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

by

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Executive Summary

Fish previously referred to as rougheye rockfish are now recognized as consisting of two species, the rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*Sebastes melanostictus*) (Orr and Hawkins 2007). 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. Since 2008, an age-structured model 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. The last full assessment for blackspotted and rougheye rockfish was presented to the Plan Team in 2012. The following changes were made relative to the November 2014 SAFE:

Summary of Changes in Assessment Inputs

Changes in the input data

1) Catch updated through October 11, 2014.
2) The survey biomass estimates and age composition data from the U.S.-Japan cooperative survey in 1980, 1983, and 1986 were removed from the assessment.
3) The 2014 AI survey biomass estimate and length composition was included in the assessment.
4) The 2012 AI survey age composition was included in the assessment.
5) The 2012 and 2013 fishery length compositions were included in the assessment

Changes in the Assessment Methodology

1) Several fishery selectivity models were evaluated, with the recommended model using a double logistic model to estimate fishery selectivity as a function of year and age.

2) The multinomial input sample sizes for the age and length composition data were obtained by an iterative reweighting procedure that ensures that the standard deviation of the normalized residuals for each composition data type is 1.

3) 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.

Summary of Results

The 2010 and 2012 assessments estimated large year class strength for the 1998 year class, and this is also the case in this assessment. This and other relatively recent year classes contribute to an estimated increase from 12,000 t in 1998 to 38,000 t in 2014.

The stock status relative to $B_{35\%}$ is a function of the years that are used to compute the mean recruitment. In 2010, the Plan Team concluded that $B_{35\%}$ should be based on a mean recruitment that excluded recent cohorts. However, in 2012 the SSC concluded that $B_{35\%}$ should be based on all the estimated recruitments. In this assessment, we recommend basing mean recruitment on those cohorts that have reached the age of 10% survey selection (which is 16 for the preferred model). Very recent cohorts are based on relatively few observations and are often imprecisely estimated. Additionally, even for cohorts that appear to be relatively well-estimated, there is a time lag between the estimation of year class strength and the contribution of the cohort to the exploitable stock and the survey biomass estimate. This problem is exacerbated for this stock because the fishery and survey select fish at relatively old ages. This results in a counter-intuitive case where our harvest control rule (when using mean recruitment from all estimated cohorts) would lower fishing mortality on stocks that are increasing.

As mentioned above, an age-structure population model was used to estimate the population size and harvest levels for the AI portion of the population. A summary of the 2014 recommended ABC's for the AI portion of the population relative to the 2013 recommendations is shown below.

Quantity	As estimated or *specified* last year for: 2014	2015	As estimated or *recommended* this year for: 2015	2016
M (natural mortality rate)	0.033	0.033	0.033	0.033
Tier	3b	3b	3b	3b
Projected total (age 3+) biomass (t)	29,087	30,062	40,391	42,445
Female spawning biomass (t)				
Projected	7,328	7,902	7,932	9,002
$B_{100\%}$	26,255	26,255	28,507	28,507
$B_{40\%}$	10,502	10,502	11,403	11,403
$B_{35\%}$	9,189	9,189	9,977	9,977
F_{OFL}	0.029	0.031	0.039	0.045
$maxF_{ABC}$	0.024	0.026	0.032	0.036
F_{ABC}	0.024	0.026	0.032	0.036
OFL (t)	459	534	516	642
maxABC (t)	382	444	420	522
ABC (t)	382	444	420	522
Status	As determined *last* year for: 2013	2014	As determined *this* year for: 2014	2015
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

The population size and harvest levels for the EBS portion of the population were obtained by applying Tier 5 methods to recent survey biomass estimates. A random effects model was used to fit a random walk smoother to the survey biomass data from the EBS portion of the stock. A summary of the 2014 recommended ABC's for the EBS portion of the population relative to the 2013 recommendations is shown below.

Quantity	As estimated or *recommended* last year for:		As estimated or *recommended* this year for:	
	2014	2015	2015	2016
M (natural mortality rate)	0.033	0.033	0.033	0.033
Tier	5	5	5	5
Biomass (t)	1389	1389	1,339	1,339
F_{OFL}	0.033	0.033	0.033	0.033
$maxF_{ABC}$	0.0248	0.0248	0.0248	0.0248
F_{ABC}	0.0248	0.0248	0.0248	0.0248
OFL (t)	46	46	44	44
maxABC (t)	34	34	33	33
ABC (t)	34	34	33	33
Status	As determined *last* year for:		As determined *this* year for:	
	2013	2014	2014	2015
Overfishing	No	n/a	No	n/a

The overall BSAI ABC and OFL are shown below.

Quantity/Status	As estimated or *specified* last year for:		As estimated or *recommended* this year for:	
	2014	2015	2015	2016
OFL (t)	505	580	560	686
ABC (t)	416	478	453	555

The BSAI blackspotted/rougheye stock complex was not subjected to overfishing in 2014. Based upon the age-structured model for the AI portion of the stock, BSAI blackspotted/rougheye rockfish is not overfished nor approaching an overfished condition.

Area Apportionment

The ABC for BSAI blackspotted/rougheye is currently apportioned among two areas: the western and central Aleutian Islands, and eastern Aleutian Islands and eastern Bering Sea. In previous assessments, a weighted average of the three most recent trawl survey biomass estimates is used to apportion the AI ABC. Weights of 4, 6, and 9 are used, with higher weights applied to the more recent surveys. Additionally, apportionments were also obtained from the random effects model to provide a comparison to the status quo method of survey averaging. Although the survey averaging work group is still evaluating the use of the random effects model for determining area apportionments, a comparison between the weighted average and the random effects model may be useful. The AI apportionment from the two methods are:

	Area			
	WAI	CAI	WAI+CAI	EAI
Weighted average biomass (t)	722	4,446	5,167	2,643
Proportion of biomass	9.2%	56.9%	66.2%	33.8%
Estimated 2014 biomass (from random effects model)	566	3,152	3,718	1,425
Proportion of biomass	11.0%	61.3%	72.3%	27.7%

The following table gives the current apportionments used in this assessment, the projected OFLs and apportioned ABCs for 2015 and 2016 and the recent OFLs, ABCs, TACs, and catches.

	BSAI	WAI+CAI	EAI+EBS	Total
OFL (2013)	462			462
ABC (2013)		209	169	378
TAC (2013)		209	169	378
Catch (2013)		146	178	324
OFL (2014)	505			576
ABC (2014)		239	177	416
TAC (2014)		239	177	416
Catch (2014)[1]		98	96	194
OFL (2015)	560			560
ABC (2015, weighted average)		278	175	453
ABC (2015, RE model)		304	149	453
OFL (2016)	686			686
ABC (2016, weighted average)		345	210	555
ABC (2016, RE model)		377	178	555

[1] BSAI catch as of October 11, 2014.

Apportionment within the WAI/CAI area

In December, 2013, the SSC requested information *"for consideration of separating the WAI ABC from the other sub-areas."* In October, 2014, the SSC recommended "*that the current stock structure policy be clarified to include a requirement for a recommended area specific catch level when a stock or stock complex is elevated to the level of 'concern'"*. Given the concern over exploitation rates in the WAI, separate ABC for the WAI and CAI from the two methods of determining apportionments are shown below:

	WAI	CAI	WAI-CAI
ABC (2015, weighted average)	39	239	278
ABC (2015, RE model)	46	257	304
ABC (2016, weighted average)	48	297	345
ABC (2016, RE model)	57	320	377

Summaries for the Plan Team

Year	Biomass[1]	OFL	ABC	TAC	Catch
2013	29,810	462	378	378	324
2014	30,476	505	475	475	194[2]
2015	41,780	560	453		
2016	43,834	686	555		

[1] Total biomass from AI age-structured projection model, and survey biomass estimates from EBS.
[2] BSAI catch as of October 11, 2014.

Responses to SSC and Plan Team Comments on Assessments in General

The SSC requests that all assessment authors of AI species evaluate AI survey information to ensure that the same standardized survey time series is used. (SSC, December 2012)

Model runs in this assessment exclude the cooperative surveys conducted in the 1980s.

"The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals. The Teams plan to inventory how their respective authors address and calculate total current year removals. Following analysis of this inventory, the Teams will provide advice to authors on the appropriate methodology for calculating current year removals to ensure consistency across assessments and FMPs." (Plan Team, September 2013)

The estimates of current year catch are inferred by expanding the catch through September, 2014, by the recent pattern of the proportion of the remaining ABC that is caught by the end of the year.

"For assessments involving age-structured models, this year's CIE review of BSAI and GOA rockfish assessments included three main recommendations for future research: Authors should consider: (1) development of alternative survey estimators, (2) evaluating selectivity and fits to the plus group, and (3) re-evaluating natural mortality rates. The SSC recommends that authors address the CIE review during full assessment updates scheduled in 2014." (SSC, December 2013)

Selectivity curves and natural mortality rates are evaluated in this 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, who are in the process of developing more refined standardization methods. Continuation of these meetings will hopefully result in progress on this task.

"During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment." (SSC December 2013)

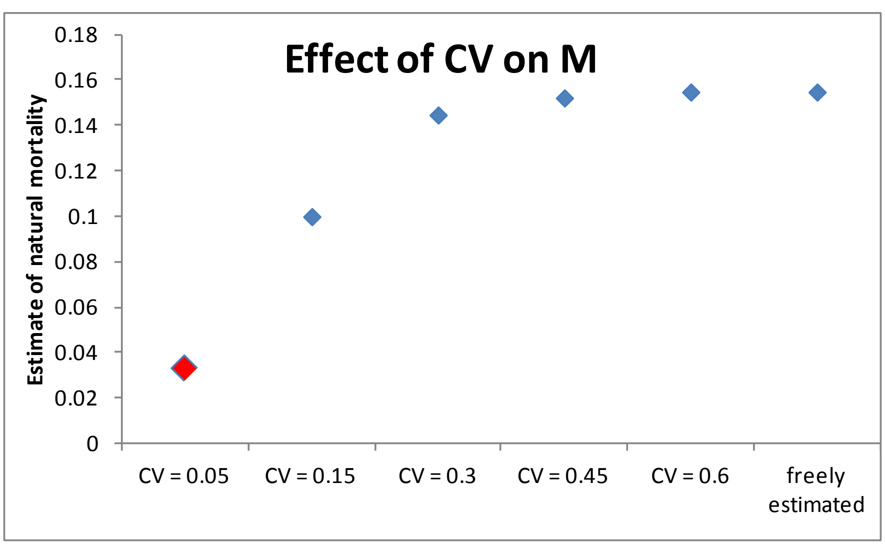
These projections were added to the phase-plane plots.

Responses to SSC and Plan Team Comments Specific to this Assessment

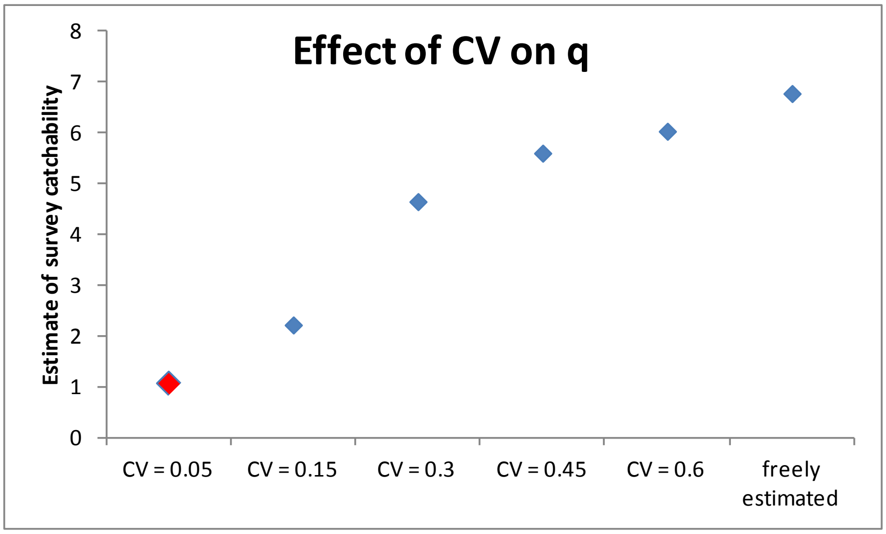
The SSC offers the following advice to assessment authors:
- *Evaluate priors on survey catchability and natural mortality.*
- *Explore alternative selectivity patterns*
- *Evaluate alternative selectivity time periods*
- *Evaluate/compare mean vs. median recruitment and which time period should be used for estimating fishery bench marks and provide rationale* (SSC, Dec 2012)

Alternative selectivity functional forms, including time-varying selectivity, are included in this assessment. The preferred model used a time-invariant double logistic equation to model fishery selectivity.

Previous attempts to estimate natural mortality (*M*) and survey catchability (*q*) within the assessment model have produced estimates that are implausible, which necessitated prior distributions with tight CVs. A series of models runs were conducted to address how sensitive the model estimates of *M* and *q* are to the prior distributions. Because *M* and *q* are inversely correlated, the runs for *M* were conducted by holding *q* fixed at the value estimated in the preferred model (and vice versa). The current model uses a prior distribution for *M* with a mean set to 0.03 (McDermott 1994, based on the a relation between *M* and the gonadosomatic index) and CV set to 0.05, and produces and estimate of 0.033 (shown in red in the graph below). The estimate obtained when *M* is freely estimated increases to 0.15.



The prior for *q* has a mean of 1 and a CV of 0.05, and a similar plot showing the effect of increasing the CV of the prior is shown below. The estimates of *q* range from 1.08 in the current model to 6.78 when estimated freely (while holding *M* fixed at 0.033). The inability to estimate *q* within the model is not surprising given that there is little contrast in the survey time series regarding how the stock has responded to exploitation, and motivates obtaining information on *q* outside the assessment model in order to develop more informative priors.



The choice of using mean or median recruitment has been evaluated by the Plan Team Stock-Recruitment Working Group. Median recruitment provides improved short-term management performance, whereas mean recruitment provides improved long-term management performance. The group recommended using mean recruitment.

In this assessment, we consider two time periods for computing mean recruitment (which is then used to compute the biomass reference points $B_{40\%}$ and $B_{35\%}$). One option is to use all of the estimated recruitment (i.e., the 1977-2011 year classes), which was used by the SSC in 2012 to set reference points. A second option is to use only those year classes which have reach the age at which they are estimated to be 10% selected in the AI trawl survey (which is age 16 for the preferred model). This is a modification of one of the options considered by the Plan Team Stock-Recruitment Working Group, and is motivated by the consideration that year classes that not reached the age of 10% survey selection may be considered incompletely observed. Using all the estimated recruitments results in a stock status of $B_{16\%}$, and the stock would thus be considered overfished. This designation results not from a declining stock (in fact, the assessment shows an increasing stock), but rather high estimates of recently observed year classes which increases the mean recruitment. Using only the year classes which are 10% selected in the survey results in a stock status of $B_{24\%}$, similar to the stock estimated in the 2012 ($B_{25\%}$).

The authors presented seven reasons for concern about fishing pressure on the Western Aleutian Island (WAI) component of the population. The Plan Team also expressed "strong concern" about the WAI component of the stock. The SSC shares this concern and agrees with the Plan Team recommendation to have the authors update the seven reasons for concern and bring this forward in 2014 for consideration of separating the WAI ABC from the other sub-areas. The SSC requests that authors include an update on species identification issues, and if possible, species composition among areas. The SSC also recommends that the authors present spatial distribution trends on catch, length frequencies, trawl survey *biomass and any other pertinent information as if the authors'/ Plan Team recommended ABC and/or OFL changes were made. The SSC recommends that the authors comment on data and research requirements that would be required to better inform stock structure and comment on any potential correlation to other species declines in the Aleutians such as Steller sea lions. The Blackspotted/Rougheye stock in the western AI stands out among other BSAI rockfish stocks as a potential conservation concern.* (SSC, Dec 2013)

The 7 attributes for BSAI blackspotted/rougheye are updated in an appendix of this assessment. The original list of attributes included a statistically significant isolation by distance relationship based on genetic samples available in 2010. An updated analysis with additional samples does not support a strongly significant relationship ($P = 0.11$). Updates of several of the attributes were presented at the September, 2014 Plan Team meeting, which reiterated its concern regarding stock structure. This conclusion was based upon disproportionate harvest rates, the observed decline in the western Aleutians, and recognition that demographic independence between spatial areas can often be difficult to infer from genetic data. The 2014 survey biomass estimate for the western Aleutians (589 t) was increased slightly from the 2012 estimate (335 t). The level of depletion can be obtained by comparing the estimated current biomass to the estimated 1991 biomass (both obtained by applying a random effects smoother the western AI trawl survey data). The estimated levels of depletion with and without the 2014 survey estimate are 81% and 85%, respectively.

The non-genetic attributes updated in the appendix present spatial patterns in catch, trawl survey biomass, and length composition.

While species identification between blackspotted and rougheye rockfish remains problematic in area where each species is relatively abundant, the species distribution of rougheye rockfish does not extend east of the eastern/central Aleutians Islands. In the western AI, the area of most concern, the complex is composed nearly entirely of blackspotted rockfish, and this is supported by the identifications in the trawl survey and several morphological and genetic analyses (as reviewed in the initial stock structure document, which is included as an appendix to the 2010 SAFE chapter (Spencer and Rooper 2010).

Additional information regarding stock structure would ideally focus on the spatial scale of dispersal at various life stages. Acquisition of this data would be challenging, given the logistical issues of field work in remote areas such as the western Aleutians, the inability to identify rockfish larvae to species without genetic techniques, and the difficulty in tagging deep-water species subject to barotrauma. It may be possible that otolith microchemistry can used to identify movement from natal areas, although this would depend on the degree to which distinct signatures in the water chemistry occur in the Aleutian Islands.

We are not well-equipped to provide a comparison to Stellar Sea lions, although we do note that the abundances of POP and northern rockfish have been increasing in the western Aleutians. One difference, however, from Stellar Sea lions is that fishing has appeared to play a major role in the decline in western Aleutian Islands blackspotted/rougheye rockfish. As noted by Spencer (2013), the available catch and survey data indicate that high rates of exploitation for western AI blackspotted rockfish have occurred in the 1990s (particularly in 1996 and 1997), and abundance in this area has decreased (beginning in the 2000 survey) and has not been replenished from neighboring areas.

The SSC requests spatial catch information by fishery (SSC, Oct 2014).

This information is presented in the assessment.

The SSC recommends that the current stock structure policy be clarified to include a requirement for a recommended area specific catch level when a stock or stock complex is elevated to the level of *"concern". This would provide a clear guide to industry regarding what reductions in catch would be needed to alleviate the "concern". This area specific catch level would likely be estimated by the assessment author with review and comment by the Plan Teams and SSC.* (SSC, Oct 2014).

Given that the concern regarding subarea exploitation pertains to the western AI, a subarea ABC for this area is documented in this assessment.

Introduction

Rougheye rockfish (*Sebastes aleutianus*) have historically been managed within various stock complexes within 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 based upon field identification may be due to errors in species identification, 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. The patterns of spatial variation in species composition noted above for this two-species complex was 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 relative small number of samples available for the genetic analysis conducted in 2010 motivated the collection and analysis of additional samples since 2010. The most recent genetic analysis does not indicate a 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 1994-2014 have been relatively evenly distributed throughout the three AI subareas, with 32%, 26%, and 36% in the WAI, CAI, and EAI, respectively, and the remaining 5% in the EBS management area (Table 4). However, biomass estimates from the AI survey indicate that a relatively small portion of the stock (approximately 9%) occurs in WAI. Information on spatial exploitation rates is updated in Appendix A.

Temporal variability has occurred in AI subareas in which blackspotted/rougheye rockfish are captured, and in the depths of capture (Figure 1). 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%. However, since the mid-1990s the proportion of the harvest in the western and central Aleutians has increased, and the proportion obtained from western Aleutians ranged between 0.58 and 0.72 from 2004 – 2006. The proportion captured at depths greater than 300 has increased recently, ranging from 3% to 20% during 1998- 2003 to 28% to 46% from 2009 – 2013.

Non-commercial catches are shown in Appendix B.

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 2014, discard rates of rougheye in the AI and EBS averaged 19% and 36%, respectively.

Recent Distribution of Catch across Areas and Target Fisheries

Rougheye rockfish in the AI have been caught primarily in the rockfish trawl, Pacific cod longline, and Atka mackerel trawl fisheries in recent years. From 2004-2012, these three fisheries accounted for 86% of the AI rougheye catch. Catches of the AI rougheye rockfish from 2004-2012 were primarily taken in the western and central Aleutians, with 43% and 30% in areas 543 and 542, respectively (Table 6). Approximately 91% of the catches of rougheye rockfish from 2004-2012 in the EBS management area were in the arrowtooth flounder trawl fishery, Pacific cod longline, halibut longline fishery, rockfish trawl fishery, turbot longline fishery, pollock midwater trawl fishery, and "other flatfish" trawl fisheries. Catches of rougheye in the EBS management area were concentrated in areas 517, 518, 519 and 521, which comprise much of the EBS slope and the area north of Unmak and Unalaska Islands (Table 6).

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 size compositions in 2003 and 2010, and the age compositions in 2004-2005, 2007-2009, and 2011 were used in the assessment model.

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 is 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. One exception to this pattern is the 1998 cohort, which 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 exist between the 1980-1986 cooperative surveys and the 1991-2012 U.S. domestic surveys with regard to the vessels and gear design used (Skip Zenger, NMFS, personal communication). For example, the Japanese nets used in the 1980, 1983, and 1986 cooperative surveys varied between years and included large roller gear, in contrast to the poly-nor'eastern nets used in the current surveys (Ronholt et al 1994), and similar variations in gear between surveys occurred in the cooperative EBS surveys. In previous assessments, these surveys were included in the assessment to provide some indication of biomass during the 1980s. Given the difficulty of documenting the methodologies for these surveys and standardizing these surveys with the NMFS surveys, this year's assessment model is conducted with only the NMFS surveys (Table 9).

The AI surveys from 1991 to 2014 indicated higher abundances in the central (542) and eastern Aleutians than in the western AI (543) or southern Bering Sea area (Figure 3,Table 10). In the western Aleutians, surveys prior to 2012 typically had positive CPUE tows near Attu Island and Tahoma Bank-Buldir Island area. 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 2014 survey biomass estimate for the western AI shows the same general spatial pattern of survey CPUE, and the biomass estimate has increased to 589 t. In the central and eastern AI, the survey biomass estimates for 2014 are reduced 65% and 74%, respectively, from the estimates in the 2012 survey. In the central AI, the 2012 survey estimate of 8,268 t was high relative to previous surveys (due primarily to one large tow near Kiska Island), and the 2014 estimate of 2,878 is low relative to the time series. The 2014 estimate of 958 t for the eastern AI is the lowest observed in the time series; the next lowest estimate occurred in 2006 and was 2,803 t. The spatial pattern of the survey CPUE was similar between the 2012 and 2014 surveys, and the magnitude of the survey CPUE was smaller for the 2014 survey in the eastern and central AI.

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. Given these low levels of biomass, the slope survey results are not used in this year's assessment, and the feasibility of incorporating this time series in the age-structured model will be evaluated as new data becomes available.

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.).

Comparison of Fishery and Survey Catches by Depth and Age

A comparison of fishery and survey catches can indicate whether fishery selectivity is suspected of being time-varying and/or dome-shaped. A comparison of the catch-weighted mean depth in the AI fishery and the AI trawl survey is shown in Figure 4, and indicates relatively constant mean depth of capture across years in the AI survey, whereas the fishery depth of capture show higher interannual variation. Additionally, the mean depth in the fishery has been increasing in the eastern and western AI since the mid-2000s, which is consistent with the pattern observed in Figure 1.

The plus group for the rougheye assessment model is 45 years, and of interest is the relative age composition of the old fish within the plus group. Fishery and survey data were binned across years in two periods from 2004 to 2011, and the age composition of ages 45 to 70+ are shown in Figure 5. Overall, survey age composition is similar to fishery age composition for the ages in the plus group. For example, in the 2004 - 2006 time period, the survey age composition exceeded the fishery age composition for 12 of 26 ages, whereas the fishery age composition exceeded the survey age composition in 10 of the 26 ages (4 ages were captured by neither the fishery or the survey). The pattern can be seen more clearly in the histogram of differences between survey and fishery age proportions (Figure 6); positive differences indicate that the survey proportion exceeded the fishery proportion for a given age. Overall, these data do not suggest that the fishery is selecting older rougheye rockfish in different proportions than the survey since 2004. Fishery age data are not available to conduct a similar analysis for years prior to 2004.

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 11 and 12, 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 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 7). 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 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 from 1991-2012 were used to estimate size at age and von Bertalannfy 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 1986 to 2010 was used to fit the growth curve. The estimated von Bertalannfy parameters are as follows, and were used to create a conversion matrix and a weight-at-age vector:

L_{inf}	K	t_0
50.87	0.06	-3.48

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 second-order polynomial model to the observed standard deviation in length at each age (obtained from the aged fish from the 1991-2012 surveys), 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 0.17 at age 3 to 0.10 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 13).

The following table summarizes the data available for the both the AI blackspotted/rougheye rockfish assessment models:

Component	BSAI
Fishery catch	1977-2014
Fishery age composition	2004-2005, 2007-2009, 2011
Fishery size composition	1979, 1990, 1992-1993, 2003, 2010, 2012-2013
Survey age composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012
Survey length composition	2014
Survey biomass estimates	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014

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 2014). 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 2011 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 2012-2014 are set at the expected mean recruitment (based upon the log-scale mean, and the value of σ_r).

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

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

The mean number at age for each year was computed as

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

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

Catch biomass at age was computed as the product of mean numbers at age, instantaneous fishing mortality, and weight at age. The predicted trawl survey biomass (*pred_biom*) was computed as

$$pred\_biom_t = qsurv \sum_a \left(\overline{N}_{t,a} * survsel_a * W_a \right)$$

where W_a is the population weight at age, $survsel_a$ is the survey selectivity, and *qsurv* is the trawl survey catchability.

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 *qsurv* followed a lognormal distribution with a mean of 1.0 and a CV of 0.05, essentially fixing *qsurv* at 1.0. In previous assessments, attempts to obtain reasonable estimates of survey catchability have not been successful. The standard deviation of log recruits, σ_r, was fixed at 0.75, a value consistent with the root mean squared error (RMSE; defined below) of recruitment deviations.

Several quantities were computed in order to compare the variance of the residuals to the assumed input variances. The root mean squared error (RMSE) should be comparable to the assumed coefficient of variation of a data series. This quantity was computed for the AI trawl survey and the estimated recruitments, and for lognormal distribution is defined as

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

where y and $\hat{y}$ are the observed and estimated values, respectively, of a series length n. The standardized deviation of normalized residuals (SDNR) is closely related to the RMSE; values of SDNR approximately at 1 indicate that the model is fitting a data component as well as would be expected for a given specified input variance. The normalized residuals for a given year i of the AI trawl survey data were computed as

$$\delta_i = \frac{\ln(B_i) - \ln(\hat{B}_i)}{\sigma_i}$$

where σ_i is the input sampling standard deviation of the estimated survey biomass. For age or length composition data assumed to follow a multinomial distribution, the normalized residuals for age/length group a in year i were computed as

$$\delta_{i,a} = \frac{(y_{i,a} - \hat{y}_{i,a})}{\sqrt{\hat{y}_{i,a}(1 - \hat{y}_{i,a})/n_i}}$$

where y and $\hat{y}$ are the observed and estimated proportion, respectively, and n is the input assumed sample size for the multinomial distribution. The effective sample size was also computed for the age and length compositions modeled with a multinomial distribution, and for a given year i was computed as

$$E_i = \frac{\sum_{a} \hat{y}_a * (1 - \hat{y}_a)}{\sum_{a} (\hat{y}_a - y_a)^2}.$$

An effective sample size that is nearly equal to the input sample size can be interpreted as having a model fit that is consistent with the input sample size.

Parameterization of fishery selectivity

Four models were evaluated that differed in the parameterization for fishery selectivity at age ($s^f_{a,t}$).

Model 1) *Logistic curve* (used in previous assessments):

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

where the $a_{50\%}$ and ϕ parameters control the age at 50% maturity and the slope of the curve at this point, respectively.

Model 2) *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.

Model 3) Cubic spline

Model 4) Bicubic spline

A mathematical definition of a spline is a smooth function that is used for either interpolating between fixed points (referred to as "knots" or "nodes") or smoothing a dataset. Splines are of interest when the underlying process for which the spline represents is a smooth, nonlinear function. Splines are constructed from separate piecewise functions that are joined at the knots, and smoothness is ensured by requiring that at each knot, the two functions joined have equal function values, first derivatives, and second derivatives. These conditions can only be met by using polynomial splines of order 3 or higher, and cubic splines are often used because they limit unnecessary bending between the knots. Splines are implemented in non-parametric modeling such as generalized additive models, and have been examined in ecological modeling as an approach for modeling time-varying parameters (Thorson et al. 2013). In stock assessment modeling, non-parameteric selectivity curves (a category that includes splines) performed well in an evaluation of various approaches for modeling fishery selectivity (Thorson and Taylor 2013).

Cubic and bicubic splines were implemented with the "vcubic_spline_function" and "bicubic_spline" functions in AD Modelbuilder. The cubic spline models time-invariant selectivity, whereas the bicubic spline model selectivity varying across time and age; each function was developed from code provided in Press et al. (1992).

Briefly, the bicubic spline function requires the user to specify a number of age and year nodes that form a grid in the year-age matrix of time-varying selectivity (with equal grid spacing), and values at these nodes are the log-scale fishery selectivity and estimated as parameters. Fishery selectivity at ages and years between the nodes are interpolated with a bicubic spline. The smoothness of the surface is controlled by the number of nodes, and also by a series of penalties estimated within the model. The bicubic spline function was originally developed by Dr. Steve Martell for the Integrated Statistical Catch at Age (iSCAM) model, which included penalties for: 1) smoothness across the ages (modeled with the sum of second differences); 2) the slope of the rate of decline when selectivity decreases with age (modeled with the sum of first differences); and 3) the smoothness across years (modeled with the sum of second differences). In addition to these penalties, an additional penalty on the interannual variability across years (modeled with the first difference) was used in this assessment to address situations in which the selectivity across years was relatively smooth but also non-constant (as would occur with a trend).

Sample sizes for age and length composition data

In previous assessments, the sample sizes were set to the number of hauls, and multiplied by 2/3 for the fishery data and 4/3 for the survey data based upon the notion that the fishery data are less reliable. This procedure has resulted in the SDNR for the age and length compositions differing substantially from 1, indicating a mismatch between the precision of the model fit and the assumed input variance. Additionally, the reliability of the fishery composition data is largely reflected in the reduced number of samples for some years, thus application of reduced weight to these data may be redundant.

In this year's assessment, the sample sizes for the composition data were obtained from an iteratively reweighted procedure using the SDNR (method TA1.2 in Francis 2011). An initial model run in which the sample sizes were specified as in the 2012 assessment (Spencer and Rooper 2012) was conducted, and a weight that is the inverse of the variance of the normalized residuals for each composition dataset was obtained. The sample sizes for the next model run were the original sample sizes multiplied by the estimated weights, which then produced a new set of weights, and the process is iterated until the weights converge.

Parameters Estimated Outside the Assessment Model

The parameters estimated independently include the age error matrix, the age-length conversion matrix, individual weight at age, and proportion mature females at age. The derivation of the age error matrix, the age-length conversion matrix, and the weight at age vector are described above. The proportion of females mature at age (Table 13) 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

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

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

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

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

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

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. Because the catch biomass is generally thought to be observed with higher precision than other variables, λ_3 is given a very high weight so as to fit the catch biomass nearly exactly. The overall negative log-likelihood function (excluding the catch component) is

$$\lambda_1\left[\sum_{t=1}^{n}\frac{\left(\nu_t+\sigma_r^{\,2}/2\right)^2}{2\sigma_r^{\,2}}+n\ln(\sigma_r)\right]+$$
$$\lambda_1\left[\sum_{a=4}^{A}\frac{\left(\gamma_a+\sigma_r^{\,2}/2\right)^2}{2\sigma_r^{\,2}}+(A-3)\ln(\sigma_r)\right]+$$
$$\lambda_2\sum_t\left(\ln(obs\_biom_t)-\ln(pred\_biom_t)\right)^2/2cv_t^2+$$
$$-n_{f,t,l}\sum_{s,t,l}(p_{f,t,l}\ln(\hat{p}_{f,t,l})+p_{f,t,l}\ln(p_{f,t,l}))+$$
$$-n_{f,t,a}\sum_{s,t,l}(p_{f,t,a}\ln(\hat{p}_{f,t,a})+p_{f,t,a}\ln(p_{f,t,a}))+$$
$$-n_{surv,t,a}\sum_{s,t,a}(p_{surv,t,a}\ln(\hat{p}_{surv,t,a})+p_{surv,t,a}\ln(p_{surv,t,a}))+$$
$$-n_{surv,t,l}\sum_{s,t,a}(p_{surv,t,l}\ln(\hat{p}_{surv,t,l})+p_{surv,t,l}\ln(p_{surv,t,l}))+$$
$$\lambda_3\sum_t\left(\ln(obs\_cat_t)-\ln(pred\_cat_t)\right)^2$$

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

The negative log-likelihood function was minimized by varying the following parameters (for the model with double logistic selectivity):

Parameter type	***Number***
1) fishing mortality mean	1
2) fishing mortality deviations	38
3) recruitment mean	1
4) recruitment deviations	35
5) historic recruitment	1
6) first year recruitment deviations	42
7) biomass survey catchability	1
8) natural mortality rate	1
9) survey selectivity parameters	2
10) fishery selectivity parameters	4
Total number of parameters	126

Results

Model Evaluation

Several attributes of the model fits are shown in Table 14. Models 0 and 0.1 are presented to demonstrate intermediate steps between the 2012 model and the recommended 2014 model (i.e., a "bridging" analysis). Model 0 has the updated data through 2014, Model 0.1 excludes the cooperative survey biomass estimates and age/size composition data, and each uses the age and length composition sample weights as produced for the 2012 assessment. The sample sizes for the composition are identical in Models 1-4, and were produced by applying iterative reweighting to Model 1 (time-invariant logistic selectivity). Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) were used to evaluate model selection. Each of these metrics penalize the negative log-likelihood by multiple of the number of parameters; in AIC, this multiple is 2 whereas in BIC is the natural log of the number of data points. In addition, the root mean squared errors in the fits to the data, and the residual patterns in fitting the composition data, were considered in model evaluation.

For all the models, the number of parameters is "nominal" number of parameters, which overestimates the number of independent parameters because of the use of penalties and prior distributions in the models. Deviance Information Criterion (DIC) could be used, but will often select the models with higher number of parameters (Martell and Stewart 2014). For these reasons, model selection considered additional information such as the root mean squared errors and negative log-likelihoods in the fits to the data, and the residual patterns in fitting the composition data.

Model 2 (time-invariant double logistic selectivity) had the lowest AIC and BIC. Although the double logistic curve has the flexibility to fit dome-shaped patterns, in this case the fitted double logistic selectivity curve showed nearly no selectivity below age 8, and an approximately linear increase in selectivity between ages 8 and 45+. Very low selectivity at the low ages is also estimated with the logistic model (Model 1), but because of the symmetry of the logistic curve, fitting very low selectivity at the youngest ages affects the overall curve and lowers the value of 50% selection relative to that obtained with the double logistic curve. Model 2 shows better fits to the fishery and survey age composition data (a combined reduction of 31.7 in the negative log likelihood), although a somewhat worse fit to the fishery length composition (an increase of 4.3 in the negative log-likelihood). Model 4 (the bicubic spline) show a similar overall negative log-likelihood to that of Model 2 (510.5 compared to 508.5, respectively) but has an additional 11 parameters (with 3 year nodes and 5 ages nodes). With only 4 years of fishery length composition data and no years of fishery age composition data available prior to 2004, there is relatively little information to estimate time-varying fishery selectivity.

A comparison of the spawning stock biomass from the models is shown in Figure 8. All models, including the bridging models, show an increase in spawning stock biomass in recent years due to the increased proportion of the strong 1998 year class becoming mature as it ages. However, in models the recent increase is stronger, and extends over an increased number of years, relative to the bridging models. The reweighting of the age and length composition input sizes has a similar effect across models 1-4, and puts increased emphasis and provides better fits to the survey age composition data. Between models 1-4, there is little effect on the recent estimates of spawning stock biomass.

Model 2 was selected as the preferred model, and the results below were obtained from this model.

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.

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 2014 to 2004, 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 9. The largest changes in estimated survey biomass occurred in years 2004, 2006, and 2010, when both survey biomass estimates and survey age composition data are added to the model. The current estimated time series of spawning biomass is approximately centrally located within the suite of 2004-2014 spawning biomass time series. 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 7.85.

Biomass Trends

The estimated survey biomass decreases from 6,842 t in 1977 to 4,180 t in 1980 due to large catches in the late 1970s, increased to 7,381 t in 1991, declined throughout the 1990s and has increased to 11,004 t in 2014 (Figure 10). 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 1998, the spawning biomass has increased from 3,701 t to 6,978 t in 2014, and the total biomass has increased from 11,822 t to 38,155 t over this period (Figure 11). 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 are shown in Table 15.

Age/size compositions

The model fits to the fishery age and size compositions are shown in Figures 12 and 13 and the model fits to the survey age and length compositions are shown in Figures 14 and 15. 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 and 2012 fishery length composition data indicate that higher proportions of relatively small rougheye (i.e., 33-36 cm in 2010, 34-40 cm in 2012) are caught by the fishery. These lengths correspond approximately to 14-17 year old fish in 2010 and 15-23 year old fish in 2012, and the 1991-1997 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 the 2010 and 2012 fishery length composition data. The 2013 fishery length composition data showed a broader range of sizes, and had better model fits.

The 2010 survey age composition data also indicates relatively strong 1998 and 1999 year classes, and the 2014 survey age composition data showed a strong 1999 year class but a reduced proportion for the 1998 year class. The 2012 survey age composition data shows relatively high proportions for ages 27 -33, which correspond to lengths between 43 and 45 cm. However, the 2014 survey length composition shows relatively low reduced proportions for lengths between 35 and 45 cm, which is inconsistent with other age and length composition data and accounts for the poor model fit. The absence of fish between 35 and 45 cm in the 2014 survey is likely related to the low survey biomass estimate.

The CVs of 5% for the priors on survey catchability and natural mortality constrained these parameters to values of 1.081 and 0.033, respectively, a slight increase from the prior distribution means of 1.0 and 0.03, respectively.

The estimated age at 50% selection for the AI trawl survey was 23.5, whereas the fishery selectivity reached 50% at age 24 (Figure 16). The change in the fishery selectivity curve from a logistic to a double logistic partially accounts for the increased fishery $a_{50\%}$ from 17.8 years in the 2012 assessment.

The estimates of instantaneous fishing mortality rate are shown in Figure 17. 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. Fishing mortality rates began to decline in late 1990s, and have been below the $F_{35\%}$ reference rate since 2000 (with the exception if 2001).

Fishing Mortality and Stock Status

A plot of fishing mortality rates and spawning stock biomass in reference to the ABC and OFL harvest control rules (Figure 18) shows stock status relative to $B_{35\%}$ computed from two different time periods of recruitment. The years labeled in black use the estimated recruitments the 1997- 2011 year classes, which has been the existing practice. Although the abundance of the AI stock is estimated to be increasing, the stock status relative to $B_{35\%}$ is diminished because of the estimation of strong year classes that have been recently observed. Applying this method would result in the 2014 abundance being below ½ of $B_{35\%}$, and thus below its minimum stock size threshold (MSST). Assuming that the intent of the MSST is to identify stocks that have declined to low levels, it appears nonsensical to apply this designation to AI blackspotted/rougheye based not on a stock decline, but rather increased recruitment.

The issue for blackspotted/rougheye is that estimated strong recruitments that are relatively recently observed immediately increase the mean recruitment and $B_{35\%}$, but do not immediately affect the survey biomass estimates, or the portion of the stock that is exploited, because of the relatively high $a_{50\%}$ values for the survey and fishery selectivity. Thus, even if the recent recruitment were well-estimated, this time lag would result in the harvest control rule lowering the harvest rate for a stock that is not only not declining, but expected to increase. Additionally, some of the most recent estimates of recruitment are based on limited observations and would be expected to be imprecisely estimated. The estimated recruitment CVs (from both the Hessian and MCMC iterations) from the 2012 and 2014 assessments are shown in Figure 19. In each assessment, the Hessian and MCMC methods produce results that are similar to each other (notwithstanding the most recent year class), and show that the 1998 year class has one of the lowest estimated CVs. In addition, the CV of the 1998 year has declined from ~ 0.5 in the 2012 model to 0.25 in the 2014 model. Recruitment CVs are generally high for most of the post-1998 year classes in the 2014 assessment model.

The relative stock status for years labeled in red in Figure 18 were obtained from an estimate of mean recruitment that only uses those cohorts which have reached ages that are at least 10% selected by the trawl survey. This corresponds to ages 16 and older, and year classes 1977 – 1998. This includes the 1998 year class, which is estimated as being very large. However, this year class has now been observed for several years in the fishery and survey data, and in previous assessments has a relatively low CV associated with its estimate. Using mean recruitment from the 1977 – 1998 year classes results in a stock status for 2014 of $B_{24\%}$.

Recruitment

Recruitment strengths by year class are shown in Figure 20. 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 1981 and were observed in several years of survey sampling. Relative to the 2012 assessment, in which both the 1998 and 1999 year classes were strong, this assessment increases the estimate for the 1998 year class and lowers the estimate for the 1999 year class. It is likely that the ageing error matrix is allowing the model to fit the apparently strong 1999 year class in the composition data. The model estimates strong 2002 and 2006 year classes, although these are based upon relatively limited data.

The plot of recruitment against spawning stock biomass is shown in Figure 21.

Harvest Recommendations

Amendment 56 reference points for AI blackspotted/rougheye rockfish

The reference fishing mortality rate for blackspotted/rougheye rockfish is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Estimates of $F_{0.40}$, $F_{0.35}$, and $SPR_{0.40}$ were obtained from a spawner-per-recruit analysis. Based on the information presented above, estimated recruitment from post-1998 year classes were not used to estimate equilibrium recruitment for future years. The average recruitment from the 1977-1998 year classes estimated in this assessment is assumed to represents 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 11,403 t. The year 2015 spawning stock biomass is estimated as 7,932 t.

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

Since reliable estimates of the 2015 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B<B_{0.40}$ (7,932 t < 11,403 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 0.032 and 0.039, respectively. The 2015 ABC and OFL for the AI blackspotted/rougheye resulting from these rates are 420 t and 516 t, respectively. A summary of these values is below.

2015 SSB estimate (B)	=	7,932 t
$B_{0.40}$	=	11,403 t
$F_{0.40}$	=	0.047
F_{ABC}	=	0.033
$F_{0.35}$	=	0.058
F_{OFL}	=	0.039

Amendment 56 reference points for EBS blackspotted/rougheye rockfish

The age-structured model pertains to the AI management area, and management reference points for the EBS management area were obtained from applying Tier 5 methods to the survey data in the EBS management area. Tier 5 reference points specify $F_{abc} = 0.75*M$ and $F_{ofl} = M$, and current estimates of M for blackspotted/rougheye rockfish obtained from the AI age structured model (0.033) were used, resulting in F_{abc} and F_{ofl} levels of 0.248 and 0.033, respectively. The ABC and OFL levels for the EBS blackspotted/rougheye rockfish were obtained by multiplying the F_{abc} and F_{ofl} values by estimated biomass. At the September 2013 Groundfish PlanTeam meeting, the Groundfish Plan Team recommended using a random effects model to estimate current biomass, and it was used in 2013 to estimate the biomass for the EBS blackspotted/rougheye rockfish.

Application of the random effects model results in a biomass estimate of 1,339 t for the EBS subarea, and was obtained by summing the estimates of biomass obtained from the EBS slope and the southern Bering Sea (SBS) area sampled by the AI trawl survey. Application of the F_{abc} and F_{ofl} values above to this biomass estimate yields the EBS OFL and ABC values to 44 t and 33 t, respectively. Summing the EBS ABC and OFL values with those obtained from the age-structured model for the AI portion of the population results in an overall BSAI ABC and OFL of 560 t and 453 t, respectively.

Population Projections for AI blackspotted/rougheye rockfish

Age-structured population projections are not possible for the EBS portion of the blackspotted/rougheye rockfish, and were conducted only for the AI blackspotted/rougheye rockfish. A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2014 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2015 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2014. 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 2015, 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 2015 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 2009-2013 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 2014 or; 2) above ½ of its MSY level in 2014 and above its MSY level in 2024 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2015 and 2016, 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 2027 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 16.

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 2015, it does not provide the best estimate of OFL for 2016, because the mean 2016 catch under Scenario 6 is predicated on the 2015 catch being equal to the 2015 OFL, whereas the actual 2015 catch will likely be less than the 2015 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

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

Is the stock being subjected to overfishing? The official BSAI catch estimate for the most recent complete year (2013) is 324 t. This is less than the 2013 BSAI OFL of 462 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. In this assessment, determination of whether the stock is overfished is complicated in that the age-structured model is applied only to the AI portion of the population; thus an estimate of MSST is only available for this portion of the population. Because current management regulations use a single OFL for the BSAI area, a meaningful measure of MSST and overfished status would need to reflect the entire BSAI population. However, the AI portion of the population composes the majority of the BSAI blackspotted/rougheye rockfish, and evaluation of its population size relative the MSST computed for the AI provides a useful index of stock condition. Harvest Scenarios #6 and #7 are used in these determinations for the AI portion of the population as follows:

Is the AI portion of the population currently below its MSST? This depends on the estimated spawning biomass in 2014:
a. If spawning biomass for 2014 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2014 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2014 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 16). If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the AI portion of the population projected to go below its MSST? This is determined by referring to harvest Scenario #7:
a. If the mean spawning biomass for 2017 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2017 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2017 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2027. 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 the AI portion of the blackspotted/rougheye rockfish stock is neither below its MSST or projected to go below its MSST. With regard whether this portion of the stock is currently below its MSST, the expected stock size in the year 2024 of Scenario 6 is 1.65 times its

$B_{35\%}$ value of 9,978 t. With regard to whether AI portion of the blackspotted/rougheye is to go below its MSST, the expected stock size in 2027 of Scenario 7 is 1.78 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. As described above, the estimated 2015 ABC for the EBS area is 44 t. Within the AI management area, weighted averages of subarea biomass from the 2010, 2012, and 2014 AI surveys were used to compute average biomass. Weights of 4-6-9 were used, with higher weights given to more recent years.

It is also of interest to estimate the area proportions using the random effects model. The survey averaging workgroup is evaluating the use of the random effects model to smooth survey time series for computing area apportionments, and its use for computing area proportion might logically be delayed until after the workgroup has completed their evaluations. However, because the procedure does not differ from that applied to obtain the biomass for the EBS area, it seems reasonable to apply it here to compare it to the current method of using a weighted average.

The proportions obtained from these two methods were applied to the 2015 AI ABC of 420 t. The results of these calculations are shown below:

	WAI	CAI	EAI
Weighted average biomass (t)	722	4,446	2,643
Proportion of biomass	9.2%	56.9%	33.8%
Area ABC	39	239	142
Estimated 2014 biomass (from random effects model)	566	3,152	1,425
Proportion of biomass	11.0%	61.3%	27.7%
Area ABC	46	257	116

The two methods for obtaining the proportions produce similar results. Combining the WAI and CAI , and adding the EBS to the EAI, produces the following subarea ABCs from the two methods for determining the proportions (the OFL are also shown).

	BSAI	WAI+CAI	EAI+EBS	Total
OFL (2015)	560			560
ABC (2015, weighted average)		278	175	453
ABC (2015, RE model)		304	149	453
OFL (2016)	686			686
ABC (2016, weighted average)		345	210	555
ABC (2016, RE model)		377	178	555

Finally, within the last year the SSC has requested that the potential subarea ABCs be computed and presented for the subareas within the AI, particularly for the western AI. These numbers are shown below for 2015 and 2016. As shown above, if an ABC were to be applied to the western AI in 2015, its value from weighted averaging is 39 t, and its value from using a random effects model is 46 t.

	WAI	CAI	WAI-CAI
ABC (2015, weighted average)	39	239	278
ABC (2015, RE model)	46	257	304
ABC (2016, weighted average)	48	297	345
ABC (2016, RE model)	57	320	377

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.

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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 2014. Catch data is through October 11, 2014, 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	209										
2005	Rougheye	298	223	223	90										
2006	Rougheye	299	224	224	203										
2007	Rougheye	269	202	202	167										
2008	Rougheye	269	202	202	214										
2009	Rougheye	660	539	539	209										
2010	Rougheye	669	547	547	256										
2011	Rougheye	549	454	454	170	Rougheye		220	220	77	Rougheye		234	234	94
2012	Rougheye	576	475	475	201	Rougheye		244	244	131	Rougheye		231	231	70
2013	Rougheye	462	378	378	324	Rougheye		209	209	146	Rougheye		169	169	178
2014	Rougheye	505	416	416	194	Rougheye		239	239	98	Rougheye		177	177	96

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			24			185	209
2005			12			78	90
2006			7			196	203
2007			10			157	167
2008			29			185	214
2009			12			197	209
2010			34			222	256
2011			39			131	170
2012			18			183	201
2013			27			297	324
2014*			21			173	194

*Catch data through October 11, 2014, 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	115	58	12	24	209
2005	43	24	11	12	90
2006	109	45	42	7	203
2007	44	42	71	10	167
2008	61	74	50	29	214
2009	74	84	39	12	209
2010	94	52	76	34	256
2011	46	31	54	39	170
2012	65	66	52	18	201
2013	84	62	151	27	324
2014*	56	42	75	21	194

* Estimated removals through October 11, 2014.

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				
Year	Species Group	Retained	Discarded	Total	Percent Discarded	Species Group	Retained	Discarded	Total	Percent Discarded
1993	RE/SR	737	403	1139	35%	Other red rockfish	367	97	464	21%
1994	RE/SR	701	224	925	24%	Other red rockfish	29	100	129	78%
1995	RE/SR	456	103	558	18%	Other red rockfish	274	70	344	20%
1996	RE/SR	751	208	959	22%	Other red rockfish	58	149	207	72%
1997	RE/SR	733	310	1043	30%	Other red rockfish	44	174	218	80%
1998	RE/SR	447	238	685	35%	Other red rockfish	38	59	97	61%
1999	RE/SR	319	195	514	38%	Other red rockfish	75	163	238	68%
2000	RE/SR	285	196	480	41%	Other red rockfish	111	141	253	56%
2001	RE/SR	476	246	722	34%	RE/SR	27	16	43	38%
2002	RE/SR	333	146	478	30%	RE/SR	50	54	105	52%
2003	RE/SR	197	84	281	30%	RE/SR	62	54	116	47%
2004	Rougheye	83	102	185	55%	Rougheye	15	9	24	39%
2005	Rougheye	72	6	78	8%	Rougheye	3	9	12	73%
2006	Rougheye	166	30	196	15%	Rougheye	5	2	7	30%
2007	Rougheye	127	30	157	19%	Rougheye	7	3	10	29%
2008	Rougheye	142	43	185	23%	Rougheye	12	17	29	58%
2009	Rougheye	162	35	197	18%	Rougheye	9	3	12	26%
2010	Rougheye	187	34	222	15%	Rougheye	20	14	34	42%
2011	Rougheye	115	16	131	12%	Rougheye	31	9	39	22%
2012	Rougheye	158	24	183	13%	Rougheye	14	5	18	25%
2013	Rougheye	243	54	297	18%	Rougheye	20	7	27	28%
2014*	Rougheye	158	15	173	9%	Rougheye	16	5	21	23%

* Estimated removals through October 11, 2014.

Table 6. Aleutian Islands and eastern Bering Sea cumulative catch (t) of blackspotted and rougheye rockfish from top gear and target combinations by management area and target fishery in 2004-2012, from the NMFS Alaska Regional Office catch accounting system database.

Aleutian Islands

		Management Area			
Target	Gear	541	542	543	Total
Rockfish	Bottom trawl	204.72	180.51	506.59	891.82
Pacific cod	Longline	25.39	123.12	73.72	222.22
Atka mackerel	Bottom trawl	33.58	92.07	66.34	191.99
Arrowtooth	Bottom trawl	73.71			73.71
Kamchatka	Bottom trawl	37.17			37.17
Sablefish	Longline	13.26	19.78		33.04
Halibut	Longline	9.05	15.01	3.80	27.85
Arrowtooth	Longline	0.02	16.31		16.33
Turbot	Longline	0.10	9.84		9.95
Pacific cod	Bottom trawl	2.69	4.36	0.35	7.40
Total (all targets and gears)		403.33	462.03	651.58	1516.94

Eastern Bering Sea

		Management Area									
Target	Gear	509	513	514	517	518	519	521	523	524	Total
Arrowtooth	Bottom trawl				15.99	18.53	8.00	3.40	0.11	0.75	46.77
Pacific cod	Longline	0.02	0.03		3.40	0.07	2.12	27.92	3.42	0.26	37.24
Rockfish	Bottom trawl				19.91	10.53	1.02	2.90	0.80		35.17
Halibut	Longline			0.02	1.73	9.85	1.24	3.75	2.09	3.53	22.20
Turbot	Longline				0.10	0.08	0.05	9.82	3.08	0.10	13.23
pollock pelagic	Pelagic trawl	0.15	0.04		5.25		1.94	1.38	0.01	0.03	8.81
Other flatfish	Bottom trawl				3.09		3.40				6.49
Flathead sole	Bottom trawl		1.07		1.02			0.46	0.48		3.03
Kamchatka	Bottom trawl					2.28	0.13			0.26	2.67
Pacific cod	Bottom trawl	0.10	0.00		0.69		0.62	0.34	0.28		2.02
Pollock bottom	Pelagic trawl	0.02	0.01		0.41		1.03	0.02			1.49
Sablefish	Longline				0.60	0.17	0.49	0.04	0.06		1.36
Atka mackerel	Bottom trawl						1.19				1.19
Total (all targets and gears)		0.27	1.16	0.02	55.45	42.33	21.79	50.28	10.42	4.94	186.66

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 1977-2013.

	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	208	80	1501	274	1709	354

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 1977-2013.

	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		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	26	172	198						
2011	22	155	177	19	154	173	12	85	97
2012	26	109	135						
2013	49	254	303						

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.

		AI survey		
Year	AI	S. Bering Sea	Total	EBS Slope survey
1979				1053
1980	8,987 (0.07)	6 (1.00)	8,993 (0.07)	
1981				816
1982				605
1983	13,104 (0.19)	2,111 (0.33)	15,215 (0.17)	
1984				
1985				1716
1986	57,351 (0.51)	2,724 (0.49)	60,076 (0.49)	
1987				
1988				876 (0.32)
1989				
1990				
1991	10,638 (0.47)	676 (0.12)	11,314 (0.44)	884 (0.30)
1992				
1993				
1994	13,415 (0.28)	1,208 (0.49)	14,623 (0.26)	
1995				
1996				
1997	10,905 (0.22)	561 (0.66)	11,466 (0.21)	
1998				
1999				
2000	14,240 (0.23)	1,054 (0.26)	15,294 (021)	
2001				
2002	8,423 (0.21)	1,251 (0.48)	9,674 (0.20)	553 (0.20)
2003				
2004	14,386 (0.26)	654 (0.31)	15,039 (0.25)	646 (0.16)
2005				
2006	8,281 (0.25)	1,224 (0.33)	9,505 (0.23)	
2007				
2008				829 (0.24)
2009				
2010	8,541 (0.26)	221 (0.28)	8,762 (0.26)	999 (0.25)
2011				
2012	12,401 (0.38)	405 (0.27)	12,807 (0.37)	1,613 (0.50)
2013				
2014	4,425 (0.19)	311 (0.20)	4,736 (0.18)	

Table 10. Blackspotted/rougheye subarea biomass estimates (t) from the 1991-2014 Aleutian Islands trawl surveys.

	Aleutian Islands Survey Sub-Areas			
Year	Western AI	Central AI	Eastern AI	Southern Bering Sea
1991	3,037	2,380	5,221	676
1994	2,908	3,470	7,037	1,208
1997	3,373	4,607	2,925	561
2000	683	9,333	4,224	1,054
2002	1,390	3,934	3,099	1,251
2004	1,185	7,681	5,520	654
2006	519	4,959	2,803	1,224
2010	1,601	2,238	4,702	221
2012	335	8,268	3,798	405
2014	589	2,878	958	311
Weighted Average (2010-2014)	722	4,445	2,643	322

Table 11. Samples sizes of blackspotted/rougheye lengths from the Aleutian Island trawl survey, with the number of hauls from which these data were collected, from 1991-2014.

	Lengths			Hauls		
Year	SBS	AI	Total	SBS	AI	Total
1991	79	981	1060	5	30	35
1992						
1993						
1994	412	1963	2375	14	90	104
1995						
1996						
1997	90	1727	1817	13	108	121
1998						
1999						
2000	165	1508	1673	18	101	119
2001						
2002	258	1030	1288	19	79	98
2003						
2004	103	1419	1522	13	104	117
2005						
2006	177	1082	1259	20	102	122
2007						
2008						
2009						
2010	27	959	986	10	82	92
2011						
2012	129	1227	1356	25	94	119
2013						
2014	62	973	1035	19	88	107

Table 12. Samples sizes of blackspotted/rougheye otoliths from the Aleutian Island (AI) trawl survey, with the number of hauls from which these data were collected, from 1991-2014. SBS is the southern Bering Sea, which is the portion of Aleutian Islands trawl survey from 165° W to 170 W°.

	Otoliths sampled			Otoliths Read			Hauls (Otoliths Read)		
Year	SBS	AI	Total	SBS	AI	Total	SBS	AI	Total
1991	79	401	480	79	397	476	6	23	29
1992									
1993									
1994	194	535	729	130	356	486	13	55	68
1995									
1996									
1997	76	790	866	52	526	578	9	83	92
1998									
1999									
2000	116	376	492	115	375	490	16	71	87
2001									
2002	114	359	473	114	337	451	15	66	81
2003									
2004	103	372	475	102	370	472	14	83	97
2005									
2006	120	339	459	120	339	459	19	83	102
2007									
2008									
2009									
2010	27	464	491	26	456	482	10	79	89
2011									
2012	92	468	560	77	468	535	13	82	95
2013									
2014	57	338	395						

Table 13. Predicted weight and proportion mature at age for BSAI rougheye rockfish.

Age	Predicted weight (g)	Proportion mature
3	59	0
4	86	0
5	117	0
6	154	0.001
7	195	0.001
8	240	0.003
9	289	0.008
10	340	0.015
11	394	0.03
12	450	0.053
13	507	0.09
14	566	0.141
15	625	0.209
16	684	0.29
17	744	0.378
18	803	0.467
19	861	0.551
20	919	0.625
21	976	0.689
22	1,031	0.742
23	1,085	0.785
24	1,138	0.82
25	1,189	0.847
26	1,239	0.87
27	1,287	0.888
28	1,333	0.902
29	1,378	0.914
30	1,421	0.924
31	1,462	0.932
32	1,502	0.939
33	1,540	0.944
34	1,576	0.949
35	1,611	0.953
36	1,644	0.956
37	1,675	0.959
38	1,706	0.962
39	1,734	0.964
40	1,762	0.966
41	1,788	0.968
42	1,812	0.969
43	1,836	0.97
44	1,858	0.971
45+	2,054	0.977

Table 14. Negative log likelihoods, and several measures of model fits, for the evaluated models for BSAI blackspotted/rougheye rockfish.

	Model 0	Model 0.1	Model 1	Model 2	Model 3	Model 4
Negative log-likelihood						
Data components						
AI survey biomass	26.29	20.78	26.26	29.17	30.64	26.60
Catch biomass	0.01	0.00	0.00	0.01	0.01	0.01
Fishery age comp	111.77	109.82	114.89	101.38	112.27	109.93
Fishery length comp	103.11	101.81	155.11	159.40	162.74	151.75
AI survey age comp	121.15	101.93	189.38	172.14	177.67	171.77
AI survey lengths comp	33.91	29.79	10.29	10.03	11.06	10.16
Priors and penalties						
Recruitment	21.02	23.52	33.38	26.97	26.32	21.97
Prior on survey q	2.33	0.50	0.61	1.27	1.40	1.04
Prior on M	4.97	1.96	2.36	1.87	1.93	1.57
Fishery selectivity	0.00	0.00	0.00	0.00	16.32	9.68
Total negative log-likelihood	430.56	395.87	538.28	508.51	546.57	510.49
Parameters		124	124	126	127	137
Number of data points		1044	1044	1044	1044	1044
BIC		1653.65	1938.46	1892.82	1975.89	1973.23
AIC		1039.75	1324.56	1269.02	1347.14	1294.97
Effective sample size						
Fishery age comp	55	57	55	60	57	57
Fishery length comp	523	433	395	195	225	148
AI survey age comp	104	153	207	244	244	259
AI survey lengths comp	129	78	67	68	67	64
Sample weights						
Fishery age comp	54	54	55	55	55	55
Fishery length comp	94	94	152	152	152	152
AI survey age comp	85	93	202	202	202	202
AI survey lengths comp	115	117	28	28	28	28
Root mean square error						
AI survey biomass	0.601	0.464	0.521	0.556	0.572	0.529
Recruitment	0.911	0.935	0.968	0.966	0.951	0.924
Fishery age comp	0.023	0.023	0.023	0.021	0.023	0.023
Fishery length comp	0.017	0.017	0.016	0.015	0.016	0.015
AI survey age comp	0.018	0.014	0.012	0.011	0.011	0.011
AI survey lengths comp	0.015	0.018	0.019	0.019	0.019	0.019
Standard Deviation of Normalized Residuals						
AI survey biomass	1.90	1.93	2.18	2.22	2.27	2.13
Fishery age comp	0.98	0.96	1.00	0.99	0.96	0.96
Fishery length comp	0.82	0.81	1.00	1.02	1.02	0.99
AI survey age comp	0.77	0.73	1.00	0.95	0.97	0.95
AI survey lengths comp	1.13	1.49	1.00	0.97	1.06	0.96

Table 15. Estimated time series of AI blackspotted/rougheye total biomass (t), spawner biomass (t), and recruitment (thousands).

	Total Biomass (ages 3+) Assessment Year		Spawner Biomass (ages 3+) Assessment Year		Recruitment (age 3) Assessment Year	
Year	2014	2012	2014	2012	2014	2012
1977	15,500	18,520	4,303	5,299	881	1,062
1978	15,992	19,106	4,433	5,474	1,044	1,265
1979	14,083	17,341	3,731	4,833	1,535	1,797
1980	11,441	14,849	3,003	4,132	1,223	1,509
1981	11,335	14,833	3,035	4,193	823	1,079
1982	11,286	14,869	3,100	4,289	838	1,078
1983	11,661	15,332	3,296	4,523	1,110	1,323
1984	12,186	15,948	3,533	4,803	1,408	1,591
1985	12,761	16,580	3,778	5,093	1,755	1,448
1986	13,359	17,221	4,031	5,390	1,416	1,166
1987	13,917	17,820	4,273	5,677	820	833
1988	14,402	18,339	4,493	5,943	670	712
1989	14,886	18,840	4,687	6,181	769	705
1990	15,047	18,998	4,674	6,207	762	616
1991	13,932	17,797	4,335	5,881	557	475
1992	14,288	18,133	4,426	6,009	460	401
1993	13,566	17,344	4,171	5,774	440	380
1994	13,078	16,798	4,016	5,640	458	397
1995	12,746	16,411	3,947	5,592	515	464
1996	12,764	16,374	3,974	5,638	670	600
1997	12,349	15,887	3,846	5,518	927	730
1998	11,822	15,258	3,701	5,372	1,645	1,019
1999	11,771	15,109	3,713	5,382	2,058	1,650
2000	11,851	15,105	3,779	5,439	1,362	1,533
2001	13,334	15,838	3,854	5,501	23,104	10,990
2002	13,902	16,673	3,839	5,466	3,283	13,342
2003	15,136	17,410	3,932	5,538	7,391	2,118
2004	16,378	18,314	4,037	5,612	2,057	2,339
2005	18,356	19,369	4,134	5,674	13,303	3,566
2006	20,256	20,494	4,258	5,756	4,044	1,549
2007	22,198	21,603	4,371	5,837	3,662	1,252
2008	24,205	22,695	4,483	5,889	3,038	1,329
2009	26,782	23,777	4,628	5,951	11,653	1,581
2010	29,042	24,857	4,829	6,048	2,011	
2011	31,281	25,907	5,136	6,208	1,560	
2012	33,663	27,040	5,597	6,488		
2013	35,973	28,079	6,208			
2014	38,155		6,978			
2015	40,391					

Table 16. Projections of Aleutian Island (AI) blackspotted/rougheye rockfish spawning biomass (t), catch (t), and fishing mortality rate for each of the several scenarios resulting from the AI model. The values of $B_{40\%}$ and $B_{35\%}$ are 11,403 t and 9,977 t, respectively.

Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2014	191	191	191	191	191	191	191
2015	420	420	211	309	0	516	420
2016	516	516	264	336	0	629	516
2017	630	630	328	365	0	761	774
2018	759	759	400	397	0	909	922
2019	828	828	433	429	0	1,001	1,007
2020	882	882	466	462	0	1,060	1,067
2021	937	937	499	496	0	1,121	1,127
2022	991	991	534	530	0	1,181	1,187
2023	1,045	1,045	569	565	0	1,239	1,245
2024	1,097	1,097	603	599	0	1,294	1,301
2025	1,147	1,147	638	634	0	1,347	1,353
2026	1,194	1,194	671	667	0	1,395	1,402
2027	1,238	1,238	703	699	0	1,439	1,445
Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2014	6,978	6,978	6,978	6,978	6,978	6,978	6,978
2015	7,932	7,932	7,944	7,939	7,956	7,927	7,932
2016	8,953	8,953	9,042	9,003	9,132	8,913	8,953
2017	10,053	10,053	10,239	10,175	10,432	9,970	10,045
2018	11,181	11,181	11,489	11,409	11,815	11,045	11,119
2019	12,311	12,311	12,769	12,687	13,263	12,111	12,185
2020	13,411	13,411	14,042	13,958	14,727	13,137	13,212
2021	14,469	14,469	15,291	15,205	16,191	14,113	14,188
2022	15,447	15,447	16,478	16,390	17,616	15,004	15,078
2023	16,316	16,316	17,570	17,482	18,968	15,780	15,854
2024	17,076	17,076	18,568	18,479	20,247	16,443	16,515
2025	17,704	17,704	19,445	19,356	21,425	16,970	17,041
2026	18,202	18,202	20,201	20,113	22,500	17,366	17,435
2027	18,579	18,579	20,843	20,756	23,478	17,640	17,706
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2014	0.016	0.016	0.016	0.016	0.016	0.016	0.016
2015	0.032	0.032	0.016	0.023	0	0.039	0.032
2016	0.036	0.036	0.018	0.023	0	0.044	0.036
2017	0.041	0.041	0.021	0.023	0	0.050	0.050
2018	0.046	0.046	0.023	0.023	0	0.056	0.056
2019	0.047	0.047	0.023	0.023	0	0.058	0.058
2020	0.047	0.047	0.023	0.023	0	0.058	0.058
2021	0.047	0.047	0.023	0.023	0	0.058	0.058
2022	0.047	0.047	0.023	0.023	0	0.058	0.058
2023	0.047	0.047	0.023	0.023	0	0.058	0.058
2024	0.047	0.047	0.023	0.023	0	0.058	0.058
2025	0.047	0.047	0.023	0.023	0	0.058	0.058
2026	0.047	0.047	0.023	0.023	0	0.058	0.058
2027	0.047	0.047	0.023	0.023	0	0.058	0.058

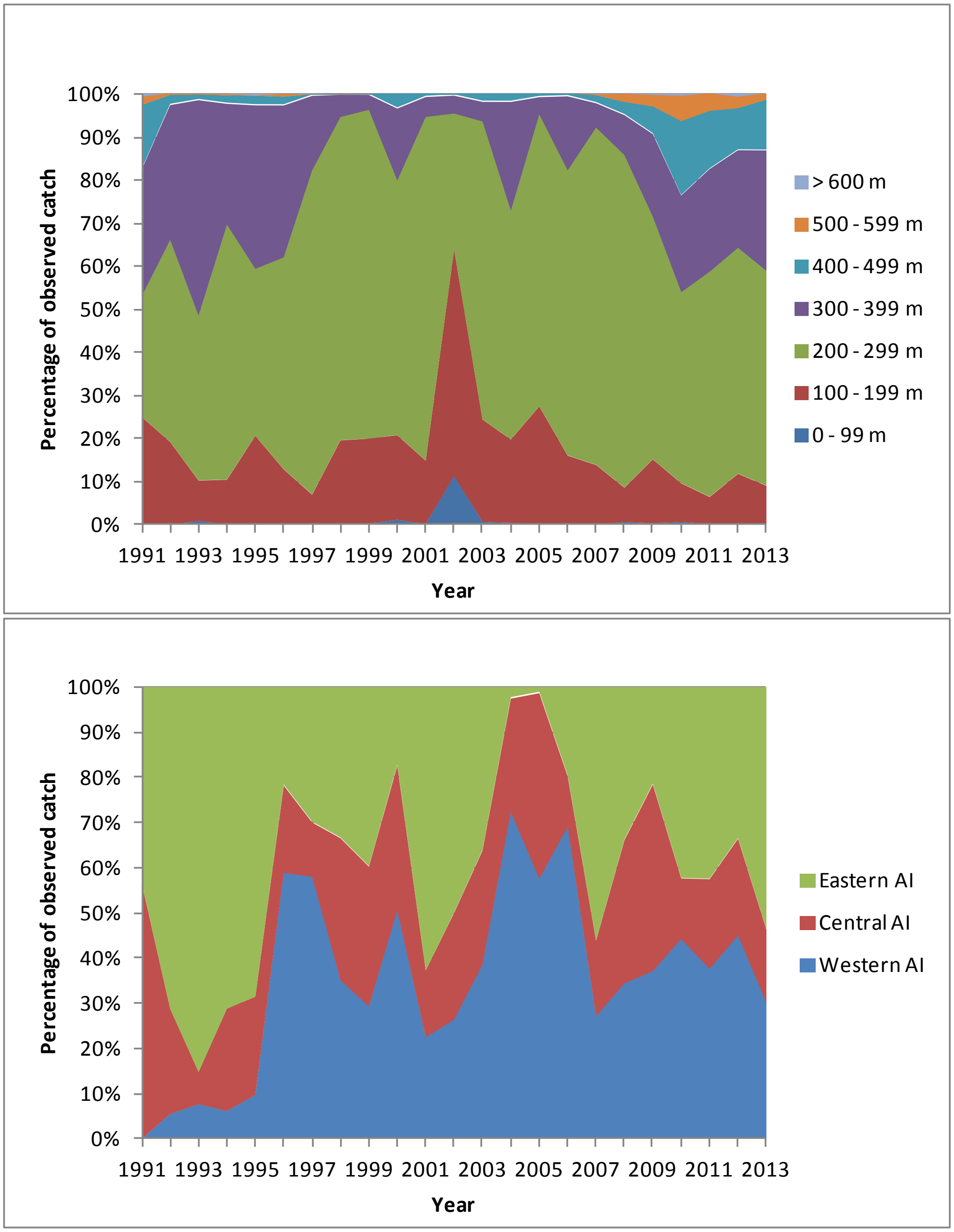


Figure 1. Distribution of observed Aleutian Islands (AI) blackspotted/rougheye rockfish catch (from North Pacific Groundfish Observer Program) by depth zone (top panel) and AI subarea (bottom panel) from 1991 to 2013.

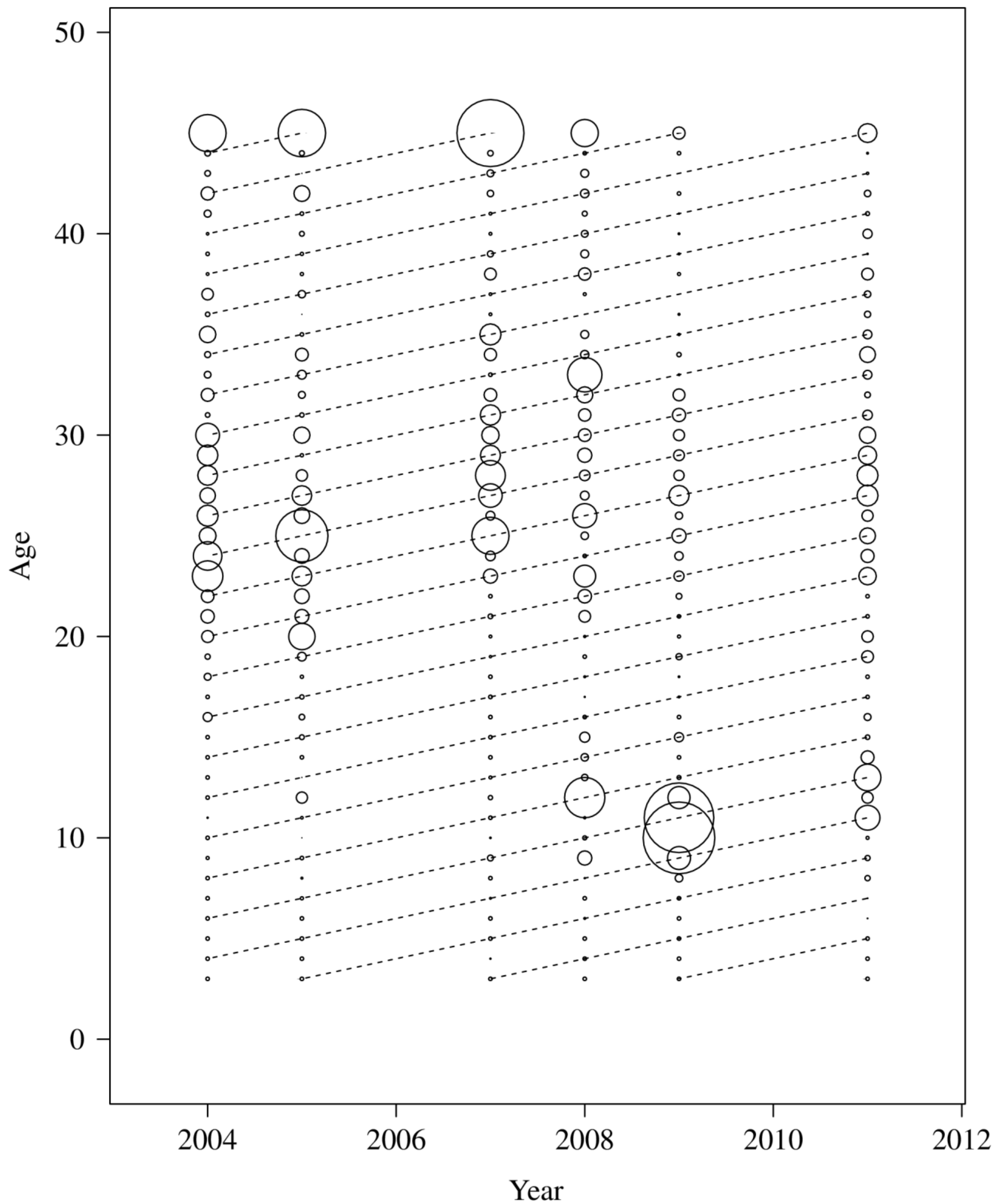


Figure 2. Fishery age composition data for the Aleutian Islands; bubbles are scaled within each year of samples and dashed lines denote cohorts.

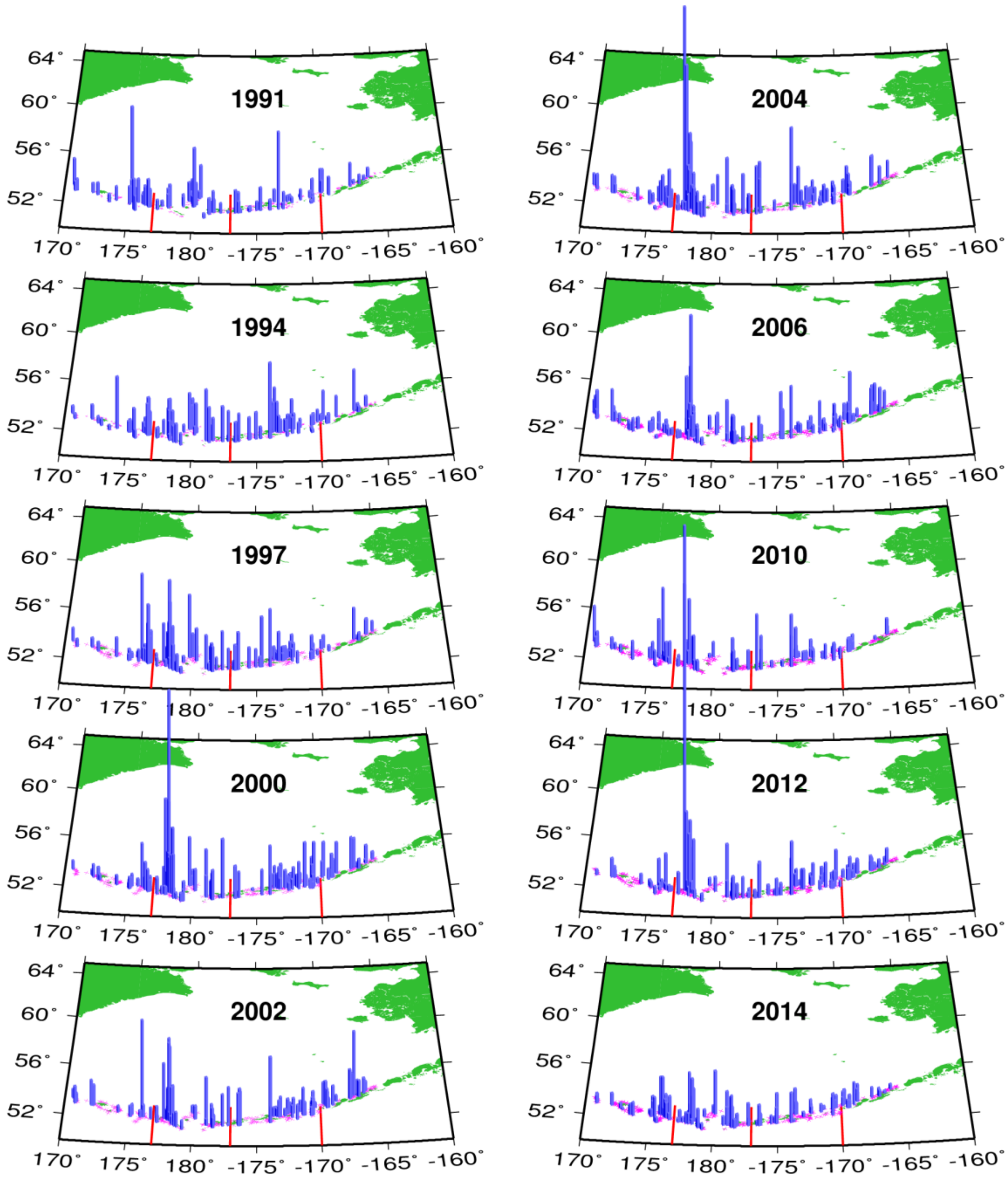


Figure 3. Scaled Aleutian Islands (AI) survey combined blackspotted and rougheye rockfish CPUE (square root of kg/km^2) from 1991-2014; the symbol × denotes tows with no catch. The red lines indicate boundaries between the western Aleutian Islands (WAI), central Aleutian Islands (CAI), eastern Aleutian Islands (EAI), and eastern Bering Sea (EBS) areas.

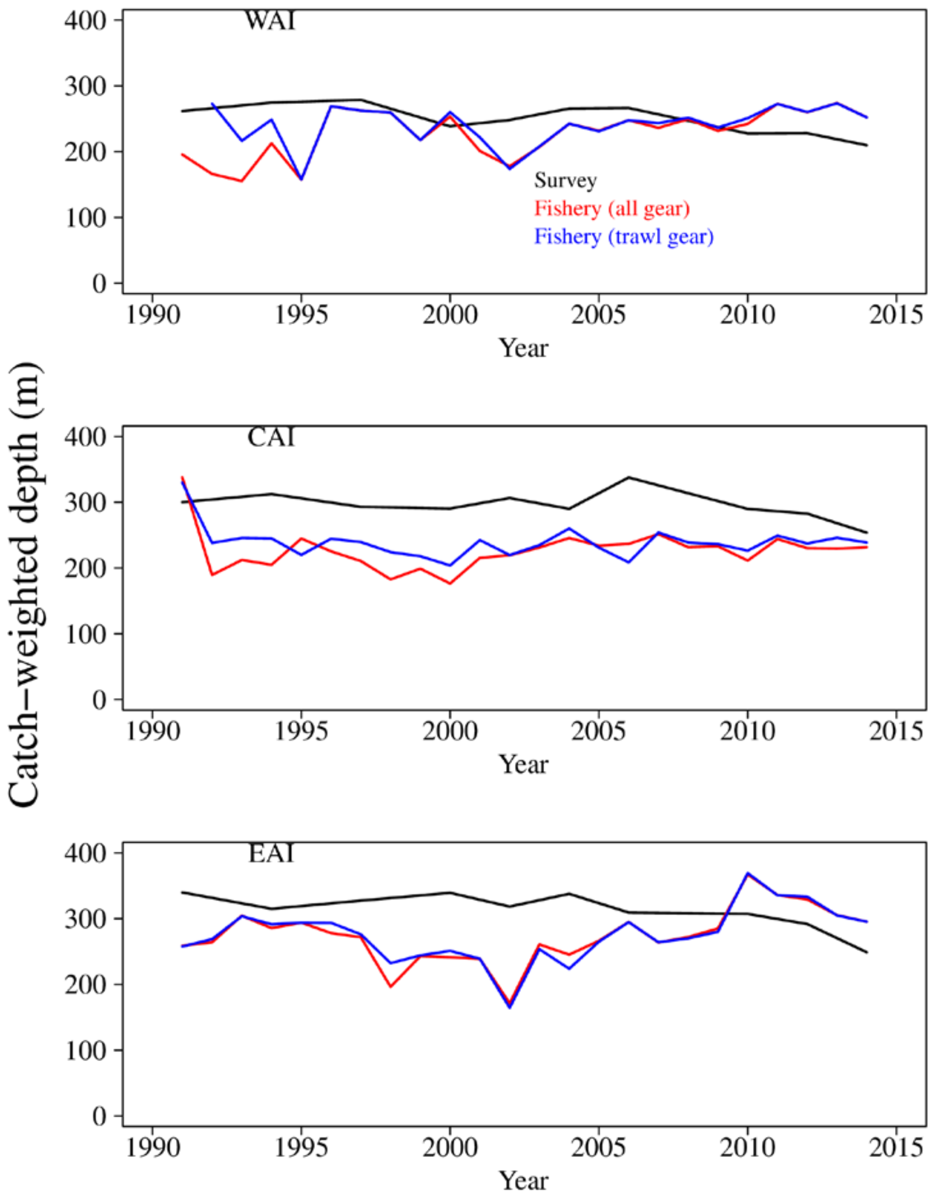


Figure 4. Catch-weighted (by numbers) depth of capture for blackspotted/rougheye rockfish in the fishery and AI survey by AI subarea from 1991 to 2014: WAI = western Aleutian Islands (top panel), CAI = central Aleutian Islands (middle panel), and EAI = eastern Aleutian Islands (bottom panel).

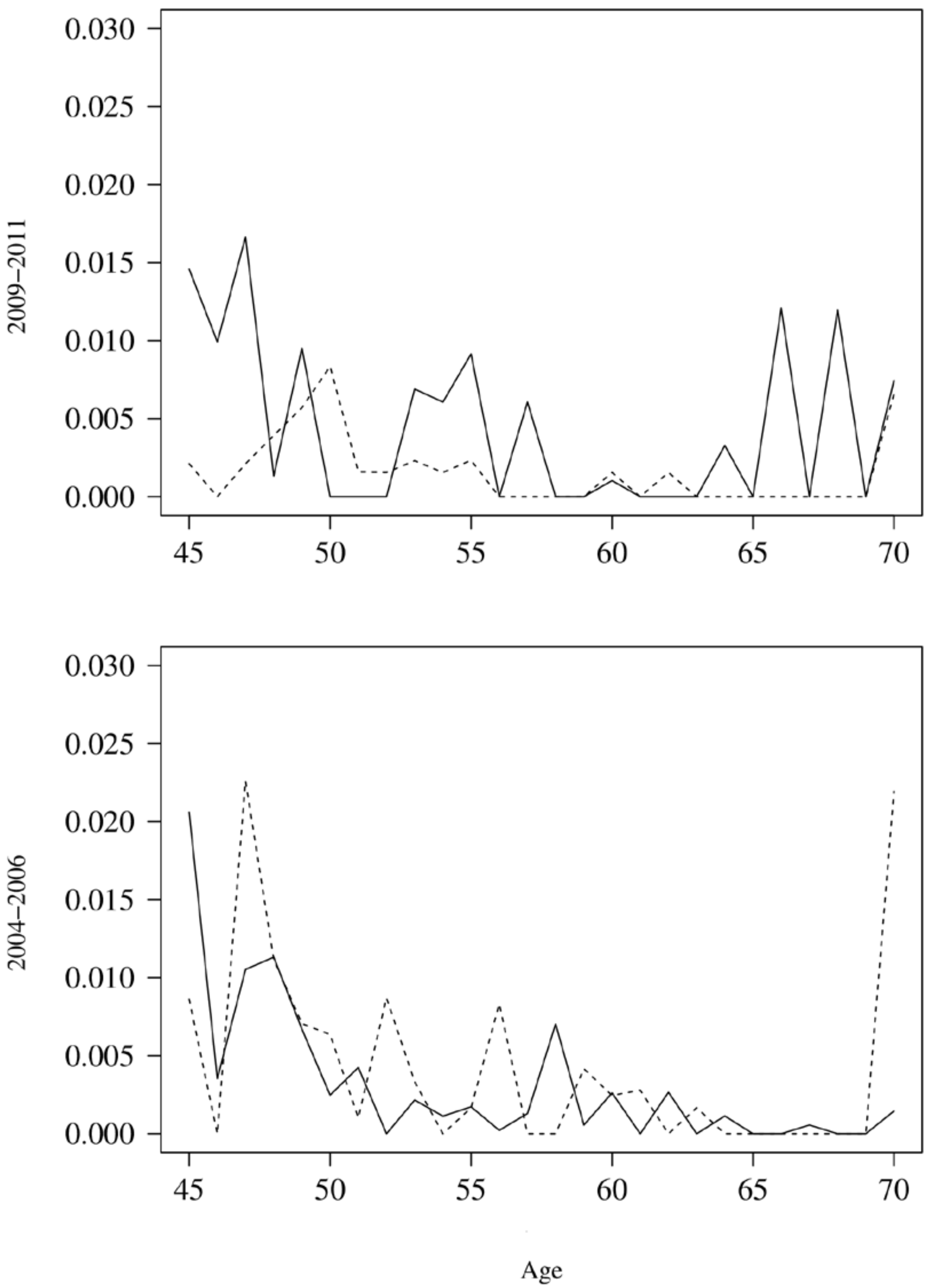


Figure 5. Age compositions in the Aleutian Islands survey (solid line) and fishery (dashed line) for ages 45 to 70+ for two time periods: 2004-2006 (bottom panel) and 2009 – 2011 (top panel).

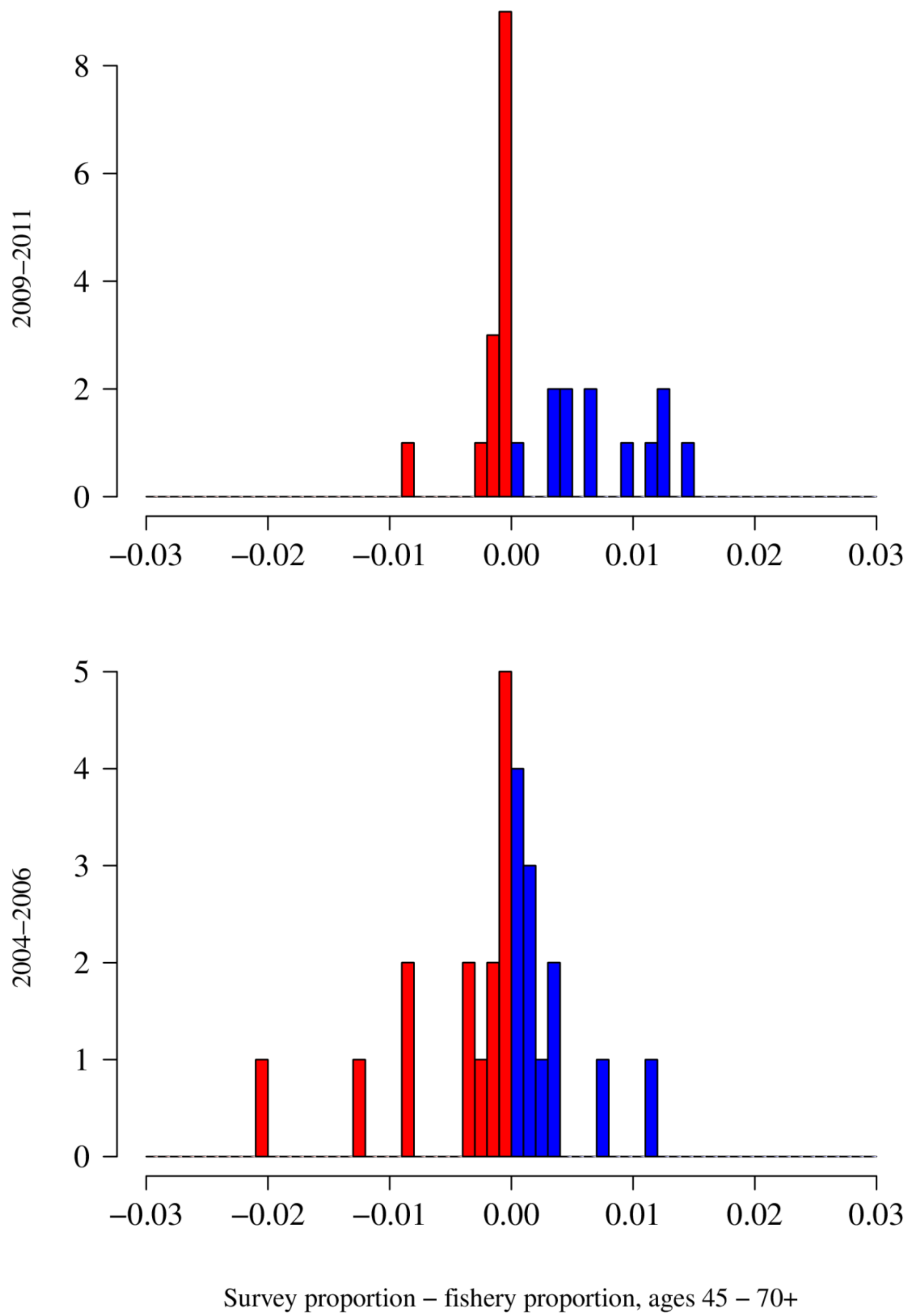


Figure 6. Histograms of the difference (survey proportion – fishery proportion) for ages 45 to 70+ for two time periods: 2004-2006 (bottom panel) and 2009 – 2011 (top panel).

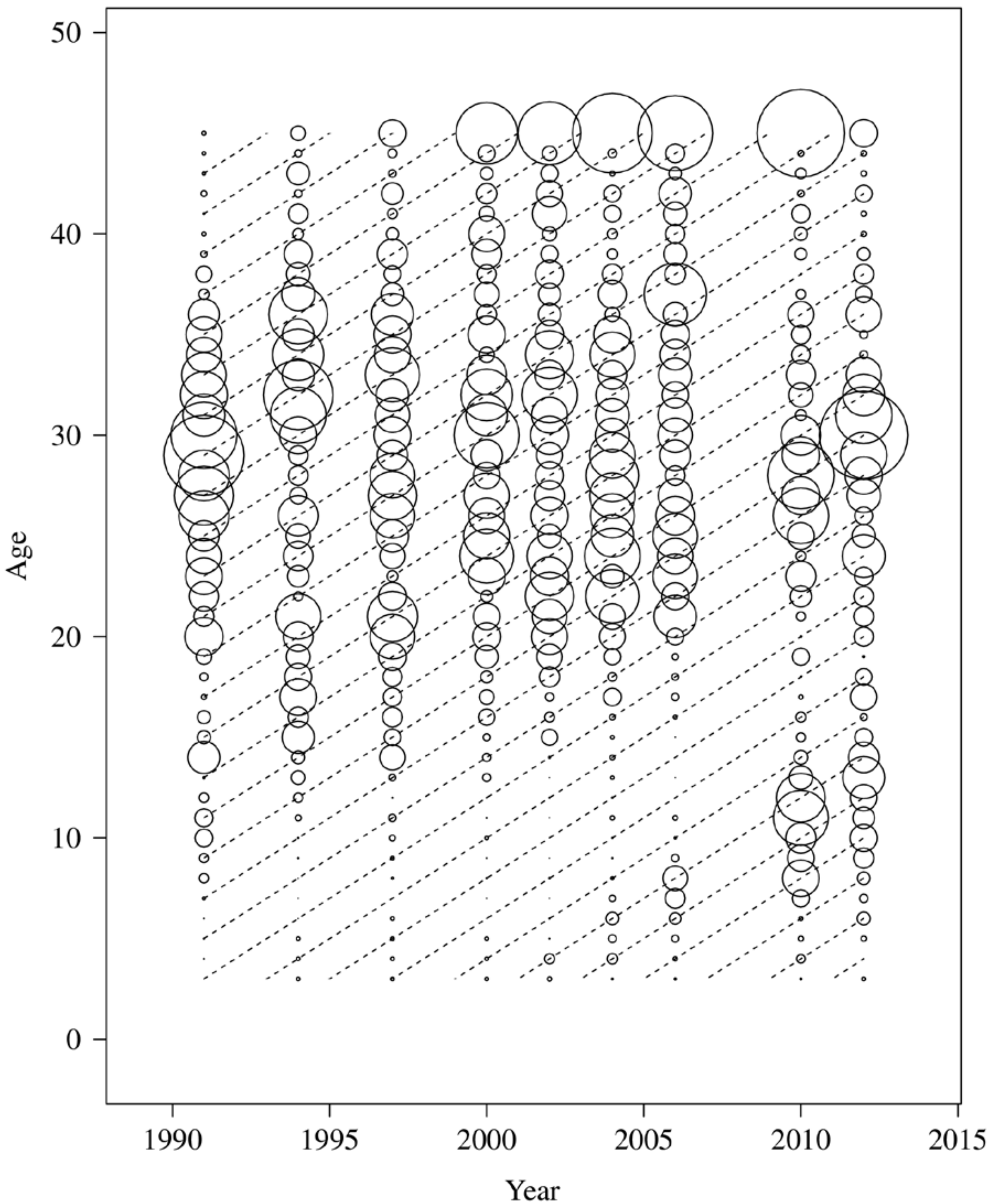


Figure 7. Age composition data from the Aleutian Islands trawl survey; bubbles are scaled within each year of samples and dashed lines denote cohorts.

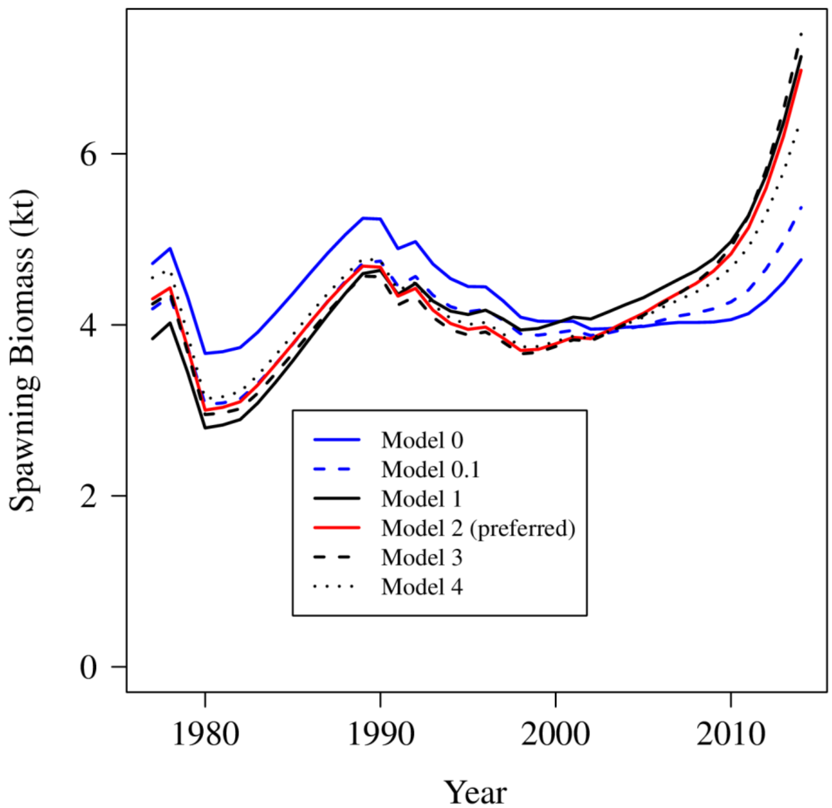


Figure 8. Estimated timer series of spawning stock biomass across the model runs

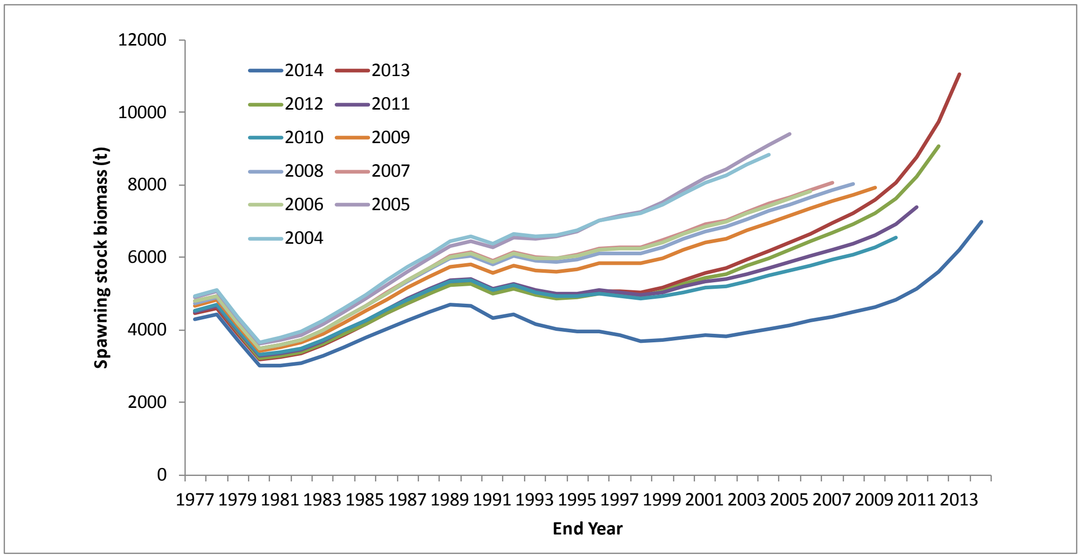


Figure 9. Retrospective estimates of spawning stock biomass for model runs with end years of 2004 to 2014.

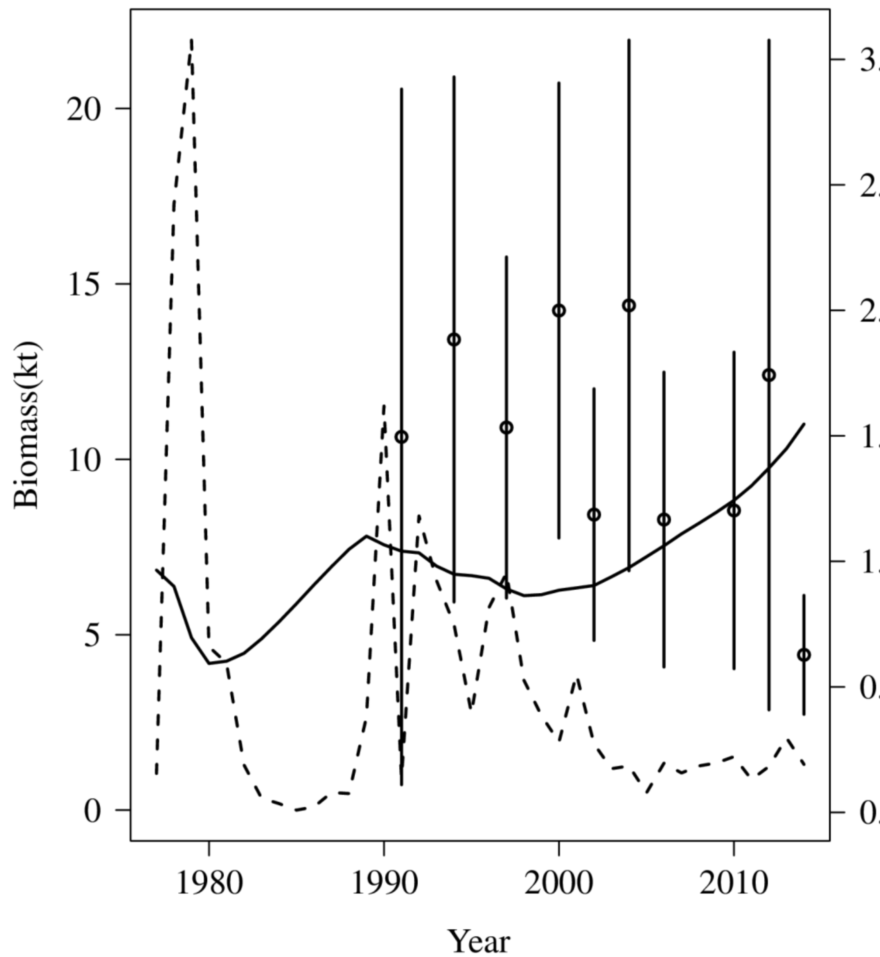


Figure 10. Observed Aleutian Islands (AI) survey biomass for blackspotted/rougheye rockfish (data points, +/- 2 standard deviations), predicted survey biomass (solid line), and AI harvest (dashed line).

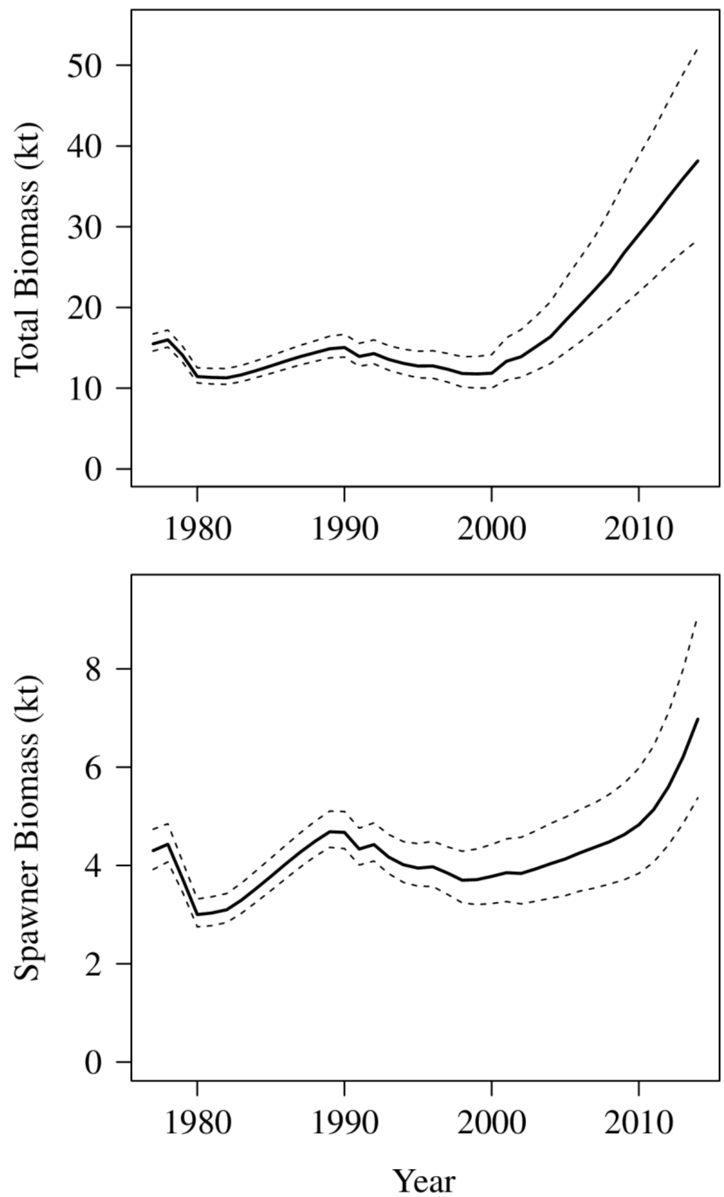


Figure 11. Total (top panel) and spawner (bottom panel) biomass for Aleutian Islands (AI) blackspotted/rougheye rockfish, with 95% confidence intervals from MCMC integration.

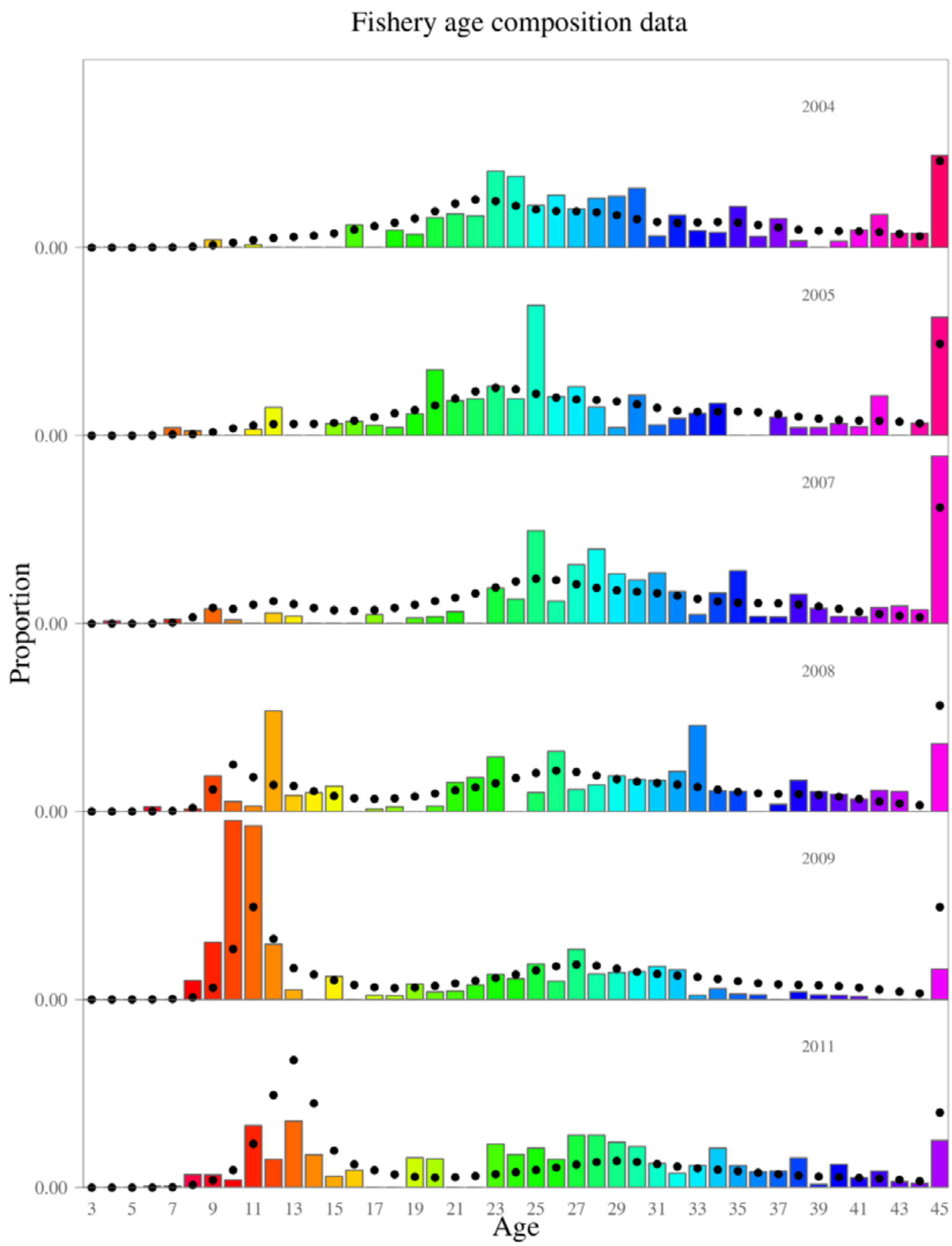


Figure 12. Model fits (dots) to the fishery age composition data (columns) for Aleutian Islands (AI) blackspotted/rougheye rockfish, 2004-2011. Colors of the bars correspond to cohorts (except for the 45+ group).

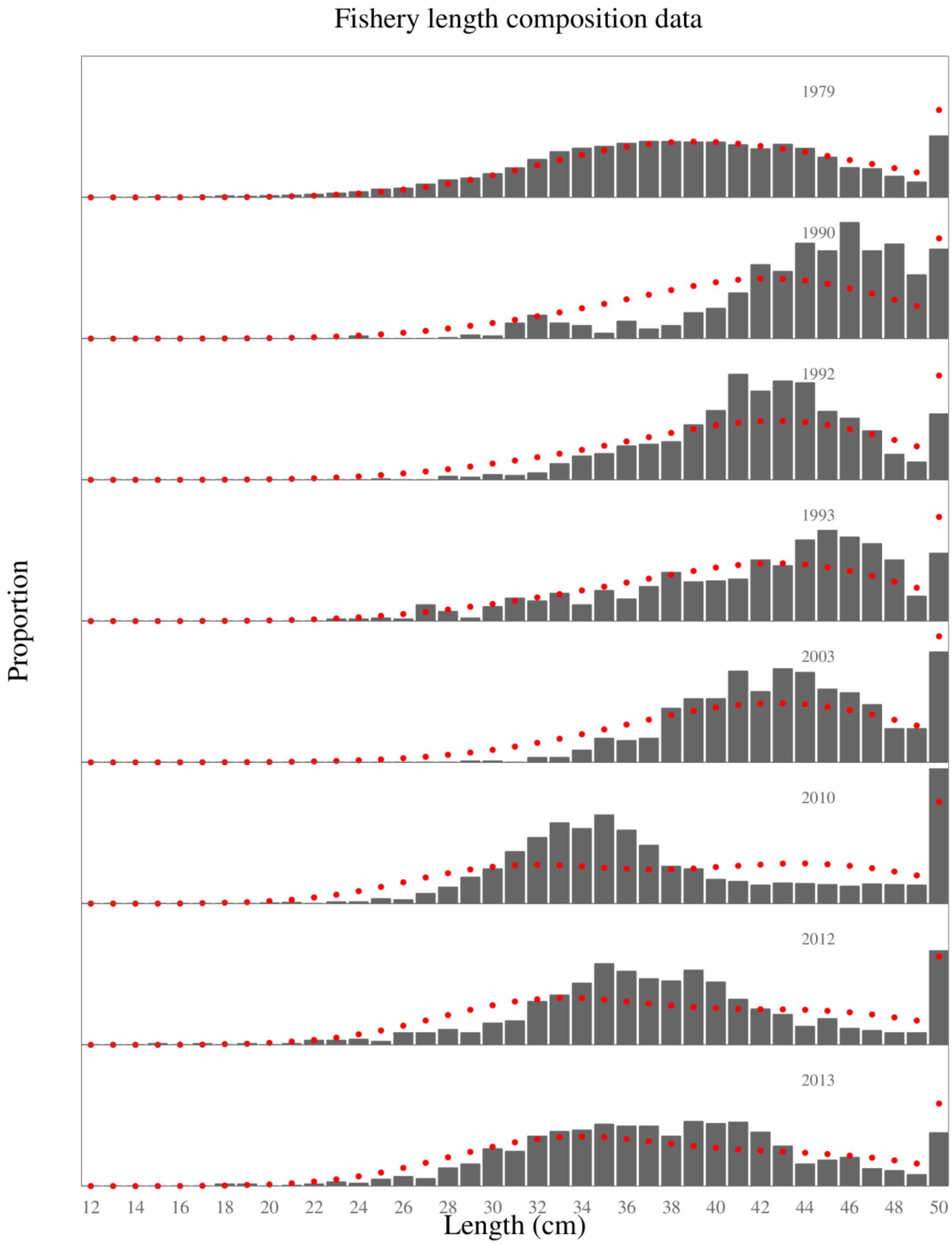


Figure 13. Model fits (dots) to the fishery length composition data (columns) for Aleutian Islands (AI) blackspotted/rougheye rockfish, 1979-2013.

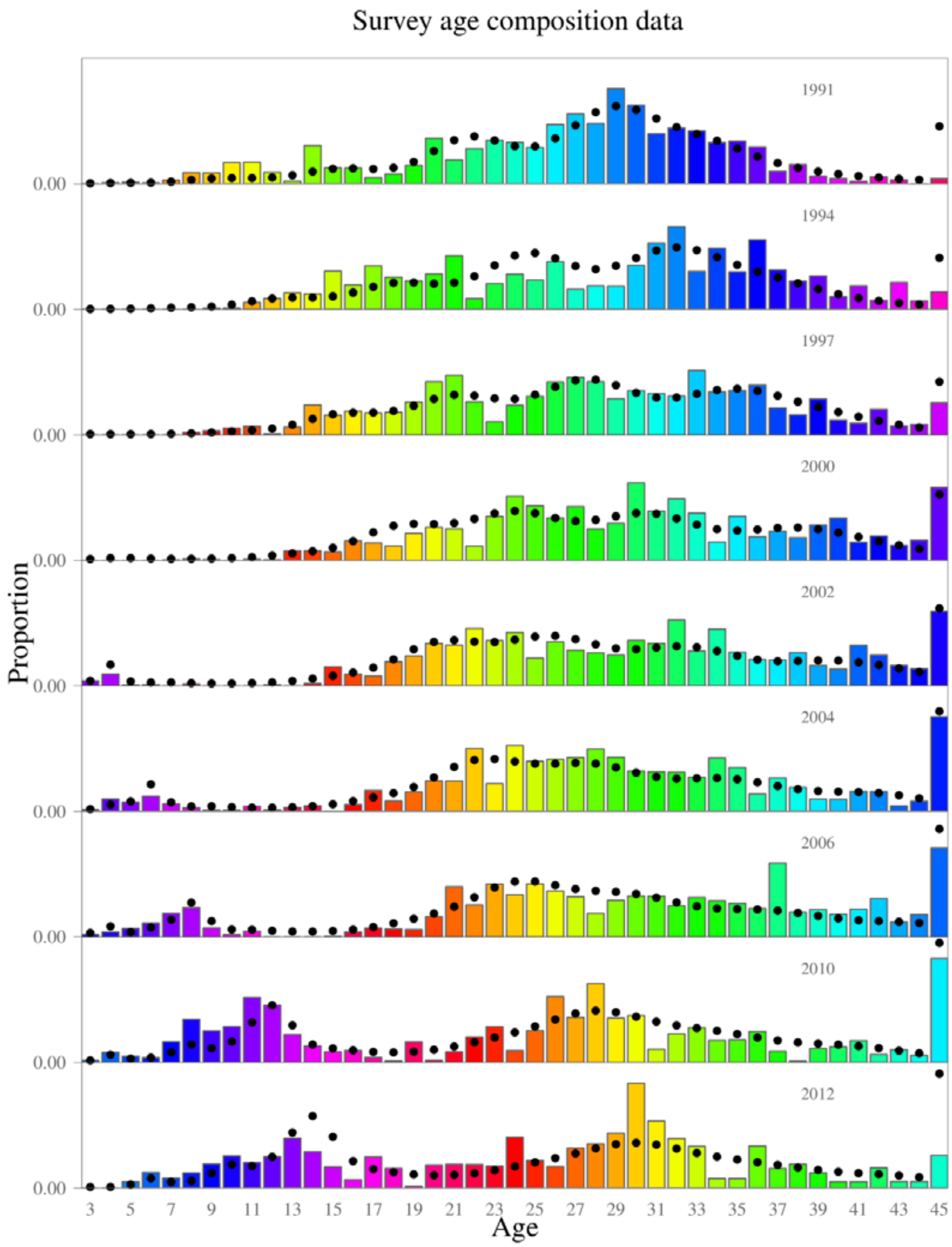


Figure 14. Model fits (dots) to the survey age composition data (columns) for Aleutian Islands (AI) blackspotted/rougheye rockfish, 1991-2012. Colors of the bars correspond to cohorts (except for the 45+ group).

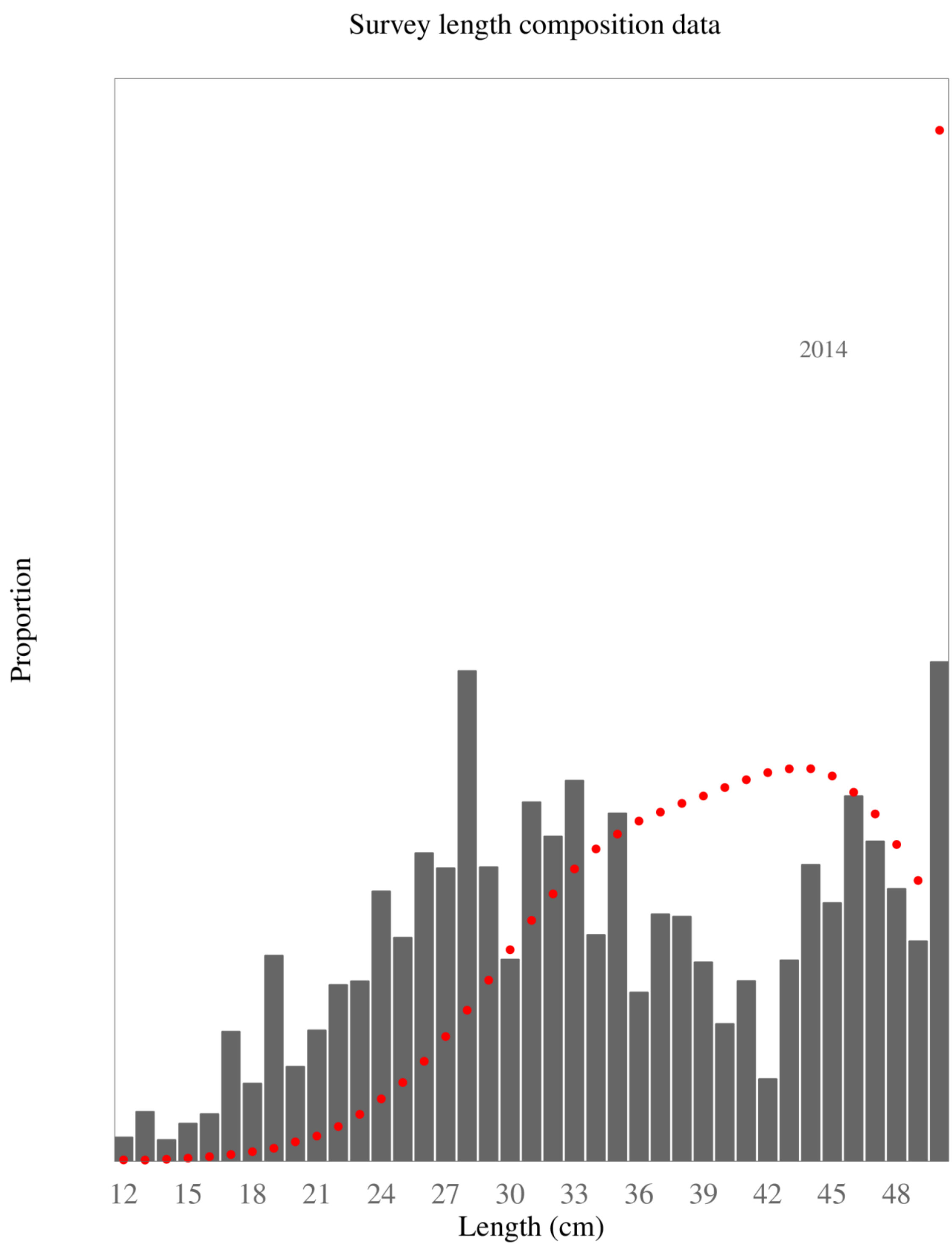


Figure 15. Model fits (dots) to the 2014 Aleutian Islands (AI) survey length composition data (columns) for the AI blackspotted/rougheye rockfish.

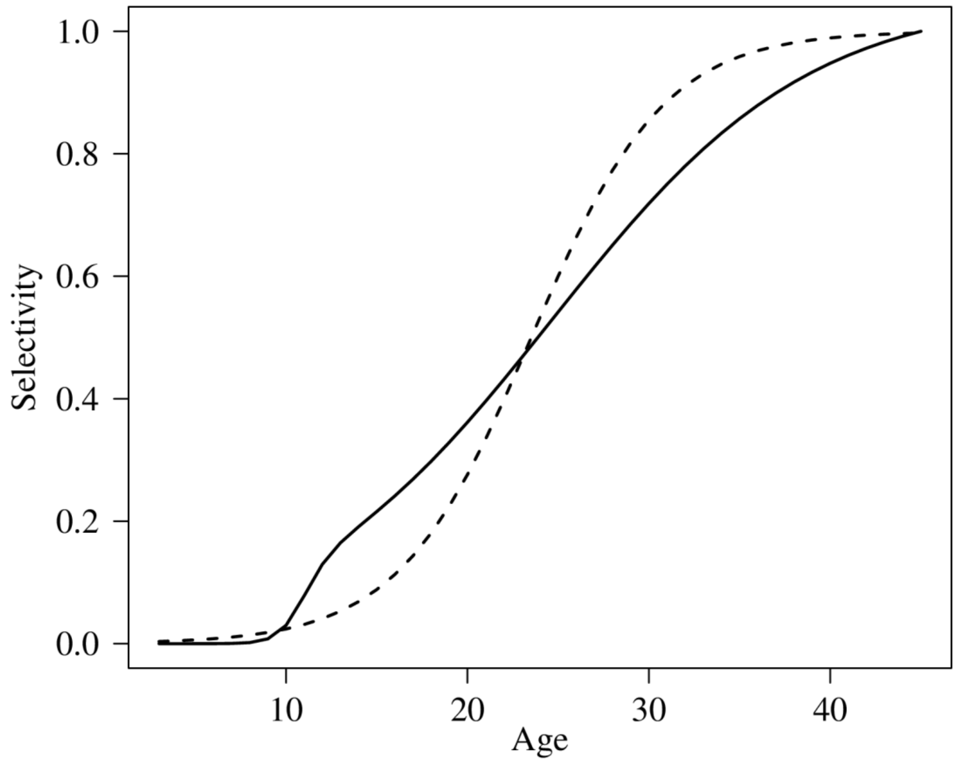


Figure 16. Estimated fishery (solid line) and survey (dashed line) selectivity curve by age for Aleutian Island (AI) blackspotted/rougheye rockfish.

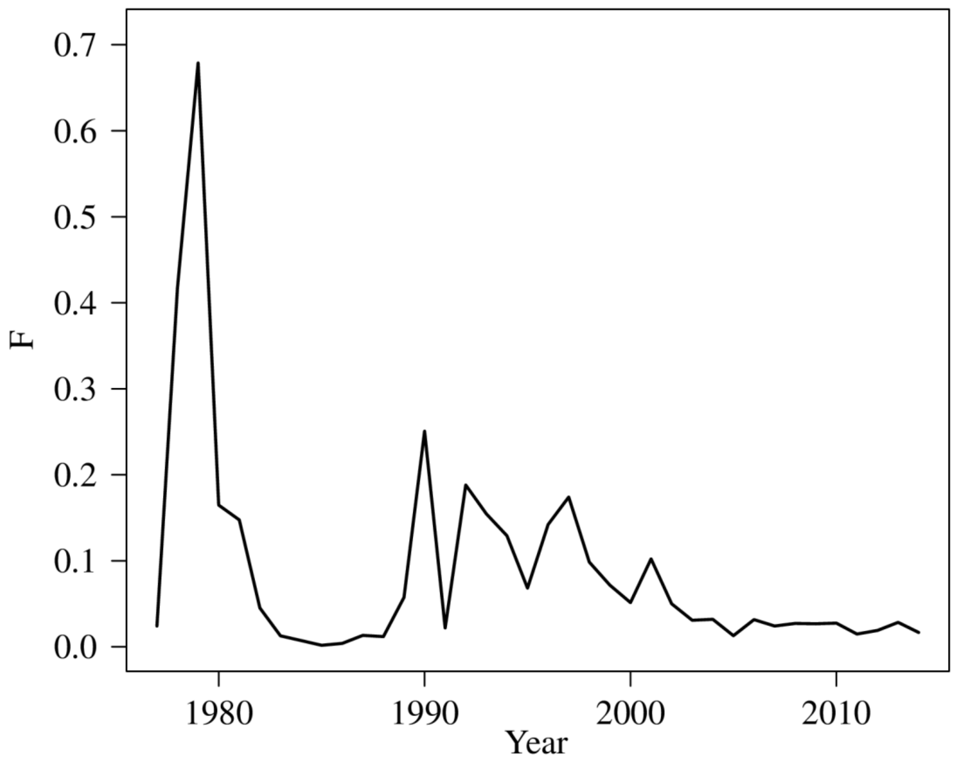
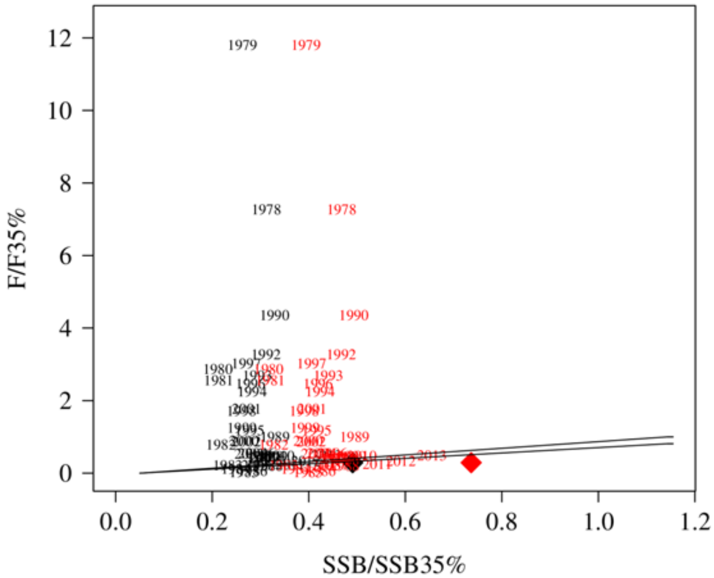


Figure 17. Estimated fully selected fishing mortality for Aleutian Islands (AI) blackspotted/rougheye rockfish.



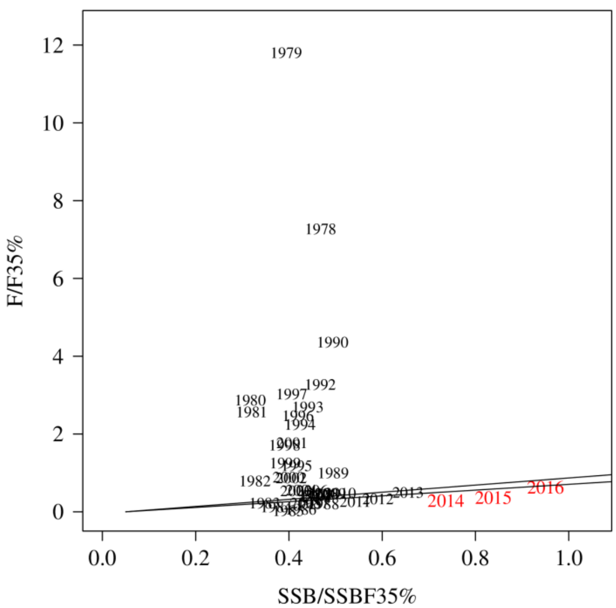
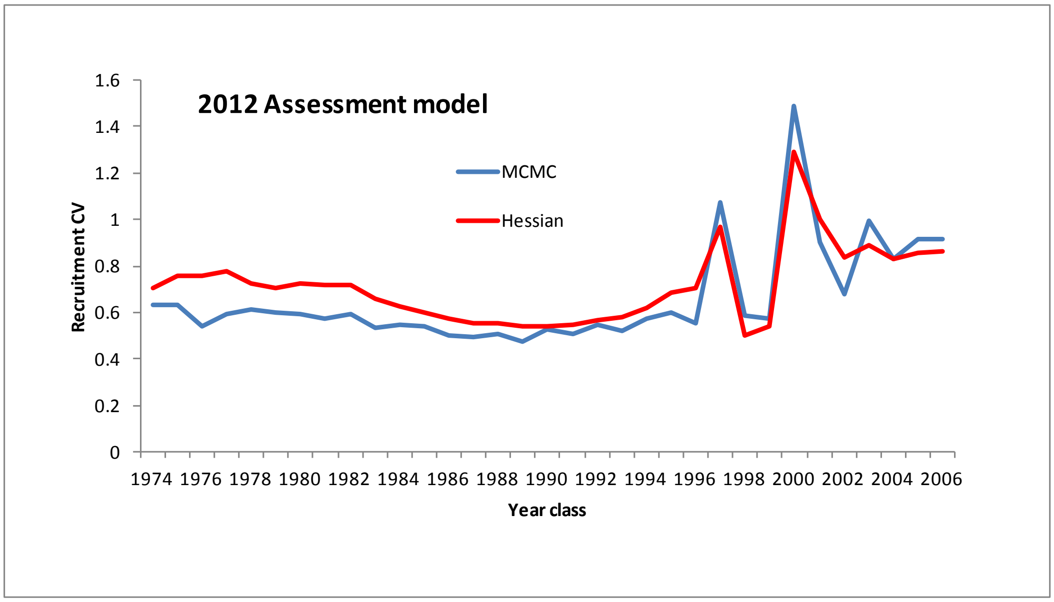


Figure 18. (Top panel) Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvest control rules, with the effect of including and excluding the post-1998 year classes shown in red and black, respectively. For each case, 2014 is shown with the diamond symbol. The bottom panel shows the projected stock status and *F* for 2015 and 2016 for the case of excluding the post-1998 year classes.



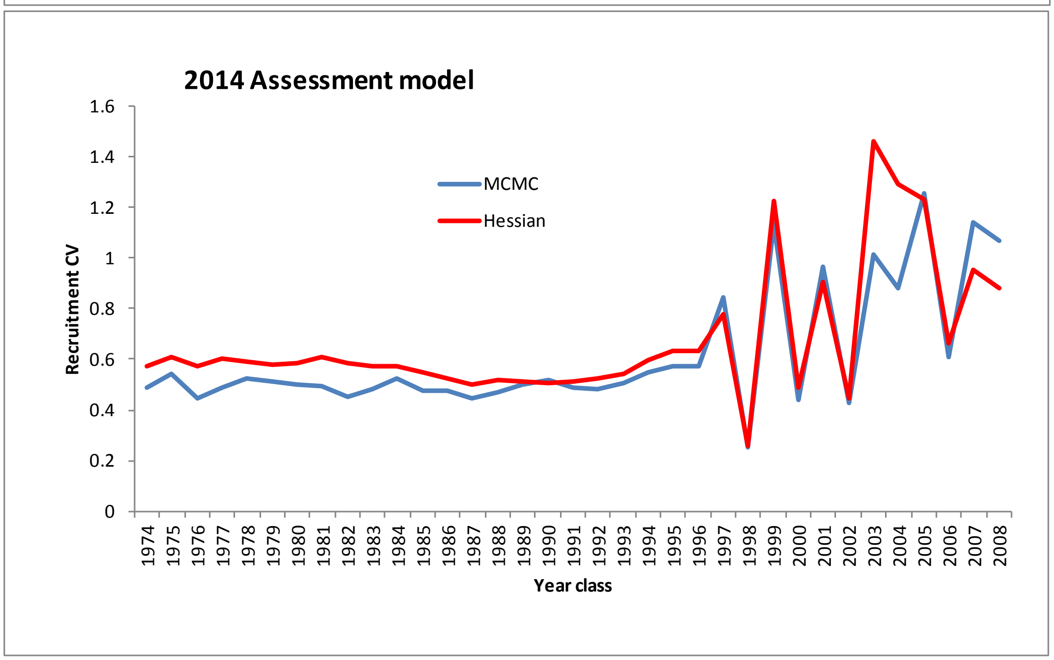


Figure 19. Recruitment CVs for BSAI blackspotted/rougheye rockfish for the 2012 and 2014 stock assessements.

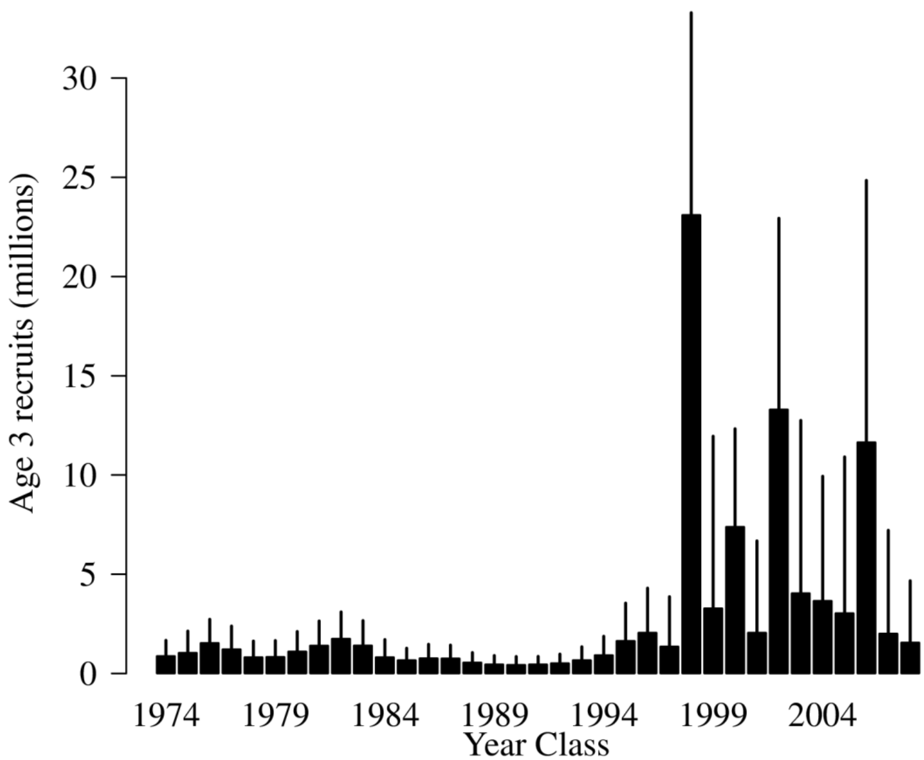


Figure 20. Estimated recruitment (age 3) of Aleutian Islands (AI) blackspotted/rougheye rockfish, with 95% CI limits obtained from MCMC integration.

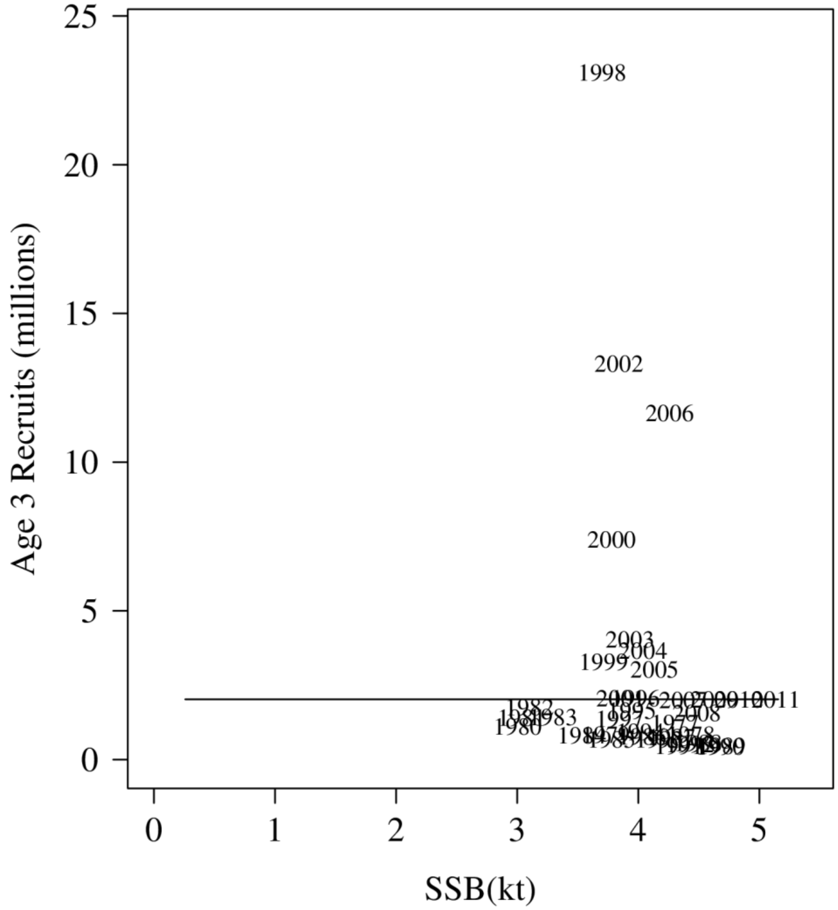


Figure 21. Scatterplot of Aleutian Islands (AI) blackspotted/rougheye rockfish spawner-recruit data; label is year class. Horizontal line is median recruitment.

Appendix A. Updated spatial analysis of BSAI blackspotted/rougheye rockfish catch in fishery and trawl survey tows

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Executive summary

In 2013, a report was presented to the BSAI Plan Team that identified 1 genetic and 6 non-genetic attributes for BSAI blackspotted rockfish (Spencer 2013). The 6 non-genetic attributes pertained to spatial analyses of catch and survey data, which the BSAI Plan Team found "compelling" and formed the basis for their "strong concern" over the harvest rates and abundance in the western Aleutian Islands. The BSAI Plan team requested an update of the 7 attributes for 2014. This report provides updates for those attributes which have updated data since 2013, which include genetic data ,catch data, the 2014 AI survey trawl data, and revised estimates of AI biomass from the 2014 stock assessment model.

New genetic samples were collected in the 2010 and 2012 Aleutian Islands trawl survey, and substantially increased the sample size and number of loci examined from the original blackspotted rockfish genetic study in 2010 (Spencer and Rooper, 2010). The previous conclusion of a strongly significant isolation by distance relationship is not supported with the updated dataset, which show a *P*-value of 0.11. A sensitivity analysis indicates that the both the change in sample size and number of loci examined contribute to the difference between the two studies, with additional loci contributing more to that difference.

The BSAI Plan Team concluded in September, 2014, that stock structure for BSAI blackspotted/rougheye rockfish is still a "concern", based upon disproportionate harvest rates, the observed decline in the western Aleutians, and recognition that demographic independence between spatial areas can often be difficult to infer from genetic data.

The update of the catch and survey data do not indicate that the non-genetic attributes have substantially changed from the analysis in 2013. The 2014 AI trawl survey do not indicate a substantial increase in abundance in the WAI, but rather decreased abundance (particularly of larger fish) in the CAI and EAI. The updated catch data indicates that the 2013 harvest of blackspotted rockfish in the western AI resulted in the second highest exploitation rate since 2006. The exploitation rate for 2014 is decreased due to industry efforts to limit bycatch, but is still exceeds the $U_{F40\%}$ rate. As noted by Spencer (2013), the available catch and survey data indicate that high rates of exploitation for western AI blackspotted rockfish have occurred in the 1990s, and abundance in this area has decreased and has not been replenished from neighboring areas. This suggests some population structure on the "ecological" scale that should be of interest to fisheries management. In cases such as blackspotted rockfish that have spatially disproportionate harvest, spatial management of fishery harvest would be expected to prevent subarea depletions and maintain stock sizes that maximize yield.

Introduction

In 2013, a report on spatial analysis of survey and fishery catch data for blackspotted rockfish was presented to the BSAI Plan Team (Spencer 2013). The report noted that BSAI blackspotted rockfish show the following attributes:

1) Genetic information showing spatial structure at scales < 500 km (Spencer and Rooper 2010)
2) High catch levels in the 1990s in the WAI that have been followed with a sharp decline in WAI survey biomass estimates beginning in 2000.
3) High estimated exploitation in the WAI, where they have exceeded $U_{F40\%}$ reference exploitation rate every year from 2004-2012 except 2011.
4) An overall decline in survey biomass estimates in the WAI from 1991-2012, as estimated by a random effects time series model.
5) An increase in the proportion of survey tows which have not caught blackspotted/rougheye over all survey strata in the WAI.
6) A large percentage of the total harvest occurring in the WAI.
7) A decline in mean size in the WAI but not other BSAI subareas.

The BSAI Plan Team concurred with these conclusions, found the quality and quantity of information to be “compelling”, and expressed “more concern over the local exploitation of this assemblage than other stocks that have been subjected to the stock structure template” (BSAI Plan Team minutes, September, 2013). The BSAI Plan Team reiterated its “strong concern” in its November, 2013 meeting, and noted that it anticipates a management response in 2014 if the SSC concurs with this level of concern. The BSAI Plan Team recommended that the 7 metrics shown above be updated and presented for the September meeting (BSAI Plan Team minutes, November, 2013). The SSC also “shares this concern” regarding the western Aleutian Islands portion of the stock, and agrees with the recommendation to update the seven metrics above (SSC minutes, December, 2013).

The purpose of this report is to present updates of the seven metrics above. Information on blackspotted rockfish genetics was originally presented in 2010 and mentioned only in passing in 2013, and new genetic samples have been subsequently analyzed and are summarized here. The new information for metrics 2-7 is the finalized 2013 catch data and estimated 2014 catch, and the 2014 AI survey biomass estimates and length composition.

Update on genetic analyses for Aleutian Islands blackspotted rockfish

Information on the genetics of blackspotted rockfish was presented to the BSAI Plan Team in 2010. The available genetic data consisted of genetic samples from 173 individuals from which 7 microsatellite loci were analyzed. The analysis was presented as one of the case studies in the 2010 report from the Stock Structure Working Group (Spencer et al. 2010), which found a significant isolation by distance (IBD) pattern, and estimated a range of lifetime dispersal distance less than 200 km. The SSWG also noted several caveats to the data: 1) the sample size is small for the large geographic scale of interest; 2) the number of loci is also small; 3) the samples may be too concentrated to prove a good estimate of the IBD relationship. However, the samples represented the best available genetic data at the time, and the finding of an IBD relation was consistent with several other rockfish species in the north Pacific. The SSWG report recommended collection of more extensive data for genetic analysis.

The genetic analysis was also presented in 2010 in the stock structure evaluation report for BSAI blackspotted rougheye (Spencer and Rooper 2010), along with additional analyses of spatial growth patterns and age composition.

Since the genetic analysis presented in 2010, blackspotted rockfish genetic samples were collected in the 2010 and 2012 Aleutian Islands trawl survey, increasing the total sample size to 942 and the number of loci analyzed to 12. A map of the sampling locations is shown in Figure A1. Additionally, the samples were obtained from many locations along the Aleutian Islands and eastern Bering Sea slope, thus addressing the concern regarding the spatial concentration of samples. With the updated dataset, a statistically significant relationship between genetic distance and geographic distance is no longer observed (P = 0.113).

The two studies differed not only in the number of loci analyzed and sample size, but also the location of samples. The Aleutian Islands samples in the initial study were to the east of Bowers Ridge, whereas the updated study had samples throughout the entire AI chain west to Stalemate Bank. Additionally, the EBS slope samples in the updated dataset showed a relatively large number of sampling locations along the EBS just northwest of Unimak Pass, whereas in the original study the EBS slope samples generally occurred farther to the northwest. Additional tests were conducted to determine whether the difference in results between the two studies is driven by having a larger and more representative sample size in the 2014 analysis, or rather by the inclusion of areas sampled in 2014 study that were not sampled in the 2010 study.

The original samples from the 2010 study were "rescored", in which the initial reading of the gel images were verified by running PCR amplification and reading the new gel images. The rescored data from the original samples yielded a significant IBD relationship for six of the original loci examined (P = 0.0074; one loci was dropped because it was viewed as relatively uninformative). Next, samples from a subset of the updated dataset in the locations sampled in the original study (n=692) yielded a marginally significant IBD relationship for six of the original loci (P = 0.0637) and an insignificant relationship for all 12 loci (P = 0.1035). These results suggest that both the change in sample size and number of loci examined contribute to the difference between the two studies, with additional loci contributing more to that difference. A final sensitivity test was performed which used the original samples but only the new loci, and yielded P = 0.1645. A summary of the tests are shown below:

Description	Sample size	Number of loci	P-value for IBD relationship
Original samples from 2010 study, rescored data	168	6	0.0074
Updated dataset, same loci and areas sampled in 2010 study	692	6	0.0637
Updated dataset and loci, same areas sampled in 2010 study	692	12	0.1035
Original samples from 2010 study, rescored data, only new loci	168	6	0.1645
Updated dataset and loci	942	12	0.1126

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. A map of the BSAI subareas is shown in Figure A2.

For each year from 2004 through 2014, the subarea biomass was obtained by partitioning the estimated total biomass (ages 3+) at the beginning of the year (obtained from 2014 BSAI blackspotted/rougheye stock assessment) into the Aleutian Islands subareas. The biomass estimates from the 2014 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. For each year, a weighted average of the subarea biomass from the three most recent surveys Aleutian Islands and eastern Bering Sea slope trawl survey (weights of 4, 6, and 9, with more recent surveys receiving higher weights) was computed, and the proportions from these averages were used to partition the biomass into subareas. Catches through October 11, 2014, were obtained from the Catch Accounting System database. To evaluate the potential impact upon the population, exploitation rates were compared to two measures of stock productivity: 1) 0.75 times the estimate rate of natural mortality (*M*), which is the fishing mortality F_{abc} that produces the allowable 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 numbers at age, and thus may be seen as more appropriate for Tier 3 stocks because harvest recommendations are based upon this age-structured information. BSAI blackspotted/rougheye rockfish were managed as a Tier 5 stock prior to 2009, and as a Tier 3 stock since 2009.

Exploitation rates for the WAI blackspotted/rougheye rockfish have been at or above 0.75*M* for from 2004-2006, 2008-2010, and 2013. The exploitation rates have exceeded $U_{F40\%}$ in all years from 2004 -2013 except 2011 (Figure A3a). These results differ slightly from those presented in 2013 due to the revised time series of biomass from the 2014 assessment model, and revised estimates of numbers at age and fishery selectivity (which affect the calculation of $U_{F40\%}$). The catch of WAI blackspotted for 2013 was 84 t, which increased the 2013 WAI exploitation rate to 2.05 times $U_{F40\%}$. The preliminary exploitation rate for 2014 is 1.27 times $U_{F40\%}$. The values of $U_{F40\%}$ are similar to 0.75**M* for 2004, and have decreased slightly from 2004-2009 because a large portion of the catch weight is derived from relatively young fish where the fishery selectivity (and thus fishing mortality) is relatively low; since 2009, the values of $U_{F40\%}$ have increased slightly. The exploitation rates for the other subareas do not exceed $U_{F40\%}$ with the exception of the EBS in 2008, 2010, and 2011.

The calculation of exploitation rates and the $U_{F40\%}$ values back to 1994 reveal high rates of exploitation for the western AI in the mid-1990s (Figure A4). In 1996 and 1997, the exploitation rates were 6.5 and 8.1 times the value of $U_{F40\%}$, respectively. A random effects model was used to obtain the area proportions, as taking an average of three most recent survey is not possible in the early 1990s because the NMFS survey time series was initiated in 1991. A comparison of the exploitation rates since 2004 produced from using either the random effects model or the weighted average of the surveys indicates that both methods produce similar results (Figure A4).

Application of the random effects model to the updated survey biomass time series

The 2014 survey biomass for the WAI area was 589 t, an increase from the estimate of 335 t from the 2012 survey. Of the 10 points in the WAI survey estimate time series since 1991, the lowest 3 estimates have been obtained since 2006. The ratio of the 2014 estimate of biomass from the random effects model to the 1991 estimate indicates an 81% decline since 1991; this is increased from the previous estimate of 85% based upon the 1991-2012 surveys (Figure A5).

The 2014 biomass estimates in the other AI subareas are reduced from their 2012 estimates. The decline in the EAI was particularly sharp, with the 2014 estimate of 958 t being a 75% decline from the 2012 estimate of 3,798 t. This decline was large enough to result in the random effects model fitting an overall decline to the EAI biomass time series, as without the 2014 data point the model fits only a mean biomass with no trend.

Survey length composition and mean size

The size composition from the 2014 AI trawl survey continues to indicate relatively small fish in the WAI (Figure A6). The percentage of the WAI survey size composition less than 35 cm was 57%, and this value has ranged between 26% and 73% in surveys from 2014 to 2012. As in the 2012 survey, few fish over 40 cm were observed in the WAI. In the CAI and EAI, fish 40 cm and larger comprised a large portion of the population in each survey from 1991 to 2012, but lower abundance of this size group was observed in the 2014 survey (particularly in the EAI).

The mean size in the WAI was 356 cm in the 2014 survey, which is an increase from the 2012 survey and similar to values in 2006 (352 cm) and 2010 (357 cm) survey (Figure A7). However, the WAI mean sizes from 2006-2014 are low than those observed in the 1991-2002 surveys, which ranged from 390 cm to 448 cm. The low numbers of large fish observed in 2014 for the CAI and EAI resulted in the 2014 mean size for these areas being substantially smaller than those observed in previous surveys.

Proportion of tows without catch of blackspotted/rougheye rockfish

The spatial pattern in the percentage of survey tows which did not catch blackspotted/rougheye rockfish in the 2014 survey is similar to that observed in the 2012 survey (Figure 8). In 2014, the WAI and EAI had the highest proportion of tows without blackspotted/rougheye rockfish (each at 88%). 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.

Spatial distribution of harvest

The high exploitation rates in the WAI reflect that a large portion of the harvest occurs in this area, relative to a small portion of the survey biomass. From 2004-2014, 40% of the harvest in the AI management area occurred in the WAI but only 9% of the survey abundance for the AI management area. In 2013, the catch in the western, central, and eastern AI were 84 t, 62 t, and 151 t, respectively; despite the relatively large catch in the western AI (second largest since 2006), the proportion was reduced to 28% due to the large catch in the eastern AI.

Within the western AI, most of the blackspotted rockfish catch occurs in the eastern portion of the western AI between 174° E and 177° E (Figure A9). The portion of the catch between 174° E and 175° E has increased since 2008. As noted in Spencer (2013), this is an area with low trawl survey catches because the fishing grounds are not sampled in the trawl survey.

Conclusions

The main difference between this updated analysis and the analysis presented in 2013 is the reanalysis of genetic data that included a much larger sample size and additional microsatellite loci. The new analysis failed to detect a strongly significant IBD relationship. In September, 2014, the BSAI Plan Team considered how to interpret both the genetic information and the spatial survey and catch data showing high exploitation rates in the western AI. The Team concluded that stock structure for BSAI blackspotted/rougheye is still a “concern”, based upon disproportionate harvest rates, the observed decline in the western Aleutians, and recognition that demographic independence between spatial areas can often be difficult to infer from genetic data.

The update of the catch and survey data do not indicate that the non-genetic attributes listed above (i.e., attributes 2-7) have substantially changed. The 2014 AI trawl survey does not indicate a substantial increase in the abundance for WAI blackspotted/rougheye, but rather decreased abundance (particularly of larger fish) in the CAI and EAI blackspotted/rougheye rockfish. The updated catch data indicates that the 2013 harvest of blackspotted rockfish in the western AI resulted in the highest exploitation rate since 2006. As noted by Spencer (2013), the available catch and survey data indicate that high rates of exploitation for western AI blackspotted rockfish have occurred in the 1990s, and abundance in this area has decreased and has not been replenished from neighboring areas. This suggests some population structure on the “ecological” scale that should be of interest to fisheries management. In cases such as blackspotted rockfish that have spatially disproportionate harvest, spatial management of fishery harvest would be expected to prevent subarea depletions and maintain stock sizes that maximize yield.

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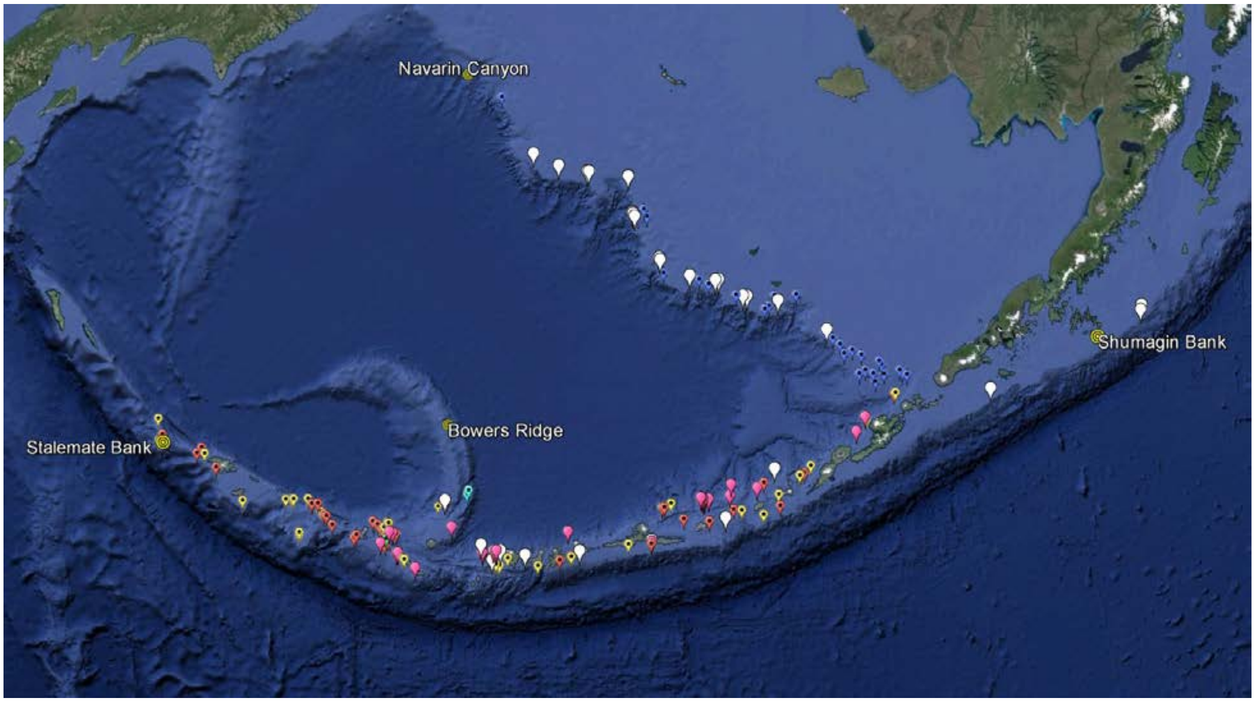

Figure A1. Map locations of genetic samples for blackspotted rockfish in the BSAI area. Symbol colors are as follows: 1) white – samples in original genetic study; 2) yellow and red – samples from two vessel in 2010 AI survey; 3) pink – samples from 2012 AI survey; 4) light blue and light green – samples from the 2010 fishery; 4) dark blue – samples from 2010 EBS slope survey.

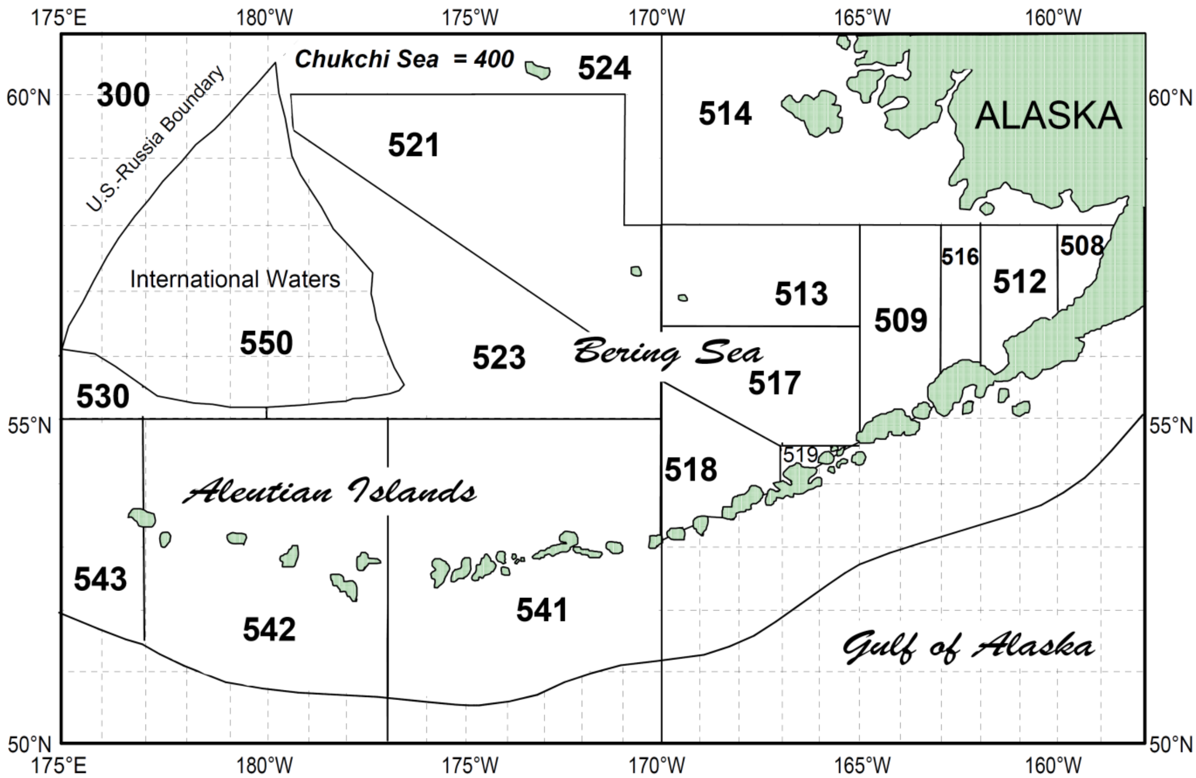

Figure A2. Map of statistical reporting zones in the BSAI management area. The western Aleutian area is zone 543 (which extends west to 170°E), the southern Bering Sea (SBS) zone comprises zones 518 and 519, and the central Aleutian Islands (CAI) and eastern Aleutian Islands (EAI) zones are 542 and 541, respectively. Figure obtained from the NOAA-Alaska Regional Management Office.

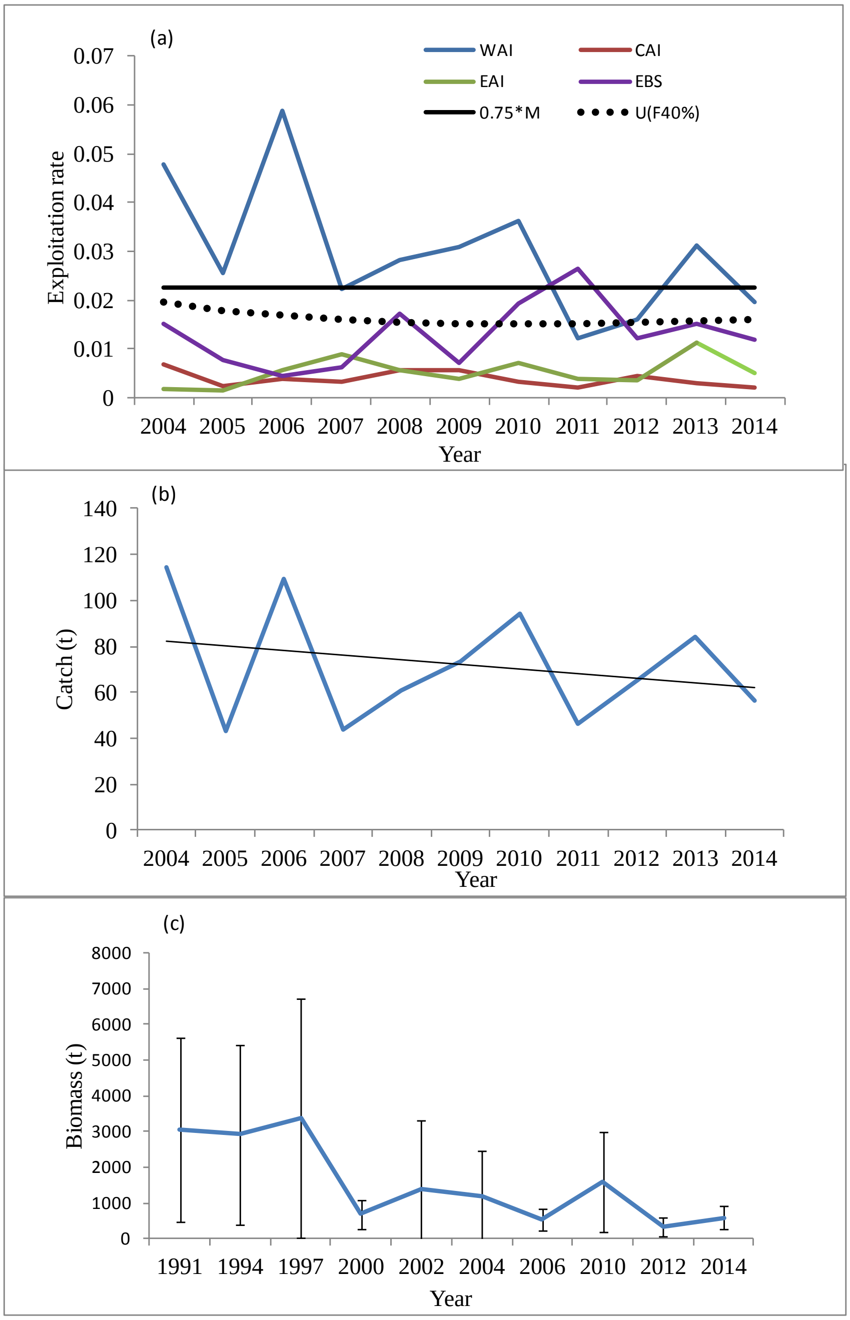

Figure A3. BSAI blackspotted/rougheye subarea exploitation rates (a), and catch (b) and trawl survey biomass estimates (c, with 95% confidence intervals) for the western Aleutian Islands. Exploitation rates and catch for 2014 are based on catches through October 11, 2014.

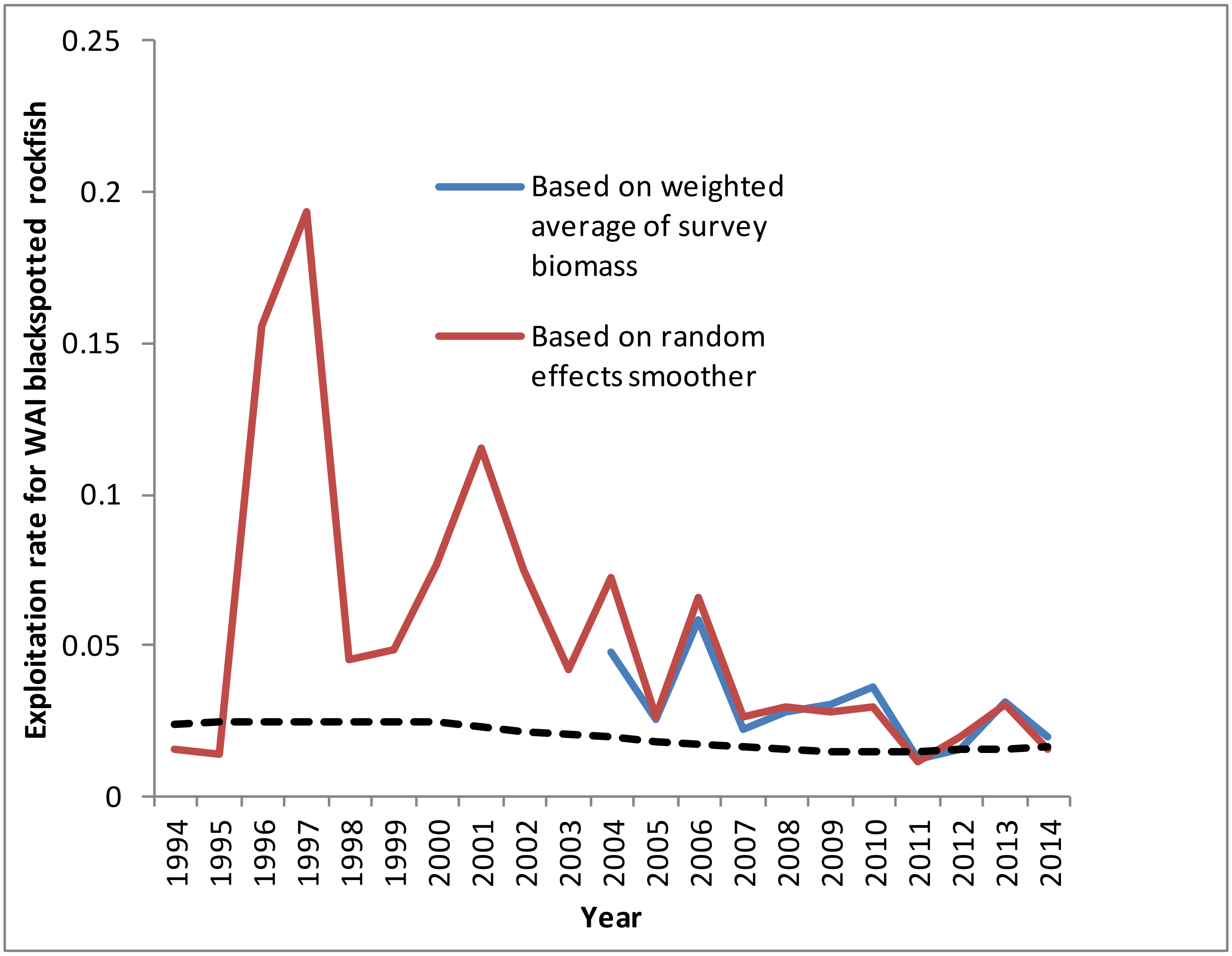

Figure A4. Estimated exploitation rates in the WAI from 1994 – 2014, with the proportion of biomass in the WAI based upon a random effects model to smooth survey biomass time series. For comparison, the exploitation rates from 2004-2014 that use a weighted average of recent surveys to obtain subarea proportions are also shown.

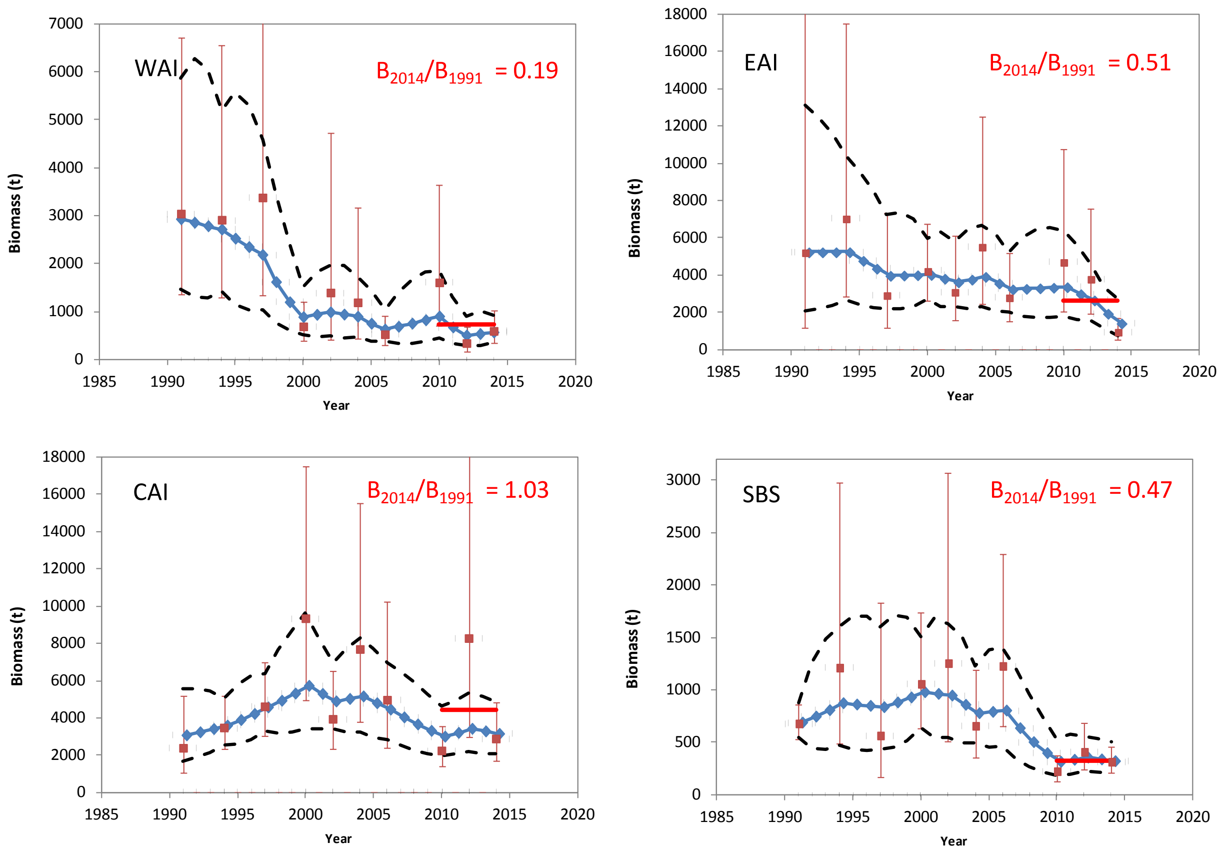

Figure A5. Time series of AI trawl survey biomass by subarea, with the fits from a random effects model to smooth the time series. The ratio of the biomass estimate in 2014 to that in 1991 indicates the estimated level of depletion over this time period. The horizontal red lines show the estimate from a weighted average of the three most recent surveys.

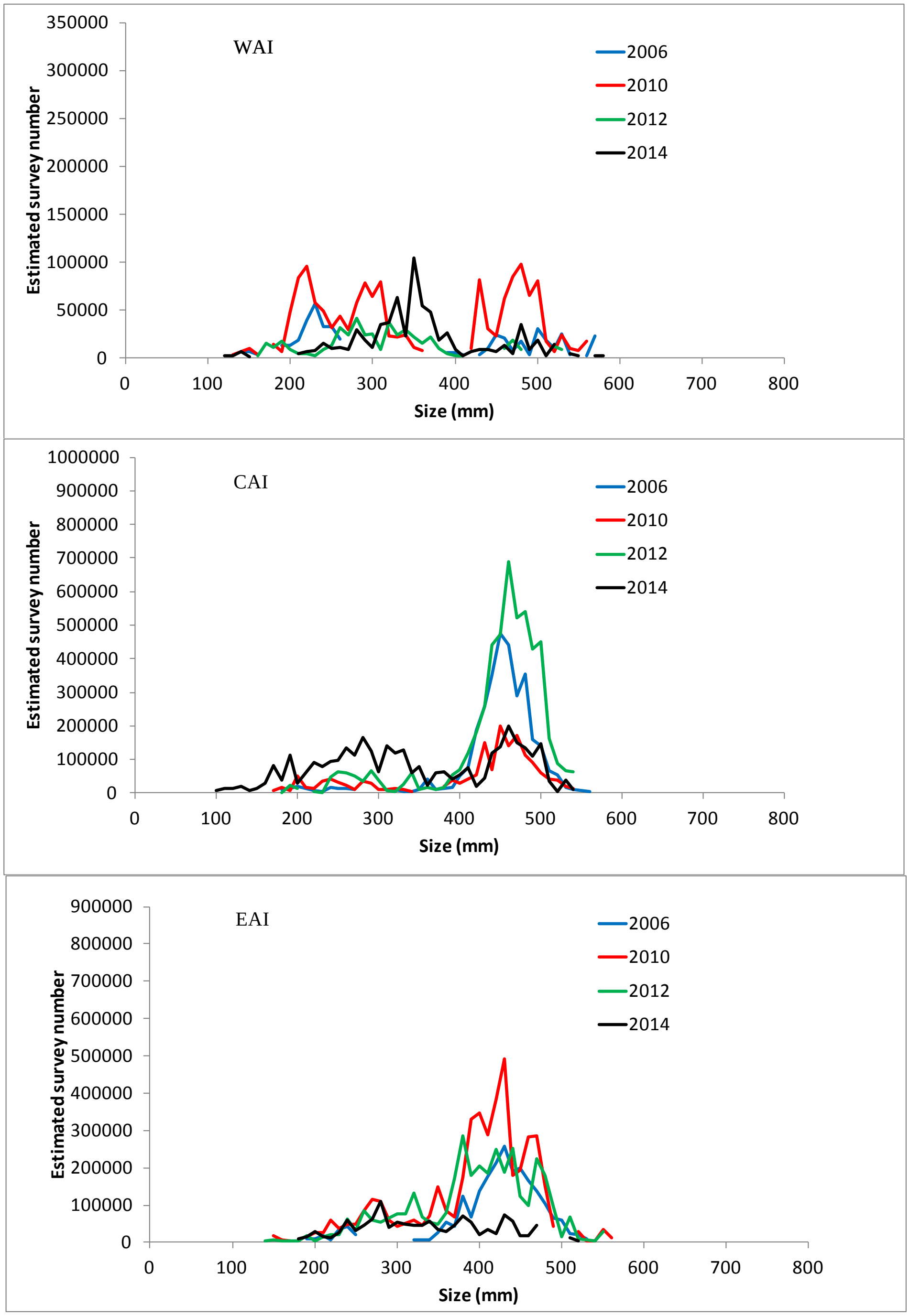

Figure A6. Size compositions of blackspotted/rougheye rockfish from the 2006-2-14 AI surveys by AI subarea.

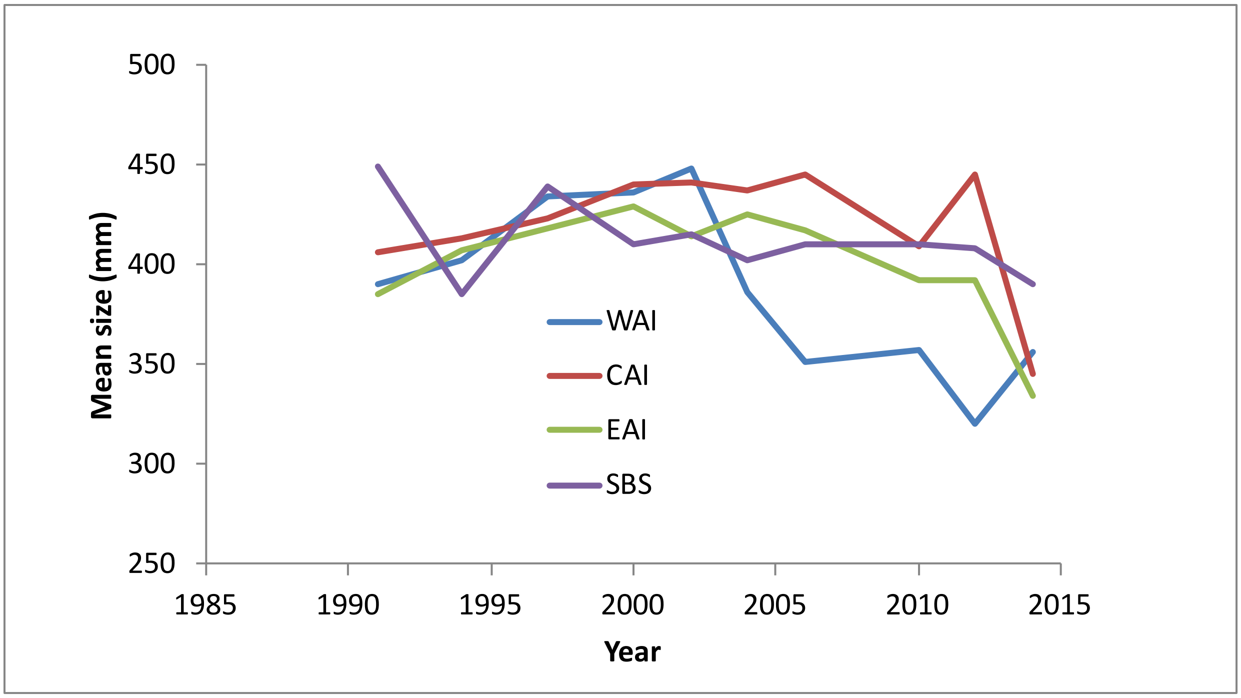

Figure A7. Mean size of blackspotted/rougheye rockfish from the 1991-2014 AI trawl surveys by subarea.

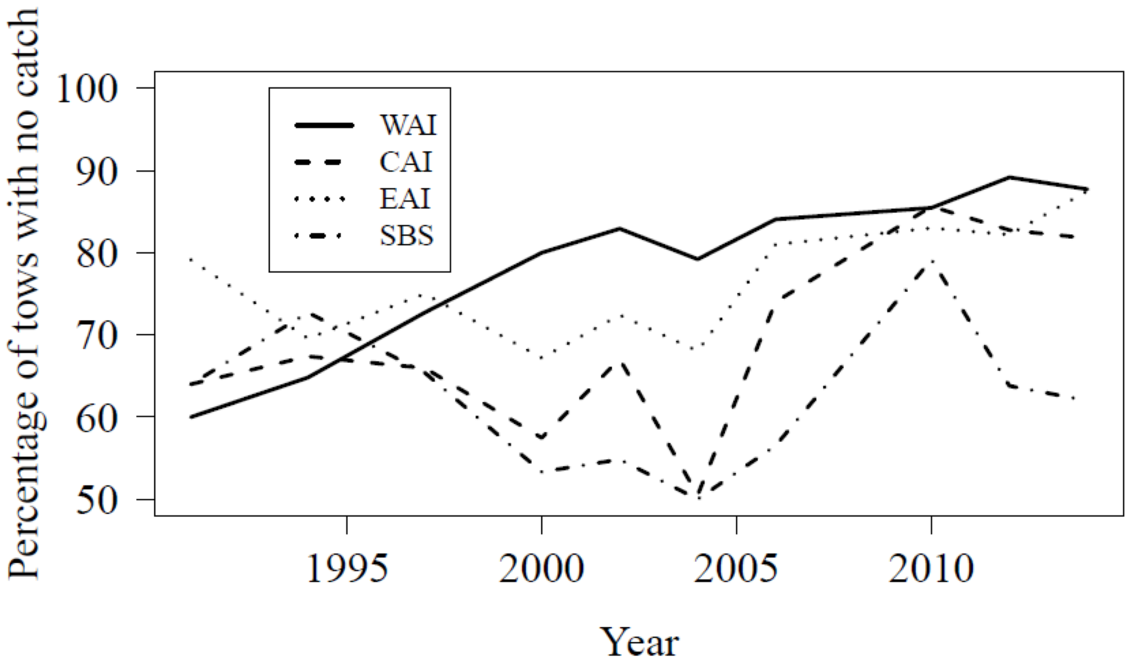

Figure A8. Percentage of survey tows with no catch of blackspotted/rougheye rockfish from the 1991-2014 AI trawl surveys by subarea.

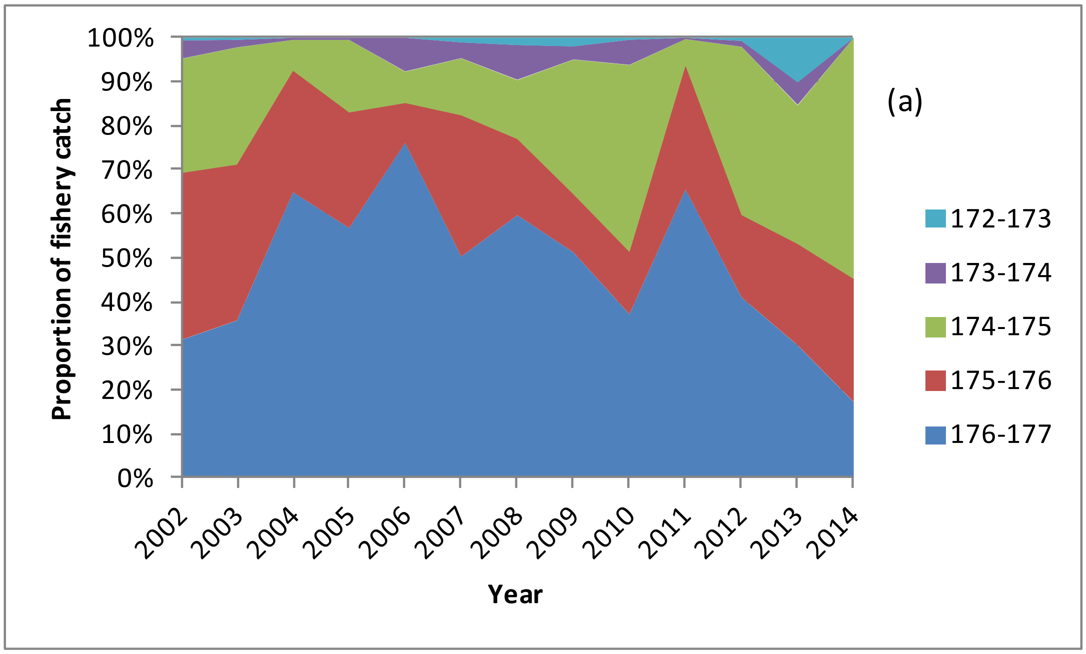

Figure A9. The proportion of fishery catch from 2002-2014 by 1° longitude bins in the WAI; the easternmost bin within the WAI occurs between 176°E and 177°E.

Appendix B. 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 0.03 t and 0.6 t between 2010 and 2014, which were less than 1.0% of the ABC in these years.

Appendix Table B1. 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		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	NMFS-AFSC survey databases	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		0.133	0.424
2011		0.005	0.154
2012	AKFIN database	0.132	0.3
2013		0.000	0.299
2014		0.032	0