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

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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, last year during an on-cycle (odd) year, we presented an executive summary similar to an off-cycle year for GOA rougheye and blackspotted (RE/BS) rockfish due to the 2013 government shutdown and extensive data updates that were needed. The GOA Plan Team (November 2013) subsequently recommended a full stock assessment be presented in 2014. We, therefore, 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 Gulf of Alaska rougheye and blackspotted rockfish (RE/BS 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 three models presented in the assessment. Model 0 is the last full assessment base model from 2011. Model 1 is an intermediate model which uses all the new and updated data but keeps the previous longline survey abundance index based on weights and the old conversion matrices. Finally, Model 2 is the author preferred model which uses all the new and updated data, the longline survey abundance index based on numbers, and the updated conversion matrices.

Summary of Changes in Assessment Inputs

Changes in the input data: New and updated data added to this model include updated catch estimates for 2011-2013, new catch estimates for 2014-2016 (see *Specified Catch Estimation* subsection in **Harvest Recommendations** section), new fishery ages for 2009 and 2012, new fishery lengths for 2011, a new trawl survey estimate for 2013, updated trawl survey ages for 2009, new trawl survey ages for 2011, and fully revised longline survey abundance estimates and length frequencies. We now use the time series of relative population numbers (RPNs) rather than relative population weights (RPWs) to represent the longline survey abundance (see *AFSC Longline Abundance Index* section). Use of the RPNs follows what is done for the sablefish assessment model. New biological data on growth and aging error were used to update the weight-at-age estimates, the size-at-age conversion matrix, and the aging error matrix.

Changes in the assessment methodology: For the preferred model (Model 2), the longline survey abundance index is fit in number instead of weight.

Summary of Results

Reference values for RE/BS rockfish are summarized in the following table, with the recommended ABC and OFL values for 2015 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:*	
	2014	2015	2015	2016
M (natural mortality rate)	0.034	0.034	0.034	0.034
Tier	3a	3a	3a	3a
Projected total (ages 3+) biomass (t)	42,810	43,337	36,584	36,610
Projected female spawning biomass (t)	12,897	13,325	12,480	12,595
$B_{100\%}$	24,329	24,329	22,449	22,449
$B_{40\%}$	9,732	9,732	8,980	8,980
$B_{35\%}$	8,515	8,515	7,857	7,857
F_{OFL}	0.047	0.047	0.045	0.045
$maxF_{ABC}$	0.039	0.039	0.038	0.038
F_{ABC}	0.039	0.039	0.038	0.038
OFL (t)	1,497	1,518	**1,345**	1,370
maxABC (t)	1,244	1,262	1,122	1,142
ABC (t)	1,244	1,262	**1,122**	1,142
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
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 2015 and 2016 are derived using estimated catch of 736 t for 2014 and projected catches of 502 t for 2015 and 501 t for 2016 based on realized catches from 2011-2013. This calculation is in response to management requests to obtain more accurate projections.

The 2013 trawl survey estimate was the lowest of the time series at 40% below average. The 2012 and 2013 longline survey abundance estimates (RPNs) were about 6% and then 16% below average. However, the 2014 longline RPN increased substantially from 2013 to be 17% above average.

Parameter estimates for all three models are provided for comparison purposes. The updated Models 1 and 2 are somewhat similar with higher trawl and longline survey catchability than the base Model 0. However, Model 1 (intermediate model) has lower mean recruitment and lower estimates of spawning biomass. Other estimates are similar between all three models.

For the 2015 fishery, we recommend the maximum allowable ABC of 1,122 t from the author preferred model (Model 2). This is a 10% decrease from last year's ABC of 1,244 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 2013 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. As an alternative to this, both the Plan Team and SSC have requested that the random effects model proposed by the Survey Averaging Working Group be considered for apportionment and provided alongside the current apportionment for comparison purposes.

The following table shows the apportionment for the 2015 and 2016 fishery using the three survey weighted average and random effects methods.

Method	Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
Three Survey Average			10.3%	56.3%	33.4%	100%
	2015	Area ABC (t)	**115**	**632**	**375**	**1,122**
		OFL (t)				**1,345**
	2016	Area ABC (t)	**117**	**643**	**382**	**1,142**
		OFL (t)				**1,370**
Random Effects			10.6%	57.3%	32.1%	100%
	2015	Area ABC (t)	**119**	**643**	**360**	**1,122**
		OFL (t)				**1,345**
	2016	Area ABC (t)	**122**	**654**	**366**	**1,142**
		OFL (t)				**1,370**

We recommend continuing with the standard three survey weighted average apportionment for RE/BS rockfish. The random effects model fit the area-specific biomass reasonably well but was sensitive to starting values for the Central GOA (see *Area Allocation of Harvests* subsection in **Harvest Recommendations** section). We will consider the random effects model for RE/BS rockfish when recommendations on estimation uncertainty and inclusion of other survey biomass estimates (e.g. AFSC longline survey) are provided by the Survey Averaging Working Group.

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
RE/BS complex	2013	42,883	1,482	1,232	1,232	574
	2014	42,810	1,497	1,244	1,244	704
	2015	36,584	1,345	1,122		
	2016	36,610	1,370	1,142		

Stock/ Assemblage	Area	2014 OFL	2014 ABC	2014 TAC	2014 Catch[2]	2015 OFL	2015 ABC	2016 OFL	2016 ABC
RE/BS complex	W		82	82	10		115		117
	C		864	864	528		632		643
	E		298	298	166		375		382
	Total	1,497	1,244	1,244	704	1,345	1,122	1,370	1,142

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

[2]Current as of October 1, 2014. 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 is pleased to see that many assessment authors have examined retrospective bias in the assessment and encourages the authors and Plan Teams to determine guidelines for how to best evaluate and present retrospective patterns associated with estimates of biomass and recruitment. We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments." (SSC, December 2011)
"For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years."
(Plan Team, September 2012)

In September 2013, the Retrospective Investigations Group responded to both of these comments with a report on retrospective analyses conducted on Alaska FMP groundfish species (Hanselman et al. 2013). We updated this analysis to the current author recommended model and include results and discussion within the **Time Series Results** section. This *Retrospective Analysis* section will be included as a standard section in the future.

"The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented. The Teams recommend that the "other" removals data set continue to be compiled, and expanded to include all sources of removal."
(Plan Team, September 2012)
"The Teams recommend that the whole time series of each category of 'other' catches be made available on the NMFS "dashboard," so that they may be listed in all SAFE chapters."
(Plan Team, November 2012)

A report for generating the time series of other removals is available on the AKFIN stock assessment dashboard entitled "Non-Commercial Catch" (http://www.akfin.org). We use this report to update the appendix of total removals and present in Table 13A-1 of Appendix 13A in this assessment. We will continue to include this appendix in the future.

"The SSC recommends that the authors consider whether it is possible to estimate M with at least two significant digits in all future stock assessments to increase validity of the estimated OFL."
(SSC, December 2012)

M is estimated inside the RE/BS rockfish assessment model and is, therefore, estimated with more than two significant digits.

"The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals. The Teams plan to inventory how their respective authors address and calculate total current year removals. Following analysis of this inventory, the Teams will provide advice to authors on the appropriate methodology for calculating current year removals to ensure consistency across assessments and FMPs." (Plan Team, September 2013)
"The Teams recommend that authors choose a method that appears to be appropriate for their stock, and this method be clearly documented. The Teams recommend authors establish their best available estimate of catch in the current year and the next two years. The Teams recommend that authors should also

document how those projected catches were determined in the Harvest Recommendations section (ideally Scenario 2)." (Plan Team, September 2013).

We estimated current year's removals by multiplying the official catch as of October 1, 2014, by an expansion factor of 1.045, which represents the average fraction of the catch taken between October 1 and December 31 in the last three complete years (2011-2013). The catch was lower in the Western GOA than in previous years because the 2014 rockfish trawl fishery in this region was not opened to directed fishing until October 15. Final catch estimates for this region will likely be similar to previous years when the directed fishery catch is included and preliminary estimates suggest this to be the case (23 t as of November 3). The expanded estimate of the 2014 catch used in the preferred assessment model (736 t) is very close to the current total catch as of November 3, 2014 (730 t). Therefore, we did not apply any correction factor to the expanded estimate for the late fishing in the Western GOA. Further description of the catch estimation method is provided in the *Specified Catch Estimation* subsection under the **Harvest Recommendations** section.

"For the GOA age-structured rockfish assessments, if length composition data are withheld, the Team recommends exploratory model runs to test sensitivity. This should include any year of fishery or survey length composition data which could serve as a proxy for the age composition, not simply the most recent survey year." (Plan Team, November 2013)

Preliminary analysis of including length composition data in the model had been conducted for GOA Pacific ocean perch (POP) and was presented to the Plan Team in September, 2014. For GOA RE/BS rockfish, the fishery primarily selects for older aged fish (16 + for ages with selectivity greater than 50%) where the variability in length-at-age provides very little distinction in age-at-length and therefore little information is contained in the length composition data to inform recent recruitment. An evaluation for GOA POP (where the ages with fishery selectivity greater than 50% is around ages 9 to 17) found that the model was essentially invariant to including the recent fishery length composition data as a proxy for age data (see GOA POP November 2014 assessment). Additional sensitivity analyses for GOA POP, northern rockfish, and dusky rockfish on including the bottom trawl survey length composition from the most recent year are presented in Appendix 9B of the GOA POP November 2014 assessment. Following Plan Team and SSC review on this sensitivity analysis, we plan to explore similar analyses for the 2015 RE/BS rockfish stock 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)

Full assessment updates for all GOA rockfish will be completed in 2015 and CIE review comments will be addressed at that time since many of the issues in the CIE review are similar across the age-structured rockfish assessments. 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

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

These projections are available in the executive summary table and are now added to the phase-plane plots (Figure 13-18). The two year projections will be standard in the phase diagrams in the future.

Responses to SSC and Plan Team Comments Specific to this Assessment

"The Team asks the [rockfish] *authors to investigate whether the conversion matrix has changed over time. Additionally, the Team requests that the criteria for omitting data in stock assessment models be based upon the quality of the data (e.g. bias, sampling methods, information content, redundancy with other data, etc.) rather than the effect of the data on modeled quantities."* (Plan Team, November 2011)

In the author preferred model of this assessment (Model 2) we update the size-at-age conversion matrix and weight-at-age estimates with the full time series of age data. Sample sizes for determining these estimates have increased by an order of magnitude. We also updated the aging error matrix with newly available age agreement tests, which now cover a range of years from 1984 – 2009. Please see the **Parameters Estimates Outside the Assessment Model** section for more details. Many of the issues regarding temporal changes in the conversion and error matrices are similar across the age-structured rockfish assessments. In order to properly address this comment we plan to conduct an investigation on developing methods for updating conversion and error matrices for these long-lived species as a group and to perform sensitivity analyses on the timeliness of updates. We anticipate this future investigation to begin next year and will incorporate relevant results into the RE/BS model following further review. Analyses of including survey length data into the Pacific ocean perch, northern rockfish, and dusky rockfish models are included in Appendix 9B of the GOA POP November 2014 assessment, and recommendations from this will be taken into account in next year's full assessment.

"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)

We plan to address the concerns over the optimum plus group for age compositions along with the conversion and error matrices investigation (see comment above on conversion matrix) as the two concepts are ultimately connected within the modeling procedures. This will further the concept of consistency among the age-structured rockfish assessments, and hopefully lead to agreement on best practices regarding updating this information.

"SSC supports the Plan Team recommendation for the author to continue to investigate difference in the longline and trawl survey to help understand the different trends." (SSC, December 2011)

We continue to use both surveys for this full assessment because we consider that the two surveys adequately sample different parts of the RE/BS population. Much of the prime habitat area for RE/BS rockfish is in 300-500 m depths on the upper continental slope. This area is often not trawlable by the bottom trawl survey's gear because of its steep and rocky bottom; therefore, trawl survey biomass estimates for RE/BS rockfish may not indicate a complete picture of the abundance trends. Conversely, the longline survey can sample a large variety of habitats. One drawback, however, is that juvenile fish are not as susceptible to longline gear. Subsequently, the longline survey does not provide much information on recruitment. The trawl survey may be limited in sampling particular habitats, but does capture juveniles. We therefore utilize both the trawl and longline (which can sample where survey trawls cannot) abundance indices within the RE/BS model to alleviate some of these concerns.

Because of the different habitats sampled and gear selectivity, we do anticipate some differences between the two survey biomass estimates and size compositions. Additionally, several recent investigations are in progress to consider the effects of untrawlable/trawlable habitat on the trawl survey estimates, and whale depredation on the longline survey estimates. We await the final results of these studies prior to conducting sensitivity analyses on trawl versus longline survey indices so that the most appropriate trawl or longline survey index is used in that comparison.

"In response to SSC comments the authors commented on the veracity of model based estimates of trawl survey catchability. The authors reported that the model based estimate of survey catchability is 1.42 compared with a submersible observations in a 2006 analysis and yielded a catchability of 0.85. The SSC encourages the author to report on the evidence to support the current model based estimate given the discrepancy between experimental and model based estimates of catchability." (SSC, December 2011)

We anticipate continuing to use the current model based estimate for catchability rather than incorporating the 2006 estimate based on submersible observations. The study that yielded the catchability of 0.85 was based on a very small region in the central GOA at depths that could not cover the entire potential habitat for RE/BS rockfish due to diving safety limitations on the submersible. Rather than a direct comparison we plan to investigate how to use this submersible based estimate as a contextual lower bound for developing the prior on RE/BS catchability. The multiple surveys and large amount of age and size data in the model allows for a more appropriate estimate of catchability that takes into account the full distribution on the RE/BS population for the GOA. In the future, we plan to conduct a synthesis of previous studies on rockfish catchability using submersibles and develop recommendations for generating informative prior distributions on catchability. This study may also incorporate the results from recent trawlable/untrawlable studies to include habitat information in the priors.

"The Team recommends a full stock assessment with updated assessment and projection model results for 2014. The Team also recommends further exploration into the effects of reduced trawl survey effort in relation to the all-time low biomass recorded in 2013." (Plan Team, November 2013)

As per this recommendation by the Plan Team, we are presenting a full assessment this year. Several current research efforts are in progress investigating issues regarding bottom trawl survey catchability and survey biomass estimation. The continued reduction in survey effort over the past several surveys should be considered in these initiatives as there was a 30% drop in stations sampled on the 2013 survey compared to the long-term average. Precision and accuracy of biomass estimates are particularly vulnerable for deep-water species like RE/BS rockfish due to the already low number of stations sampled in the deep strata. We will incorporate results of these studies when they become available to consider the effects of reduced trawl survey effort on RE/BS rockfish trawl survey biomass estimates.

"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)

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.

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).

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 types of rougheye 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

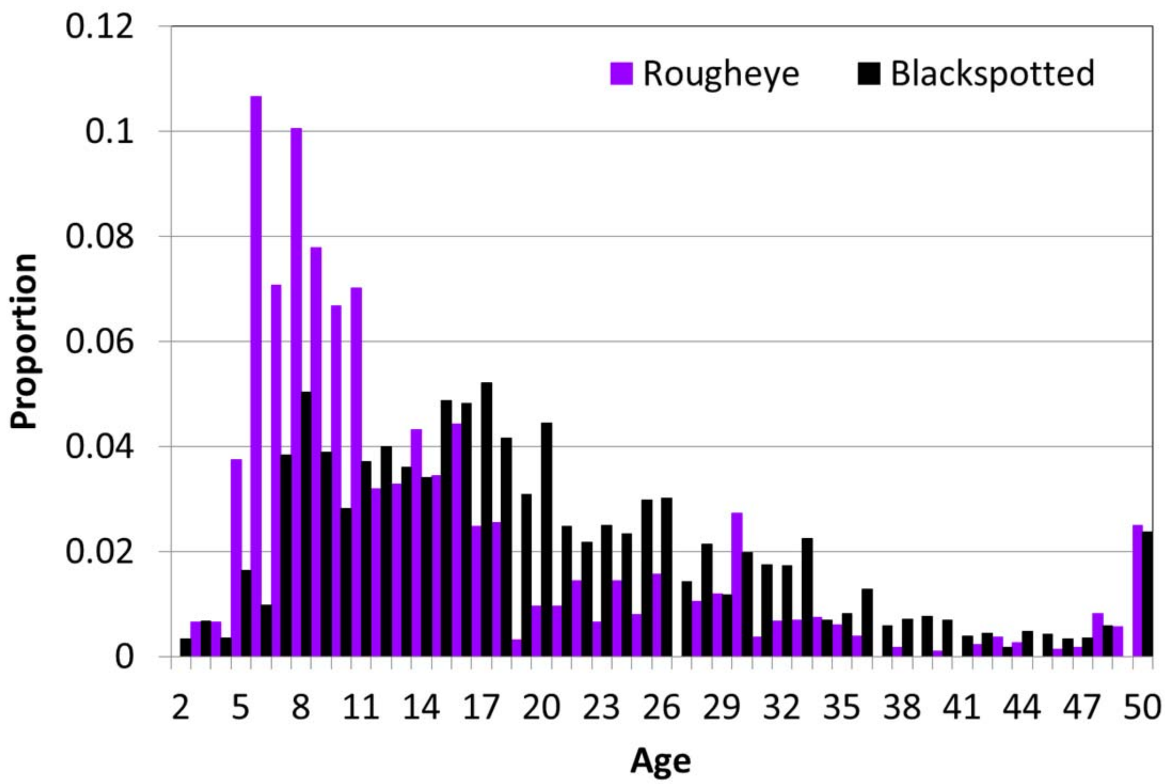
There is difficulty in accurate at-sea field identification between the two species. Previous studies have found that on average, when compared to genetic identifications, field scientists had a misidentification rate of approximately 46% (samples in eastern GOA near Yakutat), while the expert (Jay Orr) 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 and 2013 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) from most rougheye and blackspotted rockfish sampled for otoliths. Additionally, most of the unidentified rougheye/blackspotted specimens were sampled for otoliths.

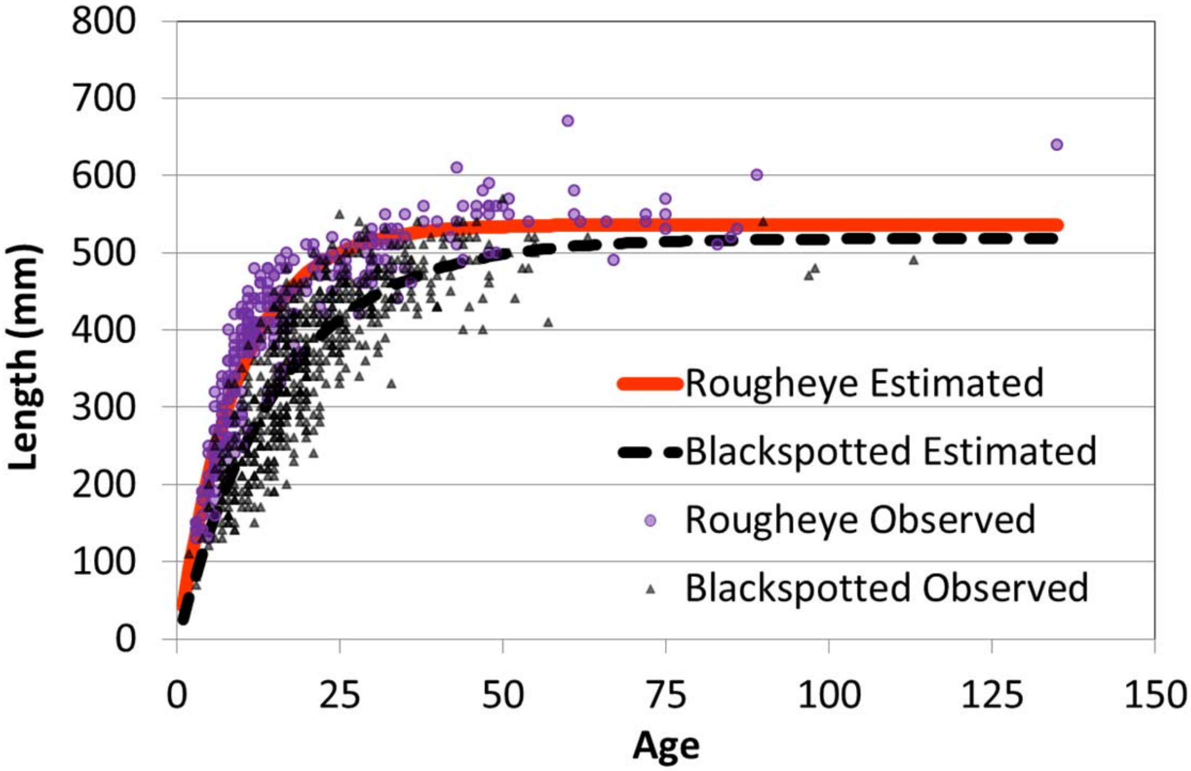
For the 2009 survey, 895 fish were genetically identified in the lab. Overall (not including hybrids or fish unidentified in the field) these results show a 23% misidentification rate. This is a substantial improvement over previous studies. Of the genetically identified rougheye rockfish (n=307), only 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, but ages have not been determined. Preliminary analysis of the 2013 survey data show that there have been continued improvements in species identification with overall misidentification rates of 13% compared to 23% from the 2009 survey.



A preliminary study on the 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 and 2013 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. In 2014, 70% of the catch was from bottom trawls, 27% from longline, and 3% from pelagic trawls. Approximately 70% of this bottom trawl catch was taken in the rockfish fishery while, 30% was taken in the flatfish fisheries. The amount of catch taken in the rockfish fishery has more than doubled in the past two 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 83% of the 2014 catch taken in the sablefish fishery and 16% 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 30-50% of potential quota (Table 13-2).

In 2013, restructuring of the AFSC Fisheries Monitoring and Analysis (FMA) Observer Program began and the extent that this program affected perceived catches of RE/BS rockfish in the small-boat fishery (due to improved coverage) is uncertain. Understanding the potential for catch accounting biases due to shifts in observer coverage 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.

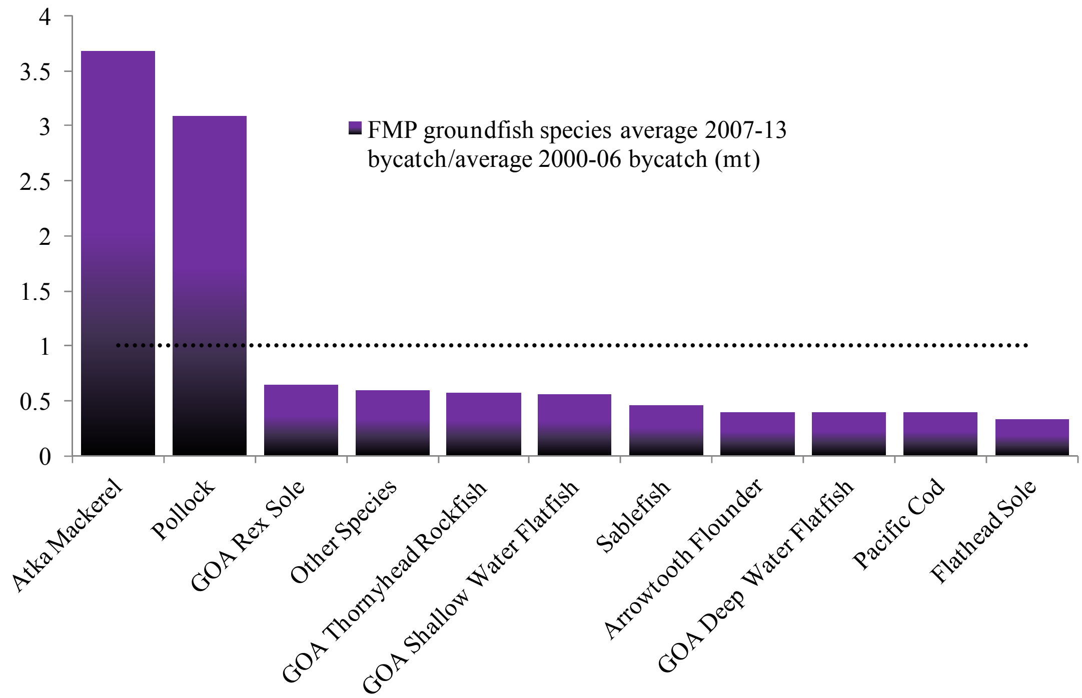
In November, 2006, NMFS issued a final rule to implement Amendment 68 of the GOA groundfish Fishery Management Plan for 2007 through 2011. This action initiated the Central Gulf of Alaska Rockfish Program (formerly the Rockfish Pilot Program) which was implemented to enhance resource conservation and 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. The program should spread out the fishery in time and space, allowing for better prices for product and reducing the pressure of what was an approximately two week fishery in July. 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 data show that the Rockfish Program has resulted in much higher observer coverage of catch in the Central GOA (Figure 13-1). There does not seem to be a major shift in the spatial distribution of RE/BS catch and it is difficult to discern whether the increases in catch levels are due to increases in the observer coverage or actual increases in fishing pressure. 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.

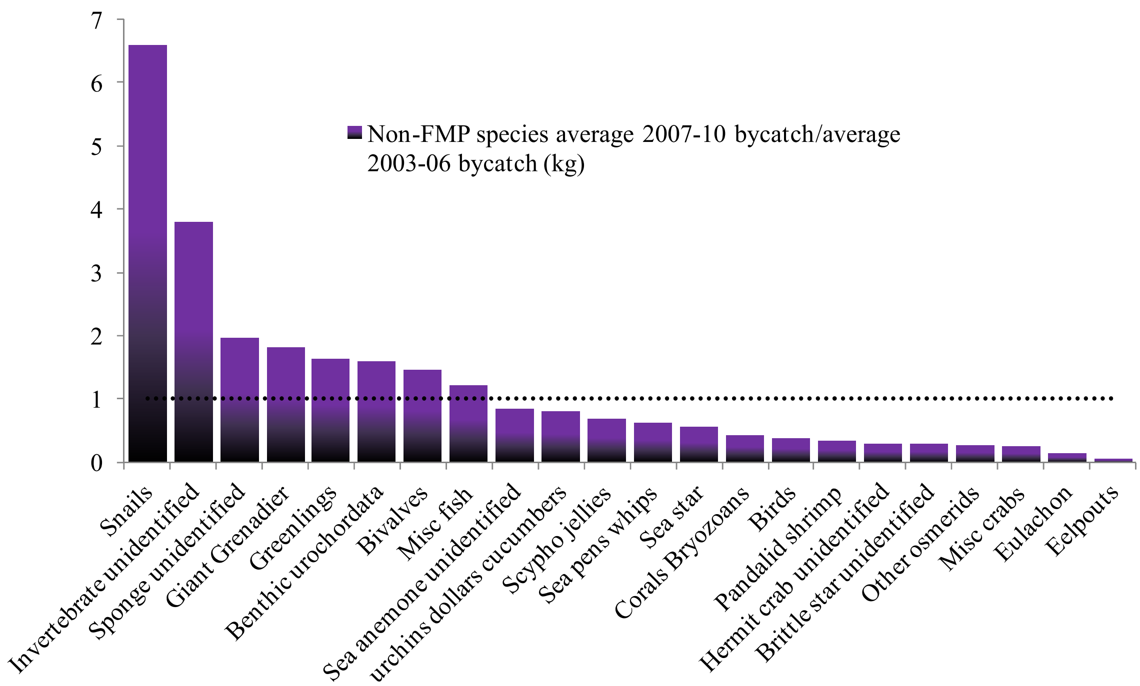
Bycatch

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 1991-2014, the largest non-rockfish bycatch groups are on average arrowtooth flounder (1,413 t/year), sablefish (869 t/year), Pacific cod (762 t/year), Atka mackerel (657 t/year) and walleye pollock (421 t/year). Total FMP groundfish species catch estimates targeted in the rockfish fishery from 2007-2014 are shown in Table 13-5. Non-FMP species catch in the rockfish target fisheries is generally dominated by giant grenadier (127 – 968 t), other grenadier (3 – 111 t), miscellaneous fish (124 – 195 t), and occasionally dark rockfish (recently removed from FMP to state management, 0 – 112 t) (Table 13-6). Prohibited species catch in the GOA rockfish fishery has been relatively steady over time. Halibut catch during rockfish targeted hauls has declined since 2007 from 136 t to 60 t in 2014. The catch of golden king crab decreased dramatically from over 3,000 animals in 2009 and 2010, to just over 100 in 2011 – 2013 (Table 13-7).

We compared bycatch from pre-2006 and post-2007 in the central GOA for the combined rockfish fisheries to determine impact of the Central GOA Rockfish Program implementation. We divided the average post-2006 bycatch (2007-2013) by the average pre-2007 bycatch (2000-2006) for non-rockfish species that had available information in both time periods. For the majority of FMP groundfish species, bycatch in the central GOA has been reduced since 2007, with the exception of Atka mackerel (414 t/year pre-2006 compared to 1,520 t/year post-2007) and walleye pollock (234 t/year pre-2006 compared to 722 t/year post-2007, see figure below):



Currently 8 of 22 nontarget species for which bycatch data were available for the two time periods resulted in an increase in bycatch post-2006 compared to pre-2007 (see figure below).



We will continue to monitor the bycatch of the combined rockfish fisheries to understand potential effects of the Rockfish Program.

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
% Discards	19.5	27.4	36.7	27.6	18.6	19.2	16.3	15.5	22.8	17.0

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

Fishery:

Catch

Catches of rougheye and blackspotted rockfish have ranged between 130 t to 2,418 t from 1977 to 2014. The catches from 1977-1992 were from Soh (1998). 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 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

[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)

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 13-2, Table 13-2).

One caveat of the observer catch data 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, recently 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 recently been aged. 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, and 2012.

New fishery ages since the last full assessment are available for 2009 and 2012. 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. In this case the 2009 fishery ages were requested and completed rather than the 2010 ages. We have subsequently requested that the 2010 fishery ages be completed as soon as possible and will incorporate the data as soon as that information is 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. Ages 25 and greater are pooled into a plus (+) group that is quite substantial in all years (Table 13-8). This may imply that our age bins are somewhat restrictive for this extremely long-lived species. We anticipate a future investigation on furthering methods for determining the plus group for rockfish species, including RE/BS, to begin next year and will incorporate relevant results into the RE/BS model. This study will likely consider the potential for increasing the number of age bins to include several older age groups following analyses completed for other rockfish (Hulson et al. 2011, Spencer and Ianelli, 2012).

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 1991-2011. 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. In the case of the 2010 fishery size compositions, we utilize that information in this model since this year was not available in the fishery ages at this time. Therefore, fishery size compositions from 1991-1992, 2002-2003, 2005, 2007, 2010 and 2011 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 38% of lengths from the trawl fishery and 62% 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 analysis 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 13-3. 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. 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. 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 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 13-3). 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, and 2013 the reverse occurred (36%, 35%, and 37% versus 64%, 65%, and 63%, 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

Increased age samples for 2009 and new ages for 2011 were added this year resulting in a total of eleven years of survey age compositions with a total sample size of 5,681 ages. Survey age sample sizes are comparable to fishery age sample sizes, ranging from 200 to 900. 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.

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 - 18, while mean age for blackspotted range from 22 - 24. We combine these two age compositions for 2007, 2009, and 2011 in the stock assessment model. The mean age for the combined compositions ranged from 15 - 19. Ages 25 and greater are pooled into a plus (+) group that is fairly substantial in nearly all years, but is much smaller than the fishery age composition. As with the fishery ages, this may imply that our age bins are somewhat restrictive for this extremely long-lived species.

AFSC Bottom Trawl Size Compositions

Gulf-wide population size compositions for RE/BS rockfish are in Table 13-12 and sample sizes range from 1,700 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 presence of a large plus group in the age composition of this survey. In the 1996 through 2011 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 35 cm. After this the mean length remained relatively steady between 36-38 cm. Since 2007, survey rougheye and blackspotted rockfish lengths were split. Rougheye have an average length of 36 cm while blackspotted have an average of 40 cm. Rougheye have a much broader range of lengths from 15-53 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. Again, this may be indicative of misidentification or a true difference in size distribution between species. Future analysis of the 2009 and 2013 trawl survey 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 this Appendix 9B of the GOA POP November 2014 assessment. The results of that analysis suggest that the utility of the most recent survey's length composition is case specific. We will investigate whether including the most recent survey's length composition in this assessment is useful in next year's full assessment.

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). In previous assessments, the longline abundance index for RE/BS rockfish was expressed as an RPW and used as a second biomass index in the model.

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 result 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. 2014), we include this information in the RE/BS longline survey index.

The updated relative population weight (RPW) index for RE/BS rockfish now uses the trawl survey information to generate the weight conversion parameters for this complex. 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 1993-2014 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 13-4). 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 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 range from 14-22% (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 13-4). 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 be so dramatic. As mentioned in the previous section, the trawl survey is not typically capable of sampling the deeper depths and 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. 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. (2014) 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 rather than the RPW 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 1993-2014 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 we are currently investigating this data point. However, setting this composition to average had a negligible effect on the assessment results so we retain this data until further information is available.

Comparison of AFSC Bottom Trawl and Longline Surveys

The spatial distribution of numbers of rougheye and blackspotted rockfish caught in the 2009, 2011, and 2013 trawl and longline surveys is depicted in Figure 13-5a. 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 the 2009 and 2011 surveys, particularly in the eastern GOA. In 2013, both estimates decreased from the previous surveys. 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. There was also a reduction in survey effort in 2013. Similar to 2011, only 2 boats were chartered for the survey (usually 3 boats are used). This resulted in even fewer stations sampled compared to previous surveys: 550 stations in 2013 compared to 670 in 2011 and 823 in 2009. The 2013 sampling level (based on number of stations) is 30% lower than the long-term mean for this survey. We will continue to monitor the number of stations sampled in the trawl survey to better understand the potential effects on estimates in the future.

Rougheye and blackspotted rockfish were identified 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); however, the difference seems to be more slope versus continental shelf oriented (Figure 13-5b). 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. We plan to revisit this analysis in the 2015 assessment using the newly computed RPNs for all strata on the AFSC longline survey.

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 result 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 13-6). 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. This year 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).

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 is available due to the large number of aged specimens for RE/BS rockfish from the AFSC bottom trawl survey. Previous growth estimates were based on data from only 1990 and 1999. We calculated an updated size-at-age conversion matrix and mean weight-at-age using the same methods as the previous growth estimates. A von Bertalanffy growth curve was fit to size and age data from 1990 to 2011. Sexes were combined and the size-at-age conversion matrix was constructed by adding normal error with a standard deviation equal to the standard deviation of the survey ages for each size class. The new estimated parameters for the growth curve are:

L_∞=51.4 cm κ=0.08 t_0=-1.27 n=5,681

And, for comparison, the old growth parameters were:

L_∞=51.2 cm κ=0.08 t_0=-1.15 n=866

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 are:

W_∞=2,171 g κ=0.08 t_0=-1.27 β=3.077 n=4,749

And, for comparison, the old growth parameters were:

W_∞=2,311 g κ=0.05 t_0=1.68 β=1.712 n=735

When this information was applied to produce the size-at-age conversion matrix and mean weight-at-age, the differences from the old growth parameters were minor and on average the new mean weight-at-age was about 36% lower than previous. Size-at-age differences were negligible.

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.

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 13-7).

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. Without utilizing empirical data to assign a CV to the catchability prior we assign it a relatively imprecise prior CV of 45% to allow the data to influence the catchability estimate. This is a better assumption than fixing the trawl survey catchability at 1 or an arbitrary value near 1. In the future, we will consider using more informative priors for the trawl survey that are based on empirical observations from submersibles and the untrawlable/trawlable work currently underway. For the longline survey, we assign a very broad CV of 100% which essentially mimics a uniform prior with a lower bound of zero (Figure 13-8). 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 13-8).

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	59
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_v	38
Fishery selectivity coefficients	fs_a	14
Survey selectivity coefficients	ss_a	25
Total		145

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 145. 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^2_M	Prior CV for natural mortality
σ^2_q	Prior CV for catchability coefficient
$\sigma^2_{\sigma_r}$	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

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

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
$L_8 = \frac{1}{2\sigma_M^2} \left(\ln \frac{M}{M_{prior}} \right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_9 = \frac{1}{2\sigma_{q_1}^2} \left(\ln \frac{q_1}{q_{1prior}} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for trawl survey
$L_{10} = \frac{1}{2\sigma_{q_2}^2} \left(\ln \frac{q_2}{q_{2prior}} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for longline survey
$L_{11} = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln \frac{\sigma_r}{\sigma_{r(prior)}} \right)^2$	Penalty on deviation from prior distribution of recruitment deviations
$L_{12} = \lambda_{12} \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln \left(\sigma_r \right) \right]$	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

We present three models in this assessment as described in the following table:

Model Number	Model Description
Model 0 (Base)	Model from Shotwell et al. (2011)
Model 1 (Intermediate)	Incorporates all new and updated data, longline RPW index, 2011 conversion matrices
Model 2 (Full update)	Same as Model 1 but uses longline RPN index and all new conversion matrices

Model 0 is the last full assessment base model from Shotwell et al. (2011). Model 1 is an intermediate model which uses all the new and updated data but keeps the previous longline RPW index for the longline survey and the mean weight-at-age, size-at-age conversion matrix, and ageing error matrix from the 2011 model. This model was run for comparison purposes only given the large amount of new data available for this assessment. Model 2 uses all the new and updated data, the RPN longline survey index, and the updated growth data to estimate new mean weight-at-age, size-at-age conversion matrix, and aging error conversion matrix.

At minimum, there is improved overall fit to the data (in terms of negative log-likelihood) with the full update Model 2, particularly in the size composition data from the intermediate Model 1 (Table 13-15). Given this information and the recommendation from the 2009 sablefish CIE to use the RPN index for the longline survey, we prefer the Model 2 full update to estimate management quantities for 2015 and discuss results of this model in the following section. Estimated numbers in 2014, fishery selectivity, trawl and longline survey selectivity and schedules of age specific weight and female maturity are provided in Table 13-16 for reference.

Time Series Results

Table 13-15 provides parameter estimates for all three models for comparison purposes. Tables 13-16 through 13-19 summarize other results for the 2014 author preferred model. Model predictions fit the age and size data relatively well (Figures 13-9, 13-10, 13-11 and 13-13), with the exception of the plus age group in some years, particularly in the fishery ages. AFSC bottom trawl survey size compositions are provided for reference (Figure 13-12).

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.

Parameter estimates for the preferred Model 2 are somewhat similar to the base Model 0 (2011) estimates, except for higher catchability in the bottom trawl and longline surveys. Natural mortality, recruitment variability, and mean recruitment estimates were all similar to Model 0 estimates (Table 13-15). The intermediate Model 1 had much higher catchability estimates, lower mean recruitment, and substantially lower spawning biomass. Spawning biomass for the preferred Model 2 compared to base Model 0 was higher overall (except in the most recent years); while total biomass was lower overall with the difference becoming more prominent in recent years. Recruitment was generally similar between the preferred Model 2 and the base Model 0 except in 1997 and slightly different in recent years (Table 13-18). This is likely due to the differences between the two survey trajectories and in using RPN versus RPW estimates. Projected total and spawning biomass decreased, while recruitment increases slightly. Estimates continue to track the influx of new recruits from the early 2000s. 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 rougheye and blackspotted rockfish.

Preferred Model 2 predictions fit the data relatively well. Model fits to bottom trawl survey biomass and longline survey relative population numbers (RPN) were fairly consistent over time with a steady value for the trawl survey estimate (more so than in the base Model 0) and a slight increase in the most recent longline survey estimates (Figures 13-3, 13-4). 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 the longline RPNs. Fit to the fishery age compositions is marginal but likely hindered by an extremely large plus group which has increased since the bin structure was originally imposed (Figure 13-9). This may be improved by increasing the age bins or allowing selectivity for older aged fish more flexibility. Fit to the fishery size compositions are slightly flattened (Figure 13-10) 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 over- or underestimation of the plus group in all years except 1987, 1990, 1996, and 2011 (Figure 13-11). Fit to the longline survey size compositions are similar to the fishery size compositions with slightly flattened peaks in most years (Figure 13-13). 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 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 bins to reduce the influence of the large plus group during estimation.

Biomass and Exploitation Trends

Estimates of total biomass are relatively steady, decreasing slightly from the beginning of the time series until 1991 and increasing slightly to the most current estimate (Figure 13-14). These estimates are slightly lower than the 2011 model estimates but not until after 1991. Spawning biomass estimates are very similar to total biomass with a slightly steeper decreasing slope to 1991 and slightly steeper increasing slope to present (Figure 13-15). In this case, the spawning biomass is slightly higher than the 2011 estimates up until the most recent years. Fairly wide credible intervals result from the MCMC simulation for biomass estimates, with decreasing certainty in the more recent estimates, particularly the upper credible intervals. Estimated selectivity curves were similar to expected (Figure 13-16). 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 somewhat 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 13-17). 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 is a slight increase 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 13-18). 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 13-19). 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 rougheye and blackspotted rockfish as recruitment is apparently unrelated to spawning stock biomass and there is little contrast in spawning stock biomass (Figure 13-6).

Uncertainty

From the MCMC chains described previously, we summarize the posterior densities of key parameters for the author recommended model using histograms (Figure 13-20) 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 13-14, 13-15, 13-19, 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_2 (longline survey catchability), which may imply that this parameter is well estimated in the model. This is possibly due to the large amount of longline survey data in the model relative to the trawl survey index. The MCMC distribution of ABC, current total biomass, and current spawning biomass are skewed (Figure 13-20) indicating potential for higher biomass estimates (see also Figure 13-14 and Figure 13-15).

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 (Hanselman et al.

2013) in female spawning biomass was 0.353, 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 13-21 (with 95% credible intervals from MCMC).

The RE/BS model is exhibiting a relatively strong retrospective pattern. The 2014 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 natural mortality and catchability because of the scale changes between retrospective peels for serial retrospective trends, but did not find any obvious shifts. We plan to further examine potential retrospective causes when we update bin structures and effective sample sizes in the 2015 full assessment.

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 1980-2012 (i.e. the 1977-2009 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 2014 estimates of these reference points are in the following table. Biomass estimates are for female spawning biomass.

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
22,449 (t)	8,980 (t)	7,857 (t)	0.038	0.045

Specification of OFL and Maximum Permissible ABC

Estimated female spawning biomass for 2015 is 12,480 t. This is above the $B_{40\%}$ value of 8,980 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 2015 yields the following *ABC* and *OFL*:

$F_{40\%}$	0.038
ABC (t)	1,122
$F_{35\%}$	0.045
OFL (t)	1,345

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 2014 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2015 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2014. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch after 2014 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 2015, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In 2015 and 2016, 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 2011-2013 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 2009-2013 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2014 or 2) above ½ of its MSY level in 2014 and above its MSY level in 2024 under this scenario, then the stock is not overfished.)

Scenario 7: In 2015 and 2016, F is set equal to max F_{ABC}, and in all subsequent years F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2016 or 2) above ½ of its MSY level in 2016 and expected to be above its MSY level in 2026 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 2015, it does not provide the best estimate of OFL for 2016, because the mean 2015 catch under Scenario 6 is predicated on the 2015 catch being equal to the 2015 OFL, whereas the actual 2015 catch will likely be less than the 2015 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

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

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2013) is 574 t. This is less than the 2013 OFL of 1,482 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 2014:

a) If spawning biomass for 2014 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2014 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c) If spawning biomass for 2014 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 13-20). If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

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

a) If the mean spawning biomass for 2016 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2016 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2016 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2026. If the mean spawning biomass for 2026 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. 2011-2013 for this year, see example figures below). For rougheye and blackspotted rockfish, the expansion factor for 2014 catch is 1.045.

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 (0.45), which was the average of the ratio of catch to ABC for the last three complete catch years (2011-2013). This yield ratio was multiplied by the projected ABCs for 2015 and 2016 from the assessment model to generate catches for those years.

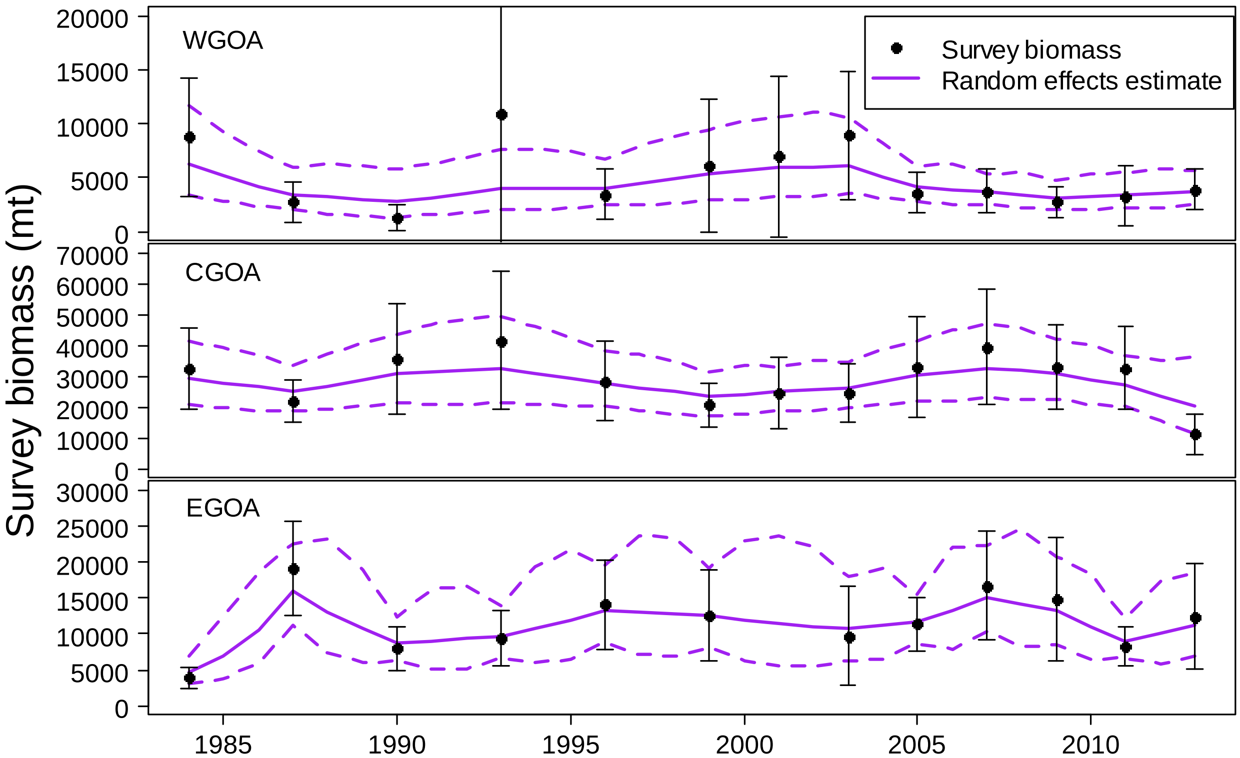
Alternative Projection

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 1980-2012 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 (0.45).

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 $2/3^{rd}$ of the total variability in predicting the distribution of biomass (a reasonable assumption), the weight of a prior survey should be $2/3^{rd}$ the weight of the preceding survey. This resulted in weights of 4:6:9 for the 2009, 2011, and 2013 surveys, respectively and apportionments for rougheye and blackspotted rockfish of 10.3% for the western area, 56.3% for the central area, and 33.4% for the eastern area (Table 13-21). This represents a shift from the central area to an approximate 4% increase in the western and a 10% increase in the eastern areas from the 2011 apportionments (6.60% for the Western area, 69.46% for the Central area, and 23.94% for the Eastern area).

The Plan Team and SSC requested that the random effects model proposed by the Survey Averaging Working Group be evaluated 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. However, there did seem to be some sensitivity to starting values in which case the model had difficulty estimating process error. This occurred in the Central GOA which contains the bulk of the RE/BS biomass and has the smallest sampling error. When the random effects model did converge, we used the random effects estimates of ending year biomass to determine the apportionment results as 10.6% for the Western area, 57.3% for the Central area, and 32.1% for the Eastern area. This is very similar to the results from the updated 4:6:9 survey average weighting method.

We recommend continuing with the standard three survey weighted average apportionment for RE/BS rockfish given the sensitivity of the random effects model to converging in the Central GOA. We will consider the random effects model for RE/BS rockfish when recommendations on model estimation procedure and potential inclusion of other survey biomass estimates (e.g. AFSC longline survey) are provided by the Survey Averaging Working Group.

The following table shows the apportionment for the 2015 and 2016 fishery when applying the percentages using the three survey weighted average and random effects methods to the ABC for RE/BS rockfish (1,122 t):

Method	Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
Three Survey Average			10.3%	56.3%	33.4%	100%
	2015	Area ABC (t)	**115**	**632**	**375**	**1,122**
		OFL (t)				**1,345**
	2016	Area ABC (t)	**117**	**643**	**382**	**1,142**
		OFL (t)				**1,370**
Random Effects			10.6%	57.3%	32.1%	100%
	2015	Area ABC (t)	**119**	**643**	**360**	**1,122**
		OFL (t)				**1,345**
	2016	Area ABC (t)	**122**	**654**	**366**	**1,142**
		OFL (t)				**1,370**

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.045), overfishing is set equal to 1,345 t in 2015 and 1,370 t in 2016 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 2005-2014 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, 4) sensitivity analyses with respect to the optimum plus groups for rockfish species, and 5) examining potential age and growth differences between RE/BS rockfish to help develop a rationale for a two-species model.

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.

Many of the comments specific to the RE/BS rockfish assessment during the 2013 Center for Independent Experts (CIE) Alaska rockfish scientific peer review may also be incorporated in this year's full assessment. Please refer to the Summary and response to the 2013 CIE review of AFSC rockfish document presented to the September 2013 Plan Team for further details.

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:	
	2014	2015	2015	2016*
M (natural mortality rate)	0.034	0.034	0.034	0.034
Tier	3a	3a	3a	3a
Projected total (ages 3+) biomass (t)	42,810	43,337	36,584	36,610
Projected female spawning biomass (t)	12,897	13,325	12,480	12,595
$B_{100\%}$	24,329	24,329	22,449	22,449
$B_{40\%}$	9,732	9,732	8,980	8,980
$B_{35\%}$	8,515	8,515	7,857	7,857
F_{OFL}	0.047	0.047	0.045	0.045
$maxF_{ABC}$	0.039	0.039	0.038	0.038
F_{ABC}	0.039	0.039	0.038	0.038
OFL (t)	1,497	1,518	**1,345**	1,370
maxABC (t)	1,244	1,262	1,122	1,142
ABC (t)	1,244	1,262	**1,122**	1,142
Status	As determined *last* year for:		As determined *this* year for:	
	2012	2013	2013	2014
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 2015 and 2016 are derived using estimated catch of 736 t for 2014 and projected catches of 502 t for 2015 and 501 t for 2016 based on realized catches from 2011-2013. 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 (1977-2013), with Gulf-wide values of acceptable biological catch (ABC) and fishing quotas[b] (t), 1991-2013. 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	293	53	126	115	1,531	1,007	1,007
2006	358	58	138	162	1,180	983	983
2007	422	71	194	157	1,148	988	988
2008	392	78	193	121	1,548	1,286	1,286
2009	282	80	101	101	1,545	1,284	1,284
2010	450	91	219	139	1,568	1,302	1,302
2011	541	26	368	148	1,579	1,312	1,312
2012	568	28	371	169	1,472	1,223	1,223
2013	574	15	384	175	1,482	1,232	1,232

[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	293	1,007	1,007	Rougheye managed separately from shortraker as age structured model accepted to determine ABC and moved to Tier 3 status
2006	358	983	983	
2007	422	988	988	Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	392	1,286	1,286	Rougheye and blackspotted formally verified as separate species so assessment now called the rougheye/blackspotted rockfish complex
2009	282	1,284	1,284	
2010	450	1,302	1,302	
2011	541	1,312	1,312	Rockfish Program continues from pilot initiative
2012	568	1,223	1,223	
2013	574	1,232	1,232	

*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 10/1/2014.

Year	Flatfish	Halibut	P. Cod	Pollock	Rockfish	Sablefish
2005	15	36	1	16	106	119
2006	40	46	2	23	83	170
2007	90	64	1	28	114	140
2008	57	55	9	41	104	115
2009	34	40	6	11	97	86
2010	64	42	6	30	180	103
2011	64	33	2	34	286	122
2012	122	26	4	21	219	177
2013	49	32	1	6	274	211
2014	149	30	3	19	346	158
Average	68	40	4	23	181	140

Table 13-5. Incidental catch of FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2007 - present. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/1/2014.

	Estimated Catch (t)							
Group Name	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Atka Mackerel	1,094	1,744	1,913	2,148	1,404	1,173	1,162	232
Pacific Cod	251	445	631	734	560	404	584	425
Pollock	124	390	1,280	1,046	813	574	829	750
Sablefish	641	503	404	388	440	470	495	468
Arrowtooth Flounder	688	517	497	706	340	764	766	1,173
Flathead Sole	18	19	32	24	13	16	26	16
Rex Sole	52	67	83	93	51	72	89	68
Deep Water Flatfish	45	29	30	48	57	54	37	68
Shallow Water Flatfish	22	71	53	47	48	65	27	17
Pacific Ocean Perch	12,641	12,135	12,397	14,974	13,120	13,953	11,555	12,814
Northern Rockfish	3,957	3,805	3,855	3,833	3,163	4,883	4,527	2,762
Dusky Rockfish						3,642	2,870	2,582
Pelagic Shelf Rockfish	3,119	3,521	2,956	2,966	2,324			
Rougheye Rockfish	114	104	97	180	286	219	274	346
Shortraker Rockfish	291	231	247	133	239	303	290	195
Other Rockfish	494	632	736	737	657	889	488	617
Demersal Shelf Rockfish	3	45	77	34	27	111	136	38
Thornyhead Rockfish	300	248	177	106	161	130	104	153
Skate, Big	0	4	4	14	8	13	2	3
Skate, Longnose	17	12	17	12	25	23	23	21
Skate, Other	20	10	13	28	14	20	18	23
Other Species	42	39	57	74				
Octopus					1	1	2	4
Sculpin					39	55	70	27
Shark					5	5	93	1
Squid					12	15	10	15

Table 13-6. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2007 - present. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/1/2014.

	Estimated Catch (t)							
Group Name	2007	2008	2009	2010	2011	2012	2013	2014
Benthic urochordata	0.03	0.27	Conf.	0.08	Conf.	Conf.	Conf.	0.07
Birds	Conf.	Conf.	-	-	Conf.	Conf.	-	-
Bivalves	-	0.00	Conf.	0.01	0.01	0.01	Conf.	Conf.
Brittle star unid.	0.01	0.04	0.03	0.02	0.01	0.03	0.03	0.04
Capelin	-	-	0.00	-	-	-	0.02	-
Corals Bryozoans	2.27	0.47	0.32	0.42	0.38	0.59	0.20	0.13
Dark Rockfish	-	17.86	46.98	112.04	12.82	59.03	42.16	13.35
Eelpouts	0.12	0.35	0.00	0.05	Conf.	0.30	0.04	0.10
Eulachon	0.05	0.01	0.03	0.00	0.00	0.01	0.10	Conf.
Giant Grenadier	127.14	160.97	224.36	476.28	418.90	347.85	968.44	599.37
Greenlings	7.74	14.73	8.10	9.52	7.91	9.05	7.25	2.80
Grenadier	70.61	2.82	3.11	34.94	110.49	89.67	39.11	6.33
Hermit crab unid.	Conf.	0.01	0.01	0.01	0.02	Conf.	0.03	0.04
Invertebrate unid.	0.01	0.23	0.30	5.05	0.36	3.86	0.18	0.00
Lanternfishes	0.00	-	0.00	Conf.	-	-	Conf.	-
Misc crabs	0.13	0.07	0.10	0.07	0.04	0.05	0.01	0.04
Misc crustaceans	-	-	0.10	0.02	Conf.	-	Conf.	Conf.
Misc deep fish	-	0.00	-	-	-	-	Conf.	-
Misc fish	186.08	195.62	134.75	167.10	133.25	156.73	163.97	124.25
Misc inverts (worms etc)	-	0.01	Conf.	-	Conf.	-	-	-
Other osmerids	0.09	Conf.	0.16	0.00	-	Conf.	0.02	Conf.
Pacific Sand lance	-	-	-	-	Conf.	-	-	-
Pandalid shrimp	0.11	0.11	0.09	0.22	0.06	0.06	0.06	0.10
Polychaete unid.	-	-	-	-	-	-	Conf.	-
Scypho jellies	0.21	0.11	0.70	1.87	0.00	0.16	0.50	6.05
Sea anemone unid.	0.20	0.69	3.24	1.56	4.10	6.33	4.20	1.11
Sea pens whips	-	Conf.	0.01	0.01	0.04	-	0.05	0.07
Sea star	0.66	1.15	1.78	1.38	1.53	0.98	0.97	1.42
Snails	0.07	0.18	10.63	0.20	0.23	1.26	0.20	0.07
Sponge unid.	0.65	2.97	6.65	3.66	4.41	1.39	1.34	0.98
Stichaeidae	-	-	0.01	-	-	-	Conf.	0.00
Urchins, dollars, cucumbers	0.17	0.26	0.49	0.22	0.44	0.31	0.30	0.18

Table 13-7. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and thousands of animals for crab and salmon, by year, for the GOA rockfish fishery 2007 - present. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/1/2014.

Group Name	2007	2008	2009	2010	2011	2012	2013	2014
Bairdi Tanner Crab	0.16	0.06	0.24	0.10	0.03	0.09	0.07	0.00
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chinook Salmon	2.03	2.28	1.39	1.57	1.02	1.60	2.32	0.00
Golden King Crab	0.13	0.34	3.28	3.00	0.13	0.11	0.10	0.00
Halibut	136.88	158.80	108.67	141.45	108.14	109.37	113.39	59.40
Herring	0.02	0.04	0.00	0.15	0.00	0.00	0.00	0.00
Other Salmon	0.72	0.50	0.47	0.37	0.21	0.31	2.02	0.00
Opilio Tanner Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 13-8. Fishery age compositions for GOA RE/BS rockfish and sample sizes by year. Pooled age 25+ includes all fish 25 and older.

Age (years)	1990	2004	2006	2008	2009	2012
3	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
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0033	0.0000	0.0000	0.0034	0.0000	0.0000
9	0.0266	0.0000	0.0028	0.0103	0.0000	0.0000
10	0.0498	0.0049	0.0000	0.0103	0.0097	0.0000
11	0.0332	0.0000	0.0000	0.0069	0.0032	0.0000
12	0.0266	0.0000	0.0083	0.0069	0.0000	0.0061
13	0.0166	0.0049	0.0055	0.0172	0.0162	0.0030
14	0.0365	0.0049	0.0083	0.0172	0.0032	0.0182
15	0.0100	0.0171	0.0193	0.0137	0.0097	0.0030
16	0.0066	0.0098	0.0193	0.0241	0.0325	0.0121
17	0.0166	0.0122	0.0138	0.0412	0.0195	0.0121
18	0.0033	0.0073	0.0055	0.0344	0.0162	0.0182
19	0.0166	0.0196	0.0110	0.0515	0.0325	0.0030
20	0.0133	0.0416	0.0110	0.0928	0.0552	0.0152
21	0.0133	0.0391	0.0138	0.0275	0.0260	0.0212
22	0.0133	0.0440	0.0303	0.0412	0.0325	0.0091
23	0.0100	0.0465	0.0331	0.0206	0.0260	0.0364
24	0.0199	0.0367	0.0441	0.0206	0.0162	0.0242
25+	0.6811	0.7115	0.7741	0.5601	0.7013	0.8182
Sample size	301	409	363	291	308	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	2010	2011
20	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0045	0.0000
22	0.0000	0.0056	0.0087	0.0000	0.0007	0.0007	0.0011	0.0010
24	0.0010	0.0065	0.0058	0.0012	0.0013	0.0007	0.0056	0.0010
26	0.0021	0.0084	0.0087	0.0020	0.0013	0.0048	0.0100	0.0020
28	0.0063	0.0130	0.0029	0.0040	0.0047	0.0054	0.0134	0.0061
30	0.0042	0.0297	0.0058	0.0032	0.0074	0.0122	0.0111	0.0081
32	0.0094	0.0270	0.0058	0.0064	0.0067	0.0115	0.0290	0.0304
34	0.0125	0.0362	0.0145	0.0095	0.0134	0.0258	0.0323	0.0314
36	0.0104	0.0455	0.0174	0.0139	0.0315	0.0326	0.0390	0.0354
38	0.0261	0.0660	0.0378	0.0382	0.0308	0.0605	0.0568	0.0354
40	0.0396	0.1004	0.0494	0.0545	0.0455	0.0713	0.0757	0.0840
42	0.1585	0.1087	0.1453	0.1010	0.0717	0.0965	0.0980	0.1083
44	0.2857	0.1645	0.1657	0.1427	0.1165	0.1209	0.1236	0.1235
46	0.2221	0.1292	0.1948	0.1924	0.1514	0.1461	0.1347	0.1306
48	0.1512	0.0790	0.1395	0.1717	0.1541	0.1352	0.1526	0.1407
50	0.0448	0.0465	0.1134	0.1125	0.1306	0.1175	0.0724	0.1113
52	0.0136	0.0344	0.0465	0.0719	0.0884	0.0822	0.0624	0.0577
54	0.0042	0.0362	0.0145	0.0322	0.0583	0.0299	0.0367	0.0425
56	0.0063	0.0251	0.0116	0.0199	0.0275	0.0190	0.0134	0.0202
58	0.0010	0.0167	0.0058	0.0079	0.0221	0.0129	0.0100	0.0162
60+	0.0010	0.0214	0.0058	0.0147	0.0362	0.0143	0.0178	0.0142
Sample size	959	1077	344	2516	1493	1472	899	988

Table 13-10. GOA RE/BS rockfish biomass estimates from NMFS triennial/biennial trawl surveys in the Gulf of Alaska. We excluded the 2001 survey because no sampling was performed in the Eastern Gulf. SE is the standard error. LCI and UCI are the lower and upper 95% confidence intervals respectively, and CV is the coefficient of variation expressed as a percent.

Year	Western	Central	Eastern	Biomass	SE	LCI	UCI	CV (%)
1984	8,779	32,416	3,896	45,091	7,313	30,758	59,425	16.2
1987	2,737	21,881	19,063	43,681	4,897	34,083	53,278	11.2
1990	1,329	35,467	8,041	44,837	9,296	26,617	63,057	20.7
1993	10,889	41,616	9,358	61,863	14,415	33,610	90,115	23.3
1996	3,449	28,396	14,067	45,913	7,432	31,346	60,481	16.2
1999	6,156	20,781	12,622	39,560	5,793	28,206	50,913	14.6
2003	8,921	24,610	9,670	43,202	6,724	30,024	56,380	15.6
2005	3,621	32,898	11,343	47,862	8,618	30,971	64,754	18.0
2007	3,773	39,410	16,697	59,880	10,380	39,536	80,225	17.3
2009	2,765	33,154	14,855	50,774	8,297	34,512	67,035	16.3
2011	3,305	32,583	8,228	44,115	7,126	30,149	58,082	16.2
2013	3,922	11,207	12,452	27,581	5,078	17,627	37,534	18.4

Table 13-11. AFSC bottom trawl survey relative age compositions for GOA RE/BS rockfish since 1984. Pooled age 25+ includes all fish 25 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	0.0429
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	0.0480
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	0.0107
25+	0.4803	0.2652	0.2267	0.1758	0.1944	0.1326	0.2554	0.1574	0.2870
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 25+ includes all fish 25 and older.

Age (yr)	2009	2011
3	0.0113	0.0124
4	0.0099	0.0096
5	0.0191	0.0575
6	0.0497	0.0322
7	0.0348	0.0491
8	0.0607	0.0427
9	0.0437	0.0978
10	0.0389	0.0436
11	0.0560	0.0762
12	0.0377	0.0764
13	0.0378	0.0559
14	0.0369	0.0407
15	0.0506	0.0543
16	0.0441	0.0273
17	0.0374	0.0257
18	0.0309	0.0152
19	0.0250	0.0260
20	0.0414	0.0090
21	0.0199	0.0176
22	0.0240	0.0232
23	0.0182	0.0095
24	0.0202	0.0253
25+	0.2519	0.1726
Sample size	928	402

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	0.0420
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	0.0558
38	0.0578	0.0721	0.0869	0.1069	0.0639	0.0720	0.0884	0.0525	0.0701	0.0804
40	0.0841	0.0817	0.0695	0.1240	0.0858	0.0788	0.0970	0.0680	0.0781	0.0874
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	0.1160
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	0.0319	0.0520
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	4,252

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
20	0.0402	0.0364	0.0637
22	0.0545	0.0507	0.0516
24	0.0593	0.0522	0.0526
26	0.0690	0.0596	0.0516
28	0.0552	0.0569	0.0598
30	0.0598	0.0704	0.0450
32	0.0440	0.0543	0.0489
34	0.0425	0.0627	0.0562
36	0.0466	0.0602	0.0724
38	0.0527	0.0638	0.0857
40	0.0691	0.0825	0.0872
42	0.0798	0.0992	0.0844
44	0.0904	0.0867	0.0595
46	0.0880	0.0603	0.0627
48	0.0662	0.0480	0.0449
50	0.0406	0.0251	0.0383
52	0.0240	0.0111	0.0183
54	0.0090	0.0098	0.0078
56	0.0041	0.0034	0.0046
58	0.0026	0.0017	0.0020
60+	0.0024	0.0049	0.0026
Sample size	4,155	2,475	1,692

Table 13-13. GOA RE/BS rockfish relative population weights (RPW) and relative population numbers (RPN) estimated from the AFSC longline survey 1993-2014. SE is the standard error. LCI and UCI are the lower and upper 95% confidence intervals respectively and CV is the coefficient of variation expressed as a percent. S.E., LCI, UCI, and CV are respective to the RPNs.

Year	RPW	RPN	SE	LCI	UCI	CV%
1993	37,694	23,269	4,336	14,597	31,942	18.6
1994	38,010	22,622	3,885	14,852	30,391	17.2
1995	44,044	27,472	4,875	17,722	37,222	17.7
1996	41,896	25,624	4,122	17,381	33,868	16.1
1997	61,150	37,070	7,578	21,913	52,227	20.4
1998	42,190	24,570	3,284	18,003	31,137	13.4
1999	46,297	27,254	4,238	18,778	35,729	15.5
2000	65,507	37,894	5,860	26,174	49,614	15.5
2001	46,163	29,523	5,056	19,411	39,634	17.1
2002	44,004	27,517	4,581	18,354	36,679	16.6
2003	43,893	24,389	3,883	16,623	32,156	15.9
2004	41,067	27,913	5,222	17,469	38,358	18.7
2005	29,288	18,863	3,657	11,549	26,177	19.4
2006	33,673	20,478	3,262	13,954	27,001	15.9
2007	50,123	33,663	5,570	22,524	44,802	16.5
2008	49,173	30,960	4,700	21,559	40,361	15.2
2009	40,747	29,751	5,398	18,956	40,547	18.1
2010	51,501	35,288	5,549	24,190	46,387	15.7
2011	57,553	39,783	8,164	23,454	56,111	20.5
2012	43,283	26,962	5,016	16,929	36,995	18.6
2013	35,197	23,939	4,960	14,019	33,860	20.7
2014	51,763	33,464	5,629	22,205	44,723	16.8

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	0.0011	0.0005	0.0000	0.0000	0.0015	0.0000	0.0006	0.0005	0.0025	0.0012
26	0.0061	0.0004	0.0027	0.0001	0.0007	0.0005	0.0034	0.0013	0.0037	0.0024
28	0.0057	0.0041	0.0055	0.0022	0.0016	0.0023	0.0061	0.0028	0.0052	0.0058
30	0.0111	0.0073	0.0087	0.0102	0.0103	0.0203	0.0116	0.0084	0.0181	0.0153
32	0.0284	0.0136	0.0196	0.0159	0.0100	0.0234	0.0159	0.0167	0.0196	0.0208
34	0.0504	0.0303	0.0294	0.0338	0.0165	0.0369	0.0378	0.0311	0.0431	0.0305
36	0.0529	0.0371	0.0432	0.0476	0.0440	0.0468	0.0541	0.0610	0.0503	0.0515
38	0.0653	0.0548	0.0742	0.0760	0.0769	0.0607	0.0704	0.0820	0.0707	0.0738
40	0.0856	0.0839	0.1123	0.1010	0.0889	0.0762	0.0943	0.0931	0.0999	0.0945
42	0.1443	0.0863	0.1192	0.1287	0.1207	0.0992	0.1085	0.1040	0.1007	0.1282
44	0.1453	0.1492	0.1379	0.1518	0.1331	0.1366	0.1484	0.1354	0.1257	0.1473
46	0.1346	0.1507	0.1308	0.1482	0.1569	0.1587	0.1616	0.1312	0.1348	0.1333
48	0.0872	0.1303	0.1101	0.1192	0.1280	0.1383	0.1248	0.1362	0.1245	0.1207
50	0.0807	0.0880	0.0920	0.0754	0.0859	0.0888	0.0808	0.0829	0.0905	0.0699
52	0.0439	0.0689	0.0428	0.0363	0.0462	0.0504	0.0435	0.0501	0.0460	0.0432
54	0.0196	0.0333	0.0334	0.0242	0.0243	0.0205	0.0153	0.0263	0.0225	0.0237
56	0.0158	0.0186	0.0175	0.0120	0.0116	0.0153	0.0051	0.0132	0.0101	0.0108
58	0.0057	0.0142	0.0093	0.0058	0.0089	0.0100	0.0034	0.0054	0.0058	0.0119
60+	0.0166	0.0286	0.0113	0.0114	0.0339	0.0153	0.0143	0.0185	0.0256	0.0153
Sample size	3,996	3,560	5,090	4,636	5,696	4,508	5,938	7,084	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	0.0005	0.0004	0.0005	0.0000
24	0.0007	0.0001	0.0013	0.0001	0.0008	0.0005	0.0015	0.0007	0.0022	0.0001
26	0.0023	0.0029	0.0036	0.0025	0.0032	0.0023	0.0027	0.0079	0.0076	0.0024
28	0.0086	0.0160	0.0130	0.0230	0.0013	0.0068	0.0118	0.0185	0.0129	0.0097
30	0.0132	0.0238	0.0265	0.0098	0.0120	0.0207	0.0469	0.0324	0.0301	0.0165
32	0.0185	0.0217	0.0341	0.0192	0.0330	0.0341	0.0272	0.0561	0.0404	0.0272
34	0.0166	0.0348	0.0334	0.0273	0.0465	0.0540	0.0421	0.0614	0.0585	0.0431
36	0.0278	0.0553	0.0508	0.0383	0.0840	0.0671	0.0555	0.0746	0.0763	0.0616
38	0.0617	0.0973	0.0535	0.0493	0.0657	0.0701	0.0844	0.0834	0.0938	0.0852
40	0.0885	0.0976	0.0704	0.0823	0.0998	0.0766	0.1038	0.0931	0.1037	0.1061
42	0.1135	0.1152	0.1166	0.1160	0.1140	0.1042	0.1222	0.1098	0.1160	0.1069
44	0.1387	0.1378	0.1430	0.1384	0.1466	0.1204	0.1148	0.1197	0.1157	0.1335
46	0.1610	0.1443	0.1452	0.1475	0.1341	0.1231	0.1092	0.1110	0.0931	0.1162
48	0.1451	0.1082	0.1363	0.1415	0.1084	0.1143	0.1046	0.0832	0.0921	0.1025
50	0.0830	0.0703	0.0687	0.0783	0.0614	0.0946	0.0703	0.0565	0.0562	0.0698
52	0.0430	0.0338	0.0350	0.0478	0.0385	0.0514	0.0488	0.0259	0.0333	0.0496
54	0.0163	0.0146	0.0224	0.0283	0.0150	0.0259	0.0223	0.0135	0.0156	0.0239
56	0.0150	0.0111	0.0108	0.0141	0.0159	0.0111	0.0147	0.0118	0.0137	0.0120
58	0.0103	0.0065	0.0101	0.0150	0.0050	0.0106	0.0047	0.0085	0.0064	0.0050
60+	0.0361	0.0084	0.0254	0.0207	0.0148	0.0116	0.0121	0.0317	0.0320	0.0287
Sample size	4,596	4,834	4,095	4,305	6,575	5,683	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
20	0.0000	0.0000
22	0.0000	0.0000
24	0.0001	0.0001
26	0.0033	0.0515
28	0.0074	0.0035
30	0.0270	0.0155
32	0.0404	0.0213
34	0.0573	0.0401
36	0.0956	0.0596
38	0.0860	0.0730
40	0.0961	0.1019
42	0.1026	0.1145
44	0.1207	0.1131
46	0.1206	0.1104
48	0.1016	0.1038
50	0.0628	0.0766
52	0.0290	0.0432
54	0.0181	0.0238
56	0.0102	0.0162
58	0.0132	0.0099
60+	0.0081	0.0221
Sample size	3,744	6,820

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.

	Model 0		***Model 1***		***Model 2***	
Likelihoods	Value	Weight	Value	Weight	Value	Weight
Catch	0.074	5/50*	0.077	5/50*	0.037	5/50*
Trawl Biomass	2.738	1	8.427	1	8.933	1
Longline Biomass	8.160	1	9.565	1	11.922	1
Fishery Ages	25.090	1	38.115	1	37.270	1
Trawl Survey Ages	35.247	1	38.766	1	39.300	1
Fishery Sizes	50.104	1	53.651	1	51.364	1
Trawl Survey Sizes	0	0	0	0	0	0
Longline Survey Sizes	104.519	1	101.469	1	97.708	1
Data-Likelihood	225.932		250.071		246.532	
Penalties/Priors						
Recruit Deviations	2.534	1	-1.031	1	-0.090	1
Fishery Selectivity	2.433	1	2.456	1	2.587	1
Trawl Selectivity	0.272	1	0.456	1	0.503	1
Longline Selectivity	0.586	1	0.542	1	0.401	1
Fish-Sel Domeshape	0	1	0	1	0.000	1
Survey-Sel Domeshp	0.038	1	0.080	1	0.103	1
LL-Sel Domeshape	0	1	0	1	0.001	1
Average Selectivity	0	0.1	0.000	0.1	0.000	0.1
F Regularity	1.193	0.1	1.110	0.1	1.146	0.1
σ_r prior	3.620		4.826		4.578	
q-trawl	0.310		0.756		0.632	
q-longline	0.013		0.174		0.056	
M	0.767		0.645		0.649	
Total penalties/priors	11.765		10.015		10.567	
Objective Fun. Total	237.697		260.085		257.099	

Parameter Estimates	Value	σ	Value	σ	Value	σ
q-trawl	1.422	0.431	1.733	0.475	1.654	0.511
q-longline	1.173	0.348	1.803	0.522	1.399	0.516
M	0.034	0.003	0.034	0.003	0.034	0.003
σ_r	0.928	0.058	0.904	0.056	0.908	0.057
Mean Recruitment (mil)	1.523		1.157		1.565	
$F_{40\%}$	0.039	0.011	0.039	0.011	0.038	0.010
Total Biomass (t)	42,856	12,143	32,046	8,962	36,583	11,588
Spawning Biomass (t)	12,610	3,791	9,856	2,971	12,479	4,140
$B_{100\%}$ (t)	24,329		18,348		22,449	
$B_{40\%}$ (t)	9,732	2,731	7,339	1,920	8,980	2,570
$\boldsymbol{ABC_{F40\%}}$ ***(t)***	1,223	511	927	390	1,122	496

*Values are weights on the catch series before the catch reliability penalty (1977-1992) and after (1993-2014).

Table 13-16. Estimated GOA RE/BS rockfish population numbers (thousands) in 2014, 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 2014 (1000s)	Percent Mature	Weight (g)	Fishery Selectivity	Trawl Survey Selectivity	LL Survey Selectivity
3	1,262	0	48	0	16	0
4	1,211	0	82	0	26	0
5	1,156	0	125	0	49	0
6	1,139	0	176	0	73	0
7	984	0	234	1	72	0
8	1,316	0	298	1	78	0
9	985	0	367	3	97	0
10	894	1	440	3	100	0
11	990	2	515	3	96	1
12	1,254	5	591	3	70	4
13	1,550	8	668	4	70	13
14	1,738	14	745	9	70	35
15	889	22	821	25	70	71
16	1,570	31	895	100	70	100
17	1,131	40	968	100	70	98
18	720	50	1038	100	70	98
19	1,239	59	1107	100	70	98
20	1,765	66	1172	100	70	98
21	587	72	1235	100	70	98
22	538	77	1295	100	70	98
23	516	81	1352	100	70	98
24	1,551	84	1406	100	70	98
25+	10,577	92	1814	100	70	98

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 (2014), 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	1.6536	1.7266	0.5110	0.5332	1.6612	0.8589	2.9078
q_2, longline survey	1.3993	1.3743	0.5160	0.4452	1.3334	0.6320	2.3345
M	0.0336	0.0341	0.0030	0.0032	0.0339	0.0283	0.0406
$F_{40\%}$	0.0376	0.0435	0.0101	0.0136	0.0413	0.0238	0.0760
SSB (2014)	12,479	16,130	4,140	6,581	14,698	8,121	33,075
ABC	1,122	1,689	496	921	1,478	594	4,103
σ_r	0.9084	1.0717	0.0567	0.0655	1.0703	0.9504	1.2045

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, 1977-2014. Estimates are shown for the author preferred model (Model 2) and from the previous assessment in 2011 (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	16,232	17,470	43,850	44,123	0.033	0.033	729	968
1978	15,522	16,792	42,367	42,625	0.013	0.013	882	1,074
1979	15,203	16,496	41,706	42,002	0.015	0.015	3,952	4,637
1980	14,860	16,172	40,941	41,304	0.033	0.033	900	1,137
1981	14,223	15,548	39,523	39,927	0.018	0.018	885	914
1982	13,891	15,215	40,084	39,770	0.014	0.014	986	955
1983	13,651	14,964	39,714	39,379	0.016	0.016	3,070	3,589
1984	13,413	14,704	39,260	38,913	0.019	0.020	1,647	1,640
1985	13,138	14,398	38,693	38,316	0.003	0.003	1,353	1,203
1986	13,147	14,375	39,644	38,768	0.011	0.011	1,371	1,347
1987	13,039	14,231	39,808	38,712	0.013	0.014	900	1,014
1988	12,905	14,063	39,788	38,537	0.041	0.042	737	802
1989	12,336	13,458	38,714	37,337	0.056	0.059	635	682
1990	11,558	12,650	36,919	35,579	0.065	0.068	709	633
1991	10,787	11,801	34,991	33,631	0.010	0.010	869	732
1992	10,850	11,844	34,898	33,659	0.032	0.033	765	834
1993	10,697	11,628	34,140	32,925	0.017	0.018	3,963	3,585
1994	10,789	11,656	33,971	32,719	0.017	0.018	1,106	1,139
1995	10,817	11,655	33,606	32,422	0.021	0.022	1,172	1,131
1996	10,805	11,608	34,456	32,401	0.016	0.017	1,358	1,176
1997	10,865	11,631	34,441	32,243	0.016	0.017	4,970	3,382
1998	10,913	11,648	34,429	32,084	0.019	0.021	1,635	2,264
1999	10,893	11,601	34,364	31,814	0.009	0.010	1,091	1,251
2000	11,007	11,690	36,221	32,265	0.015	0.016	1,604	1,864
2001	11,236	11,938	37,075	32,909	0.016	0.018	2,121	2,454
2002	11,154	11,812	37,188	32,824	0.007	0.008	1,098	1,338
2003	11,208	11,800	37,793	33,137	0.010	0.012	2,320	2,524
2004	11,238	11,746	38,501	33,462	0.008	0.009	2,285	2,176
2005	11,500	11,962	39,170	34,141	0.007	0.009	1,679	1,701
2006	11,666	12,008	40,093	34,682	0.009	0.010	1,125	1,298
2007	11,825	12,014	40,926	35,077	0.010	0.012	1,046	1,132
2008	12,001	12,036	41,465	35,382	0.009	0.011	1,043	1,206
2009	12,188	12,082	41,713	35,638	0.007	0.008	1,160	1,557
2010	12,444	12,191	41,965	35,938	0.011	0.012	1,076	1,126
2011	12,653	12,263	41,984	36,065	0.013	0.015	1,082	1,260
2012		12,314		36,112		0.016		1,237
2013		12,385		36,081		0.016		1,253
2014		12,480		36,062		0.020		1,262

Table 13-19. Estimated time series of recruitment, total biomass (3+), and female spawning biomass for RE/BS rockfish in the Gulf of Alaska, 1977-2015. 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	968	134	3,666	44,379	31,718	85,210	17,470	11,772	31,950
1978	1,074	142	5,280	42,870	30,409	84,417	16,792	11,275	31,774
1979	4,637	721	10,242	42,424	30,369	85,292	16,496	11,164	31,890
1980	1,137	145	5,368	41,853	29,944	85,015	16,172	11,036	31,762
1981	914	127	3,620	40,603	28,988	84,373	15,548	10,535	31,310
1982	955	137	4,010	40,021	28,651	84,434	15,215	10,386	31,236
1983	3,589	429	8,603	39,735	28,549	84,800	14,964	10,289	31,385
1984	1,640	207	6,403	39,389	28,324	85,152	14,704	10,136	31,234
1985	1,203	157	4,309	38,923	28,009	85,005	14,398	10,012	31,162
1986	1,347	171	4,176	39,120	28,307	85,777	14,375	10,123	31,104
1987	1,014	162	3,376	39,009	28,226	86,127	14,231	10,097	31,092
1988	802	122	2,613	38,814	28,008	86,030	14,063	9,964	31,119
1989	682	121	2,206	37,552	26,886	85,125	13,458	9,365	30,616
1990	633	113	1,898	35,758	25,116	83,441	12,650	8,644	29,668
1991	732	125	2,256	33,796	23,262	81,570	11,801	7,890	28,829
1992	834	131	3,121	33,832	23,346	81,566	11,844	7,925	29,027
1993	3,585	1,289	8,275	33,250	22,707	80,990	11,628	7,721	28,915
1994	1,139	148	4,463	33,156	22,630	80,858	11,656	7,750	29,326
1995	1,131	146	3,994	32,986	22,483	81,065	11,655	7,751	29,409
1996	1,176	161	4,757	32,680	22,173	81,057	11,608	7,655	29,667
1997	3,382	464	8,787	32,631	22,037	81,038	11,631	7,670	29,785
1998	2,264	250	7,408	32,599	21,981	81,526	11,648	7,650	29,973
1999	1,251	155	5,459	32,450	21,760	81,957	11,601	7,611	29,933
2000	1,864	224	7,178	32,719	21,938	82,608	11,690	7,702	30,181
2001	2,454	327	6,985	33,321	22,268	84,688	11,938	7,816	31,005
2002	1,338	177	5,554	33,301	22,290	84,961	11,812	7,705	30,821
2003	2,524	406	7,543	33,651	22,556	85,307	11,800	7,718	30,658
2004	2,176	300	7,664	33,923	22,711	85,726	11,746	7,672	30,508
2005	1,701	231	5,898	34,691	23,299	87,714	11,962	7,797	31,120
2006	1,298	178	4,665	35,133	23,663	88,760	12,008	7,872	31,118
2007	1,132	156	4,447	35,433	23,864	90,074	12,014	7,877	31,245
2008	1,206	165	5,357	35,682	24,018	90,555	12,036	7,877	31,456
2009	1,557	214	6,540	35,941	24,236	91,341	12,082	7,929	31,469
2010	1,126	135	6,058	36,257	24,463	91,791	12,191	7,999	31,554
2011	1,260	162	6,799	36,397	24,546	92,661	12,263	8,035	31,996
2012	1,237	145	9,783	36,403	24,529	92,916	12,314	8,047	32,185
2013	1,253	149	9,430	36,386	24,477	93,290	12,385	8,087	32,422
2014	1,262	150	10,427	36,367	24,435	93,562	12,480	8,119	32,760
2015	1,627	---	---	36,583	---	---	12,480	8,146	32,859

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. $B_{40\%}$ = 8,980 t, $B_{35\%}$ = 7,857 t, $F_{40\%}$ = 0.038 and $F_{35\%}$ = 0.045.

Year	Maximum permissible F	Author's F*	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning Biomass (t)				
2014	12,182	12,182	12,182	12,182	12,182	12,182	12,182
2015	12,373	12,480	12,469	12,466	12,565	12,334	12,373
2016	12,234	12,595	12,556	12,545	12,886	12,105	12,234
2017	12,095	12,598	12,639	12,621	13,209	11,880	12,057
2018	11,954	12,443	12,717	12,691	13,530	11,656	11,827
2019	11,959	12,439	12,948	12,915	14,022	11,578	11,744
2020	11,832	12,296	13,034	12,993	14,362	11,375	11,535
2021	11,611	12,055	13,007	12,960	14,578	11,087	11,239
2022	11,430	11,854	13,016	12,961	14,833	10,842	10,986
2023	11,277	11,683	13,049	12,988	15,115	10,628	10,765
2024	11,037	11,422	12,970	12,902	15,262	10,338	10,466
2025	10,885	11,250	12,982	12,908	15,511	10,136	10,257
2026	10,708	11,048	12,949	12,870	15,698	9,916	10,028
2027	10,508	10,826	12,875	12,790	15,826	9,681	9,785
			Fishing Mortality				
2014	0.025	0.025	0.025	0.025	0.025	0.025	0.025
2015	0.038	0.017	0.019	0.019	-	0.045	0.045
2016	0.038	0.016	0.019	0.019	-	0.045	0.045
2017	0.038	0.038	0.019	0.019	-	0.045	0.045
2018	0.038	0.038	0.019	0.019	-	0.045	0.045
2019	0.038	0.038	0.019	0.019	-	0.045	0.045
2020	0.038	0.038	0.019	0.019	-	0.045	0.045
2021	0.038	0.038	0.019	0.019	-	0.045	0.045
2022	0.038	0.038	0.019	0.019	-	0.045	0.045
2023	0.038	0.038	0.019	0.019	-	0.045	0.045
2024	0.038	0.038	0.019	0.019	-	0.045	0.045
2025	0.038	0.038	0.019	0.019	-	0.045	0.045
2026	0.038	0.038	0.019	0.019	-	0.045	0.045
2027	0.038	0.038	0.019	0.019	-	0.045	0.045
			Yield (t)				
2014	736	736	736	736	736	736	736
2015	502	502	566	584	-	1,345	502
2016	1,119	501	575	593	-	1,333	1,119
2017	1,111	1,156	581	599	-	1,313	1,332
2018	1,094	1,137	582	599	-	1,285	1,303
2019	1,082	1,123	585	603	-	1,262	1,279
2020	1,061	1,100	583	600	-	1,228	1,245
2021	1,037	1,074	579	596	-	1,193	1,208
2022	1,020	1,056	579	595	-	1,167	1,182
2023	1,001	1,035	577	593	-	1,138	1,152
2024	979	1,011	572	588	-	1,107	1,120
2025	963	993	571	586	-	1,083	1,095
2026	946	974	568	583	-	1,059	1,070
2027	930	956	565	579	-	1,035	1,045

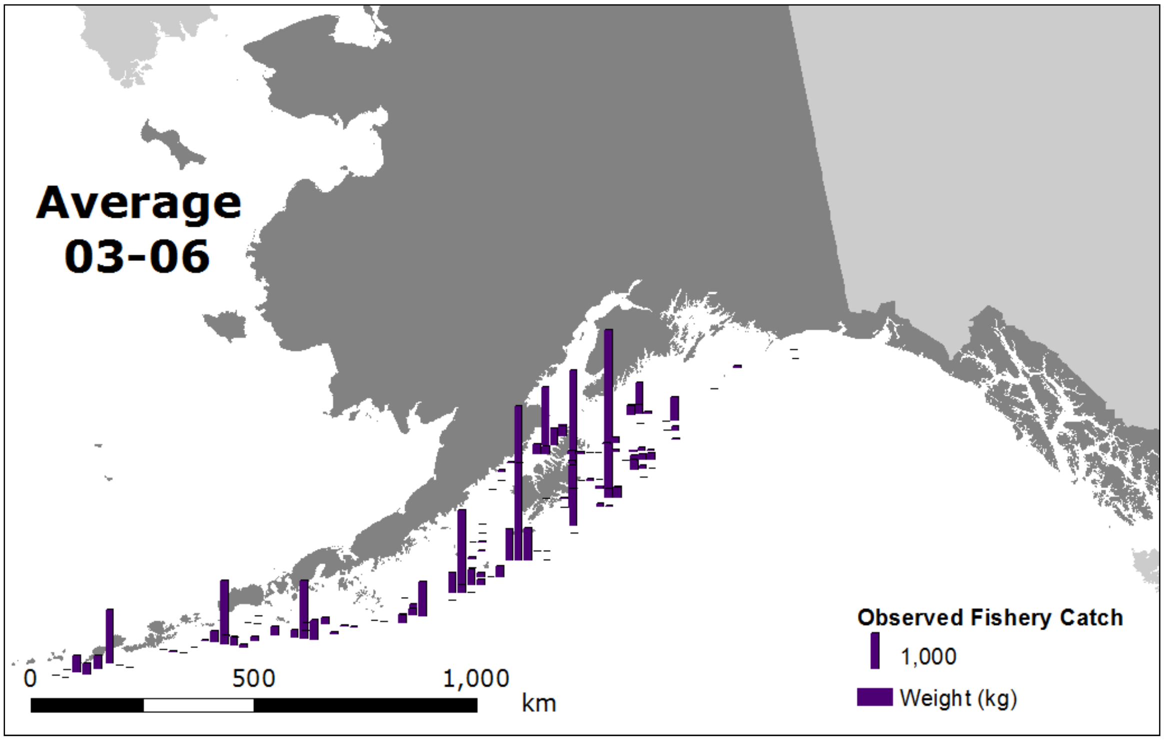
*Projected ABCs and OFLs for 2015 and 2016 are derived using estimated catch of 736 t for 2014 and projected catch of 502 t for 2015 based on realized catches from 2011-2013. This calculation is in response to management requests to obtain more accurate projections.

Table 13-21. Recommended allocation of ABC and OFL for 2015 and 2016 GOA RE/BS rockfish based on the preferred weighted survey average method.

Year	Weights	Western Gulf	Central Gulf	Eastern Gulf	Total
2009	4	6%	65%	29%	100%
2011	6	7%	74%	19%	100%
2013	9	14%	41%	45%	100%
Weighted Mean	19				
Area Allocation		10.3%	56.3%	33.4%	100%
2015	Area ABC (t)	**115**	**632**	**375**	**1,122**
	OFL (t)				**1,345**
2016	Area ABC (t)	**117**	**643**	**382**	**1,142**
	OFL (t)				**1,370**

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



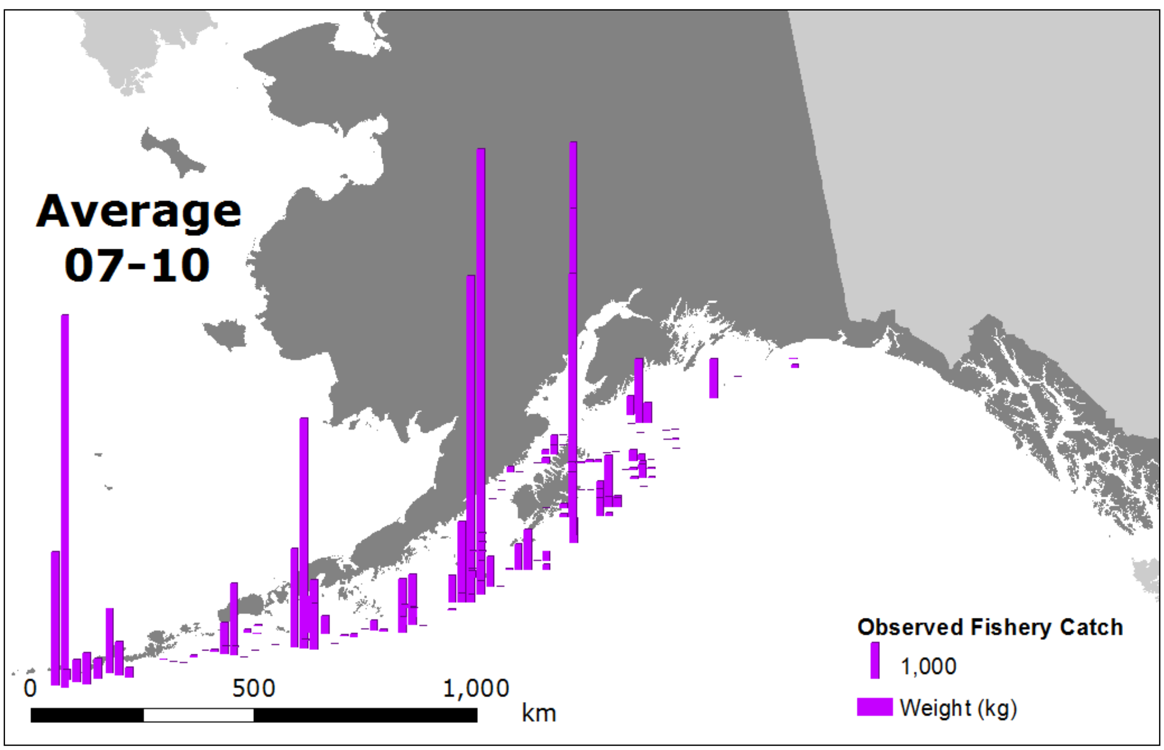


Figure 13-1. Spatial distribution of observed rougheye and blackspotted rockfish trawl fishery catch in the Gulf of Alaska (GOA) based on observer data aggregated by 400 km^2 blocks and averaged by four years prior to central GOA Rockfish Pilot Program, 2003-2006 (upper panel), and four years after implementation of program, 2007-2010 (lower panel). Source: Observer Program (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

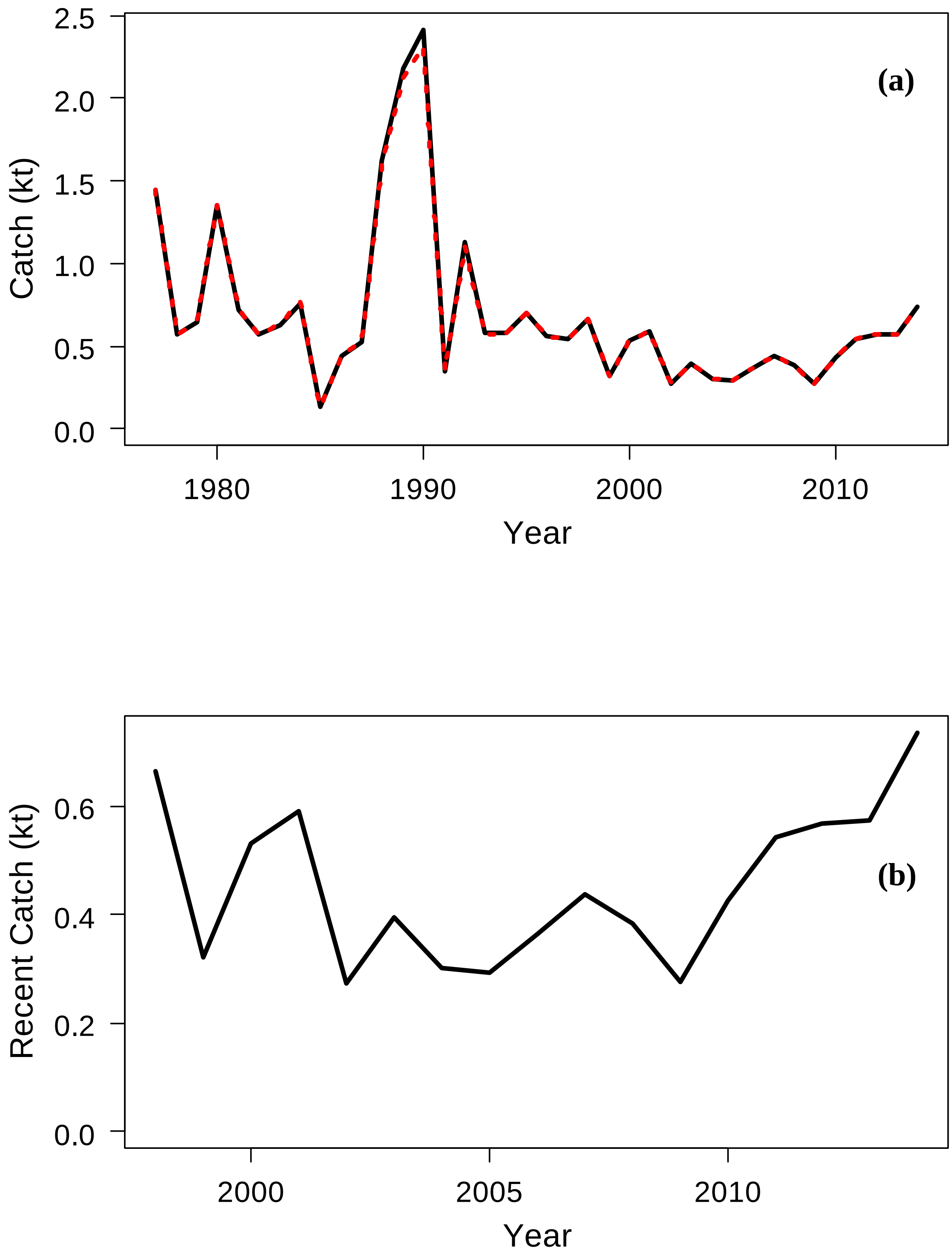


Figure 13-2. Estimated long-term (a) and short-term (b) commercial catches for Gulf of Alaska RE/BS rockfish. Solid line is observed catch and red dashed line (in a only) is predicted catch from the author preferred model.

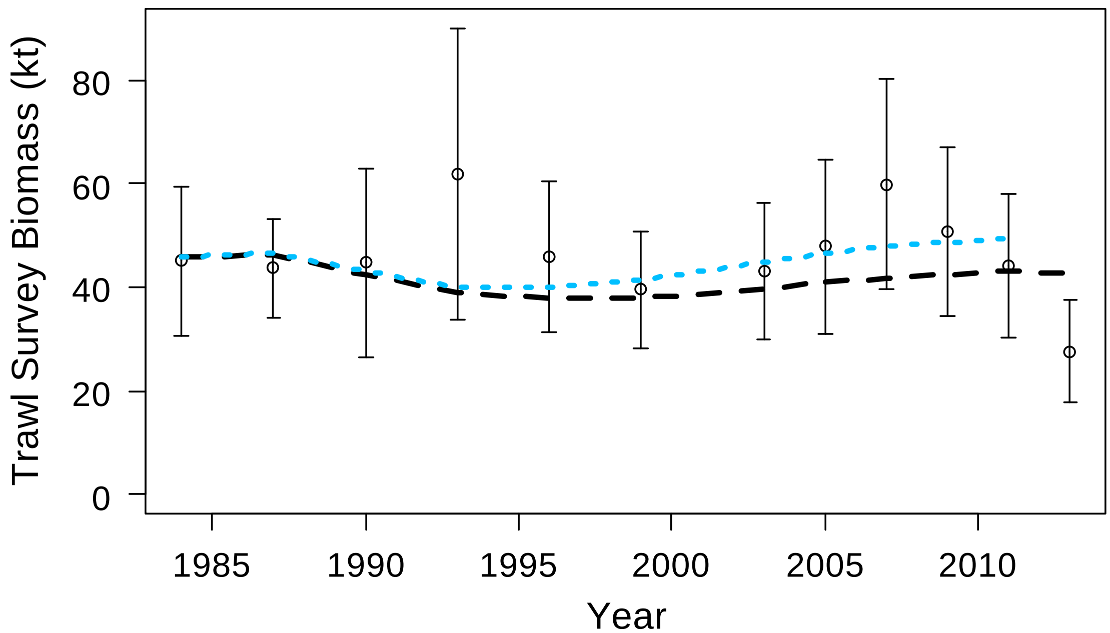


Figure 13-3. AFSC bottom trawl survey observed biomass estimates (open circles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the preferred model (dashed black line) are compared with the last full assessment model fit (dotted blue line).

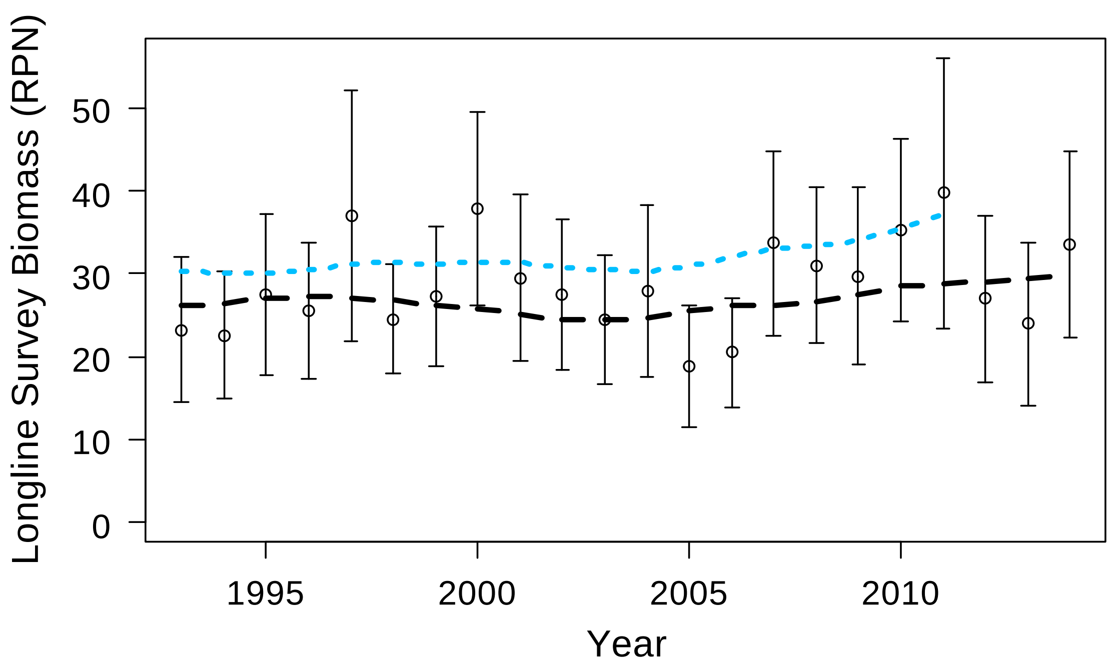


Figure 13-4. AFSC longline survey relative population numbers (RPN in thousands, open circles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the preferred model (dashed black line) are compared with the last full assessment model fit (dotted blue line) which was based on relative population weights (RPW).

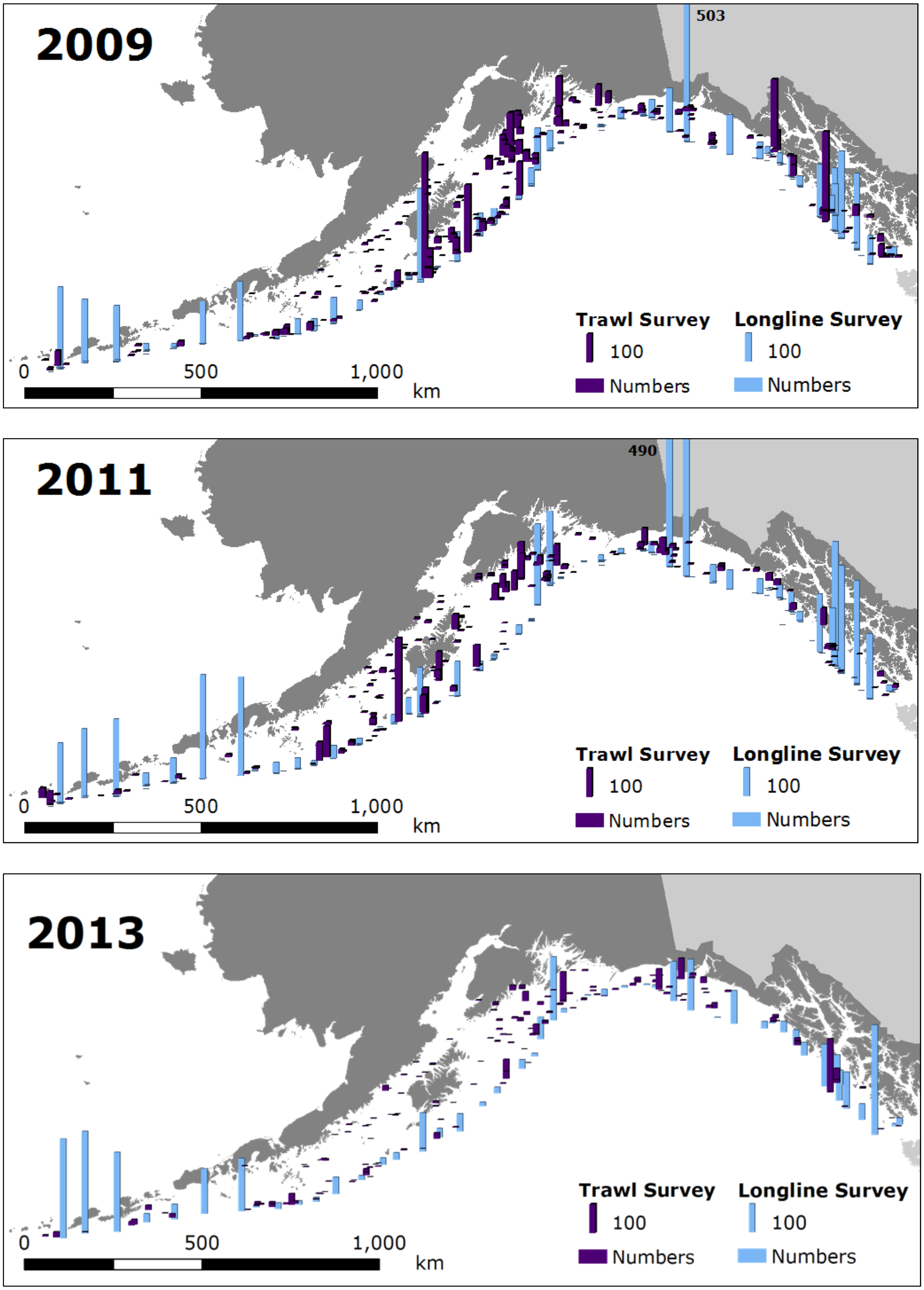


Figure 13-5a. Spatial distribution of rougheye and blackspotted rockfish in the Gulf of Alaska during the 2009, 2011, and 2013 AFSC trawl (dark purple) and AFSC longline (blue) surveys.

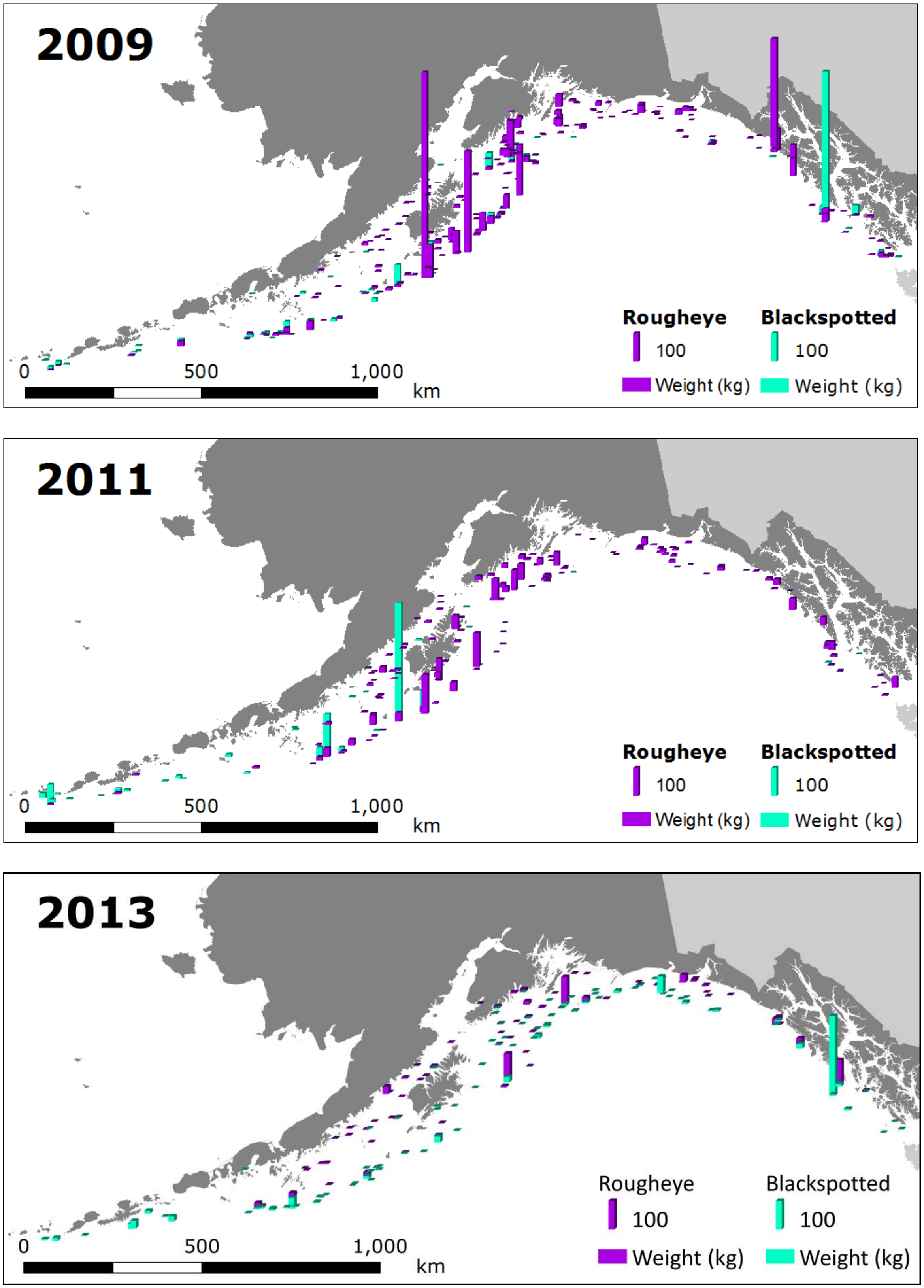


Figure 13-5b. Comparison of the spatial distribution between at-sea identified rougheye (purple) and blackspotted (green) rockfish in the Gulf of Alaska during the 2009, 2011, 2013 AFSC trawl surveys.

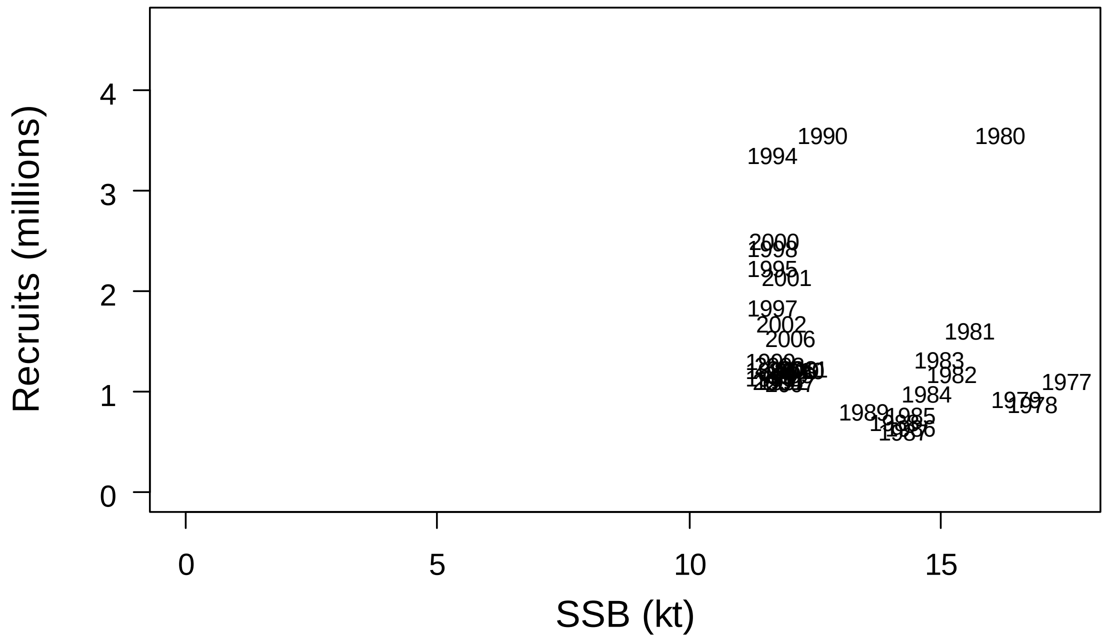


Figure 13-6. Scatterplot of spawner-recruit data for GOA RE/BS rockfish author preferred model. Label is year class of age 3 recruits. Recruits are in millions and SSB = Spawning stock biomass in tons.

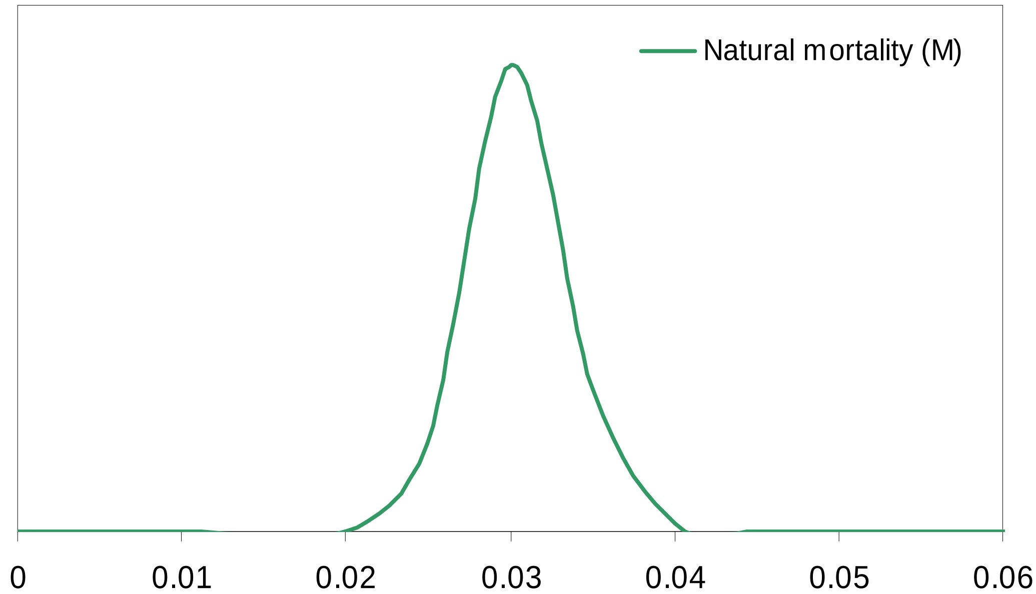


Figure 13-7. Prior distribution for natural mortality (M, μ=0.03, CV=10%) of GOA RE/BS rockfish.

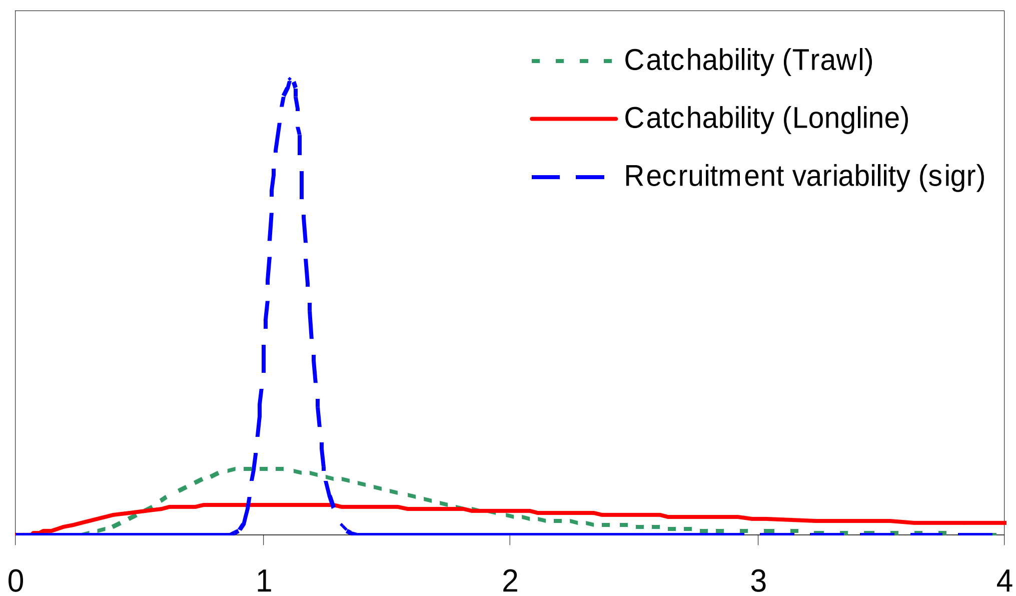


Figure 13-8. Prior distributions for NMFS trawl survey catchability ($q1$, μ=1, CV=45%), AFSC longline survey catchability ($q2$, μ=1, CV=100%), and recruitment variability (σ_r, μ=1.1, CV=6%) of GOA RE/BS rockfish.

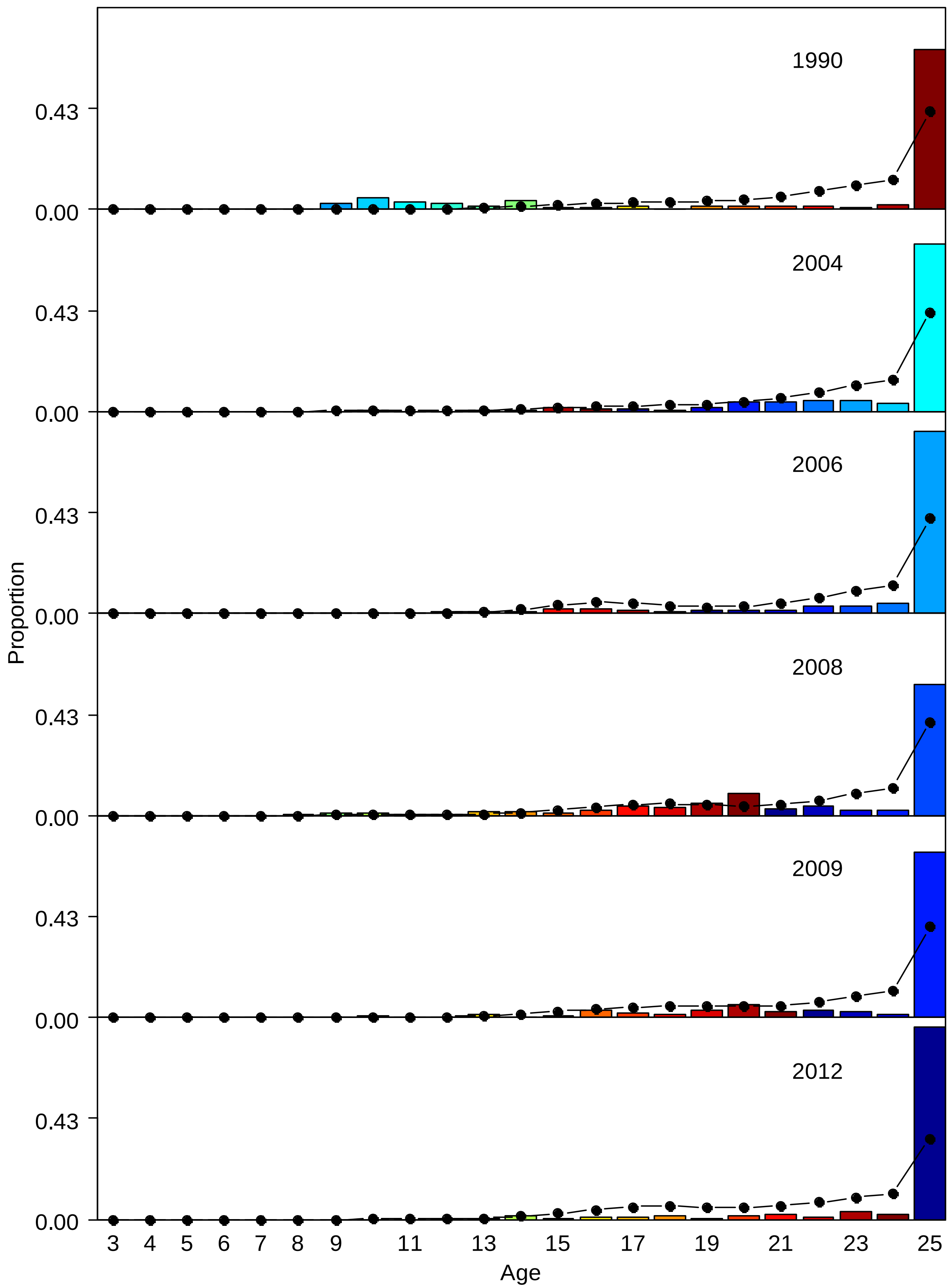


Figure 13-9. Fishery age compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

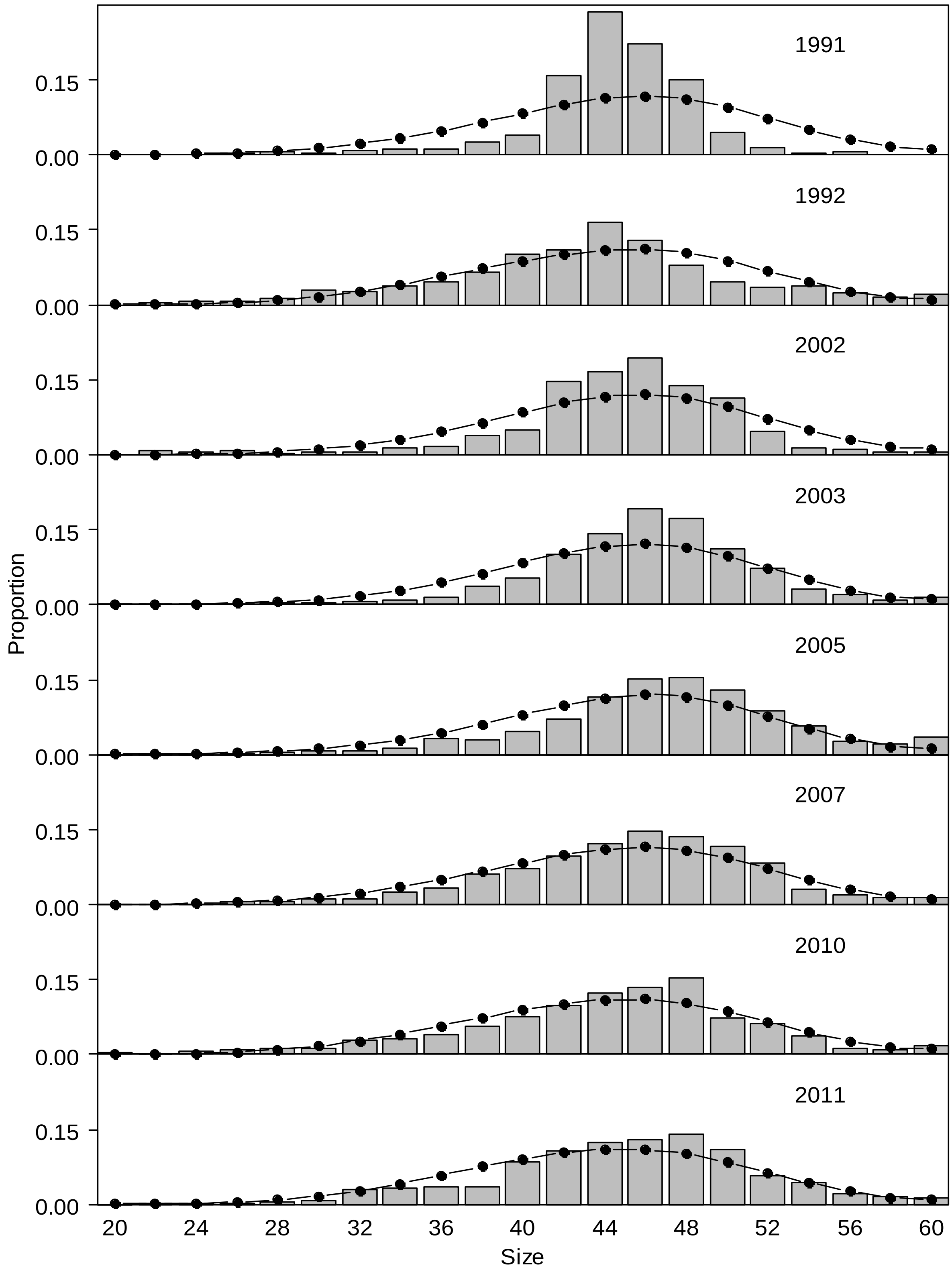


Figure 13-10. Fishery length compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

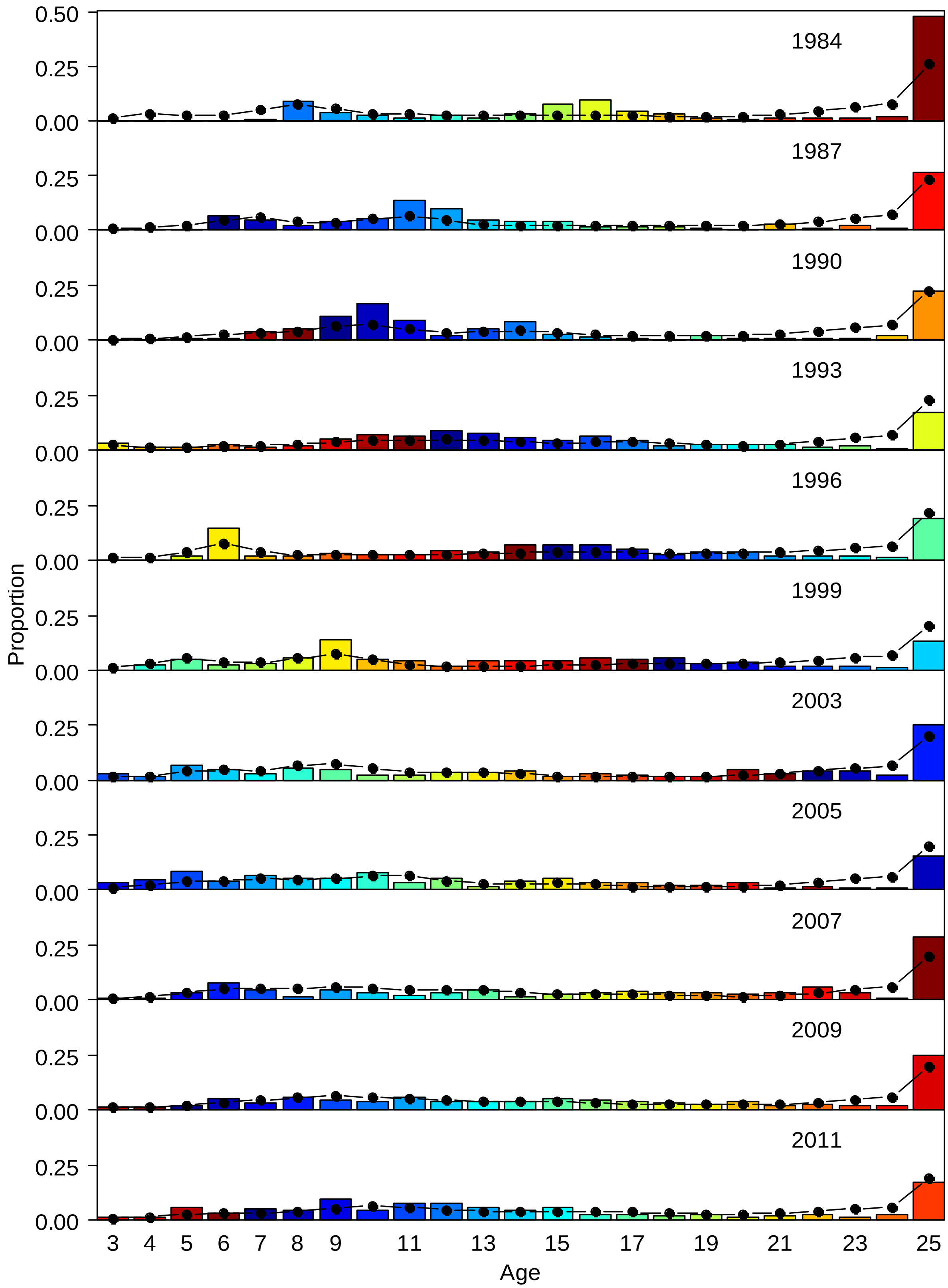


Figure 13-11. AFSC bottom trawl survey age composition by year for GOA RE/BS rockfish**.** Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

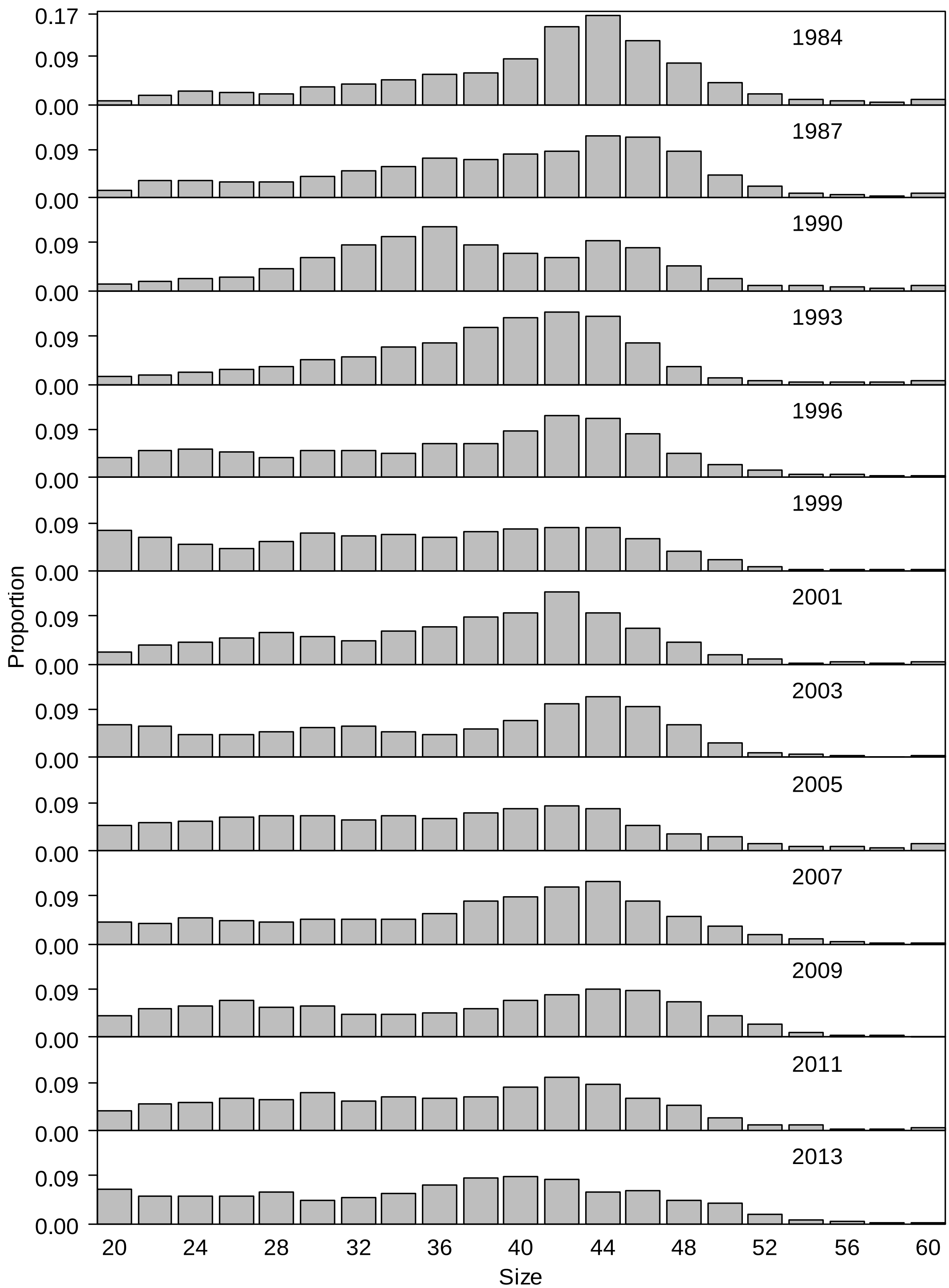


Figure 13-12. AFSC bottom trawl survey length composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in the model.

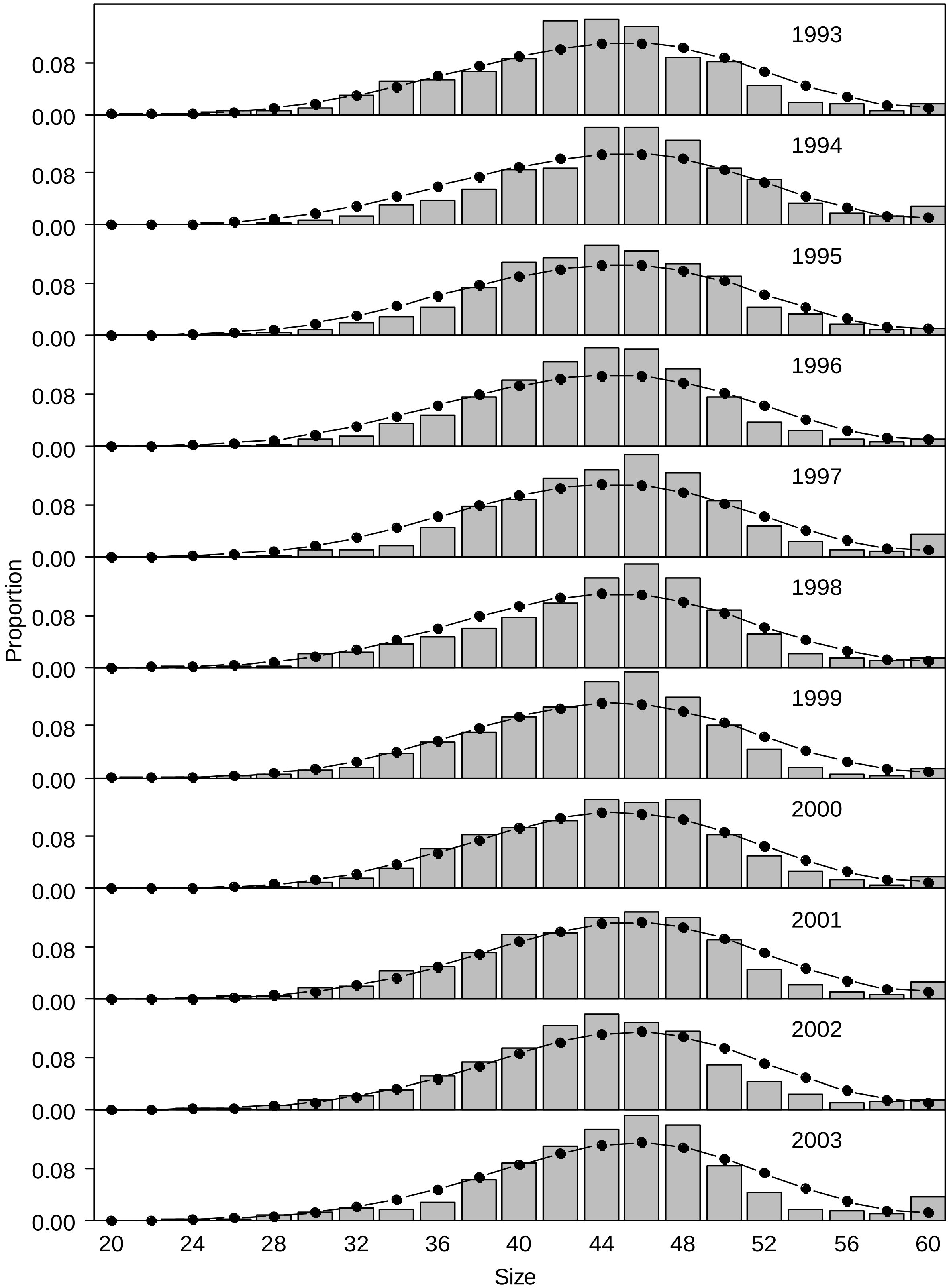


Figure 13-13. AFSC longline survey length composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

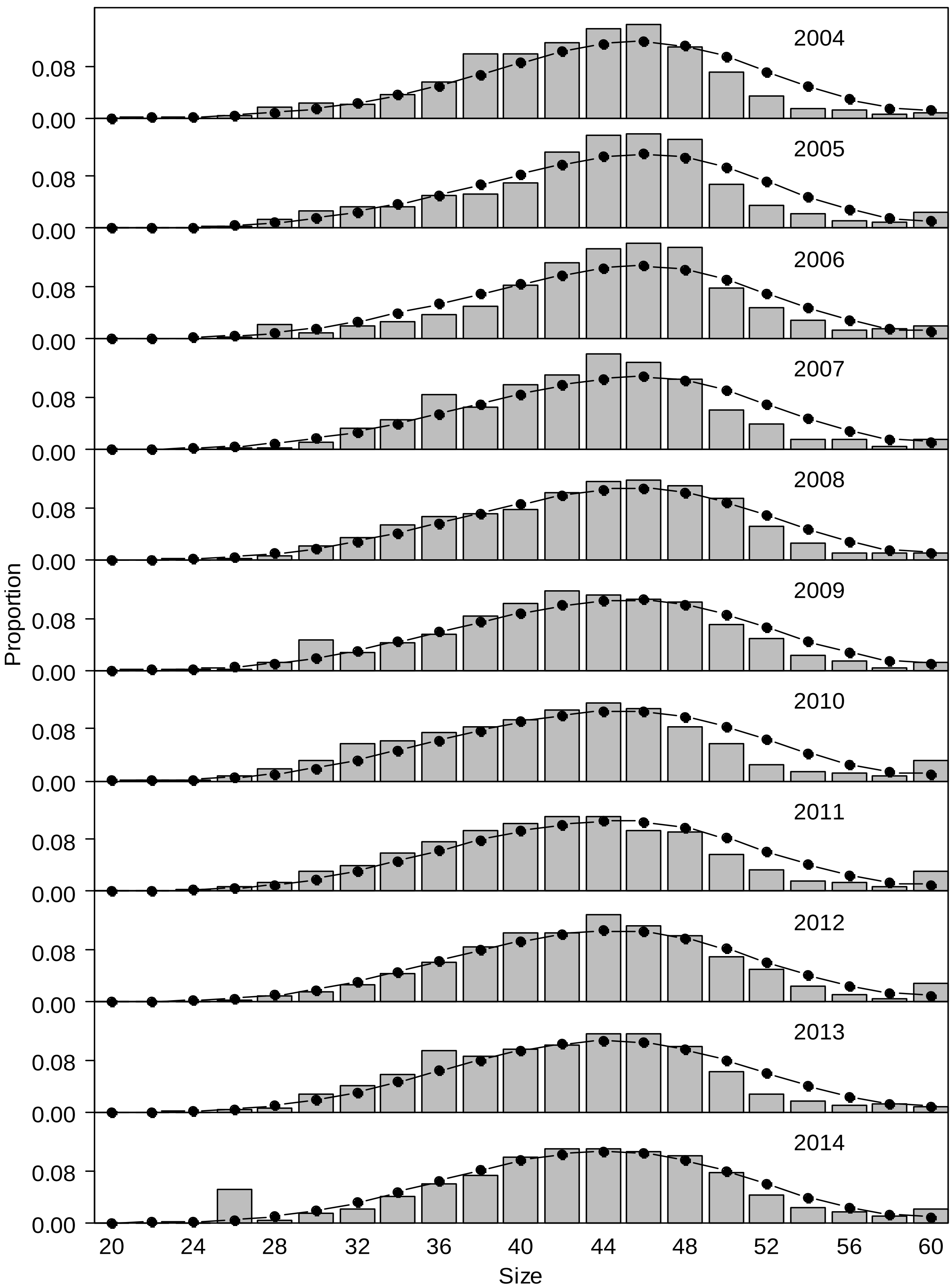


Figure 13-13 (continued). AFSC longline survey length composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

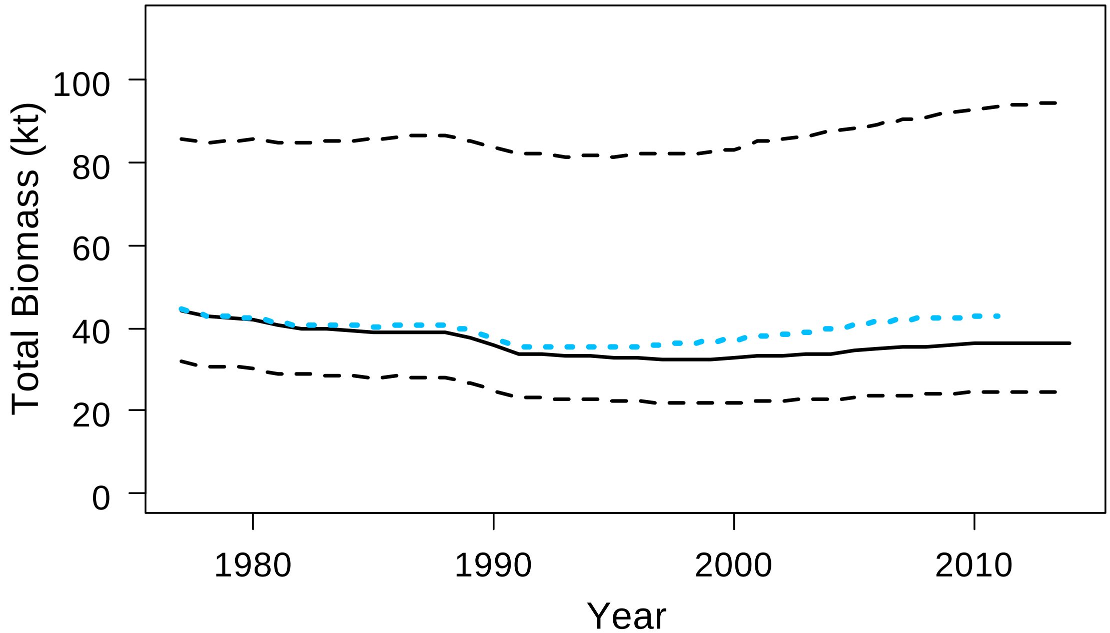


Figure 13-14. Time series of predicted total biomass from author preferred model (solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last year's model estimates included for comparison (dotted blue line).

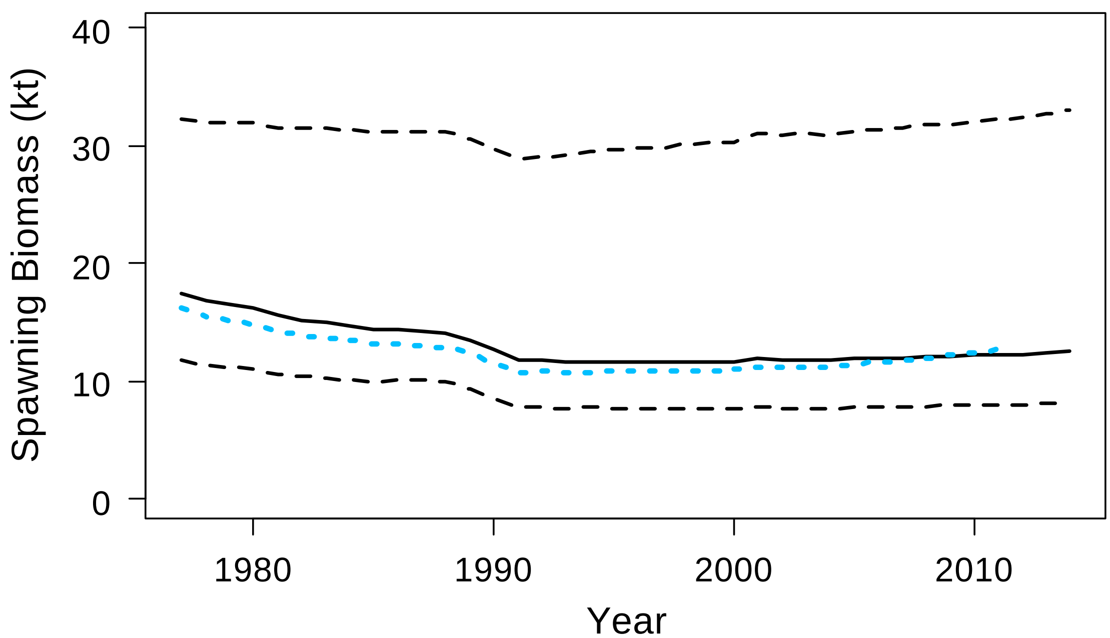


Figure 13-15. Time series of predicted spawning biomass from author preferred model (solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last year's model estimates included for comparison (dotted blue line).

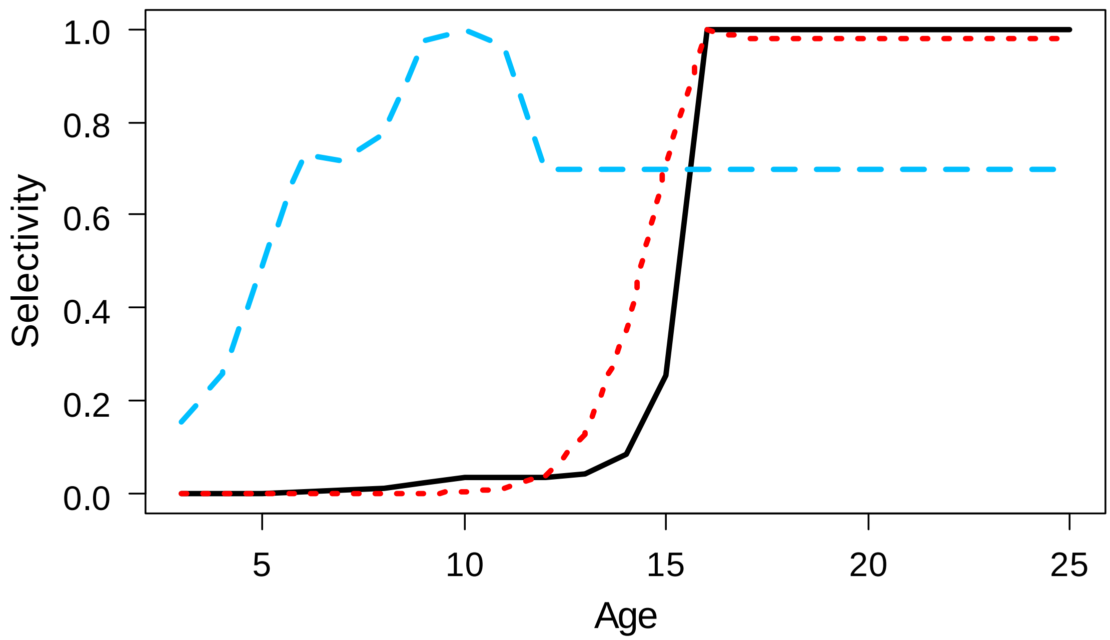


Figure 13-16. Estimated selectivity curves for GOA RE/BS rockfish from author preferred model. Dashed blue line = AFSC bottom trawl survey selectivity, dotted red line = AFSC longline survey selectivity, and solid black line = combined fishery selectivity.

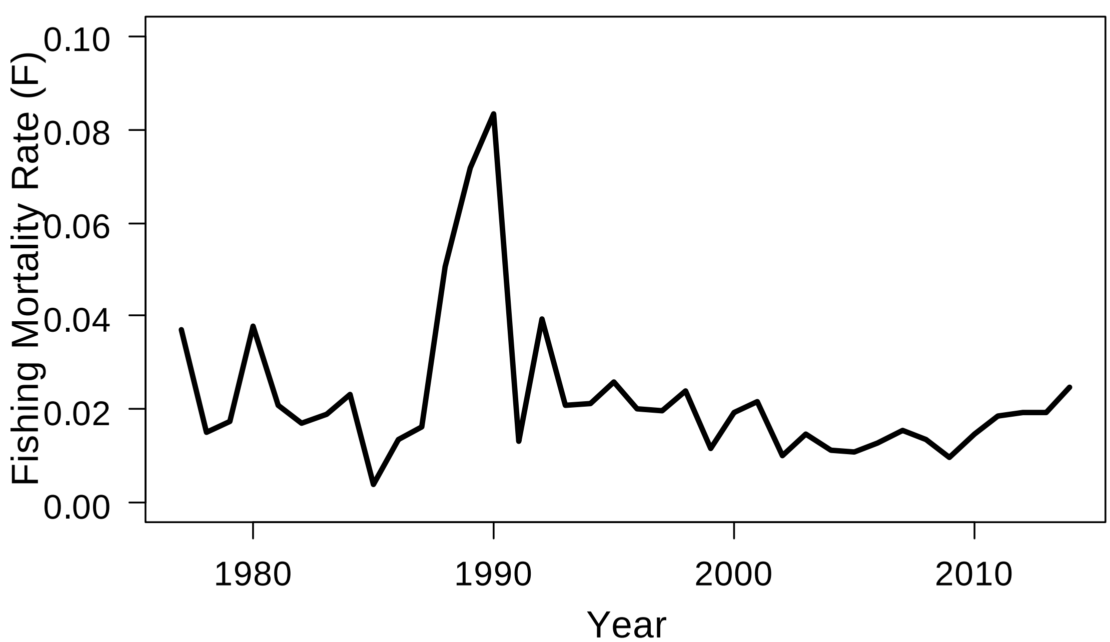


Figure 13-17. Time series of estimated fully selected fishing mortality for GOA RE/BS rockfish from author preferred model.

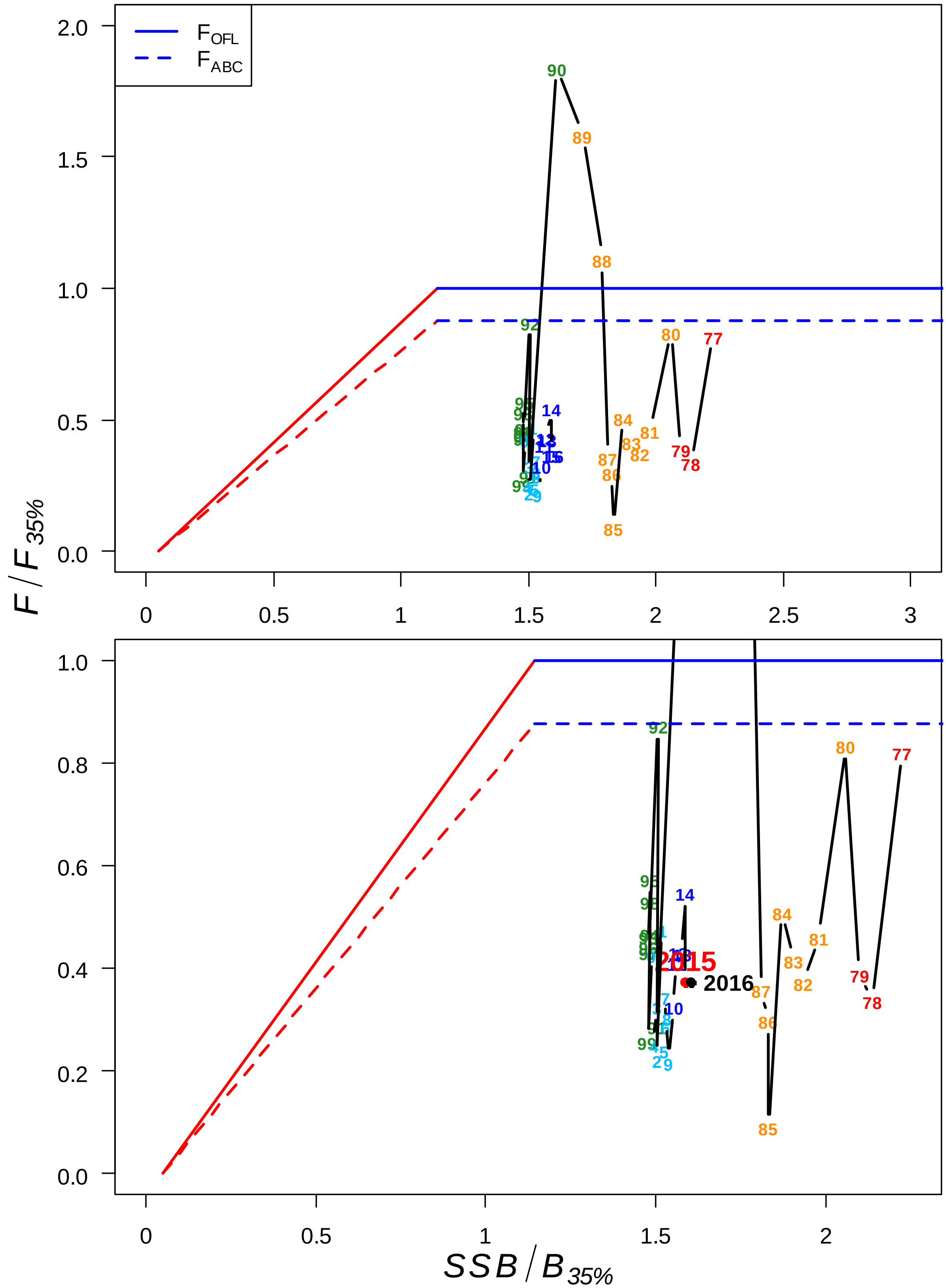


Figure 13-18. Time series of GOA RE/BS rockfish estimated spawning biomass relative to the target $B_{35\%}$ level and fishing mortality relative to F_{OFL} for author preferred model. The upper panel provides the entire time series while bottom panel presents the more recent management path.

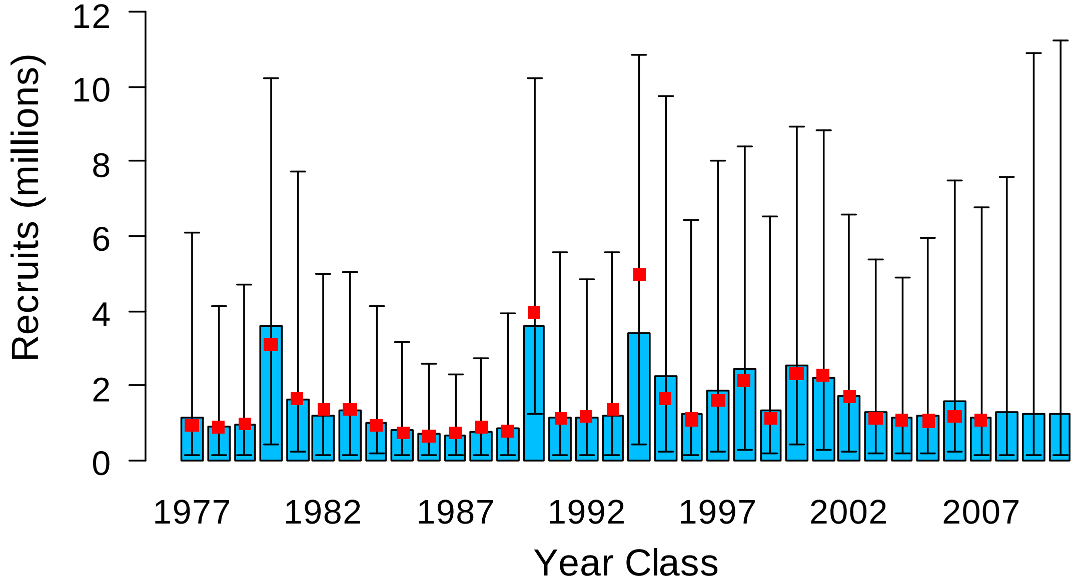


Figure 13-19. Estimated recruitments (age 3) of GOA RE/BS rockfish from author preferred model by year class with 95% credible intervals derived from MCMC. Red square in top graph presents last year's recruitment estimates for comparison.

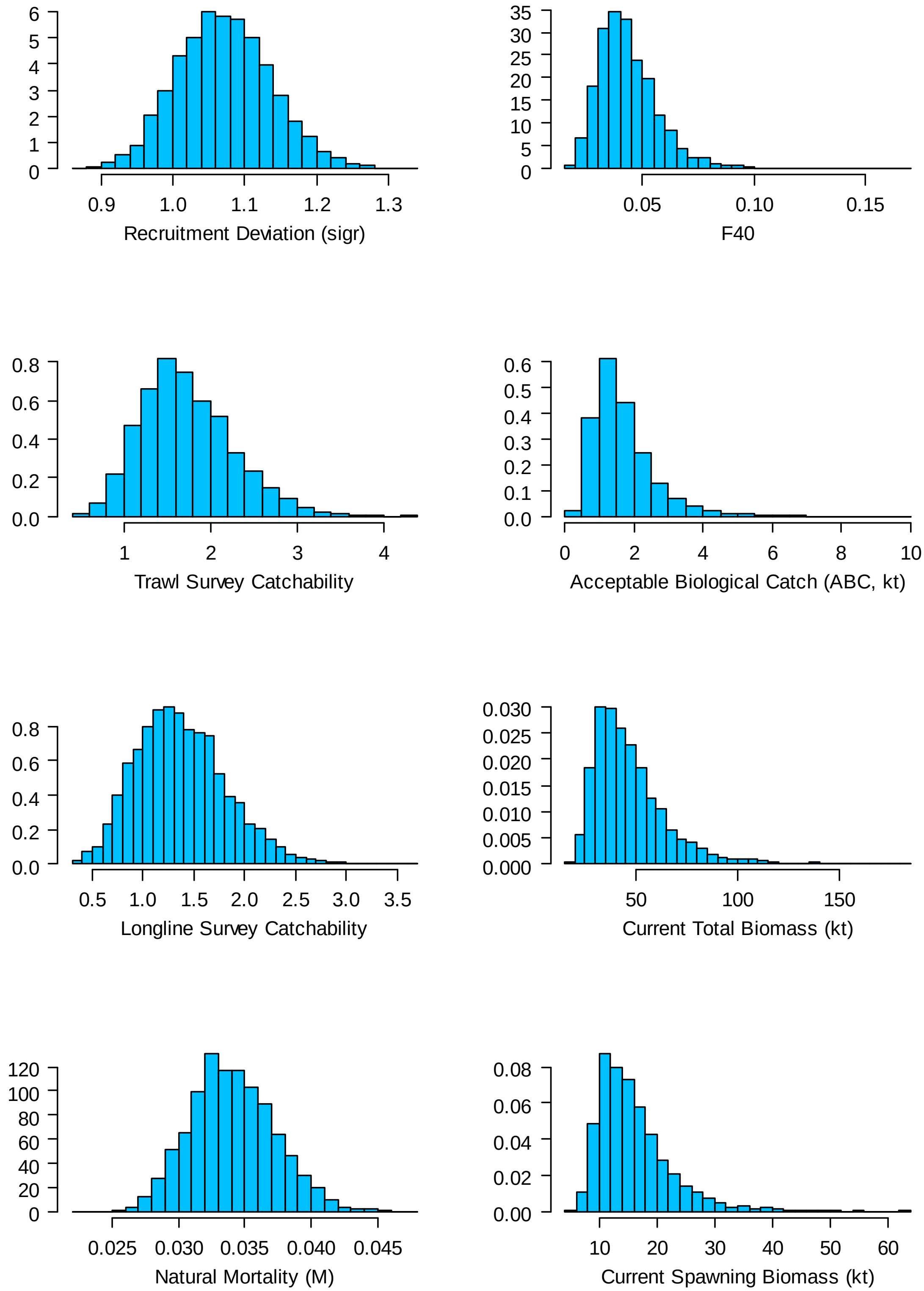


Figure 13-20: Histograms of estimated posterior distributions for key parameters derived from MCMC for GOA RE/BS rockfish.

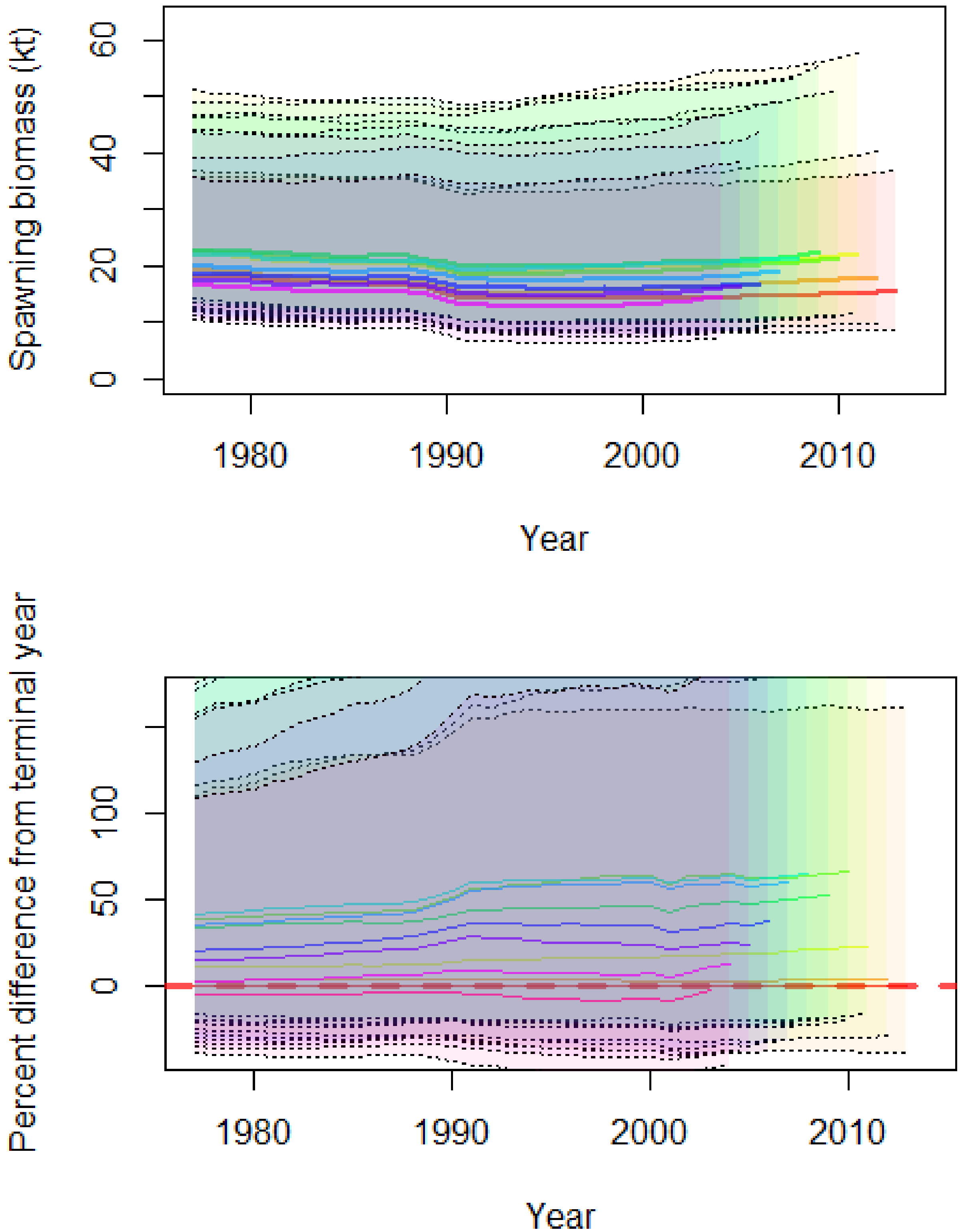


Figure 13-21: Retrospective peels of estimated female spawning biomass for the past 10 years from the preferred model with 95% credible intervals derived from MCMC (top), and the percent difference in female spawning biomass from the preferred model in the terminal year with 95% credible intervals from MCMC (bottom).

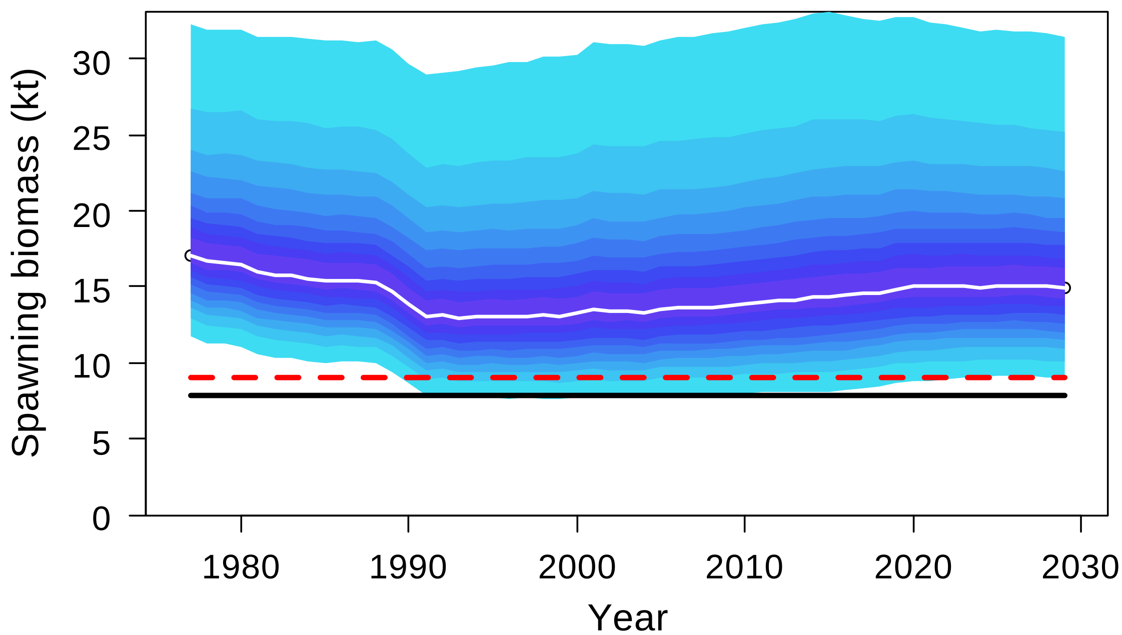


Figure 13-22: Bayesian credible intervals for entire spawning stock biomass series including projections through 2029. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1980-2012. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

Appendix 13A. Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two new 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 13A-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, Shotwell et al. 2011). 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 6 t in 2013. This is 0.5% of the 2013 recommended ABC of 1,232 t and represents a low risk to the RE/BS stock. Research harvests dominate this with three major surveys taking significant amounts of RE/BS rockfish. 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 13A-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 13A-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 is 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

Table 13A-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.