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

by

Paul D. Spencer and Chris N. Rooper

Executive Summary

Fish previously referred to as rougheye rockfish are now recognized as consisting of two species, the 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 assessments from 2008-2015 were based on an age-structured model which has been applied to the Aleutian Islands (AI) portion of the population whereas the eastern Bering Sea (EBS) portion of the population are assessed with Tier 5 methods applied to survey biomass estimates. In this assessment, we recommend an age- structured model applied to the BSAI area, and use of the EBS slope survey biomass estimates and age composition.

The last full assessment for blackspotted and rougheye rockfish was presented to the Plan Team in 2014. The following changes were made relative to the November 2014 SAFE:

Summary of Changes in Assessment Inputs

Changes in the input data

1) Catch data was updated through 2015, and total catch for 2016 was projected.
2) The AI survey age/length composition data, and survey biomass estimates, were recomputed to incorporate the entire survey area (including the southern Bering Sea area).
3) The fishery age/length compositional data was recomputed to include the data in the EBS management area.
4) The fishery age and length composition data were recomputed to weight the length composition within subareas by the observed subareas catch.
5) The eastern Bering Sea slope survey biomass estimates and age composition data (through 2012) were included in the assessment.
6) The 2016 AI survey biomass estimate and length composition were included in the assessment.
7) The 2012 AI survey age composition was included in the assessment.
8) The 2014 and 2015 BSAI fishery length compositions were included in the assessment.
9) 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) In the 2014 assessment, the weights for the age/length composition data were obtained such that the standardized deviation of normalized residuals was a constant value (1) for all composition data types. Several methods for weighting the composition data were considered in this assessment, with the preferred model using the McAllister-Ianelli method.

2) An age-structured model is proposed for the BSAI area as a whole; previously the EBS area was assessed using Tier 5 methods.

Summary of Results

Previous assessments have large estimates for the 1998 year class, from 12.5 million in the 2010 assessment, 11.0 million in the 2012 assessment, and 23.1 in the 2014 assessment (Spencer and Rooper 2014), and this year class has composed a large share of the biomass. In this assessment, the estimated size of the 1998 year class is lowered to 9.5 million, more consistent with the 2010 and 2012 assessments. This reduction is based on new compositional data, including the EBS slope survey age compositions and recent fishery length compositional data, which do not support such a dominant 1998 year class. The 1998 year class is still estimated as relatively large, but in this assessment it is one of a few large year classes rather than a sole dominant year class. The reduction in the estimated size of the 1998 year class results in lower estimated biomass in recent years.

The EBS slope survey data are largely consistent with the AI-only data used in previous model, particularly the increase in biomass in recent years. However, some differences exist in the magnitude of strong year classes such as the 1998 year class, which are not as prominent in the EBS age composition data. The EBS slope survey has higher proportions of young fish than in the AI survey, which resulted in an EBS survey selectivity curve with relatively low age at 50% selection of 5.3 years.

BSAI blackspotted/rougheye rockfish remain a Tier 3b stock, and the degree to which the current spawning biomass is below B40% is sensitive to the set of years used to compute average recruitment. The protocol recommended by the Plan Team workgroup on recruitment would include the 1977-2002 cohorts, but the year class for 2002 is very large and results in a large $B_{40\%}$ that lowers relative stock status and F for 2017. The recommended set of year classes in this assessment is to use year classes 1977-2000, which avoids use of the 2002 year class until more observations of that year class become available in the future.

The survey biomass in the western AI remains low, with the survey biomass estimate for the area decreasing from 589 t in 2014 to 501 t in 2016. Mean size is also remains low in this area, although in the 2016 survey mean size was relatively low across all AI survey subareas. The 2016 survey biomass in the eastern AI increased from a very low value in 2014, and now is relatively consistent with other high estimates in the time series. The increase of biomass in this area lowers the relative proportion in other AI areas, which results in changes in the partitioning of the subarea ABCs.

A summary of the 2016 recommended ABC’s (from the BSAI model) relative to the 2015 recommendations (from an AI model) is shown below.

Quantity	As estimated or *specified* last year for: 2016	2017	As estimated or *recommended* this year for: 2017*	2018*
M (natural mortality rate)	0.033	0.033	0.033	0.033
Tier	3b	3b	3b	3b
Projected total (age 3+) biomass (t)	42,605	44,682	35,669	37,474
Female spawning biomass (t)				
Projected	9,076	10,307	7,305	8,188
$B_{100\%}$	28,507	28,507	20,777	20,777
$B_{40\%}$	11,403	11,403	8,311	8,311
$B_{35\%}$	9,977	9,977	7,272	7,272
F_{OFL}	0.045	0.051	0.048	0.054
$maxF_{ABC}$	0.037	0.042	0.039	0.044
F_{ABC}	0.037	0.042	0.039	0.044
OFL (t)	649	811	612	750
maxABC (t)	528	661	501	614
ABC (t)	528	661	501	614
Status	As determined *last* year for: 2014	2015	As determined *this* year for: 2015	2016
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 169 t and 183 t used in place of maximum permissible ABC for 2017 and 2018.

The BSAI blackspotted/rougheye stock complex was not subjected to overfishing in 2016, and 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 2017 and 2018 and the recent OFLs, ABCs, TACs, and catches.

Area/subarea	Year	Total Biomass (t)[1]	OFL	ABC	TAC	Catch[2]
BSAI	2015	41,780	560	453	349	173
	2016	43,944	693	561	300	149
	2017	35,669	612	501	n/a	n/a
	2018	37,474	750	614	n/a	n/a
Western/Central Aleutian Islands	2015			304	200	117
	2016			382	200	85
	2017			207	n/a	n/a
	2018			252	n/a	n/a
Eastern AI/Eastern Bering Sea	2015			149	149	64
	2016			179	100	64
	2017			294	n/a	n/a
	2018			362	n/a	n/a

[1] For 2015-16, the total biomass from AI age-structured model, and survey biomass estimates from EBS. For 2017-2018, the total biomass from a BSAI age-structured model
[2] BSAI catch as of October 10, 2016.

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 2017 and 2018 MSSC values are shown below.

	WAI MSSC	CAI MSSC
2017 MSSCs	31	176
2018 MSSCs	37	215

Responses to SSC and Plan Team Comments on Assessments in General

(Joint Plan Team, November, 2014) *For assessments involving age-structured models, this year's CIE review of BSAI and GOA rockfish assessments included three main recommendations for future research:*

1. *Selectivity/fit to plus group (e.g., explore dome-shaped selectivity, cubic splines)*
2. *Reevaluation of natural mortality*
3. *Alternative statistical models for survey data (e.g., GAM, GLM, hurdle models)*

The Team agreed that development of alternative survey estimators is a high priority, but concluded that this priority is not specific to rockfish, and should be explored in a Center-wide initiative (see "Alternative statistical models for survey data" under Joint Team minutes). For the remaining two items, the Team recommended that selectivity and fit to the plus group should be given priority over reevaluation of the natural mortality rate.

Selectivity curves and natural mortality rates were evaluated in the 2014 assessment. The development of alternative survey estimators (i.e., model-based standardization of survey catch data) affects all NPFMC assessments that use survey data. Potential methodologies have been discussed in a limited number of meetings in 2014 among AFSC scientists, and between AFSC scientists and NWFSC scientists. Recently, scientists at the NWFSC have developed geostatistical models for survey standardization.

The minutes of the September, 2016 meeting of the Joint Groundfish Plan Team indicate that a workgroup is currently being formed to evaluate statistical models for survey standardization.

(GOA Plan Team, November 2015) *The Team recommends an evaluation on how best to tailor the RE model to accommodate multiple indices.*

Although this comment originated from the GOA Plan Team, it is also relevant the BSAI assessments. The random effects model is applied to the biomass estimates of the AI trawl survey and EBS slope survey to obtain ABC apportionments. In previous assessments, a simple summation of the smoothed estimates was done, implying that the catchability and selectivity of the two surveys were equivalent. The recommended model in this assessment estimates catchability and selectivity for both surveys, and this information was used to adjust the smoothed EBS slope survey index into units consistent with the AI survey.

(SSC, December 2015) *Many assessments are currently exploring ways to improve model performance by re-weighting historic survey data. The SSC encourages the authors and PTs to refer to the forthcoming CAPAM data-weighting workshop report.*

(SSC, October 2016) *The SSC recommends that the Gulf of Alaska Groundfish Plan Team (GOA GPT), BSAI GPT, and CPT encourage the continued use of multiple approaches to data weighting (not just the Francis (2011) method, but also including the harmonic mean and others).*

In this assessment, we evaluate several methods for weighting the age and length composition data. Weighting of the survey biomass indices has been deferred until an evaluation of model-based vs design-based survey estimators is conducted.

(SSC, October 2016) *The SSC requests that stock assessment authors bookmark their assessment documents and commends those that have already adopted this practice.*

Bookmarks for the major sections of the assessment were added to the 2016 document.

Responses to SSC and Plan Team Comments Specific to this Assessment

(BSAI Plan Team, November, 2013) *The Team recommended that the authors continue to examine how the estimates of the random effects model (including process error variance) are impacted by changes in survey estimates and variances. The Team also recommended reconsideration of split-tier management of this stock complex.*

The effects of changes in survey estimates and variances on the smoothed estimates obtained from the random effects model have been evaluated with the Plan Team workgroup on survey averaging, where the latest efforts evaluated using life-history information to constrain the estimate of process error variance (and thus the “smoothness” of the estimates from the random walk smoother).

The split-tier assessment procedure was evaluated in this assessment, with the recommendation for a BSAI-wide model.

(BSAI Plan Team, November, 2014) *The Team expressed concern that the estimates of biomass from the model do not have much similarity to the trend in survey biomass estimates and recommend that the authors attempt to reconcile this discrepancy in future assessments.*

The blackspotted/rougheye assessment has inconsistencies between the AI survey biomass data (which show a flat or slightly decreasing trend) and the AI survey age composition data (which show the presence of recent strong cohorts). The tension in these data is somewhat reduced in this assessment model from the addition of data sources, such as the EBS slope survey data, that suggest reduced strength of the 1998 year class. Improved fits to the AI survey, relative to the 2014 model, were obtained under all 3 weighting methods for the age/length compositional data, with the recommended method being the McAllister-Ianelli weights. The "Francis method" of weighting show the best fit to the AI survey trend, but several survey estimates are still underfitted, and this method results in much lower recent biomass levels than other data weighting methods.

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.

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. This distribution pattern has also been observed in recent AI trawl surveys, where rougheye rockfish are rarely found in the central and western AI. Some differences in species composition may be due to errors in field identifications, particularly in areas where both species are common, as blackspotted and rougheye rockfish are similar in appearance. This issue appears to 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. The title of this assessment was changed to "blackspotted and rougheye rockfish" in 2008 upon recognition of blackspotted rockfish and its high abundance in the BSAI relative to rougheye rockfish. 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. These attributes are updated with the most recent survey and catch data in Appendix A of this assessment.

The relatively 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 strong significant pattern of isolation by distance (*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 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 1, and those from 2004 to present are shown in Table 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 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 1994-2016 have been relatively evenly distributed throughout the three AI subareas, with 32%, 27%, and 35% in the WAI, CAI, and EAI, respectively, and the remaining 6% in the EBS management area (Table 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 A. 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 1). The proportion of the harvest in the western Aleutian Islands increased during 2004 – 2006, averaging 67%, 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 1). The proportion captured at depths greater than 300 has increased recently, ranging from 3% to 20% during 1999 - 2003 to 28% to 46% from 2009 – 2015.

Non-commercial catches are shown in Appendix A.

Discards

Estimates of discarding by species complex are shown in Table 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 26%. 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 2016, discard rates of rougheye in the AI and EBS averaged 17% and 32%, 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 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 percent of 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 prima rily in the POP fishery (90% of the observed catch since 2004), and the bycatch rates here declined from 2.5% in 2004 to 0.43% in 2007, increased to 1.5% in 2010, and have declined since 201 to 0.29% in 2016 (using data through Oct 5, 2016). 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. Bycatch rates in the Pacific cod fishery in the central Aleutian Islands increased from 0.35% in 2011 to 0.90% in 2013, and has since decreased to 0.16% in 2016. In the eastern Aleutian Islands, the bottom trawl pollock fishery had the highest bycatch rates from 2013-2015 and were above 1%, but has declined to 0.3% in 2016. 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%.

Data

Fishery data

The catch data used in the assessment model are the estimates of single species catch described above and shown in Table 3.

Prior to 1999, the fishery data is characterized by inconsistent sampling of lengths (Table 7) and ages (Table 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 2). 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.

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 and 2014, and the AI trawl survey in 2008, were canceled due to lack of funding. 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, in contrast to the poly-nor'eastern nets used in the current surveys (Ronholt et al. 1994), and similar variations in gear between surveys occurred in the cooperative EBS surveys. The cooperative surveys from the 1980s are not used in the assessment.

The AI surveys from 1991 to 2016 indicated higher abundances in the central and eastern Aleutians than in the western AI (or southern Bering Sea area (Table 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 2016 survey biomass of 501 t in the western AI is a 15% decline from the value of 589 t in the 2014 survey. The 2014 and 2016 survey biomass estimates for the western AI shows the same general spatial pattern of survey CPUE (Figure 3). In the central AI, the 2016 survey biomass estimate of 2,803 t is a decrease from the estimate of 2878 t in the 2014 survey, whereas the eastern AI estimate increased from 958 t to 6165 t between the 2014 and 2016 surveys.

Length compositions from the survey indicate the reduction in biomass in the western AI can be attributed reduced number of fish in the 30 – 40 cm size range relative to the 2014 survey (Figure 4). The percentage of the WAI survey size composition less than 35 cm was 46%, a decrease from the value of 57% in the 2014 survey, and this value has ranged between 26% and 73% in surveys from 2014 to 2012. The increase in 2016 survey biomass in the eastern AI results from substantially larger number of fish in the 25- 40 cm range, whereas much of the length composition in the 2006-2012 surveys was between the 35 and 50 cm.

The mean size in the western AI was 37 cm in the 2016 survey, which is a slight increase from the 2014 survey (36 cm) and similar to values in 2006 (35 cm) and 2010 (36 cm) survey (Figure 5). However, the western AI mean sizes from 2006-2014 are lower than those observed in the 1991-2002 surveys, which 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 have increased to 39 cm and 35 cm, respectively, in the 2016 survey. However, an overall decline in mean size in the central and eastern AI has occurred 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 and 2014 surveys were 15 and 19 years, respectively.

The spatial pattern in the percentage of survey tows which did not catch blackspotted/rougheye rockfish in the 2016 survey is similar to that observed in the 2012 and 2014 surveys (Figure 6). In 2016, the WAI had the highest proportion of tows without blackspotted/rougheye rockfish (89%). The percentages appear to have increased since the early 1990s in the WAI, CAI, and EAI, but the rate of increase in the percentage appears to be higher and less variable for the WAI. In the 1991-1994 surveys, the WAI had the lowest percentage of tows without blackspotted/rougheye rockfish among the subareas, whereas beginning in 2000 the WAI had the highest percentage (or tied of the highest percentage) of tows without blackspotted/rougheye rockfish.

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 2008 EBS slope survey was completed, but the 2006 survey was canceled due to lack of funding. 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 7. 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. This assessment evaluates incorporation of the EBS slope survey time series (and associated composition data), but excludes the 2016 survey data.

A random effects smoothing model was applied to the time series of subarea biomass levels from the AI and EBS surveys (Figure 8). The increase in biomass in 2016 in the eastern AI from a very low value in 2014 increased the current smoothed biomass estimate for this area from 1,587 t for 2014 to 4,022 t for 2016, whereas the results from the smoother for 2016 in other subareas are relatively consistent with smoothed estimates for 2014. These smoothed estimates are used for subarea partitioning of the ABC, and the estimation of subarea exploitation rates shown in Appendix B.

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.).

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 10 and 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 indicates that in most surveys, blackspotted/rougheye rockfish have a relatively even distribution across a broad range of ages (i.e., ages 20 to 40) (Figure 9). 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 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 10).

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 2014 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
51.66	0.06	-4.20

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 1991-2014 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 0.15 at age 3 to 0.08 at age 45.

A length-weight relationship of the form $W = aL^b$ was fit from the survey data, and produced estimates of $a = 6.60 \times 10^{-6}$ 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 12).

The following table summarizes the data available for the blackspotted/rougheye rockfish assessment models (assuming use of the EBS data):

Component	BSAI
Fishery catch	1977-2016
Fishery age composition	2004-2005, 2007-2009, 2011
Fishery size composition	1979, 1990, 1992-1993, 2003, 2010, 2012-2015
AI Survey age composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014
AI Survey length composition	2016
AI Survey biomass estimates	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014
EBS Survey age composition	2002, 2004, 2008, 2010, 2012
EBS Survey biomass estimates	2002, 2004, 2008, 2010, 2012

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 2016). 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 2013 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 2014-2016 are set at the expected mean recruitment (based upon the log-scale mean, and the value of σ_r).

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

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

The mean number at age for each year was computed as

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

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

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

In previous assessments, the Aleutian Islands trawl survey catchability incorporated the processes of availability (either areal or vertical) and vulnerability to the gear. The potential introduction of the EBS trawl survey catchability requires consideration of how much of the BSAI stock is "available" to the each survey. The availability ($a_{\text{AI,t}}$) in each year to the AI survey was obtained by using the random effects model to smooth the AI and EBs survey biomass and computing the proportion of the total smoothed biomass in the AI area. The predicted survey biomass for the AI trawl survey biomass $\hat{B}^{twl}_{AI,t}$ was computed as

$$\hat{B}^{twl}_{AI,t} = a_{AI,t} q_{AI}{}^{twl} \sum_a (\overline{N}_{t,a} s^{twl}_a W_a)$$

where W_a is the population weight-at-age, s^{twl}_a is the survey selectivity, and q^{twl} is the trawl survey catchability. The predicted survey biomass for the EBS trawl survey biomass $\hat{B}^{twl}_{EBS,t}$ is similar but model availability as (1- $a_{\text{AI,t}}$):

$$\hat{B}^{twl}_{EBS,t} = (1 - a_{AI,t}) q_{EBS}{}^{twl} \sum_a (\overline{N}_{t,a} s^{twl}_a W_a)$$

Selectivities for the AI and EBS trawl surveys were modeled with logistic functions.

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. EBS survey catchability was estimated freely.

Fishery selectivity was estimated with a double logistic curve

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

where fishing selectivity is the product of two logistic curves, and allows for dome-shaped selectivity when the descending slope parameter (ϕ_{des}) is negative.

In previous assessment models, the age-structured model was applied to the portion of the stock with the AI management area, and Tier 5 methods were applied to the portion in the EBS management area. 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). The model considered are:

Model 0) The 2014 AI model results. This is shown in some plots as a basis for comparing the new models.

Model 14) The 2014 AI model with data updated through 2016. The weighting of the age and length composition data was unchanged from 2014.

Model 16.1) Incorporation of the EBS slope survey biomass estimates and age and length composition data. The data weighting was unchanged from the 2014 model, with weights for the EBS age and length composition data set to 1.

The remaining models involve different methods for reweighting the age and length composition data. In each of these methods, the multinomial sample size $N_{j,y}$ for data type *j* and year *y* is computed as

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

where $\tilde{N}_{j,y}$ is the original “first stage” sample size (set to the square root of number of fish lengthed or aged), and w_j is a weight for data type *j*. The weights are a function of the fit of 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.

Model 16.2) Model 14, but computes the weights as the harmonic mean of the ratio of effective sample size to first stage sample size (method TA1.1 in Francis (2011), which is from McAllister and Ianelli (1997) and often referred to as the “McAllister-Ianelli method”).

Model 16.3) Model 14, but computes the weights as the inverse of the variance of the standardized residuals (method TA1.2 in Francis (2011); this method was used in the 2014 assessment).

Model 16.4) Model 14, but computes the weights 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”.

Model 16.5) Model 16.1, but computes the weights with the McAllister-Ianelli method.

Model 16.6) Model 16.1, but computes the weights as the inverse of the variance of the standardized residuals (method TA1.2 in Francis (2011).

Model 16.7) Model 16.1, but computes the weights with the Francis method.

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, the proportion mature females at age, and the proportion of the stock available to the AI survey. 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 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 2016 is obtained by estimating the Oct-Dec catch (based on the remaining ABC available after October, and the average proportion in recent years of the remaining ABC caught from Oct-Dec) and adding this to the observed catch through October. 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

$$\begin{aligned}
&\lambda_1 \left[\sum_{t=1}^{n} \frac{\left(\nu_t + \sigma_r{}^2/2\right)^2}{2\sigma_r{}^2} + n\ln(\sigma_r) \right] + \\
&\lambda_1 \left[\sum_{a=4}^{A} \frac{\left(\gamma_a + \sigma_r{}^2/2\right)^2}{2\sigma_r{}^2} + (A-3)\ln(\sigma_r) \right] + \\
&\lambda_2 \sum_t \left(\ln(obs_biom_t) - \ln(pred_biom_t)\right)^2 / 2cv_t^2 + \\
&- n_{f,t,l} \sum_{s,t,l} (p_{f,t,l} \ln(\hat{p}_{f,t,l}) + p_{f,t,l} \ln(p_{f,t,l})) + \\
&- n_{f,t,a} \sum_{s,t,l} (p_{f,t,a} \ln(\hat{p}_{f,t,a}) + p_{f,t,a} \ln(p_{f,t,a})) + \\
&- n_{surv,t,a} \sum_{s,t,a} (p_{surv,t,a} \ln(\hat{p}_{surv,t,a}) + p_{surv,t,a} \ln(p_{surv,t,a})) + \\
&- n_{surv,t,l} \sum_{s,t,a} (p_{surv,t,l} \ln(\hat{p}_{surv,t,l}) + p_{surv,t,l} \ln(p_{surv,t,l})) + \\
&\lambda_3 \sum_t \left(\ln(obs_cat_t) - \ln(pred_cat_t)\right)^2
\end{aligned}$$

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 including the EBS slope survey data):

Parameter type	***Number***
1) fishing mortality mean	1
2) fishing mortality deviations	40
3) recruitment mean	1
4) recruitment deviations	37
5) historic recruitment	1
6) first year recruitment deviations	42
7) biomass survey catchability	2
8) natural mortality rate	1
9) survey selectivity parameters	4
10) fishery selectivity parameters	4
Total number of parameters	133

Results

Model Evaluation

Comparison of models 14 and 16.1 indicate the effect of expanding the model to the BSAI area and including the EBS slope survey biomass estimates and age composition data. The estimated total biomass of model 16.1 is larger than that of model 14 and model 16.1 until about 2000 (i.e., near the start of the EBS slope survey time series), but in recent years the estimated biomass from models 14 and 16.1 are lower the estimates from model 0 (Figure 11a). This reduction in total biomass comes, in large part, from a reduction of the 1998 year class, which was estimated at 23 million in model 0, 14 million in model 14, and 12 million in model 16.1 (Figure 12). The estimated recruitments from models 0, 14, and 16.1 indicate that the 1998 year class has not disappeared, but rather is being estimated in models 14 and 16.1 as one of a small number of strong year classes rather than a sole dominant year class.

An example of how data added to the model since the 2014 assessment does not support such a dominant 1998 year class is shown in Figure 13. In the 2014 assessment, approximately 30% of the estimated “exploitable” numbers at age for 2013 (the product of numbers at age and the fishery selectivity curve) were composed of the 1998 year class (Figure 13a). The dominance of this year class resulted in the estimated fishery length composition showing a mode at approximately 34 cm, consistent with the mode of the length distribution for the age 15 fish (i.e., the 1998 year class) from the age-length conversion matrix Figure 13b. In contrast, the observed 2014 fishery length composition shows a mode shifted to approximately 37 to 40 cm, larger than the expected value of lengths from the 1998 year class (Figure 13c). Relative to the estimated length composition from model 0, the estimated fishery length composition for 2014 from model 16.1 shows a reduced proportion at the length expected for the 1998 year class and an increased proportion at older ages, which is achieved by reducing the magnitude of the 1998 year class (Figure 13d).

Additional evidence for a lack of support of a dominant 1998 year class is the EBS survey age composition data (Figure 14). The 1998 year classes contributes a small percentage to the 2012 age composition, and the fitted values (based primarily in the AI data) from model 16.1 also overestimate this year class in the 2010 and 2008 age compositions by wide margins. In particular, the fits across all ages in the 2002 and 2012 EBS survey age seem especially poor. The EBS survey age composition had the largest RMSE values across the age/length composition data (indicating relatively poor fits) whereas the AI survey age compositions has the lowest RMSE values (Table 13).

The fit to the AI survey is improved in models 14 and 16.1 relative to model 0, as the RMSE for models 0, 14, and 16.1 were 0.56, 0.52, and 0.48, respectively. The increase in estimated total biomass in the 1990s from model 16.1 allows improved fits to the AI survey during this time, and the predicted AI survey trend is more consistent with the trend in the survey biomass estimates (Figure 15). The fit to the EBS trawl survey appears consistent with the survey estimates, although the model predicted a slightly larger rate of increase in the EBS survey biomass than survey estimates imply (Figure 16).

Although it is counter-intuitive that the total biomass in recent years from model 16.1 is smaller than from model 14, this difference can be attributed to the different information added to model 16.1 regarding the strength of the 1998 year class. Broadly speaking, the recruitment estimates from models 14 and 16.1 indicate a consistency in the set of strong year classes (1998, 2002, 2005), although the scale of the recruits for these year classes differs somewhat. The overall trend in the EBS survey biomass estimates is also consistent with the trend in biomass predicted from model 0 and earlier assessments. In addition to improving the fit to the AI survey, the reduced strength of the 1998 year class in model 16.1 results in lower CV for this year class relative to model 14, as well as a reduced CV for the estimated 2016 total biomass (Table 14).

The reweighted models 16.2 – 16.4, and 16.5- 16.7, produce similar estimates of total biomass to their corresponding models using the weights from the 2014 assessment (models 14 and 16.1, respectively), although the models using the Francis weights produce considerably lower biomass estimates (Figure 11). The models using the Francis weights addresses the inconsistencies between the composition data and the survey biomass indices by downweighting all the composition data, with particularly strong downweighting of the AI survey age data and the fishery age data resulting in low values for the weights (Figure 17). This slightly improves the fit to the AI survey biomass estimates, although the general pattern is similar and the survey biomass estimates from the mod-1990s to the early 2000s are still being underfitted. The models with the Francis weightings do, however, result in substantially lower estimates of the 1998 year class and recent total biomass. Acceptance of these large changes in biomass does not seem supported by the relatively minor change in the fit to the AI survey.

A potential concern with the Francis method is that unreliable estimates of the variance of the residuals may be obtained with data types with a small number of years (as a single residual is computed for each year). For the blackspotted/rougheye model, none of the 5 composition data types has more than 10 years of data, and 3 have 6 years or less. In this assessment, the weights used for the AI survey length composition data were paired to the age composition from the same survey. It is unclear how the choice of pairing would affect the model results or, more generally, how sensitive the results of the Francis method are to small numbers of available years for some data types.

Models 16.5 and 16.6 provide very similar results. We recommend model 16.5 (the McAllister-Ianelli method), partly because its common usage in other assessment models eases communication of the methodology. The results reported in this assessment were obtained from model 16.5. Estimated values of model parameters and their standard deviations are shown in Table 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 2016 to 2006, 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 18. The retrospective runs for 2015 and 2014 are very similar to the model results with data through 2016, but the remaining retrospective runs all show much higher biomass, consistent with the results in this assessment that the recent data do not support estimation of the high biomass levels obtained in previous assessments. The retrospective runs appear to change the most in years when new survey data are added. Mohn's rho can be used to evaluate the severity of any retrospective pattern, and compares an estimated quantity (in this case, spawning stock biomass) in the terminal year of each retrospective model run with the estimated quantity in the same year of the model using the full data set . The absence of any retrospective pattern would result in a Mohn's rho of 0, and would result from either identical estimates from the model runs, or from positive deviations from the reference model being offset by negative deviations. The Mohn's rho for these retrospective runs was 0.715, similar to the value of 0.785 obtained in the 2014 assessment.

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 decreases from 9,834 t in 1977 to 6,857 t in 1980 due to large catches in the late 1970s, increased to 10,301 t in 1989, declined throughout the 1990s and has increased to 11,648 t in 2016 (Figure 19). As mentioned above, the predicted EBS survey abundance largely tracks the increase in survey biomass estimates (Figure 16). 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 1999, the spawning biomass has increased from 3,709 t to 6,543 t in 2014, and the total biomass has increased from 11,124 t to 35,754 t over this period (Figure 20). 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, such as the 1998 year classes. The time series of estimated total biomass, spawner biomass, and recruitment, and their estimated CVs (from the Hessian approximation) are shown in Table 16, and the estimated numbers age are shown in Table 17.

Age/size compositions

The model fits to the fishery age and size compositions are shown in Figures 21 and 22 and the model fits to the survey composition data are shown in Figures 23-25. The 2009 fishery age composition shows strong year class strengths for the 1998 and 1999 year classes, whereas the size of these year classes appears reduced in the 2011 fishery age composition data (particularly for the 1999 year class). The model essentially splits the difference in the fit to these years of fishery age compositions. The 2010, 2012, and 2015 fishery length composition data indicate that higher proportions of relatively small rougheye (i.e., 33-36 cm in 2010, 35-40 cm in 2012, and 38- 41 cm in 2015) are caught by the fishery. These lengths correspond approximately to 13-16 year old fish in 2010, 15-22 year old fish in 2012, 19-23 year-old fish in 2015, and the 1990-1997 year classes. Because these year classes are not consistently observed in other age and length compositions, the model does not produce a strong fit to these fishery length composition data. The 2014 fishery length composition data showed a broader range of sizes, and had better model fits.

The 2010 and 2014 AI survey age composition data also indicates relatively strong 1998 and 1999 year classes, but the 2012 AI survey age composition data showed a strong 1999 year class but a reduced proportion for the 1998 year class. The 2014 survey age composition data shows relatively high proportions for ages 27 -33, which correspond to lengths between 44 and 47 cm in 2016. However, the

2016 survey length composition shows relatively low proportions for these lengths, which is inconsistent with other age and length composition data and accounts for the poor model fit.

The CVs of 5% for the priors on survey catchability and natural mortality constrained these parameters to values of 1.1 and 0.033, respectively, a slight increase from the prior distribution means of 1.0 and 0.03, respectively. The EBS survey catchability was estimated at 0.75.

The estimated age at 50% selection for the AI trawl survey was 20.6, a decrease from 23.5 in the 2014 assessment (Figure 26). The EBS slope survey estimates higher selectivity at young ages, with an estimated of age at 50% selection of 5.2. The fishery selectivity reached 50% at age 23, similar to the value of 24 in the 2014 assessment.

The estimates of instantaneous fishing mortality rate are shown in Figure 27. 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.

Fishing Mortality and Stock Status

The stock status, relative to $B_{40\%}$, is sensitive to the 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, 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 13, and would use recruitments from year classes 1977 – 2002. The 2002 year class is estimated at 12.3 million in the recommended model, and is the largest estimated year class. The B40% resulting from the mean recruitment from these year classes is 10,728 t, and the ratio of spawning stock biomass in 2016 to B40% is 0.59 (Table 14). Because BSAI blackspotted/rougheye are a Tier 3b stock, a lower ratio of B/B40% results in a lower F rate and ABC for 2017 (which would be 381 t).

Evaluating the implications for stock status and management is complicated by slight variations in the AI survey selectivity curve used to determine the cohorts used for the mean recruitment. For example, model 16.2 estimates the critical age for the mean recruitments as 15, corresponding to the 1977-2000 year classes. Even though both the mean (Figure 28a) and CV (Figure 28b, from the Hessian) of the 2002 year class are very similar between models 16.2 and 16.5, this year class would be exclude in model 16.2 but included in model 16.5. For model 16.2, exclusion of this year class lowers the value of $B_{40\%}$ to 8,632 t, with a ratio of spawning stock biomass in 2016 to B40% of 0.74 and a 2017 ABC of 469 t. Although large year classes may be expected to have low CVs, for recent year classes a low CV could result from a small number of consistent observations on year class strength. More information added in the future may provide conflicting views of year class strength, which can change both the mean and the CV.

Use of a consistent set of years for mean recruitment from 1977 to 2000 results in more consistency regarding the 2017 ABC across the various models considered in this assessment (Table 14). In particular, the ABC for the preferred model increases from 381 t with the mean recruitment based on cohorts through 2002, and 511 t with cohorts through 2000. A plot of fishing mortality rates and spawning stock biomass in reference to the ABC and OFL harvest control rules (Figure 29) shows stock status relative to $B_{35\%}$ computed from these two different time periods of recruitment. We recommend using cohorts based through 2000 until more information can be obtained about the large year class estimate for 2002.

Recruitment

Recruitment strengths by year class, with credibility bounds from the MCMC integration, are shown in Figure 30. There is little information to discern strong recruitments in the early years of the model, although relatively strong year classes were estimated for 1976 and 1982 and were observed in several years of survey sampling. Relative to the 2014 assessment, several of the post-2005 cohorts are estimated as strong, although based on limited data.

The plot of recruitment against spawning stock biomass is shown in Figure 31.

Harvest Recommendations

Amendment 56 reference points for 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 1977-2000 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 8,311 t. The year 2017 spawning stock biomass is estimated as 7,305 t.

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

Since reliable estimates of the 2017 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B<B_{0.40}$ (7,305 t < 8,311 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 values of F_{abc} and F_{OFL} are 0.039 and 0.048, respectively. The 2017 ABC and OFL for the AI blackspotted/rougheye resulting from these rates are 501 t and 612 t, respectively. A summary of these values is below.

2017 SSB estimate (B)	=	7,305 t
$B_{0.40}$	=	8,311 t
$F_{0.40}$	=	0.045
F_{ABC}	=	0.039
$F_{0.35}$	=	0.055
F_{OFL}	=	0.048

ABC recommendation

We recommend the maximum permissible ABC of 501 t.

Projections

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

For each scenario, the projections begin with the vector of 2016 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2017 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2016. 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 2017, 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 2017 recommended in the assessment to the *max* F_{ABC} for 2013. (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 2011-2015 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 2016 or; 2) above ½ of its MSY level in 2016 and above its MSY level in 2026 under this scenario, then the stock is not overfished.)

Scenario 7: In 2017 and 2018, *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 2029 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 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 2017, it does not provide the best estimate of OFL for 2018, because the mean 2018 catch under Scenario 6 is predicated on the 2017 catch being equal to the 2017 OFL, whereas the actual 2017 catch will likely be less than the 2017 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL. Catches for 2017 and 2018 were obtained by setting the *F* rate for these years to the estimated *F* rate for 2016.

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 (2015) is 180 t. This is less than the 2015 BSAI OFL of 560 t. Therefore, the stock is not being subjected to overfishing.

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

Is the stock currently overfished? This depends on the estimated spawning biomass in 2014:
a. If spawning biomass for 2016 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2016 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2016 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 18). If the mean spawning biomass for 2026 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:
a. If the mean spawning biomass for 2019 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2019 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2019 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2029. If the mean spawning biomass for 2027 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 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 2026 of Scenario 6 is 1.88 times its $B_{35\%}$ value of 7,272 t. With regard to whether the stock is likely to be overfished in the future, the expected stock size in 2029 of Scenario 7 is 2.04 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. Additionally, the subarea ABC for the western and central Aleutians Islands is partitioned into “maximum subarea species catch” for each area.

A random effects model is used to smooth subarea survey biomass estimates to obtain the proportions. This procedure assumes equivalent survey catchability and selectivity across subareas, such that any difference in survey biomass between areas can be attributed to true changes in biomass rather than differences in catchability and selectivity. In previous years this assumption was reasonable because the selectivity and catchability of the EBS slope survey had not been estimated. Estimates of these quantities are now available from this assessment, and indicate that the EBS slope survey has a lower catchability and a much large selectivity for young fish relative to the AI survey.

In order to use the survey biomass estimates to partition the ABC, we propose the following equation to produce an adjusted EBS survey biomass estimate in year *t* ($B_{adj,t}$) that is in comparable units to the AI survey:

$$B_{adj,t} = B_t \left(\frac{\sum_a q_{AI} s_{AI,a} w_a N_{a,t}}{\sum_a q_{EBS} s_{EBS,a} w_a N_{a,t}} \right)$$

where $N_{a,t}$ is the estimated numbers at age, *s* is selectivity, and *q* is catchability, and B_t is the smoothed unadjusted EBS survey slope estimate. The adjustment factor has declined since 2001 as the proportion of old fish in the population has been reduced (Figure 32), and has declined to 0.53 in 2016, lowering the 2016 smoothed EBS slope survey biomass from 1,010 t to 538 t:

	Area				
	WAI	CAI	EAI	SBS	EBS slope
Unadjusted smoothed biomass	520	2,995	4,022	462	1,010
percentage	5.78%	33.24%	44.64%	5.13%	11.21%
Adjusted smoothed biomass	520	2,995	4,022	462	538
percentage	6.10%	35.08%	47.11%	5.41%	6.30%

The apportioned ABCs and MSSCs for 2017 and 2018 from the two methods are as follows:

	Area				
	WAI MSSC	CAI MSSC	WAI/CAI ABC	EAI/EBS ABC	Total ABC
2017 ABCs-MSSCs, unadjusted	29	166	195	306	501
2018 ABCs-MSSCs, unadjusted	35	204	240	374	614
2017 ABCs-MSSCs, adjusted	31	176	207	294	501
2018 ABCs-MSSCs, adjusted	37	215	252	362	614

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”.

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.

References

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Spencer, P.D., and C.N. Rooper. 2014. Assessment of the blackspotted and rougheye rockfish complex in the eastern Bering Sea and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, pp. 1453-1536. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501.

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

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

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

Table 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	Manageme Group	OFL	ABC (t)	TAC (t)	Catch (t)	Management Group	OFL	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		4685	4685	137	Other red		1670	1670	106
1992						RE/SR	1220	1220	1220	1181	ORR	1400	1400	1400	77
1993						RE/SR	1220	1220	1100	924	ORR	1400	1400	1200	146
1994						RE/SR	1220	1220	1220	749	ORR	1400	1400	1400	22
1995						RE/SR	1220	1220	1098	395	ORR	1400	1400	1260	28
1996						RE/SR	1250	1250	1125	816	ORR	1400	1400	1260	34
1997						RE/SR	1250	938	938	954	ORR	1400	1050	1050	15
1998						RE/SR	1290	965	965	526	ORR	356	267	267	16
1999						RE/SR	1290	965	965	385	ORR	356	267	267	9
2000						RE/SR	1180	885	885	280	ORR	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 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 2016. Catch data is through October 10, 2016, from NMFS Alaska Regional Office. The “rougheye” management group includes both blackspotted rockfish and rougheye rockfish.

	BSAI					WAI/CAI					EAI/EBS				
Year	Manageme Group	OFL	ABC (t)	TAC (t)	Catch (t)	Management Group	OFL	ABC	TAC	Catch	Management Group	OFL	ABC	TAC	Catch
2004	Rougheye	259	195	195	207.98										
2005	Rougheye	298	223	223	89.63										
2006	Rougheye	299	224	224	203.36										
2007	Rougheye	269	202	202	167.59										
2008	Rougheye	269	202	202	192.74										
2009	Rougheye	660	539	539	197.09										
2010	Rougheye	669	547	547	231.7										
2011	Rougheye	549	454	454	163	Rougheye		220	220	74	Rougheye		234	234	89
2012	Rougheye	576	475	475	191	Rougheye		244	244	124	Rougheye		231	231	67
2013	Rougheye	462	378	378	322	Rougheye		209	209	146	Rougheye		169	169	177
2014	Rougheye	505	416	416	196	Rougheye		239	239	98	Rougheye		177	177	98
2015	Rougheye	560	453	349	180	Rougheye		304	200	117	Rougheye		149	149	64
2016	Rougheye	693	561	300	149	Rougheye		382	200	85	Rougheye		179	100	64

Table 3. Catch of blackspotted and rougheye rockfish (t) in the BSAI area.

	Eastern Bering Sea			Aleutian Islands			BSAI
Year	Foreign	JV	Domestic	Foreign	JV	Domestic	Total
1977	2	0		155	0		157
1978	99	0		2,423	0		2,522
1979	477	0		3,077	0		3,553
1980	160	0		660	0		820
1981	283	0		595	0		878
1982	124	0		189	0		312
1983	53	0		56	2		111
1984	79	0		31	4		114
1985	18	0		1	9		27
1986	3	1	48	0	2	19	74
1987	1	2	96	0	3	76	179
1988	0	1	110	0	5	70	185
1989	0	2	202	0	0	381	585
1990			369			1,619	1,988
1991			106			137	243
1992			77			1,181	1,258
1993			146			924	1,070
1994			22			749	770
1995			28			395	423
1996			34			816	850
1997			15			954	969
1998			16			526	542
1999			9			385	394
2000			26			280	307
2001			15			550	565
2002			12			273	284
2003			17			174	191
2004			23			185	208
2005			12			78	90
2006			7			197	203
2007			10			157	168
2008			22			171	193
2009			13			184	197
2010			30			202	232
2011			36			127	163
2012			17			174	191
2013			27			296	322
2014			24			172	196
2015			31			150	180
2016*			39			110	149

*Catch data through October 10, 2016, from NMFS Alaska Regional Office.

Table 4. Area-specific catches (t) of blackspotted and rougheye rockfish (t) in the BSAI area, obtained from the North Pacific Groundfish Observer Program, NMFS Alaska Regional Office. BSAI subareas are the western Aleutians Islands (WAI), central Aleutian Islands (CAI), and eastern Aleutian Islands (EAI), and eastern Bering Sea (EBS).

Year	WAI	CAI	EAI	EBS	Total
1994	49	197	503	22	770
1995	43	100	252	28	423
1996	446	184	186	34	850
1997	513	138	303	15	969
1998	109	232	185	16	542
1999	88	161	136	9	394
2000	103	139	39	26	307
2001	128	133	289	15	565
2002	96	63	114	12	284
2003	66	58	51	17	191
2004	112	64	10	23	208
2005	43	24	11	12	90
2006	109	45	43	7	203
2007	43	42	72	10	168
2008	58	67	47	22	193
2009	67	81	37	13	197
2010	85	43	74	30	232
2011	46	28	54	36	163
2012	65	58	50	17	191
2013	84	62	150	27	322
2014	56	42	74	24	196
2015	67	50	33	31	180
2016*	37	47	25	39	149

* Estimated removals through October 10, 2016.

Table 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				
	Species				Percent	Species				Percent
Year	Group	Retained	Discarded	Total	Discarded	Group	Retained	Discarded	Total	Discarded
1993	RE/SR	737	403	1139	35%	Other red rockfish	367	97	464	21%
1994	RE/SR	701	224	925	24%	Other red rockfish	29	100	129	78%
1995	RE/SR	456	103	558	18%	Other red rockfish	274	70	344	20%
1996	RE/SR	751	208	959	22%	Other red rockfish	58	149	207	72%
1997	RE/SR	733	310	1043	30%	Other red rockfish	44	174	218	80%
1998	RE/SR	447	238	685	35%	Other red rockfish	38	59	97	61%
1999	RE/SR	319	195	514	38%	Other red rockfish	75	163	238	68%
2000	RE/SR	285	196	480	41%	Other red rockfish	111	141	253	56%
2001	RE/SR	476	246	722	34%	RE/SR	27	16	43	38%
2002	RE/SR	333	146	478	30%	RE/SR	50	54	105	52%
2003	RE/SR	197	84	281	30%	RE/SR	62	54	116	47%
2004	Rougheye	83	102	185	55%	Rougheye	15	8	23	36%
2005	Rougheye	72	6	78	8%	Rougheye	3	8	12	70%
2006	Rougheye	167	30	197	15%	Rougheye	5	2	7	30%
2007	Rougheye	127	30	157	19%	Rougheye	7	3	10	29%
2008	Rougheye	137	35	171	20%	Rougheye	12	10	22	46%
2009	Rougheye	155	30	184	16%	Rougheye	10	3	13	23%
2010	Rougheye	174	28	202	14%	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	53	296	18%	Rougheye	19	7	27	27%
2014	Rougheye	158	14	172	8%	Rougheye	17	7	24	30%
2015	Rougheye	134	16	150	11%	Rougheye	22	9	31	28%
2016*	Rougheye	99	11	110	10%	Rougheye	32	7	39	18%

* Estimated removals through October 10, 2016.

Table 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	POP	Atka mackerel	Pacific cod
2004	2.53%	0.11%	0.19%
2005	1.15%	0.02%	0.00%
2006	1.63%	0.03%	0.00%
2007	0.42%	0.06%	0.27%
2008	0.59%	0.03%	0.11%
2009	1.24%	0.07%	0.47%
2010	1.48%	0.05%	0.26%
2011	0.65%	0.24%	
2012	1.04%	0.53%	0.88%
2013	1.07%	10.14%	0.43%
2014	0.76%		0.00%
2015	0.83%	0.09%	0.96%
2016	0.29%	0.09%	0.27%

Central Aleutian Islands

	Fishery			
Year	POP	Atka mackerel	Pacific cod	Other species
2004	1.49%	0.01%	0.98%	1.65%
2005	1.39%	0.02%	0.05%	0.20%
2006	0.82%	0.01%	0.25%	0.30%
2007	0.71%	0.01%	0.24%	0.24%
2008	0.86%	0.01%	1.18%	0.96%
2009	1.78%	0.04%	0.26%	0.50%
2010	0.73%	0.02%	0.48%	0.14%
2011	0.54%	0.02%	0.35%	0.42%
2012	0.80%	0.03%	0.81%	0.26%
2013	0.76%	0.01%	0.90%	0.70%
2014	0.59%	0.00%	0.80%	0.08%
2015	0.68%	0.01%	0.54%	0.70%
2016	0.83%	0.03%	0.16%	0.19%

Eastern Aleutian Islands

	Fishery				
Year	POP	Atka mackerel	AR/KM	Bottom pollock	Other species
2004	0.14%	0.00%	0.56%	0.03%	0.70%
2005	0.00%	0.00%	0.18%	0.00%	0.10%
2006	0.94%	0.01%	0.24%	0.00%	0.21%
2007	1.21%	0.00%	0.33%	0.00%	0.09%
2008	0.76%	0.00%	0.46%	0.01%	0.50%
2009	0.44%	0.00%	0.21%	0.00%	0.22%
2010	1.00%	0.00%	0.53%	0.94%	0.21%
2011	0.25%	0.01%	0.82%	0.83%	0.14%
2012	0.37%	0.01%	0.72%	4.67%	0.22%
2013	0.63%	0.05%	1.24%	1.25%	0.44%
2014	0.40%	0.01%	0.93%	1.04%	0.55%
2015	0.31%	0.01%	0.60%	1.35%	0.33%
2016	0.21%	0.01%	0.87%	0.32%	0.22%

Eastern Bering Sea

	Fishery				
Year	POP	Other species	Bottom pollock	Pacific cod	pelagic pollock
2004	0.69%	0.12%	0.04%	0.11%	0.00%
2005	0.22%	0.09%	0.03%	0.09%	0.00%
2006	0.17%	0.01%	0.02%	0.06%	0.00%
2007	0.00%	0.03%	0.01%	0.10%	0.00%
2008	0.08%	0.13%	0.03%	0.09%	0.00%
2009	0.20%	0.03%	0.04%	0.01%	0.00%
2010	0.36%	0.06%	0.15%	0.05%	0.00%
2011	0.19%	0.06%	0.08%	0.07%	0.00%
2012	0.25%	0.02%	0.01%	0.02%	0.01%
2013	0.07%	0.79%	0.15%	0.07%	0.00%
2014	0.09%	0.08%	0.07%	0.03%	0.00%
2015	0.01%	0.07%	0.08%	0.05%	0.00%
2016	0.14%	0.11%	0.08%	0.03%	0.00%

Table 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 1977-2015.

	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	42	17	399	96	441	113

Table 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 1977-2016.

	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						
2016	8	72	80						

Table 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	683 (0.30)	9,333 (0.33)	4,224 (0.24)	1,054 (0.26)	15,294 (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 (0.34)	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)

Table 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 1991-2016.

	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	1259	122		
2008			213	43
2010	986	92	267	43
2012	1356	119	230	37
2014	1035	107		
2016			162	21

Table 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 1991-2016

	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	535	99	162	161	36
2014	441	441	82			
2016	329			150		

Table 12. Predicted weight and proportion mature at age for BSAI rougheye rockfish.

Age	Predicted weight (g)	Proportion mature
3	72	0
4	101	0
5	135	0
6	173	0.001
7	215	0.001
8	260	0.003
9	309	0.008
10	361	0.015
11	415	0.03
12	471	0.053
13	529	0.09
14	587	0.141
15	646	0.209
16	705	0.29
17	764	0.378
18	823	0.467
19	882	0.551
20	940	0.625
21	997	0.689
22	1,052	0.742
23	1,107	0.785
24	1,160	0.82
25	1,212	0.847
26	1,262	0.87
27	1,311	0.888
28	1,359	0.902
29	1,404	0.914
30	1,448	0.924
31	1,491	0.932
32	1,532	0.939
33	1,571	0.944
34	1,608	0.949
35	1,644	0.953
36	1,679	0.956
37	1,712	0.959
38	1,744	0.962
39	1,774	0.964
40	1,803	0.966
41	1,830	0.968
42	1,856	0.969
43	1,881	0.97
44	1,905	0.971
45+	2,024	0.977

Table 13. Negative log likelihoods, effective sample sizes, and root mean squared errors, for the evaluated models for BSAI blackspotted/rougheye rockfish.

	Model 0	Model 14	Model 16.1	Model 16.2	Model 16.3	Model 16.4	Model 16.5	Model 16.6	Model 16.7
Negative log-likelihood									
Data components									
AI survey biomass	29.17	26.68	26.26	25.77	27.40	17.21	25.00	26.47	19.06
EBS survey biomass			5.13				4.87	5.63	2.68
Catch biomass	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00
Fishery ages	101.38	102.73	107.26	86.58	122.78	23.18	85.72	133.00	22.41
Fishery lengths	159.40	178.69	224.90	148.32	184.55	48.99	139.51	183.28	57.30
AI survey ages	172.14	204.18	190.69	177.66	247.67	42.18	176.80	253.33	53.41
AI survey lengths	10.03	4.08	3.90	14.07	17.67	6.32	13.50	17.85	7.88
EBS survey ages			52.59				69.87	112.59	52.91
Priors and penalties									
Recruitment	26.97	32.28	25.23	31.27	41.77	-4.45	25.18	33.34	2.39
Prior on survey q	1.27	1.66	1.92	1.68	2.04	0.35	2.03	2.47	0.64
Prior on M	1.87	2.07	2.49	1.99	2.40	0.77	2.31	2.74	1.25
Total negative log-likelihood	508.51	558.85	645.08	493.75	652.85	140.39	549.43	775.50	224.07
Parameters	126	130	133	130	130	130	133	133	133
Effective sample size									
Fishery ages	60	56	66	57	58	48	69	71	54
Fishery lengths	195	234	220	224	226	197	208	205	233
AI survey ages	244	226	270	220	235	98	278	294	159
AI survey lengths	68	102	116	114	128	71	130	143	106
EBS survey ages			51				53	53	62
Root mean square error									
AI survey biomass	0.556	0.518	0.483	0.510	0.528	0.402	0.473	0.489	0.401
Recruitment	0.966	1.064	0.994	1.070	1.179	0.620	1.010	1.097	0.746
EBS survey biomass			0.466				0.457	0.485	0.361
Fishery ages	0.021	0.020	0.019	0.020	0.020	0.021	0.019	0.019	0.022
Fishery lengths	0.015	0.013	0.014	0.013	0.013	0.014	0.015	0.014	0.015
AI survey ages	0.011	0.010	0.009	0.010	0.010	0.015	0.009	0.009	0.012
AI survey lengths	0.019	0.016	0.015	0.015	0.014	0.019	0.014	0.013	0.015
EBS survey ages			0.023				0.022	0.022	0.021

Table 14. Key parameter estimates and management quantities for the models for BSAI blackspotted/rougheye rockfish. "2017 ABC, recs from 1997-2000" is the 2017 ABC obtained from using year classes 1977-2000 to estimates mean recruitment and $B_{40\%}$.

	Model 0	Model 14	Model 16.1	Model 16.2	Model 16.3	Model 16.4	Model 16.5	Model 16.6	Model 16.7
Key parameters and management quantities									
EBS Survey catchability			0.704				0.755	0.754	0.780
CV									
AI Survey catchability	1.082	1.094	1.102	1.095	1.105	1.042	1.105	1.116	1.057
CV	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
2016 total biomass (t)		36988	36413	35167	40557	18105	33846	37200	24313
CV		0.167	0.154	0.184	0.189	0.171	0.157	0.158	0.147
2016 Spawniing stock biomass (t)		6842	7199	6411	6701	4893	6543	6681	5881
CV		0.156	0.139	0.158	0.162	0.150	0.140	0.141	0.132
Recruitment, 1998 year class (millions)		14.361	11.884	12.936	13.298	6.872	9.506	10.023	6.157
CV		0.255	0.212	0.274	0.258	0.391	0.216	0.197	0.267
Final year class for mean recruitment		1999	2002	2000	2000	2006	2002	2002	2003
Mean recruitment (millions)		1.484	2.071	1.513	1.630	1.077	1.905	2.040	1.448
$B_{40\%}$ (t)		8440	11579	8632	9147	6545	10728	11299	8554
$B(2016)/B_{40\%}$		0.811	0.622	0.743	0.733	0.748	0.610	0.591	0.687
2017 ABC		544	426	469	488	318	383	381	391
2017 ABC, recs from 1977-2000 YC		494	540	469	488	357	501	511	489

Table 15. Estimated parameter values and standard deviations for the BSAI blackspotted/rougheye.

Parameter	Estimate	Standard Deviation	Parameter	Estimate	Standard Deviation	Parameter	Estimate	Standard Deviation
sel_aslope_fish	1.25	0.32	fmort_dev	-0.69	0.12	fydev	-0.17	0.63
sel_dslope_fish	0.15	0.04	fmort_dev	-0.23	0.12	fydev	0.25	0.79
sel_a50_fish	10.51	0.59	fmort_dev	-0.81	0.12	fydev	0.93	0.89
sel_d50_fish	22.64	2.29	fmort_dev	-0.98	0.12	fydev	0.74	1.06
sel_aslope_ai	0.27	0.01	fmort_dev	-1.22	0.13	fydev	0.38	0.85
sel_a50_ai	20.64	0.54	rec_dev	-0.69	0.50	fydev	0.23	0.78
sel_aslope_srv_ebs	1.55	0.38	rec_dev	-0.46	0.53	fydev	0.21	0.76
sel_a50_srv_ebs	5.18	0.31	rec_dev	0.14	0.47	fydev	0.28	0.79
M	0.03	0.00	rec_dev	-0.13	0.52	fydev	0.38	0.87
log_avg_fmort	-3.09	0.14	rec_dev	-0.66	0.51	fydev	0.39	0.96
fmort_dev	-0.90	0.13	rec_dev	-0.70	0.50	fydev	2.20	0.44
fmort_dev	1.94	0.12	rec_dev	-0.43	0.51	fydev	0.31	0.91
fmort_dev	2.49	0.11	rec_dev	-0.04	0.49	fydev	0.33	0.91
fmort_dev	1.14	0.12	rec_dev	0.10	0.47	fydev	0.42	0.99
fmort_dev	1.21	0.11	rec_dev	-0.29	0.48	fydev	0.52	1.19
fmort_dev	0.16	0.11	rec_dev	-0.87	0.47	fydev	1.75	0.93
fmort_dev	-0.93	0.11	rec_dev	-1.08	0.46	fydev	0.44	1.06
fmort_dev	-0.96	0.11	rec_dev	-0.90	0.43	fydev	0.25	0.86
fmort_dev	-2.46	0.11	rec_dev	-0.91	0.41	fydev	0.10	0.76
fmort_dev	-1.51	0.11	rec_dev	-1.30	0.43	fydev	-0.04	0.71
fmort_dev	-0.69	0.11	rec_dev	-1.50	0.43	fydev	-0.15	0.67
fmort_dev	-0.70	0.11	rec_dev	-1.41	0.42	fydev	-0.25	0.65
fmort_dev	0.42	0.11	rec_dev	-1.26	0.41	fydev	-0.33	0.64
fmort_dev	1.70	0.10	rec_dev	-1.21	0.43	fydev	-0.39	0.62
fmort_dev	-0.36	0.11	rec_dev	-1.04	0.44	fydev	-0.44	0.61
fmort_dev	1.30	0.10	rec_dev	-0.47	0.40	fydev	-0.48	0.61
fmort_dev	1.20	0.10	rec_dev	-0.03	0.39	fydev	-0.49	0.61
fmort_dev	0.91	0.10	rec_dev	0.12	0.37	fydev	-0.50	0.60
fmort_dev	0.32	0.10	rec_dev	-0.19	0.52	fydev	-0.50	0.60
fmort_dev	1.04	0.10	rec_dev	1.93	0.17	fydev	-0.50	0.60
fmort_dev	1.23	0.10	rec_dev	1.08	0.44	fydev	-0.49	0.61
fmort_dev	0.69	0.10	rec_dev	1.27	0.36	fydev	-0.48	0.61
fmort_dev	0.38	0.10	rec_dev	0.27	0.64	fydev	-0.46	0.61
fmort_dev	0.13	0.10	rec_dev	2.18	0.21	fydev	-0.45	0.61
fmort_dev	0.77	0.10	rec_dev	0.59	0.70	fydev	-0.44	0.62
fmort_dev	0.07	0.10	rec_dev	1.38	0.37	fydev	-0.42	0.62
fmort_dev	-0.34	0.11	rec_dev	0.22	0.69	fydev	-0.41	0.62
fmort_dev	-0.26	0.11	rec_dev	1.51	0.41	fydev	-0.39	0.63
fmort_dev	-1.13	0.11	rec_dev	0.74	0.77	fydev	-0.38	0.63
fmort_dev	-0.33	0.11	rec_dev	1.33	0.77	fydev	-0.37	0.63
fmort_dev	-0.55	0.11	rec_dev	1.50	0.74	fydev	-1.19	0.48
fmort_dev	-0.44	0.11	rec_dev	1.19	0.89	q_ai	1.10	0.06
fmort_dev	-0.47	0.11	mean_log_rec	0.33	0.13	q_srv_ebs	0.76	0.12
fmort_dev	-0.36	0.11	log_rinit	-0.32	0.13			
fmort_dev	-0.78	0.11	fydev	-0.41	0.58			

Table 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			
	2016		2014		2016		2014		2016		2014	
Year	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
1977	18,454	0.040	15,500	0.041	5,182	0.054	4,303	0.058	695	0.515	881	0.519
1978	18,984	0.039	15,992	0.040	5,365	0.050	4,433	0.054	872	0.544	1,044	0.543
1979	17,053	0.041	14,083	0.043	4,662	0.050	3,731	0.053	1,593	0.457	1,535	0.490
1980	13,986	0.043	11,441	0.047	3,821	0.052	3,003	0.056	1,220	0.519	1,223	0.528
1981	13,741	0.045	11,335	0.049	3,828	0.051	3,035	0.055	718	0.520	823	0.529
1982	13,412	0.046	11,286	0.050	3,833	0.051	3,100	0.055	686	0.504	838	0.518
1983	13,657	0.047	11,661	0.051	4,020	0.050	3,296	0.054	906	0.510	1,110	0.519
1984	14,124	0.046	12,186	0.050	4,264	0.048	3,533	0.052	1,331	0.496	1,408	0.542
1985	14,606	0.046	12,761	0.050	4,508	0.046	3,778	0.050	1,540	0.470	1,755	0.517
1986	15,145	0.046	13,359	0.051	4,773	0.045	4,031	0.048	1,034	0.487	1,416	0.513
1987	15,601	0.046	13,917	0.051	5,007	0.044	4,273	0.047	583	0.484	820	0.522
1988	15,924	0.046	14,402	0.051	5,195	0.043	4,493	0.046	471	0.469	670	0.503
1989	16,226	0.047	14,886	0.052	5,342	0.043	4,687	0.046	566	0.436	769	0.476
1990	16,099	0.048	15,047	0.054	5,228	0.044	4,674	0.047	556	0.420	762	0.461
1991	14,519	0.053	13,932	0.060	4,743	0.048	4,335	0.051	379	0.444	557	0.480
1992	14,672	0.054	14,288	0.062	4,779	0.049	4,426	0.052	310	0.444	460	0.478
1993	13,772	0.059	13,566	0.067	4,467	0.053	4,171	0.058	339	0.437	440	0.478
1994	13,039	0.063	13,078	0.073	4,237	0.058	4,016	0.063	394	0.432	458	0.483
1995	12,588	0.067	12,746	0.078	4,132	0.062	3,947	0.068	412	0.446	515	0.499
1996	12,476	0.070	12,764	0.081	4,117	0.065	3,974	0.071	489	0.459	670	0.513
1997	11,937	0.075	12,349	0.088	3,940	0.070	3,846	0.078	868	0.425	927	0.557
1998	11,297	0.082	11,822	0.097	3,746	0.078	3,701	0.087	1,342	0.413	1,645	0.584
1999	11,124	0.087	11,771	0.103	3,709	0.082	3,713	0.093	1,570	0.393	2,058	0.586
2000	11,093	0.091	11,851	0.108	3,724	0.086	3,779	0.097	1,141	0.546	1,362	0.705
2001	11,765	0.097	13,334	0.119	3,739	0.090	3,854	0.102	9,506	0.216	23,104	0.248
2002	11,998	0.105	13,902	0.128	3,666	0.095	3,839	0.109	4,102	0.476	3,283	0.983
2003	12,704	0.110	15,136	0.136	3,692	0.099	3,932	0.112	4,949	0.382	7,391	0.462
2004	13,418	0.113	16,378	0.142	3,740	0.101	4,037	0.115	1,823	0.671	2,057	0.793
2005	14,928	0.120	18,356	0.151	3,781	0.103	4,134	0.118	12,288	0.247	13,303	0.428
2006	16,172	0.123	20,256	0.155	3,853	0.105	4,258	0.120	2,510	0.730	4,044	1.083
2007	17,612	0.128	22,198	0.161	3,886	0.108	4,371	0.124	5,534	0.395	3,662	0.998
2008	18,967	0.131	24,205	0.166	3,939	0.110	4,483	0.127	1,724	0.722	3,038	0.976
2009	20,677	0.136	26,782	0.172	4,005	0.113	4,628	0.131	6,257	0.441	11,653	0.614
2010	22,287	0.139	29,042	0.176	4,105	0.116	4,829	0.136	2,912	0.799	2,011	0.824
2011	24,112	0.143	31,281	0.180	4,264	0.120	5,136	0.141	5,264	0.794	1,560	0.777
2012	26,175	0.147	33,663	0.183	4,516	0.123	5,597	0.146	6,235	0.753		
2013	28,218	0.149	35,973	0.186	4,853	0.127	6,208	0.153	4,576	0.922		
2014	30,000	0.153	38,155	0.189	5,266	0.132	6,978	0.160				
2015	31,919	0.155	40,391	0.192	5,841	0.136						
2016	33,846	0.157			6,543	0.140						
2017	35,699				7,305							
Mean recruitment of post-1976 year classes									2,486		2,993	

Table 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	0.69	0.47	0.57	0.84	1.62	1.29	0.87	0.72	0.69	0.71	0.76	0.75	4.39	0.64	0.63	0.67	0.72	2.36	0.62	0.50
1978	0.87	0.67	0.45	0.55	0.82	1.56	1.24	0.84	0.70	0.66	0.69	0.73	0.72	4.22	0.62	0.61	0.64	0.69	2.26	0.59
1979	1.59	0.84	0.65	0.44	0.54	0.79	1.51	1.20	0.80	0.66	0.61	0.63	0.67	0.65	3.76	0.55	0.53	0.55	0.59	1.91
1980	1.22	1.54	0.82	0.63	0.42	0.52	0.76	1.45	1.13	0.74	0.59	0.54	0.54	0.57	0.54	3.09	0.44	0.42	0.43	0.45
1981	0.72	1.18	1.49	0.79	0.61	0.41	0.50	0.73	1.39	1.08	0.70	0.55	0.50	0.51	0.53	0.50	2.85	0.40	0.39	0.39
1982	0.69	0.69	1.14	1.44	0.76	0.59	0.40	0.48	0.71	1.33	1.02	0.66	0.52	0.47	0.47	0.49	0.46	2.61	0.37	0.35
1983	0.91	0.66	0.67	1.10	1.39	0.74	0.57	0.38	0.47	0.68	1.28	0.98	0.63	0.50	0.45	0.45	0.46	0.44	2.47	0.35
1984	1.33	0.88	0.64	0.65	1.07	1.35	0.71	0.55	0.37	0.45	0.66	1.23	0.94	0.61	0.48	0.43	0.43	0.45	0.42	2.37
1985	1.54	1.29	0.85	0.62	0.63	1.03	1.30	0.69	0.53	0.36	0.44	0.63	1.19	0.91	0.59	0.46	0.42	0.42	0.43	0.40
1986	1.03	1.49	1.24	0.82	0.60	0.61	1.00	1.26	0.67	0.51	0.34	0.42	0.61	1.15	0.88	0.57	0.44	0.40	0.40	0.41
1987	0.58	1.00	1.44	1.20	0.79	0.58	0.59	0.97	1.22	0.65	0.50	0.33	0.41	0.59	1.10	0.85	0.55	0.43	0.39	0.39
1988	0.47	0.56	0.97	1.39	1.16	0.77	0.56	0.57	0.93	1.18	0.62	0.48	0.32	0.39	0.57	1.06	0.81	0.52	0.41	0.37
1989	0.57	0.46	0.54	0.94	1.35	1.13	0.74	0.54	0.55	0.90	1.13	0.60	0.46	0.31	0.38	0.54	1.02	0.78	0.50	0.39
1990	0.56	0.55	0.44	0.53	0.91	1.30	1.09	0.72	0.52	0.53	0.86	1.08	0.57	0.44	0.29	0.36	0.51	0.96	0.73	0.47
1991	0.38	0.54	0.53	0.43	0.51	0.88	1.26	1.05	0.69	0.49	0.49	0.80	1.00	0.52	0.40	0.26	0.32	0.45	0.84	0.64
1992	0.31	0.37	0.52	0.51	0.41	0.49	0.85	1.22	1.01	0.66	0.48	0.47	0.77	0.96	0.50	0.38	0.25	0.30	0.43	0.80
1993	0.34	0.30	0.35	0.50	0.49	0.40	0.48	0.82	1.17	0.97	0.62	0.45	0.44	0.71	0.88	0.46	0.35	0.23	0.27	0.39
1994	0.39	0.33	0.29	0.34	0.49	0.48	0.39	0.46	0.78	1.11	0.91	0.59	0.42	0.41	0.66	0.82	0.42	0.32	0.21	0.25
1995	0.41	0.38	0.32	0.28	0.33	0.47	0.46	0.37	0.44	0.75	1.06	0.87	0.56	0.39	0.39	0.62	0.76	0.39	0.29	0.19
1996	0.49	0.40	0.37	0.31	0.27	0.32	0.46	0.45	0.36	0.43	0.72	1.01	0.83	0.53	0.38	0.37	0.59	0.72	0.37	0.28
1997	0.87	0.47	0.39	0.36	0.30	0.26	0.31	0.44	0.43	0.34	0.40	0.68	0.96	0.78	0.49	0.35	0.34	0.54	0.66	0.34
1998	1.34	0.84	0.46	0.37	0.34	0.29	0.25	0.30	0.42	0.41	0.32	0.38	0.64	0.89	0.72	0.46	0.32	0.31	0.49	0.60
1999	1.57	1.30	0.81	0.44	0.36	0.33	0.28	0.24	0.29	0.40	0.39	0.31	0.36	0.60	0.84	0.68	0.43	0.30	0.29	0.46
2000	1.14	1.52	1.26	0.79	0.43	0.35	0.32	0.27	0.24	0.28	0.39	0.37	0.29	0.34	0.57	0.80	0.64	0.41	0.28	0.27
2001	9.51	1.10	1.47	1.21	0.76	0.41	0.34	0.31	0.26	0.23	0.27	0.37	0.36	0.28	0.33	0.55	0.76	0.61	0.38	0.27
2002	4.10	9.19	1.07	1.42	1.17	0.73	0.40	0.33	0.30	0.25	0.22	0.25	0.35	0.34	0.27	0.31	0.51	0.71	0.57	0.36
2003	4.95	3.97	8.89	1.03	1.37	1.14	0.71	0.39	0.31	0.29	0.24	0.21	0.24	0.34	0.32	0.25	0.29	0.49	0.67	0.54
2004	1.82	4.79	3.84	8.60	1.00	1.33	1.10	0.69	0.37	0.30	0.28	0.23	0.20	0.23	0.32	0.31	0.24	0.28	0.46	0.64
2005	12.29	1.76	4.63	3.71	8.32	0.97	1.29	1.06	0.66	0.36	0.29	0.27	0.22	0.19	0.22	0.31	0.30	0.23	0.27	0.44
2006	2.51	11.88	1.71	4.48	3.59	8.05	0.93	1.24	1.03	0.64	0.35	0.28	0.26	0.21	0.18	0.21	0.30	0.28	0.22	0.26
2007	5.53	2.43	11.49	1.65	4.33	3.47	7.78	0.90	1.20	0.99	0.62	0.33	0.27	0.25	0.20	0.18	0.21	0.28	0.27	0.21
2008	1.72	5.35	2.35	11.12	1.60	4.19	3.36	7.52	0.87	1.16	0.95	0.59	0.32	0.26	0.24	0.19	0.17	0.20	0.27	0.26
2009	6.26	1.67	5.18	2.27	10.75	1.54	4.05	3.25	7.27	0.84	1.12	0.92	0.57	0.31	0.25	0.23	0.19	0.16	0.19	0.26
2010	2.91	6.05	1.61	5.01	2.20	10.40	1.49	3.92	3.14	7.01	0.81	1.07	0.88	0.55	0.30	0.24	0.22	0.18	0.16	0.18
2011	5.26	2.82	5.85	1.56	4.84	2.12	10.06	1.44	3.78	3.02	6.75	0.78	1.03	0.85	0.53	0.28	0.23	0.21	0.17	0.15
2012	6.23	5.09	2.72	5.66	1.51	4.68	2.05	9.72	1.39	3.65	2.92	6.50	0.75	0.99	0.81	0.51	0.27	0.22	0.20	0.16
2013	4.58	6.03	4.92	2.63	5.48	1.46	4.53	1.99	9.40	1.35	3.52	2.81	6.26	0.72	0.95	0.78	0.49	0.26	0.21	0.19
2014	1.84	4.43	5.83	4.76	2.55	5.30	1.41	4.38	1.92	9.06	1.29	3.38	2.70	6.00	0.69	0.91	0.75	0.46	0.25	0.20
2015	1.84	1.78	4.28	5.64	4.61	2.46	5.12	1.36	4.23	1.85	8.74	1.25	3.26	2.60	5.78	0.67	0.88	0.72	0.44	0.24
2016	1.84	1.78	1.72	4.14	5.46	4.46	2.38	4.95	1.32	4.09	1.79	8.42	1.20	3.14	2.50	5.56	0.64	0.84	0.69	0.43

Table 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	0.41	0.35	0.30	0.26	0.23	0.21	0.20	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.47
1978	0.48	0.39	0.33	0.29	0.25	0.22	0.20	0.19	0.17	0.17	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.57
1979	0.49	0.39	0.32	0.27	0.23	0.20	0.17	0.16	0.14	0.13	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.49
1980	1.42	0.36	0.28	0.22	0.18	0.15	0.13	0.11	0.10	0.09	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.33
1981	0.40	1.28	0.32	0.25	0.20	0.16	0.13	0.11	0.10	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.33
1982	0.35	0.36	1.14	0.28	0.22	0.17	0.14	0.12	0.10	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.31
1983	0.33	0.33	0.34	1.07	0.27	0.20	0.16	0.13	0.11	0.09	0.08	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.32
1984	0.33	0.32	0.32	0.32	1.02	0.25	0.20	0.15	0.12	0.10	0.09	0.07	0.07	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.34
1985	2.28	0.32	0.30	0.30	0.31	0.97	0.24	0.19	0.15	0.12	0.10	0.08	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.36
1986	0.39	2.20	0.31	0.29	0.29	0.30	0.94	0.23	0.18	0.14	0.11	0.09	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.38
1987	0.40	0.37	2.11	0.30	0.28	0.28	0.29	0.90	0.22	0.17	0.14	0.11	0.09	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.40
1988	0.37	0.38	0.36	2.02	0.28	0.27	0.27	0.27	0.86	0.21	0.16	0.13	0.10	0.09	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.41
1989	0.35	0.35	0.36	0.34	1.92	0.27	0.25	0.25	0.26	0.82	0.20	0.16	0.12	0.10	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.42
1990	0.37	0.33	0.33	0.34	0.32	1.78	0.25	0.23	0.23	0.24	0.75	0.19	0.14	0.11	0.09	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.42
1991	0.40	0.31	0.28	0.28	0.28	0.26	1.45	0.20	0.19	0.19	0.19	0.59	0.14	0.11	0.09	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.34
1992	0.61	0.38	0.30	0.26	0.26	0.26	0.25	1.37	0.19	0.18	0.18	0.18	0.55	0.14	0.10	0.08	0.07	0.05	0.05	0.04	0.03	0.03	0.35
1993	0.72	0.54	0.34	0.26	0.23	0.23	0.23	0.21	1.17	0.16	0.15	0.15	0.15	0.46	0.11	0.09	0.07	0.05	0.04	0.04	0.03	0.03	0.31
1994	0.35	0.64	0.48	0.30	0.23	0.20	0.20	0.20	0.18	1.00	0.14	0.13	0.13	0.13	0.39	0.10	0.07	0.06	0.05	0.04	0.03	0.03	0.28
1995	0.23	0.32	0.58	0.43	0.27	0.21	0.18	0.18	0.18	0.16	0.88	0.12	0.11	0.11	0.11	0.34	0.08	0.06	0.05	0.04	0.03	0.03	0.27
1996	0.18	0.21	0.30	0.54	0.40	0.25	0.19	0.17	0.16	0.16	0.15	0.81	0.11	0.10	0.10	0.10	0.31	0.08	0.06	0.05	0.04	0.03	0.27
1997	0.25	0.16	0.19	0.27	0.49	0.36	0.22	0.17	0.15	0.14	0.14	0.13	0.70	0.10	0.09	0.09	0.09	0.27	0.07	0.05	0.04	0.03	0.25
1998	0.30	0.22	0.14	0.17	0.24	0.42	0.31	0.19	0.14	0.13	0.12	0.12	0.11	0.59	0.08	0.07	0.07	0.07	0.22	0.05	0.04	0.03	0.24
1999	0.55	0.28	0.21	0.13	0.15	0.21	0.38	0.28	0.17	0.13	0.11	0.11	0.11	0.10	0.53	0.07	0.07	0.06	0.06	0.20	0.05	0.04	0.24
2000	0.43	0.52	0.26	0.19	0.12	0.14	0.20	0.35	0.26	0.16	0.12	0.10	0.10	0.10	0.09	0.48	0.07	0.06	0.06	0.06	0.18	0.04	0.25
2001	0.26	0.40	0.49	0.25	0.18	0.12	0.13	0.18	0.33	0.24	0.15	0.11	0.10	0.09	0.09	0.08	0.45	0.06	0.06	0.05	0.05	0.17	0.27
2002	0.25	0.24	0.37	0.44	0.22	0.16	0.10	0.12	0.17	0.30	0.22	0.13	0.10	0.08	0.08	0.08	0.07	0.39	0.05	0.05	0.05	0.05	0.38
2003	0.34	0.23	0.22	0.35	0.42	0.21	0.15	0.10	0.11	0.15	0.27	0.20	0.12	0.09	0.08	0.08	0.07	0.07	0.36	0.05	0.05	0.04	0.40
2004	0.51	0.32	0.22	0.21	0.33	0.39	0.20	0.14	0.09	0.11	0.15	0.26	0.19	0.11	0.09	0.07	0.07	0.07	0.06	0.34	0.05	0.04	0.42
2005	0.61	0.49	0.30	0.21	0.20	0.31	0.37	0.19	0.14	0.09	0.10	0.14	0.24	0.18	0.11	0.08	0.07	0.07	0.07	0.06	0.32	0.04	0.43
2006	0.42	0.58	0.47	0.29	0.20	0.19	0.30	0.36	0.18	0.13	0.08	0.10	0.13	0.23	0.17	0.10	0.08	0.07	0.06	0.06	0.06	0.31	0.45
2007	0.24	0.40	0.56	0.44	0.28	0.19	0.18	0.28	0.34	0.17	0.12	0.08	0.09	0.12	0.22	0.16	0.10	0.07	0.06	0.06	0.06	0.05	0.71
2008	0.20	0.23	0.39	0.53	0.42	0.26	0.18	0.17	0.27	0.32	0.16	0.12	0.07	0.08	0.12	0.21	0.15	0.09	0.07	0.06	0.06	0.05	0.72
2009	0.25	0.19	0.22	0.37	0.50	0.40	0.25	0.17	0.16	0.25	0.30	0.15	0.11	0.07	0.08	0.11	0.19	0.14	0.09	0.06	0.05	0.05	0.73
2010	0.25	0.24	0.18	0.21	0.35	0.48	0.38	0.24	0.16	0.15	0.24	0.28	0.14	0.10	0.07	0.08	0.10	0.18	0.13	0.08	0.06	0.05	0.73
2011	0.17	0.24	0.22	0.17	0.20	0.33	0.45	0.36	0.22	0.15	0.15	0.23	0.27	0.13	0.10	0.06	0.07	0.10	0.17	0.12	0.08	0.06	0.74
2012	0.14	0.16	0.23	0.21	0.17	0.19	0.31	0.43	0.34	0.21	0.15	0.14	0.21	0.25	0.13	0.09	0.06	0.07	0.09	0.16	0.12	0.07	0.75
2013	0.16	0.14	0.16	0.22	0.20	0.16	0.18	0.30	0.41	0.32	0.20	0.14	0.13	0.20	0.24	0.12	0.09	0.06	0.06	0.09	0.15	0.11	0.78
2014	0.18	0.15	0.13	0.15	0.20	0.19	0.15	0.17	0.28	0.38	0.30	0.19	0.13	0.12	0.19	0.23	0.11	0.08	0.05	0.06	0.08	0.14	0.83
2015	0.19	0.17	0.14	0.12	0.14	0.19	0.18	0.14	0.16	0.27	0.37	0.29	0.18	0.12	0.12	0.18	0.21	0.11	0.08	0.05	0.06	0.08	0.92
2016	0.23	0.18	0.17	0.14	0.12	0.14	0.19	0.18	0.14	0.16	0.26	0.35	0.28	0.17	0.12	0.11	0.17	0.20	0.10	0.07	0.05	0.05	0.95

Table 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 8,311 t and 7,272 t, respectively.

Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2016	155	155	155	155	155	155	155
2017	501	501	252	301	0	612	501
2018	596	596	307	326	0	721	596
2019	658	658	339	353	0	797	805
2020	706	706	367	382	0	849	857
2021	755	755	397	413	0	904	912
2022	804	804	427	444	0	959	967
2023	851	851	457	475	0	1,011	1,019
2024	898	898	487	506	0	1,061	1,069
2025	943	943	517	537	0	1,110	1,117
2026	986	986	547	567	0	1,155	1,163
2027	1,027	1,027	576	597	0	1,196	1,204
2028	1,063	1,063	603	625	0	1,233	1,241
2029	1,096	1,096	629	651	0	1,265	1,272
Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2016	6,516	6,516	6,516	6,516	6,516	6,516	6,516
2017	7,305	7,305	7,320	7,317	7,334	7,299	7,305
2018	8,073	8,073	8,179	8,161	8,288	8,026	8,073
2019	8,876	8,876	9,094	9,068	9,321	8,781	8,867
2020	9,697	9,697	10,044	10,011	10,409	9,547	9,634
2021	10,530	10,530	11,020	10,980	11,542	10,319	10,408
2022	11,346	11,346	11,994	11,947	12,692	11,070	11,159
2023	12,136	12,136	12,955	12,900	13,848	11,789	11,877
2024	12,888	12,888	13,892	13,828	15,001	12,466	12,554
2025	13,593	13,593	14,796	14,722	16,138	13,092	13,179
2026	14,232	14,232	15,644	15,561	17,239	13,649	13,734
2027	14,788	14,788	16,419	16,326	18,284	14,120	14,203
2028	15,248	15,248	17,105	17,001	19,254	14,494	14,574
2029	15,604	15,604	17,690	17,575	20,135	14,764	14,841
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2016	0.013	0.013	0.013	0.013	0.013	0.013	0.013
2017	0.039	0.039	0.020	0.023	0	0.048	0.039
2018	0.044	0.044	0.022	0.023	0	0.053	0.044
2019	0.045	0.045	0.022	0.023	0	0.055	0.055
2020	0.045	0.045	0.022	0.023	0	0.055	0.055
2021	0.045	0.045	0.022	0.023	0	0.055	0.055
2022	0.045	0.045	0.022	0.023	0	0.055	0.055
2023	0.045	0.045	0.022	0.023	0	0.055	0.055
2024	0.045	0.045	0.022	0.023	0	0.055	0.055
2025	0.045	0.045	0.022	0.023	0	0.055	0.055
2026	0.045	0.045	0.022	0.023	0	0.055	0.055
2027	0.045	0.045	0.022	0.023	0	0.055	0.055
2028	0.045	0.045	0.022	0.023	0	0.055	0.055
2029	0.045	0.045	0.022	0.023	0	0.055	0.055

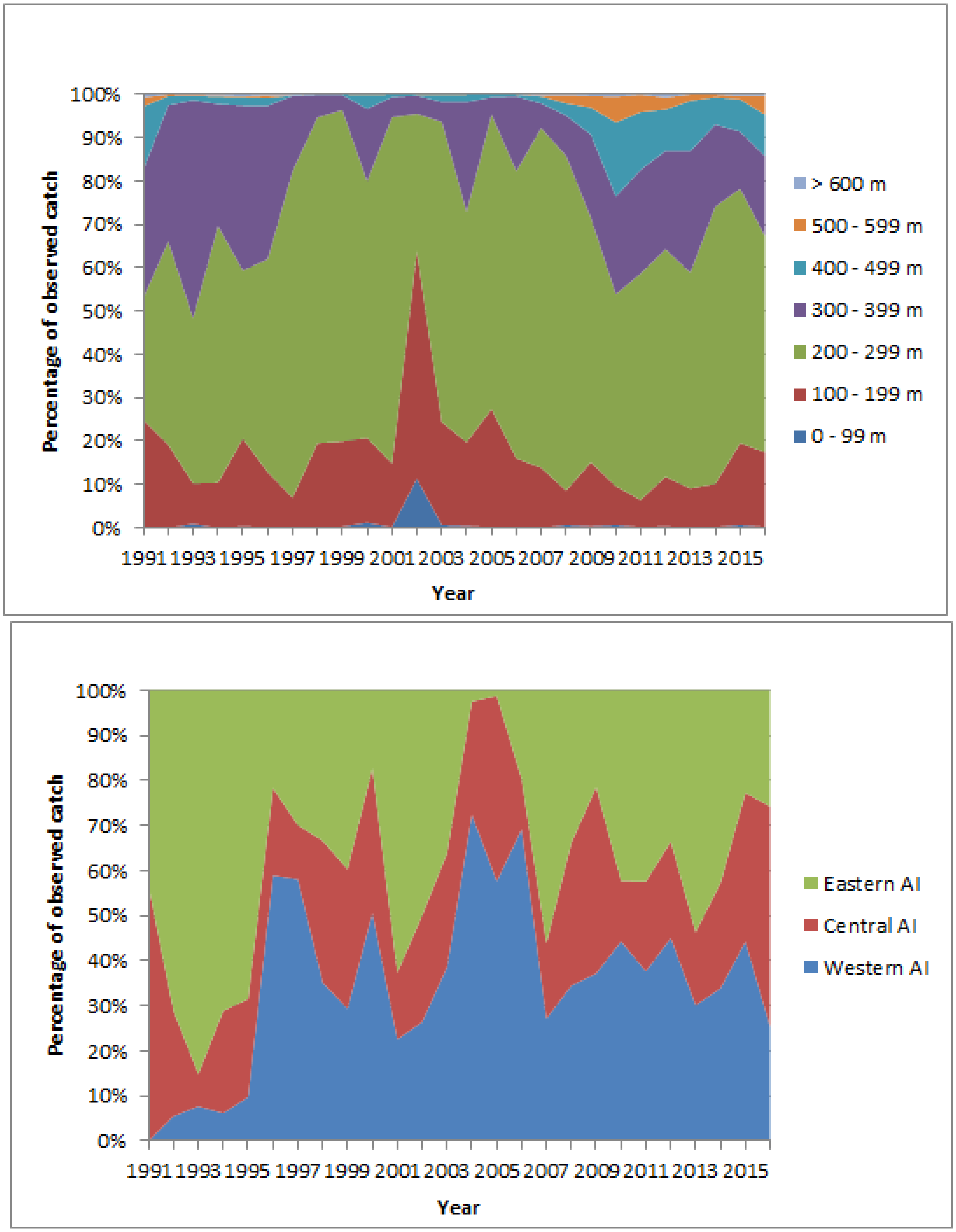

Figure 1. Distribution of observed Aleutian Islands (AI) blackspotted/rougheye rockfish catch (from North Pacific Groundfish Observer Program) by depth zone (top panel) and AI subarea (bottom panel) from 1991 to 2015.

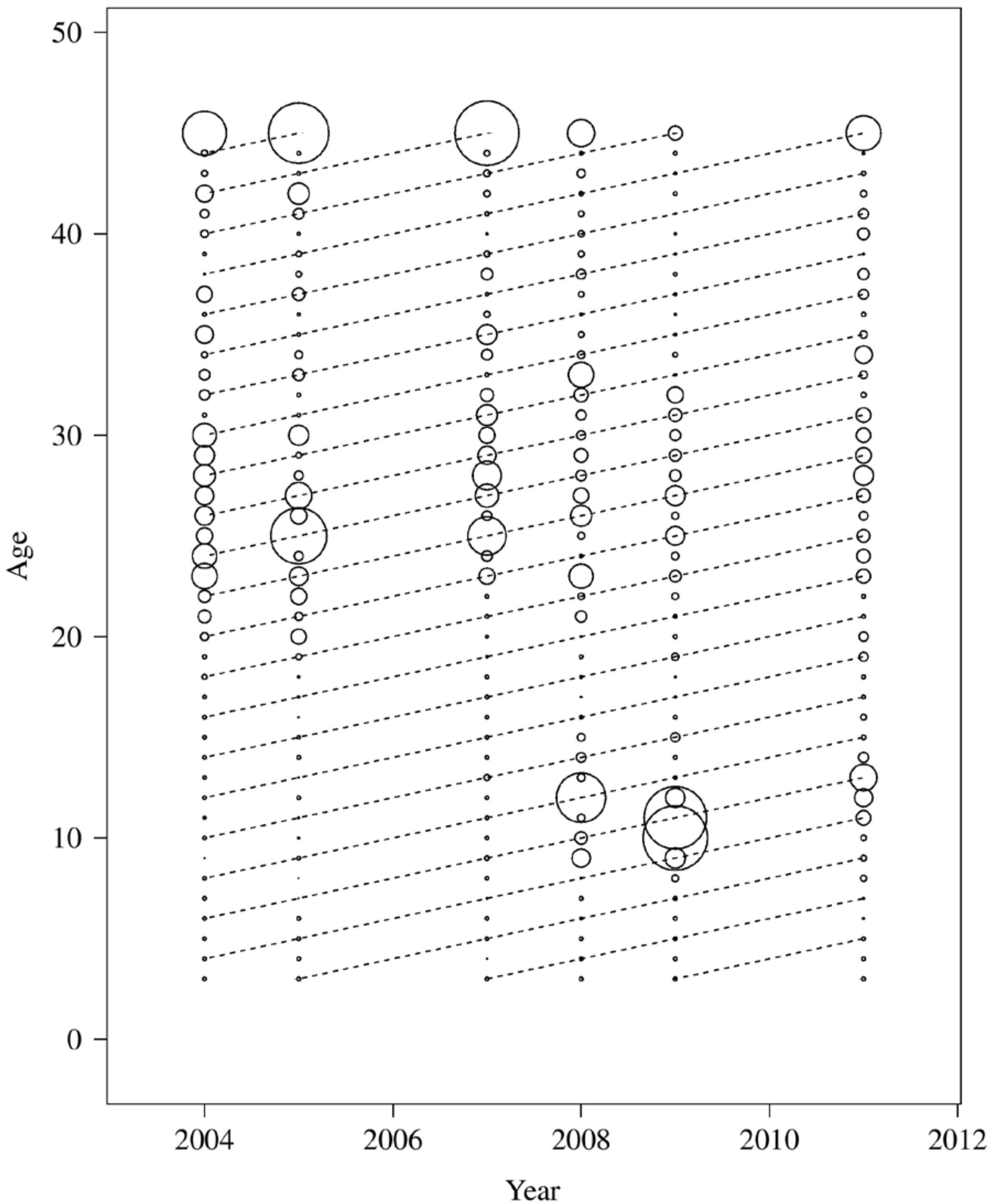

Figure 2. Fishery age composition data for the BSAI; bubbles are scaled within each year of samples and dashed lines denote cohorts.

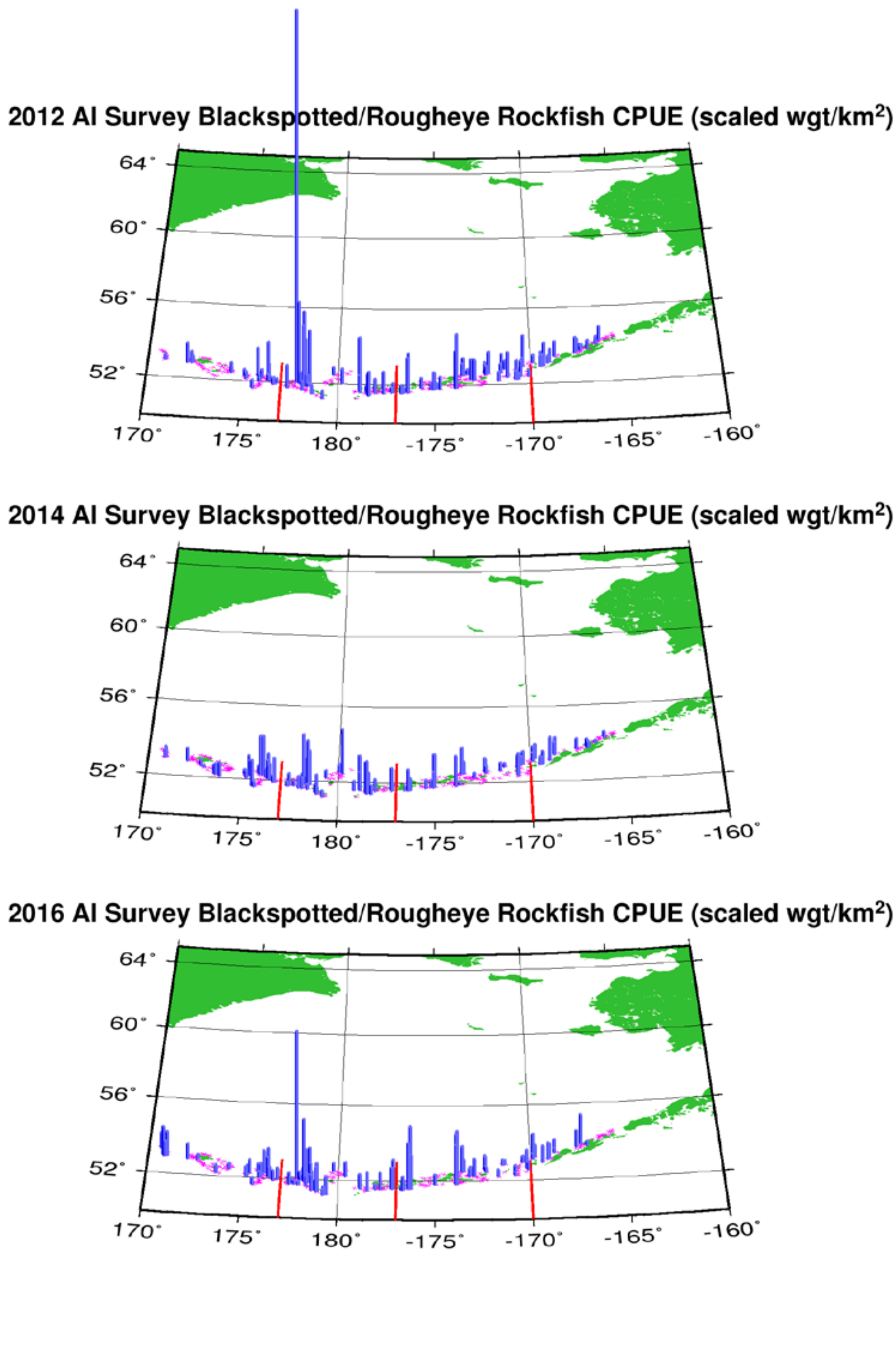

Figure 3. Scaled Aleutian Islands (AI) survey combined blackspotted and rougheye rockfish CPUE (square root of kg/km^2) from 1991-2016; the symbol × denotes tows with no catch. The red lines indicate boundaries between the western Aleutian Islands (WAI), central Aleutian Islands (CAI), eastern Aleutian Islands (EAI), and eastern Bering Sea (EBS) areas.

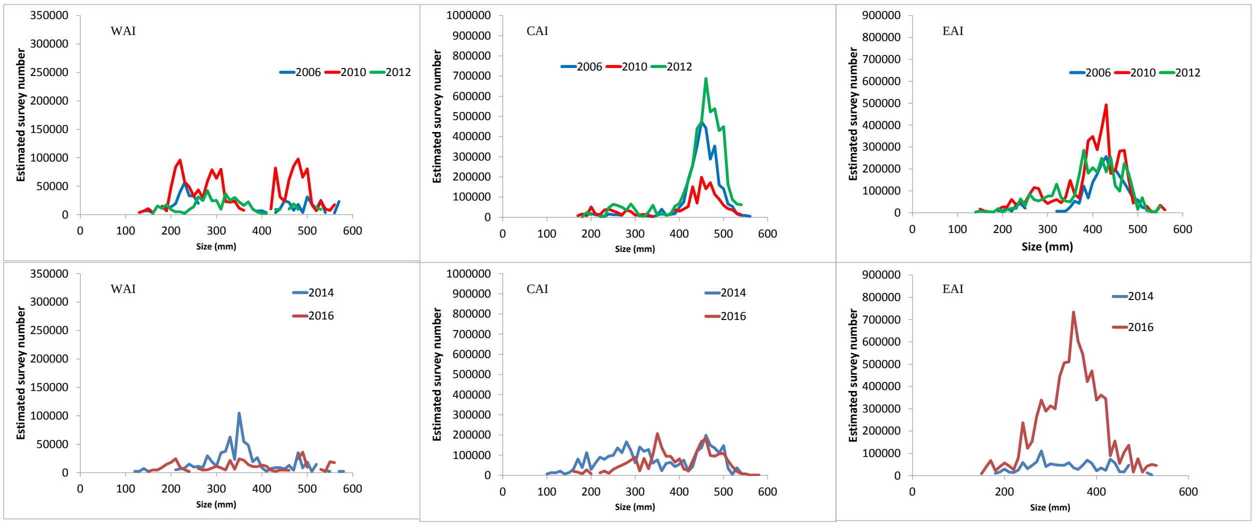

Figure 4. Size compositions of blackspotted/rougheye rockfish from the 2006-2016 AI surveys by AI subarea.

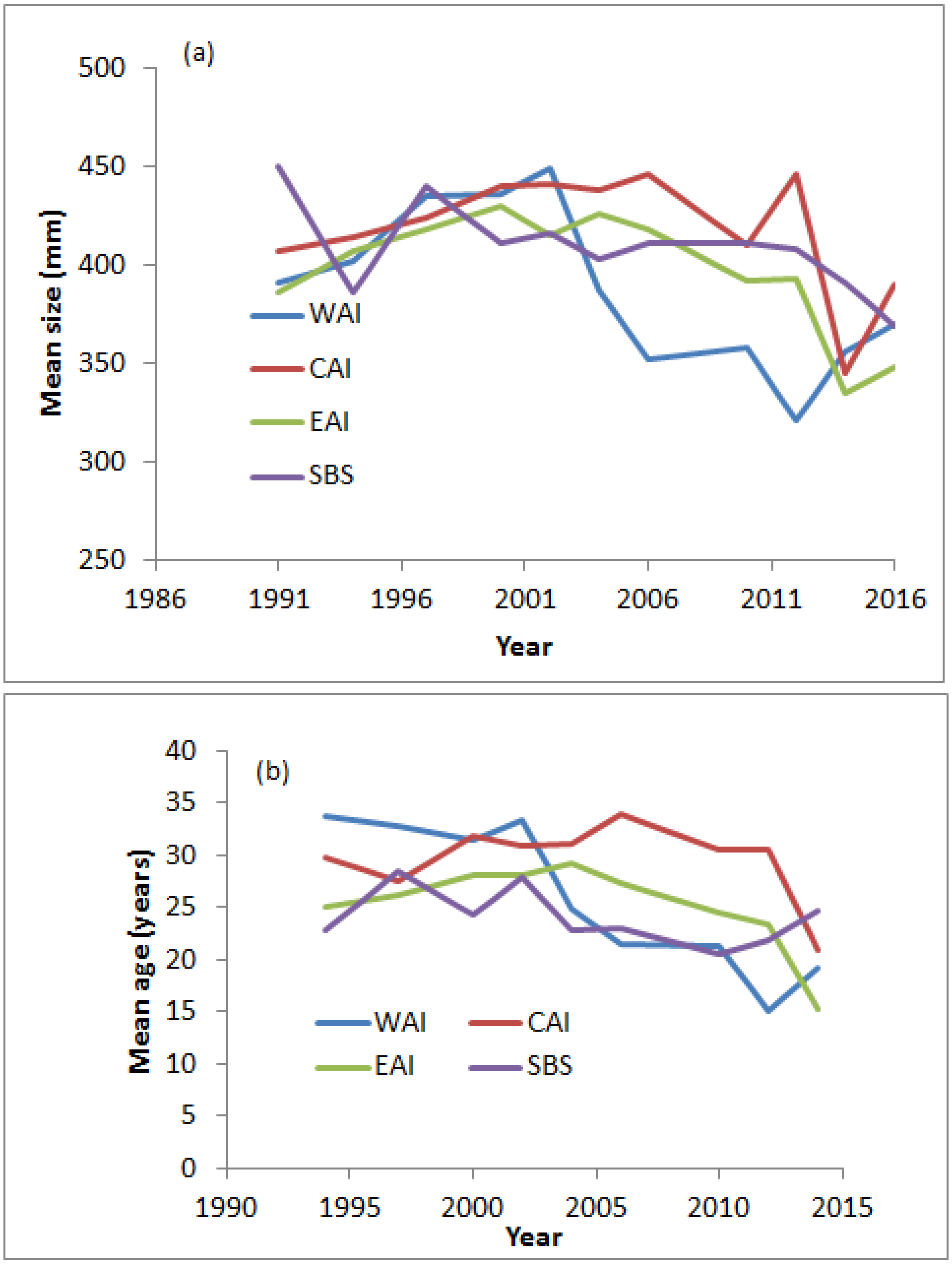

Figure 5. Mean size (a) and age (b) of blackspotted/rougheye rockfish from the 1991-2016 AI trawl surveys by subarea.

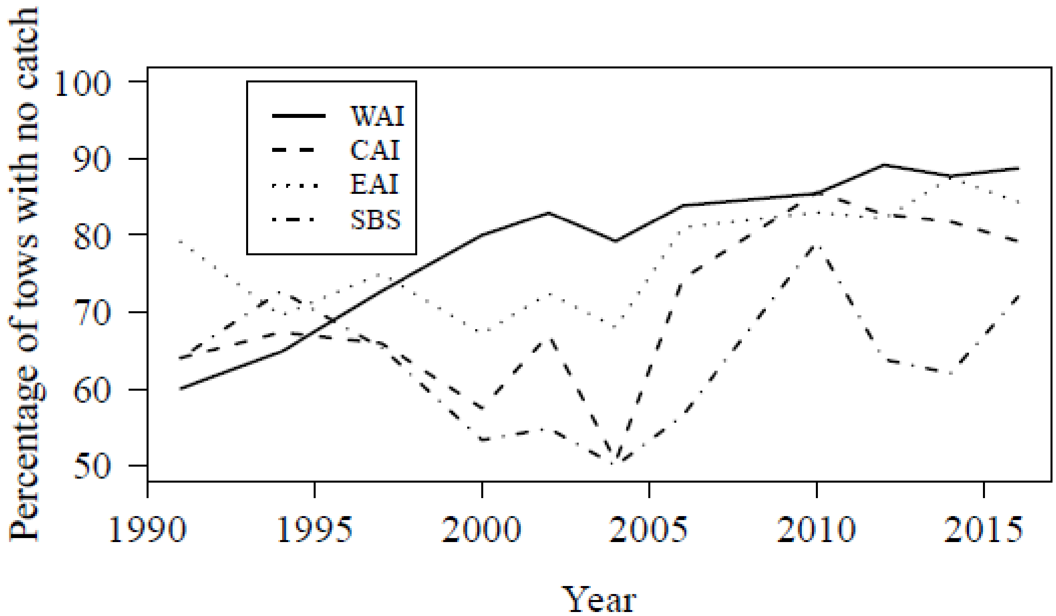

Figure 6. Percentage of survey tows with no catch of blackspotted/rougheye rockfish from the 1991-2016 AI trawl surveys by subarea.

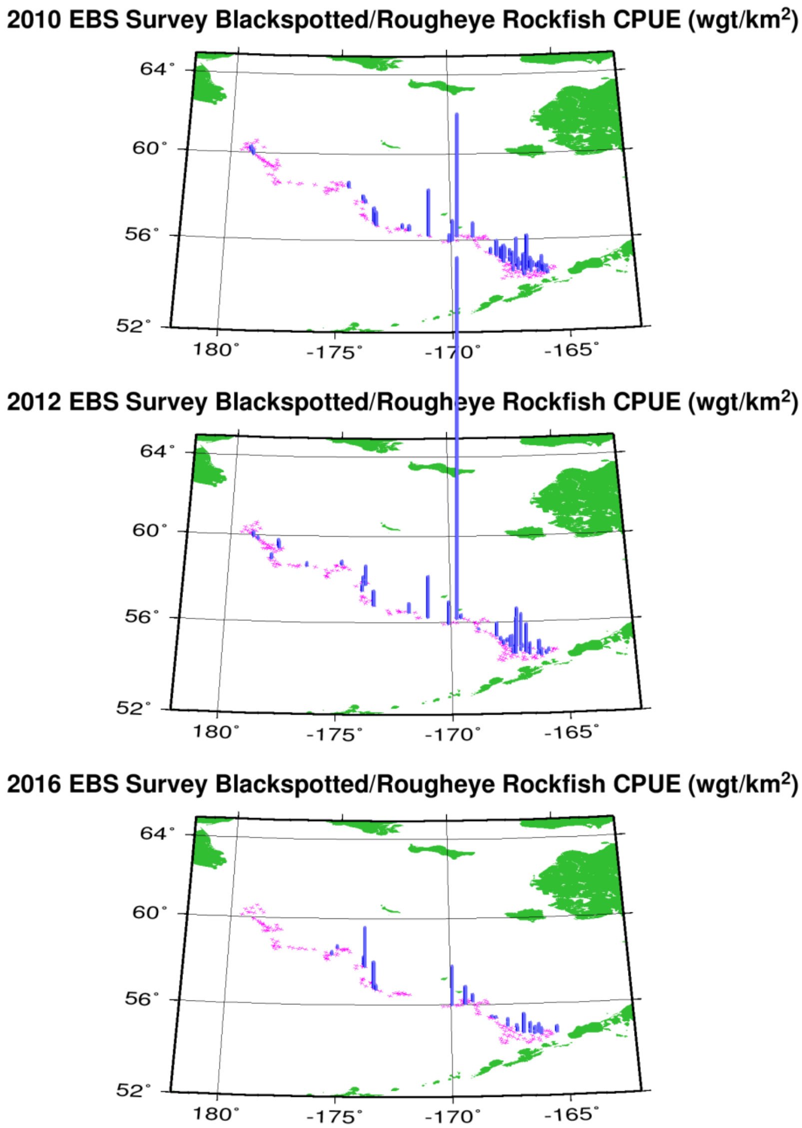

Figure 7. Scaled EBS survey combined blackspotted and rougheye rockfish CPUE (kg/km^2) from 2010-2016; the symbol × denotes tows with no catch.

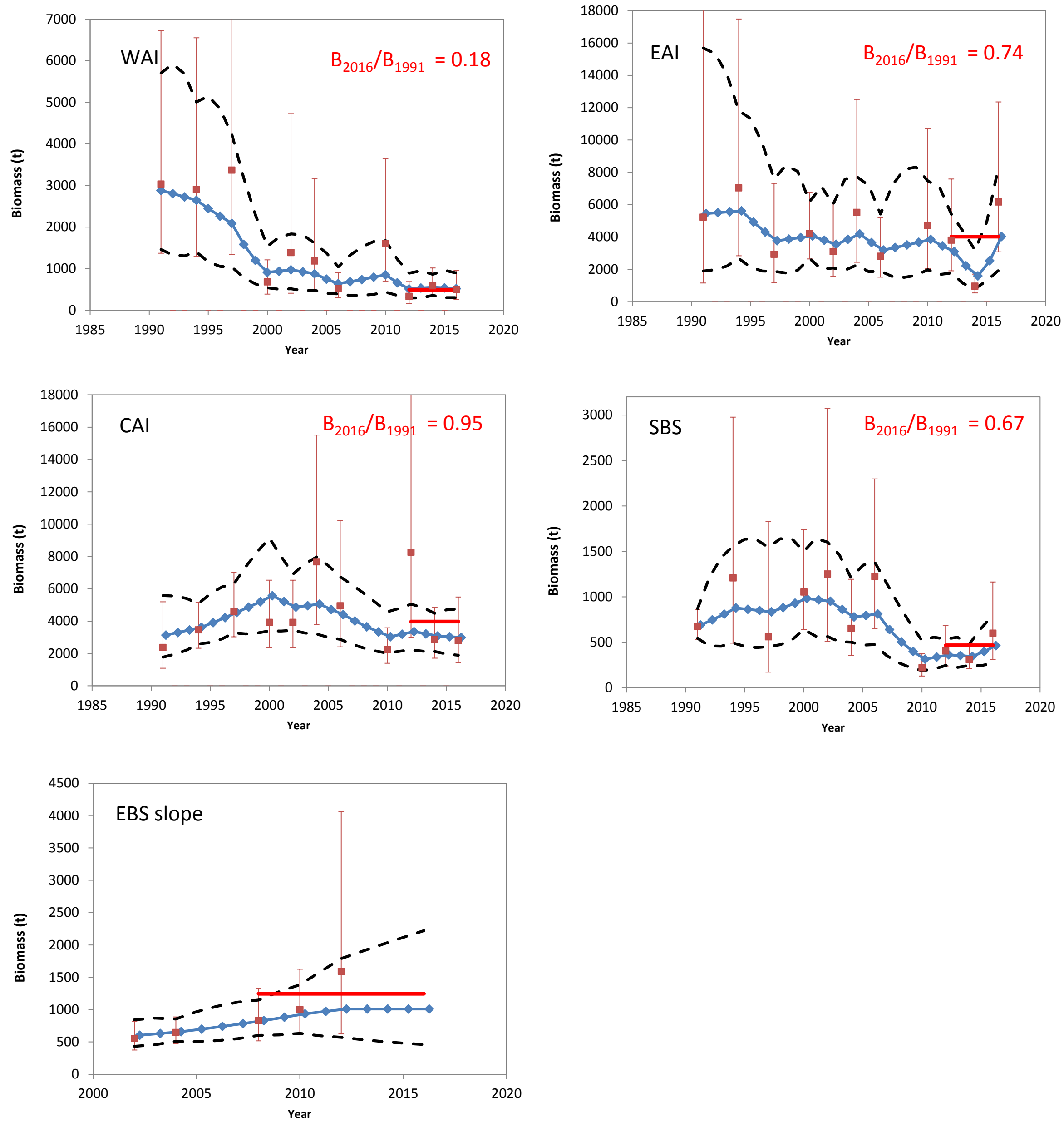

Figure 8. Time series of AI and EBS slope trawl survey biomass by subarea, with the fits from a random effects model to smooth the time series. The ratio of the biomass estimate in 2016 to that in 1991 indicates the estimated level of depletion over this time period. The horizontal red lines show the estimate from a weighted average of the three most recent surveys.

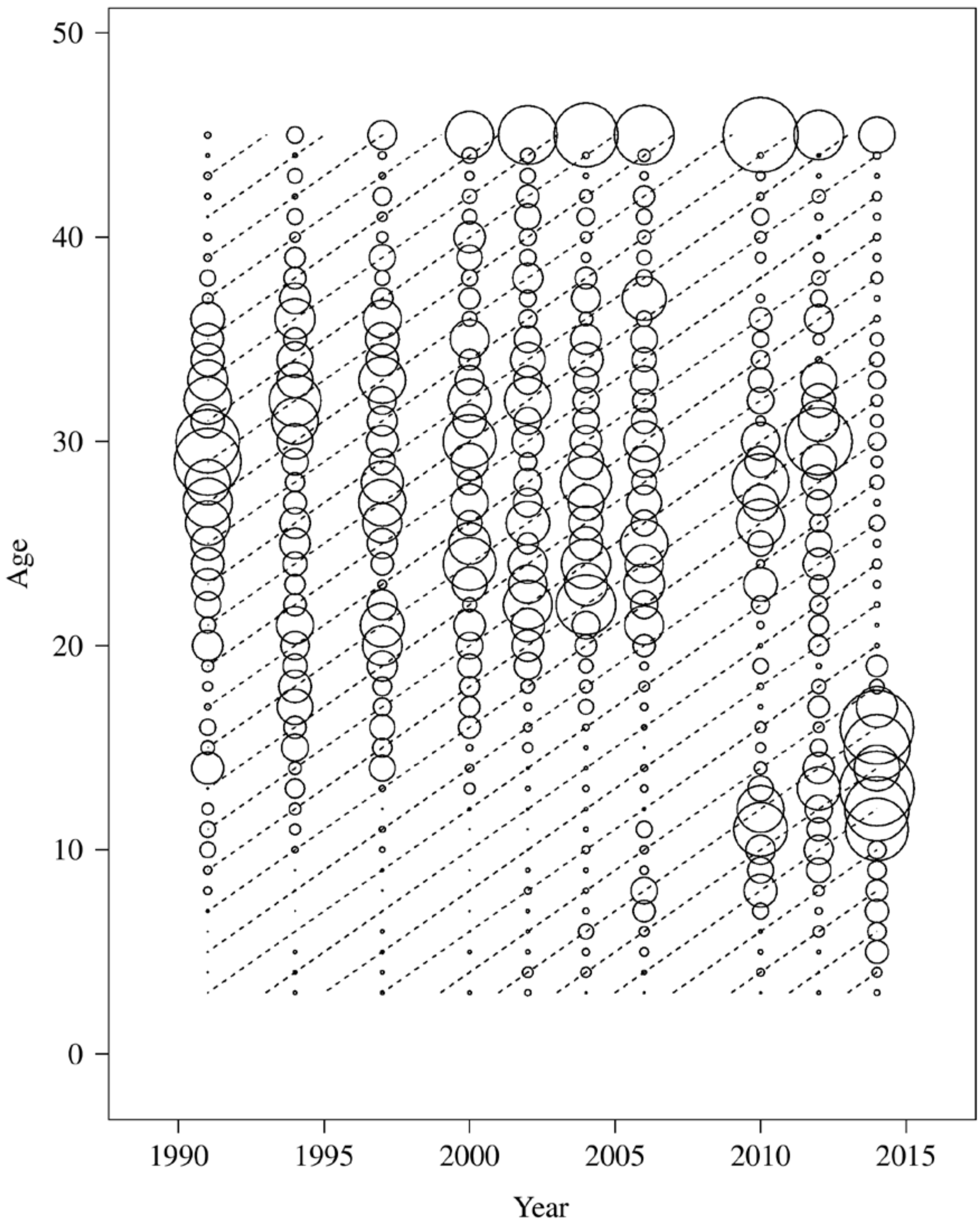

Figure 9. Age composition data from the Aleutian Islands trawl survey; bubbles are scaled within each year of samples and dashed lines denote cohorts.

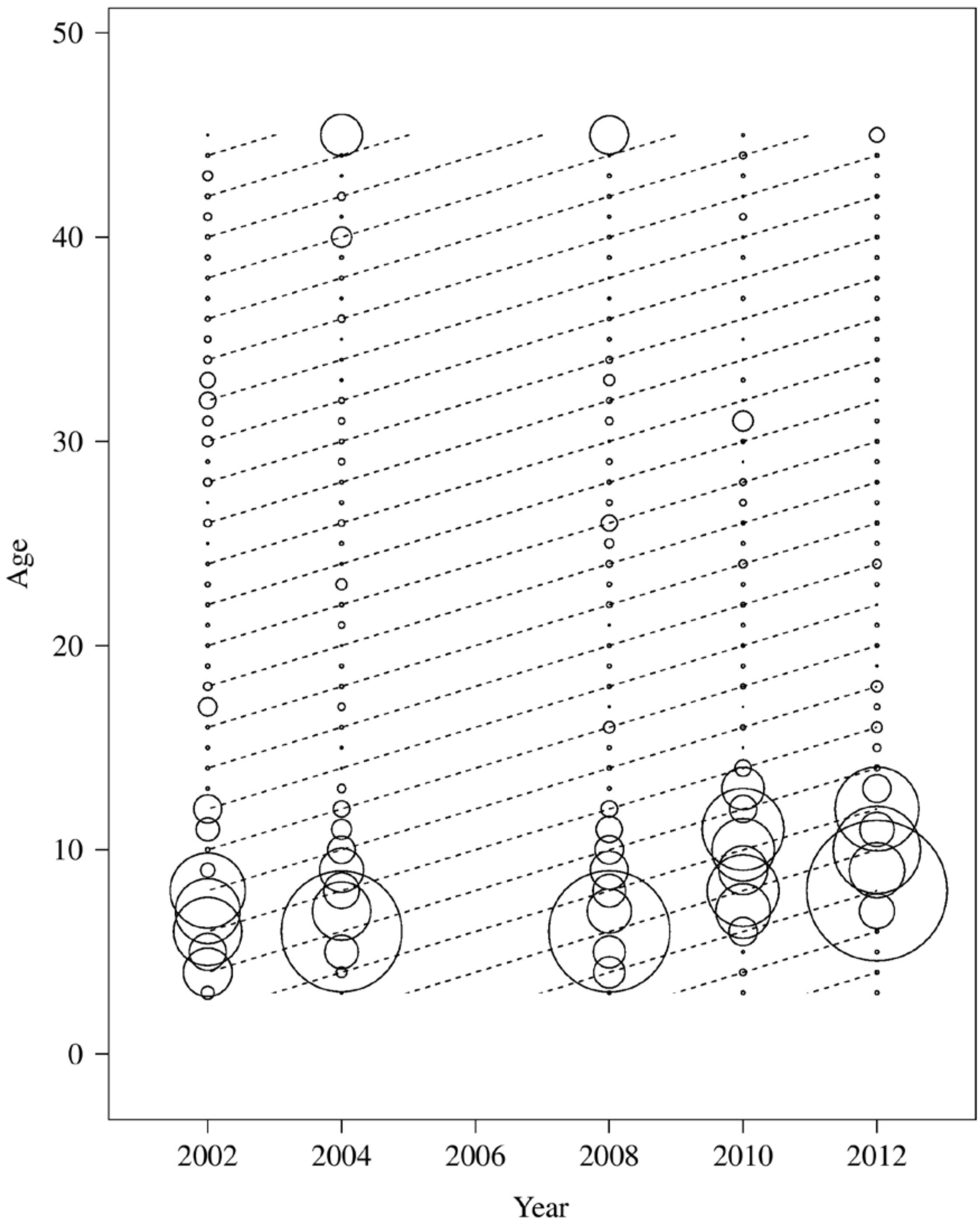

Figure 10. Age composition data from the EBS trawl survey; bubbles are scaled within each year of samples and dashed lines denote cohorts.

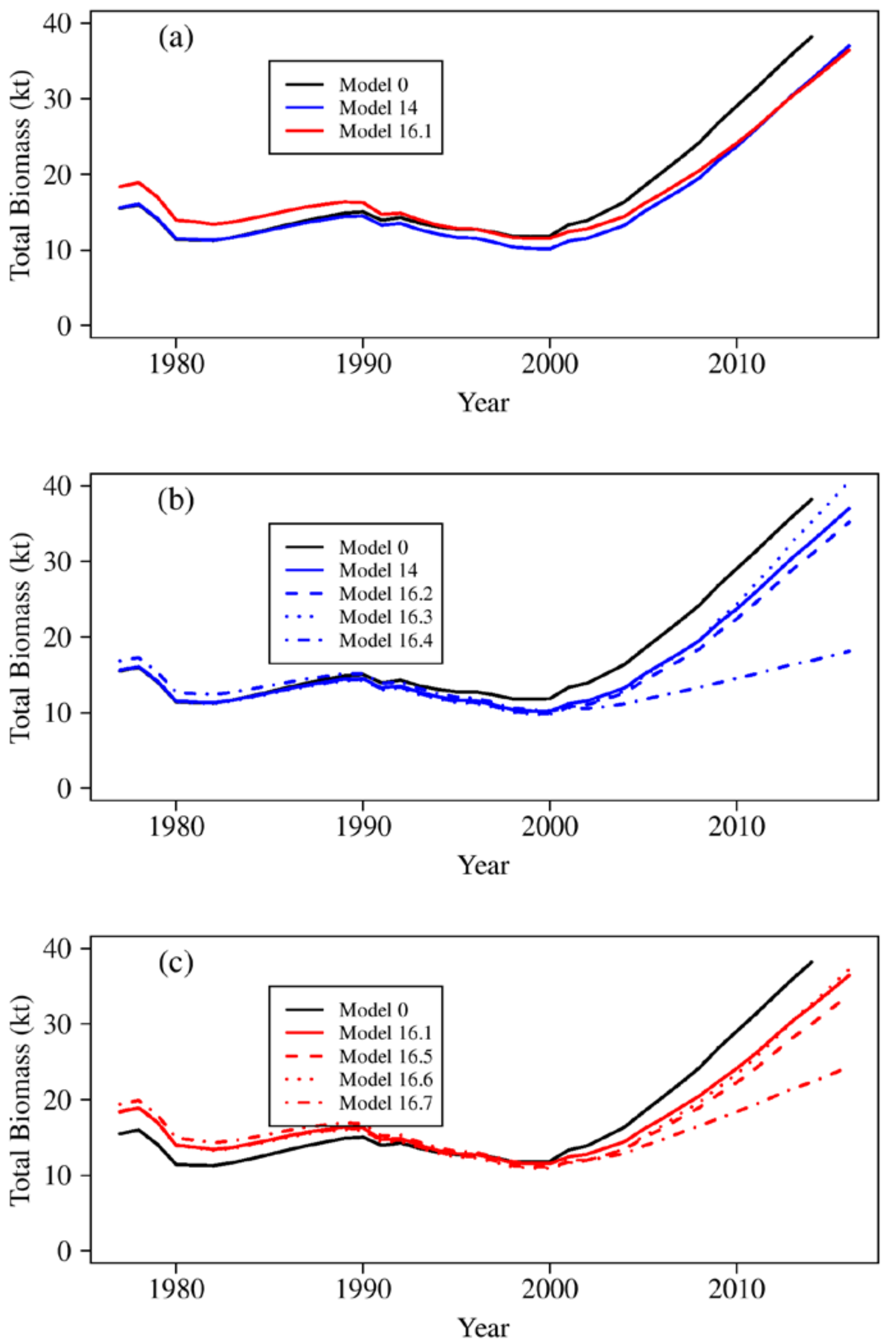

Figure 11. Estimated total biomass for the models evaluated in this assessment. Panel (a) shows models using the data weights in the 2014 assessments; panels (b) and (c) show AI models and BSAI models, respectively.

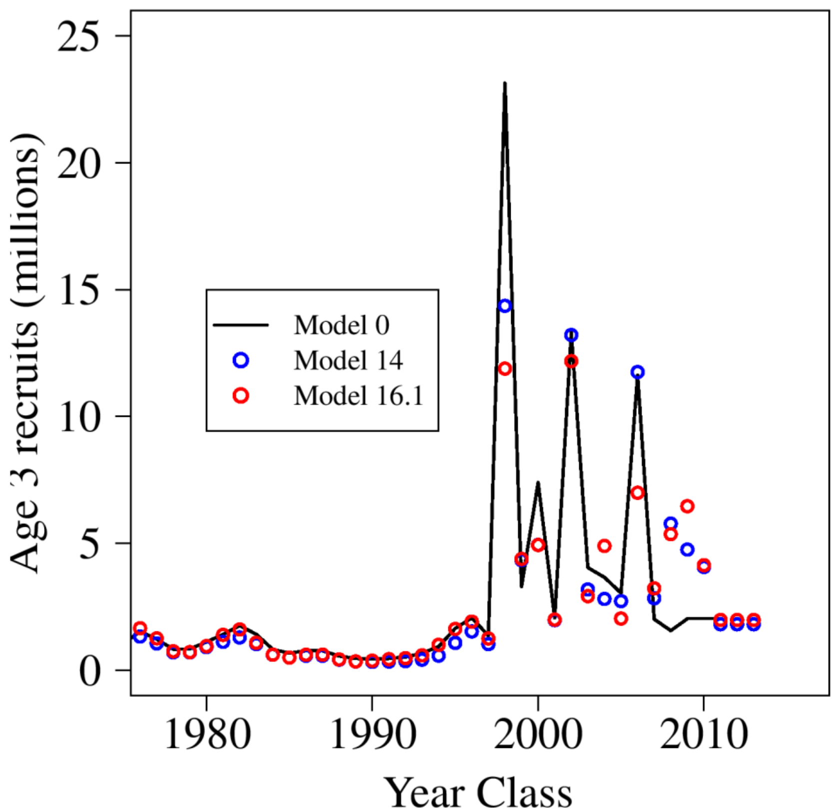

Figure 12. Estimated recruitment from models 0, 14, and 16.1.

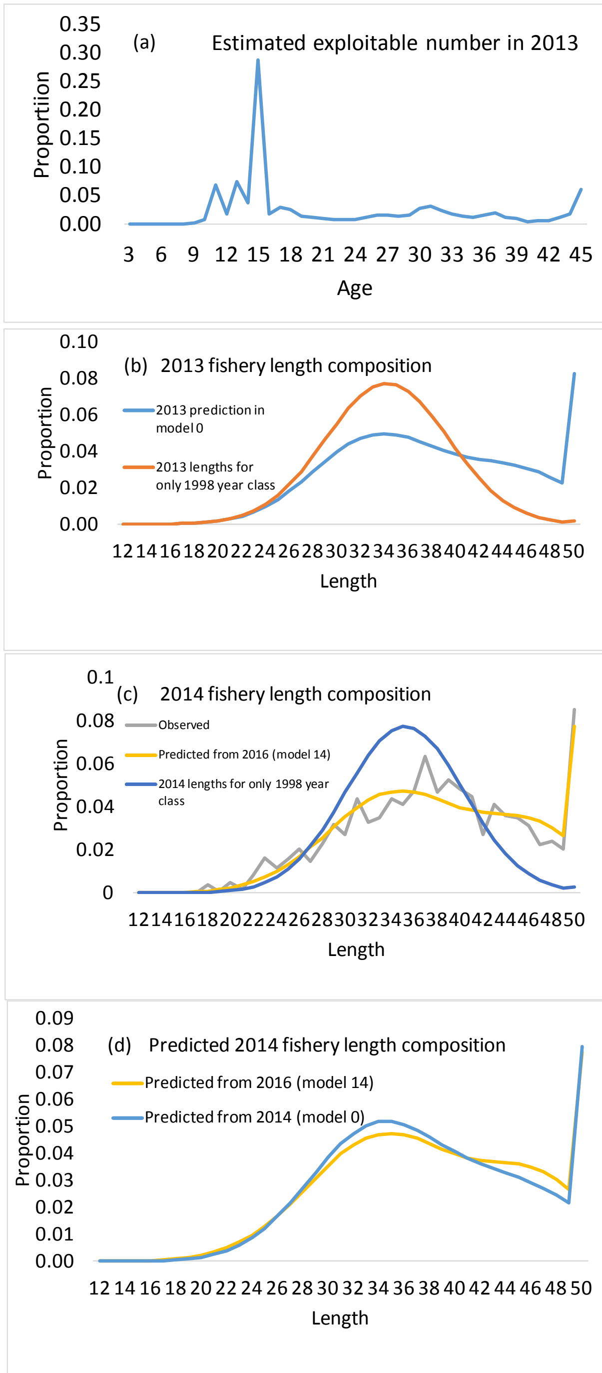

Figure 13. Comparison of observed and fitted fishery length composition data from model 0 and model 14.

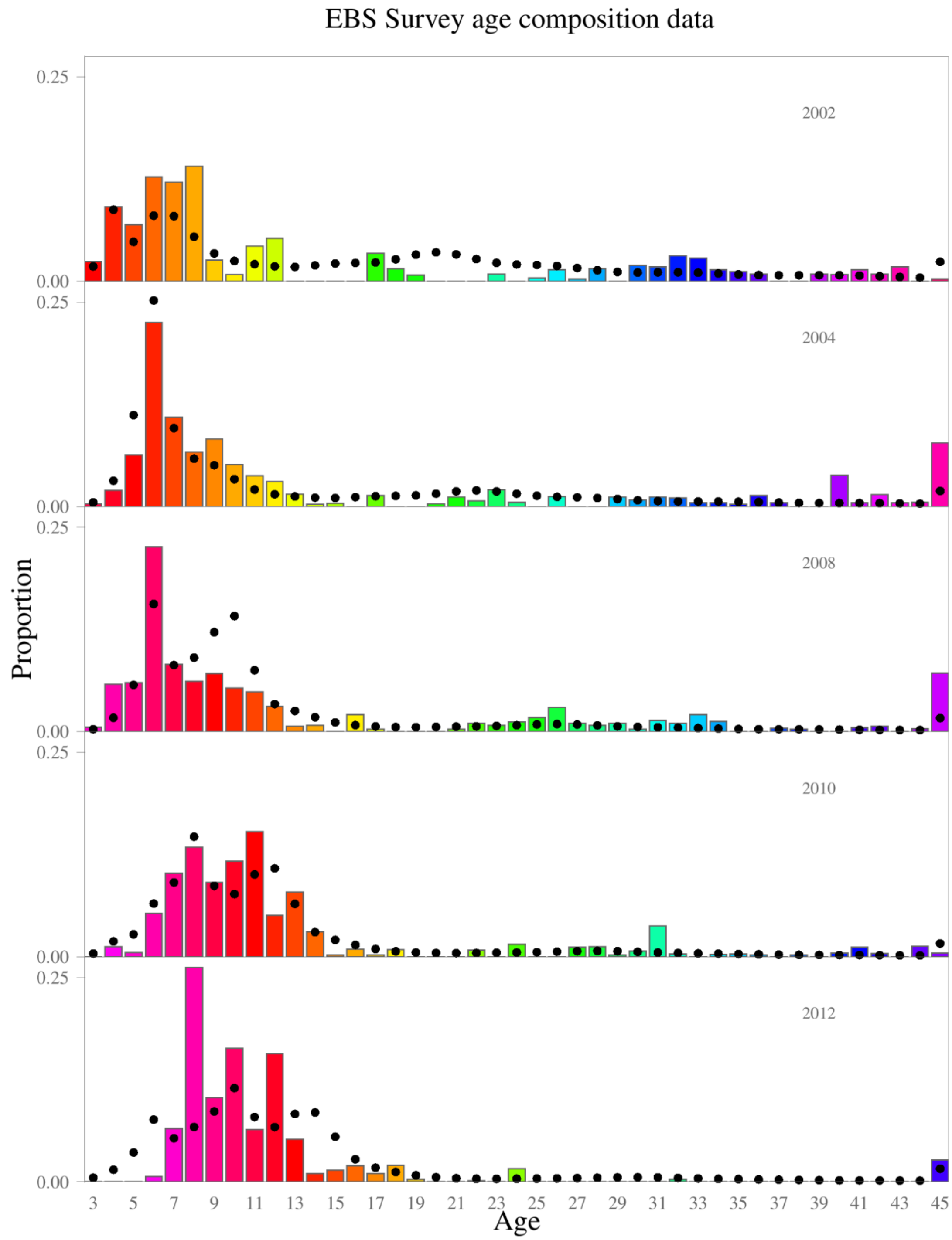

Figure 14. Observed and fitted EBS survey age composition from model 16.1.

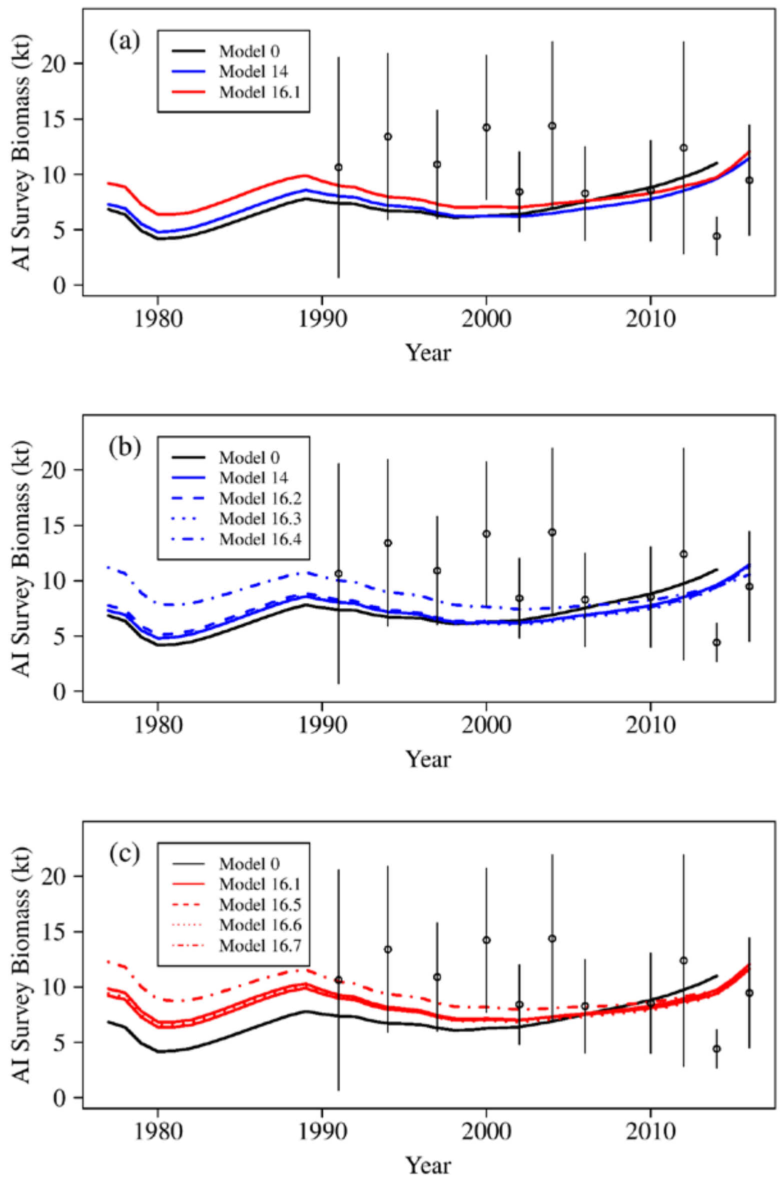

Figure 15. Estimated AI survey biomass for the models evaluated in this assessment. Panel (a) shows models using the data weights in the 2014 assessments; panels (b) and (c) show AI models and BSAI models, respectively.

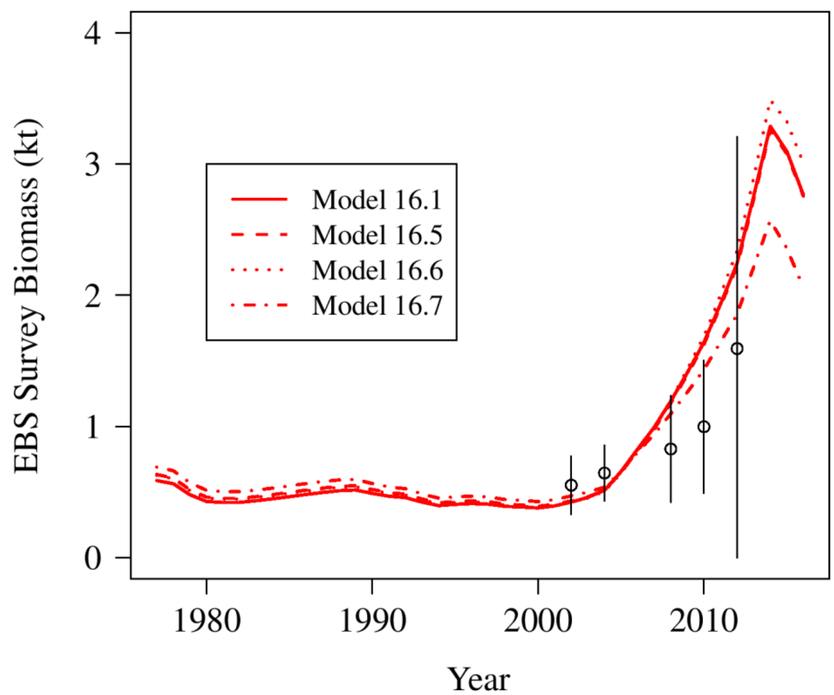

Figure 16. Estimated EBS survey biomass for the BSAI models evaluated in this assessment.

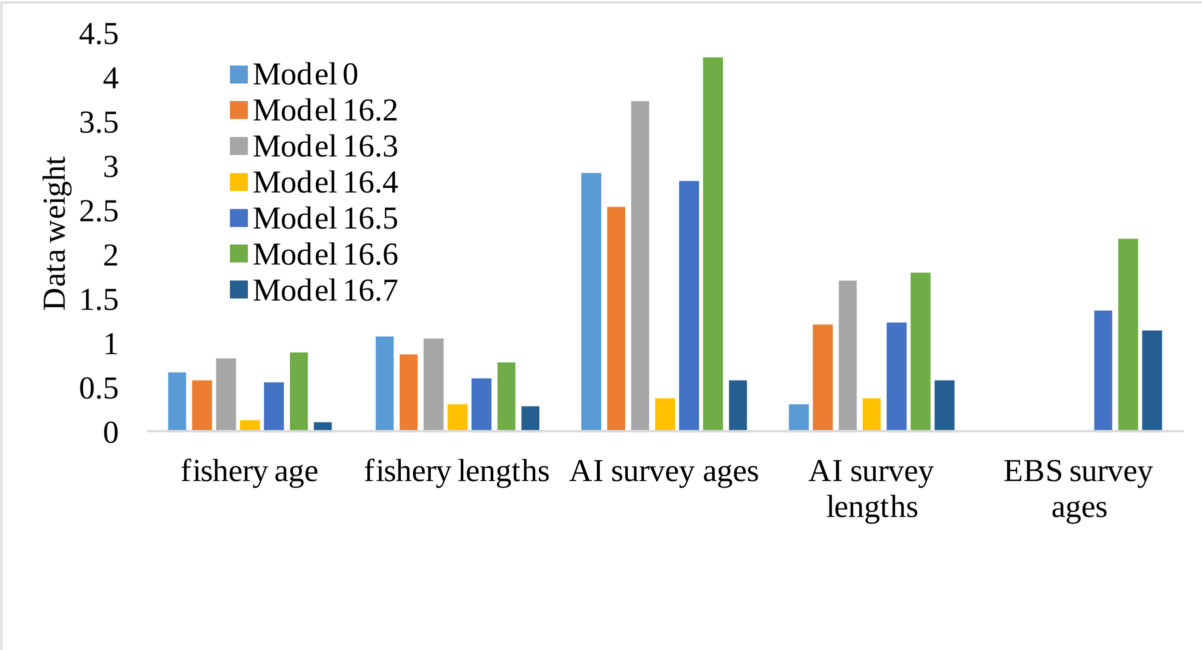

Figure 17. Weights for the age and length compositional data for the models evaluated in this assessment.

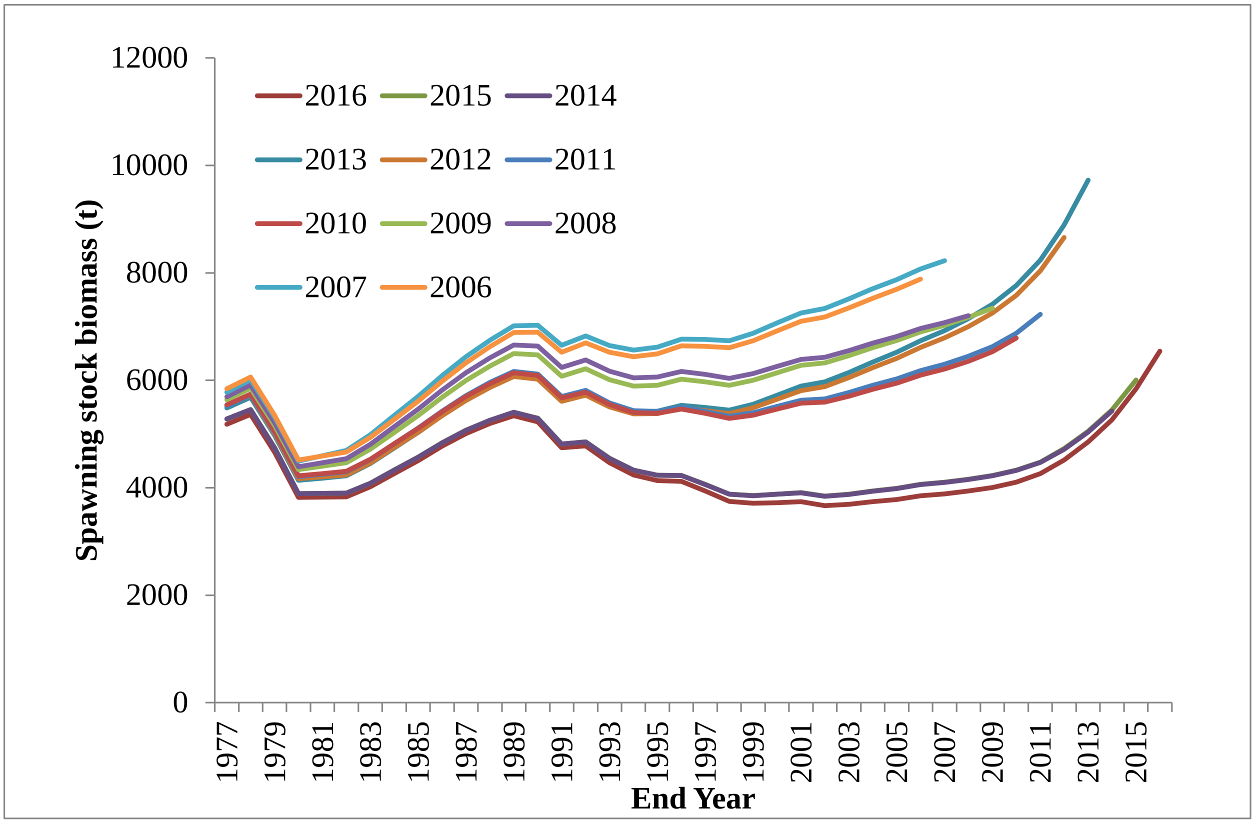

Figure 18. Retrospective estimates of spawning stock biomass for model runs with end years of 2006 to 2016.

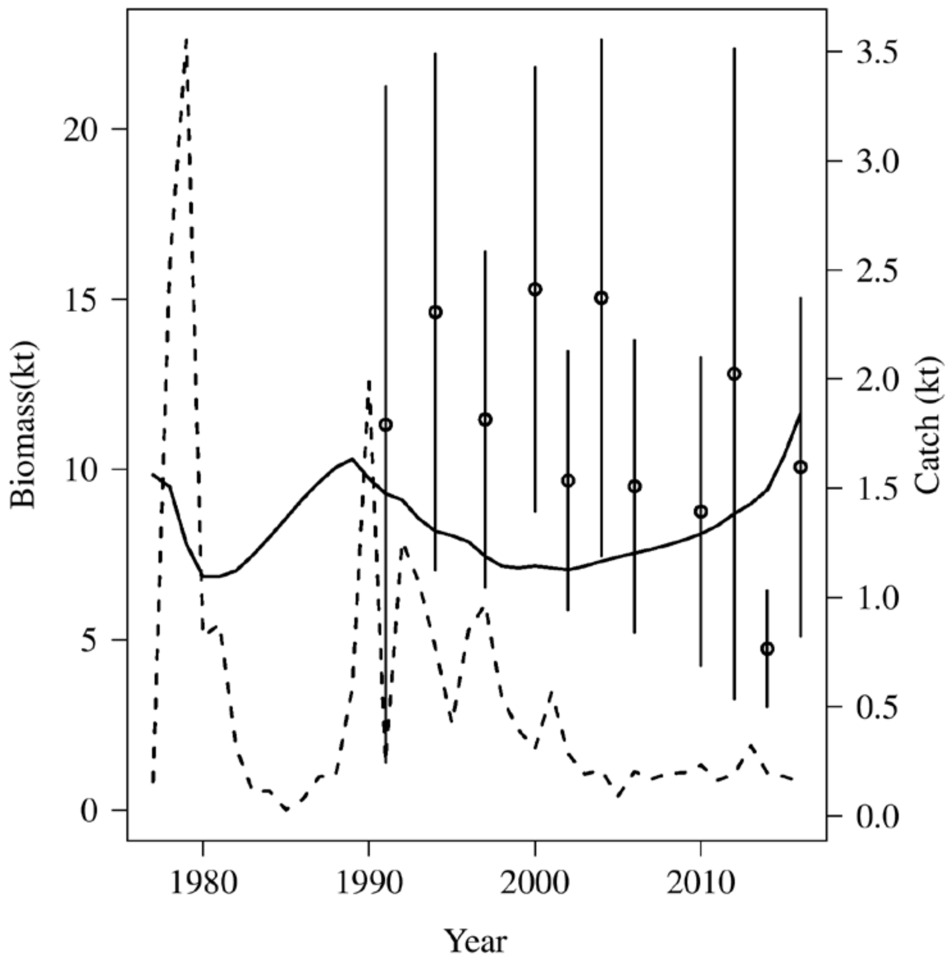

Figure 19. Observed Aleutian Islands (AI) survey biomass for blackspotted/rougheye rockfish (data points, +/- 2 standard deviations), predicted survey biomass (solid line), and harvest (dashed line).

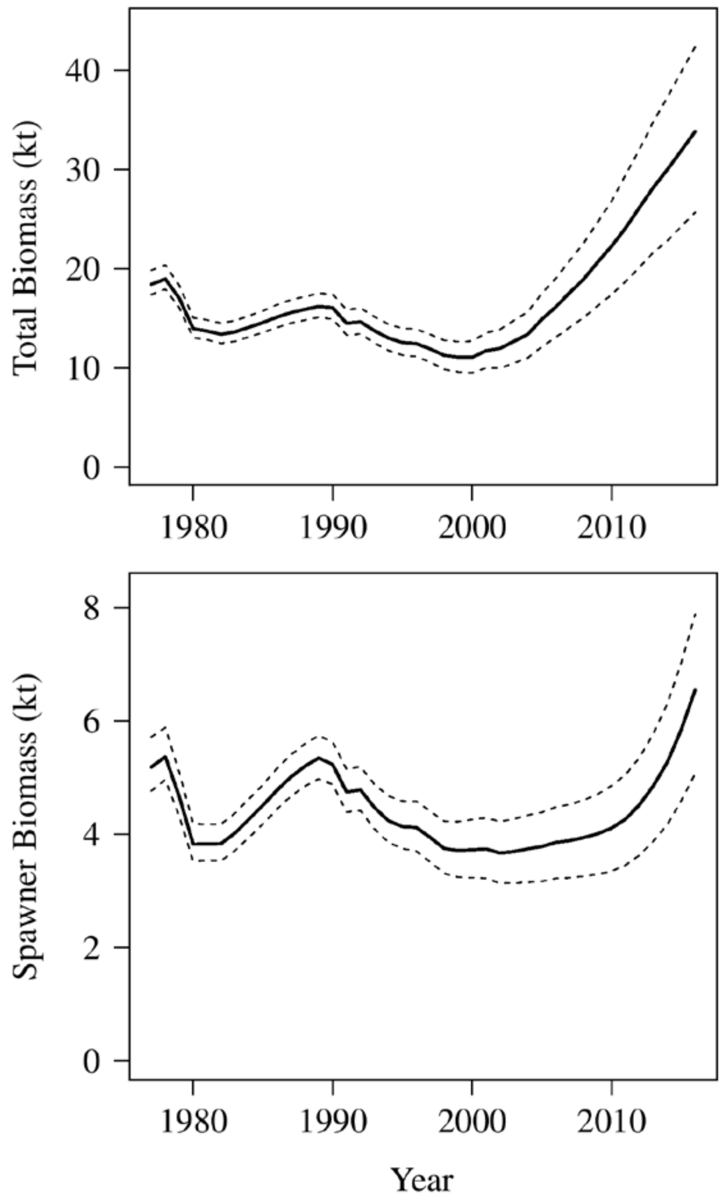

Figure 20. Total (top panel) and spawner (bottom panel) biomass for BSAI blackspotted/rougheye rockfish, with 95% confidence intervals from MCMC integration.

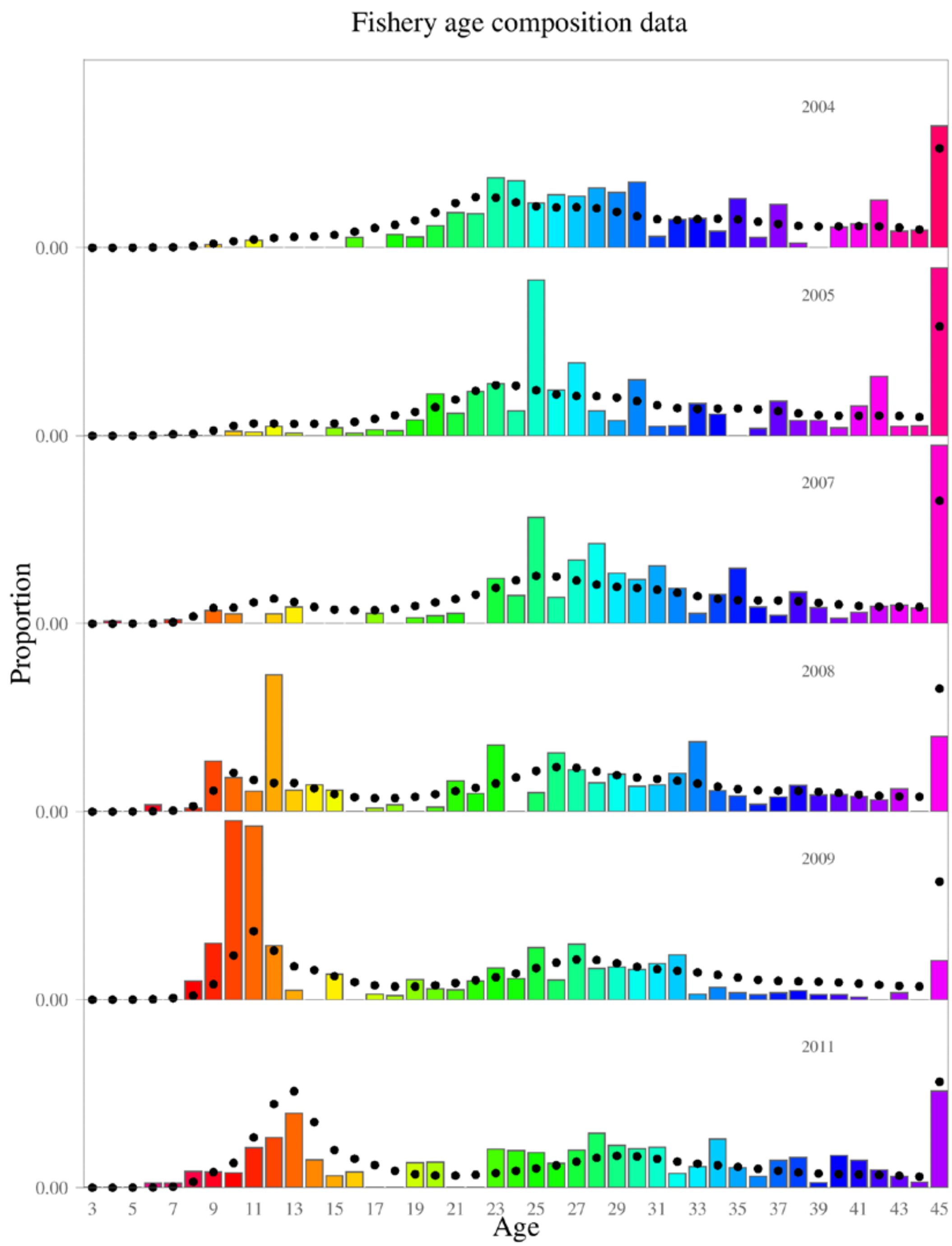

Figure 21. Model fits (dots) to the fishery age composition data (columns) for BSAI blackspotted/rougheye rockfish, 2004-2011. Colors of the bars correspond to cohorts (except for the 45+ group).

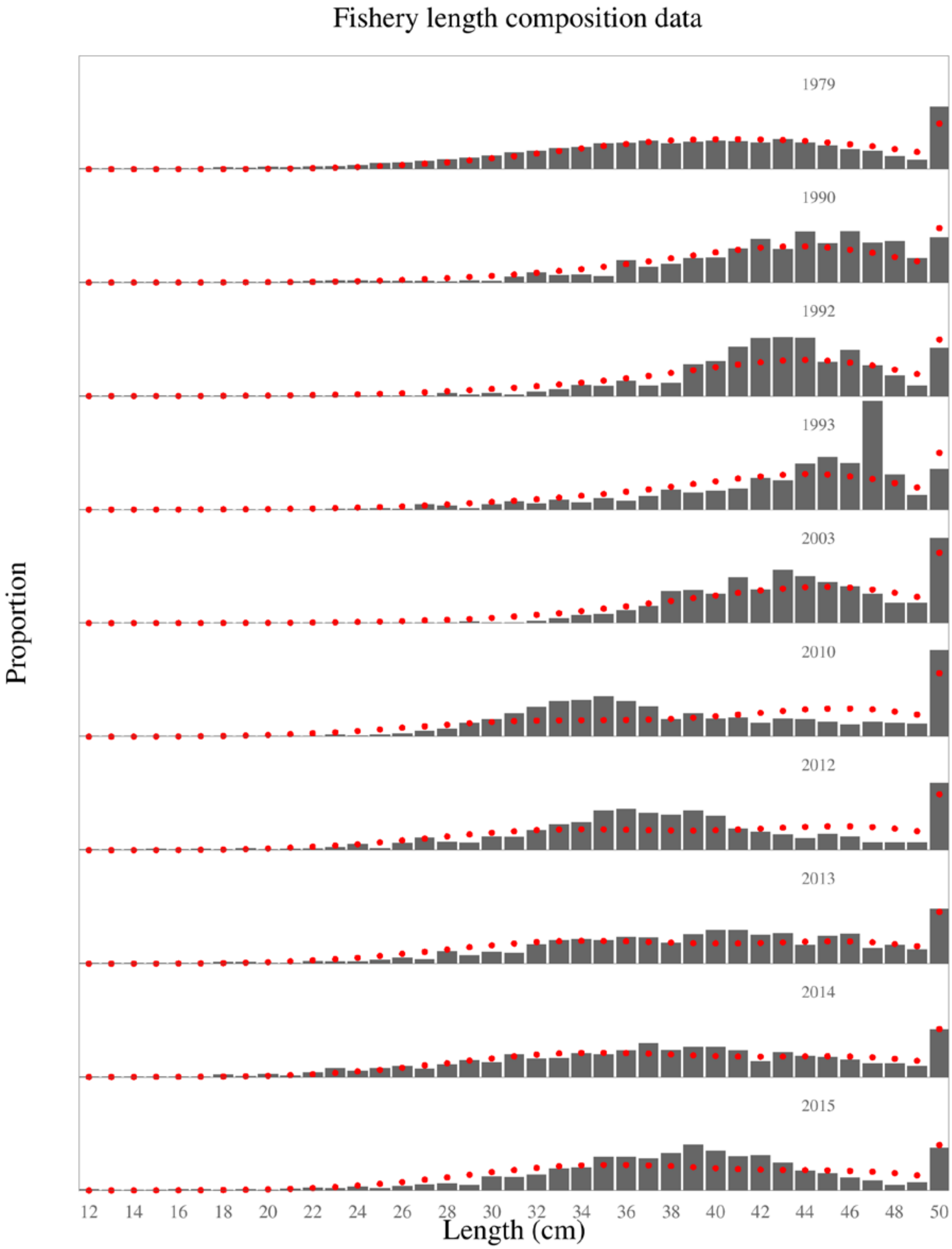

Figure 22. Model fits (dots) to the fishery length composition data (columns) for BSAI blackspotted/rougheye rockfish, 1979-2015.

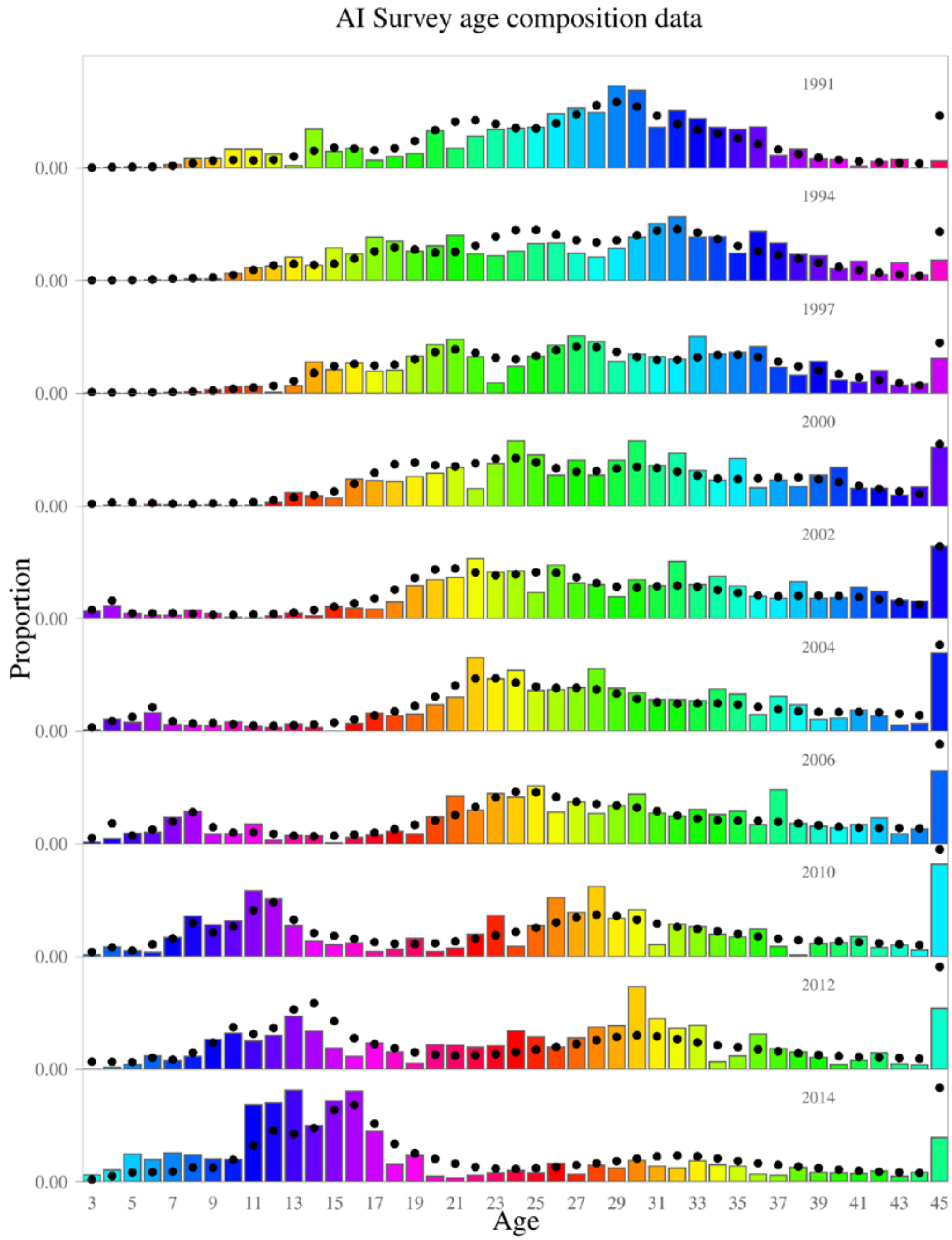

Figure 23. Model fits (dots) to the survey age composition data (columns) for Aleutian Islands (AI) blackspotted/rougheye rockfish, 1991-2014. Colors of the bars correspond to cohorts (except for the 45+ group).

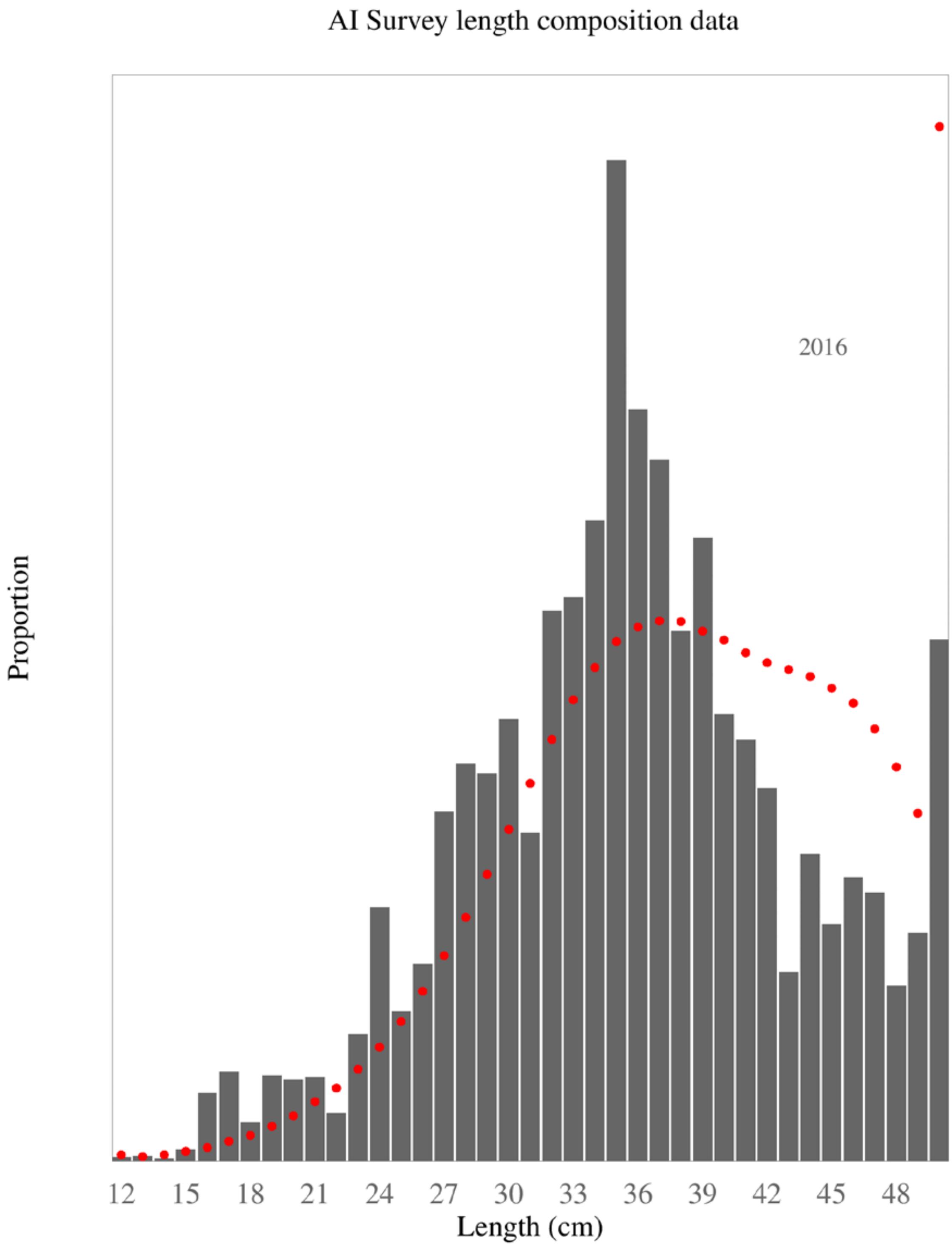

Figure 24. Model fits (dots) to the 2016 Aleutian Islands (AI) survey length composition data (columns) for the blackspotted/rougheye rockfish.

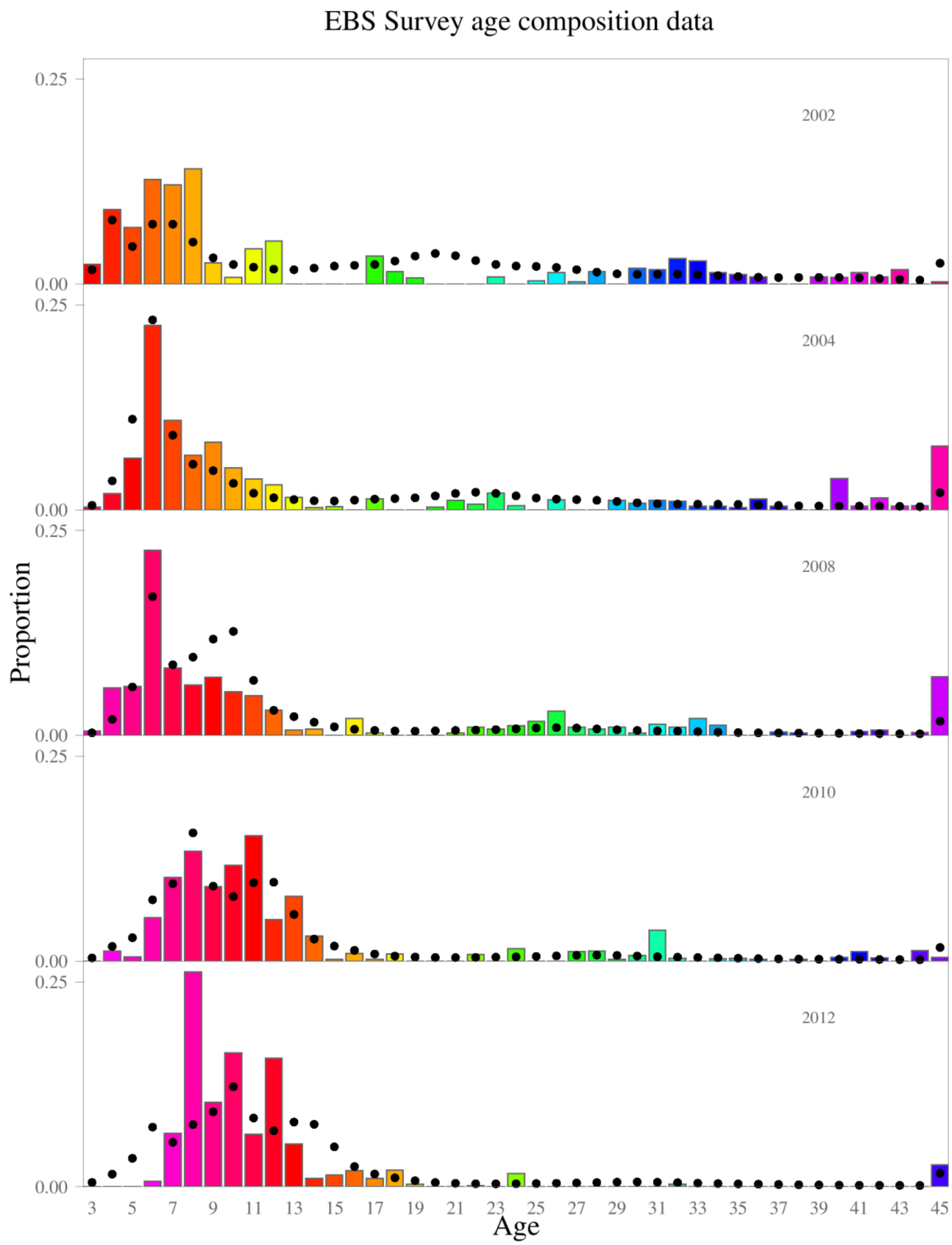

Figure 25. Observed and fitted EBS survey age composition.

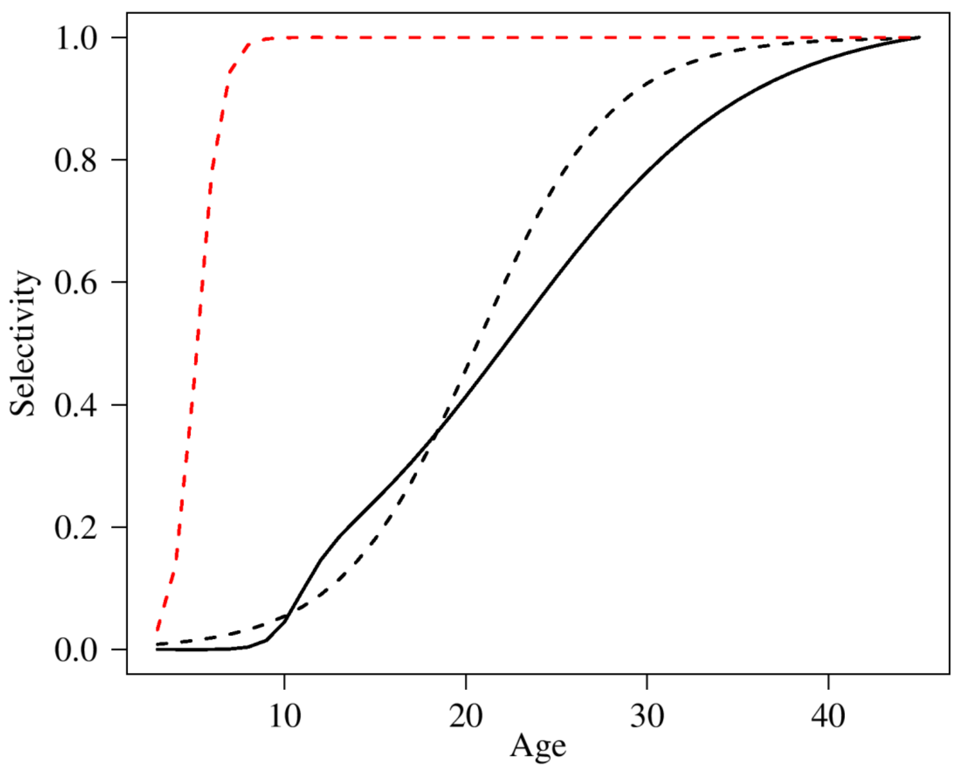

Figure 26. Estimated fishery (solid line) and AI survey (black dashed line) and EBS survey (red dashed line) selectivity curves by age for blackspotted/rougheye rockfish.

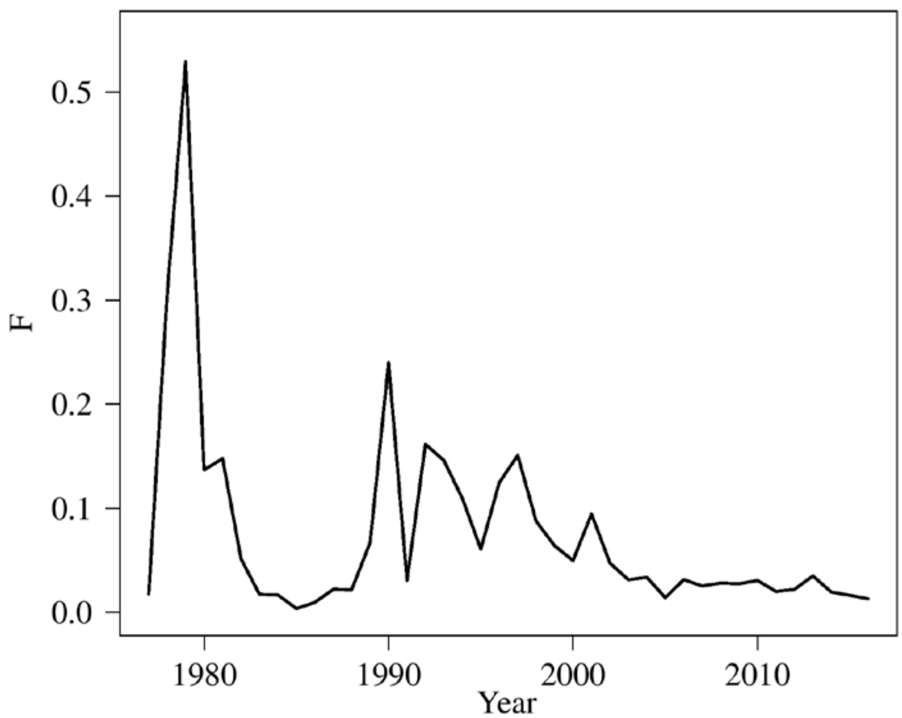

Figure 27. Estimated fully selected fishing mortality for blackspotted/rougheye rockfish.

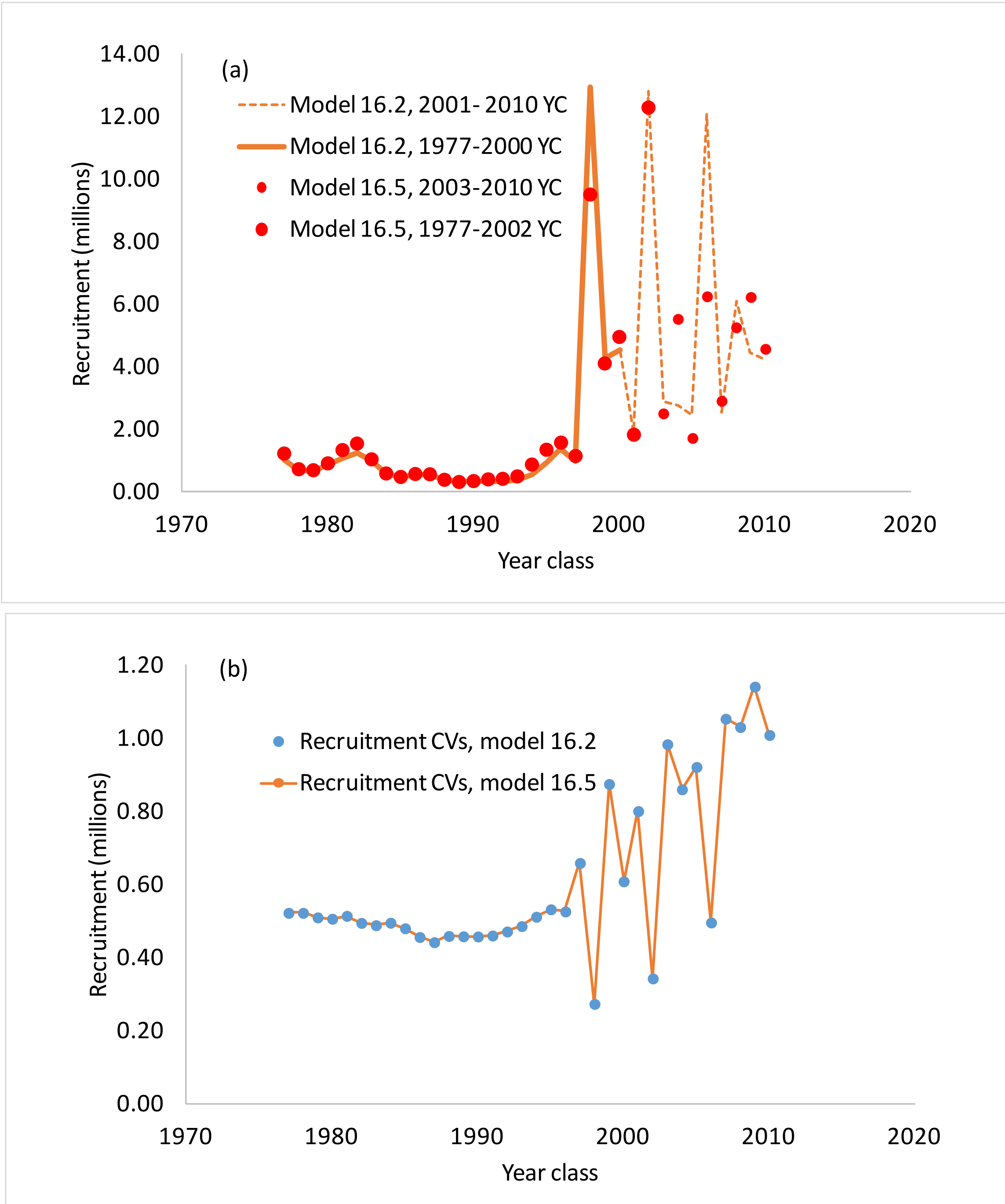

Figure 28 Panel (a): Estimated recruitment from models 16.2 and 16.5. The recommended policy from the Plan Team workgroup on recruitment would use the large 2002 year class to estimates mean recruitment in model 16.5, but exclude it in model 16.2. Panel (b): Estimated recruitment CVs for models 16.2 and 16.5.

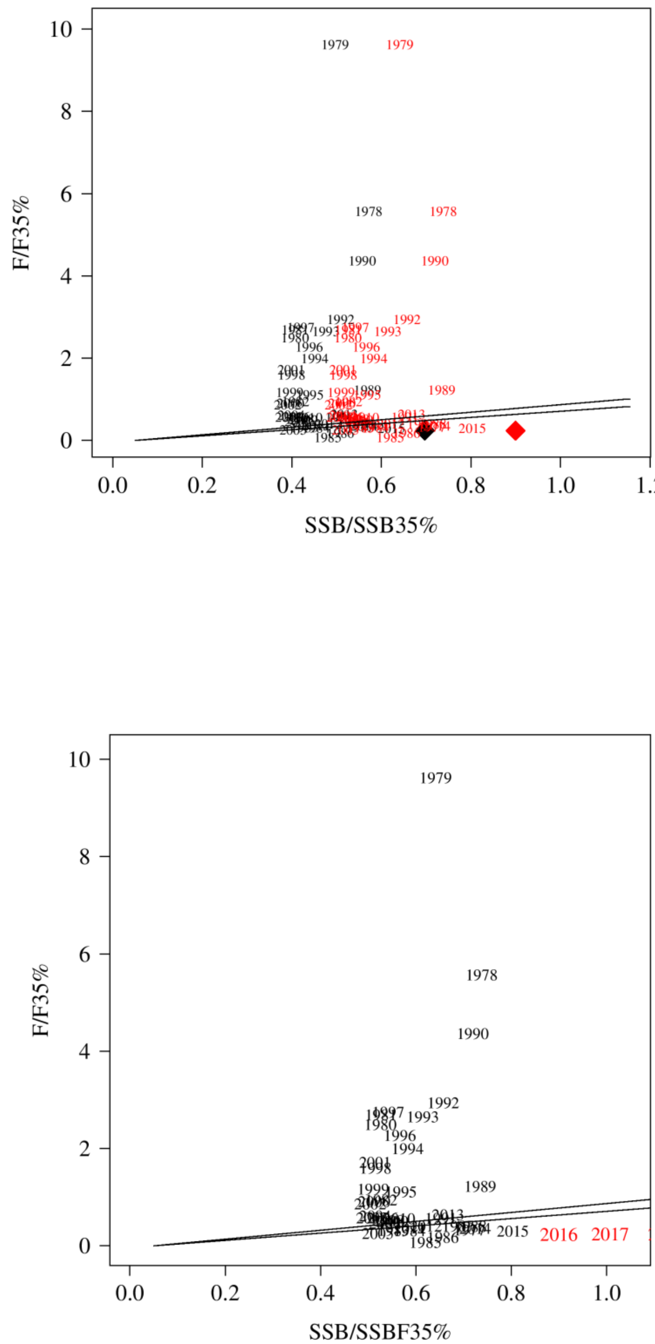

Figure 29. (Top panel) Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvest control rules, with the effect of year classes 1977-2002 and 1977-2000 the estimates mean recruitment shown in black and red, respectively. For each case, 2016 is shown with the diamond symbol. The bottom panel shows the projected stock status and *F* for 2017 and 2018 for the case of using year classes 1977-2000.

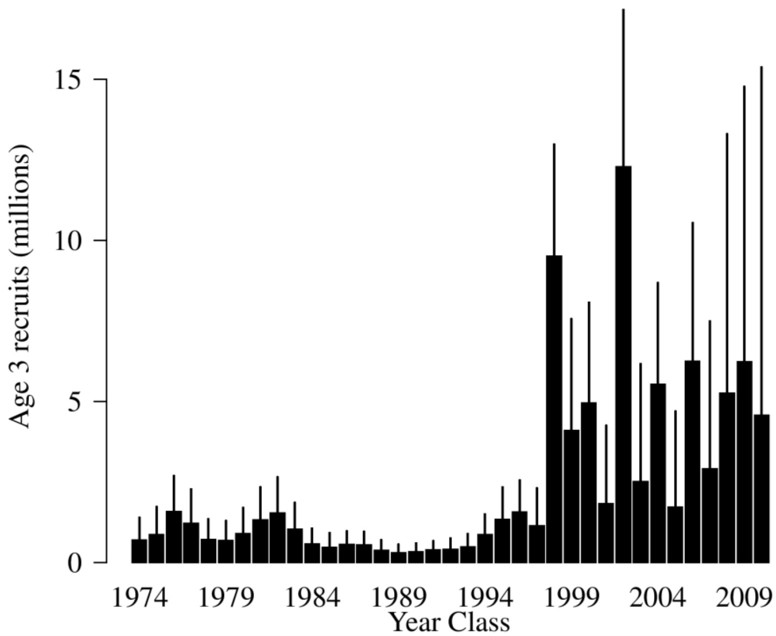

Figure 30. Estimated recruitment (age 3) of blackspotted/rougheye rockfish, with 95% CI limits obtained from MCMC integration.

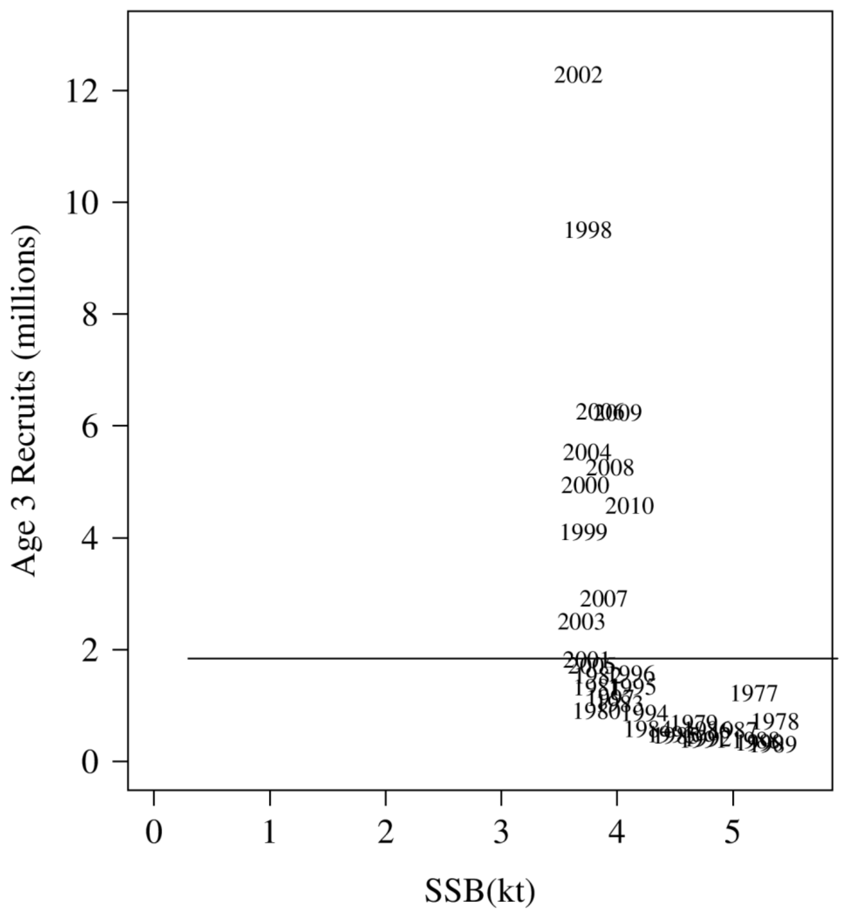

Figure 31. Scatterplot of blackspotted/rougheye rockfish spawner-recruit data; label is year class. Horizontal line is median recruitment.

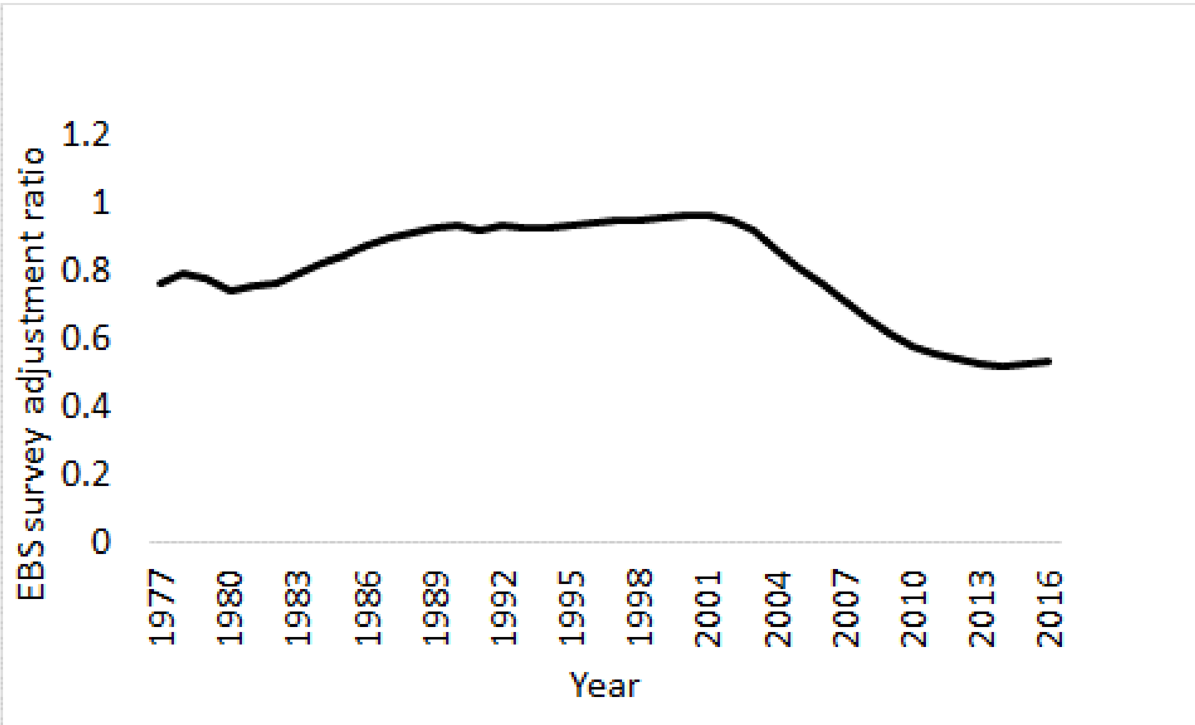

Figure 32. Estimated adjustment ratio to convert the EBS survey biomass into comparable units to the AI survey biomass, accounting for differences in the catchability and selectivity between the surveys, and changes in age composition over time.

Appendix A. Supplemental Catch Data.

In order to comply with the Annual Catch Limit (ACL) requirements, non-commercial removals that do not occur during directed groundfish fishing activities are reported (Table A1). 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 0.5 t. Total removals ranged between 2010 and 2015 ranged between 0.016 t and 0.6 t, which were less than 1.0% of the ABC in these years.

Appendix Table A1. 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

Appendix B. 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 2016, the biomass for the subareas was obtained by partitioning the estimated total BSAI biomass (ages 3+) at the beginning of the year (obtained from 2016 BSAI blackspotted/rougheye stock assessment). The biomass estimates from the 2016 stock assessment are assumed to be the best available information on the time series of total biomass, and this method can be considered a "retrospective" look at past exploitation rates. The distribution of biomass across the 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 EBS slope were adjusted to account for differences in catchability and selectivity from the AI survey, as described in the assessment. Catches through October 10, 2016, 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 2016 (to date) have declined from generally higher levels from 2004-2013 (Figure B1). Reduced estimates of total biomass in recent years in the 2016 assessment have increased the area-specific exploitation rates relative previous estimates. The 2015 WAI exploitation rate was 44% higher than $U_{F40\%}$, whereas the preliminary 2016 WAI exploitation rate is 88% of the $U_{F40\%}$ level. The U_{abc} values have decreased since 2009 (the first year in which ABC was determined from an age-structured model) (Figure 4a). 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 been below $U_{F40\%}$

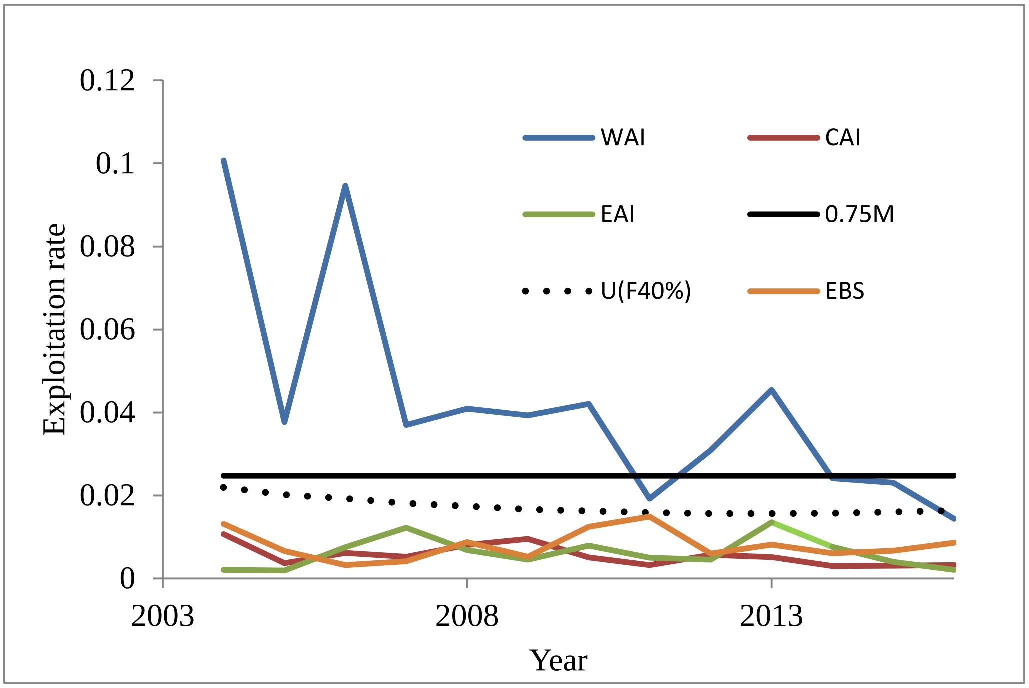

Figure B1. Exploitation rates within BSAI subareas for blackspptted/rougheye rockfish , with reference exploitation rates of 0.75*M and $U_{F40\%}$.