13. Assessment of the Rougheye and Blackspotted Rockfish stock complex in the Gulf of Alaska

S. Kalei Shotwell, Dana H. Hanselman, Jonathan Heifetz, and Peter-John F. Hulson
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Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska (GOA) rockfish in off-cycle (even) years, we typically present an executive summary to recommend harvest levels for the next two years. However, per recommendations from the GOA Plan Team (November 2013), we presented a full stock assessment in 2014. For this on-cycle (odd) year, we return to the standard protocol and present a full stock assessment document with updated assessment and projection model results to recommend harvest levels for the next two years.

We use a statistical age-structured model as the primary assessment tool for the Gulf of Alaska rougheye and blackspotted (RE/BS) rockfish complex which qualifies as a Tier 3 stock. This assessment consists of a population model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses results from the population model to predict future population estimates and recommended harvest levels. The data sets used in this assessment include total catch biomass, fishery age and size compositions, trawl and longline survey abundance estimates, trawl survey age compositions, and longline survey size compositions. For this assessment year, there are six models presented in the assessment. Model 0, or M0, is the last full assessment base model from 2014. The remaining models are hierarchal in that each subsequent model includes the changes from the previous model. The final two models (M3 and M4) also include sub-models to explore sensitivity to the trawl survey selectivity functional form and the interaction with the age composition plus group.

Summary of Changes in Assessment Inputs

Changes in the input data: New and updated data added to this model include the following:

1.) Updated catch estimate for 2014, new catch estimates for 2015-2017 (see *Specified Catch Estimation* subsection in **Harvest Recommendations** section)
2.) New fishery ages for 2010, new fishery lengths for 2013
3.) New trawl survey estimate for 2015, new trawl survey ages for 2013
4.) New longline survey relative population number (RPN) for 2015, and new longline survey lengths for 2015.

Changes in the assessment methodology: Several changes to the assessment methodology are presented and incorporate the following:

1.) In past assessments the trawl survey age samples have been treated as if they were randomly collected which incurs bias in the growth parameters since age samples are collected using a length-stratified sampling design. We now account for this design in the growth estimation by weighting the age samples by the total number of fish measured at a given length.
2.) Ageing error transition matrix was updated to appropriately model the ages at or near the plus age group which heretofore were consistently overestimated. The new matrix extends the modeled ages compared to ages fit in the data until >99.9% are in the plus age group of the data.
3.) Plus age group extension and new functional forms for the trawl survey selectivity are explored. Selection of the final plus age group and trawl survey selectivity curve balance (1) reducing the plus age group proportion to no more than 10-15% of the total samples, (2) ensuring plus age

group is less than the maximum proportion in the remainder of the age composition data, (3) minimizing age bins with zero samples, (4) examining model fits and residuals, and (5) sensitivity to selectivity changes while adding age bins.

Summary of Results

Reference values for RE/BS rockfish are summarized in the following table, with the recommended ABC and OFL values for 2016 in bold. The stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:*	
	2015	2016	2016	2017
M (natural mortality rate)	0.034	0.034	0.036	0.036
Tier	3a	3a	3a	3a
Projected total (ages 3+) biomass (t)	36,584	36,610	41,864	41,597
Projected female spawning biomass (t)	12,480	12,595	13,804	13,733
$B_{100\%}$	22,449	22,449	20,566	20,566
$B_{40\%}$	8,980	8,980	8,226	8,226
$B_{35\%}$	7,857	7,857	7,198	7,198
F_{OFL}	0.045	0.045	0.048	0.048
$maxF_{ABC}$	0.038	0.038	0.040	0.040
F_{ABC}	0.038	0.038	0.040	0.040
OFL (t)	**1,345**	1,370	**1,596**	1,592
maxABC (t)	1,122	1,142	1,328	1,325
ABC (t)	**1,122**	1,142	**1,328**	1,325
Status	As determined *last* year for:		As determined *this* year for:	
	2013	2014	2014	2015
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projected ABCs and OFLs for 2016 and 2017 are derived using estimated catch of 530 t for 2015 and projected catches of 700 t for 2016 and 686 t for 2017 based on the average of the ratio of catch to ABC from the last three complete catch years (2012-2014). This calculation is in response to management requests to obtain more accurate projections.

The 2015 trawl survey estimate increased 25% from the low 2013 estimate and is now 24% below average. The 2015 longline survey abundance estimate (RPN) decreased about 6% from the 2014 estimate and is 10% above average. Since 2005, the total allowable catches (TACs) for RE/BS rockfish have not been fully taken, and are generally between 20-60% of potential quota. This is particularly true for the Western GOA since 2011, where catches have been between 20-35% of potential quota.

For the 2016 fishery, we recommend the maximum allowable ABC of 1,328 t from the author preferred model (M4a). This is an 18% increase from last year's ABC of 1,122 t. Recent recruitments are steady and near the median of the recruitment time series. This is evident in the ages for the trawl survey with more young fish over time. Female spawning biomass is well above $B_{40\%}$, and projected to be stable.

Area Allocation of Harvests

The apportionment percentages have changed with the addition of the 2015 trawl survey biomass. In past assessments, we determine apportionment using a 4:6:9 weighted average of the proportion of biomass in each area from the three most recent bottom trawl surveys. This exponential moving average was used to smooth the estimates but weight the most recent observation most heavily (see *Area Allocation of Harvests* subsection in **Harvest Recommendation** section for further details). As an alternative to this, both the Plan Team and SSC have requested that the random effects model developed by the Survey Averaging Working Group be used for apportionment as a default method and provided alongside the current apportionment for comparison purposes.

The following table shows the apportionment for the 2016 and 2017 fishery using the three survey weighted average and random effects methods.

Method	Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
Three Survey Weighted Average			7.9%	53.2%	38.9%	100%
	2016	Area ABC (t)	**105**	**707**	**516**	**1,328**
		OFL (t)				**1,596**
	2017	Area ABC (t)	**105**	**705**	**515**	**1,325**
		OFL (t)				**1,592**
Random Effects			4.5%	54.2%	41.3%	100%
	2016	Area ABC (t)	**60**	**719**	**549**	**1,328**
		OFL (t)				**1,596**
	2017	Area ABC (t)	**60**	**717**	**548**	**1,325**
		OFL (t)				**1,592**

We recommend continuing with the status quo (three survey weighted average) apportionment for RE/BS rockfish at this time. The assessment model utilizes both trawl and longline survey data to adequately sample the RE/BS population. In general, the trawl survey samples more of the continental shelf than the longline survey due to differences in survey design. The trawl survey also tends to catch more RE/BS rockfish in the central GOA, while the longline survey catches more RE/BS rockfish in the eastern and western GOA. Sampling error also differs by region and survey. On average there is higher sampling error in the eastern GOA for the trawl survey and lower sampling error in this region for the longline survey. The reverse is true in recent years for the western GOA with low sampling error in the trawl survey and high sampling error in the longline survey. The random effects model does not currently allow for inclusion of more than one survey index; however, this option is planned for future versions of the model. Rather than switching the apportionment scheme several times, we prefer to shift to a new method when the two survey option has been vetted and becomes available. Using both surveys indices for apportionment should provide for a better reflection of the RE/BS spatial population structure over either the status quo three survey average or the current one survey index random effects model.

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
RE/BS complex	2014	42,810	1,497	1,244	1,244	738
	2015	36,584	1,345	1,122	1,122	522
	2016	41,864	1,596	1,328		
	2017	41,597	1,592	1,325		

Stock/ Assemblage	Area	2015 OFL	ABC	TAC	Catch[2]	2016 OFL	ABC	2017 OFL	ABC
RE/BS complex	W		115	115	25		105		105
	C		632	632	540		707		705
	E		375	375	173		516		515
	Total	1,345	1,122	1,122	738	1,596	1,328	1,592	1,325

[1]Total biomass (ages 3+) from the age-structured model

[2]Current as of October 1, 2015. Source: NMFS Alaska Regional Office Catch Accounting System via the AKFIN database (http://www.akfin.org).

Responses to SSC and Plan Team Comments on Assessments in General

"The SSC requests that stock assessment authors utilize the following model naming conventions in SAFE chapters:

1.) *Model 0: last years' model with no new data,*
2.) *Model 1: last years' model with updated data, and*
3.) *Model numbers higher than 1 are for proposed new models."* (SSC December 2014)

"For this year's final assessments, the Teams recommend that each author of an age-structured assessment use one of the following model naming conventions ("TPA" represents the alternative described in the Team procedures document)…" (Plan Team, September 2015)

"Of the options presented in the Joint Plan Teams minutes, the SSC agrees that that Option 4 has several advantages and recommends that this Option be advanced next year." (SSC, October 2015)

For this assessment, we will use the simplified convention suggest in the December 2014 SSC minutes and will investigate further detailed naming for the next assessment cycle in 2016.

"The Team recommends using the random effects model, rather than the weighted survey average approach to the extent practical for POP and for rockfish in general [for apportionment]." (Plan Team, September 2014)

"The SSC also requests that stock assessment authors utilize the random effects model for area apportionment of ABCs" (SSC, December 2014)

"The Teams recommend that the random effects survey smoothing model be used as a default for determining current survey biomass and apportionment among areas." (Plan Team, September 2015)

Similar to last year's assessment, we include both the weighted survey average and the random effects model approach for estimating apportionment in this assessment. Please see the *Area Allocation of Harvests* subsection in **Harvest Recommendations** section for further details.

Responses to SSC and Plan Team Comments Specific to this Assessment

"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)

An AFSC response to the rockfish CIE review was prepared that addresses some of their concerns. Please refer to the "Summary and response to the 2013 CIE review of the AFSC rockfish" document presented to the September 2013 Plan Team for further details regarding this response: http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/2013_Rockfish_CIE_Response.pdf

In response to #1 of the above comment, the 2015 dusky rockfish assessment proposed an alternative methodology for computing trawl survey biomass estimates through the use of a geostatistical generalized linear mixed effects model developed by Thorson et al. 2015. This method uses available catch data more efficiently than conventional design-based estimators resulting in reducing the interannual variability in the biomass estimates. We will consider use of this new method in future assessments for RE/BS rockfish; however, some of the current issues with the design-based trawl survey estimates are alleviated in the RE/BS assessment because we include the longline survey estimates that sample where the trawl survey cannot.

For #2 in the above comment, an analysis of different selectivity options for the trawl survey selectivity in conjunction with extending the plus age group was presented at the 2015 September Plan Team for RE/BS rockfish. The results of this analysis are included in this year's assessment as two alternative models. We also provide more details on the selectivity/plus age group sensitivity analysis in Appendix 13A of this assessment.

Natural mortality (*M*) is estimated inside the assessment model for RE/BS rockfish with the use of prior distributions as penalties. The prior for RE/BS rockfish natural mortality estimate is 0.03 which is based on McDermott (1994). In general, natural mortality is a notoriously difficult parameter to estimate within the model so we assign a precise prior CV of 10%. We also considered several other alternatives for estimating natural mortality and provide these estimates within the main text of the document (see **Parameters Estimated Inside the Assessment Model** section for more details).

"The Team supports the author's suggestion to conduct sensitivity analysis on optimum plus group for age comps. The Team also supports the author's interest to explore selectivity patterns. The Team also encouraged the author to continue to investigate difference in the longline and trawl survey to help understand the different trends." (Plan Team, November 2011)

"The assessment authors note that the choice of the plus group age, and the computation of the age error for the plus group, will be addressed in the 2015 assessment. The Plan Team supports the planned work to address these issues." (Plan Team, November 2014)

"The Team recommends moving forward with these three improvements and encourages the authors to further examine choosing the appropriate plus age groups. To facilitate model evaluation, the Team recommends the authors present the two alternative models suggested." (Plan Team, September 2015)

"The Team recommends the authors present last year's base model with updated data along with an alternative model that explores updated growth information and an extended ageing error matrix, and

second alternative model that also incorporates new selectivity curves and new plus age groups." (Plan Team, September 2015)

As stated in the above comment, an analysis on the trawl survey selectivity and plus age group was presented at the September 2015 Plan Team for RE/BS rockfish and results have been incorporated into this assessment. We also present an additional model in this assessment that 1) updates the growth estimates using length-stratified estimation rather than assuming a random sampling design and 2) extends the ageing error matrix to more appropriately model the plus age group. Please see the **Model Structure** section for more details regarding these alternative models.

"The authors examined the performance of the existing 4:6:9 weighting for area apportionments and the random effects approach. The SSC requests that the authors bring forward both approaches in the full assessment in 2015." (SSC, December 2014)

Similar to last year's assessment, we include both the weighted survey average and the random effects model approach for estimating apportionment in this assessment. Please see the *Area Allocation of Harvests* subsection in **Harvest Recommendations** section for further details.

"The SSC requests that the authors further examine trawl selectivity, as it seems unusual for age 9-11 rockfish to be selected 20% more than other ages. The SSC supports the authors' intent to re-evaluate that age of the plus group and suggests the authors update with an appendix to acknowledge the restructuring of the observer program." (SSC, December 2014)

Per this recommendation by the SSC, we provide a sensitivity analysis to the selection of the trawl survey selectivity in Appendix 13A of this assessment. We examine model results using several functional forms from non-parametric differences (similar to the base model) to the parametric curves from the logistic and gamma functions. Choice of the selectivity function is somewhat confounded with selecting the location of the plus age group which the SSC also suggested for evaluation. This interaction is also detailed in the Appendix 13A. Models evaluating two equally plausible trawl survey selectivity forms and plus groups are provided in the **Analytical Approach** and **Results** section of this assessment.

Introduction

Life History and Distribution

Rougheye (*Sebastes aleutianus*) and blackspotted (*S. melanostictus*) rockfish inhabit the outer continental shelf and upper continental slope of the northeastern Pacific. Their distribution extends around the arc of the North Pacific from Japan to Point Conception, California and includes the Bering Sea (Kramer and O'Connell 1988). The two species occur in sympatric distribution, with rougheye extending farther south along the Pacific Rim and blackspotted extending into the western Aleutian Islands (Orr and Hawkins 2008). The overlap of the two species is quite extensive, ranging primarily from southeast Alaska through the Alaska Peninsula (Gharrett et al. 2005, Orr and Hawkins 2008). The center of abundance for both species appears to be Alaskan waters, particularly the eastern Gulf of Alaska (GOA). Adults in the GOA inhabit a narrow band along the upper continental slope at depths of 300-500 m; outside of this depth interval, abundance decreases considerably (Ito, 1999). These species often co-occur with shortraker rockfish (*Sebastes borealis*).

Though relatively little is known about their biology and life history, rougheye and blackspotted (RE/BS) rockfish appear to be K-selected with late maturation, slow growth, extreme longevity, and low natural mortality. As with other *Sebastes* species, RE/BS rockfish are ovoviviparous, where fertilization and incubation of eggs is internal and embryos receive at least some maternal nourishment. There have been no studies on fecundity of RE/BS in Alaska. One study on their reproductive biology indicated that rougheye had protracted reproductive periods, and that parturition (larval release) may take place in December through April (McDermott 1994). There is no information as to when males inseminate females or if migrations for spawning/breeding occur. The larval stage is pelagic, but larval studies are hindered because the larvae at present can only be positively identified by genetic analysis, which is labor-intensive. The post-larvae and early young-of-the-year stages also appear to be pelagic (Matarese et al. 1989, Gharrett et al. 2002). Genetic techniques have been used recently to identify post-larval RE/BS rockfish from opportunistically collected samples in epipelagic waters far offshore in the Gulf of Alaska, which is the only documentation of habitat preference for this life stage.

There is no information on when juvenile RE/BS rockfish become demersal. Juvenile rougheye and blackspotted rockfish (15- to 30-cm fork length) are frequently taken in Gulf of Alaska bottom trawl surveys, implying the use of low relief, trawlable bottom substrates. They are generally found at shallower, more inshore areas than adults and have been taken in variety of locations, ranging from inshore fiords to offshore waters of the continental shelf. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981, Straty 1987, Krieger 1993). Another submersible study on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). Although these studies did not specifically identify rougheye or blackspotted rockfish, it is reasonable to suspect that juvenile RE/BS rockfish may be among the species that utilize this habitat as refuge during their juvenile stage.

Adult rougheye and blackspotted rockfish are demersal and are known to inhabit particularly steep, rocky areas of the continental slope, with highest catch rates generally at depths of 300 to 400 m in longline surveys (Zenger and Sigler 1992) and at depths of 300 to 500 m in bottom trawl surveys and in the commercial trawl fishery (Ito 1999). Observations from a manned submersible in this habitat indicate that these species prefer steep slopes and are often associated with boulders and sometimes with *Primnoa* spp. coral (Krieger and Ito 1999, Krieger and Wing 2002). Within this habitat, rougheye rockfish tend to have a relatively even distribution when compared with the highly aggregated and patchy distribution of other rockfish such as Pacific ocean perch (*Sebastes alutus*) (Clausen and Fujioka, 2007). A recent study developing habitat-based indices of abundance for several species of rockfish found that a variety of environmental factors such as local slope, bottom depth, and coral/sponge abundance were significant in the best-fitting RE/BS rockfish habitat model (Rooper and Martin, 2012).

Food habit studies in Alaska indicate that the diet of adult rougheye and blackspotted rockfish is primarily shrimp (especially pandalids) and that fish species such as myctophids are also consumed (Yang and Nelson 2000, Yang 2003). However, juvenile RE/BS rockfish (less than 30-cm fork length) in the GOA also consume a substantial amount of smaller invertebrates such as amphipods, mysids, and isopods (Yang and Nelson 2000). Recent food studies show the most common prey of RE/BS as pandalid shrimp, euphausiids, and tanner crab (Chionoecetes bairdi). Other prey include octopi and copepods (Yang et al. 2006). Predators of RE/BS rockfish likely include halibut (*Hippoglossus stenolepis*), Pacific cod (*Gadus macrocephalus*), and sablefish (*Anoplopoma fimbria*).

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-truncation could be deleterious to a population with highly episodic recruitment like rockfish (Longhurst 2002). Recent work on black rockfish (*Sebastes melanops*) has shown that larval survival may dramatically increase with the age of the mother (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. Pacific ocean perch (*S. alutus*) and rougheye/blackspotted rockfish were examined by de Bruin et al. (2004) for senescence in reproductive activity of older fish and they found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. Such relationships have not yet been determined to exist for rougheye and blackspotted rockfish or other rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. However, in a recent study on Pacific ocean perch, Spencer et al. (2007) showed that the effects of enhanced larval survival from older mothers decreased estimated F_{msy} (the fishing rate that produces maximum sustainable yield) by 3% to 9%, and larger decreases in stock productivity were associated at higher fishing mortality rates that produced reduced age compositions.

Evidence of Stock Structure

Since 2007, we have responded to requests regarding the difficulty identifying rougheye and blackspotted rockfish and the development of a rationale for assessment decisions regarding this mixed stock. Reports have included summaries of recent studies on the genetic and phenotypic differences between rougheye and blackspotted rockfish, discussion of the current research regarding at-sea misidentification rates, and new projects developed to understand species specific life history characteristics (Shotwell et al. 2008, 2009). We completed a full stock structure evaluation of rougheye and blackspotted rockfish following the template provided by the Stock Structure Working Group (SSWG, Spencer et al. 2010) and provided this evaluation in **Appendix A** of the 2010 GOA rougheye and blackspotted rockfish executive summary SAFE report (Shotwell et. al 2010). Brief summaries of rougheye and blackspotted rockfish speciation, the stock structure template, and current research are provided below.

Rougheye and Blackspotted Speciation

Several studies on the genetic differences between the observed types of rougheye rockfish indicate two distinct species (Gharrett et al. 2005, Hawkins et al. 2005, Orr and Hawkins 2006, summarized in Shotwell et al. 2009). The proposed speciation was initiated by Tsuyuki and Westrheim (1970) after electrophoretic studies of hemoglobin resolved distinct banding patterns in rougheye rockfish. Subsequent allozyme-based studies demonstrated clear isolation between samples (Seeb 1986) and five distinguishable loci for the two types of rougheye (Hawkins et al. 1997). A later extended allozyme study found the two types occurred in sympatry (overlapping distribution without interbreeding), and samples with depth information demonstrated a significantly deeper depth for what was later described as blackspotted rockfish (Hawkins et al. 2005). Another study analyzed the variation in mitochondrial DNA and microsatellite loci and determined the two distinct species with relatively little hybridization (Gharrett et al. 2005).

In 2008, the presence of the two species was formally verified (Orr and Hawkins 2008). Rougheye rockfish is typically pale with spots absent from the spinous dorsal fin and possibly has mottling on the body. Blackspotted rockfish is darker with spotting almost always present on the dorsal fin and body. However, the distributions of these phenotypic parameters tend to overlap with only slight differences in gill-rakers, body depth, and coloration (Gharrett et al. 2006). Spatially, rougheye rockfish has been defined as the southern species extending farther south along the Pacific Rim, while blackspotted rockfish was considered the northern species extending farther into the western Aleutian Islands and Bering Sea (Orr and Hawkins 2008).

Stock Structure Template Summary

We summarize the available information on stock structure for the GOA rougheye and blackspotted rockfish complex in Table 13-1. Since the formal verification of the two species has only recently occurred, most data on rougheye and blackspotted rockfish is for both species combined. We follow the example framework recommended by the SSWG for defining spatial management units (Spencer et al. 2010) and elaborate on each category within this template to evaluate stock structure for rougheye and blackspotted rockfish. Please refer to Shotwell et al. (2010) for the complete stock structure evaluation.

Non-genetic information suggests population structure by large management areas of eastern, central, and western GOA. This is evident in opposite trajectories for population trends by area, significantly different age, length, and growth parameters by area, and significant differences in parasite prevalence and intensity by area. Genetic studies have generally been focused on the speciation of the RE/BS complex; however, consistencies between the two species also suggest population structure by management area. One such study showed genetic structure consistent with a neighborhood model of dispersion and significant isolation by distance for blackspotted rockfish (Gharrett et al. 2007). However, these data have been reanalyzed with a much larger sample size, and no longer exhibit a significant isolation by distance pattern in the Aleutian Islands and Bering Sea (see Spencer et al. 2014 BSAI blackspotted/rougheye assessment for more details).

Currently, GOA RE/BS rockfish is managed as a Tier 3a species with area-specific Acceptable Biological Catch (ABC) and gulf-wide Overfishing Level (OFL). Given the multiple layers of precaution instituted with relatively low Maximum Retained Allowance (MRA) percentages, a bycatch only fishery status, and the generally low area-specific harvest rates, we continue to recommend the current management specifications for RE/BS rockfish.

Current Research

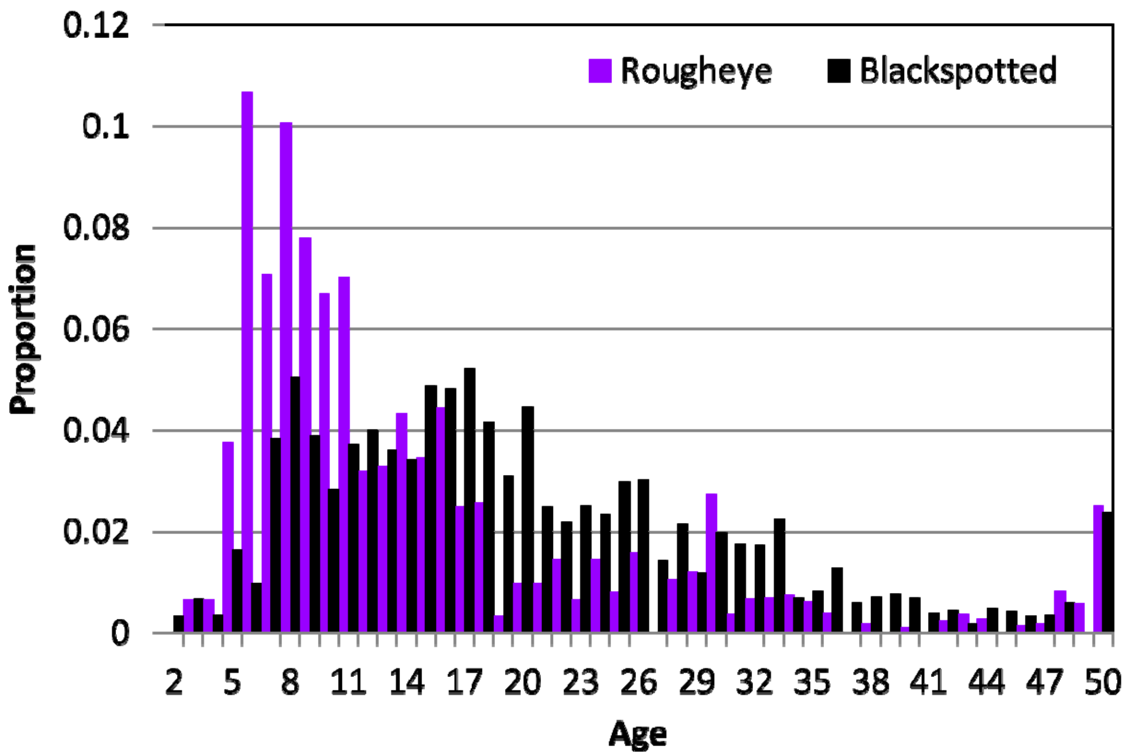
There is difficulty in accurate at-sea field identification between the two species. Previous studies have found that on average, when compared to genetic identifications, field scientists had a misidentification rate of approximately 46% (samples in eastern GOA near Yakutat), while the expert (Jay Orr) had misidentification rates of 9% (Shotwell et al. 2009). In addition, if differences in growth and maturity exist, one species may be at greater risk to overfishing than the other. This may be particularly true in areas where the two species are caught together in the same haul such as in central and eastern GOA (Gharrett et al. 2005).

In response to these concerns, special projects were initiated during the 2009, 2013, and 2015 Alaska Fisheries Science Center (AFSC) GOA bottom trawl survey. The goals of these projects were to collect relevant biological and genetic data to improve at-sea identification, adjust the species-specific biomass estimates based on misidentification rates, and examine differences in life history characteristics between the two species. Field scientists collected length, weight, and muscle tissue (2009) or fin clips (2013 and 2015) from most rougheye and blackspotted rockfish sampled for otoliths. Additionally, most of the unidentified rougheye/blackspotted specimens were sampled for otoliths.

For the 2009 survey, 895 fish were genetically identified in the lab. Overall (not including hybrids or fish unidentified in the field) these results show a 23% misidentification rate. This is a substantial improvement over previous studies. Of the genetically identified rougheye rockfish (n=307), only 6% were incorrectly identified in the field as blackspotted rockfish and 1% were unidentified. Of the genetically identified blackspotted rockfish (n=577), 31% were incorrectly identified in the field as rougheye rockfish and 3% were unidentified. Hybrids existed between the two species (n=11). These hybrids were mostly identified as rougheye rockfish in the field (82 %).

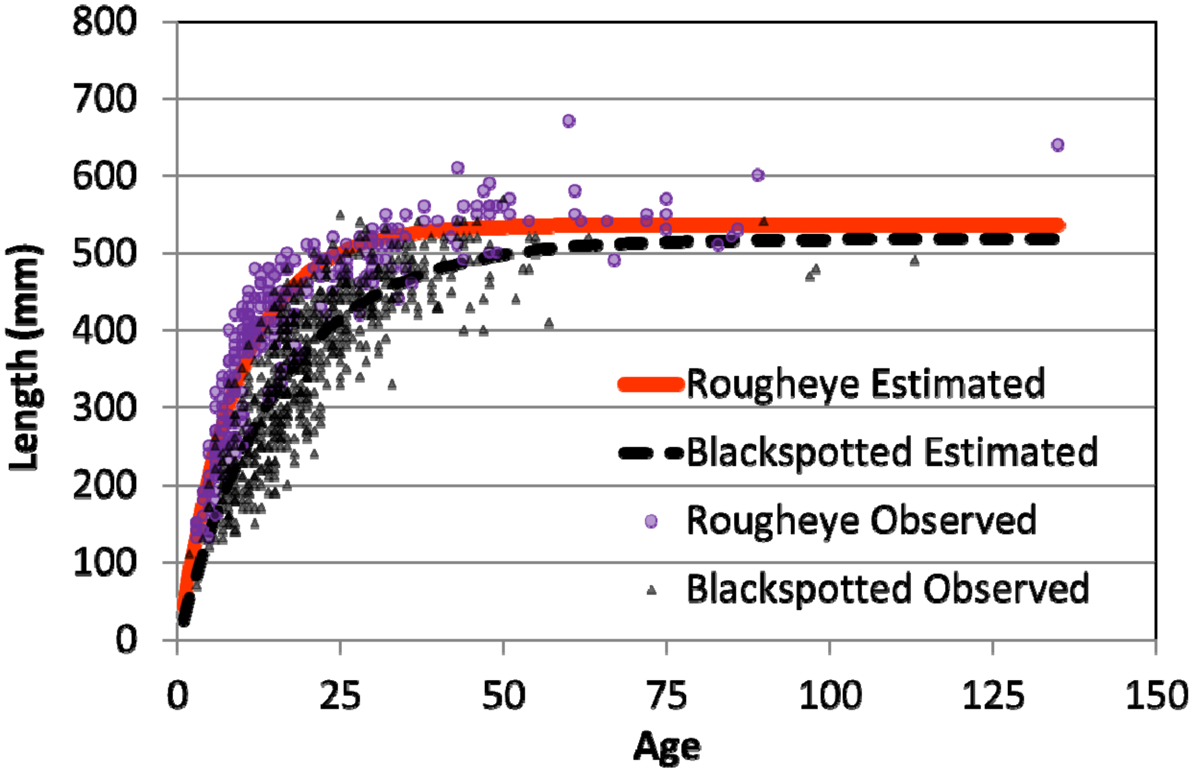
Trawl survey data were adjusted for species misidentification rates to compute species specific biomass estimates and age compositions. For the 2009 survey the adjusted data indicated that 47%, 51%, and 2% of the estimated biomass was comprised of rougheye, blackspotted, and hybrids, respectively. Prior to this adjustment the estimated biomass was 63% rougheye and 37% blackspotted rockfish.

Trawl survey age compositions based on samples taken in 2009 indicate that the average age of blackspotted rockfish was 20 years and 15 years in rougheye rockfish (see figure below). The majority of the trawl survey age composition for rougheye rockfish was less than 20 years old whereas blackspotted rockfish had a more uniform age composition. Data from the 2013 trawl survey have been analyzed for species misidentification rates, and analysis of aging data is in progress.



Data from the 2013 trawl survey have been analyzed for species misidentification rates. The 2013 survey data show that there have been some continued improvements in species identification with overall misidentification rates of 13% compared to 23% from the 2009 survey. The identification of blackspotted rockfish improved substantially compared to 2009. Of the genetically identified blackspotted rockfish (n=424), only 15% were incorrectly identified in the field as rougheye rockfish compared to 31% in 2009. The identification of rougheye rockfish somewhat worsened compared to 2009. Of the genetically identified rougheye rockfish (n=429), 11% were incorrectly identified in the field as rougheye rockfish compared to 6% in 2009. Analysis of age samples collected in the 2013 and 2015 surveys will be completed in the future.

Analysis of 2009 genetically identified and aged otoliths (n=879, hybrids=11) found differences in growth between the two species. Rougheye rockfish grow faster and typically attain a greater maximum size than blackspotted rockfish (see figure below).



The estimated Von Bertalanffy growth parameters for the two species based on the samples taken in the 2009 bottom trawl survey were as follows:

	Rougheye	Blackspotted
Sample Size	298	570
L_∞ (mm)	536	519
κ	0.109	0.065
t_0	0.250	0.250

Scientists and observers are currently evaluating new techniques to determine whether rapid and accurate field identification can occur; however, until reliable identification of both species exists, we will continue to model rougheye and blackspotted rockfish as if they are a single species. The special projects in the 2009, 2013, and 2015 GOA trawl surveys will enhance training and field identification guides, accurately specify misidentification rates, and estimate biological parameters such as growth and distribution by species. Additionally, recently developed techniques utilizing diagnostic single-nucleotide polymorphisms (SNPs) for rougheye and blackspotted rockfish may reduce the cost and processing time for genetic identification of large sample sizes (Garvin et al. 2011).

In the future, we would like to extend this sampling to commercial fisheries as a special project requested of the Observer Program. When combined with accurate species-specific catch and survey data, such information will help determine the utility of a split-species complex model or separate species models for examining if one species may be at greater risk to overfishing. At present, the area-specific harvest rates for RE/BS rockfish have been on average low and catches have consisted of approximately half the ABC in recent years. We consider current management specifications for this two species, non-targeted complex to be sufficiently precautionary.

Fishery

History

Rougheye and blackspotted rockfish have been managed as a "bycatch" only species complex since the creation of the shortraker/rougheye rockfish management subgroup in the Gulf of Alaska in 1991. Since 1977, gulf-wide catches of the rougheye and blackspotted rockfish have been between 130-2,418 t (Table 13-2). Catches peaked in the late 80s and early 90s, declined rapidly in the mid-90s and have been relatively stable, with recent increases since 2009. RE/BS rockfish are generally caught in either bottom trawls or with longline gear and the majority of the recent catch increase was in the Central GOA bottom trawl fishery. Small increases in recent catch occurred in the Eastern GOA longline fishery, while catches have decreased across both bottom trawl and longline gear in the Western GOA. In 2015, 57% of the catch was from bottom trawls, 41% from longline, and 2% from pelagic trawls. Approximately 74% of this bottom trawl catch was taken in the rockfish fishery while 24% was taken in the flatfish fisheries. The amount of catch taken in the rockfish fishery has more than doubled in the past several years, probably due to increased Pacific ocean perch ABC allocated to the central GOA. For longline gear, nearly all the RE/BS catch appears to come as "true" bycatch in the sablefish or halibut longline fisheries, with 81% of the 2015 catch taken in the sablefish fishery and 18% in the halibut fishery. Since catch accounting was established separately for RE/BS rockfish in 2005, the TACs for RE/BS rockfish are not fully taken, and are generally between 20-60% of total quota (Table 13-2).

In response to Annual Catch Limits (ACLs) requirements, assessments now document all removals including catch that is not associated with a directed fishery and reported in the Catch Accounting System (CAS). These types of removals may include sport fishery harvest, research catches, or subsistence catch. Research catches of RE/BS rockfish have been reported in previous stock assessments (Shotwell et al. 2009, 2011, 2014). For this year, estimates of all removals not associated with a directed fishery including research catches are available and are presented in Appendix 13B. In summary, non-directed removals for RE/BS rockfish have typically been less than 10 t and research catches of this magnitude do not pose a significant risk to the RE/BS stock in the GOA.

In 2013, the North Pacific Groundfish and Halibut Observer Program was restructured with the objective to create a more rigorous scientific method for deploying observers onto more vessels in federal fisheries. The extent that this program affected perceived catches of RE/BS rockfish in the small-boat fishery (due to improved coverage) is uncertain. We may expect to see changes in the southeast sablefish fishery due to increased observer coverage; however, a relatively large catch occurred in this fishery in 2012 and has since decreased. Understanding the potential for catch accounting and stock assessment biases due to shifts in observer coverage and the spatial distribution of biological samples from the fishery will require further study.

Management Measures

In 1991, the North Pacific Fishery Management Council (NPFMC) divided the slope assemblage in the Gulf of Alaska into three management subgroups: Pacific ocean perch, shortraker/rougheye rockfish, and all other species of slope rockfish. Although each management subgroup was assigned its own value of ABC (acceptable biological catch) and TAC (total allowable catch), shortraker/rougheye rockfish and other slope rockfish were discussed in the same SAFE chapter because all species in these groups were classified into tiers 4 or lower in the overfishing definitions. This resulted in an assessment approach based primarily on survey biomass estimates rather than age-structured modeling. In 1993, a fourth management subgroup, northern rockfish (*Sebastes polyspinis*), was also created. In 2004, shortraker rockfish and rougheye rockfish were divided into separate subgroups. These subgroups were established to protect Pacific ocean perch, shortraker rockfish, rougheye rockfish, and northern rockfish (the four most sought-after commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual ABC and TAC, whereas prior to 1991, one ABC and TAC was assigned to the entire assemblage. Each subgroup ABC and TAC is apportioned to the three management areas of the Gulf of Alaska (Western, Central, and Eastern) based on the distribution of survey biomass.

In 2007 the Central Gulf of Alaska Rockfish Program was implemented to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central Gulf of Alaska rockfish fishery. This rationalization program establishes cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish species. This implementation impacts primary rockfish management groups but will also affect secondary rockfish groups with a maximum retained allowance (MRA). The primary rockfish management groups are Pacific ocean perch, northern rockfish, and pelagic shelf rockfish (changed to dusky rockfish only in 2012), while the secondary species include rougheye, blackspotted, and shortraker rockfish. Potential effects of this program to rougheye and blackspotted rockfish include: 1) an extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA, 3) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, and 4) a higher potential to harvest 100% of the TAC in the Central GOA region. Recent comparison of catches show that the Rockfish Program has resulted in much higher observer coverage of catch in the Central GOA; however, there does not seem to be a major shift in the spatial distribution of RE/BS catch (Shotwell et al. 2014b, Figure 13-1). We will continue to monitor available fishery data to help understand potential effects the Rockfish Program may have on the RE/BS rockfish stock in the Central GOA.

A summary of key management measures since the creation of the slope rockfish assemblage in 1988 and a time series of catch, OFL, ABC, and TAC are shown in Table 13-3.

Bycatch

The only analysis of bycatch for rougheye rockfish is that of Ackley and Heifetz (2001) from 1994-1996 on hauls they identified as targeted on shortraker/rougheye rockfish. The major bycatch species were arrowtooth flounder (*Atheresthes stomias*), sablefish, and shortspine thornyhead (*Sebastolobus alascanus*), in descending order. The primary fisheries that catch rougheye and blackspotted rockfish as bycatch are the targeted rockfish and sablefish fisheries with occasional surges from the flatfish fishery (Table 13-4). For the combined GOA rockfish trawl fisheries during 2011-2015 (Table 13-5), the largest non-rockfish bycatch groups are on average arrowtooth flounder (933 t/year), sablefish (468 t/year), Pacific cod (587 t/year), Atka mackerel (1,032 t/year) and walleye pollock (915 t/year). Non-FMP species catch in the rockfish target fisheries is generally dominated by giant grenadier (578 t/year), miscellaneous fish (142 t/year), and occasionally dark rockfish (recently removed from FMP to state management, 47 t/year) (Table 13-6). Prohibited species catch in the GOA rockfish fishery has been generally low for most species and this has been particularly true since the implementation of the Central GOA Rockfish Program (Shotwell et al. 2014b). Halibut catch during rockfish targeted hauls increased in 2015. The catch of golden king crab and chinook salmon continued to decrease in 2014-2015 (Table 13-7).

Discards

Gulf-wide discard rates (percent of the total catch discarded within management categories) of fish in the shortraker/rougheye subgroup were available for the years 1991-2004, and are listed in the following table[1]. Beginning in 2005, discards for rougheye and blackspotted rockfish were reported separately.

Shortraker / Rougheye / Blackspotted Complex

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
% Discards	42.0	10.4	26.8	44.8	30.7	22.2	22.0	27.9	30.6	21.2	29.1	20.8	28.3	27.6

Rougheye / Blackspotted Complex

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% Discards	19.5	27.4	36.7	27.6	18.6	19.2	16.3	15.5	22.9	17.3	22.1

The above table indicates that discards of rougheye and blackspotted rockfish have ranged from approximately 15% to 38% with an average of 22%. These values are relatively high when compared to other *Sebastes* species in the Gulf of Alaska.

Data

The following table summarizes the data used for this assessment (bold denotes new or updated data for this assessment):

Source	Data	Years
Fisheries	Catch	1977-2013**, 2014, 2015**
	Age	1990, 2004, 2006, 2008, 2009, **2010**, 2012
	Length	1991-1992, 2002-2003, 2005, 2007, 2011, **2013**
AFSC bottom trawl survey	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, **2015**
	Age	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, **2013**
AFSC longline survey	Relative Population Number (RPN)	1993-**2015**
	Length	1993-**2015**

Fishery:

Catch

Catches of rougheye and blackspotted rockfish have ranged between 130 t to 2,418 t from 1977 to 2015. The catches from 1977-1992 were from Soh (1998), which reconstructs the catch history using an information weighting factor (λ) to combine catch histories from both survey and fishery information. Catches from 1993-2004 were available as the shortraker/rougheye subgroup from the NMFS Alaska Regional Office. Originally we used information from a document presented to the NPFMC in 2003 to

[1] Data from 1991-2004 from NMFS, AKRO, Juneau, AK weekly production and observer reports. Data from 2005 through present are from NMFS, AKRO, Catch Accounting System via Alaska Fisheries Information Network (AKFIN). Most recent estimate is current as of October 1, 2014 (http://www.akfin.org)

determine the proportion of rougheye rockfish in this catch (Ianelli 2003). This proportion was based on the NMFS Regional Office catch accounting system ("blend estimates"). The SSC recommended using the average of the values provided in the document, 0.43. In 2004 another method was developed for determining the proportion of rougheye/blackspotted in the catch based on data from the FMA Observer Program (Clausen et al. 2004, Appendix A). Observed catches were available from the FMA database by area, gear, and species for hauls sampled by observers. This information was used to calculate proportions of RE/BS catch by gear type. These proportions were then applied to the combined shortraker/rougheye catch from the NMFS Alaska Regional Office to yield estimates of total catch for RE/BS rockfish (Figure 13-1, Table 13-2).

One caveat of the observer catch data prior to 2014 is that these data are based only on trips that had observers on board. Consequently, they may be biased toward larger vessels, which had more complete observer coverage. This bias may be a particular problem for rougheye and blackspotted rockfish that were caught by longliners. Much of the longline catch is taken by small vessels that have no observer coverage. Hence, the observer catch data probably reflects more what the trawl fishery catches. However, this data may provide a more accurate estimate of the true proportion of RE/BS catch than the proportion based on the blend estimates. The blend estimates are derived from a combination of data turned in by fishermen, processors, and observers. In the case of fishermen and processors, prior to 2004 there was no requirement to report catches of shortraker/rougheye rockfish by species, and fishermen and processors were free to report their catch as either shortraker, rougheye, or shortraker/rougheye combined. Shortraker and rougheye rockfish are often difficult for an untrained person to separate taxonomically, and fishermen and processors had no particular incentive to accurately identify the fish to species. In contrast, all observers in the FMA Observer Program are trained in identification of Alaska groundfish, and they are instructed as to the importance of accurate identifications. Consequently, the catch data based on information from the FMA Observer Program may be more reliable than those based on the blend estimate. We use the observer estimates of catch from 1993-2004. Catches are reported separately for RE/BS and shortraker since 2005.

Age composition

Rougheye and blackspotted rockfish appear to be among the longest-lived of all *Sebastes* species (Chilton and Beamish 1982, Munk 2001). Interpretation of annuli on otoliths is extremely difficult; however, NMFS age readers determined that aging of RE/BS rockfish could be moved into a production mode. Ages were determined from the break-and-burn method (Chilton and Beamish 1982). Rougheye and blackspotted rockfish otolith samples from onshore processing facilities have been aged; however, the sample sizes from onshore processing facilities are generally low and the distribution of ages is quite different from the at-sea samples. Therefore, we do not use these samples in calculating the fishery age compositions. The FMA Observer Program began in 1990 and although this first year was considered preliminary, the 1990 ages are the only age compositions we have from the fishery prior to 2004. We, therefore, utilize this data in the model since it is considered important for estimating catch at age in the early 1990s. Table 13-8 summarizes the available fishery age compositions from 1990, 2004, 2006, 2008, 2009, 2010, and 2012.

New fishery ages since the last full assessment are available for 2010. We generally request fishery ages only for years that do not overlap with an AFSC bottom trawl survey since analyzing otoliths for long-lived rockfish such as RE/BS rockfish is time-consuming. Previously, the 2009 fishery ages were requested and completed rather than the 2010 ages. We requested that the 2010 fishery ages be completed in the last full assessment and they are now available. Sample sizes from the fishery are typically between 300 and 400 otoliths (Table 13-8). The mean ages for a given year range between 28-35 years and are relatively old when compared to other aged rockfish species.

Size composition

Observers aboard fishing vessels and at onshore processing facilities have provided data on size composition of the commercial catch of rougheye and blackspotted rockfish. Table 13-9 summarizes the available size compositions from 1991-2013. Sample sizes from 1993-2001 were limited for RE/BS rockfish and in other years range from 300 to 2500 (Table 13-9). In general, we do not use size compositions in the model when age compositions are available because we consider age data to be a more reliable measure of population structure for these long-lived species. Since we anticipate fishery ages for non-trawl survey years, we do not include the size compositions for off-cycle years in the model. Additionally, in long-lived rockfish species the fish are selected late to the fishery and size compositions tend to be relatively uninformative as year classes will blend together. Therefore, fishery size compositions from 1991-1992, 2002-2003, 2005, 2007, 2011, and 2013 are included in this full assessment.

Length samples from onshore processing facilities also exist for RE/BS rockfish; however, the distribution between onshore and at-sea lengths differ dramatically and the samples sizes are quite low. Therefore, as with age samples, we do not use these onshore length samples in calculating the fishery size compositions. Lengths were binned into 2 cm categories to obtain better sample sizes per bin from 20-60+ with the (+) group containing all the fish 60 cm and larger. On average, approximately 34% of the lengths are taken from the trawl fishery and 66% from the longline fishery for at-sea samples. This percentage is consistent for the data used in the model with 39% of lengths from the trawl fishery and 61% from the longline fishery. The mode of lengths for the 1991-1992 samples is approximately 45 cm and from 2002-2011 has remained relatively steady between 45 to 48 cm. Moderate presence of fish smaller than 40 cm is present in most years, particularly 1991 and 1992.

Survey:

AFSC Bottom Trawl Biomass Estimates

Bottom trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and 1999. These surveys became biennial starting in 2001. The surveys provide much information on rougheye and blackspotted rockfish, including an abundance index, age composition, and growth characteristics. The surveys are theoretically an estimate of absolute biomass, but we treat them as an index in the stock assessment model. The triennial surveys covered all areas of the Gulf of Alaska out to a depth of 500 m (in some surveys to 700 m or 1,000 m), but the 2001 biennial survey did not sample the eastern Gulf of Alaska. Because the 2001 survey did not cover the entire Gulf of Alaska, we omitted this survey from our assessment model for RE/BS rockfish.

Summaries of biomass estimates from the 1984-2013 surveys are provided in Table 13-10. Trawl survey biomass estimates are shown in Figure 13-2. Historically estimates by region indicate that the western and eastern GOA time series of biomass tended to be in opposite phase (Table 13-10). From 2003-2007, the central and eastern GOA estimates increased, while the western GOA decreased. In 2009, all regions decreased and in 2011 both the eastern and central GOA decreased while the western GOA slightly increased. Given that the regional patterns are quite different and that the 2001 survey did not sample the eastern GOA, omitting this survey estimate from the model is reasonable. Additionally, data for 2001 are available from the longline survey.

The 2013 biomass estimate was an all-time low for this time series. The decrease was 37% below the 2011 estimate and 40% below the mean biomass estimate for the time series. The estimates by area were not consistently down as there was a 66% decrease in the central GOA with increases in the western and eastern GOA by 19% and 51%, respectively. The 2015 biomass estimate increased by 25% from 2013 and is now 24% below the mean estimate for the time series. Compared to the 2013 survey, central and eastern GOA increased by 62% and 21% respectively, but western GOA decreased by 66%. This is the second lowest estimate for the western GOA in the time series.

The 1984 and 1987 survey results should be treated with some caution. A different survey design was used in the eastern GOA in 1984; furthermore, much of the survey effort in the western and central GOA in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this latter problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates discussed here, and the estimates are believed to be the best available. Even so, the reader should be aware that an element of uncertainty exists as to the standardization of the 1984 and 1987 surveys.

The biomass estimates for rougheye and blackspotted rockfish have been relatively constant among the surveys, with the exception of 1993, 2007, and 2013. Generally, inter-survey changes in biomass are not statistically significant from each other (Table 13-10; Figure 13-2). Compared with other species of *Sebastes*, the biomass estimates for rougheye and blackspotted rockfish show relatively tight confidence intervals and low coefficients of variations (CV), ranging between 11% and 23%. The low CVs are an indication of the rather uniform distribution for this species compared with other slope rockfish (discussed previously in *Life History and Distribution* section). Despite this precision, however, trawl surveys are believed to do a relatively poor job of assessing abundance of adult RE/BS rockfish on the upper continental slope. Nearly all the catch of these fish is found at depths of 300-500 m. Much of this area is not trawlable by the survey's gear because of its steep and rocky bottom, except for gully entrances where the bottom is not as steep. If RE/BS rockfish are located disproportionately on rough, untrawlable bottom, then the trawl survey may underestimate their abundance. Conversely, if the bulk of their biomass is on smoother, trawlable bottom, then we could be overestimating their abundance with the trawl survey estimates. Consequently, trawl survey biomass estimates for RE/BS rockfish are mostly based on the relatively few hauls in gully entrances, and they may not indicate a true picture of the abundance trends. However, the utilization of both the trawl and longline (which can sample where survey trawls cannot) biomass estimates should alleviate some of this concern.

In 2007, the trawl survey began separating rougheye rockfish from blackspotted rockfish using a species key developed by J. Orr (Orr and Hawkins, 2008). Biomass estimates by region of the two species somewhat support the broad southern and northern distribution of rougheye versus blackspotted rockfish in that blackspotted estimates were higher in the western GOA and rougheye estimates were higher in the eastern GOA (discussed previously in *Evidence of Stock Structure* section). However, both species were identified in all regions, implying some overlap throughout the GOA. Over all areas, more blackspotted rockfish were identified than rougheye in 2007 (56% versus 44%), while in 2009, 2011, 2013, and 2015 the reverse occurred (36%, 35%, 37%, and 27% versus 64%, 65%, 63%, and 73%, respectively). This shift may be due to the decreases in misidentification rates at-sea between the two species as new identification keys and more training have been incorporated. Despite this improvement, given the lack of species-specific catch we will continue to combine all survey data for both species until more information regarding species' specific life history characteristics is determined.

AFSC Bottom Trawl Age Compositions

New ages for 2013 were added this year resulting in a total of twelve years of survey age compositions with a total sample size of 6,738 ages. Survey age sample sizes are generally higher than fishery age sample sizes, ranging from 200 to 1,000. Although rougheye and blackspotted rockfish have been reported to be greater than 200 years old (Munk 2001), the highest age collected over these survey years was 135 (AFSC 2010). The average age ranged from 15 to 23 over all survey years available (Table 13-11). Compositions from 1984, 1987, 1990, 1996, 1999 showed especially prominent modes in the younger ages, suggesting periods of large year classes from the mid to late 1970s, early 1980s and then again in the late 1980s early 1990s. Since 2003, compositions were spread more evenly across age groups 3-15 corresponding to the strong year classes of the early 1990s and another period of increased recruitment in the early 2000s that is tracked through each survey year. In 2011, a higher proportion of five year old fish suggests another period of increased recruitment in the mid-2000s. This is tracked through to 2013 along with a high proportion of three year old fish, suggesting a period of increased recruitment from the mid and late 2000s. Additionally in 2013, there was a higher proportion of samples in the older ages than previously observed.

Since 2007, when the survey began identifying by individual species of rougheye and blackspotted rockfish, rougheye compositions tend to be spread evenly across ages, while blackspotted tend to be much older. Mean age of rougheye range from 13 - 17, while mean age for blackspotted range from 21 - 24. We combine these two age compositions for 2007, 2009, 2011, and 2013 in the stock assessment model. Ages 42 and greater are pooled into a plus (+) group following the author recommended model (Table 13-11). The following **Analytical Approach** and **Results** sections detail the justification for this age bin as the plus group, which is now no longer larger than any other composition.

AFSC Bottom Trawl Size Compositions

Gulf-wide population size compositions for RE/BS rockfish are in Table 13-12 and sample sizes range from 1,900 to 5,600. The size composition of RE/BS rockfish in the 1984 survey indicated that a sizeable portion of the population was >40 cm in length. This is consistent with the large proportion of ages in the 25-32 year range. In the 1996 through 2015 surveys there is a substantial increase in compositions of fish <30 cm in length suggesting that at least a moderate level of recruitment has been occurring throughout these years or there are fewer larger fish in the population. Compositions from all surveys (with the possible exception of 1990) were all skewed to the right, with a mode of about 43-45 cm. The 1990 size composition appears somewhat bimodal. The average length steadily decreased from 1984-1999, ranging from 41 to 34 cm. After this the mean length remained relatively steady between 33-37 cm. Since 2007, survey rougheye and blackspotted rockfish lengths were split. Rougheye have an average length of 33 cm while blackspotted have an average of 38 cm. Rougheye have a much broader range of lengths from 10-60 cm, while blackspotted tend to be more confined to the 35-50 cm range. However, in the 2013 survey, a larger composition of small blackspotted rockfish (< 25cm) were sampled and continued in the 2015 survey. Again, this may be indicative of misidentification or a true difference in size distribution between species. Future analysis of the 2009, 2013, and 2015 trawl survey genetics experiment will aid in understanding some of these differences. Trawl survey size data are used in constructing the size-age conversion matrix, but are not used as data to be fit in the stock assessment model since survey ages for most years were available. Investigations into including the most recent survey's length composition as a proxy for unavailable age composition were presented in Appendix 9B of the GOA POP November 2014 assessment. The results of that analysis suggest that the utility of using only the most recent survey's length composition is case specific and may be a subject for future research.

AFSC Longline Abundance Index

Catch, effort, and length data were collected for rougheye and blackspotted rockfish during longline surveys. Data were collected separately for RE/BS rockfish and shortraker since 1990. These longline surveys likely provide an accurate index of sablefish abundance (Sigler 2000) and may also provide a reasonable index for rougheye and blackspotted rockfish in addition to the AFSC bottom trawl survey (Rodgveller et al. 2011). Relative population abundance indices are computed annually using survey catch per unit of effort (CPUE) rates that are multiplied by the area size of the stratum within each geographic area. These relative population indices are available by numbers (RPN) and weights (RPW) for a given species (Rodgveller et al. 2011).

There have been several updates to the longline survey database since the 2011 assessment. These include updated growth parameters for all species except sablefish, updated species coding for shortraker and rougheye rockfish, and new area estimates for all strata including the shallow stratum from 150-200 m (Echave et. al. 2013). These updates resulted in a full revision of longline survey estimates for RE/BS rockfish. Due to the updated data checks on the length codes for shortraker and rougheye rockfish, it was determined that the time series for RE/BS should start in 1993. The new area estimates for the shallow stratum now allow the catch data from 150 to 200 m to be included in the survey index. Since RE/BS rockfish are often caught in this stratum (Shotwell et al. 2014a), we include this information in the RE/BS longline survey index.

During the 2009 CIE for sablefish the use of both relative population number (RPN) and weight (RPW) survey indices in the model was discussed. The CIE recommendation was to use only the RPN index to avoid the added uncertainty that results from converting lengths to weight, estimating numbers at age and then converting back to weight for the ultimate ABC recommendation. We follow this recommendation for RE/BS and now use the RPN index since the weight conversion data is already incorporated into the assessment model. The final longline survey RPN index for RE/BS rockfish runs from 1993-2015 with all available strata updated with new area estimates (Table 13-13).

In addition to recalculating RPN values, variance estimates were computed for RE/BS rockfish (Figure 13-3). These estimates were derived by assuming that the mean CPUE of a station in a depth stratum were a representative sample, but recognizing that there is covariance between hachis (also termed a skate which is equal to 45 hooks spaced 2 meters apart) and between depth stratum since hachis and stratum means are not independent among stations. Previously, the variance of the RPW index was assumed to have a CV of 20% across all years based on the interannual variance. New estimates of CVs for the RPN index range from 13-20% (Table 13-13).

The RPN estimates for RE/BS rockfish have been relatively constant since 1993, with the exception of large increases in 1997 and again in 2000. A sharp decline occurred in 2005 and estimates generally increased until 2011 when the survey reached an all-time high for this time series. Another sharp decline occurred in 2012 with an additional decrease in 2013. However, the current 2014 survey increased by 40% from 2013 and is 17% above the average for the time series (Figure 13-3). The agreement between the trawl and longline surveys in 2013 may be indicative of a decrease in the RE/BS rockfish biomass; however, the 2014 longline estimates suggest that the decline may not have been so dramatic. The 2015 survey estimate was about 6% lower than the 2014 estimate and about 10% above the long term average.

As mentioned in the previous section, the trawl survey does not typically sample the high relief habitat of rougheye and blackspotted rockfish. This is not the case with the longline survey which can sample a large variety of habitats. One drawback, however, is that juvenile fish are not susceptible to longline gear. Subsequently, the longline survey does not provide much information on recruitment because most fish are similar in size once they have reached full selection of the longline gear and there is no age data for the longline survey on RE/BS rockfish. The trawl survey may be limited in sampling particular habitats, but does capture juveniles. Another potential concern is the unknown effect due to competition between larger predators for hooks (Rodgveller et al. 2008). However, Shotwell et al. (2014a) investigated the potential for hook competition in the longline survey and found that it was very unlikely to be large, and if it occurs it happens only in occasional specific year and station combinations. In the future, if competition is deemed more important, it will be straightforward to include a competition parameter into the RPN index. Incorporating both longline and trawl survey estimates in the model should remedy some of these issues and offset the variable pattern in both surveys that may be an artifact of sampling issues.

AFSC Longline Size Compositions

Large samples of lengths were collected gulf-wide of RE/BS rockfish from 1990 - 2005. Efficiency has improved in recent surveys and lengths are now collected for nearly all RE/BS rockfish caught ranging from 3,500 to 7,000 (Table 13-14). The influence of such large sample sizes in the stock assessment model are somewhat remedied by taking the square root of sample size relative to the max of the series and scaling to 100 to determine the weight for each year. However, the implications of these assumptions toward weighting of samples sizes should be addressed and is a likely area for future research.

Since the longline survey does not sample in proportion to area, we used area weighted longline survey size compositions instead of compositions based on raw sample size. Updated longline survey size compositions are also now available from 1993-2015 using all strata information and are calculated using the same length bins as the fishery and AFSC bottom trawl data. The longline survey size compositions show that small fish were rarely caught in the longline survey and that the length distribution was fairly stable through time (Table 13-14). Compositions for all years were normally distributed with a mode between 45 and 47 cm in length. An unusually large amount of fish appeared in the 26 cm length bin in 2014 and may reflect the bump in 7 year old fish from the 2013 trawl ages.

Comparison of AFSC Bottom Trawl and Longline Surveys

The spatial distribution of numbers of rougheye and blackspotted rockfish caught in the 2011, 2013, and 2015 trawl and the 2010-2015 longline surveys is depicted in Figure 13-4a. The trawl survey samples more of the continental shelf than the longline survey due to differences in survey design. However, the trawl survey tends to catch more RE/BS rockfish in the central GOA, while the longline survey catches more RE/BS rockfish in the eastern and western GOA. This can be seen in all surveys, particularly in the eastern GOA. In 2013, both survey estimates decreased from the previous surveys. The decrease was primarily in the central GOA for the trawl survey and the eastern GOA for the longline survey. The spatial distribution of hauls that encountered RE/BS rockfish seemed to be the opposite of the 2011 survey with many small catches throughout the central GOA and a few relatively large catches in the eastern GOA. In 2015, both surveys estimates were up from the 2013 surveys with increases in the central and eastern GOA for the trawl survey and gulfwide for the longline survey. The 2015 trawl survey estimate in the western GOA was near the all-time low for this survey. The distribution of the hauls that typically sample RE/BS rockfish in this region are near the slope, where there may be a higher proportion of steep, rocky, untrawlable habitat. The longline survey effectively samples this habitat and catches increased in the western GOA compared to the 2013 surveys. This may suggest that the 2015 trawl survey western GOA drop may not be indicative of an actual decline in the western GOA.

Rougheye and blackspotted rockfish were identified at-sea separately since 2007 in the trawl surveys. The spatial distribution of the two species somewhat reflects the area differences seen in the trawl survey biomass estimates (discussed previously in *AFSC Bottom Trawl Biomass Estimates* section), with more blackspotted in the western GOA and more rougheye encountered in the eastern GOA. There are also more rougheye identified gulfwide than blackspotted (~2/3 rougheye to 1/3 blackspotted). There also seem to be some differences across the shelf/slope region (Figure 13-4b). In general, more rougheye are identified in the shallower depths than blackspotted, particularly in the central GOA. The changes in spatial distribution of the two species over time may be an area of future research when determining differences in life history characteristics.

Sensitivity Analysis of AFSC Bottom Trawl and Longline Surveys

In response to comments by the SSC in December 2005, a preliminary sensitivity analysis was conducted in the 2006 RE/BS rockfish assessment on the relative influence of the trawl and longline survey estimates. Data for the RE/BS model substantially increased for the 2007 assessment; therefore, we included a more thorough sensitivity analysis that also included the relative influence of the trawl survey age and longline survey length compositions. The trajectory of female spawning biomass (SSB) was relatively similar over all model runs; however, the magnitude of SSB depended on the specification of precision of input data. We altered the specified precision by changing the assumed CV for each data source. In general, model estimates were robust to only altering the precision on the trawl survey biomass estimates or the longline survey length compositions. Estimates of SSB increased with a moderately high precision on the trawl survey biomass coupled with decreased precision on the longline survey biomass or a decrease in weight on the trawl survey age compositions. Model estimates decreased with high precision on only the longline survey or high precision on the trawl survey age compositions.

In two scenarios, B_{2008} fell below $B_{40\%}$. The first scenario was very high precision on only the longline survey. In this case, the relatively low weight of the catch index allowed the model to predict highly anomalous values resulting in fairly low fit to the catch data. The second scenario was very high precision on the trawl survey biomass combined with very high weight on the trawl survey age compositions. In this second case, trawl survey selectivity shifts to the right and catchability increased dramatically, resulting in reduced overall biomass trajectory. Results of this sensitivity analysis suggest increasing the weight on the catch index to increase robustness of the model to the assumed specification of precision. We may also explore the effects of increasing the age bins as we update the size-at-age matrix and weight-at-age vector when considering model assumptions. At this time, we do not feel that any particular increase or decrease of the current precision or weighting scheme on the trawl or longline biomass estimates or compositions is warranted, given that they all provide information on different aspects of the rougheye and blackspotted rockfish population.

International Pacific Halibut Commission (IPHC) Longline Estimates

The IPHC conducts a longline survey each year to assess Pacific halibut. This survey differs from the AFSC longline survey in gear configuration and sampling design, but also catches rougheye and blackspotted rockfish. More information on this survey can be found in Soderlund et al. (2009). A major difference between the two surveys is that the IPHC survey samples the shelf consistently from 1-500 meters, whereas the AFSC longline survey samples the slope and select gullies from 200 to 1000 meters. Because the majority of effort occurs on the shelf in shallower depths, the IPHC survey may catch smaller and younger rougheye and blackspotted rockfish than the AFSC longline survey; however, lengths of RE/BS rockfish are not taken on the IPHC survey.

We conducted a preliminary comparison between the three surveys from 1998-2008 in Shotwell et al. (2011). IPHC relative population numbers (RPN) were calculated similar to the AFSC survey, the only difference being the depth stratum increments. Area sizes used to calculate biomass in the AFSC bottom trawl surveys were utilized for IPHC RPN calculations. A Student's t normalized residuals was used to compare between the IPHC longline, AFSC longline, and AFSC bottom trawl surveys. The IPHC and AFSC longline surveys track well until about 2004 and then have somewhat diverging trends. The consistently shallower IPHC survey may better capture variability of younger RE/BS rockfish. Since the abundance of younger RE/BS rockfish will be more variable as year classes pass through, the IPHC survey should more closely resemble the AFSC bottom trawl survey. Potential use of the IPHC survey in this assessment is an area for future research.

Analytic Approach

Model Structure

We present model results for the RE/BS rockfish complex based on an age-structured model using AD Model Builder software (Fournier et al. 2012). This consists of an assessment model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model which uses results from the assessment model to predict future population estimates and recommended harvest levels. The GOA RE/BS model closely follows the GOA Pacific ocean perch model which was built from the northern rockfish model (Courtney et al. 1999; Hanselman et al. 2003, Courtney et al. 2007). As with other rockfish age-structured models, this model does not attempt to fit a stock-recruitment relationship but estimates a mean recruitment, which is adjusted by estimated recruitment deviations for each year. We do this because there does not appear to be an obvious stock-recruitment relationship in the model estimates, and there little contrast in the spawner/recruits data (Figure 13-5). The main difference between the RE/BS model and the Pacific ocean perch model is the addition of data from the AFSC longline survey. Unlike the Pacific ocean perch model, the starting point for the RE/BS model is 1977, so the population at the starting point has already sustained fishing pressure. The parameters, population dynamics and equations of the model are described in Box 1 (below). The model has been in its current configuration since 2005. In 2009, further modifications were made to accommodate MCMC projections that use a pre-specified proportion of ABC for annual catch. In 2014, a modification was made to allow for a numbers index rather than a weight index in the model following the configuration used in the sablefish assessment model (Hanselman et al. 2013).

Several changes were made to the input data and model configuration in this year's assessment compared to the 2014 assessment. In general, the models are built in a stepwise fashion in that each subsequent model includes the changes from the previous model. The final two models also include sub-models to provide examples of a sensitivity analysis on evaluating the trawl survey selectivity functional form and the interaction with the age composition plus group (see Appendix 13A). These models are detailed in the following table:

Model Number	**Model Description**
Model 0 (M0)	Model from Shotwell et al. (2014b)
Model 1 (M1)	Same as M0 but incorporates all new and updated data
Model 2 (M2)	Same as M1 but with new length-stratified growth and updated ageing error conversion matrix
Model 3a (M3a)	Same as M2 but uses 3rd differences (non-parametric high penalty) trawl survey selectivity and new plus age at 42
Model 3b (M3b)	Same as M2 but with 3rd differences (non-parametric high penalty) trawl survey selectivity and new plus age at 53
Model 4a (M4a)	Same as M2 but uses the gamma function for trawl survey selectivity and new plus age at 42
Model 4b (M4b)	Same as M2 but uses the gamma function for trawl survey selectivity and new plus age at 53

Descriptions of each model change (M2 through M4) are provided below.

M2: Length-stratified growth and updated ageing error

Otolith collections for rockfish in the AFSC bottom trawl survey are done following a length-stratified design (i.e., a specified number of otoliths are collected for each length category). Corresponding growth estimates are then derived with these samples. In previous rockfish assessments growth observations have been treated as if they were collected randomly. However, this assumption incurs bias in the growth parameters because these samples should be weighted by the total number of lengths sampled to account for the length-stratified sampling design used to collect age specimens. In this year's assessment we use new estimates of growth based on length-stratified methods rather than random methods (Quinn and Deriso 1999, Bettoli and Miranda 2001). This is applied to both the weight-at-age vector and the size-age conversion matrix used in the assessment model. Following the method presented in Bettoli and Miranda (2001), mean length was calculated as:

$$\bar{L}_a = \frac{\sum N_{a,l}\bar{l}_{a,l}}{N_a}$$

where $N_{a,l}$ is the estimated age-length key (estimated total numbers at age-*a* and length-*l*) and $\bar{l}_{a,l}$ is the measured length at age-*a* and length-*l*, which is simply the length bin label. The age-length key is calculated as:

$$N_{a,l} = N_l \frac{n_{a,l}}{n_l}$$

where N_l is the total number of fish measured at length-*l*, $n_{a,l}$ is the number of fish sampled at age-*a* and length-*l*, and n_l is the number of fish sampled for ages at length-*l* (the sum of $n_{a,l}$ across ages). The standard deviation for in length for age-*a* is calculated as:

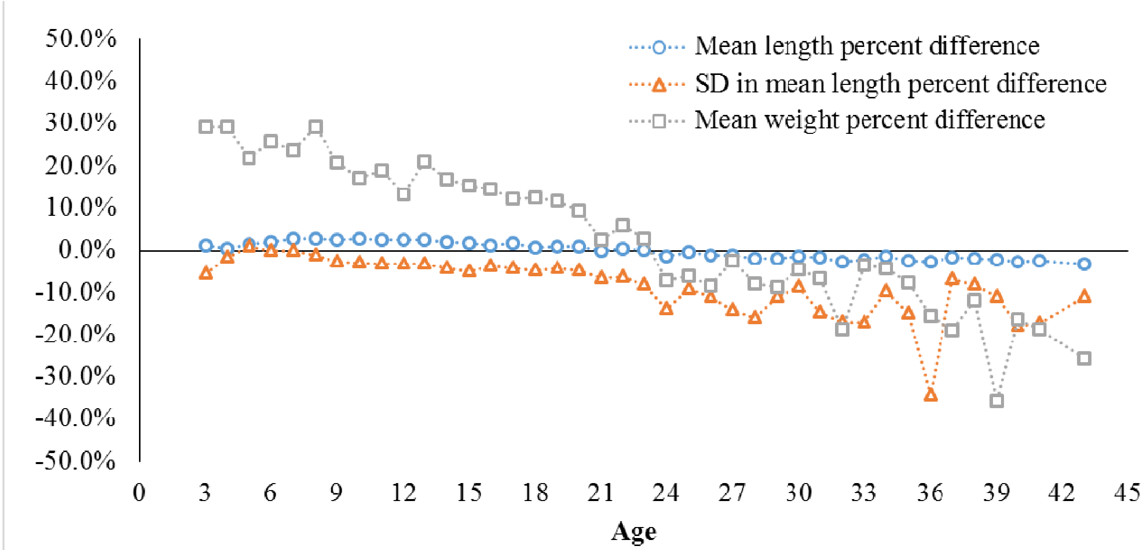
$$SD_a = \sqrt{\frac{\sum N_{a,l}\left(\bar{l}_{a,l} - \bar{L}_a\right)^2}{N_a - 1}}$$

Mean weight is calculated in a similar manner (Quinn and Deriso 1999). The same age-length key used to calculate mean length is used to calculate mean weight ($N_{a,l}$), the only difference between the two is that $\bar{l}_{a,l}$, which is the length bin label, is replaced above with the mean weight observed at age-*a* and length-*l* (for which there can be multiple weight observations). Thus, mean weight is given by:

$$\bar{W}_a = \frac{\sum N_{a,l}\bar{W}_{a,l}}{N_a}$$

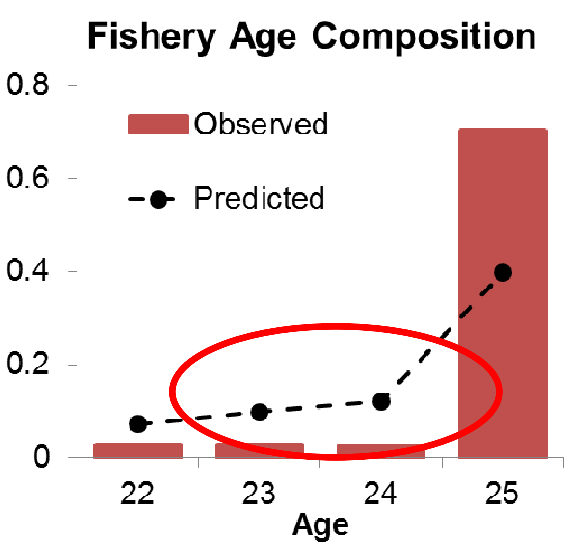
where $\bar{W}_{a,l}$ is the mean weight observed at age-*a* and length-*l*.

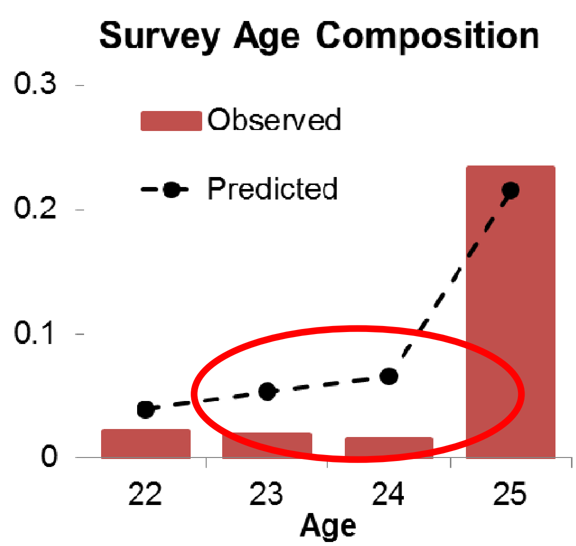
The following figure compares the percent difference between random and length-stratified mean length, standard deviation (SD) in mean length, and mean weight (positive values indicate that the mean value from length-stratified method was larger than the mean value from random method).



Overall, the differences in mean length were small between length-stratified and random methods (<1%, blue circles). However, the SD in mean length was, on average, 8.5% smaller for length-stratified methods versus random methods and the differences were higher for ages greater than 20 (orange triangles). Mean weight was, on average, 3.1% larger for length-stratified versus random methods, but this was not consistent across ages (gray squares). There seemed to be a switch at about age 24 where weight for length-stratified methods shifts to be smaller than random methods. In the following section, 'Parameters Estimated Outside the Assessment Model', the parameter estimates from the von Bertalanffy growth curve that are shown were obtained from length-stratified methods to determine mean length and weight. This data change is reflected in model case M2 and is used in all subsequent models.

In last year's assessment, the aging error matrix was updated with new age agreement data through 2009. We further update and extend this aging error matrix to alleviate the consistently over-estimated proportions in the age classes adjacent to the plus age group in both the trawl survey and fishery age composition datasets. An example of the average 2014 model fit to the average of the most recent fishery and trawl survey age compositions is shown in figure below (only presented are the last four age classes for this example, circles identify the ages with lack of fit from the model).





Recent investigations revealed that this overestimation was due to the construction of the ageing error matrix. In its current form, the ageing error matrix distributes the fish in the plus age group based on the ageing error of the first age in the plus age group. For example, in the 2014 RE/BS rockfish assessment the plus age group was started at age 25. Thus, the distribution of fish in the plus age group into age classes younger than the plus age group were based on the ageing error of only age 25, rather than based on the ageing error of all the fish age 25 and older. This translates into a greater probability of fish in the plus age group being in the adjacent age classes that are younger than the plus age group than would be present for all fish older than the plus age group. The result is consistent over estimation of the age class proportions that are adjacent to the plus age group. In this model change we provide an alternative ageing error matrix that extends the plus age group in the model compared to the plus age group in the data until 99.9% of the fish in the model's plus age group are within the plus age group of the data.

M3 and M4: Trawl survey selectivity

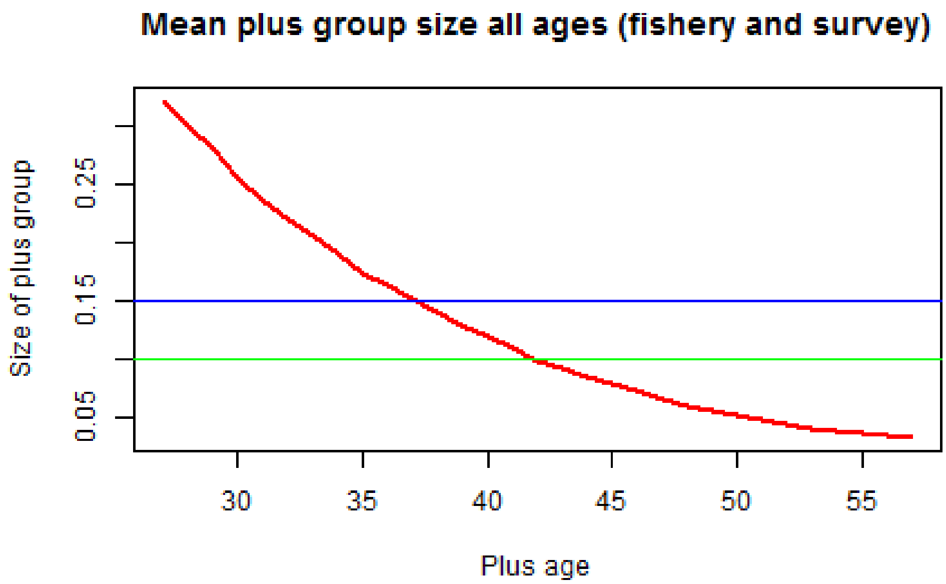
In December 2014, the SSC requested that authors examine the trawl survey selectivity as the implied dome-shape over ages 9-11 from the non-parametric selectivity by age estimates seemed unusual. Additionally, the SSC supported the evaluation of the plus age group as there was a large proportion of age composition in the plus group, particularly in the fishery ages. Per this recommendation, we provide a sensitivity analysis to the selection of the trawl survey selectivity in Appendix 13A of this assessment. In previous assessments, we estimate a vector of non-parametric selectivity coefficients up to a maximum age and hold the rest of the estimates at that value up to the plus group. These coefficients are "regularized" by 2nd differences (differences between the differences) and a very light penalty is applied that minimizes the differences. The resulting shape of the trawl survey selectivity seemed to imply some form of dome-shape. We, therefore, examined several selectivity options from the base model (very low 2nd difference penalty) which implied a linear shape *a priori* through several dome-shaped options. These included using 3rd differences with different penalties, the gamma function, and logistic function. The use of the functional forms dramatically reduces the number of parameters used to estimate the selectivity from the base model. However, choice of the selectivity function is somewhat confounded with the location of the plus age group. This interaction is detailed in Appendix 13A through a series of heat maps that demonstrate the change in the negative log likelihood due to fits of different data sources. Results from the total data negative log likelihood suggest that the gamma function and a 3rd difference model (3rd Diff Max 5) were equally good at fitting the data overall. The 3rd Diff Max 5 uses the 3rd differences (rather than 2nd differences as in the base model) with a high penalty (100) and selectivity is fixed at 5 ages before the maximum age of the modeled age data. See Appendix 13A for comparison of different selectivity options.

For this assessment, we consider these two selectivity options that were equally good at fitting the data per the results of the sensitivity analysis of the trawl survey selectivity. Both models imply a dome-shape *a priori*. Model 3 (M3) uses the 3rd Diff Max 5 selectivities while Model 4 (M4) applies the gamma function which allows for a more restricted dome-shaped but reduces the parameters to only two. To include the interaction with the plus age group we provide two sub-models (a and b) to each of these selectivity models that captures the range of appropriate plus age group following guidance as detailed in the following section.

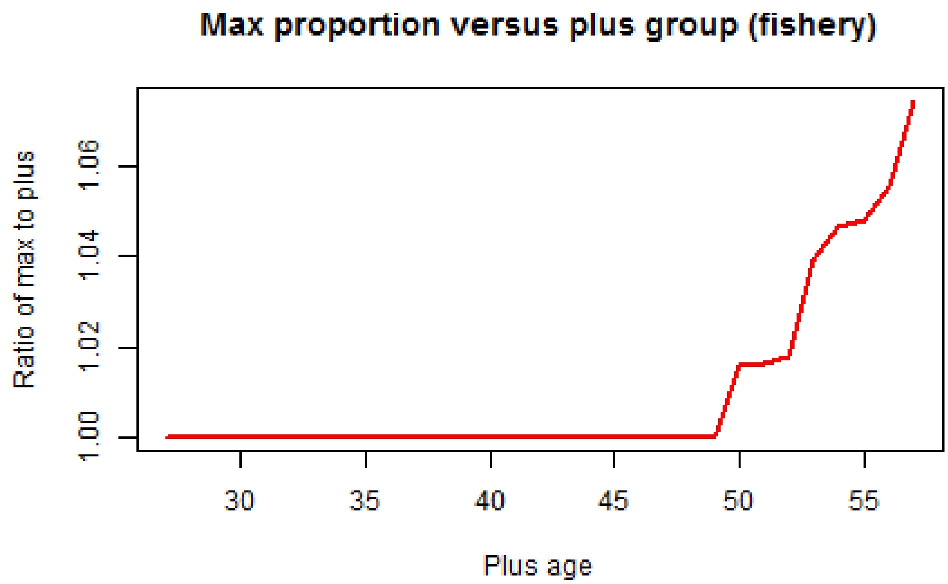
Sub-models a and b: Selecting the plus age group

Recently, several investigations in both the GOA and BSAI rockfish assessments have been attempting to determine rules of thumb for setting the appropriate plus age group for the data fit by the assessment model (e.g., Hulson et al. 2011, Spencer and Ianelli 2012). These explorations evaluated the changes to the likelihood values of the fitted data in the model to determine the appropriate age group, but have not provided clear guidance as to where to set the plus age group. Responses from the most recent Plan Team and SSC suggested following these basic guidelines for setting the plus group: (1) reduce the plus age group proportion to no more than 10-15% of the total samples, (2) ensure plus age group is less than the maximum proportion in the remainder of the age composition data, (3) minimize age bins with zero samples, (4) examine model fits and residuals, and (5) consider sensitivity to selectivity changes while adding age bins.

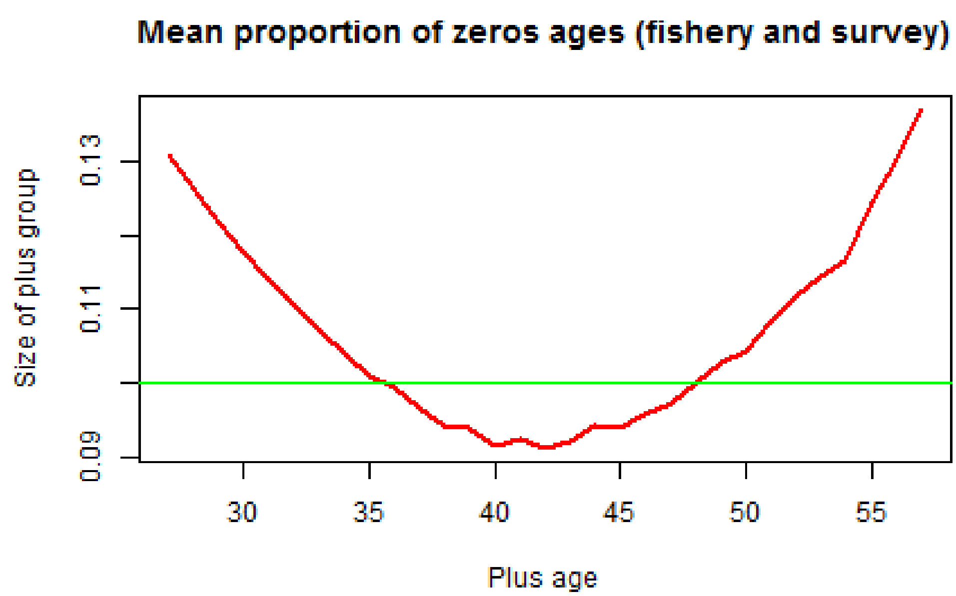
A graphical analysis of these guidelines while successively extending the plus group reveals a relatively consistent location for the RE/BS plus age group at about age bin 42. Reducing the plus age group to no more than 10-15% of the total samples depends on how the data is weighted. We allowed each year of age samples to have equal weighting rather than using averages to give the fishery and trawl survey samples equal weighting. This resulted in a mean plus group of no more than 10% at age bin 42 and no more than 15% at age bin 38 as seen in the figure below.



Ensuring that the plus age group proportion was less than the maximum proportion of any other composition data was already satisfied for the trawl survey data at a plus age of 25. However, for the fishery this does not occur until the older ages. We compared the ratio of the maximum proportion of non-plus age group to the proportion in the plus age group in the following figure. The proportion in the plus age group for the fishery data does not go below the maximum proportion of the other age compositions until after around age 50 when the ratio begins to exceed 1.



When considering the number of age bins with zero samples, we also decided to allow equal weighting for each year of age samples as with establishing the 10-15% bin. This resulted in a bottoming out of the mean proportion of zeros between ages 40 and 45 as seen in the following figure. This occurs because there are a number of younger age bins with zeros in the fishery data as the fishery does not really capture any small RE/BS rockfish. This is also reflected in the steep slope of the fishery selectivity curve.



To examine model fits and residuals we consider two plus age groups at 42 and 53 that basically satisfy guidelines 1-3 mentioned above. These make the sub-models when combined with the two potential trawl survey selectivity curves from the sensitivity analysis in Appendix 13A.

Parameters Estimated Outside the Assessment Model

Size at 50% maturity has been determined for 430 specimens of rougheye rockfish (McDermott 1994). This was converted to 50% maturity-at-age using the size-age matrix from this stock assessment. These data are summarized below (size is in cm fork length and age is in years).

Sample size	Size at 50% maturity (cm)	Age at 50% maturity
430	43.9	19

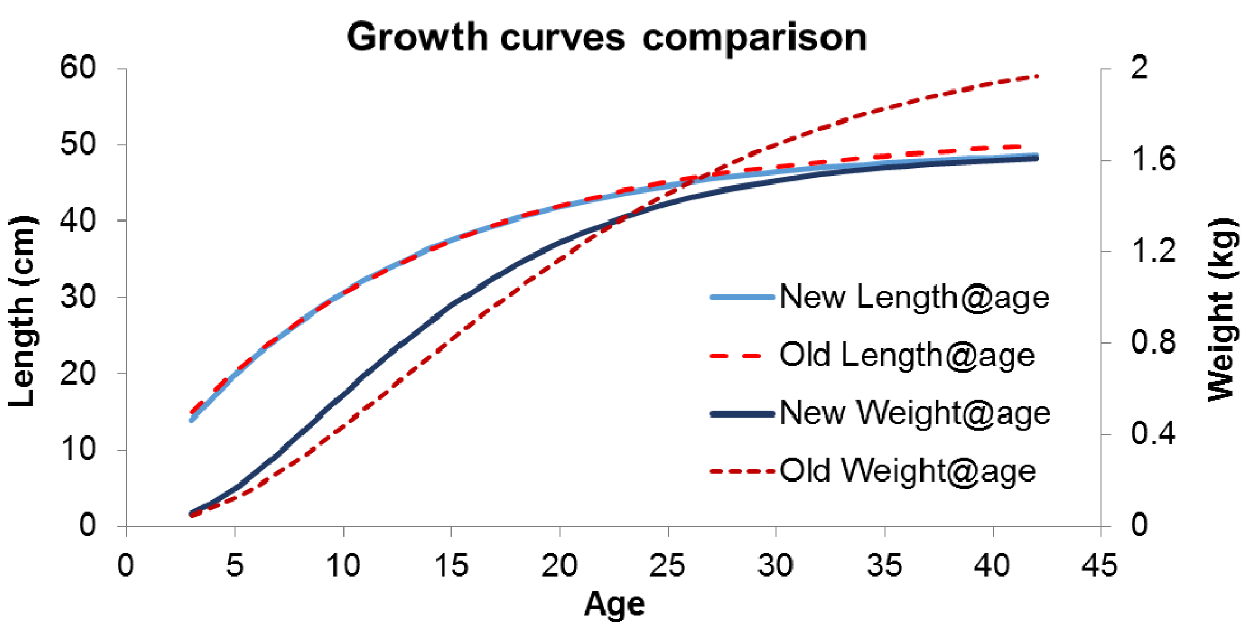
New information on growth was incorporated into last year's assessment and estimates were updated using data from 1990 through 2011. In this year's assessment the size at age data was updated through the 2013 survey, and growth was estimated with length-stratified methods (Quinn and Deriso 1999, Bettoli and Miranda 2001) as described above. A von Bertalanffy growth curve was fit to size and age data from 1990 to 2013. Sexes were combined and the size-at-age conversion matrix was constructed by adding normal error with a standard deviation equal to the survey data for the probability of different size classes for each age. The new estimated parameters for the growth curve are:

New (2015) size at age parameters:	L_∞= 49.6 cm	κ=0.09	t_0=-0.69	n=6,738
Old (2014) size at age parameters:	L_∞= 51.4 cm	κ=0.08	t_0=-1.27	n=5,681

The mean weight-at-age was constructed from the same data set as the size-at-age matrix and a correction of $(W_\infty - W_{25})/2$ was used for the weight of the pooled ages (Schnute et al. 2001). The new estimated growth parameters (including the length-weight parameters) from the length-stratified methods are:

New (2015) weight at age parameters:	W_∞= 1,639 g	κ=0.12	t_0=-0.38	β=3.086	n=5,806
Old (2014) weight at age parameters:	W_∞= 2,171 g	κ=0.08	t_0=-1.27	β=3.077	n=4,749

A comparison graph of the new versus old growth curves is provided in the figure below.



Aging error matrices were constructed by assuming that the break-and-burn ages were unbiased but had a given amount of normal error around each age. Originally we used the error structure of the Pacific ocean perch model because we used approximately the same age bins for the RE/BS assessment. Newly available age samples allowed for an update of the 2011 age-error matrix. Age agreement tests have now been run on samples from 1984, 1987, 1990, 1993, 1996, 1999, 2003-2007, and 2009 for RE/BS rockfish for a total of 1,589 specimens. We estimated a new age error structure based on the percent agreement for each age from these tests. Additionally, as described above, we extend the plus age group in the model compared to the plus age group in the data until 99.9% of the fish in the model's plus age group are within the plus age group of the data. This was done to alleviate the consistent over-estimation of the proportion at age in the age bins adjacent to the plus group age.

New Research

A new maturity study on RE/BS rockfish species was recently initiated through the RACE Division (C. Conrath and B. Knoth). Samples were collected throughout the year on a variety of scientific surveys and observed fishery vessels. Preliminary results suggest slightly lower age at 50% maturity; however, substantial number of adults appeared to be skip spawning. More samples from a larger variety of areas and during different years and/or seasons are needed to adequately assess the spawning state (C. Conrath, pers. comm.). We plan to use this new maturity information as it becomes available and will follow the method that was recently developed to incorporate estimated maturity within the assessment model (Hulson et al. 2011, Lunsford et al. 2011, Spencer and Ianelli, 2012).

Parameters Estimated Inside the Assessment Model

The estimates of natural mortality (*M*), catchability (*q*), and recruitment deviations (σ_r) are estimated with the use of prior distributions as penalties. The prior for RE/BS rockfish natural mortality estimate is 0.03 which is based on McDermott (1994). She used the gonadosomatic index (GSI) following the methodology described by Gunderson and Dygert (1988) to estimate a range of natural mortalities specifically for rougheye/blackspotted (0.03 – 0.04). In general, natural mortality is a notoriously difficult parameter to estimate within the model so we assign a precise prior CV of 10% (Figure 13-6).

Several other alternatives to estimating natural mortality for rockfish are available such as catch-curve analysis, empirical life history relationships, and simplified maximum age equations (Malecha et al. 2007). Each of these methodologies was detailed in the draft response of the Rockfish Working Group to the center of independent expert's review of Alaskan Rockfish Harvest Strategies and Stock Assessment Methods (ftp://ftp.afsc.noaa.gov/afsc/public/rockfish/RWG response to CIE review.pdf). We applied the various methods to data from RE/BS rockfish and used a maximum age of 132 (AFSC 2006). Values are shown below.

Method	***M***
Current stock assessment prior	0.030
Catch Curve Analysis	0.072
Empirical Life-History: Growth	0.004
Empirical Life-History: Longevity	0.035
Rule of Thumb: Maximum Age	0.035

The Hoenig (1983) methods based on longevity and the "rule-of-thumb" approach both produce natural mortality estimates similar to McDermott (1994). Catch-curve analysis produced an estimate of Z=0.094 and average fishing mortality (0.022) is subtracted to yield a natural mortality 0.072 which is the highest estimate. The Alverson and Carney (1975) estimate was much lower. Several assumptions of catch-curve analysis must be met before this method can be considered viable, and there is a likely time trend in recruitment for GOA rockfish. The method described by Alverson and Carney (1975) for developing an estimate of critical age is based on a regression of 63 other population estimates and may not be representative of extremely long-lived fish such as rougheye and blackspotted rockfish (Malecha et al. 2007). McDermott (1994) collected 430 samples of rougheye/blackspotted rockfish from across the

Pacific Northwest to the Bering Sea, providing a representative sample of RE/BS rockfish distribution. Since the value of 0.03 estimated by McDermott (1994) is within the range of most other estimates of natural mortality and designed specifically for RE/BS rockfish, we feel that this is the most suitable estimate for a prior mean.

Catchability is a parameter that is somewhat uncertain for rockfish. We assign a prior mean of 1 for both the trawl and longline survey. For the trawl survey, a value of 1 assumes all fish in the area swept are captured, there is no herding of fish from outside the area swept, and there is no effect of untrawlable grounds. This area-swept concept does not apply to the longline survey; however, since the RPNs for rougheye and blackspotted rockfish are of the same magnitude as the trawl survey estimates we deemed this a logical starting point. We also assume a lognormal distribution to bind the minimum at zero. For both the trawl and longline survey, we assign a very broad CV of 100% which essentially mimics a uniform prior with a lower bound of zero (Figure 13-7). These prior distributions allow the catchability parameters more freedom than that allowed to natural mortality.

Recruitment deviation is the amount of variability that the model assigns recruitment estimates. Rougheye and blackspotted rockfish are likely the longest-lived rockfish and information on recruitment is quite limited, but is expected to be episodic similar to Pacific ocean perch. Therefore, we assign a relatively high prior mean to this parameter of 1.1 with a precise CV of 6% to allow recruitments to be potentially variable (Figure 13-7).

Other parameters estimated conditionally include, but are not limited to: selectivity (up to full selectivity) for surveys and fishery, mean recruitment, fishing mortality, and reference fishing morality rates. The numbers of estimated parameters as determined by ADMB are shown below. Other derived parameters are described in Box 1.

Parameter name	Symbol	Number
Natural mortality	M	1
Catchability	q	2
Log-mean-recruitment	μ_r	1
Recruitment variability	σ_r	1
Fishing mortality rates	$F_{35\%}$, $F_{40\%}$, $F_{50\%}$	3
Recruitment deviations	τ_v	87
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_v	39
Fishery selectivity coefficients	fs_a	14
Survey selectivity coefficients	ss_a	17
Total		166

Uncertainty

Evaluation of model uncertainty has recently become an integral part of the "precautionary approach" in fisheries management. In complex stock assessment models such as this model, evaluating the level of uncertainty is difficult. One way is to examine the standard errors of parameter estimates from the Maximum Likelihood (ML) approach derived from the Hessian matrix. While these standard errors give some measure of variability of individual parameters, they often underestimate their variance and assume that the joint distribution is multivariate normal. An alternative approach is to examine parameter distributions through Markov Chain Monte Carlo (MCMC) methods (Gelman et al. 1995). When treated this way, our stock assessment is a Bayesian model, which includes informative (e.g., lognormal natural mortality with a small CV) and noninformative (or nearly so, such as a parameter bounded between 0 and 10) prior distributions. In the models presented in this SAFE report, the number of parameters estimated is 166. In a low-dimensional model, an analytical solution for the uncertainty might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, the chain will converge (Jones and Hobert 2001). The "burn-in" is a set of iterations removed at the beginning of the chain. This method is not strictly necessary but we use it as a precautionary measure. In our simulations we removed the first 4,000,000 iterations out of 20,000,000 and "thinned" the chain to one value out of every 4,000, leaving a sample distribution of 4,000. Further assurance that the chain had converged was to compare the mean of the first half of the chain with the second half after removing the "burn-in" and "thinning". Because these two values were similar we concluded that convergence had been attained. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% credible intervals for some parameters.

BOX 1. AD Model Builder Rougheye Model Description

Parameter definitions	
y	Year
a	Age classes
l	Length classes
w_a	Vector of estimated weight at age, $a_0 \rightarrow a_+$
m_a	Vector of estimated maturity at age, $a_0 \rightarrow a_+$
a_0	Age it first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
ϕ_y	Annual fishing mortality deviation
τ_y	Annual recruitment deviation
σ_r	Recruitment standard deviation
fs_a	Vector of selectivities at age for fishery, $a_0 \rightarrow a_+$
ss_a	Vector of selectivities at age for survey, $a_0 \rightarrow a_+$
M	Natural mortality, log-scale estimation
$F_{y,a}$	Fishing mortality for year y and age class a ($fs_a \mu_f e^{\varepsilon}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
$\varepsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length conversion matrix
q_1	Trawl survey catchability coefficient
q_2	Longline survey catchability coefficient
SB_y	Spawning biomass in year y, ($=m_a\, w_a\, N_{y,a}$)
M_{prior}	Prior mean for natural mortality
q_{prior}	Prior mean for catchability coefficient
$\sigma_{r(prior)}$	Prior mean for recruitment variance
σ_M^2	Prior CV for natural mortality
σ_q^2	Prior CV for catchability coefficient
$\sigma_{\sigma_r}^2$	Prior CV for recruitment deviations

BOX 1 (Continued)

Equations describing the observed data

$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1-e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$	Catch equation
$\hat{I}_{1y} = q_1 * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$	Trawl survey biomass index (t)
$\hat{I}_{2y} = q_2 \sum_a N_{y,a} * \frac{s_a}{\max(s_a)}$	Longline survey abundance index (RPN)
$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,a'}$	Survey age distribution Proportion at age
$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,l}$	Survey length distribution Proportion at length
$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$	Fishery age composition Proportion at age
$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$	Fishery length composition Proportion at length

Equations describing population dynamics

Start year

$$N_a = \begin{cases} e^{\left(\mu_r + \tau_{styr-a_0-a-1}\right)}, & a = a_0 \\ e^{\left(\mu_r + \tau_{styr-a_0-a-1}\right)} e^{-(a-a_0)M}, & a_0 < a < a_+ \\ \frac{e^{(\mu_r)} e^{-(a-a_0)M}}{\left(1-e^{-M}\right)}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

$$N_{y,a} = \begin{cases} e^{(\mu_r + \tau_y)}, & a = a_0 \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Formulae for likelihood components	**BOX 1 (Continued)**
$L_1 = \lambda_1 \sum_y \left(\ln \left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$	Catch likelihood
$L_2 = \lambda_2 \sum_y \left(\ln I_{1y} - \ln \hat{I}_{1y} \right)^2 / \left(2\sigma_{I_1}^2 \right)$	Trawl survey biomass index likelihood
$L_3 = \lambda_3 \sum_y \left(\ln I_{2y} - \ln \hat{I}_{2y} \right)^2 / \left(2\sigma_{I_2}^2 \right)$	Longline survey abundance index (RPN) likelihood
$L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*{}_y \sum_{l}^{l+} \left(P_{y,l} + 0.001 \right) * \ln \left(\hat{P}_{y,l} + 0.001 \right)$	Fishery length composition likelihood
$L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*{}_y \sum_{a}^{a+} \left(P_{y,a} + 0.001 \right) * \ln \left(\hat{P}_{y,a} + 0.001 \right)$	Trawl survey age composition likelihood
$L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*{}_y \sum_{l}^{l+} \left(P_{y,l} + 0.001 \right) * \ln \left(\hat{P}_{y,l} + 0.001 \right)$	Trawl survey size composition likelihood
$L_7 = \lambda_7 \sum_{styr}^{endyr} -n^*{}_y \sum_{l}^{l+} \left(P_{y,l} + 0.001 \right) * \ln \left(\hat{P}_{y,l} + 0.001 \right)$	Longline survey size composition likelihood
$L_8 = \frac{1}{2\sigma_M^2} \left(\ln M / M_{prior} \right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_9 = \frac{1}{2\sigma_{q_1}^2} \left(\ln q_1 / q_{1\,prior} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for trawl survey
$L_{10} = \frac{1}{2\sigma_{q_2}^2} \left(\ln q_2 / q_{2\,prior} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for longline survey
$L_{11} = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln \sigma_r / \sigma_{r(prior)} \right)^2$	Penalty on deviation from prior distribution of recruitment deviations
$L_{12} = \lambda_{12} \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln(\sigma_r) \right]$	Penalty on recruitment deviations
$L_{13} = \lambda_{13} \sum_y \varepsilon_y^2$	Fishing mortality regularity penalty
$L_{14} = \lambda_{14} \bar{s}^2$	Average selectivity penalty (attempts to keep average selectivity near 1)
$L_{15} = \lambda_{15} \sum_{a_0}^{a_+} \left(s_i - s_{i+1} \right)^2$	Selectivity dome-shapedness penalty – only penalizes when the next age's selectivity is lower than the previous (penalizes a downward selectivity curve at older ages)
$L_{16} = \lambda_{16} \sum_{a_0}^{a_+} \left(FD(FD(s_i - s_{i+1})) \right)^2$	Selectivity regularity penalty (penalizes large deviations from adjacent selectivities by adding the square of second differences)
$L_{total} = \sum_{i=1}^{16} L_i$	Total objective function value

Results

Model Evaluation

The recommended changes to this year's assessment compared to the model used in 2014 were described above in the 'Model Selection' section. In summary, four changes are recommended for this year's assessment: (1) updating growth information to use length-stratified rather than random methods, (2) updating and extending the ageing error matrix, (3) evaluating the trawl survey selectivity, and (4) setting the plus age group. When we present alternative model configurations, our usual criteria for choosing a superior model are: (1) the best overall fit to the data (in terms of negative log-likelihood), (2) biologically reasonable patterns of estimated recruitment, catchabilities, and selectivities, (3) a good visual fit to length and age compositions, and (4) parsimony.

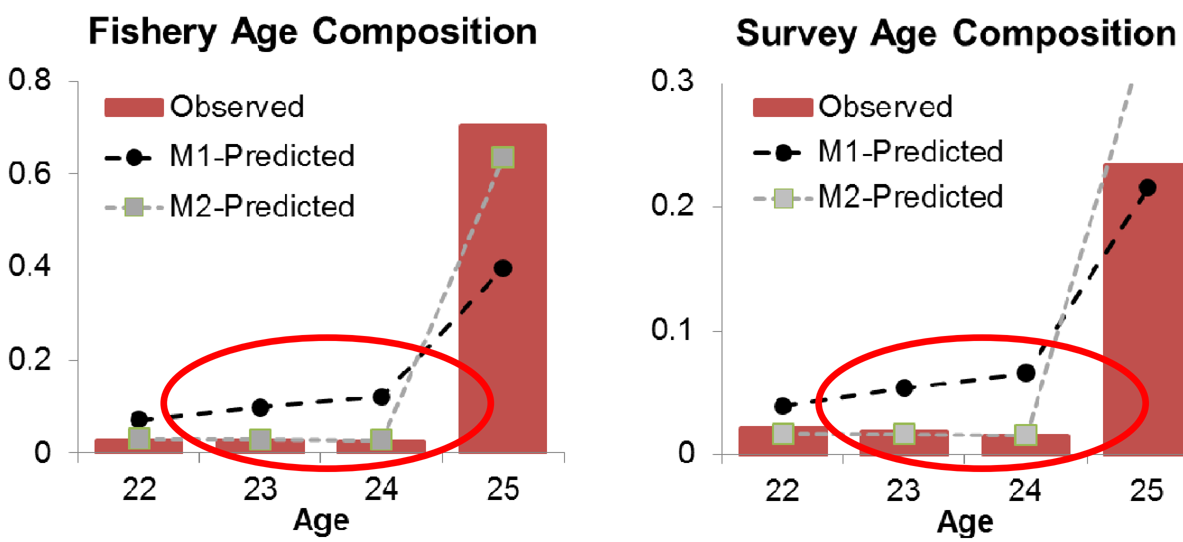
M0 is the last full assessment model from Shotwell et al. (2014b). M1 is the base model M0 with all new and updated data. M2 combines the updated data of M1 with length-stratified growth and the extended ageing error matrix. M3 utilizes the 3rd Diff Max 5 trawl survey selectivity while M4 incorporates the gamma function for trawl survey selectivity. Additional sub-models on M3 and M4 consider plus age groups of 42 and 53 for sub-models *a* and *b*, respectively. Negative log-likelihood and estimates of key parameters over the six presented models are provided in Table 13-15 for comparison. Observed and model predictions for the age and size composition data are provided in Figures 13-8, 13-9, 13-10 and 13-12. AFSC bottom trawl survey size compositions are provided for reference (Figure 13-11). We first present results on model fit and some key comparisons in a stepwise fashion and then continue with several overall comparisons between the different model results.

M1: 2014 model with updated data

The addition of new data to the 2014 model increases the overall objective function as would be expected (Table 13-15). Trawl survey catchability increases while longline survey catchability decreases. Other parameters are all relatively similar to M0, the base model with slight increase in spawning biomass. The lack of fit to the fishery age composition (Figure 13-8a, top graph, black line) or survey age composition (Figure 13-10a, top graph, black line) adjacent to the plus age group (age bins 22-24) remains.

M2: Length-stratified growth and updated ageing error

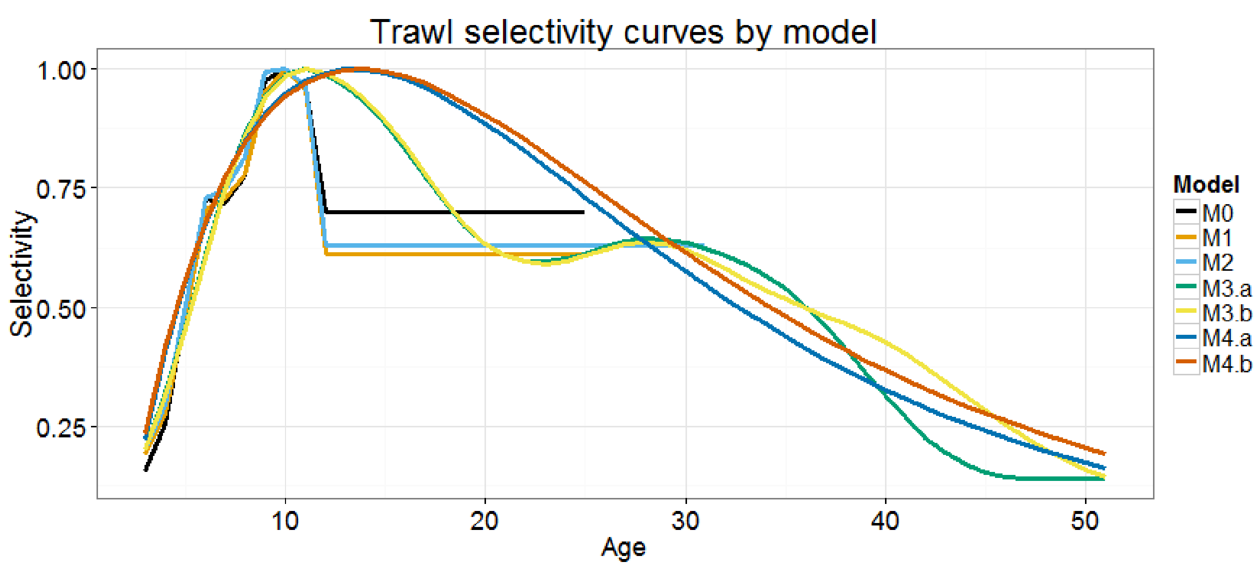
Accounting for the length-stratified growth and updating the ageing error matrix produces a dramatic decrease in the total data negative log-likelihood by about 17%. The shift is particularly obvious in the fit to the fishery ages (Figure 13-8a, top graph, gray line) and also somewhat in the fit to the trawl survey ages (Figure 13-10a, top graph, gray line). The associated reductions in the negative log-likelihood for the fishery and survey ages were 67% and 17%, respectively. There is also some improvement in the fit to the longline survey sizes with a 10% decrease in negative log-likelihood. Fits to the survey indices were fairly similar between M1 and M2, as were the majority of the parameters. A comparison of the average fit to the last four age classes adjacent to the plus age group for both fishery and survey age compositions is provided in the figure below.



The large improvement in the fit to the age composition for both the fishery and survey is primarily due to the improved fit to the age classes adjacent to the plus age group. There is also some improvement to the plus age group fit for the fishery age compositions.

M3 and M4: Trawl survey selectivity and plus age group (sub-models a and b)

The trawl survey selectivity curves for each of the models are presented in the following figure.



The black line is the 2014 model base case (M0) which was non-parametric with penalized second differences out to the plus group age of 25. Model cases M1 and M2 use the same form as the base case but the estimated coefficients were smaller for ages 12 to 25, implying reduced selection of these older ages in the trawl survey. M3 is the most highly parameterized model explored using the 3rd Diff Max 5 selectivity while M4 contains the lowest parameters (2) by using the gamma function. Sub-models with the two plus age groups were nearly identical within the form except for the older ages where the higher flexibility of the 3rd Diff Max 5 selectivity allowed for some differences in the curve.

The negative log-likelihoods cannot be directly compared between models with different plus age groups due to the increase in the estimated recruitment deviations. However, the sub-models with the differing selectivity can be compared and in general the fits are very similar between using a very flexible non-parametric selectivity such as the 3rd Diff Max 5 and the dome-shaped gamma function. There was only a slight difference in fit for the survey age compositions between age classes 9-23 (Figure 13-10a, middle and bottom graphs). Difference in the fit to the fishery or longline sizes was negligible across all models.

Catchability estimates for the trawl survey do increase slightly for the non-parametric selectivity models (M3) while remaining nearly the same for the gamma model with 42 age classes (M4a) and decreasing for the gamma model with the 53 age classes (M4b). Longline catchability stays fairly consistent across all models and is near 1. The natural mortality estimate increased slightly over both selectivity options and plus age groups (M3a, M3b, M4a, M4b). Recruitment variability was slightly lower for both selectivity options and plus age groups (M3a, M3b, M4a, M4b) likely due to the additional initial age composition recruitment deviations. Mean recruitment increases as well but more for the larger plus age group option (M3b, M4b).

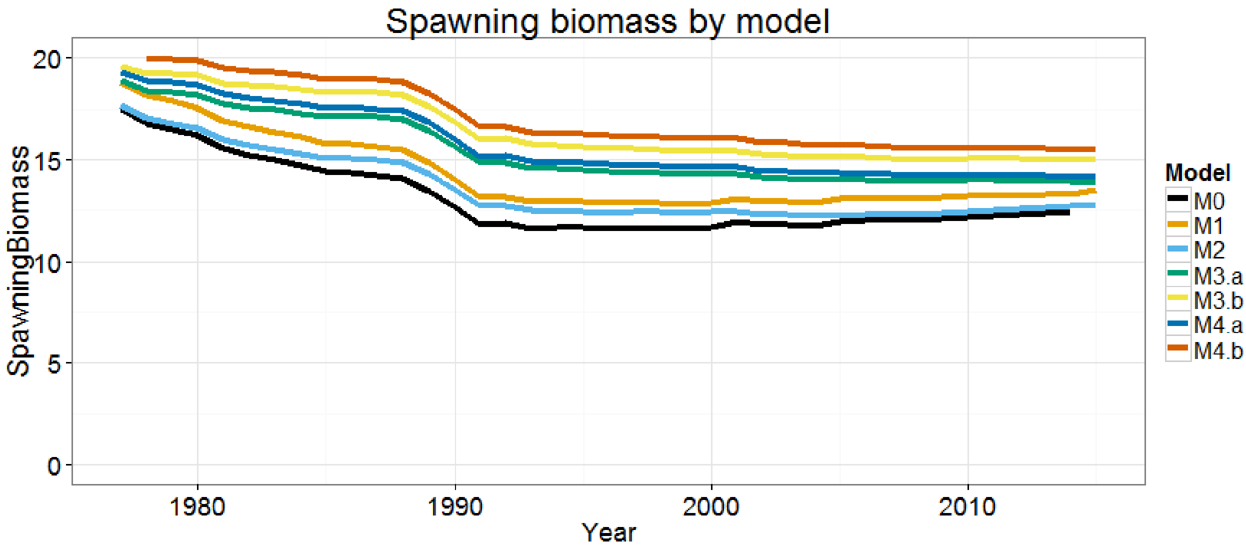
All model comparisons

There is some lack of fit for the fishery age compositions between ages 15 and 20 and for some years in the plus age group (Figure 13-8a,b). Fit to the fishery size compositions are slightly flattened (Figure 13-9) particularly in 1991. This may be due to the slight right or left skew in most years. Fit to the bottom trawl survey age compositions are generally very good with some underestimation for the large composition ages such as that of the 1990 year class (Figure 13-10a,b). Fit to the longline survey size compositions are similar to the fishery size compositions with slightly flattened peaks in most years (Figure 13-12). The model does not fit the relatively large composition of size 26 cm fish in 2014.

The consistent patterns of positive residuals in the fishery and longline survey size compositions could be due to a variety of confounding issues between selectivity, growth, and ageing. In the future we may consider applying different shaped selectivity curves or explore separate selectivity curves for trawl and longline fisheries. Additionally, we may experiment with increasing the age classes for the fishery data separately from the trawl survey to further reduce the proportion in the plus age group. However, as more age classes are added, the sample size within each age class is further reduced and increases the potential for more age classes with zero samples.

In general, fits to the bottom trawl survey biomass and longline survey relative population numbers (RPN) were fairly consistent across all models over time. Models with the different trawl survey selectivity options (M3 and M4) produced only slightly higher estimates in the earlier part of the time series (Figure 13-2a). Conversely, models with only the updated data or the growth and ageing error adjustments (M1 and M2) produced slightly higher estimates for RPN in recent years (Figure 13-3a).

Total and spawning biomass (kt) for all models with associated error estimates are provided in Figures 13-13a and 13-14a for comparison purposes; however, due to the relatively large upper error bound it is difficult to see the differences between models. We provide the following figure without error bounds so that the different spawning biomass trajectories can be visualized.



The trajectory of spawning biomass was similar across models; however, the magnitude shifted upward as the model changes were implemented. New data added to the model shifted the total by about 9% on average (M1 versus M0). Updating the growth and ageing error matrix (M2) had little influence on the estimates of spawning biomass compared to the base model (M0). Spawning biomass was higher for all models exploring different trawl survey selectivity forms (M3 and M4), but the change decreased toward the end of the time series. Sub-models using the plus age group of 42 (M3a, M4a) were nearly identical and models using the plus age group of 53 (M3b, M4b) had the highest increase in spawning biomass over time (27% to 32% on average).

In the second report from the Retrospective Working Group (Hanselman et al. 2013), GOA RE/BS rockfish exhibited a fairly strong retrospective pattern and was ranked fifth among all Alaska stocks. The results of this report were based on the RE/BS 2011 author recommended model and produced a Mohn's revised ρ of 0.34 and a Wood's Hole ρ of 0.25. We examined these two statistics across all models and provide the results in the following table.

Statistic	M1	M2	M3a	M3b	M4a	M4b
Mohn's revised ρ	-0.615	-0.581	-0.404	-0.350	-0.371	-0.330
Wood's Hole ρ	-0.496	-0.461	-0.336	-0.288	-0.274	-0.244

With the addition of new data the retrospective pattern has increased dramatically (M1). However, the magnitude decreases for each sequential model case and is lowest for the gamma function with the larger plus age group (M4b). The Wood's hole ρ follows a similar pattern an indicates that there is a retrospective trend throughout the time series, but less than last 10 years. These retrospective statistics still are undesirably large, but the lack of contrast in the catch and biomass time series makes estimating scale challenging in these models.

Given that the fit is greatly improved in the fishery and trawl survey age compositions when going from M1 to M2, we recommend utilizing the length-stratified methods for growth and the ageing error update. Also since the overall data fit is similar for either selectivity option or plus age group, we prefer the most parsimonious model that uses the gamma function with a plus age group of 42. This model achieves a similar fit to the data with approximately 43 less parameters than the more flexible M3a model and has similar management results. There is also not much improvement in fit to the fishery age data with the addition of more age classes in the M4b model, even though 14 more parameters were estimated. Therefore, we recommend M4a to update management quantities for 2016. We discuss results of this model in the following section. Estimated numbers in 2015, fishery selectivity, trawl and longline survey selectivity and schedules of age specific weight and female maturity are provided in Table 13-16 for reference based on this author preferred model.

Time Series Results

Table 13-15 provides parameter estimates for all six models for comparison purposes. Tables 13-16 through 13-19 summarize other results for the 2015 author preferred model (M4a).

Definitions

Spawning biomass is the biomass estimate of mature females. Total biomass is the biomass estimate of all rougheye/blackspotted rockfish age three and greater. Recruitment is measured as number of age three RE/BS rockfish. Fishing mortality is fully-selected F, meaning the mortality at the age the fishery has fully selected the fish.

Total and spawning biomass for the author preferred model (M4a) compared to base model (M0) was higher for the entire time series (Figure 13-13b, Figure 13-14b). Recruitment was generally similar between the preferred model and the base model except in 1980, 1981, 1994, and in recent years (Table 13-18). This is likely due to the additional initial age composition and potentially differences between the two survey trajectories. Projected total and spawning biomass decreased, while recruitment increases slightly. Estimates continue to track the influx of new recruits from the early 2000s; however, the new bump in recruits at age 3 in the 2013 survey is not well captured (Figure 13-10). This may change when more information becomes available on this year class in subsequent surveys. Catchability, selectivity, and recruitment are all somewhat confounded within the model. As the surveys estimate fewer fish, and age compositions suggest less recruitment, catchability estimates tend to increase so that large swings in biomass do not occur. This seems reasonable for long-lived fish such as RE/BS rockfish.

Biomass and Exploitation Trends

Predicted values for the bottom trawl survey were relatively steady over time (similar to the base model M0) and a slight decrease over the past six longline survey estimates compared to the base model (Figures 13-2b, 13-3b). Predicted values for the trawl survey do not capture the recent low 2013 estimate and predicted values for the longline survey do not capture the fluctuating high and low spikes since 1997. Average longline RPNs surrounding these years combined with corresponding average trawl survey biomass estimates likely restrict the model from large swings in predictions for either survey.

Estimates of total biomass are relatively steady, decreasing slightly from the beginning of the time series until 1991 and then stable to the most current estimate (Figure 13-13b). Spawning biomass estimates are very similar to total biomass with a slightly steeper decreasing slope to 1991 and again stable to the present (Figure 13-14b). Fairly wide credible intervals result from the MCMC simulation for biomass estimates, with slight decreasing certainty in the more recent estimates. These intervals are somewhat wider for the time series than in last year's assessment, particularly for the upper interval. We show the estimated selectivity curves for both the base M0 model and the author preferred model for comparison (Figure 13-15). Estimated selectivity curves for the fishery and longline were similar to expected and the new gamma function allows for a more realistic dome-shape of the trawl survey (Figure 13-15b). The commercial fishery should target larger and subsequently older fish and the trawl survey should sample a larger range of ages. The longline survey samples deeper depths and small fish are not susceptible to the gear. The fishery selectivity curve is similar to the longline selectivity curve with a steeper knife-edge at about 15 years. This is expected as the fish caught in the fishery are slightly larger on average than the fish caught on the longline survey. The trawl survey is dome-shaped for older fish since adult habitat is typically in rocky areas along the shelf break where the trawl survey gear may have difficulty sampling.

Fully selected fishing mortality increased in the late 1980s and early 1990s due to the high levels of estimated catch and returned to relatively low levels from 1993 to present (Figure 13-16). The spike may be due to the management of rougheye/blackspotted rockfish in the slope rockfish complex prior to 1991 and the disproportionate harvest on shortraker due to their high value. Rougheye would also be caught as they often co-occur with shortraker. In general, fishing mortality is relatively low because historically most of the available TAC has not been caught. There has been a slight increase in fishing mortality in the most recent years.

Goodman et al. (2002) suggested that stock assessment authors use a "management path" graph as a way to evaluate management and assessment performance over time. We present a similar graph termed a phase plane which plots the ratio of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to $B_{35\%}$. Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The phase for RE/BS rockfish has been above the F_{OFL} adjusted limit for only three years in the late 1980s and 1990 (Figure 13-17). Since 1990, spawning biomass of RE/BS rockfish has been above $B_{40\%}$ and fishing mortality has been below $F_{40\%}$.

Recruitment

MCMC credible intervals (CI) for recruitment have continued to narrow with the addition of more age data (Figure 13-18). This is particularly true for the 1990 year class, which exists as a large proportion in the age compositions. In general, though recruitment is highly variable, particularly in the most recent years where very little information exists on this part of the population. There also does not seem to be a clear spawner-recruit relationship for RE/BS rockfish as recruitment is apparently unrelated to spawning stock biomass and there is little contrast in spawning stock biomass (Figure 13-5).

Uncertainty

From the MCMC chains described previously, we summarize the posterior densities of key parameters for the author recommended model using histograms (Figure 13-19) and credible intervals (Table 13-17). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass and recruitment (Figures 13-13, 13-14, 13-18, Table 13-19).

Table 13-17 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviation derived from the Hessian matrix. Also shown are the MCMC standard deviation and the corresponding Bayesian 95% credible intervals (BCI). The MLE and MCMC standard deviations are similar for q_1 (trawl survey catchability), q_2 (longline survey catchability), and M, but the MCMC standard deviations are larger for the estimates of projected female spawning biomass, and ABC, and σ_r (recruitment deviation). The larger standard deviations indicate that these parameters are more uncertain than indicated by the standard modeling, especially in the case of σ_r in which the MLE estimate is slightly out of the Bayesian credible intervals. This highlights a concern that σ_r requires a fairly informative prior distribution since it is confounded with available data on recruitment variability. To illustrate this problem, imagine a stock that truly has variable recruitment. If this stock lacks age data (or the data are very noisy), then the modal estimate of σ_r is near zero. As an alternative, we could run sensitivity analyses to determine an optimum value for σ_r and fix it at that value instead of estimating it within the model. In contrast the Hessian standard deviation was larger for the estimate of q_1 (trawl survey catchability), which may imply that this parameter is well estimated in the model. This is possibly due to the increased age bins. The MCMC distribution of ABC, current total biomass, and current spawning biomass are skewed (Figure 13-19) indicating potential for higher biomass estimates (see also Figure 13-13 and Figure 13-14).

Retrospective Analysis

A within-model retrospective analysis of the preferred model was conducted for the last 10 years of the time-series by dropping data one year at a time. The revised Mohn's "rho" statistic (indicates size and direction of bias, Hanselman et al. 2013) in female spawning biomass was -0.371, indicating that the model decreases the estimate of female spawning biomass in the retrospective model's terminal year as data is added to the assessment. The retrospective female spawning biomass and the relative difference in female spawning biomass from the 2014 model are shown in Figure 13-20.

The RE/BS model is exhibiting a relatively strong retrospective pattern. The 2015 value of the revised Mohn's "rho" statistic was similar to the value of 0.34 in Hanselman et al. (2013) which ranked GOA RE/BS rockfish as the 5th strongest retrospective of the 20 stocks investigated. We examined fixing natural mortality and catchability because of the scale changes between retrospective peels for serial retrospective trends, and these only reduced some of the retrospective trend. Recruitment estimates appear to have little obvious trend over time fluctuating somewhat around average recruitment (Figure 13-21).

Harvest Recommendations

Amendment 56 to the GOA Groundfish Fishery Management Plan defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, rougheye and blackspotted rockfish in the GOA are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing.

Estimation of the $B_{40\%}$ reference point requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the average of age 3 recruits from 1980-2013 (i.e. the 1977-2010 year classes). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. The 2015 estimates of these reference points are in the following table. Biomass estimates are for female spawning biomass.

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
20,566 (t)	8,226 (t)	7,198 (t)	0.040	0.048

Specification of OFL and Maximum Permissible ABC

Estimated female spawning biomass for 2016 is 13,804 t. This is above the $B_{40\%}$ value of 8,226 t. Under Amendment 56, Tier 3, the maximum permissible fishing mortality for *ABC* is $F_{40\%}$ and fishing mortality for *OFL* is $F_{35\%}$. Applying these fishing mortality rates for 2016 yields the following *ABC* and *OFL*:

$F_{40\%}$	0.040
ABC (t)	1,328
$F_{35\%}$	0.048
OFL (t)	1,596

Population Projections

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

For each scenario, the projections begin with the vector of 2015 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2016 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2015. 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 after 2015 is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 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 2016, 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 2016 and 2017, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the realized catches in 2012-2014 to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio of F will yield more realistic projections.)

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 2010-2014 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 2015 or 2) above ½ of its MSY level in 2015 and above its MSY level in 2025 under this scenario, then the stock is not overfished.)

Scenario 7: In 2016 and 2017, 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 1) above its MSY level in 2017 or 2) above ½ of its MSY level in 2017 and expected to be above its MSY level in 2027 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios (Table 13-20). The difference for this assessment for projections is in Scenario 2 (Author's F); we use pre-specified catches to increase accuracy of short-term projections in fisheries (such as rougheye and blackspotted) where the catch is usually less than the ABC. This was suggested to help management with setting preliminary ABCs and OFLs for two year ahead specifications. The methodology for determining these pre-specified catches is described below in *Specified Catch Estimation*.

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 2016, it does not provide the best estimate of OFL for 2017, because the mean 2016 catch under Scenario 6 is predicated on the 2016 catch being equal to the 2016 OFL, whereas the actual 2016 catch will likely be less than the 2016 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 catch estimate for the most recent complete year (2014) is 738 t. This is less than the 2014 OFL of 1,497 t. Therefore, the stock is not being subjected to overfishing.

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

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2015:

a) If spawning biomass for 2015 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2015 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c) If spawning biomass for 2015 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 13-20). If the mean spawning biomass for 2025 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

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

a) If the mean spawning biomass for 2017 is below ½ $B_{35\%}$, 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 ½ $B_{35\%}$ 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.

Based on the above criteria and Table 13-20, the stock is not overfished and is not approaching an overfished condition.

Specified Catch Estimation

In response to Gulf of Alaska Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. In the past, two standard approaches in rockfish models have been employed; assume the full TAC will be taken, or use a certain date prior to publication of assessments as a final estimate of catch for that year. Both methods have disadvantages. If the author assumes the full TAC is taken every year, but it rarely is, the ABC will consistently be underestimated. Conversely, if the author assumes that the catch taken by around October is the final catch, and substantial catch is taken thereafter, ABC will consistently be overestimated. Therefore, going forward in the Gulf of Alaska rockfish assessments, for current year catch, we are using an expansion factor to the catch in early October by the 3-year average of catch taken between October 1 and December 31 in the last three complete catch years (e.g. 2012-2014 for this year, see example figures below). For rougheye and blackspotted rockfish, the expansion factor for 2015 catch is 1.031.

For catch projections into the next two years, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, based on both the lower catch in the first year out, and based on the amount of catch taken before spawning in the projection two years out. To estimate future catches, we updated the yield ratio (0.53), which was the average of the ratio of catch to ABC for the last three complete catch years (2012-2014). This yield ratio was multiplied by the projected ABCs for 2016 and 2017 from the assessment model to generate catches for those years.

Alternative Projection

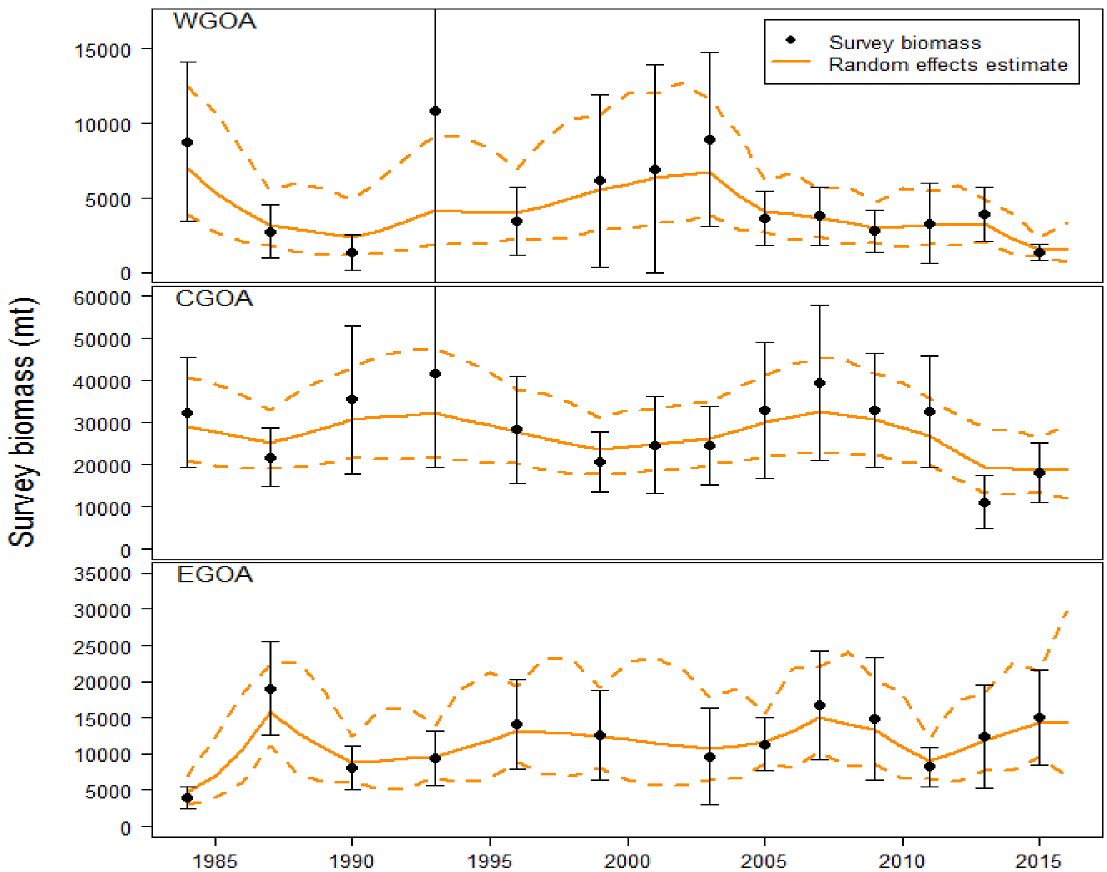
During the 2006 CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. We continue to present an alternative projection scenario using the uncertainty of the full assessment model, harvesting at author's F (0.3 maximum permissible based on recent ratios of catch to ABC). This is conservative relative to a max ABC or alternative 1 projection scenario. This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 20,000,000. The projection shows wide credibility intervals on future spawning biomass (Figure 13-22). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1980-2013 age-3 recruitments, and this projection predicts that the median spawning biomass is well above these reference points for the entire time series and will steadily increase as average recruitment is consistently applied and the very low proportion of ABC is taken (0.53).

Area Allocation of Harvests

We determine apportionment of ABC among areas utilizing a method that was recommended by the Plan Team and accepted by the Council in 1996. This method weights prior surveys based on the relative proportion of variability attributed to survey error. Assuming that survey error contributes 2/3rd of the total variability in predicting the distribution of biomass (a reasonable assumption), the weight of a prior survey should be 2/3rd the weight of the preceding survey. This resulted in weights of 4:6:9 for the 2011, 2013, and 2015 surveys, respectively and apportionments for rougheye and blackspotted rockfish of 7.9% for the western area, 53.2% for the central area, and 38.9% for the eastern area (Table 13-21). This represents a 23% decrease in the western area to an approximate 6% decrease in the central and a 16%

increase in the eastern areas from the 2014 apportionments (10.3% for the Western area, 56.3% for the Central area, and 33.4% for the Eastern area).

The Plan Team and SSC requested that the random effects model recommended by the Survey Averaging Working Group and Plan Teams be used as the default method for apportionment. The random effects model was fit to the survey biomass estimates (with associated variance) for the Western, Central, and Eastern Gulf of Alaska. The random effects model estimates a process error parameter (constraining the variability of the modeled estimates among years) and random effects parameters in each year modeled. The fit of the random effects model to survey biomass in each area is shown in the figure below. For illustration purposes the 95% confidence intervals are shown for the survey biomass (error bars) and the random effects estimates of survey biomass (dashed lines).



In general the random effects model fits the area-specific survey biomass reasonably well. We used the random effects estimates of ending year biomass to determine the apportionment results as 4.5% for the Western area, 54.2% for the Central area, and 41.3% for the Eastern area. This is somewhat similar to the results from the updated 4:6:9 survey average weighting method with the exception that the low western GOA 2015 biomass estimate is highly influential. This results in a recommended 56% reduction in the western GOA apportionment and an additional increase in the eastern GOA apportionment.

We recommend continuing with the status quo (three survey weighted average) apportionment for RE/BS rockfish at this time. The assessment model utilizes both trawl and longline survey data to overcome sampling issues of each survey for the RE/BS rockfish population. In general, the trawl survey samples more of the continental shelf than the longline survey due to differences in survey design. The trawl survey also tends to catch more RE/BS rockfish in the central GOA, while the longline survey catches more RE/BS rockfish in the eastern and western GOA. This can be seen in the recent trawl versus longline survey comparison maps (Figure 13-4a). Sampling error also differs by region and survey (Table 13-10, 13-13). On average there is higher sampling error in the eastern GOA for the trawl survey and lower sampling error in this region for the longline survey. The reverse is true in recent years for the western GOA with low sampling error in the trawl survey and high sampling error in the longline survey. The random effects model does not currently allow for inclusion of more than one survey index; however, this option is planned for future versions of the model. Rather than switching the apportionment scheme several times, we prefer to shift to a new method when the two survey option has been vetted and becomes available. Using both survey indices for apportionment should provide for a better reflection of the RE/BS spatial population structure over either the status quo three survey average or the current one survey index random effects model. In addition, using two indices will likely result in less variation in apportionment due solely to sampling variability.

The following table shows the apportionment for the 2016 and 2017 fishery when applying the percentages using the three survey weighted average and random effects methods to the ABC for RE/BS rockfish (1,328 t):

Method	Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
Three Survey Weighted Average			7.9%	53.2%	38.9%	100%
	2016	Area ABC (t)	**105**	**707**	**516**	**1,328**
		OFL (t)				**1,596**
	2017	Area ABC (t)	**105**	**705**	**515**	**1,325**
		OFL (t)				**1,592**
Random Effects			4.5%	54.2%	41.3%	100%
	2016	Area ABC (t)	**60**	**719**	**549**	**1,328**
		OFL (t)				**1,596**
	2017	Area ABC (t)	**60**	**717**	**548**	**1,325**
		OFL (t)				**1,592**

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.048), overfishing is set equal to 1,596 t in 2016 and 1,592 t in 2017 for rougheye and blackspotted rockfish.

Ecosystem Considerations

In general, a determination of ecosystem considerations for the rougheye/blackspotted rockfish complex is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 13-22.

Ecosystem Effects on the Stock

Prey availability/abundance trends: similar to many other rockfish species, stock condition of rougheye/blackspotted rockfish appears to be influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval rockfish may be an important determining factor of year class strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and year class strength; moreover, identification to the species level for field collected larval RE/BS rockfish is difficult. Visual identification is not possible though genetic techniques allow identification to species level for larval RE/BS rockfish (Gharrett et. al 2001). Food habit studies in Alaska indicate that the diet of RE/BS rockfish is primarily shrimp (especially pandalids) and that various fish species such as myctophids are also consumed (Yang and Nelson 2000, Yang 2003). Juvenile RE/BS rockfish in the GOA also consume a substantial amount of smaller invertebrates such as amphipods, mysids, and isopods (Yang and Nelson 2000). Recent food studies show the most common prey of RE/BS as pandalid shrimp, euphausiids, and tanner crab (*Chionoecetes bairdi*). Other prey include octopi and copepods (Yang et al. 2006). Little if anything is known about abundance trends of likely rockfish prey items.

Predator population trends: Rockfish are preyed on by a variety of other fish at all life stages and to some extent marine mammals during late juvenile and adult stages. Likely predators of RE/BS rockfish likely include halibut, Pacific cod, and sablefish. Whether the impact of any particular predator is significant or dominant is unknown. Predator effects would likely be more important on larval, post-larval, and small juvenile rockfish, but information on these life stages and their predators is unknown.

Changes in physical environment: Strong year classes corresponding to the period around 1976-77 have been reported for many species of groundfish in the Gulf of Alaska, including Pacific ocean perch, northern rockfish, sablefish, and Pacific cod. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including RE/BS rockfish. The environmental mechanism for this increased survival remains unknown. Changes in water temperature and currents could have effect on prey item abundance and success of transition of rockfish from pelagic to demersal stage. Rockfish in early juvenile stage have been found in floating kelp patches which would be subject to ocean currents.

Anthropogenic causes of changes in physical environment: Bottom habitat changes from effect of various fisheries could alter survival rates by altering available shelter, prey, or other functions. The Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of groundfish are minimal or temporary. The steady trend in abundance of rougheye and blackspotted rockfish suggests that at current abundance and exploitation levels, habitat effects from fishing are not limiting this stock.

There is little information on when juvenile fish become demersal. Juvenile RE/BS rockfish 6 to 16 inches (15 to 40 cm) fork length have been frequently taken in Gulf of Alaska bottom trawl surveys, implying the use of low relief, trawlable bottom substrates (Clausen et al. 2003). They are generally found at shallower, more inshore areas than adults and have been taken in a variety of locations, ranging from inshore fiords to offshore waters of the continental shelf. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981, Straty 1987). Another submersible study on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). Although these studies did not specifically identify rougheye or blackspotted rockfish, it is reasonable to suspect that juvenile rougheye and blackspotted rockfish may be among the species that utilize this habitat as refuge during their juvenile stage.

Fishery Effects on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the Gulf of Alaska, bottom trawl fisheries for RE/BS rockfish account for very little bycatch of HAPC biota. This low bycatch may be explained by the fact that these fish are taken as bycatch or topping off in fisheries classified as targeting other species, thus any bycatch is attributed to other target species.

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: Unknown

Fishery-specific effects on amount of large size target fish: Unknown

Fishery contribution to discards and offal production: Fishery discard rates during 2005-2015 have been 15-36% for the RE/BS rockfish stock complex.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: Unknown.
Fishery-specific effects on EFH living and non-living substrate: unknown, but the heavy-duty "rockhopper" trawl gear commonly used in the fishery can move around rocks and boulders on the bottom. Table 13-6 shows the estimated bycatch of living structure such as benthic urochordates, corals, sponges, sea pens, and sea anemones by the GOA rockfish fisheries.

Data Gaps and Research Priorities

Future assessment priorities include 1) a synthesis of previous studies on rockfish catchability using submersibles to develop informative prior distributions on catchability, 2) assessment of RE/BS rockfish density between trawlable and untrawlable grounds, 3) analyses of fishery spatial patterns and behavior given the observer restructuring, and 5) examining potential age and growth differences between RE/BS rockfish to potentially develop species-specific life history parameters for this two-species complex.

There is little information on early life history of rougheye and blackspotted rockfish. Recruitment processes influencing the early life stages or habitat requirements for all stages are mostly unknown. A better understanding of early life stage distribution, habitat utilization, and species interactions would improve understanding of the processes that determine the productivity of the stock. Better estimation of recruitment and year class strength would improve assessment and management of the RE/BS population.

We also hope to collect and age subsamples of rougheye otoliths from the longline survey for future use in the stock assessment model. Additional analyses may then include implications of sampling methodology and comparisons between trawl and longline survey age and length compositions.

The Essential Fish Habitat 5-year Update will begin in 2016 and new habitat suitability models will be distributed on all life history stages for FMP species where data were available. Following evaluation of this information for RE/BS rockfish, we plan to include the new EFH model results and maps in future assessments. A newly revamped species-specific ecosystem consideration (SEC) protocol is also planned to be introduced over the next several years. The SECs will likely replace the Ecosystem Consideration section of the single-species assessment reports and include updated species profiles, climate vulnerability analyses, and stock/habitat prioritization information. The intention of these SECs is to improve the process of integrating ecosystem information into the stock assessments and facilitate ecosystem based fishery management.

A summary of the primary reference values (i.e. biomass levels, exploitation rates, recommended ABCs and OFLs) for RE/BS rockfish are provided in the following table. Recommended values are in bold.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:*	
	2015	2016	2016	2017
M (natural mortality rate)	0.034	0.034	0.036	0.036
Tier	3a	3a	3a	3a
Projected total (ages 3+) biomass (t)	36,584	36,610	41,864	41,597
Projected female spawning biomass (t)	12,480	12,595	13,804	13,733
$B_{100\%}$	22,449	22,449	20,566	20,566
$B_{40\%}$	8,980	8,980	8,226	8,226
$B_{35\%}$	7,857	7,857	7,198	7,198
F_{OFL}	0.045	0.045	0.048	0.048
$maxF_{ABC}$	0.038	0.038	0.040	0.040
F_{ABC}	0.038	0.038	0.040	0.040
OFL (t)	**1,345**	1,370	**1,596**	1,592
maxABC (t)	1,122	1,142	1,328	1,325
ABC (t)	**1,122**	1,142	**1,328**	1,325
Status	As determined *last* year for:		As determined *this* year for:	
	2013	2014	2014	2015
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projected ABCs and OFLs for 2016 and 2017 are derived using estimated catch of 530 t for 2015 and projected catches of 700 t for 2016 and 686 t for 2017 based on realized catches from 2012-2014. This calculation is in response to management requests to obtain more accurate projections.

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Table 13-1: Summary of available data on stock structure for GOA RE/BS rockfish.

Factor and criterion	Available information
Harvest and trends	
Fishing mortality (5-year average percent of F_{ABC})	Recent catch in the Western GOA are near F_{ABC}, and far below F_{ABC} in the Central and Eastern GOA
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	Catches are distributed similarly to survey abundance, except for a potential nursery area in Amatuli Gully region
Population trends (Different areas show different trend directions)	Population trend is stable for overall Gulf of Alaska, declining toward the Western GOA, and increasing toward the Eastern GOA
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	The generation time is > 19 years
Physical limitations (Clear physical inhibitors to movement)	No known physical barriers; predominant current patterns move from east to west, potential restriction in gullies and canyons
Growth differences (Significantly different LAA, WAA, or LW parameters)	Significantly different growth curves and length-at-age relationships between the Western GOA, Central GOA, and Eastern GOA.
Age/size-structure (Significantly different size/age compositions)	Mean length is significantly higher in WGOA, mean age is significantly higher in WGOA
Spawning time differences (Significantly different mean time of spawning)	Unknown
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Unknown
Morphometrics (Field identifiable characters)	Unknown within species, hypothesized pigmentation differences between species (Gharrett et al. 2006, Orr and Hawkins 2008)
Meristics (Minimally overlapping differences in counts)	Unknown within species, significantly different means of dorsal spines and gill rakers (Gharrett et al. 2006)
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Unknown
Mark-recapture data (Tagging data may show limited movement)	Mark-recapture data not available, but potential to reduce barotrauma with new pressure tanks
Natural tags (Acquired tags may show movement smaller than management areas)	Parasite analysis shows structure by INPFC management area and between species (Moles et al. 1998, Hawkins et al. 2005)
Genetics	
Isolation by distance (Significant regression)	No significant isolation by distance for Type I or Type II rougheye (likely blackspotted and rougheye, respectively) (Gharrett et al. 2007)
Dispersal distance (<<Management areas)	Low, but significant F_{st} for both types indicates some limits to dispersal (Gharrett et al. 2007)
Pairwise genetic differences (Significant differences between geographically distinct collections)	Adjacency analysis suggests genetic structure on scale of INPFC management areas for Type I (blackspotted) and potentially finer scale structure for Type II (rougheye) (Gharrett et al. 2007)

Table 13-2. Estimated commercial catch[a] (t) for GOA RE/BS rockfish (1977-2014), with Gulf-wide values of acceptable biological catch (ABC) and fishing quotas[b] (t), 1991-2014. Catch is provided through the most recent full year estimate.

Year	Catch (t)				OFL	ABC	TAC
	Commercial	Western GOA	Central GOA	Eastern GOA			
1977	1443						
1978	568						
1979	645						
1980	1353						
1981	719						
1982	569						
1983	628						
1984	760						
1985	130						
1986	438						
1987	525						
1988	1621						
1989	2185						
1990	2418						
1991	350					2,000	2,000
1992	1127					1,960	1,960
1993	583					1,960	1,764
1994	579					1,960	1,960
1995	704					1,910	1,910
1996	558					1,910	1,910
1997	545					1,590	1,590
1998	665					1,590	1,590
1999	320					1,590	1,590
2000	530					1,730	1,730
2001	591					1,730	1,730
2002	273					1,620	1,620
2003	394					1,620	1,620
2004	301					1,318	1,318
2005	294	53	126	115	1,531	1,007	1,007
2006	372	58	141	172	1,180	983	983
2007	440	71	195	174	1,148	988	988
2008	382	75	190	117	1,548	1,286	1,286
2009	275	76	98	100	1,545	1,284	1,284
2010	426	86	213	127	1,568	1,302	1,302
2011	541	26	368	148	1,579	1,312	1,312
2012	568	28	371	168	1,472	1,223	1,223
2013	575	15	384	176	1,482	1,232	1,232
2014	738	25	540	173	1,497	1,244	1,244

[a]Catch defined as follows: 1977-1992 from Soh (1998), 1993-2004 from observer program, 2005-present from NMFS AKRO Catch Accounting System via Alaska Fisheries Information Network (AKFIN, www.akfin.org).

[b]ABC and TAC were available for the shortraker/rougheye rockfish complex from 1991-2004 (gray shade). Separate catch accounting were established for GOA RE/BS rockfish since 2005.

Table 13-3. History of management measures with associated time series of catch, ABC, and TAC for GOA RE/BS rockfish.

Year	Catch (t)*	ABC	TAC	Management Measures
1988	1,621	16,800	16,800	The slope rockfish assemblage, including rougheye, is one of three management groups for Sebastes implemented by the North Pacific Management Council. Previously, Sebastes in Alaska were managed as “Pacific ocean perch complex” (rougheye included) or “other rockfish”
1989	2,185	20,000	20,000	
1990	2,418	17,700	17,700	
1991	350	2,000	2,000	Slope assemblage split into three management subgroups with separate ABCs and TACs: Pacific ocean perch, shortraker/rougheye rockfish, and all other slope species
1992	1,127	1,960	1,960	
1993	583	1,960	1,764	
1994	579	1,960	1,960	
1995	704	1,910	1,910	
1996	558	1,910	1,910	
1997	545	1,590	1,590	
1998	665	1,590	1,590	
1999	320	1,590	1,590	Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	530	1,730	1,730	Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	591	1,730	1,730	
2002	273	1,620	1,620	
2003	394	1,620	1,620	
2004	301	1,318	1,318	Shortraker and rougheye rockfish divided into separate subgroups and assigned individual ABCs and TACs
2005	294	1,007	1,007	Rougheye managed separately from shortraker as age structured model accepted to determine ABC and moved to Tier 3 status
2006	372	983	983	
2007	440	988	988	Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	382	1,286	1,286	Rougheye and blackspotted formally verified as separate species so assessment now called the rougheye/blackspotted rockfish complex
2009	275	1,284	1,284	
2010	426	1,302	1,302	
2011	541	1,312	1,312	Rockfish Program continues from pilot initiative
2012	568	1,223	1,223	
2013	575	1,232	1,232	
2014	738	1,244	1,244	

*Catch since 2005 of RE/BS rockfish is provided through the most recent full year estimate. Source: NMFS Alaska Region (AKRO) Catch Accounting System via Alaska Fisheries Information Network (AKFIN) database (http://www.akfin.org/).

Table 13-4. Catch (t) of RE/BS rockfish as bycatch in other fisheries from 2005 - present. Other fisheries category not included due to confidentiality (# vessels or # processors is fewer than or equal to 2). Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/24/2015.

Year	Flatfish	Halibut	P. Cod	Pollock	Rockfish	Sablefish
2005	15	36	1	16	106	119
2006	40	46	2	23	83	179
2007	90	64	1	28	114	144
2008	57	55	9	41	104	115
2009	34	40	6	11	97	86
2010	64	42	6	30	183	103
2011	64	33	2	34	287	121
2012	122	26	4	21	219	177
2013	49	33	1	6	274	211
2014	154	32	4	22	359	167
2015	72	39	3	11	223	176
Average	69	41	4	22	186	145

Table 13-5. Incidental catch of FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2011 - 2015. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/15/2015.

Group Name	2011	2012	2013	2014	2015	Average
Pacific Ocean Perch	13,120	13,953	11,555	15,283	15,895	13,961
Northern Rockfish	3,164	4,883	4,527	3,650	3,600	3,965
Dusky Rockfish	2,315	3,642	2,870	2,752	2,480	2,812
Arrowtooth Flounder	340	764	766	1,425	1,370	933
Walleye Pollock	813	574	829	1,339	1,022	915
Atka Mackerel	1,404	1,173	1,162	446	973	1,032
Pacific cod	560	404	584	624	763	587
Harlequin Rockfish	350	603	305	437	565	452
Sablefish	440	470	495	527	410	468
Shortraker Rockfish	239	303	290	243	237	262
Rougheye Rockfish	286	219	274	359	223	272
Thornyhead Rockfish	161	130	104	243	216	171
Rex Sole	51	72	89	84	115	82
Yelloweye Rockfish	69	188	179	86	113	127
Sharpchin Rockfish	112	82	45	93	96	86
Flathead Sole	13	16	25	30	44	26
Sculpin	39	55	70	33	43	48
Redstripe Rockfish	67	54	22	70	42	51
Dover Sole	15	37	24	30	33	28
Longnose Skate	25	23	23	26	31	26
Silvergray Rockfish	57	28	14	25	30	31
Rock Sole	44	61	26	28	26	37
Redbanded Rockfish	25	14	14	31	24	22
Majestic Squid	12	15	10	19	23	16
Skate, Other	14	14	18	36	22	21

Table 13-6. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2011 - 2015. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/15/2015.

Group Name	2011	2012	2013	2014	2015
Benthic urochordata	Conf.	Conf.	Conf.	Conf.	Conf.
Birds	27	60.	Conf.	20	Conf.
Bivalves	0.01	0.01	Conf.	0.01	Conf.
Brittle star unidentified	0.01	0.04	0.02	0.05	0.06
Capelin	-	-	0.02	-	-
Corals Bryozoans	0.11	Conf.	Conf.	Conf.	Conf.
Dark Rockfish	12.82	55.38	42.16	47.91	45.12
Eelpouts	Conf.	.30	.04	.13	Conf.
Eulachon	Conf.	Conf.	0.07	0.02	0.03
Giant Grenadier	449.33	310.82	889.11	512.50	727.33
Greenlings	7.67	8.76	6.99	4.16	8.14
Pacific Grenadier	-	-	-	-	-
Hermit crab unidentified	0.02	Conf.	0.03	.04	0.03
Invertebrate unidentified	0.35	3.85	0.18	Conf.	0.19
Lanternfishes	-	-	Conf.	-	0.04
Misc crabs	0.04	0.04	0.01	0.04	Conf.
Misc crustaceans	Conf.	-	Conf.	Conf.	Conf.
Misc deep fish	-	-	Conf.	-	-
Misc fish	129.52	151.71	159.64	124.55	142.73
Misc inverts (worms etc)	Conf.	-	-	-	-
Other osmerids	-	Conf.	0.02	Conf.	-
Pacific Sand lance	Conf.	-	-	-	-
Pandalid shrimp	0.06	0.06	0.06	0.10	0.05
Polychaete unidentified	-	-	Conf.	-	-
Scypho jellies	0.02	0.16	0.39	5.13	1.23
Sea anemone unidentified	4.07	6.27	4.02	2.15	1.12
Sea pens whips	0.04	-	0.04	0.06	-
Sea star	1.46	0.92	0.89	1.60	3.46
Snails	0.23	1.26	0.15	0.12	0.26
Sponge unidentified	3.95	1.37	1.28	1.81	5.45
Stichaeidae	-	-	Conf.	Conf.	Conf.
Urchins, dollars cucumbers	0.44	0.30	0.28	0.21	0.98

Table 13-7. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and counts of animals for crab and salmon, by year, for the GOA rockfish fishery 2011 - 2015. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/15/2015.

Group Name	**2011**	**2012**	**2013**	**2014**	**2015**	**Average**
Bairdi Crab	25	87	69	173	49	81
Blue King Crab	0	0	0	0	0	0
Chinook Salmon	1,013	1,580	2,319	1,247	878	1,407
Golden K. Crab	129	111	102	34	19	79
Halibut	122	109	113	127	144	123
Herring	0	0	0	0	0	0
Other Salmon	210	308	2,020	555	336	686
Opilio Crab	0	0	0	0	28	6
Red King Crab	0	0	0	0	0	0

Table 13-8. Fishery age compositions for GOA RE/BS rockfish and sample sizes by year. Pooled age 42+ includes all fish 42 and older.

Age (years)	1990	2004	2006	2008	2009	2010	2012
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0040	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0026	0.0000	0.0000	0.0033	0.0000	0.0040	0.0000
9	0.0209	0.0000	0.0028	0.0098	0.0000	0.0081	0.0000
10	0.0393	0.0049	0.0000	0.0131	0.0095	0.0040	0.0000
11	0.0262	0.0000	0.0000	0.0066	0.0032	0.0162	0.0000
12	0.0209	0.0000	0.0083	0.0066	0.0032	0.0202	0.0061
13	0.0131	0.0073	0.0055	0.0164	0.0158	0.0162	0.0030
14	0.0288	0.0049	0.0083	0.0164	0.0032	0.0283	0.0182
15	0.0079	0.0170	0.0193	0.0131	0.0095	0.0162	0.0030
16	0.0052	0.0097	0.0193	0.0230	0.0315	0.0121	0.0121
17	0.0131	0.0121	0.0138	0.0426	0.0189	0.0121	0.0121
18	0.0026	0.0073	0.0055	0.0361	0.0158	0.0243	0.0182
19	0.0131	0.0194	0.0110	0.0492	0.0315	0.0405	0.0030
20	0.0105	0.0413	0.0110	0.0951	0.0536	0.0202	0.0152
21	0.0183	0.0388	0.0138	0.0262	0.0284	0.0405	0.0212
22	0.0131	0.0437	0.0303	0.0393	0.0347	0.0243	0.0091
23	0.0157	0.0461	0.0331	0.0197	0.0284	0.0162	0.0364
24	0.0183	0.0364	0.0441	0.0230	0.0158	0.0202	0.0242
25	0.0262	0.0316	0.0468	0.0492	0.0536	0.0607	0.0152
26	0.0288	0.0170	0.0358	0.0426	0.0505	0.0162	0.0152
27	0.0393	0.0243	0.0331	0.0164	0.0505	0.0283	0.0212
28	0.0131	0.0194	0.0331	0.0393	0.0410	0.0405	0.0273
29	0.0393	0.0267	0.0413	0.0230	0.0379	0.0445	0.0212
30	0.0366	0.0194	0.0165	0.0131	0.0505	0.0202	0.0545
31	0.0393	0.0364	0.0275	0.0262	0.0189	0.0405	0.0545
32	0.0340	0.0316	0.0275	0.0262	0.0347	0.0405	0.0273
33	0.0445	0.0243	0.0165	0.0426	0.0189	0.0121	0.0182
34	0.0524	0.0243	0.0165	0.0131	0.0095	0.0121	0.0273
35	0.0366	0.0243	0.0138	0.0033	0.0315	0.0202	0.0152
36	0.0393	0.0291	0.0358	0.0098	0.0158	0.0162	0.0333
37	0.0314	0.0097	0.0193	0.0197	0.0126	0.0243	0.0182
38	0.0157	0.0340	0.0193	0.0066	0.0284	0.0162	0.0182
39	0.0288	0.0291	0.0083	0.0230	0.0126	0.0202	0.0212
40	0.0262	0.0316	0.0275	0.0164	0.0189	0.0121	0.0212
41	0.0183	0.0146	0.0386	0.0033	0.0189	0.0040	0.0182
42+	0.1780	0.2840	0.3168	0.1869	0.1924	0.2429	0.3909
Sample size	301	409	363	291	308	242	330

Table 13-9. Fishery size compositions for GOA RE/BS rockfish and sample size by year and pooled pairs of adjacent lengths.

Length (cm)	1991	1992	2002	2003	2005	2007	2011	2013
20	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000
22	0.0000	0.0056	0.0087	0.0000	0.0007	0.0007	0.0010	0.0030
24	0.0010	0.0065	0.0058	0.0012	0.0013	0.0007	0.0010	0.0040
26	0.0021	0.0084	0.0087	0.0020	0.0013	0.0048	0.0020	0.0069
28	0.0063	0.0130	0.0029	0.0040	0.0047	0.0054	0.0061	0.0040
30	0.0042	0.0297	0.0058	0.0032	0.0074	0.0122	0.0081	0.0050
32	0.0094	0.0270	0.0058	0.0064	0.0067	0.0115	0.0304	0.0099
34	0.0125	0.0362	0.0145	0.0095	0.0134	0.0258	0.0314	0.0099
36	0.0104	0.0455	0.0174	0.0139	0.0315	0.0326	0.0354	0.0188
38	0.0261	0.0660	0.0378	0.0382	0.0308	0.0605	0.0354	0.0386
40	0.0396	0.1004	0.0494	0.0545	0.0455	0.0713	0.0840	0.0960
42	0.1585	0.1087	0.1453	0.1010	0.0717	0.0965	0.1083	0.1327
44	0.2857	0.1645	0.1657	0.1427	0.1165	0.1209	0.1235	0.1455
46	0.2221	0.1292	0.1948	0.1924	0.1514	0.1461	0.1306	0.1297
48	0.1512	0.0790	0.1395	0.1717	0.1541	0.1352	0.1407	0.1119
50	0.0448	0.0465	0.1134	0.1125	0.1306	0.1175	0.1113	0.0634
52	0.0136	0.0344	0.0465	0.0719	0.0884	0.0822	0.0577	0.0416
54	0.0042	0.0362	0.0145	0.0322	0.0583	0.0299	0.0425	0.0386
56	0.0063	0.0251	0.0116	0.0199	0.0275	0.0190	0.0202	0.0436
58	0.0010	0.0167	0.0058	0.0079	0.0221	0.0129	0.0162	0.0228
60+	0.0010	0.0214	0.0058	0.0147	0.0362	0.0143	0.0142	0.0743
Sample size	959	1,077	344	2,516	1,493	1,472	988	1,010

Table 13-10. GOA RE/BS rockfish biomass estimates from NMFS triennial/biennial trawl surveys by region and gulfwide for 1984-2015. No sampling was performed in the Eastern GOA for the 2001 survey and we exclude this year from our assessment model. Estimates for the Western and Central GOA are provided here for reference. CV is the coefficient of variation expressed as a percent and provided in parentheses next to the biomass estimate. SE is the standard error. LCI and UCI are the lower and upper 95% confidence intervals respectively. SE, LCI, UCI are respective to the gulfwide biomass estimates.

Year	Western		Central		Eastern		Gulfwide		SE	LCI	UCI
1984	8,779	(31.7)	32,416	(20.7)	3,896	(20.2)	45,091	(16.2)	7,313	30,758	59,425
1987	2,737	(34.3)	21,881	(15.9)	19,063	(17.4)	43,681	(11.2)	4,897	34,083	53,278
1990	1,329	(47.7)	35,467	(25.8)	8,041	(19.3)	44,837	(20.7)	9,296	26,617	63,057
1993	10,889	(78.5)	41,616	(27.5)	9,358	(20.7)	61,863	(23.3)	14,415	33,610	90,115
1996	3,449	(34.6)	28,396	(23.3)	14,067	(22.6)	45,913	(16.2)	7,432	31,346	60,481
1999	6,156	(51.3)	20,781	(17.4)	12,622	(25.7)	39,560	(14.6)	5,793	28,206	50,913
2001	6,945	(54.8)	24,740	(23.8)	NA	NA	--	--	--	--	--
2003	8,921	(34.1)	24,610	(19.7)	9,670	(36.3)	43,202	(15.6)	6,724	30,024	56,380
2005	3,621	(25.8)	32,898	(25.4)	11,356	(16.4)	47,875	(18.0)	8,618	30,983	64,767
2007	3,773	(26.8)	39,419	(24.3)	16,697	(23.2)	59,889	(17.3)	10,380	39,544	80,234
2009	2,765	(26.5)	33,154	(21.1)	14,855	(29.7)	50,774	(16.3)	8,297	34,512	67,035
2011	3,305	(42.8)	32,583	(21.0)	8,228	(16.8)	44,115	(16.2)	7,126	30,149	58,082
2013	3,922	(24.2)	11,207	(29.3)	12,452	(30.2)	27,581	(18.4)	5,078	17,627	37,534
2015	1,345	(21.9)	18,129	(20.0)	15,079	(22.4)	34,553	(14.4)	4,970	24,811	44,295

Table 13-11. AFSC bottom trawl survey relative age compositions for GOA RE/BS rockfish since 1984. Pooled age 42+ includes all fish 42 and older.

Age (yr)	1984	1987	1990	1993	1996	1999	2003	2005	2007
3	0.0000	0.0000	0.0011	0.0342	0.0023	0.0000	0.0285	0.0375	0.0065
4	0.0005	0.0006	0.0025	0.0122	0.0003	0.0247	0.0184	0.0468	0.0093
5	0.0000	0.0061	0.0058	0.0108	0.0204	0.0518	0.0669	0.0844	0.0331
6	0.0000	0.0652	0.0105	0.0237	0.1446	0.0251	0.0466	0.0385	0.0794
7	0.0035	0.0460	0.0395	0.0155	0.0173	0.0327	0.0275	0.0652	0.0430
8	0.0892	0.0249	0.0503	0.0211	0.0201	0.0587	0.0554	0.0510	0.0130
9	0.0338	0.0401	0.1100	0.0492	0.0321	0.1376	0.0509	0.0532	0.0465
10	0.0215	0.0533	0.1684	0.0727	0.0232	0.0505	0.0233	0.0791	0.0331
11	0.0075	0.1381	0.0918	0.0665	0.0246	0.0434	0.0203	0.0339	0.0220
12	0.0255	0.0959	0.0231	0.0898	0.0458	0.0186	0.0376	0.0504	0.0318
13	0.0100	0.0474	0.0548	0.0755	0.0410	0.0433	0.0387	0.0178	0.0481
14	0.0310	0.0445	0.0876	0.0571	0.0710	0.0442	0.0427	0.0403	0.0150
15	0.0747	0.0445	0.0285	0.0486	0.0698	0.0451	0.0136	0.0513	0.0273
16	0.0938	0.0156	0.0132	0.0633	0.0682	0.0546	0.0309	0.0327	0.0362
17	0.0400	0.0171	0.0075	0.0457	0.0517	0.0463	0.0254	0.0339	0.0411
18	0.0280	0.0149	0.0036	0.0229	0.0277	0.0565	0.0169	0.0226	0.0349
19	0.0120	0.0078	0.0206	0.0244	0.0353	0.0298	0.0195	0.0205	0.0315
20	0.0036	0.0038	0.0073	0.0242	0.0387	0.0362	0.0466	0.0315	0.0282
21	0.0094	0.0257	0.0088	0.0235	0.0212	0.0188	0.0312	0.0108	0.0308
22	0.0083	0.0070	0.0074	0.0114	0.0200	0.0192	0.0396	0.0179	0.0572
23	0.0113	0.0246	0.0098	0.0221	0.0187	0.0175	0.0396	0.0117	0.0344
24	0.0160	0.0117	0.0211	0.0098	0.0116	0.0130	0.0246	0.0116	0.0108
25	0.0272	0.0068	0.0044	0.0153	0.0094	0.0097	0.0297	0.0121	0.0197
26	0.0259	0.0070	0.0101	0.0054	0.0114	0.0055	0.0297	0.0147	0.0279
27	0.0403	0.0045	0.0000	0.0045	0.0073	0.0071	0.0173	0.0166	0.0297
28	0.0462	0.0064	0.0104	0.0113	0.0100	0.0122	0.0112	0.0068	0.0243
29	0.0369	0.0311	0.0196	0.0037	0.0058	0.0074	0.0113	0.0082	0.0103
30	0.0540	0.0253	0.0051	0.0138	0.0106	0.0070	0.0198	0.0055	0.0037
31	0.0637	0.0229	0.0174	0.0107	0.0095	0.0092	0.0122	0.0031	0.0243
32	0.0295	0.0287	0.0110	0.0105	0.0100	0.0048	0.0098	0.0083	0.0129
33	0.0198	0.0262	0.0162	0.0101	0.0141	0.0051	0.0113	0.0096	0.0025
34	0.0128	0.0103	0.0181	0.0108	0.0154	0.0080	0.0048	0.0035	0.0022
35	0.0125	0.0076	0.0204	0.0076	0.0171	0.0033	0.0076	0.0105	0.0226
36	0.0093	0.0151	0.0280	0.0174	0.0133	0.0134	0.0080	0.0089	0.0139
37	0.0067	0.0124	0.0106	0.0043	0.0052	0.0066	0.0054	0.0000	0.0155
38	0.0085	0.0070	0.0075	0.0072	0.0082	0.0034	0.0030	0.0038	0.0148
39	0.0086	0.0073	0.0067	0.0028	0.0058	0.0033	0.0008	0.0029	0.0010
40	0.0213	0.0000	0.0094	0.0128	0.0062	0.0053	0.0059	0.0000	0.0025
41	0.0148	0.0057	0.0077	0.0038	0.0059	0.0059	0.0057	0.0059	0.0112
42+	0.0424	0.0408	0.0241	0.0237	0.0293	0.0153	0.0620	0.0369	0.0479
Sample size	369	348	194	775	701	617	488	424	435

Table 13-11 (continued). AFSC bottom trawl survey relative age compositions for GOA RE/BS rockfish since 1984. Pooled age 42+ includes all fish 42 and older.

Age (yr)	2009	2011	2013
3	0.0113	0.0124	0.0490
4	0.0099	0.0096	0.0367
5	0.0191	0.0575	0.0357
6	0.0497	0.0322	0.0360
7	0.0348	0.0491	0.0700
8	0.0607	0.0427	0.0555
9	0.0437	0.0978	0.0387
10	0.0389	0.0436	0.0480
11	0.0560	0.0762	0.0674
12	0.0377	0.0764	0.0669
13	0.0378	0.0559	0.0561
14	0.0369	0.0407	0.0387
15	0.0506	0.0543	0.0302
16	0.0441	0.0273	0.0296
17	0.0374	0.0257	0.0250
18	0.0309	0.0152	0.0178
19	0.0250	0.0260	0.0117
20	0.0414	0.0090	0.0202
21	0.0199	0.0176	0.0127
22	0.0240	0.0232	0.0244
23	0.0182	0.0095	0.0142
24	0.0202	0.0253	0.0104
25	0.0258	0.0180	0.0141
26	0.0229	0.0124	0.0111
27	0.0083	0.0256	0.0157
28	0.0145	0.0127	0.0081
29	0.0139	0.0086	0.0093
30	0.0217	0.0070	0.0111
31	0.0128	0.0186	0.0092
32	0.0127	0.0060	0.0070
33	0.0194	0.0014	0.0077
34	0.0072	0.0078	0.0040
35	0.0064	0.0071	0.0129
36	0.0086	0.0055	0.0042
37	0.0029	0.0035	0.0025
38	0.0045	0.0029	0.0076
39	0.0040	0.0033	0.0053
40	0.0048	0.0054	0.0053
41	0.0029	0.0011	0.0035
42+	0.0586	0.0257	0.0667
Sample size	928	402	1,057

Table 13-12. AFSC bottom trawl survey length compositions for GOA RE/BS rockfish. Data are not explicitly used in the model because trawl survey ages were available for most years.

Length (cm)	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007
20	0.0068	0.0143	0.0133	0.0158	0.0380	0.0751	0.0223	0.0602	0.0481	0.0399
22	0.0162	0.0328	0.0173	0.0176	0.0509	0.0625	0.0360	0.0579	0.0523	0.0393
24	0.0258	0.0314	0.0244	0.0236	0.0540	0.0501	0.0421	0.0437	0.0548	0.0488
26	0.0236	0.0294	0.0271	0.0288	0.0485	0.0416	0.0498	0.0423	0.0636	0.0443
28	0.0190	0.0286	0.0428	0.0341	0.0382	0.0552	0.0594	0.0484	0.0667	0.0421
30	0.0331	0.0404	0.0626	0.0472	0.0511	0.0699	0.0517	0.0570	0.0652	0.0470
32	0.0369	0.0515	0.0854	0.0519	0.0509	0.0642	0.0448	0.0579	0.0589	0.0462
34	0.0449	0.0572	0.1022	0.0692	0.0463	0.0685	0.0614	0.0473	0.0659	0.0469
36	0.0562	0.0727	0.1201	0.0772	0.0623	0.0621	0.0706	0.0418	0.0603	0.0557
38	0.0578	0.0721	0.0869	0.1069	0.0639	0.0720	0.0884	0.0525	0.0701	0.0803
40	0.0841	0.0817	0.0695	0.1240	0.0858	0.0788	0.0970	0.0680	0.0781	0.0873
42	0.1448	0.0858	0.0622	0.1337	0.1158	0.0821	0.1341	0.1003	0.0835	0.1063
44	0.1660	0.1147	0.0938	0.1259	0.1117	0.0802	0.0965	0.1146	0.0791	0.1159
46	0.1200	0.1120	0.0820	0.0764	0.0816	0.0614	0.0668	0.0963	0.0480	0.0794
48	0.0773	0.0872	0.0464	0.0323	0.0464	0.0369	0.0410	0.0598	0.0320	0.0521
50	0.0398	0.0418	0.0225	0.0116	0.0236	0.0220	0.0164	0.0261	0.0272	0.0332
52	0.0191	0.0223	0.0101	0.0067	0.0149	0.0076	0.0085	0.0099	0.0140	0.0167
54	0.0094	0.0080	0.0094	0.0036	0.0053	0.0033	0.0028	0.0069	0.0087	0.0096
56	0.0057	0.0054	0.0073	0.0034	0.0061	0.0017	0.0052	0.0029	0.0070	0.0036
58	0.0044	0.0034	0.0052	0.0031	0.0025	0.0023	0.0018	0.0022	0.0045	0.0022
60+	0.0090	0.0073	0.0096	0.0070	0.0024	0.0027	0.0034	0.0040	0.0121	0.0031
Sample size	4,701	3,994	3,522	5,639	3,943	3,758	1,959	2,924	4,089	4,253

Table 13-12 (continued). AFSC bottom trawl survey length compositions for GOA RE/BS rockfish. Data are not explicitly used in model because trawl survey ages were available for most years.

Length (cm)	2009	2011	2013	2015
20	0.0402	0.0364	0.0637	0.0604
22	0.0545	0.0507	0.0516	0.0638
24	0.0593	0.0522	0.0526	0.0623
26	0.0690	0.0596	0.0516	0.0510
28	0.0552	0.0569	0.0598	0.0591
30	0.0598	0.0704	0.0450	0.0534
32	0.0440	0.0543	0.0489	0.0617
34	0.0425	0.0627	0.0562	0.0727
36	0.0466	0.0602	0.0724	0.0752
38	0.0527	0.0638	0.0857	0.0847
40	0.0691	0.0825	0.0872	0.0916
42	0.0798	0.0992	0.0844	0.0781
44	0.0904	0.0867	0.0595	0.0545
46	0.0880	0.0603	0.0627	0.0465
48	0.0662	0.0480	0.0449	0.0310
50	0.0406	0.0251	0.0383	0.0188
52	0.0240	0.0111	0.0183	0.0120
54	0.0090	0.0098	0.0078	0.0088
56	0.0041	0.0034	0.0046	0.0044
58	0.0026	0.0017	0.0020	0.0042
60+	0.0024	0.0049	0.0026	0.0057
Sample size	4,155	2,475	1,692	2,588

Table 13-13. GOA RE/BS rockfish relative population numbers (RPN) estimated from the AFSC longline survey by region and gulfwide for 1993-2015. CV is the coefficient of variation expressed as a percent and provided in parentheses next to the RPN. SE is the standard error. LCI and UCI are the lower and upper 95% confidence intervals respectively. SE, LCI, UCI are respective to the gulfwide RPNs.

	Western		Central		Eastern		Gulfwide		SE	LCI	UCI
1993	6,286	(44.0)	5,279	(31.5)	11,704	(24.8)	23,269	(18.6)	4,336	14,770	31,768
1994	4,371	(37.4)	2,513	(31.7)	15,737	(21.8)	22,622	(17.2)	3,885	15,007	30,236
1995	9,988	(38.5)	7,962	(27.1)	9,522	(21.8)	27,472	(17.7)	4,875	17,917	37,027
1996	5,675	(45.3)	5,613	(33.6)	14,337	(18.2)	25,624	(16.1)	4,122	17,545	33,703
1997	7,314	(46.6)	7,729	(38.4)	22,027	(27.6)	37,070	(20.4)	7,578	22,216	51,923
1998	6,032	(30.6)	5,751	(38.2)	12,787	(12.5)	24,570	(13.4)	3,284	18,134	31,006
1999	6,112	(28.7)	6,338	(35.3)	14,803	(21.2)	27,254	(15.5)	4,238	18,948	35,560
2000	10,454	(36.7)	8,917	(29.5)	18,522	(19.3)	37,894	(15.5)	5,860	26,408	49,380
2001	9,039	(38.0)	8,990	(30.1)	11,493	(22.1)	29,523	(17.1)	5,056	19,613	39,432
2002	9,792	(34.0)	7,454	(36.0)	10,271	(16.1)	27,517	(16.6)	4,581	18,538	36,496
2003	6,003	(35.3)	5,231	(38.6)	13,155	(19.4)	24,389	(15.9)	3,883	16,778	32,001
2004	10,312	(42.5)	4,479	(36.9)	13,122	(17.5)	27,913	(18.7)	5,222	17,678	38,149
2005	3,031	(56.9)	5,777	(32.9)	10,055	(25.9)	18,863	(19.4)	3,657	11,695	26,031
2006	5,240	(32.8)	6,320	(35.9)	8,918	(17.8)	20,478	(15.9)	3,262	14,085	26,871
2007	11,064	(39.1)	9,315	(27.3)	13,285	(18.2)	33,663	(16.5)	5,570	22,747	44,579
2008	6,407	(38.2)	7,414	(24.1)	17,139	(21.0)	30,960	(15.2)	4,700	21,747	40,173
2009	7,213	(36.1)	10,790	(41.1)	11,749	(13.9)	29,751	(18.1)	5,398	19,172	40,331
2010	12,746	(35.4)	7,741	(31.0)	14,801	(14.7)	35,288	(15.7)	5,549	24,412	46,165
2011	13,344	(45.3)	8,863	(32.7)	17,576	(26.5)	39,783	(20.5)	8,164	23,781	55,785
2012	7,967	(36.9)	5,364	(41.9)	13,632	(24.8)	26,962	(18.6)	5,016	17,130	36,795
2013	9,493	(43.9)	5,420	(33.4)	9,026	(22.0)	23,939	(20.7)	4,960	14,217	33,661
2014	8,827	(40.5)	7,030	(36.0)	17,607	(20.1)	33,464	(16.8)	5,629	22,430	44,497
2015	10,894	(44.6)	6,482	(45.0)	14,073	(20.1)	31,448	(20.1)	6,337	19,028	43,868

Table 13-14. AFSC longline survey size compositions for GOA RE/BS rockfish. Lengths are area-weighted by all available strata and are binned in adjacent pairs and pooled at 60 and greater cm.

Length (cm)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0006	0.0002
24	0.0013	0.0006	0.0000	0.0000	0.0001	0.0000	0.0006	0.0005	0.0026	0.0013
26	0.0070	0.0005	0.0029	0.0001	0.0008	0.0006	0.0036	0.0013	0.0039	0.0026
28	0.0055	0.0045	0.0059	0.0025	0.0018	0.0024	0.0061	0.0030	0.0046	0.0063
30	0.0122	0.0062	0.0096	0.0113	0.0108	0.0214	0.0109	0.0082	0.0187	0.0163
32	0.0286	0.0126	0.0213	0.0163	0.0099	0.0248	0.0145	0.0154	0.0189	0.0214
34	0.0559	0.0250	0.0287	0.0351	0.0171	0.0360	0.0371	0.0301	0.0425	0.0276
36	0.0537	0.0329	0.0402	0.0478	0.0446	0.0458	0.0513	0.0603	0.0484	0.0486
38	0.0709	0.0501	0.0667	0.0706	0.0762	0.0596	0.0672	0.0805	0.0661	0.0657
40	0.0912	0.0784	0.0884	0.0976	0.0814	0.0740	0.0891	0.0922	0.0929	0.0845
42	0.1060	0.0860	0.1078	0.1164	0.1089	0.0918	0.1066	0.1005	0.1010	0.1256
44	0.1226	0.1429	0.1376	0.1399	0.1243	0.1318	0.1494	0.1327	0.1276	0.1509
46	0.1429	0.1513	0.1406	0.1474	0.1598	0.1600	0.1658	0.1316	0.1365	0.1382
48	0.0995	0.1393	0.1216	0.1296	0.1339	0.1423	0.1295	0.1365	0.1269	0.1274
50	0.0922	0.0953	0.1036	0.0844	0.0931	0.0922	0.0841	0.0864	0.0942	0.0729
52	0.0487	0.0745	0.0481	0.0411	0.0501	0.0530	0.0456	0.0535	0.0477	0.0448
54	0.0220	0.0362	0.0368	0.0276	0.0268	0.0216	0.0157	0.0278	0.0233	0.0250
56	0.0170	0.0201	0.0188	0.0134	0.0127	0.0161	0.0054	0.0141	0.0106	0.0115
58	0.0056	0.0148	0.0102	0.0065	0.0097	0.0106	0.0032	0.0058	0.0061	0.0129
60+	0.0171	0.0288	0.0111	0.0123	0.0377	0.0158	0.0144	0.0194	0.0269	0.0163
Sample size	3,998	3,560	5,090	4,636	5,696	4,508	5,940	7,086	4,767	4,768

Table 13-14 (continued). AFSC longline survey size compositions for GOA RE/BS rockfish.

Length (cm)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
20	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0002	0.0005	0.0005	0.0000
24	0.0008	0.0001	0.0014	0.0001	0.0005	0.0005	0.0013	0.0007	0.0023	0.0001
26	0.0010	0.0031	0.0038	0.0027	0.0030	0.0021	0.0017	0.0080	0.0078	0.0020
28	0.0086	0.0167	0.0130	0.0221	0.0012	0.0072	0.0073	0.0149	0.0131	0.0102
30	0.0136	0.0253	0.0270	0.0096	0.0114	0.0217	0.0439	0.0305	0.0300	0.0169
32	0.0151	0.0221	0.0315	0.0194	0.0337	0.0351	0.0243	0.0504	0.0389	0.0276
34	0.0138	0.0346	0.0337	0.0225	0.0437	0.0551	0.0395	0.0573	0.0550	0.0416
36	0.0226	0.0546	0.0483	0.0365	0.0859	0.0670	0.0514	0.0731	0.0726	0.0573
38	0.0495	0.0993	0.0493	0.0471	0.0640	0.0702	0.0813	0.0817	0.0900	0.0838
40	0.0725	0.0940	0.0646	0.0812	0.0985	0.0755	0.1011	0.0930	0.0996	0.1029
42	0.1111	0.1099	0.1135	0.1150	0.1116	0.0999	0.1238	0.1118	0.1159	0.1055
44	0.1462	0.1341	0.1441	0.1389	0.1462	0.1199	0.1199	0.1239	0.1195	0.1352
46	0.1733	0.1464	0.1488	0.1520	0.1364	0.1233	0.1130	0.1133	0.0959	0.1214
48	0.1544	0.1119	0.1401	0.1467	0.1098	0.1167	0.1100	0.0865	0.0956	0.1099
50	0.0882	0.0714	0.0717	0.0800	0.0630	0.0948	0.0736	0.0588	0.0591	0.0725
52	0.0462	0.0340	0.0363	0.0471	0.0385	0.0519	0.0512	0.0273	0.0343	0.0512
54	0.0173	0.0150	0.0238	0.0280	0.0155	0.0255	0.0236	0.0142	0.0162	0.0246
56	0.0159	0.0118	0.0115	0.0129	0.0165	0.0106	0.0155	0.0124	0.0140	0.0114
58	0.0108	0.0067	0.0107	0.0158	0.0052	0.0108	0.0048	0.0086	0.0067	0.0054
60+	0.0391	0.0089	0.0270	0.0214	0.0153	0.0116	0.0127	0.0330	0.0329	0.0204
Sample size	4,596	4,840	4,095	4,306	6,575	5,684	4,642	5,949	5,778	5,095

Table 13-14 (continued). AFSC longline survey size compositions for GOA RE/BS rockfish.

Length (cm)	2013	2014	2015
20	0.0000	0.0000	0.0000
22	0.0000	0.0000	0.0000
24	0.0001	0.0001	0.0007
26	0.0028	0.0535	0.0007
28	0.0075	0.0037	0.0041
30	0.0276	0.0128	0.0064
32	0.0427	0.0219	0.0215
34	0.0568	0.0406	0.0177
36	0.0925	0.0577	0.0453
38	0.0755	0.0732	0.0565
40	0.0922	0.1031	0.0796
42	0.1029	0.1090	0.1317
44	0.1252	0.1154	0.1558
46	0.1267	0.1101	0.1383
48	0.1068	0.1069	0.1128
50	0.0628	0.0768	0.0969
52	0.0299	0.0438	0.0609
54	0.0177	0.0231	0.0279
56	0.0089	0.0161	0.0195
58	0.0139	0.0101	0.0166
60+	0.0077	0.0221	0.0072
Sample size	3,744	6,820	5,382

Table 13-15. Likelihoods and MLE estimates of key parameters with estimates of standard error (σ) derived from the Hessian matrix for GOA RE/BS rockfish models.

	M0	***M1***	***M2***	***M3a***	***M3b***	***M4a***	***M4b***
Likelihoods							
Catch	0.037	0.026	0.027	0.026	0.024	0.023	0.024
Trawl Biomass	8.933	9.527	9.538	8.400	8.184	8.807	8.767
Longline Biomass	11.922	12.181	12.365	13.553	13.572	13.650	13.633
Fishery Ages	37.270	41.581	13.657	19.989	24.090	19.608	23.760
Trawl Survey Ages	39.300	44.402	36.669	34.375	38.884	35.682	40.284
Fishery Sizes	51.364	58.390	57.638	55.754	55.640	55.695	55.561
Trawl Survey Sizes	0	0	0	0	0	0	0
Longline Survey Sizes	97.708	103.489	93.352	97.696	97.239	98.277	97.696
Data-Likelihood	246.532	269.595	223.246	229.793	237.634	231.743	239.724
Penalties/Priors							
Recruit Deviations	-0.090	-0.714	-4.062	-12.347	-19.429	-11.943	-19.172
Selectivity Penalties							
Fishery	2.587	2.523	2.308	2.039	2.054	1.997	2.009
Trawl Survey	0.606	0.811	0.745	0.461	0.353	0	0
Longline	0.402	0.331	0.409	0.256	0.249	0.259	0.255
F Regularity	1.146	1.143	1.131	1.125	1.132	1.126	1.131
σ_r prior	4.578	4.848	6.440	11.442	15.489	11.298	15.390
q-trawl	0.632	0.705	0.561	0.007	0.005	0.004	0.002
q-longline	0.056	0.031	0.014	0.000	0.001	0.000	0.003
M	0.649	0.592	0.664	1.386	2.171	1.540	2.364
Total penalties/priors	10.567	10.270	8.209	4.368	2.025	4.281	1.982
Objective Fun. Total	257.099	279.865	231.455	234.161	239.659	236.025	241.706
Parameter Estimates							
Number Parameters	145	147	153	209	237	166	180
q-trawl	1.654	1.701	1.606	1.799	1.648	1.602	1.422
q-longline	1.399	1.283	1.184	1.031	0.956	1.008	0.921
M	0.034	0.033	0.034	0.035	0.037	0.036	0.037
σ_r	0.908	0.903	0.877	0.813	0.774	0.814	0.774
Mean Recruitment (mil)	1.565	1.582	1.684	1.732	1.922	1.775	1.996
$F_{40\%}$	0.038	0.037	0.039	0.040	0.041	0.040	0.041
Total Biomass (t)	36,583	38,563	39,167	40,936	44,291	41,863	46,063
Spawning Biomass (t)	12,479	13,312	12,554	13,559	14,606	13,803	15,129
$B_{100\%}$ (t)	22,449	22,838	21,114	20,317	21,039	20,566	21,585
$B_{40\%}$ (t)	8,980	9,135	8,445	8,127	8,416	8,226	8,634
$ABC_{F40\%}$ (t)	1,122	1,187	1,190	1,293	1,442	1,328	1,507

Table 13-16. Estimated GOA RE/BS rockfish population numbers (thousands) in 2015, fishery selectivity, trawl and longline (LL) survey selectivity of GOA RE/BS rockfish from the author preferred model. Also shown are schedules of age specific weight and female maturity estimated outside the assessment model.

Age	Numbers in 2015 (1000s)	Percent Mature	Weight (g)	Fishery Selectivity	Trawl Survey Selectivity	LL Survey Selectivity
3	1,611	0	53	0	22	0
4	1,538	0	99	0	41	0
5	2,419	0	159	0	56	0
6	1,664	0	228	0	68	0
7	1,368	0	306	1	77	0
8	1,122	0	388	2	85	0
9	1,649	0	473	4	91	1
10	1,111	1	558	6	95	2
11	967	2	642	7	98	7
12	1,045	5	723	7	99	19
13	1,331	8	801	8	100	39
14	1,451	14	875	12	100	65
15	1,498	22	945	30	99	84
16	882	31	1,010	100	98	99
17	1,591	40	1,070	100	96	100
18	1,103	50	1,125	100	94	100
19	797	59	1,176	100	91	100
20	1,168	66	1,222	100	89	100
21	1,278	72	1,265	100	86	100
22	620	77	1,303	100	83	100
23	497	81	1,338	100	80	100
24	531	84	1,369	100	76	100
25	1,513	92	1,398	100	73	100
26	398	92	1,423	100	70	100
27	373	92	1,446	100	67	100
28	337	92	1,467	100	64	100
29	330	92	1,485	100	61	100
30	368	92	1,502	100	58	100
31	441	92	1,517	100	55	100
32	513	92	1,530	100	52	100
33	464	92	1,542	100	49	100
34	727	92	1,553	100	46	100
35	671	92	1,562	100	44	100
36	355	92	1,571	100	41	100
37	278	92	1,578	100	39	100
38	294	92	1,585	100	37	100
39	897	92	1,591	100	35	100

Table 13-16 (continued). Estimated GOA RE/BS rockfish population numbers (thousands) in 2015, fishery selectivity, trawl and longline (LL) survey selectivity of GOA RE/BS rockfish from the author preferred model. Also shown are schedules of age specific weight and female maturity estimated outside the assessment model.

Age	Numbers in 2015 (1000s)	Percent Mature	Weight (g)	Fishery Selectivity	Trawl Survey Selectivity	LL Survey Selectivity
40	298	92	1,596	100	33	100
41	228	92	1,601	100	31	100
42	220	92	1,605	100	29	100
43	222	92	1,609	100	27	100
44	211	92	1,612	100	26	100
45	228	92	1,615	100	24	100
46	278	92	1,618	100	22	100
47	274	92	1,620	100	21	100
48	222	92	1,622	100	20	100
49	193	92	1,624	100	18	100
50	178	92	1,626	100	17	100
51	168	92	1,627	100	16	100
52	4,396	92	1,634	100	15	100

Table 13-17. Estimates of key parameters from the author preferred model (μ) with Hessian estimates of standard deviation (σ), MCMC standard deviations (σ (MCMC)) and 95% Bayesian credible intervals (BCI) derived from MCMC simulations for GOA RE/BS. *q* is catchability, *M* is natural mortality, $F_{40\%}$ is a fishing mortality rate (see **Harvest Recommendations** for complete definition), SSB is spawning stock biomass for the current year (2015), ABC is acceptable biological catch, and σ_r is the recruitment standard deviation parameter.

	μ		σ		MCMC		
Parameter	Hessian	MCMC	Hessian	MCMC	Median	BCI-Lower	BCI-Upper
q_1, trawl survey	1.6018	1.4247	0.5582	0.5265	1.3960	0.4846	2.5126
q_2, longline survey	1.0080	1.0805	0.3873	0.4241	1.0435	0.3651	1.9791
M	0.0358	0.0359	0.0031	0.0032	0.0358	0.0298	0.0424
$F_{40\%}$	0.0398	0.0459	0.0108	0.0141	0.0438	0.0248	0.0798
SSB (2014)	13,803	18,725	5,539	11,553	15,543	7,825	48,681
ABC	1,328	2,111	672	1,609	1,665	634	6,229
σ_r	0.8144	1.0533	0.0515	0.0632	1.0525	0.9326	1.1809

Table 13-18. Estimated time series of female spawning biomass, 6+ biomass (ages 6 and greater), catch divided by 6 + biomass, and number of age 3 recruits for GOA RE/BS rockfish, 1977-2015. Estimates are shown for the author preferred model (Model 4a) and from the previous assessment in 2014 (Model 0).

	Spawning Biomass (t)		6+ Biomass (t)		Catch/6+ Biomass		Age 3 Recruits (1000's)	
Year	Previous	Current	Previous	Current	Previous	Current	Previous	Current
1977	17,470	19,310	44,123	54,064	0.033	0.027	968	1,383
1978	16,792	18,890	42,625	52,780	0.013	0.011	1,074	1,646
1979	16,496	18,812	42,002	52,334	0.015	0.012	4,637	4,671
1980	16,172	18,684	41,304	51,770	0.033	0.026	1,137	1,438
1981	15,548	18,244	39,927	50,533	0.018	0.014	914	1,288
1982	15,215	18,055	39,770	50,549	0.014	0.011	955	1,556
1983	14,964	17,923	39,379	50,229	0.016	0.013	3,589	2,784
1984	14,704	17,763	38,913	49,803	0.020	0.015	1,640	2,856
1985	14,398	17,545	38,316	49,269	0.003	0.003	1,203	1,728
1986	14,375	17,590	38,768	49,605	0.011	0.009	1,347	1,807
1987	14,231	17,502	38,712	49,695	0.014	0.011	1,014	1,481
1988	14,063	17,375	38,537	49,530	0.042	0.033	802	1,175
1989	13,458	16,801	37,337	48,309	0.059	0.045	682	999
1990	12,650	16,011	35,579	46,497	0.068	0.052	633	976
1991	11,801	15,163	33,631	44,434	0.010	0.008	732	1,030
1992	11,844	15,178	33,659	44,309	0.033	0.025	834	1,048
1993	11,628	14,910	32,925	43,370	0.018	0.013	3,585	3,810
1994	11,656	14,870	32,719	42,929	0.018	0.013	1,139	1,276
1995	11,655	14,830	32,422	42,445	0.022	0.017	1,131	1,139
1996	11,608	14,746	32,401	42,365	0.017	0.013	1,176	1,355
1997	11,631	14,726	32,243	42,043	0.017	0.013	3,382	2,667
1998	11,648	14,705	32,084	41,689	0.021	0.016	2,264	2,326
1999	11,601	14,617	31,814	41,234	0.010	0.008	1,251	1,508
2000	11,690	14,652	32,265	41,381	0.016	0.013	1,864	1,983
2001	11,938	14,612	32,909	41,312	0.018	0.014	2,454	2,713
2002	11,812	14,460	32,824	41,061	0.008	0.007	1,338	1,423
2003	11,800	14,428	33,137	41,224	0.012	0.010	2,524	2,319
2004	11,746	14,346	33,462	41,433	0.009	0.007	2,176	2,163
2005	11,962	14,328	34,141	41,533	0.009	0.007	1,701	1,912
2006	12,008	14,320	34,682	41,805	0.010	0.009	1,298	1,448
2007	12,014	14,276	35,077	41,998	0.012	0.010	1,132	1,291
2008	12,036	14,222	35,382	42,093	0.011	0.009	1,206	1,430
2009	12,082	14,203	35,638	42,154	0.008	0.007	1,557	2,045
2010	12,191	14,244	35,938	42,263	0.012	0.010	1,126	1,342
2011	12,263	14,242	36,065	42,208	0.015	0.013	1,260	1,578
2012	12,314	14,211	36,112	42,135	0.016	0.013	1,237	1,852
2013	12,385	14,186	36,081	41,902	0.016	0.014	1,253	2,599
2014	12,480	14,170	36,062	41,684	0.020	0.018	1,262	1,594
2015		14,133		41,346		0.013		1,611

Table 13-19. Estimated time series of recruitment, total biomass (3+), and female spawning biomass for RE/BS rockfish in the Gulf of Alaska, 1977-2016. Columns headed with 2.5% and 97.5% represent the lower and upper 95% credible intervals from the MCMC posterior distribution.

	Recruits (Age 3, 1000s)			Total Biomass (3+)			Spawning biomass (t)		
Year	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%
1977	1,383	200	5,669	54,507	37,385	145,358	19,310	13,001	48,958
1978	1,646	225	8,076	53,212	36,243	143,677	18,890	12,699	49,066
1979	4,671	1,155	13,981	52,941	36,100	144,137	18,812	12,664	49,289
1980	1,438	207	6,638	52,535	35,618	144,581	18,684	12,508	49,704
1981	1,288	186	5,164	51,427	34,483	144,153	18,244	12,136	49,728
1982	1,556	250	6,664	50,966	33,985	143,918	18,055	11,960	49,899
1983	2,784	422	10,203	50,714	33,834	144,087	17,923	11,887	49,747
1984	2,856	444	10,302	50,449	33,507	144,673	17,763	11,708	49,886
1985	1,728	269	7,285	50,044	32,992	144,256	17,545	11,528	49,701
1986	1,807	294	6,832	50,286	33,274	145,102	17,590	11,589	49,859
1987	1,481	271	5,709	50,201	33,074	145,608	17,502	11,540	50,199
1988	1,175	218	4,699	50,000	32,848	145,586	17,375	11,437	49,992
1989	999	201	3,832	48,692	31,711	144,539	16,801	10,904	49,336
1990	976	215	3,603	46,817	29,989	142,465	16,011	10,169	48,574
1991	1,030	204	3,801	44,729	28,185	140,243	15,163	9,415	47,851
1992	1,048	176	3,998	44,607	28,096	139,696	15,178	9,393	47,817
1993	3,810	2,331	10,652	43,822	27,332	139,296	14,910	9,133	47,622
1994	1,276	212	5,040	43,515	26,985	138,410	14,870	9,074	47,653
1995	1,139	193	4,366	43,189	26,686	137,902	14,830	9,001	47,718
1996	1,355	228	5,297	42,733	26,192	137,354	14,746	8,941	47,961
1997	2,667	633	9,565	42,481	25,950	137,056	14,726	8,894	48,194
1998	2,326	412	8,445	42,266	25,744	137,160	14,705	8,857	48,339
1999	1,508	232	6,380	41,929	25,443	137,075	14,617	8,751	48,415
2000	1,983	333	8,045	41,973	25,451	137,174	14,652	8,769	48,567
2001	2,713	683	9,150	41,867	25,266	136,995	14,612	8,721	48,623
2002	1,423	229	5,664	41,688	25,089	137,327	14,460	8,565	48,463
2003	2,319	737	8,000	41,882	25,181	137,738	14,428	8,553	48,327
2004	2,163	482	7,915	41,978	25,188	138,504	14,346	8,481	48,094
2005	1,912	448	6,848	42,182	25,307	139,637	14,328	8,462	47,852
2006	1,448	297	5,506	42,383	25,529	140,324	14,320	8,468	47,771
2007	1,291	252	4,689	42,487	25,545	140,917	14,276	8,413	47,576
2008	1,430	266	5,590	42,505	25,527	140,820	14,222	8,323	47,523
2009	2,045	522	7,741	42,589	25,563	141,156	14,203	8,301	47,691
2010	1,342	217	5,515	42,740	25,653	141,293	14,244	8,327	47,822
2011	1,578	288	6,587	42,721	25,665	141,311	14,242	8,319	47,868
2012	1,852	313	8,866	42,582	25,544	140,621	14,211	8,259	47,859
2013	2,599	484	13,295	42,449	25,412	140,705	14,186	8,188	47,812
2014	1,594	201	11,993	42,289	25,306	140,628	14,170	8,146	47,952
2015	1,611	217	12,796	41,966	24,954	140,070	14,133	8,048	48,253
2016	1,836	199	10,049	41,864	24,846	139,964	13,804	7,844	47,219

Table 13-20. Set of projections of spawning biomass (SB) and yield for GOA RE/BS rockfish. Seven harvest scenarios designed to satisfy the requirements of Amendment 56, NEPA, and MSFCMA. For a description of scenarios see *Harvest Recommendations* section. Spawning biomass and yield are in t. $B_{40\%}$ = 8,226 t, $B_{35\%}$ = 7,198 t, $F_{40\%}$ = 0.040 and $F_{35\%}$ = 0.048.

Year	Maximum permissible F	Author's F*	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning Biomass (t)				
2015	13,835	13,835	13,835	13,835	13,835	13,835	13,835
2016	13,697	13,804	13,809	13,823	13,922	13,651	13,697
2017	13,374	13,733	13,748	13,793	14,132	13,223	13,374
2018	13,058	13,553	13,683	13,760	14,338	12,809	13,014
2019	12,759	13,235	13,624	13,732	14,549	12,419	12,615
2020	12,453	12,908	13,544	13,682	14,735	12,029	12,214
2021	12,140	12,573	13,443	13,609	14,892	11,641	11,816
2022	11,846	12,256	13,347	13,540	15,048	11,278	11,443
2023	11,574	11,963	13,260	13,480	15,207	10,945	11,100
2024	11,305	11,671	13,159	13,404	15,341	10,622	10,766
2025	11,070	11,414	13,082	13,350	15,493	10,338	10,473
2026	10,852	11,175	13,009	13,301	15,642	10,077	10,203
2027	10,649	10,951	12,939	13,253	15,786	9,836	9,952
2028	10,459	10,741	12,868	13,207	15,924	9,612	9,720
			Fishing Mortality				
2015	0.016	0.016	0.016	0.016	0.016	0.016	0.016
2016	0.040	0.021	0.020	0.018	-	0.048	0.048
2017	0.040	0.020	0.020	0.018	-	0.048	0.048
2018	0.040	0.040	0.020	0.018	-	0.048	0.048
2019	0.040	0.040	0.020	0.018	-	0.048	0.048
2020	0.040	0.040	0.020	0.018	-	0.048	0.048
2021	0.040	0.040	0.020	0.018	-	0.048	0.048
2022	0.040	0.040	0.020	0.018	-	0.048	0.048
2023	0.040	0.040	0.020	0.018	-	0.048	0.048
2024	0.040	0.040	0.020	0.018	-	0.048	0.048
2025	0.040	0.040	0.020	0.018	-	0.048	0.048
2026	0.040	0.040	0.020	0.018	-	0.048	0.048
2027	0.040	0.040	0.020	0.018	-	0.048	0.048
2028	0.040	0.040	0.020	0.018	-	0.048	0.048
			Yield (t)				
2015	530	530	530	530	530	530	530
2016	1,328	1,328	670	591	-	1,596	1,328
2017	1,301	1,325	669	591	-	1,551	1,301
2018	1,269	1,316	665	589	-	1,502	1,525
2019	1,231	1,275	657	583	-	1,446	1,468
2020	1,193	1,235	648	576	-	1,391	1,412
2021	1,162	1,201	642	571	-	1,345	1,364
2022	1,139	1,176	639	570	-	1,311	1,328
2023	1,108	1,142	631	564	-	1,267	1,283
2024	1,084	1,116	627	561	-	1,233	1,248
2025	1,069	1,099	626	561	-	1,209	1,223
2026	1,063	1,091	629	565	-	1,197	1,210
2027	1,041	1,068	625	562	-	1,167	1,179
2028	1,023	1,047	621	559	-	1,141	1,152

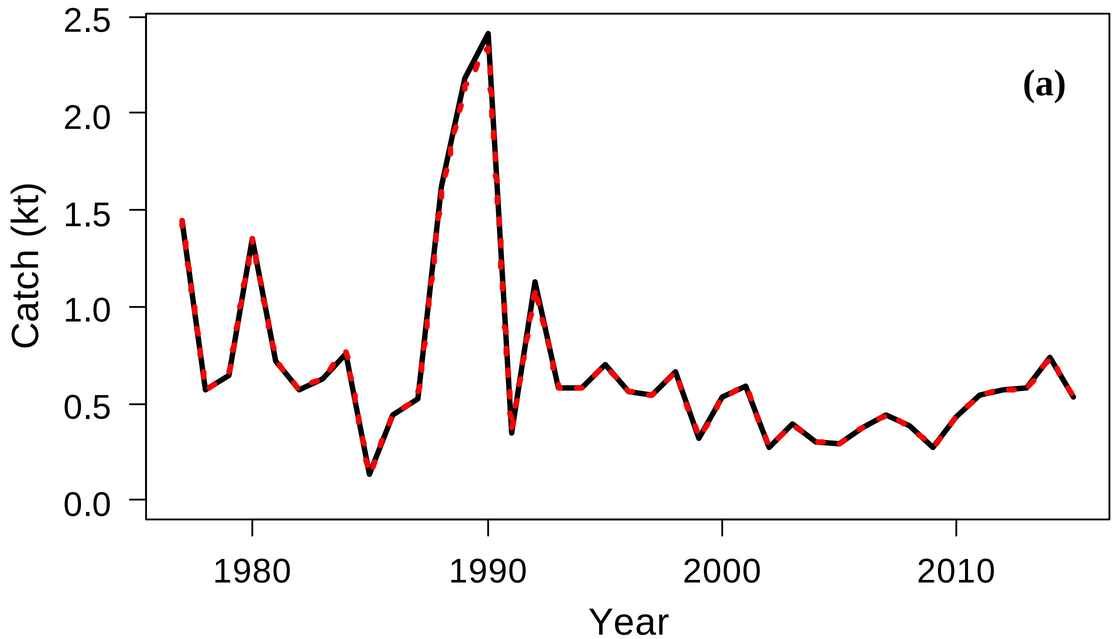
*Projected ABCs and OFLs for 2016 and 2017 are derived using estimated catch of 530 t for 2015 and projected catch of 700 t for 2016 and 686 t for 2017 based on realized catches from 2012-2014. This calculation is in response to management requests to obtain more accurate projections.

Table 13-21. Recommended allocation of ABC and OFL for 2016 and 2017 GOA RE/BS rockfish based on the preferred weighted survey average method.

Year	Weights	Western Gulf	Central Gulf	Eastern Gulf	Total
2011	4	7%	74%	19%	100%
2013	6	14%	41%	45%	100%
2015	9	4%	52%	44%	100%
Weighted Mean	19				
Area Allocation		7.9%	53.2%	38.9%	100%
2016	Area ABC (t)	**105**	**707**	**516**	**1,328**
	OFL (t)				**1,596**
2017	Area ABC (t)	**105**	**705**	**515**	**1,325**
	OFL (t)				**1,592**

Table 13-22: Analysis of ecosystem considerations for GOA RE/BS rockfish.

Ecosystem effects on *GOA rougheye rockfish*			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Phytoplankton and Zooplankton	Important for larval and post-larval survival but no information known	May help determine year class strength, no time series	Possible concern if some information available
Predator population trends			
Marine mammals	Not commonly eaten by marine mammals	No effect	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Halibut, arrowtooth, lingcod)	Arrowtooth have increased, others stable	More predation on juvenile rockfish	Possible concern
Changes in habitat quality			
Temperature regime	Higher recruitment after 1977 regime shift	Contributed to rapid stock recovery	No concern
Winter-spring environmental conditions	Affects pre-recruit survival	Different phytoplankton bloom timing	Causes natural variability, rockfish have varying larval release to compensate
Production	Relaxed downwelling in summer brings in nutrients to Gulf shelf	Some years are highly variable like El Nino 1998	Probably no concern, contributes to high variability of rockfish recruitment
GOA rougheye rockfish fishery effects on ecosystem			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored (P. cod most common)	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Medium bycatch levels of sponge and corals	Bycatch levels small relative to total HAPC biota, but can be large in specific areas	Probably no concern
Marine mammals and birds	Very minor take of marine mammals, trawlers overall cause some bird mortality	Rockfish fishery is short compared to other fisheries	No concern
Sensitive non-target species	Likely minor impact on non-target rockfish	Data limited, likely to be harvested in proportion to their abundance	Probably no concern
Fishery concentration in space and time	Duration is short and in patchy areas	Not a major prey species for marine mammals	No concern, fishery is being extended for several month starting 2006
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Probably no concern
Fishery contribution to discards and offal production	Decreasing	Improving, but data limited	Possible concern with non-target rockfish
Fishery effects on age-at-maturity and fecundity	Black rockfish show older fish have more viable larvae	Inshore rockfish results may not apply to longer-lived slope rockfish	Definite concern, studies being initiated in 2005



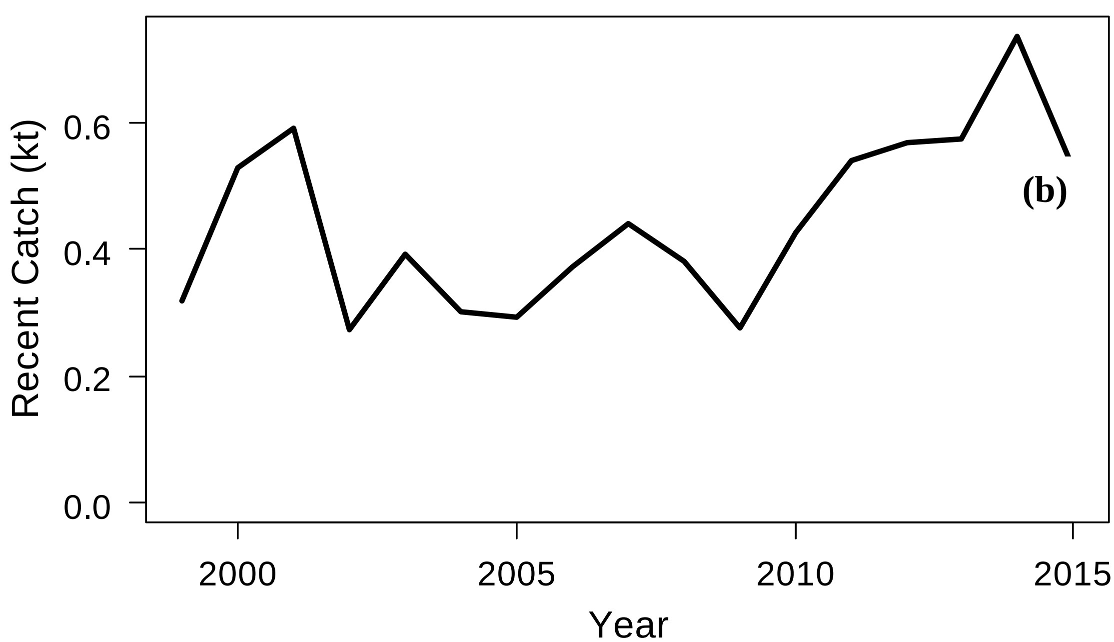


Figure 13-1. Estimated long-term (a) and short-term (b) commercial catches for Gulf of Alaska **RE/BS** rockfish. Solid line is observed catch and red dashed line (in a only) is predicted catch from the author preferred model.

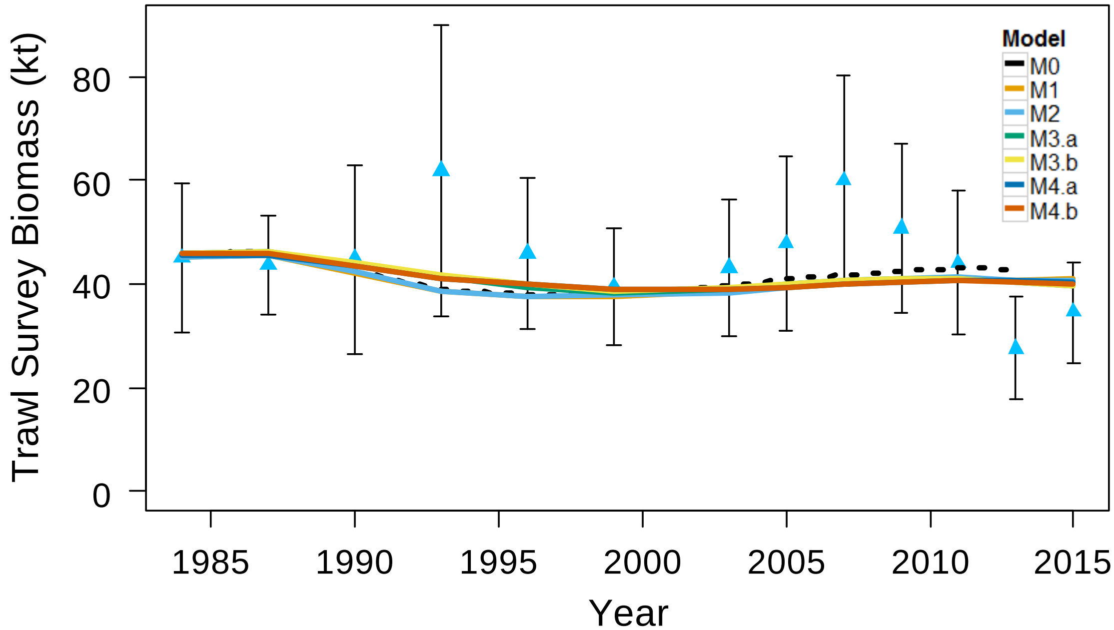


Figure 13-2a. AFSC bottom trawl survey observed biomass estimates (blue triangles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from all models considered (M1-M4b) are compared with the last full assessment model fit (M0, dotted black line).

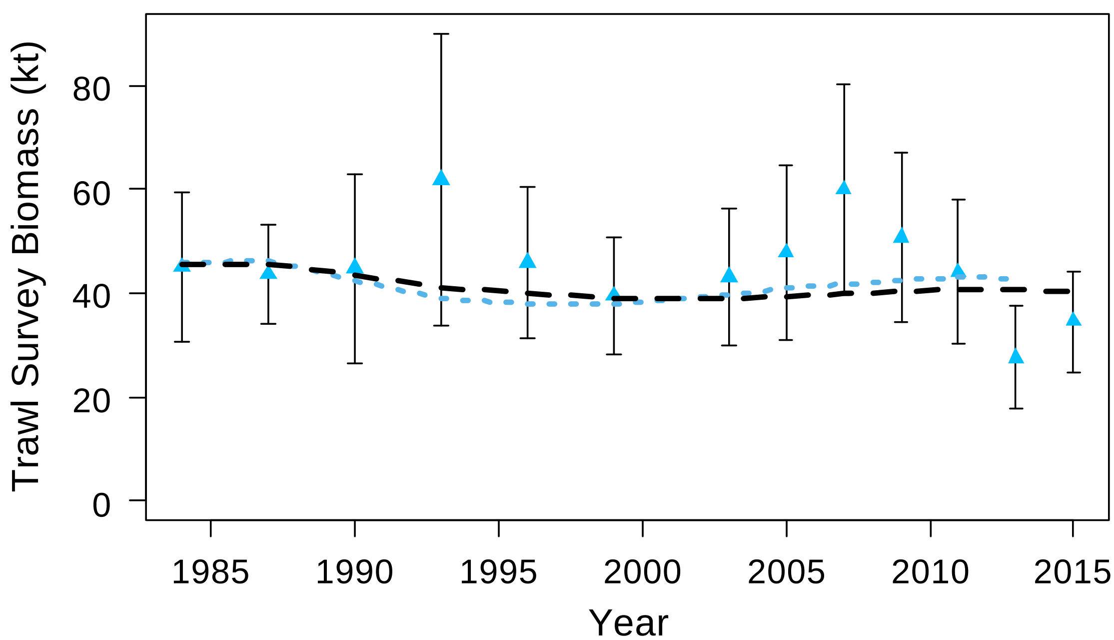


Figure 13-2b. AFSC bottom trawl survey observed biomass estimates (blue triangles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the author preferred model (M4a, dashed black line) are compared with the last full assessment model fit (M0, dotted blue line).

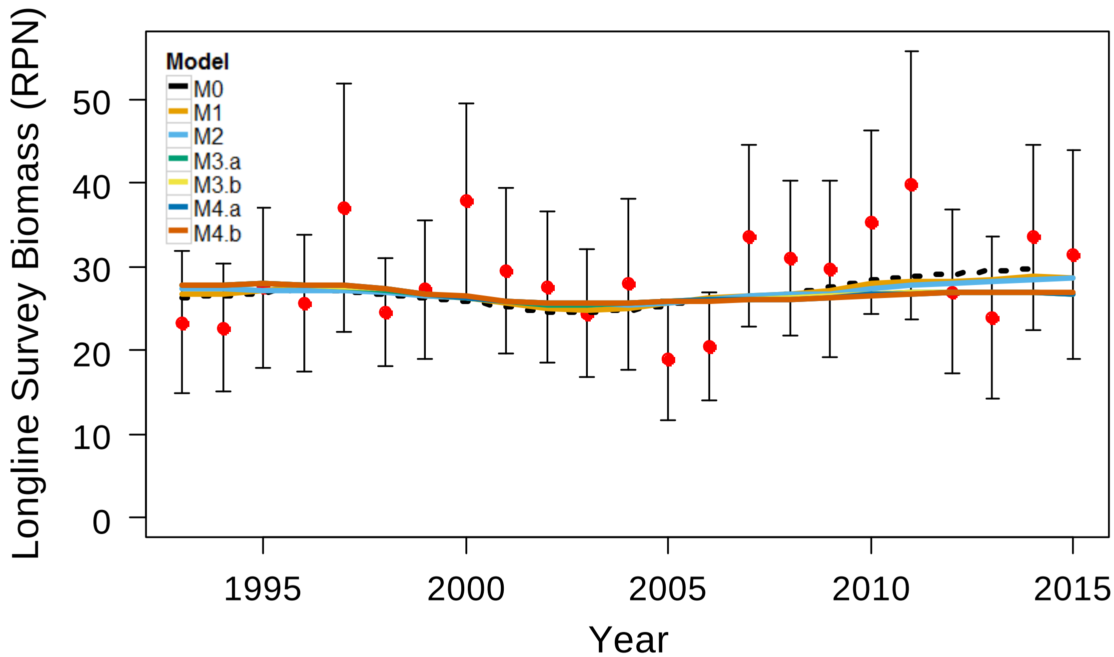


Figure 13-3a. AFSC longline survey relative population numbers (RPN in thousands, red circles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from all models considered (M1-M4b) are compared with the last full assessment model fit (M0, dotted black line).

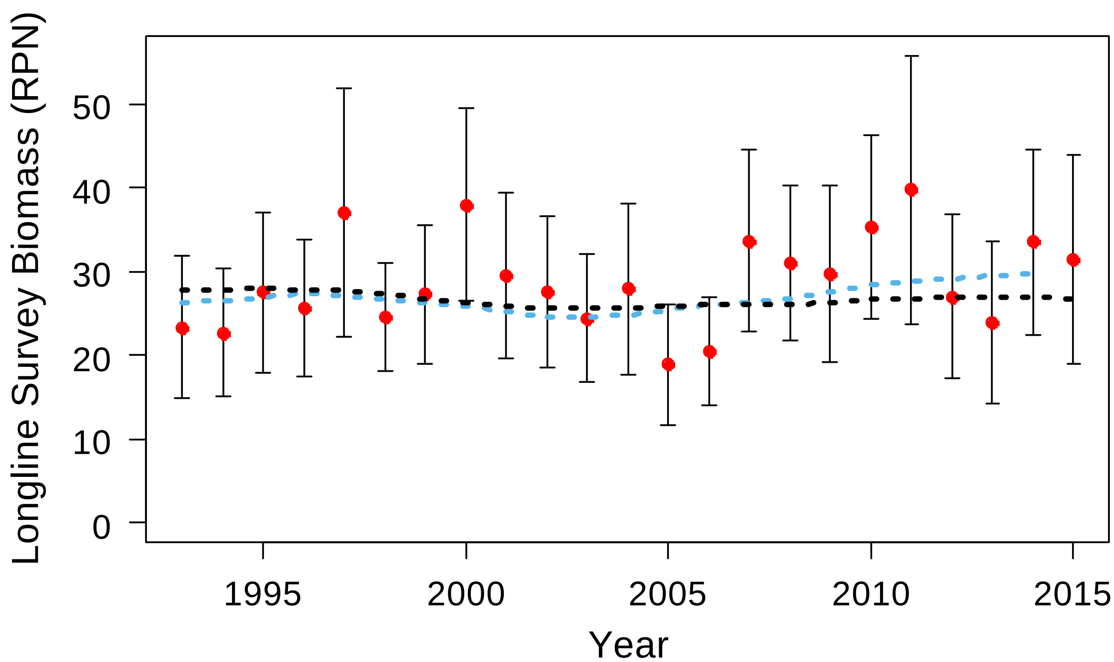


Figure 13-3b. AFSC longline survey relative population numbers (RPN in thousands, red circles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the author preferred model (M4a, dashed black line) are compared with the last full assessment model fit (M0, dotted blue line).

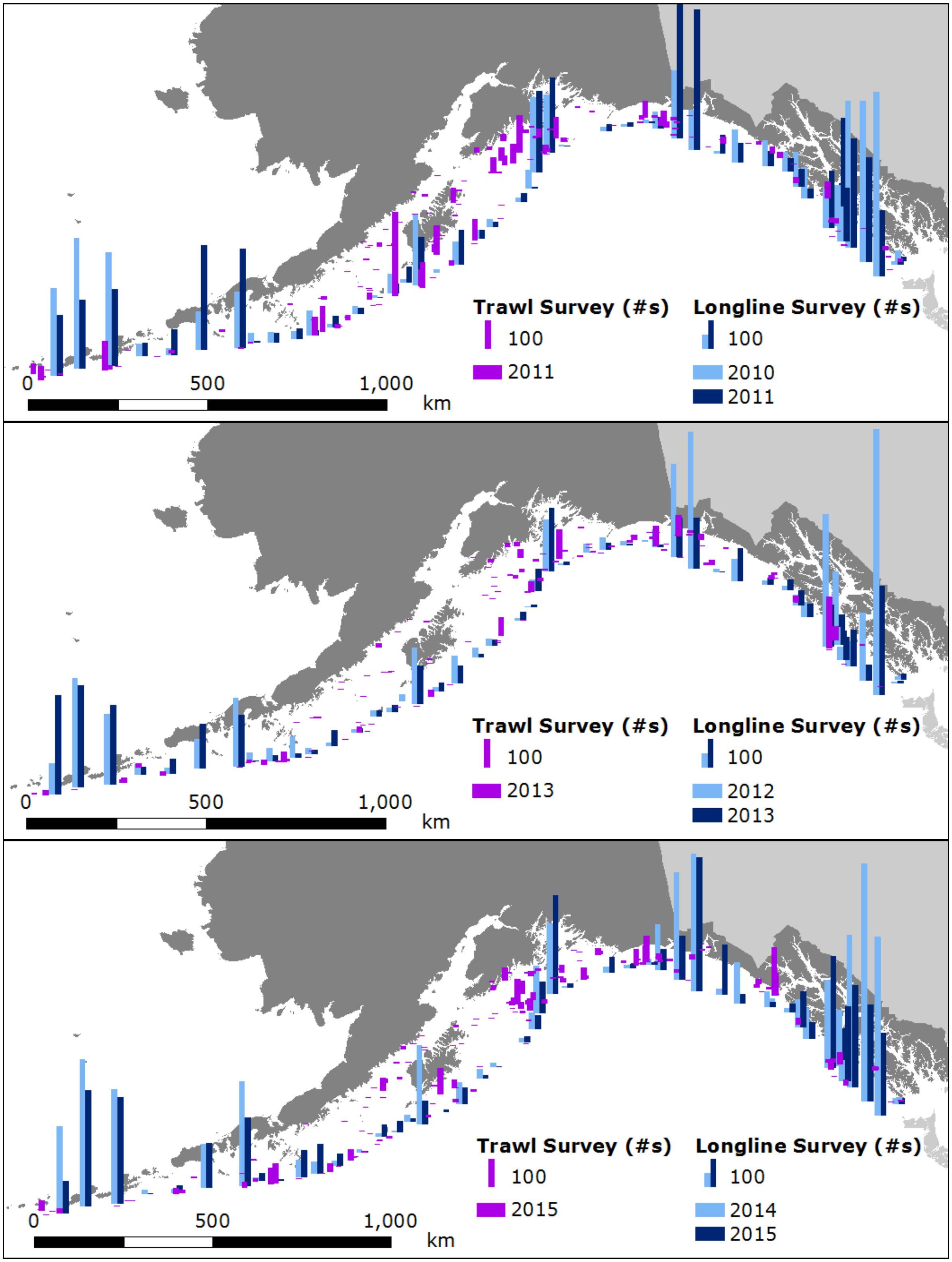


Figure 13-4a. Spatial distribution of rougheye and blackspotted rockfish in the Gulf of Alaska during the 2011, 2013, and 2015 AFSC trawl (purple) and 2010-2015 AFSC longline (blue/navy) surveys.

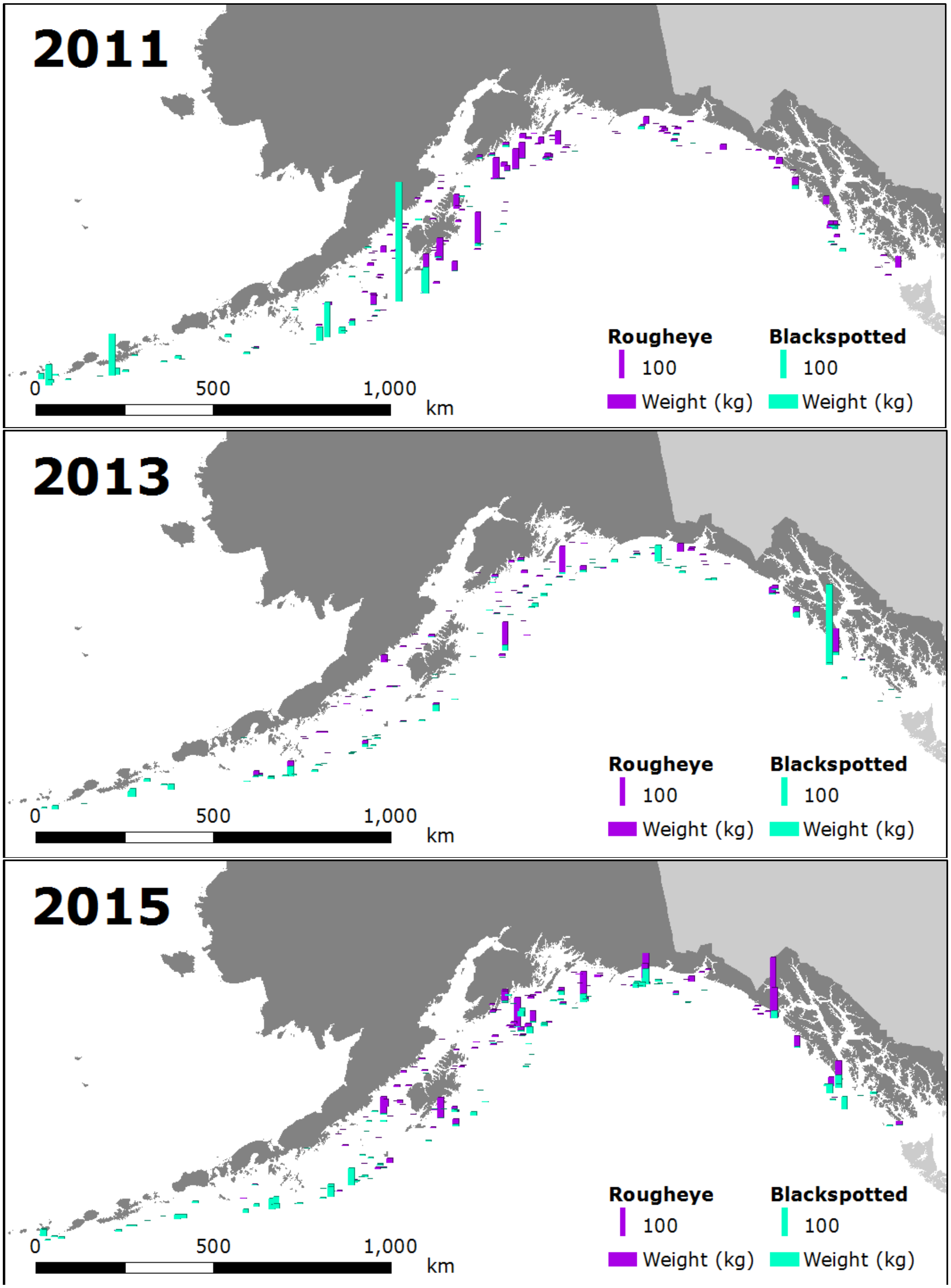


Figure 13-4b. Comparison of the spatial distribution between at-sea identified rougheye (purple) and blackspotted (green) rockfish in the Gulf of Alaska during the 2011, 2013, 2015 AFSC trawl surveys.

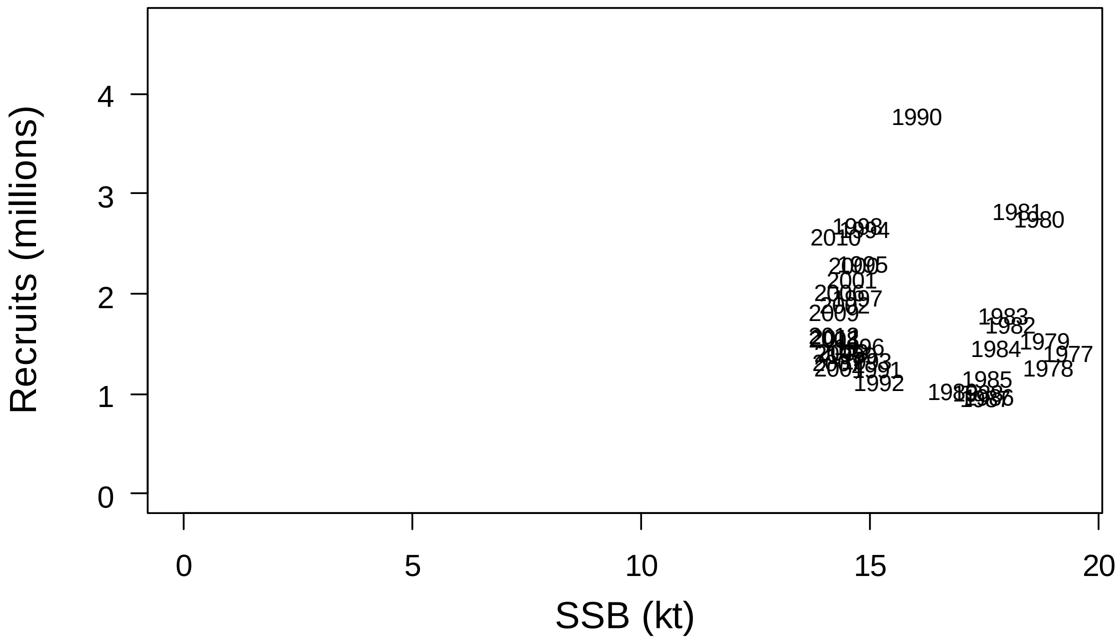


Figure 13-5. Scatterplot of spawner-recruit data for GOA RE/BS rockfish author preferred model. Label is year class of age 3 recruits. Recruits are in millions and SSB = Spawning stock biomass in tons.

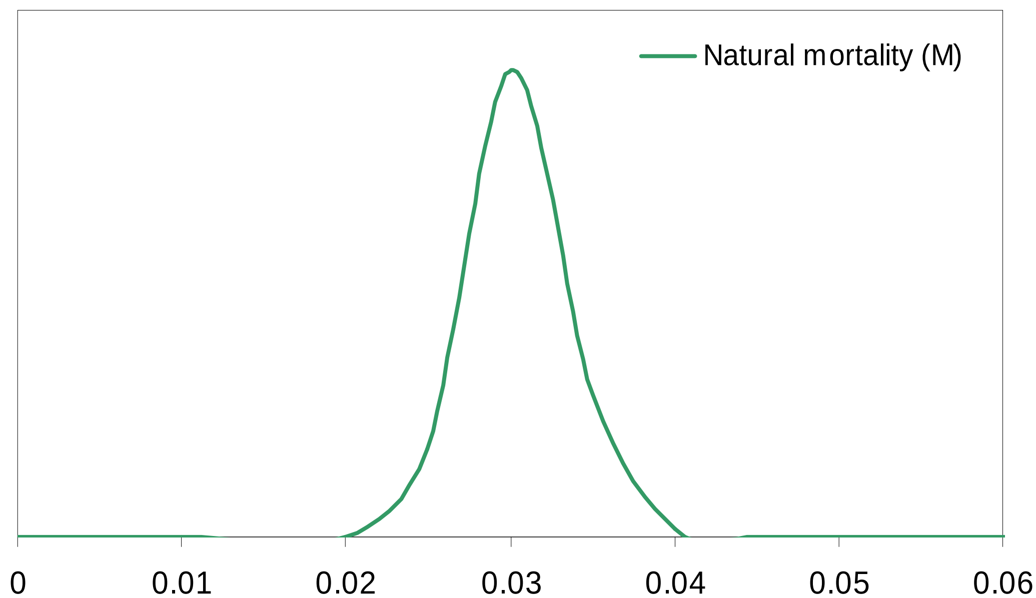


Figure 13-6. Prior distribution for natural mortality (M, μ=0.03, CV=10%) of GOA RE/BS rockfish.

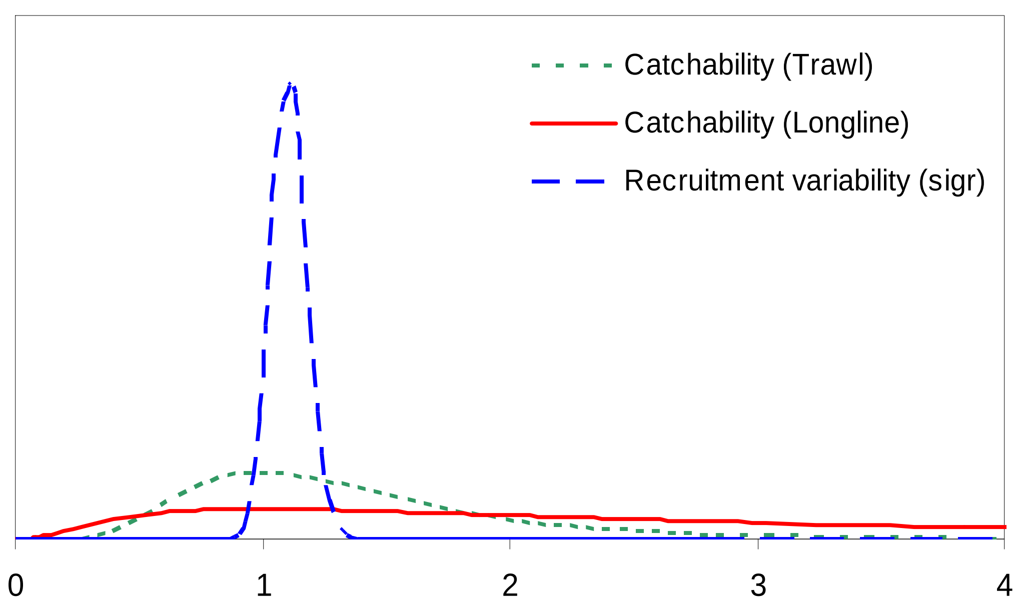


Figure 13-7. Prior distributions for NMFS trawl survey catchability ($q1$, μ=1, CV=45%), AFSC longline survey catchability ($q2$, μ=1, CV=100%), and recruitment variability (σ_r, μ=1.1, CV=6%) of GOA RE/BS rockfish.

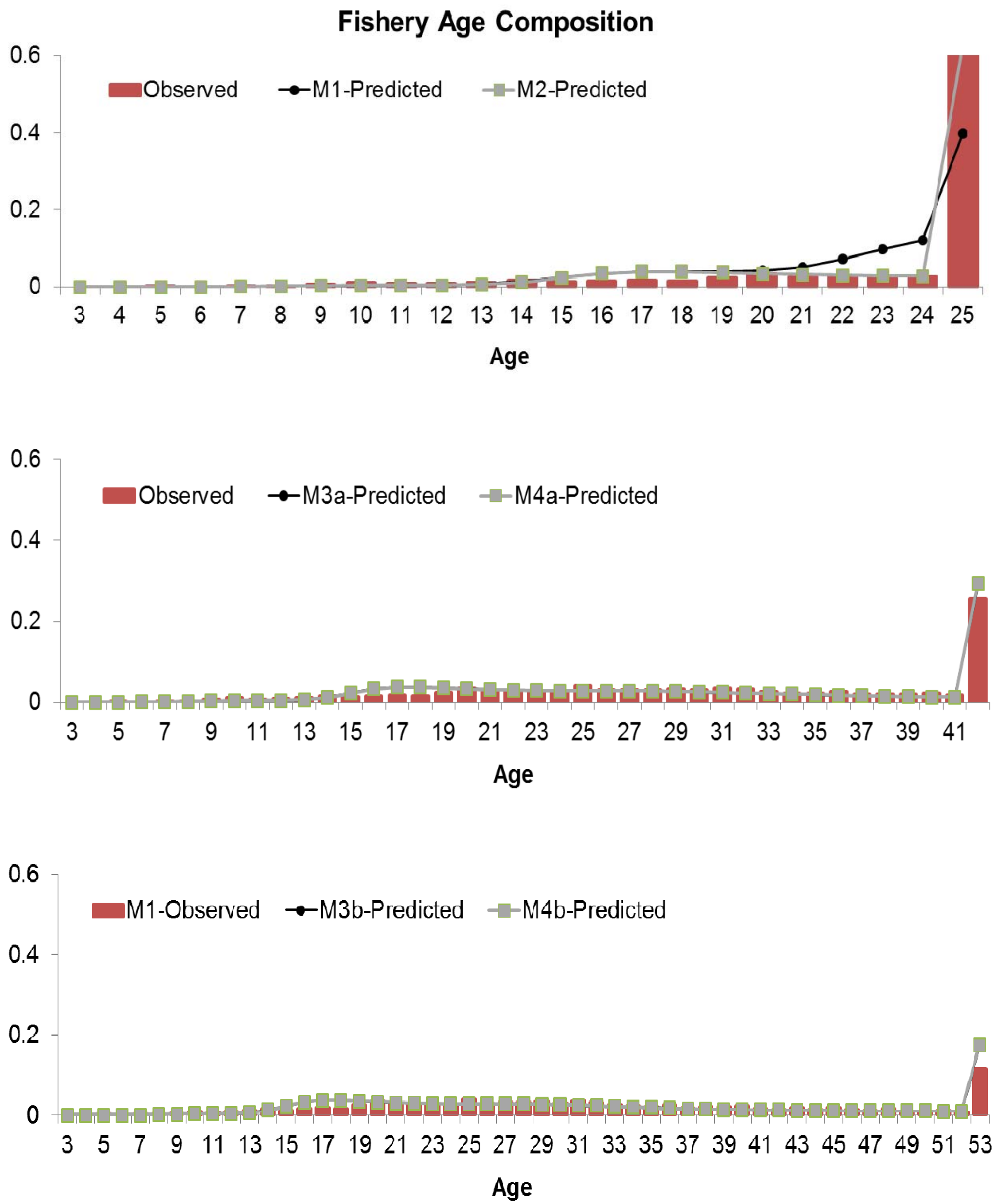


Figure 13-8a. Average fishery age compositions for GOA RE/BS rockfish over all models considered (M1/M2, M3a/M4a, M3b/M4b). Observed = bars, predicted = lines with circles.

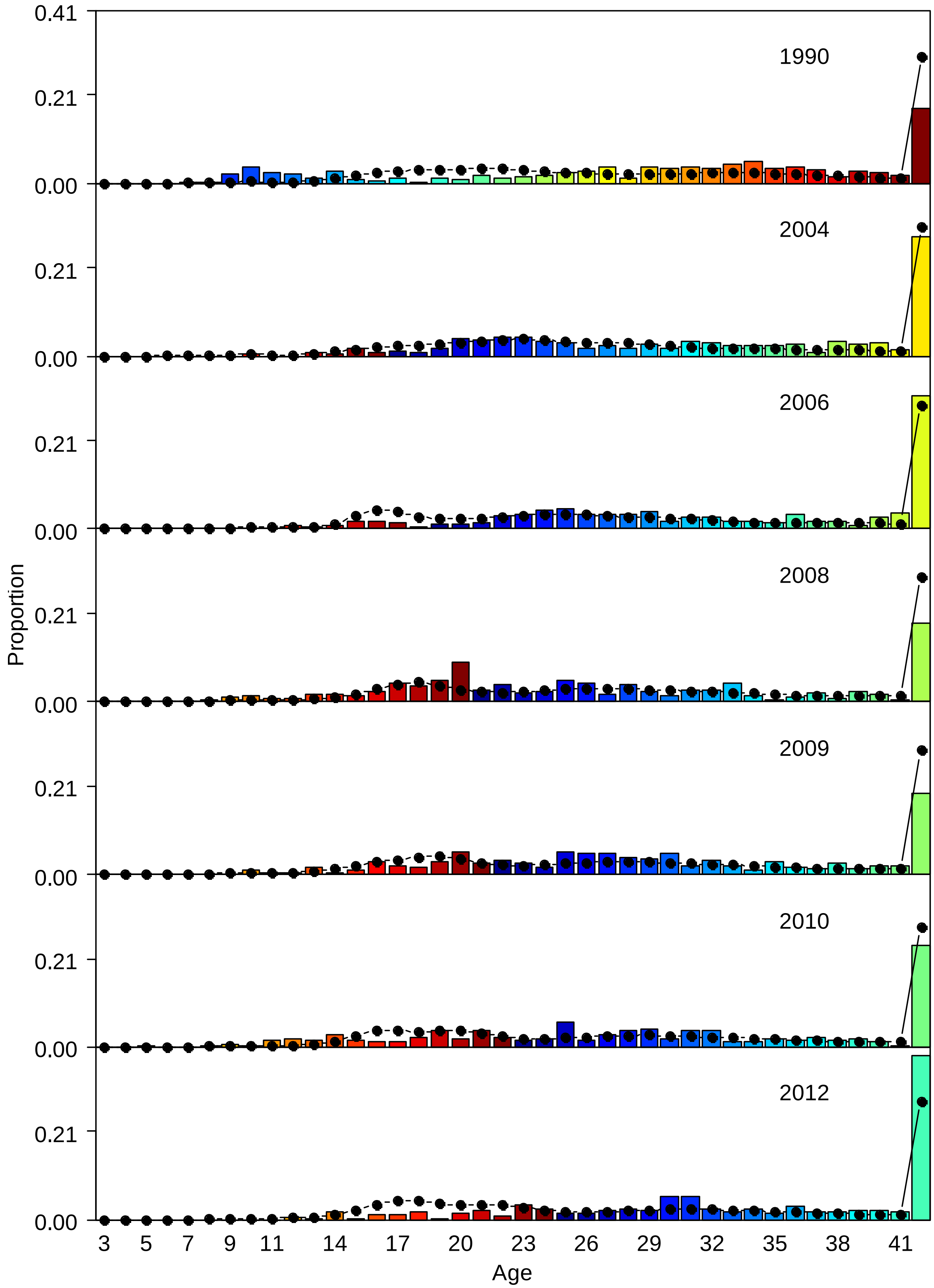


Figure 13-8b. Fishery age compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

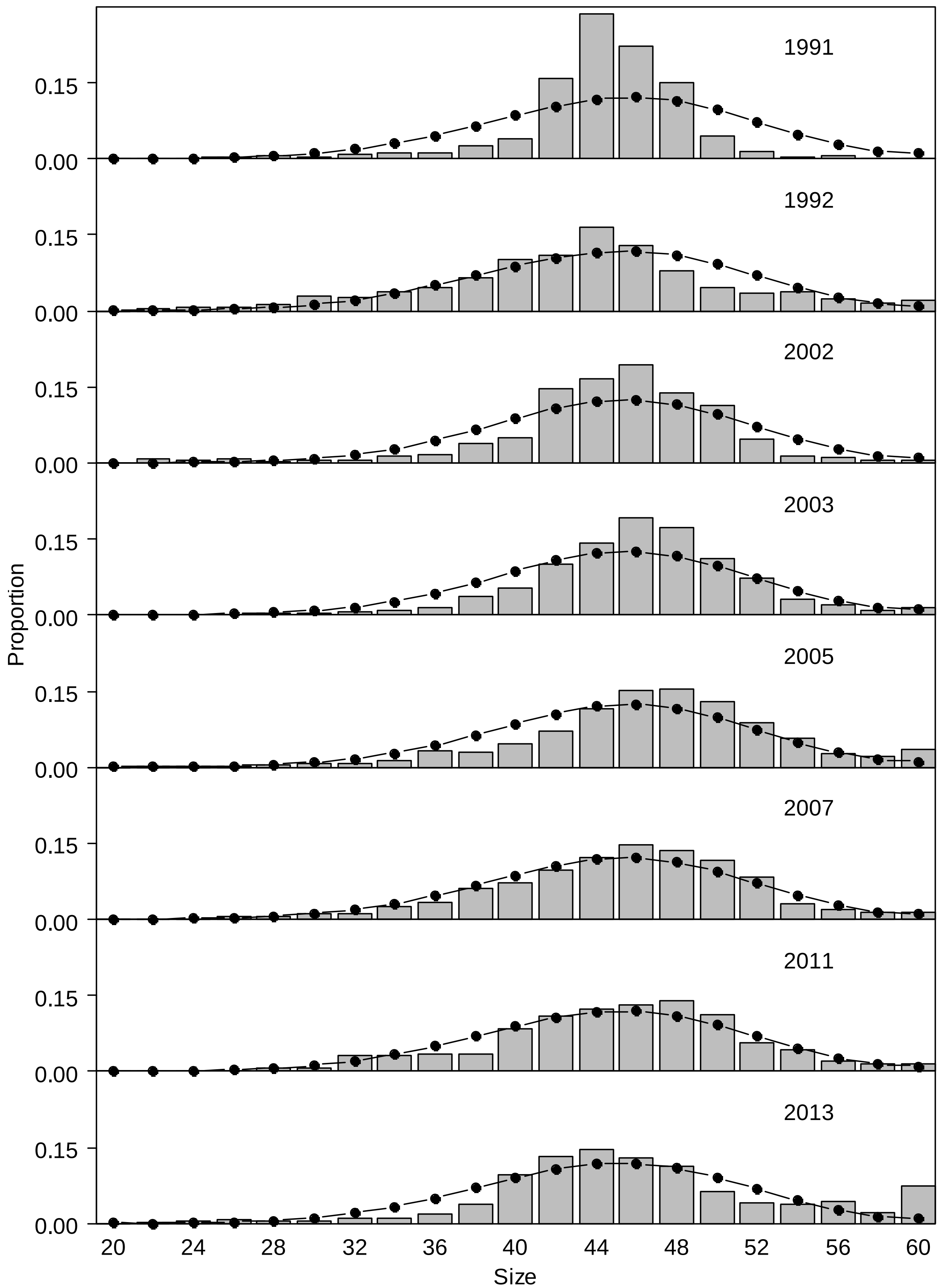


Figure 13-9. Fishery length (cm) compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

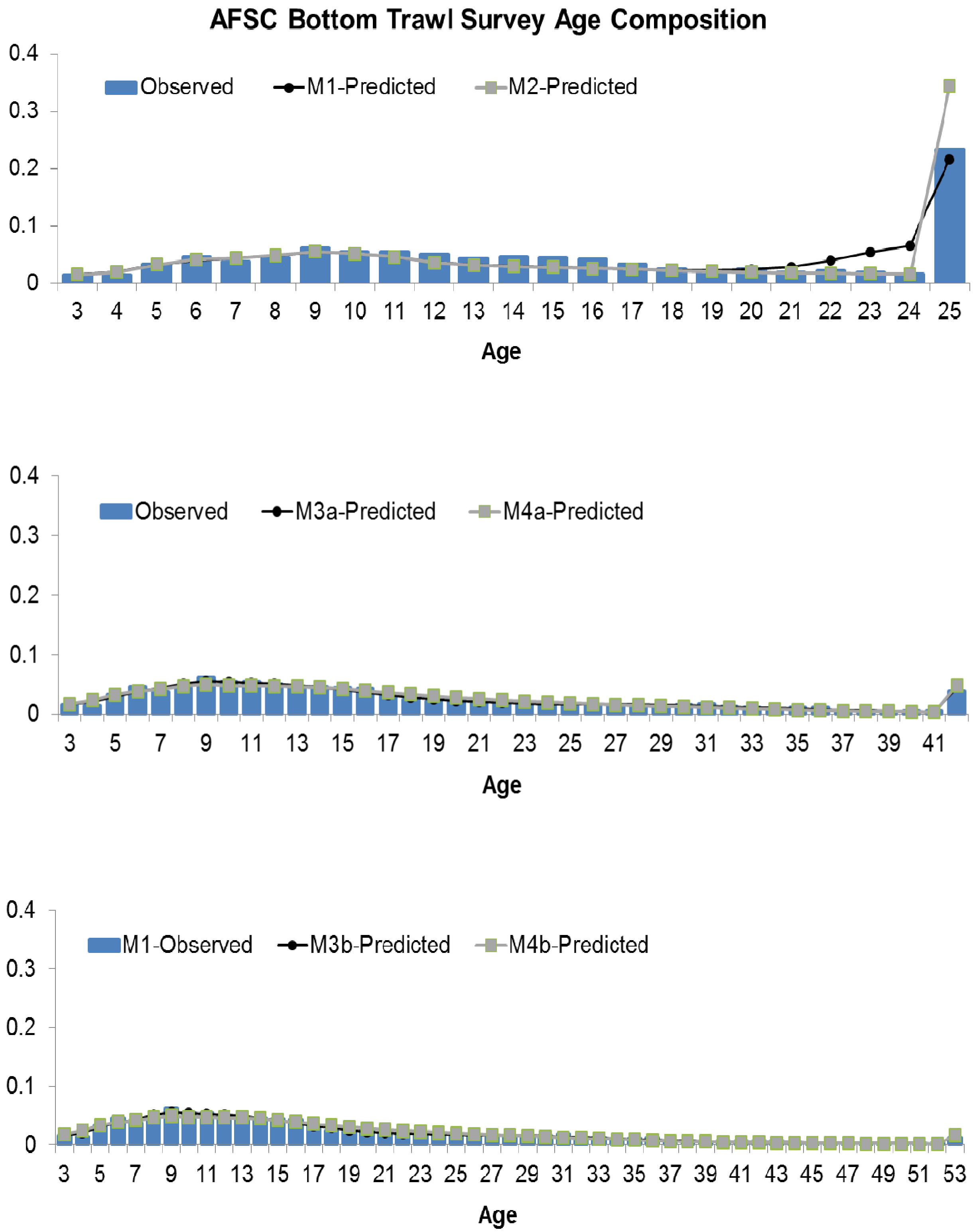


Figure 13-10a. Average AFSC bottom trawl survey age compositions for GOA RE/BS rockfish over all models considered (M1/M2, M3a/M4a, M3b/M4b). Observed = bars, predicted = lines with circles.

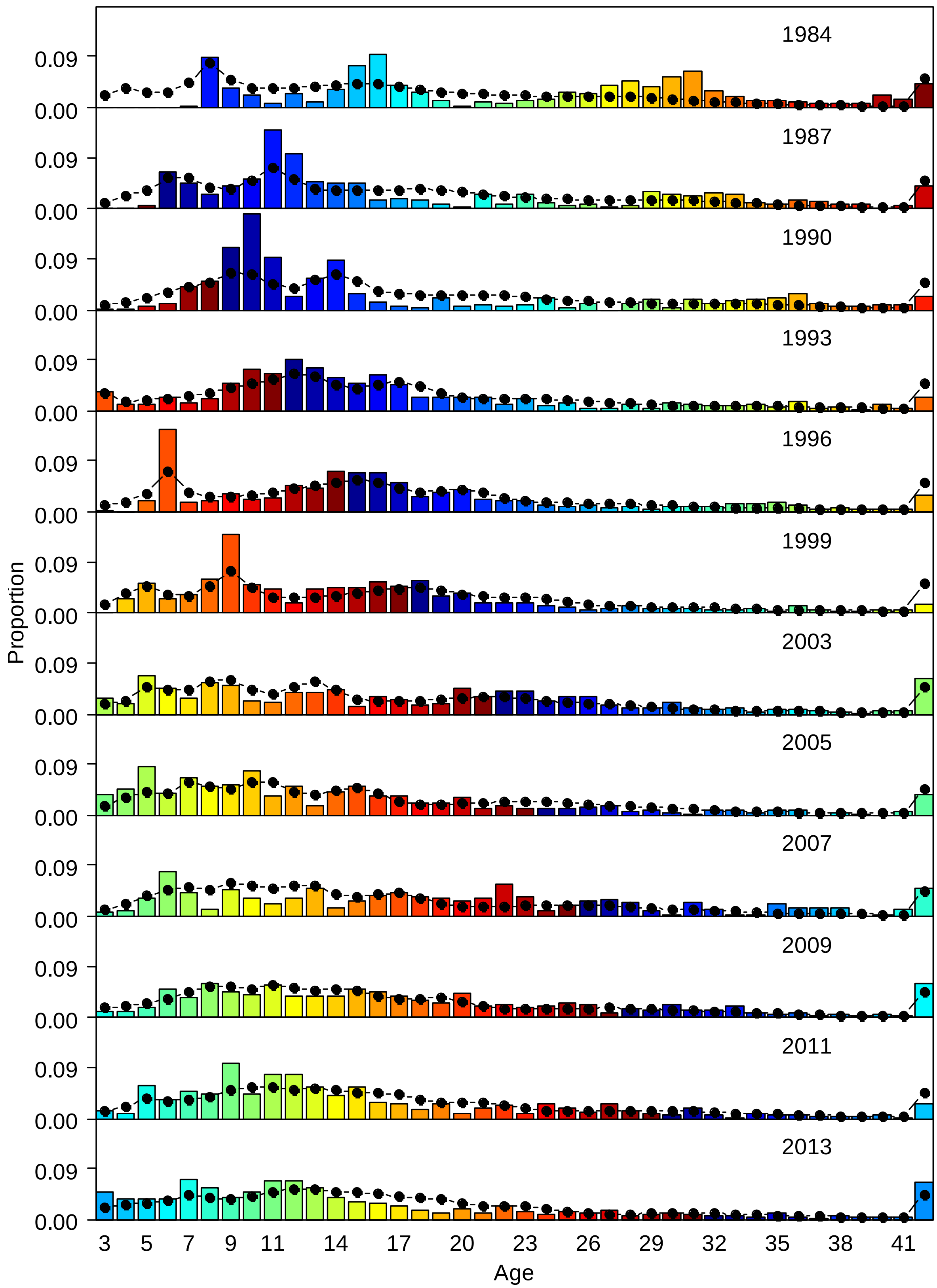


Figure 13-10b. AFSC bottom trawl survey age composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

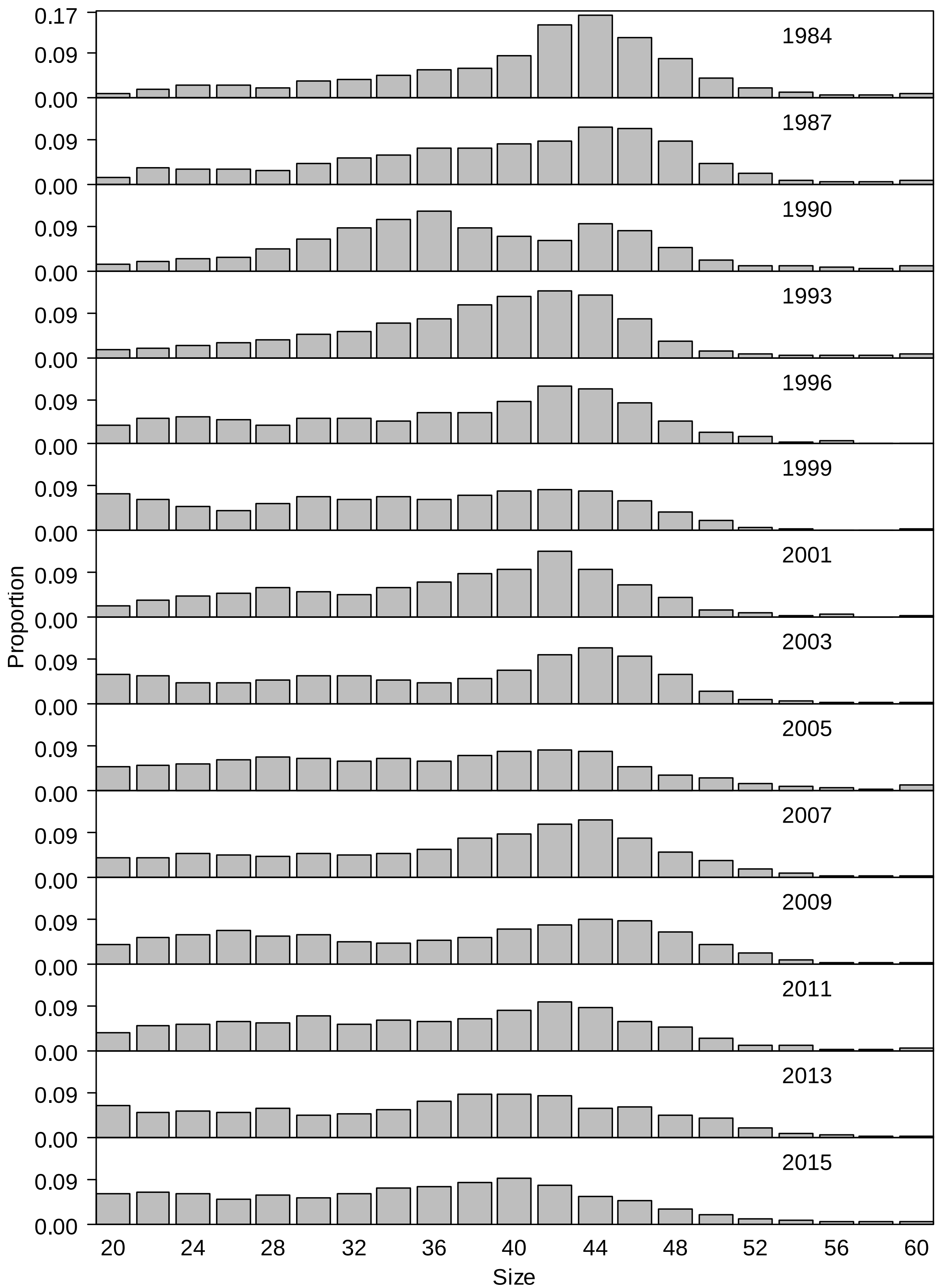


Figure 13-11. AFSC bottom trawl survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in the model.

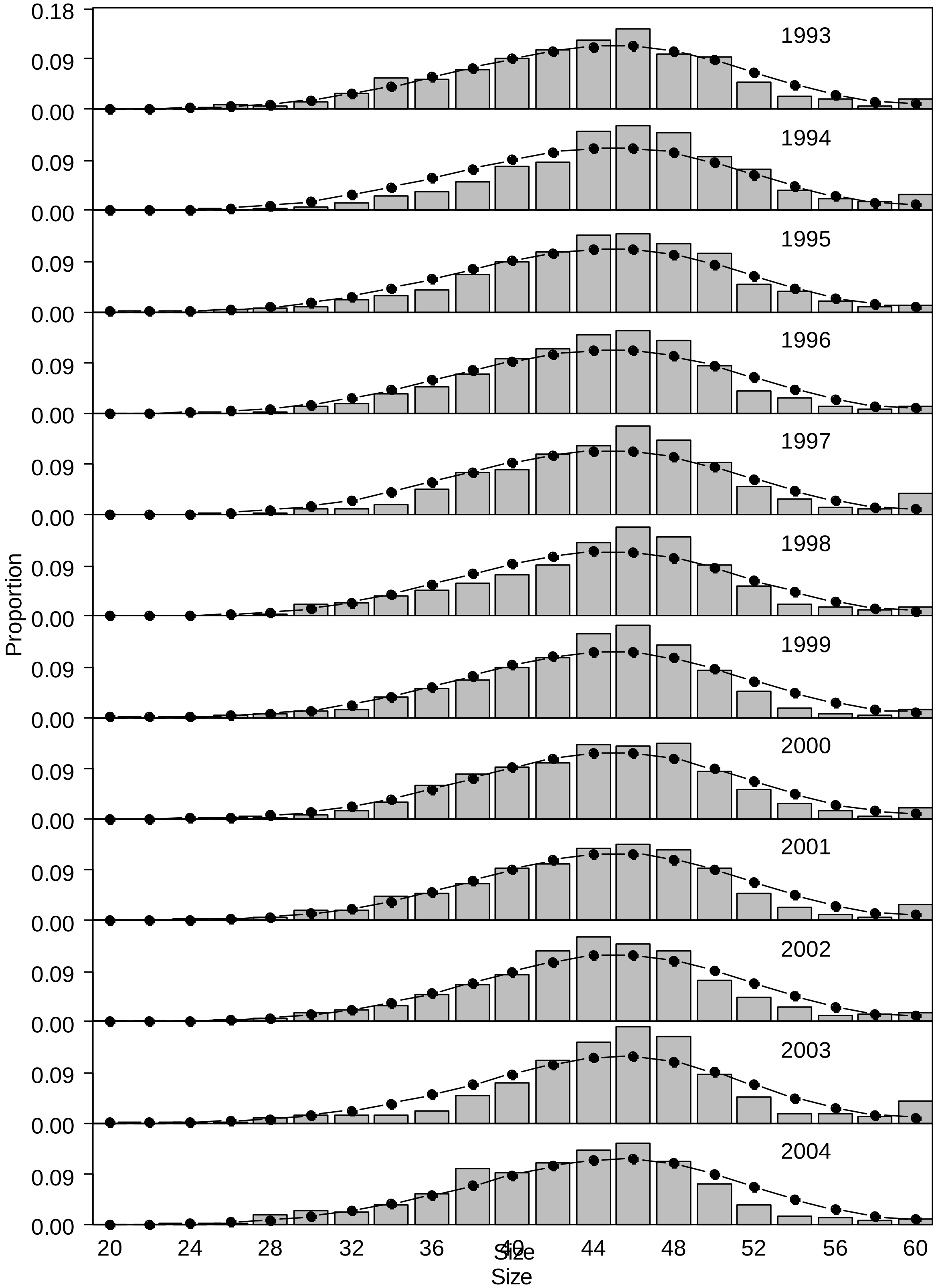


Figure 13-12. AFSC longline survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

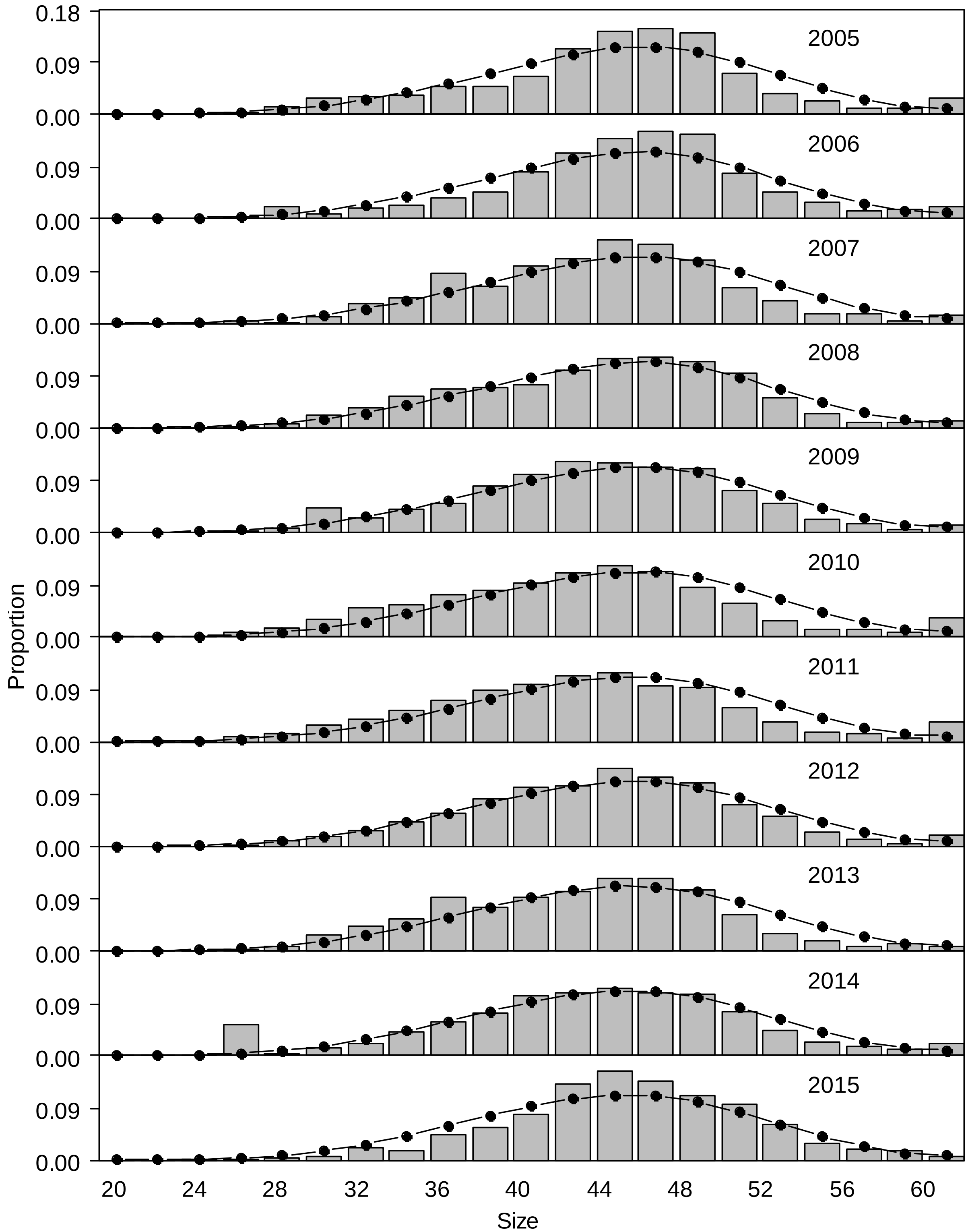


Figure 13-12 (continued). AFSC longline survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

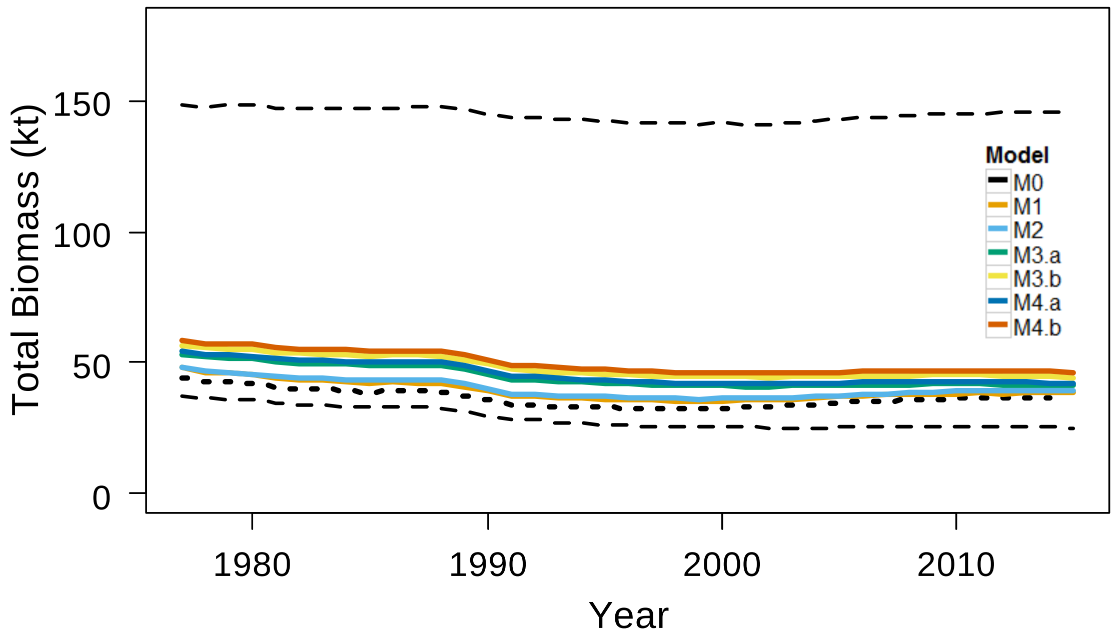


Figure 13-13a. Time series of predicted total biomass from all models considered (M1-M4b) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last year's model estimates included for comparison (M0, dotted black line).

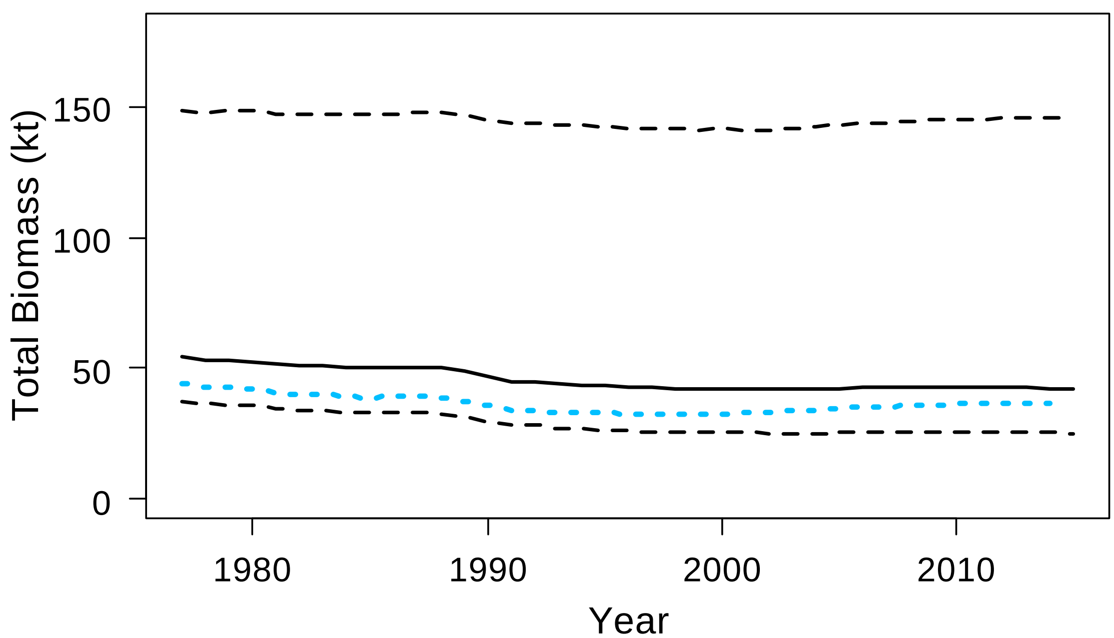


Figure 13-13b. Time series of predicted total biomass from author preferred model (M4a, solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last year's model estimates included for comparison (M0, dotted blue line).

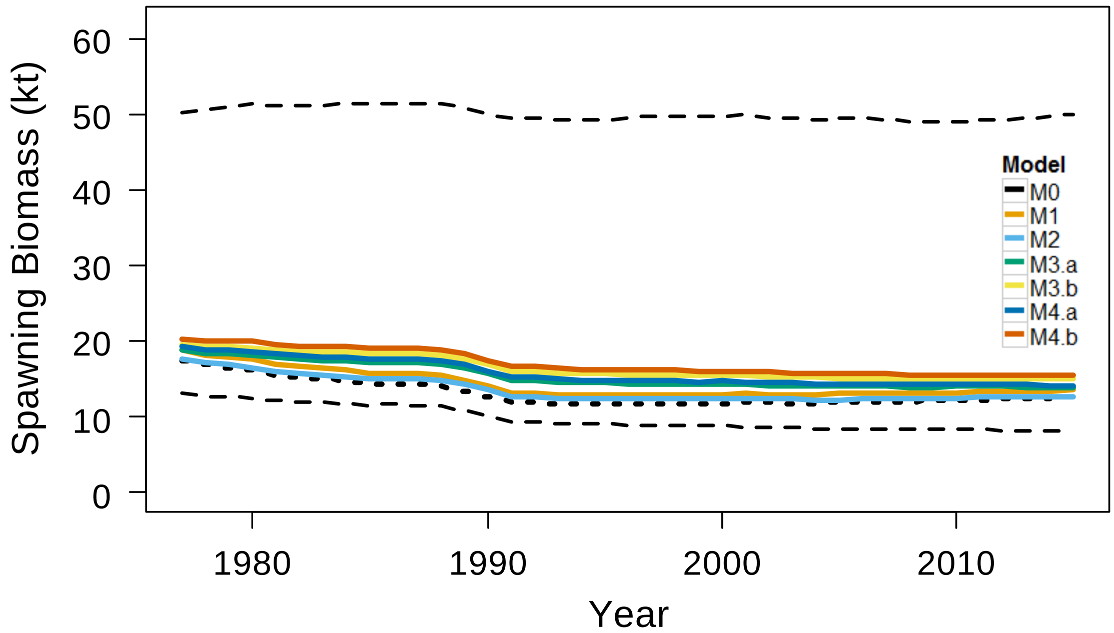


Figure 13-14a. Time series of predicted spawning biomass from all models considered (M1-M4b) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last year's model estimates included for comparison (dotted black line).

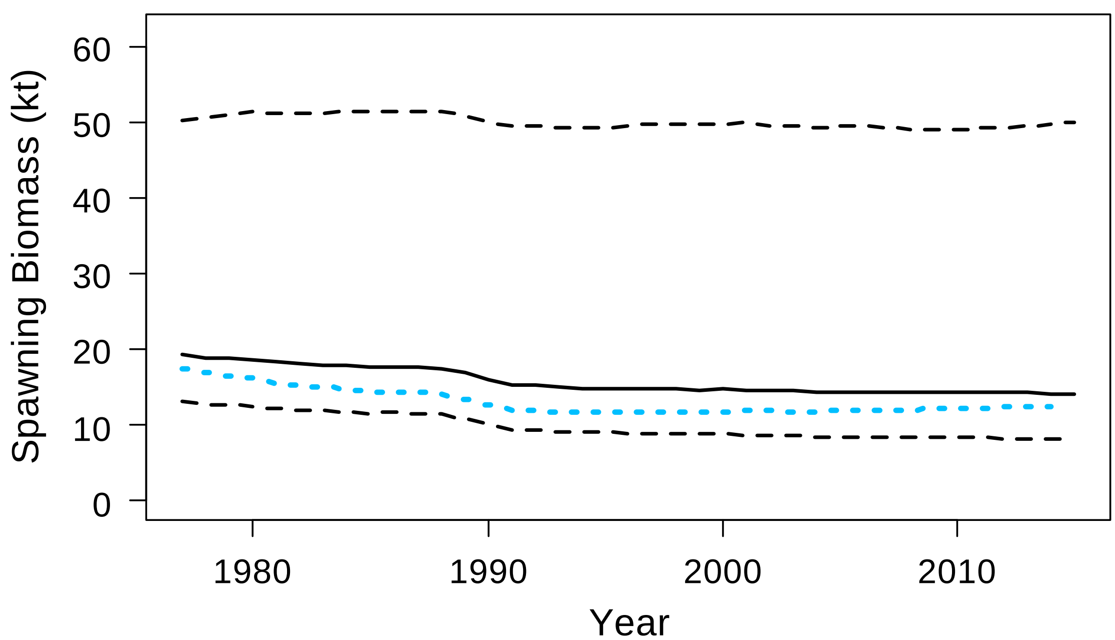


Figure 13-14b. Time series of predicted spawning biomass from author preferred model (solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last year's model estimates included for comparison (dotted blue line).

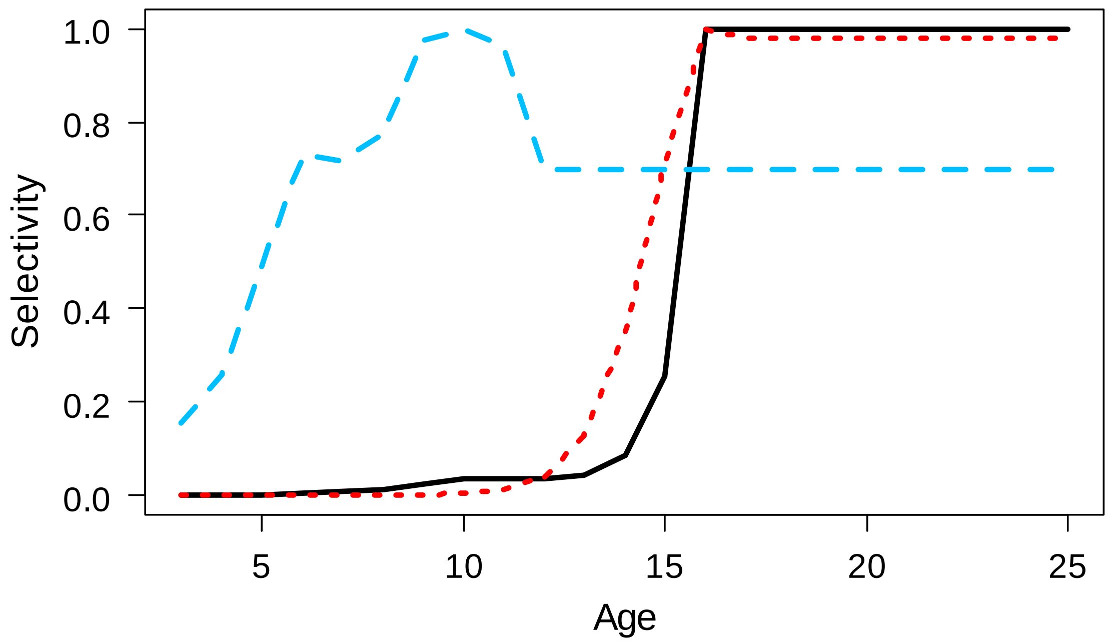


Figure 13-15a. Estimated selectivity curves for GOA RE/BS rockfish from base model, M0. Dashed blue line = AFSC bottom trawl survey selectivity, dotted red line = AFSC longline survey selectivity, and solid black line = combined fishery selectivity.

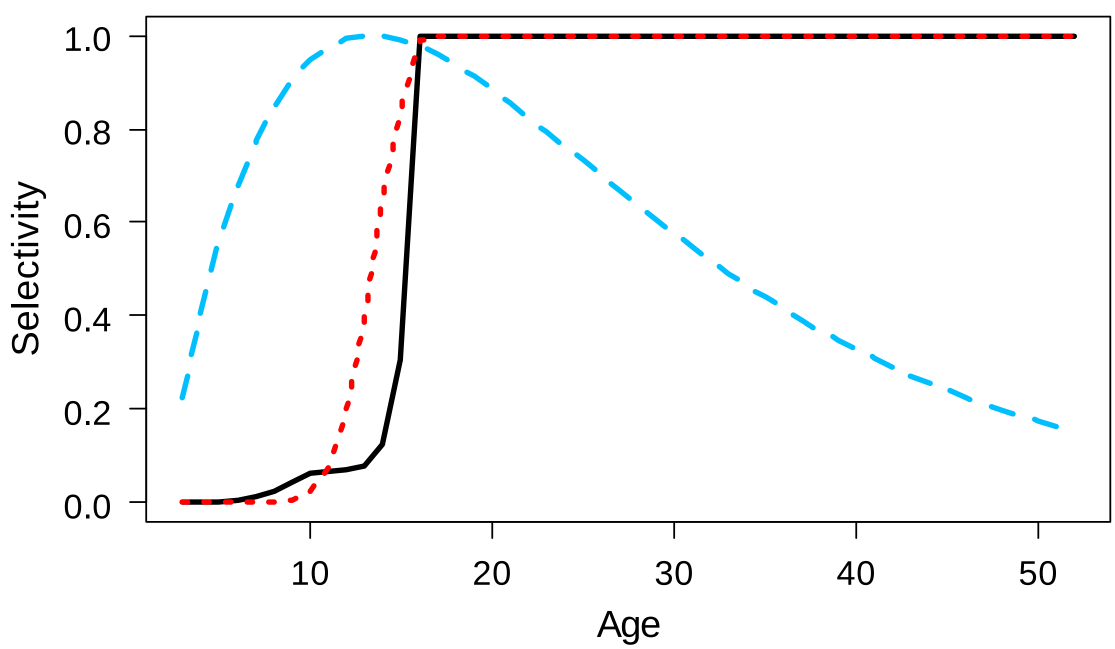


Figure 13-15b. Estimated selectivity curves for GOA RE/BS rockfish from author preferred model. Dashed blue line = AFSC bottom trawl survey selectivity, dotted red line = AFSC longline survey selectivity, and solid black line = combined fishery selectivity.

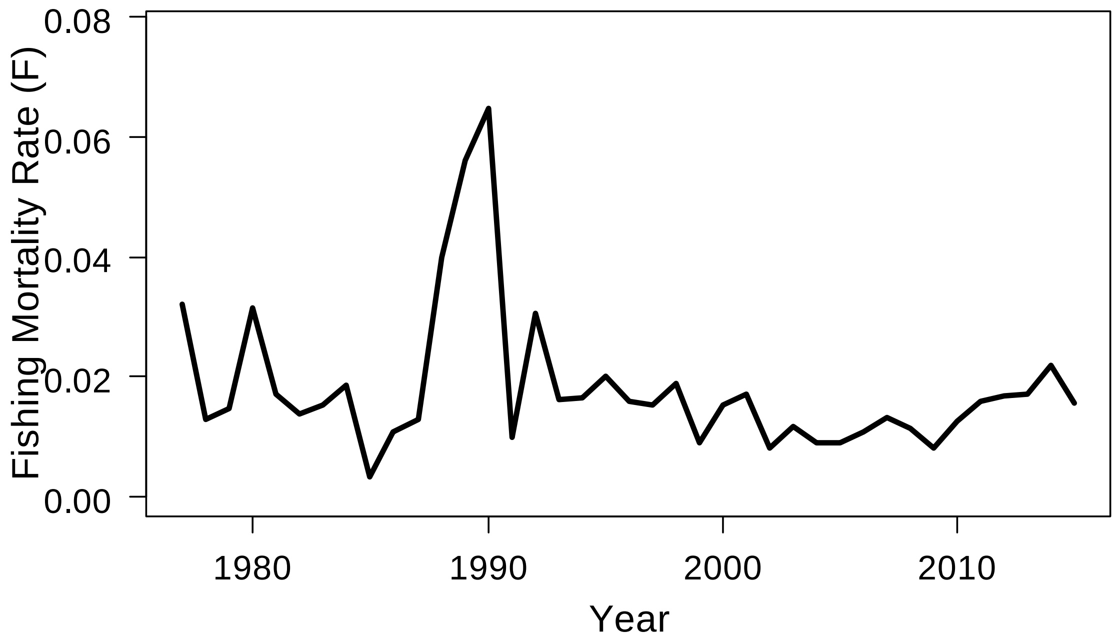


Figure 13-16. Time series of estimated fully selected fishing mortality for GOA RE/BS rockfish from author preferred model.

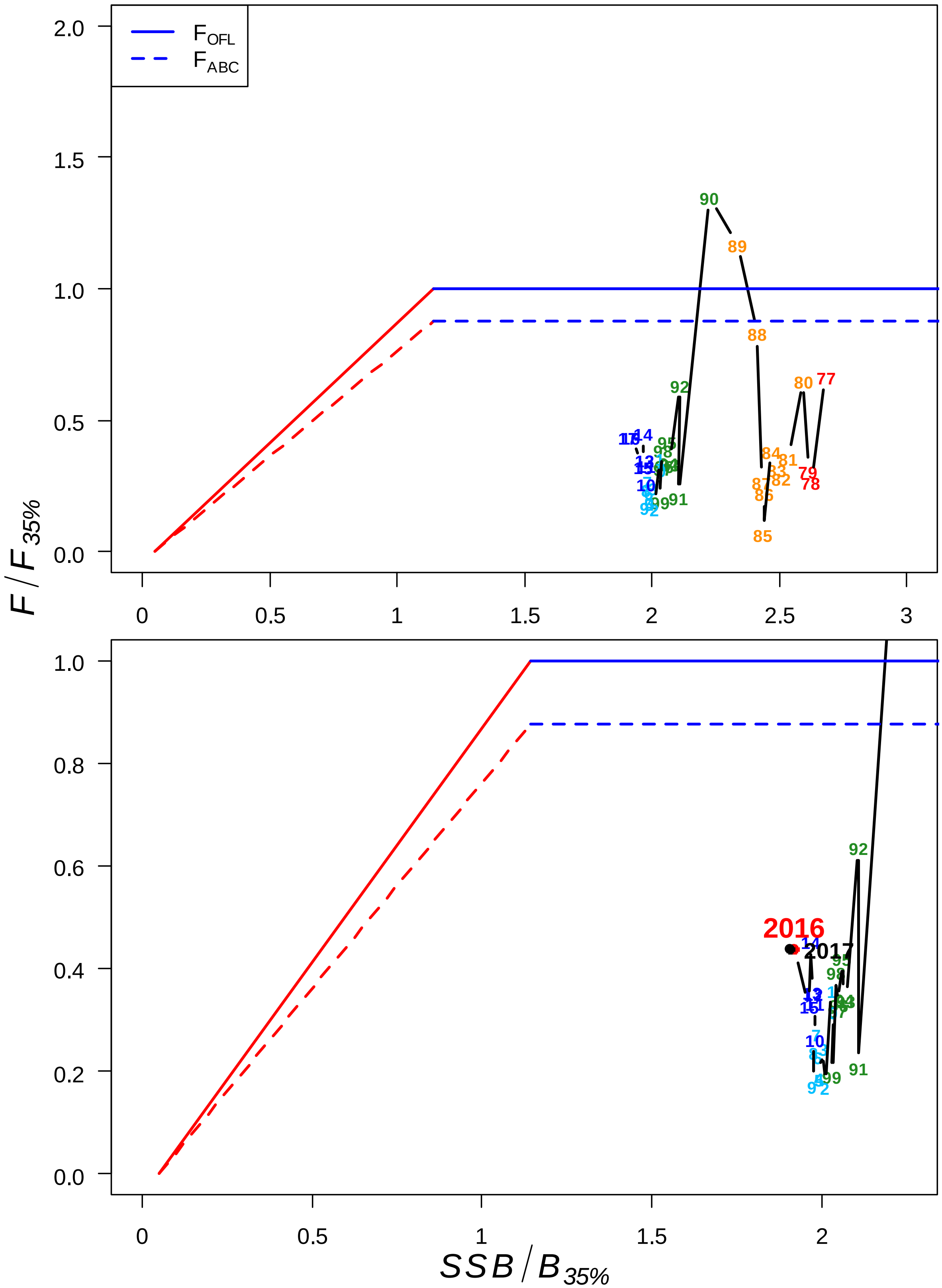


Figure 13-17. Time series of GOA RE/BS rockfish estimated spawning biomass relative to the target $B_{35\%}$ level and fishing mortality relative to F_{OFL} for author preferred model. The upper panel provides the entire time series while bottom panel presents the more recent management path.

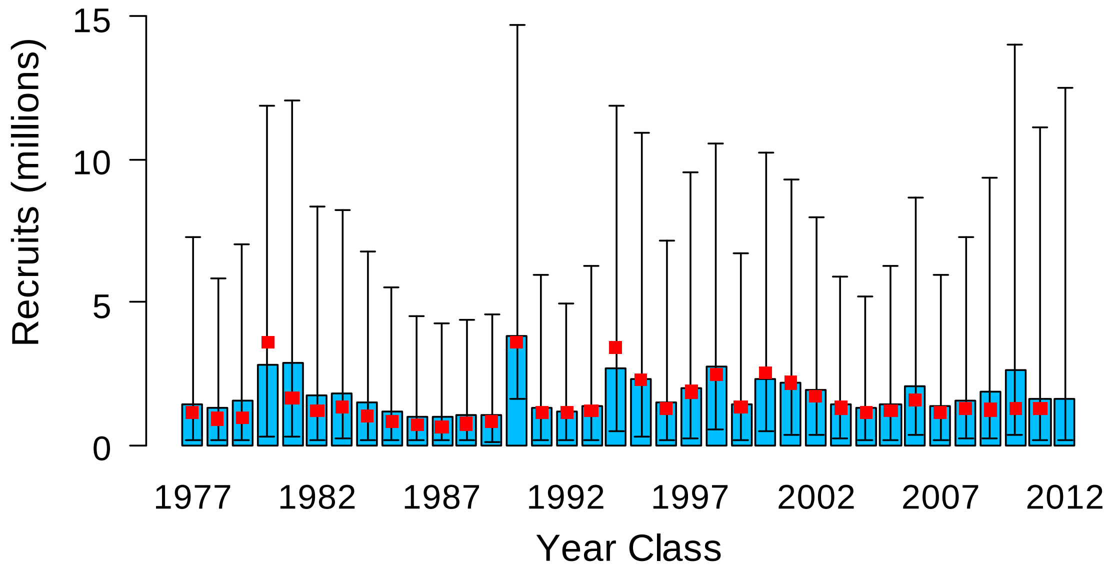


Figure 13-18. Estimated recruitments (age 3) of GOA RE/BS rockfish from author preferred model by year class with 95% credible intervals derived from MCMC. Red square in top graph presents last year's recruitment estimates for comparison.

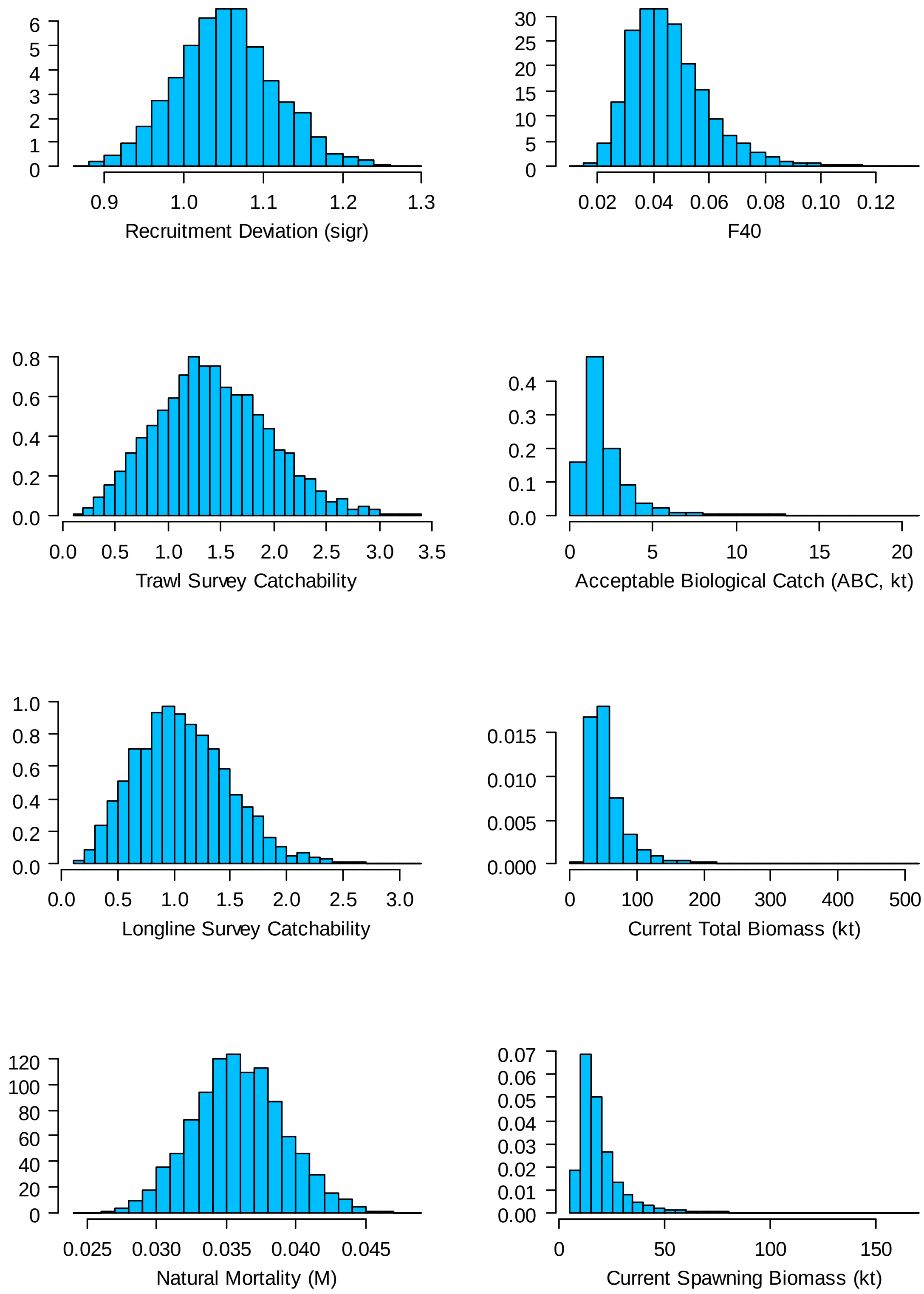


Figure 13-19: Histograms of estimated posterior distributions for key parameters derived from MCMC for GOA RE/BS rockfish.

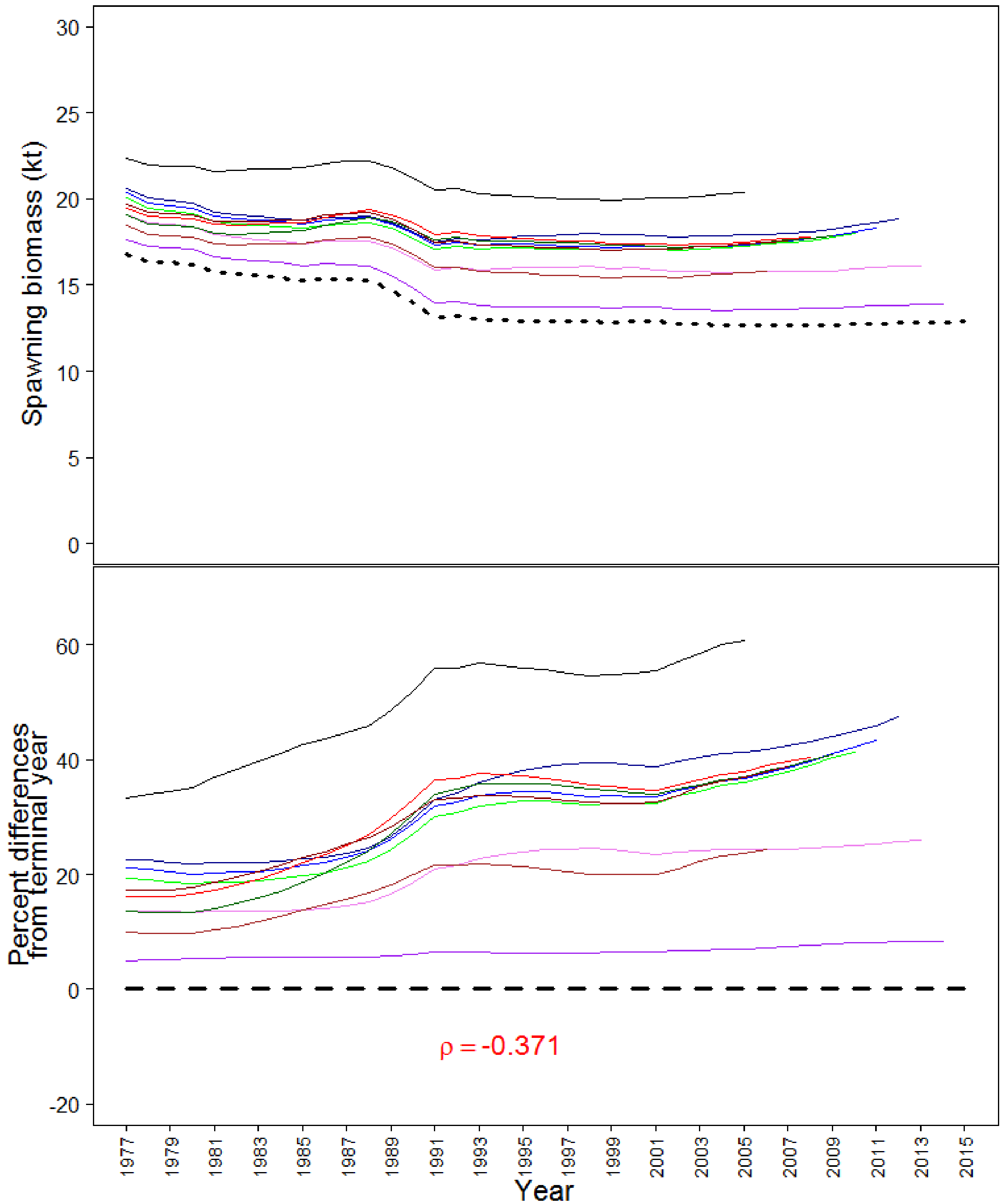


Figure 13-20: Retrospective peels of estimated female spawning biomass for the past 10 years from the author preferred model (top), and the percent difference in female spawning biomass from the preferred model in the terminal year (bottom).

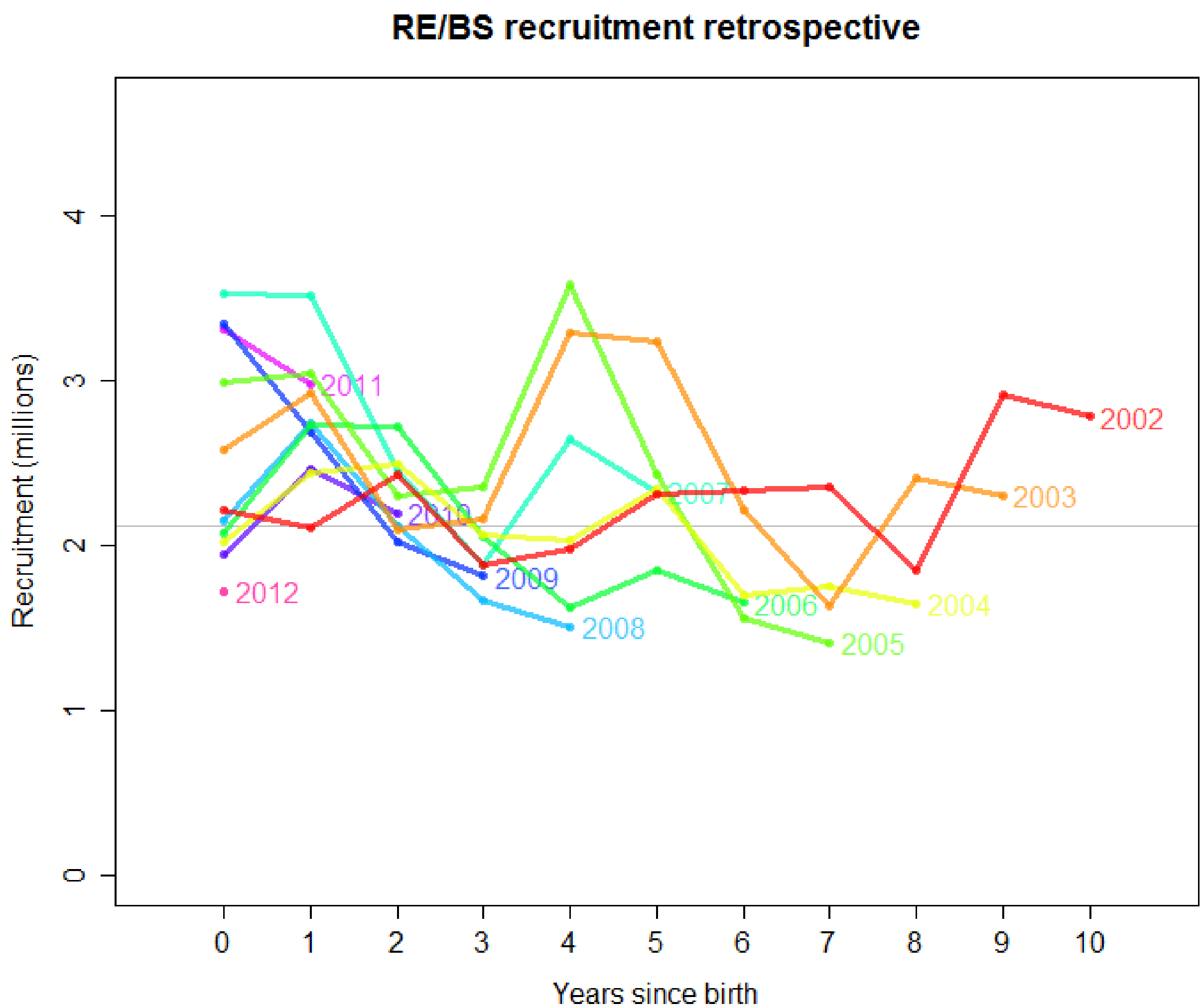


Figure 13-21: Squid plot of the development of initial estimates of age-3 recruitment since year class 2002 through year class 2012 from retrospective analysis. Number to the right of the terminal year indicates the year class.

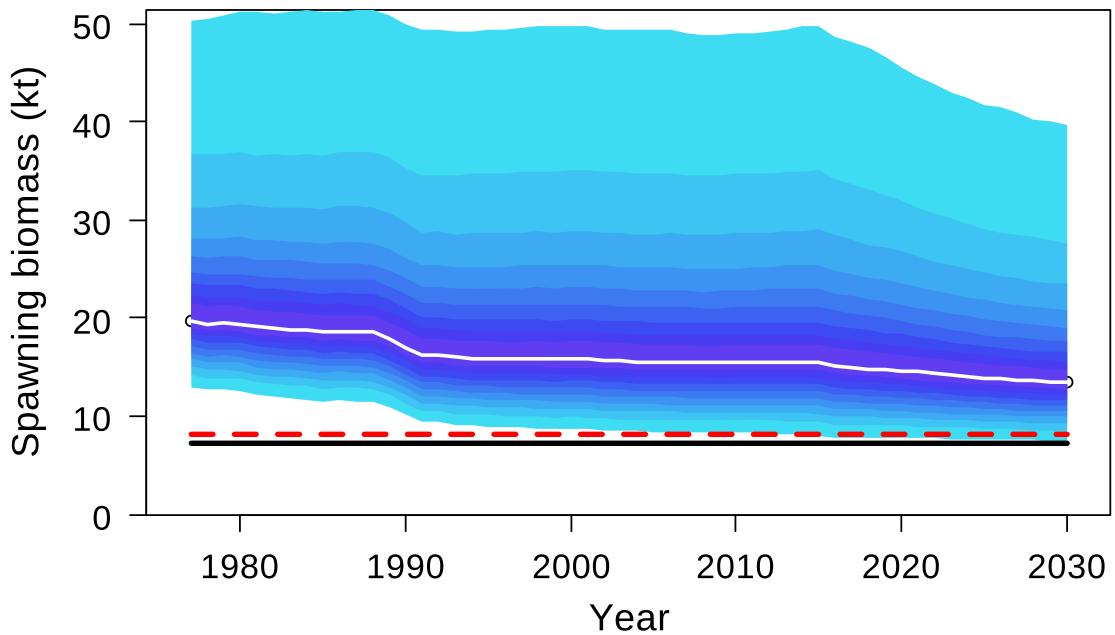


Figure 13-22: Bayesian credible intervals for entire spawning stock biomass series including projections through 2030. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1980-2013. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

Appendix 13A: Evaluation of some selectivity options for the Gulf of Alaska rougheye/blackspotted rockfish complex

Background

The SSC and Plan Team in 2014 recommended that the authors examine why the trawl survey selectivity exhibited a peculiar pattern that peaked for a few early years and plateaued at a value less than 1. The original rockfish template (Courtney et al. 2001), was developed with non-parametric selectivity as the preferred alternative. This method was based on penalizing the second differences between log selectivity parameters to prevent the curve from becoming dome-shaped depending on severity of the penalty. This method was employed in all of the Gulf of Alaska rockfish models until 2009, when the Pacific ocean perch model switched to parametric alternatives. This method was subsequently followed in the dusky and northern rockfish models. At that time, these species selectivity shapes were also deemed to have somewhat "unnatural" shapes, so the simpler, but more assumptive logistic or gamma curves were estimated instead. Additionally, it has been noted in the past that the plus age group for this assessment was too low and had extremely large proportions in the fishery plus age group when it was set at age 25. In this appendix, we explore some parametric and non-parametric alternative selectivities across different plus age groups for the trawl survey selectivity pattern.

Methods

Here we extend the non-parametric approach to examine 3rd differences which allows more flexibility and tends toward a dome-shape *a priori*, which seems to be what we would expect given the extremely old fish caught in the fishery and the relatively younger fish caught in the trawl survey. Since the basis of the non-parametric approach is to estimate a parameter for every age-class, the number of parameters was constrained by setting a maximum age after which each parameter is the same as that age. In the base model this was age 12, and for our additional explorations we set this to 20. We also explored one alternative where the age of last estimation was a moving parameter that was 5 less than the plus age. Additionally, we considered two parametric alternatives, the logistic and gamma curves which are both two-parameter models that can be asymptotic or dome-shaped, respectively (Table 13A-1).

Table 13A-1. Selectivity shapes explored for the 2015 September Plan Team meeting for GOA rougheye/blackspotted rockfish

BASE (very low 2nd difference penalty) implies linear *a priori*
3rd Diff_10 (penalty of 100 on 3rd differences), fixed selectivity after age 12
3rd Diff_Hi (penalty of 100 on 3rd differences), fixed selectivity after age 20
3rd Diff_Lo (penalty of 20 on 3rd differences), fixed selectivity after age 20
3rd Diff_max_5 (penalty of 100 on 3rd differences), selectivity is fixed at 5 ages before maximum age
Gamma (imposes a dome, though can be slight)
Logistic (forces asymptotic)

We examined these selectivity curves while simultaneously looking at the effect across the plus age group. To do this we use heat maps that show the relative quantities in three dimensions across plus age group and selectivity curve. We choose this method because there have not been specific methods developed to address choosing a plus age group that have quantitative criteria. The heat maps are a visual tool for choosing a reasonable range of plus ages which seem to have stabilized key quantities. In terms of model selection for selectivity curves, we evaluate the relative negative log-likelihood fits to the overall data and compositional data.

Results

Plus age groups between 25 and 77 were evaluated across seven selectivity alternatives. We highlight in the heat maps a band of plus age groups between 40-45 which appears to be a reasonable inflection point where the gradient of change in the degradation of fit slows down as more ages are added to the plus age group. We show Figure 13A-1 as a comparative example of the selectivity curves at a plus age of 42. These give a snapshot of one plus group alternative that the different selectivity models yield in terms of shape. The shapes range from sharp domes in the BASE model that flat line to the gentle dome shapes of the gamma and 3rd Diff_max_5 model. The negative log-likelihood (NLL) for the total fit to all data showed clear support for the trawl selectivity with the dome beginning at older ages (Figure 13A-2). The primary composition component that provides these reductions in the NLL is the fit to the trawl survey age data as this is the primary determinant of the trawl survey selectivity curve (Figure 13A-3). The fits to the fishery age compositions are generally similar and change much less relative to the fits to the trawl survey ages across plus groups and selectivity scenarios (Figure 13A-4). The superior fits of the more dome-shaped selectivities represent a compromise with the fit to the longline survey size data (Figure 13A-5), but these changes are also small relative to the improvements in fit to the trawl survey age data.

The effects on management quantities of both the choice of plus group and selectivity shape are substantial (Figure 13A-6). The estimated ABCs range from 1,000 to 1,800 t across all scenarios with the lowest ABCs resulting from the logistic curve at the current plus group (25) to 1,800 t for one of the sharper dome shapes (3rd_diff_Lo). Recent recommended ABCs have been between 1,100 and 1,200 t. The time series trajectories of spawning biomass estimated at the selectivity curves and plus age 42 shown in Figure 13A-1 generally bracket the BASE model configuration used in past assessments and all show the same trend, with differences in scale (Figure 13A-7).

Conclusions

The selectivity forms compared here were just one set of myriad possible selectivity options, but generally bracket a reasonable set of scenarios. The analysis presented here shows that some kind of dome-shaped selectivity is largely supported for trawl survey selectivity. The gamma selectivity and the most flexible non-parametric option (3rd Diff_max_5) models show the largest overall improvement in fit to the data, and a substantial improvement over the base model selectivity form. These two models largely show the same selectivity with some additional variability in the non-parametric form that on average is similar to the gamma curve. The gamma curve has only two parameters, while the non-parametric version has 44 parameters. Statistical catch at age models are generally not easily comparable with traditional model selection models such as Akaike Information Criterion (AIC), but if AIC were to be used here, it clearly would select the gamma distribution.

The choice of an optimum plus group is also not readily determined by standard model selection. As more age bins are added, the overall likelihood increases, despite adding additional parameters to the model to estimate the initial age composition. We suggest that the 40-45 range of plus ages, across all selectivity models, highlights an inflection point where the fits start degrading faster. The gamma selectivity curve provides a significant improvement to the current assessment model fits with a reduction in parameters. The extension of the plus group to the range of 40-45 would represent a reasonable compromise between model fit and additional parameters. In summary, we recommend that these improvements be considered for rougheye/blackspotted assessments in the future.

Figures

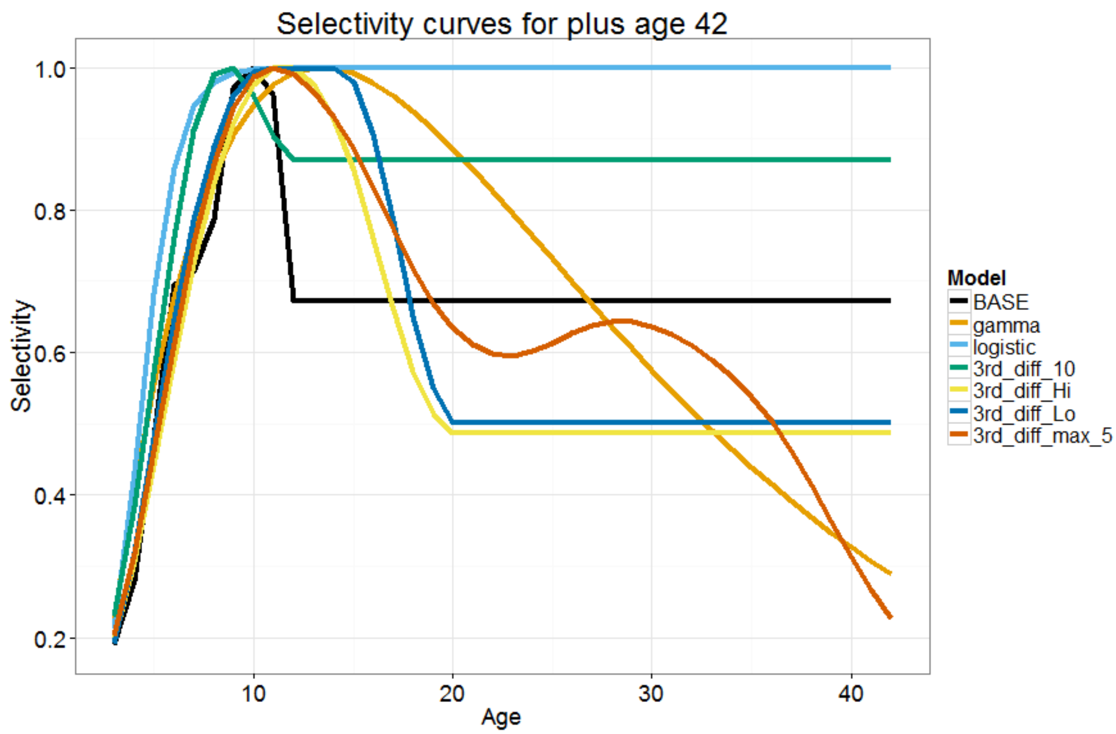


Figure 13A-1. Comparison of seven selectivity alternatives using a data plus group at age 42.

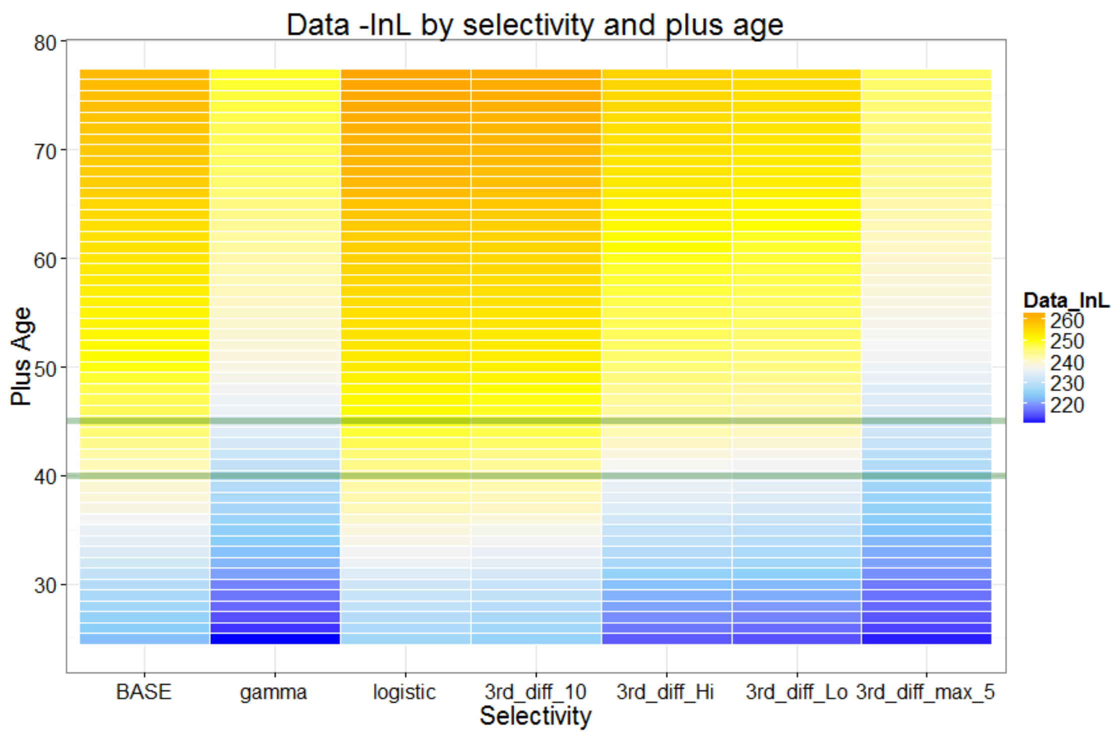


Figure 13A-2. Comparison of the negative log likelihoods of the total fit to the data components across plus group and selectivity scenarios.

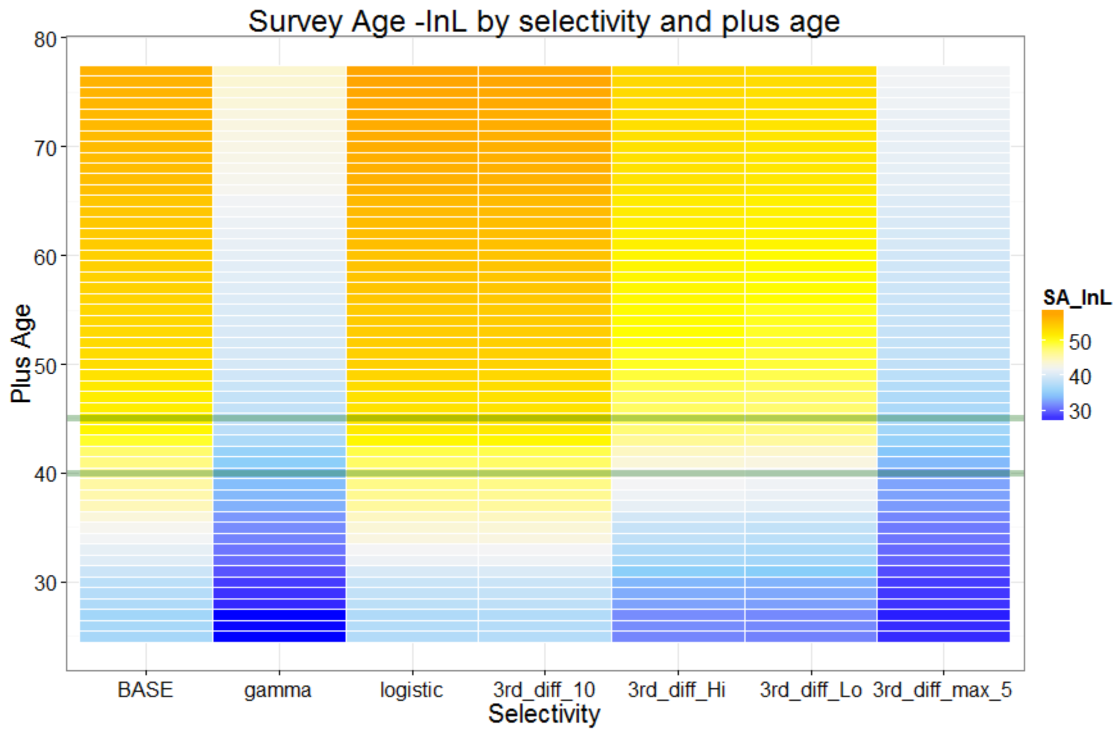


Figure 13A-3. Comparison of the negative log likelihoods of the fit to the trawl survey age composition data across plus group and selectivity scenarios.

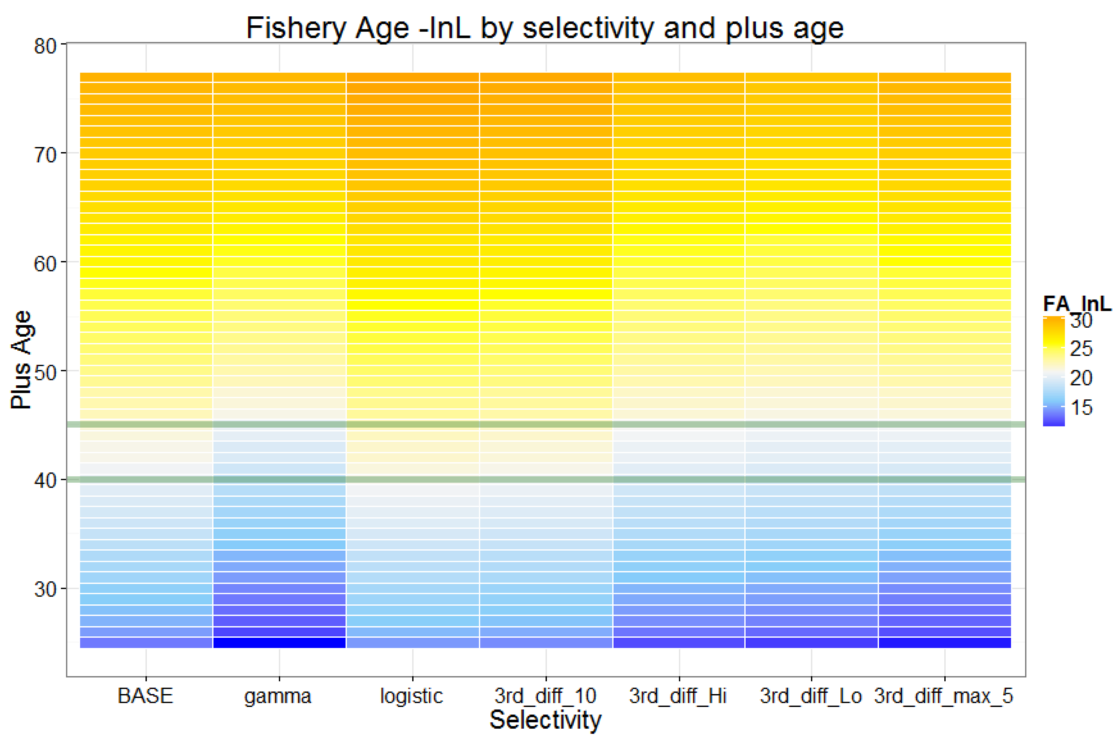


Figure 13A-4. Comparison of the negative log likelihoods of the fit to the fishery age composition data across plus group and selectivity scenarios.

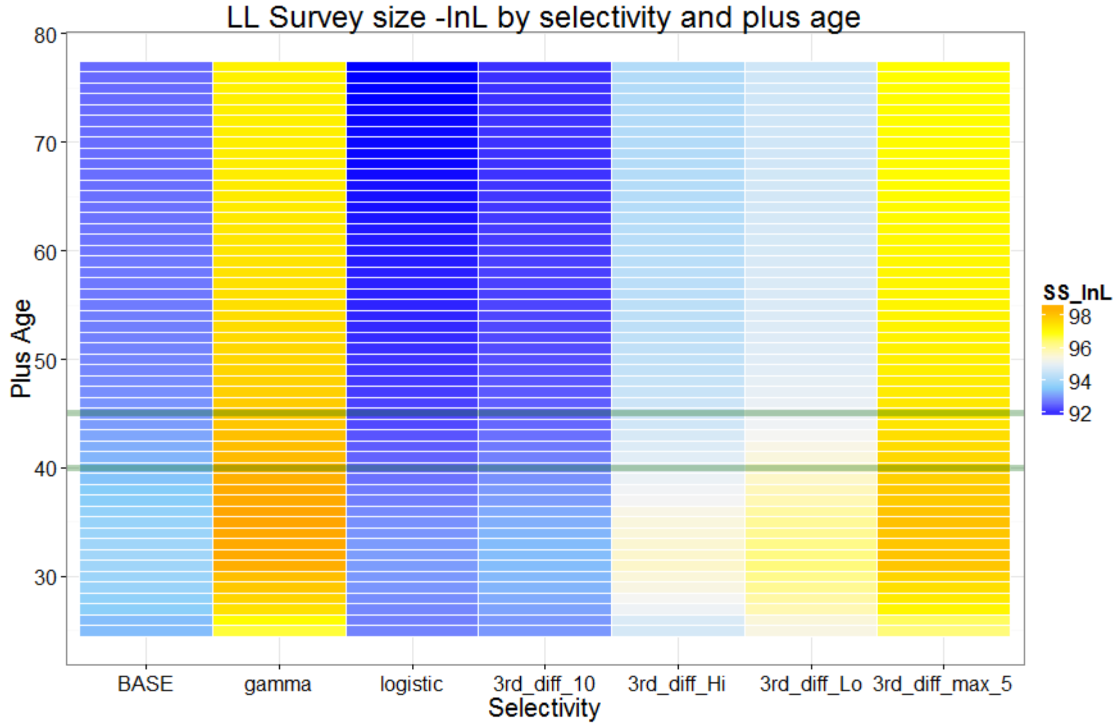


Figure 13A-5. Comparison of the negative log likelihoods of the fit to the longline survey size composition data across plus group and selectivity scenarios.

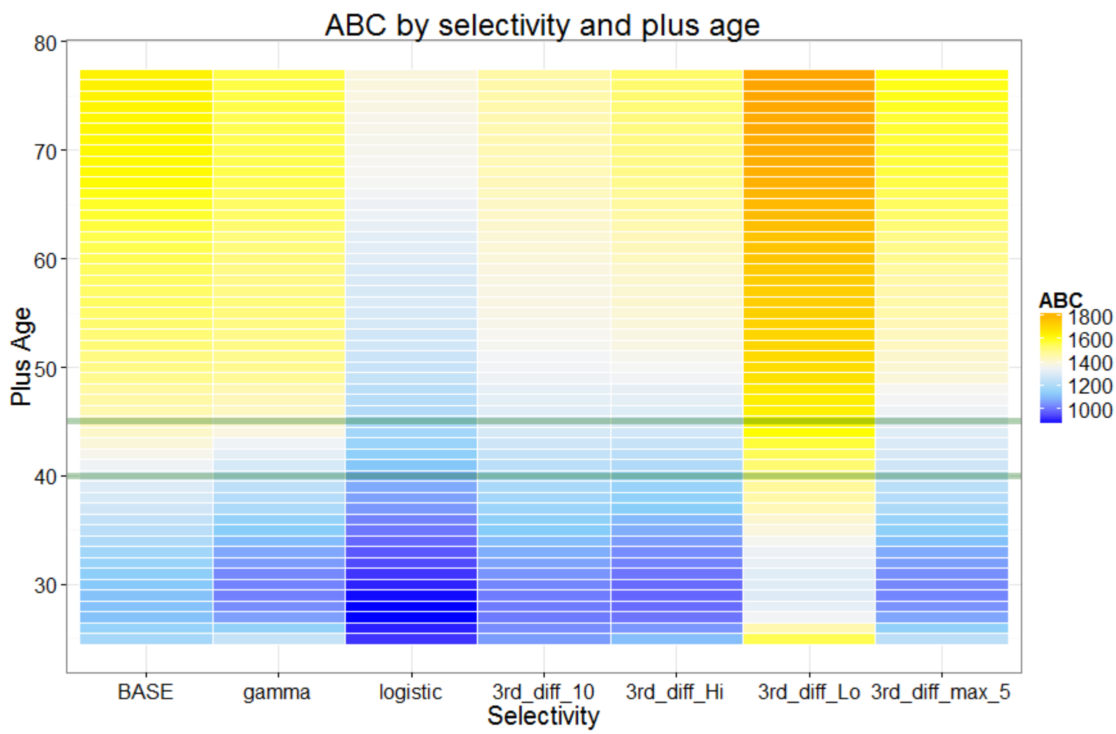


Figure 13A-6. Comparison of the Acceptable Biological Catch (ABC) estimated across plus group and selectivity scenarios.

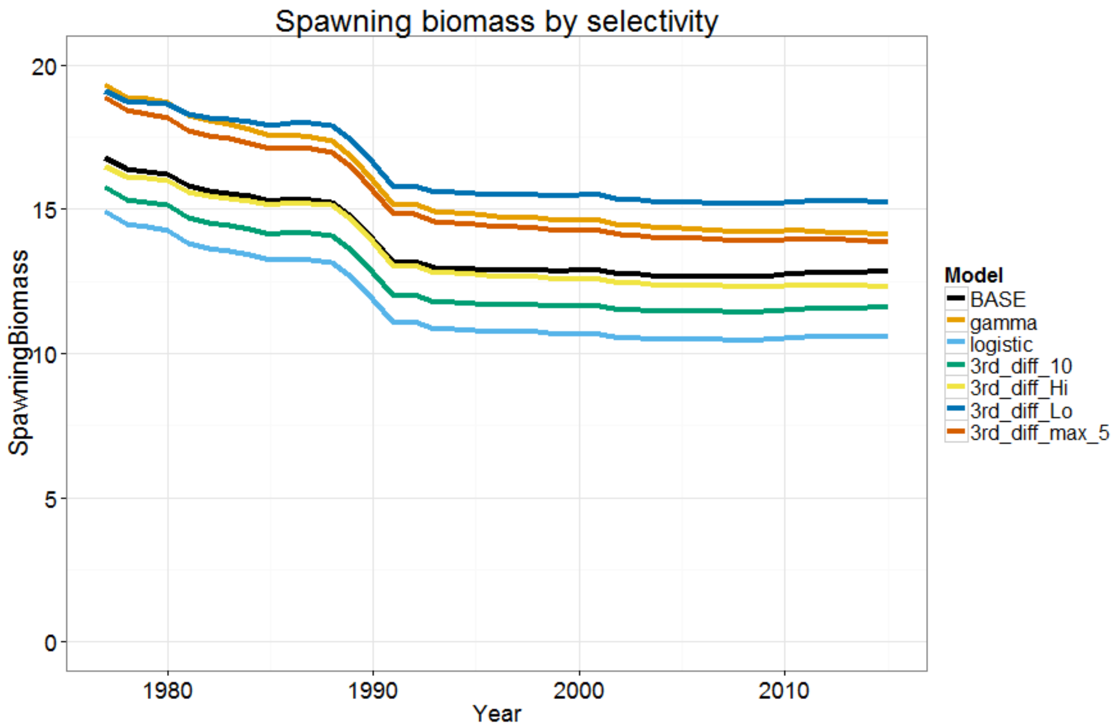


Figure 13A-7. Comparison of the spawning biomass trajectories estimated at plus group 42 and seven selectivity scenarios.

Appendix 13B. Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska.

The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities (Table 13B-1). 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 Gulf of Alaska (GOA) rougheye and blackspotted (RE/BS) rockfish stock, these estimates can be compared to the research removals reported in previous assessments (Shotwell et al. 2009, 2011, 2014). The majority of research removals are taken by the Alaska Fisheries Science Center's (AFSC) biennial bottom trawl survey and by the AFSC's longline survey and International Pacific Halibut Commission's (IPHC) longline survey. Other research activities that harvest RE/BS rockfish are minor but include other trawl research activities, scallop dredge, and recreational harvests.

Although data are not available for a complete accounting of all research catches, the values in Table 13A-1 indicate that generally RE/BS stock research removals have been modest relative to the fishery catch and compared to the research removals for many other species. The exceptions are in 1998 and 1999 where a total of 52 and 36 t, respectively were taken, mostly by research trawling. However, because commercial catches for the shortraker/rougheye rockfish complex during these years were below ABC (please refer to Table 13-3 in the main document) this relatively large catch was not a conservation concern. Total removals from activities other than a directed fishery were 10 t in 2014. This is 0.9% of the 2014 recommended ABC of 1,122 t and represents a low risk to the RE/BS stock. Even research catches of this magnitude, however, do not pose a significant risk to the RE/BS stock in the GOA.

The second dataset, Halibut Fishery Incidental Catch Estimation (HFICE), is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011).

These estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between "retained" or "discarded" catch. These estimates should be considered a separate time series from the current CAS estimates of total catch. Because of potential overlaps HFICE removals should not be added to the CAS produced catch estimates. The overlap will apply when groundfish are retained or discarded during an IFQ halibut trip. IFQ halibut landings that also include landed groundfish are recorded as retained in eLandings and a discard amount for all groundfish is estimated for such landings in CAS. Discard amounts for groundfish are not currently estimated for IFQ halibut landings that do not also include landed groundfish. For example, catch information for a trip that includes both landed IFQ halibut and sablefish would contain the total amount of sablefish landed (reported in eLandings) and an estimate of discard based on at-sea observer information. Further, because a groundfish species was landed during the trip, catch accounting would also estimate discard for all groundfish species based on available observer information and following methods described in Cahalan et al. (2010). The HFICE method estimates all groundfish caught during a halibut IFQ trip and thus is an estimate of groundfish caught whether landed or discarded. This prevents simply adding the CAS total with the HFICE estimate because it would be analogous to counting both retained and discarded groundfish species twice. Further, there are situations where the HFICE estimate includes groundfish caught in State waters and this would need to be considered with respect to ACLs (e.g. Chatham Strait sablefish fisheries). Therefore, the HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery will become available following restructuring of the FMA Program in 2013. At this time all vessels greater than 25 ft will be monitored for groundfish catch.

The HFICE estimates of GOA RE/BS stock catch are highly variable but also significant ranging from 28 – 78 t per year (Table 13B-2). The majority of catch occurs in the Southeast and Southeast Inside waters. It should be noted that Southeast Inside waters are managed by the State of Alaska and catches from these areas are generally not included in groundfish assessments in the Gulf of Alaska Federal Management Plan. It is unknown what level of RE/BS catch is double-counted in these estimates and the Catch Accounting System. Regardless, the estimated catch from the unobserved halibut fishery is substantial and improved catch estimates from this fishery are warranted.

Literature Cited

Cahalan J., J. Mondragon., and J. Gasper. 2010. Catch Sampling and Estimation in the Federal Groundfish Fisheries off Alaska. NOAA Technical Memorandum NMFS-AFSC-205. 42 p.

Shotwell, S.K., D. Hanselman, and D. Clausen. 2009. Gulf of Alaska rougheye rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2010. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. pp. 993-1066.

Tribuzio, CA, S Gaichas, J Gasper, H Gilroy, T Kong, O Ormseth, J Cahalan, J DiCosimo, M Furuness, H Shen, K Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams of the North Pacific Fishery Management Council.

Table 13B-1. Total removals of Gulf of Alaska rougheye/blackspotted rockfish (t) from activities not related to directed fishing, since 1977. Trawl survey sources are a combination of the NMFS echo-integration, large-mesh, GOA bottom trawl surveys, and occasional short-term research projects. Longline may include the IPHC and AFSC longline surveys. Other includes personal use, recreational, scallop dredge, and subsistence harvest.

Year	Source	Trawl	Longline	Other	Total
1977	**Assessment of RE/BS stock complex in the Gulf of Alaska (Shotwell et al. 2009)**	1			1
1978		2			2
1979		1			1
1980		1			1
1981		6			6
1982		3			3
1983		3			3
1984		17			17
1985		7			7
1986		2			2
1987		13			13
1988		0			0
1989		1			1
1990		5			5
1991		0			0
1992		0			0
1993		10			10
1994		0			0
1995		0			0
1996		5	8		13
1997		0	16		16
1998		45	7		52
1999		28	8		36
2000		0	10		10
2001		2	7		9
2002		0	6		6
2003		3	6		9
2004		0	6		6
2005		5	4		9
2006		0	5		5
2007		8	7		15
2008		0	11		11
2009		6	9		15
2010	AKRO	<1	7	<1	7
2011	AKRO	<1	6	<1	8
2012	AKRO	2	5	<1	6
2013	AKRO	2	4	<1	6
2014	AKRO	<1	<1	<1	1

Table 13B-2. Estimates of Gulf of Alaska RE/BS stock catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group. WGOA = Western Gulf of Alaska, CGOA = Central Gulf of Alaska, EGOA = Eastern Gulf of Alaska, PWS = Prince William Sound.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
WGOA	<1	4	7	1	5	3	2	5	3	<1
CGOA-Shumagin	<1	2	1	<1	3	<1	<1	<1	6	1
CGOA-Kodiak	4	<1	6	8	1	9	<1	7	28	22
EGOA-Yakutat/PWS*	<1	<1	<1	4	2	5	3	5	7	12
EGOA-Southeast	2	18	9	14	15	8	11	9	6	7
Southeast Inside*	21	29	31	24	51	19	31	11	7	4
Total	28	53	54	51	78	44	46	37	56	46

*These areas include removals from the state of Alaska waters.

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