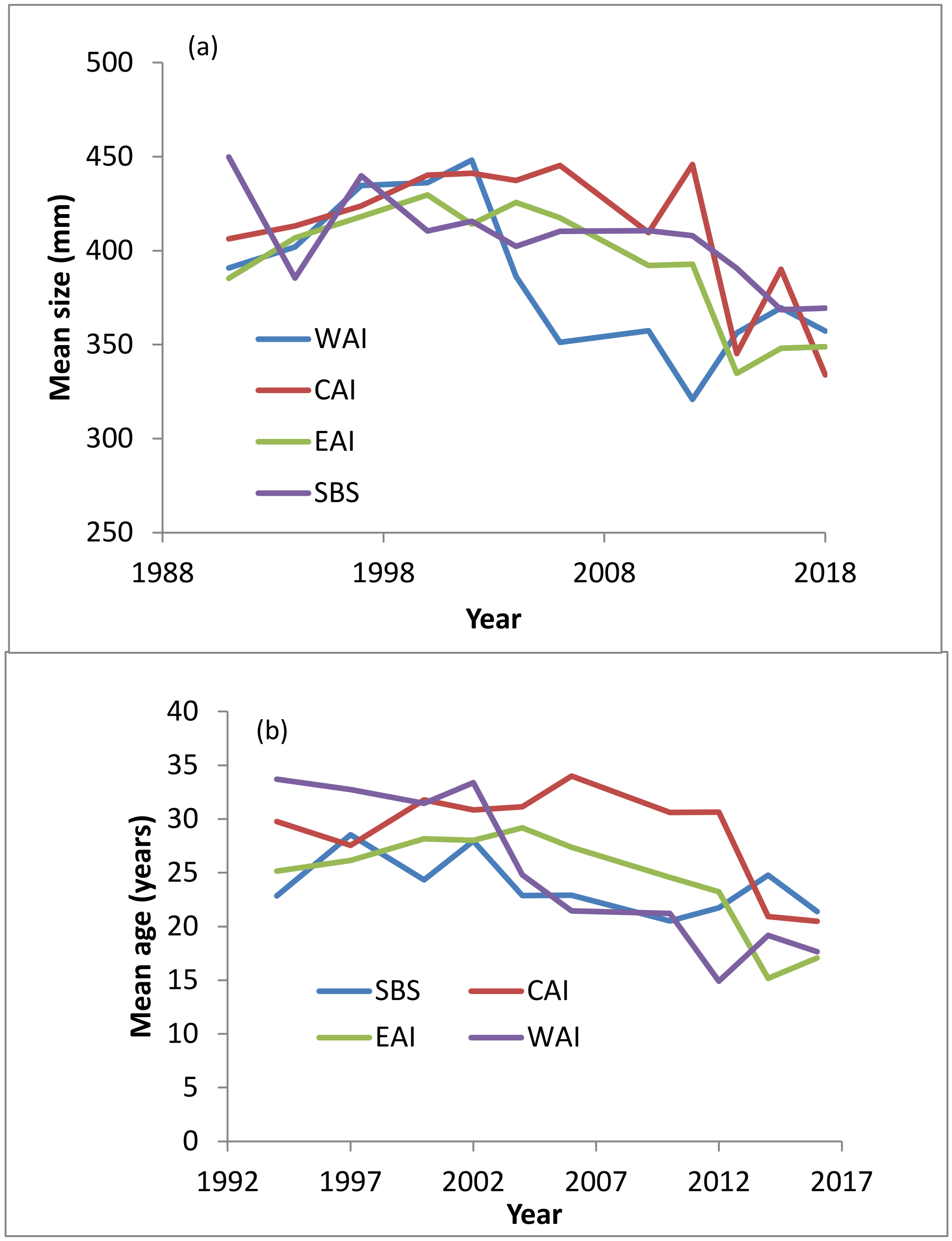


Figure 14.11. Mean size (a) and age (b) of blackspotted/rougheye rockfish from the 1991-2018 AI trawl surveys by subarea.

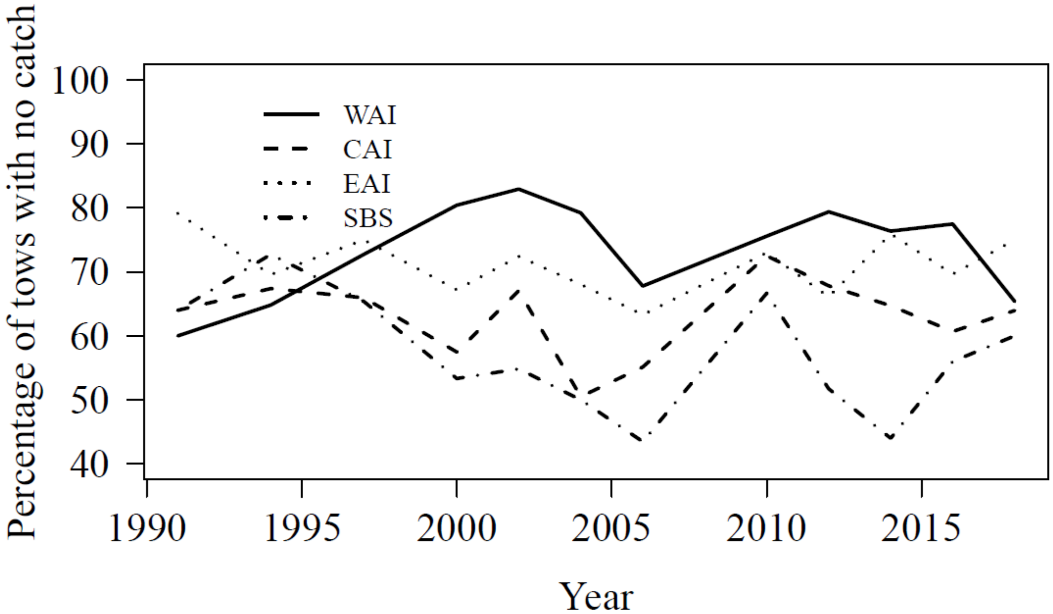


Figure 14.12. Percentage of survey tows with no catch of blackspotted/rougheye rockfish from the 1991-2018 AI trawl surveys by subarea.

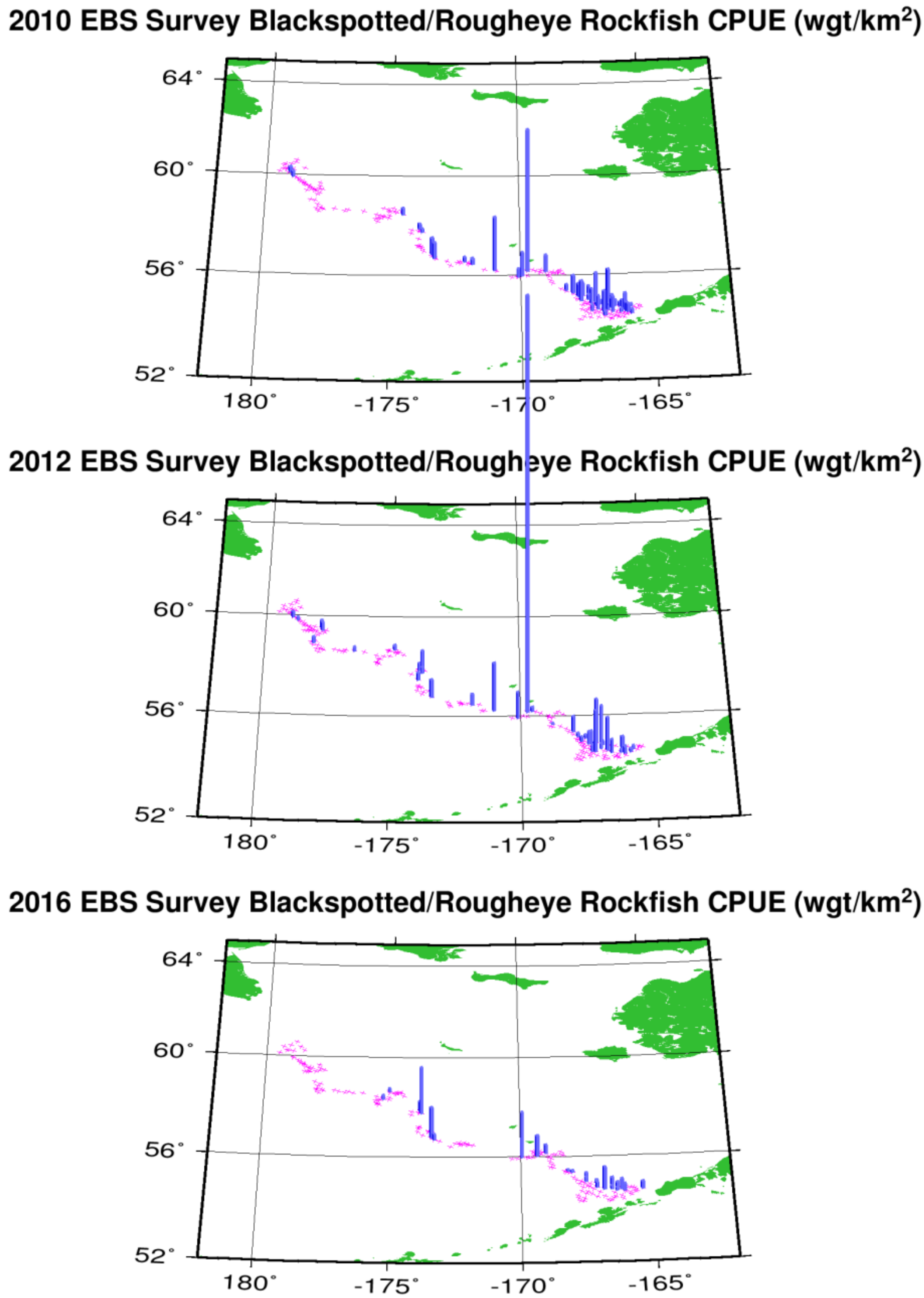


Figure 14.13. Scaled EBS survey combined blackspotted and rougheye rockfish CPUE (kg/km^2) from 2010-2016; the symbol × denotes tows with no catch.

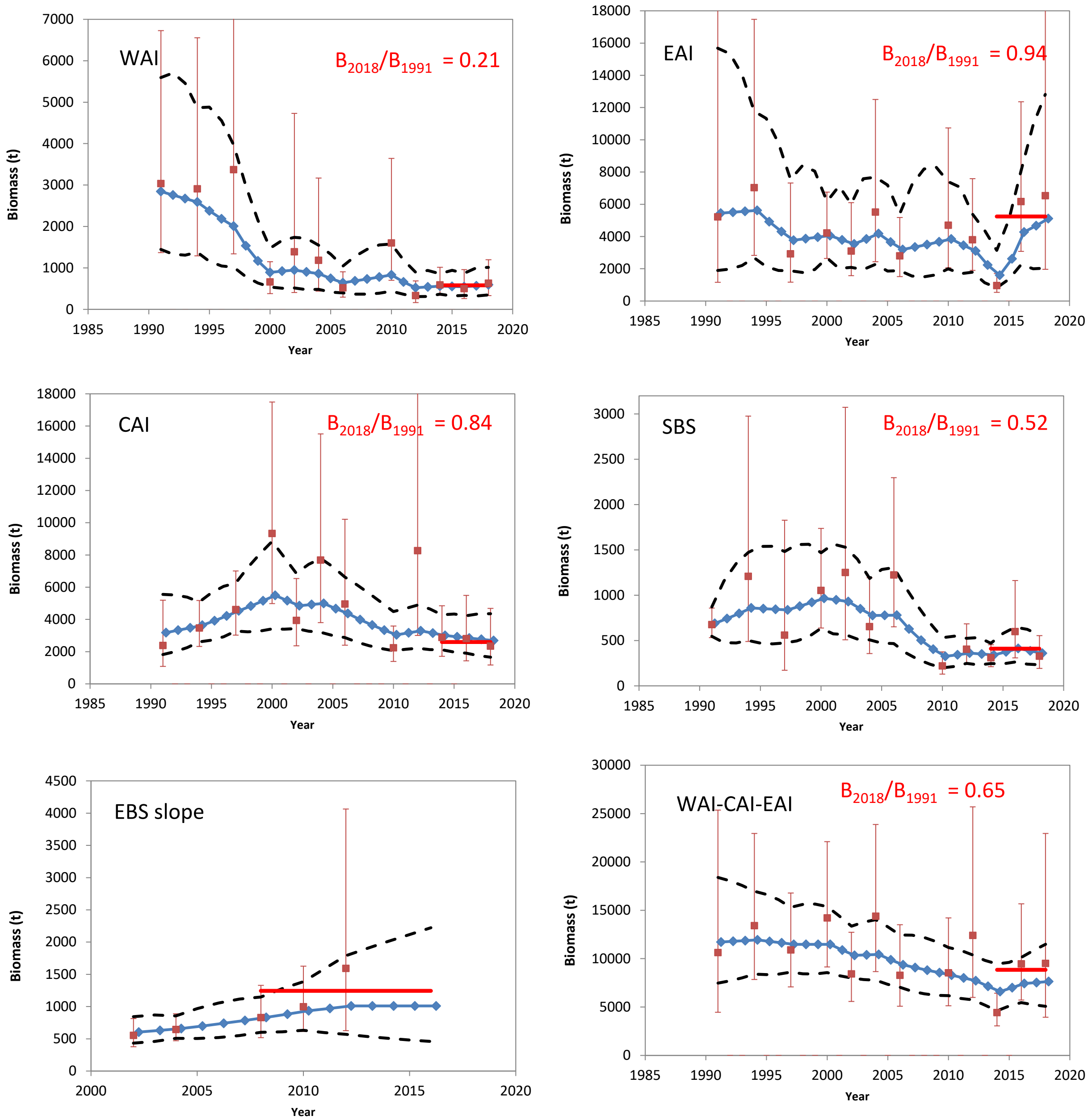


Figure 14.14. Time series of AI and EBS slope trawl survey biomass by subarea, with the fits from a random effects model to smooth the time series. The ratio of the biomass estimate in 2018 to that in 1991 indicates the estimated level of depletion over this time period. The horizontal red lines show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

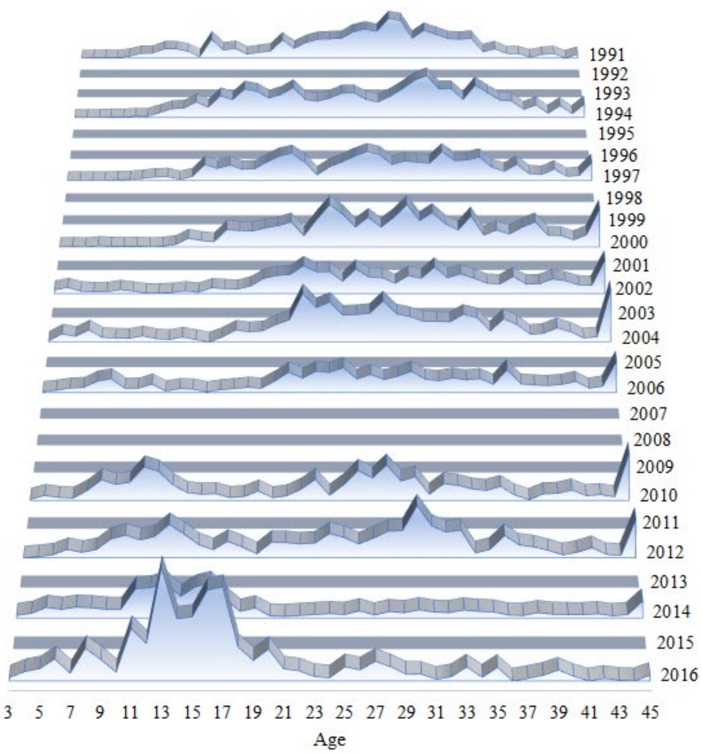


Figure 14.15. Estimated abundance by age from the Aleutian Islands trawl survey, 1991-2016.

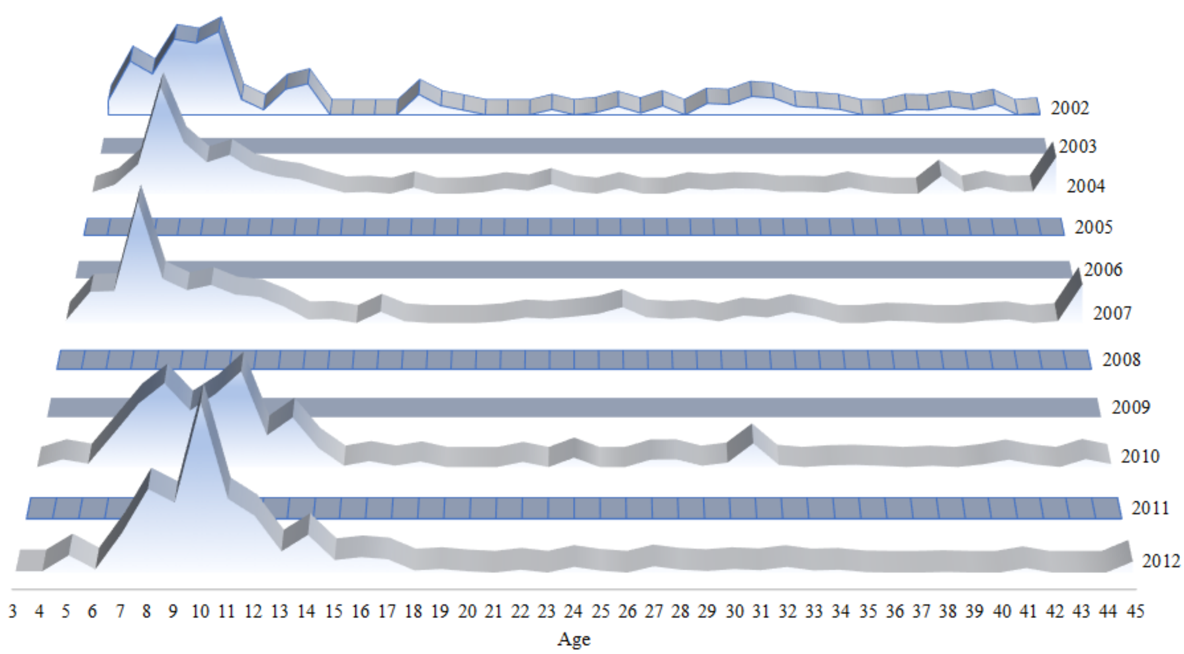
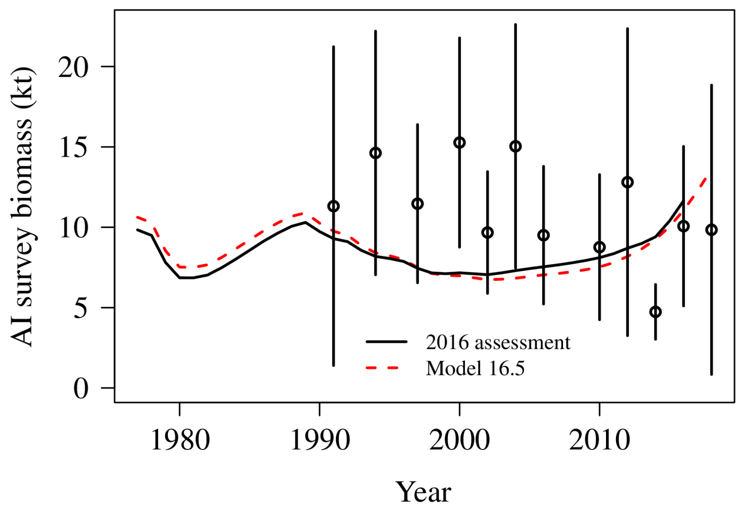


Figure 14.16. Estimated abundance by age from the eastern Bering Sea slope trawl survey, 2002-2012.



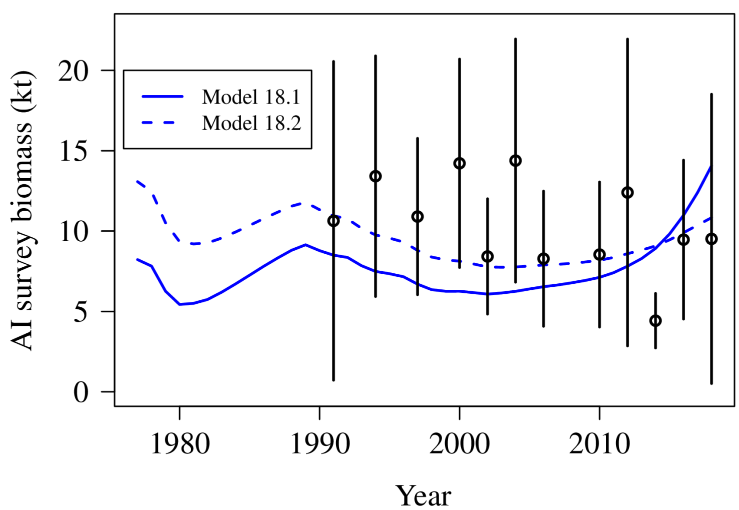


Figure 14.17. Estimated AI survey biomass for the BSAI models (a) and AI models (b) evaluated in this assessment.

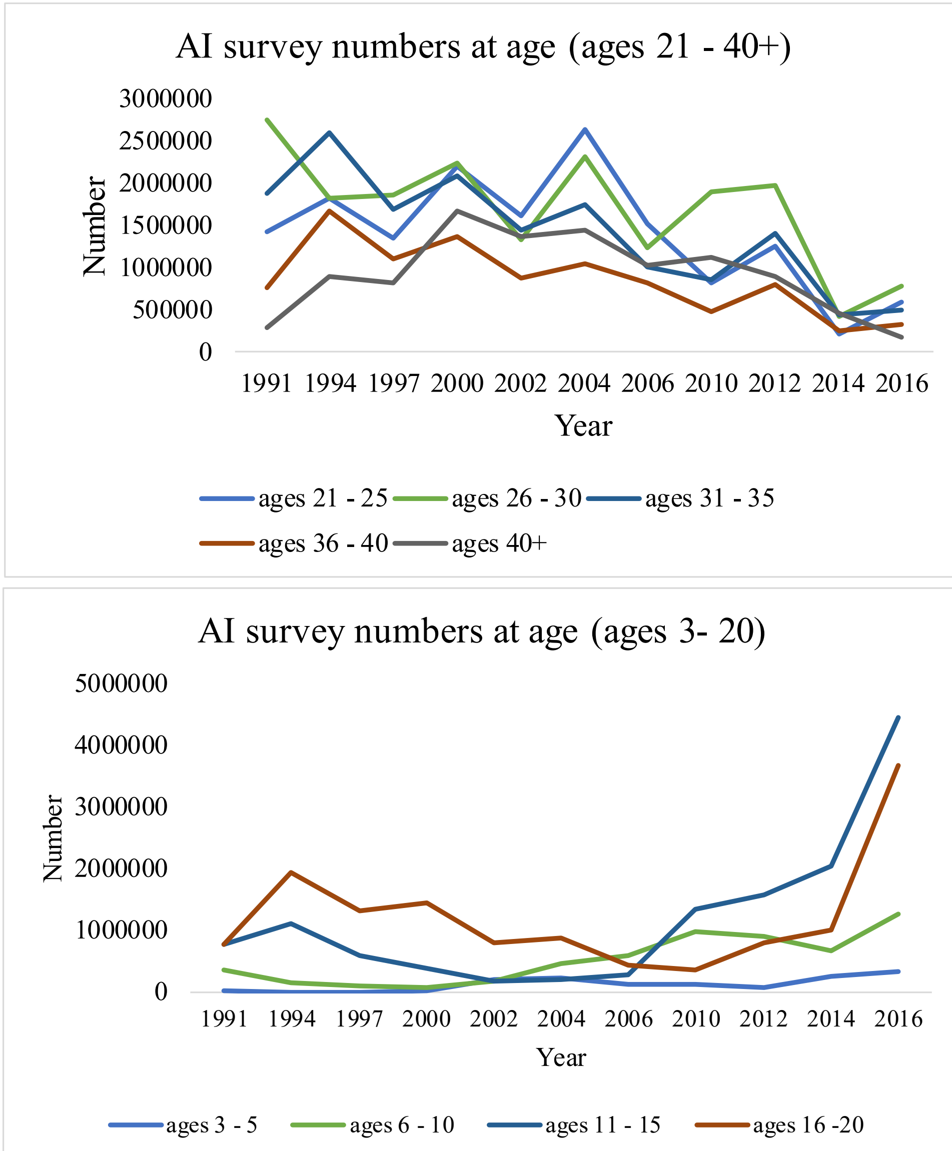


Figure 14.18. Estimated numbers, by age groups, from the AI trawl survey, 1991-2016.

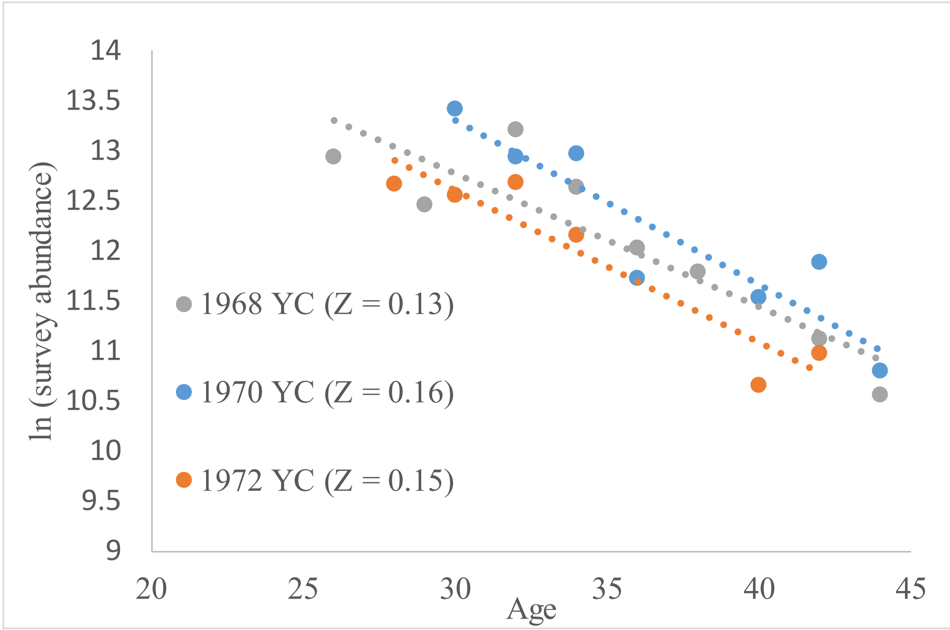


Figure 14.19. Catch curves applied to the estimated numbers at age from the AI trawl survey for the 1968, 1970, and 1972 cohorts.

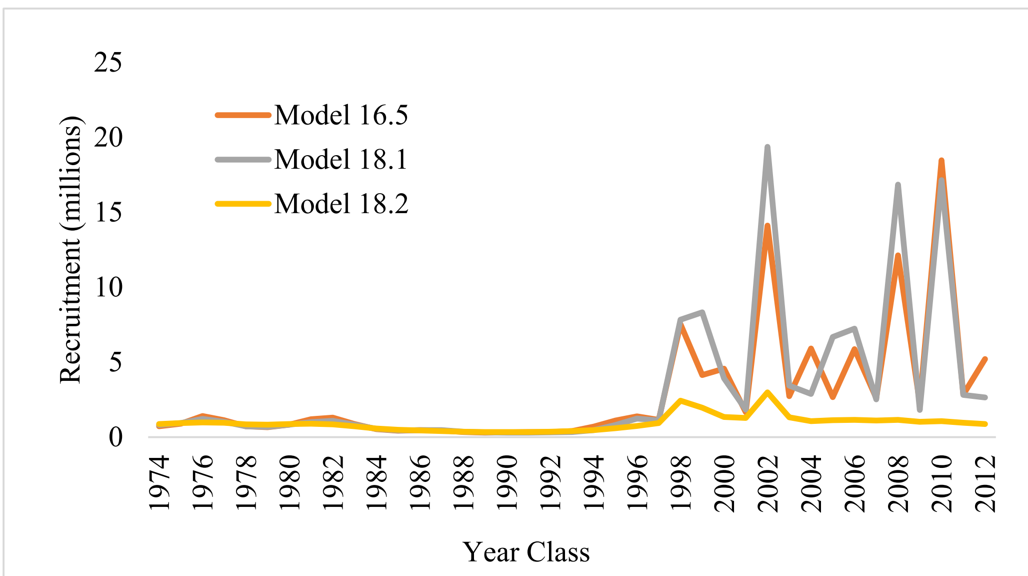


Figure 14.20. Estimated recruitment from the models considered in this assessment.

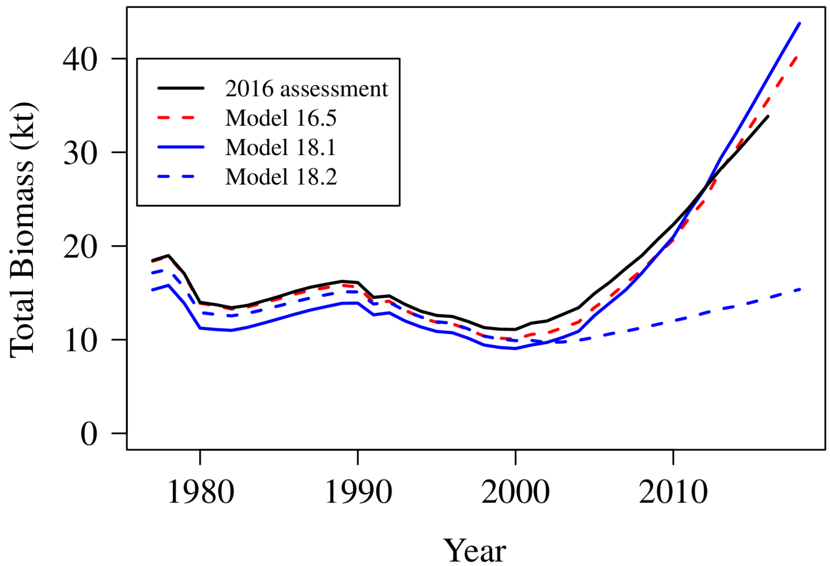


Figure 14.21. Estimated total biomass for the models evaluated in this assessment.

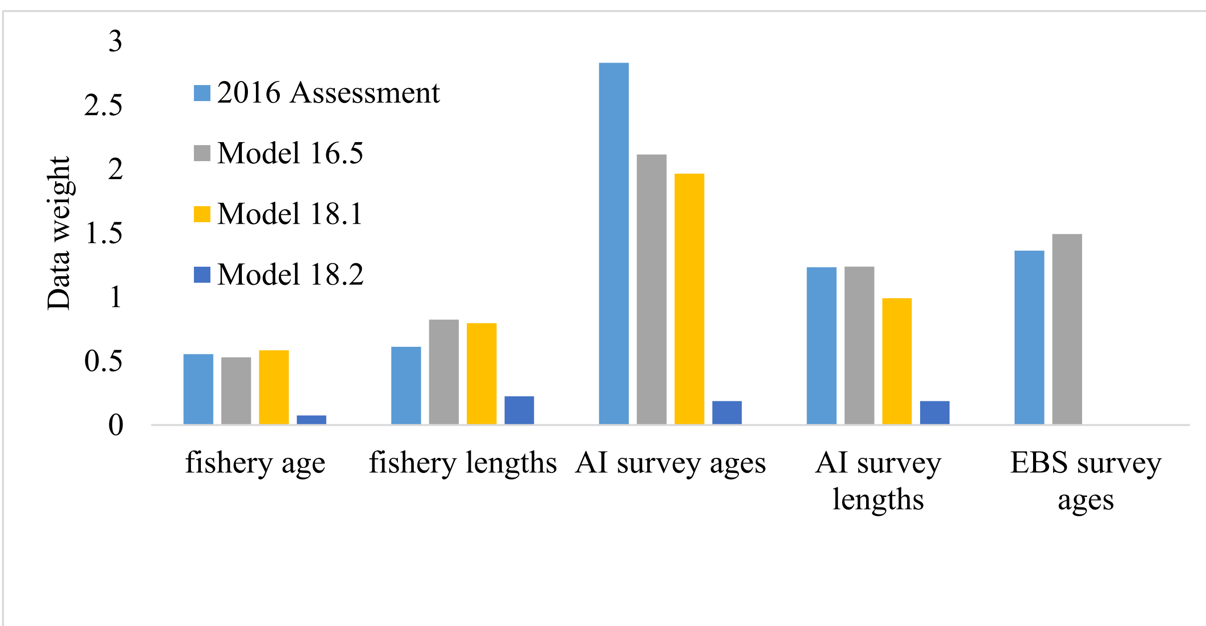


Figure 14.22. Weights for the age and length compositional data for the models evaluated in this assessment.

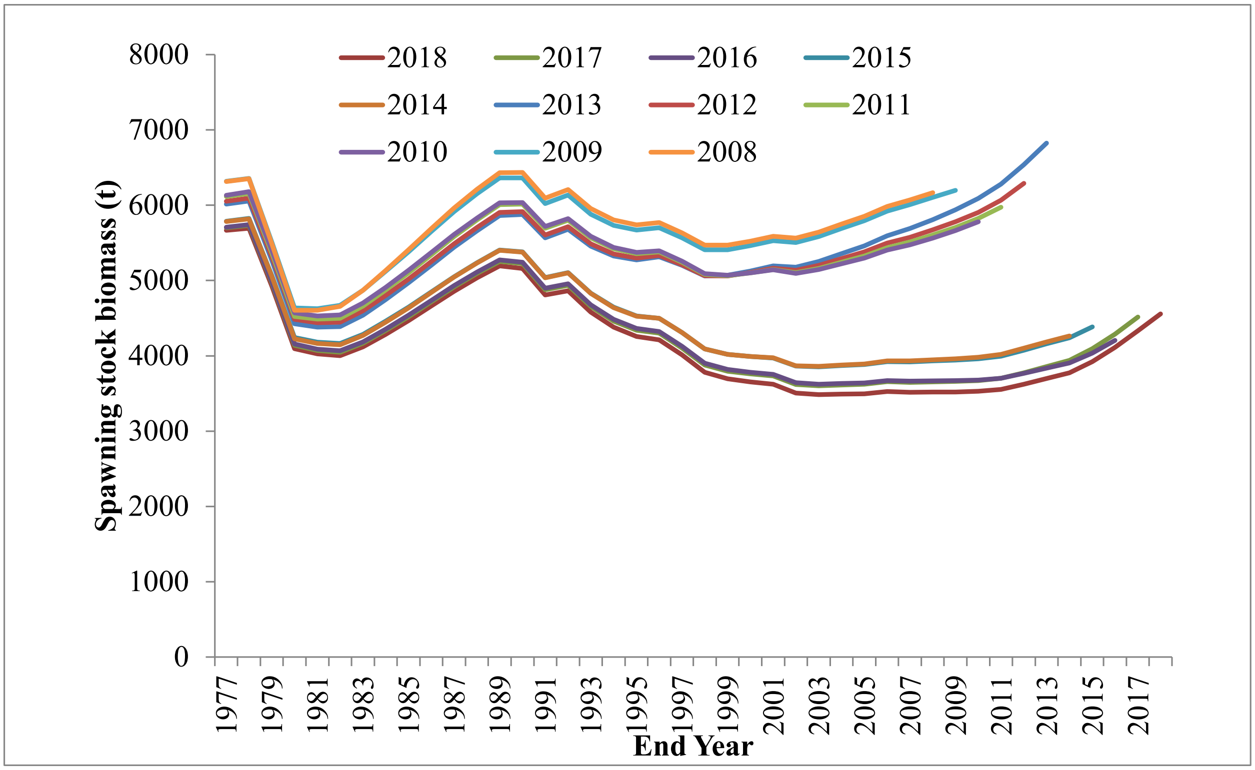


Figure 14.23. Retrospective estimates of spawning stock biomass for model runs with end years of 2008 to 2018.

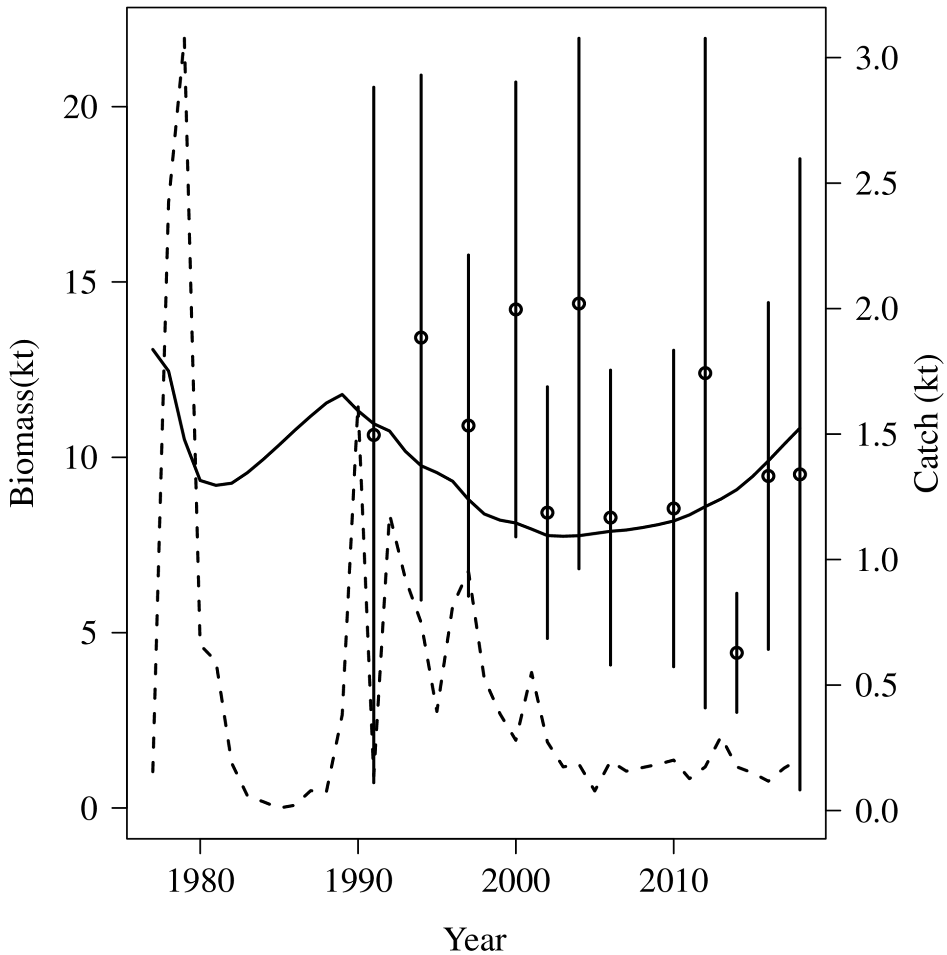


Figure 14.24. Observed Aleutian Islands (AI) survey biomass for blackspotted/rougheye rockfish (data points, +/- 2 standard deviations), predicted survey biomass (solid line), and harvest (dashed line).

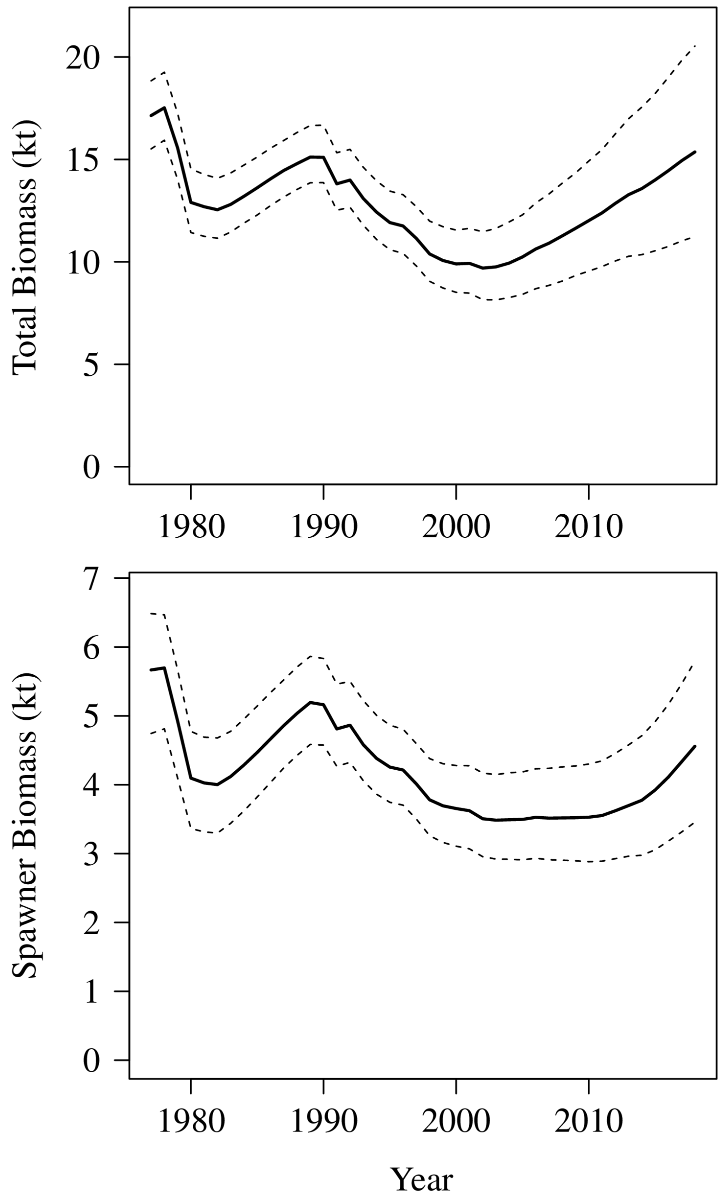


Figure 14.25. Total (top panel) and spawner (bottom panel) biomass for BSAI blackspotted/rougheye rockfish, with 95% confidence intervals from MCMC integration.

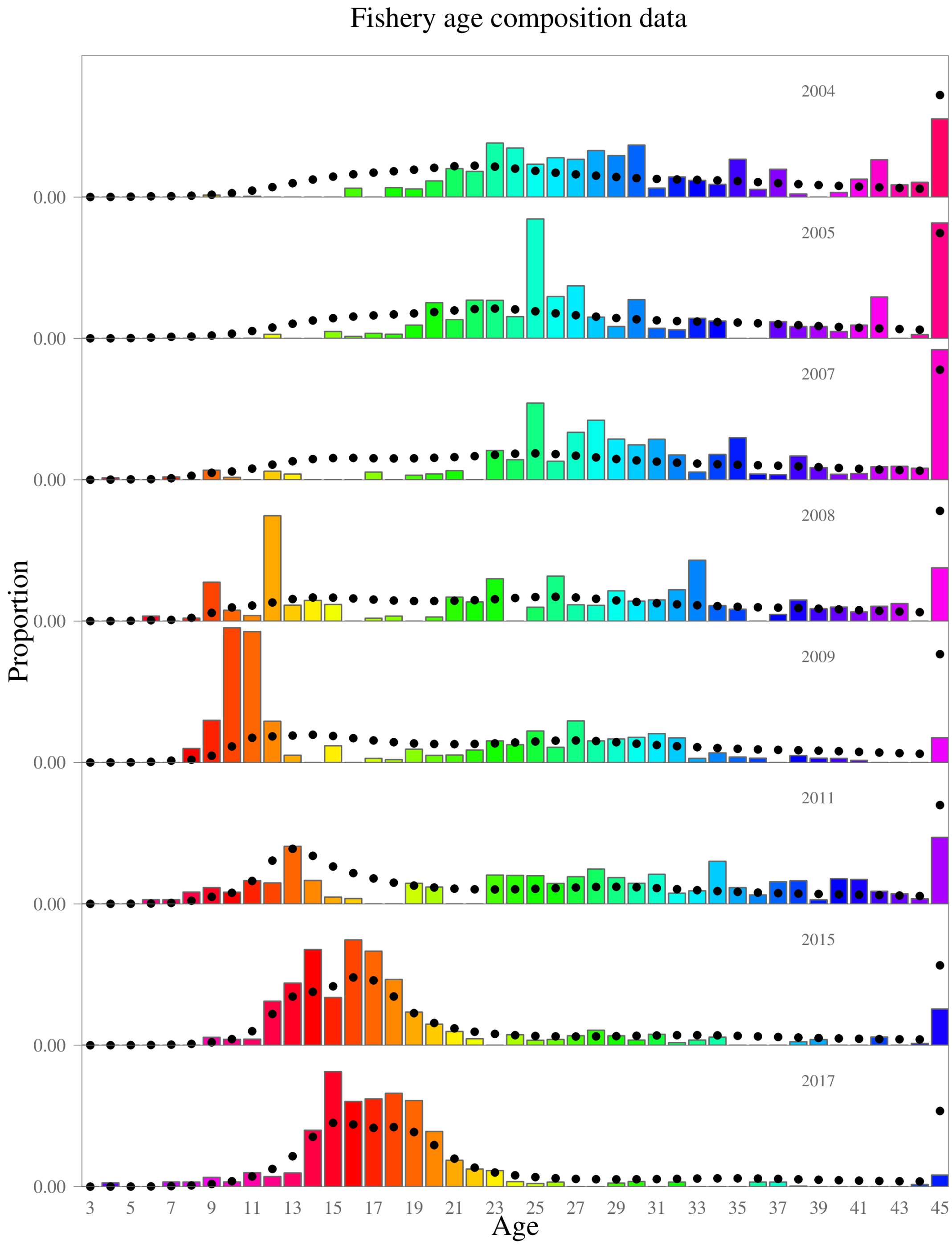


Figure 14.26. Model fits (dots) to the fishery age composition data (columns) for AI blackspotted/rougheye rockfish, 2004-2017. Colors of the bars correspond to cohorts (except for the 45+ group).

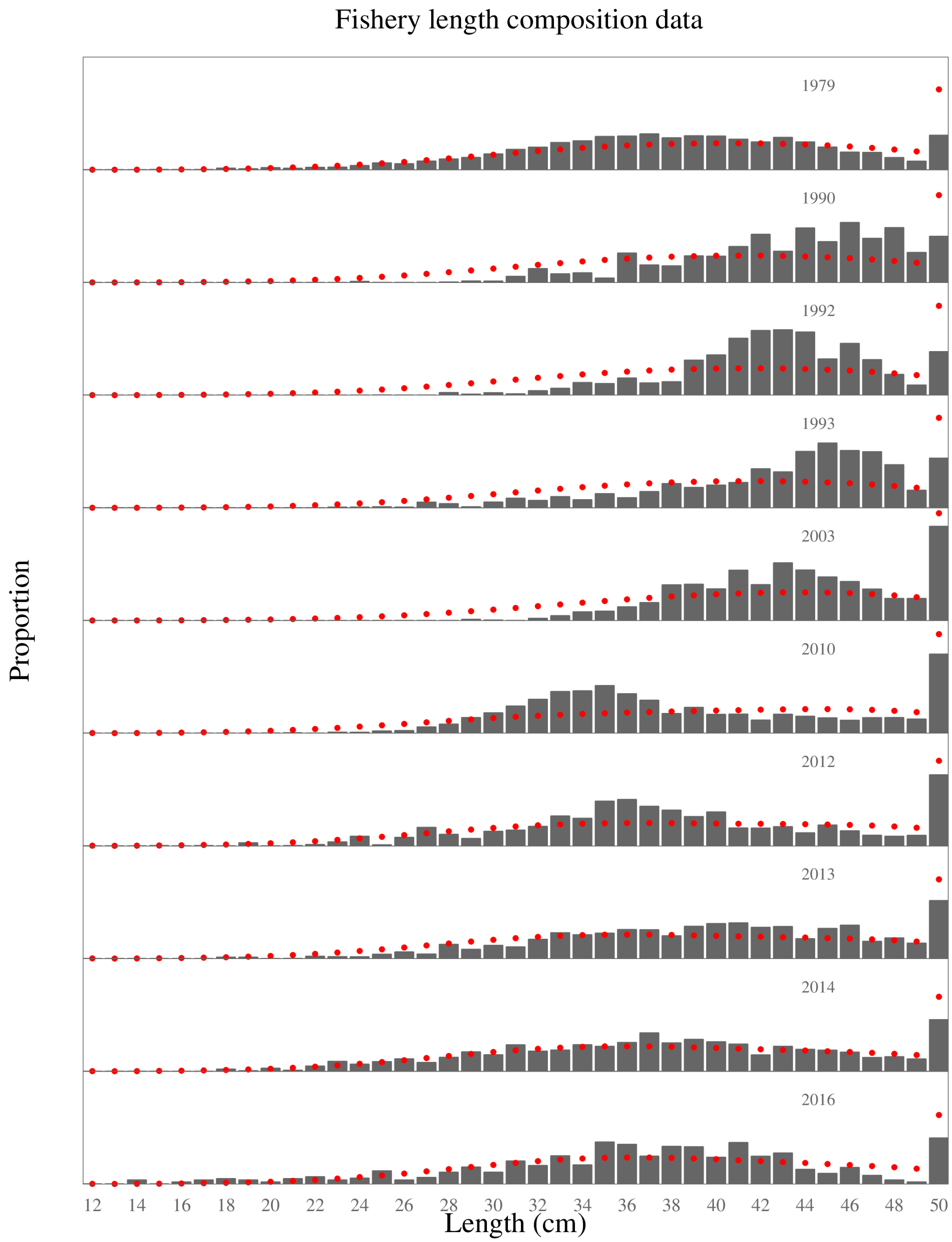


Figure 14.27. Model fits (dots) to the fishery length composition data (columns) for AI blackspotted/rougheye rockfish, 1979-2016.

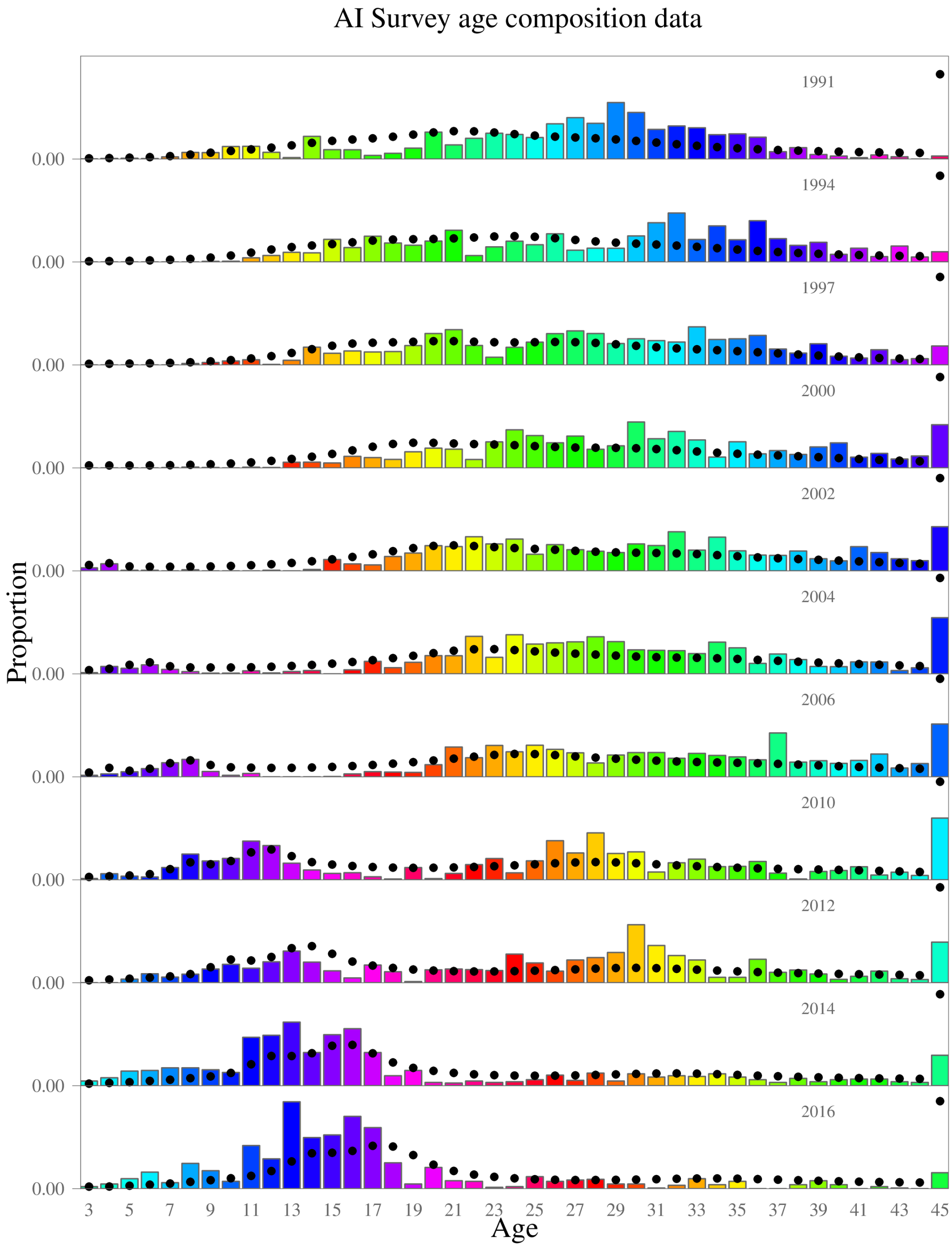


Figure 14.28. Model fits (dots) to the survey age composition data (columns) for Aleutian Islands (AI) blackspotted/rougheye rockfish, 1991-2016. Colors of the bars correspond to cohorts (except for the 45+ group).

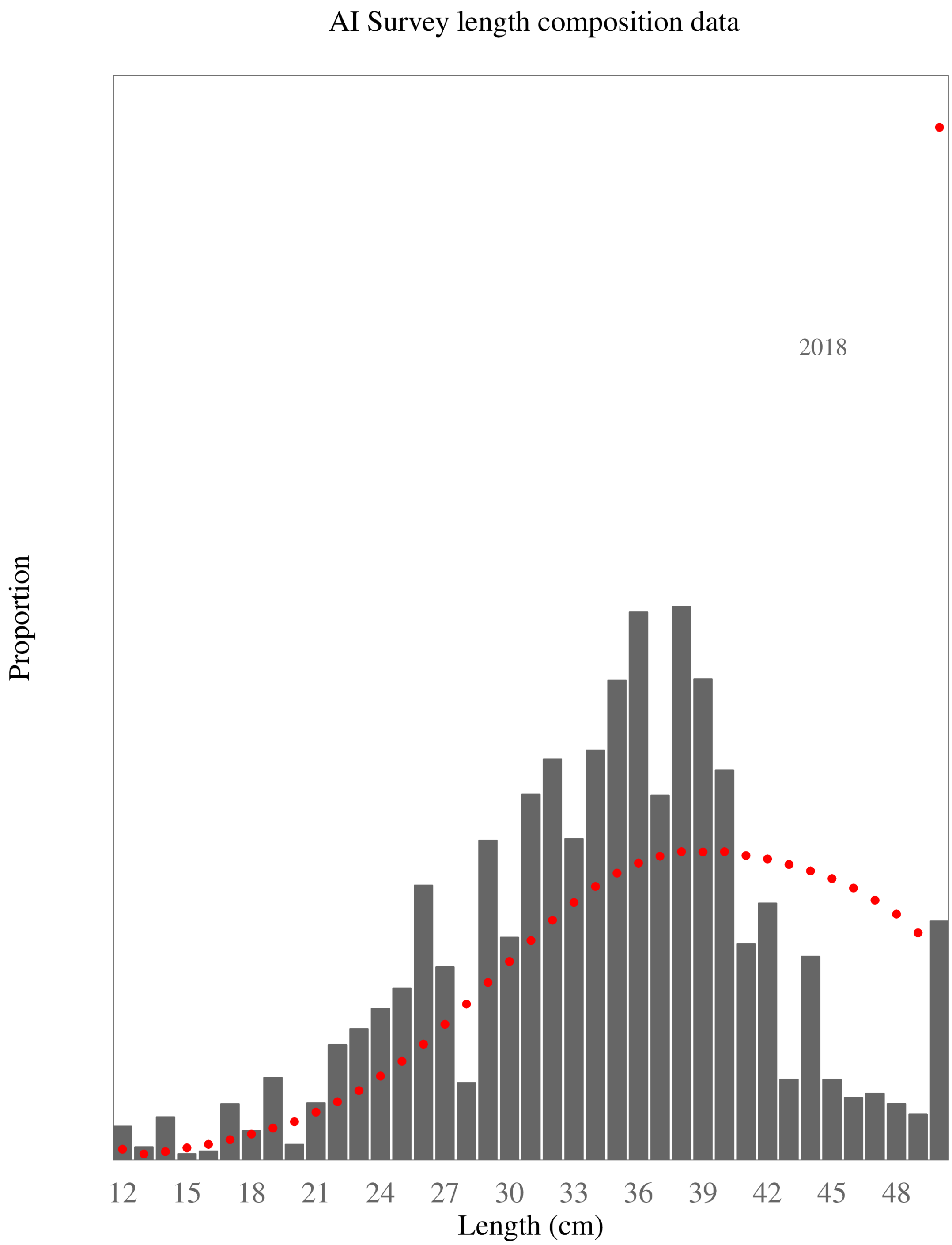


Figure 14.29. Model fits (dots) to the 2018 Aleutian Islands (AI) survey length composition data (columns) for the blackspotted/rougheye rockfish.

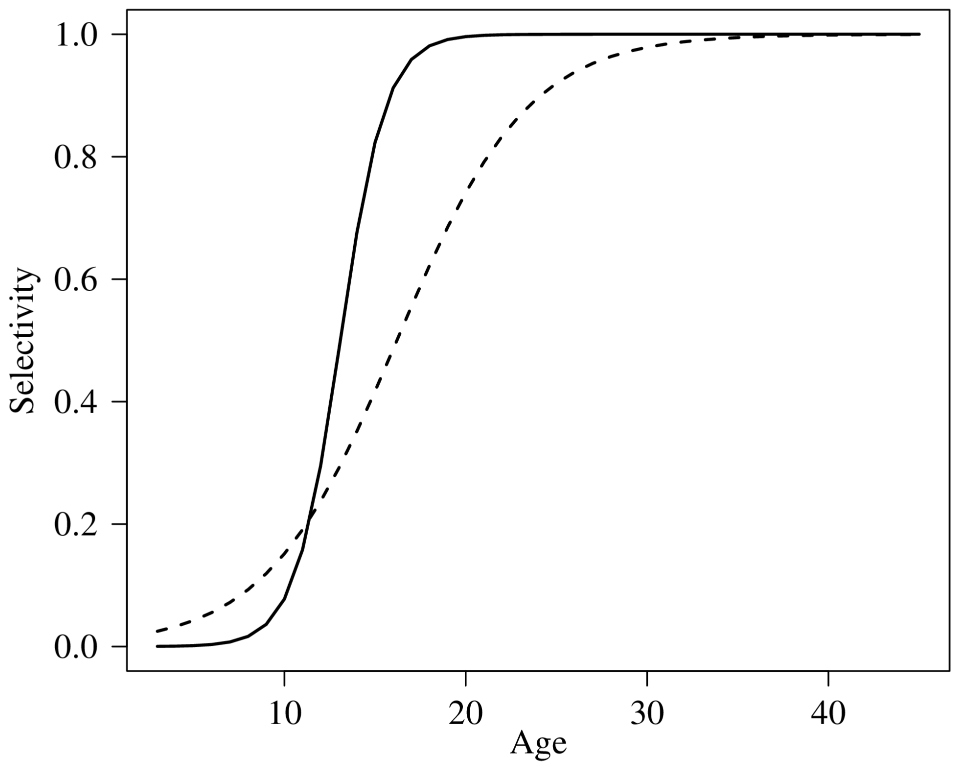


Figure 14.30. Estimated fishery (solid line) and AI survey (black dashed line) selectivity curves by age for blackspotted/rougheye rockfish.

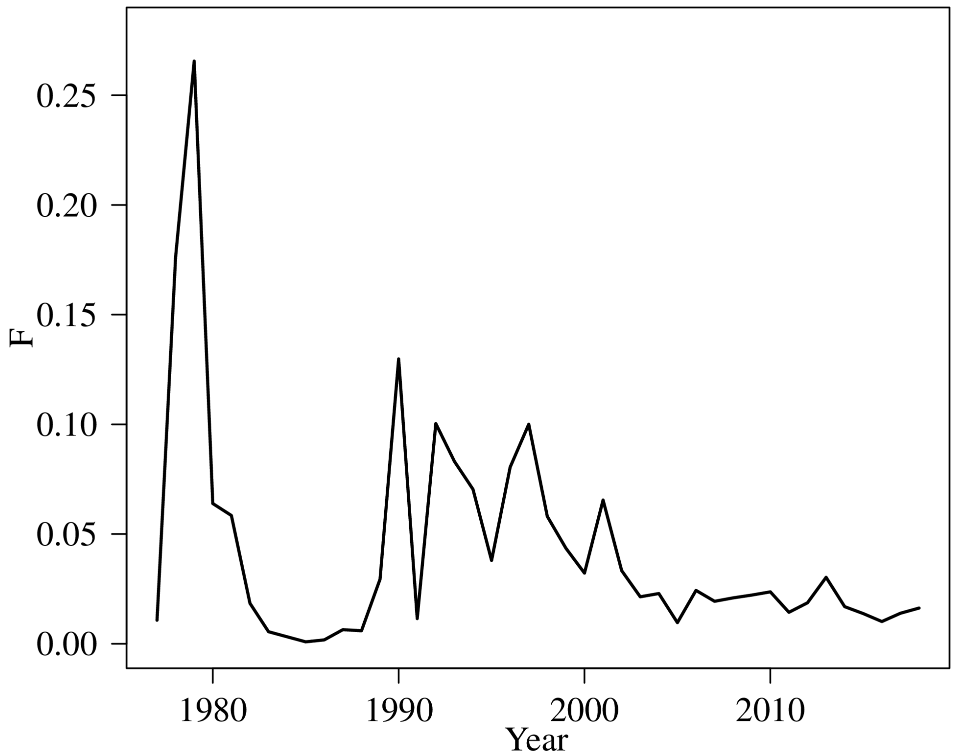


Figure 14.31. Estimated fully selected fishing mortality for blackspotted/rougheye rockfish.

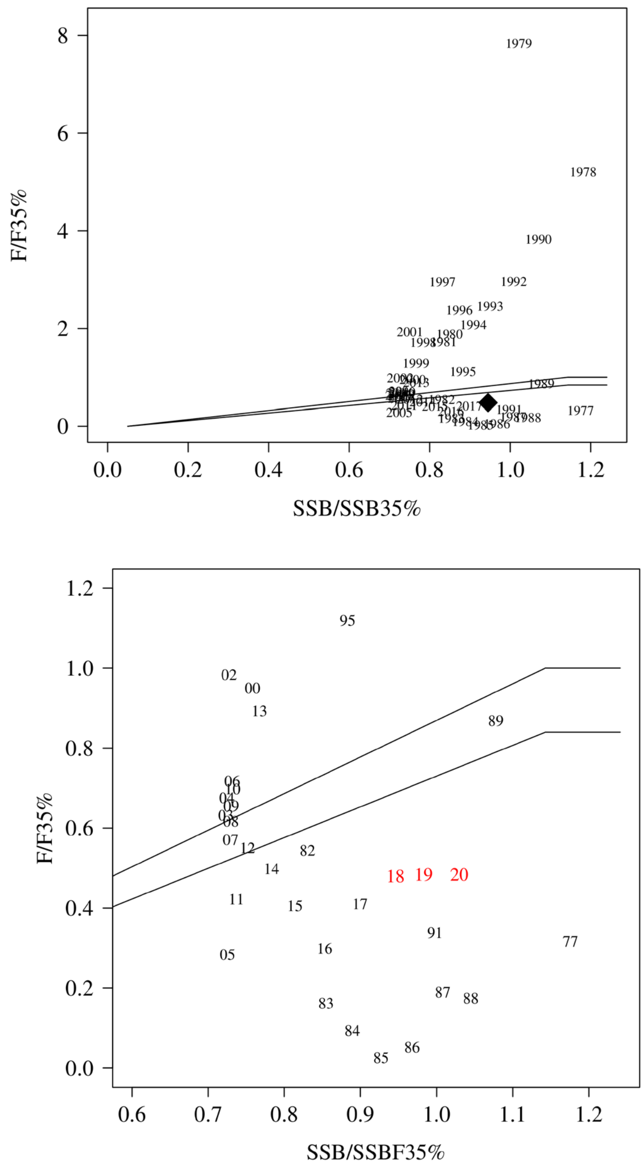


Figure 14.32. (Top panel) Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvest control rules, with 2018 shown as the diamond symbol. The bottom panel shows the projected stock status and *F* for 2019 and 2020.

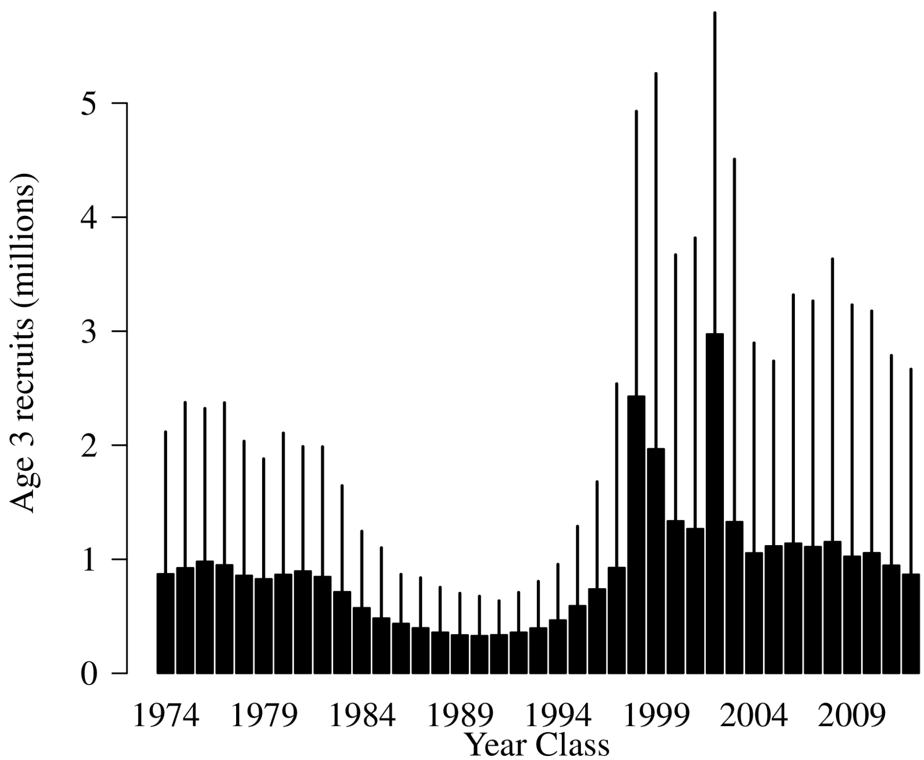


Figure 14.33. Estimated recruitment (age 3) of blackspotted/rougheye rockfish, with 95% CI limits obtained from MCMC integration.

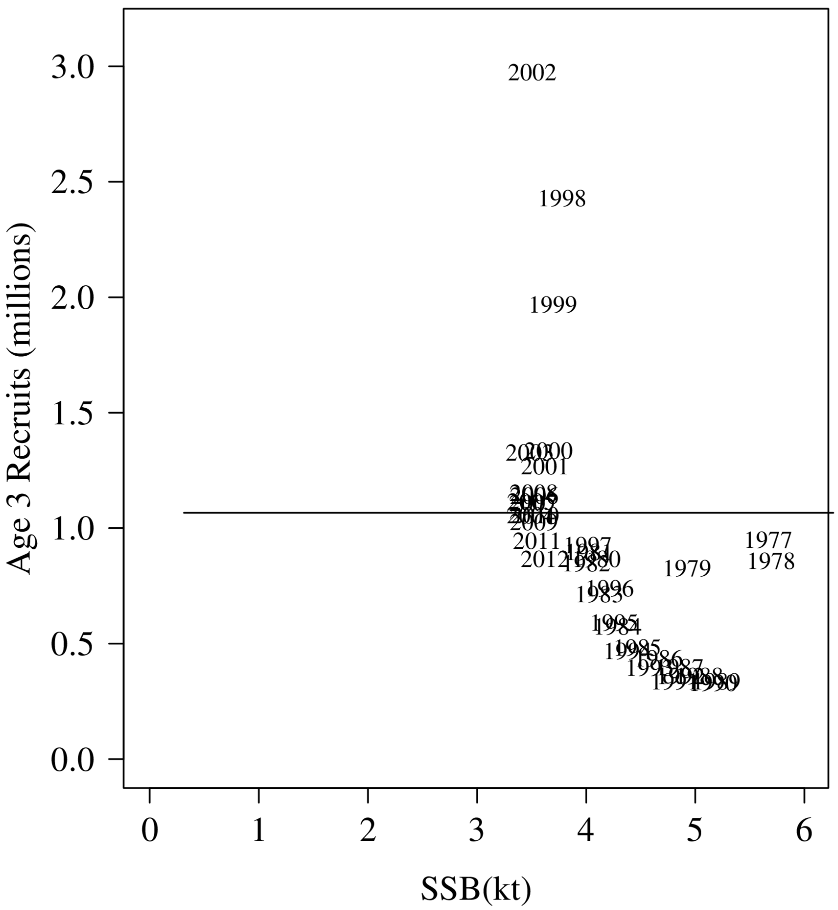


Figure 14.34. Scatterplot of blackspotted/rougheye rockfish spawner-recruit data; label is year class. Horizontal line is median recruitment.

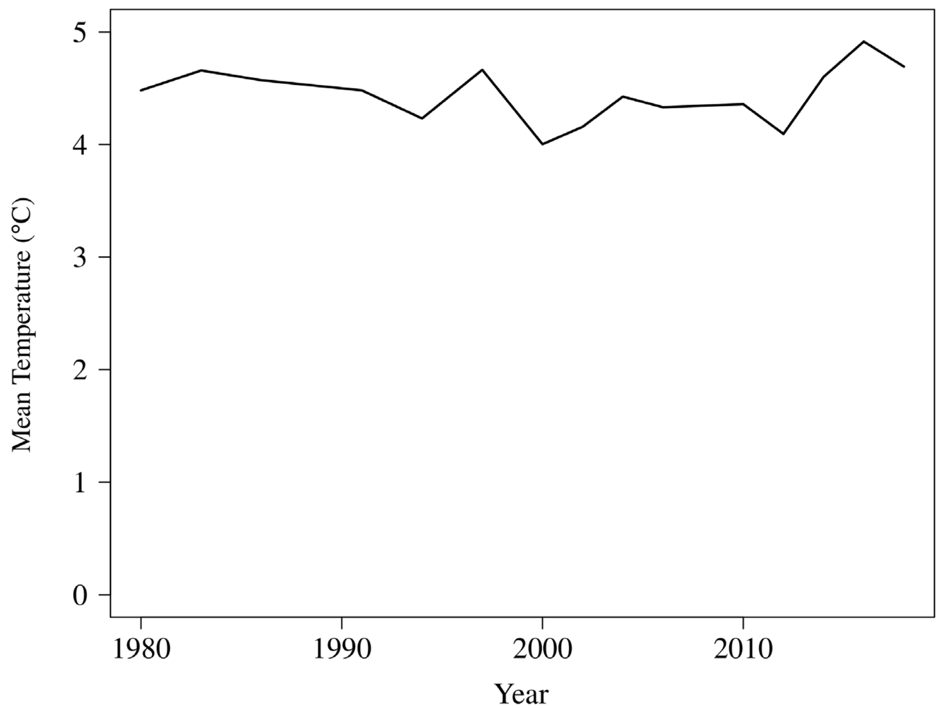
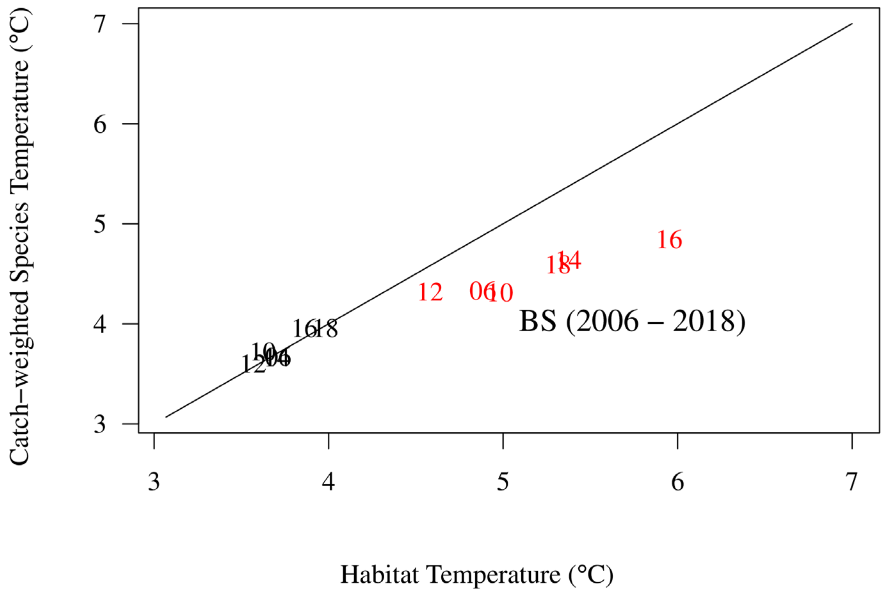


Figure 14.34. Mean temperature at trawl gear from AI bottom trawl surveys, 1980 – 2018.



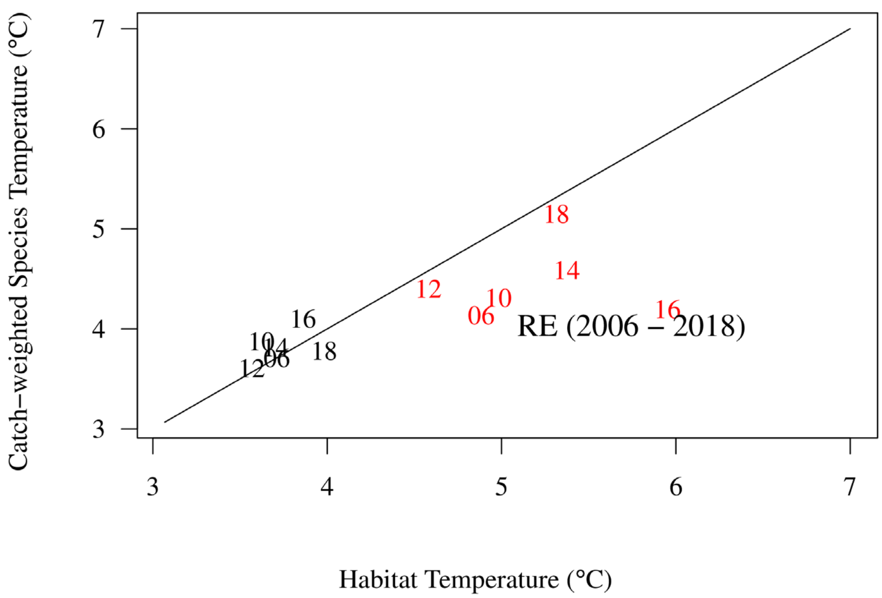


Figure 14.35. Temperatures at 10th (black) and 90th (red) percentiles of distributions of catch-weighted temperature, and overall habitat temperature, from the AI trawl survey (labeled by survey year) for blackspotted rockfish (top panel) and rougheye rockfish (bottom panel).

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 2018, the biomass for the subareas was obtained by partitioning the estimated total AI biomass (ages 3+) at the beginning of the year (obtained from 2018 AI blackspotted/rougheye age structured model). The biomass estimates from the 2018 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 6, 2018, 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 2018 (to date) have declined from generally higher levels from 2004-2013 (Figure 14A.1). However, the WAI exploitation rate in 2018 increased to 0.06, approximately 2.5 times $U_{F40\%}$ reference value of 0.024. The 2018 WAI exploitation rate is largest observed since 2013, which was 0.084. Reduced estimates of total biomass in recent years in the 2018 AI assessment model have increased the area-specific exploitation rates relative to estimates in previous assessments. 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 F40%. Exploitation rates for the other subareas have generally been at or below $U_{F40\%}$

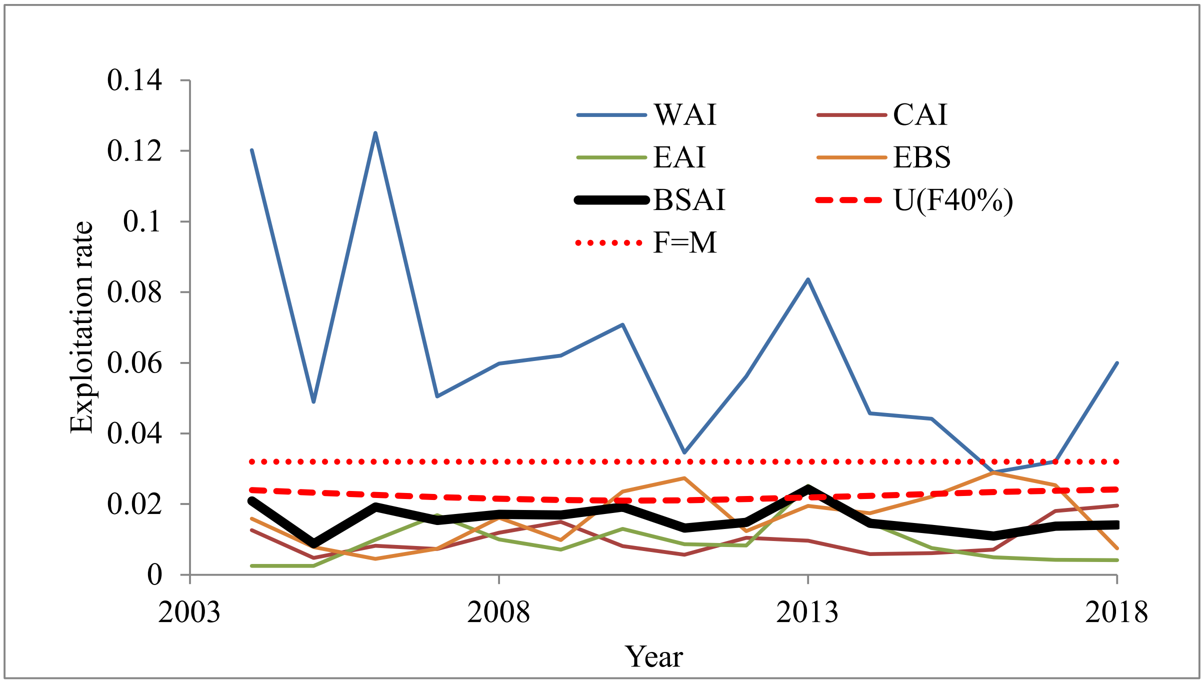


Figure 14A.1. Exploitation rates within BSAI subareas for blackspotted/rougheye rockfish, with reference exploitation rates of 0.75*M and $U_{F40\%}$.

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 0.6 t. Total removals ranged between 2010 and 2017 ranged between 0.016 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		0.000	0.299
2014		0.032	0.508
2015		0.004	0.216
2016		0.048	0.334
2017		0.000	1.08

Appendix 14C. Rockfish (BSAI) Economic Performance Report for 2017

Ben Fissel, Alaska Fisheries Science Center

November, 2018

Rockfish catch in the BSAI showed little change in 2017 from 2016 levels with a total catch of 38 thousand t and a retained catch 35 thousand t and remains near the recent highs over the past decade (Table 14C.1). Catches were similarly stable for both of the primary rockfish species northern rockfish and Pacific ocean perch. Rockfish are an important component of the Amendment 80 fleet's catch portfolio.[1] First-wholesale value of rockfish was up 21% in 2017 to $42 million with a 22% increase in the first-wholesale price to $1.09 per pound (Table 14C.1).

The most significant rockfish species caught in the BSAI in terms of volume and value is Pacific ocean perch, which typically accounts for approximately 90% of the total BSAI rockfish value (Table 14C.1). Northern rockfish is also caught in significant quantities, typically accounting for under 10% of the value. Other rockfish, such as rougheye and shortraker rockfish are caught in significantly smaller quantities. Rockfish in the BSAI are predominantly caught by catcher/processors in the Amendment 80 Fleet, which accounts for approximately 90% of the Pacific ocean perch and northern rockfish production volume and value. Vessels in the Amendment 80 fleet also target flatfish and Atka mackerel. Rockfish are among the more valuable species caught by the Amendment 80 fleet with an average price per pound that is roughly 80% higher than the flatfish prices, however the volume of catch is significantly smaller than flatfish catch. Rockfish are typically harvested close to the total allowable catch (TAC) and TACs for Pacific ocean perch are set at close to the Allowable Biological Catches (ABC). Because of this, annual changes in catch and production largely reflect changes in abundance and TAC. In recent years approximately 90-95% of the total rockfish catch has been retained.

Pacific ocean perch catch and production were stable in 2017 at 30.3 thousand t and 14.9 thousand t, respectively. Catch and production of northern rockfish was also stable at 3 thousand t and 2 thousand t, respectively. Rockfish are primarily processed in the headed-and gutted (H&G) product form which accounts for over 95% of the production value. Because of this changes in production volume largely reflect changes in catch (Table 14C.1). First-wholesale prices increased 23% for Pacific ocean perch to $1.12 per pound and increased 18% for northern rockfish to $0.76 per pound. Commensurate with the increase in price and stable production catch production and first-wholesale values were up. BSAI Pacific ocean perch first-wholesale value increased 22% to $36.9 million and northern rockfish value increased 21% to $3.4 million.

The majority of rockfish produced in the U.S. are exported, primarily to Asian markets. Pacific ocean perch is the only rockfish species with specific information in the U.S. trade data. Other species are aggregated into a non-specific category. Approximately 60% of the Pacific ocean perch exported from the U.S. goes to China (Table 14C.2). Exported H&G rockfish to China is re-processed (e.g., as fillets) and re-exported to domestic and international markets. Rockfish are also sold to Chinese consumers, as whole fish. The U.S. has accounted for just over 15% of global rockfish production in recent years and 85-90% of global Pacific ocean perch production. Global production of rockfish has increased 10% from the 2008-2012 average to 313 thousand t in 2016 and global production of Pacific ocean perch has increased

[1] The Amendment 80 Fleet is the group of catcher processors managed under Amendment 80 to the BSAI FMP which rationalized the non-pollock groundfish fisheries in the BSAI.

52%. Global production of Atlantic redfish, a market competitor to Pacific ocean perch, has remained stable. The U.S. dollar was relative stability in 2017 against other currencies, such as the Chinese Yuan, which mitigates its potential impact on market price. Export price data through July 2018 indicate a potential drop in the Pacific ocean perch price (Table 14C.2). Tariffs implemented in 2018 between the U.S. and China and the associated uncertainty with trade policy has the potential to negatively affect rockfish markets, both as a direct market for rockfish exports and because of China's significance as a re-processor of rockfish products.

Table 14C.1. BSAI rockfish catch and first-wholesale market data. Total and retained catch (thousand metric tons), Pacific ocean perch and northern share of retained catch, number of vessel, first-wholesale production (thousand metric tons), value (million US$), Pacific ocean perch and northern share of value and price (US$ per pound), and head and gut share of value; 2008-20012 average and 2013-2017.

	2008-2012 Average	2013	2014	2015	2016	2017
Total catch K mt	24.2	34.9	36.1	39.6	36.9	38.4
Retained catch K mt	21.1	31.7	32.3	37.5	35.3	35.5
Pac. Ocn. perch share of retained	85%	91%	91%	80%	86%	85%
Northern share of retained	10%	5%	6%	18%	12%	12%
Vessels #	18.4	20	23	20	21	20
First-wholesale production K mt	11.3	16.9	18.0	19.4	17.6	17.4
First-wholesale value M US$	$31.5	$39.7	$47.1	$42.8	$34.7	$42.0
First-wholesale price/lb US$	$1.26	$1.07	$1.18	$1.00	$0.90	$1.09
Pac. Ocn. perch share of value	86%	92%	90%	83%	87%	88%
Pac. Ocn. perch price/lb US$	$1.26	$1.06	$1.19	$1.05	$0.91	$1.12
Northern rockfish share of value	7%	3%	5%	14%	8%	8%
Northern rockfish price/lb US$	$1.00	$0.72	$0.91	$0.74	$0.64	$0.76
H&G share of value	96%	97%	97%	97%	94%	95%

Source: NMFS Alaska Region Blend and Catch-accounting System estimates; NMFS Alaska Region At-sea Production Reports; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Table 14C.2. Rockfish U.S. trade and global market data. Global production (thousand metric tons), U.S. share of global production, BSAI share of U.S. production. U.S. yellowfin sole and rock sole export volume (thousand metric tons), U.S. export value (million US$), U.S. export price (US$ per pound), the share of U.S. export value from China, and the Chinese Yuan/U.S. Dollar exchange rate; 2008-20012 average and 2013-2017.

	Avg 08-12	2013	2014	2015	2016	2017	2018 (thru July)
Global production of rockfish K mt	283.8	289.1	285.5	301.9	313.4	-	-
Global production of Pac. Ocn. perch K mt	38.6	49.7	53.0	55.5	58.5	-	-
perch	84.1%	86.6%	89.5%	86.6%	88.5%	-	-
U.S. Pac. Ocn. perch share of global rockfish	11.4%	14.9%	16.6%	15.9%	16.5%	-	-
Export volume of Pac. Ocn. perch K mt	10.2	20.1	23.8	22.7	25.6	22.7	11.1
Export value of Pac. Ocn. perch M US$	$19.2	$66.4	$79.6	$77.7	$84.6	$76.1	$34.0
Export price/lb of Pac. Ocn. perch US$	$0.85	$1.50	$1.52	$1.55	$1.50	$1.52	$1.39
China's share of U.S. Pac. Ocn. perch export value	63%	42%	65%	52%	67%	55%	66%
Exchange rate, Yuan/Dollar	6.66	6.20	6.14	6.23	6.64	6.76	6.31

Source: FAO Fisheries & Aquaculture Dept. Statistics http://www.fao.org/fishery/statistics/en. NOAA Fisheries, Fisheries Statistics Division, Foreign Trade Division of the U.S. Census Bureau, http://www.st.nmfs.noaa.gov/commercial-fisheries/foreign-trade/index. U.S. Department of Agriculture http://www.ers.usda.gov/data-products/agricultural-exchange-rate-data-set.aspx.

1 - The BSAI FMP share of U.S. production is calculated as the BSAI retained catch divided by the FAO's U.S. production of flounder, halibut and sole.