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 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 years, we 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 GOA 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 2019.

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 2020, new catch estimates used in projections for 2021-2023 (see *Specified Catch Estimation* subsection in **Harvest Recommendations** section)
2.) New fishery lengths for 2019
3.) New fishery ages for 2018 and 2020
4.) New bottom trawl survey biomass estimate for 2021. The 2019 trawl survey ages are still being processed and will be included in the next full assessment in 2023.
5.) New longline survey relative population numbers (RPN) for 2020 and 2021, and new longline survey RPN-weighted length frequencies for 2020 and 2021.

Updated geographic area sizes and variance calculations were implemented in the longline database in 2021 which resulted in small changes to the longline survey data. The updated RPNs and RPN-weighted length frequencies are used in this assessment. A description of these data is provided in the *AFSC Longline Abundance Index* and *AFSC Longline Size Compositions* subsections of the **Survey** section.

Changes in the assessment methodology: There were no changes in the assessment methodology. We continue to use the 2015 assessment model (15.4) that we also used in the 2019 full assessment. Please see Shotwell et al. (2015) for more details on the 2015, 2017, and 2019 assessment methodology (https://apps-afsc.fisheries.noaa.gov/refm/docs/2015/GOArougheye.pdf) and Shotwell et al. (2019) for more details on the last full assessment (https://apps-afsc.fisheries.noaa.gov/refm/docs/2019/GOArougheye.pdf).

Summary of Results

We recommend the maximum allowable ABC of 788 t from the updated projection model for the 2022 RE/BS fishery. This ABC is 35% lower than the 2022 projected ABC of 1,221 t from the 2020 partial assessment. Reference values for the RE/BS rockfish stock complex are summarized in the following table, with the recommended ABC and OFL values in bold.

	As estimated or specified *last* year for:		As estimated or recommended *this* year for:	
Quantity/Status	2021	2022	2022	2023
M (natural mortality)	0.036	0.036	0.034	0.034
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)	40,432	40,454	26,060	25,997
Projected female spawning biomass (t)	12,540	12,563	8,648	8,627
$B_{100\%}$	20,658	20,658	14,776	14,776
$B_{40\%}$	8,263	8,263	5,911	5,911
$B_{35\%}$	7,230	7,230	5,172	5,172
F_{OFL}	0.048	0.048	0.046	0.046
$maxF_{ABC}$	0.040	0.040	0.038	0.038
F_{ABC}	0.040	0.040	0.038	0.038
OFL (t)	1,456	1,467	**947**	937
max ABC (t)	1,212	1,221	**788**	781
ABC (t)	1,212	1,221	**788**	781
Status	As determined *last* year for:		As determined *this* year for:	
	2019	2020	2020	2021
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 384 t for 2021, and estimates of 356 t and 345 t used in place of maximum permissible ABC for 2022 and 2023 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.

Relative to past assessments, the 2021 assessment model exhibited a strong positive retrospective pattern (Mohn's rho=0.611), indicating that estimates of spawning biomass in the terminal year decrease when a subsequent year of data is added to the model. The 2021 trawl survey biomass estimate decreased 56% from the 2019 estimate and is the lowest in the time series. The 2021 longline survey abundance estimate decreased 36% since 2019, and 2020 was the lowest in the time series. These declines had significant impacts on the parameters that govern the scale of the population. In particular, estimates of trawl survey catchability increased from 1.7 to 2.2, longline survey catchability increased from 1.2 to nearly 1.7, and mean recruitment decreased from approximately 1.6 to 1.2 million fish. These changes resulted in a significant down grade in biomass trajectories, recruitment, and estimates of unfished spawning biomass.

The stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished. The test for determining whether overfishing is occurring is based on the 2020 catch compared to OFL. The official total catch for 2020 is 383 t which is less than the 2020 OFL of 1,452 t; therefore, the stock is not being subjected to overfishing. The tests for evaluating whether a stock is overfished or approaching a condition of being overfished require examining model projections of female spawning biomass relative to $B_{35\%}$ for 2022 and 2023. The estimates of spawning biomass for 2022 and 2023 from the current year projection model are 8,648 t and 8,627 t, respectively. Both estimates are above the $B_{35\%}$ estimate of 5,172 t and, therefore, the stock is not currently overfished nor approaching an overfished condition.

Area Allocation of Harvests

We use a two survey version of the random effects model, which equally weights the longline and trawl survey relative abundance indices (see Area Allocation of Harvests subsection in the Harvest Recommendations section below for more details). The following table shows the apportionment for the 2022 and 2023 fishery using the two survey random effects method.

Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
		23.3%	29.9%	46.8%	100.0%
2022	Area ABC (t)	**184**	**235**	**369**	**788**
	OFL (t)				**947**
2023	Area ABC (t)	**182**	**234**	**365**	**781**
	OFL (t)				**937**

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
RE/BS complex	2020	40,336	1,452	1,209	1,209	383
	2021	40,432	1,456	1,212	1,212	370
	2022	26,062	947	788		
	2023	25,957	937	781		

Stock/ Assemblage	Area	2021 OFL	2021 ABC	2021 TAC	2021 Catch[2]	2022 OFL	2022 ABC	2023 OFL	2023 ABC
RE/BS complex	W		168	168	21		184		182
	C		456	456	171		235		234
	E		588	588	178		369		365
	Total	1,456	1,212	1,212	370	947	788	937	781

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

[2]Current as of October 25, 2021. 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

SSC and Plan Team comments related VAST, ESPs, spatial management, and other general topics not applicable to this assessment were omitted for brevity.

Risk Tables:

"The SSC requests that all authors fill out the risk table in 2019…" (SSC December 2018)
"…risk tables only need to be produced for groundfish assessments that are in 'full' year in the cycle." (SSC, June 2019)
"The Teams recommended that authors continue to fill out the risk tables for full assessments. The Teams recommended that adjustment of ABC in response to levels of concern should be left to the discretion of the author, the Team(s), and/or the SSC, but should not be mandated by the inclusion of a >1 level in any particular category. The Teams request clarification and guidance from the SSC regarding the previously noted issues associated with completing the risk table, along with any issues noted by the assessment authors. The Teams plan to discuss the risk table process at the September meeting." **(**Plan Team Nov 2019).
"The SSC continues to support that reductions from the maximum permissible ABC should be infrequent and only for exceptional circumstances (Appendix A, Preliminary Guidance and SSC recommendations, bullet 9)." (SSC, June 2021)
"*The SSC also recommends that stock assessment authors and the Plan Teams review all recommendations and provide feedback.*" (SSC, June 2021)

SSC Risk Table Guidelines (formalized SSC, October 2021, distributed via email by Anne Hallowed October 25, 2021)

1. *The SSC concluded that the risk table framework is working well. The tables have expanded communication among assessment authors and between assessment authors and ecosystem/process researchers. The framework is intended to provide a clear and transparent basis for communicating assessment-related and stock condition concerns that are not directly captured in model-based uncertainty, the tier system, or harvest control rules.*
2. *The SSC recommended no changes to the language in the Risk Table template.*
3. *The SSC recognizes that within the context of the risk tables, "risk" is the risk of the ABC exceeding the true (but unknown) OFL. The risk tables are intended to inform the process of adjusting the ABC from the maximum permissible when needed. Recommendations of an ABC reduction from the maximum permissible requires justification. The risk tables provide an avenue for articulating that justification.*
4. *The SSC recommends that consideration for reductions from maxABC be based on current year information unless relevant risk factors for a stock continue to be present from previous years.*
5. *The SSC recommends that for stocks managed in Tiers 1-3, that risk tables are produced for all full assessments of groundfish (and perhaps crab) stocks and stock complexes in the fishery. Risk tables can be produced in other years at the discretion of the lead author if there have been notable changes to previous conditions.*
6. *The SSC recommends that Risk Tables should not be mandatory for other Tiers; however, stock assessments must include compelling rationale for why a Risk Table would not be informative.*
7. *For stock complexes, the SSC recommends that the decision concerning which species (or multiple species) to focus on be up to the author.*
8. *The SSC recommended maintaining the status quo, where authors are encouraged (but not required) to provide a recommendation on a reduction from maxABC, if warranted, and the Plan Teams and SSC would then evaluate and modify the reductions (if needed) based on the information available for the stock.*
9. *Risk scores should be specific to a given stock or stock complex. While comparison across species (e.g., within a tier, with similar life histories) or stocks is useful for consistency, the SSC does not support trying to prescribe a common reduction from the maximum permissible ABC for a given risk score across species or stocks because the processes underlying the score may differ among species and stocks. The SSC recommends that considerations of reductions in ABCs below the maximum permissible continue to be made on a case-by-case basis with justification based on risk scoring. The risk table rankings include qualitative information that requires a certain amount of subjective but well-informed interpretation of the available data by the author(s), the*

Plan Teams and the SSC, and as such, the SSC feels that blanket comparisons across species or stocks for the purpose of explicitly defining reductions in ABC below the maximum permissible are not prudent.

10. *The SSC encourages the inclusion of LK/TK/S as a source of knowledge about the condition of the stock, a shift in the spatial or temporal distribution of the resource, or changes in the size or condition of species in the fishery.*
11. *The SSC recommends that the fishery/community performance column should focus on information that would inform the biological status of the resource (e.g., an unexplained drop in CPUE that could indicate un-modelled stock decline, or a spatial shift indicating changes in species' range), and not the effects of proposed ABCs on the fishery or communities or bycatch-related considerations. The SSC recognizes that the community impact information is critical for Council decision making and supports efforts to effectively communicate where this information can be accessed.*
12. *The SSC appreciates the discussion of avoiding double-counting information, in the assessment/Tier system and risk table, or among columns of the risk table. The SSC agrees that authors should avoid inclusion of stock trends/processes that are incorporated in the assessment or reflected in the Tier when scoring the risk tables. For cases where a process external to the assessment is relevant to two or more risk categories, the SSC recommends that the narrative reflect the interconnected relationships that exist between rankings among risk categories.*
13. *The SSC suggests a revision to the category levels: from the existing four to three categories (normal, increased, extreme). The SSC recommends postponing this change until 2022 as many authors have already begun working on risk tables for 2021.*
14. *The SSC reiterates that reductions in ABC below the maximum permissible should be applied sparingly and that the tier system should be regarded as the primary basis for establishing the ABC. If they begin to become commonplace, that should warrant further review of the assessment and/or the Tier system.*

We provide a risk table as recommended by the SSC. The highest score for this stock is a Level 2 (substantially increased assessment-related concerns), however, we do not recommend that the ABC be reduced below maximum permissible ABC. Please see the Harvest Recommendations section for further details for each category of this risk table.

The authors maintained the four categorical scoring levels for this year's risk table and understand that the future iterations will likely have only three scoring levels. Any recommendations provided within this risk table were reviewed by all of the assessment authors as well as AFSC ecosystem staff and internal reviewers prior to presentation to the Plan Team and the SSC. The risk table presented in this assessment follows the previous guidelines to not include positive trends in the Assessment, Ecosystem or Fishery Performance categories.

Responses to SSC and Plan Team Comments Specific to this Assessment

"The author summarized the findings of the 2019 bottom trawl and longline surveys with respect to RE/BS. The bottom trawl survey indicated that the RE/BS biomass is slowly increasing since 2013, with spatial distribution generally even along the slope. The 2019 survey biomass is 22 percent above the long-term average. The longline survey does not track the increases seen in the trawl survey, but the author noted that using both surveys collectively picks up more signals about changes in the RE/BS stock. The Team recommended that the authors investigate depth strata in which there is overlap between the trawl and longline surveys to evaluate consistency in catch between the two surveys." (GOA Plan Team, November 2019)

This comment prompted an update to the *Comparison of AFSC Bottom Trawl and Longline Surveys* subsection of the **Survey** data section of this SAFE chapter. Please refer to that section and Figures 13-4a and 13-4b for an analysis comparing the trawl and longline survey indices by geographic area and depth stratum.

"The same model that was used in 2015 and 2017 was used for the 2019 assessment, with similar parameters to 2017. Results included slightly higher survey catchability and slightly lower mean recruitments, and the longline survey selectivity is now slightly dome-shaped in the 2019 assessment. The model fit was similar to that seen in 2017. The Team recommended that the author investigate how selectivity is modeled. In particular, there were some abrupt changes between ages in the average fishery selectivity." (Plan Team, November 2019)

We agree with the Plan Team and plan to explore these modeling concerns in the next off-year assessment with results presented in the following full assessment. In light of the continued changes in recruitment and survey catchability estimates in the 2021 assessment, we appreciate further comments and recommendations from the Teams and SSC on this topic.

<u>Multispecies stock assessment and species identification</u>
"The issues of how to meaningfully assess and manage a two species complex remains. The authors noted the SSC recommendation for an analysis that provides a more realistic range of management risk of combining RE/BS as one stock. Methods to enhance the assessment could include catch composition analysis, genetic species identification, and maturity curve differences. The author noted that it could be possible to use otolith morphometrics to address this in the future, but that methodology is not yet robust enough to use in the RE/BS model. The assessment includes an appendix that summarizes current efforts related to RE/BS stock i.d., growth, and maturity analyses. The Team recommended that the authors incorporate additional information about species identification obtained through otolith morphology in future assessments." (GOA Plan Team, November 2019)

"An important ongoing issue with this assessment is that it is a complex of two distinct species. The SSC appreciates the appendix that describes the current state of genetic research on mis-identification rates, otolith morphology, growth and maturity for this complex. It is clear that a number of positive steps are being made to understand how the species within this complex are both similar and different. As the author notes, many of these projects are ongoing. Of note is an updated maturity study on both species (Conrath 2017) that clearly demonstrates a difference in age at 50% maturity (19.6 years and 27.4 years for rougheye and blackspotted, respectively) between these species. The SSC continues to encourage effort to incorporate this information into the assessment as much as possible, to improve species-specific information in this assessment and move towards splitting this complex. Alternative model configurations that incorporate these data would be highly encouraged as a step in this direction." (SSC, December 2019)

"…the SSC registers some concern regarding age structure collections moving forward, particularly if otolith morphology is a valid method for differentiating these species. Special collections may be appropriate if otolith metrics become an operational tool for species differentiation." (SSC, December 2019)

We appreciate the SSC and Plan Team's comments related to the challenges of doing a data limited, multispecies stock assessment for long-lived and cryptic rockfish species. A recent study used otolith shape analysis (i.e. morphometrics), weight, and age to accurately identify RE/BS rockfish 86% and 97% of the time, respectively (Harris et al. 2019). In comparison, field-based identification rates range from 62-66% for rougheye rockfish and 92-94% for blackspotted rockfish. These findings, which were based on 1,847 specimens collected during research surveys and confirmed using genetics, demonstrated that otolith morphometrics can be used to improve species identification rates, especially for rougheye rockfish. Although time consuming and potentially costly to implement, this method could be used to reliably identify archived otoliths from the past 20-30 years.

The GOA RE/BS assessment is currently transitioning authors, and therefore we did not make substantial model progress during the 2021 assessment cycle. In the future we will continue to provide updates on relevant research projects related to RE/BS biology and species identification and make revisions to the population model as needed to align with the best available science for this complex.

Apportionment:
"The Team accepted the new RE apportionment methodology, and recommended that this also be used in the future." (Plan Team, November 2019)
"The methodology for area apportionment was re-evaluated in this assessment. Previously, a weighted average of the area-specific biomass proportion from the last three trawl surveys was utilized. The authors responded directly to previous GPT and SSC comments by developing a random effects model with equal weighting between the bottom trawl survey and the AFSC longline survey. The use of two survey random effects method uses more information for apportioning than the previous method. A comparison of both methods indicates a shift of ABC allocation to the eastern and western GOA from the central GOA. The SSC supports the authors' and GPT's recommendation to use the two-survey random effects model for area allocation." (SSC, December 2019)

We used the recommended two survey random effects model for apportionment in 2021.

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 (*S. 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 RE/BS 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 observed in a 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 RE/BS 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 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). A recent Essential Fish Habitat (EFH) analysis (e.g. Laman et al. 2017) provided species distribution models from the bottom trawl survey for RE/BS 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 RE/BS 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). Research 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 and RE/BS 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 *Sebastes* individuals have slightly higher egg dry weight than their middle-aged counterparts. A study of Pacific ocean perch near Kodiak Island found a significant effect of maternal age on offspring provisioning, which may imply greater fitness for older females (Arnold et al. 2018). Despite empirical evidence supporting age-dependent fecundity and reproductive success of *Sebastes* and other marine teleosts (Hixon et al. 2014), stock assessments for Alaska rockfish assume that the reproductive success of mature fish is proportional to weight and therefore independent of age.

Evidence of Stock Structure

Since 2007, we have responded to issues regarding the difficulty identifying RE/BS rockfish and the development of a rationale for assessment decisions regarding this mixed stock. Reports have included summaries of studies on the genetic and phenotypic differences between RE/BS rockfish, discussion of the research regarding at-sea misidentification rates, and projects developed to understand species-specific life history characteristics (Shotwell et al. 2008, 2009). We completed a full stock structure evaluation of RE/BS 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 RE/BS rockfish executive summary SAFE report (Shotwell et. al 2010). Brief summaries of RE/BS rockfish speciation and the stock structure template 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 distinguished the two 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 are typically pale with spots absent from the spinous dorsal fin and possibly has mottling on the body. Blackspotted rockfish are 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).

A recent study used otolith shape analysis (i.e. morphometrics), weight, and age to accurately identify RE/BS rockfish 86% and 97% of the time, respectively (Harris et al. 2019). In comparison, field-based identification rates range from 62-66% for rougheye rockfish and 92-94% for blackspotted rockfish. These findings, which were based on 1,847 specimens collected during research surveys and confirmed using genetics, demonstrated that otolith morphometrics can be used to improve species identification rates, especially for rougheye rockfish. This method could be used to reliably identify archived otoliths from the past 20-30 years.

Stock Structure Template Summary

We summarize the available information on stock structure for the GOA RE/BS rockfish complex in Table 13-1. Since the formal verification of the two species has only recently occurred, most data on RE/BS 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 RE/BS 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, subarea ABCs and TACs, and the generally low area-specific harvest rates, we continue to recommend the current management specifications for RE/BS rockfish.

Fishery

History

RE/BS 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 RE/BS 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 since 2010. RE/BS rockfish are generally caught in either bottom trawls or with hook-and-line (i.e. “longline”) gear, with approximately 55-75% taken in the trawl fisheries and 30-45% taken in the longline fisheries in recent years.

The majority of the recent catch has been taken in the Central GOA bottom trawl fishery. Increases in recent catch have also occurred in the Eastern GOA longline fishery, particularly in 2018 in Southeast. Catches have remained relatively low and stable across both bottom trawl and longline gear in the Western GOA. In 2021, approximately 50% of the catch was from bottom trawls, 35% from longline, and 10% from pelagic trawls. The majority of catch by trawl gear occurs in the rockfish, flatfish, and pollock fisheries. For longline gear, nearly all the RE/BS catch appears to come as bycatch in the sablefish or halibut longline fisheries. Since catch accounting was established separately for RE/BS rockfish complex in 2005, between 20-60% of the TAC for RE/BS rockfish has been caught (Table 13-2). The 2021 catch is at 31% of the TAC as of October 25, 2021.

The legalization of pot gear in the GOA IFQ sablefish fishery in 2017, coupled with the introduction of the novel lightweight, collapsible ‘slinky’ pot to Alaska, has translated to a rapid increase in the proportion of sablefish catch from pots. This shift in fishing behavior has resulted in an increase in the percentage of RE/BS catch from pots (<0.001% prior to 2017 to 6% in 2021). Pot gear generally has less bycatch of non-target species compared to hook-and-line gear, and we may expect an overall reduction in bycatch rates in the sablefish fishery as pot gear increases in popularity. While there is some evidence of decreased bycatch rates of RE/BS in the sablefish fishery in 2020 and 2021 (Figure below), anomalously high bycatch rates in 2017-2019 in multiple regulatory areas confuse this trend. We will continue to monitor bycatch trends and resultant changes in selectivity patterns as the sablefish pot fishery evolves.

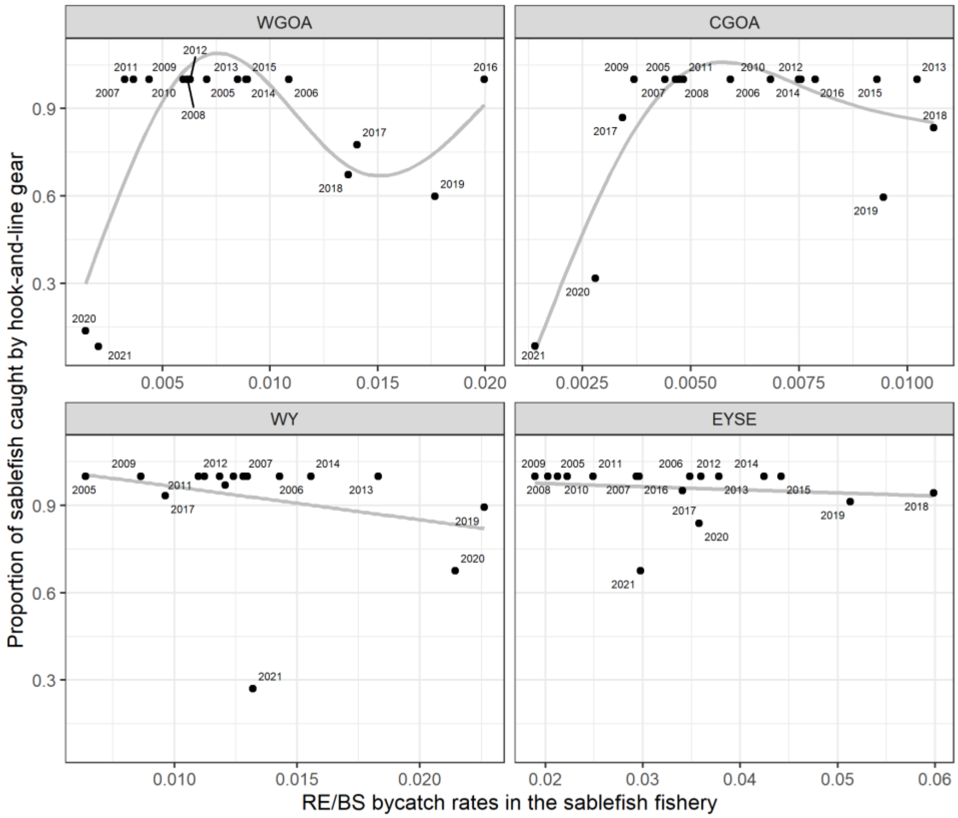

Figure. The proportion of sablefish caught by hook-and-line gear as a function of RE/BS bycatch (total catch of RE/BS / total catch of sablefish) on trips identified as targeting sablefish. A generalized additive model (grey) smoother is added to aid in visualization.

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 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. This program has subsequently shifted towards increased electronic monitoring, first for fixed gear longline and pot vessels and more recently for trawl vessels. Understanding the potential for catch accounting and stock assessment biases due to shifts in observer and EM coverage and the resultant 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 rockfish 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 (*S. 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 established cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish species. This implementation impacts primary rockfish management groups but will affects 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. Effects of this program to RE/BS 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 RE/BS 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 2018-2021 (Table 13-5), the largest non-rockfish bycatch groups are on average arrowtooth flounder (1,251 t/year), walleye pollock (923 t/year), Atka mackerel (757 t/year), sablefish (705 t/year), and Pacific cod (347 t/year). Non-FMP species catch in the rockfish target fisheries is generally dominated on average by giant grenadier and miscellaneous fish (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 been steady since 2015, averaging 0.12 t.

Discards

The table below indicates that discards of RE/BS rockfish have ranged from approximately 10% to 41% with an average of 21.5% in the most recent ten years. These values are relatively high when compared to other *Sebastes* species in the Gulf of Alaska. The most recent large increase in 2018 may be due to an increase in discards in the sablefish longline fishery in the Eastern GOA but is not completely understood and may simply exist due to enforcement concerns or changes to observer coverage (Echave and Hulson, 2019). Regardless of the cause, the discard rate for RE/BS rockfish has decreased to below average levels in 2020 and 2021.

Rougheye / Blackspotted Complex

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
% Discards	14.8	22.2	17.4	22.1	26.6	20.7	41.2	25.2	10.4	14.6

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	1977-2019, **2020, 2021**
	Age	1990, 2004, 2006, 2008, 2009, 2010, 2012, 2014, 2016, **2018, 2020**
	Length	1991-1992, 2002-2003, 2005, 2007, 2011, 2013, 2015, 2017, **2019**
AFSC bottom trawl survey	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, **2021**
	Age	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017
AFSC longline survey	Relative Population Number (RPN)	1993-2019, **2020, 2021**
	Length	1993-2019, **2020, 2021**

Fishery:

Catch

Catches of RE/BS rockfish have ranged between 130 t to 2,418 t since 1977. 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 RE/BS 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

RE/BS 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. RE/BS 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 Domestic 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.

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). On average, approximately 34% of the age samples are taken from the bottom trawl fishery and 66% taken from the longline fishery for at-sea samples. This percentage is similar for the data used in the model with 33% of lengths from the trawl fishery and 67% from the longline fishery. 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 RE/BS rockfish. Table 13-9 summarizes the available size compositions from 1991-2019. 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, 2015, 2017, and 2019 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 42% of the lengths are taken from the bottom trawl fishery and 58% from the longline fishery for at-sea samples. This percentage is different for the data used in the model with 37% of lengths from the trawl fishery and 63% from the longline fishery. The mean of lengths for the 1991-1992 samples is approximately 45 cm and from 2002-2017 has remained relatively steady between 45 to 48 cm. Moderate presence of fish smaller than 40 cm is present in most years, particularly 1991 and 1992.

Survey:

AFSC Bottom Trawl Biomass Estimates

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

Summaries of biomass estimates from the 1984-2021 surveys are provided in Table 13-10. Trawl survey biomass estimates are shown in Figure 13-2. The 2021 biomass estimate was an all-time low for this time series. The decrease was 56% below the 2019 estimate and 43% below the mean biomass estimate for the time series. The trends by area were not consistent, as there were decreases in the central and eastern GOA and an increase in the western GOA.

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 at-sea identified RE/BS rockfish have been somewhat inversely correlated among the surveys, but when combined there is a somewhat decadal oscillation to the survey trajectory over time. However, 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 trawl survey biomass estimates for RE/BS rockfish show relatively tight confidence intervals and low coefficients of variations (CV), ranging between 11% and 23%. The exception to this was the 2019 survey where the CV was approximately 69% in the central GOA, which is the largest on record for this stock. This was due to on particularly large tow near Kodiak. The otherwise 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 RE/BS catch from this survey 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, utilization of both the trawl survey and longline survey (which can sample where trawl surveys cannot) abundance indices should alleviate some of this concern.

In 2007, the trawl survey began separating rougheye rockfish from blackspotted rockfish using a species identification key (Orr and Hawkins, 2008). Biomass estimates of the two species by region somewhat support distributional differences; 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 subsequent surveys the reverse occurred, with 63% to 73% rougheye and 37% to 27% blackspotted. The initial shift may have been due to 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

No new ages were added in 2019 due to a delay in processing. As of 2017 there are a total of fourteen years of survey age compositions with a total sample size of 7,744 ages. Survey age sample sizes are generally higher than fishery age sample sizes, ranging from 200 to 1,000. Although RE/BS 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, 2015, and 2017 along with a high proportion of three, five, and now seven 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 RE/BS rockfish, rougheye compositions tend to be spread evenly across ages, while blackspotted tend to be much older, although this has changed since the 2013 survey as the fish in general are younger overall. Mean age of rougheye range from 13 - 16, while mean age for blackspotted range from 16 - 24. Given, the misidentification rates, we combine these two age compositions for 2007, 2009, 2011, 2013, 2105, and 2017 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 2019 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. Since 2007, survey RE/BS rockfish lengths were split. Rougheye have an average length of 33 cm while blackspotted have an average of 38 cm. Rougheye have a much broader range of lengths from 10-60 cm, while blackspotted tend to be more confined to the 35-50 cm range. 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 RE/BS 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 RE/BS 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).

Like the trawl survey biomass, the RPN estimates for RE/BS rockfish have been variable throughout the time series (Figure 13-3). The 2021 RPN was 36% lower than 2019, and 2020 was the lowest in the time series. This trend was driven by declines in the central and western GOA, whereas the eastern GOA is around the time series mean.

There have been several changes to the longline survey indices 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. Compared to the trawl survey, the longline survey may do a better job sampling RE/BS at shallower depths.

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 1993-2021 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 strata 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).

As mentioned in the previous section, the trawl survey does not typically sample the high relief habitat of RE/BS 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 RE/BS age data for the longline survey. 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 on 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

Although no rockfish otoliths are collected on the longline survey, large samples of RE/BS lengths have been collected gulfwide since 1993. 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 an area for future research.

Since the longline survey does not sample in proportion to area, we weight longline survey size compositions by area abundance (RPNs) instead of raw sample size. Updated longline survey size compositions are available from 1993-2021 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.

Comparison of AFSC Bottom Trawl and Longline Surveys

We have asserted that the use of both the AFSC bottom trawl and longline surveys allows us to pick up more signals about the changes in the RE/BS stock. However, as described in the previous sections, both surveys exhibit considerable noise and inter-annual variability and frequently exhibit divergent trends. The 2019 assessment prompted a recommendation from the Plan Team to investigate depth strata in which there is an overlap between the trawl and longline surveys to evaluate consistency in catch between the two surveys. To address this recommendation, we compared Pearson correlation coefficients of the standardized time series of trawl survey biomass and longline survey RPNs by regulatory area and depth strata. Because the two surveys use different depth strata definitions between 300 and 700 m, we examined alternatives for overlapping strata and present the alternative with the highest number of positive correlation coefficients (see table below).

Table. Depth strata definitions from the GOA trawl and longline surveys with three depth overlap alternatives to compare correlations between the indices.

<table>
<tr><th>Depth</th><th>GOA trawl</th><th>Longline survey</th><th>Alternative 1</th><th>Alternative 2</th><th>Alternative 3</th></tr>
<tr><td>1-100</td><td>1-100</td><td>1-100</td><td>1-100</td><td>1-100</td><td>1-100</td></tr>
<tr><td>101-200</td><td>101-200</td><td>101-200</td><td>101-200</td><td>101-200</td><td>101-200</td></tr>
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<tr><td>301-400</td><td rowspan="2">301-500</td><td>301-400</td><td rowspan="3">301-500/600</td><td rowspan="2">301-400/500</td><td rowspan="4">301-600/700</td></tr>
<tr><td>401-500</td><td rowspan="2">401-600</td></tr>
<tr><td>501-600</td><td rowspan="2">501-700</td><td rowspan="5">401/501-1000</td></tr>
<tr><td>601-700</td><td rowspan="2">601-800</td><td rowspan="4">501/601-1000</td></tr>
<tr><td>701-800</td><td rowspan="3">701-1000</td><td rowspan="3">601/701-1000</td></tr>
<tr><td>801-900</td><td rowspan="2">801-1000</td></tr>
<tr><td>901-1000</td></tr>
</table>

The overlap in the 301-500 m trawl and 301-600 m longline strata (Alternative 1 in the table above), resulted in the largest number of positive correlation coefficients for the full set of depth-area combinations (8/14; Figure 13-4a). Overall there were mixed results of positive and negative correlations between the indices by area and depth (Figure 13-4a). The areas with the highest correlations were in the 101-200 m depth stratum in the Western GOA (rho=0.51) and Central GOA (rho=0.37). The lack of consistent trends between the surveys becomes further confused when interpreted in the context of the overall biomass or RPN by area and depth strata. For example, the strata with the greatest estimated biomass in both surveys (201-300 m and 301-500/600 m) frequently resulted in weak or even negative correlations. Additionally, the surveys apportion biomass disparately between regions, which may indicate that the overall scale and trend of the population is poorly determined by either or both of these surveys.

In 2021, this assessment saw large changes in survey catchability estimates that resulted in a downward shift in the long term biomass trajectory for this stock. However, because the surveys exhibit inconsistent trends and partition biomass differently among areas, it is unclear if these signals reflect a genuine conservation concern or are the byproduct of survey data conflicts. Moving forward it may be a useful exercise to estimate survey indices using the same depth strata definitions, however such a task would require support from at least one of the survey data teams. It may also be useful to weight CPUE by a variable other than total geographic area that may be more relevant to this complex (e.g. Essential Fish Habitat within a stratum). Finally, it may be informative to revisit sensitivity analyses initiated in 2005, the results of which are summarized in the following section.

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 RE/BS 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 RE/BS 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 RE/BS 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 with estimated annual recruitment deviations. We do this because there does not appear to be an obvious stock-recruitment relationship in the model estimates, and there is little contrast in the spawner-recruit 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.

Model Number	Model Description
Model 15.4 (2017)	Model M4.a from Shotwell et al. (2015)
Model 15.4 (2019)	Same Model 15.4 but incorporates all new and updated data from 2019
Model 15.4 (2021)	Same Model 15.4 but incorporates all new and updated data from 2021

There are no model alternatives to consider for the 2021 assessment. We continue to use the recommended model from the 2015 assessment which was the fourth model evaluated (Model M4.a). We updated the model name to Model 15.4 to use the correct naming convention, and this change is detailed in the following table for clarity:

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

A study by Conrath (2017) provided species-specific estimates for length and age maturity for RE/BS rockfish using samples collected on research surveys in 2010-2014 that relied on field-based species identification. Parameter estimates from this study showed comparable estimates of length at 50% maturity (l_{50}), but blackspotted rockfish had a slower maturation rate (δ_l). In order for these species to exhibit comparable l_{50}s but different maturation rates, it means blackspotted rockfish start maturing at smaller sizes and don't reach 100% maturity until they are larger than rougheye. Estimates of age-based maturity were very different between the species, with rougheye reaching 50% maturity eight years younger than blackspotted rockfish, and rougheye exhibiting a higher maturation rate (δ_a).

Length and age-based maturity estimates from Conrath (2017)			
	Parameter	**Rougheye rockfish**	**Blackspotted rockfish**
Length-based maturity	l_{50}	45.0 cm	45.3 cm
	δ_l	0.48	0.31
Age-based maturity	a_{50}	19.5 y	27.4 y
	δ_a	0.33	0.25

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_∞= 49.6 cm κ=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_∞= 1,639 g κ=0.12 t_0=-0.38 β=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. Additional available age samples allowed for an update of the age-error matrix in 2011. 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. In the 2015 assessment the plus age group was extended in the model compared to the plus age group in the data to alleviate the consistent over-estimation of the proportion at age in the age bins adjacent to the plus group age.

Parameters Estimated Inside the Assessment Model

The estimates of natural mortality (*M*), catchability (*q*), and recruitment deviations (σ_r) are estimated with the use of prior distributions as penalties. The prior for RE/BS rockfish natural mortality estimate is 0.03 which is based on McDermott (1994). She used the gonadosomatic index (GSI) following the methodology described by Gunderson and Dygert (1988) to estimate a range of natural mortalities specifically for RE/BS (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 (https://media.fisheries.noaa.gov/dam-migration/center_for_independent_experts_summary_report_for_the_2006_alaska_rockfish_review-508.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 RE/BS 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.

Since these analyses were completed, Hamel (2014) and Then et al. (2015) have updated many of the natural mortality estimators. When new methods were applied to the Bering Sea and Aleutian Islands blackspotted and rougheye rockfish stock assessment, Spencer et al. (2020) found a natural mortality near 0.045. Additionally, natural mortality is known to be correlated with catchability in population models. Given the difficulties estimating survey catchability parameters, it may be advantageous to fix rather than estimate natural mortality. We intend to revisit natural mortality assumptions in future iterations of this assessment.

Catchability parameters are highly 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 RE/BS 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 (100% for both surveys) 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. RE/BS 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:

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

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

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	μ_r	1
Recruitment variability	σ_r	1
Fishing mortality rates	$F_{35\%}, F_{40\%}, F_{50\%}$	3
Recruitment deviations	σ_y	93
Average fishing mortality	μ_f	1
Fishing mortality deviations	F_y	45
Fishery selectivity coefficients	fs_a	14
Survey selectivity coefficients	ss_a	17
Total		178

Uncertainty

Evaluation of model uncertainty has 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 178. 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□a_+
m_a	Vector of estimated maturity at age, a_0□a_+
a_0	Age it first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
F_y	Annual fishing mortality deviation
σ_y	Annual recruitment deviation
σ_r	Recruitment standard deviation
fs_a	Vector of selectivities at age for fishery, a_0□a_+
ss_a	Vector of selectivities at age for survey, a_0□a_+
M	Natural mortality, log-scale estimation
$F_{y,a}$	Fishing mortality for year y and age class a ($fs_a \mu_f e^{\varepsilon}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
$\varepsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length conversion matrix
q_1	Trawl survey catchability coefficient
q_2	Longline survey catchability coefficient
SB_y	Spawning biomass in year y, ($=m_a\, w_a\, N_{y,a}$)
M_{prior}	Prior mean for natural mortality
q_{prior}	Prior mean for catchability coefficient
$\sigma_{r(prior)}$	Prior mean for recruitment variance
σ_M^2	Prior CV for natural mortality
σ_q^2	Prior CV for catchability coefficient
$\sigma_{\sigma_r}^2$	Prior CV for recruitment deviations

BOX 1 (Continued)

Equations describing the observed data

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

Catch equation

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

Trawl survey biomass index (t)

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

Longline survey abundance index (RPN)

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

Survey age distribution
Proportion at age

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

Survey length distribution
Proportion at length

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

Fishery age composition
Proportion at age

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

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

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

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

Results

Model Evaluation

There were no recommended changes to this year's assessment model compared to the model used in 2015, 2017, and 2019. Negative log-likelihood and estimates of key parameters for last year's full assessment (2019 Model 15.4) and this year's updated model (2021 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 but are not fit within the model (Figure 13-11).

Declines in trawl survey biomass and longline survey RPNs since 2019 had significant impacts on the parameters that govern the scale of the population. In particular, estimates of trawl survey catchability increased from 1.7 to 2.2, longline survey catchability increased from 1.2 to nearly 1.7, and mean recruitment decreased from approximately 1.6 to 1.2 million fish (Table 13-5). These changes resulted in a significant downgrade in biomass trajectories, recruitment, and estimates of unfished spawning biomass.

Model 15.4 continues to rely heavily on size composition data, with lengths from the fishery and longline survey contributing over 50% to the overall likelihood (Table 13-5). Fits to the age and size composition are very similar to the 2019 assessment. 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). Fits to the fishery size compositions are slightly flattened (Figure 13-9), particularly in 1991. Fits to the bottom trawl survey age compositions are generally good, with some underestimation of abundant cohorts such as the 1990 and 2010 year-classes (Figure 13-10). Fits 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 proportion of size 30 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 functional forms for selectivity or explore separate selectivity curves for trawl and longline fisheries.

We continue to recommend model 15.4 to update management quantities for 2022. We discuss results of this model in the following section. Estimated numbers in 2021, 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 the 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 2021 author preferred model (Model 15.4).

Definitions

Spawning biomass is the biomass estimate of mature females. Total biomass is the biomass estimate of all RE/BS rockfish age three and greater. Recruitment is measured as number of age-3 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 substantially lower for the entire time series (Figure 13-13, Figure 13-14). The 2019 assessment estimated a stable total biomass between 1995 and 2019; the updated 2021 assessment now shows a steady decline in biomass between 2010 and 2021. Recruitment trends were generally similar between the preferred model and the estimates from the last full assessment, however the scale of recruitment is lower due to the reduced estimate of log mean recruitment in the 2021 assessment (Tables 13-15 and 13-18).

Biomass and Exploitation Trends

Up until 2010, predicted values for the bottom trawl and longline surveys were similar in the 2019 and 2021 assessments, after which time predicted values in the 2021 assessment began decreasing in order to fit the below-average survey observations in 2020 and 2021 (Figures 13-2 and 13-3). The addition of new survey data and subsequent change in the predicted trajectories for the survey indices translated into a change in the scale of total and spawning biomass for RE/BS (Figures 13-13 and 13-14). Mean total biomass from 1993-2019 was 39,800 t and 29,726 t in the 2019 and 2021 assessments, respectively, reflecting a 48% reduction in the average scale of the total population. Estimated mean spawning biomass over the same time period was 13,358 t and 10,179 t in the 2019 and 2021 assessments, respectively, reflecting a 24% reduction in the scale of the spawning population. In addition to the downward shifts in population scale, the 2021 assessment model also shows declines in biomass trajectories since 2010 (Figures 13-13 and 13-14) and continuing beyond 2022 in model projections (Figure 13-21). The associated estimated MCMC credible intervals for total and spawning biomass are wide (Figures 13-13 and 13-14), suggesting high uncertainty in these derived values.

Fishery, trawl survey, and longline survey selectivity estimates were similar between the 2019 and 2021 assessment models and were consistent with expected fishery and survey dynamics for the most part (Figure 13-15; Shotwell and Hanselman 2019). The commercial fishery captures larger and subsequently older fish compared to the trawl survey, which samples a larger range of ages. The longline survey samples deeper depths than the trawl survey, making younger less 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 selectivity is dome-shaped because adult habitat is typically in rocky areas along the shelf break where the trawl survey gear may have difficulty sampling. However, estimates suggest that selectivity is changing considerably for older aged fish in the survey, which we would not expect given occupied habitat should not change above a certain age. Future research could consider alternative parameterizations that would allow for more constrained estimates of selectivity at older ages.

Along with other population-scaling parameters like catchability and recruitment, estimates of fishing mortality (F) also changed in the 2021 assessment (Figure 13-16). For comparison, the mean F from 1993-2019 was estimated to be 0.0161 and 0.0214 in the 2019 and 2021 assessment, respectively. Although mean estimates of F have increased, the overall trend and estimated deviations in fishing mortality remained stable.

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 RE/BS 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 was an increasing trend in fishing mortality from 2010-2019, but this trend reversed in 2020 and 2021 due to decreased catch of RE/BS.

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 1988, 1989, and 1990 (Figure 13-17). Overfishing did not occur during those years based on the F_{OFL}

estimate at the time. Since 1990, spawning biomass of RE/BS rockfish has been above $B_{40\%}$ and fishing mortality has been below $F_{40\%}$.

Recruitment

In general, recruitment is highly variable, particularly in the most recent years when 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 (Figures 13-5 and 13-18). As previously described, there was a downward shift in the estimates of log mean recruitment, which resulted in a 33% decrease in mean recruitment between 1977 and 2017 from 1.84 to 1.24 million fish. Annual recruitment patterns were relatively consistent between the two models, with 2006, 2009, and 2010 year classes estimated to be the largest cohorts in recent years.

Uncertainty

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

Table 13-17 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviation derived from the Hessian matrix. Also shown are the MCMC standard deviation and the corresponding Bayesian 95% credible intervals (BCI). The MLE and MCMC standard deviations are similar for q_1 (trawl survey catchability), q_2 (longline survey catchability), and M, but the MCMC standard deviations are larger for the estimates of projected female spawning biomass, and ABC, and σ_r (recruitment deviation). The larger standard deviations indicate that these parameters are more uncertain than indicated by the standard modeling, especially in the case of σ_r in which the MLE estimate is slightly out of the Bayesian credible intervals. This highlights a concern that σ_r requires a fairly informative prior distribution since it is confounded with available data on recruitment variability. To illustrate this problem, imagine a stock that truly has variable recruitment. If this stock lacks age data (or the data are very noisy), then the modal estimate of σ_r is near zero. As an alternative, we could run sensitivity analyses to determine an optimum value for σ_r and fix it at that value instead of estimating it within the model. In contrast the Hessian standard deviation was larger for the estimate of q_1 (trawl survey catchability) and q_2 (longline survey catchability), which may imply that these parameters are 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 2021 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 0.611, indicating that the model estimates of spawning biomass increase relative to the terminal year estimates as data is removed from the assessment. Alternatively, a positive statistic means that as data are added the model decreases the estimates of spawning biomass.

Compared to the previous two assessments, the current RE/BS model exhibits a strong retrospective pattern in the current assessments. A comparison of the revised Mohn's "rho" statistic presented in the 2017 through 2021 assessments is presented in the table below.

Statistic	**2017 (M15.4)**	**2019 (M15.4)**	**2021 (M15.4)**
Mohn's revised ρ	0.009	0.167	0.611

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 strong, and it could be a cause for concern that there is a "one-way" pattern in the retrospective time series. We hypothesize that the reason for this strong retrospective pattern is due to the recent sudden declines in both population indices that are used in the assessment. It appears that the "loose" estimation of catchabilities within this model results in some shifts in scale that become accentuated with sudden changes in these indices. We intend to investigate the prior uncertainty on catchability in future assessments and how that relates to this retrospective pattern.

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, RE/BS 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 1980-2019 (i.e. the 1977-2016 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 2022 estimates of these reference points are in the following table. Biomass estimates are for female spawning biomass.

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
14,776 (t)	5,911 (t)	5,172 (t)	0.038	0.046

Specification of OFL and Maximum Permissible ABC

Estimated female spawning biomass for 2022 is 8,648 t. This is above the $B_{40\%}$ value of 5,911 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 2022 yields the following *ABC* and *OFL*:

$F_{40\%}$	0.038
ABC (t)	788
$F_{35\%}$	0.046
OFL (t)	947

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 2021 numbers-at-age as estimated in the assessment. This vector is then projected forward to the beginning of 2022 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2021. 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 2021 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 2022, 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 2022 and 2023, 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 2018-2020 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 2016-2020 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 2021 or 2) above ½ of its MSY level in 2021 and above its MSY level in 2031 under this scenario, then the stock is not overfished.)

Scenario 7: In 2022 and 2023, 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 2023 or 2) above ½ of its MSY level in 2023 and expected to be above its MSY level in 2033 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 RE/BS 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 2022, it does not provide the best estimate of OFL for 2023, because the mean 2022 catch under Scenario 6 is predicated on the 2022 catch being equal to the 2022 OFL, whereas the actual 2022 catch will likely be less than the 2022 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 (2020) is 383 t. This is less than the 2020 OFL of 1,452 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 2021:

a) If spawning biomass for 2021 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2021 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c) If spawning biomass for 2021 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 2031 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 2023 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b) If the mean spawning biomass for 2023 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2023 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2033. If the mean spawning biomass for 2033 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. The *F* that would have produced a catch for 2020 equal to the OFL of 2020 was 0.07.

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 GOA 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. 2018-2020 for this year, see example figures below).

New data added to the projection model included updated catch data from 2020 (383 t) and new estimated catches for 2021-2023. The 2021 catch was estimated by increasing the official catch as of 2021-10-25 by an expansion factor of 1.03, which accounts for the average fraction of catch taken after October 25 in the last three complete years (2018-2020). This expansion factor resulted in an estimated catch for 2021 of 384 t. To estimate future catches, we updated the yield ratio to 0.45, which was the average ratio of catch to ABC for the last three complete catch years (2018-2020). This yield ratio was multiplied by the projected ABCs from the updated projection model to generate catches of 356 t in 2022 and 345 t in 2023.

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 the estimated yield ratio (0.45) as in Scenario 2, except for all years instead of only the next two. This is conservative relative to assuming max ABC or the Scenario 1 projection. This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 10,000,000. 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 1980-2018 age-3 recruitments (i.e. 1977-2015 year classes). This projection predicts that the median spawning biomass is above these reference points for the entire time series but will steadily decrease over time. The credible intervals on this projection scenario suggests there is a small (<5%) probability that spawning biomass is currently below the $B_{40\%}$ reference point or will be in the near future.

Area Allocation of Harvests

Historically, the RE/BS assessment has used an exponential (4:6:9) weighting of the last three trawl surveys as a way to capture recent changes in biomass, but also provide stability and a buffer to measurement error. 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. We use a two survey version of the random effects model developed for GOA shortraker (Echave and Hulson 2019). This approach has been recommended for RE/BS apportionment by the SSC and Plan Team.

The random effects model was fit to the trawl survey biomass estimates and relative population weights (RPW) from the longline survey (with associated variance) for the western, central, and eastern GOA. 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. Unlike the shortraker assessment (Tier 5) that is attempting to produce a smoothed absolute biomass estimate, the purpose of this model is to produce best estimates of relative proportions across areas. In this version, catchability is not estimated and fixed at 1 for the longline survey Thus, the fits to the total abundance for each index is relatively good, but the area estimates show a clear compromise between each index as the two surveys are sampling a different part of the population.

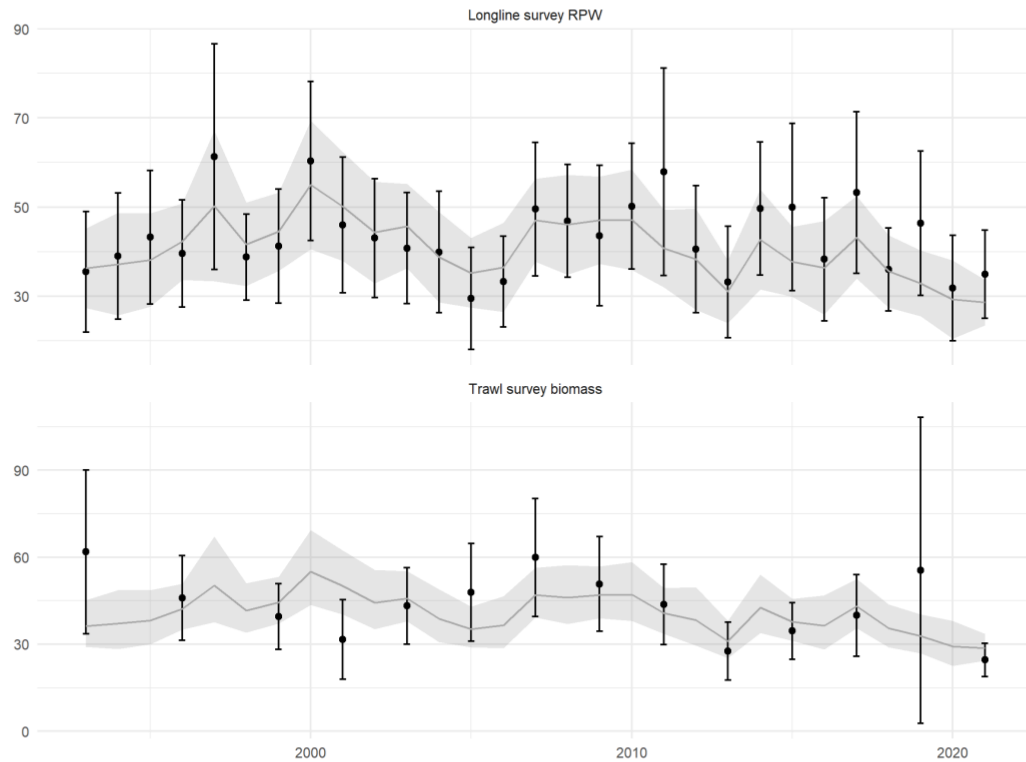

Figure. Combined random effects model fits (grey lines) to survey biomass (black points) for longline survey relative population weights (RPWs) and trawl survey biomass in the Gulf of Alaska. Shaded regions and error bars show 95% confidence intervals for the model fits and survey biomass data, respectively.

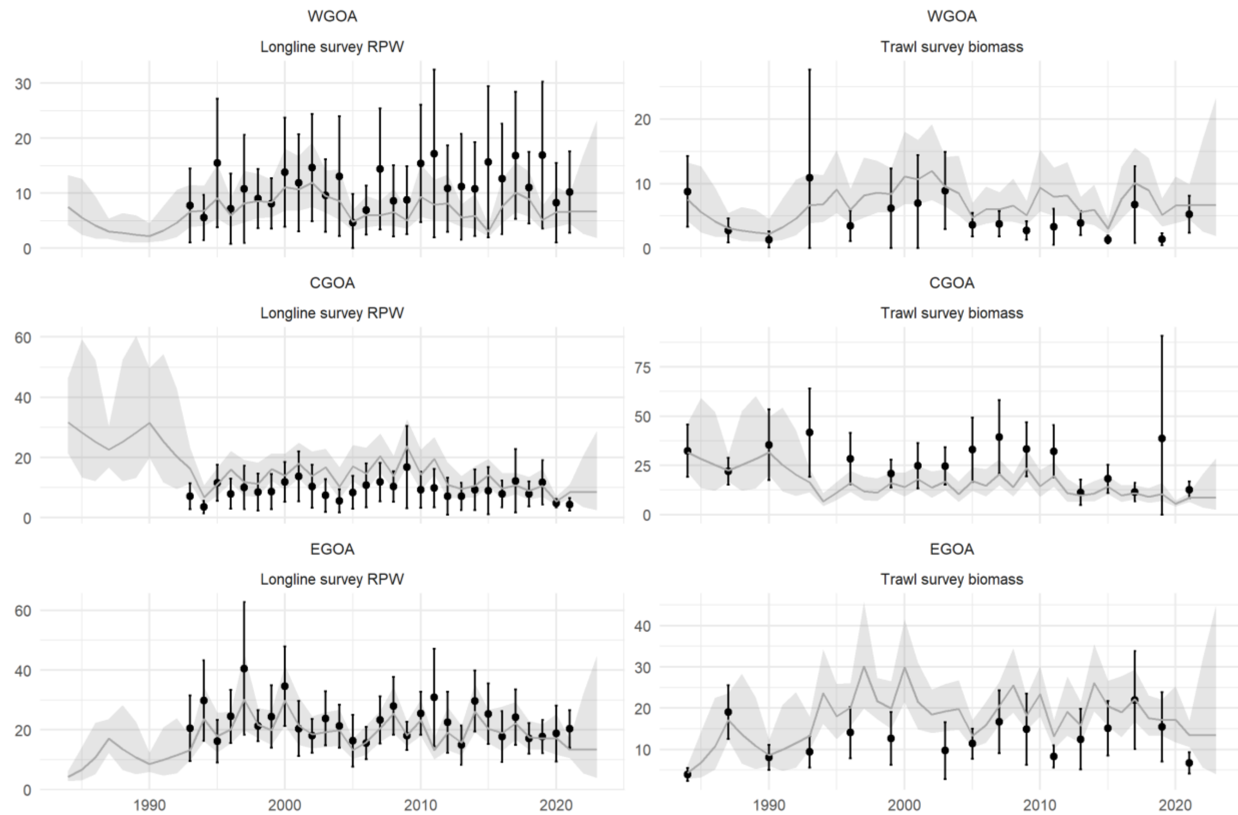

Figure. Random effects model fits (grey lines) to survey biomass (black points) for longline survey relative population weights (RPWs) and trawl survey biomass by regulatory area in the Gulf of Alaska. Shaded regions and error bars show 95% confidence intervals for the model fits and survey biomass data, respectively.

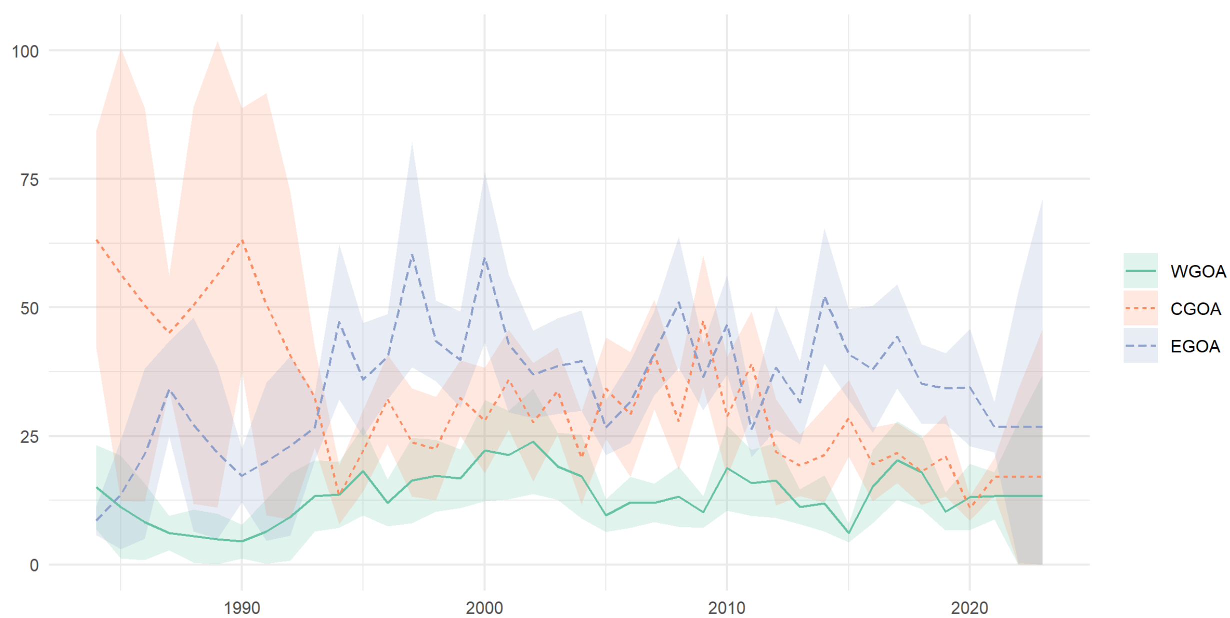

Figure. The combined longline and trawl survey biomass as estimated by the combined random effects model in each Gulf of Alaska regulatory area.

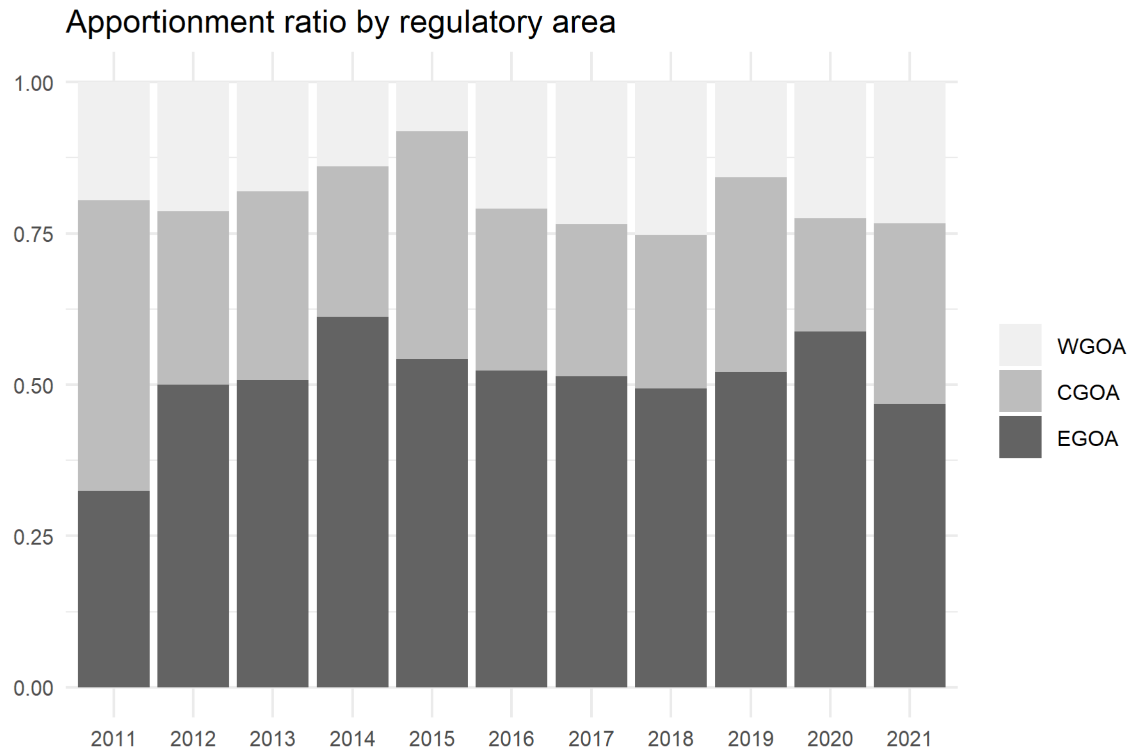

Figure. The time series of apportionments as estimated by the combined random effects model.

Using the random effects model estimates of biomass to determine apportionment results in 23.3% for the western GOA, 29.9% for the central GOA, and 46.8% for the eastern GOA. This apportionment 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. Sampling error also differs by region and survey (Tables 13-10 and 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 eastern GOA for the longline survey versus the trawl survey. The average sampling error is relatively similar in the western GOA; however, the variability in the mean estimates is much higher in the trawl survey versus the longline survey.

The following table shows the apportionment of ABC for the 2022 and 2023 RE/BS fishery:

Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
		23.3%	29.9%	46.8%	100.0%
2022	Area ABC (t)	**184**	**235**	**369**	**788**
	OFL (t)				**947**
2023	Area ABC (t)	**182**	**234**	**365**	**781**
	OFL (t)				**937**

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.046), the overfishing level is set equal to 947 t in 2022 and 937 t in 2023 for RE/BS rockfish. The recommended 2022 OFL is 509 t less than the 2021 OFL of 1,456 t, which reflects a 35% decrease in OFL.

Should the ABC be reduced below the maximum permissible ABC?

The SSC in its December 2018 minutes recommended that all assessment authors use the risk table when determining whether to recommend an ABC lower than the maximum permissible. The SSC also requested the addition of a fourth column on fishery performance, which has been included in the table below.

	Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
Level 1: Normal	Typical to moderately increased uncertainty/minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns
Level 2: Substantially increased concerns	Substantially increased assessment uncertainty/ unresolved issues.	Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or recruitment pattern is atypical.	Some indicators showing an adverse signals relevant to the stock but the pattern is not consistent across all indicators.	Some indicators showing adverse signals but the pattern is not consistent across all indicators
Level 3: Major Concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock)	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types
Level 4: Extreme concern	Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented; More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock; Potential for cascading effects on other ecosystem components	Extreme anomalies in multiple performance indicators that are highly likely to impact the stock

The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. These considerations are stock assessment considerations, population dynamics considerations, environmental/ecosystem considerations, and fishery performance. Examples of the types of concerns that might be relevant include the following:

1. Assessment considerations—data-inputs: biased ages, skipped surveys, lack of fishery-independent trend data; model fits: poor fits to fits to fishery or survey data, inability to simultaneously fit multiple data inputs; model performance: poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds; estimation uncertainty: poorly-estimated but influential year classes; retrospective bias in biomass estimates.
2. Population dynamics considerations—decreasing biomass trend, poor recent recruitment, inability of the stock to rebuild, abrupt increase or decrease in stock abundance.
3. Environmental/ecosystem considerations—adverse trends in environmental/ecosystem indicators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.
4. Fishery performance—fishery CPUE is showing a contrasting pattern from the stock biomass trend, unusual spatial pattern of fishing, changes in the percent of TAC taken, changes in the duration of fishery openings.

Assessment considerations

The current RE/BS rockfish assessment has a high retrospective bias (Mohn's rho = 0.611), which increased considerably since the 2019 assessment (Mohn's rho = 0.167). This increase in retrospective bias is explained by abrupt and synchronous declines in the trawl and longline survey indices of abundance, which caused a subsequent shift in parameter estimates that govern population scale. Trawl survey catchability increased from 1.7 to 2.2, longline survey catchability increased from 1.2 to nearly 1.7, and mean recruitment decreased from approximately 1.6 to 1.2 million fish (Table 13-5). As a result, we saw a significant downgrade in biomass trajectories, recruitment, and estimates of unfished spawning biomass for this stock.

Survey catchabilities greater than 1.0 are generally an indicator of herding, shoaling behavior, or an unobserved expansion into unsampled areas. Herdinlg or shoaling behaviors are inconsistent with the biology of RE/BS, though most rockfish species are known to be patchily distributed. The trawl and longline survey indices of abundance for RE/BS have exhibited high inter-annual variability, are frequently negatively correlated, and do not partition abundance consistently among regulatory areas. In past assessments, this high inter-annual variability and inconsistency in the surveys has resulted in a flat, trendless biomass trajectory, and high standard errors for catchability parameters. In 2021, synchronous declines in both surveys provided information to the model that had substantial impacts on parameter estimates, suggesting high uncertainty in the overall scale of the RE/BS population.

We rated the assessment-related concern as Level 2, substantially increased concerns, due to the large changes in catchability estimates and the strong retrospective bias. This assessment is currently transitioning authors, and consequently no model updates were recommended in this cycle. Plans to address model and data concerns for this assessment are outlined in the Data Gaps and Research Priorities section.

Population dynamics considerations

In 2021, there was an unprecedented drop in both the trawl and longline survey indices of abundance. As previously described, these survey observations had impacts on the population model's scaling parameters, resulting in a substantial downgrade in total and spawning biomass trajectories, recruitment, and biological reference points. However, because the survey indices are highly variable, rarely track one another, and lack consistency among areas or by depth (Figures 13-2, 13-3, 13-4a, and 13-4b), it is difficult to evaluate whether the recent decline in these indices are the result of sampling error or reflect a genuine conservation concern. We determined the influence of these surveys on biomass trajectories was best characterized as an assessment-related concern rather than a population dynamics concern. We rate this category as Level 1, normal or unknown, and will continue to monitor catch, survey indices, and make improvements to stabilize the assessment model. Ongoing issues related to differences in growth and maturity between rougheye and blackspotted rockfish will be revisited in future assessments.

Environmental/Ecosystem considerations

We scored this category as level 1 (normal concern) given moderate environmental conditions, limited and mixed information on the abundance of prey, predators, and competitors, and a lack of a mechanistic understanding for the direct and indirect effects of environmental change on the survival and productivity of RE/BS rockfish.

Adult RE/BS rockfish are demersal and are known from longline and trawl surveys (Zenger and Sigler 1992, Krieger and Ito 1999) and the commercial trawl fishery (Ito 1999) to inhabit particularly steep, rocky areas of the continental slope primarily from 300 to 500 m. The post-larval rockfish period is documented in epipelagic offshore waters of the Gulf of Alaska (GOA) (Kondzela et al. 2007). While optimal spawning and larval survival temperature ranges are not known for RE/BS rockfish, it is reasonable to expect that the 2021 and predicted 2022 average deeper ocean temperatures will provide good spawning habitat and average to cooler surface temperatures contributing to good pelagic conditions for age-0 rockfish during a time when they are growing to a size that promotes over winter survival. Sea temperatures at the surface and at depth on the shelf were around the long-term average in 2021 (not a marine heatwave year, Watson 2021; AFSC Bottom Trawl Survey, Laman 2021; AFSC EcoFOCI survey, Rogers 2021; Seward Line Survey, Danielson 2021), although western GOA started the year with warmer surface waters (satellite data; Watson 2021) and there was slightly above average warmth (5.2°C) at 200m depth along the outer edge of the shelf during the summer (AFSC Longline Survey; Siwicke 2021). Numerous temperature time series showed signs of cooling from previous surveys (returning to average from recent marine heatwave years 2014-2016, 2019) at the surface and at depth and 2022 surface temperatures are predicted to continue cooling, in alignment with La Niña conditions and a negative Pacific Decadal Oscillation. Additional epifauna habitat and rockfish distribution data show a continued decline in sponges since 2015, particularly the Shumagin and Kodiak areas (AFSC Bottom Trawl Survey; Palsson 2021) and no change in relative abundance of soft corals (AFSC Bottom Trawl Survey; Palsson 2021). In general, no changes have been observed over the AFSC Bottom Trawl catch time series (1989-2021) in the distribution of rougheye rockfish catch relative to depth, temperature, or east/west position in the GOA (AFSC Bottom Trawl Survey; Palsson 2021).

Little is known about the adult prey base but there are indications of positive foraging conditions. Primary prey items of adult RE/BS rockfish include shrimp (especially pandalids), euphausiids, tanner crab (*Chionoecetes bairdi*) and other various fish species such as myctophids (Yang and Nelson 2000, Yang 2003, Yang et al., 2006). 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). Tanner crab around Kodiak (EGOA crab status is not known) have been increasing (ADF&G trawl survey, Worton 2021). Shrimp have been increasing around Chirikof, Yakutat, and southeastern GOA regions, but declining around Kodiak over the past 5 years (Bottom Trawl Survey; Palsson 2021). Euphausiids are below the long-term average around Kodiak (although larger sizes are undersampled) and above the long-term average in inside waters of Icy Strait (SEAK). Evidence of competition with sablefish is seen through hook competition in the AFSC longline survey and increasing biomass of juvenile sablefish is being found at deeper depths on the GOA slope (> 400 m), potentially increasing spatial overlap and competition with RE/BS rockfish (Goethel et al. 2021). RE/BS rockfish also overlap in distribution with shortraker rockfish, although there is no reason to suspect negative competitive impacts.

Little is known about the impacts of predators, such as fish and marine mammals, on RE/BS rockfish. In aggregate, biomass of apex groundfish predators (largely driven by halibut, cod, arrowtooth flounder, and sablefish) remain relatively low in the GOA, with all but sablefish below their long-term average (Bottom Trawl Survey: Whitehouse 2021). There is no cause to suspect increased predation pressure on larval or adult demersal shelf rockfish.

Fishery performance:

There is no directed fishing of RE/BS rockfish, and they can only be retained as "incidentally-caught." Catch of RE/BS rockfish fluctuates moderately by gear type and year, but trends are relatively stable by area and catch has always remained well below the TAC. Overall, we rated the fishery performance concern as Level 1, normal, due to the low stable catch of this non-directed fishery species that historically has remained below the TAC.

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*
Level 2: Substantially increased concerns	**Level 1:** Normal	**Level 1:** Normal	**Level 1:** Normal

Although we scored the assessment-related concerns a Level 2, we do not recommend a reduction from maximum permissible ABC at this time.

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 RE/BS 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 RE/BS 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 updates to or analysis of (1) biological assumptions and fixed parameters in the model (e.g., size-age transition matrix, natural mortality, growth, reproductive biology, ageing error, etc.), (2) data weighting approaches and the model's reliance on length composition data, (3) assumptions related to catchability (i.e. priors, consideration of time-varying parameters), (4) refinements to survey index data and the use of one versus two survey indices, (5) survey and fishery selectivity assumptions, and (6) and the treatment of fishery catch and composition data, which currently combines longline and trawl fishery data.

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Tables

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)	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)
Time-varying maturity, fecundity, and skip-spawning rates	No changes in maturity or fecundity rates were observed for rougheye rockfish between 2008 and 2015, though estimated skip spawning rates were significantly less in 2016 (22%) than 2010 (37%) (Conrath and Hulson 2021)
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)
Otolith morpohometrics	New study uses otolith morphometrics, weight, and age to accurately identify RE/BS rockfish 86.2% and 97.3% of the time, respectively (Harris et al. 2019)
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 (t) for GOA RE/BS rockfish (1977-2020), with Gulf-wide values of acceptable biological catch (ABC) and fishing quotas (t), 1991-2020. Catch is provided through the most recent full year estimate.

Year	Catch (t)				OFL	ABC	TAC
	Total	Western GOA	Central GOA	Eastern GOA			
1977	1443	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).				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.	
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	371	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	274	76	98	100	1,545	1,284	1,284
2010	426	89	211	126	1,568	1,302	1,302
2011	534	25	366	143	1,579	1,312	1,312
2012	564	28	369	167	1,472	1,223	1,223
2013	571	15	382	174	1,482	1,232	1,232
2014	739	25	539	175	1,497	1,244	1,244
2015	533	32	345	156	1,345	1,122	1,122
2016	642	40	488	114	1,596	1,328	1,328
2017	522	34	326	162	1,594	1,327	1,327
2018	744	80	437	227	1,735	1,444	1,444
2019	744	77	439	228	1,715	1,428	1,428
2020	383	4	185	194	1,452	1,209	1,209

Table 13-3. History of management measures with associated time series of catch, ABC, and TAC for GOA RE/BS rockfish. Catch since 2005 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/).

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	371	983	983	
2007	440	988	988	Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	382	1,286	1,286	RE/BS formally verified as separate species so assessment called the rougheye/blackspotted rockfish complex
2009	274	1,284	1,284	
2010	426	1,302	1,302	
2011	534	1,312	1,312	Rockfish Program continues from pilot initiative
2012	564	1,223	1,223	
2013	571	1,232	1,232	
2014	739	1,244	1,244	
2015	533	1,122	1,122	
2016	642	1,328	1,328	
2017	522	1,327	1,327	
2018	744	1,444	1,444	
2019	744	1,428	1,428	
2020	383	1,209	1,209	

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 with catch through 10/23/2021.

Year	Flatfish	Halibut	P. Cod	Walleye 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	65	43	4	30	183	101
2011	64	32	2	35	287	114
2012	122	26	4	21	219	173
2013	49	33	1	6	274	206
2014	154	31	4	22	359	170
2015	77	39	2	13	225	177
2016	91	21	3	49	351	126
2017	81	30	11	3	269	128
2018	132	39	8	9	317	239
2019	107	34	2	41	320	241
2020	87	21	0	31	89	156
2021	22	21	3	38	161	128
Average	76	36	4	25	209	153

Table 13-5. Incidental catch of FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska for the previous 5 years. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN with catch through 10/23/2021.

Group Name	2018	2018	2019	2020	2021	Average
Pacific Ocean Perch	19,045	22,172	22,258	22,881	24,522	22,176
Dusky Rockfish	2,192	2,691	2,151	2,061	2,662	2,351
Northern Rockfish	1,601	2,152	2,313	2,317	2,303	2,137
Arrowtooth Flounder	1,416	761	733	890	2,457	1,251
Walleye Pollock	1,061	917	686	647	1,304	923
Other Rockfish	749	992	669	522	972	781
Atka Mackerel	543	1,140	824	602	674	757
Sablefish	590	708	801	646	780	705
Pacific Cod	253	401	322	170	591	347
Shortraker Rockfish	257	269	269	225	237	251
Rougheye Rockfish	269	317	320	89	161	231
Thornyhead Rockfish	363	362	177	138	106	229
Rex Sole	112	136	117	189	96	130
Flathead Sole	80	48	40	95	131	79
Sculpin	42	65	53	30	--	48
Deep Water Flatfish	64	66	39	19	19	41
Longnose Skate	42	46	28	24	30	34
Demersal Shelf Rockfish	40	57	56	11	5	34
Shark	38	48	62	26	22	39
Shallow Water Flatfish	12	57	34	22	26	30
Squid	22	29	--	--	--	25
Skate, Other	22	28	26	9	18	21
Big Skate	6	6	5	5	4	5
Octopus	1	3	9	1	1	3

Table 13-6. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2015 - 2021. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN with catch through 9/25/2021.

Species Group Name	2015	2016	2017	2018	2019	2020	2021
Benthic urochordata	0.28	0.50	0.20	0.07	0.40	0.12	0.01
Birds - Northern Fulmar	0.00	0.00	Conf.	Conf.	Conf.	0.00	Conf.
Birds - Shearwaters	0.00	0.00	0.00	0.00	Conf.	0.00	0.00
Bivalves	Conf.	Conf.	0.01	Conf.	Conf.	0.00	Conf.
Bristlemouths	0.00	0.00	0.00	0.00	0.00	Conf.	0.00
Brittle star unidentified	0.05	0.03	0.60	0.01	0.02	0.01	0.05
Capelin	Conf.	Conf.	0.00	0.00	0.16	0.04	Conf.
Corals Bryozoans - Corals Bryozoans Unidentified	0.70	0.90	0.47	1.36	0.88	0.17	1.72
Corals Bryozoans - Red Tree Coral	Conf.	0.00	0.00	0.00	0.00	0.00	0.00
Eelpouts	0.01	0.02	0.13	0.22	0.00	0.01	Conf.
Eulachon	0.03	0.04	0.13	0.13	0.27	0.10	0.22
Giant Grenadier	903.72	451.09	5274.15	1690.57	780.80	301.74	226.73
Greenlings	8.14	5.81	3.90	4.51	9.57	3.50	3.16
Grenadier - Rattail Grenadier Unidentified	47.40	5.45	12.34	5.33	4.01	1.73	Conf.
Gunnels	Conf.	0.00	0.00	0.00	0.00	0.00	0.00
Hermit crab unidentified	0.03	0.01	0.03	0.01	Conf.	0.00	0.01
Invertebrate unidentified	0.19	0.09	0.09	0.11	0.07	Conf.	0.02
Lanternfishes (myctophidae)	0.04	Conf.	0.00	Conf.	0.06	0.02	0.05
Misc crabs	0.16	0.35	1.10	0.38	0.14	0.09	0.10
Misc crustaceans	Conf.	0.03	0.01	Conf.	0.20	0.07	0.06
Misc deep fish	0.00	Conf.	Conf.	0.00	Conf.	0.00	0.00
Misc fish	142.01	103.11	114.15	137.36	519.93	87.03	136.82
Misc inverts (worms etc)	0.00	Conf.	0.00	0.00	0.00	Conf.	0.00
Other osmerids	Conf.	Conf.	Conf.	0.00	Conf.	0.98	0.11
Pacific Hake	Conf.	Conf.	Conf.	0.07	Conf.	0.03	0.00
Pacific Sand lance	0.00	0.00	0.00	0.00	0.00	0.00	Conf.
Pandalid shrimp	0.05	0.22	0.14	0.07	0.11	0.17	0.29
Polychaete unidentified	0.00	0.00	0.02	0.00	Conf.	0.00	0.00
Sculpin	0.00	0.00	0.00	0.00	0.00	0.00	20.08
Scypho jellies	1.65	8.13	0.54	0.92	8.43	3.52	2.83
Sea anemone unidentified	1.14	1.27	0.72	0.46	1.57	1.24	0.78
Sea pens whips	Conf.	0.02	0.03	0.00	0.03	0.00	Conf.
Sea star	3.42	1.55	3.68	4.33	1.36	1.12	1.44
Snails	0.26	0.18	0.18	5.67	1.79	0.08	1.18
Sponge unidentified	5.45	2.88	3.21	13.66	5.88	0.52	1.22
Squid	0.00	0.00	0.00	0.00	10.87	31.80	25.60
State-managed Rockfish	47.30	13.34	24.48	52.88	46.43	53.11	10.69

Table 13-7. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and counts in thousands of animals for crab and salmon, by year, for the GOA rockfish fishery. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN with catch through 9/25/2021.

Species Group Name	2015	2016	2017	2018	2019	2020	2021	Average
Chinook Salmon	1.91	0.38	0.52	0.34	0.41	0.66	0.57	0.68
Other Salmon	0.34	0.22	0.64	0.33	0.38	0.72	1.61	0.60
Bairdi Crab	0.05	0.00	0.76	0.32	0.06	1.15	0.30	0.38
Golden K. Crab	0.02	0.02	0.21	0.32	0.22	0.06	0.11	0.14
Halibut	0.16	0.12	0.13	0.10	0.12	0.11	0.14	0.12
Blue King Crab	0	0	0	0	0	0	0	0
Herring	0	0	0	0	0	0	0	0
Opilio Crab	0	0	0	0	0	0	0	0
Red King Crab	0	0	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 13-8. (continued)

Age (years)	2018	2020
3	0.0000	0.0000
4	0.0000	0.0000
5	0.0000	0.0000
6	0.0000	0.0000
7	0.0000	0.0000
8	0.0028	0.0157
9	0.0085	0.0105
10	0.0056	0.0105
11	0.0056	0.0209
12	0.0141	0.0209
13	0.0225	0.0471
14	0.0225	0.0262
15	0.0254	0.0366
16	0.0225	0.0366
17	0.0507	0.0209
18	0.0423	0.0471
19	0.0366	0.0157
20	0.0620	0.0576
21	0.0451	0.0314
22	0.0310	0.0262
23	0.0197	0.0157
24	0.0225	0.0471
25	0.0225	0.0366
26	0.0197	0.0314
27	0.0225	0.0314
28	0.0169	0.0157
29	0.0254	0.0366
30	0.0141	0.0209
31	0.0169	0.0052
32	0.0366	0.0419
33	0.0141	0.0314
34	0.0225	0.0419
35	0.0225	0.0314
36	0.0366	0.0262
37	0.0169	0.0157
38	0.0113	0.0105
39	0.0113	0.0052
40	0.0085	0.0052
41	0.0085	0.0105
42+	0.2338	0.1152
Sample size	355	191

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

Length	1991	1992	2002	2003	2005	2007	2011	2013	2015	2017	2019
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.004
22	0.000	0.005	0.008	0.000	0.000	0.000	0.001	0.003	0.000	0.004	0.002
24	0.001	0.006	0.005	0.001	0.001	0.000	0.001	0.004	0.003	0.007	0.009
26	0.002	0.008	0.008	0.002	0.001	0.004	0.002	0.006	0.002	0.008	0.010
28	0.006	0.013	0.002	0.004	0.004	0.005	0.006	0.004	0.006	0.016	0.009
30	0.004	0.029	0.005	0.003	0.007	0.012	0.008	0.005	0.007	0.019	0.017
32	0.009	0.027	0.005	0.006	0.006	0.011	0.030	0.009	0.010	0.025	0.020
34	0.012	0.036	0.014	0.009	0.013	0.025	0.031	0.009	0.020	0.031	0.023
36	0.010	0.045	0.017	0.013	0.031	0.032	0.035	0.018	0.019	0.041	0.034
38	0.026	0.066	0.037	0.038	0.030	0.060	0.035	0.038	0.036	0.063	0.040
40	0.039	0.100	0.049	0.054	0.045	0.071	0.084	0.096	0.058	0.080	0.054
42	0.158	0.108	0.145	0.101	0.071	0.096	0.108	0.132	0.102	0.122	0.104
44	0.285	0.164	0.165	0.142	0.116	0.120	0.123	0.145	0.121	0.124	0.132
46	0.222	0.129	0.194	0.192	0.151	0.146	0.130	0.129	0.161	0.107	0.136
48	0.151	0.079	0.139	0.171	0.154	0.135	0.140	0.111	0.151	0.086	0.128
50	0.044	0.046	0.113	0.112	0.130	0.117	0.111	0.063	0.122	0.099	0.102
52	0.013	0.034	0.046	0.071	0.088	0.082	0.057	0.041	0.069	0.062	0.057
54	0.004	0.036	0.014	0.032	0.058	0.029	0.042	0.038	0.040	0.035	0.032
56	0.006	0.025	0.011	0.019	0.027	0.019	0.020	0.043	0.017	0.025	0.026
58	0.001	0.016	0.005	0.007	0.022	0.012	0.016	0.022	0.016	0.012	0.017
60+	0.001	0.021	0.005	0.014	0.036	0.014	0.014	0.074	0.031	0.022	0.032
Sample	959	1077	344	2516	1493	1472	988	1010	1793	1711	2013

Table 13-10. GOA RE/BS rockfish biomass estimates from NMFS triennial/biennial trawl surveys by region and gulfwide. 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	59,424
1987	2,737	(34)	21,881	(16)	19,063	(17)	43,681	(11)	4,897	34,083	53,279
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	(27)	9,358	(21)	61,865	(23)	14,415	33,612	90,118
1996	3,449	(35)	28,396	(23)	14,067	(23)	45,912	(16)	7,432	31,344	60,480
1999	6,156	(51)	20,781	(17)	12,622	(26)	39,559	(15)	5,793	28,205	50,913
2001	6,945	(55)	24,740	(24)	--	--	--	--	--	--	--
2003	8,921	(34)	24,610	(20)	9,670	(36)	43,201	(16)	6,724	30,023	56,379
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	34,513	67,035
2011	3,305	(43)	32,181	(21)	8,228	(17)	43,714	(16)	7,065	29,866	57,562
2013	3,922	(24)	11,207	(29)	12,452	(30)	27,581	(18)	5,078	17,628	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
2019	1,381	(34)	38,696	(69)	15,417	(28)	55,494	(48)	26,901	2,768	108,220
2021	5,242	(28)	12,661	(17)	6,709	(19)	24,612	(12)	2,928	18,873	30,351

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	2017
3	0.0113	0.0125	0.0490	0.0055	0.0213
4	0.0099	0.0096	0.0367	0.0125	0.0241
5	0.0191	0.0578	0.0357	0.0831	0.0068
6	0.0498	0.0324	0.0360	0.0434	0.0295
7	0.0349	0.0493	0.0700	0.0400	0.1343
8	0.0608	0.0429	0.0555	0.0416	0.1051
9	0.0438	0.0982	0.0387	0.0676	0.0790
10	0.0389	0.0438	0.0480	0.0680	0.0333
11	0.0561	0.0765	0.0674	0.0583	0.0786
12	0.0377	0.0766	0.0669	0.0601	0.0534
13	0.0378	0.0560	0.0561	0.0553	0.0451
14	0.0369	0.0408	0.0387	0.0725	0.0387
15	0.0506	0.0544	0.0302	0.0481	0.0535
16	0.0441	0.0273	0.0296	0.0475	0.0324
17	0.0374	0.0257	0.0250	0.0395	0.0341
18	0.0309	0.0151	0.0178	0.0502	0.0177
19	0.0250	0.0260	0.0117	0.0094	0.0309
20	0.0414	0.0089	0.0202	0.0169	0.0089
21	0.0199	0.0176	0.0127	0.0212	0.0261
22	0.0240	0.0230	0.0244	0.0115	0.0068
23	0.0182	0.0095	0.0142	0.0173	0.0077
24	0.0202	0.0250	0.0104	0.0122	0.0036
25	0.0258	0.0179	0.0141	0.0155	0.0065
26	0.0229	0.0123	0.0111	0.0067	0.0027
27	0.0083	0.0253	0.0157	0.0051	0.0066
28	0.0145	0.0126	0.0081	0.0103	0.0013
29	0.0139	0.0085	0.0093	0.0050	0.0058
30	0.0217	0.0069	0.0111	0.0060	0.0056
31	0.0128	0.0184	0.0092	0.0159	0.0046
32	0.0127	0.0060	0.0070	0.0061	0.0232
33	0.0194	0.0013	0.0077	0.0042	0.0059
34	0.0072	0.0077	0.0040	0.0024	0.0057
35	0.0063	0.0070	0.0129	0.0036	0.0040
36	0.0086	0.0054	0.0042	0.0019	0.0000
37	0.0029	0.0035	0.0025	0.0044	0.0063
38	0.0044	0.0029	0.0076	0.0011	0.0011
39	0.0040	0.0032	0.0053	0.0036	0.0000
40	0.0048	0.0054	0.0053	0.0051	0.0003
41	0.0029	0.0011	0.0035	0.0050	0.0094
42+	0.0585	0.0256	0.0667	0.0162	0.0400
Sample size	928	402	1,057	518	488

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	0.007	0.014	0.013	0.016	0.037	0.073	0.022	0.059	0.046	0.039
22	0.016	0.032	0.017	0.018	0.050	0.061	0.035	0.057	0.050	0.039
24	0.026	0.031	0.024	0.023	0.053	0.049	0.042	0.043	0.053	0.048
26	0.023	0.029	0.027	0.029	0.048	0.040	0.049	0.042	0.061	0.044
28	0.019	0.028	0.043	0.034	0.038	0.054	0.059	0.048	0.064	0.041
30	0.033	0.040	0.062	0.047	0.050	0.068	0.051	0.056	0.063	0.046
32	0.037	0.051	0.085	0.052	0.050	0.063	0.044	0.057	0.057	0.046
34	0.045	0.057	0.102	0.069	0.046	0.067	0.061	0.047	0.064	0.046
36	0.056	0.072	0.119	0.077	0.062	0.061	0.070	0.041	0.058	0.055
38	0.058	0.071	0.086	0.106	0.063	0.070	0.087	0.052	0.068	0.079
40	0.084	0.081	0.069	0.123	0.085	0.077	0.096	0.067	0.075	0.086
42	0.144	0.085	0.062	0.133	0.114	0.080	0.132	0.099	0.081	0.105
44	0.165	0.113	0.093	0.125	0.110	0.078	0.095	0.113	0.076	0.114
46	0.119	0.111	0.081	0.076	0.081	0.060	0.066	0.095	0.046	0.078
48	0.077	0.086	0.046	0.032	0.046	0.036	0.040	0.059	0.031	0.051
50	0.040	0.041	0.022	0.012	0.023	0.021	0.016	0.026	0.026	0.033
52	0.019	0.022	0.010	0.007	0.015	0.007	0.008	0.010	0.014	0.016
54	0.009	0.008	0.009	0.004	0.005	0.003	0.003	0.007	0.008	0.009
56	0.006	0.005	0.007	0.003	0.006	0.002	0.005	0.003	0.007	0.004
58	0.004	0.003	0.005	0.003	0.002	0.002	0.002	0.002	0.004	0.002
60+	0.009	0.007	0.010	0.007	0.002	0.003	0.003	0.004	0.012	0.003
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	2019	2021
20	0.040	0.036	0.062	0.059	0.035	0.029	0.049
22	0.054	0.050	0.050	0.062	0.031	0.034	0.065
24	0.059	0.051	0.051	0.061	0.055	0.040	0.071
26	0.068	0.059	0.050	0.050	0.082	0.053	0.069
28	0.055	0.056	0.058	0.058	0.088	0.063	0.106
30	0.059	0.069	0.044	0.052	0.061	0.045	0.094
32	0.043	0.053	0.048	0.060	0.066	0.053	0.071
34	0.042	0.062	0.055	0.071	0.073	0.054	0.071
36	0.046	0.059	0.070	0.074	0.062	0.054	0.057
38	0.052	0.063	0.083	0.083	0.074	0.067	0.068
40	0.068	0.081	0.085	0.090	0.062	0.110	0.064
42	0.079	0.097	0.082	0.076	0.069	0.163	0.067
44	0.089	0.084	0.058	0.053	0.055	0.116	0.040
46	0.087	0.059	0.061	0.046	0.058	0.055	0.027
48	0.065	0.047	0.044	0.030	0.042	0.022	0.024
50	0.040	0.025	0.037	0.018	0.027	0.013	0.013
52	0.024	0.011	0.018	0.012	0.018	0.005	0.010
54	0.009	0.010	0.008	0.009	0.005	0.004	0.005
56	0.004	0.003	0.005	0.004	0.003	0.002	0.001
58	0.003	0.002	0.002	0.004	0.003	0.003	0.002
60+	0.002	0.005	0.002	0.006	0.012	0.004	0.004
Sample size	4,155	2,475	1,692	2,588	2,173	2,078	1,790

Table 13-13. GOA RE/BS rockfish relative population numbers (RPN) estimated from the AFSC longline survey by region and gulfwide for 1993-2021. 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		GOA		SE	LCI	UCI
1993	2,002	(24.1)	5,279	(31.5)	6,286	(44.0)	23,567	(18.4)	4,336	15,068	32,066
1994	15,857	(21.6)	2,513	(31.7)	4,371	(37.4)	22,741	(17.1)	3,885	15,127	30,356
1995	9,646	(21.5)	7,962	(27.1)	9,988	(38.5)	27,597	(17.7)	4,875	18,041	37,152
1996	14,487	(18.0)	5,613	(33.6)	5,675	(45.3)	25,774	(16.0)	4,122	17,696	33,853
1997	22,165	(27.4)	7,729	(38.4)	7,314	(46.6)	37,208	(20.4)	7,578	22,354	52,061
1998	12,847	(12.4)	5,751	(38.2)	6,032	(30.6)	24,630	(13.3)	3,284	18,194	31,066
1999	15,030	(20.9)	6,338	(35.3)	6,112	(28.7)	27,480	(15.4)	4,238	19,174	35,787
2000	18,985	(18.8)	8,917	(29.5)	10,454	(36.7)	38,357	(15.3)	5,860	26,871	49,843
2001	11,650	(21.8)	8,990	(30.1)	9,039	(38.0)	29,679	(17.0)	5,056	19,770	39,589
2002	10,470	(15.8)	7,454	(36.0)	9,792	(34.0)	27,715	(16.5)	4,581	18,736	36,695
2003	13,364	(19.1)	5,162	(38.0)	6,003	(35.3)	24,530	(15.7)	3,852	16,980	32,080
2004	13,266	(17.3)	4,479	(36.9)	10,312	(42.5)	28,057	(18.6)	5,222	17,822	38,293
2005	10,179	(25.6)	5,777	(32.9)	3,031	(56.9)	18,987	(19.3)	3,657	11,819	26,155
2006	9,146	(17.4)	6,320	(35.9)	5,240	(32.8)	20,706	(15.8)	3,262	14,312	27,099
2007	13,679	(17.7)	9,315	(27.3)	11,064	(39.1)	34,057	(16.4)	5,570	23,141	44,973
2008	17,620	(20.4)	7,414	(24.1)	6,407	(38.2)	31,441	(15.0)	4,700	22,228	40,653
2009	12,014	(13.6)	10,790	(41.1)	7,213	(36.1)	30,017	(18.0)	5,398	19,437	40,596
2010	15,121	(14.4)	7,741	(31.0)	12,746	(35.4)	35,608	(15.6)	5,549	24,732	46,485
2011	18,313	(25.5)	8,863	(32.7)	13,344	(45.3)	40,520	(20.1)	8,164	24,518	56,522
2012	14,009	(24.2)	5,364	(41.9)	7,967	(36.9)	27,340	(18.3)	5,016	17,507	37,172
2013	9,188	(21.6)	5,420	(33.4)	9,493	(43.9)	24,102	(20.6)	4,960	14,380	33,824
2014	17,910	(19.8)	7,030	(36.0)	8,827	(40.5)	33,767	(16.7)	5,629	22,734	44,801
2015	14,346	(19.7)	6,482	(45.0)	10,894	(44.6)	31,721	(20.0)	6,337	19,302	44,141
2016	9,968	(23.9)	5,055	(28.4)	9,632	(40.5)	24,655	(19.4)	4,793	15,260	34,050
2017	14,567	(19.4)	9,034	(44.7)	13,239	(34.9)	36,840	(18.3)	6,754	23,602	50,078
2018	10,620	(16.5)	5,761	(27.3)	9,158	(30.3)	25,539	(14.3)	3,642	18,400	32,678
2019	9,915	(16.9)	8,499	(32.4)	14,506	(40.2)	32,920	(20.2)	6,660	19,866	45,973
2020	9,893	(25.0)	2,864	(14.7)	6,015	(44.8)	18,772	(19.6)	3,683	11,553	25,992
2021	10,498	(15.9)	3,063	(24.7)	7,609	(37.1)	21,170	(15.9)	3,365	14,574	27,766

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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
24	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001
26	0.006	0.001	0.002	0.000	0.001	0.000	0.004	0.002	0.005	0.002
28	0.005	0.003	0.006	0.002	0.002	0.003	0.006	0.003	0.007	0.006
30	0.014	0.006	0.008	0.012	0.011	0.008	0.012	0.007	0.022	0.016
32	0.031	0.015	0.021	0.017	0.009	0.015	0.016	0.015	0.019	0.021
34	0.053	0.020	0.020	0.035	0.020	0.028	0.037	0.029	0.040	0.027
36	0.048	0.030	0.040	0.043	0.042	0.041	0.048	0.054	0.052	0.053
38	0.065	0.047	0.065	0.069	0.074	0.053	0.065	0.078	0.068	0.069
40	0.095	0.075	0.085	0.095	0.080	0.080	0.090	0.091	0.091	0.090
42	0.110	0.091	0.111	0.116	0.109	0.097	0.113	0.104	0.107	0.119
44	0.133	0.143	0.156	0.143	0.131	0.139	0.149	0.133	0.126	0.132
46	0.137	0.151	0.144	0.149	0.156	0.156	0.162	0.134	0.134	0.134
48	0.101	0.141	0.128	0.132	0.134	0.151	0.129	0.136	0.120	0.124
50	0.090	0.096	0.095	0.086	0.093	0.101	0.086	0.088	0.092	0.082
52	0.051	0.073	0.041	0.040	0.049	0.059	0.045	0.057	0.046	0.051
54	0.022	0.036	0.038	0.026	0.025	0.025	0.016	0.028	0.026	0.027
56	0.017	0.022	0.015	0.014	0.014	0.017	0.005	0.015	0.011	0.013
58	0.005	0.017	0.012	0.006	0.011	0.013	0.003	0.006	0.006	0.015
60+	0.016	0.031	0.012	0.013	0.037	0.017	0.012	0.019	0.025	0.017
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	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.000
24	0.001	0.000	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.000
26	0.001	0.004	0.006	0.003	0.003	0.003	0.002	0.006	0.004	0.002
28	0.004	0.014	0.016	0.018	0.001	0.006	0.006	0.012	0.013	0.010
30	0.014	0.024	0.032	0.017	0.014	0.021	0.020	0.025	0.028	0.019
32	0.015	0.022	0.036	0.018	0.040	0.035	0.023	0.042	0.043	0.028
34	0.016	0.037	0.041	0.023	0.044	0.054	0.039	0.055	0.057	0.039
36	0.026	0.051	0.055	0.036	0.084	0.071	0.052	0.075	0.076	0.059
38	0.059	0.094	0.066	0.051	0.069	0.074	0.084	0.078	0.093	0.082
40	0.081	0.088	0.079	0.075	0.092	0.075	0.100	0.091	0.096	0.098
42	0.110	0.106	0.105	0.113	0.111	0.102	0.120	0.112	0.116	0.111
44	0.141	0.131	0.129	0.144	0.144	0.120	0.125	0.130	0.116	0.134
46	0.165	0.143	0.134	0.152	0.133	0.125	0.116	0.121	0.099	0.127
48	0.152	0.118	0.128	0.139	0.109	0.114	0.115	0.088	0.090	0.108
50	0.087	0.079	0.068	0.084	0.063	0.087	0.078	0.060	0.061	0.074
52	0.046	0.039	0.034	0.048	0.041	0.050	0.053	0.031	0.033	0.048
54	0.018	0.020	0.022	0.027	0.016	0.026	0.026	0.017	0.019	0.025
56	0.015	0.013	0.011	0.014	0.015	0.012	0.016	0.013	0.013	0.011
58	0.011	0.006	0.009	0.016	0.005	0.011	0.007	0.009	0.008	0.006
60+	0.038	0.010	0.027	0.022	0.015	0.013	0.015	0.034	0.030	0.020
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	2018	2019	2020	2021
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.001	0.000	0.001	0.004	0.002	0.000	0.000
26	0.002	0.001	0.001	0.002	0.003	0.004	0.002	0.001	0.002
28	0.006	0.004	0.005	0.006	0.005	0.005	0.009	0.004	0.005
30	0.025	0.014	0.009	0.014	0.016	0.015	0.017	0.010	0.009
32	0.038	0.024	0.022	0.028	0.032	0.029	0.036	0.023	0.017
34	0.056	0.042	0.023	0.045	0.055	0.046	0.057	0.027	0.032
36	0.088	0.064	0.048	0.058	0.059	0.060	0.079	0.054	0.057
38	0.074	0.082	0.062	0.070	0.064	0.080	0.100	0.062	0.060
40	0.094	0.114	0.081	0.090	0.095	0.104	0.110	0.080	0.074
42	0.108	0.110	0.128	0.093	0.116	0.120	0.105	0.097	0.096
44	0.131	0.121	0.148	0.116	0.140	0.148	0.113	0.103	0.131
46	0.125	0.114	0.134	0.122	0.136	0.133	0.114	0.127	0.140
48	0.110	0.110	0.121	0.124	0.118	0.110	0.088	0.137	0.141
50	0.064	0.082	0.088	0.096	0.069	0.066	0.066	0.105	0.096
52	0.030	0.046	0.061	0.062	0.040	0.037	0.042	0.062	0.058
54	0.018	0.022	0.029	0.033	0.023	0.016	0.025	0.042	0.029
56	0.009	0.018	0.012	0.018	0.010	0.014	0.012	0.014	0.019
58	0.013	0.011	0.015	0.007	0.009	0.003	0.009	0.020	0.010
60+	0.009	0.020	0.011	0.015	0.007	0.006	0.018	0.031	0.024
Sample size	3,744	6,820	5,382	4,478	6,011	5,753	5,963	4,409	4,741

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 these models so likelihood component values are not comparable.

		2019 (Model 15.4)	*2021 (Model 15.4)*
Likelihoods	Weight		
Catch (1977-2005/2005-present)	5/50	0.023	0.088
Trawl Biomass	1	9.753	13.499
Longline Biomass	1	15.904	19.387
Fishery Ages	1	26.097	30.603
Trawl Survey Ages	1	38.972	41.837
Fishery Sizes	1	64.373	70.673
Trawl Survey Sizes	0	0.000	0
Longline Survey Sizes	1	109.850	97.993
Data-Likelihood		264.972	274.079
Penalties/Priors			
Recruit Deviations	1	-13.181	-14.228
Selectivity Penalties			
Fishery	1	2.319	2.149
Fishery Domeshape	1	0.002	0.003
Trawl Survey	1	0	0
Trawl Domeshape	1	0	0
Longline	1	0.315	0.462
Longline Domeshape	1	0.007	0.026
F Regularity	0.1	1.143	1.135
σ_r prior		12.154	12.738
q-trawl		0.006	0.012
q-longline		0.013	0.129
M		1.639	0.941
Total penalties/priors		4.419	3.369
Objective Fun. Total		269.391	280.817
Parameter Estimates			
Number Parameters		174	178
q-trawl		1.714	2.195
q-longline		1.178	1.663
M		0.036	0.034
σ_r		0.805	0.799
Mean Recruitment (mil)		1.591	1.183
$F_{40\%}$		0.040	0.038
Total Biomass (t)		40,336	26,062
Spawning Biomass (t)		12,517	8,648
$B_{100\%}$ (t)		20,658	14,776
$B_{40\%}$ (t)		8,263	5,911
$ABC_{F40\%}$ (t)		1,209	788

Table 13-16. Estimated GOA RE/BS rockfish population numbers (thousands) in 2021, 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 2021 (1000s)	Percent Mature	Weight (g)	Fishery Selectivity	Trawl Survey Selectivity	LL Survey Selectivity
3	1,159	0	53	0	25	0
4	1,073	0	99	0	44	0
5	978	0	159	0	59	0
6	884	0	228	1	71	0
7	856	0	306	2	81	0
8	753	0	388	4	88	0
9	591	0	473	8	93	0
10	604	1	558	10	97	1
11	1,622	2	642	10	99	2
12	994	5	723	10	100	8
13	721	8	801	10	100	22
14	530	14	875	14	99	53
15	783	22	945	30	98	90
16	597	31	1,010	100	96	100
17	576	40	1,070	100	94	85
18	565	50	1,125	100	91	85
19	663	59	1,176	100	88	85
20	697	66	1,222	100	85	85
21	595	72	1,265	100	82	85
22	357	77	1,303	100	79	85
23	619	81	1,338	100	75	85
24	458	84	1,369	100	72	85
25	359	92	1,398	100	69	85
26	519	92	1,423	100	65	85
27	545	92	1,446	100	62	85
28	309	92	1,467	100	59	85
29	262	92	1,485	100	56	85
30	261	92	1,502	100	53	85
31	730	92	1,517	100	50	85
32	207	92	1,530	100	47	85
33	191	92	1,542	100	45	85
34	175	92	1,553	100	42	85
35	182	92	1,562	100	40	85
36	205	92	1,571	100	37	85
37	232	92	1,578	100	35	85
38	243	92	1,585	100	33	85
39	213	92	1,591	100	31	85

Table 13-16 (continued). Estimated GOA RE/BS rockfish population numbers (thousands) in 2021, 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 2021 (1000s)	Percent Mature	Weight (g)	Fishery Selectivity	Trawl Survey Selectivity	LL Survey Selectivity
40	356	92	1,596	100	29	85
41	297	92	1,601	100	27	85
42+	153	92	1,605	100	25	85

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 (2021), ABC is acceptable biological catch, and σ_r is the recruitment standard deviation parameter.

	μ		σ		MCMC		
Parameter	Hessian	MCMC	Hessian	MCMC	Median	BCI-Lower	BCI-Upper
q_1, trawl survey	2.1955	2.0309	0.5406	0.5298	2.0330	0.9963	3.0604
q_2, longline survey	1.6630	1.7205	0.6088	0.5212	1.6788	0.7940	2.9143
M	0.0344	0.0350	0.0030	0.0033	0.0349	0.0291	0.0418
$F_{40\%}$	0.0381	0.0440	0.0103	0.0138	0.0416	0.0238	0.0778
SSB (2021)	8,645	10,213	2,584	4,500	9,176	5,517	21,103
ABC	788	1,088	334	677	933	411	2,628
σ_r	0.7994	1.0457	0.0504	0.0632	1.0433	0.9281	1.1740

Table 13-18. Estimated time series of female spawning biomass, 3+ biomass (ages 3 and greater), catch divided by 3+ biomass, and number of age-3 recruits for GOA RE/BS rockfish. Estimates are shown for the author preferred model (MLE approach) and from the previous full assessment.

	Spawning Biomass (t)		3+ Biomass (t)		Catch/3+ Biomass		Age-3 Recruits (1000's)	
Year	Previous	Current	Previous	Current	Previous	Current	Previous	Current
1977	18,656	15,523	52,070	43,701	0.028	0.033	1,357	1,069
1978	18,218	15,097	50,743	42,421	0.011	0.013	1,598	1,241
1979	18,124	15,010	50,264	42,108	0.013	0.015	4,313	3,379
1980	17,980	14,876	49,676	41,674	0.027	0.033	1,385	1,080
1981	17,521	14,436	48,412	40,544	0.015	0.018	1,212	918
1982	17,316	14,243	48,345	40,042	0.012	0.014	1,454	1,051
1983	17,167	14,106	47,990	39,723	0.013	0.016	2,609	1,924
1984	16,991	13,942	47,528	39,380	0.016	0.020	2,720	2,169
1985	16,756	13,722	46,953	38,894	0.003	0.003	1,627	1,225
1986	16,786	13,762	47,235	39,046	0.009	0.011	1,744	1,311
1987	16,683	13,670	47,276	38,879	0.011	0.014	1,483	1,191
1988	16,543	13,540	47,067	38,612	0.034	0.042	1,180	994
1989	15,954	12,976	45,806	37,286	0.048	0.059	997	832
1990	15,147	12,205	43,966	35,439	0.055	0.069	944	761
1991	14,283	11,376	41,888	33,412	0.008	0.011	1,005	790
1992	14,285	11,362	41,762	33,282	0.027	0.034	1,023	816
1993	14,000	11,065	40,821	32,482	0.014	0.018	3,493	2,747
1994	13,945	10,986	40,387	32,167	0.014	0.018	1,204	934
1995	13,890	10,902	39,914	31,836	0.018	0.022	1,098	889
1996	13,792	10,773	39,789	31,379	0.014	0.018	1,287	999
1997	13,759	10,708	39,460	31,096	0.014	0.018	2,366	1,679
1998	13,727	10,647	39,104	30,839	0.017	0.022	2,088	1,518
1999	13,633	10,529	38,646	30,455	0.008	0.011	1,352	994
2000	13,663	10,541	38,742	30,426	0.014	0.018	1,693	1,200
2001	13,618	10,477	38,621	30,207	0.015	0.020	2,191	1,528
2002	13,470	10,332	38,327	29,909	0.007	0.009	1,186	828
2003	13,442	10,310	38,413	29,945	0.010	0.013	2,076	1,299
2004	13,363	10,238	38,488	29,868	0.008	0.010	2,342	1,433
2005	13,345	10,223	38,488	29,888	0.008	0.010	2,100	1,286
2006	13,335	10,217	38,653	29,906	0.010	0.013	1,733	1,027
2007	13,286	10,172	38,821	29,837	0.011	0.015	1,584	978
2008	13,224	10,108	38,913	29,688	0.010	0.013	1,847	958
2009	13,192	10,072	39,015	29,597	0.007	0.009	2,542	1,205
2010	13,215	10,082	39,195	29,586	0.011	0.015	1,419	785
2011	13,187	10,034	39,266	29,414	0.014	0.018	1,922	1,030
2012	13,127	9,945	39,376	29,138	0.014	0.020	2,561	1,368
2013	13,067	9,846	39,273	28,880	0.015	0.020	4,654	2,150
2014	13,015	9,747	39,245	28,590	0.019	0.026	1,332	772
2015	12,940	9,603	39,189	28,123	0.014	0.019	1,270	729
2016	12,909	9,509	39,803	27,865	0.016	0.023	1,668	896
2017	12,854	9,370	39,814	27,493	0.013	0.019	1,781	982
2018	12,863	9,283	39,899	27,236	0.019	0.028	1,594	980
2019	12,800	9,108	39,791	26,752	0.015	0.028	1,592	1,048
2020		8,922		26,269		0.015		1,111
2021		8,685		26,161		0.015		1,159

Table 13-19. Estimated time series of recruitment, total biomass (3+), and female spawning biomass for RE/BS rockfish in the Gulf of Alaska, 1977-2021. Columns headed with 2.5% and 97.5% represent the lower and upper 95% credible intervals from the MCMC posterior distribution.

Year	Recruits (Age-3, 1000s)			Total Biomass (3+)			Spawning biomass (t)		
	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%
1977	1,069	160	4,321	43,701	33,695	81,280	15,523	11,714	27,702
1978	1,241	172	5,986	42,421	32,413	80,163	15,097	11,352	27,519
1979	3,379	891	10,249	42,108	32,209	80,234	15,010	11,357	27,742
1980	1,080	153	4,599	41,674	31,853	80,074	14,876	11,254	27,844
1981	918	147	3,562	40,544	30,767	78,772	14,436	10,849	27,503
1982	1,051	160	4,399	40,042	30,330	78,467	14,243	10,710	27,545
1983	1,924	328	6,927	39,723	30,065	78,158	14,106	10,626	27,360
1984	2,169	372	7,364	39,380	29,736	77,677	13,942	10,490	27,199
1985	1,225	198	5,141	38,894	29,245	77,400	13,722	10,299	26,996
1986	1,311	248	4,883	39,046	29,383	77,603	13,762	10,364	27,103
1987	1,191	207	4,603	38,879	29,245	77,351	13,670	10,290	26,940
1988	994	181	3,850	38,612	29,048	77,028	13,540	10,173	26,868
1989	832	154	3,059	37,286	27,724	75,946	12,976	9,643	26,251
1990	761	163	2,794	35,439	25,880	73,526	12,205	8,878	25,369
1991	790	160	2,851	33,412	24,058	71,015	11,376	8,135	24,472
1992	816	138	2,933	33,282	24,011	70,610	11,362	8,136	24,314
1993	2,747	1,730	7,549	32,482	23,251	69,961	11,065	7,842	24,025
1994	934	155	3,665	32,167	22,978	69,673	10,986	7,758	23,932
1995	889	164	3,249	31,836	22,679	69,143	10,902	7,670	23,858
1996	999	176	3,679	31,379	22,259	68,532	10,773	7,527	23,702
1997	1,679	435	5,799	31,096	21,986	67,993	10,708	7,460	23,653
1998	1,518	307	5,296	30,839	21,783	67,642	10,647	7,402	23,624
1999	994	171	3,786	30,455	21,430	67,118	10,529	7,277	23,518
2000	1,200	242	4,439	30,426	21,399	67,207	10,541	7,291	23,599
2001	1,528	398	4,887	30,207	21,150	66,864	10,477	7,225	23,527
2002	828	151	2,853	29,909	20,842	66,448	10,332	7,101	23,311
2003	1,299	435	4,173	29,945	20,909	66,418	10,310	7,087	23,231
2004	1,433	367	4,635	29,868	20,803	66,347	10,238	7,025	23,019
2005	1,286	372	4,174	29,888	20,836	66,392	10,223	7,018	23,002
2006	1,027	218	3,582	29,906	20,870	66,435	10,217	7,025	22,967
2007	978	235	3,210	29,837	20,808	66,302	10,172	6,982	22,924
2008	958	213	3,478	29,688	20,631	66,031	10,108	6,935	22,784
2009	1,205	391	3,953	29,597	20,571	65,858	10,072	6,906	22,734
2010	785	167	2,799	29,586	20,586	65,649	10,082	6,928	22,715
2011	1,030	240	3,588	29,414	20,429	65,404	10,034	6,886	22,656
2012	1,368	338	5,066	29,138	20,197	64,966	9,945	6,788	22,529
2013	2,150	840	6,725	28,880	19,950	64,699	9,846	6,690	22,383
2014	772	125	2,774	28,590	19,665	64,237	9,747	6,588	22,239
2015	729	107	2,531	28,123	19,241	63,567	9,603	6,427	22,143
2016	896	148	3,710	27,865	18,963	63,163	9,509	6,328	22,005
2017	982	160	4,073	27,493	18,550	62,705	9,370	6,196	21,841
2018	980	131	5,052	27,236	18,259	62,311	9,283	6,104	21,738
2019	1,048	145	5,879	26,752	17,814	61,687	9,108	5,924	21,569
2020	1,111	142	6,644	26,269	17,291	61,038	8,922	5,725	21,392
2021	1,159	144	8,179	26,161	17,181	60,720	8,685	5,681	21,320

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. $B_{40\%}$ = 5,911 t, $B_{35\%}$ = 5,172 t, $F_{40\%}$ = 0.038 and $F_{35\%}$ = 0.046.

Year	Maximum permissible F	Author's F*	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning Biomass (t)				
2021	8,685	8,685	8,685	8,685	8,685	8,685	8,685
2022	8,574	8,648	8,641	8,617	8,709	8,546	8,574
2023	8,378	8,627	8,602	8,520	8,832	8,287	8,378
2024	8,185	8,527	8,558	8,421	8,948	8,036	8,159
2025	8,012	8,341	8,528	8,338	9,077	7,810	7,926
2026	7,849	8,164	8,501	8,260	9,209	7,597	7,708
2027	7,688	7,988	8,470	8,179	9,335	7,389	7,493
2028	7,527	7,812	8,432	8,094	9,451	7,185	7,284
2029	7,369	7,639	8,389	8,006	9,559	6,989	7,081
2030	7,217	7,472	8,344	7,918	9,660	6,801	6,888
2031	7,074	7,315	8,303	7,836	9,762	6,627	6,708
2032	6,938	7,164	8,258	7,754	9,854	6,462	6,538
2033	6,817	7,030	8,223	7,685	9,953	6,317	6,388
2034	6,715	6,913	8,199	7,629	10,060	6,191	6,257
			Fishing Mortality				
2021	0.018	0.018	0.018	0.018	0.018	0.018	0.018
2022	0.038	0.017	0.019	0.026	-	0.046	0.046
2023	0.038	0.017	0.019	0.026	-	0.046	0.046
2024	0.038	0.038	0.019	0.026	-	0.046	0.046
2025	0.038	0.038	0.019	0.026	-	0.046	0.046
2026	0.038	0.038	0.019	0.026	-	0.046	0.046
2027	0.038	0.038	0.019	0.026	-	0.046	0.046
2028	0.038	0.038	0.019	0.026	-	0.046	0.046
2029	0.038	0.038	0.019	0.026	-	0.046	0.046
2030	0.038	0.038	0.019	0.026	-	0.046	0.046
2031	0.038	0.038	0.019	0.026	-	0.046	0.046
2032	0.038	0.038	0.019	0.026	-	0.046	0.046
2033	0.038	0.038	0.019	0.026	-	0.046	0.046
2034	0.038	0.038	0.019	0.026	-	0.046	0.046
			Yield (t)				
2021	385	385	385	385	385	385	385
2022	788	788	398	539	-	947	788
2023	765	781	393	530	-	912	765
2024	749	779	392	524	-	886	899
2025	741	770	394	524	-	871	883
2026	741	768	400	529	-	866	877
2027	720	746	395	520	-	835	846
2028	700	724	390	510	-	806	817
2029	683	706	387	503	-	783	792
2030	669	691	384	497	-	762	771
2031	656	676	382	492	-	744	752
2032	645	664	380	487	-	728	736
2033	637	654	380	484	-	715	722
2034	630	646	379	482	-	704	711

* Projections are based on an estimated catch of 383 t for 2021, and estimates of 336 t and 326 t used in place of maximum permissible ABC for 2022 and 2023 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.

Table 13-21. Allocation of ABC for 2022 and 2023 GOA RE/BS rockfish based on the two survey random effects model (trawl and longline surveys). Recommended ABC and OFL in bold.

Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
		23.3%	29.9%	46.8%	100.0%
2022	Area ABC (t)	**184**	**235**	**369**	**788**
	OFL (t)				**947**
2023	Area ABC (t)	**182**	**234**	**365**	**781**
	OFL (t)				**937**

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

Figures

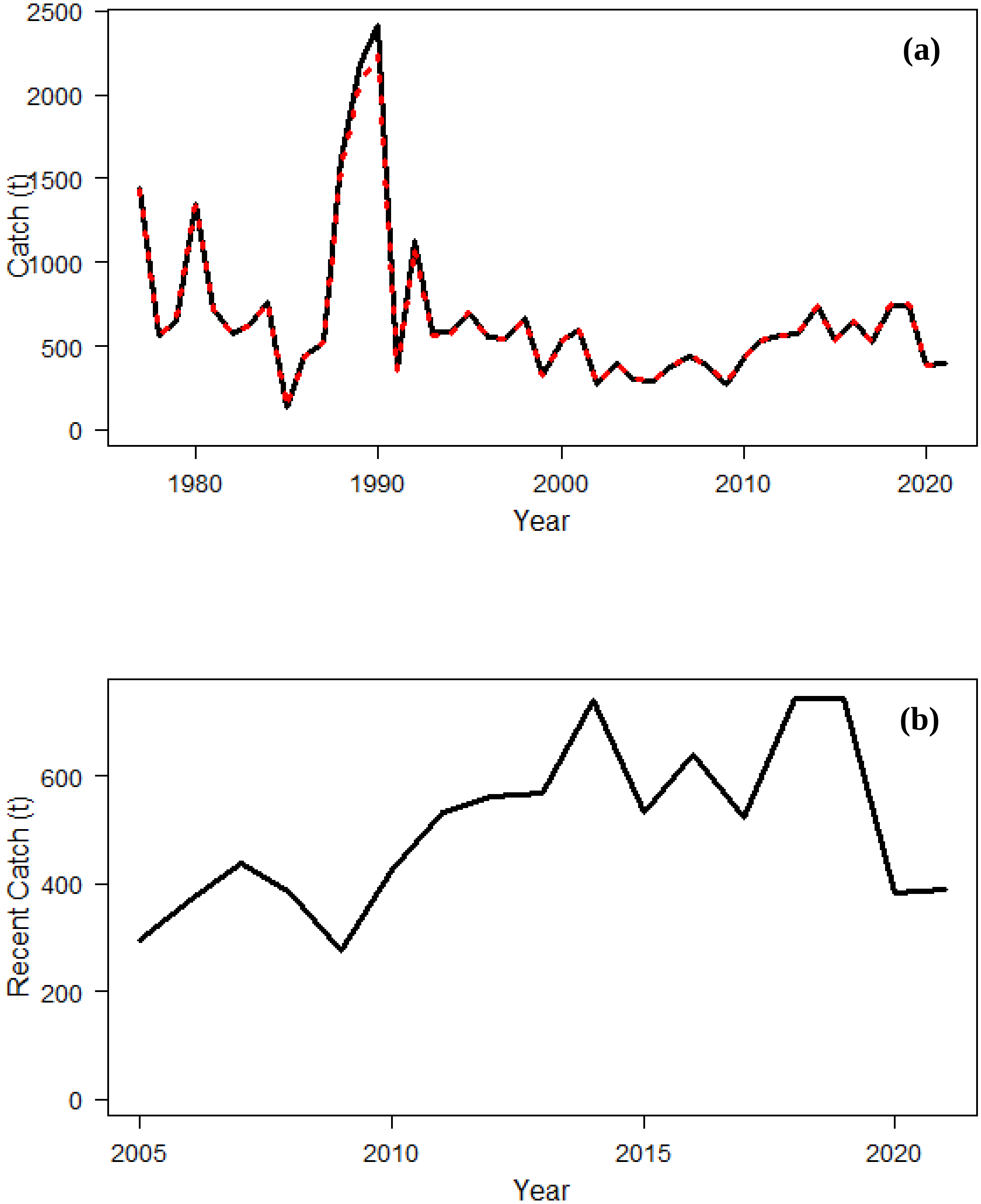

Figure 13-1. Estimated long-term (a) and short-term (b) commercial catches for Gulf of Alaska RE/BS rockfish. Solid line is observed catch and red dashed line (in a only) is predicted catch from the author preferred model.

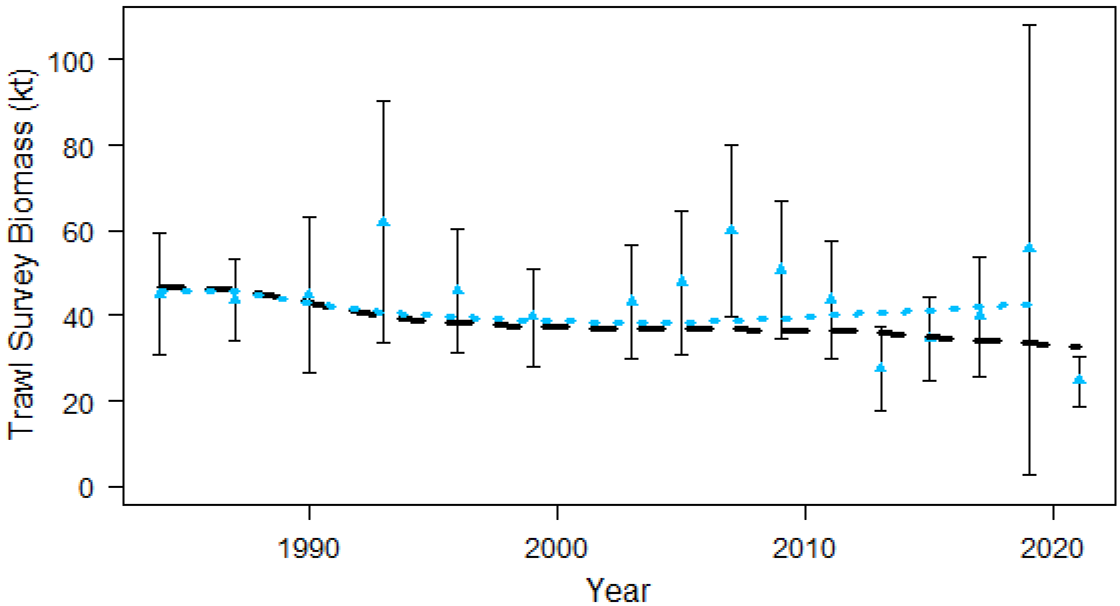

Figure 13-2. AFSC bottom trawl survey observed biomass estimates (blue triangles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the author preferred model (dashed black line) are compared with the last full assessment model fit (dotted blue line).

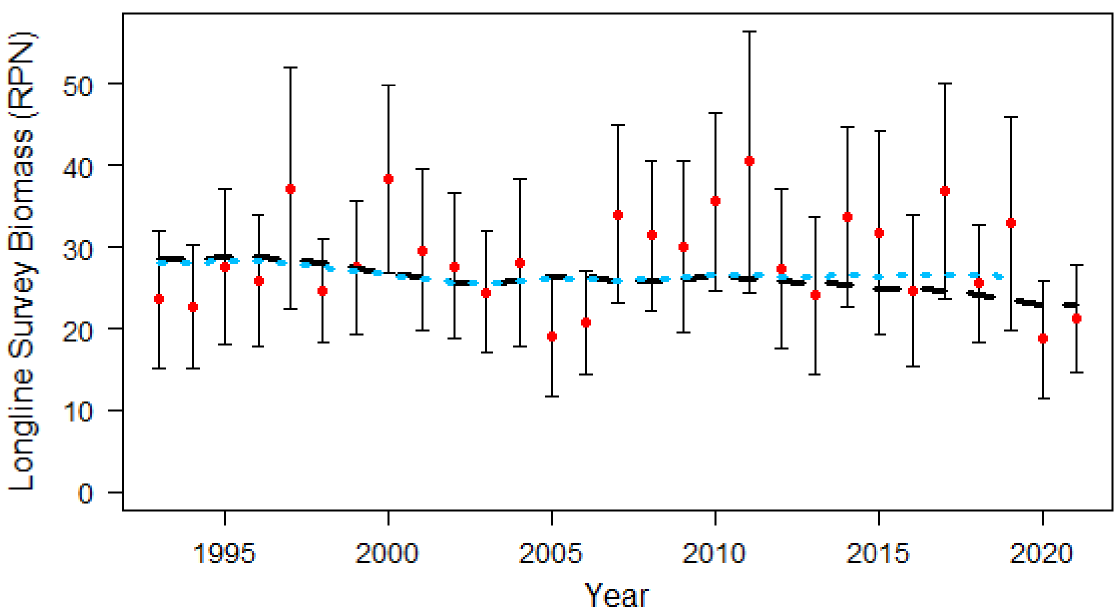

Figure 13-3. AFSC longline survey relative population numbers (RPN in thousands, red circles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the author preferred model (dashed black line) are compared with the last full assessment model fit (dotted blue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

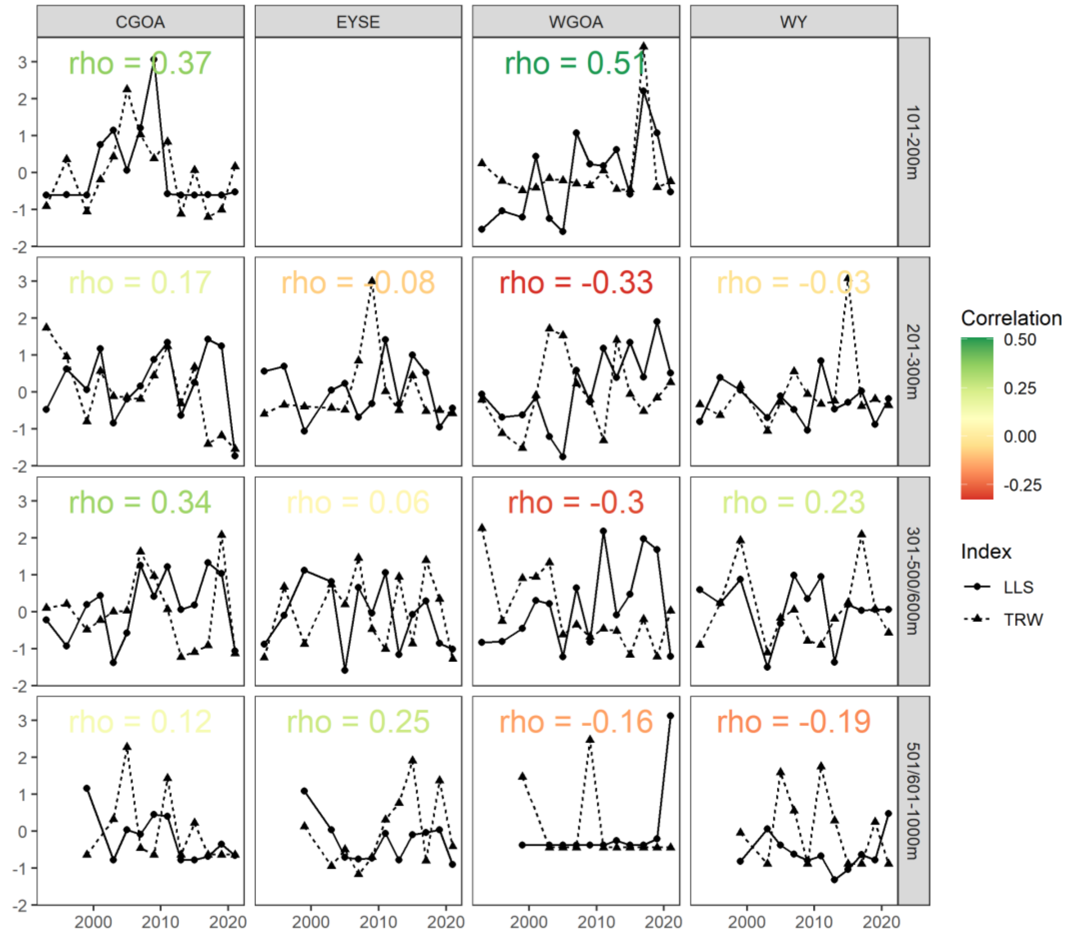

Figure 13-4a. Pearson's correlation coefficients (rho) for standardized trawl and longline survey indices by regulatory area and depth strata.

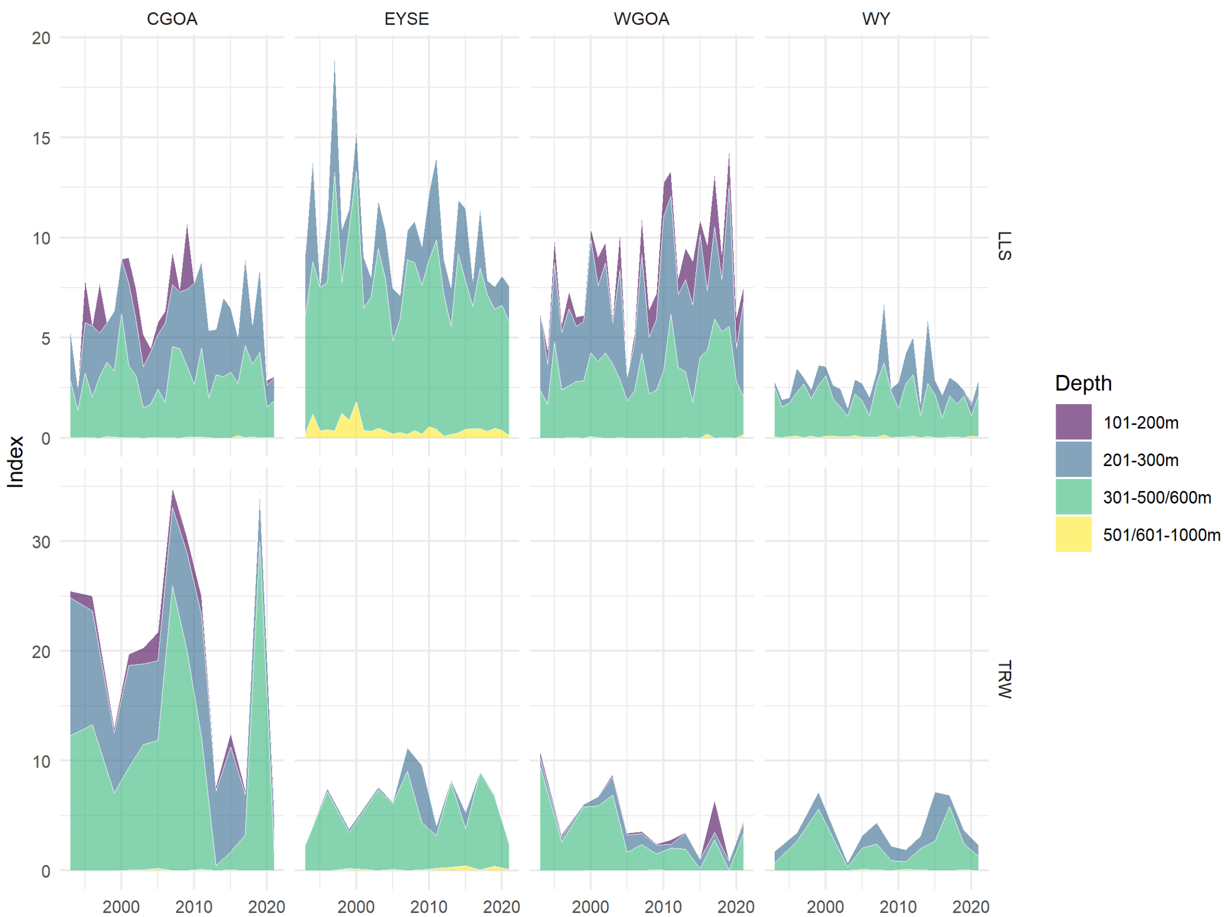

Figure 13-4b. Relative population numbers from the AFSC longline survey (LLS) and trawl survey biomass estimates (TRW) by regulatory area and depth strata.

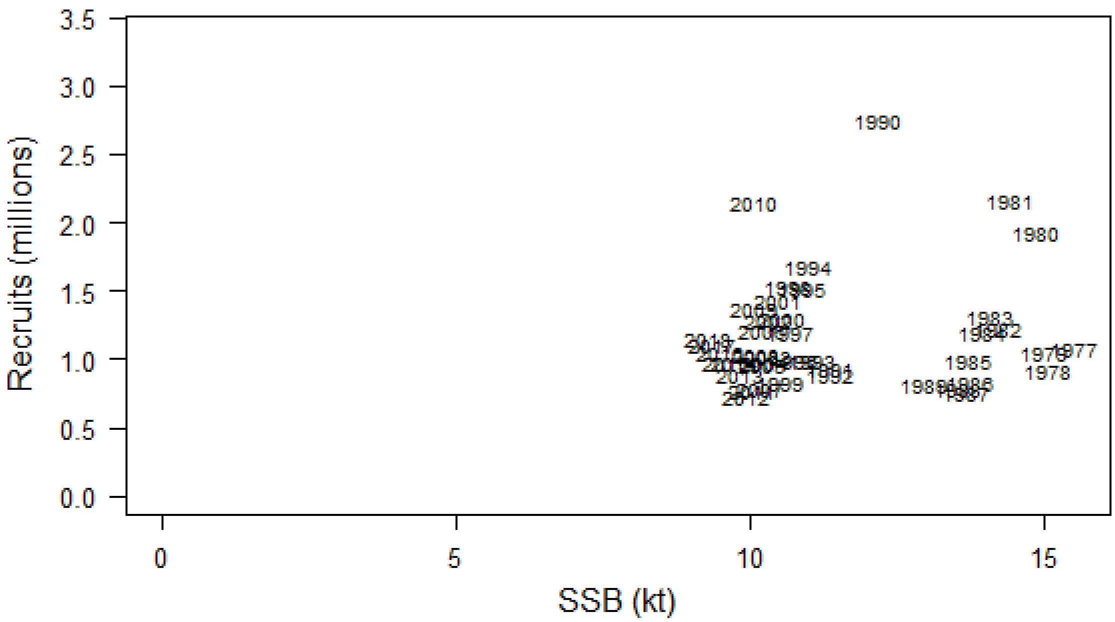

Figure 13-5. Scatterplot of spawner-recruit data for GOA RE/BS rockfish author preferred model. Label is year-class of age-3 recruits. Recruits are in millions and SSB = Spawning stock biomass in kilotons.

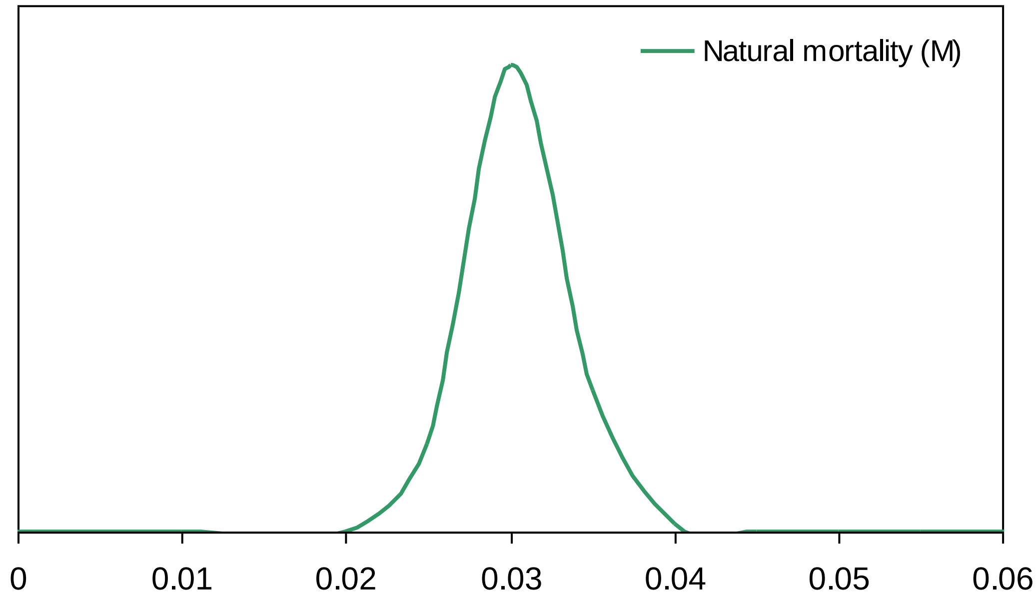

Figure 13-6. Prior distribution for natural mortality (M, μ=0.03, CV=10%) of GOA RE/BS rockfish.

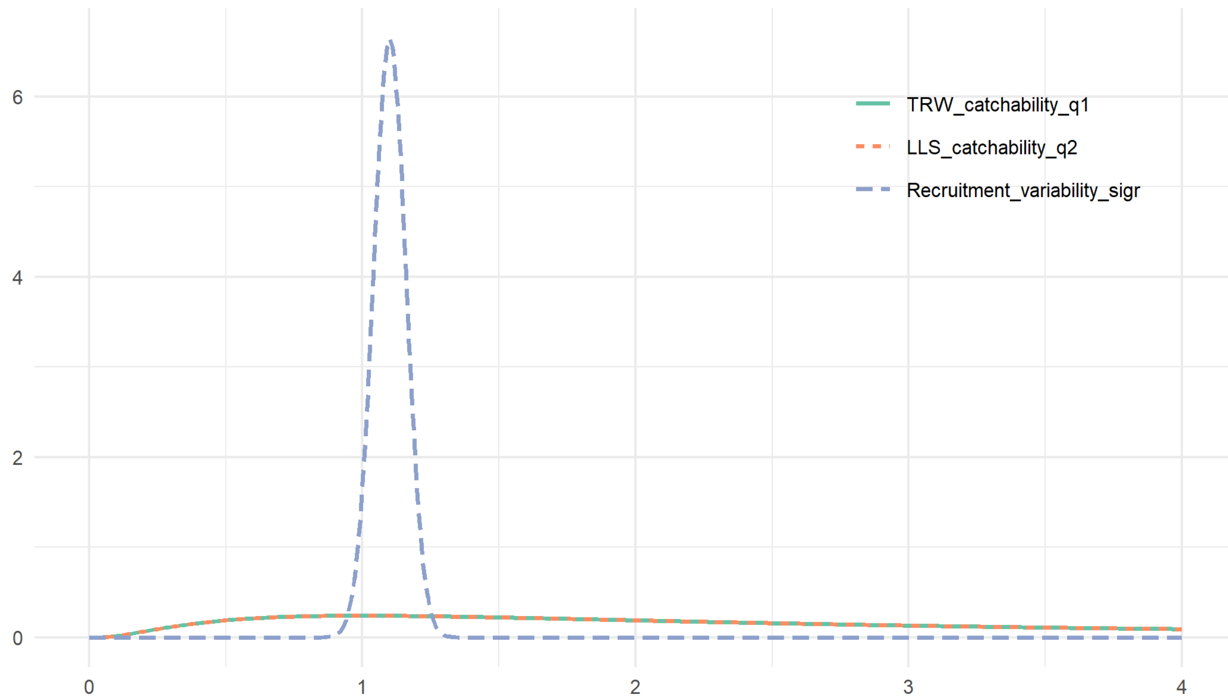

Figure 13-7. Prior distributions for NMFS trawl survey catchability (q1, μ=1, CV=100%), AFSC longline survey catchability (q2, μ=1, CV=100%), and recruitment variability (σ_r, μ=1.1, CV=6%) of GOA RE/BS rockfish.

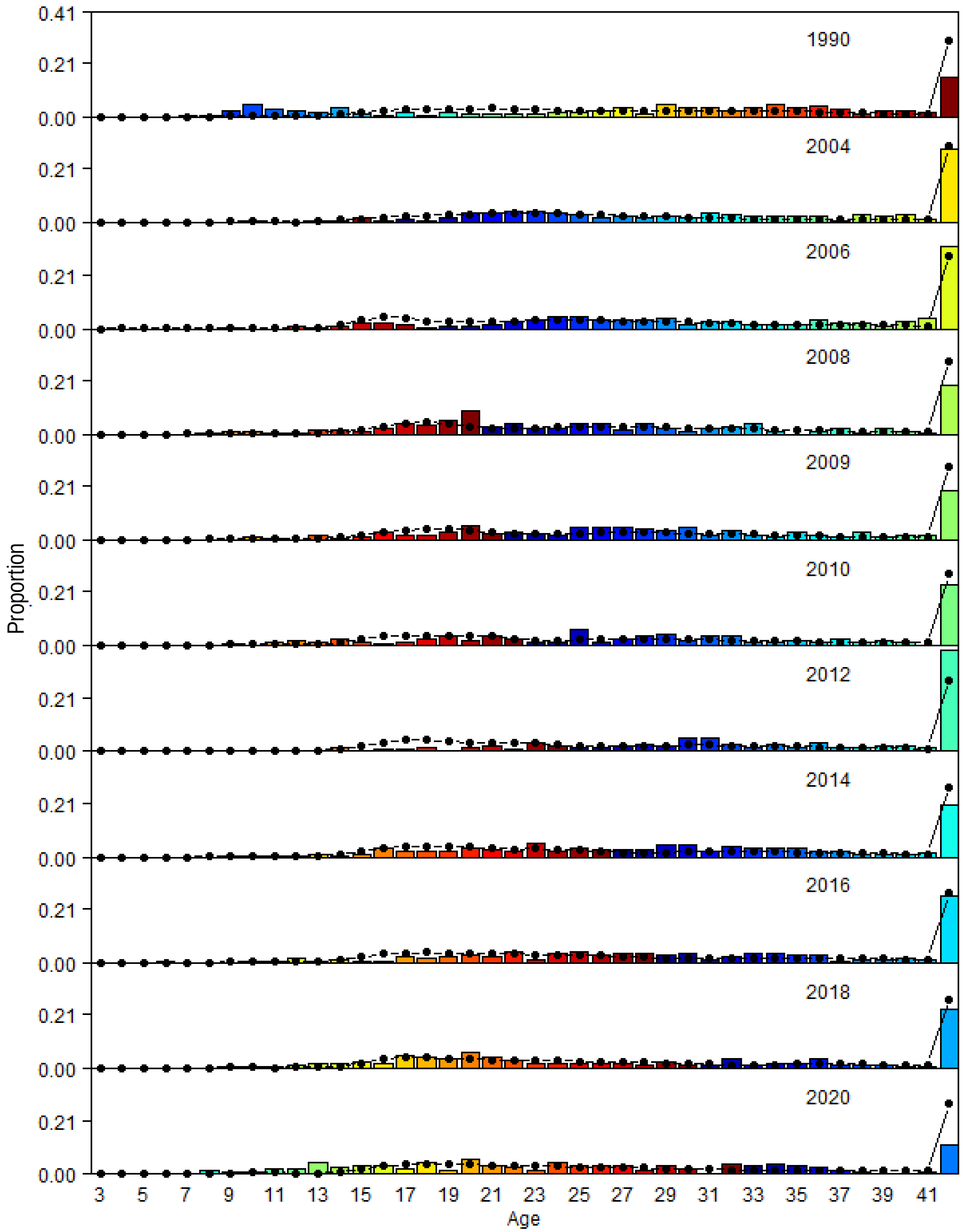

Figure 13-8. Fishery age compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

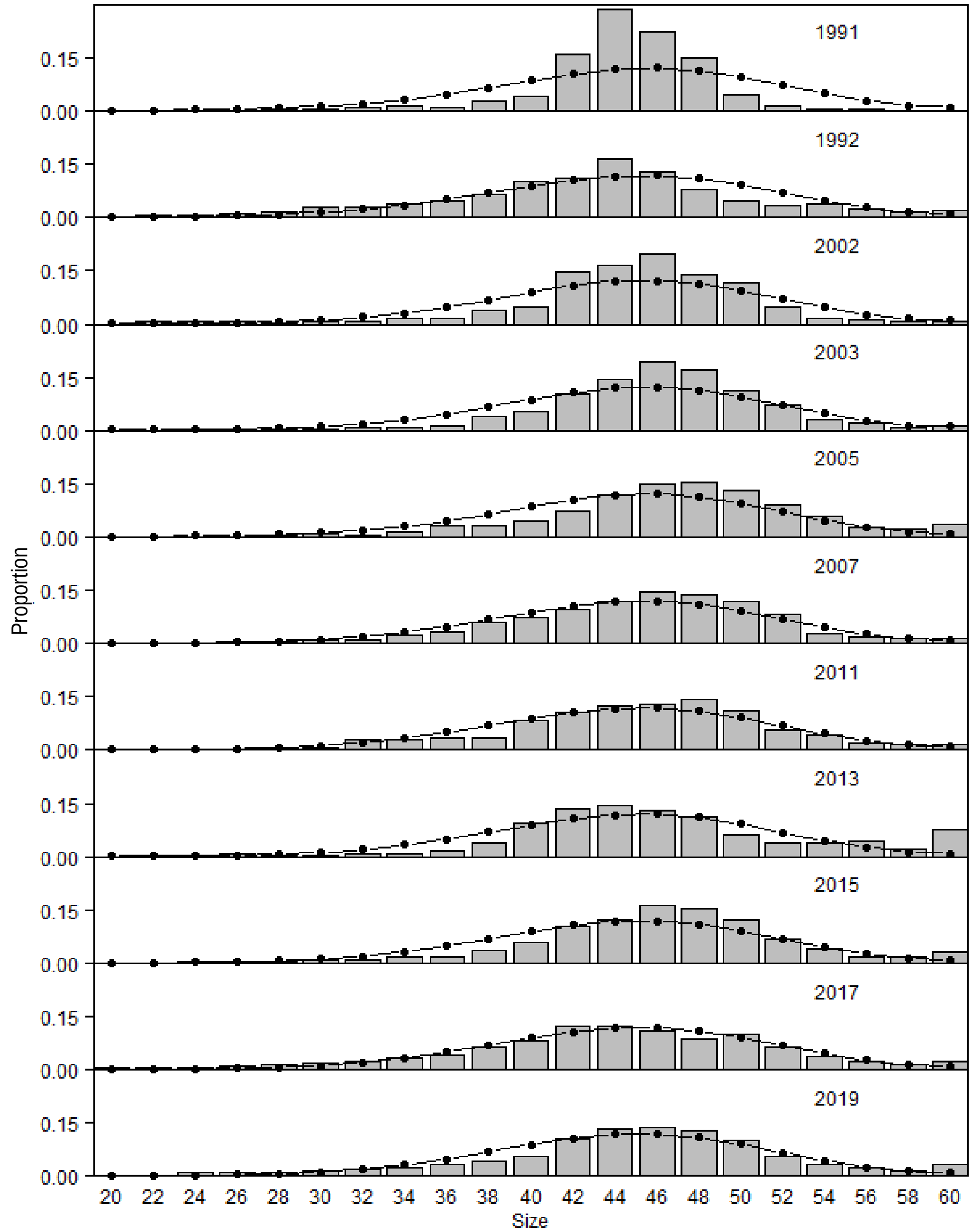

Figure 13-9. Fishery length (cm) compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

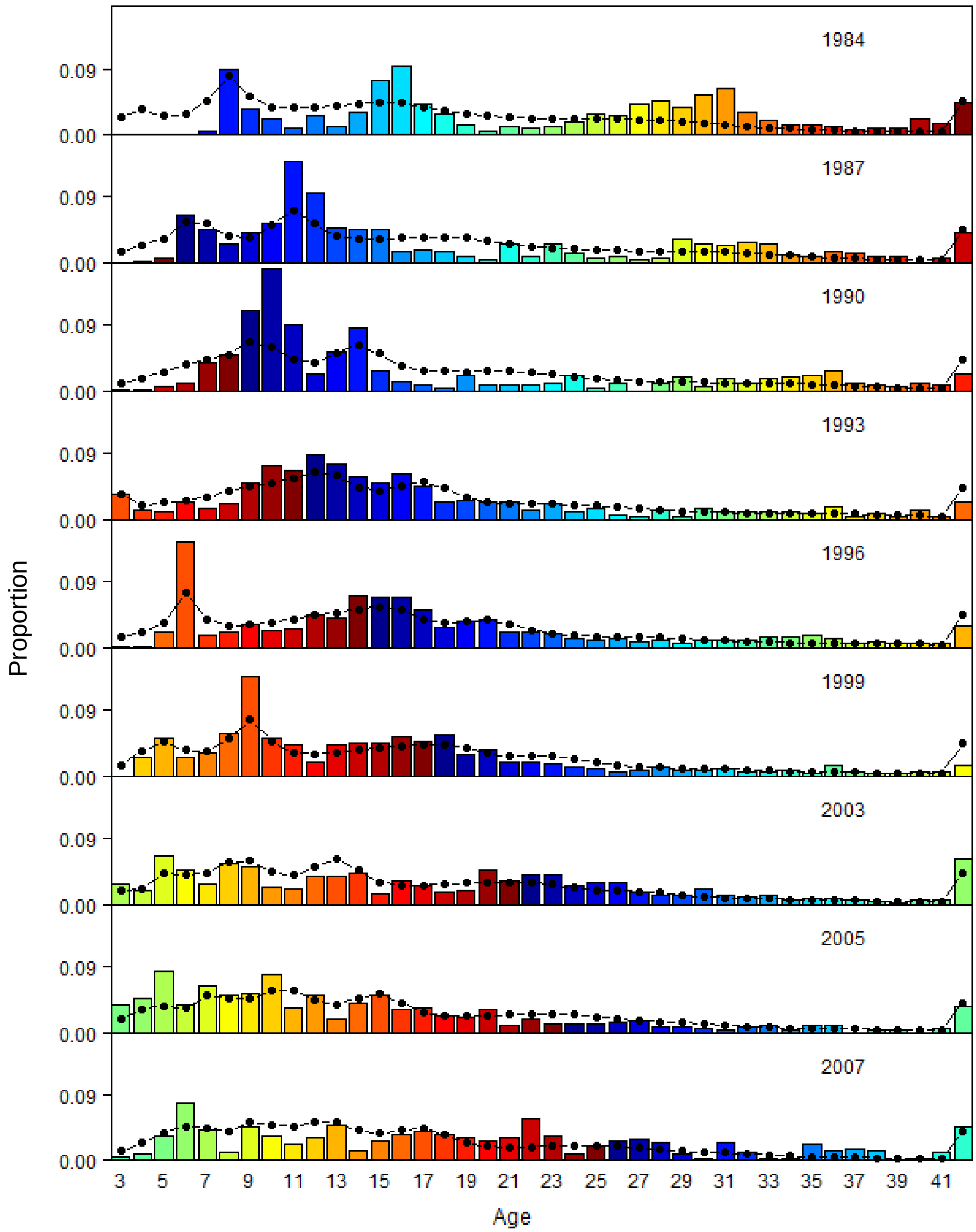

Figure 13-10. AFSC bottom trawl survey age composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

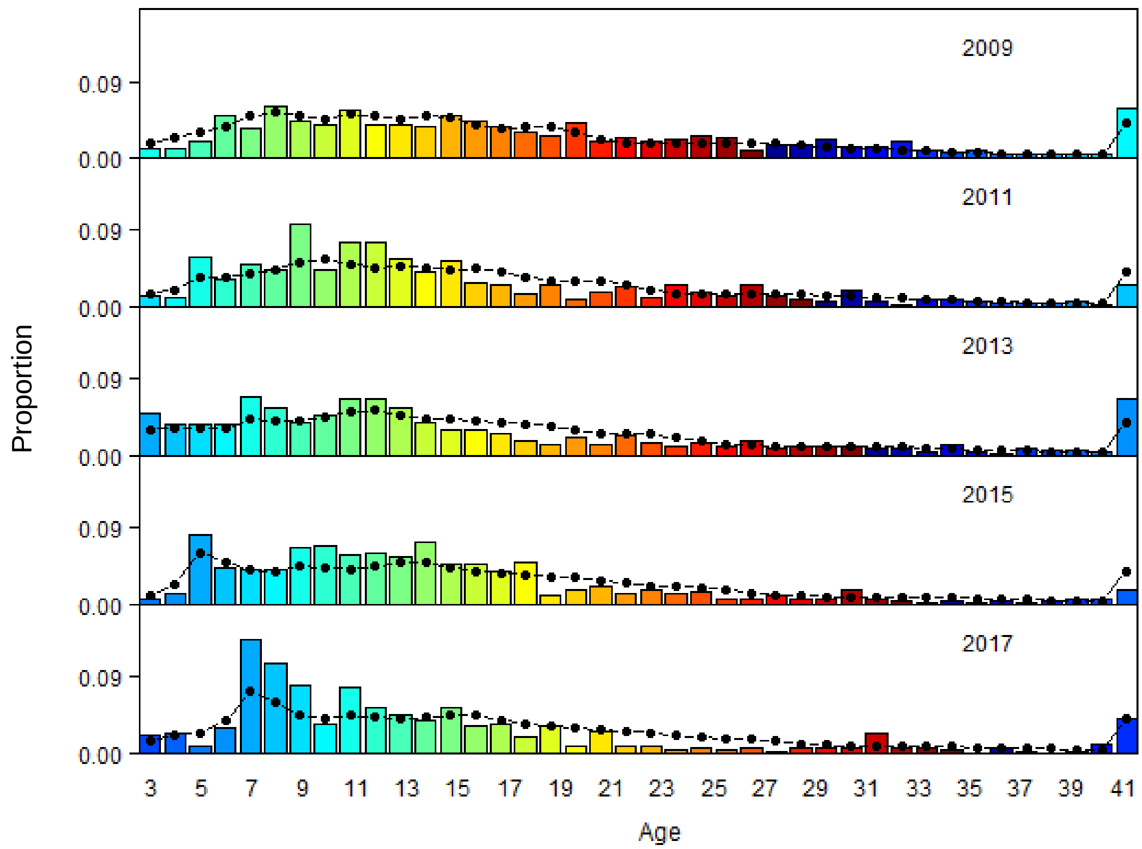

Figure 13-10 (continued). AFSC bottom trawl survey age composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

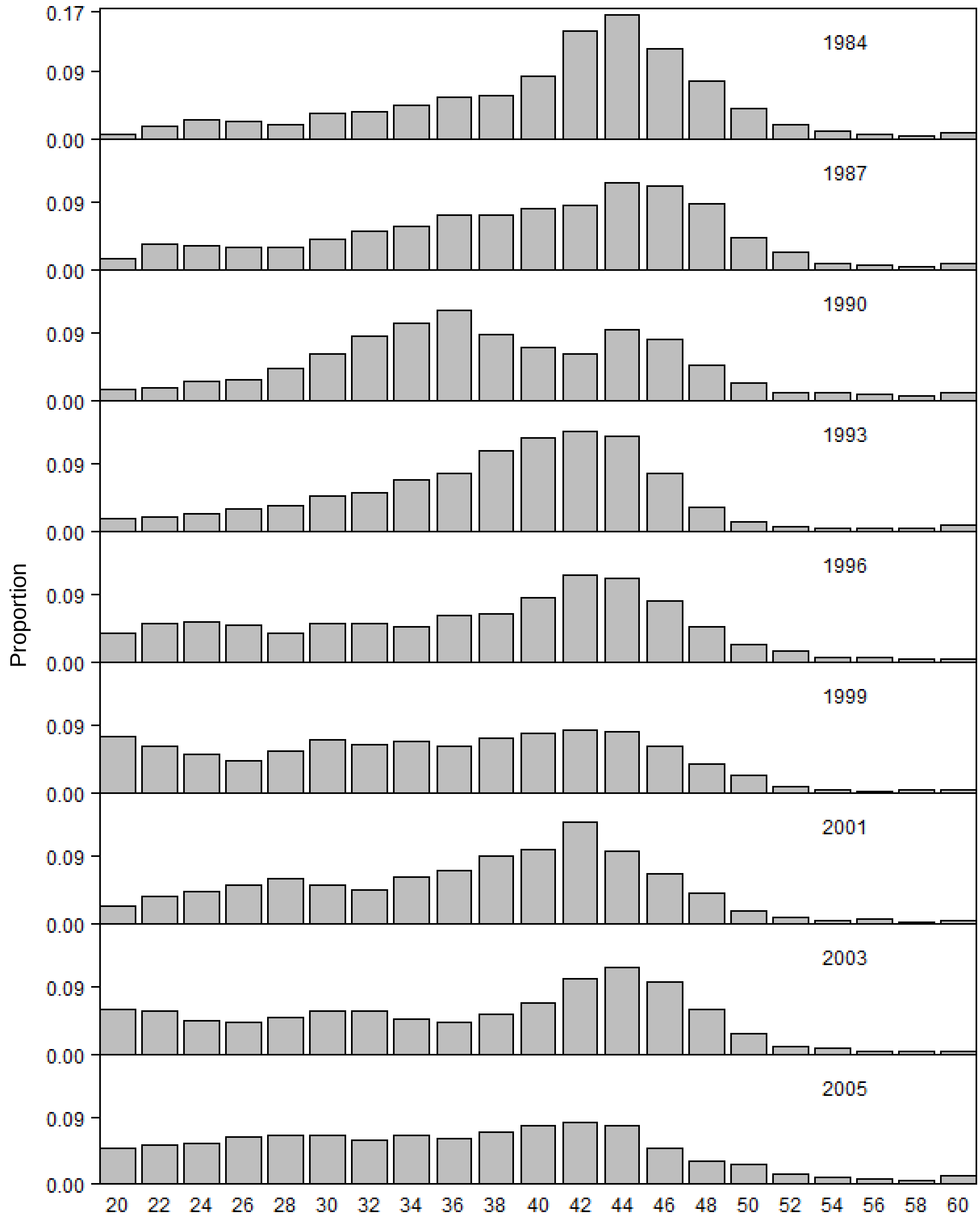

Figure 13-11. AFSC bottom trawl survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in the model.

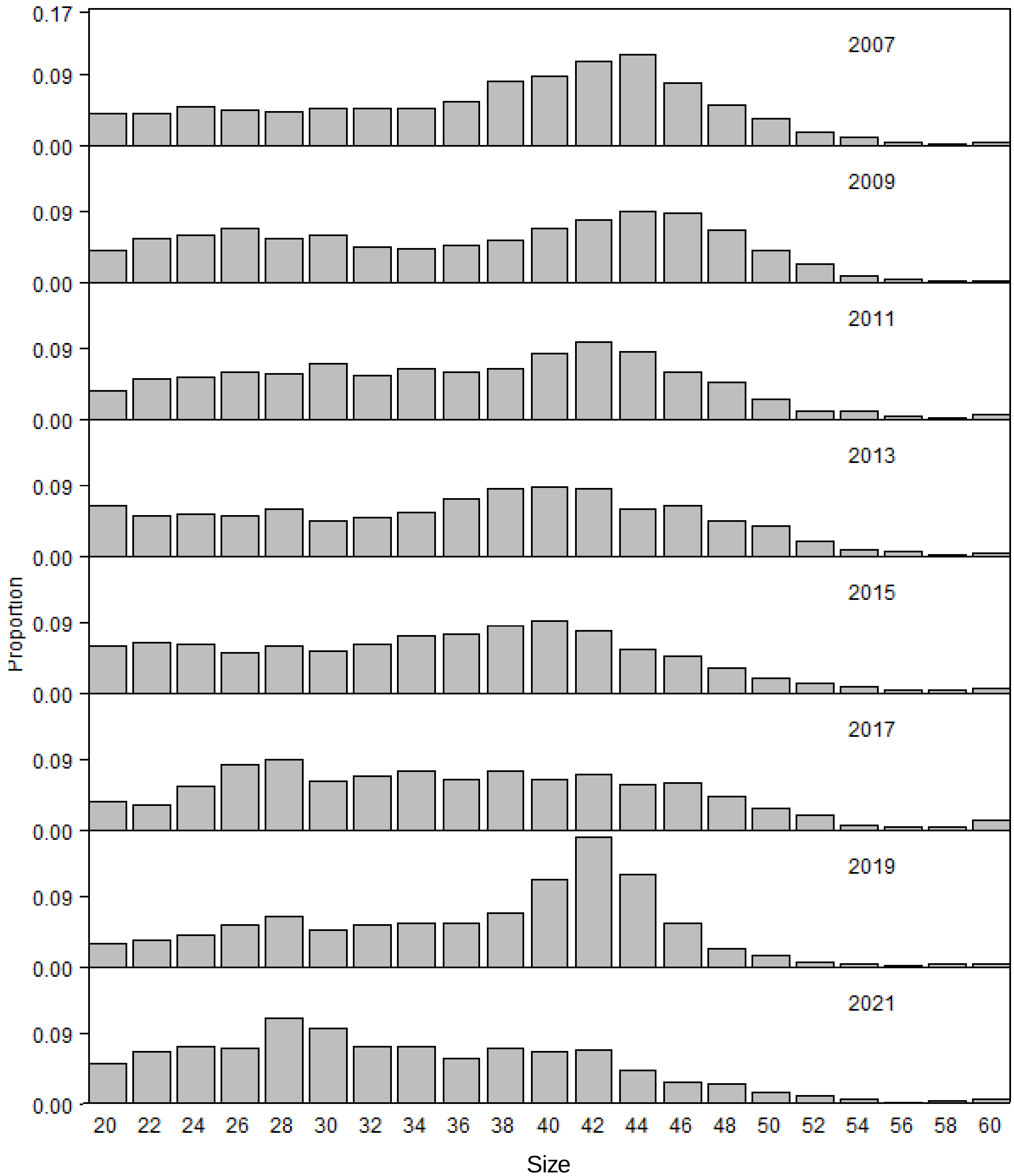

Figure 13-11 (Continued). AFSC bottom trawl survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in the model.

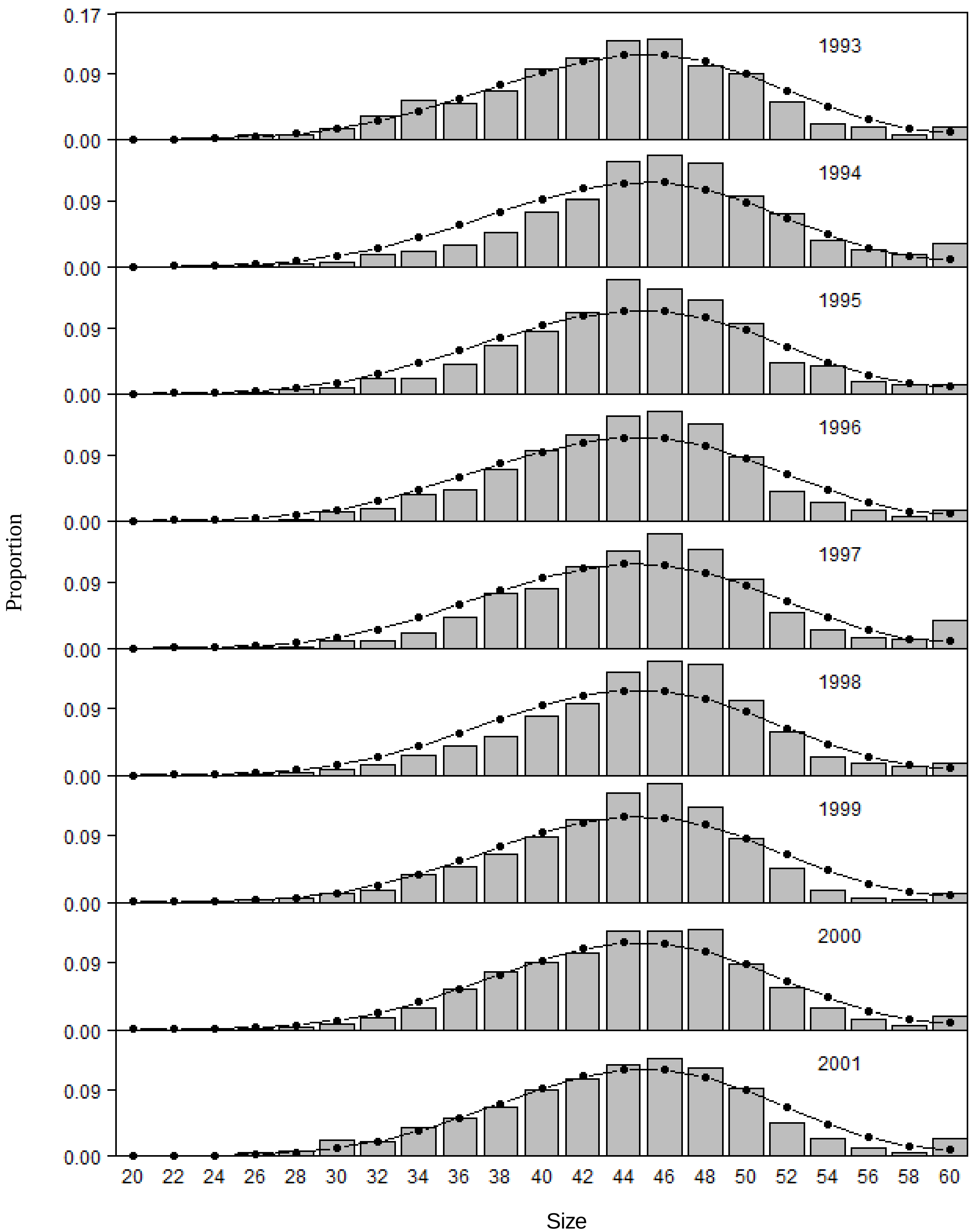

Figure 13-12. AFSC longline survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

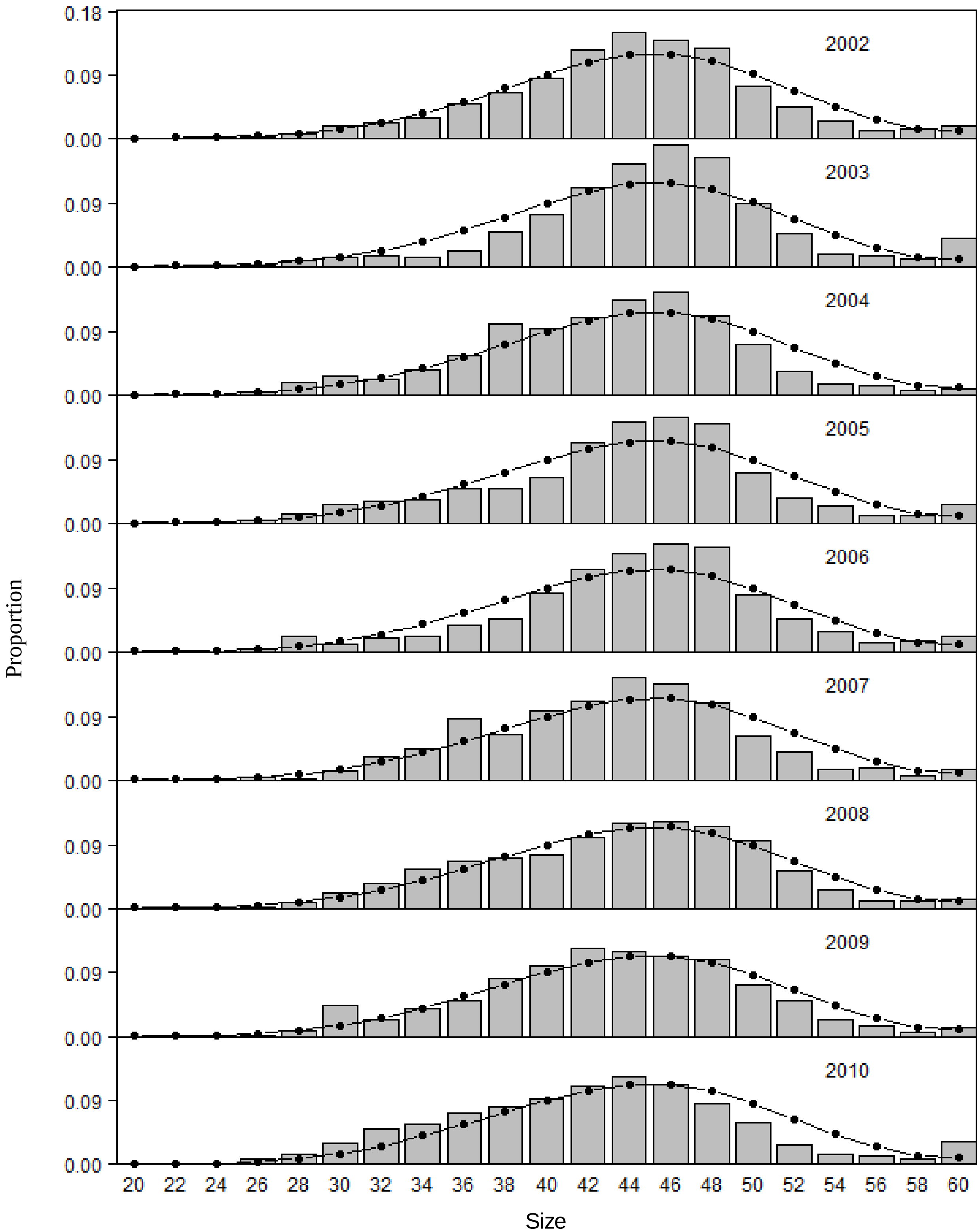

Figure 13-12 (continued). AFSC longline survey length (cm) composition by year for GOA RE/BS rockfish**.** Observed = bars, predicted from author preferred model = lines with circles**.**

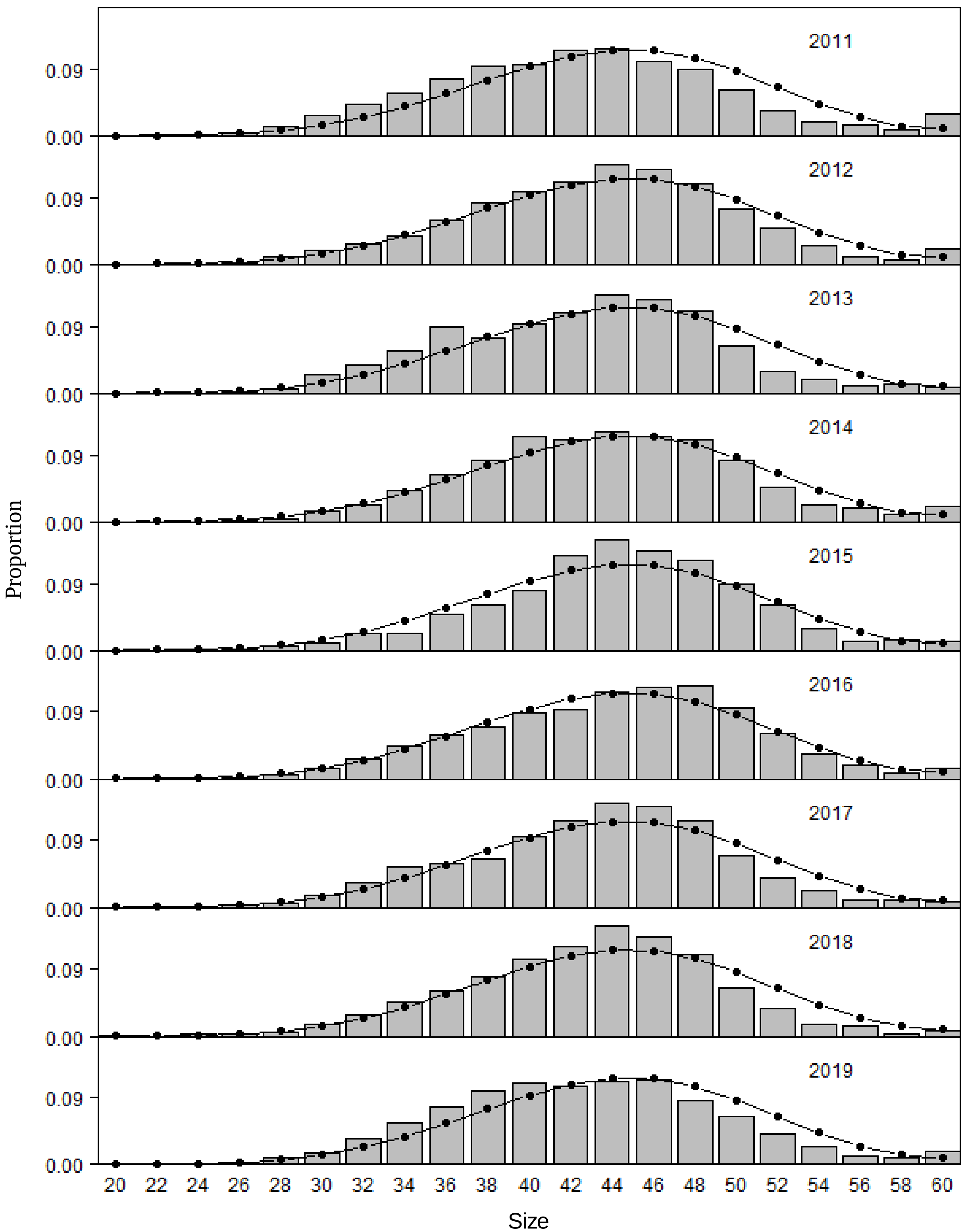
2011
2012
2013
2014
2015
2016
2017
2018
2019
0.09
0.00
Proportion
20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60
Size

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.

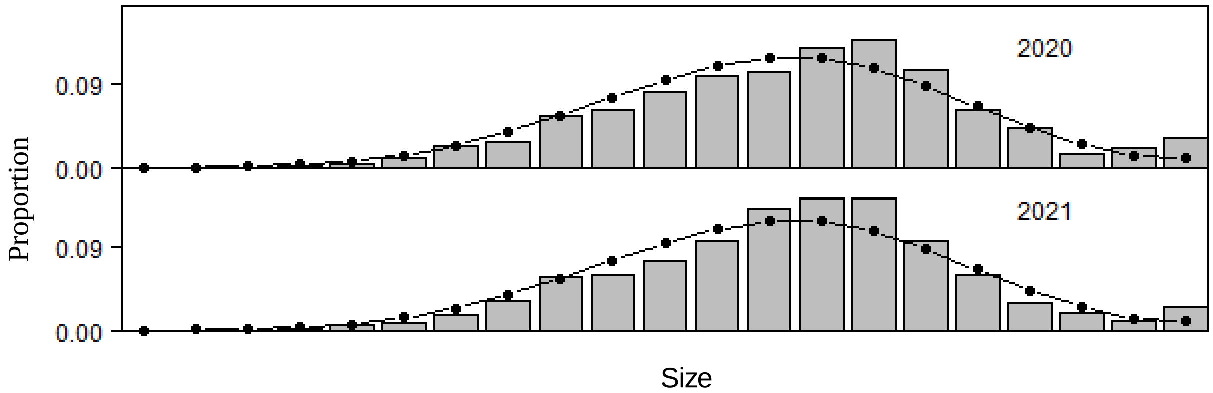

Figure 13-12 (continued) AFSC longline survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

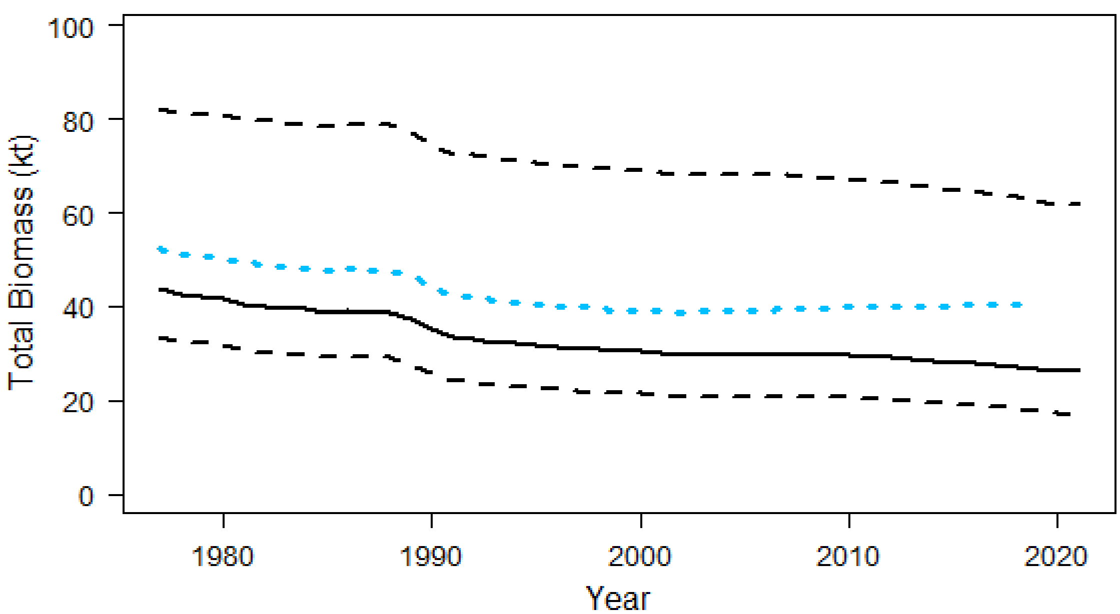

Figure 13-13. Time series of predicted total biomass from author preferred model (solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last full assessment model estimates included for comparison (dotted blue line).

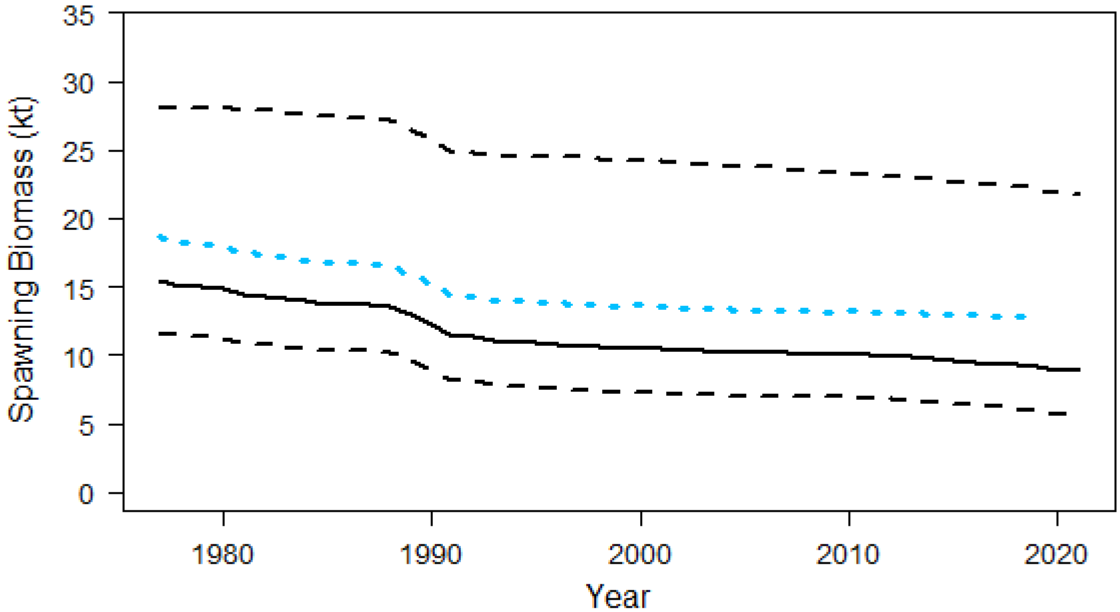

Figure 13-14. Time series of predicted spawning biomass from author preferred model (solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last full assessment model estimates included for comparison (dotted blue line).

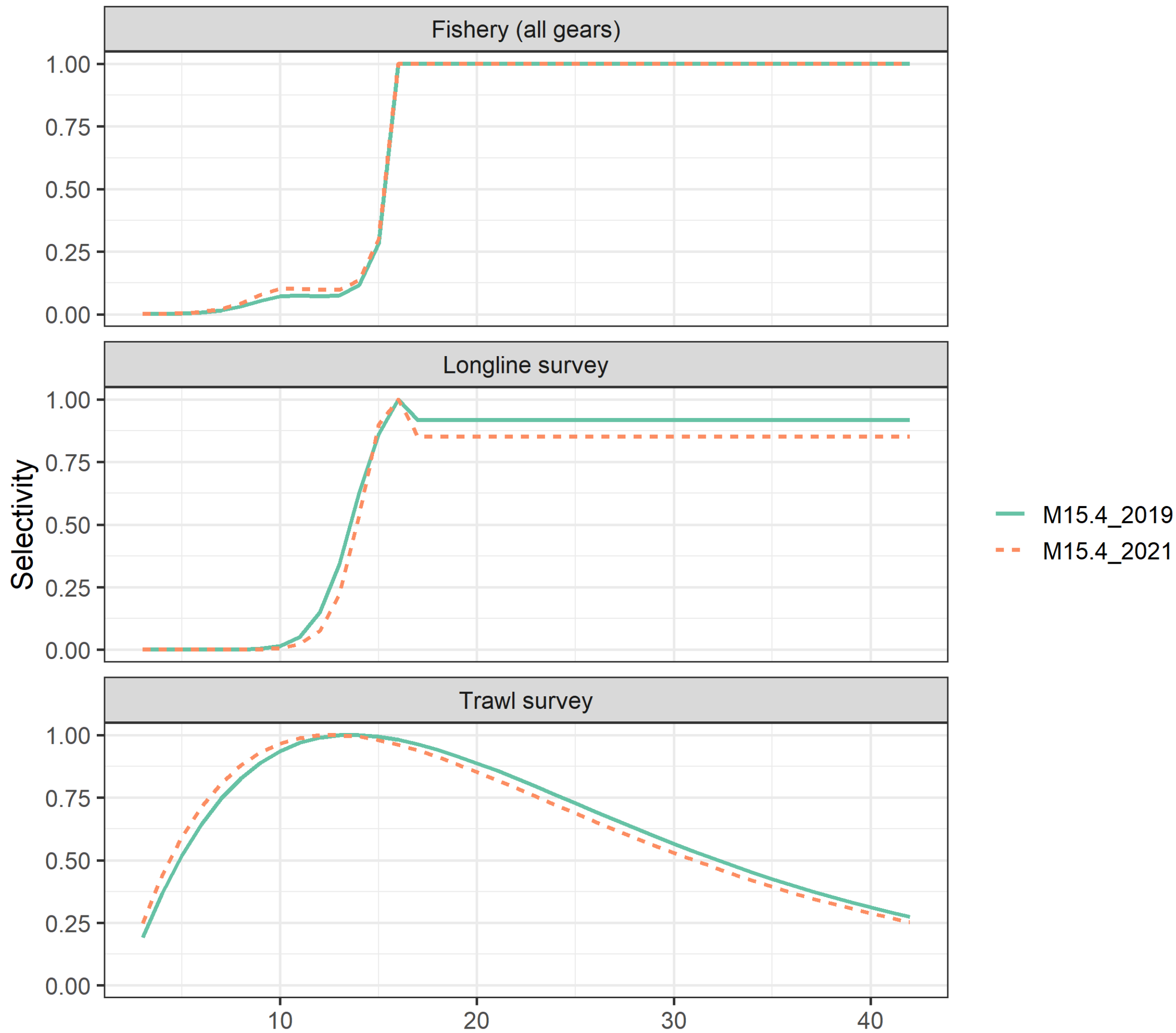

Figure 13-15. Estimated selectivity curves for GOA RE/BS rockfish from the author preferred model (M15.4_2021) and the most recent full assessment in 2019 (M15.4_2019).

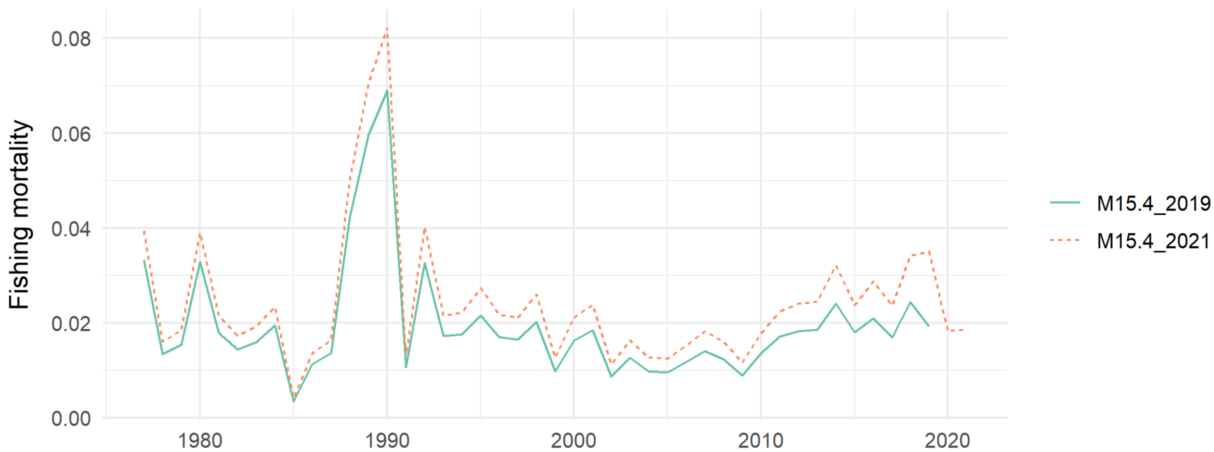

Figure 13-16. Time series of estimated fully-selected fishing mortality for GOA RE/BS rockfish from the author preferred model (M15.4_2021) and the most recent full assessment in 2019 (M15.4_2019).

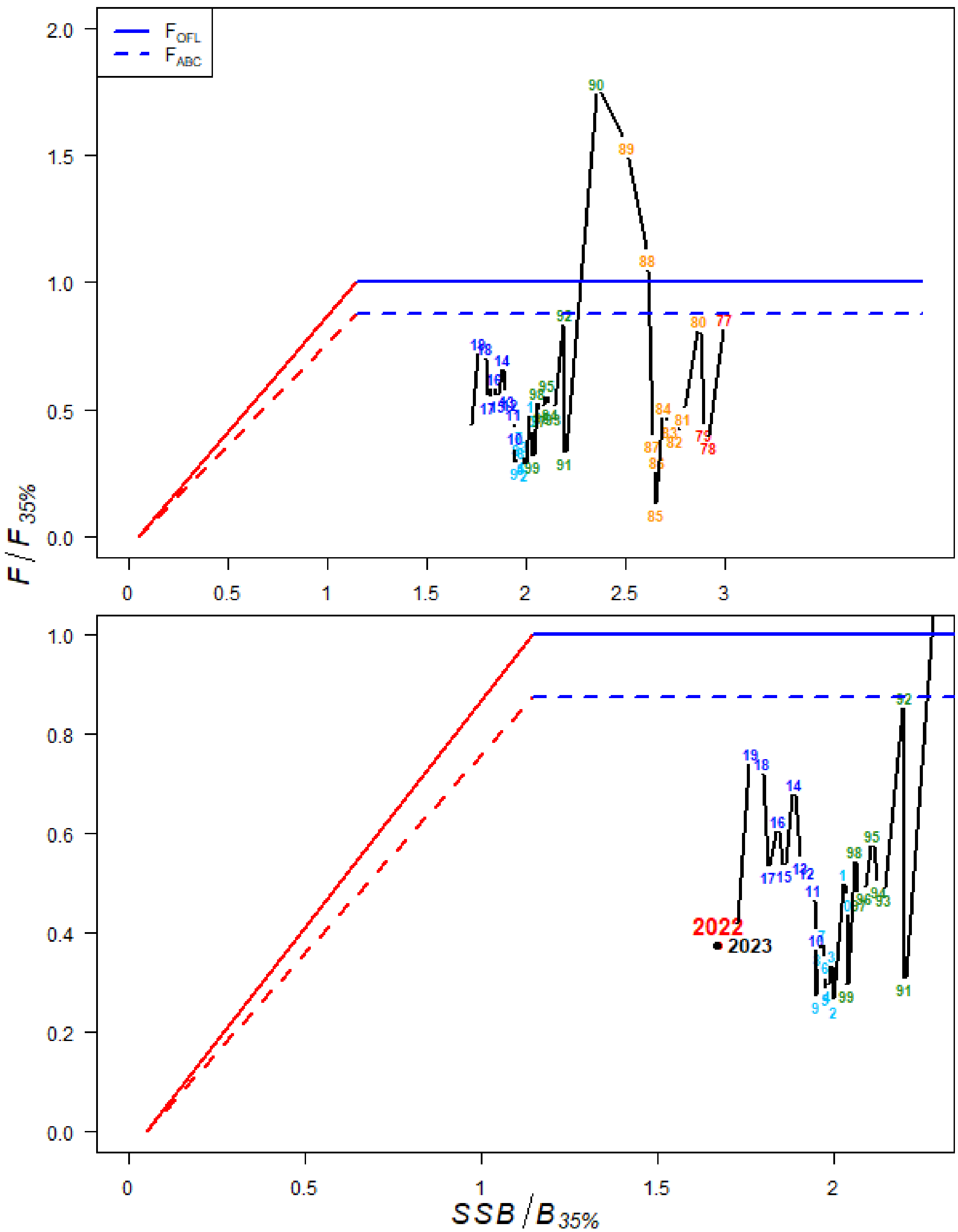

Figure 13-17. Time series of GOA RE/BS rockfish estimated spawning biomass relative to the target $B_{35\%}$ level and fishing mortality relative to F_{OFL} for author preferred model. The upper panel provides the entire time series while bottom panel presents the more recent management path.

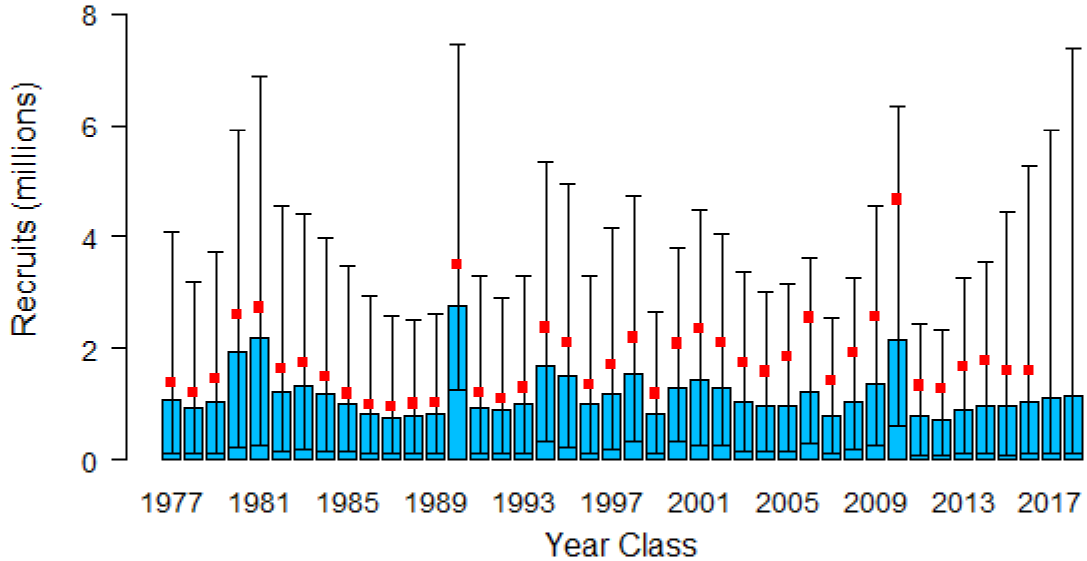

Figure 13-18. Estimated recruitments (age 3) of GOA RE/BS rockfish from author preferred model by year class with 95% credible intervals derived from MCMC. Last full assessment model estimates included for comparison (red squares).

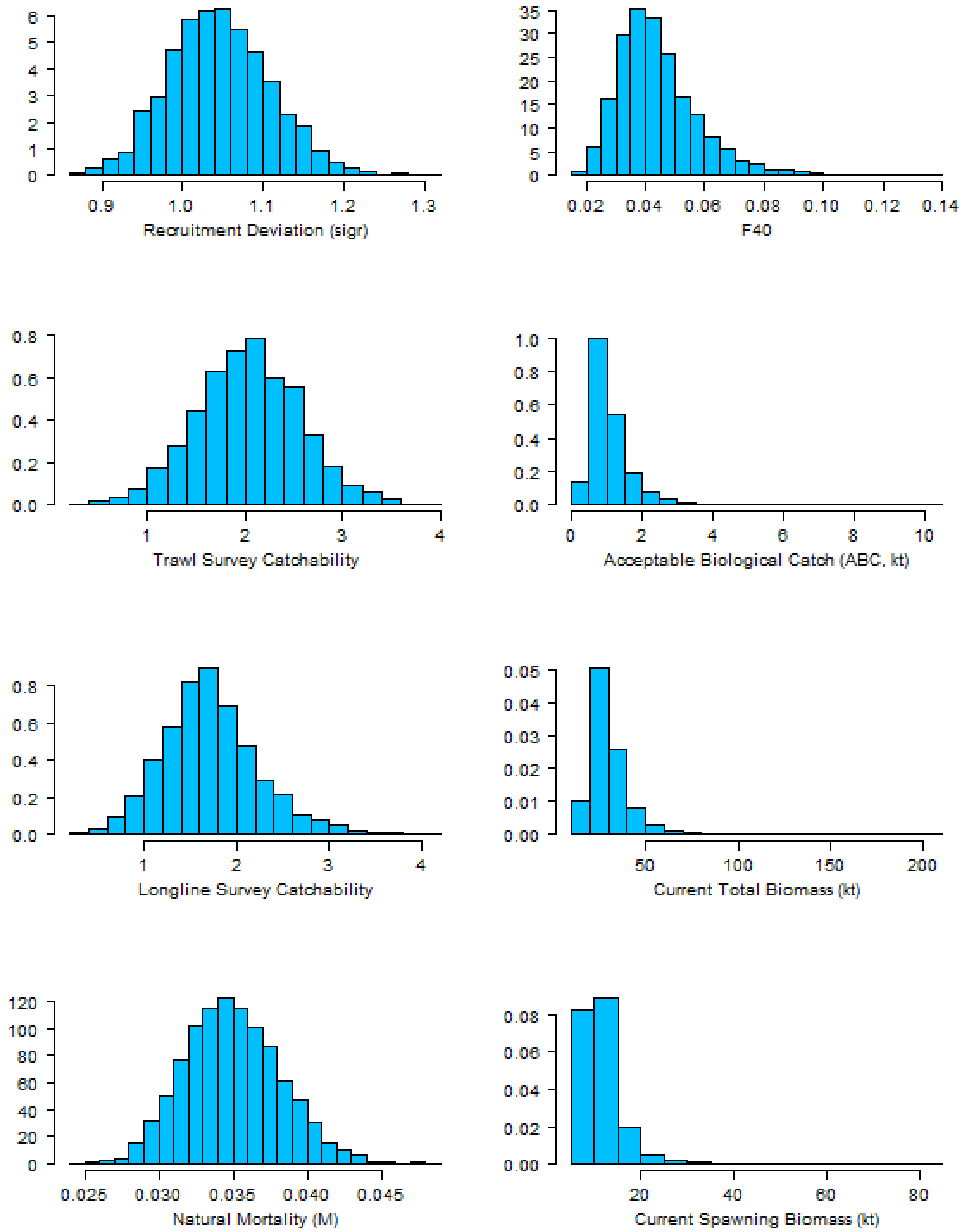

Figure 13-19: Histograms of estimated posterior distributions for key parameters derived from MCMC for GOA RE/BS rockfish.

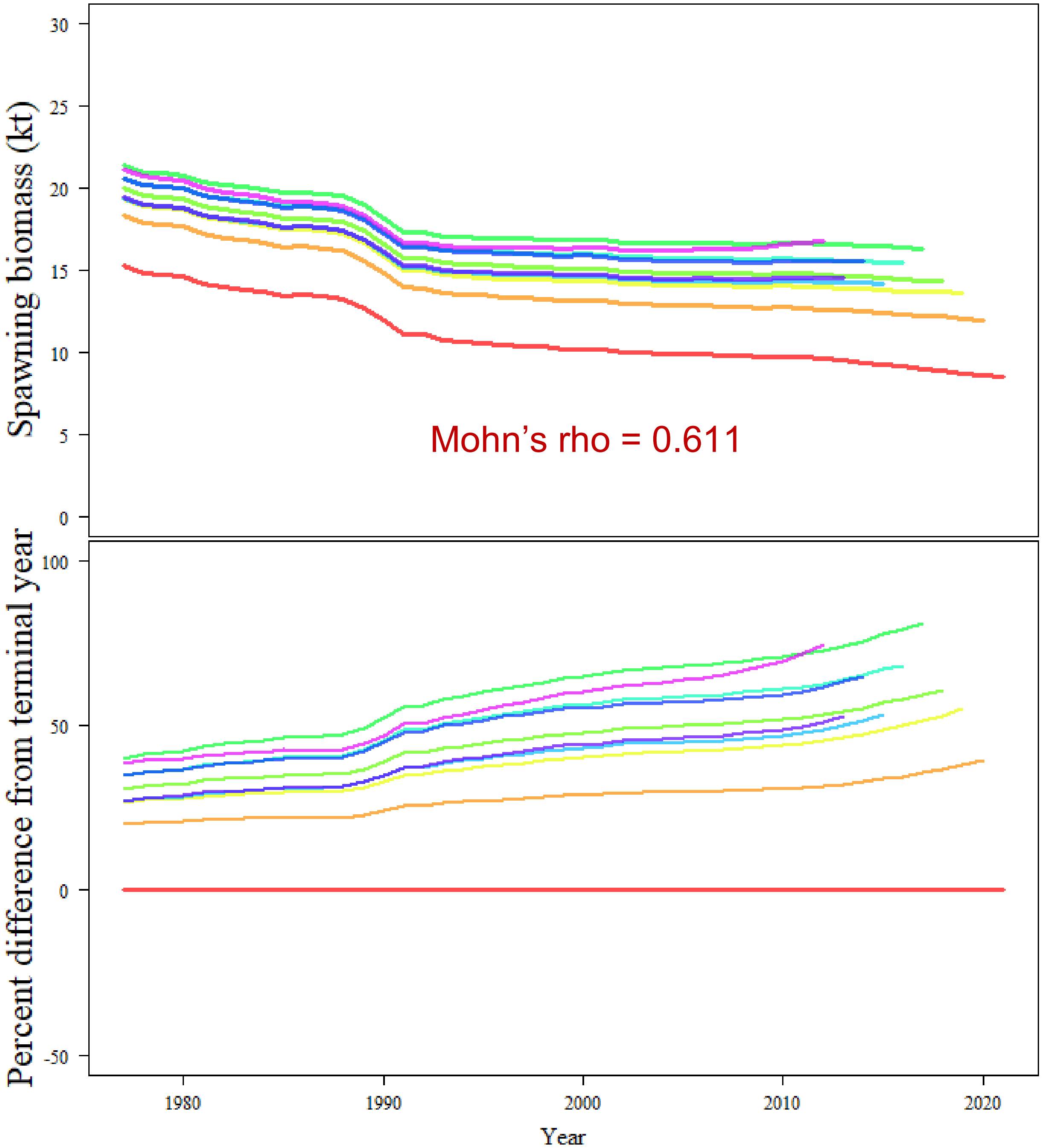

Figure 13-20: Retrospective peels of estimated female spawning biomass for the past 10 years from the author preferred model (top), and the percent difference in female spawning biomass from the preferred model in the terminal year (bottom).

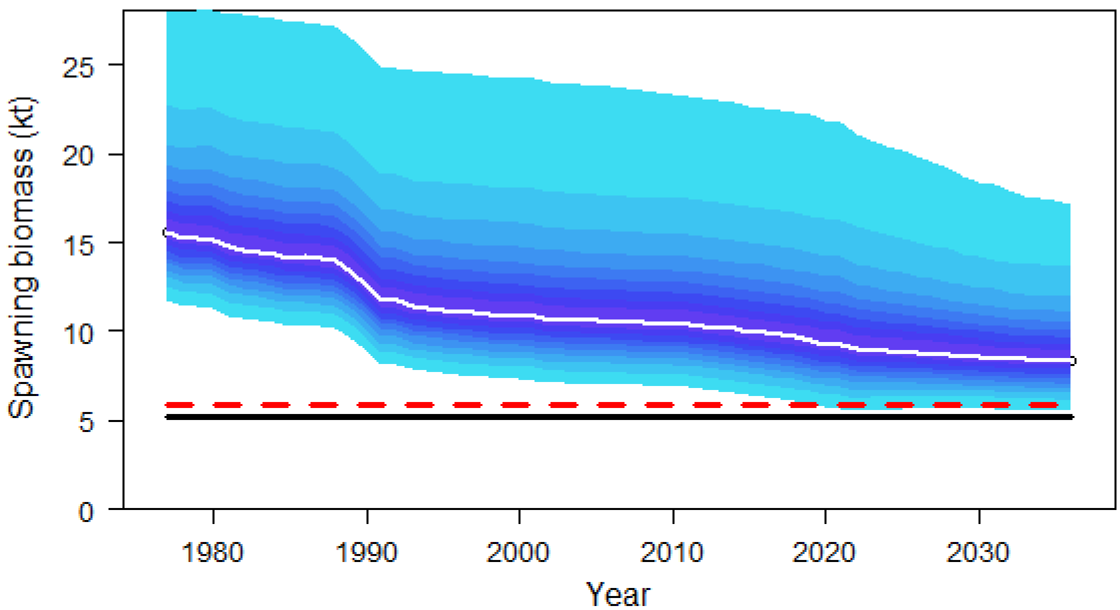

Figure 13-21: Bayesian credible intervals for entire spawning stock biomass series including projections through 2036. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1980-2019 (i.e. the 1977-2016 year classes). The white line is the median of MCMC simulations. 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 (Appendix 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 Appendix 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 since 2010 have been less than 8 t overall, and between 1 and 3 t since 2014. These catches represent <1% of the recommended ABC in these years and represents a low risk to the RE/BS stock.

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 (Appendix Table 13A-2). The majority of catch occurs in the Southeast and Southeast Inside waters. It should be noted that Southeast Inside waters are managed by the State of Alaska and catches from these areas are generally not included in groundfish assessments in the Gulf of Alaska Federal Management Plan. It is unknown what level of RE/BS catch is double-counted in these estimates and the Catch Accounting System. Regardless, the estimated catch from the unobserved halibut fishery is substantial and improved catch estimates from this fishery are warranted.

Literature Cited

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

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

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

Appendix 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		<1	7	<1	7
2011		<1	6	<1	8
2012		2	5	<1	6
2013		2	4	<1	6
2014		<1	<1	<1	1
2015	**AKRO**	2	<1	<1	3
2016		na	1	<1	1
2017		2	<1	<1	3
2018		1	2	<1	3
2019		1	2	<1	3
2020		<1	1	<1	2

Appendix 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.