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

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## Executive Summary

The scheduled frequency for some stock assessments was recently changed in response to the National Stock Assessment Prioritization effort (Methot 2015; Hollowed et al. 2016). In previous years, all Gulf of Alaska (GOA) rockfish stocks were assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. There was no change in this schedule for the rougheye and blackspotted (RE/BS) rockfish complex. For this on-cycle (odd) year, we present a full stock assessment document with updated assessment and projection model results to recommend harvest levels for the next two years. In off-cycle (even) years, we will present a partial assessment consisting of an executive summary with recent fishery catch and survey trends as well as recommend harvest levels for the next two years.

We use a statistical age-structured model as the primary assessment tool for the Gulf of Alaska rougheye and blackspotted (RE/BS) rockfish complex which qualifies as a Tier 3 stock. This assessment consists of a population model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses results from the population model to predict future population estimates and recommended harvest levels. The data sets used in this assessment include total catch biomass, fishery age and size compositions, trawl and longline survey abundance estimates, trawl survey age compositions, and longline survey size compositions. For this assessment year, we use the last full assessment base model from 2015.

### Summary of Changes in Assessment Inputs

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

1.) Updated catch estimate for 2016, new catch estimates for 2017-2019 (see *Specified Catch Estimation* subsection in **Harvest Recommendations** section)
2.) New fishery ages for 2014 and 2016, new fishery lengths for 2015
3.) New trawl survey biomass estimate for 2017, new trawl survey ages for 2015
4.) New longline survey relative population numbers (RPN) for 2016 and 2017, and new longline survey lengths for 2016 and 2017.

*Changes in the assessment methodology*: There were no changes in the assessment methodology as we continue to use the last full assessment model which we corrected to the name 15.4 (referred to as Model M4.a in the 2015 full assessment). Please see Shotwell et al. (2015) for more details on the last full assessment methodology (https://www.afsc.noaa.gov/REFM/Docs/2015/GOArougheye.pdf).

## Summary of Results

Reference values for RE/BS rockfish are summarized in the following table, with the recommended ABC and OFL values for 2018 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: * | |
|---|---|---|---|---|
| | 2017 | 2018 | 2018 | 2019 |
| *M* (natural mortality rate) | 0.036 | 0.036 | 0.036 | 0.036 |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (ages 3+) biomass (t) | 41,650 | 41,403 | 45,624 | 45,346 |
| Projected female spawning biomass (t) | 13,754 | 13,685 | 15,059 | 14,972 |
| $B_{100\%}$ | 20,566 | 20,566 | 22,495 | 22,495 |
| $B_{40\%}$ | 8,226 | 8,226 | 8,998 | 8,998 |
| $B_{35\%}$ | 7,198 | 7,198 | 7,873 | 7,873 |
| $F_{OFL}$ | 0.048 | 0.048 | 0.048 | 0.048 |
| $maxF_{ABC}$ | 0.040 | 0.040 | 0.040 | 0.040 |
| $F_{ABC}$ | 0.040 | 0.040 | 0.040 | 0.040 |
| OFL (t) | 1,594 | 1,583 | **1,735** | 1,715 |
| maxABC (t) | 1,327 | 1,318 | 1,444 | 1,427 |
| ABC (t) | 1,327 | 1,318 | **1,444** | 1,427 |
| **Status** | As determined *last* year for: | | As determined *this* year for: | |
| | 2015 | 2016 | 2016 | 2017 |
| Overfishing | No | n/a | No | n/a |
| Overfished | n/a | No | n/a | No |
| Approaching overfished | n/a | No | n/a | No |

*Projections are based on an estimated catch of 503 t for 2017, and estimates of 747 t and 725 t used in place of maximum permissible ABC for 2018 and 2019 in response to a Plan Team request to obtain more accurate two-year projections. Please see section on Specified Catch Estimation subsection in the Harvest Recommendations section for more details regarding these calculations.

The 2017 trawl survey estimate increased 16% from the 2015 estimate and is now 11% below average. The 2016 longline survey abundance estimate (RPN) decreased about 22% from the 2015 estimate and the 2017 longline RPN estimate increased about 17% from the 2015 estimate and 50% from the 2016 estimate. The longline survey is now 27% above average. Since 2005, the total allowable catches (TACs) for RE/BS rockfish have not been fully taken, and are generally between 20-60% of the TAC. This is particularly true for the Western GOA since 2011, where catches have been between 20-40% of TAC.

For the 2018 fishery, we recommend the maximum allowable ABC of 1,444 t from the author recommended model. This is a 9% increase from last year's ABC of 1,327 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 a similar amount of 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 2017 trawl survey biomass. In past assessments, we determined apportionment using a 4:6:9 weighted average of the proportion of biomass in each area from the three most recent bottom trawl surveys. This exponential moving average was used to smooth the estimates but weight the most recent observation most heavily (see *Area Allocation of Harvests* subsection in **Harvest Recommendation** section for further details). As an alternative to this, both the Plan Team and SSC have requested that the random effects model developed by the Survey Averaging Working Group be applied to the bottom trawl survey data and used for apportionment as a default method and provided alongside the current apportionment for comparison purposes.

The following table shows the apportionment for the 2018 and 2019 fishery using the three survey weighted average and random effects methods.

| Method | Area Allocation | | Western GOA | Central GOA | Eastern GOA | Total |
|---|---|---|---|---|---|---|
| Three Survey Weighted Average | | | 12.2% | 38.5% | 49.3% | 100% |
| | 2018 | Area ABC (t) | **176** | **556** | **712** | **1,444** |
| | | OFL (t) | | | | **1,735** |
| | 2019 | Area ABC (t) | **174** | **550** | **703** | **1,427** |
| | | OFL (t) | | | | **1,715** |
| Random Effects | | | 8.6% | 38.4% | 53.0% | 100% |
| | 2018 | Area ABC (t) | **124** | **554** | **766** | **1,444** |
| | | OFL (t) | | | | **1,735** |
| | 2019 | Area ABC (t) | **123** | **548** | **756** | **1,427** |
| | | OFL (t) | | | | **1,715** |

We recommend continuing with the status quo (three survey weighted average) apportionment for RE/BS rockfish at this time. Please see Area Allocation of Harvests subsection in the Harvest Recommendations section below for more details on this justification.

## Summaries for Plan Team

| Species | Year | Biomass[1] | OFL | ABC | TAC | Catch[2] |
|---|---|---|---|---|---|---|
| RE/BS complex | 2016 | 41,864 | 1,596 | 1,328 | 1,328 | 640 |
| | 2017 | 41,650 | 1,594 | 1,327 | 1,327 | 494 |
| | 2018 | 45,624 | 1,735 | 1,444 | | |
| | 2019 | 45,346 | 1,715 | 1,427 | | |

| Stock/ Assemblage | Area | 2017 OFL | ABC | TAC | Catch[2] | 2018 OFL | ABC | 2019 OFL | ABC |
|---|---|---|---|---|---|---|---|---|---|
| RE/BS complex | W | | 105 | 105 | 32 | | 176 | | 174 |
| | C | | 706 | 706 | 298 | | 556 | | 550 |
| | E | | 516 | 516 | 164 | | 712 | | 703 |
| | Total | 1,594 | 1,327 | 1,327 | 494 | 1,735 | 1,444 | 1,715 | 1,427 |

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

[2]Current as of October 1, 2017. 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

*"In an effort improve record keeping as assessment authors formulate various stock status evaluation models, the Plan Team has recommended a systematic cataloging convention. Any new model that diverges substantial from the currently accepted model will be marked with the two-digit year and a "0"*

*version designation (e.g., 16.0 for a model from 2016). Variants that incorporate major changes are then distinguished by incremental increases in the version integer (e.g., 16.1 then 16.2), and minor changes are identified by the addition of a letter designation (e.g., 16.1a). The SSC recommends this method of model naming and notes that it should reduce confusion and simplify issues associated with tracking model development over time." (SSC December 2016)*

For the 2017 assessment, we begin using this naming convention with the recommended model from the 2015 assessment (Model 15.4).

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

*"Secondly, a few assessments incorporate multiple indices that could also be used for apportionment. The Team recommends an evaluation on how best to tailor the RE model to accommodate multiple indices."* (Plan Team, November 2015)

*"Finally, an area apportionment approach using the RE model which specifies a common "process error" has been developed and should be considered. This may help in some situations where observation errors are particularly high and/or vary between regions"* (Plan Team, November 2015)

In last year's assessment, we included both the weighted survey average and the random effects model approach for estimating apportionment for RE/BS rockfish. Please see the *Area Allocation of Harvests* subsection in **Harvest Recommendations** section for further details regarding these apportionment methods. We recommended continuing with the status quo (three survey weighted average) apportionment for RE/BS rockfish until a multiple survey option was available which may be possible through the VAST model (Thorson et al. 2015). The assessment model utilizes both trawl and longline survey data to adequately sample the RE/BS population; therefore, using both survey indices for apportionment should provide for a better reflection of the RE/BS spatial population abundance over either the status quo three year survey average or the one survey index random effects model. We continue to recommend the status quo rather than switching the apportionment scheme until the Survey Averaging Working Group can provide recommendations on what apportionment to use for stocks with multiple surveys and regional variability in the sampling error.

*"…The SSC also recommends explicit consideration and documentation of ecosystem and stock assessment status for each stock, perhaps following the framework suggested below, during the December Council meeting to aid in identifying areas of concern.*" (SSC October 2017)

A newly proposed framework for considering ecosystem and socioeconomic factors has been submitted as an appendix in some assessments this year. This is an attempt to document these factors with respect to stock status and also provide indicators for continued monitoring to identify areas of concern. These reports are currently submitted as an appendix and in future years it is anticipated that they would be available for all stocks as the framework is adaptable for data-limited to data-rich stocks. We plan to evaluate and potentially incorporate this new ecosystem/socioeconomic report as an appendix when it becomes available for rougheye and blackspotted rockfish stock complex.

## Responses to SSC and Plan Team Comments Specific to this Assessment

*"The Team recommends exploring apportionment methods (such as the random effects model) for the next full assessment."* (Plan Team, November 2015)

Please refer to the response in the previous section regarding application of the random effects model to the RE/BS rockfish stock complex.

*"The retrospective pattern for M4a is poor (Mohn's ρ = -0.371) and the SSC requests that the author explores the reason for this result."* (SSC, December 2015)

In the second report from the Retrospective Working Group (Hanselman et al. 2013), GOA RE/BS rockfish exhibited a fairly strong retrospective pattern and was ranked fifth among all Alaska stocks. The results of this report were based on the RE/BS 2011 author recommended model and produced a Mohn's revised ρ of -0.34. We examined this statistic in the 2015 assessment and also found an undesirably large Mohn's revised ρ and were requested to investigate the underlying cause of this large retrospective pattern for this full assessment. After further inspection of the retrospective model, we determined that there was a coding error and have updated the Mohn's revised ρ using the correct successive data peel. The previous large retrospective pattern is now much reduced and does not pose a concern. Below is a table of Mohn's revised ρ reported in the 2015 full assessment, the updated value in the 2015 assessment using the correct code, and the new value in the 2017 assessment using the correct code.

| Statistic | 2015 (M15.4) | 2015 (M15.4) Updated | 2017 (M15.4) |
|---|---|---|---|
| Mohn's revised ρ | -0.371 | 0.105 | 0.009 |

*"The Team recommends evaluating a Tier 5 approach by species with "worst-case" scenarios that consider total catch comprised of one species."* (Plan Team, November 2016)

We evaluated a simple Tier 5 approach at the extreme by comparing the total catch to what an individual OFL would be for each species in the complex. We do not use any survey averaging techniques for two reasons: 1) the time series only runs back to 2007, and 2) we only have 3 years of genetically identified data. Thus, we compute an OFL for each year of both time series. The OFL for the Tier 5 approach is simply the most current estimate of natural mortality (M=0.036) multiplied by the bottom trawl survey biomass for that species in that year.

The two time series are 1) the "naïve" time series that assumes that survey ID is completely accurate (Figure 1), and 2) the "genetic" adjusted years (2009, 2011 and 2015) which have been corrected by misidentification rates derived from genetics (Figure 2). In these figures we can see that the genetics does change the biomass of the two species some (e.g., 2009 and 2013), but it goes in both directions and generally there is almost always more rougheye rockfish biomass than blackspotted rockfish biomass (except for the naïve estimates of survey biomass in 2007).

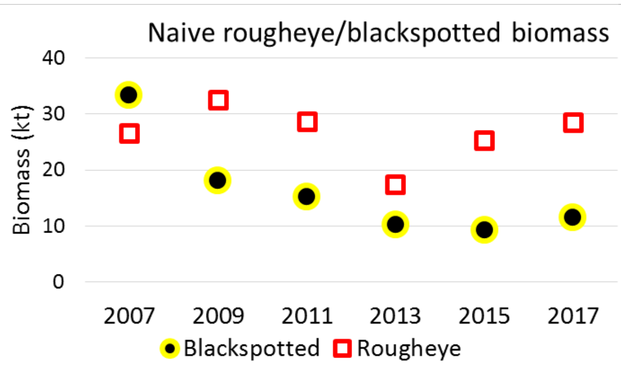



Figure 1.

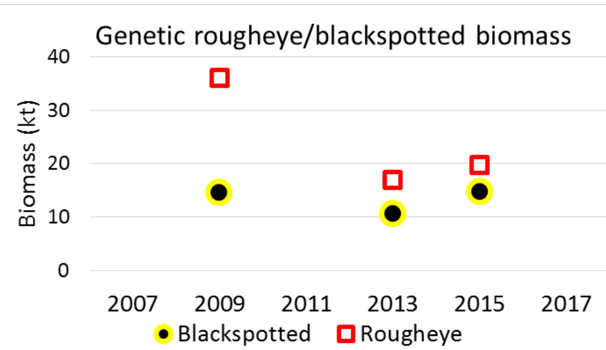



Figure 2.

We compare the total catches of the complex to hypothetical OFLs for each species as an extreme case for illustration. If all the catch were taken just from blackspotted rockfish, the hypothetical OFL would have been exceeded in some years in both the naïve ID and genetic ID cases (Figures 3 and 4). However, on average neither ID cases are over the OFL, but the genetic mean is very close (0.98).

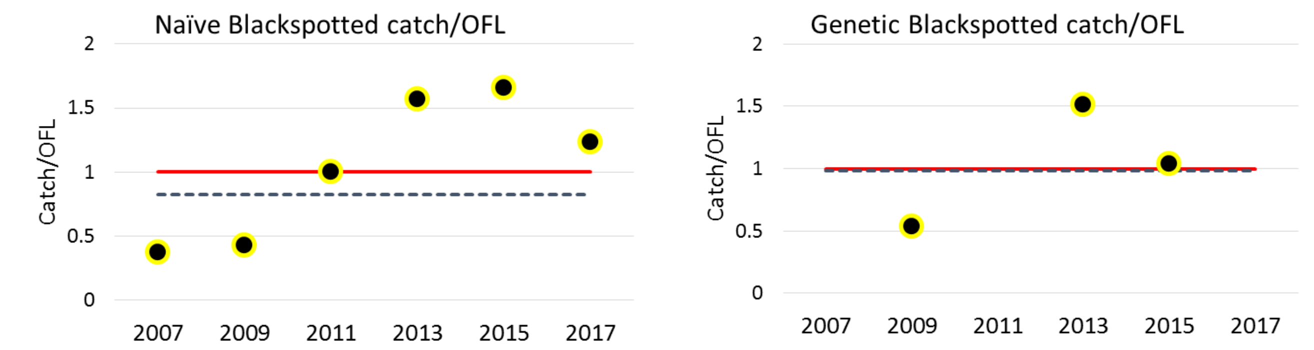



Figure 3, 4. Blue dashed line is the average ratio of catch to OFL. Red line is when catch is equal to OFL.

If all the complex catch were taken from the rougheye species, the hypothetical OFLs would never have been reached in any year, and on average were significantly below OFL (Figures 5 and 6).

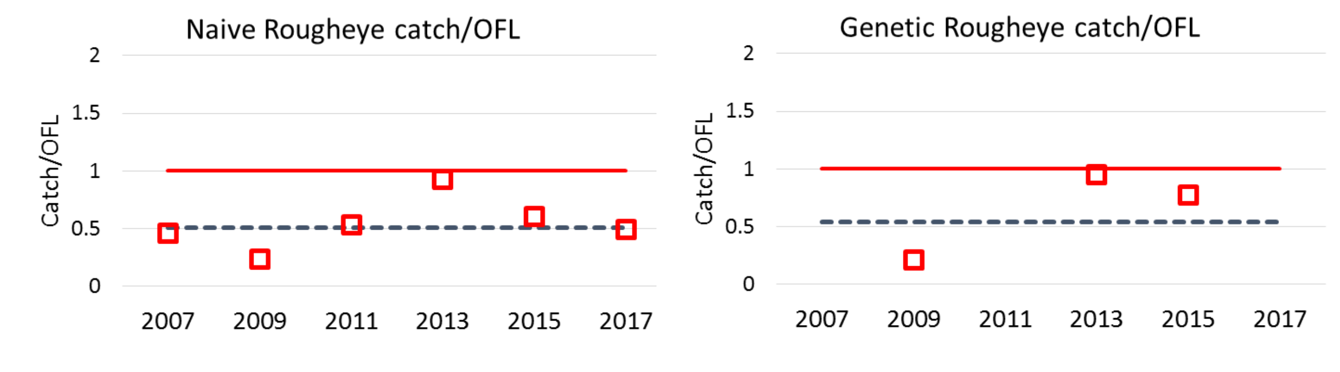



Figure 5, 6. Blue dashed line is the average ratio of catch to OFL. Red line is when catch is equal to OFL.

In summary, in the extreme case that every fish caught by the fishery were a blackspotted rockfish, we could approach or exceed Tier 5 OFLs for that species on a regular basis. However, given that they are caught together in trawl surveys, this extreme result is highly unlikely. It may still be worthwhile to have some type of test in the fishery to have a better idea what the ratio of blackspotted to rougheye is to better inform our fisheries data. A new study has been initiated to look at the otolith metrics for fishery ages of RE/BS rockfish and if combined with a genetic test in the fishery may be a potential avenue to gain a better understanding of the rougheye to blackspotted ratio in the fishery data.

*"The Team recommends the authors work with the observer program to request a one year sampling program to collect tissue for genetic analysis during otolith collection in the fishery."* (Plan Team, November 2016)

*"As in previous years, the SSC encourages the author to explore methods to improve species identification in the fishery. The observed differences in spatial distributions and growth suggest that*

*these rougheye and blackspotted rockfish should be assessed separately once the information is sufficient to make this change. With this in mind, the SSC requests that the author evaluate the available information to separately assess the two stocks and where there are data gaps."* (SSC, December 2015)

Please refer to the "Current Research" subsection in the "Evidence of Stock Structure" section of the Introduction for an update on the available data for evaluating misidentification rates and differing life history characteristics for the two species.

We will continue to monitor the progress of evaluating the data from these special projects and may extend this sampling protocol to commercial fisheries as a one-year special project requested of the Observer Program. Additionally, a promising approach using otolith morphology combined with genetics may enable the species composition in historical samples to be assessed. Such information will help determine the utility and cost-effectiveness 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 non-targeted complex to be sufficiently precautionary under current fishing practices and will continue to model rougheye and blackspotted rockfish as if they are a single species.

# 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 fjords to offshore waters of the continental shelf. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981, Straty 1987, Krieger 1993). Another submersible study on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). Although these studies did not specifically identify rougheye or blackspotted rockfish, it is reasonable to suspect that juvenile RE/BS rockfish may be among the species that utilize this habitat as refuge during their juvenile stage.

Adult rougheye and blackspotted rockfish are demersal and are known to inhabit particularly steep, rocky areas of the continental slope, with highest catch rates generally at depths of 300 to 400 m in longline surveys (Zenger and Sigler 1992) and at depths of 300 to 500 m in bottom trawl surveys and in the commercial trawl fishery (Ito 1999). Observations from a manned submersible in this habitat indicate that these species prefer steep slopes and are often associated with boulders and sometimes with *Primnoa* spp. coral (Krieger and Ito 1999, Krieger and Wing 2002). Within this habitat, rougheye rockfish tend to have a relatively even distribution when compared with the highly aggregated and patchy distribution of other rockfish such as Pacific ocean perch (*Sebastes alutus*) (Clausen and Fujioka, 2007). A recent study developing habitat-based indices of abundance for several species of rockfish found that a variety of environmental factors such as local slope, bottom depth, and coral/sponge abundance were significant in the best-fitting RE/BS rockfish habitat model (Rooper and Martin, 2012). The most recent Essential Fish Habitat (EFH) update (e.g. Laman et al. 2017) provided newly developed species distribution models from the bottom trawl survey for rougheye and blackspotted late juveniles and adults, separated by species. However, the at-sea identification was used to develop these models (which can have high misidentification rates, please see the **Evidence for Stock Structure** section below) and our recommendation was to combine the two species for the next EFH update and use the models for general distribution of juveniles and adults but not abundance trends.

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). McGilliard et al. (2017) showed that this type of offspring size effect or different spawning times by age may lead to increased recruitment variability with increased fishing mortality. 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.

## Evidence of Stock Structure

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

*Rougheye and Blackspotted Speciation*

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

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

*Stock Structure Template Summary*

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

Non-genetic information suggests population structure by large management areas of eastern, central, and western GOA. This is evident in opposite trajectories for population trends by area, significantly different age, length, and growth parameters by area, and significant differences in parasite prevalence and intensity by area. Genetic studies have generally been focused on the speciation of the RE/BS complex; however, even studies on the two species separately suggested population structure at the size of the management areas. 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*

Several recent research projects are focused on evaluating different aspects of the rougheye and blackspotted rockfish population including estimation of at-sea misidentification rates, evaluation of biomass, age, and length compositions by species, species-specific maturity and skip-spawning, species-specific growth, and otolith morphometric feasibility. We present a table of these research projects (see below) that shows the source and data for a given project along with the years that the data are available.

| Source | Project Data | Years Available |
|---|---|---|
| Fisheries | Otolith metrics* | 1990, 2004, 2009, 2012, 2013, 2014 |
| | Maturity | 2008-2014 (Conrath 2017) |
| AFSC bottom trawl survey | Genetic ID* | 2009, 2013, 2015 |
| | Biomass Index | 2007, 2009, 2011, 2013, 2015, 2017 |
| | Age | 2007, 2009, 2011, 2013, 2015, 2017 |
| | Length | 2007, 2009, 2011, 2013, 2015, 2017 |
| | Otolith metrics* | 1990, 1999 |
| | Maturity | 2008-2014 (Conrath 2017) |

*Analysis is in progress

There is difficulty in accurate at-sea field identification between the two species. Comparison of the misidentification rates for the 2009, 2013, and 2015 trawl surveys was recently completed via special projects (see Figure below). The goals of these projects were to collect relevant biological and genetic data to improve at-sea identification, adjust the species-specific biomass estimates based on misidentification rates, and examine differences in life history characteristics between the two species. Field scientists collected length, weight, and muscle tissue (2009) or fin clips (2013 and 2015) from most rougheye and blackspotted rockfish sampled for otoliths. When compared to genetic identifications, field scientists had overall misidentification rates of 23%, 13%, and 18% for the three years, respectively. There appears to be continued improvement for correctly identifying blackspotted rockfish in the field (from 31% to 9%), while the opposite seems to be occurring for rougheye rockfish with increased misidentification rates over the three surveys (6% to 25%). Hybrids also exist between the two species. For example, the 2009 survey genetics identified that 11% of the fish were hybrids. These hybrids were mostly identified as rougheye rockfish in the field (82 %).

Presently genetic identification of the two species sampled in the bottom trawl survey is not part the standard sampling procedure for these two species and must be conducted via special project requests. In the laboratory genetic identification of the species via fin clips is rapid and cost effective. Given the variability of misidentification rates we recommend that a genetic sampling protocol be developed that is included as part of the standard otolith collection for these two species. Genetic sampling should also be considered for a subsample of the length samples taken during the longline survey.

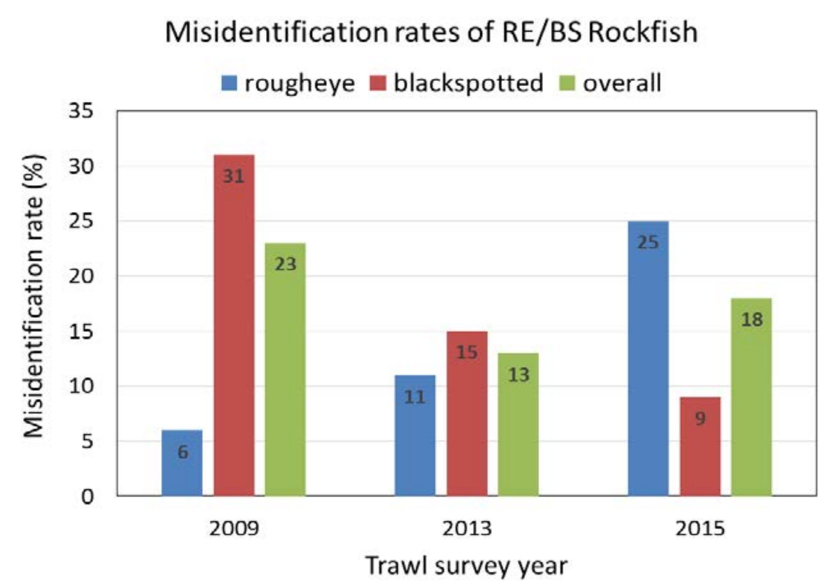
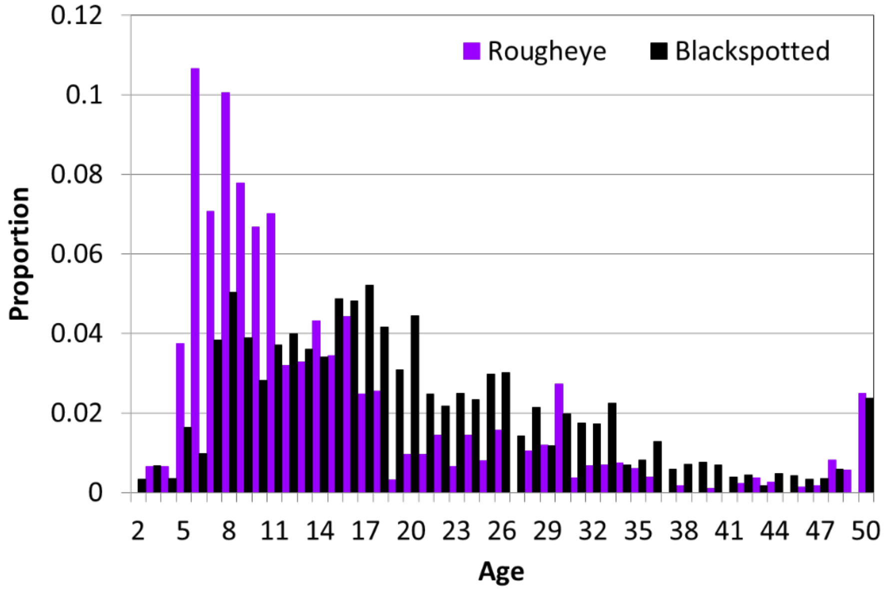
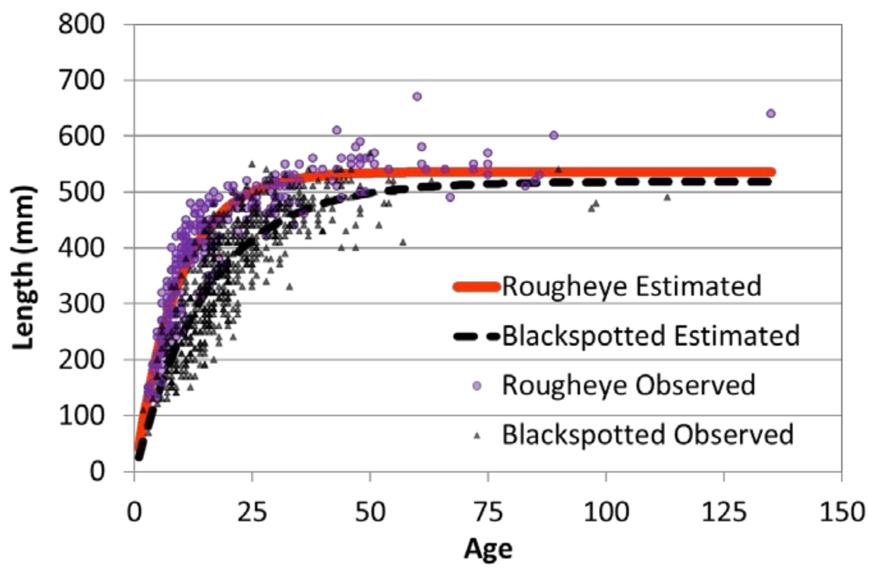



Figure above shows misidentification rates of rougheye and blackspotted rockfish for three bottom trawl surveys in the Gulf of Alaska (2009, 2013, 2015). Text values in bars indicate actual rate.

Trawl survey age compositions from samples taken in 2009 indicate that the average age of blackspotted and rougheye rockfish was 20 and 15 years, respectively (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 over the 7-20 year old age range. Data from the 2013 and 2015 trawl survey have been analyzed for species misidentification rates, and analysis of aging data is in progress.




Analysis of 2009 genetically identified and aged otoliths (n=879, hybrids=11) from the trawl survey found differences in growth between the two species. Rougheye rockfish grow faster and typically attain a slightly 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 |
| $L_\infty$ (mm) | 536 | 519 |
| $\kappa$ | 0.109 | 0.065 |
| $t_0$ | 0.250 | 0.250 |

A recent the study by Conrath (2017) focused on the reproductive biology of the two species. The fork length at 50% maturity was similar for rougheye rockfish (45.0 cm) and blackspotted rockfish (45.3 cm), but the age at 50% maturity was considerably younger for rougheye rockfish (19.6 years) than for blackspotted Rockfish (27.4 years).

A promising approach using otolith morphology combined with ageing data and genetics may enable the species composition in historical samples to be assessed. For example, preliminary application of this method using age samples collected from the 2009 fishery indicated that the catch in numbers was 57% blackspotted rockfish and 43% rougheye rockfish (Charles Hutchinson AFSC REFM, *Pers. comm.*)

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 non-targeted complex to be sufficiently precautionary under current fishing practices and will continue to model rougheye and blackspotted rockfish as if they are a single species.

# Fishery

## History

Rougheye and blackspotted rockfish have been managed as a "bycatch" only species complex since the creation of the shortraker/rougheye rockfish management subgroup in the Gulf of Alaska in 1991. Since 1977, gulf-wide catches of the rougheye and blackspotted rockfish have been between 130-2,418 t (Table 13-2). Catches peaked in the late 80s and early 90s, declined rapidly in the mid-90s and have been relatively stable, with recent increases since 2009. RE/BS rockfish are generally caught in either bottom trawls or with longline gear and the majority of the recent catch increase was in the Central GOA bottom trawl fishery. Small increases in recent catch occurred in the Eastern GOA longline fishery, while catches have decreased across both bottom trawl and longline gear in the Western GOA. In 2017, 66% of the catch was from bottom trawls, 33% from longline, and 1% from pelagic trawls. Approximately 78% of this bottom trawl catch was taken in the rockfish fishery while 22% was taken in the flatfish fisheries. For longline gear, nearly all the RE/BS catch appears to come as "true" bycatch in the sablefish or halibut longline fisheries, with 70% of the 2017 catch taken in the sablefish fishery and 15% in the halibut fishery. Since catch accounting was established separately for RE/BS rockfish in 2005, the TACs for RE/BS rockfish are not fully taken, and are generally between 20-60% of total quota (Table 13-2).

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

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

## Management Measures

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

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

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

### *Bycatch*

The only analysis of bycatch for rougheye rockfish is that of Ackley and Heifetz (2001) from 1994-1996 on hauls they identified as targeted on shortraker/rougheye rockfish. The major bycatch species were arrowtooth flounder (*Atheresthes stomias*), sablefish, and shortspine thornyhead (*Sebastolobus alascanus*), in descending order. The primary fisheries that catch rougheye and blackspotted rockfish as bycatch are the targeted rockfish and sablefish fisheries with occasional surges from the flatfish fishery (Table 13-4). For the combined GOA rockfish trawl fisheries during 2013-2017 (Table 13-5), the largest non-rockfish bycatch groups are on average arrowtooth flounder (1,207 t/year), sablefish (492 t/year), Pacific cod (516 t/year), Atka mackerel (735 t/year) and walleye pollock (968 t/year). Non-FMP species catch in the rockfish target fisheries is generally dominated on average by giant grenadier (674 t/year) and miscellaneous fish (128 t/year) (Table 13-6). Prohibited species catch in the GOA rockfish fishery has been generally low for most species and this has been particularly true since the implementation of the Central GOA Rockfish Program (Shotwell et al. 2014b). Halibut catch during rockfish targeted hauls has decreased since 2015. The catch of Bairdi tanner crab increased dramatically as well as golden king crab and Chinook salmon to a slightly lesser extent. Chinook salmon catch continues to decrease, however, non-Chinook salmon increased in 2017 (Table 13-7).

### *Discards*

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

Shortraker / Rougheye / Blackspotted Complex

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

Rougheye / Blackspotted Complex

| Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % Discards | 19.5 | 27.4 | 36.7 | 27.6 | 18.6 | 19.2 | 16.3 | 15.5 | 22.9 | 17.3 | 22.1 | 26.5 | 20.2 |

The above table indicates that discards of rougheye and blackspotted rockfish have ranged from approximately 15% to 38% with an average of 23%. 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 | 1977-2015, **2016**, **2017** |
| | Age | 1990, 2004, 2006, 2008, 2009, 2010, 2012, **2014**, **2016** |
| | Length | 1991-1992, 2002-2003, 2005, 2007, 2011, 2013, **2015** |
| AFSC bottom trawl survey | Biomass index | 1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, 2015, **2017** |
| | Age | 1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, **2015** |
| AFSC longline survey | Relative Population Number (RPN) | 1993-2015, **2016**, **2017** |
| | Length | 1993-2015, **2016**, **2017** |

[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)

## Fishery:

*Catch*

Catches of rougheye and blackspotted rockfish have ranged between 130 t to 2,418 t from 1977 to 2017. The catches from 1977-1992 were from Soh (1998), which reconstructs the catch history using an information weighting factor (λ) to combine catch histories from both survey and fishery information. Catches from 1993-2004 were available as the shortraker/rougheye subgroup from the NMFS Alaska Regional Office. Originally, we used information from a document presented to the NPFMC in 2003 to determine the proportion of rougheye rockfish in this catch (Ianelli 2003). This proportion was based on the NMFS Regional Office catch accounting system ("blend estimates"). The SSC recommended using the average of the values provided in the document, 0.43. In 2004 another method was developed for determining the proportion of rougheye/blackspotted in the catch based on data from the FMA Observer Program (Clausen et al. 2004, Appendix A). Observed catches were available from the FMA database by area, gear, and species for hauls sampled by observers. This information was used to calculate proportions of RE/BS catch by gear type. These proportions were then applied to the combined shortraker/rougheye catch from the NMFS Alaska Regional Office to yield estimates of total catch for RE/BS rockfish (Figure 13-1, Table 13-2).

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

*Age composition*

Rougheye and blackspotted rockfish appear to be among the longest-lived of all *Sebastes* species (Chilton and Beamish 1982, Munk 2001). Interpretation of annuli on otoliths is extremely difficult; however, NMFS age readers determined that aging of RE/BS rockfish could be moved into a production mode. Ages were determined from the break-and-burn method (Chilton and Beamish 1982). We use ages from both the bottom trawl and longline fishery but only the at-sea processed samples. Rougheye and blackspotted rockfish otolith samples from onshore processing facilities have been aged; however, the sample sizes from onshore processing facilities are generally low and the distribution of ages is quite different from the at-sea samples. Fishery age compositions are treated as a random and representative sample for that year and the overall GOA fishery. Therefore, we do not use these samples in calculating the fishery age compositions. The FMA Observer Program began in 1990 and although this first year was considered preliminary, the 1990 ages are the only age compositions we have from the fishery prior to 2004. We, therefore, utilize this data in the model since it is considered important for estimating catch at age in the early 1990s. Table 13-8 summarizes the available fishery age compositions from 1990, 2004, 2006, 2008, 2009, 2010, 2012, 2014, and 2016.

New fishery ages since the last full assessment are available for 2014 and 2016. 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. However, we do have two overlapping years with the bottom trawl survey samples in 1990 and 2009 for comparison. Sample sizes from the fishery are typically between 300 and 400 otoliths (Table 13-8). The mean ages for a given year range between 29-40 years and are relatively old when compared to other aged rockfish species.

*Size composition*

Observers aboard fishing vessels and at onshore processing facilities have provided data on size composition of the commercial catch of rougheye and blackspotted rockfish. Table 13-9 summarizes the available size compositions from 1991-2015. Sample sizes from 1993-2001 were limited for RE/BS rockfish and in other years range from 300 to 2500 (Table 13-9). In general, we do not use size compositions in the model when age compositions are available because we consider age data to be a more reliable measure of population structure for these long-lived species. Since we anticipate fishery ages for non-trawl survey years, we do not include the size compositions for off-cycle years in the model. Additionally, in long-lived rockfish species the fish are selected late to the fishery and size compositions tend to be relatively uninformative as year classes will blend together. Therefore, fishery size compositions from 1991-1992, 2002-2003, 2005, 2007, 2011, 2013, and 2015 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. Fishery length compositions are treated as a random and representative sample from the overall catch-at-length. On average, approximately 49% of the lengths are taken from the bottom trawl fishery and 51% from the longline fishery for at-sea samples. This percentage is consistent for the data used in the model with 49% of lengths from the trawl fishery and 50% from the longline fishery. The mean of lengths for the 1991-1992 samples is approximately 45 cm and from 2002-2015 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, and again in 2013 and 2105.

## Survey:

*AFSC Bottom Trawl Biomass Estimates*

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

Summaries of biomass estimates from the 1984-2017 surveys are provided in Table 13-10. Trawl survey biomass estimates are shown in Figure 13-2. Historically estimates by region indicate that the western and eastern GOA time series of biomass tended to be in opposite phase (Table 13-10). From 2003-2007, the central and eastern GOA estimates increased, while the western GOA decreased. In 2009, all regions decreased and in 2011 both the eastern and central GOA decreased while the western GOA slightly increased. Given that the regional patterns are quite different and that the 2001 survey did not sample the eastern GOA, omitting this survey estimate from the model is reasonable. Additionally, data for 2001 are available from the longline survey.

The 2013 biomass estimate was an all-time low for this time series. The decrease was 37% below the 2011 estimate and 40% below the mean biomass estimate for the time series. The estimates by area were not consistently down as there was a 66% decrease in the central GOA with increases in the western and eastern GOA by 19% and 51%, respectively. The 2015 biomass estimate increased by 25% from 2013 and is now 24% below the mean estimate for the time series. Compared to the 2013 survey, central and eastern GOA increased by 62% and 21% respectively, but western GOA decreased by 66%. This is the second lowest estimate for the western GOA in the time series. In 2017, the biomass estimate increased by 16% from the 2015 survey and is now only 11% below the long term mean estimate for the time series. The western GOA increased dramatically, while the central GOA decreased by 38% and eastern GOA increased by 45%

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

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

In 2007, the trawl survey began separating rougheye rockfish from blackspotted rockfish using a species key developed by J. Orr (Orr and Hawkins, 2008). Biomass estimates by region of the two species somewhat support the broad southern and northern distribution of rougheye versus blackspotted rockfish in that blackspotted estimates were higher in the western GOA and rougheye estimates were higher in the eastern GOA (discussed previously in *Evidence of Stock Structure* section). However, both species were identified in all regions, implying some overlap throughout the GOA. Over all areas, more blackspotted rockfish were identified than rougheye in 2007 (56% versus 44%), while in all remaining surveys the reverse occurred with 63% to 73% rougheye and 37% to 27% blackspotted. 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 apparent improvement, misidentification rates are still shifting from year to year and given the lack of species-specific catch we continue to combine all survey data for both species until a complete evaluation of the genetically corrected species' specific life history characteristics are made available.

*AFSC Bottom Trawl Age Compositions*

New ages for 2015 were added this year resulting in a total of thirteen years of survey age compositions with a total sample size of 7,256 ages. Survey age sample sizes are generally higher than fishery age sample sizes, ranging from 200 to 1,000. Although rougheye and blackspotted rockfish have been reported to be greater than 200 years old (Munk 2001), the highest age collected over these survey years was 135 (AFSC 2010). The average age ranged from 15 to 23 over all survey years available (Table 13-11). Compositions from 1984, 1987, 1990, 1996, 1999 showed especially prominent modes in the younger to mid ages (6 to 12 year olds for this species), suggesting periods of large year classes from the late 1970s, early 1980s and then again in the late 1980s early 1990s. Since 2003, compositions were spread more evenly across age groups 3-15 corresponding to the strong year classes of the early 1990s and another period of increased recruitment in the early 2000s that is tracked through each survey year. In 2011, a higher proportion of five year old fish suggests another period of increased recruitment in the mid-2000s. This is tracked through to 2013 and 2015 along with a high proportion of three and five year old fish, suggesting a period of increased recruitment from the mid and late 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 with the exception of 2013 and 2015 when all the fish were generally younger. Mean age of rougheye range from 13 - 17, while mean age for blackspotted range from 16 - 24. We combine these two age compositions for 2007, 2009, 2011, 2013, and 2105 in the stock assessment model. Ages 42 and greater are pooled into a plus (+) group following the author recommended model (Table 13-11).

*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 large proportion of ages in the 25-32 year range. In the 1996 through 2017 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 average length steadily decreased from 1984-1999, ranging from 41 to 34 cm. After this the mean length remained relatively steady between 33-37 cm. Since 2007, survey rougheye and blackspotted rockfish lengths were split. Rougheye have an average length of 33 cm while blackspotted have an average of 37 cm. Rougheye have a much broader range of lengths from 10-60 cm, while blackspotted tend to be more confined to the 35-50 cm range, although this has somewhat shifted in the three most recent surveys with a larger composition of small blackspotted rockfish (< 25cm). Again, this may be indicative of misidentification or a true difference in size distribution between species. Future analysis of the 2009, 2013, and 2015 trawl survey genetics experiment will aid in understanding some of these differences. Trawl survey size data are used in constructing the size-age conversion matrix, but are not used as data to be fit in the stock assessment model since survey ages for most years were available. Investigations into including the most recent survey's length composition as a proxy for unavailable age composition were presented in Appendix 9B of the GOA POP November 2014 assessment. The results of that analysis suggest that the utility of using only the most recent survey's length composition is case specific and may be a subject for future research.

*AFSC Longline Abundance Index*

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

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

During the 2009 CIE for sablefish the use of both relative population number (RPN) and weight (RPW) survey indices in the model was discussed. The CIE recommendation was to use only the RPN index to avoid the added uncertainty that results from converting lengths to weight, estimating numbers at age and then converting back to weight for the ultimate ABC recommendation. We follow this recommendation for RE/BS and now use the RPN index since the weight conversion data is already incorporated into the assessment model. The final longline survey RPN index for RE/BS rockfish runs from 1993-2017 with all available strata updated with new area estimates (Table 13-13).

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

The RPN estimates for RE/BS rockfish have been somewhat cyclic throughout the time series, but seem to be on an overall slightly increasing trend since 2005. The 2016 survey decreased by 22% from the 2015 survey and the 2017 survey increased by 50% from the 2016 survey and 17% from the 2015 survey. The most current 2017 survey RPN is 27% above the average for the time series (Figure 13-3). The agreement between the decrease in both the trawl and longline surveys in 2013 may have been indicative of a decrease in the RE/BS rockfish biomass; however, the subsequent estimates have generally been increasing in both surveys suggesting that the decline may not have been so dramatic.

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

*AFSC Longline Size Compositions*

Large samples of lengths have been collected gulf-wide of RE/BS rockfish throughout the time series. 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. 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 1993-2017 using all strata information and are calculated using the same length bins as the fishery and AFSC bottom trawl data. The longline survey size compositions show that small fish were rarely caught in the longline survey and that the length distribution was fairly stable through time (Table 13-14). Compositions for all years were normally distributed with a mode between 45 and 47 cm in length. An unusually large amount of fish appeared in the 26 cm length bin in 2014 and may reflect the bump in 7 year old fish from the 2013 trawl ages.

*Comparison of AFSC Bottom Trawl and Longline Surveys*

The spatial distribution of numbers of rougheye and blackspotted rockfish caught in the 2013, 2015, and 2017 trawl and the 2012-2017 longline surveys is depicted in Figure 13-4a. The trawl survey samples more of the continental shelf than the longline survey due to differences in survey design. However, the trawl survey tends to catch more RE/BS rockfish in the central GOA, while the longline survey catches more RE/BS rockfish in the eastern and western GOA. This can be seen in all surveys, particularly in the eastern GOA. In 2013, both survey estimates decreased from the previous surveys. The decrease was primarily in the central GOA for the trawl survey and the eastern GOA for the longline survey. In 2015, both surveys estimates were up from the 2013 surveys with increases in the central and eastern GOA for the trawl survey and gulfwide for the longline survey. The 2015 trawl survey estimate in the western GOA was near the all-time low for this survey. The distribution of the hauls that typically sample RE/BS rockfish in this region are near the slope, where there may be a higher proportion of steep, rocky, untrawlable habitat. The longline survey effectively samples this habitat and catches increased in the western GOA compared to the 2013 surveys. This may suggest that the 2015 trawl survey western GOA drop may not be indicative of an actual decline in the western GOA. In 2017, both the eastern and western GOA increased on the trawl survey with a decrease in the central GOA similar to that seen in 2013. In contrast, all survey areas increased in the longline survey. Most notably the central GOA estimate on the longline survey is now higher than it has been since 2009.

Rougheye and blackspotted rockfish were identified at-sea separately since 2007 in the trawl surveys. The spatial distribution of the two species somewhat reflects the area differences seen in the trawl survey biomass estimates (discussed previously in *AFSC Bottom Trawl Biomass Estimates* section), with more blackspotted in the western GOA and more rougheye encountered in the eastern GOA. There are also more rougheye identified gulfwide than blackspotted (~2/3 rougheye to 1/3 blackspotted). There seem to be some differences across the shelf/slope region (Figure 13-4b). In general, more rougheye are identified in the shallower depths than blackspotted, particularly in the central GOA. The changes in spatial distribution of the two species over time may be an area of future research when determining differences in life history characteristics. However, interpretation of these maps should be with caution as these are at-sea identifications that are not corrected to the genetic identification.

*Sensitivity Analysis of AFSC Bottom Trawl and Longline Surveys*

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

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

*International Pacific Halibut Commission (IPHC) Longline Estimates*

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

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

# Analytic Approach

## Model Structure

We present model results for the RE/BS rockfish complex based on an age-structured model using AD Model Builder software (Fournier et al. 2012). This consists of an assessment model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model which uses results from the assessment model to predict future population estimates and recommended harvest levels. The GOA RE/BS model closely follows the GOA Pacific ocean perch model which was built from the northern rockfish model (Courtney et al. 1999; Hanselman et al. 2003, Courtney et al. 2007). As with other rockfish age-structured models, this model does not attempt to fit a stock-recruitment relationship but estimates a mean recruitment, which is adjusted by estimated recruitment deviations for each year. We do this because there does not appear to be an obvious stock-recruitment relationship in the model estimates, and there little contrast in the spawner/recruits data (Figure 13-5). The main difference between the RE/BS model and the Pacific ocean perch model is the addition of data from the AFSC longline survey. Unlike the Pacific ocean perch model, the starting point for the RE/BS model is 1977, so the population at the starting point has already sustained fishing pressure. The parameters, population dynamics and equations of the model are described in Box 1 (below). The model was originally configured in 2005, when catch accounting was established separately for RE/BS rockfish and shortraker rockfish. In 2009, further modifications were made to accommodate MCMC projections that use a pre-specified proportion of ABC for annual catch. In 2014, a modification was made to allow for a numbers index rather than a weight index for the longline survey in the model following the configuration used in the sablefish assessment model (Hanselman et al. 2013). Several changes to the assessment methodology were made in 2015 that included (1) updating growth information to account for length-stratified sampling, (2) updating and extending the ageing error matrix, (3) using the gamma function for trawl survey selectivity, and (4) setting the plus age group to a higher age of 42.

There are no model alternatives to consider for the 2017 assessment. We continue to use the recommended model from the 2015 assessment which was the fourth model evaluated (Model M4.a). We update the model name to Model 15.4 to use the correct naming convention and this change is detailed in the following table for clarity:

| Model Number | Model Description |
|---|---|
| Model 15.4 (2015) | Model M4.a from Shotwell et al. (2015) |
| Model 15.4 (2017) | Same Model 15.4 but incorporates all new and updated data from 2017 |

## 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 |

Size at age data and resulting growth estimates were the same as used in the last full assessment where data was updated through the 2013 survey and appropriate length-stratified methods (Quinn and Deriso 1999, Bettoli and Miranda 2001) were incorporated. A von Bertalanffy growth curve was fit to size and age data from 1990 to 2013. Sexes were combined and the size-at-age conversion matrix was constructed by adding normal error with a standard deviation equal to the survey data for the probability of different size classes for each age. The estimated parameters for the growth curve are:

2015 size at age parameters: $L_\infty$= 49.6 cm $\kappa$=0.09 $t_0$=-0.69 n=6,738

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 estimated growth parameters (including the length-weight parameters) from the length-stratified methods are:

2015 weight at age parameters: $W_\infty$= 1,639 g $\kappa$=0.12 $t_0$=-0.38 $\beta$=3.086 n=5,806

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 use the same age error structure as presented in the 2015 assessment that was based on the percent agreement for each age from these tests. Additionally, in the 2015 assessment the plus age group was extended in the model compared to the plus age group in the data until 99.9% of the fish in the model's plus age group are within the plus age group of the data. This was done to alleviate the consistent over-estimation of the proportion at age in the age bins adjacent to the plus group age.

*New Research*

A new maturity study on RE/BS rockfish species was recently published (Conrath 2017). Samples were collected throughout the year on a variety of scientific surveys and observed fishery vessels from 2008-2014. Results from this study show higher age at 50% maturity for blackspotted rockfish (27.4 years versus 19.6 years for rougheye). However, the samples in this study were not genetically identified to species, so it is not clear whether there was little change in rougheye rockfish age at 50% maturity or whether the change in blackspotted rockfish was as dramatic as estimated. It is difficult to immediately determine how to best utilize the results from this study within our assessment model. Since the maturity samples were not collected randomly in proportion to the actual **or** genetically identified species composition, the data cannot be pooled and fit as one maturity curve. One method might be to use the separately fit curves and apply weights of either the mean of the naïve species ratio or the 3 years of genetic ID. Clearly if that proportion is largely composed of blackspotted rockfish, then the maturity-at-age will be higher and would result in lower estimates of reference points. We plan to evaluate this new maturity information in the next full assessment.

## Parameters Estimated Inside the Assessment Model

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

Several other alternatives to estimating natural mortality for rockfish are available such as catch-curve analysis, empirical life history relationships, and simplified maximum age equations (Malecha et al. 2007). Each of these methodologies was detailed in the draft response of the Rockfish Working Group to the Center for 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 based on growth was much lower. Several assumptions of catch-curve analysis must be met before this method can be considered viable, and there is a likely time trend in recruitment for GOA rockfish. The method described by Alverson and Carney (1975) for developing an estimate of critical age is based on a regression of 63 other population estimates and may not be representative of extremely long-lived fish such as rougheye and blackspotted rockfish (Malecha et al. 2007). McDermott (1994) collected 430 samples of rougheye/blackspotted rockfish from across the Pacific Northwest to the Bering Sea, providing a representative sample of RE/BS rockfish distribution. Since the value of 0.03 estimated by McDermott (1994) is within the range of most other estimates of natural mortality and designed specifically for RE/BS rockfish, we feel that this is the most suitable estimate for a prior mean.

Catchability is a parameter that is somewhat uncertain for rockfish. We assign a prior mean of 1 for both the trawl and longline survey. For the trawl survey, a value of 1 assumes all fish in the area swept are captured, there is no herding of fish from outside the area swept, and there is no effect of untrawlable grounds. This area-swept concept does not apply to the longline survey; however, since the RPNs for rougheye and blackspotted rockfish are of the same magnitude as the trawl survey estimates we deemed this a logical starting point. We also assume a lognormal distribution to bind the minimum at zero. For both the trawl and longline survey, we assign a fairly broad CV (45% and 100%, respectively) which essentially mimics a uniform prior with a lower bound of zero (Figure 13-7). These prior distributions allow the catchability parameters more freedom than that allowed to natural mortality.

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

Selectivity for the trawl survey is estimated with a reparametrized gamma function, which was chosen to be the most reasonable in parsimonious fit in Shotwell et al. (2015). The equation for this is:

$$s_{a,s}^{g} = \left(\frac{a}{a_{\max}}\right)^{a_{\max,g,s}/p} e^{(a_{\max,g,s}-a)/p}$$

$$p = 0.5\left[\sqrt{a_{\max,g,s}{}^{2} + 4\delta_{g,s}{}^{2}} - a_{\max,g,s}\right]$$

Selectivities for the longline survey and the combined (trawl and longline fisheries) continue to be fit with the non-parametric first-differences methods that were used in the original rockfish template (Courtney et al. 2007).

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 | $\mu_r$ | 1 |
| Recruitment variability | $\sigma_r$ | 1 |
| Fishing mortality rates | $F_{35\%}$, $F_{40\%}$, $F_{50\%}$ | 3 |
| Recruitment deviations | $\tau_y$ | 89 |
| Average fishing mortality | $\mu_f$ | 1 |
| Fishing mortality deviations | $\phi_y$ | 41 |
| Fishery selectivity coefficients | $fs_a$ | 14 |
| Survey selectivity coefficients | $ss_a$ | 17 |
| Total | | 170 |

*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 170. 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. Values from MCMC simulations are not used to derive any quantities for management advice for this stock assessment, but are helpful in more fully illustrating the uncertainty of these results.

**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 |
| $\mu_r$ | Average annual recruitment, log-scale estimation |
| $\mu_f$ | Average fishing mortality |
| $\phi_y$ | Annual fishing mortality deviation |
| $\tau_y$ | Annual recruitment deviation |
| $\sigma_r$ | 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 |
| $\sigma_M^2$ | Prior CV for natural mortality |
| $\sigma_q^2$ | Prior CV for catchability coefficient |
| $\sigma_{\sigma_r}^2$ | Prior CV for recruitment deviations |

**BOX 1 (Continued)**

Equations describing the observed data

$$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1 - e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$$

Catch equation

$$\hat{I}_{1y} = q_1 * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$$

Trawl survey biomass index (t)

$$\hat{I}_{2y} = q_2 \sum_a N_{y,a} * \frac{s_a}{\max(s_a)}$$

Longline survey abundance index (RPN)

$$\hat{P}_{y,a'} = \sum_a \left( \frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,a'}$$

Survey age distribution
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left( \frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,l}$$

Survey length distribution
Proportion at length

$$\hat{P}_{y,a'} = \sum_a \left( \frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$$

Fishery age composition
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left( \frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$$

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

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

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 |
| $L_2 = \lambda_2 \sum_y \left( \ln I_{1y} - \ln \hat{I}_{1y} \right)^2 / \left( 2\sigma_{I_1}^2 \right)$ <br> $L_3 = \lambda_3 \sum_y \left( \ln I_{2y} - \ln \hat{I}_{2y} \right)^2 / \left( 2\sigma_{I_2}^2 \right)$ | Trawl survey biomass index likelihood <br> Longline survey abundance index (RPN) likelihood |
| $L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left( P_{y,l} + 0.001 \right) * \ln \left( \hat{P}_{y,l} + 0.001 \right)$ <br> $L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left( P_{y,a} + 0.001 \right) * \ln \left( \hat{P}_{y,a} + 0.001 \right)$ <br> $L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left( P_{y,l} + 0.001 \right) * \ln \left( \hat{P}_{y,l} + 0.001 \right)$ <br> $L_7 = \lambda_7 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left( P_{y,l} + 0.001 \right) * \ln \left( \hat{P}_{y,l} + 0.001 \right)$ | Fishery length composition likelihood <br> Trawl survey age composition likelihood <br> Trawl survey size composition likelihood <br> Longline survey size composition likelihood |
| $L_8 = \frac{1}{2\sigma_M^2} \left( \ln M / M_{prior} \right)^2$ <br> $L_9 = \frac{1}{2\sigma_{q_1}^2} \left( \ln q_1 / q_{1\,prior} \right)^2$ <br> $L_{10} = \frac{1}{2\sigma_{q_2}^2} \left( \ln q_2 / q_{2\,prior} \right)^2$ <br> $L_{11} = \frac{1}{2\sigma_{\sigma_r}^2} \left( \ln \sigma_r / \sigma_{r(prior)} \right)^2$ | Penalty on deviation from prior distribution of natural mortality <br> Penalty on deviation from prior distribution of catchability coefficient for trawl survey <br> Penalty on deviation from prior distribution of catchability coefficient for longline survey <br> 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 |
| $L_{14} = \lambda_{14} \bar{s}^2$ <br> $L_{15} = \lambda_{15} \sum_{a_0}^{a_+} \left( s_i - s_{i+1} \right)^2$ <br> $L_{16} = \lambda_{16} \sum_{a_0}^{a_+} \left( FD(FD(s_i - s_{i+1}) \right)^2$ <br> $L_{total} = \sum_{i=1}^{16} L_i$ | Average selectivity penalty (attempts to keep average selectivity near 1) <br> 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) <br> Selectivity regularity penalty (penalizes large deviations from adjacent selectivities by adding the square of second differences) <br> Total objective function value |

# Results

## Model Evaluation

There were no recommended changes to this year's assessment model compared to the model used in 2015. Negative log-likelihood and estimates of key parameters for last year's full assessment (2015 Model 15.4) and this year's updated model (2017 Model 15.4) are provided in Table 13-15 for comparison. Observed and model predictions for the age and size composition data are provided in Figures 13-8, 13-9, 13-10 and 13-12. AFSC bottom trawl survey size compositions are provided for reference (Figure 13-11).

There is some lack of fit for the fishery age compositions between ages 15 and 20 and for some years in the plus age group (Figure 13-8). Fit to the fishery size compositions are slightly flattened (Figure 13-9) particularly in 1991. This may be due to the slight right or left skew in most years. Fit to the bottom trawl survey age compositions are generally very good with some underestimation for the large composition ages such as that of the 1990 year class (Figure 13-10). Fit to the longline survey size compositions are similar to the fishery size compositions with slightly flattened peaks in most years (Figure 13-12). The model does not fit the relatively large composition of size 26 cm fish in 2014. The consistent patterns of positive residuals in the fishery and longline survey size compositions could be due to a variety of confounding issues between selectivity, growth, and ageing. In the future we may consider applying different shaped selectivity curves or explore separate selectivity curves for trawl and longline fisheries.

We continue to recommend model 15.4 to update management quantities for 2018. We discuss results of this model in the following section. Estimated numbers in 2017, fishery selectivity, trawl and longline survey selectivity and schedules of age specific weight and female maturity are provided in Table 13-16 for reference based on this author preferred model.

## Time Series Results

Table 13-15 provides parameter estimates for the last full assessment model and the current updated model for comparison purposes. Tables 13-16 through 13-19 summarize other results for the 2017 author preferred model (M15.4).

*Definitions*

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

Total and spawning biomass for the author preferred model compared to the last full assessment was higher for the entire time series (Figure 13-13, Figure 13-14). Recruitment was generally similar between the preferred model and the estimates from the last full assessment except in 2010 (Table 13-18). This is likely due to the new trawl survey age composition of 2015 that shows a larger composition of age 5 fish and confirms the larger recruitment of the 2010 year class (Figure 13-10). Projected total and spawning biomass decreased, while recruitment increases slightly. Catchability, selectivity, and recruitment are all somewhat confounded within the model. As the surveys estimate fewer fish, and age compositions suggest less recruitment, catchability estimates tend to increase so that large swings in biomass do not occur. This seems reasonable for long-lived fish such as RE/BS rockfish.

*Biomass and Exploitation Trends*

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

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

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

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

*Recruitment*

MCMC credible intervals (CI) for recruitment have continued to narrow with the addition of more age data (Figure 13-18). This is particularly true for the 1990 and more recently the 2010 year class, which exist as a larger proportion in the age compositions. The recruitment estimate for 2010 also increased from the last full assessment. In general, recruitment is highly variable, particularly in the most recent years where very little information exists on this part of the population. There also does not seem to be a clear spawner-recruit relationship for RE/BS rockfish as recruitment is apparently unrelated to spawning stock biomass and there is little contrast in spawning stock biomass (Figure 13-5).

*Uncertainty*

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

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

*Retrospective Analysis*

Retrospective analysis is the examination of the consistency among successive estimates of the same parameters obtained as new data are added to a model. Retrospective analysis has been applied most commonly to age-structured assessments and can arise for many reasons, ranging from bias in the data (e.g., catch misreporting, non-random sampling) to different types of model misspecification (e.g., incorrect values of natural mortality, temporal trends in values set to be invariant). For this assessment, 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 from the current preferred model.

The retrospective female spawning biomass and the relative difference in female spawning biomass from the 2017 model are shown in Figure 13-20. One common measure of the retrospective bias is Mohn's revised ρ ("rho") which indicates the size and direction of the bias (Hanselman et al. 2013). The revised Mohn's ρ statistic is very low at 0.009 (compared to most assessments, Hanselman et al. 2013), indicating that the model increases the estimate of female spawning biomass slightly in the retrospective model's terminal year as data is added to the assessment. There is some pattern in the retrospective where there was a series of overestimates and a series of underestimates and the low value of ρ is related to the 10-year peel. For example, a five year peel was chosen, there would be a stronger negative value of ρ.

The RE/BS model is no longer exhibiting a relatively strong retrospective pattern due to an update in the retrospective model code. A comparison of the revised Mohn's "rho" statistic presented in the 2015 assessment relative to the estimate using the updated code as well as the new 2017 estimate is presented in the table below.

| Statistic | 2015 (M15.4) | 2015 (M15.4) Updated | 2017 (M15.4) |
|---|---|---|---|
| Mohn's revised ρ | -0.371 | 0.105 | 0.009 |

Examining retrospective trends can show potential biases in the model, but may not identify what their source is. Other times a retrospective trend is merely a matter of the model having too much inertia in the age-structure and other historic data to respond to the most recent data. This retrospective pattern is likely to be considered mild, but an issue may be the "one-way" pattern in the early and late part of the retrospective time series. It is difficult to isolate the cause of this pattern but several possibilities exist. For example, hypotheses could include environmental changes in catchability, time-varying natural mortality, or changes in selectivity of the fishery or survey. However, these new results no longer pose a significant concern regarding the retrospective pattern for RE/BS rockfish.

## 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 1980-2015 (i.e. the 1977-2012 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 2017 estimates of these reference points are in the following table. Biomass estimates are for female spawning biomass.

| $B_{100\%}$ | $B_{40\%}$ | $B_{35\%}$ | $F_{40\%}$ | $F_{35\%}$ |
|---|---|---|---|---|
| 22,495 (t) | 8,998 (t) | 7,873 (t) | 0.040 | 0.048 |

*Specification of OFL and Maximum Permissible ABC*

Estimated female spawning biomass for 2018 is 15,059 t. This is above the $B_{40\%}$ value of 8,998 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 2017 yields the following *ABC* and *OFL*:

| | |
|---|---|
| $F_{40\%}$ | 0.040 |
| ABC (t) | 1,444 |
| $F_{35\%}$ | 0.048 |
| OFL (t) | 1,735 |

*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 2017 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2018 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2017. 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 2017 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 2018, 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 2018 and 2019, $F$ is set equal to a constant fraction of *max* $F_{ABC}$, where this fraction is equal to the ratio of the realized catches in 2014-2016 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 2012-2016 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 2017 or 2) above ½ of its MSY level in 2017 and above its MSY level in 2027 under this scenario, then the stock is not overfished.)

*Scenario 7*: In 2018 and 2019, $F$ 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 2019 or 2) above ½ of its MSY level in 2019 and expected to be above its MSY level in 2029 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 based on maximum likelihood estimates from the main assessment (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 2018, it does not provide the best estimate of OFL for 2019, because the mean 2018 catch under Scenario 6 is predicated on the 2018 catch being equal to the 2018 OFL, whereas the actual 2018 catch will likely be less than the 2018 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 (2016) is 640 t. This is less than the 2016 OFL of 1,596 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 2017:

a) If spawning biomass for 2017 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2017 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c) If spawning biomass for 2017 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 2027 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

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

a) If the mean spawning biomass for 2019 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2019 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2019 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2029. If the mean spawning biomass for 2029 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 currently 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. 2014-2016 for this year, see example figures below). For rougheye and blackspotted rockfish, the expansion factor for 2017 catch is 1.017.

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 (0.52), which was the average of the ratio of catch to ABC for the last three complete catch years (2014-2016). This yield ratio was multiplied by the projected ABCs for 2018 and 2019 from the assessment model to generate catches for those years.

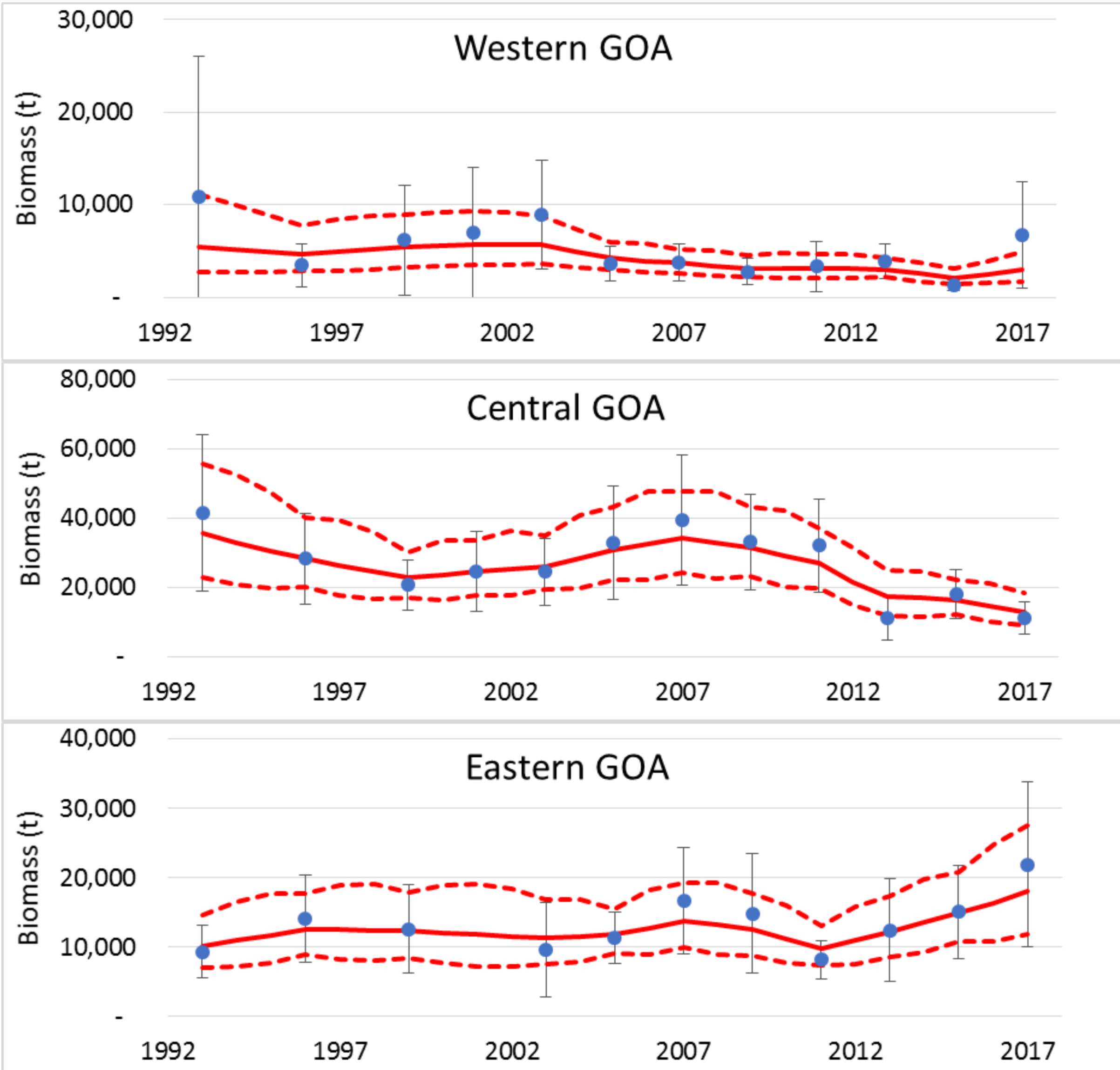
*Alternative Projection*

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 13-21). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1980-2015 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 (0.52).

*Area Allocation of Harvests*

We determine apportionment of ABC among areas utilizing a method that was recommended by the Plan Team and accepted by the Council in 1996. This method weights prior surveys based on the relative proportion of variability attributed to survey error. Assuming that survey error contributes 2/3rd of the total variability in predicting the distribution of biomass (a reasonable assumption), the weight of a prior survey should be 2/3rd the weight of the preceding survey. This resulted in weights of 4:6:9 for the 2013, 2015, and 2017 surveys, respectively and apportionments for rougheye and blackspotted rockfish of 12.2% for the western area, 38.5% for the central area, and 49.3% for the eastern area (Table 13-21). This represents a 54% increase in the western area to an approximate 28% decrease in the central and a 27% increase in the eastern areas from the 2015 apportionments (7.9% for the Western area, 53.2% for the Central area, and 38.9% for the Eastern area).

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




In general the random effects model fits the area-specific survey biomass reasonably well. We used the random effects estimates of ending year biomass to determine the apportionment results as 8.6% for the Western area, 38.4% for the Central area, and 53.0% for the Eastern area. This is similar to the results from the updated 4:6:9 survey average weighting method with the exception that the lower western GOA 2015 biomass estimate is still fairly influential and the random effects model does not fit the 2017 increase in the WGOA very well. This results in a reduction in the western GOA apportionment from the survey average approach and an additional increase in the eastern GOA apportionment.

We recommend continuing with the status quo (three survey weighted average) apportionment for RE/BS rockfish at this time. The assessment model utilizes both trawl and longline survey data to overcome sampling issues of each survey for the RE/BS rockfish population. In general, the trawl survey samples more of the continental shelf than the longline survey due to differences in survey design. The trawl survey also tends to catch more RE/BS rockfish in the central GOA, while the longline survey catches more RE/BS rockfish in the eastern and western GOA. This can be seen in the recent trawl versus longline survey comparison maps (Figure 13-4a). Sampling error also differs by region and survey (Table

13-10, 13-13). On average there is higher sampling error in the central GOA for the longline survey versus the trawl survey and lower sampling error in the EGOA for the longline survey versus the trawl survey. The average sampling error is relatively similar in the WGOA; however, the variability is much higher in the trawl survey versus the longline survey. The random effects model does not currently allow for inclusion of more than one survey index. However, a recent preliminary analysis using the VAST model (Thorson et al. 2015) for estimating area apportionment shows promise to dampen the high variability of the regional survey estimates and potentially include more than one gear type. It is anticipated that the Survey Averaging Working Group will provide recommendations for stocks with highly variable and multiple survey estimates. Rather than switching the apportionment scheme several times, we prefer to shift to a new method when the recommendations from the Survey Averaging Working Group become available. There is also new research regarding the proportion of rougheye and blackspotted rockfish in the survey based on a three-year genetics experiment. We would also like to consider the results from this study for evaluating the appropriate apportionment approach. Using both surveys indices for apportionment and consideration of the amount of each species within these estimates should provide for a better reflection of the RE/BS spatial population structure over either the status quo three survey average or the current one survey index random effects model. In addition, using two survey indices will likely result in less variation in apportionment due solely to sampling variability.

The following table shows the apportionment for the 2018 and 2019 fishery when applying the percentages using the three survey weighted average and random effects methods to the ABC for RE/BS rockfish (1,444 t):

| Method | Area Allocation | | Western GOA | Central GOA | Eastern GOA | Total |
|---|---|---|---|---|---|---|
| Three Survey Weighted Average | | | 12.2% | 38.5% | 49.3% | 100% |
| | 2018 | Area ABC (t) | **176** | **556** | **712** | **1,444** |
| | | OFL (t) | | | | **1,735** |
| | 2019 | Area ABC (t) | **174** | **550** | **703** | **1,427** |
| | | OFL (t) | | | | **1,715** |
| Random Effects | | | 8.6% | 38.4% | 53.0% | 100% |
| | 2018 | Area ABC (t) | **124** | **554** | **766** | **1,444** |
| | | OFL (t) | | | | **1,735** |
| | 2019 | Area ABC (t) | **123** | **548** | **756** | **1,427** |
| | | OFL (t) | | | | **1,715** |

*Overfishing Definition*

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.048), overfishing is set equal to 1,735 t in 2018 and 1,715 t in 2019 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 2005-2017 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) assessment of RE/BS rockfish density between trawlable and untrawlable grounds, 2) analyses of different fishery fleet spatial patterns and behavior given the Rockfish Program and observer restructuring, and 3) examining potential age and growth differences between RE/BS rockfish to consider the utility of developing species-specific life history parameters for this two-species complex.

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

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

A newly revamped stock ecosystem-socioeconomic profile (ESP) report framework is also planned to be introduced over the next several years. The ESPs may replace the Ecosystem Consideration section of the single-species assessment reports in some manner. The new reports can be considered a companion to the main SAFE chapter and will likely include a stock-specific factor profiles for identifying research priorities and data gaps, a life history conceptual model for understanding relationships between environmental and socioeconomic influences on the stock, and finally a report card of potential indicators with an accompanying decision table and recommendations with regard to potential use within the main stock assessment. The intention of these ESP reports is to improve the process of integrating ecosystem information into the stock assessments and facilitate the ecosystem approach to fishery management.

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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) | New study suggests age at 50% maturity younger for rougheye rockfish (19.6 years) than blackspotted rockfish (27.4 years), no genetic ID confirmation on samples (Conrath 2017). |
| 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 (1977-2016), with Gulf-wide values of acceptable biological catch (ABC) and fishing quotas[b] (t), 1991-2016. Catch is provided through the most recent full year estimate.

| Year | Catch (t) | | | | OFL | ABC | TAC |
|---|---|---|---|---|---|---|---|
| | Commercial | Western GOA | Central GOA | Eastern GOA | | | |
| 1977 | 1443 | | | | | | |
| 1978 | 568 | | | | | | |
| 1979 | 645 | | | | | | |
| 1980 | 1353 | | | | | | |
| 1981 | 719 | | | | | | |
| 1982 | 569 | | | | | | |
| 1983 | 628 | | | | | | |
| 1984 | 760 | | | | | | |
| 1985 | 130 | | | | | | |
| 1986 | 438 | | | | | | |
| 1987 | 525 | | | | | | |
| 1988 | 1621 | | | | | | |
| 1989 | 2185 | | | | | | |
| 1990 | 2418 | | | | | | |
| 1991 | 350 | | | | | 2,000 | 2,000 |
| 1992 | 1127 | | | | | 1,960 | 1,960 |
| 1993 | 583 | | | | | 1,960 | 1,764 |
| 1994 | 579 | | | | | 1,960 | 1,960 |
| 1995 | 704 | | | | | 1,910 | 1,910 |
| 1996 | 558 | | | | | 1,910 | 1,910 |
| 1997 | 545 | | | | | 1,590 | 1,590 |
| 1998 | 665 | | | | | 1,590 | 1,590 |
| 1999 | 320 | | | | | 1,590 | 1,590 |
| 2000 | 530 | | | | | 1,730 | 1,730 |
| 2001 | 591 | | | | | 1,730 | 1,730 |
| 2002 | 273 | | | | | 1,620 | 1,620 |
| 2003 | 394 | | | | | 1,620 | 1,620 |
| 2004 | 301 | | | | | 1,318 | 1,318 |
| 2005 | 294 | 53 | 126 | 115 | 1,531 | 1,007 | 1,007 |
| 2006 | 372 | 58 | 141 | 172 | 1,180 | 983 | 983 |
| 2007 | 440 | 71 | 195 | 174 | 1,148 | 988 | 988 |
| 2008 | 382 | 75 | 190 | 117 | 1,548 | 1,286 | 1,286 |
| 2009 | 275 | 76 | 98 | 100 | 1,545 | 1,284 | 1,284 |
| 2010 | 429 | 89 | 213 | 127 | 1,568 | 1,302 | 1,302 |
| 2011 | 542 | 25 | 368 | 148 | 1,579 | 1,312 | 1,312 |
| 2012 | 568 | 28 | 371 | 168 | 1,472 | 1,223 | 1,223 |
| 2013 | 575 | 15 | 384 | 176 | 1,482 | 1,232 | 1,232 |
| 2014 | 737 | 26 | 540 | 171 | 1,497 | 1,244 | 1,244 |
| 2015 | 549 | 45 | 348 | 157 | 1,345 | 1,122 | 1,122 |
| 2016 | 640 | 42 | 484 | 115 | 1,596 | 1,328 | 1,328 |

[a]Catch defined as follows: 1977-1992 from Soh (1998), 1993-2004 from observer program, 2005-present from NMFS AKRO Catch Accounting System via Alaska Fisheries Information Network (AKFIN, www.akfin.org).
[b]ABC and TAC were available for the shortraker/rougheye rockfish complex from 1991-2004 (gray shade). Separate catch accounting were established for GOA RE/BS rockfish since 2005.

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

| Year | Catch (t)* | ABC | TAC | Management Measures |
|---|---|---|---|---|
| 1988 | 1,621 | 16,800 | 16,800 | The slope rockfish assemblage, including rougheye, is one of three management groups for Sebastes implemented by the North Pacific Management Council. Previously, Sebastes in Alaska were managed as “Pacific ocean perch complex” (rougheye included) or “other rockfish” |
| 1989 | 2,185 | 20,000 | 20,000 | |
| 1990 | 2,418 | 17,700 | 17,700 | |
| 1991 | 350 | 2,000 | 2,000 | Slope assemblage split into three management subgroups with separate ABCs and TACs: Pacific ocean perch, shortraker/rougheye rockfish, and all other slope species |
| 1992 | 1,127 | 1,960 | 1,960 | |
| 1993 | 583 | 1,960 | 1,764 | |
| 1994 | 579 | 1,960 | 1,960 | |
| 1995 | 704 | 1,910 | 1,910 | |
| 1996 | 558 | 1,910 | 1,910 | |
| 1997 | 545 | 1,590 | 1,590 | |
| 1998 | 665 | 1,590 | 1,590 | |
| 1999 | 320 | 1,590 | 1,590 | Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned |
| 2000 | 530 | 1,730 | 1,730 | Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W. |
| 2001 | 591 | 1,730 | 1,730 | |
| 2002 | 273 | 1,620 | 1,620 | |
| 2003 | 394 | 1,620 | 1,620 | |
| 2004 | 301 | 1,318 | 1,318 | Shortraker and rougheye rockfish divided into separate subgroups and assigned individual ABCs and TACs |
| 2005 | 294 | 1,007 | 1,007 | Rougheye managed separately from shortraker as age structured model accepted to determine ABC and moved to Tier 3 status |
| 2006 | 372 | 983 | 983 | |
| 2007 | 440 | 988 | 988 | Amendment 68 created the Central Gulf Rockfish Pilot Project |
| 2008 | 382 | 1,286 | 1,286 | Rougheye and blackspotted formally verified as separate species so assessment now called the rougheye/blackspotted rockfish complex |
| 2009 | 275 | 1,284 | 1,284 | |
| 2010 | 426 | 1,302 | 1,302 | |
| 2011 | 541 | 1,312 | 1,312 | Rockfish Program continues from pilot initiative |
| 2012 | 568 | 1,223 | 1,223 | |
| 2013 | 575 | 1,232 | 1,232 | |
| 2014 | 737 | 1,244 | 1,244 | |
| 2015 | 549 | 1,122 | 1,122 | |
| 2016 | 640 | 1,328 | 1,328 | |

*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 10/18/2017.

| Year | Flatfish | Halibut | P. Cod | Pollock | Rockfish | Sablefish |
|---|---|---|---|---|---|---|
| 2005 | 15 | 36 | 1 | 16 | 106 | 119 |
| 2006 | 40 | 46 | 2 | 23 | 83 | 179 |
| 2007 | 90 | 64 | 1 | 28 | 114 | 144 |
| 2008 | 57 | 55 | 9 | 41 | 104 | 115 |
| 2009 | 34 | 40 | 6 | 11 | 97 | 86 |
| 2010 | 64 | 42 | 6 | 30 | 183 | 103 |
| 2011 | 64 | 33 | 2 | 35 | 287 | 121 |
| 2012 | 122 | 26 | 4 | 21 | 219 | 177 |
| 2013 | 49 | 33 | 1 | 6 | 274 | 211 |
| 2014 | 154 | 32 | 4 | 22 | 359 | 167 |
| 2015 | 76 | 55 | 3 | 12 | 225 | 178 |
| 2016 | 91 | 22 | 3 | 44 | 351 | 128 |
| 2017 | 75 | 26 | 9 | 2 | 283 | 119 |
| Average | 72 | 39 | 4 | 22 | 206 | 142 |

Table 13-5. Incidental catch of FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2013 - 2017. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/18/2017.

| Group Name | 2013 | 2014 | 2015 | 2016 | 2017 | Average |
|---|---|---|---|---|---|---|
| Pacific Ocean Perch | 11,555 | 15,283 | 17,566 | 20,402 | 16,339 | 16,229 |
| Northern Rockfish | 4,527 | 3,647 | 3,632 | 3,155 | 1,402 | 3,273 |
| GOA Dusky Rockfish | 2,870 | 2,752 | 2,492 | 3,004 | 2,077 | 2,639 |
| Arrowtooth Flounder | 766 | 1,425 | 1,397 | 1,200 | 1,248 | 1,207 |
| Pollock | 829 | 1,339 | 1,329 | 572 | 773 | 968 |
| Other Rockfish | 488 | 735 | 849 | 972 | 692 | 747 |
| Atka Mackerel | 1,162 | 446 | 988 | 595 | 483 | 735 |
| Pacific Cod | 584 | 624 | 785 | 365 | 223 | 516 |
| Sablefish | 495 | 527 | 434 | 481 | 524 | 492 |
| GOA Rougheye Rockfish | 274 | 359 | 225 | 351 | 283 | 298 |
| GOA Shortraker Rockfish | 290 | 243 | 238 | 291 | 224 | 257 |
| GOA Thornyhead Rockfish | 104 | 243 | 220 | 336 | 318 | 244 |
| GOA Rex Sole | 89 | 84 | 116 | 140 | 100 | 106 |
| GOA Demersal Shelf Rockfish | 135 | 38 | 39 | 40 | 40 | 59 |
| GOA Deep Water Flatfish | 37 | 68 | 44 | 64 | 47 | 52 |
| Sculpin | 70 | 33 | 44 | 43 | 43 | 47 |
| Flathead Sole | 26 | 30 | 46 | 26 | 74 | 40 |
| GOA Skate, Longnose | 23 | 26 | 33 | 46 | 37 | 33 |
| Shark | 93 | 2 | 6 | 12 | 24 | 28 |
| GOA Skate, Other | 18 | 45 | 21 | 18 | 21 | 25 |
| GOA Shallow Water Flatfish | 27 | 28 | 27 | 15 | 11 | 22 |
| Squid | 10 | 19 | 24 | 12 | 20 | 17 |
| Octopus | 2 | 7 | 11 | 2 | 1 | 5 |
| GOA Skate, Big | 2 | 4 | 7 | 5 | 2 | 4 |
| Halibut | Conf. | 1 | 0 | 1 | 6 | 2 |

Table 13-6. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2013 - 2017. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/18/2017.

| Group Name | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| Benthic urochordata | Conf. | Conf. | 0.28 | 0.50 | 0.20 |
| Birds - Northern Fulmar | - | Conf. | - | - | Conf. |
| Bivalves | Conf. | 0.01 | Conf. | Conf. | 0.009 |
| Brittle star unidentified | 0.02 | 0.05 | 0.05 | 0.03 | 0.60 |
| Capelin | 0.02 | - | - | Conf. | - |
| Corals Bryozoans - Corals Bryozoans Unidentified | 0.18 | 1.92 | 0.70 | 0.85 | 0.47 |
| Corals Bryozoans - Red Tree Coral | Conf. | Conf. | Conf. | - | - |
| Eelpouts | 0.04 | 0.13 | 0.01 | 0.02 | 0.81 |
| Eulachon | 0.07 | 0.02 | 0.03 | 0.04 | 0.13 |
| Giant Grenadier | 889 | 512 | 786 | 438 | 743 |
| Greenlings | 7 | 4 | 8 | 6 | 4 |
| Grenadier - Rattail Grenadier Unidentified | 28 | Conf. | 44 | 3 | Conf. |
| Gunnels | - | - | Conf. | - | - |
| Hermit crab unidentified | 0.03 | 0.04 | 0.03 | 0.01 | 0.03 |
| Invertebrate unidentified | 0.18 | Conf. | 0.19 | 0.09 | 0.06 |
| Lanternfishes (myctophidae) | Conf. | - | 0.04 | 0.14 | 0.00 |
| Misc crabs | 0.05 | 0.08 | 0.16 | 0.35 | 0.57 |
| Misc crustaceans | Conf. | Conf. | Conf. | 0.03 | 0.01 |
| Misc deep fish | Conf. | - | - | Conf. | Conf. |
| Misc fish | 160 | 125 | 143 | 102 | 110 |
| Misc inverts (worms etc) | - | - | - | Conf. | - |
| Other osmerids | 0.02 | Conf. | Conf. | 0.03 | Conf. |
| Pacific Hake | - | - | Conf. | 0.04 | Conf. |
| Pandalid shrimp | 0.06 | 0.10 | 0.05 | 0.22 | 0.14 |
| Polychaete unidentified | Conf. | - | - | - | 0.02 |
| Scypho jellies | 0.39 | 5.13 | 1.63 | 8.05 | 0.54 |
| Sea anemone unidentified | 4.02 | 2.15 | 1.14 | 1.27 | 0.69 |
| Sea pens whips | 0.04 | 0.06 | Conf. | 0.02 | 0.03 |
| Sea star | 0.89 | 1.60 | 3.48 | 1.72 | 3.00 |
| Snails | 0.15 | 0.10 | 0.26 | 0.18 | 0.17 |
| Sponge unidentified | 1.27 | 1.81 | 5.45 | 2.88 | 3.17 |
| State-managed Rockfish | 67 | 50 | 47 | 13 | 24 |
| Stichaeidae | Conf. | Conf. | Conf. | - | Conf. |
| urchins dollars cucumbers | 0.28 | 0.21 | 0.99 | 0.34 | 0.40 |

Table 13-7. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and counts of animals for crab and salmon, by year, for the GOA rockfish fishery 2013 - 2017. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/18/2017.

| Group Name | **2013** | **2014** | **2015** | **2016** | **2017** | **Average** |
|---|---|---|---|---|---|---|
| Bairdi Tanner Crab | 69 | 191 | 49 | 5 | 740 | 211 |
| Blue King Crab | 0 | 0 | 0 | 0 | 0 | 0 |
| Chinook Salmon | 2,320 | 1,247 | 1,906 | 383 | 167 | 1,205 |
| Golden (Brown) King Crab | 102 | 34 | 19 | 20 | 184 | 72 |
| Halibut | 113 | 127 | 157 | 124 | 102 | 125 |
| Herring | 0 | 0 | 0 | 0 | 0 | 0 |
| Non-Chinook Salmon | 2,020 | 555 | 337 | 216 | 561 | 738 |
| Opilio Tanner (Snow) Crab | 0 | 0 | 0 | 0 | 0 | 0 |
| Red King Crab | 0 | 0 | 0 | 0 | 0 | 0 |

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

| Age (years) | 1990 | 2004 | 2006 | 2008 | 2009 | 2010 | 2012 | 2014 | 2016 |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0041 | 0.0000 | 0.0000 | 0.0000 |
| 6 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0081 |
| 7 | 0.0033 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8 | 0.0033 | 0.0000 | 0.0000 | 0.0034 | 0.0000 | 0.0041 | 0.0000 | 0.0000 | 0.0027 |
| 9 | 0.0266 | 0.0000 | 0.0028 | 0.0103 | 0.0000 | 0.0083 | 0.0000 | 0.0045 | 0.0000 |
| 10 | 0.0498 | 0.0049 | 0.0000 | 0.0103 | 0.0097 | 0.0041 | 0.0000 | 0.0023 | 0.0054 |
| 11 | 0.0332 | 0.0000 | 0.0000 | 0.0069 | 0.0032 | 0.0165 | 0.0000 | 0.0068 | 0.0081 |
| 12 | 0.0266 | 0.0000 | 0.0083 | 0.0069 | 0.0000 | 0.0207 | 0.0061 | 0.0045 | 0.0161 |
| 13 | 0.0166 | 0.0049 | 0.0055 | 0.0172 | 0.0162 | 0.0165 | 0.0030 | 0.0091 | 0.0054 |
| 14 | 0.0365 | 0.0049 | 0.0083 | 0.0172 | 0.0032 | 0.0289 | 0.0182 | 0.0045 | 0.0134 |
| 15 | 0.0100 | 0.0171 | 0.0193 | 0.0137 | 0.0097 | 0.0165 | 0.0030 | 0.0091 | 0.0081 |
| 16 | 0.0066 | 0.0098 | 0.0193 | 0.0241 | 0.0325 | 0.0083 | 0.0121 | 0.0363 | 0.0081 |
| 17 | 0.0166 | 0.0122 | 0.0138 | 0.0412 | 0.0195 | 0.0124 | 0.0121 | 0.0204 | 0.0242 |
| 18 | 0.0033 | 0.0073 | 0.0055 | 0.0344 | 0.0162 | 0.0248 | 0.0182 | 0.0204 | 0.0215 |
| 19 | 0.0166 | 0.0196 | 0.0110 | 0.0515 | 0.0325 | 0.0372 | 0.0030 | 0.0249 | 0.0242 |
| 20 | 0.0133 | 0.0416 | 0.0110 | 0.0928 | 0.0552 | 0.0207 | 0.0152 | 0.0363 | 0.0323 |
| 21 | 0.0133 | 0.0391 | 0.0138 | 0.0275 | 0.0260 | 0.0413 | 0.0212 | 0.0295 | 0.0242 |
| 22 | 0.0133 | 0.0440 | 0.0303 | 0.0412 | 0.0325 | 0.0248 | 0.0091 | 0.0227 | 0.0430 |
| 23 | 0.0100 | 0.0465 | 0.0331 | 0.0206 | 0.0260 | 0.0165 | 0.0364 | 0.0522 | 0.0134 |
| 24 | 0.0199 | 0.0367 | 0.0441 | 0.0206 | 0.0162 | 0.0165 | 0.0242 | 0.0204 | 0.0376 |
| 25 | 0.0199 | 0.0318 | 0.0468 | 0.0447 | 0.0519 | 0.0620 | 0.0152 | 0.0340 | 0.0403 |
| 26 | 0.0266 | 0.0171 | 0.0358 | 0.0447 | 0.0519 | 0.0165 | 0.0152 | 0.0272 | 0.0323 |
| 27 | 0.0365 | 0.0244 | 0.0331 | 0.0172 | 0.0519 | 0.0289 | 0.0212 | 0.0317 | 0.0349 |
| 28 | 0.0133 | 0.0196 | 0.0331 | 0.0412 | 0.0422 | 0.0413 | 0.0273 | 0.0317 | 0.0349 |
| 29 | 0.0498 | 0.0269 | 0.0413 | 0.0206 | 0.0357 | 0.0455 | 0.0212 | 0.0476 | 0.0296 |
| 30 | 0.0365 | 0.0196 | 0.0165 | 0.0103 | 0.0519 | 0.0207 | 0.0545 | 0.0476 | 0.0376 |
| 31 | 0.0399 | 0.0367 | 0.0275 | 0.0241 | 0.0195 | 0.0413 | 0.0545 | 0.0227 | 0.0134 |
| 32 | 0.0266 | 0.0318 | 0.0275 | 0.0275 | 0.0357 | 0.0413 | 0.0273 | 0.0431 | 0.0242 |
| 33 | 0.0399 | 0.0244 | 0.0165 | 0.0447 | 0.0195 | 0.0124 | 0.0182 | 0.0385 | 0.0349 |
| 34 | 0.0498 | 0.0244 | 0.0165 | 0.0137 | 0.0097 | 0.0124 | 0.0273 | 0.0340 | 0.0376 |
| 35 | 0.0365 | 0.0244 | 0.0138 | 0.0000 | 0.0325 | 0.0207 | 0.0152 | 0.0385 | 0.0296 |
| 36 | 0.0432 | 0.0293 | 0.0358 | 0.0103 | 0.0162 | 0.0165 | 0.0333 | 0.0227 | 0.0296 |
| 37 | 0.0299 | 0.0098 | 0.0193 | 0.0206 | 0.0130 | 0.0248 | 0.0182 | 0.0204 | 0.0081 |
| 38 | 0.0100 | 0.0342 | 0.0193 | 0.0069 | 0.0292 | 0.0165 | 0.0182 | 0.0136 | 0.0134 |
| 39 | 0.0233 | 0.0269 | 0.0083 | 0.0241 | 0.0130 | 0.0207 | 0.0212 | 0.0091 | 0.0108 |
| 40 | 0.0266 | 0.0318 | 0.0275 | 0.0137 | 0.0162 | 0.0124 | 0.0212 | 0.0136 | 0.0215 |
| 41 | 0.0166 | 0.0147 | 0.0386 | 0.0034 | 0.0195 | 0.0041 | 0.0182 | 0.0181 | 0.0134 |
| 42+ | 0.1561 | 0.2836 | 0.3168 | 0.1924 | 0.1916 | 0.2397 | 0.3909 | 0.2018 | 0.2581 |
| Sample size | 301 | 409 | 363 | 291 | 308 | 242 | 330 | 441 | 372 |

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

| Length (cm) | 1991 | 1992 | 2002 | 2003 | 2005 | 2007 | 2011 | 2013 | 2015 |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 0.0000 | 0.0000 | 0.0000 | 0.0004 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 22 | 0.0000 | 0.0056 | 0.0087 | 0.0000 | 0.0007 | 0.0007 | 0.0010 | 0.0030 | 0.0006 |
| 24 | 0.0010 | 0.0065 | 0.0058 | 0.0012 | 0.0013 | 0.0007 | 0.0010 | 0.0040 | 0.0034 |
| 26 | 0.0021 | 0.0084 | 0.0087 | 0.0020 | 0.0013 | 0.0048 | 0.0020 | 0.0069 | 0.0028 |
| 28 | 0.0063 | 0.0130 | 0.0029 | 0.0040 | 0.0047 | 0.0054 | 0.0061 | 0.0040 | 0.0067 |
| 30 | 0.0042 | 0.0297 | 0.0058 | 0.0032 | 0.0074 | 0.0122 | 0.0081 | 0.0050 | 0.0073 |
| 32 | 0.0094 | 0.0270 | 0.0058 | 0.0064 | 0.0067 | 0.0115 | 0.0304 | 0.0099 | 0.0101 |
| 34 | 0.0125 | 0.0362 | 0.0145 | 0.0095 | 0.0134 | 0.0258 | 0.0314 | 0.0099 | 0.0201 |
| 36 | 0.0104 | 0.0455 | 0.0174 | 0.0139 | 0.0315 | 0.0326 | 0.0354 | 0.0188 | 0.0195 |
| 38 | 0.0261 | 0.0660 | 0.0378 | 0.0382 | 0.0308 | 0.0605 | 0.0354 | 0.0386 | 0.0363 |
| 40 | 0.0396 | 0.1004 | 0.0494 | 0.0545 | 0.0455 | 0.0713 | 0.0840 | 0.0960 | 0.0581 |
| 42 | 0.1585 | 0.1087 | 0.1453 | 0.1010 | 0.0717 | 0.0965 | 0.1083 | 0.1327 | 0.1027 |
| 44 | 0.2857 | 0.1645 | 0.1657 | 0.1427 | 0.1165 | 0.1209 | 0.1235 | 0.1455 | 0.1212 |
| 46 | 0.2221 | 0.1292 | 0.1948 | 0.1924 | 0.1514 | 0.1461 | 0.1306 | 0.1297 | 0.1619 |
| 48 | 0.1512 | 0.0790 | 0.1395 | 0.1717 | 0.1541 | 0.1352 | 0.1407 | 0.1119 | 0.1519 |
| 50 | 0.0448 | 0.0465 | 0.1134 | 0.1125 | 0.1306 | 0.1175 | 0.1113 | 0.0634 | 0.1223 |
| 52 | 0.0136 | 0.0344 | 0.0465 | 0.0719 | 0.0884 | 0.0822 | 0.0577 | 0.0416 | 0.0698 |
| 54 | 0.0042 | 0.0362 | 0.0145 | 0.0322 | 0.0583 | 0.0299 | 0.0425 | 0.0386 | 0.0402 |
| 56 | 0.0063 | 0.0251 | 0.0116 | 0.0199 | 0.0275 | 0.0190 | 0.0202 | 0.0436 | 0.0179 |
| 58 | 0.0010 | 0.0167 | 0.0058 | 0.0079 | 0.0221 | 0.0129 | 0.0162 | 0.0228 | 0.0162 |
| 60+ | 0.0010 | 0.0214 | 0.0058 | 0.0147 | 0.0362 | 0.0143 | 0.0142 | 0.0743 | 0.0313 |
| Sample size | 959 | 1,077 | 344 | 2,516 | 1,493 | 1,472 | 988 | 1,010 | 1,793 |

Table 13-10. GOA RE/BS rockfish biomass estimates from NMFS triennial/biennial trawl surveys by region and gulfwide for 1984-2017. No sampling was performed in the Eastern GOA for the 2001 survey and we exclude this year from our assessment model. Estimates for the Western and Central GOA are provided here for reference. CV is the coefficient of variation expressed as a percent and provided in parentheses next to the biomass estimate. SE is the standard error. LCI and UCI are the lower and upper 95% confidence intervals respectively. SE, LCI, UCI are respective to the gulfwide biomass estimates.

| Year | Western | | Central | | Eastern | | Gulfwide | | SE | LCI | UCI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1984 | 8,779 | (32) | 32,416 | (21) | 3,896 | (20) | 45,091 | (16) | 7,313 | 30,758 | 59,425 |
| 1987 | 2,737 | (34) | 21,881 | (16) | 19,063 | (17) | 43,681 | (11) | 4,897 | 34,083 | 53,278 |
| 1990 | 1,329 | (48) | 35,467 | (26) | 8,041 | (19) | 44,837 | (21) | 9,296 | 26,617 | 63,057 |
| 1993 | 10,891 | (79) | 41,616 | (28) | 9,358 | (21) | 61,864 | (23) | 14,415 | 33,611 | 90,117 |
| 1996 | 3,449 | (35) | 28,396 | (23) | 14,067 | (23) | 45,913 | (16) | 7,432 | 31,346 | 60,481 |
| 1999 | 6,156 | (51) | 20,781 | (17) | 12,622 | (26) | 39,560 | (15) | 5,793 | 28,206 | 50,913 |
| 2001 | 6,945 | (55) | 24,740 | (24) | NA | NA | -- | -- | -- | -- | -- |
| 2003 | 8,921 | (34) | 24,610 | (20) | 9,670 | (36) | 43,202 | (16) | 6,724 | 30,024 | 56,380 |
| 2005 | 3,621 | (26) | 32,898 | (25) | 11,356 | (16) | 47,875 | (18) | 8,618 | 30,983 | 64,767 |
| 2007 | 3,773 | (27) | 39,419 | (24) | 16,697 | (23) | 59,889 | (17) | 10,380 | 39,544 | 80,234 |
| 2009 | 2,765 | (27) | 33,154 | (21) | 14,855 | (30) | 50,774 | (16) | 8,297 | 34,512 | 67,035 |
| 2011 | 3,305 | (43) | 32,181 | (21) | 8,228 | (17) | 43,714 | (16) | 7,065 | 29,866 | 57,561 |
| 2013 | 3,922 | (24) | 11,207 | (29) | 12,452 | (30) | 27,581 | (18) | 5,078 | 17,627 | 37,534 |
| 2015 | 1,345 | (22) | 18,135 | (20) | 15,079 | (22) | 34,559 | (14) | 4,970 | 24,817 | 44,301 |
| 2017 | 6,722 | (45) | 11,297 | (21) | 21,900 | (28) | 39,919 | (18) | 7,185 | 25,836 | 54,002 |

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

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

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

| Age (yr) | 2009 | 2011 | 2013 | 2015 |
|---|---|---|---|---|
| 3 | 0.0113 | 0.0125 | 0.0490 | 0.0055 |
| 4 | 0.0099 | 0.0096 | 0.0367 | 0.0125 |
| 5 | 0.0191 | 0.0578 | 0.0357 | 0.0831 |
| 6 | 0.0498 | 0.0324 | 0.0360 | 0.0434 |
| 7 | 0.0349 | 0.0493 | 0.0700 | 0.0400 |
| 8 | 0.0608 | 0.0429 | 0.0555 | 0.0416 |
| 9 | 0.0438 | 0.0982 | 0.0387 | 0.0676 |
| 10 | 0.0389 | 0.0438 | 0.0480 | 0.0680 |
| 11 | 0.0561 | 0.0765 | 0.0674 | 0.0583 |
| 12 | 0.0377 | 0.0766 | 0.0669 | 0.0601 |
| 13 | 0.0378 | 0.0560 | 0.0561 | 0.0553 |
| 14 | 0.0369 | 0.0408 | 0.0387 | 0.0725 |
| 15 | 0.0506 | 0.0544 | 0.0302 | 0.0481 |
| 16 | 0.0441 | 0.0273 | 0.0296 | 0.0475 |
| 17 | 0.0374 | 0.0257 | 0.0250 | 0.0395 |
| 18 | 0.0309 | 0.0151 | 0.0178 | 0.0502 |
| 19 | 0.0250 | 0.0260 | 0.0117 | 0.0094 |
| 20 | 0.0414 | 0.0089 | 0.0202 | 0.0169 |
| 21 | 0.0199 | 0.0176 | 0.0127 | 0.0212 |
| 22 | 0.0240 | 0.0230 | 0.0244 | 0.0115 |
| 23 | 0.0182 | 0.0095 | 0.0142 | 0.0173 |
| 24 | 0.0202 | 0.0250 | 0.0104 | 0.0122 |
| 25 | 0.0258 | 0.0179 | 0.0141 | 0.0155 |
| 26 | 0.0229 | 0.0123 | 0.0111 | 0.0067 |
| 27 | 0.0083 | 0.0253 | 0.0157 | 0.0051 |
| 28 | 0.0145 | 0.0126 | 0.0081 | 0.0103 |
| 29 | 0.0139 | 0.0085 | 0.0093 | 0.0050 |
| 30 | 0.0217 | 0.0069 | 0.0111 | 0.0060 |
| 31 | 0.0128 | 0.0184 | 0.0092 | 0.0159 |
| 32 | 0.0127 | 0.0060 | 0.0070 | 0.0061 |
| 33 | 0.0194 | 0.0013 | 0.0077 | 0.0042 |
| 34 | 0.0072 | 0.0077 | 0.0040 | 0.0024 |
| 35 | 0.0063 | 0.0070 | 0.0129 | 0.0036 |
| 36 | 0.0086 | 0.0054 | 0.0042 | 0.0019 |
| 37 | 0.0029 | 0.0035 | 0.0025 | 0.0044 |
| 38 | 0.0044 | 0.0029 | 0.0076 | 0.0011 |
| 39 | 0.0040 | 0.0032 | 0.0053 | 0.0036 |
| 40 | 0.0048 | 0.0054 | 0.0053 | 0.0051 |
| 41 | 0.0029 | 0.0011 | 0.0035 | 0.0050 |
| 42+ | 0.0585 | 0.0256 | 0.0667 | 0.0162 |
| Sample size | 928 | 402 | 1,057 | 518 |

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

| Length (cm) | 1984 | 1987 | 1990 | 1993 | 1996 | 1999 | 2001 | 2003 | 2005 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 0.0068 | 0.0143 | 0.0133 | 0.0158 | 0.0380 | 0.0751 | 0.0223 | 0.0602 | 0.0481 | 0.0399 |
| 22 | 0.0162 | 0.0328 | 0.0173 | 0.0176 | 0.0509 | 0.0625 | 0.0360 | 0.0579 | 0.0523 | 0.0393 |
| 24 | 0.0258 | 0.0314 | 0.0244 | 0.0236 | 0.0540 | 0.0501 | 0.0421 | 0.0437 | 0.0548 | 0.0488 |
| 26 | 0.0236 | 0.0294 | 0.0271 | 0.0288 | 0.0485 | 0.0416 | 0.0498 | 0.0423 | 0.0636 | 0.0443 |
| 28 | 0.0190 | 0.0286 | 0.0428 | 0.0341 | 0.0382 | 0.0552 | 0.0594 | 0.0484 | 0.0667 | 0.0421 |
| 30 | 0.0331 | 0.0404 | 0.0626 | 0.0472 | 0.0511 | 0.0699 | 0.0517 | 0.0570 | 0.0652 | 0.0470 |
| 32 | 0.0369 | 0.0515 | 0.0854 | 0.0519 | 0.0509 | 0.0642 | 0.0448 | 0.0579 | 0.0589 | 0.0462 |
| 34 | 0.0449 | 0.0572 | 0.1022 | 0.0692 | 0.0463 | 0.0685 | 0.0614 | 0.0473 | 0.0659 | 0.0469 |
| 36 | 0.0562 | 0.0727 | 0.1201 | 0.0772 | 0.0623 | 0.0621 | 0.0706 | 0.0418 | 0.0603 | 0.0557 |
| 38 | 0.0578 | 0.0721 | 0.0869 | 0.1068 | 0.0639 | 0.0720 | 0.0884 | 0.0525 | 0.0701 | 0.0803 |
| 40 | 0.0841 | 0.0817 | 0.0695 | 0.1240 | 0.0858 | 0.0788 | 0.0970 | 0.0680 | 0.0781 | 0.0873 |
| 42 | 0.1448 | 0.0858 | 0.0622 | 0.1337 | 0.1158 | 0.0821 | 0.1341 | 0.1003 | 0.0835 | 0.1063 |
| 44 | 0.1660 | 0.1147 | 0.0938 | 0.1259 | 0.1117 | 0.0802 | 0.0965 | 0.1146 | 0.0791 | 0.1159 |
| 46 | 0.1200 | 0.1120 | 0.0820 | 0.0764 | 0.0816 | 0.0614 | 0.0668 | 0.0963 | 0.0480 | 0.0794 |
| 48 | 0.0773 | 0.0872 | 0.0464 | 0.0323 | 0.0464 | 0.0369 | 0.0410 | 0.0598 | 0.0320 | 0.0521 |
| 50 | 0.0398 | 0.0418 | 0.0225 | 0.0116 | 0.0236 | 0.0220 | 0.0164 | 0.0261 | 0.0272 | 0.0332 |
| 52 | 0.0191 | 0.0223 | 0.0101 | 0.0067 | 0.0149 | 0.0076 | 0.0085 | 0.0099 | 0.0140 | 0.0167 |
| 54 | 0.0094 | 0.0080 | 0.0094 | 0.0036 | 0.0053 | 0.0033 | 0.0028 | 0.0069 | 0.0087 | 0.0096 |
| 56 | 0.0057 | 0.0054 | 0.0073 | 0.0034 | 0.0061 | 0.0017 | 0.0052 | 0.0029 | 0.0070 | 0.0036 |
| 58 | 0.0044 | 0.0034 | 0.0052 | 0.0031 | 0.0025 | 0.0023 | 0.0018 | 0.0022 | 0.0045 | 0.0022 |
| 60+ | 0.0090 | 0.0073 | 0.0096 | 0.0070 | 0.0024 | 0.0027 | 0.0034 | 0.0040 | 0.0121 | 0.0031 |
| Sample size | 4,701 | 3,994 | 3,522 | 5,639 | 3,943 | 3,758 | 1,959 | 2,924 | 4,089 | 4,253 |

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

| Length (cm) | 2009 | 2011 | 2013 | 2015 | 2017 |
|---|---|---|---|---|---|
| 20 | 0.0402 | 0.0366 | 0.0637 | 0.0604 | 0.0359 |
| 22 | 0.0545 | 0.0510 | 0.0516 | 0.0638 | 0.0318 |
| 24 | 0.0593 | 0.0525 | 0.0526 | 0.0623 | 0.0561 |
| 26 | 0.0691 | 0.0599 | 0.0516 | 0.0510 | 0.0836 |
| 28 | 0.0553 | 0.0571 | 0.0598 | 0.0593 | 0.0892 |
| 30 | 0.0598 | 0.0708 | 0.0450 | 0.0534 | 0.0621 |
| 32 | 0.0441 | 0.0544 | 0.0489 | 0.0617 | 0.0671 |
| 34 | 0.0425 | 0.0629 | 0.0562 | 0.0726 | 0.0741 |
| 36 | 0.0466 | 0.0604 | 0.0724 | 0.0752 | 0.0633 |
| 38 | 0.0527 | 0.0639 | 0.0857 | 0.0847 | 0.0751 |
| 40 | 0.0691 | 0.0825 | 0.0872 | 0.0916 | 0.0628 |
| 42 | 0.0797 | 0.0987 | 0.0844 | 0.0780 | 0.0708 |
| 44 | 0.0901 | 0.0859 | 0.0595 | 0.0545 | 0.0564 |
| 46 | 0.0879 | 0.0598 | 0.0627 | 0.0465 | 0.0594 |
| 48 | 0.0661 | 0.0477 | 0.0449 | 0.0310 | 0.0428 |
| 50 | 0.0406 | 0.0250 | 0.0383 | 0.0188 | 0.0277 |
| 52 | 0.0239 | 0.0110 | 0.0183 | 0.0120 | 0.0188 |
| 54 | 0.0090 | 0.0099 | 0.0078 | 0.0088 | 0.0048 |
| 56 | 0.0041 | 0.0034 | 0.0046 | 0.0044 | 0.0025 |
| 58 | 0.0026 | 0.0017 | 0.0020 | 0.0042 | 0.0033 |
| 60+ | 0.0024 | 0.0048 | 0.0026 | 0.0057 | 0.0125 |
| Sample size | 4,155 | 2,475 | 1,692 | 2,588 | 2,173 |

Table 13-13. GOA RE/BS rockfish relative population numbers (RPN) estimated from the AFSC longline survey by region and gulfwide for 1993-2017. CV is the coefficient of variation expressed as a percent and provided in parentheses next to the RPN. SE is the standard error. LCI and UCI are the lower and upper 95% confidence intervals respectively. SE, LCI, UCI are respective to the gulfwide RPNs.

| | Western | | Central | | Eastern | | Gulfwide | | SE | LCI | UCI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1993 | 6,286 | (44.0) | 5,279 | (31.5) | 11,704 | (24.8) | 23,269 | (18.6) | 4,336 | 14,770 | 31,768 |
| 1994 | 4,371 | (37.4) | 2,513 | (31.7) | 15,737 | (21.8) | 22,622 | (17.2) | 3,885 | 15,007 | 30,236 |
| 1995 | 9,988 | (38.5) | 7,962 | (27.1) | 9,522 | (21.8) | 27,472 | (17.7) | 4,875 | 17,917 | 37,027 |
| 1996 | 5,675 | (45.3) | 5,613 | (33.6) | 14,337 | (18.2) | 25,624 | (16.1) | 4,122 | 17,545 | 33,703 |
| 1997 | 7,314 | (46.6) | 7,729 | (38.4) | 22,027 | (27.6) | 37,070 | (20.4) | 7,578 | 22,216 | 51,923 |
| 1998 | 6,032 | (30.6) | 5,751 | (38.2) | 12,787 | (12.5) | 24,570 | (13.4) | 3,284 | 18,134 | 31,006 |
| 1999 | 6,112 | (28.7) | 6,338 | (35.3) | 14,803 | (21.2) | 27,254 | (15.5) | 4,238 | 18,948 | 35,560 |
| 2000 | 10,454 | (36.7) | 8,917 | (29.5) | 18,522 | (19.3) | 37,894 | (15.5) | 5,860 | 26,408 | 49,380 |
| 2001 | 9,039 | (38.0) | 8,990 | (30.1) | 11,493 | (22.1) | 29,523 | (17.1) | 5,056 | 19,613 | 39,432 |
| 2002 | 9,792 | (34.0) | 7,454 | (36.0) | 10,271 | (16.1) | 27,517 | (16.6) | 4,581 | 18,538 | 36,496 |
| 2003 | 6,003 | (35.3) | 5,231 | (38.6) | 13,155 | (19.4) | 24,389 | (15.9) | 3,883 | 16,778 | 32,001 |
| 2004 | 10,312 | (42.5) | 4,479 | (36.9) | 13,122 | (17.5) | 27,913 | (18.7) | 5,222 | 17,678 | 38,149 |
| 2005 | 3,031 | (56.9) | 5,777 | (32.9) | 10,055 | (25.9) | 18,863 | (19.4) | 3,657 | 11,695 | 26,031 |
| 2006 | 5,240 | (32.8) | 6,320 | (35.9) | 8,918 | (17.8) | 20,478 | (15.9) | 3,262 | 14,085 | 26,871 |
| 2007 | 11,064 | (39.1) | 9,315 | (27.3) | 13,285 | (18.2) | 33,663 | (16.5) | 5,570 | 22,747 | 44,579 |
| 2008 | 6,407 | (38.2) | 7,414 | (24.1) | 17,139 | (21.0) | 30,960 | (15.2) | 4,700 | 21,747 | 40,173 |
| 2009 | 7,213 | (36.1) | 10,790 | (41.1) | 11,749 | (13.9) | 29,751 | (18.1) | 5,398 | 19,172 | 40,331 |
| 2010 | 12,746 | (35.4) | 7,741 | (31.0) | 14,801 | (14.7) | 35,288 | (15.7) | 5,549 | 24,412 | 46,165 |
| 2011 | 13,344 | (45.3) | 8,863 | (32.7) | 17,576 | (26.5) | 39,783 | (20.5) | 8,164 | 23,781 | 55,785 |
| 2012 | 7,967 | (36.9) | 5,364 | (41.9) | 13,632 | (24.8) | 26,962 | (18.6) | 5,016 | 17,130 | 36,795 |
| 2013 | 9,493 | (43.9) | 5,420 | (33.4) | 9,026 | (22.0) | 23,939 | (20.7) | 4,960 | 14,217 | 33,661 |
| 2014 | 8,827 | (40.5) | 7,030 | (36.0) | 17,607 | (20.1) | 33,464 | (16.8) | 5,629 | 22,430 | 44,497 |
| 2015 | 10,894 | (44.6) | 6,482 | (45.0) | 14,073 | (20.1) | 31,448 | (20.1) | 6,337 | 19,028 | 43,868 |
| 2016 | 9,632 | (40.5) | 5,055 | (28.4) | 9,864 | (24.2) | 24,552 | (19.5) | 4,793 | 15,156 | 33,947 |
| 2017 | 13,239 | (34.9) | 9,034 | (44.7) | 14,434 | (19.6) | 36,707 | (18.4) | 6,754 | 23,469 | 49,945 |

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

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

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

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

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

| Length (cm) | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| 20 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 22 | 0.0000 | 0.0000 | 0.0000 | 0.0008 | 0.0003 |
| 24 | 0.0001 | 0.0001 | 0.0007 | 0.0002 | 0.0009 |
| 26 | 0.0028 | 0.0535 | 0.0007 | 0.0005 | 0.0028 |
| 28 | 0.0075 | 0.0037 | 0.0041 | 0.0051 | 0.0048 |
| 30 | 0.0276 | 0.0128 | 0.0064 | 0.0108 | 0.0166 |
| 32 | 0.0427 | 0.0219 | 0.0215 | 0.0270 | 0.0320 |
| 34 | 0.0568 | 0.0406 | 0.0177 | 0.0421 | 0.0578 |
| 36 | 0.0925 | 0.0577 | 0.0453 | 0.0587 | 0.0597 |
| 38 | 0.0755 | 0.0732 | 0.0565 | 0.0665 | 0.0618 |
| 40 | 0.0922 | 0.1031 | 0.0796 | 0.0980 | 0.0946 |
| 42 | 0.1029 | 0.1090 | 0.1317 | 0.0939 | 0.1128 |
| 44 | 0.1252 | 0.1154 | 0.1558 | 0.1134 | 0.1397 |
| 46 | 0.1267 | 0.1101 | 0.1383 | 0.1250 | 0.1387 |
| 48 | 0.1068 | 0.1069 | 0.1128 | 0.1219 | 0.1163 |
| 50 | 0.0628 | 0.0768 | 0.0969 | 0.0928 | 0.0721 |
| 52 | 0.0299 | 0.0438 | 0.0609 | 0.0640 | 0.0411 |
| 54 | 0.0177 | 0.0231 | 0.0279 | 0.0396 | 0.0217 |
| 56 | 0.0089 | 0.0161 | 0.0195 | 0.0181 | 0.0098 |
| 58 | 0.0139 | 0.0101 | 0.0166 | 0.0069 | 0.0088 |
| 60+ | 0.0077 | 0.0221 | 0.0072 | 0.0148 | 0.0076 |
| Sample size | 3,744 | 6,820 | 5,382 | 4,478 | 6,011 |

Table 13-15. Likelihoods and MLE estimates of key parameters with estimates of standard error (σ) derived from the Hessian matrix for the last full assessment model and the current author preferred model for GOA RE/BS. Note that the amounts of data differ between the 2015 and 2017 model update so likelihood component values are not comparable.

| | | ***2015 ( Model 15.4)*** | ***2017 (Model 15.4)*** |
|---|---|---|---|
| **Likelihoods** | Weight | | |
| Catch | 5/50* | 0.023 | 0.017 |
| Trawl Biomass | 1 | 8.807 | 8.629 |
| Longline Biomass | 1 | 13.650 | 15.053 |
| Fishery Ages | 1 | 19.608 | 25.866 |
| Trawl Survey Ages | 1 | 35.682 | 37.009 |
| Fishery Sizes | 1 | 55.695 | 61.141 |
| Trawl Survey Sizes | 0 | 0 | 0.000 |
| Longline Survey Sizes | 1 | 98.277 | 104.056 |
| *Data-Likelihood* | | 231.743 | 251.770 |
| **Penalties/Priors** | | | |
| Recruit Deviations | 1 | -11.943 | -12.983 |
| Selectivity Penalties | | | |
| Fishery | 1 | 1.997 | 2.224 |
| Fishery Domeshape | 1 | 0 | 0.001 |
| Trawl Survey | 1 | 0 | 0 |
| Trawl Domeshape | 1 | 0 | 0 |
| Longline | 1 | 0.259 | 0.282 |
| Longline Domeshape | 1 | 0 | 0.004 |
| F Regularity | 0.1 | 1.126 | 1.153 |
| $\sigma_r$ prior | | 11.298 | 11.877 |
| $q$-trawl | | 0.004 | 0.004 |
| $q$-longline | | 0.000 | 0.000 |
| M | | 1.540 | 1.547 |
| *Total penalties/priors* | | 4.281 | 4.108 |
| ***Objective Fun. Total*** | | 236.025 | 255.878 |
| **Parameter Estimates** | | | |
| Number Parameters | | 166 | 170 |
| $q$-trawl | | 1.602 | 1.525 |
| $q$-longline | | 1.008 | 0.983 |
| $M$ | | 0.036 | 0.036 |
| $\sigma_r$ | | 0.814 | 0.808 |
| Mean Recruitment (mil) | | 1.775 | 1.914 |
| $F_{40\%}$ | | 0.040 | 0.040 |
| Total Biomass (t) | | 41,863 | 45,624 |
| Spawning Biomass (t) | | 13,803 | 15,059 |
| $B_{100\%}$ (t) | | 20,566 | 22,495 |
| $B_{40\%}$ (t) | | 8,226 | 8,998 |
| ***$ABC_{F40\%}$ (t)*** | | 1,328 | 1,444 |

Table 13-16. Estimated GOA RE/BS rockfish population numbers (thousands) in 2017, 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.

| Age | Numbers in 2017 (1000s) | Percent Mature | Weight (g) | Fishery Selectivity | Trawl Survey Selectivity | LL Survey Selectivity |
|---|---|---|---|---|---|---|
| 3 | 1,732 | 0 | 53 | 0 | 21 | 0 |
| 4 | 1,671 | 0 | 99 | 0 | 40 | 0 |
| 5 | 1,462 | 0 | 159 | 0 | 55 | 0 |
| 6 | 1,357 | 0 | 228 | 1 | 67 | 0 |
| 7 | 3,096 | 0 | 306 | 1 | 77 | 0 |
| 8 | 1,699 | 0 | 388 | 3 | 85 | 0 |
| 9 | 1,373 | 0 | 473 | 5 | 91 | 1 |
| 10 | 1,115 | 1 | 558 | 7 | 95 | 2 |
| 11 | 1,754 | 2 | 642 | 8 | 98 | 6 |
| 12 | 1,240 | 5 | 723 | 8 | 99 | 17 |
| 13 | 1,057 | 8 | 801 | 8 | 100 | 36 |
| 14 | 1,116 | 14 | 875 | 12 | 100 | 63 |
| 15 | 1,389 | 22 | 945 | 29 | 99 | 85 |
| 16 | 1,554 | 31 | 1010 | 100 | 97 | 100 |
| 17 | 1,368 | 40 | 1070 | 100 | 95 | 94 |
| 18 | 746 | 50 | 1125 | 100 | 93 | 94 |
| 19 | 1,335 | 59 | 1176 | 100 | 90 | 94 |
| 20 | 982 | 66 | 1222 | 100 | 87 | 94 |
| 21 | 729 | 72 | 1265 | 100 | 84 | 94 |
| 22 | 1,094 | 77 | 1303 | 100 | 81 | 94 |
| 23 | 1,211 | 81 | 1338 | 100 | 78 | 94 |
| 24 | 611 | 84 | 1369 | 100 | 74 | 94 |
| 25 | 498 | 92 | 1398 | 100 | 71 | 94 |
| 26 | 525 | 92 | 1423 | 100 | 68 | 94 |
| 27 | 1,491 | 92 | 1446 | 100 | 64 | 94 |
| 28 | 402 | 92 | 1467 | 100 | 61 | 94 |
| 29 | 380 | 92 | 1485 | 100 | 58 | 94 |
| 30 | 341 | 92 | 1502 | 100 | 55 | 94 |
| 31 | 340 | 92 | 1517 | 100 | 52 | 94 |
| 32 | 382 | 92 | 1530 | 100 | 49 | 94 |
| 33 | 457 | 92 | 1542 | 100 | 46 | 94 |
| 34 | 521 | 92 | 1553 | 100 | 44 | 94 |
| 35 | 461 | 92 | 1562 | 100 | 41 | 94 |
| 36 | 733 | 92 | 1571 | 100 | 39 | 94 |
| 37 | 678 | 92 | 1578 | 100 | 36 | 94 |
| 38 | 349 | 92 | 1585 | 100 | 34 | 94 |
| 39 | 274 | 92 | 1591 | 100 | 32 | 94 |

Table 13-16 (continued). Estimated GOA RE/BS rockfish population numbers (thousands) in 2017, 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.

| Age | Numbers in 2017 (1000s) | Percent Mature | Weight (g) | Fishery Selectivity | Trawl Survey Selectivity | LL Survey Selectivity |
|---|---|---|---|---|---|---|
| 40 | 293 | 92 | 1596 | 100 | 30 | 94 |
| 41 | 889 | 92 | 1601 | 100 | 28 | 94 |
| 42 | 299 | 92 | 1605 | 100 | 26 | 94 |
| 43 | 233 | 92 | 1609 | 100 | 25 | 94 |
| 44 | 222 | 92 | 1612 | 100 | 23 | 94 |
| 45 | 224 | 92 | 1615 | 100 | 22 | 94 |
| 46 | 214 | 92 | 1618 | 100 | 20 | 94 |
| 47 | 229 | 92 | 1620 | 100 | 19 | 94 |
| 48 | 276 | 92 | 1622 | 100 | 18 | 94 |
| 49 | 270 | 92 | 1624 | 100 | 16 | 94 |
| 50 | 220 | 92 | 1626 | 100 | 15 | 94 |
| 51 | 191 | 92 | 1627 | 100 | 14 | 94 |
| 52 | 4,788 | 92 | 1634 | 100 | 13 | 94 |

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 (2017), ABC is acceptable biological catch, and $\sigma_r$ is the recruitment standard deviation parameter.

| | $\mu$ | | $\sigma$ | | MCMC | | |
|---|---|---|---|---|---|---|---|
| Parameter | Hessian | MCMC | Hessian | MCMC | Median | BCI-Lower | BCI-Upper |
| $q_1$, trawl survey | 1.5251 | 1.3374 | 0.5527 | 0.5204 | 1.3243 | 0.3832 | 2.4047 |
| $q_2$, longline survey | 0.9827 | 1.0109 | 0.4231 | 0.4127 | 0.9858 | 0.2991 | 1.9011 |
| $M$ | 0.0358 | 0.0360 | 0.0030 | 0.0032 | 0.0359 | 0.0302 | 0.0427 |
| $F_{40\%}$ | 0.0398 | 0.0457 | 0.0108 | 0.0143 | 0.0437 | 0.0251 | 0.0790 |
| SSB (2017) | 15,056 | 22,877 | 6,226 | 27,293 | 17,122 | 8,599 | 65,290 |
| ABC | 1,444 | 2,545 | 747 | 3,156 | 1,831 | 709 | 8,013 |
| $\sigma_r$ | 0.8082 | 1.0522 | 0.0511 | 0.0654 | 1.0488 | 0.9304 | 1.1841 |

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, 1977-2017. Estimates are shown for the author preferred model (MLE approach) and from the previous full assessment in 2015.

| | Spawning Biomass (t) | | 6+ Biomass (t) | | Catch/6+ Biomass | | Age 3 Recruits (1000's) | |
|---|---|---|---|---|---|---|---|---|
| Year | Previous | Current | Previous | Current | Previous | Current | Previous | Current |
| 1977 | 19,310 | 20,550 | 54,064 | 57,506 | 0.027 | 0.025 | 1,383 | 1,513 |
| 1978 | 18,890 | 20,141 | 52,780 | 56,228 | 0.011 | 0.010 | 1,646 | 1,774 |
| 1979 | 18,812 | 20,073 | 52,334 | 55,788 | 0.012 | 0.012 | 4,671 | 4,982 |
| 1980 | 18,684 | 19,954 | 51,770 | 55,232 | 0.026 | 0.024 | 1,438 | 1,548 |
| 1981 | 18,244 | 19,519 | 50,533 | 54,001 | 0.014 | 0.013 | 1,288 | 1,372 |
| 1982 | 18,055 | 19,334 | 50,549 | 54,064 | 0.011 | 0.011 | 1,556 | 1,659 |
| 1983 | 17,923 | 19,204 | 50,229 | 53,759 | 0.013 | 0.012 | 2,784 | 3,048 |
| 1984 | 17,763 | 19,046 | 49,803 | 53,343 | 0.015 | 0.014 | 2,856 | 3,124 |
| 1985 | 17,545 | 18,829 | 49,269 | 52,818 | 0.003 | 0.002 | 1,728 | 1,867 |
| 1986 | 17,590 | 18,875 | 49,605 | 53,196 | 0.009 | 0.008 | 1,807 | 1,999 |
| 1987 | 17,502 | 18,788 | 49,695 | 53,336 | 0.011 | 0.010 | 1,481 | 1,673 |
| 1988 | 17,375 | 18,663 | 49,530 | 53,201 | 0.033 | 0.030 | 1,175 | 1,331 |
| 1989 | 16,801 | 18,088 | 48,309 | 52,011 | 0.045 | 0.042 | 999 | 1,127 |
| 1990 | 16,011 | 17,294 | 46,497 | 50,223 | 0.052 | 0.048 | 976 | 1,079 |
| 1991 | 15,163 | 16,443 | 44,434 | 48,178 | 0.008 | 0.007 | 1,030 | 1,148 |
| 1992 | 15,178 | 16,467 | 44,309 | 48,086 | 0.025 | 0.023 | 1,048 | 1,159 |
| 1993 | 14,910 | 16,207 | 43,370 | 47,168 | 0.013 | 0.012 | 3,810 | 4,118 |
| 1994 | 14,870 | 16,178 | 42,929 | 46,750 | 0.013 | 0.012 | 1,276 | 1,385 |
| 1995 | 14,830 | 16,152 | 42,445 | 46,286 | 0.017 | 0.015 | 1,139 | 1,255 |
| 1996 | 14,746 | 16,082 | 42,365 | 46,262 | 0.013 | 0.012 | 1,355 | 1,468 |
| 1997 | 14,726 | 16,078 | 42,043 | 45,965 | 0.013 | 0.012 | 2,667 | 2,783 |
| 1998 | 14,705 | 16,075 | 41,689 | 45,632 | 0.016 | 0.015 | 2,326 | 2,400 |
| 1999 | 14,617 | 16,005 | 41,234 | 45,196 | 0.008 | 0.007 | 1,508 | 1,523 |
| 2000 | 14,652 | 16,057 | 41,381 | 45,358 | 0.013 | 0.012 | 1,983 | 1,950 |
| 2001 | 14,612 | 16,035 | 41,312 | 45,292 | 0.014 | 0.013 | 2,713 | 2,520 |
| 2002 | 14,460 | 15,896 | 41,061 | 45,027 | 0.007 | 0.006 | 1,423 | 1,335 |
| 2003 | 14,428 | 15,875 | 41,224 | 45,155 | 0.010 | 0.009 | 2,319 | 2,324 |
| 2004 | 14,346 | 15,804 | 41,433 | 45,287 | 0.007 | 0.007 | 2,163 | 2,506 |
| 2005 | 14,328 | 15,798 | 41,533 | 45,311 | 0.007 | 0.006 | 1,912 | 2,151 |
| 2006 | 14,320 | 15,800 | 41,805 | 45,512 | 0.009 | 0.008 | 1,448 | 1,665 |
| 2007 | 14,276 | 15,761 | 41,998 | 45,699 | 0.010 | 0.010 | 1,291 | 1,519 |
| 2008 | 14,222 | 15,710 | 42,093 | 45,781 | 0.009 | 0.008 | 1,430 | 1,718 |
| 2009 | 14,203 | 15,692 | 42,154 | 45,835 | 0.007 | 0.006 | 2,045 | 2,342 |
| 2010 | 14,244 | 15,728 | 42,263 | 45,948 | 0.010 | 0.009 | 1,342 | 1,435 |
| 2011 | 14,242 | 15,713 | 42,208 | 45,917 | 0.013 | 0.012 | 1,578 | 1,703 |
| 2012 | 14,211 | 15,664 | 42,135 | 45,885 | 0.013 | 0.012 | 1,852 | 2,033 |
| 2013 | 14,186 | 15,616 | 41,902 | 45,665 | 0.014 | 0.013 | 2,599 | 3,573 |
| 2014 | 14,170 | 15,575 | 41,684 | 45,465 | 0.018 | 0.016 | 1,594 | 1,510 |
| 2015 | 14,133 | 15,515 | 41,346 | 45,159 | 0.013 | 0.012 | 1,611 | 1,570 |
| 2016 | | 15,482 | | 45,368 | | 0.014 | | 1,732 |
| 2017 | | 15,416 | | 45,166 | | 0.011 | | 1,732 |

Table 13-19. Estimated time series of recruitment, total biomass (3+), and female spawning biomass for RE/BS rockfish in the Gulf of Alaska, 1977-2018. Columns headed with 2.5% and 97.5% represent the lower and upper 95% credible intervals from the MCMC posterior distribution.

| | Recruits (Age 3, 1000s) | | | Total Biomass (3+) | | | Spawning biomass (t) | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Mean | 2.5% | 97.5% | Mean | 2.5% | 97.5% | Mean | 2.5% | 97.5% |
| 1977 | 1,513 | 229 | 6,162 | 57,983 | 39,397 | 196,445 | 20,550 | 13,806 | 67,271 |
| 1978 | 1,774 | 238 | 8,624 | 56,696 | 38,169 | 195,363 | 20,141 | 13,445 | 67,851 |
| 1979 | 4,982 | 1,153 | 15,216 | 56,442 | 37,869 | 196,468 | 20,073 | 13,440 | 68,422 |
| 1980 | 1,548 | 227 | 7,506 | 56,051 | 37,540 | 197,062 | 19,954 | 13,326 | 68,447 |
| 1981 | 1,372 | 211 | 5,508 | 54,957 | 36,412 | 196,520 | 19,519 | 12,934 | 68,746 |
| 1982 | 1,659 | 253 | 6,989 | 54,510 | 35,958 | 196,123 | 19,334 | 12,759 | 68,801 |
| 1983 | 3,048 | 485 | 11,503 | 54,281 | 35,808 | 196,893 | 19,204 | 12,589 | 68,705 |
| 1984 | 3,124 | 507 | 11,225 | 54,043 | 35,521 | 198,092 | 19,046 | 12,503 | 68,308 |
| 1985 | 1,867 | 280 | 7,944 | 53,665 | 35,090 | 198,459 | 18,829 | 12,296 | 68,012 |
| 1986 | 1,999 | 337 | 7,555 | 53,940 | 35,329 | 199,119 | 18,875 | 12,358 | 68,376 |
| 1987 | 1,673 | 293 | 6,487 | 53,891 | 35,269 | 199,151 | 18,788 | 12,271 | 68,296 |
| 1988 | 1,331 | 268 | 5,160 | 53,726 | 35,039 | 199,448 | 18,663 | 12,112 | 67,748 |
| 1989 | 1,127 | 218 | 4,190 | 52,444 | 33,700 | 197,810 | 18,088 | 11,562 | 67,317 |
| 1990 | 1,079 | 218 | 4,044 | 50,584 | 32,152 | 195,442 | 17,294 | 10,824 | 66,759 |
| 1991 | 1,148 | 220 | 4,069 | 48,507 | 30,146 | 193,837 | 16,443 | 10,049 | 66,069 |
| 1992 | 1,159 | 200 | 4,306 | 48,416 | 30,116 | 193,540 | 16,467 | 10,031 | 66,210 |
| 1993 | 4,118 | 2,501 | 11,522 | 47,665 | 29,351 | 192,647 | 16,207 | 9,761 | 65,865 |
| 1994 | 1,385 | 214 | 5,554 | 47,387 | 29,032 | 192,553 | 16,178 | 9,727 | 66,377 |
| 1995 | 1,255 | 239 | 4,738 | 47,092 | 28,822 | 192,225 | 16,152 | 9,680 | 66,713 |
| 1996 | 1,468 | 239 | 5,909 | 46,664 | 28,425 | 191,550 | 16,082 | 9,618 | 67,027 |
| 1997 | 2,783 | 670 | 9,823 | 46,436 | 28,213 | 191,380 | 16,078 | 9,610 | 67,271 |
| 1998 | 2,400 | 437 | 8,832 | 46,241 | 27,961 | 191,521 | 16,075 | 9,574 | 67,444 |
| 1999 | 1,523 | 249 | 6,302 | 45,916 | 27,669 | 191,364 | 16,005 | 9,491 | 67,395 |
| 2000 | 1,950 | 359 | 7,682 | 45,960 | 27,677 | 191,952 | 16,057 | 9,537 | 67,329 |
| 2001 | 2,520 | 685 | 8,357 | 45,835 | 27,551 | 191,809 | 16,035 | 9,508 | 67,342 |
| 2002 | 1,335 | 218 | 5,101 | 45,625 | 27,286 | 191,334 | 15,896 | 9,374 | 66,860 |
| 2003 | 2,324 | 758 | 7,936 | 45,777 | 27,390 | 191,372 | 15,875 | 9,354 | 66,715 |
| 2004 | 2,506 | 589 | 8,719 | 45,838 | 27,364 | 191,544 | 15,804 | 9,284 | 66,498 |
| 2005 | 2,151 | 499 | 7,483 | 46,006 | 27,438 | 192,198 | 15,798 | 9,274 | 66,596 |
| 2006 | 1,665 | 338 | 6,090 | 46,175 | 27,622 | 192,503 | 15,800 | 9,264 | 66,742 |
| 2007 | 1,519 | 309 | 5,704 | 46,255 | 27,611 | 193,037 | 15,761 | 9,283 | 66,610 |
| 2008 | 1,718 | 326 | 6,533 | 46,262 | 27,514 | 193,346 | 15,710 | 9,218 | 66,579 |
| 2009 | 2,342 | 639 | 8,526 | 46,346 | 27,598 | 193,928 | 15,692 | 9,214 | 66,624 |
| 2010 | 1,435 | 242 | 5,533 | 46,501 | 27,751 | 193,977 | 15,728 | 9,245 | 66,919 |
| 2011 | 1,703 | 340 | 6,829 | 46,489 | 27,758 | 193,971 | 15,713 | 9,202 | 66,836 |
| 2012 | 2,033 | 409 | 8,808 | 46,366 | 27,718 | 193,400 | 15,664 | 9,137 | 66,848 |
| 2013 | 3,573 | 1,035 | 14,618 | 46,298 | 27,604 | 193,766 | 15,616 | 9,052 | 66,887 |
| 2014 | 1,510 | 204 | 7,284 | 46,186 | 27,425 | 194,656 | 15,575 | 8,987 | 66,851 |
| 2015 | 1,570 | 218 | 7,756 | 45,913 | 27,143 | 195,344 | 15,515 | 8,911 | 67,161 |
| 2016 | 1,732 | 220 | 13,895 | 45,832 | 27,118 | 196,879 | 15,482 | 8,873 | 67,303 |
| 2017 | 1,732 | 225 | 13,504 | 45,654 | 26,735 | 196,728 | 15,416 | 8,800 | 67,138 |
| 2018 | 2,009 | 226 | 13,132 | 45,624 | 26,614 | 196,793 | 15,059 | 8,586 | 65,447 |

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. $B_{40\%}$ = 8,998 t, $B_{35\%}$ = 7,873 t, $F_{40\%}$ = 0.040 and $F_{35\%}$ = 0.048.

| Year | Maximum permissible F | Author's F* | Half maximum F | 5-year average F | No fishing | Overfished | Approaching overfished |
|---|---|---|---|---|---|---|---|
| | | | Spawning Biomass (t) | | | | |
| 2017 | 15,105 | 15,105 | 15,105 | 15,105 | 15,105 | 15,105 | 15,105 |
| 2018 | 14,939 | 15,059 | 15,062 | 15,084 | 15,186 | 14,889 | 14,939 |
| 2019 | 14,572 | 14,972 | 14,980 | 15,052 | 15,400 | 14,407 | 14,572 |
| 2020 | 14,204 | 14,754 | 14,884 | 15,005 | 15,597 | 13,933 | 14,156 |
| 2021 | 13,835 | 14,362 | 14,771 | 14,941 | 15,773 | 13,467 | 13,679 |
| 2022 | 13,489 | 13,992 | 14,668 | 14,883 | 15,953 | 13,032 | 13,233 |
| 2023 | 13,170 | 13,648 | 14,577 | 14,837 | 16,141 | 12,632 | 12,821 |
| 2024 | 12,859 | 13,312 | 14,477 | 14,780 | 16,310 | 12,248 | 12,426 |
| 2025 | 12,587 | 13,015 | 14,404 | 14,748 | 16,501 | 11,910 | 12,077 |
| 2026 | 12,335 | 12,739 | 14,339 | 14,722 | 16,694 | 11,598 | 11,754 |
| 2027 | 12,090 | 12,469 | 14,267 | 14,689 | 16,874 | 11,299 | 11,444 |
| 2028 | 11,854 | 12,209 | 14,191 | 14,650 | 17,041 | 11,014 | 11,149 |
| 2029 | 11,628 | 11,960 | 14,112 | 14,606 | 17,197 | 10,746 | 10,871 |
| 2030 | 11,419 | 11,729 | 14,037 | 14,568 | 17,352 | 10,498 | 10,615 |
| | | | Fishing Mortality | | | | |
| 2017 | 0.014 | 0.014 | 0.014 | 0.014 | 0.014 | 0.014 | 0.014 |
| 2018 | 0.040 | 0.020 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2019 | 0.040 | 0.020 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2020 | 0.040 | 0.040 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2021 | 0.040 | 0.040 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2022 | 0.040 | 0.040 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2023 | 0.040 | 0.040 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2024 | 0.040 | 0.040 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2025 | 0.040 | 0.040 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2026 | 0.040 | 0.040 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2027 | 0.040 | 0.040 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2028 | 0.040 | 0.040 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2029 | 0.040 | 0.040 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| 2030 | 0.040 | 0.040 | 0.020 | 0.016 | - | 0.048 | 0.048 |
| | | | Yield (t) | | | | |
| 2017 | 503 | 503 | 503 | 503 | 503 | 503 | 503 |
| 2018 | 1,444 | 1,444 | 729 | 603 | - | 1,735 | 1,444 |
| 2019 | 1,401 | 1,427 | 721 | 599 | - | 1,670 | 1,401 |
| 2020 | 1,359 | 1,410 | 712 | 593 | - | 1,607 | 1,633 |
| 2021 | 1,324 | 1,372 | 706 | 590 | - | 1,554 | 1,578 |
| 2022 | 1,297 | 1,343 | 704 | 590 | - | 1,513 | 1,535 |
| 2023 | 1,259 | 1,302 | 695 | 584 | - | 1,458 | 1,479 |
| 2024 | 1,230 | 1,270 | 690 | 581 | - | 1,416 | 1,435 |
| 2025 | 1,213 | 1,251 | 690 | 583 | - | 1,388 | 1,406 |
| 2026 | 1,215 | 1,250 | 699 | 592 | - | 1,384 | 1,400 |
| 2027 | 1,184 | 1,217 | 691 | 587 | - | 1,341 | 1,356 |
| 2028 | 1,156 | 1,187 | 685 | 583 | - | 1,302 | 1,316 |
| 2029 | 1,132 | 1,161 | 679 | 579 | - | 1,269 | 1,282 |
| 2030 | 1,111 | 1,138 | 675 | 577 | - | 1,240 | 1,252 |

*Projected ABCs and OFLs for 2018 and 2019 are derived using estimated catch of 503 t for 2017 and projected catch of 747 t for 2018 and 725 t for 2019 based on the average of realized catches from 2014-2016. This calculation is in response to management requests to obtain more accurate projections.

Table 13-21. Recommended allocation of ABC and OFL for 2018 and 2019 GOA RE/BS rockfish based on the preferred weighted survey average method.

| Year | Weights | Western Gulf | Central Gulf | Eastern Gulf | Total |
|---|---|---|---|---|---|
| 2013 | 4 | 14% | 41% | 45% | 100% |
| 2015 | 6 | 4% | 52% | 44% | 100% |
| 2017 | 9 | 17% | 28% | 55% | 100% |
| Weighted Mean | 19 | | | | |
| Area Allocation | | 12.2% | 38.5% | 49.3% | 100% |
| 2018 | Area ABC (t) | **176** | **556** | **712** | **1,444** |
| | OFL (t) | | | | **1,735** |
| 2019 | Area ABC (t) | **174** | **550** | **703** | **1,427** |
| | OFL (t) | | | | **1,715** |

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

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

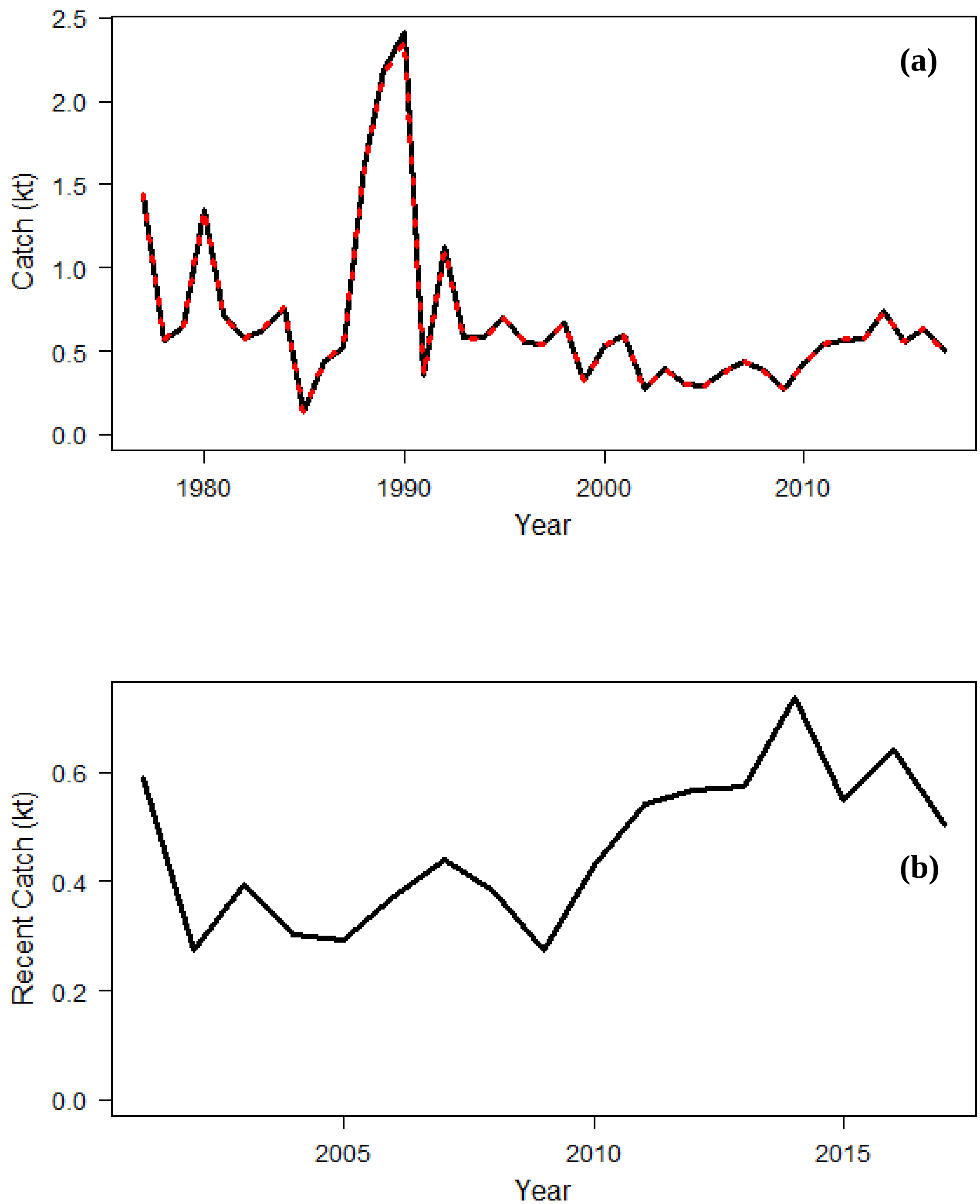


Figure 13-1. Estimated long-term (a) and short-term (b) commercial catches for Gulf of Alaska RE/BS rockfish. Solid line is observed catch and red dashed line (in **a** only) is predicted catch from the author preferred model.

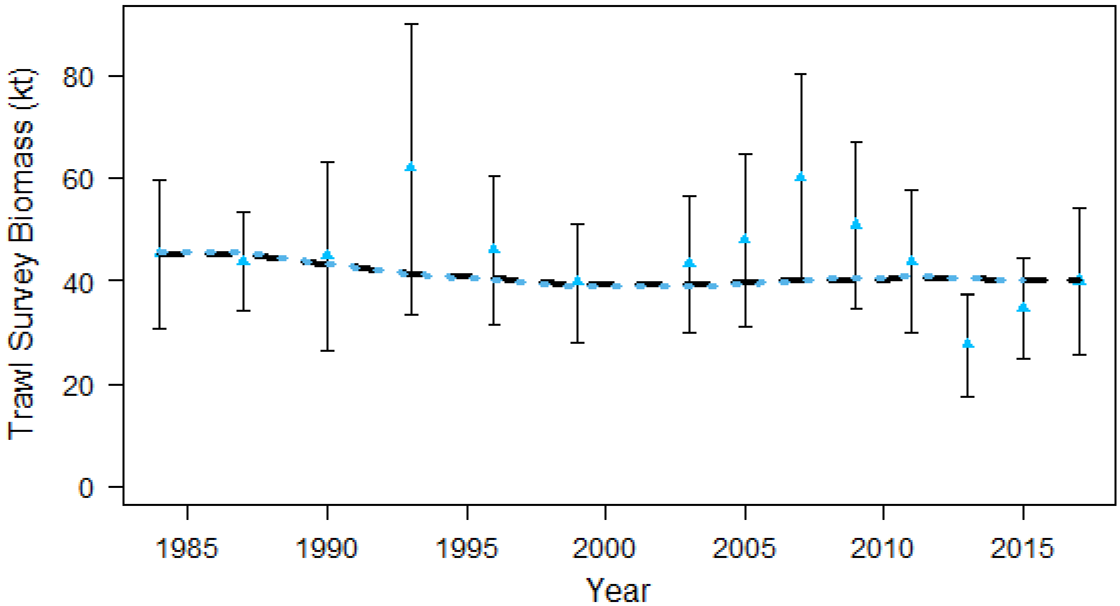


Figure 13-2. AFSC bottom trawl survey observed biomass estimates (blue triangles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the author preferred model (dashed black line) are compared with the last full assessment model fit (dotted blue line).

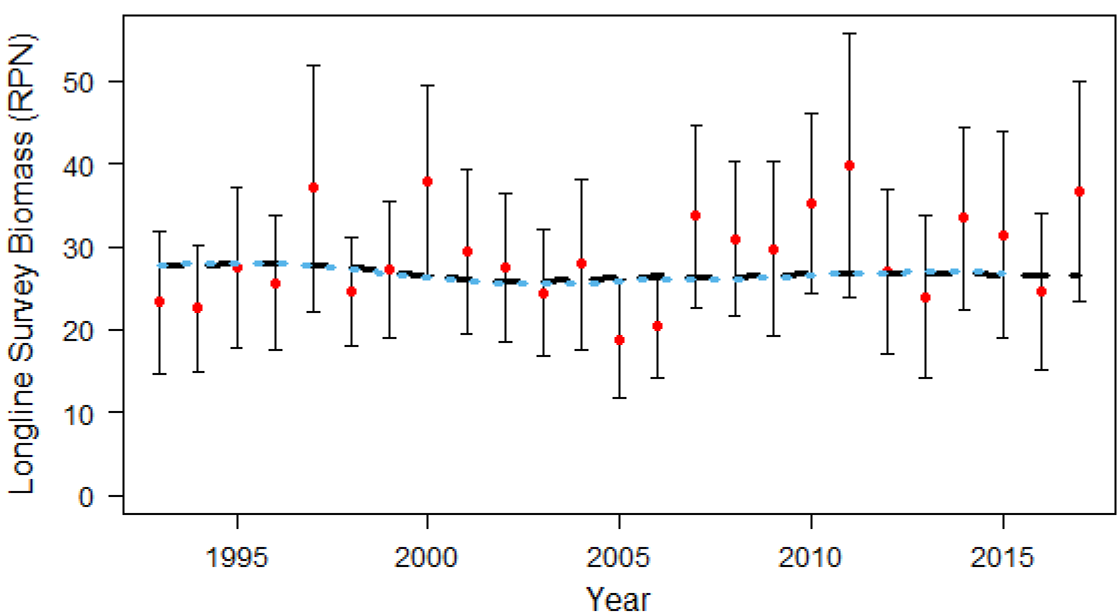


Figure 13-3. AFSC longline survey relative population numbers (RPN in thousands, red circles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the author preferred model (dashed black line) are compared with the last full assessment model fit (dotted blue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

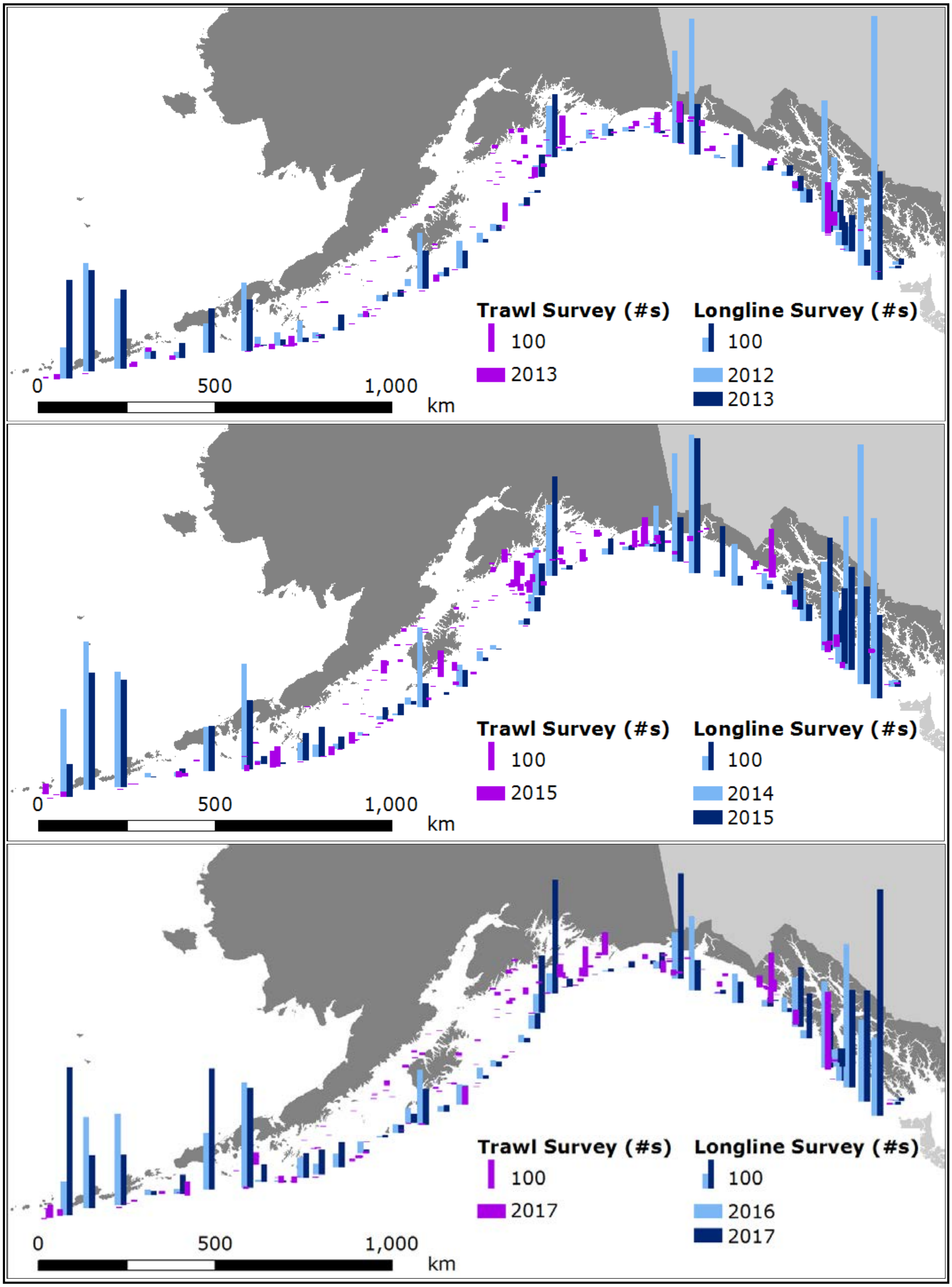


Figure 13-4a. Spatial distribution of rougheye and blackspotted rockfish in the Gulf of Alaska during the 2013, 2015, and 2017 AFSC trawl (purple) and 2012-2017 AFSC longline (blue/navy) surveys.

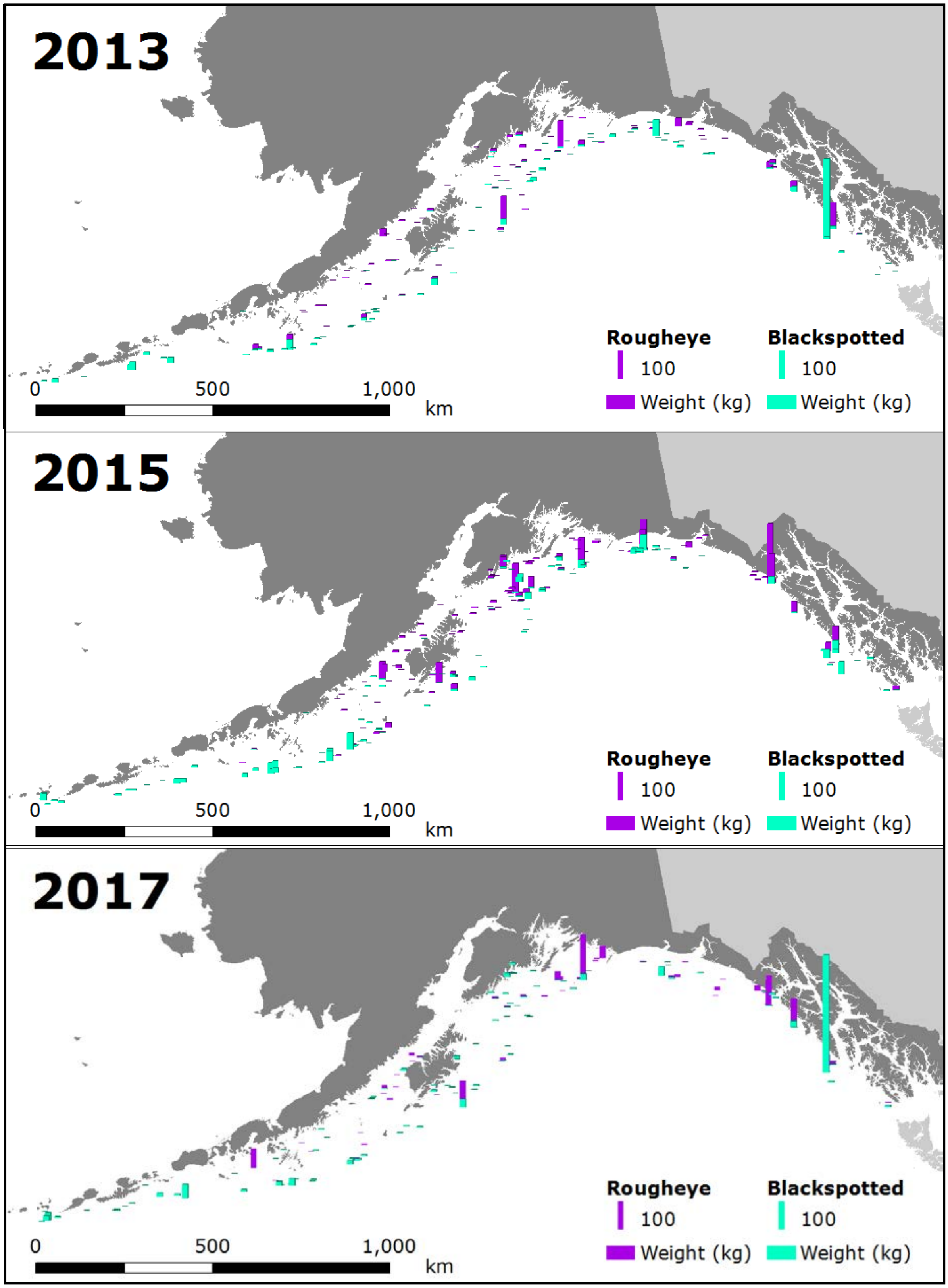


Figure 13-4b. Comparison of the spatial distribution between at-sea identified rougheye (purple) and blackspotted (green) rockfish in the Gulf of Alaska during the 2013, 2015, 2017 AFSC trawl surveys.

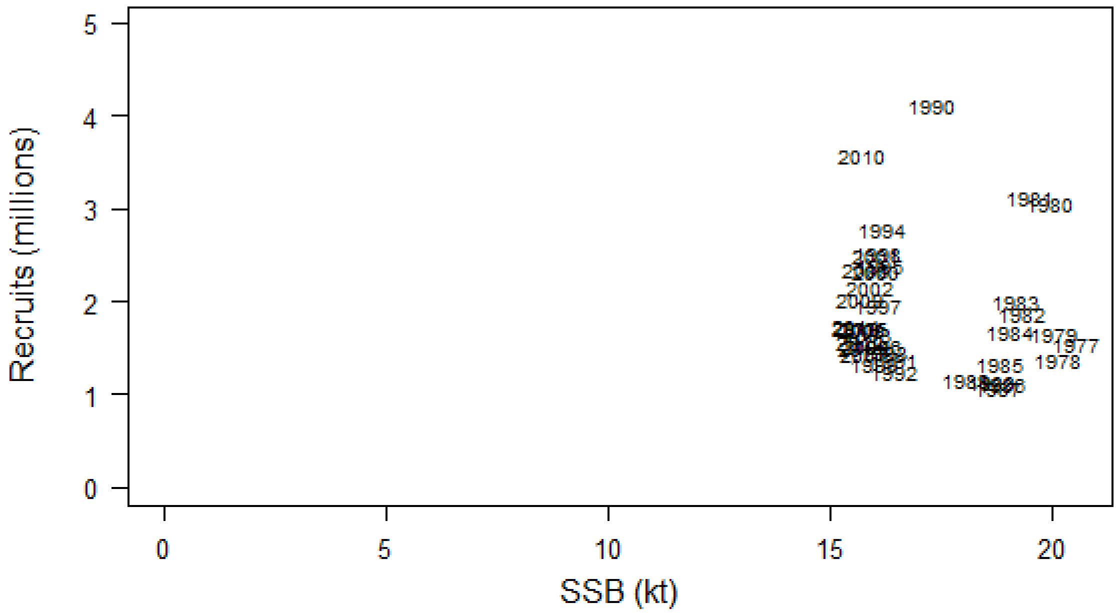


Figure 13-5. Scatterplot of spawner-recruit data for GOA RE/BS rockfish author preferred model. Label is year class of age 3 recruits. Recruits are in millions and SSB = Spawning stock biomass in tons.

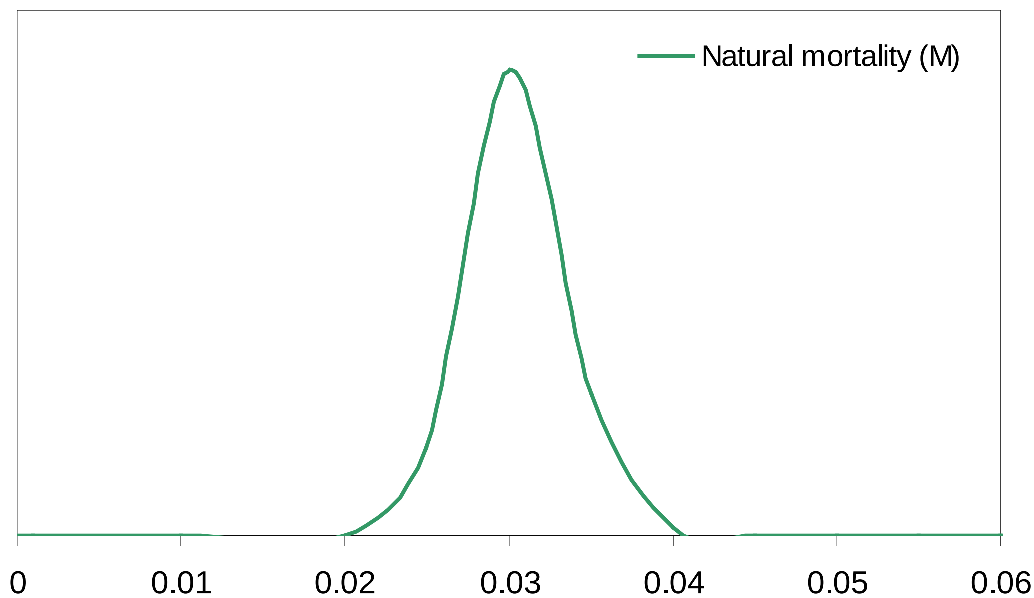


Figure 13-6. Prior distribution for natural mortality ($M$, μ=0.03, CV=10%) of GOA RE/BS rockfish.

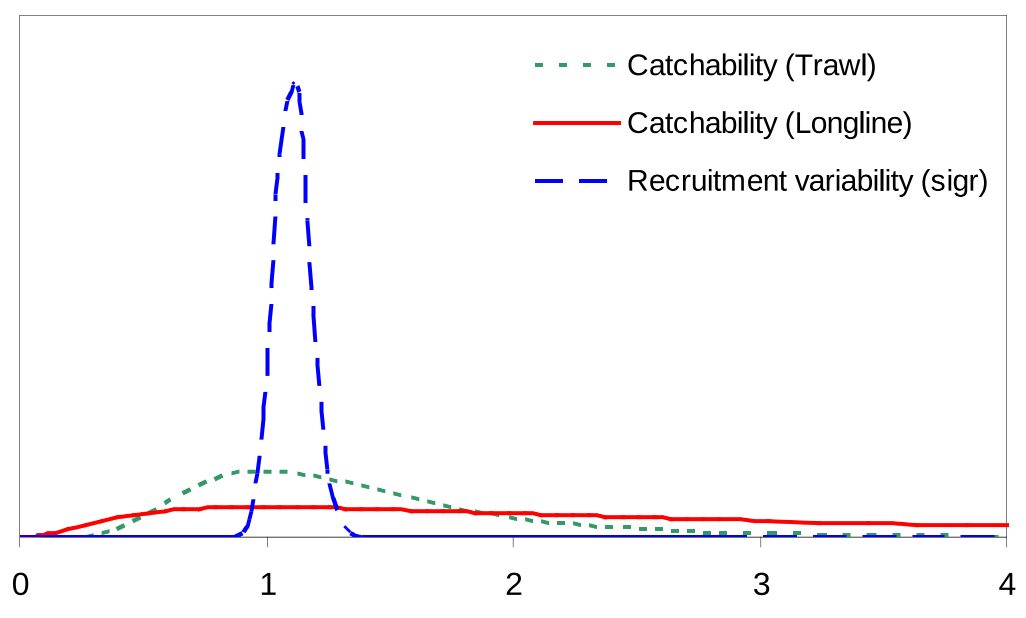


Figure 13-7. Prior distributions for NMFS trawl survey catchability ($q1$, μ=1, CV=45%), AFSC longline survey catchability ($q2$, μ=1, CV=100%), and recruitment variability ($\sigma_r$, μ=1.1, CV=6%) of GOA RE/BS rockfish.

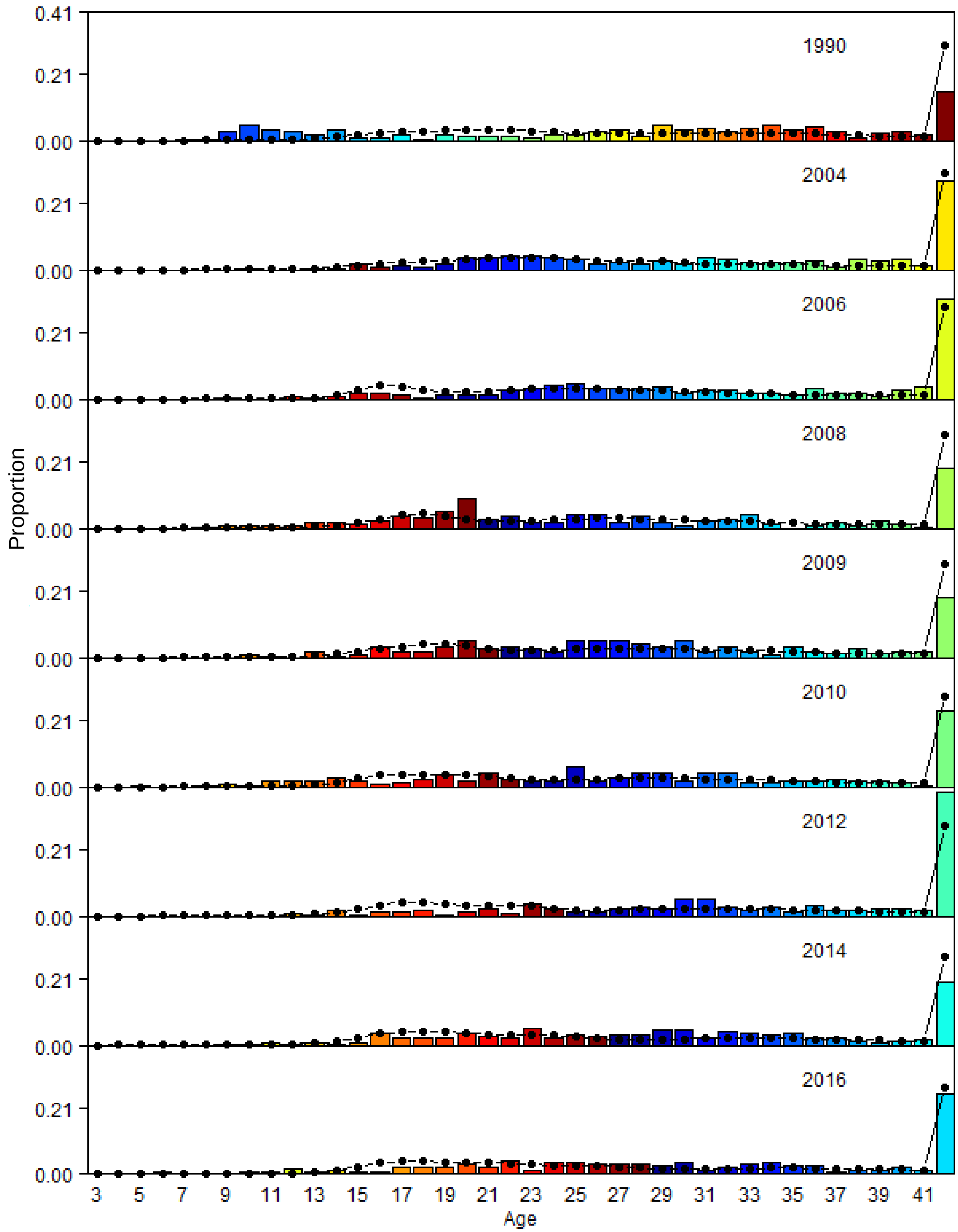


Figure 13-8. Fishery age compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

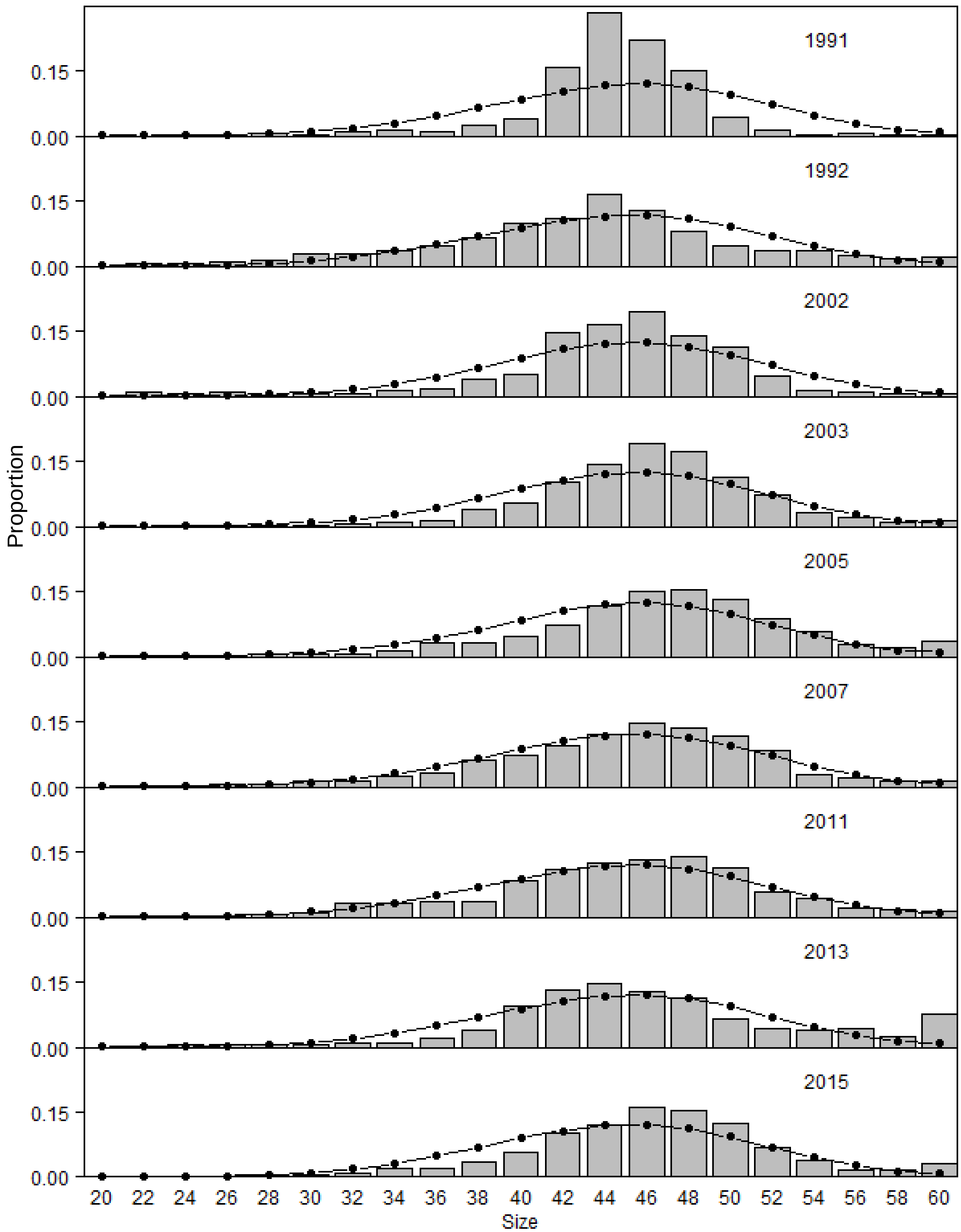

Figure 13-9. Fishery length (cm) compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

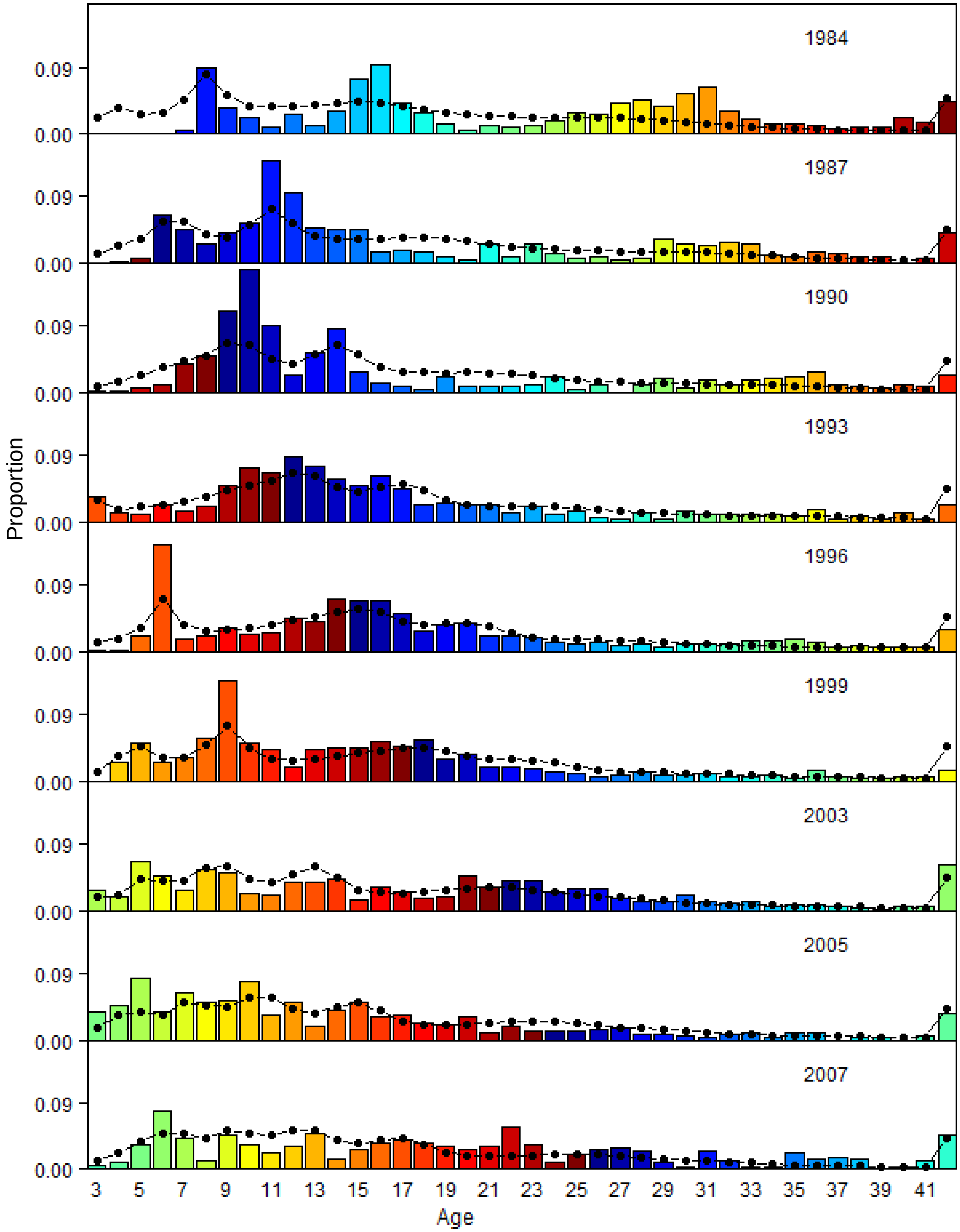

Figure 13-10. AFSC bottom trawl survey age composition by year for GOA RE/BS rockfish**.** Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

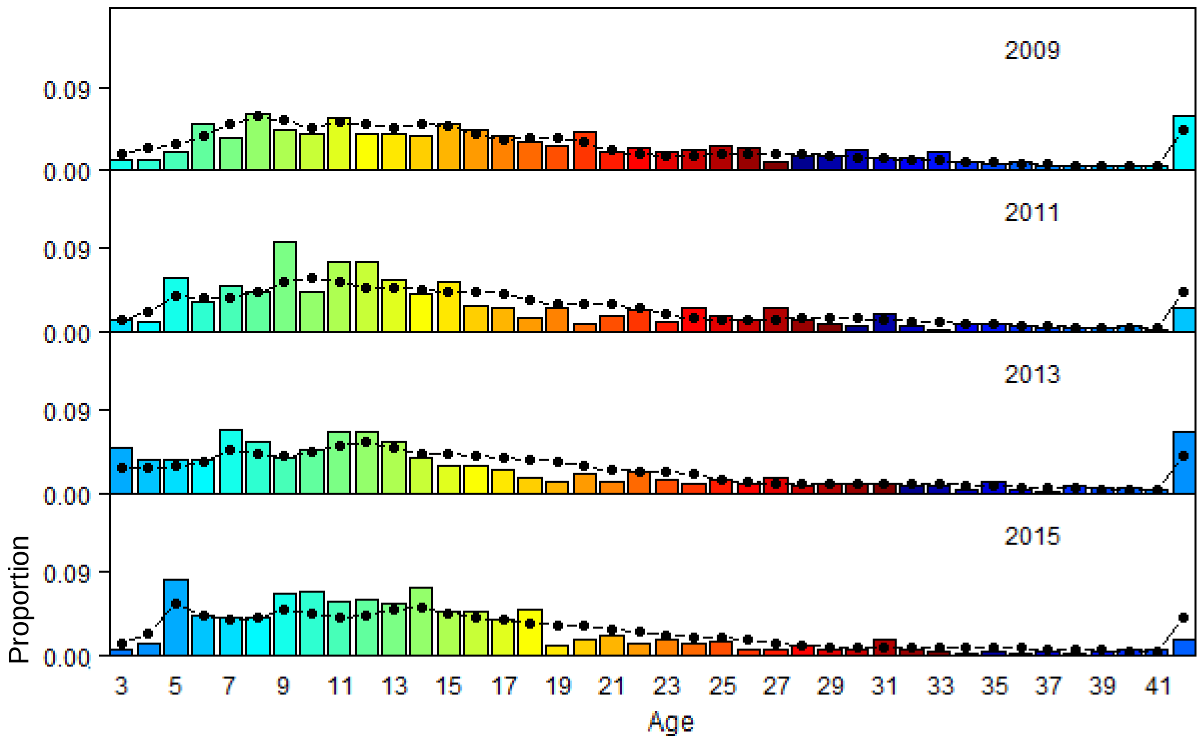


Figure 13-10 (continued). AFSC bottom trawl survey age composition by year for GOA RE/BS rockfish**.** Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

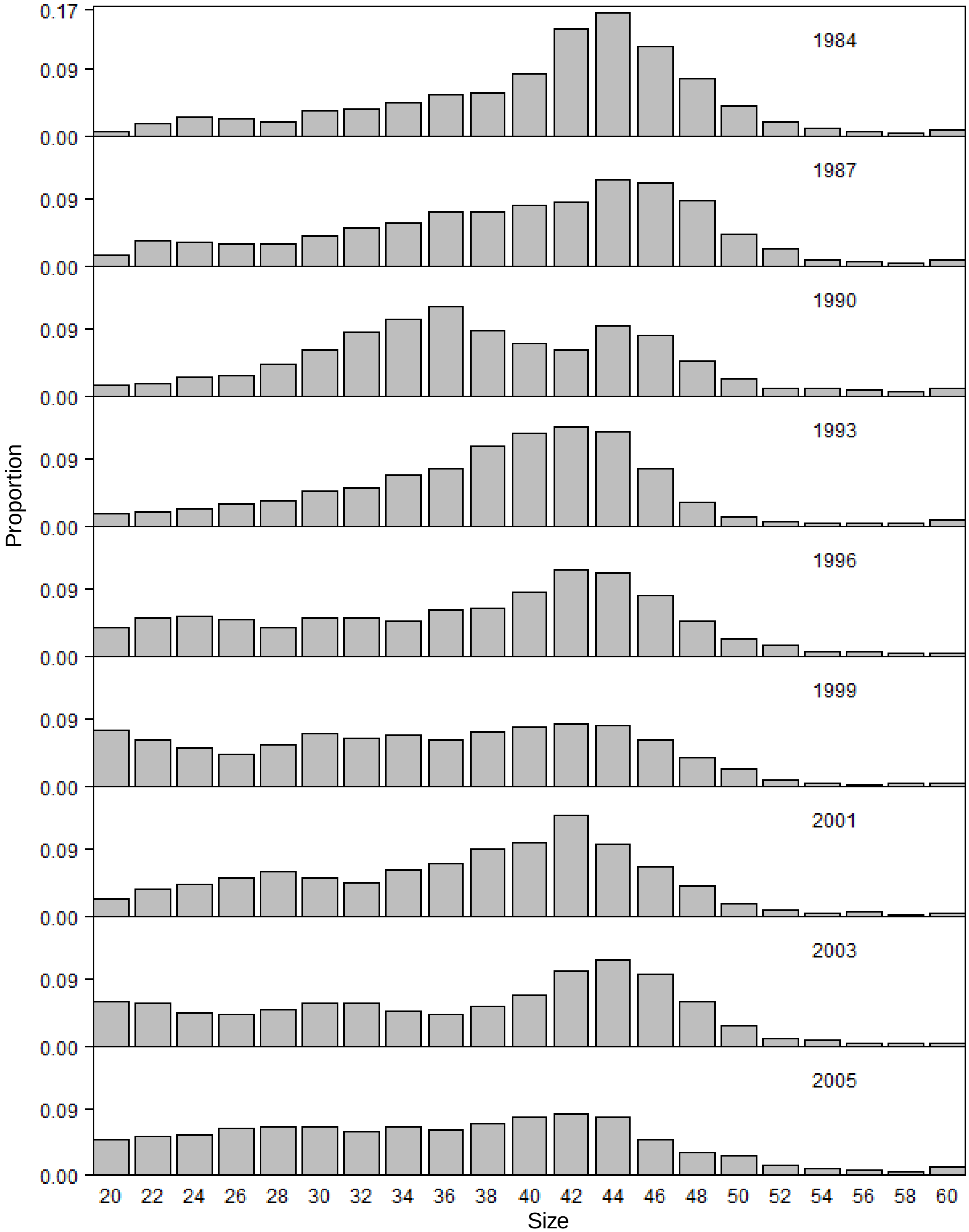

Figure 13-11. AFSC bottom trawl survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in the model.

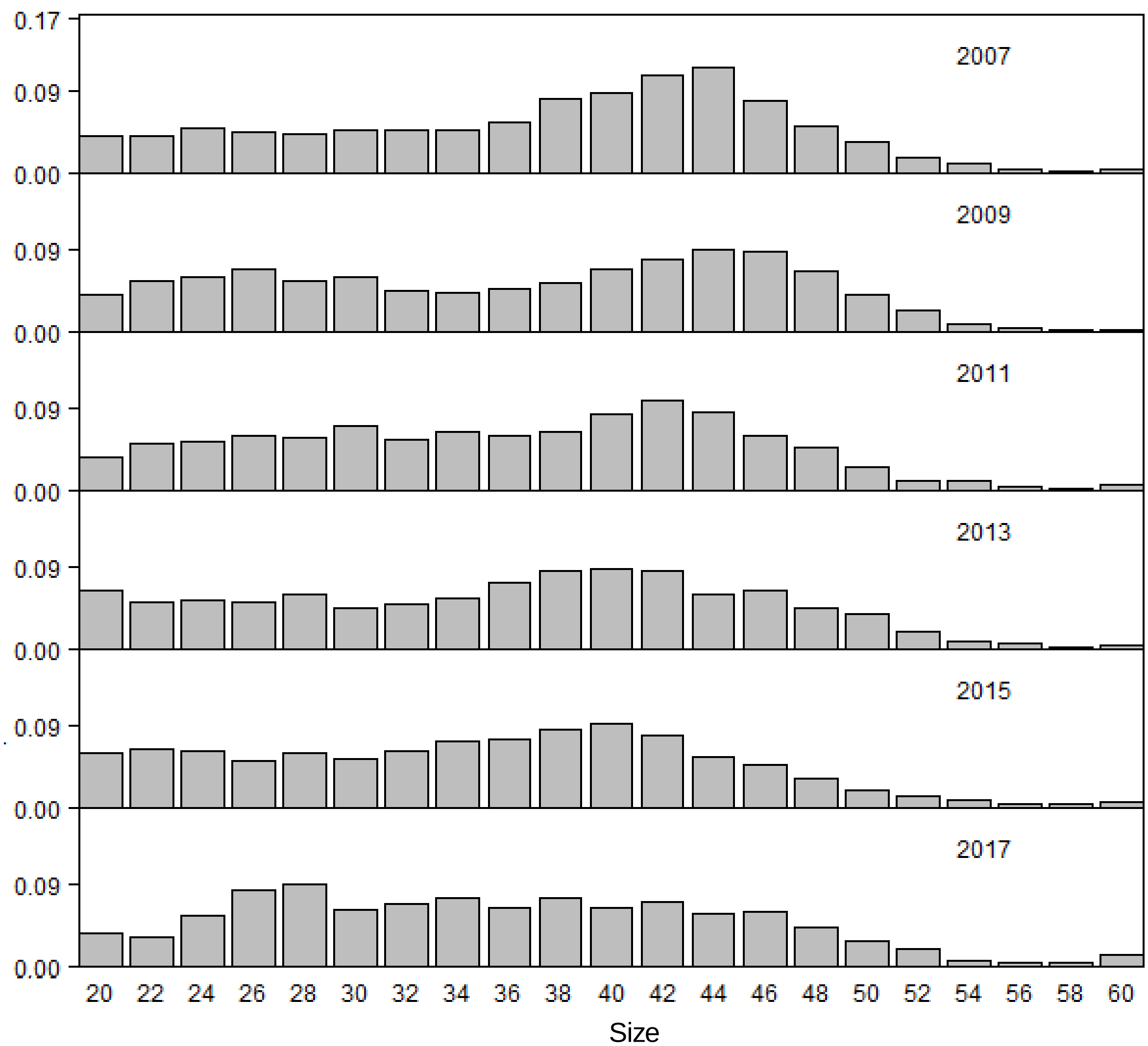


Figure 13-11 (Continued). AFSC bottom trawl survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in the model.

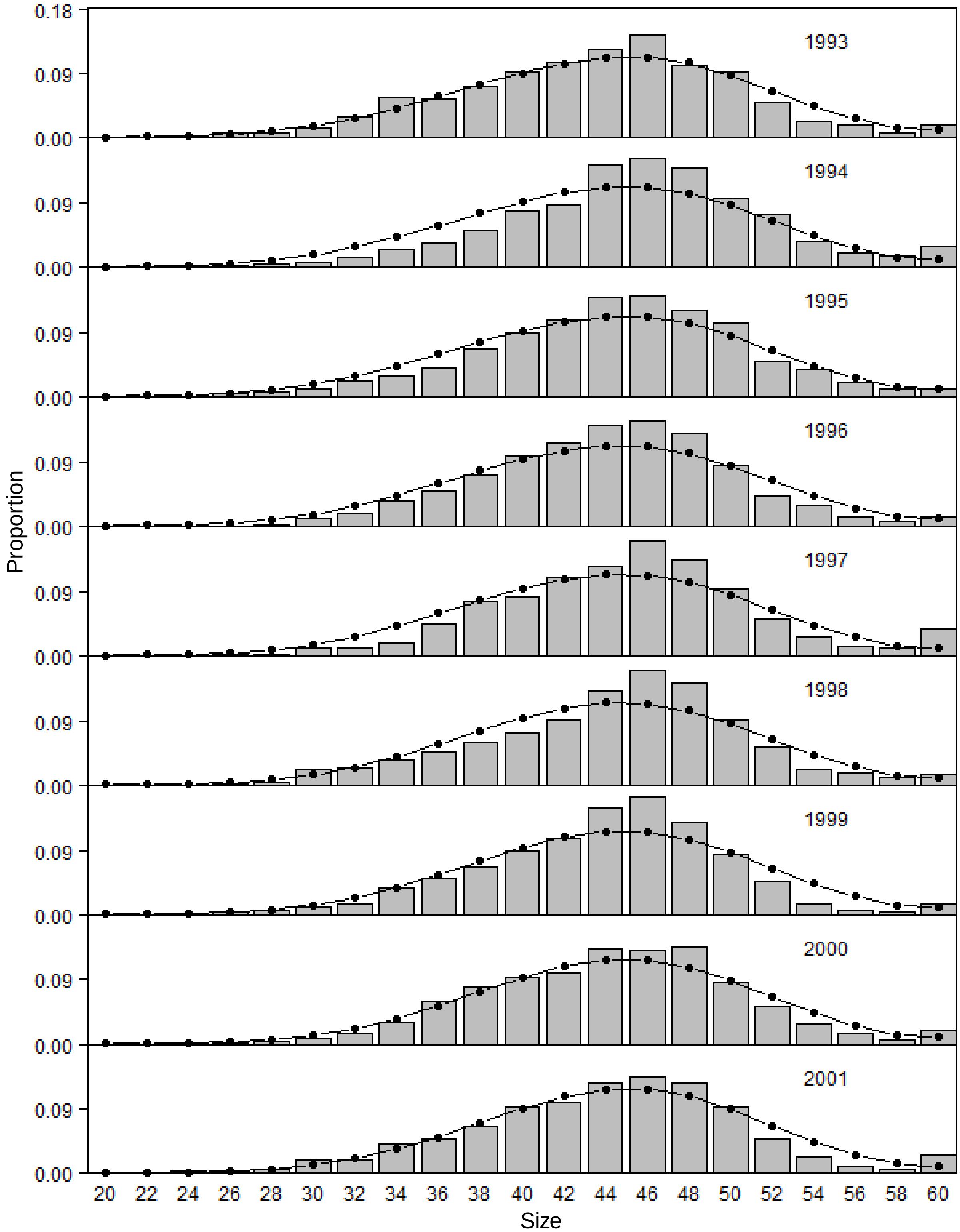


Figure 13-12. AFSC longline survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

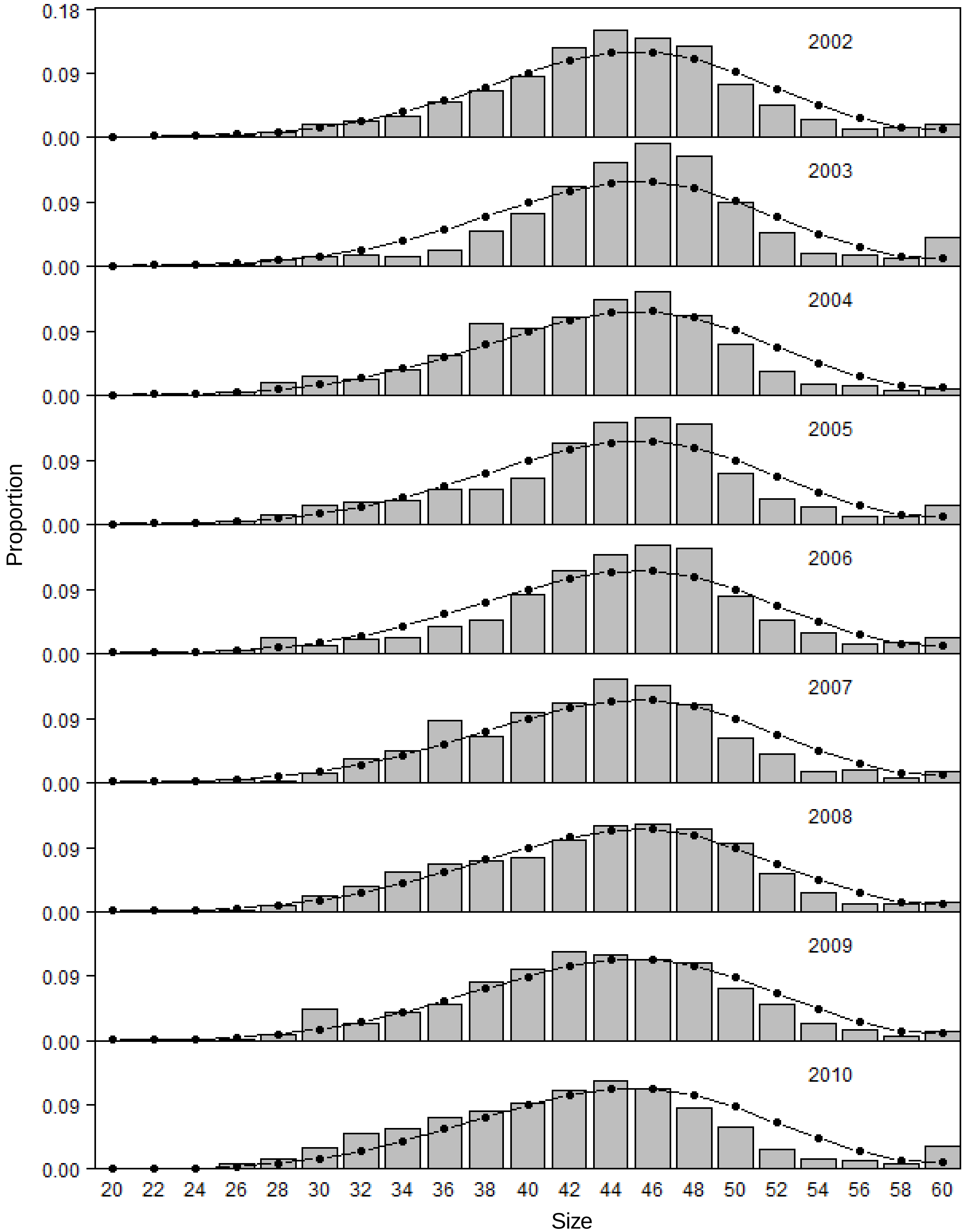


Figure 13-12 (continued). AFSC longline survey length (cm) composition by year for GOA RE/BS rockfish**.** Observed = bars, predicted from author preferred model = lines with circles.

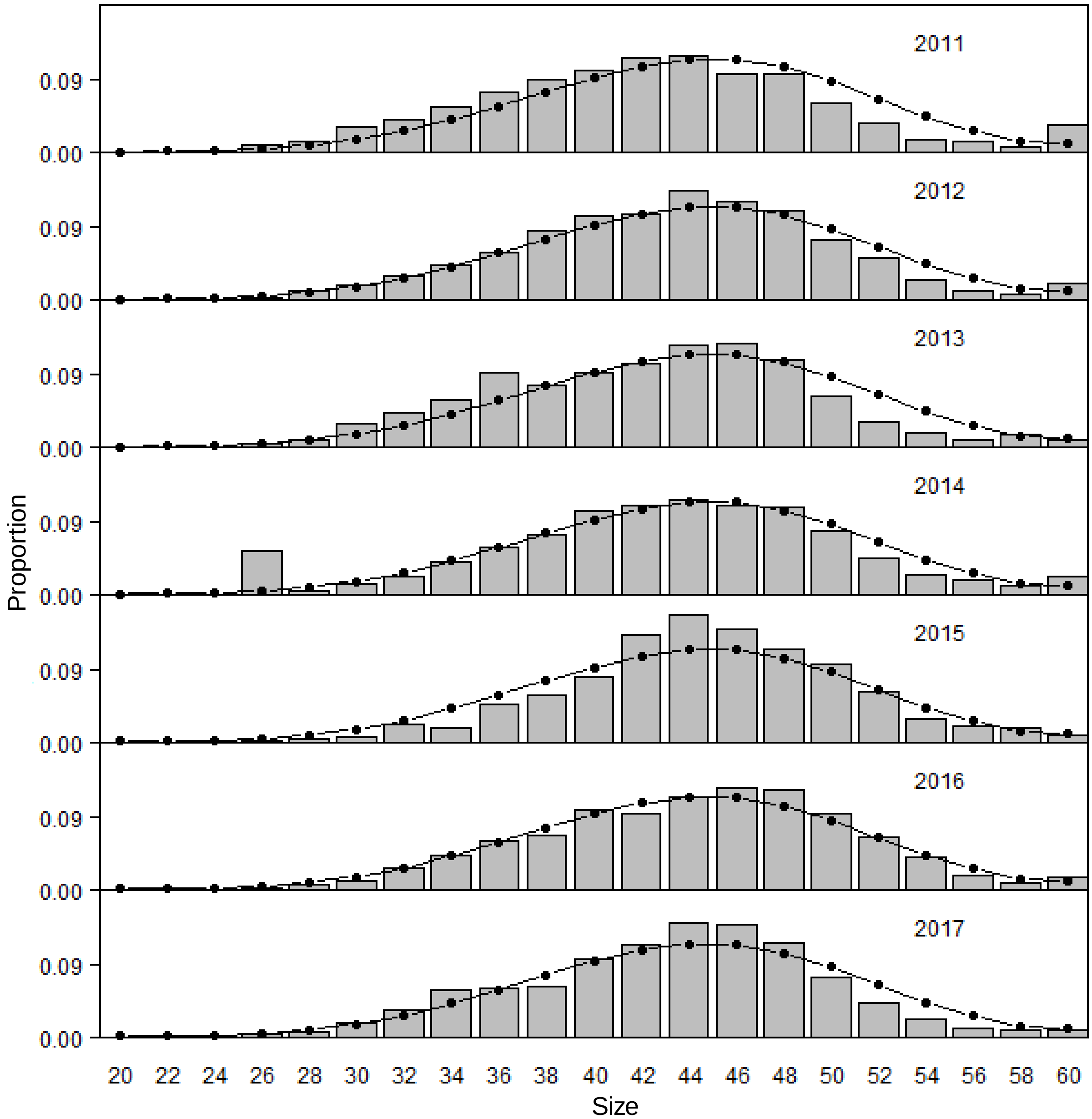


Figure 13-12 (continued). AFSC longline survey length (cm) composition by year for GOA RE/BS rockfish**.** Observed = bars, predicted from author preferred model = lines with circles.

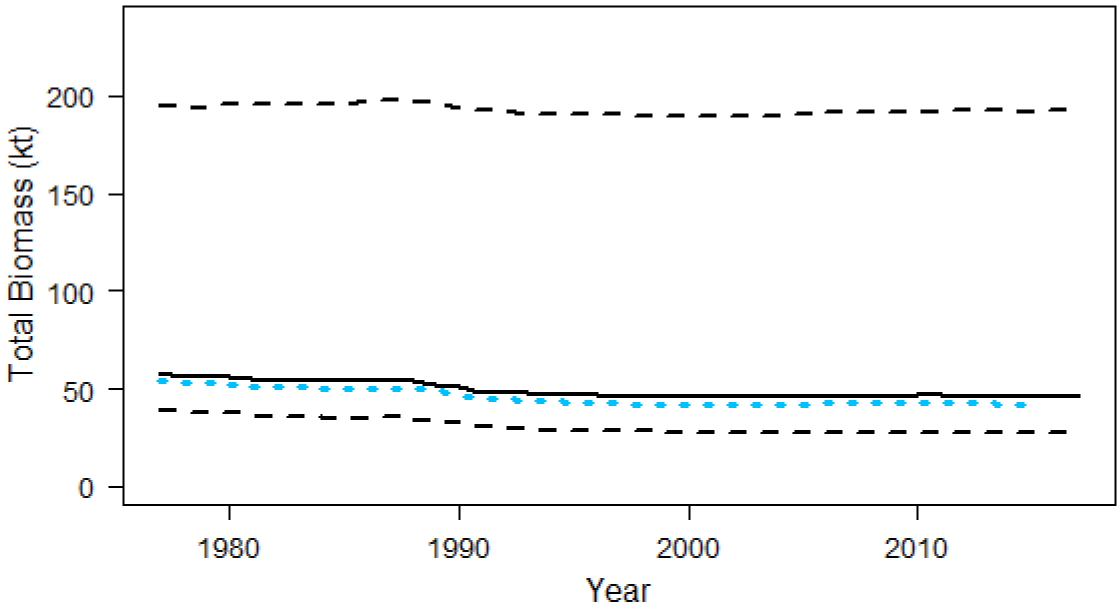


Figure 13-13. Time series of predicted total biomass from author preferred model (solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last full assessment model estimates included for comparison (dotted blue line).

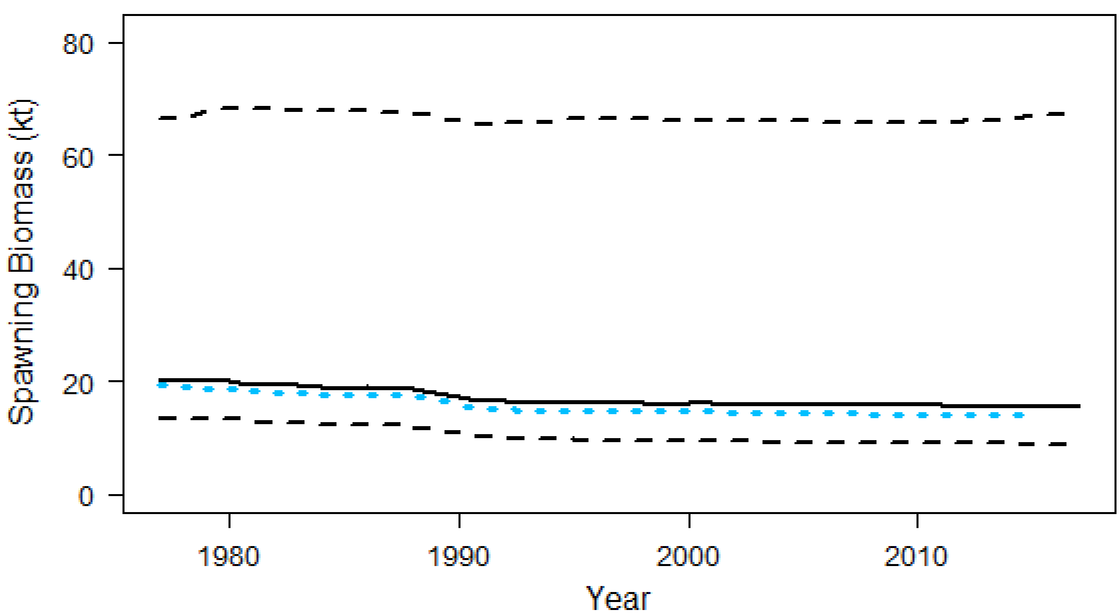


Figure 13-14. Time series of predicted spawning biomass from author preferred model (solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last full assessment model estimates included for comparison (dotted blue line).

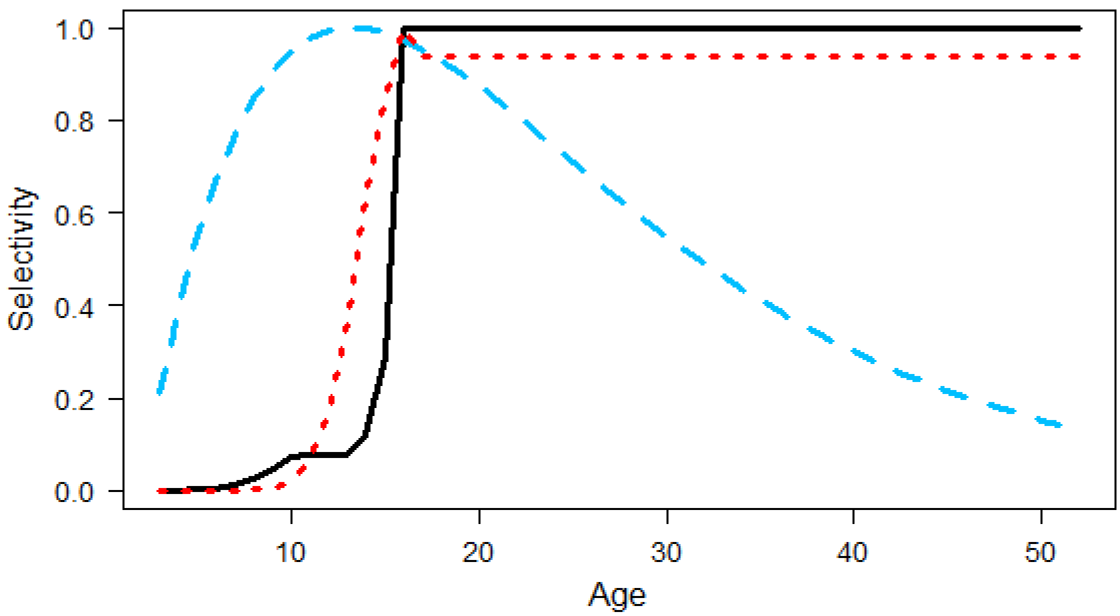


Figure 13-15. Estimated selectivity curves for GOA RE/BS rockfish from author preferred model. Dashed blue line = AFSC bottom trawl survey selectivity, dotted red line = AFSC longline survey selectivity, and solid black line = combined fishery selectivity.

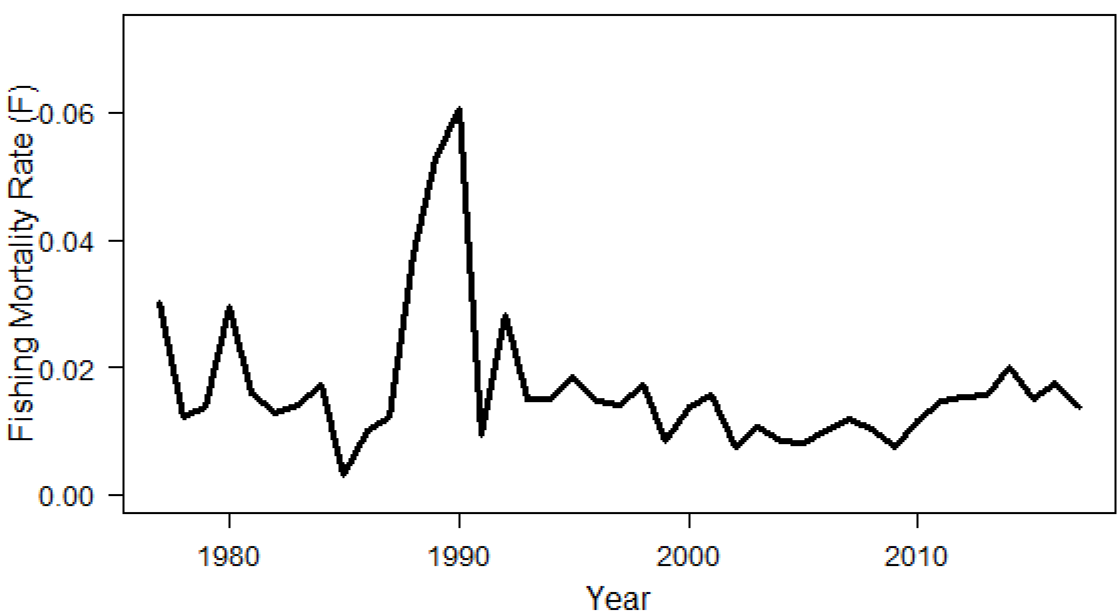


Figure 13-16. Time series of estimated fully selected fishing mortality for GOA RE/BS rockfish from author preferred model.

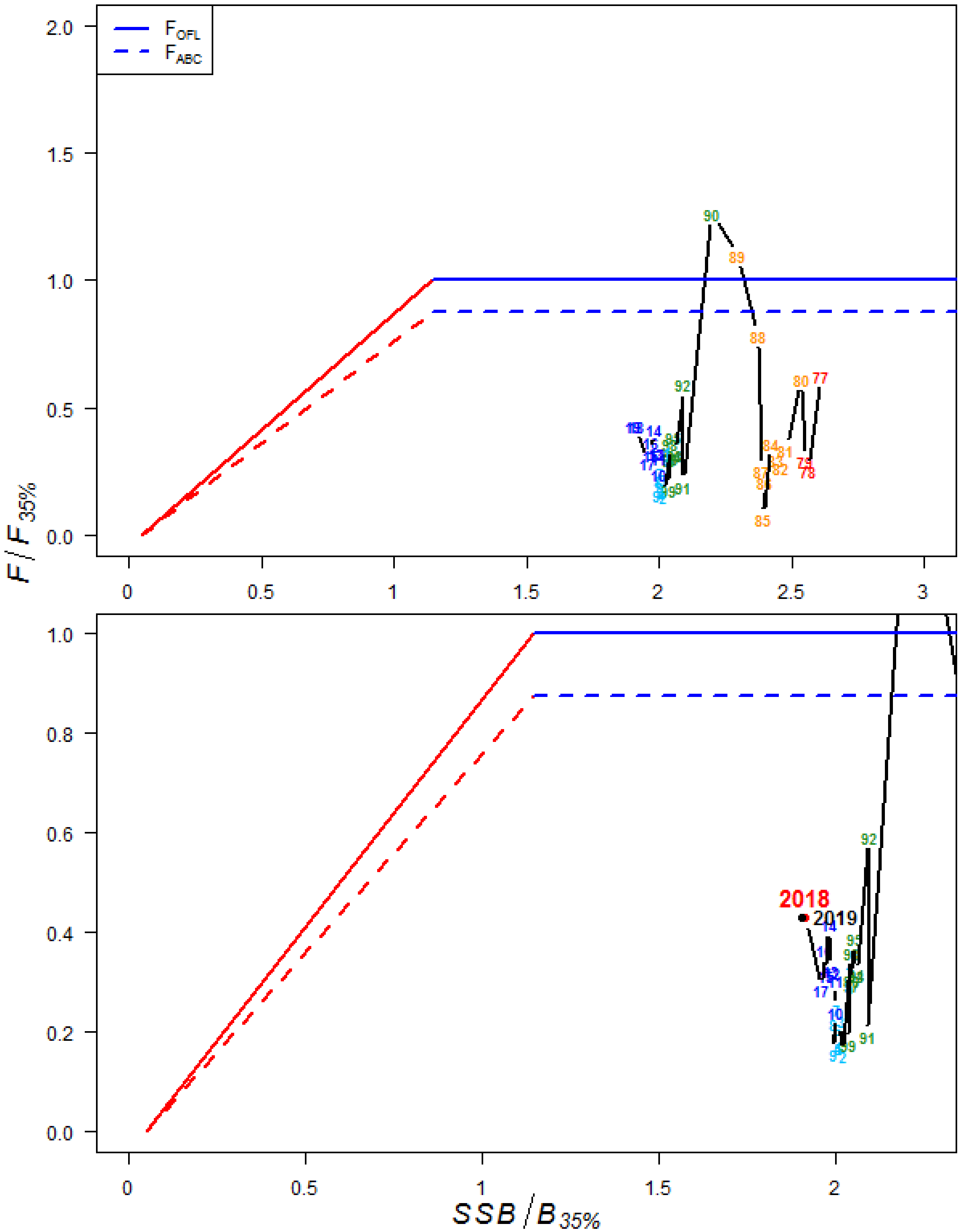


Figure 13-17. Time series of GOA RE/BS rockfish estimated spawning biomass relative to the target $B_{35\%}$ level and fishing mortality relative to $F_{OFL}$ for author preferred model. The upper panel provides the entire time series while bottom panel presents the more recent management path.

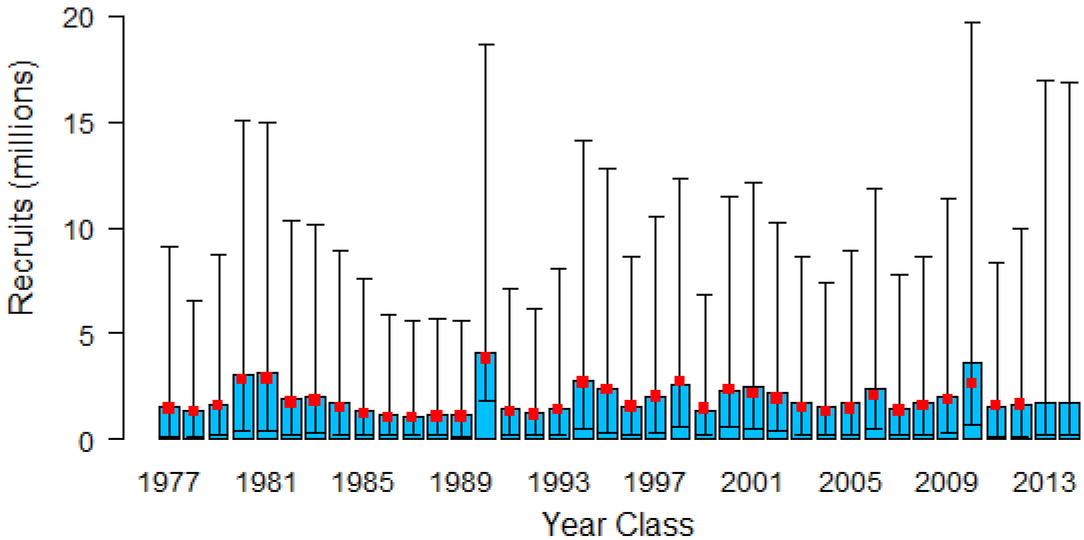


Figure 13-18. Estimated recruitments (age 3) of GOA RE/BS rockfish from author preferred model by year class with 95% credible intervals derived from MCMC. Last full assessment model estimates included for comparison (red squares).

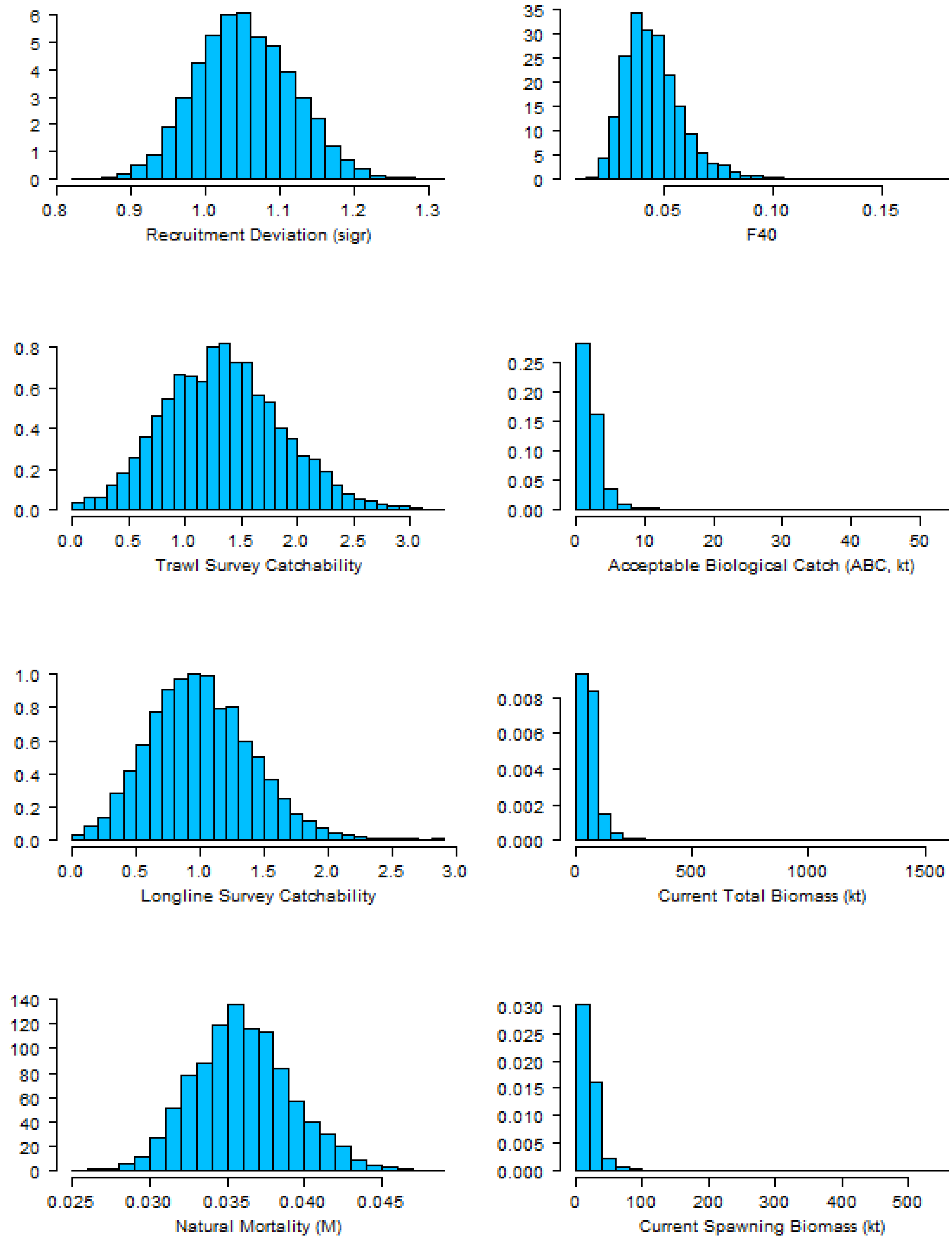


Figure 13-19: Histograms of estimated posterior distributions for key parameters derived from MCMC for GOA RE/BS rockfish.

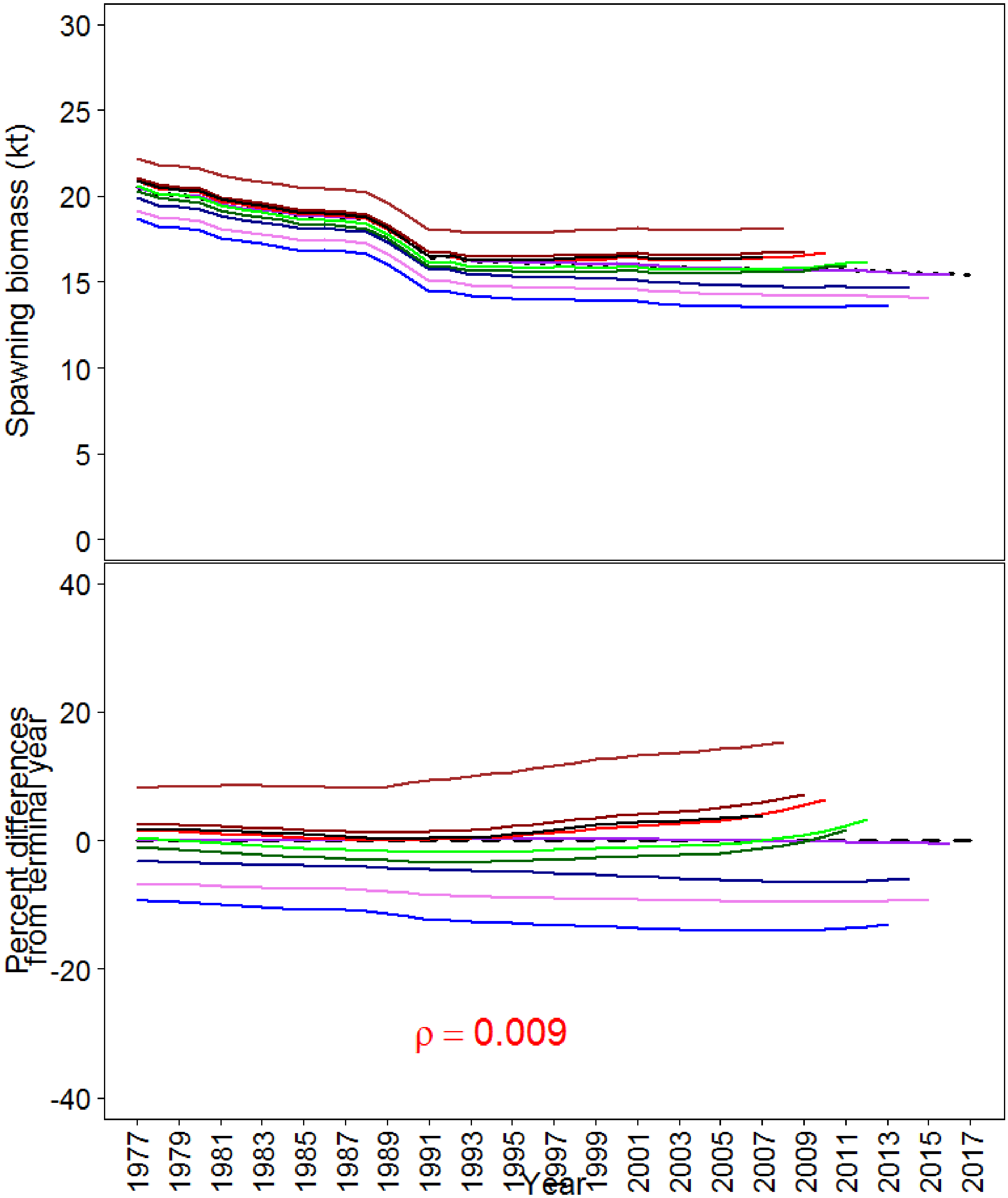


Figure 13-20: Retrospective peels of estimated female spawning biomass for the past 10 years from the author preferred model (top), and the percent difference in female spawning biomass from the preferred model in the terminal year (bottom).

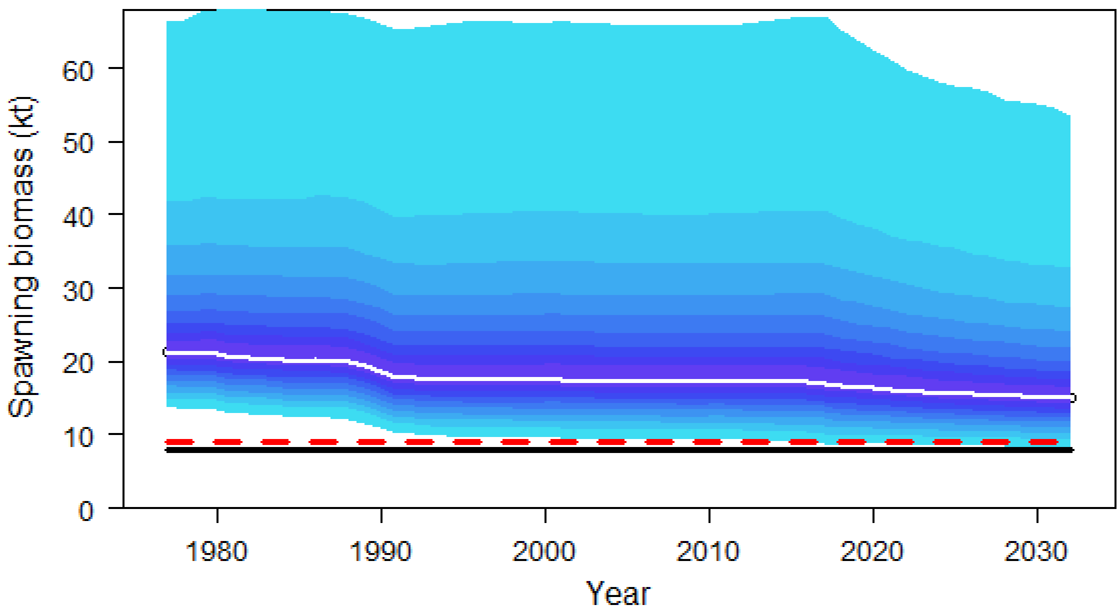


Figure 13-21: Bayesian credible intervals for entire spawning stock biomass series including projections through 2032. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1980-2015. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

# Appendix 13A. Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two 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, 2011, 2014). Trawl surveys include NMFS echo-integration, large-mesh, and GOA bottom trawl surveys. Longline surveys include IPHC and AFSC surveys. Other includes personal use, recreational, scallop dredge, and subsistence harvest. 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 1 t in 2016. This is 0.08% of the 2016 recommended ABC of 1,328 t and represents a low risk to the RE/BS stock. Even research catches of this magnitude, however, do not pose a significant risk to the RE/BS stock in the GOA.

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

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

The HFICE estimates of GOA RE/BS stock catch are highly variable but also significant ranging from 28 – 78 t per year (Table 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


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Table 13A-1. Total removals of Gulf of Alaska rougheye/blackspotted rockfish (t) from activities not related to directed fishing, since 1977.

| Year | Source | Trawl | Longline | Other | Total |
|---|---|---|---|---|---|
| 1977 | | 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 | **Assessment of RE/BS stock complex in the Gulf of Alaska (Shotwell et al. 2009)** | 0 | | | 0 |
| 1993 | | 10 | | | 10 |
| 1994 | | 0 | | | 0 |
| 1995 | | 0 | | | 0 |
| 1996 | | 5 | 8 | | 13 |
| 1997 | | 0 | 16 | | 16 |
| 1998 | | 45 | 7 | | 52 |
| 1999 | | 28 | 8 | | 36 |
| 2000 | | 0 | 10 | | 10 |
| 2001 | | 2 | 7 | | 9 |
| 2002 | | 0 | 6 | | 6 |
| 2003 | | 3 | 6 | | 9 |
| 2004 | | 0 | 6 | | 6 |
| 2005 | | 5 | 4 | | 9 |
| 2006 | | 0 | 5 | | 5 |
| 2007 | | 8 | 7 | | 15 |
| 2008 | | 0 | 11 | | 11 |
| 2009 | | 6 | 9 | | 15 |
| 2010 | AKRO | <1 | 7 | <1 | 7 |
| 2011 | AKRO | <1 | 6 | <1 | 8 |
| 2012 | AKRO | 2 | 5 | <1 | 6 |
| 2013 | AKRO | 2 | 4 | <1 | 6 |
| 2014 | AKRO | <1 | <1 | <1 | 1 |
| 2015 | AKRO | 2 | <1 | <1 | 3 |
| 2016 | AKRO | | 1 | | 1 |

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.