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

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Executive Summary

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

We use a statistical age-structured model as the primary assessment tool for the Gulf of Alaska rougheye and blackspotted (RE/BS) rockfish complex which qualifies as a Tier 3 stock. This assessment consists of a population model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses results from the population model to predict future population estimates and recommended harvest levels. The data sets used in this assessment include total catch biomass, fishery age and size compositions, trawl and longline survey abundance estimates, trawl survey age compositions, and longline survey size compositions. For this assessment year, we use the last full assessment base model from 2017.

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 2018, new catch estimates for 2019-2021 (see *Specified Catch Estimation* subsection in **Harvest Recommendations** section)
2.) New fishery lengths for 2017
3.) New trawl survey biomass estimate for 2019, new trawl survey ages for 2017
4.) New longline survey relative population numbers (RPN) for 2018 and 2019, and new longline survey lengths for 2018 and 2019.

Changes in the assessment methodology: There were no changes in the assessment methodology as we continue to use the 2015 assessment model (15.4) that we also used in the 2017 full assessment. Please see Shotwell et al. (2015) for more details on the 2015 and 2017 assessment methodology (https://www.afsc.noaa.gov/REFM/Docs/2015/GOArougheye.pdf) and Shotwell et al. (2017) for more details on the last full assessment (https://www.afsc.noaa.gov/REFM/Docs/2017/GOArougheye.pdf).

Summary of Results

The summarized results of the risk table exercise for RE/BS rockfish are in the table below. The overall score of Level 1 suggests no need to set the ABC below the maximum permissible. Further details for each category of this risk table are provided in the *Harvest Recommendations* section.

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*	*Overall score (highest of the individual scores)*
Level 1: Normal	**Level 1:** Normal	**Level 1:** Normal	**Level 1:** Normal	**Level 1:** Normal

Reference values for RE/BS rockfish are summarized in the following table, with the recommended ABC and OFL values for 2020 in bold. The stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for: *	
	2019	2020	2020	2021
M (natural mortality rate)	0.036	0.036	0.036	0.036
Tier	3a	3a	3a	3a
Projected total (ages 3+) biomass (t)	45,363	45,186	40,336	40,393
Projected female spawning biomass (t)	14,992	14,926	12,518	12,530
$B_{100\%}$	22,495	22,495	20,658	20,658
$B_{40\%}$	8,998	8,998	8,263	8,263
$B_{35\%}$	7,873	7,873	7,230	7,230
F_{OFL}	0.048	0.048	0.048	0.048
$maxF_{ABC}$	0.040	0.040	0.040	0.040
F_{ABC}	0.040	0.040	0.040	0.040
OFL (t)	1,715	1,699	**1,452**	1,455
maxABC (t)	1,428	1,414	1,209	1,211
ABC (t)	1,428	1,414	**1,209**	1,211
Status	As determined *last* year for:		As determined *this* year for:	
	2017	2018	2018	2019
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 589 t for 2019, and estimates of 564 t and 553 t used in place of maximum permissible ABC for 2020 and 2021 in response to a Plan Team request to obtain more accurate two-year projections. Please see section on Specified Catch Estimation subsection in the Harvest Recommendations section for more details regarding these calculations.

The 2019 trawl survey estimate increased 39% from the 2017 estimate and is now 22% above average. The 2018 longline survey abundance estimate (RPN) decreased about 31% from the 2017 estimate and the 2019 longline RPN estimate decreased about 11% from the 2017 estimate and increased 29% from the 2018 estimate. The longline survey is now 13% above average. Since 2005, the total allowable catches (TACs) for RE/BS rockfish have not been fully taken, and are generally between 20-60% of the TAC and is at 40% as of October 1, 2019. This ratio has been declining in the eastern GOA (by about 20%) and increasing in the central GOA (by about 20%) since 2012, whereas catches in the western GOA have been relatively steady over time (about 40% of regional apportionment).

For the 2020 fishery, we recommend the maximum allowable ABC of 1,209 t from the author recommended model. This is a 15% decrease from last year's ABC of 1,428 t. While the population total numbers remain relatively steady, there has been a lack of larger exploitable fish in the population in the last several years of trawl survey age composition and longline survey length compositions. The trawl survey age compositions have particularly shown an increase in younger fish from the 2010 year-class. Thus, the ABC is decreasing despite the large uncertain increase in the trawl survey biomass estimate because of the shift in age and length compositions to the appearance of a younger stock. Female spawning biomass is well above $B_{40\%}$, and projected to be stable.

Area Allocation of Harvests

The apportionment percentages have changed with the addition of the 2017 trawl survey biomass. In past assessments, we determined apportionment using a 4:6:9 weighted average of the proportion of biomass in each area from the three most recent bottom trawl surveys. This exponential moving average was used to smooth the estimates but weight the most recent observation most heavily (see *Area Allocation of Harvests* subsection in **Harvest Recommendation** section for further details). As an alternative to this, both the Plan Team and SSC have requested that the random effects model developed by the Survey Averaging Working Group be applied to the bottom trawl survey data and used for apportionment as a default method and provided alongside the current apportionment for comparison purposes. In this assessment, we use a version of the random effects model incorporating both the longline and trawl survey relative abundance indices (equally weighted).

The following table shows the apportionment for the 2020 and 2021 fishery using the three-survey weighted average and random effects methods.

Method	Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
Three Survey Weighted Average			6.63%	55.70%	37.67%	**100%**
	2020	Area ABC (t)	**80**	**673**	**456**	**1,209**
		OFL (t)				**1,452**
	2021	Area ABC (t)	**80**	**675**	**456**	**1,211**
		OFL (t)				**1,455**
Two Survey Random Effects			13.88%	37.61%	48.51%	**100%**
	2020	Area ABC (t)	**168**	**455**	**586**	**1,209**
		OFL (t)				**1,452**
	2021	Area ABC (t)	**169**	**455**	**587**	**1,211**
		OFL (t)				**1,455**

We recommend using the new two survey random effects model as opposed to the three-survey weighted average apportionment for RE/BS rockfish at this time, because it is effectively using the most available data. Please see Area Allocation of Harvests subsection in the Harvest Recommendations section below for more details on this justification.

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
RE/BS complex	2018	45,624	1,735	1,444	1,444	754
	2019	45,363	1,715	1,428	1,428	568
	2020	40,336	1,452	1,209		
	2021	40,393	1,455	1,211		

Stock/ Assemblage	Area	2019 OFL	2019 ABC	2019 TAC	2019 Catch[2]	2020 OFL	2020 ABC	2021 OFL	2021 ABC
RE/BS complex	W		174	174	72		168		169
	C		550	550	361		455		455
	E		704	704	135		586		587
	Total	1,715	1,428	1,428	568	1,452	1,209	1,455	1,211

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

[2]Current as of October 1, 2019. Source: NMFS Alaska Regional Office Catch Accounting System via the AKFIN database (http://www.akfin.org).

Responses to SSC and Plan Team Comments on Assessments in General

"The SSC considers the risk table approach an efficient method to organize and report this information and worthy of further investigation…The SSC recommends that one additional column be added to include concerns related to fishery/resource-use performance and behavior, considering commercial as well as local/traditional knowledge for a broader set of observations. This additional column should not include socio-economic considerations, but rather indications of concern such as inability to catch the TAC, or dramatic changes in spatial or temporal distribution that could indicate anomalous biological conditions. The SSC requests that all authors fill out the risk table in 2019, and that the PTs provide comment on the author's results in any cases where a reduction to the ABC may be warranted (concern levels 2-4)." (SSC, December 2018)

"Given that the risk table and ESP are clearly in development and are likely to evolve in important ways, the SSC suspends its requests for "OK-ness" and "inference of impending decline" for individual stock authors of all assessments…The SSC would like to see how these new processes and products develop to determine if they are able to provide the type of information needed to provide an early detection of ecosystem change. In addition, risk tables only need to be produced for groundfish assessments that are in a "full" year in the cycle. (SSC, June 2019)

"The SSC recommends the authors complete the risk table and note important concerns or issues associated with completing the table." (SSC, October 2019)

The comments that pertain to the risk table have been grouped together. Since this is a full assessment year for RE/BS rockfish, we provide a risk table as recommended by the SSC. Following the completion of this exercise, the highest score for this stock is a Level 1 and the authors 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.

Responses to SSC and Plan Team Comments Specific to this Assessment

"The Team recommend that the authors implement as worst case (bookended), dynamic weighting or apply genetically verified data to adjust the model for differences in maturity." (Plan Team November 2017)

"The SSC supports the Plan Team recommendation for an analysis that provides a more realistic range of management risk of combining RE/BS in one stock than is currently in the assessment. A variety of

methods could be used, including catch composition analysis, genetic vs visual survey ids, maturity curve differences, etc." (SSC December 2017)

Stock identification analyses of GOA RE/BS rockfish are ongoing. We have collected a short summary of these studies as depicted in previous SAFE reports in Appendix 13.B so that the current status of this information is all in one place. When these analyses are completed, we plan to provide an updated summary report of these studies, potentially in the next full assessment. We believe this report and future updated reports will help guide management concerns in response to disproportionate harvest by species within this complex.

"The Team agreed with the authors that apportionment using the 4:6:9 standard was acceptable until the longline and trawl survey inputs can be combined to determine apportionment." (Plan Team November 2017)

In the current assessment, we evaluate both the previously accepted 4:6:9 trawl survey weighting method and the combined trawl survey and longline survey random effects models. For this assessment, we recommend using the new two survey random effects model as opposed to the three-survey weighted average apportionment for RE/BS rockfish, because it is effectively using the most available data.

"Species identification continues to be a problem both in the survey and fishery data. The SSC appreciates the authors continued work on this issue and highlights the importance of improving species composition information. As noted in the assessment, there appears to be continued improvement for correctly identifying blackspotted rockfish in the field (from 31% to 9%), while the opposite seems to be occurring for rougheye rockfish with increased misidentification rates over the three surveys (6% to 25%). In addition to genetic methods, otolith morphology identification methods would be useful for evaluating historical and future data collections- near-infrared reflectance (NIR) spectroscopy maybe one area of further investigation. The SSC also looks forward to results on the AFSC observer program special project that collected multi-spectral images, paired with genetics, from survey samples of BS/RE for development of an image analysis application for species identification." (SSC December 2017)

The principal investigator of the genetics research on RE/BS rockfish retired prior to completion of this work. The AFSC considers this a high priority and will complete these studies when possible. We will provide details on the progress of the species identification projects in the next full assessment.

"The SSC continues to be concerned about grouping species in the assessment without considering important differences in life history. Specifically, Conrath (2017) found age at maturity for the species fork length at 50% maturity was similar for rougheye rockfish (45.0 cm) and blackspotted rockfish (45.3 cm), but the age at 50% maturity was considerably younger for rougheye rockfish (19.6 years) than for blackspotted Rockfish (27.4 years). The SSC supports the authors' recommendation to evaluate maturity information and explore fitting separate maturity curves. This would allow treatment of the differences in maturity between the species within the assessment." (SSC December 2017)

We have provided a brief summary of the new maturity information from Conrath (2017) and future plans for using this information within the stock assessment in Appendix 13.B. At this time we do not evaluate the new maturity information within the current stock assessment model due to concerns over the samples not being identified to species. Additionally, there are more maturity samples from a December 2015 survey that should be incorporated into the analysis. We are investigating the potential to use morphometrics on the otoliths from this maturity study to identify the samples to species. This will provide a more accurate estimate of the species-specific age at 50% maturity and we will evaluate the potential for use within the operational stock assessment model when that information becomes available.

"The authors should clarify how the fishery age data by gear type is being incorporated into the model. It appears that longline and trawl ages are being combined. However, these fisheries have different sampling methods, catch characteristics, and sampling rates (e.g., full coverage versus partial coverage) that influence sample size for each gear type. A description of sample sizes from each gear-type, and the

years for which age data by each gear-type was used for the model would provide additional information on this potential issue." (SSC December 2017)

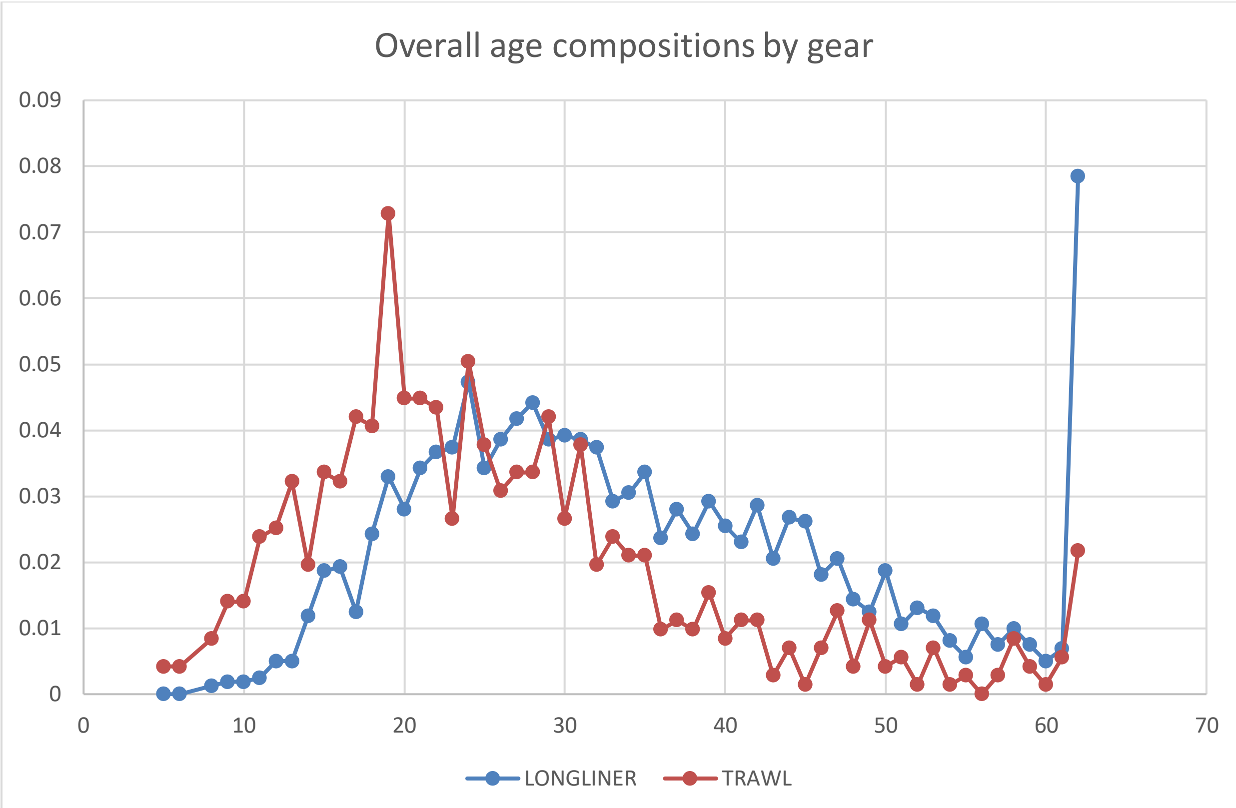
Below is a brief comparison of age data and catch for both longline and trawl gear types by area and time.

	Longline	**Trawl**	**Total**	**%Longline**	**Longline**	**Trawl**	**Total**	**%Longline**
Year	**Ages**				**Catch (t)**			
2006	325	38	363	90%	229	120	349	66%
2008	206	99	305	68%	167	173	339	49%
2009	248	69	317	78%	124	140	263	47%
2010	163	84	247	66%	144	251	395	36%
2012	194	136	330	59%	197	349	546	36%
2014	317	124	441	72%	205	516	721	28%
2016	201	171	372	54%	154	483	637	24%

The gear mixture of age samples has been dominated by longline gear, but trawl samples have increased recently. When compared to catch by gear type, we are getting more samples for longline gear per ton of catch than we are for trawl gear. Changes to observer collections including effects on compositional data due to electronic monitoring (EM) may be responsible but are unknown. The proportion of ages collected by area has not changed, indicating there has not been a spatial shift in observer age collections as seen in the following table.

Year	**CG/WG**	**WY/SE**	**Total**	**%West**
2006	158	205	363	44%
2008	197	108	305	65%
2009	204	113	317	64%
2010	171	76	247	69%
2012	187	143	330	57%
2014	264	177	441	60%
2016	248	124	372	67%

The different gear types do catch different components of the population as can be seen in the overall comparison of age compositions below.



Because of the relatively small sample sizes of ages for rougheye/blackspotted fisheries, we have always estimated one aggregate selectivity curve because separating the two fisheries with such a broad age range and small sample size would stretch the data too thin. Since the selectivity for the fishery is estimated as one curve, future assessments should evaluate weighting the age compositions by their respective gear type. The likelihood of acquiring additional ages is unlikely considering the capacity of the AFSC Ageing Group to age additional rockfish and the changes expected in the future due to EM. With the onset of EM in fleets that catch RE/BS rockfish, the sample size of the at-sea samples may decrease for RE/BS rockfish and this potential impact should be considered in the future.

Introduction

Life History and Distribution

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

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

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

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

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

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-truncation could be deleterious to a population with highly episodic recruitment like rockfish (Longhurst 2002). Recent work on black rockfish (*Sebastes melanops*) has shown that larval survival may dramatically increase with the age of the mother (Berkeley et al. 2004, Bobko and Berkeley 2004). McGilliard et al. (2017) showed that this type of offspring size effect or different spawning times by age may lead to increased recruitment variability with increased fishing mortality. Pacific ocean perch (*S. alutus*) and rougheye/blackspotted rockfish were examined by de Bruin et al. (2004) for senescence in reproductive activity of older fish and they found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. Such relationships have not yet been determined to exist for rougheye and blackspotted rockfish or other rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age.

Evidence of Stock Structure

Since 2007, we have responded to issues regarding the difficulty identifying rougheye and blackspotted rockfish and the development of a rationale for assessment decisions regarding this mixed stock. Reports have included summaries of recent studies on the genetic and phenotypic differences between rougheye and blackspotted rockfish, discussion of the current research regarding at-sea misidentification rates, and new projects developed to understand species specific life history characteristics (Shotwell et al. 2008, 2009). We completed a full stock structure evaluation of rougheye and blackspotted rockfish following the template provided by the Stock Structure Working Group (SSWG, Spencer et al. 2010) and provided this evaluation in **Appendix A** of the 2010 GOA rougheye and blackspotted rockfish executive summary SAFE report (Shotwell et. al 2010). Brief summaries of rougheye and blackspotted rockfish speciation 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 determined the two distinct species with relatively little hybridization (Gharrett et al. 2005).

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

Stock Structure Template Summary

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

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

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

Fishery

History

Rougheye and blackspotted rockfish have been managed as a "bycatch" only species complex since the creation of the shortraker/rougheye rockfish management subgroup in the Gulf of Alaska in 1991. Since 1977, gulf-wide catches of the rougheye and blackspotted rockfish have been between 130-2,418 t (Table 13-2). Catches peaked in the late 80s and early 90s, declined rapidly in the mid-90s and have been relatively stable since 2010. RE/BS rockfish are generally caught in either bottom trawls or with longline gear with approximately 60% taken in the trawl fisheries and 30% 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 2019, 65% of the catch was from bottom trawls, 30% from longline, and 5% from pelagic trawls. Approximately 79% of this bottom trawl catch was taken in the rockfish fishery while 21% was taken in the flatfish fisheries. For longline gear, nearly all the RE/BS catch appears to come as "true" bycatch in the sablefish or halibut longline fisheries, with 84% of the 2019 catch taken in the sablefish fishery and 15% in the halibut fishery. Since catch accounting was established separately for RE/BS rockfish in 2005, the TACs for RE/BS rockfish are not fully taken, and are generally between 20-60% of total quota (Table 13-2).

In response to Annual Catch Limits (ACLs) requirements, assessments now document all removals including catch that is not associated with a directed fishery and reported in the Catch Accounting System (CAS). These types of removals may include sport fishery harvest, research catches, or subsistence catch. Research catches of RE/BS rockfish have been reported in previous stock assessments (Shotwell et al. 2009, 2011, 2014, 2015, 2017) and estimates of all removals not associated with a directed fishery including research catches are presented in Appendix 13A. In summary, non-directed removals for RE/BS rockfish have typically been less than 10 t and research catches of this magnitude do not pose a significant risk to the RE/BS stock in the GOA.

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

Management Measues

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

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

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

Bycatch

The only analysis of bycatch for rougheye rockfish is that of Ackley and Heifetz (2001) from 1994-1996 on hauls they identified as targeted on shortraker/rougheye rockfish. The major bycatch species were arrowtooth flounder (*Atheresthes stomias*), sablefish, and shortspine thornyhead (*Sebastolobus alascanus*), in descending order. The primary fisheries that catch rougheye and blackspotted rockfish as bycatch are the targeted rockfish and sablefish fisheries with occasional surges from the flatfish fishery (Table 13-4). For the combined GOA rockfish trawl fisheries during 2015-2019 (Table 13-5), the largest non-rockfish bycatch groups are on average arrowtooth flounder (1,085 t/year), walleye pollock (872 t/year), Atka mackerel (817 t/year), sablefish (589 t/year), and Pacific cod (418 t/year). Non-FMP species catch in the rockfish target fisheries is generally dominated on average by giant grenadier (706 t/year) and miscellaneous fish (120 t/year) (Table 13-6). Prohibited species catch in the GOA rockfish fishery has been generally low for most species and this has been particularly true since the implementation of the Central GOA Rockfish Program (Shotwell et al. 2014b). Halibut catch during rockfish targeted hauls has decreased since 2015. The catch of Bairdi tanner crab, golden king crab, and salmon increased in 2017 but have since decreased (Table 13-7).

Discards

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

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

Shortraker / Rougheye / Blackspotted Complex

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

Rougheye / Blackspotted Complex

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
% Discards	19.6	29.0	37.4	27.6	18.6	18.8	15.1	14.8	22.9	17.6	24.4	26.6	20.8	42.0
Year	2019													
% Discards	16.4													

The above table indicates that discards of rougheye and blackspotted rockfish have ranged from approximately 15% to 42% with an average of 23%. 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 rougheye and blackspotted rockfish has decreased to below average levels in 2019.

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

Fishery:

Catch

Catches of rougheye and blackspotted rockfish have ranged between 130 t to 2,418 t from 1977 to 2019. The catches from 1977-1992 were from Soh (1998), which reconstructs the catch history using an information weighting factor (λ) to combine catch histories from both survey and fishery information. Catches from 1993-2004 were available as the shortraker/rougheye subgroup from the NMFS Alaska Regional Office. Originally, we used information from a document presented to the NPFMC in 2003 to determine the proportion of rougheye rockfish in this catch (Ianelli 2003). This proportion was based on the NMFS Regional Office catch accounting system ("blend estimates"). The SSC recommended using the average of the values provided in the document, 0.43. In 2004 another method was developed for determining the proportion of rougheye/blackspotted in the catch based on data from the FMA Observer Program (Clausen et al. 2004, Appendix A). Observed catches were available from the FMA database by area, gear, and species for hauls sampled by observers. This information was used to calculate proportions of RE/BS catch by gear type. These proportions were then applied to the combined shortraker/rougheye catch from the NMFS Alaska Regional Office to yield estimates of total catch for RE/BS rockfish (Figure 13-1, Table 13-2).

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

Age composition

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

New fishery ages since the last full assessment were not available for 2018 due to the extensive processing time for RE/BS rockfish and limited aging capacity this past year. 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 rougheye and blackspotted rockfish. Table 13-9 summarizes the available size compositions from 1991-2017. 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, and 2017 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 rougheye and blackspotted rockfish, including an abundance index, age composition, and growth characteristics. The surveys are theoretically an estimate of absolute biomass, but we treat them as an index in the stock assessment model. The triennial surveys covered all areas of the Gulf of Alaska out to a depth of 500 m (in some surveys to 700 m or 1,000 m), but the 2001 biennial survey did not sample the eastern Gulf of Alaska. Because the 2001 survey did not cover the entire Gulf of Alaska, we omitted this survey from our assessment model for RE/BS rockfish since we have an additional survey in 2001.

Summaries of biomass estimates from the 1984-2019 surveys are provided in Table 13-10. Trawl survey biomass estimates are shown in Figure 13-2. Historically estimates by region indicate that the western and eastern GOA time series of biomass tended to be in opposite phase (Table 13-10). From 2003-2007, the central and eastern GOA estimates increased, while the western GOA decreased. In 2009, all regions decreased and in 2011 both the eastern and central GOA decreased while the western GOA slightly increased. Given that the regional patterns are quite different and that the 2001 survey did not sample the eastern GOA, omitting this survey estimate from the model is reasonable. Additionally, data for 2001 are available from the longline survey.

The 2013 biomass estimate was an all-time low for this time series. The decrease was 37% below the 2011 estimate and 40% below the mean biomass estimate for the time series. The estimates by area were not consistently down as there was a 66% decrease in the central GOA with increases in the western and eastern GOA by 19% and 51%, respectively. The 2015 biomass estimate increased by 25% from 2013 and is now 24% below the mean estimate for the time series. Compared to the 2013 survey, central and eastern GOA increased by 62% and 21% respectively, but western GOA decreased by 66%. This is the second lowest estimate for the western GOA in the time series. In 2017, the biomass estimate increased by 16% from the 2015 survey and is now only 11% below the long term mean estimate for the time series. The western GOA increased dramatically, while the central GOA decreased by 38% and eastern GOA increased by 45%. The 2019 biomass estimate is the third largest estimate in the time series. This is likely due to one particularly large haul of at-sea identified blackspotted rockfish in the central GOA (Kodiak, 300-500 m). Although, these are at-sea identifications and do have limited utility given the mis-identification rates, it is useful to note that this large estimate reverses the previous declining trend of blackspotted rockfish in the central GOA. Estimates in the western and eastern GOA were down from the previous survey and the western GOA estimate is near the all-time low for the time series.

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

The biomass estimates for at-sea identified rougheye and blackspotted 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 rougheye and blackspotted rockfish show relatively tight confidence intervals and low coefficients of variations (CV), ranging between 11% and 23%. The exception to this is the most current 2019 survey where the CV was approximately 69% in the central GOA, which is the largest on record for this stock. As stated, 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 catch of these fish is found at depths of 300-500 m. Much of this area is not trawlable by the survey's gear because of its steep and rocky bottom, except for gully entrances where the bottom is not as steep. If RE/BS rockfish are located disproportionately on rough, untrawlable bottom, then the trawl survey may underestimate their abundance. Conversely, if the bulk of their biomass is on smoother, trawlable bottom, then we could be overestimating their abundance with the trawl survey estimates. Consequently, trawl survey biomass estimates for RE/BS rockfish are mostly based on the relatively few hauls in gully entrances, and they may not indicate a true picture of the abundance trends. However, the utilization of both the trawl and longline (which can sample where survey trawls cannot) abundance indices should alleviate some of this concern.

In 2007, the trawl survey began separating rougheye rockfish from blackspotted rockfish using a species key developed by J. Orr (Orr and Hawkins, 2008). Biomass estimates by region of the two species somewhat support the broad southern and northern distribution of rougheye versus blackspotted rockfish in that blackspotted estimates were higher in the western GOA and rougheye estimates were higher in the eastern GOA (discussed previously in *Evidence of Stock Structure* section). However, both species were identified in all regions, implying some overlap throughout the GOA. Over all areas, more blackspotted rockfish were identified than rougheye in 2007 (56% versus 44%), while in all remaining surveys the reverse occurred with 63% to 73% rougheye and 37% to 27% blackspotted. In the 2019 survey the trend reversed with more blackspotted identified than rougheye (largely in that one tow). 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

New ages for 2017 were added this year resulting in 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 rougheye and blackspotted rockfish have been reported to be greater than 200 years old (Munk 2001), the highest age collected over these survey years was 135 (AFSC 2010). The average age ranged from 15 to 23 over all survey years available (Table 13-11). Compositions from 1984, 1987, 1990, 1996, 1999 showed especially prominent modes in the younger to mid ages (6 to 12 year olds for this species), suggesting periods of large year classes from the late 1970s, early 1980s and then again in the late 1980s early 1990s. Since 2003, compositions were spread more evenly across age groups 3-15 corresponding to the strong year classes of the early 1990s and another period of increased recruitment in the early 2000s that is tracked through each survey year. In 2011, a higher proportion of five year old fish suggests another period of increased recruitment in the mid-2000s. This is tracked through to 2013, 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 rougheye and blackspotted 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. After this the mean length remained relatively steady between 33-37 cm, but in 2019 there was a marked peak around 42 cm, due to the large blackspotted rockfish tow. Since 2007, survey rougheye and blackspotted rockfish lengths were split. Rougheye have an average length of 33 cm while blackspotted have an average of 38 cm. Rougheye have a much broader range of lengths from 10-60 cm, while blackspotted tend to be more confined to the 35-50 cm range. Again, this may be indicative of misidentification or a true difference in size distribution between species. Future analysis of the 2009, 2013, and 2015 trawl survey genetics experiment will aid in understanding some of these differences. Trawl survey size data are used in constructing the size-age conversion matrix, but are not used as data to be fit in the stock assessment model since survey ages for most years were available. Investigations into including the most recent survey's length composition as a proxy for unavailable age composition were presented in Appendix 9B of the GOA POP November 2014 assessment. The results of that analysis suggest that the utility of using only the most recent survey's length composition is case specific and may be a subject for future research.

AFSC Longline Abundance Index

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

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

During the 2009 CIE for sablefish the use of both relative population number (RPN) and weight (RPW) survey indices in the model was discussed. The CIE recommendation was to use only the RPN index to avoid the added uncertainty that results from converting lengths to weight, estimating numbers at age and then converting back to weight for the ultimate ABC recommendation. We follow this recommendation for RE/BS and now use the RPN index since the weight conversion data is already incorporated into the assessment model. The final longline survey RPN index for RE/BS rockfish runs from 1993-2019 with all available strata updated with new area estimates (Table 13-13).

In addition to recalculating RPN values, variance estimates were computed for RE/BS rockfish (Figure 13-3). These estimates were derived by assuming that the mean CPUE of a station in a depth stratum were a representative sample, but recognizing that there is covariance between hachis (also termed a skate which is equal to 45 hooks spaced 2 meters apart) and between depth stratum since hachis and stratum means are not independent among stations. Previously, the variance of the RPW index was assumed to have a CV of 20% across all years based on the interannual variance. New estimates of CVs for the RPN index range from 13-33% (Table 13-13), with increases in the most recent two surveys.

The RPN estimates for RE/BS rockfish have been somewhat cyclic throughout the time series, but seem to be on an overall slightly increasing trend since 2005. The 2018 survey decreased by 31% from the 2017 survey and the 2019 survey increased by 29% from the 2018 survey and decreased by 11% from the 2017 survey. The most current 2019 survey RPN is 13% above the average for the time series (Figure 13-3). The agreement between the decrease in both the trawl and longline surveys in 2013 may have been indicative of a decrease in the RE/BS rockfish biomass; however, the subsequent estimates have generally been increasing in both surveys suggesting that the decline may not have been so dramatic. RPN estimates in the eastern GOA have been fairly steady over time while quite cyclic in the central GOA and increasing in the western GOA. This is in contrast to the bottom trawl survey decreasing trend in the western GOA and confirms the benefit of using the two surveys in concert.

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

AFSC Longline Size Compositions

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

Since the longline survey does not sample in proportion to area, we used area weighted longline survey size compositions instead of compositions based on raw sample size. Updated longline survey size compositions are available from 1993-2019 using all strata information and are calculated using the same length bins as the fishery and AFSC bottom trawl data. The longline survey size compositions show that small fish were rarely caught in the longline survey and that the length distribution was fairly stable through time (Table 13-14). Compositions for all years were normally distributed with a mode between 45 and 47 cm in length. An unusually large amount of fish appeared in the 26 cm length bin in 2014 and may reflect the bump in 7 year-old fish from the 2013 trawl ages.

Comparison of AFSC Bottom Trawl and Longline Surveys

The spatial distribution of numbers of rougheye and blackspotted rockfish caught in the 2015, 2017, and 2019 trawl and the 2014-2019 longline surveys is depicted in Figure 13-4a. The trawl survey samples more of the continental shelf than the longline survey due to differences in survey design. However, the trawl survey tends to catch more RE/BS rockfish in the central GOA, while the longline survey catches more RE/BS rockfish in the eastern and western GOA. This can be seen in all surveys, particularly in the eastern GOA. In 2013, both survey estimates decreased from the previous surveys. The decrease was primarily in the central GOA for the trawl survey and the eastern GOA for the longline survey. In 2015, both surveys estimates were up from the 2013 surveys with increases in the central and eastern GOA for the trawl survey and gulfwide for the longline survey. The 2015 trawl survey estimate in the western GOA was near the all-time low for this survey. The distribution of the hauls that typically sample RE/BS rockfish in this region are near the slope, where there may be a higher proportion of steep, rocky, untrawlable habitat. The longline survey effectively samples this habitat and catches increased in the western GOA compared to the 2013 surveys. This may suggest that the 2015 trawl survey western GOA drop may not be indicative of an actual decline in the western GOA. In 2017, both the eastern and western GOA increased on the trawl survey with a decrease in the central GOA similar to that seen in 2013. In contrast, all survey areas increased in the longline survey. Most notably the central GOA estimate on the longline survey was higher than it had been since 2009. The 2019 trawl survey increased from 2017 but has an exceptionally large standard error due to the large tow in the central GOA. The 2019 longline survey showed increases in the western GOA and central GOA, but decreases in the eastern GOA.

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

Sensitivity Analysis of AFSC Bottom Trawl and Longline Surveys

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

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

International Pacific Halibut Commission (IPHC) Longline Estimates

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

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

Analytic Approach

Model Structure

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

There are no model alternatives to consider for the 2019 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:

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

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 recent study by Conrath (2017) provided new species-specific estimates for size and age at 50% maturity for rougheye and blackspotted rockfish. We present this information in Appendix 13B and provide discussion on future use for the growth model.

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. Newly available age samples allowed for an update of the 2011 age-error matrix. Age agreement tests have now been run on samples from 1984, 1987, 1990, 1993, 1996, 1999, 2003-2007, and 2009 for RE/BS rockfish for a total of 1,589 specimens. We use the same age error structure as presented in the 2015 assessment that was based on the percent agreement for each age from these tests. Additionally, in the 2015 assessment the plus age group was extended in the model compared to the plus age group in the data until 99.9% of the fish in the model's plus age group are within the plus age group of the data. This was done to alleviate the consistent over-estimation of the proportion at age in the age bins adjacent to the plus group age.

Parameters Estimated Inside the Assessment Model

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

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

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

The Hoenig (1983) methods based on longevity and the "rule-of-thumb" approach both produce natural mortality estimates similar to McDermott (1994). Catch-curve analysis produced an estimate of Z=0.094 and average fishing mortality (0.022) is subtracted to yield a natural mortality 0.072 which is the highest estimate. The Alverson and Carney (1975) estimate based on growth was much lower. Several assumptions of catch-curve analysis must be met before this method can be considered viable, and there is a likely time trend in recruitment for GOA rockfish. The method described by Alverson and Carney (1975) for developing an estimate of critical age is based on a regression of 63 other population estimates and may not be representative of extremely long-lived fish such as rougheye and blackspotted rockfish (Malecha et al. 2007). McDermott (1994) collected 430 samples of rougheye/blackspotted rockfish from across the Pacific Northwest to the Bering Sea, providing a representative sample of RE/BS rockfish distribution. Since the value of 0.03 estimated by McDermott (1994) is within the range of most other estimates of natural mortality and designed specifically for RE/BS rockfish, we feel that this is the most suitable estimate for a prior mean.

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

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

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

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

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

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

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

Parameter name	Symbol	Number
Natural mortality	M	1
Catchability	q	2
Log-mean-recruitment	μ_r	1
Recruitment variability	σ_r	1
Fishing mortality rates	$F_{35\%}$, $F_{40\%}$, $F_{50\%}$	3
Recruitment deviations	τ_y	91
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	43
Fishery selectivity coefficients	fs_a	14
Survey selectivity coefficients	ss_a	17
Total		174

Uncertainty

Evaluation of model uncertainty has recently become an integral part of the "precautionary approach" in fisheries management. In complex stock assessment models such as this model, evaluating the level of uncertainty is difficult. One way is to examine the standard errors of parameter estimates from the Maximum Likelihood (ML) approach derived from the Hessian matrix. While these standard errors give some measure of variability of individual parameters, they often underestimate their variance and assume that the joint distribution is multivariate normal. An alternative approach is to examine parameter distributions through Markov Chain Monte Carlo (MCMC) methods (Gelman et al. 1995). When treated this way, our stock assessment is a Bayesian model, which includes informative (e.g., lognormal natural mortality with a small CV) and noninformative (or nearly so, such as a parameter bounded between 0 and 10) prior distributions. In the models presented in this SAFE report, the number of parameters estimated is 174. In a low-dimensional model, an analytical solution for the uncertainty might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, the chain will converge (Jones and Hobert 2001). The "burn-in" is a set of iterations removed at the beginning of the chain. This method is not strictly necessary but we use it as a precautionary measure. In our simulations we removed the first 4,000,000 iterations out of 20,000,000 and "thinned" the chain to one value out of every 4,000, leaving a sample distribution of 4,000. Further assurance that the chain had converged was to compare the mean of the first half of the chain with the second half after removing the "burn-in" and "thinning". Because these two values were similar we concluded that convergence had been attained. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% credible intervals for some parameters. Values from MCMC simulations are not used to derive any quantities for management advice for this stock assessment, but are helpful in more fully illustrating the uncertainty of these results.

BOX 1. AD Model Builder Rougheye Model Description

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

BOX 1 (Continued)

Equations describing the observed data

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

Equations describing population dynamics

Start year

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

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

Results

Model Evaluation

There were no recommended changes to this year's assessment model compared to the model used in 2015 and 2017. Negative log-likelihood and estimates of key parameters for last year's full assessment (2017 Model 15.4) and this year's updated model (2019 Model 15.4) are provided in Table 13-15 for comparison. Observed and model predictions for the age and size composition data are provided in Figures 13-8, 13-9, 13-10 and 13-12. AFSC bottom trawl survey size compositions are provided for reference (Figure 13-11).

There is some lack of fit for the fishery age compositions between ages 15 and 20 and for some years in the plus age group (Figure 13-8). Fit to the fishery size compositions are slightly flattened (Figure 13-9) particularly in 1991. Fit to the bottom trawl survey age compositions are generally very good with some underestimation of abundant cohorts such as the 1990 and 2010 year-classes (Figure 13-10). Fit to the longline survey size compositions are similar to the fishery size compositions with slightly flattened peaks in most years (Figure 13-12). The model does not fit the relatively large proportion of size 26 cm fish in 2014. The consistent patterns of positive residuals in the fishery and longline survey size compositions could be due to a variety of confounding issues between selectivity, growth, and ageing. In the future we may consider applying different shaped selectivity curves or explore separate selectivity curves for trawl and longline fisheries.

We continue to recommend model 15.4 to update management quantities for 2020. We discuss results of this model in the following section. Estimated numbers in 2019, fishery selectivity, trawl and longline survey selectivity and schedules of age specific weight and female maturity are provided in Table 13-16 for reference based on this author preferred model.

Time Series Results

Table 13-15 provides parameter estimates for the last full assessment model and the current updated model for comparison purposes. Tables 13-16 through 13-19 summarize other results for the 2019 author preferred model (M15.4).

Definitions

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

Total and spawning biomass for the author preferred model compared to the last full assessment was lower for the entire time series (Figure 13-13, Figure 13-14). Recruitment was generally similar between the preferred model and the estimates from the last full assessment except in 2010 (Table 13-18). This is likely due to the new trawl survey age composition of 2017 that shows a larger composition of age 7 and 8 year-old fish and confirms the large estimate of the 2010 year class (Figure 13-10). Catchability, selectivity, natural mortality, and recruitment are all somewhat confounded within the model. As the age and length compositions observed in the surveys fluctuate, catchability estimates tend to vary accordingly so that large swings in biomass do not occur. This seems reasonable for long-lived fish such as RE/BS rockfish.

Biomass and Exploitation Trends

Predicted values for the bottom trawl and longline survey were relatively steady over time similar to the last full assessment model with a slight increase in the trawl survey estimate for 2019 (Figures 13-2, 13-

3). Predicted values for the trawl survey do not capture the recent low 2013 estimate and predicted values for the longline survey do not capture the fluctuating high and low spikes since 1997, likely due to the contrasting trends during these years between the two surveys. Average longline RPNs surrounding these years combined with corresponding average trawl survey biomass estimates likely restrict the model from large swings in predictions for either survey.

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

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

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

Recruitment

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

Uncertainty

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

Table 13-17 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviation derived from the Hessian matrix. Also shown are the MCMC standard deviation and the corresponding Bayesian 95% credible intervals (BCI). The MLE and MCMC standard deviations are similar for q_1 (trawl survey catchability), q_2 (longline survey catchability), and M, but the MCMC standard deviations are larger for the estimates of projected female spawning biomass, and ABC, and 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 2019 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 moderate at 0.167 (compared to most AFSC assessments, Hanselman et al. 2013), indicating that the model estimates of spawning biomass increase relative to the terminal year estimates as data is removed from the assessment. Compared to last year where there were negative and positive peels, all of the peels are positive in the 2019 model.

The RE/BS model has not exhibited a strong retrospective pattern in the last three assessments. A comparison of the revised Mohn's "rho" statistic presented in the 2015 through 2019 assessments is presented in the table below.

Statistic	2015 (M15.4)	2017 (M15.4)	2019 (M15.4)
Mohn's revised ρ	0.105	0.009	0.167

Examining retrospective trends can show potential biases in the model, but may not identify what their source is. Other times a retrospective trend is merely a matter of the model having too much inertia in the age-structure and other historic data to respond to the most recent data. This retrospective pattern is likely to be considered mild, but an issue may be the "one-way" pattern in the retrospective time series. It is difficult to isolate the cause of this pattern but several possibilities exist. For example, hypotheses could include environmental changes in catchability, time-varying natural mortality, or changes in selectivity of the fishery or survey. It appears that the "loose" estimation of catchabilities of the model results in some shifts in scale that affect the retrospective bias in different assessments.

Harvest Recommendations

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

Estimation of the $B_{40\%}$ reference point requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the average of age 3 recruits from 1980-2017 (i.e. the 1977-2014 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 2019 estimates of these reference points are in the following table. Biomass estimates are for female spawning biomass.

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
20,658 (t)	8,263 (t)	7,230 (t)	0.040	0.048

Specification of OFL and Maximum Permissible ABC

Estimated female spawning biomass for 2020 is 12,518 t. This is above the $B_{40\%}$ value of 8,263 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 2019 yields the following *ABC* and *OFL*:

$F_{40\%}$	0.040
ABC (t)	1,209
$F_{35\%}$	0.048
OFL (t)	1,452

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 2019 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2020 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2019. 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 2019 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 2020, 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 2020 and 2021, 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 2016-2018 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 2014-2018 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 2019 or 2) above ½ of its MSY level in 2019 and above its MSY level in 2029 under this scenario, then the stock is not overfished.)

Scenario 7: In 2020 and 2021, 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 2021 or 2) above ½ of its MSY level in 2021 and expected to be above its MSY level in 2031 under this scenario, then the stock is not approaching an overfished condition.)

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

Status Determination

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2020, it does not provide the best estimate of OFL for 2021, because the mean 2020 catch under Scenario 6 is predicated on the 2020 catch being equal to the 2020 OFL, whereas the actual 2020 catch will likely be less than the 2020 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 (2018) is 754 t. This is less than the 2018 OFL of 1,735 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 2019:

a) If spawning biomass for 2019 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2019 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c) If spawning biomass for 2019 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 2029 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 2021 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2021 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2021 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2031. If the mean spawning biomass for 2031 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

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

Specified Catch Estimation

In response to Gulf of Alaska Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. In the past, two standard approaches in rockfish models have been employed; assume the full TAC will be taken, or use a certain date prior to publication of assessments as a final estimate of catch for that year. Both methods have disadvantages. If the author assumes the full TAC is taken every year, but it rarely is, the ABC will consistently be underestimated. Conversely, if the author assumes that the catch taken by around October is the final catch, and substantial catch is taken thereafter, ABC will consistently be overestimated. Therefore, going forward in the Gulf of Alaska rockfish assessments, for current year catch, we are using an expansion factor to the catch in early October by the 3-year average of catch taken between October 1 and December 31 in the last three complete catch years (e.g. 2016-2018 for this year, see example figures below). For rougheye and blackspotted rockfish, the expansion factor for 2019 catch is 1.036.

For catch projections into the next two years, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, based on both the lower catch in the first year out, and based on the amount of catch taken before spawning in the projection two years out. To estimate future catches, we updated the yield ratio (0.47), which was the average of the ratio of catch to ABC for the last three complete catch years (2016-2018). This yield ratio was multiplied by the projected ABCs for 2020 and 2021 from the assessment model to generate catches for those years.

Alternative Projection

During the 2006 CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. We continue to present an alternative projection scenario using the uncertainty of the full assessment model, harvesting at author's F (0.3 maximum permissible based on recent ratios of catch to ABC). This is conservative relative to a max ABC or alternative 1 projection scenario. This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 20,000,000. The projection shows wide credibility intervals on future spawning biomass (Figure 13-21). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1980-2017 age-3 recruitments, and this projection predicts that the median spawning biomass is well above these reference points for the entire time series and will steadily increase as average recruitment is consistently applied and the very low proportion of ABC is taken (0.47).

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 have contended that since we use two surveys for the assessment that we should wait until the random effects model was adapted to fit two surveys simultaneously. Echave and Hulson (2019) have adopted this approach for shortraker, so we now recommend this as the default for RE/BS rockfish.

The random effects model was fit to the trawl survey biomass estimates and relative population weights 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 both surveys. 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. This lack of fit in each area is an expected and desirable outcome of this model.

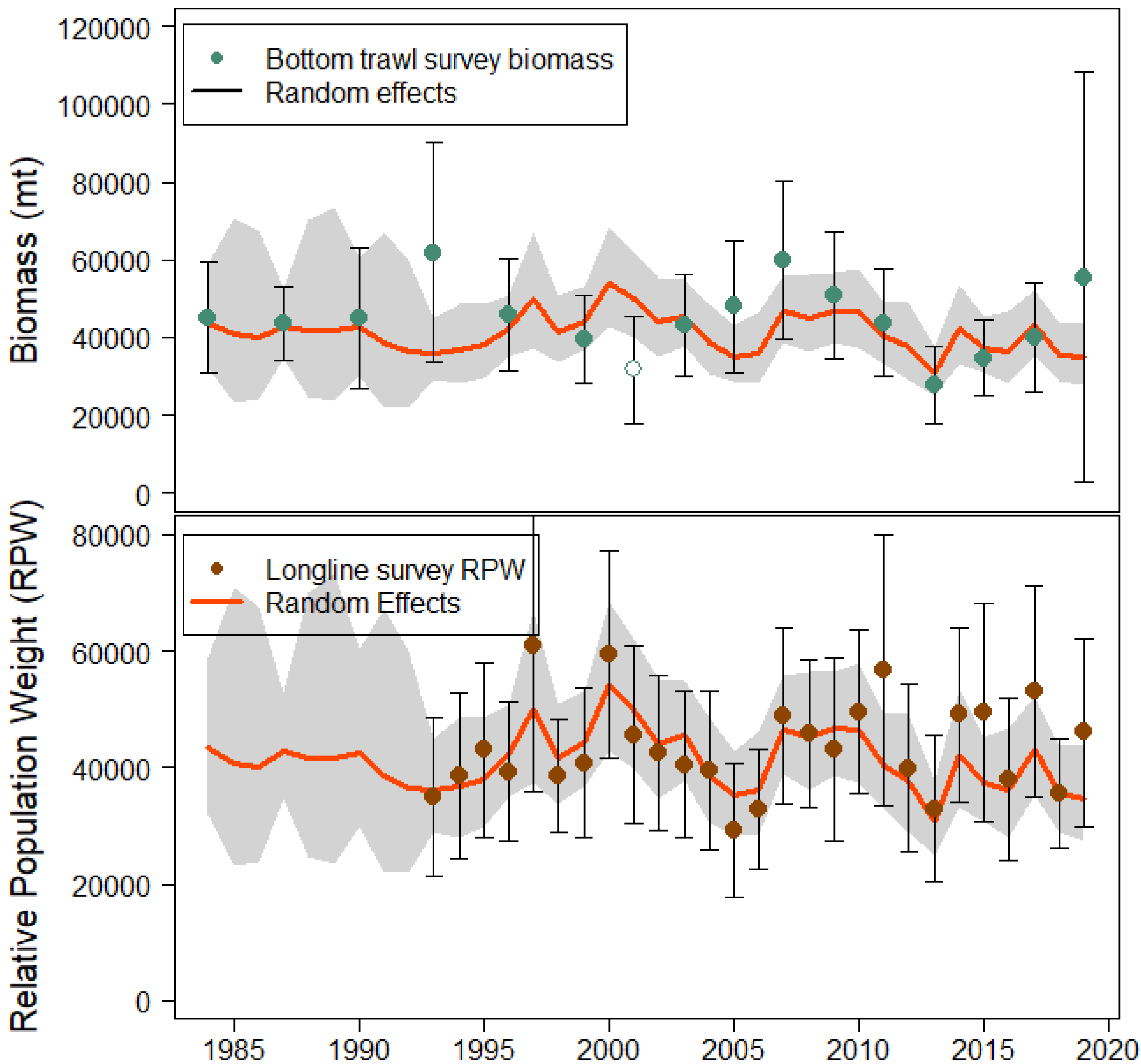


Figure. The sum of random effect fits to the area abundance indices for the trawl and longline surveys with 95% confidence intervals.

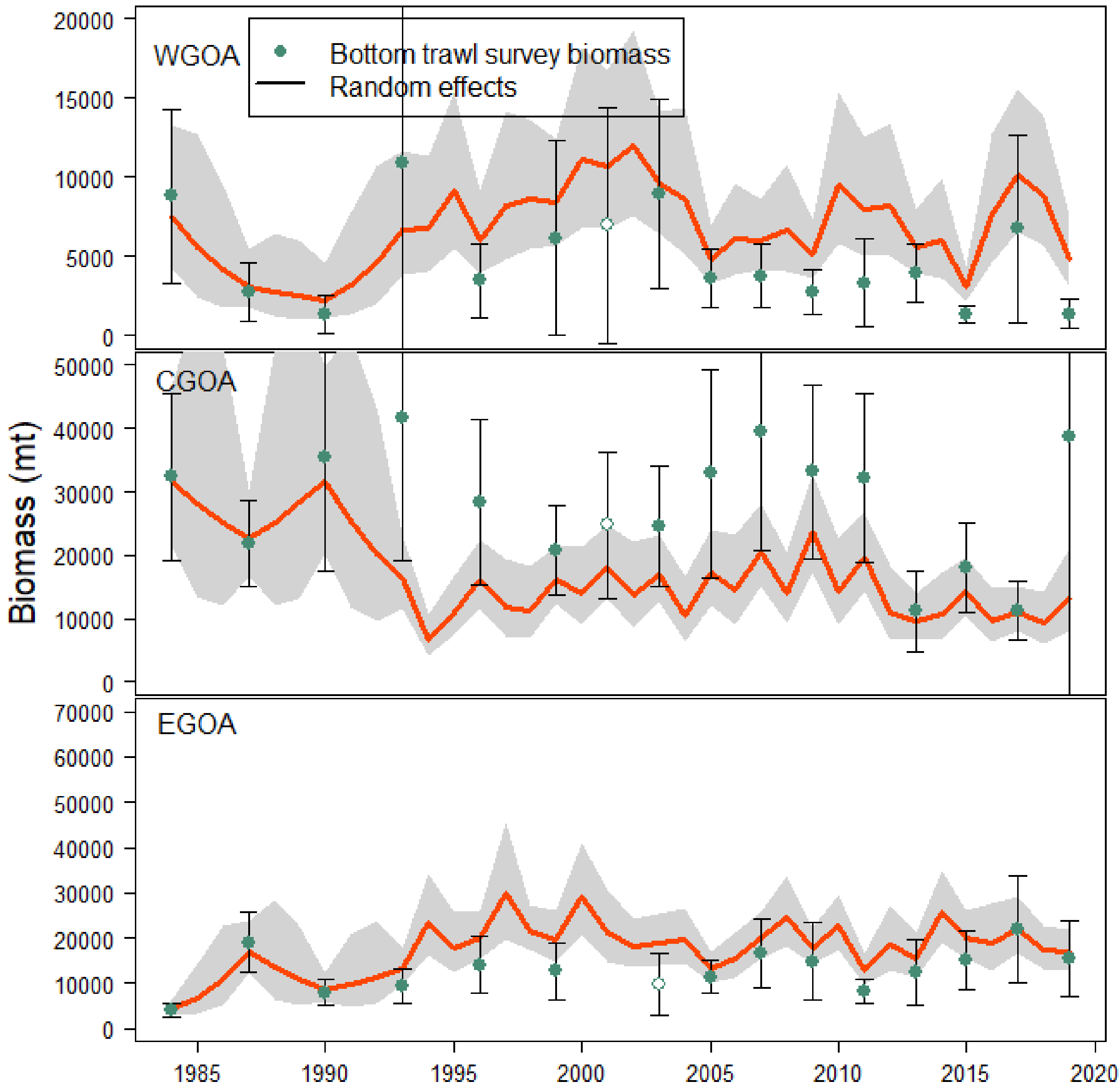


Figure. The random effect fits to each area abundance indices for the trawl survey with 95% confidence intervals.

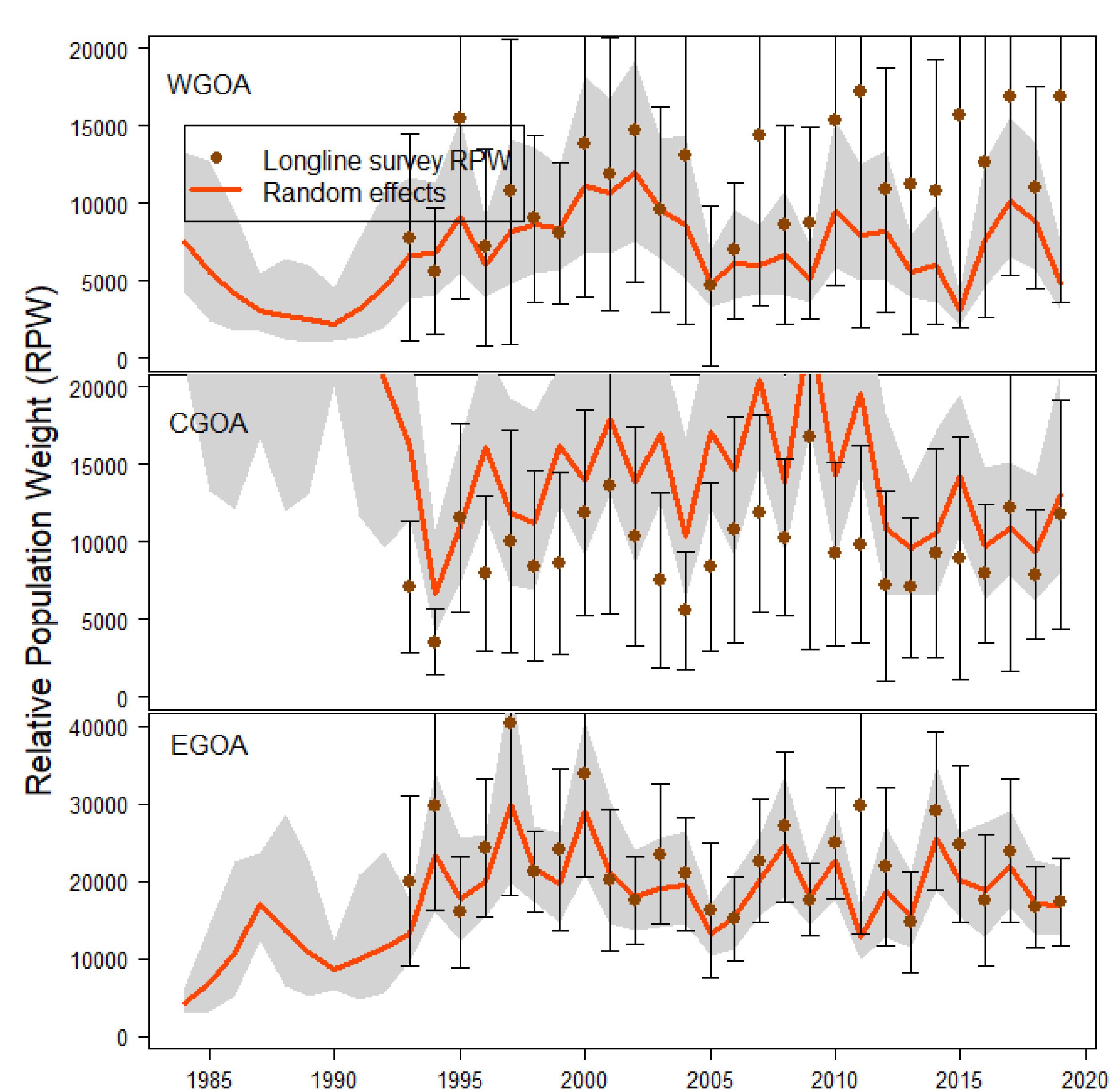


Figure. The random effect fits to each area abundance indices for the longline survey with 95% confidence intervals.

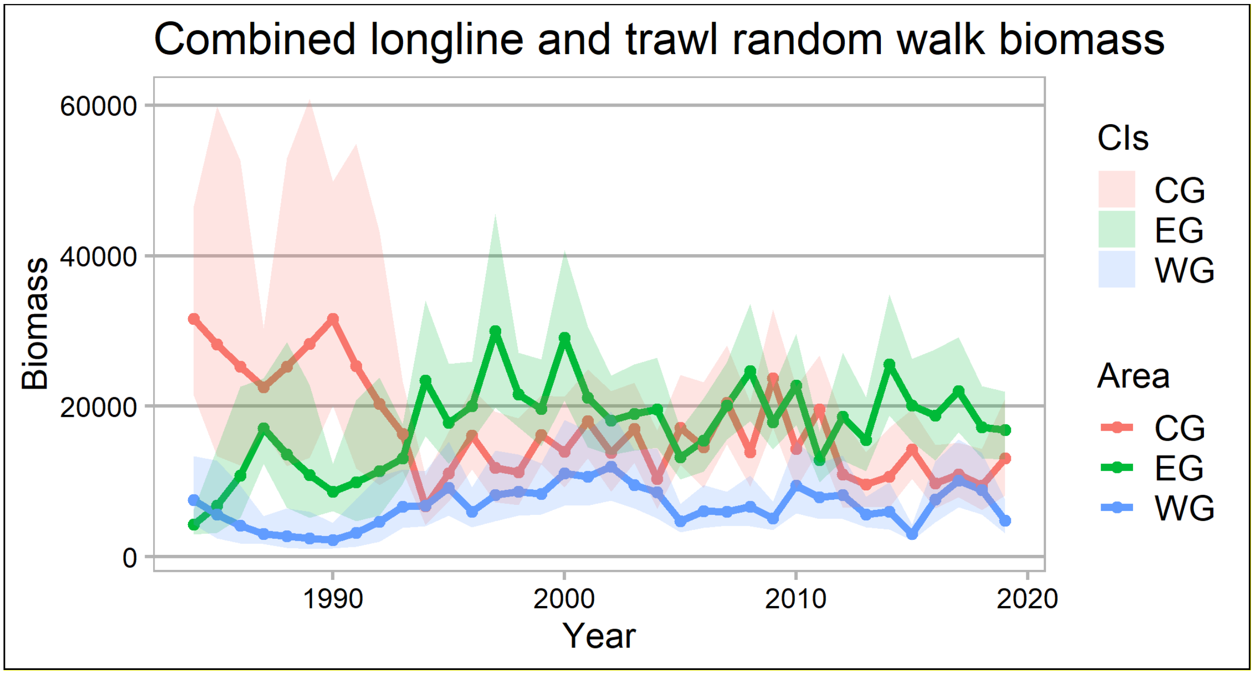


Figure. The time series of biomass as estimated by the combined random effects model.

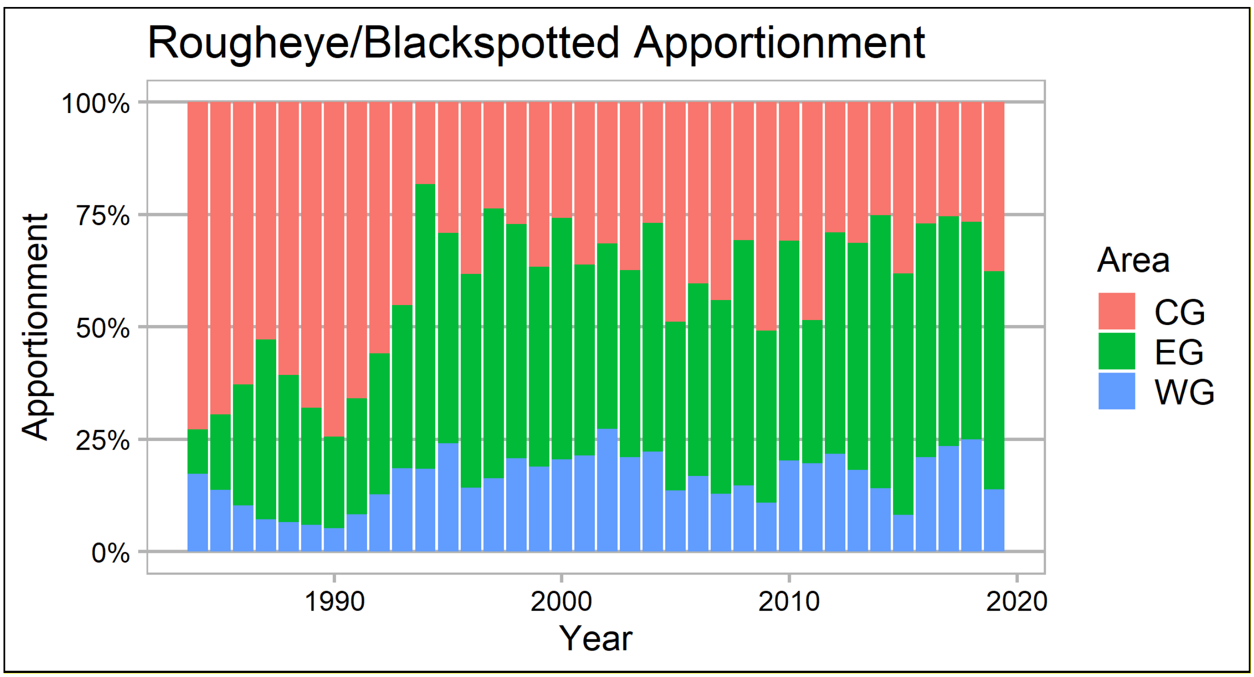


Figure. The time series of apportionments as estimated by the combined random effects model.

Using the random effects model estimates of biomass to determine apportionment results in 13.9% for the western area, 37.6% for the central area, and 48.5% for the eastern area. This differs from the results from the updated 4:6:9 survey average weighting method by shifting the apportionment away from the Central area and moving it into the western and eastern areas.

We recommend moving from the status quo (three-survey weighted average) to the new two-survey random effects apportionment for RE/BS rockfish at this time. 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. This can be seen in the recent trawl versus longline survey comparison maps (Figure 13-4a). Sampling error also differs by region and survey (Table 13-10, 13-13). On average there is higher sampling error in the central GOA for the longline survey versus the trawl survey and lower sampling error in the 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. In addition, using two survey indices will likely result in less variation in apportionment due solely to sampling variability.

The following table shows the apportionment for the 2020 and 2021 fishery when applying the percentages using the three-survey weighted average of the bottom trawl survey and random effects methods of the trawl and longline survey to the ABC for RE/BS rockfish (1,209 t):

Method	Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
Three Survey Weighted Average			6.63%	55.70%	37.67%	100%
	2020	Area ABC (t)	80	673	456	1,209
		OFL (t)				1,452
	2021	Area ABC (t)	80	675	456	1,211
		OFL (t)				1,455
Two Survey Random Effects			13.88%	37.61%	48.51%	100%
	2020	Area ABC (t)	**168**	**455**	**586**	**1,209**
		OFL (t)				**1,452**
	2021	Area ABC (t)	**169**	**455**	**587**	**1,211**
		OFL (t)				**1,455**

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.048), overfishing is set equal to 1,452 t in 2020 and 1,455 t in 2021 for rougheye and blackspotted rockfish.

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 REBS rockfish assessment has a moderate retrospective bias (Mohn's rho = 0.167), and fits to the age composition data for the fishery and surveys are generally adequate with some lack of fit for the plus group but not consistently in all years. The REBS assessment is fit to multiple abundance indices, AFSC bottom trawl survey biomass estimates and longline survey RPNs. In the past, there have been some contrasting trends in the survey abundance indices, with bottom trawl indices showing a somewhat decadal pattern, and longline surveys showing a more interdecadal pattern (Figures 13-2 and 13-3). Since neither survey has any distinct trend, this has resulted in a fairly flat fit to the survey indices over time with only slight increases or decreases when the surveys were in similar directions. We do anticipate this divergence in trend, however, due to the different habitat that the two surveys sample for REBS rockfish and it is the primary reason we utilize the two surveys in the assessment. Additionally, the fit to the two surveys is within nearly all the confidence bounds for the two surveys with the exception of the very low trawl survey estimate in 2013. In general, the CVs for the two surveys have been fairly low historically (~20% on average) with some large CVs regionally. This was particularly true in the trawl survey this year with a very large CV in the central GOA. This was due to one large haul in the Kodiak region of what were identified at-sea as blackspotted rockfish. These large single tows are typical of some slope rockfish, although this is quite rare for RE/BS rockfish historically. There is also some sensitivity in this model to the size@age matrix due to the large number of length compositions in the model and relatively loose priors on the catchability and its relationship with selectivity. We plan to investigate the sensitivity during the next full update. We rated the assessment-related concern as Level 1, normal because the trends in the two surveys is similar to what we have seen historically and we have not changed the size@age matrix for several years.

Population dynamics considerations

New research on rougheye and blackspotted rockfish maturity (Conrath, 2017) suggests a much older age at 50% maturity for blackspotted rockfish than rougheye rockfish which may have impacts on population productivity. However, no genetics or otolith morphometrics were used to accurately assign the species and it is unknown the impacts on the resulting updated maturity estimates or the degree to which skip spawning occurred which was much more prevalent in blackspotted than rougheye. At present, we are exploring avenues to generate a set of otolith morphometrics (area and weight of otolith) that are good at disseminating the two species for these maturity samples. However, at this point the impact of the different maturity schedules is unknown. Misidentification rates on the survey may result from switching from survey to survey and the results of the genetics experiments have not been written up. There may be some difference in growth between the two species with rougheye growing slightly faster at age than blackspotted based on preliminary results from special projects on the bottom trawl survey. We plan to investigate this further in future assessments but at this point the impact to the population dynamics remains unknown. There has only been one large recruitment event in the past decade (2010) and the estimate for this year class has increased slightly with this full assessment. Recruitment remains average for the following years with no unusual trends. This is very consistent for this species. The stock is estimated to be well above $B_{40\%}$ and only half the ABC is typically harvested as this is a bycatch species. We rate this as Level 1, normal or unknown because the maturity data was not identified genetically, so we do not know the actual species split or the level of skip spawning.

Environmental/Ecosystem *considerations*

Adult rougheye and blackspotted rockfish are demersal and are known to inhabit particularly steep, rocky areas of the continental slope (300 to 500 m) in longline and trawl surveys (Zenger and Sigler 1992, Krieger and Ito 1999) and in the commercial trawl fishery (Ito 1999). The post-larval rockfish period is documented in epipelagic offshore waters of the Gulf of Alaska (GOA) (Kondzela et al. 2007). Limited information on temperature, zooplankton, and condition of other marine species indicates potentially less favorable foraging and growing conditions for RE/BS rockfish during 2019. There have been increased sea surface warming in the GOA and BSAI ecosystems and the presence of a series of major heatwaves from 2014-2016 and potentially again in 2019 (Barbeaux, 2019). This warming is also evident in bottom temperatures taken on the AFSC bottom trawl surveys and the International Pacific Halibut Commission (IPHC) surveys in hotspots throughout the continental shelf region. However, the warming was not particularly present over much of the slope environment, which may provide a buffer during spawning and egg deposition for rougheye and blackspotted rockfish that are found at these depths. Specifically, the 250-m slope temperature index from the longline survey which is in prime sablefish habitat, has not deviated greatly from the 15-year mean (Siwicke, *pers. commun.*). The AFSC bottom trawl survey temperature profiles were similar to 2015 profiles with warmer anomalies (7.0°C) consistently observed across the entire survey area and penetrating to 200 m depths (Laman 2019a). It is reasonable to expect that the current heat wave may impact age-0 rockfish in pelagic waters during a time when they are growing to a size that promotes over-winter survival, however it is unknown what this impact will be.

Primary prey items of adult rougheye and blackspotted 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). Warm conditions tend to be associated with zooplankton (prey for shrimp, squid, and larval fish) that are dominated by smaller and less lipid rich species in the GOA (Kimmel et al. 2019). The mesozooplankton biomass in the central and eastern GOA has been fairly high since 2014 on the shelf and high to average offshore except for 2018 (Batten, 2019). This most recent decline was largely due to a drop in large copepods which may have to do with the recent declines in the phytoplankton community (Batten, 2019). The euphausiid abundance index in the central GOA region has been steadily decreasing since 2011 but has returned to near average conditions in 2019 (Ressler, 2019). The biomass of copepods and euphausiids were slightly below the long-term mean along the Seward Line (Danielson and Hopcroft 2019) and around Kodiak Island (Kimmel et al. 2019). The body condition of 8 species of adult groundfish species captured near the sea floor in the 2019 AFSC bottom trawl surveys were below average except for adult Pacific cod (Laman 2019b). Little is known about the impacts of predators, such as fish and marine mammals, on rougheye and blackspotted rockfish. The 2019 foraging conditions were below average for larval rockfish in the GOA, but those fish were not identified to species. Given the mixed signals in the zooplankton prey base and the buffering potential in rougheye and blackspotted primary habitat, we scored this category as Level 1, normal concern.

Fishery performance:

There is no directed fishing of rougheye and blackspotted 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. Due to their moderately high value, discard rates of RE/BS rockfish have generally been low, however, there was an increased discard rate in 2018 likely in the sablefish longline fishery. It is unknown the cause of the increase but the current 2019 estimated discard rate decreased to a below average level. 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*	*Overall score (highest of the individual scores)*
Level 1: Normal	**Level 1:** Normal	**Level 1:** Normal	**Level 1:** Normal	**Level 1:** Normal

The overall score of Level 1 suggests no need to consider an ABC below the maximum permissible.

Ecosystem Considerations

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

Ecosystem Effects on the Stock

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

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

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

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

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

Fishery Effects on the Ecosystem

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

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

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

Fishery contribution to discards and offal production: Fishery discard rates during 2005-2017 have been 15-36% for the RE/BS rockfish stock complex.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: Unknown.

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

Data Gaps and Research Priorities

Future assessment priorities include 1) assessment of RE/BS rockfish density between trawlable and untrawlable grounds, 2) analyses of different fishery fleet spatial patterns and behavior given the Rockfish Program and observer restructuring, and 3) examining potential age and growth differences between RE/BS rockfish to consider the utility of developing species-specific life history parameters for this two-species complex.

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

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

A newly revamped stock ecosystem-socioeconomic profile (ESP) report framework is also planned to be introduced over the next several years. The ESPs may replace the Ecosystem Consideration section of the single-species assessment reports in some manner. The new reports can be considered a companion to the main SAFE chapter and will likely include several standardized products that review the ecosystem and socioeconomic pressures on a given stock and provide a subsequent evaluation of relevant indicators for monitoring shifts in stock productivity. The intention of the ESP report is to improve the process of integrating ecosystem information into the stock assessments and facilitate the ecosystem approach to fishery management. In the future, we may consider conducting and ESP for rougheye and blackspotted rockfish if this becomes a priority for this stock complex.

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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)	New study suggests age at 50% maturity younger for rougheye rockfish (19.6 years) than blackspotted rockfish (27.4 years), no genetic ID confirmation on samples (Conrath 2017).
Morphometrics (Field identifiable characters)	Unknown within species, hypothesized pigmentation differences between species (Gharrett et al. 2006, Orr and Hawkins 2008)
Meristics (Minimally overlapping differences in counts)	Unknown within species, significantly different means of dorsal spines and gill rakers (Gharrett et al. 2006)
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Unknown
Mark-recapture data (Tagging data may show limited movement)	Mark-recapture data not available, but potential to reduce barotrauma with new pressure tanks
Natural tags (Acquired tags may show movement smaller than management areas)	Parasite analysis shows structure by INPFC management area and between species (Moles et al. 1998, Hawkins et al. 2005)
Genetics	
Isolation by distance (Significant regression)	No significant isolation by distance for Type I or Type II rougheye (likely blackspotted and rougheye, respectively) (Gharrett et al. 2007)
Dispersal distance (<<Management areas)	Low, but significant F_{st} for both types indicates some limits to dispersal (Gharrett et al. 2007)
Pairwise genetic differences (Significant differences between geographically distinct collections)	Adjacency analysis suggests genetic structure on scale of INPFC management areas for Type I (blackspotted) and potentially finer scale structure for Type II (rougheye) (Gharrett et al. 2007)

Table 13-2. Estimated commercial catch[a] (t) for GOA RE/BS rockfish (1977-2018), with Gulf-wide values of acceptable biological catch (ABC) and fishing quotas[b] (t), 1991-2018. Catch is provided through the most recent full year estimate.

Year	Catch (t)				OFL	ABC	TAC
	Commercial	Western GOA	Central GOA	Eastern GOA			
1977	1443						
1978	568						
1979	645					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.	
1980	1353						
1981	719						
1982	569						
1983	628						
1984	760						
1985	130						
1986	438						
1987	525						
1988	1621	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).					
1989	2185						
1990	2418						
1991	350					2,000	2,000
1992	1127					1,960	1,960
1993	583					1,960	1,764
1994	579					1,960	1,960
1995	704					1,910	1,910
1996	558					1,910	1,910
1997	545					1,590	1,590
1998	665					1,590	1,590
1999	320					1,590	1,590
2000	530					1,730	1,730
2001	591					1,730	1,730
2002	273					1,620	1,620
2003	394					1,620	1,620
2004	301					1,318	1,318
2005	294	53	126	115	1,531	1,007	1,007
2006	372	58	141	172	1,180	983	983
2007	440	71	195	174	1,148	988	988
2008	382	75	190	117	1,548	1,286	1,286
2009	275	76	98	100	1,545	1,284	1,284
2010	426	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	575	15	384	176	1,482	1,232	1,232
2014	741	25	541	175	1,497	1,244	1,244
2015	549	45	348	157	1,345	1,122	1,122
2016	642	42	485	115	1,596	1,328	1,328
2017	523	34	329	159	1,594	1,327	1,327
2018	754	83	440	231	1,735	1,444	1,444

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

Year	Catch (t)*	ABC	TAC	Management Measures
1988	1,621	16,800	16,800	The slope rockfish assemblage, including rougheye, is one of three management groups for Sebastes implemented by the North Pacific Management Council. Previously, Sebastes in Alaska were managed as "Pacific ocean perch complex" (rougheye included) or "other rockfish"
1989	2,185	20,000	20,000	
1990	2,418	17,700	17,700	
1991	350	2,000	2,000	Slope assemblage split into three management subgroups with separate ABCs and TACs: Pacific ocean perch, shortraker/rougheye rockfish, and all other slope species
1992	1,127	1,960	1,960	
1993	583	1,960	1,764	
1994	579	1,960	1,960	
1995	704	1,910	1,910	
1996	558	1,910	1,910	
1997	545	1,590	1,590	
1998	665	1,590	1,590	
1999	320	1,590	1,590	Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	530	1,730	1,730	Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	591	1,730	1,730	
2002	273	1,620	1,620	
2003	394	1,620	1,620	
2004	301	1,318	1,318	Shortraker and rougheye rockfish divided into separate subgroups and assigned individual ABCs and TACs
2005	294	1,007	1,007	Rougheye managed separately from shortraker as age structured model accepted to determine ABC and moved to Tier 3 status
2006	372	983	983	
2007	440	988	988	Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	382	1,286	1,286	Rougheye and blackspotted formally verified as separate species so assessment called the rougheye/blackspotted rockfish complex
2009	275	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	575	1,232	1,232	
2014	741	1,244	1,244	
2015	549	1,122	1,122	
2016	642	1,328	1,328	
2017	523	1,327	1,327	
2018	754	1,444	1,444	

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

Table 13-4. Catch (t) of RE/BS rockfish as bycatch in other fisheries from 2005 - present. Other fisheries category not included due to confidentiality (# vessels or # processors is fewer than or equal to 2). Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/1/2019.

Year	Flatfish	Halibut	P. Cod	Pollock	Rockfish	Sablefish
2005	15	36	1	16	106	119
2006	40	46	2	23	83	179
2007	90	64	1	28	114	144
2008	57	55	9	41	104	115
2009	34	40	6	11	97	86
2010	65	42	4	30	183	102
2011	64	32	2	35	287	114
2012	122	26	4	21	219	173
2013	49	33	1	6	274	211
2014	154	33	4	22	359	170
2015	76	55	3	12	225	178
2016	92	22	3	44	351	129
2017	81	28	12	3	269	129
2018	132	34	8	9	317	254
2019	78	25	2	31	289	144
Average	77	38	4	22	218	150

Table 13-5. Incidental catch of FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2015 - 2019. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/1/2019.

Group Name	2015	2016	2017	2018	2019	Average
Pacific Ocean Perch	17,566	20,402	19,077	22,165	19,888	19,819
Northern Rockfish	3,632	3,155	1,602	2,152	2,233	2,555
GOA Dusky Rockfish	2,492	3,004	2,192	2,691	2,048	2,485
Arrowtooth Flounder	1,397	1,200	1,405	738	682	1,085
Pollock	1,330	572	1,057	906	494	872
Other Rockfish	849	972	748	993	662	845
Atka Mackerel	988	595	543	1,138	819	817
Sablefish	434	481	585	679	764	589
Pacific Cod	785	365	253	392	295	418
GOA Rougheye Rockfish	225	351	269	317	289	290
GOA Thornyhead Rockfish	220	336	360	358	172	289
GOA Shortraker Rockfish	238	291	254	268	237	257
GOA Rex Sole	116	140	112	133	113	123
GOA Deep Water Flatfish	44	64	58	65	36	53
Sculpin	44	43	45	65	53	50
Flathead Sole	46	26	81	44	39	47
GOA Demersal Shelf Rockfish	39	40	40	57	56	47
GOA Skate, Longnose	33	46	42	44	25	38
Shark	6	12	40	47	61	33
GOA Skate, Other	21	18	22	27	26	23
GOA Shallow Water Flatfish	27	15	11	19	33	21
Squid	24	12	22	29		22
Octopus	11	2	1	3	9	5
GOA Skate, Big	7	5	6	3	4	5

Table 13-6. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2015 - 2019. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/1/2019.

Group Name	2015	2016	2017	2018	2019
Benthic urochordata	0.28	0.50	0.20	0.07	0.07
Birds - Northern Fulmar			Conf.	50	57
Birds - Shearwaters					119
Bivalves	Conf.	Conf.	0.01	0.00	0.00
Brittle star unidentified	0.05	0.03	0.60	0.01	0.02
Capelin		Conf.			Conf.
Corals Bryozoans - Corals Bryozoans Unidentified	0.70	0.85	0.47	1.57	0.76
Corals Bryozoans - Red Tree Coral	0.01				
Deep sea smelts (bathylagidae)				Conf.	
Eelpouts	0.01	0.02	0.13	0.22	0.00
Eulachon	0.03	0.04	0.13	0.13	0.32
Giant Grenadier	786	426	1,008	756	551
Greenlings	8	6	4	4	6
Grenadier - Rattail Grenadier Unidentified	45	5	12	22	8
Gunnels	Conf.				
Hermit crab unidentified	Conf.	0.01	0.03	0.01	Conf.
Invertebrate unidentified	0.19	0.09	0.07	0.64	0.07
Lanternfishes (myctophidae)	0.04	0.14	0.00	0.00	0.06
Misc crabs	0.16	0.35	1.14	0.72	0.16
Misc crustaceans	Conf.	0.03	0.01	0.13	0.21
Misc deep fish		Conf.	Conf.		Conf.
Misc fish	144	102	115	139	101
Misc inverts (worms etc)		Conf.			
Other osmerids	Conf.	0.03	Conf.		Conf.
Pacific Hake	0.08	0.04	Conf.	0.06	
Pandalid shrimp	0.05	0.22	0.14	0.07	0.08
Polychaete unidentified			0.02		
Scypho jellies	1.63	8.07	0.54	0.97	7.37
Sea anemone unidentified	1.14	1.28	0.79	0.50	1.23
Sea pens whips	Conf.	0.02	0.03	0.00	0.02
Sea star	3.48	1.72	3.65	4.67	1.36
Snails	0.26	0.18	0.18	6.19	1.71
Sponge unidentified	5.45	2.88	3.20	14.63	5.82
Squid					10.28
State-managed Rockfish	47	13	24	50	43
Stichaeidae	Conf.		Conf.	0.64	
urchins dollars cucumbers	0.99	0.34	0.43	0.29	0.19

Table 13-7. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and counts of animals for crab and salmon, by year, for the GOA rockfish fishery 2015 - 2019. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/1/2019.

Group Name	**2015**	**2016**	**2017**	**2018**	**2019**	**Average**
Bairdi Tanner Crab	49	5	756	202	64	215
Blue King Crab	0	0	0	0	0	0
Chinook Salmon	1,915	383	520	325	337	696
Golden (Brown) King Crab	19	20	209	324	223	159
Halibut	157	124	126	78	72	111
Herring	0	0	0	0	0	0
Non-Chinook Salmon	337	217	641	314	236	349
Opilio Tanner (Snow) Crab	0	0	0	0	0	0
Red King Crab	0	0	0	0	0	0

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

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

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

Length	1991	1992	2002	2003	2005	2007	2011	2013	2015	2017
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
22	0.000	0.005	0.008	0.000	0.000	0.000	0.001	0.003	0.000	0.004
24	0.001	0.006	0.005	0.001	0.001	0.000	0.001	0.004	0.003	0.007
26	0.002	0.008	0.008	0.002	0.001	0.004	0.002	0.006	0.002	0.008
28	0.006	0.013	0.002	0.004	0.004	0.005	0.006	0.004	0.006	0.016
30	0.004	0.029	0.005	0.003	0.007	0.012	0.008	0.005	0.007	0.019
32	0.009	0.027	0.005	0.006	0.006	0.011	0.030	0.009	0.010	0.025
34	0.012	0.036	0.014	0.009	0.013	0.025	0.031	0.009	0.020	0.031
36	0.010	0.045	0.017	0.013	0.031	0.032	0.035	0.018	0.019	0.041
38	0.026	0.066	0.037	0.038	0.030	0.060	0.035	0.038	0.036	0.063
40	0.039	0.100	0.049	0.054	0.045	0.071	0.084	0.096	0.058	0.080
42	0.158	0.108	0.145	0.101	0.071	0.096	0.108	0.132	0.102	0.122
44	0.285	0.164	0.165	0.142	0.116	0.120	0.123	0.145	0.121	0.124
46	0.222	0.129	0.194	0.192	0.151	0.146	0.130	0.129	0.161	0.107
48	0.151	0.079	0.139	0.171	0.154	0.135	0.140	0.111	0.151	0.086
50	0.044	0.046	0.113	0.112	0.130	0.117	0.111	0.063	0.122	0.099
52	0.013	0.034	0.046	0.071	0.088	0.082	0.057	0.041	0.069	0.062
54	0.004	0.036	0.014	0.032	0.058	0.029	0.042	0.038	0.040	0.035
56	0.006	0.025	0.011	0.019	0.027	0.019	0.020	0.043	0.017	0.025
58	0.001	0.016	0.005	0.007	0.022	0.012	0.016	0.022	0.016	0.012
60+	0.001	0.021	0.005	0.014	0.036	0.014	0.014	0.074	0.031	0.022
Sample size	959	1,077	344	2,516	1,493	1,472	988	1,010	1,793	1,711

Table 13-10. GOA RE/BS rockfish biomass estimates from NMFS triennial/biennial trawl surveys by region and gulfwide for 1984-2019. No sampling was performed in the Eastern GOA for the 2001 survey and we exclude this year from our assessment model. Estimates for the Western and Central GOA are provided here for reference. CV is the coefficient of variation expressed as a percent and provided in parentheses next to the biomass estimate. SE is the standard error. LCI and UCI are the lower and upper 95% confidence intervals respectively. SE, LCI, UCI are respective to the gulfwide biomass estimates.

Year	Western		Central		Eastern		Gulfwide		SE	LCI	UCI
1984	8,779	(32)	32,416	(21)	3,896	(20)	45,091	(16)	7,313	30,758	59,425
1987	2,737	(34)	21,881	(16)	19,063	(17)	43,681	(11)	4,897	34,083	53,278
1990	1,329	(48)	35,467	(26)	8,041	(19)	44,837	(21)	9,296	26,617	63,057
1993	10,891	(79)	41,616	(28)	9,358	(21)	61,864	(23)	14,415	33,611	90,117
1996	3,449	(35)	28,396	(23)	14,067	(23)	45,913	(16)	7,432	31,346	60,481
1999	6,156	(51)	20,781	(17)	12,622	(26)	39,560	(15)	5,793	28,206	50,913
2001	6,945	(55)	24,740	(24)	NA	NA	--	--	--	--	--
2003	8,921	(34)	24,610	(20)	9,670	(36)	43,202	(16)	6,724	30,024	56,380
2005	3,621	(26)	32,898	(25)	11,356	(16)	47,875	(18)	8,618	30,983	64,767
2007	3,773	(27)	39,419	(24)	16,697	(23)	59,889	(17)	10,380	39,544	80,234
2009	2,765	(27)	33,154	(21)	14,855	(30)	50,774	(16)	8,297	34,512	67,035
2011	3,305	(43)	32,181	(21)	8,228	(17)	43,714	(16)	7,065	29,866	57,561
2013	3,922	(24)	11,207	(29)	12,452	(30)	27,581	(18)	5,078	17,627	37,534
2015	1,345	(22)	18,135	(20)	15,079	(22)	34,559	(14)	4,970	24,817	44,301
2017	6,722	(45)	11,297	(21)	21,900	(28)	39,919	(18)	7,185	25,836	54,002
2019	1,381	(34)	38,696	(69)	15,417	(28)	55,494	(49)	26,901	2,768	108,220

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	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007
20	0.006	0.014	0.013	0.015	0.038	0.075	0.022	0.060	0.048	0.039
22	0.016	0.032	0.017	0.017	0.050	0.062	0.036	0.057	0.052	0.039
24	0.025	0.031	0.024	0.023	0.054	0.050	0.042	0.043	0.054	0.048
26	0.023	0.029	0.027	0.028	0.048	0.041	0.049	0.042	0.063	0.044
28	0.019	0.028	0.042	0.034	0.038	0.055	0.059	0.048	0.066	0.042
30	0.033	0.040	0.062	0.047	0.051	0.069	0.051	0.057	0.065	0.047
32	0.036	0.051	0.085	0.051	0.050	0.064	0.044	0.057	0.058	0.046
34	0.044	0.057	0.102	0.069	0.046	0.068	0.061	0.047	0.065	0.046
36	0.056	0.072	0.120	0.077	0.062	0.062	0.070	0.041	0.060	0.055
38	0.057	0.072	0.086	0.106	0.063	0.072	0.088	0.052	0.070	0.080
40	0.084	0.081	0.069	0.124	0.085	0.078	0.097	0.068	0.078	0.087
42	0.144	0.085	0.062	0.133	0.115	0.082	0.134	0.100	0.083	0.106
44	0.166	0.114	0.093	0.125	0.111	0.080	0.096	0.114	0.079	0.115
46	0.120	0.112	0.082	0.076	0.081	0.061	0.066	0.096	0.048	0.079
48	0.077	0.087	0.046	0.032	0.046	0.036	0.041	0.059	0.032	0.052
50	0.039	0.041	0.022	0.011	0.023	0.022	0.016	0.026	0.027	0.033
52	0.019	0.022	0.010	0.006	0.014	0.007	0.008	0.009	0.014	0.016
54	0.009	0.008	0.009	0.003	0.005	0.003	0.002	0.006	0.008	0.009
56	0.005	0.005	0.007	0.003	0.006	0.001	0.005	0.002	0.007	0.003
58	0.004	0.003	0.005	0.003	0.002	0.002	0.001	0.002	0.004	0.002
60+	0.009	0.007	0.009	0.007	0.002	0.002	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
20	0.0402	0.0366	0.0637	0.0604	0.0359	0.0298
22	0.0545	0.0510	0.0516	0.0638	0.0318	0.0344
24	0.0593	0.0525	0.0526	0.0623	0.0561	0.0403
26	0.0691	0.0599	0.0516	0.0510	0.0836	0.0536
28	0.0553	0.0571	0.0598	0.0593	0.0892	0.0633
30	0.0598	0.0708	0.0450	0.0534	0.0621	0.0457
32	0.0441	0.0544	0.0489	0.0617	0.0671	0.0536
34	0.0425	0.0629	0.0562	0.0726	0.0741	0.0548
36	0.0466	0.0604	0.0724	0.0752	0.0633	0.0547
38	0.0527	0.0639	0.0857	0.0847	0.0751	0.0679
40	0.0691	0.0825	0.0872	0.0916	0.0628	0.1109
42	0.0797	0.0987	0.0844	0.0780	0.0708	0.1652
44	0.0901	0.0859	0.0595	0.0545	0.0564	0.1173
46	0.0879	0.0598	0.0627	0.0465	0.0594	0.0556
48	0.0661	0.0477	0.0449	0.0310	0.0428	0.0220
50	0.0406	0.0250	0.0383	0.0188	0.0277	0.0132
52	0.0239	0.0110	0.0183	0.0120	0.0188	0.0055
54	0.0090	0.0099	0.0078	0.0088	0.0048	0.0038
56	0.0041	0.0034	0.0046	0.0044	0.0025	0.0016
58	0.0026	0.0017	0.0020	0.0042	0.0033	0.0025
60+	0.0024	0.0048	0.0026	0.0057	0.0125	0.0042
Sample size	4,155	2,475	1,692	2,588	2,173	2,078

Table 13-13. GOA RE/BS rockfish relative population numbers (RPN) estimated from the AFSC longline survey by region and gulfwide for 1993-2019. CV is the coefficient of variation expressed as a percent and provided in parentheses next to the RPN. SE is the standard error. LCI and UCI are the lower and upper 95% confidence intervals respectively. SE, LCI, UCI are respective to the gulfwide RPNs.

	Western		Central		Eastern		Gulfwide		SE	LCI	UCI
1993	6,286	(44.0)	5,279	(31.5)	11,704	(24.8)	23,269	(18.6)	4,336	14,770	31,768
1994	4,371	(37.4)	2,513	(31.7)	15,737	(21.8)	22,622	(17.2)	3,885	15,007	30,236
1995	9,988	(38.5)	7,962	(27.1)	9,522	(21.8)	27,472	(17.7)	4,875	17,917	37,027
1996	5,675	(45.3)	5,613	(33.6)	14,337	(18.2)	25,624	(16.1)	4,122	17,545	33,703
1997	7,314	(46.6)	7,729	(38.4)	22,027	(27.6)	37,070	(20.4)	7,578	22,216	51,923
1998	6,032	(30.6)	5,751	(38.2)	12,787	(12.5)	24,570	(13.4)	3,284	18,134	31,006
1999	6,112	(28.7)	6,338	(35.3)	14,803	(21.2)	27,254	(15.5)	4,238	18,948	35,560
2000	10,454	(36.7)	8,917	(29.5)	18,522	(19.3)	37,894	(15.5)	5,860	26,408	49,380
2001	9,039	(38.0)	8,990	(30.1)	11,493	(22.1)	29,523	(17.1)	5,056	19,613	39,432
2002	9,792	(34.0)	7,454	(36.0)	10,271	(16.1)	27,517	(16.6)	4,581	18,538	36,496
2003	6,003	(35.3)	5,231	(38.6)	13,155	(19.4)	24,389	(15.9)	3,883	16,778	32,001
2004	10,312	(42.5)	4,479	(36.9)	13,122	(17.5)	27,913	(18.7)	5,222	17,678	38,149
2005	3,031	(56.9)	5,777	(32.9)	10,055	(25.9)	18,863	(19.4)	3,657	11,695	26,031
2006	5,240	(32.8)	6,320	(35.9)	8,918	(17.8)	20,478	(15.9)	3,262	14,085	26,871
2007	11,064	(39.1)	9,315	(27.3)	13,285	(18.2)	33,663	(16.5)	5,570	22,747	44,579
2008	6,407	(38.2)	7,414	(24.1)	17,139	(21.0)	30,960	(15.2)	4,700	21,747	40,173
2009	7,213	(36.1)	10,790	(41.1)	11,749	(13.9)	29,751	(18.1)	5,398	19,172	40,331
2010	12,746	(35.4)	7,741	(31.0)	14,801	(14.7)	35,288	(15.7)	5,549	24,412	46,165
2011	13,344	(45.3)	8,863	(32.7)	17,576	(26.5)	39,783	(20.5)	8,164	23,781	55,785
2012	7,967	(36.9)	5,364	(41.9)	13,632	(24.8)	26,962	(18.6)	5,016	17,130	36,795
2013	9,493	(43.9)	5,420	(33.4)	9,026	(22.0)	23,939	(20.7)	4,960	14,217	33,661
2014	8,827	(40.5)	7,030	(36.0)	17,607	(20.1)	33,464	(16.8)	5,629	22,430	44,497
2015	10,894	(44.6)	6,482	(45.0)	14,073	(20.1)	31,448	(20.1)	6,337	19,028	43,868
2016	9,632	(40.5)	5,055	(28.4)	9,864	(24.2)	24,552	(19.5)	4,793	15,156	33,947
2017	13,239	(34.9)	9,034	(44.7)	14,434	(19.6)	36,707	(18.4)	6,754	23,469	49,945
2018	9,158	(30.3)	5,761	(27.3)	10,433	(23.8)	25,352	(14.4)	3,642	18,213	32,491
2019	14,506	(40.2)	8,499	(32.4)	9,740	(24.2)	32,745	(20.3)	6,660	19,691	45,798

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	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	0.000	0.000
24	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001
26	0.007	0.000	0.002	0.000	0.000	0.000	0.003	0.001	0.003	0.002
28	0.005	0.004	0.005	0.002	0.001	0.002	0.006	0.003	0.004	0.006
30	0.012	0.006	0.009	0.011	0.010	0.021	0.010	0.008	0.018	0.016
32	0.028	0.012	0.021	0.016	0.009	0.024	0.014	0.015	0.018	0.021
34	0.055	0.025	0.028	0.035	0.017	0.036	0.037	0.030	0.042	0.027
36	0.053	0.032	0.040	0.047	0.044	0.045	0.051	0.060	0.048	0.048
38	0.070	0.050	0.066	0.070	0.076	0.059	0.067	0.080	0.066	0.065
40	0.091	0.078	0.088	0.097	0.081	0.074	0.089	0.092	0.092	0.084
42	0.106	0.086	0.107	0.116	0.108	0.091	0.106	0.100	0.101	0.125
44	0.122	0.142	0.137	0.139	0.124	0.131	0.149	0.132	0.127	0.150
46	0.142	0.151	0.140	0.147	0.159	0.160	0.165	0.131	0.136	0.138
48	0.099	0.139	0.121	0.129	0.133	0.142	0.129	0.136	0.126	0.127
50	0.092	0.095	0.103	0.084	0.093	0.092	0.084	0.086	0.094	0.072
52	0.048	0.074	0.048	0.041	0.050	0.053	0.045	0.053	0.047	0.044
54	0.022	0.036	0.036	0.027	0.026	0.021	0.015	0.027	0.023	0.025
56	0.017	0.020	0.018	0.013	0.012	0.016	0.005	0.014	0.010	0.011
58	0.005	0.014	0.010	0.006	0.009	0.010	0.003	0.005	0.006	0.012
60+	0.017	0.028	0.011	0.012	0.037	0.015	0.014	0.019	0.026	0.016
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	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	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.002	0.000
26	0.001	0.003	0.003	0.002	0.003	0.002	0.001	0.008	0.007	0.002
28	0.008	0.016	0.013	0.022	0.001	0.007	0.007	0.014	0.013	0.010
30	0.013	0.025	0.027	0.009	0.011	0.021	0.043	0.030	0.030	0.016
32	0.015	0.022	0.031	0.019	0.033	0.035	0.024	0.050	0.038	0.027
34	0.013	0.034	0.033	0.022	0.043	0.055	0.039	0.057	0.055	0.041
36	0.022	0.054	0.048	0.036	0.085	0.067	0.051	0.073	0.072	0.057
38	0.049	0.099	0.049	0.047	0.064	0.070	0.081	0.081	0.090	0.083
40	0.072	0.094	0.064	0.081	0.098	0.075	0.101	0.093	0.099	0.102
42	0.111	0.109	0.113	0.115	0.111	0.099	0.123	0.111	0.115	0.105
44	0.146	0.134	0.144	0.138	0.146	0.119	0.119	0.123	0.119	0.135
46	0.173	0.146	0.148	0.152	0.136	0.123	0.113	0.113	0.095	0.121
48	0.154	0.111	0.140	0.146	0.109	0.116	0.110	0.086	0.095	0.109
50	0.088	0.071	0.071	0.080	0.063	0.094	0.073	0.058	0.059	0.072
52	0.046	0.034	0.036	0.047	0.038	0.051	0.051	0.027	0.034	0.051
54	0.017	0.015	0.023	0.028	0.015	0.025	0.023	0.014	0.016	0.024
56	0.015	0.011	0.011	0.012	0.016	0.010	0.015	0.012	0.014	0.011
58	0.010	0.006	0.010	0.015	0.005	0.010	0.004	0.008	0.006	0.005
60+	0.039	0.008	0.027	0.021	0.015	0.011	0.012	0.033	0.032	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
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
22	0.0000	0.0000	0.0000	0.0008	0.0003	0.0000	0.0000
24	0.0001	0.0001	0.0007	0.0002	0.0009	0.0037	0.0014
26	0.0028	0.0535	0.0007	0.0005	0.0028	0.0043	0.0016
28	0.0075	0.0037	0.0041	0.0051	0.0048	0.0040	0.0078
30	0.0276	0.0128	0.0064	0.0108	0.0166	0.0164	0.0176
32	0.0427	0.0219	0.0215	0.0270	0.0320	0.0299	0.0399
34	0.0568	0.0406	0.0177	0.0421	0.0578	0.0469	0.0661
36	0.0925	0.0577	0.0453	0.0587	0.0597	0.0619	0.0844
38	0.0755	0.0732	0.0565	0.0665	0.0618	0.0806	0.0983
40	0.0922	0.1031	0.0796	0.0980	0.0946	0.1055	0.1042
42	0.1029	0.1090	0.1317	0.0939	0.1128	0.1203	0.1010
44	0.1252	0.1154	0.1558	0.1134	0.1397	0.1482	0.1174
46	0.1267	0.1101	0.1383	0.1250	0.1387	0.1313	0.1093
48	0.1068	0.1069	0.1128	0.1219	0.1163	0.1082	0.0801
50	0.0628	0.0768	0.0969	0.0928	0.0721	0.0656	0.0649
52	0.0299	0.0438	0.0609	0.0640	0.0411	0.0341	0.0413
54	0.0177	0.0231	0.0279	0.0396	0.0217	0.0164	0.0241
56	0.0089	0.0161	0.0195	0.0181	0.0098	0.0128	0.0129
58	0.0139	0.0101	0.0166	0.0069	0.0088	0.0036	0.0082
60+	0.0077	0.0221	0.0072	0.0148	0.0076	0.0064	0.0194
Sample size	3,744	6,820	5,382	4,478	6,011	5,753	5,963

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

		2017 (Model 15.4)	***2019 (Model 15.4)***
Likelihoods	Weight		
Catch	5/50*	0.017	0.023
Trawl Biomass	1	8.629	9.753
Longline Biomass	1	15.053	15.904
Fishery Ages	1	25.866	26.097
Trawl Survey Ages	1	37.009	38.972
Fishery Sizes	1	61.141	64.373
Trawl Survey Sizes	0	0.000	0.000
Longline Survey Sizes	1	104.056	109.850
Data-Likelihood		251.770	264.972
Penalties/Priors			
Recruit Deviations	1	-12.983	-13.181
Selectivity Penalties			
Fishery	1	2.224	2.319
Fishery Domeshape	1	0.001	0.002
Trawl Survey	1	0	0
Trawl Domeshape	1	0	0
Longline	1	0.282	0.315
Longline Domeshape	1	0.004	0.007
F Regularity	0.1	1.153	1.143
σ_r prior		11.877	12.154
q-trawl		0.004	0.006
q-longline		0.000	0.013
M		1.547	1.639
Total penalties/priors		4.108	4.419
Objective Fun. Total		255.878	269.391
Parameter Estimates			
Number Parameters		170	
q-trawl		1.525	1.714
q-longline		0.983	1.178
M		0.036	0.036
σ_r		0.808	0.805
Mean Recruitment (mil)		1.914	1.794
$F_{40\%}$		0.040	0.040
Total Biomass (t)		45,624	40,336
Spawning Biomass (t)		15,059	12,517
$B_{100\%}$ (t)		22,495	20,658
$B_{40\%}$ (t)		8,998	8,263
ABC$_{F40\%}$ (t)		1,444	1,209

Table 13-16. Estimated GOA RE/BS rockfish population numbers (thousands) in 2019, 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 2019 (1000s)	Percent Mature	Weight (g)	Fishery Selectivity	Trawl Survey Selectivity	LL Survey Selectivity
3	1,592	0	53	0	19	0
4	1,537	0	99	0	37	0
5	1,657	0	159	0	52	0
6	1,497	0	228	1	64	0
7	1,099	0	306	1	75	0
8	1,112	0	388	3	83	0
9	3,747	0	473	5	89	0
10	1,986	1	558	7	94	2
11	1,436	2	642	8	97	5
12	1,022	5	723	7	99	15
13	1,762	8	801	8	100	34
14	1,233	14	875	11	100	63
15	1,018	22	945	28	99	86
16	1,068	31	1,010	100	98	100
17	1,221	40	1,070	100	96	92
18	1,291	50	1,125	100	94	92
19	1,082	59	1,176	100	92	92
20	585	66	1,222	100	89	92
21	1,021	72	1,265	100	86	92
22	747	77	1,303	100	83	92
23	565	81	1,338	100	79	92
24	830	84	1,369	100	76	92
25	895	92	1,398	100	73	92
26	465	92	1,423	100	69	92
27	378	92	1,446	100	66	92
28	394	92	1,467	100	63	92
29	1,091	92	1,485	100	60	92
30	305	92	1,502	100	57	92
31	286	92	1,517	100	54	92
32	256	92	1,530	100	51	92
33	258	92	1,542	100	48	92
34	289	92	1,553	100	45	92
35	345	92	1,562	100	43	92
36	386	92	1,571	100	40	92
37	340	92	1,578	100	38	92
38	539	92	1,585	100	35	92
39	489	92	1,591	100	33	92

Table 13-16 (continued). Estimated GOA RE/BS rockfish population numbers (thousands) in 2019, 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 2019 (1000s)	Percent Mature	Weight (g)	Fishery Selectivity	Trawl Survey Selectivity	LL Survey Selectivity
40	257	92	1,596	100	31	92
41	203	92	1,601	100	29	92
42	220	92	1,605	100	27	92
43	641	92	1,609	100	26	92
44	224	92	1,612	100	24	92
45	172	92	1,615	100	22	92
46	162	92	1,618	100	21	92
47	163	92	1,620	100	20	92
48	156	92	1,622	100	18	92
49	166	92	1,624	100	17	92
50	199	92	1,626	100	16	92
51	194	92	1,627	100	15	92
52	3,766	92	1,634	100	14	92

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 (2019), ABC is acceptable biological catch, and σ_r is the recruitment standard deviation parameter.

	μ		σ		MCMC		
Parameter	Hessian	MCMC	Hessian	MCMC	Median	BCI-Lower	BCI-Upper
q_1, trawl survey	1.7138	1.5619	0.5391	0.5249	1.5478	0.5862	2.6559
q_2, longline survey	1.1781	1.2422	0.4750	0.4558	1.2063	0.4727	2.2503
M	0.0360	0.0361	0.0031	0.0032	0.0360	0.0301	0.0427
$F_{40\%}$	0.0400	0.0457	0.0108	0.0143	0.0435	0.0252	0.0795
SSB (2019)	12,517	16,049	4,599	9,629	13,660	7,267	38,998
ABC	1,209	1,798	581	1,296	1,457	577	5,266
σ_r	0.8053	1.0530	0.0509	0.0639	1.0497	0.9380	1.1822

Table 13-18. Estimated time series of female spawning biomass, 6+ biomass (ages 6 and greater), catch divided by 6 + biomass, and number of age 3 recruits for GOA RE/BS rockfish, 1977-2019. Estimates are shown for the author preferred model (MLE approach) and from the previous full assessment in 2017.

	Spawning Biomass (t)		6+ Biomass (t)		Catch/6+ Biomass		Age 3 Recruits	
Year	Previous	Current	Previous	Curren	Previous	Current	Previous	Current
1977	20,550	18,656	57,506	52,070	0.025	0.028	1,513	1,357
1978	20,141	18,218	56,228	50,743	0.010	0.011	1,774	1,598
1979	20,073	18,124	55,788	50,264	0.012	0.013	4,982	4,313
1980	19,954	17,980	55,232	49,676	0.024	0.027	1,548	1,385
1981	19,519	17,521	54,001	48,412	0.013	0.015	1,372	1,212
1982	19,334	17,316	54,064	48,345	0.011	0.012	1,659	1,454
1983	19,204	17,167	53,759	47,990	0.012	0.013	3,048	2,609
1984	19,046	16,991	53,343	47,528	0.014	0.016	3,124	2,720
1985	18,829	16,756	52,818	46,953	0.002	0.003	1,867	1,627
1986	18,875	16,786	53,196	47,235	0.008	0.009	1,999	1,744
1987	18,788	16,683	53,336	47,276	0.010	0.011	1,673	1,483
1988	18,663	16,543	53,201	47,067	0.030	0.034	1,331	1,180
1989	18,088	15,954	52,011	45,806	0.042	0.048	1,127	997
1990	17,294	15,147	50,223	43,966	0.048	0.055	1,079	944
1991	16,443	14,283	48,178	41,888	0.007	0.008	1,148	1,005
1992	16,467	14,285	48,086	41,762	0.023	0.027	1,159	1,023
1993	16,207	14,000	47,168	40,821	0.012	0.014	4,118	3,493
1994	16,178	13,945	46,750	40,387	0.012	0.014	1,385	1,204
1995	16,152	13,890	46,286	39,914	0.015	0.018	1,255	1,098
1996	16,082	13,792	46,262	39,789	0.012	0.014	1,468	1,287
1997	16,078	13,759	45,965	39,460	0.012	0.014	2,783	2,366
1998	16,075	13,727	45,632	39,104	0.015	0.017	2,400	2,088
1999	16,005	13,633	45,196	38,646	0.007	0.008	1,523	1,352
2000	16,057	13,663	45,358	38,742	0.012	0.014	1,950	1,693
2001	16,035	13,618	45,292	38,621	0.013	0.015	2,520	2,191
2002	15,896	13,470	45,027	38,327	0.006	0.007	1,335	1,186
2003	15,875	13,442	45,155	38,413	0.009	0.010	2,324	2,076
2004	15,804	13,363	45,287	38,488	0.007	0.008	2,506	2,342
2005	15,798	13,345	45,311	38,488	0.006	0.008	2,151	2,100
2006	15,800	13,335	45,512	38,653	0.008	0.010	1,665	1,733
2007	15,761	13,286	45,699	38,821	0.010	0.011	1,519	1,584
2008	15,710	13,224	45,781	38,913	0.008	0.010	1,718	1,847
2009	15,692	13,192	45,835	39,015	0.006	0.007	2,342	2,542
2010	15,728	13,215	45,948	39,195	0.009	0.011	1,435	1,419
2011	15,713	13,187	45,917	39,266	0.012	0.014	1,703	1,922
2012	15,664	13,127	45,885	39,376	0.012	0.014	2,033	2,561
2013	15,616	13,067	45,665	39,273	0.013	0.015	3,573	4,654
2014	15,575	13,015	45,465	39,245	0.016	0.019	1,510	1,332
2015	15,515	12,940	45,159	39,189	0.012	0.014	1,570	1,270
2016	15,482	12,909	45,368	39,803	0.014	0.016	1,732	1,668
2017	15,416	12,854	45,166	39,814	0.011	0.013	1,732	1,781
2018		12,863		39,899		0.019		1,594
2019		12,800		39,791		0.015		1,592

Table 13-19. Estimated time series of recruitment, total biomass (3+), and female spawning biomass for RE/BS rockfish in the Gulf of Alaska, 1977-2020. Columns headed with 2.5% and 97.5% represent the lower and upper 95% credible intervals from the MCMC posterior distribution.

	Recruits (Age 3, 1000s)			Total Biomass (3+)			Spawning biomass (t)		
Year	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%
1977	1,357	208	5,566	61,265	36,994	123,999	21,190	12,886	42,453
1978	1,598	207	7,563	60,002	35,612	123,118	20,899	12,504	42,601
1979	4,313	1,200	12,941	59,817	35,458	123,474	20,935	12,533	42,393
1980	1,385	209	6,139	59,469	35,112	122,856	20,901	12,456	42,472
1981	1,212	188	4,508	58,348	33,832	121,828	20,512	12,008	42,281
1982	1,454	242	6,214	57,913	33,276	121,980	20,370	11,822	42,622
1983	2,609	388	9,711	57,693	33,083	121,819	20,271	11,674	42,690
1984	2,720	445	9,697	57,458	32,807	121,861	20,133	11,524	42,496
1985	1,627	258	6,546	57,072	32,347	121,721	19,928	11,330	42,506
1986	1,744	289	6,627	57,363	32,514	121,897	19,990	11,400	42,568
1987	1,483	270	5,686	57,308	32,305	121,964	19,905	11,288	42,509
1988	1,180	215	4,412	57,125	32,170	121,979	19,775	11,184	42,243
1989	997	191	3,650	55,790	30,905	121,171	19,180	10,637	41,861
1990	944	214	3,307	53,835	29,112	119,438	18,348	9,910	40,974
1991	1,005	211	3,630	51,653	27,198	117,175	17,459	9,109	40,070
1992	1,023	187	3,647	51,520	27,118	116,757	17,477	9,092	40,087
1993	3,493	2,221	9,803	50,710	26,358	116,008	17,198	8,810	39,897
1994	1,204	194	4,515	50,387	26,153	115,417	17,161	8,746	39,893
1995	1,098	208	4,065	50,067	25,825	115,096	17,134	8,665	39,953
1996	1,287	240	4,890	49,607	25,344	114,778	17,063	8,567	39,969
1997	2,366	598	8,246	49,360	25,076	114,495	17,057	8,522	39,940
1998	2,088	373	7,403	49,144	24,880	114,178	17,051	8,462	39,817
1999	1,352	228	5,412	48,797	24,443	113,605	16,977	8,364	39,756
2000	1,693	301	6,469	48,826	24,469	113,389	17,026	8,388	39,881
2001	2,191	620	7,066	48,696	24,276	113,476	17,004	8,336	39,996
2002	1,186	226	4,436	48,471	24,054	113,401	16,852	8,206	39,836
2003	2,076	650	6,972	48,626	24,151	113,691	16,814	8,203	39,829
2004	2,342	556	7,865	48,703	24,109	113,868	16,729	8,133	39,725
2005	2,100	487	7,198	48,904	24,262	114,170	16,712	8,109	39,756
2006	1,733	344	6,349	49,128	24,414	114,758	16,703	8,132	39,713
2007	1,584	281	6,011	49,275	24,469	114,899	16,653	8,096	39,554
2008	1,847	331	7,364	49,377	24,418	115,256	16,593	8,023	39,531
2009	2,542	706	8,911	49,601	24,446	116,145	16,567	7,981	39,526
2010	1,419	235	5,961	49,899	24,600	116,662	16,598	7,996	39,601
2011	1,922	398	7,284	50,066	24,682	117,105	16,581	7,972	39,549
2012	2,561	505	11,238	50,187	24,540	117,343	16,536	7,902	39,529
2013	4,654	1,700	17,499	50,486	24,595	118,010	16,495	7,851	39,667
2014	1,332	183	5,828	50,705	24,521	118,940	16,463	7,772	39,868
2015	1,270	192	5,878	50,765	24,341	119,668	16,427	7,654	39,903
2016	1,668	227	9,005	51,041	24,349	120,566	16,417	7,621	39,992
2017	1,781	251	10,646	51,225	24,310	121,677	16,387	7,563	40,022
2018	1,594	197	12,144	51,520	24,355	122,723	16,425	7,564	40,115
2019	1,592	196	12,074	51,564	24,073	123,767	16,401	7,462	40,361
2020	1,592	195	9,684	51,759	24,051	124,312	16,044	7,254	39,504

Table 13-20. Set of projections of spawning biomass (SB) and yield for GOA RE/BS rockfish. Seven harvest scenarios designed to satisfy the requirements of Amendment 56, NEPA, and MSFCMA. For a description of scenarios see *Harvest Recommendations* section. Spawning biomass and yield are in t. $B_{40\%}$ = 8,263 t, $B_{35\%}$ = 7,230 t, $F_{40\%}$ = 0.040 and $F_{35\%}$ = 0.048.

Year	Maximum permissible F	Author's F*	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning Biomass (t)				
2019	12,511	12,511	12,511	12,511	12,511	12,511	12,511
2020	12,408	12,518	12,510	12,510	12,612	12,366	12,408
2021	12,163	12,530	12,501	12,502	12,850	12,026	12,163
2022	11,944	12,450	12,511	12,512	13,106	11,718	11,904
2023	11,756	12,243	12,543	12,545	13,384	11,447	11,624
2024	11,582	12,047	12,577	12,580	13,662	11,196	11,364
2025	11,445	11,889	12,641	12,644	13,969	10,988	11,147
2026	11,321	11,743	12,711	12,715	14,283	10,796	10,946
2027	11,190	11,589	12,767	12,772	14,584	10,602	10,743
2028	11,050	11,427	12,804	12,810	14,862	10,404	10,536
2029	10,899	11,253	12,820	12,827	15,115	10,200	10,323
2030	10,744	11,076	12,821	12,830	15,347	9,996	10,111
2031	10,591	10,902	12,813	12,825	15,567	9,800	9,906
2032	10,424	10,714	12,776	12,792	15,747	9,596	9,694
			Fishing Mortality				
2019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
2020	0.040	0.018	0.020	0.020	-	0.048	0.048
2021	0.040	0.018	0.020	0.020	-	0.048	0.048
2022	0.040	0.040	0.020	0.020	-	0.048	0.048
2023	0.040	0.040	0.020	0.020	-	0.048	0.048
2024	0.040	0.040	0.020	0.020	-	0.048	0.048
2025	0.040	0.040	0.020	0.020	-	0.048	0.048
2026	0.040	0.040	0.020	0.020	-	0.048	0.048
2027	0.040	0.040	0.020	0.020	-	0.048	0.048
2028	0.040	0.040	0.020	0.020	-	0.048	0.048
2029	0.040	0.040	0.020	0.020	-	0.048	0.048
2030	0.040	0.040	0.020	0.020	-	0.048	0.048
2031	0.040	0.040	0.020	0.020	-	0.048	0.048
2032	0.040	0.040	0.020	0.020	-	0.048	0.048
			Yield (t)				
2019	589	589	589	589	589	589	589
2020	1,209	1,209	610	609	-	1,452	1,209
2021	1,186	1,211	610	609	-	1,414	1,186
2022	1,173	1,221	614	613	-	1,388	1,409
2023	1,144	1,190	610	609	-	1,344	1,364
2024	1,130	1,173	613	611	-	1,319	1,337
2025	1,133	1,173	623	622	-	1,315	1,332
2026	1,159	1,197	645	644	-	1,338	1,355
2027	1,129	1,165	639	637	-	1,295	1,310
2028	1,101	1,134	632	631	-	1,255	1,269
2029	1,080	1,111	629	628	-	1,224	1,237
2030	1,061	1,090	627	625	-	1,197	1,209
2031	1,041	1,068	623	621	-	1,168	1,179
2032	1,022	1,048	619	618	-	1,142	1,152

*Projections are based on an estimated catch of 589 t for 2019, and estimates of 564 t and 553 t used in place of maximum permissible ABC for 2020 and 2021 in response to a Plan Team request to obtain more accurate two-year projections.

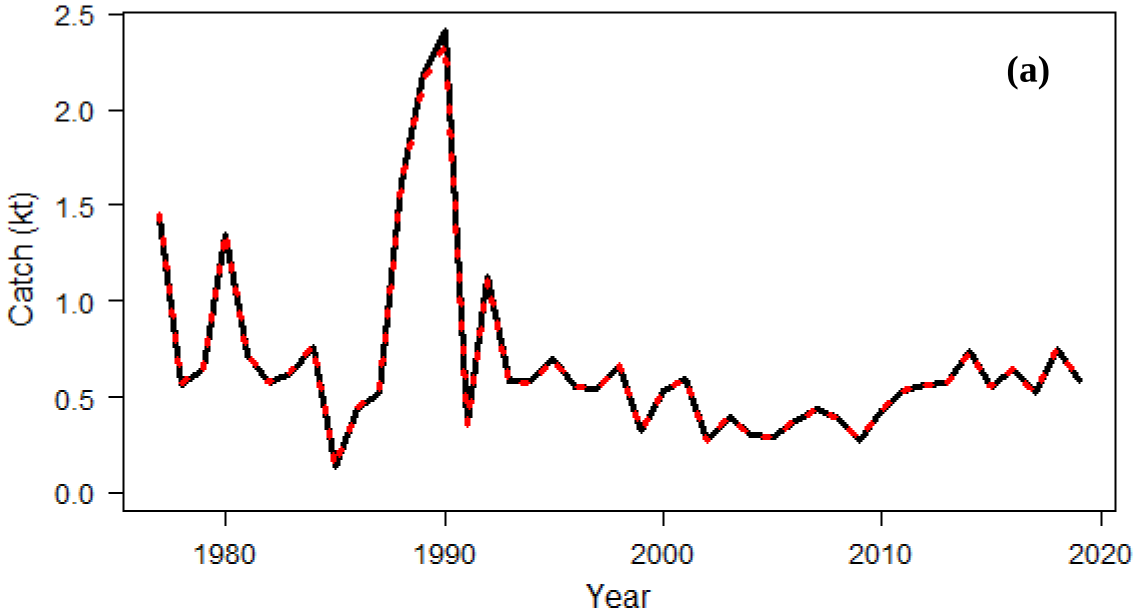
Table 13-21. Allocation comparison table of ABC and OFL for 2020 and 2021 GOA RE/BS rockfish based on the three bottom trawl survey years weighted average method and the two survey random effects model (trawl and longline survey). Recommended allocation of ABC and OFL in bold.

Method	Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
Three Survey Weighted Average			6.63%	55.70%	37.67%	100%
	2020	Area ABC (t)	80	673	456	1,209
		OFL (t)				1,452
	2021	Area ABC (t)	80	675	456	1,211
		OFL (t)				1,455
Two Survey Random Effects			13.88%	37.61%	48.51%	100%
	2020	Area ABC (t)	**168**	**455**	**586**	**1,209**
		OFL (t)				**1,452**
	2021	Area ABC (t)	**169**	**455**	**587**	**1,211**
		OFL (t)				**1,455**

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



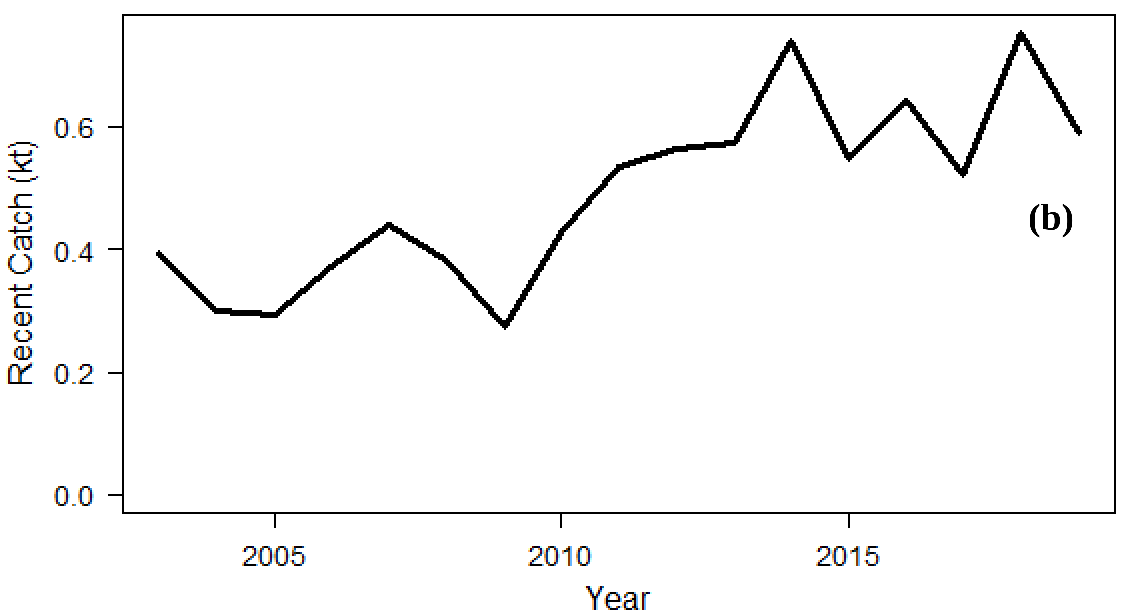


Figure 13-1. Estimated long-term (a) and short-term (b) commercial catches for Gulf of Alaska RE/BS rockfish. Solid line is observed catch and red dashed line (in a only) is predicted catch from the author preferred model.

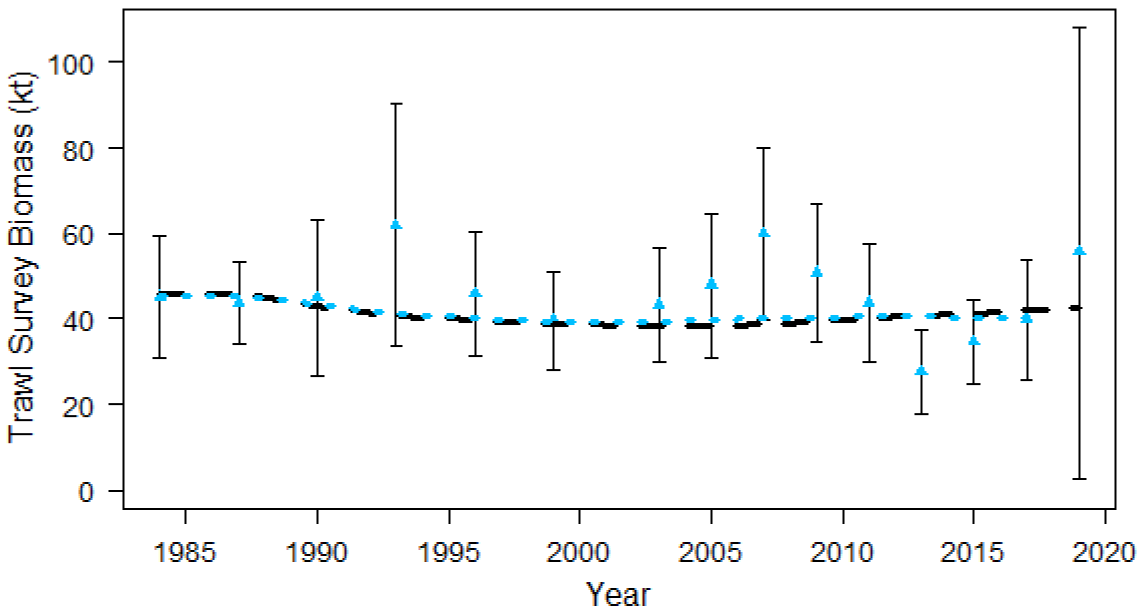


Figure 13-2. AFSC bottom trawl survey observed biomass estimates (blue triangles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the author preferred model (dashed black line) are compared with the last full assessment model fit (dotted blue line).

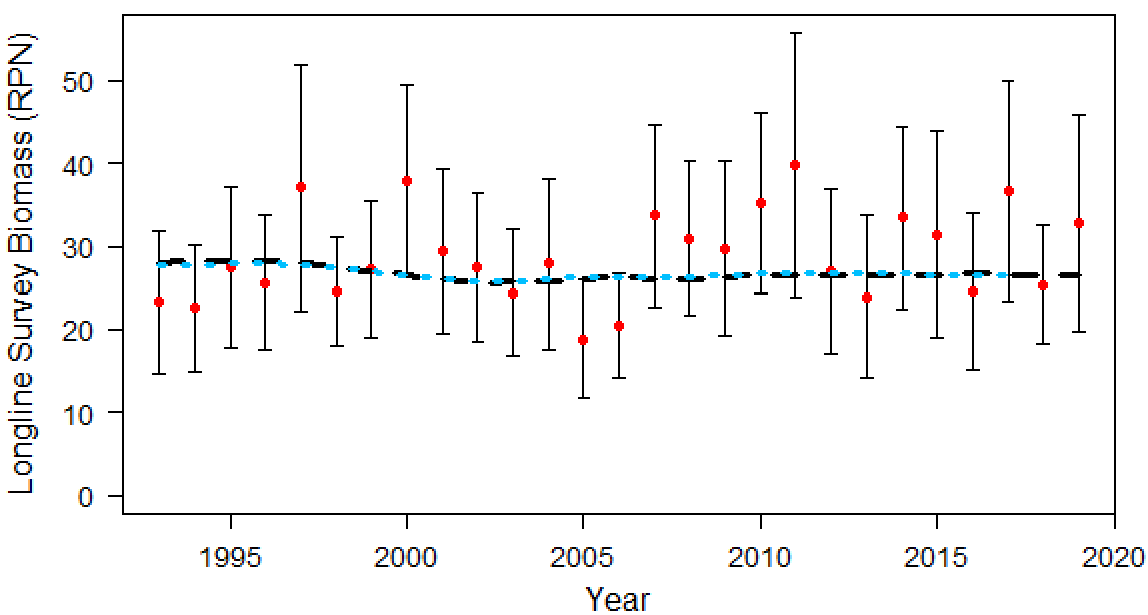


Figure 13-3. AFSC longline survey relative population numbers (RPN in thousands, red circles) with 95% sampling error confidence intervals for GOA RE/BS rockfish. Predicted estimates from the author preferred model (dashed black line) are compared with the last full assessment model fit (dotted blue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

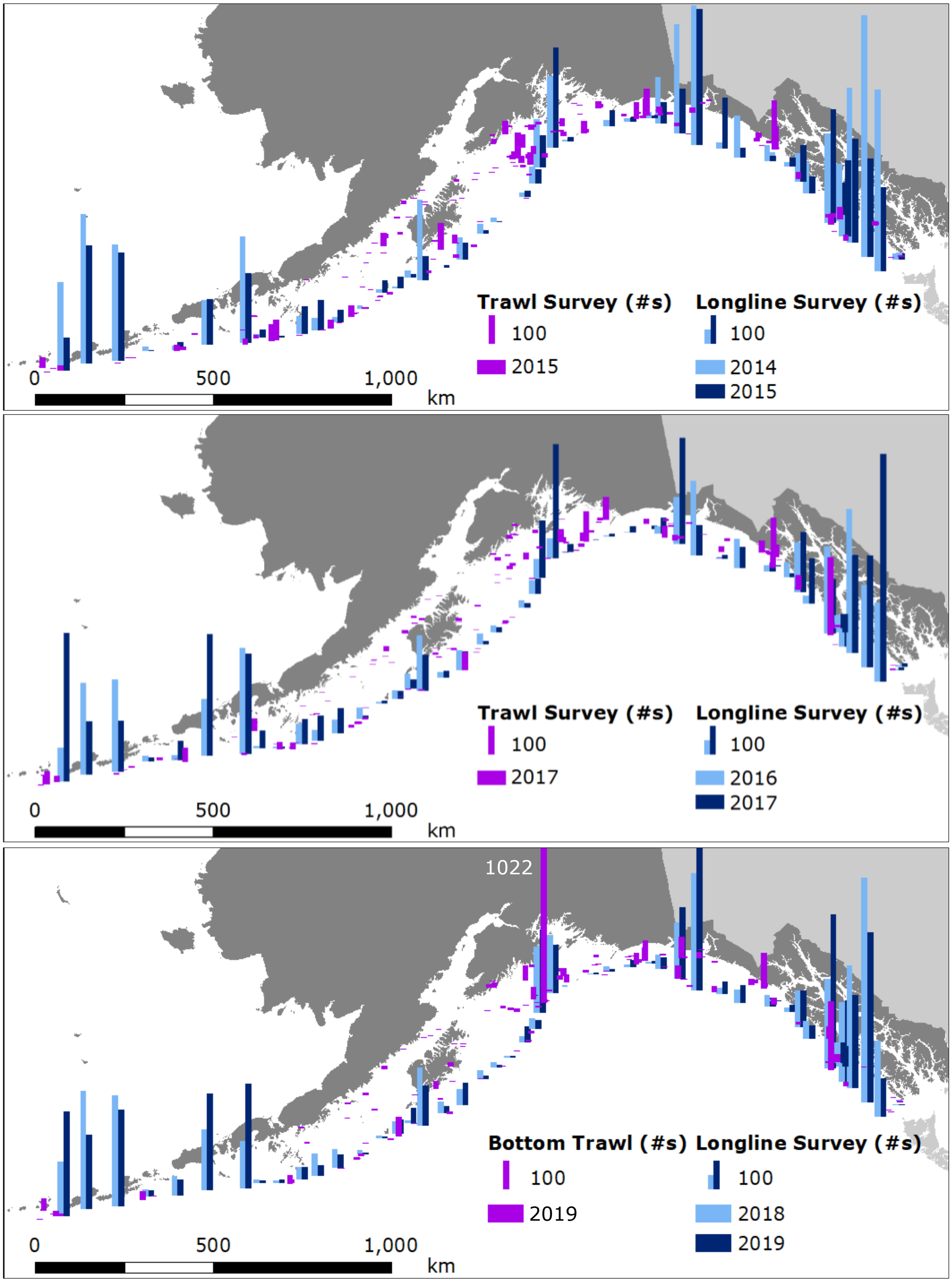


Figure 13-4a. Spatial distribution of rougheye and blackspotted rockfish in the Gulf of Alaska during the 2015, 2017, and 2019 AFSC trawl (purple) and 2014-2019 AFSC longline (blue/navy) surveys.

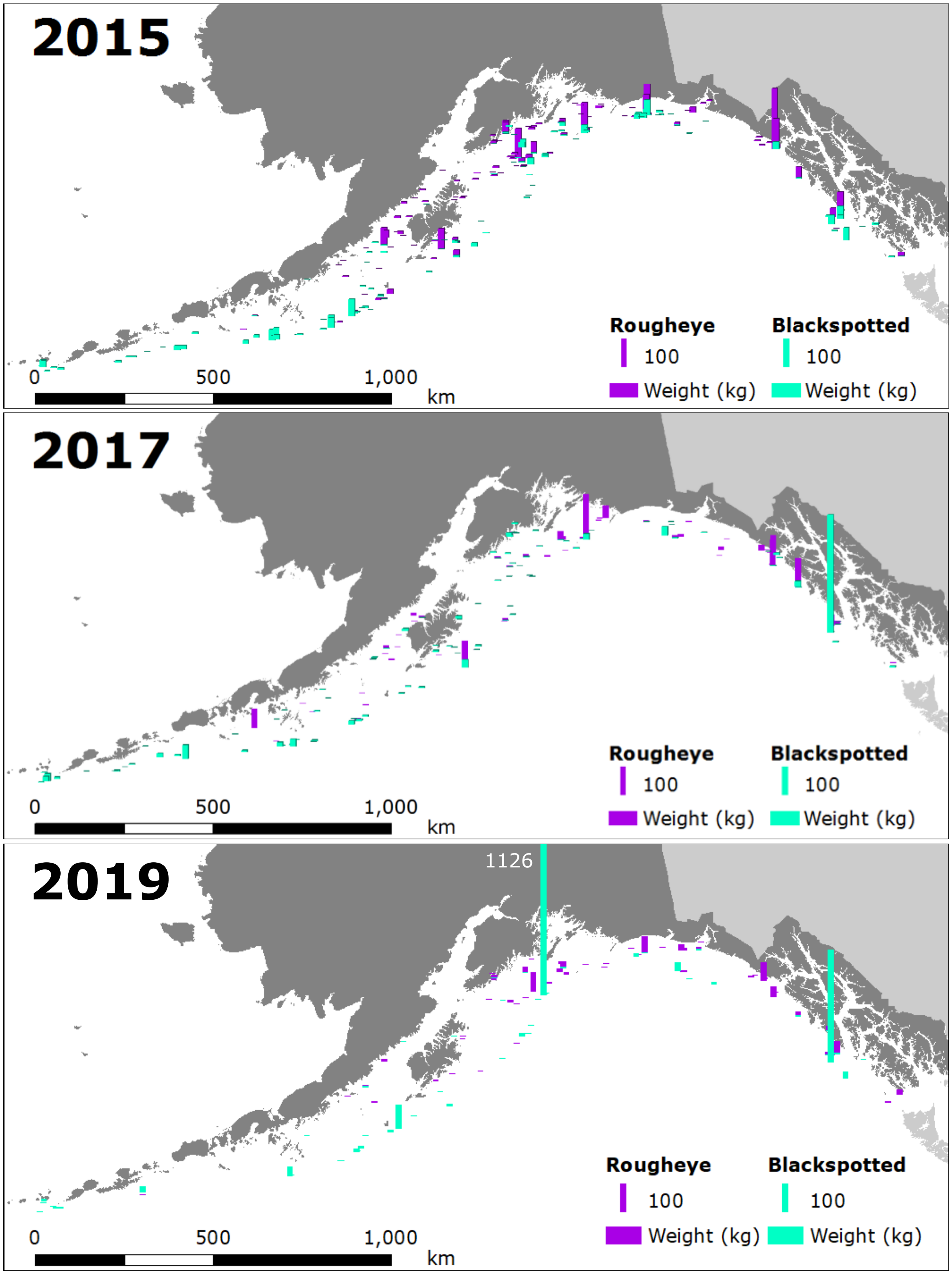


Figure 13-4b. Comparison of the spatial distribution between at-sea identified rougheye (purple) and blackspotted (green) rockfish in the Gulf of Alaska during the 2015, 2017, 2019 AFSC trawl surveys.

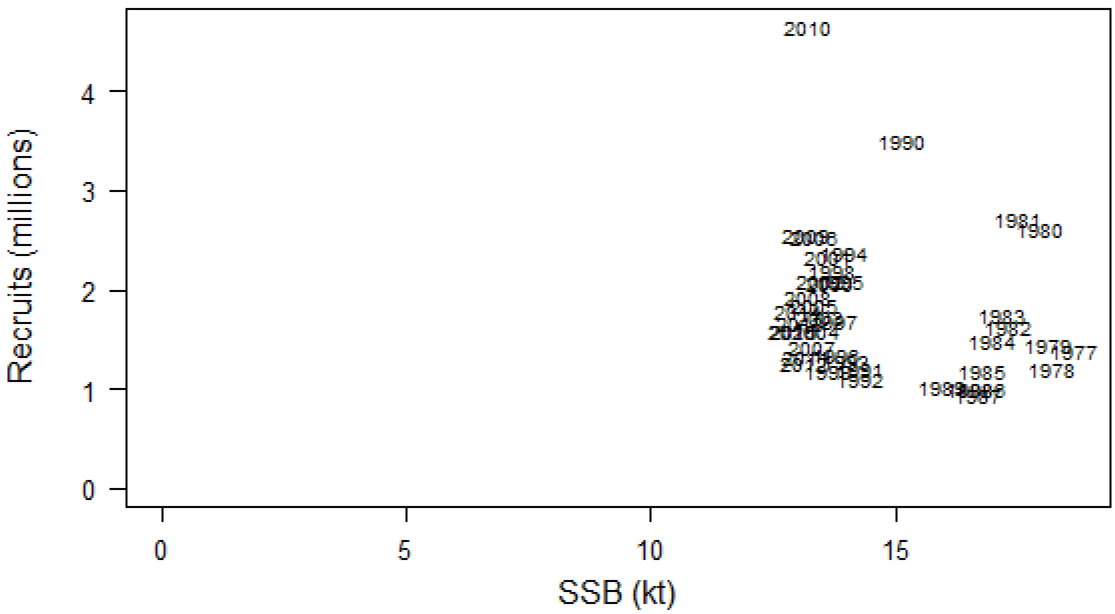


Figure 13-5. Scatterplot of spawner-recruit data for GOA RE/BS rockfish author preferred model. Label is year-class of age-3 recruits. Recruits are in millions and SSB = Spawning stock biomass in kilotons.

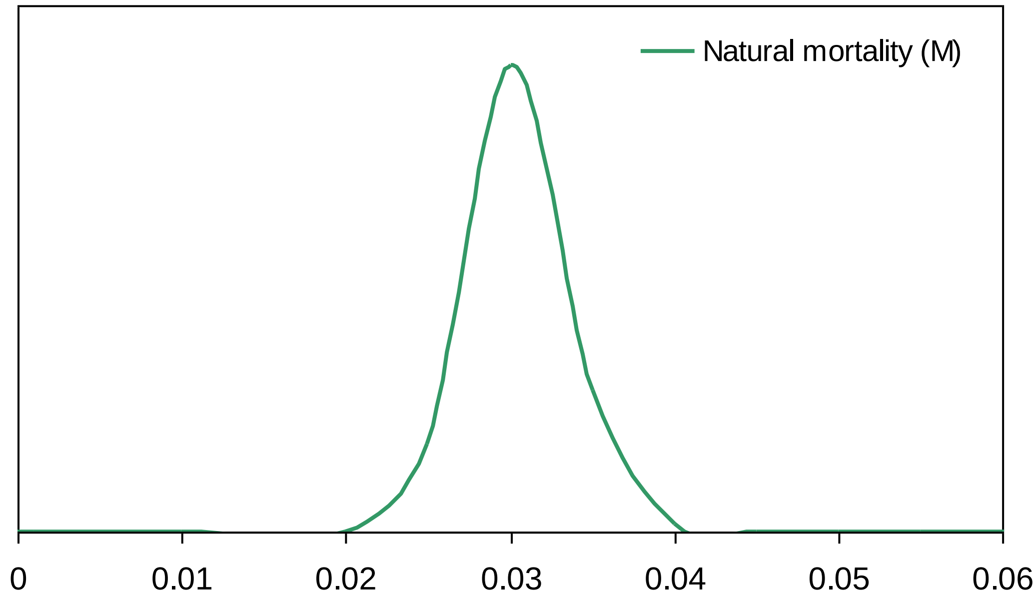


Figure 13-6. Prior distribution for natural mortality (M, μ=0.03, CV=10%) of GOA RE/BS rockfish.

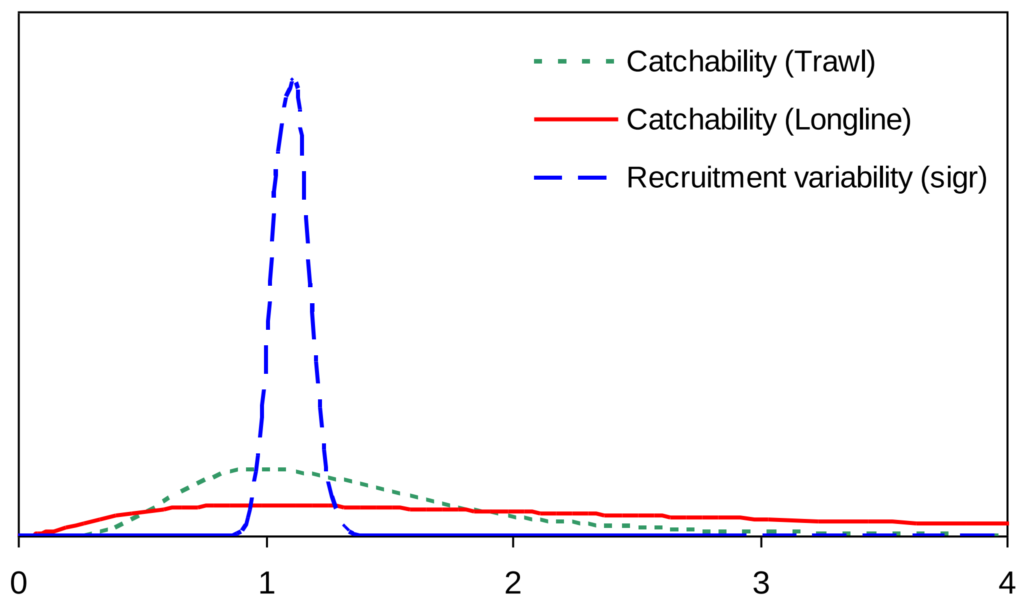


Figure 13-7. Prior distributions for NMFS trawl survey catchability (q1, μ=1, CV=45%), AFSC longline survey catchability (q2, μ=1, CV=100%), and recruitment variability (σ_r, μ=1.1, CV=6%) of GOA RE/BS rockfish.

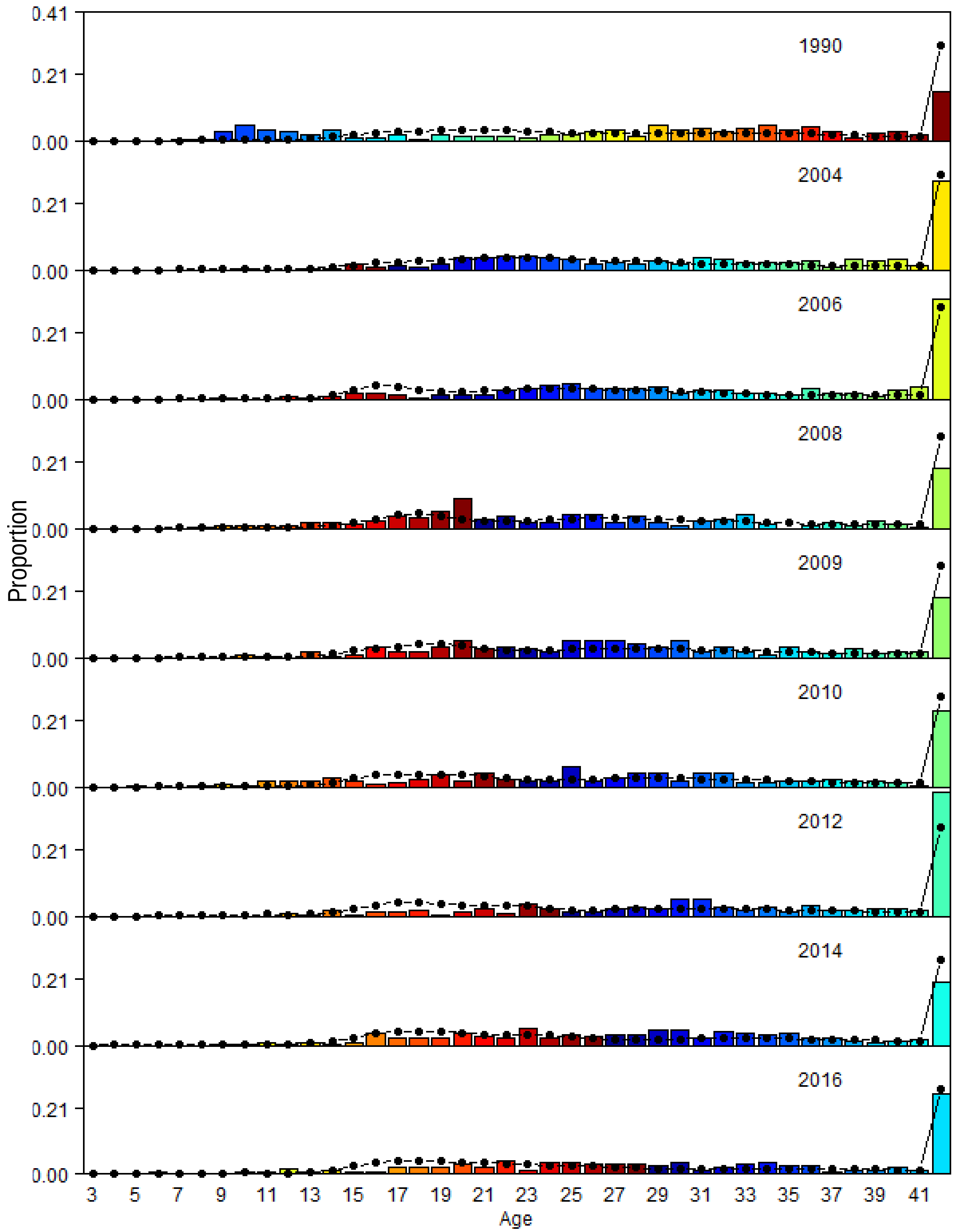


Figure 13-8. Fishery age compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

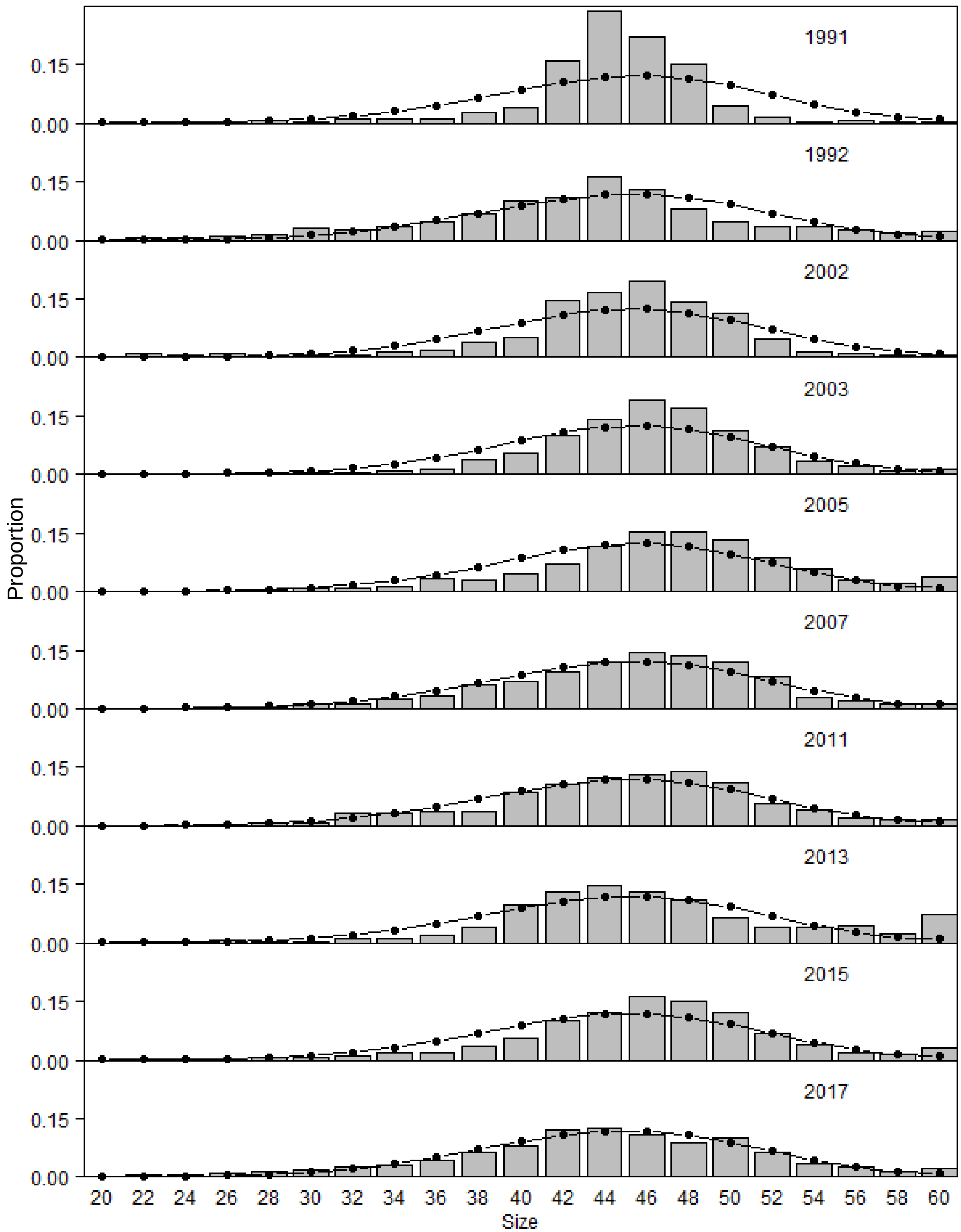


Figure 13-9. Fishery length (cm) compositions for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

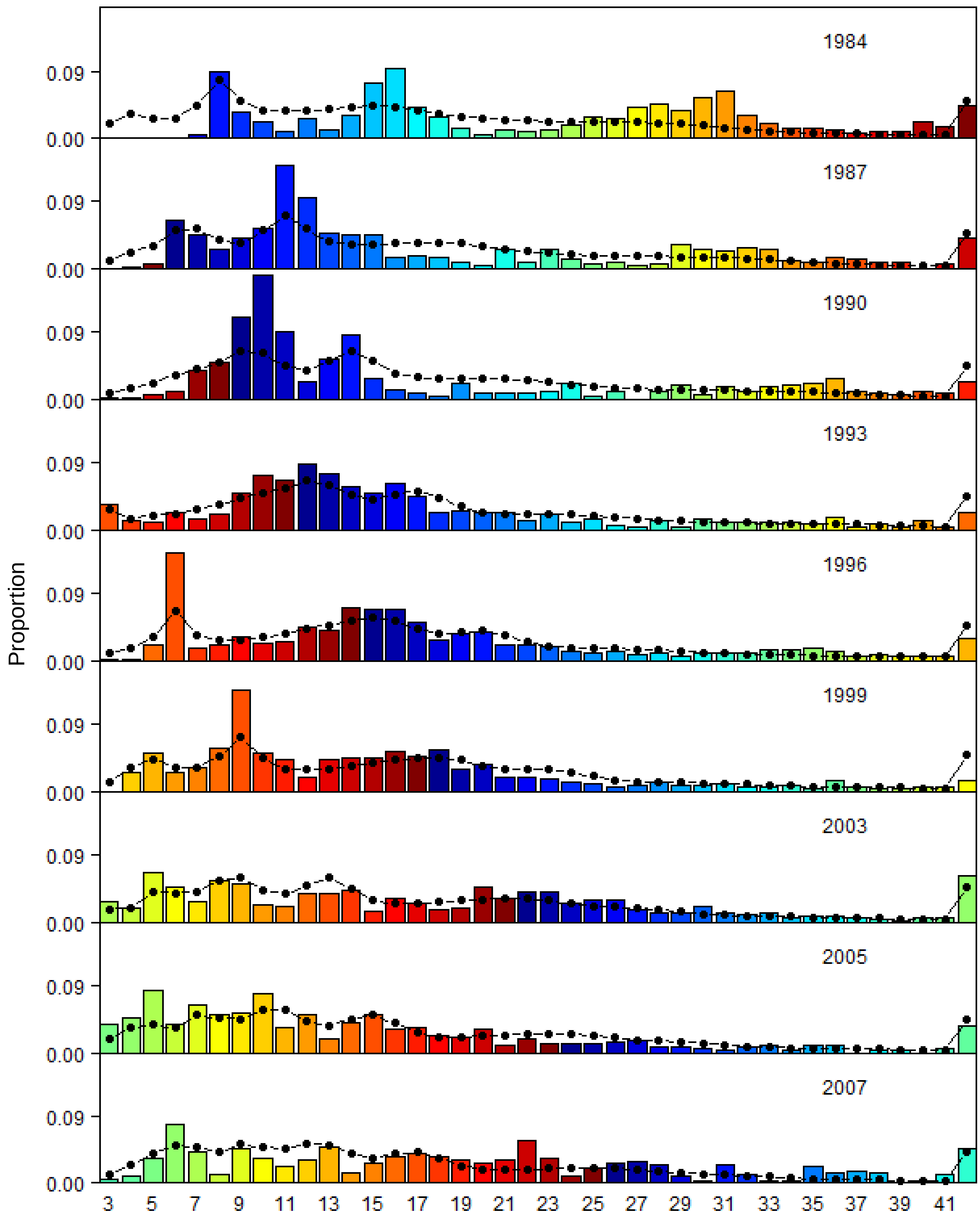


Figure 13-10. AFSC bottom trawl survey age composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

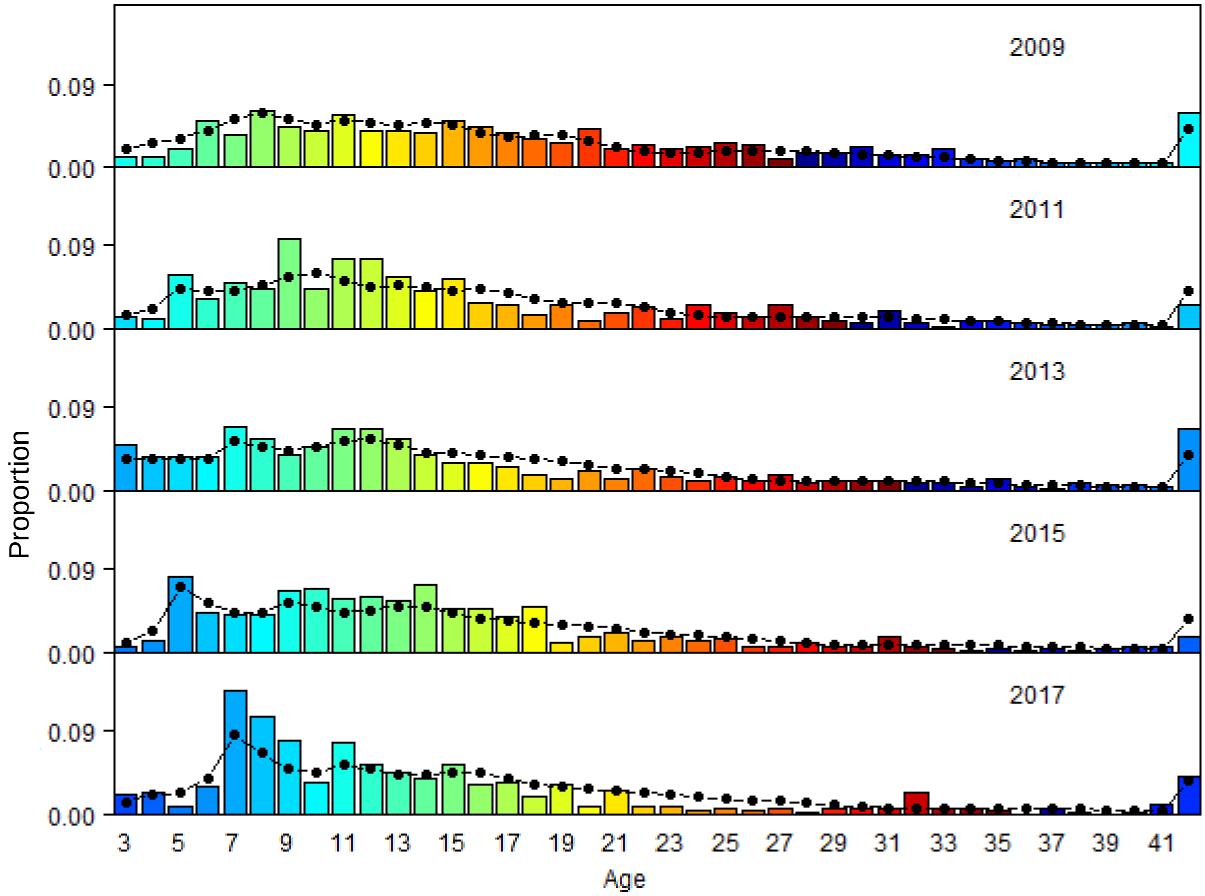


Figure 13-10 (continued). AFSC bottom trawl survey age composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles. Colors follow cohorts.

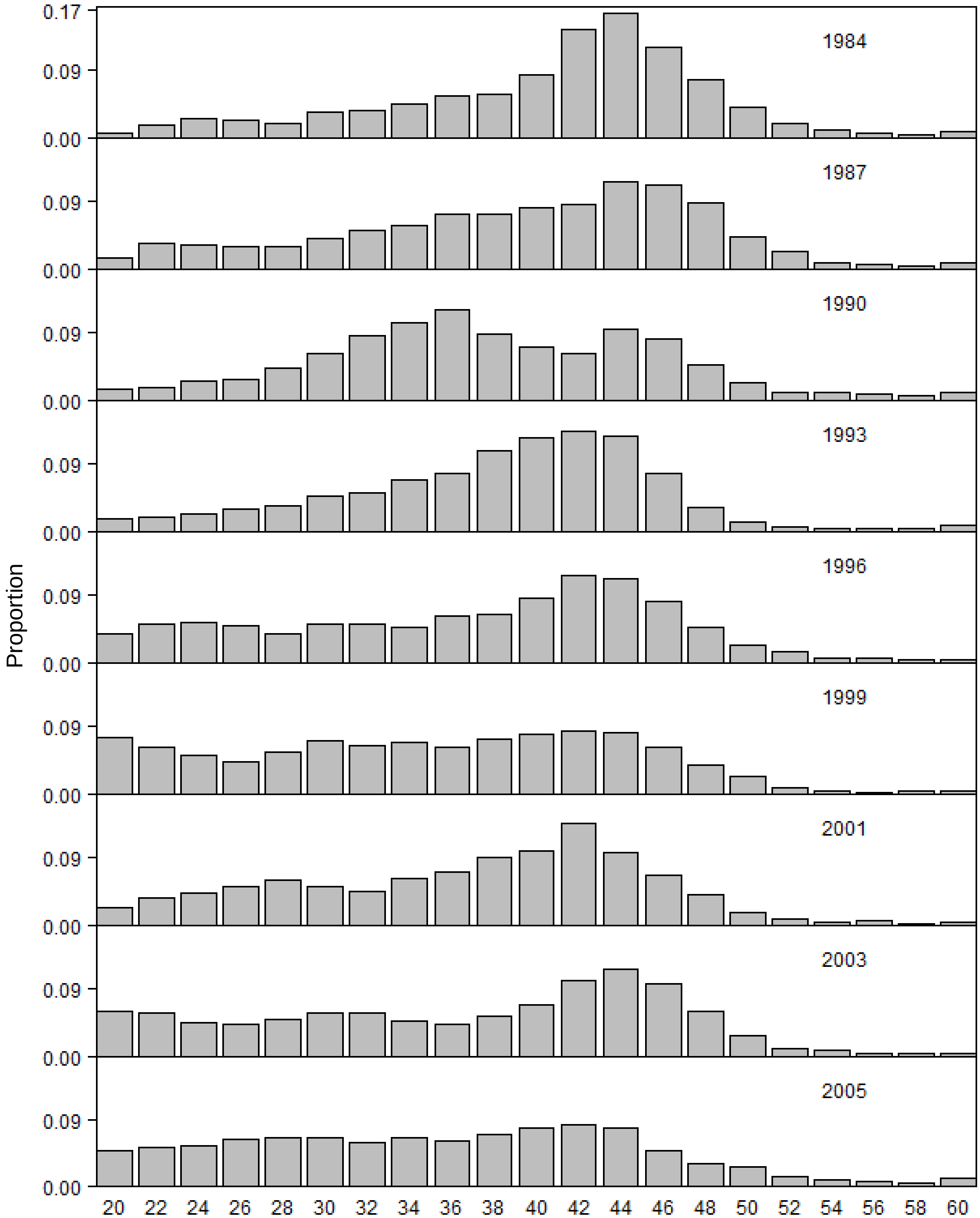


Figure 13-11. AFSC bottom trawl survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in the model.

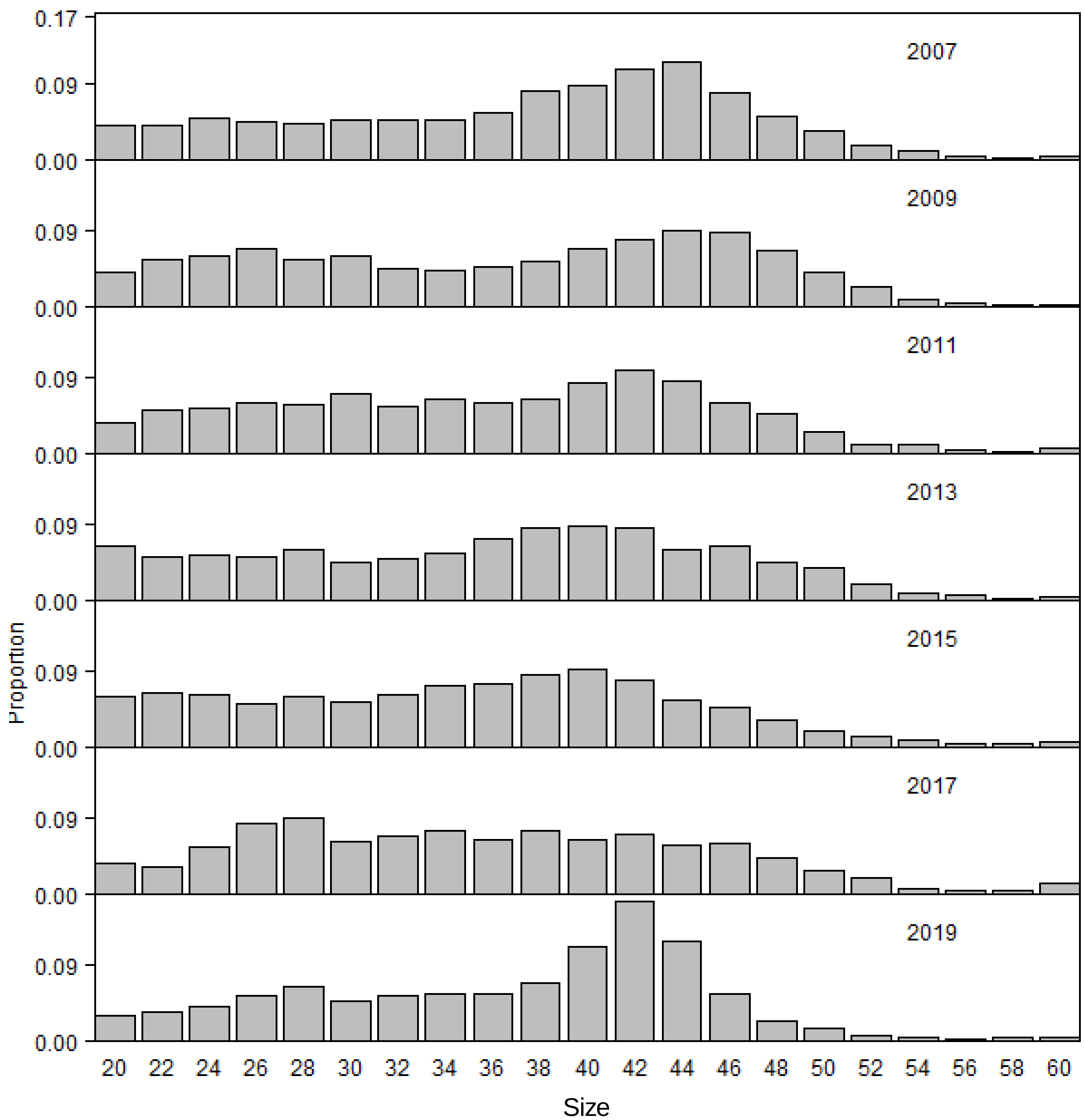


Figure 13-11 (Continued). AFSC bottom trawl survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in the model.

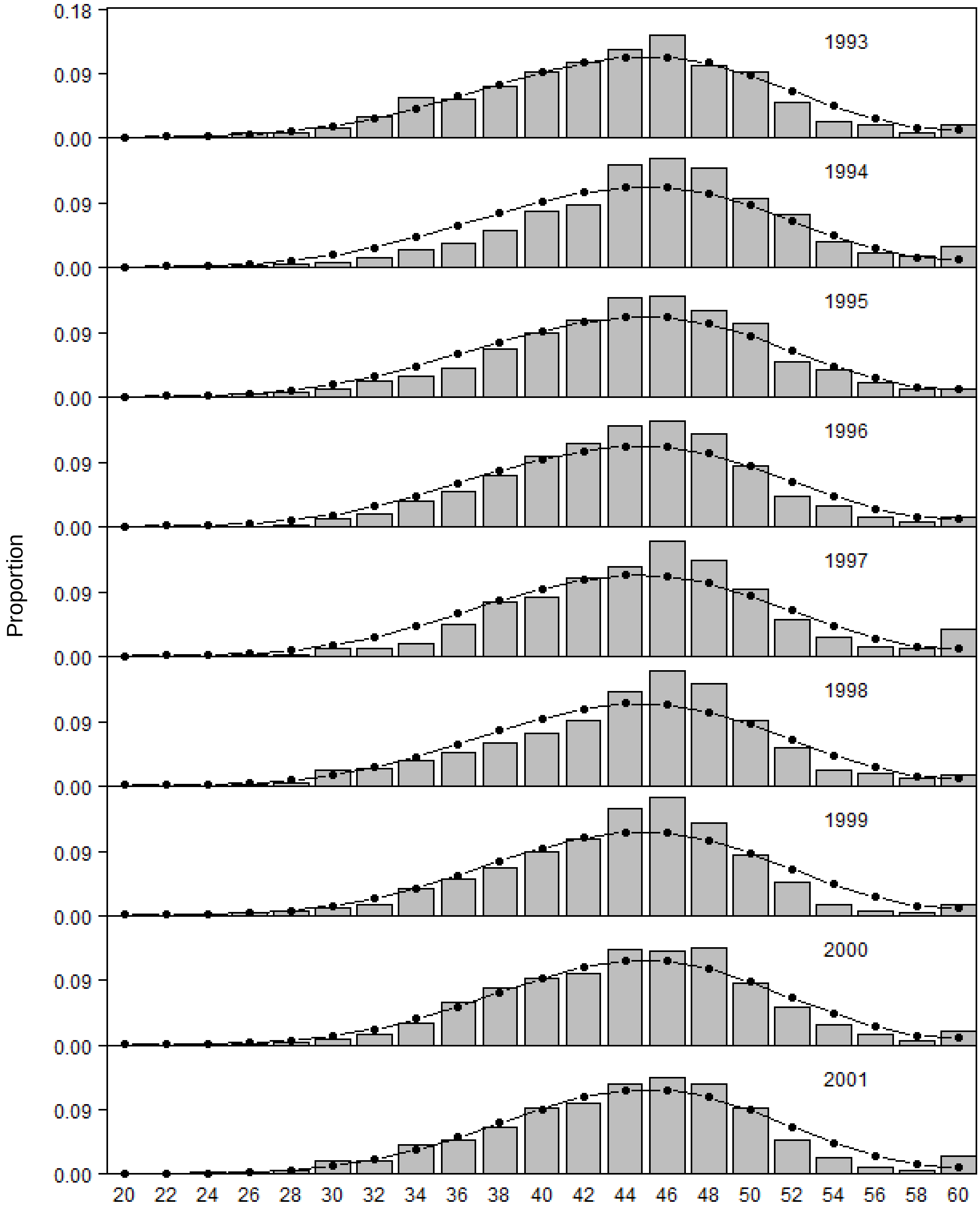


Figure 13-12. AFSC longline survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

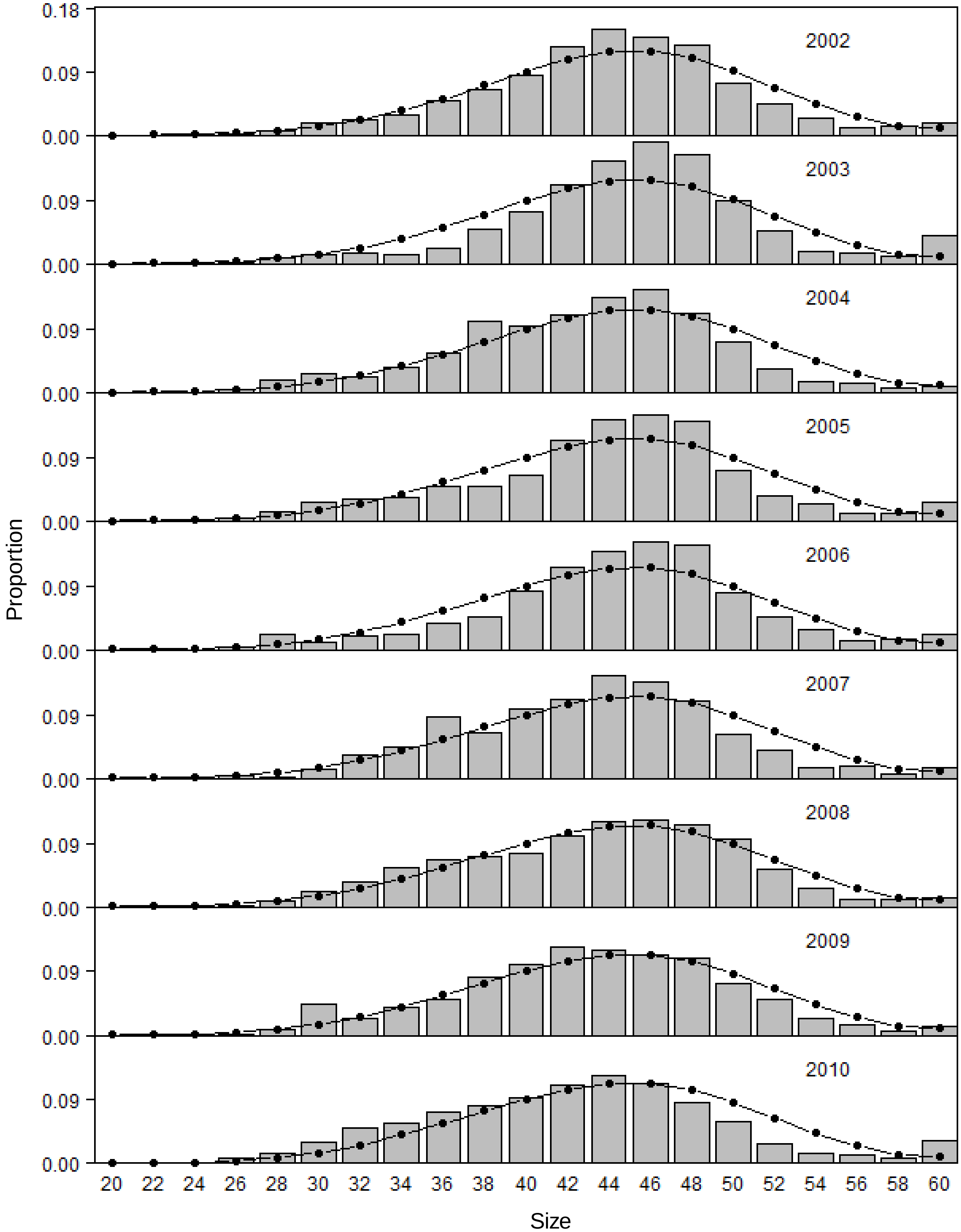


Figure 13-12 (continued). AFSC longline survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

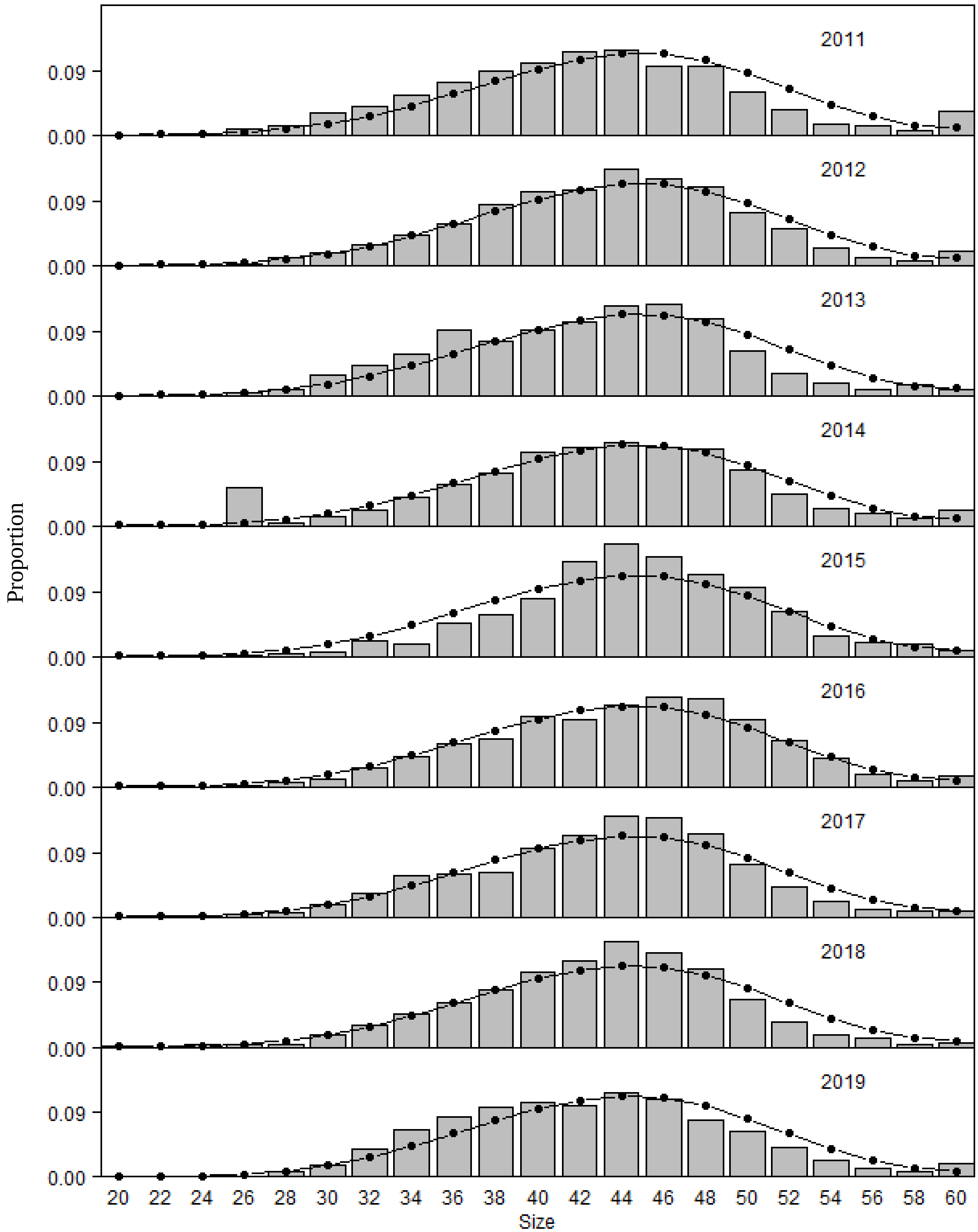


Figure 13-12(continued) AFSC longline survey length (cm) composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author preferred model = lines with circles.

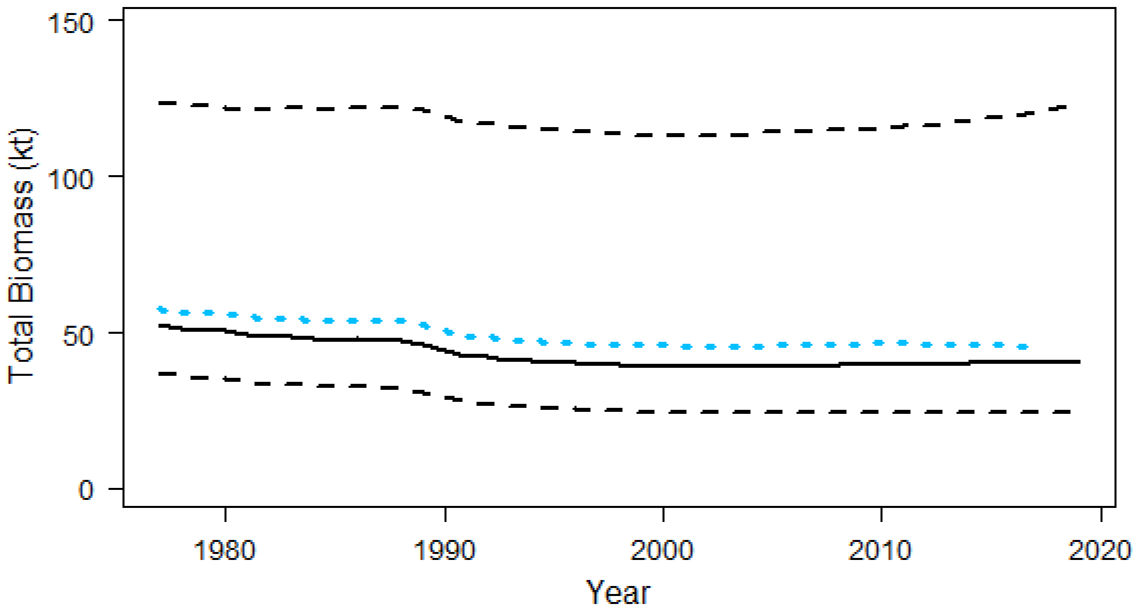


Figure 13-13. Time series of predicted total biomass from author preferred model (solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last full assessment model estimates included for comparison (dotted blue line).

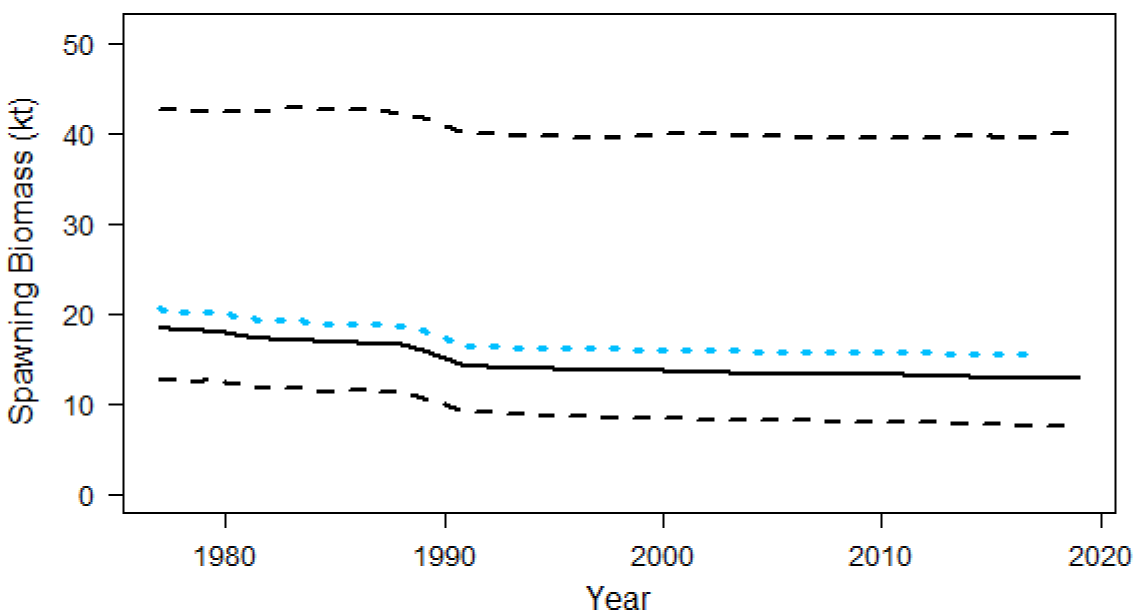


Figure 13-14. Time series of predicted spawning biomass from author preferred model (solid black line) with 95% credible intervals determined by MCMC (dashed black lines) for GOA RE/BS rockfish. Last full assessment model estimates included for comparison (dotted blue line).

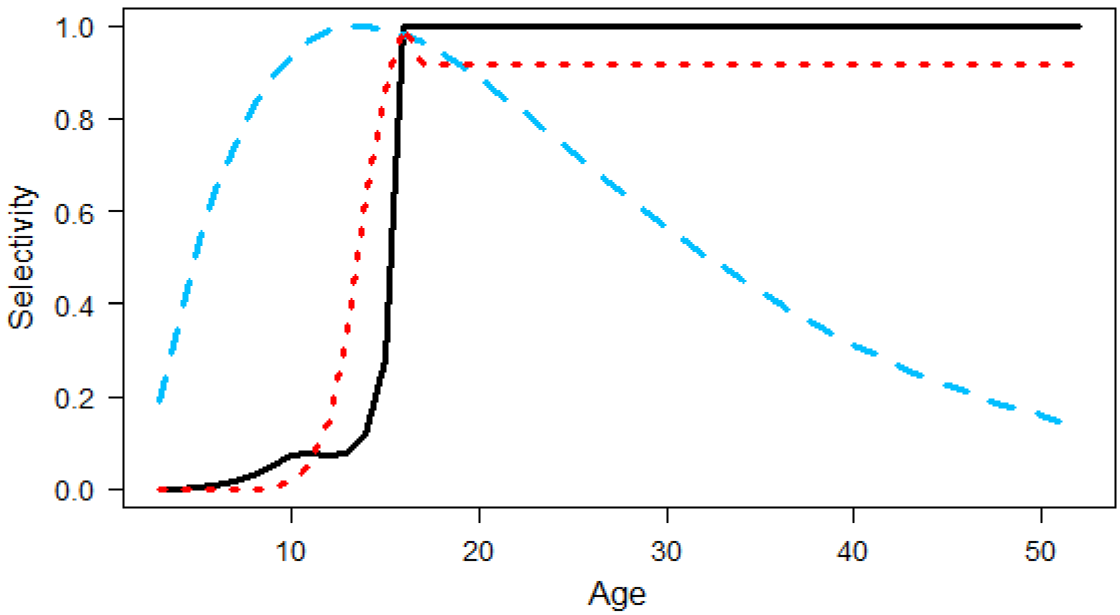


Figure 13-15. Estimated selectivity curves for GOA RE/BS rockfish from author preferred model. Dashed blue line = AFSC bottom trawl survey selectivity, dotted red line = AFSC longline survey selectivity, and solid black line = combined fishery selectivity.

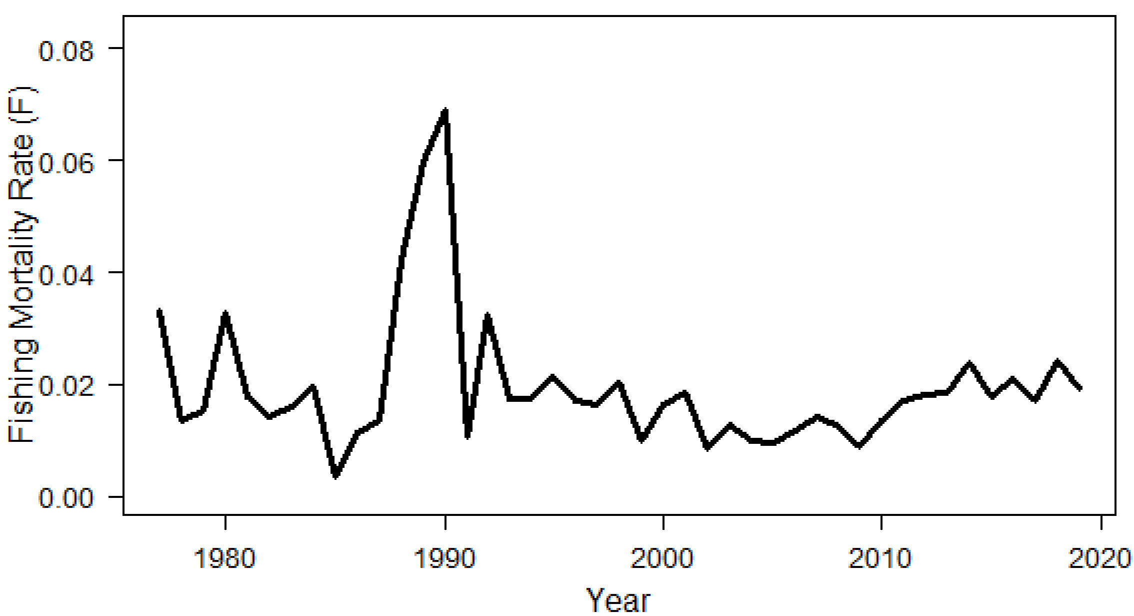


Figure 13-16. Time series of estimated fully selected fishing mortality for GOA RE/BS rockfish from author preferred model.

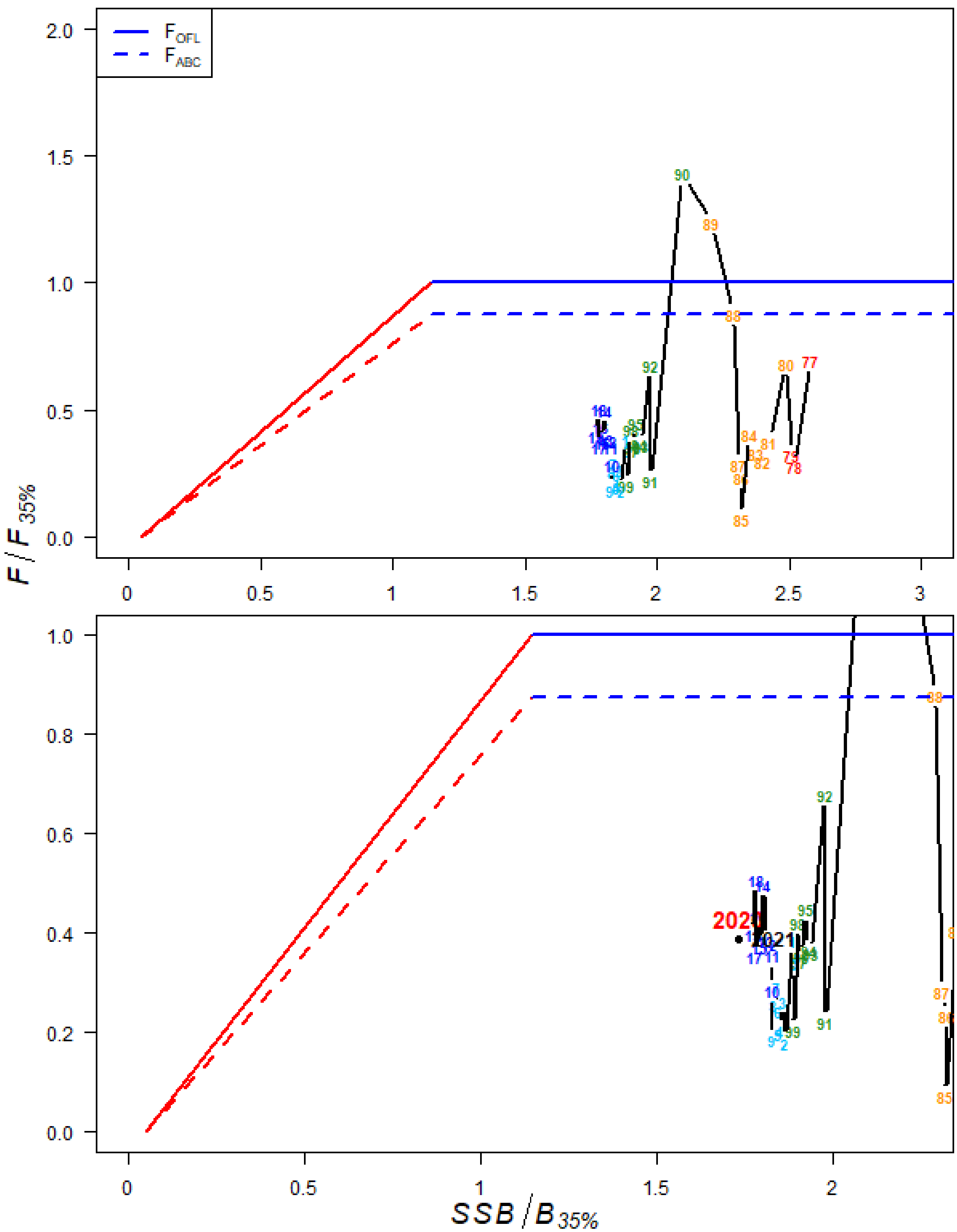


Figure 13-17. Time series of GOA RE/BS rockfish estimated spawning biomass relative to the target $B_{35\%}$ level and fishing mortality relative to F_{OFL} for author preferred model. The upper panel provides the entire time series while bottom panel presents the more recent management path.

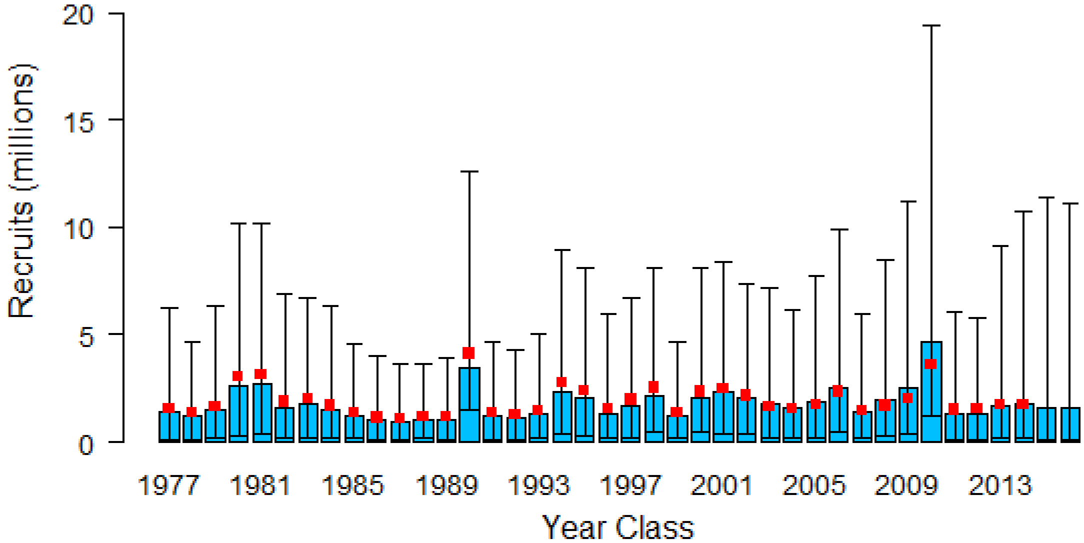


Figure 13-18. Estimated recruitments (age 3) of GOA RE/BS rockfish from author preferred model by year class with 95% credible intervals derived from MCMC. Last full assessment model estimates included for comparison (red squares).

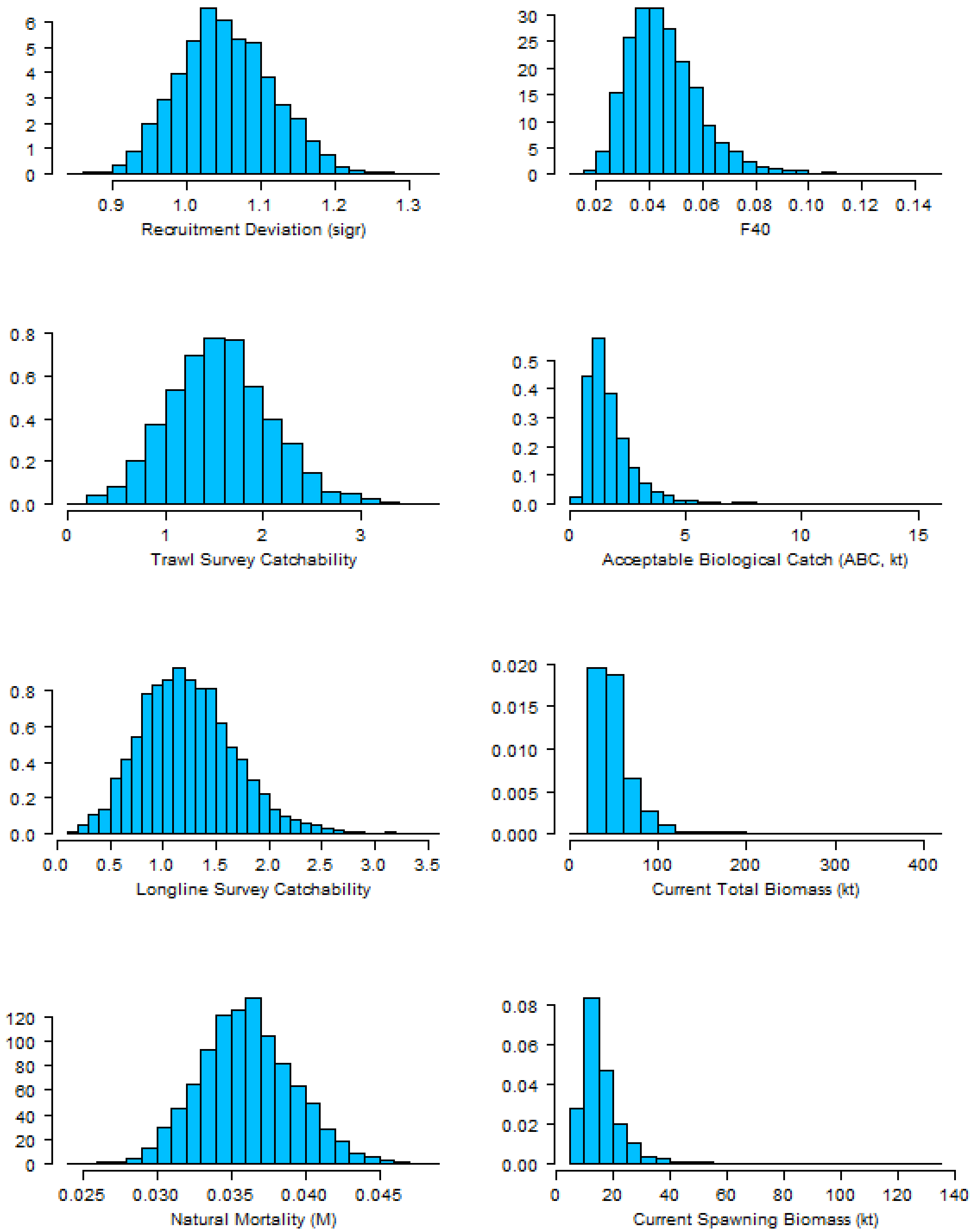


Figure 13-19: Histograms of estimated posterior distributions for key parameters derived from MCMC for GOA RE/BS rockfish.

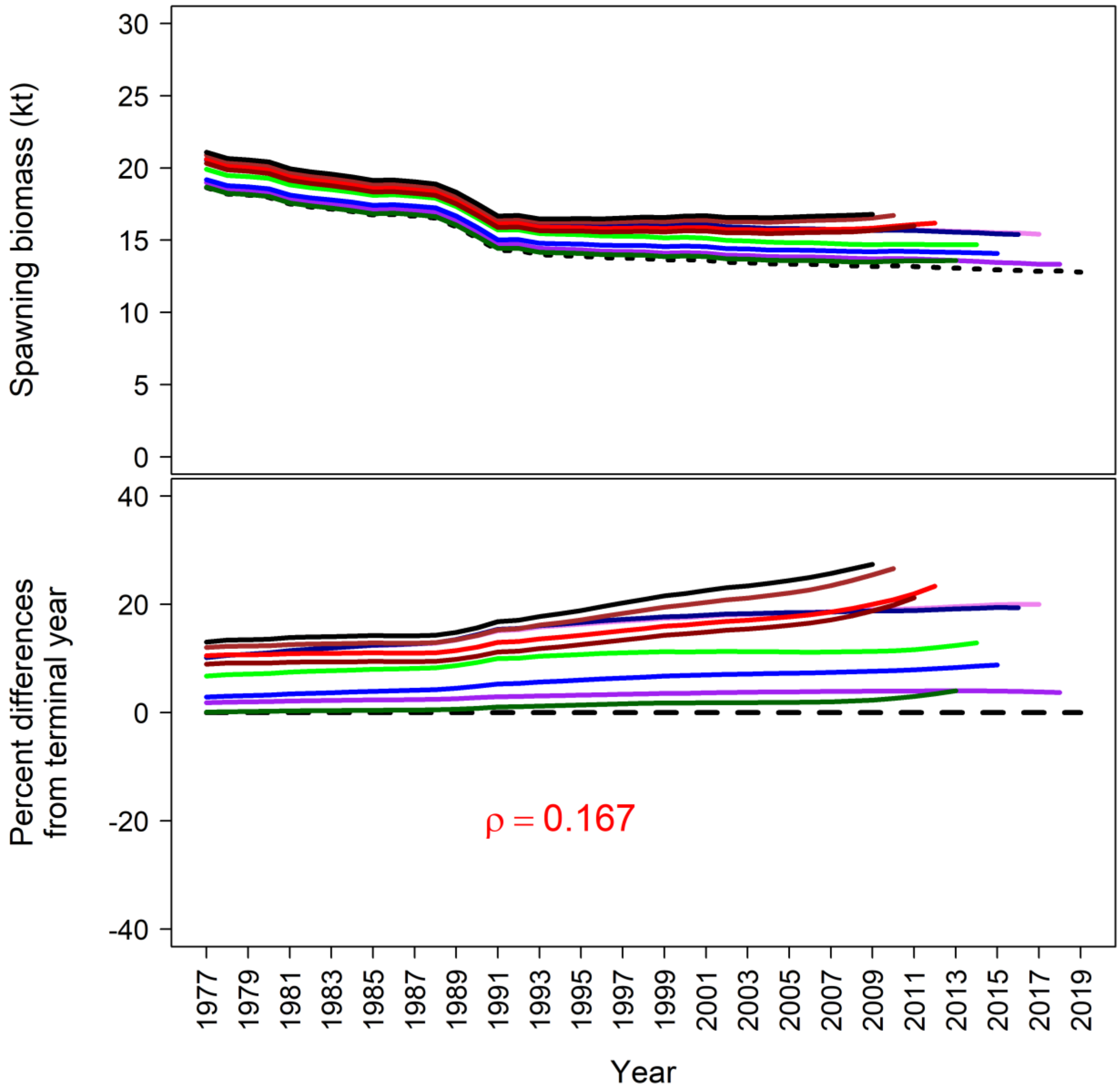


Figure 13-20: Retrospective peels of estimated female spawning biomass for the past 10 years from the author preferred model (top), and the percent difference in female spawning biomass from the preferred model in the terminal year (bottom).

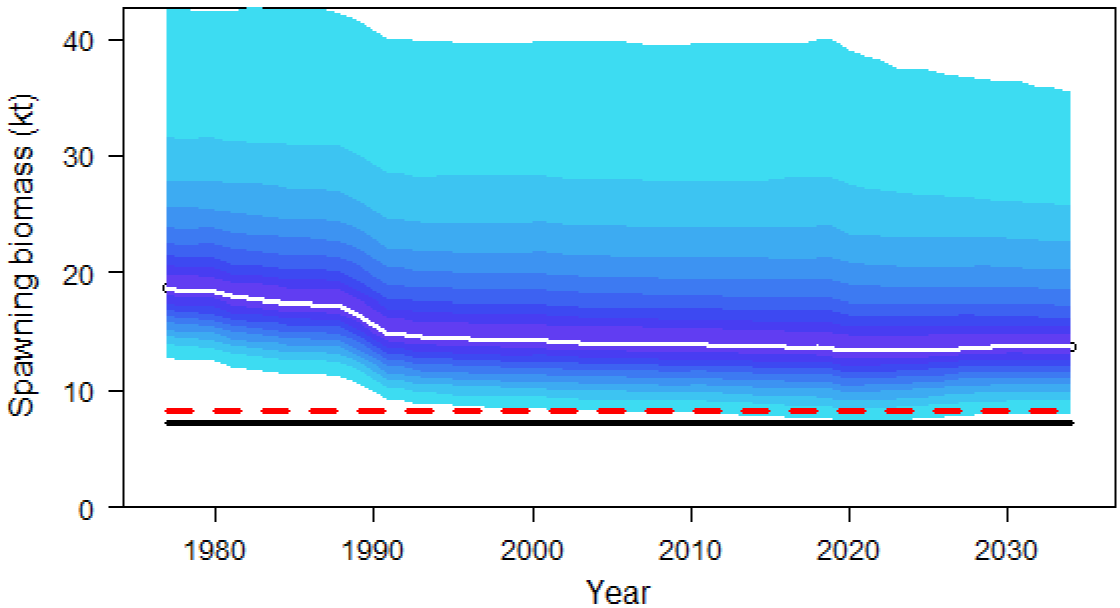


Figure 13-21: Bayesian credible intervals for entire spawning stock biomass series including projections through 2034. Red dashed line is B40% and black solid line is B35% based on recruitments from 1980-2017. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

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 were 1 t in 2016. This is 0.08% of the 2016 recommended ABC of 1,328 t and represents a low risk to the RE/BS stock. Even research catches of this magnitude, however, do not pose a significant risk to the RE/BS stock in the GOA.

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

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

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

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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	**Assessment of RE/BS stock complex in the Gulf of Alaska (Shotwell et al. 2009)**	1			1
1978		2			2
1979		1			1
1980		1			1
1981		6			6
1982		3			3
1983		3			3
1984		17			17
1985		7			7
1986		2			2
1987		13			13
1988		0			0
1989		1			1
1990		5			5
1991		0			0
1992		0			0
1993		10			10
1994		0			0
1995		0			0
1996		5	8		13
1997		0	16		16
1998		45	7		52
1999		28	8		36
2000		0	10		10
2001		2	7		9
2002		0	6		6
2003		3	6		9
2004		0	6		6
2005		5	4		9
2006		0	5		5
2007		8	7		15
2008		0	11		11
2009		6	9		15
2010	AKRO	<1	7	<1	7
2011	AKRO	<1	6	<1	8
2012	AKRO	2	5	<1	6
2013	AKRO	2	4	<1	6
2014	AKRO	<1	<1	<1	1
2015	AKRO	2	<1	<1	3
2016	AKRO	na	1	<1	1
2017	AKRO	2	<1	<1	3
2018	AKRO	<1	2	<1	3

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.

Appendix 13.B Summary of Current Research on Rougheye and Blackspotted Rockfish Speciation

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Introduction

Rougheye (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*) 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 center of abundance appears to be Alaskan waters, particularly the eastern 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). Though relatively little is known about their biology and life history, rougheye and blackspotted rockfish have relatively high fecundity, late maturation, slow growth, extreme longevity, and low natural mortality. These species often co-occur with shortraker rockfish (*Sebastes borealis*) in trawl or longline hauls.

Studies on the genetic differences between the observed types of rougheye rockfish indicate two distinct species (Gharrett et al. 2005, Hawkins et al. 2005). 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 in samples (Seeb 1986) and five distinguishable loci for an Aleutian and Southeast type (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 the Aleutian type rougheye (Hawkins et al. 2005). Additional studies analyzed the variation in mitochondrial DNA and microsatellite loci and determined the two distinct types with relatively little hybridization (Gharrett et al. 2005). Please refer to Shotwell et al. (2009) for more detail on these genetic studies.

In 2005 and 2006, the AFSC longline survey conducted two-day sampling experiments in the eastern GOA near Yakutat Bay. Approximately 250 samples were collected across a depth range of 200-400 m. Three identification methods were performed on each sample: at-sea identification of the fresh fish, expert (J. Orr) identification based on photographs of the fresh fish, and genetic identification in the laboratory to positively determine the species. Initially, misidentification rates in the field and by the expert were 46% and 29%, respectively. The results from these identification exercises led AFSC scientists to be concerned about their ability to accurately distinguish between the two species during surveys. In December 2007, the Science and Statistical Committee (SSC) requested rougheye assessment authors develop a rationale for decisions regarding mixed stock species groups with attention to overfishing the weaker stock.

In 2008, Orr and Hawkins formally verified the two species as rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*). They used combined genetic analyses of 339 specimens from Oregon to Alaska to identify the two species and formulated general distribution and morphological characteristics for each. Rougheye rockfish is typically pale with spots absent from the spinous dorsal fin and potential mottling on the body. Blackspotted rockfish is darker with spotting almost always present on the dorsal fin and body. The two species occur in sympatric distribution with rougheye extending farther south along the Pacific Rim and blackspotted extending into the western Aleutian Islands. The overlap is quite extensive (Gharrett et al. 2005, 2006). Following the Orr and Hawkins (2008) paper, several other morphological features were deemed important for blackspotted rockfish identification. Upon re-examination, the expert misidentification rate was reduced to 9% from the previous 29%. At the time, there was no information on whether the two species had significantly different life history traits (e.g. age of maturity, growth). If differences in growth and maturity existed, one species may be at greater risk to overfishing than the other. This may be particularly true in areas where the two species are caught together in the same haul such as in central and eastern GOA (Gharrett et al. 2005). Additionally, gulf-wide OFLs for this species complex may result in bycatch consisting of a large proportion of one species or the other.

The SSC recognized that a key step toward developing a split species model would be the improvement in the accuracy of species identification. In response to these comments, special projects were initiated during the 2009, 2013, and 2015 AFSC GOA bottom trawl survey. The goals of these projects were to collect relevant biological and genetic data to improve at-sea identification, adjust the species-specific biomass estimates based on misidentification rates, and examine differences in life history characteristics between the two species. Also, an analysis of stock structure for rougheye and blackspotted rockfish was completed in 2010 and included as an Appendix in the partial stock assessment report (Shotwell et al., 2010). Non-genetic information suggested population structure by large management areas of eastern, central, and western GOA. This was 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 were generally focused on the speciation of the RE/BS complex; however, consistencies between the two species also suggested population structure by management area. One such study showed genetic structure consistent with a neighborhood model of dispersion and significant isolation by distance for blackspotted rockfish (Gharrett et al. 2007). However, these data were reanalyzed with a much larger sample size, and no longer exhibited 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). GOA RE/BS rockfish is managed as a Tier 3a species with area-specific Acceptable Biological Catch (ABC) and gulf-wide Overfishing Level (OFL). Given the multiple layers of precaution instituted with relatively low Maximum Retained Allowance (MRA) percentages, a bycatch only fishery status, and the generally low area-specific harvest rates, the current management specifications for RE/BS rockfish were recommended to continue. Catches of RE/BS rockfish have been well below TAC since shortraker and rougheye were separated into different subgroups in 2004.

In 2016, the SSC encouraged the authors to explore methods to improve species identification in the fishery. Preliminary observed differences in spatial distributions and growth from the initial special projects on the bottom trawl survey suggested to the SSC that rougheye and blackspotted rockfish should be assessed separately once the information was sufficient to make this change. The SSC requested that the author evaluate the available information to separately assess the two stocks and any associated data gaps. To date, several recent research projects are focused on evaluating different aspects of the rougheye and blackspotted rockfish population including estimation of at-sea misidentification rates, evaluation of biomass, age, and length compositions by species, species-specific maturity and skip-spawning, species-specific growth, and otolith morphometric feasibility. We present the current status of several of these projects along with previous summaries from the Shotwell et al., (2017) SAFE report to provide a comprehensive accounting of the available information for evaluating the status of rougheye and blackspotted rockfish and the potential for implementing a split species model in the future.

Data

We present a table of current research projects that shows the source and data for a given project along with the years that the data are available.

Source	Project Data	Years Available
Fisheries	Otolith metrics*	1990, 2004, 2009, 2012, 2013, 2014
	Maturity*	2008-2014 (Conrath 2017), 2015
AFSC bottom trawl survey	Genetic ID*	2009, 2013, 2015
	Biomass Index	2007, 2009, 2011, 2013, 2015, 2017, 2019 (at-sea ID)
	Age	2007, 2009, 2011, 2013, 2015, 2017, 2019 (at-sea ID)
	Length	2007, 2009, 2011, 2013, 2015, 2017, 2019 (at-sea ID)
	Otolith metrics*	1990, 1999
	Maturity	2008-2016 (Conrath 2017)

*Analysis is in progress

Research Projects

We organized the current research projects on rougheye and blackspotted rockfish into three main categories of Identification, Growth, and Maturity. Many projects are currently in progress and we plan to provide updates to this research in the next full assessment as they become available.

Identification: Genetics

There is difficulty in accurate at-sea field identification between the two species. Early studies in 2005 and 2006 found that on average, when compared to genetic identifications, field scientists had a misidentification rate of approximately 46% (samples in eastern GOA near Yakutat), while the expert (Jay Orr) had misidentification rates of 9% (Shotwell et al. 2009). Special projects were initiated during the 2009, 2013, and 2015 AFSC GOA bottom trawl survey to more fully evaluate the misidentification rates given an updated field identification key for rougheye and blackspotted rockfish. The goals of these projects were to collect relevant biological and genetic data to improve at-sea identification, adjust the species-specific biomass estimates based on misidentification rates, and examine differences in life history characteristics between the two species. Field scientists collected length, weight, and muscle tissue (2009, n=895) or fin clips (2013, n=853, and 2015, n= 518) from most rougheye and blackspotted rockfish sampled for otoliths. These samples included most of the unidentified rougheye/blackspotted specimens that were sampled for otoliths.

Misidentification rates for the 2009, 2013, and 2015 trawl surveys were calculated and compared between surveys (see Figure below). When compared to genetic identifications, field scientists had overall misidentification rates of 23%, 13%, and 18% for the three years, respectively. There appears to be continued improvement for correctly identifying blackspotted rockfish in the field (from 31% to 9%), while the opposite seems to be occurring for rougheye rockfish with increased misidentification rates over the three surveys (6% to 25%). Hybrids also exist between the two species. For example, the 2009 survey genetics identified that 11% of the fish were hybrids. These hybrids were mostly identified as rougheye rockfish in the field (82 %).

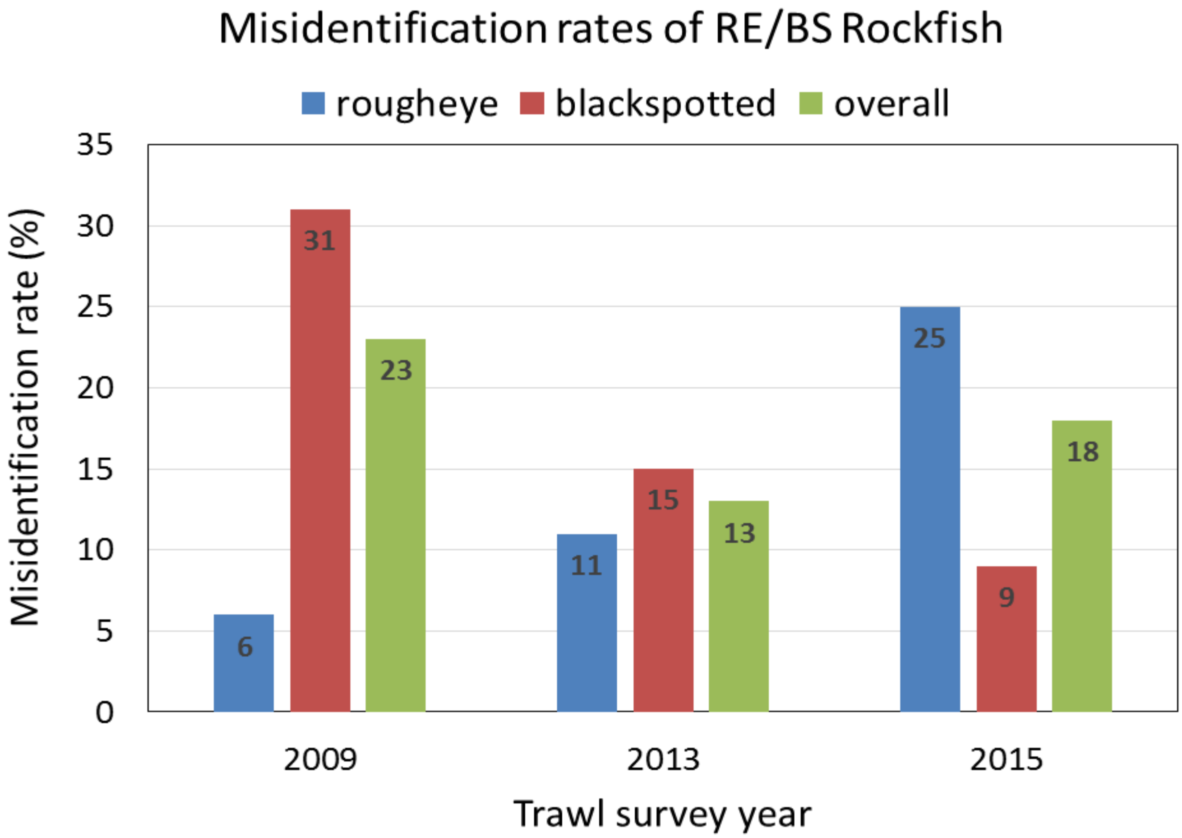


Figure above shows misidentification rates of rougheye and blackspotted rockfish for three bottom trawl surveys in the Gulf of Alaska (2009, 2013, 2015). Text values in bars indicate actual rate.

Trawl survey data were adjusted for species misidentification rates to compute species specific biomass estimates and age compositions.

Year	Rougheye	Blackspotted	Total
2009	22,270	25,092	47,362
2013	17,246	9,695	26,941
2015	24,134	8,212	32,346

For the 2009 survey the adjusted data indicated that 44%, 49%, and 7% of the estimated biomass was comprised of rougheye, blackspotted, and hybrids, respectively. These percentages shifted to 63%, 35%, 2% for the 2013 survey and 70%, 24%, and 6% for the 2015 survey, for rougheye, blackspotted and hybrids, respectively. Using at-sea identifications for these years, resulted in percentages for rougheye and blackspotted, respectively of 64% and 36% for 2009, 64% and 37% for 2013, and 73% and 27% for 2015, with only half a percent of hybrids identified in 2009.

Even though the misidentification rates were fairly large, the corrected biomass estimates for 2013 and 2015 are fairly similar to the uncorrected estimates. However, given the large shift from 2009 to 2013, it seems important to continue to evaluate the mis-identification rates of these species to determine whether that early shift was due to true changes in distribution or an artifact of training to identify a new set of species. Also, this shift could be due to actual changes in the distribution of the two species by area/depth or an artifact of changes in the survey sampling protocol to not sample the deeper stations.

Identification: Otolith Morphometrics

A promising approach using otolith morphology combined with ageing data and genetics may enable the species composition in historical samples to be assessed. For example, preliminary application of this method using age samples collected from the 2009 fishery indicated that the catch in numbers was 57% blackspotted rockfish and 43% rougheye rockfish which is somewhat higher than the 2009 survey estimates but fairly close (C. Hutchinson, *Pers. comm.*).

Preliminary plots of the otolith metrics by age using the 2009 data that were also genetically identified are shown below:

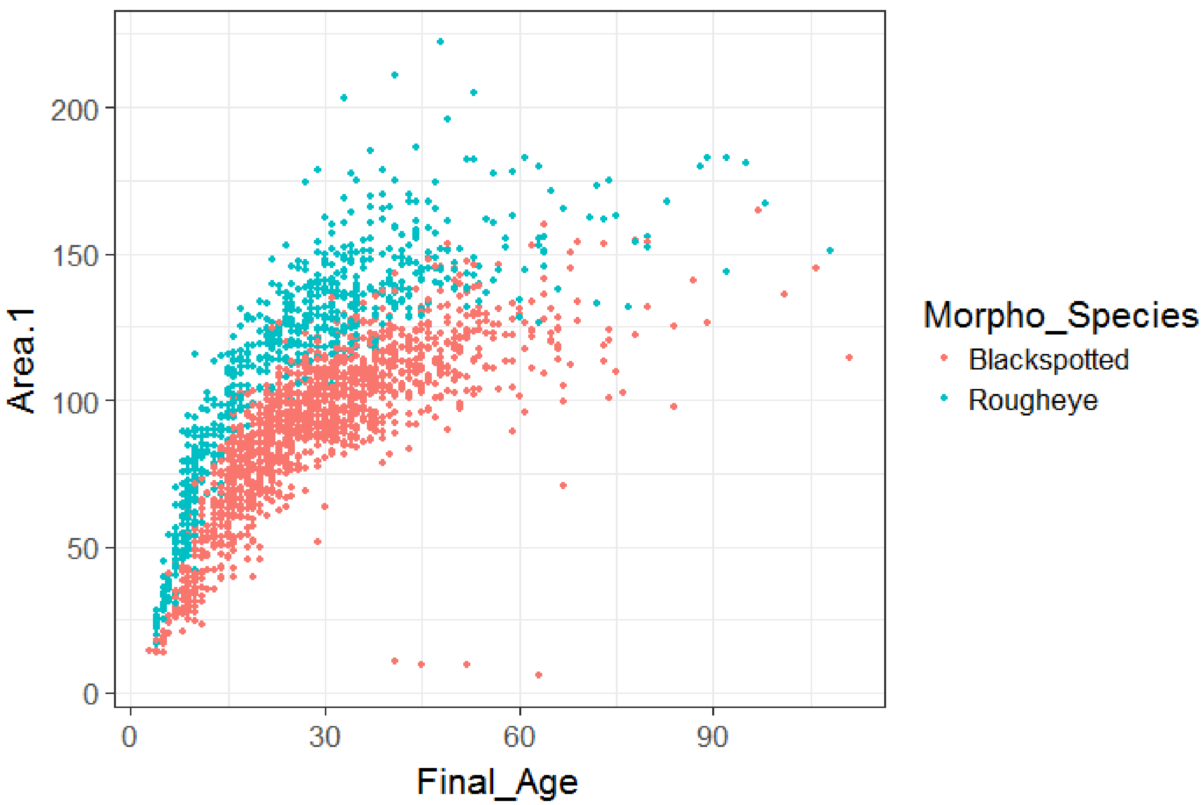


Figure showing otolith area by age for rougheye (green dot) and blackspotted (red dot) rockfish.

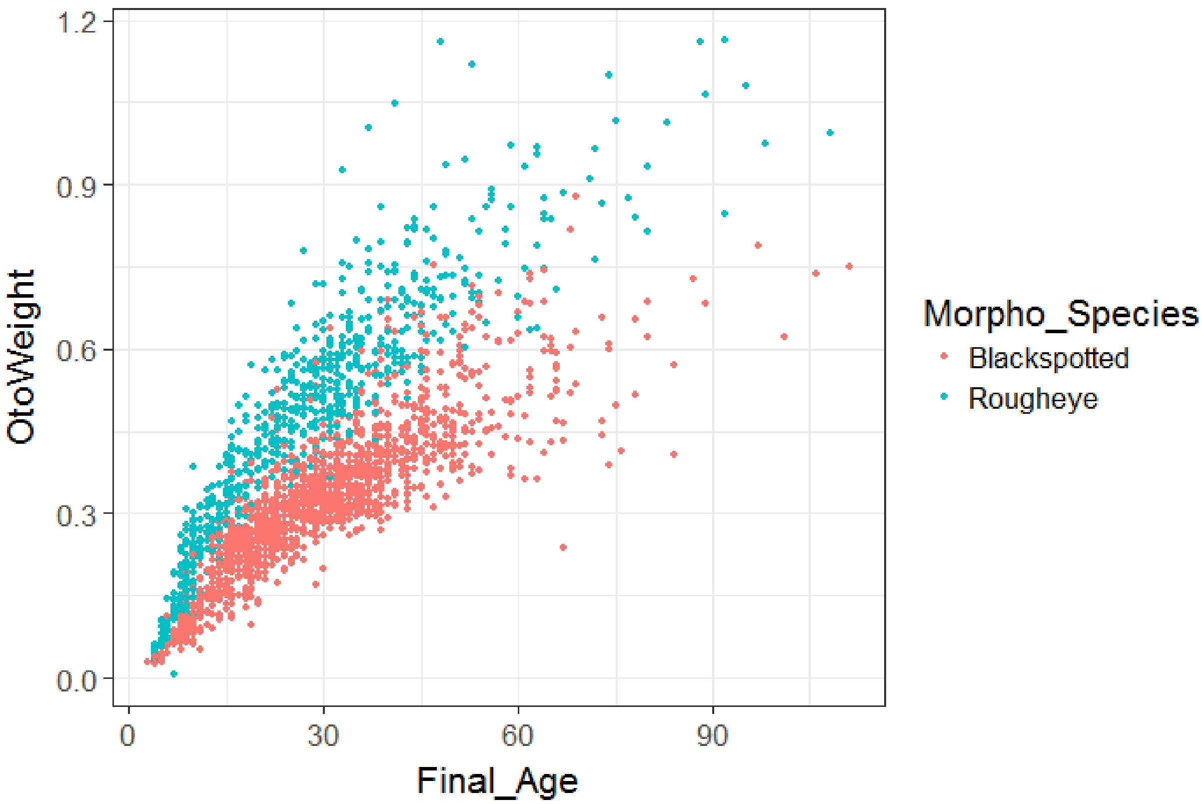
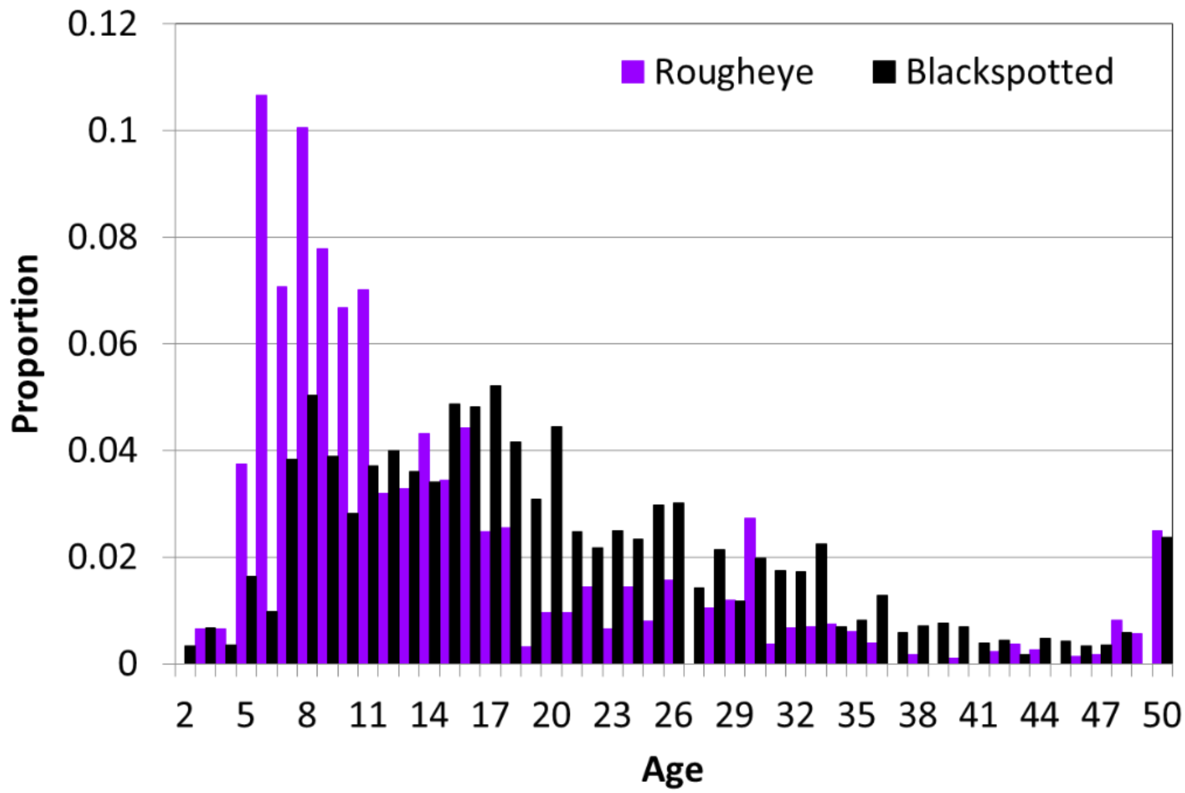


Figure showing otolith weight by age for rougheye (green dot) and blackspotted (red dot) rockfish.

Both measures of otolith area and otolith weight separate the species relatively well. Preliminary linear models to examine the characteristics of both the standard (age, length) and otolith metrics (area, weight) show that otolith weight and area contribute the most to the discrimination between species.

Growth

Trawl survey age compositions from samples taken in 2009 indicate that the average age of blackspotted and rougheye rockfish was 20 and 15 years, respectively (see figure below). The majority of the trawl survey age composition for rougheye rockfish was less than 20 years old whereas blackspotted rockfish had a more uniform age composition over the 7-20 year old age range. Data from the 2013 and 2015 trawl survey have been analyzed for species misidentification rates, and analysis of aging data is in progress.



A comparison of length by age for all samples from the 2009 survey illustrates the difference between the at-sea identification and the genetic identification (see figures below).

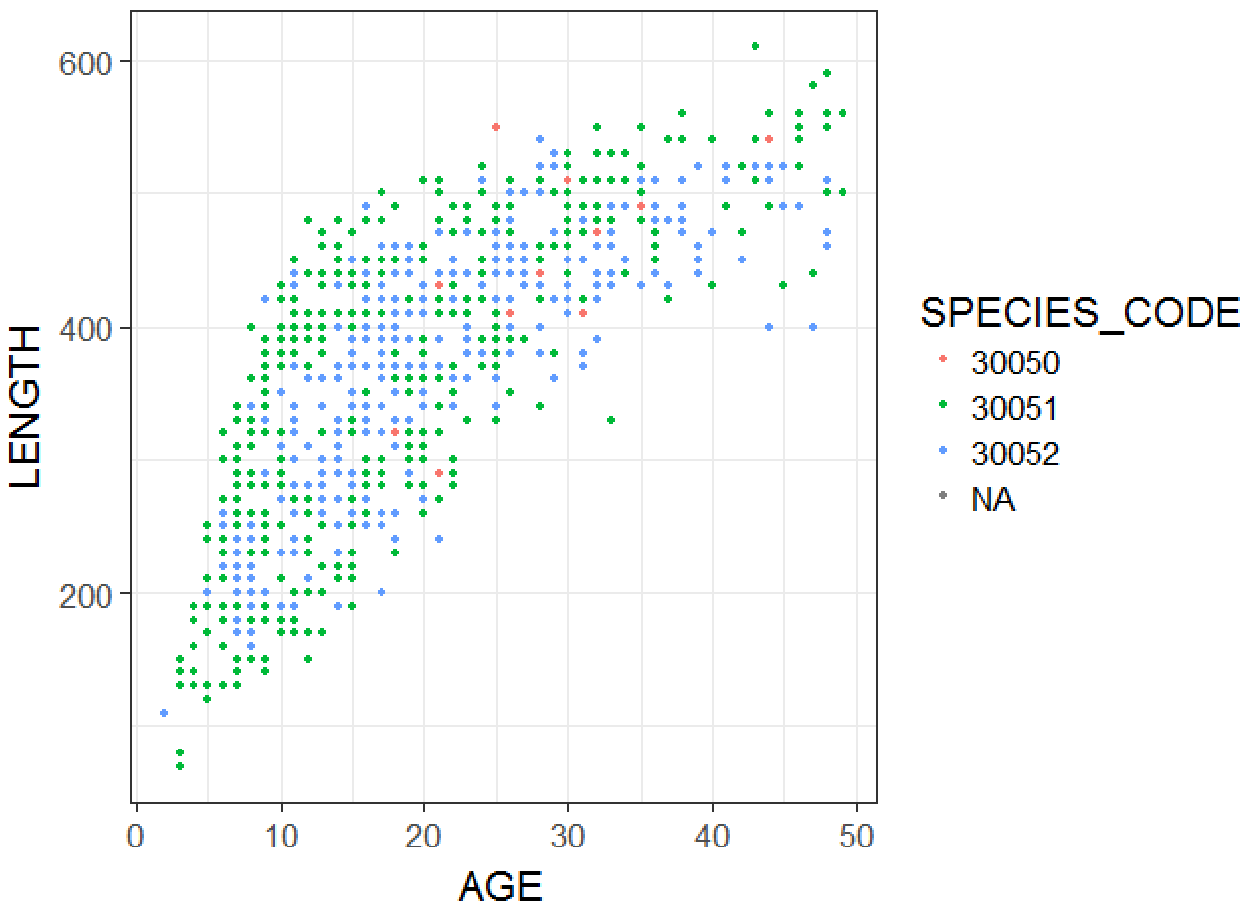


Figure above shows at-sea identified age and length data of rougheye and blackspotted rockfish for 2009 bottom trawl survey. 30050 are unidentified, 30051 are rougheye, and 30052 are blackspotted.

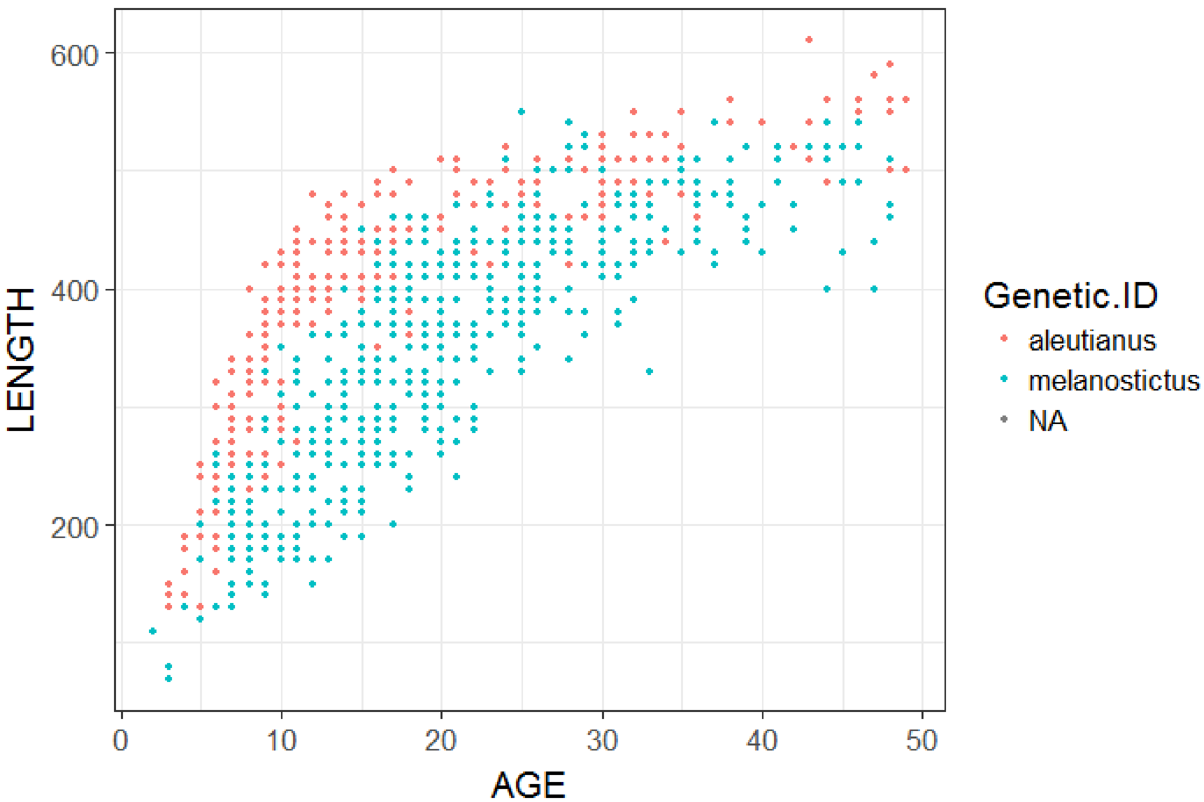
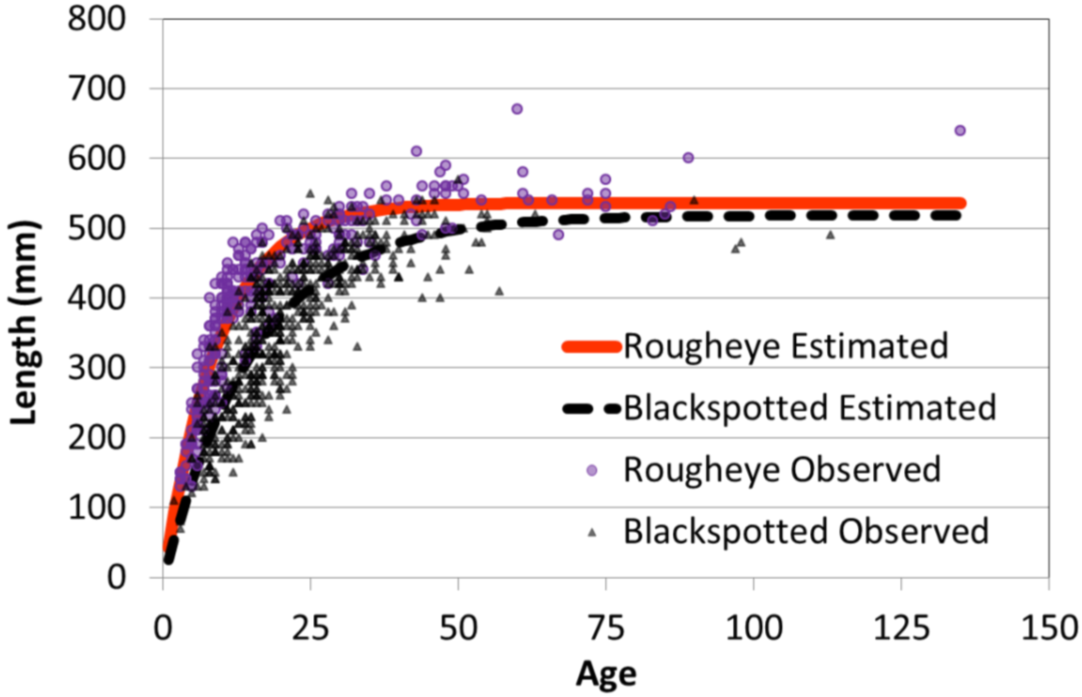


Figure above shows genetically identified age and length data of rougheye and blackspotted rockfish for the 2009 bottom trawl survey. NA is 30050 and are unidentified, 30051 are rougheye or aleutianus, and 30052 are blackspotted or melanostictus.

The at-sea data are completely mixed while the genetic data seem quite separable. Subsequent analysis of the 2009 data found differences in growth between the two species (see figure below).



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

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

Rougheye rockfish grow faster and typically attain a slightly greater maximum size than blackspotted rockfish.

Maturity

A new maturity study on RE/BS rockfish species was recently published (Conrath 2017). Samples were collected throughout the year on a variety of scientific surveys and observed fishery vessels from 2008-2014. The fork length at 50% maturity was similar for rougheye rockfish (45.0 cm) and blackspotted rockfish (45.3 cm), but the age at 50% maturity was considerably younger for rougheye rockfish (19.6 years) than for blackspotted rockfish (27.4 years). Unfortunately, the samples in this study were not genetically identified to species, so it is not clear whether there was little change in rougheye rockfish age at 50% maturity or whether the change in blackspotted rockfish was as dramatic as estimated. It is difficult to immediately determine how to best utilize the results from this study within our assessment model. Since the maturity samples were not collected randomly in proportion to the actual **or** genetically identified species composition, the data cannot be pooled and fit as one maturity curve. One method might be to use the separately fit curves and apply weights of either the mean of the naïve species ratio of the 3 years of genetic ID. Clearly if that proportion is largely composed of blackspotted rockfish, then the maturity-at-age will be higher and would result in lower estimates of reference points.

Additional, maturity data are available from a 2015 December cruise that can be included with the samples through 2014 (C. Conrath, *pers. commun.*). We are also exploring if the otoliths for this study can be measured and identified to species using otolith morphometrics. This would allow true identification of shifts in age at 50% maturity and increase potential to use the information in future research on a split species model. We hope to evaluate the new maturity within the model once it is determined if the otolith samples may be processed.

Discussion

When completed, the results from these studies will help determine the utility and cost-effectiveness of a split-species complex model or separate species models for examining if one species may be at greater risk to overfishing. Presently genetic identification of the two species sampled in the bottom trawl survey is not part of the standard sampling procedure for these two species and must be conducted via special project requests. In the laboratory genetic identification of the species via fin clips is rapid and cost effective. Recently developed techniques utilizing diagnostic single-nucleotide polymorphisms (SNPs) for rougheye and blackspotted rockfish reduce the cost and processing time for genetic identification of large sample sizes (Garvin et al. 2011). Given the high and variable misidentification rates of the two species in surveys and potentially the fishery, some genetic sampling protocol that is included within the standard otolith collection for the two species may be necessary to enable direct monitoring of long-term population trends.

Depending on the time required to measure the otoliths, the morphometrics could also be set as a standard part of the protocol for these two species. Along with the fully reconstructed historical measurements, this would allow for preliminary testing of a split species model. Also, somewhat intermediate and simpler ways forward could be to adjust the biological characteristics of the catch and surveys (growth and maturity) to reflect the various research project results and run alternative models for comparing the implications of including this information in the model.

At present, the area-specific harvest rates for RE/BS rockfish have been on average low and catches have consisted of approximately half the ABC in recent years. We consider current management specifications for this non-targeted complex to be sufficiently precautionary under current fishing practices and will continue to model roughyeye and blackspotted rockfish as if they are a single species.

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