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

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Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. We use a separable age-structured model as the primary assessment tool for Gulf of Alaska rougheye and blackspotted rockfish (RE/BS complex). This consists of an assessment model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses result from the assessment model to predict future population estimates and recommended harvest levels. For Gulf of Alaska rockfish in alternate (even) years we present an executive summary to recommend harvest levels for the next (odd) year. For this on-cycle year, we update the 2009 assessment model estimates with new data collected since the last full assessment. The data sets used in this assessment include total catch biomass, fishery age and size compositions, trawl and longline survey biomass estimates, trawl survey age compositions, and longline survey size compositions.

Summary of Changes in Assessment Inputs

Changes in the input data: New data added to this model include a revised catch estimate for 2010, an estimated catch for 2011, fishery ages for 1990 and 2008, trawl survey biomass estimate for 2011, trawl survey age compositions for 2009, longline survey relative population weights for 2010-2011, and longline survey size compositions for 2010-2011.

Changes in the assessment methodology: There were no changes in assessment methodology.

Summary of Results

We provide results from the 2009 model and the updated 2011 model for comparison purposes. Parameter estimates are similar to the 2009 estimates, with very similar trawl survey catchability, slightly higher longline survey catchability, and lower mean recruitment. The 2011 trawl survey estimate decreased by 13% from 2009 and is now about 8% below the long term average for the time series. The longline survey relative population weight increased by 27% in 2010 and another 12% in 2011. The current estimate is about 30% above the long term average.

For the 2012 fishery, we recommended the maximum allowable ABC of 1,223 t from the updated model. This is a 7 % decrease from last year's ABC of 1,312 t. Recommended ABCs from area apportionments are 80 t for the Western area, 850 t for the Central area, and 293 t for the Eastern area. Recent recruitments are steady and near the median of the recruitment time series. This is evident in the ages for both fishery and survey with more young fish over time. Female spawning biomass is well above $B_{40\%}$, with projected biomass stable.

Reference values for RE/BS rockfish are summarized in the following table, with the recommended ABC and OFL values 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:*	
	2011	2012	2012	2013
M (natural mortality)	0.034	0.034	0.034	0.034
Tier	3a	3a	3a	3a
Projected total (ages 3+) biomass (t)	45,907	46,154	42,856	43,085
Female spawning biomass (t)				
Projected	13,720	13,684	12,610	12,877
$B_{100\%}$	25,463	25,463	24,329	24,329
$B_{40\%}$	10,185	10,185	9,732	9,732
$B_{35\%}$	8,912	8,912	8,515	8,515
F_{OFL}	0.048	0.048	0.047	0.047
$maxF_{ABC}$	0.040	0.040	0.039	0.039
F_{ABC}	0.040	0.040	0.039	0.039
OFL (t)	1,579	1,579	**1,472**	1,492
maxABC (t)				
ABC (t)	1,312	1,312	**1,223**	1,240
Status	As determined *last* year for:		As determined *this* year for?	
	2009	2010	2010	2011
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projected ABCs and OFLs for 2012 and 2013 are derived using estimated catch of 525 t for 2011 and projected catch of 355 t for 2012 based on realized catches from 2008-2010. This calculation is in response to management requests to obtain more accurate projections.

Area Apportionment

The apportionment percentages have changed with the addition of the 2011 survey biomass. The following table shows the recommended apportionment for 2012.

	Western	Central	Eastern	Total
Area Apportionment	6.60%	69.46%	23.94%	100%
Area ABC (t)	**80**	**850**	**293**	**1,223**
OFL (t)				**1,472**

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
RE/BS complex	2010	45,751	1,568	1,302	1,302	450
	2011	45,907	1,579	1,312	1,312	535
	2012	42,856	1,472	1,223		
	2013	43,085	1,492	1,240		

[1]Total biomass from the age-structured model

Stock/ Assemblage	Area	2011 OFL	ABC	TAC	Catch[2]	2012 OFL	ABC	2013 OFL	ABC
	W		81	81	28		80		82
RE/BS	C		868	868	361		850		861
complex	E		363	363	146		293		297
	Total	1,579	1,312	1,312	535	1,472	1,223	1,492	1,240

[2]Current as of October 24, 2011. Source: NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database (http://www.akfin.org).

Responses to SSC comments since the last full assessment

"The SSC agrees that currently using a mixed species model does not pose a conservation concern because directed fisheries are prohibited, and the incidental catch of rougheye and blackspotted rockfish remains well below the recommended ABC. However, the catch should be monitored to prevent overfishing. In particular, the authors should monitor the bycatch trends in the sablefish, halibut longline fisheries, and look for evidence of "topping off" in the POP fishery." (December 2009)

The original paper cited regarding "topping off" was Ackley and Heifetz (2001), which stated there was anecdotal evidence of "topping off" by some Aleutian Islands vessels, but it was primarily attributed to hauls targeting sablefish. A preliminary examination of recent observer data showed that most catches of rougheye and blackspotted rockfish in the rockfish fishery were part of normal vessel operations, while deeper hauls appeared to be catching more shortraker and sablefish than rougheye and blackspotted rockfish (Hanselman pers. comm.). In the future, we intend to utilize the Alaska Fisheries Information Network (AKFIN) to monitor and report bycatch trends in these fisheries.

"The SSC notes that the MCMC estimate of trawl survey q for the rougheye complex (0.381 Model 2) is considerably different than the q for dusky rockfish (0.911 Model 2). It would be useful to compare the model estimates of q for different species of rockfish and consider whether the estimates are reasonable." (December 2009)

In this comment, the SSC was referring to the contribution of the prior distribution of trawl survey *q* to the objective function for GOA rougheye and blackspotted rockfish, not the point estimate. The catchability estimate for the RE/BS is 1.42, which is higher than northerns and dusky (0.67 and 0.90), but lower than Pacific ocean perch (2.03). These estimates at least relative to each other correspond with our perception from submersible studies on how the species range from untrawlable to trawlable habitat. Pacific ocean perch has been the subject of three studies which all yielded catchabilities above 1 (2.1, 1.3, and 2.1). Rougheye and blackspotted catches were compared with submersible observations in a 2006 analysis and yielded a catchability of 0.85. However, rougheye and blackspotted trawl catchability is confounded with longline survey catchability so it may not be a direct comparison with the other rockfish. In the future we hope to synthesize the results of these studies to derive informative prior distributions for our catchability estimates.

"As noted in the assessment, the rockfish pilot project may allow improved utilization of the rockfish quotas. The authors should continue to consider the impact of the rockfish pilot program on catch." (December 2009)

We examined bycatch trends and spatial distribution of the combined rockfish fisheries in the central GOA from several years before and after the implementation of the Central GOA Rockfish Pilot Program

(RPP). Details of this analysis can be found in the *Historical Background* and *Bycatch* subsections under the ***Fishery*** section. We will continue to monitor the impact of the RPP in future assessments.

"The methods for area apportionment of the ABC that are used in the specific chapters are different from those given in the general introductory material to the SAFE on page 4. The SSC suggests that the table be updated. Also, a different number of years are used for various species (e.g., 5 years for sablefish, 4 years for pollock, 3 surveys, most recent survey). SSC members recall extensive discussions about these issues but the rationale for the decision is not given in the SAFE chapters. The SSC suggests that description of the apportionment rationale in each SAFE chapter of area-apportioned species would be helpful to the reader." (December 2009)

The annual allocation of the Gulf-wide ABC for rougheye and blackspotted rockfish amongst the three regulatory areas in the Gulf has been based on the geographic distribution of biomass in the trawl surveys. Since the 1996 SAFE report, this distribution has been computed as a weighted average of the percent biomass distribution for each area in the three most recent trawl surveys. Details on this apportionment rationale can be found in the *Area Allocation of Harvests* subsection under ***Projections and Harvest Alternatives***.

"For greater consistency in the way the terminal year catch is specified, the SSC requests that authors incorporate their best estimate of total landings that will occur for the entire year. This information will be used to generate projections and should be incorporated into BSAI and GOA specification tables." (December 2010)

We discuss a modified methodology for estimating full-year catch for the current year and for projecting future catches for the two year projection of ABC and OFL in the *Specified Catch Estimation* subsection under ***Projections and Harvest Alternatives***.

"The SSC recommends that stock assessment authors and plan teams address this issue in the upcoming stock assessment cycle. Stock assessment authors should clearly lay out which sources of removals are currently included in the assessment, how removals from each source are estimated, and how they are being included in (A) and (B) above. To the extent possible, authors should discuss all known sources of mortality (including handling mortality, indirect mortality, subsistence, etc.) and which of these sources are considered in the assessment." (June 2011, Section D-1(b)

Estimates of non-commercial catch and HFICE estimates of rougheye and blackspotted rockfish are documented in Appendix 13A.

Responses to Plan Team comments since the last full assessment

"Applying the stock structure template to rockfish species was discussed and the Team encouraged rockfish authors to use the template for at least one GOA rockfish species (and also one flatfish species). The Team noted that Dusky rockfish would be a good candidate for GOA rockfish and either flathead sole or rocksole as a candidate for GOA Flatfish." (November 2010)

We completed the stock structure template for rougheye and blackspotted rockfish and presented results to the Plan Team in September 2010. Results of the template and a discussion on distribution, speciation, misidentification and implications for management were included in an appendix to the rougheye and blackspotted 2010 executive summary SAFE report (Shotwell et al. 2010). Brief summaries of rougheye and blackspotted rockfish speciation, the stock structure template, and current research are provided in the ***Evidence of stock structure*** section of this report.

"The Team discussed the different catch assumptions made across assessments…The Team noted that authors should be clear in how catch is projected and what assumptions are made to make the catch estimate for the projection." (November 2010)

We discuss a modified methodology for estimating full-year catch for the current year and for projecting future catches for the two year projection of ABC and OFL in the *Specified Catch Estimation* subsection under ***Projections and Harvest Alternatives***.

"The Teams recommended that all authors provide the 2001-2010 HFICE and the 2010 CAS total catch estimates as an appendix to each assessment chapter in November 2011. Since these estimates are preliminary and the Teams have not reviewed the complete database or assessed the potential effects on determination of OFL and ABC for each stock, further analysis is needed before the Teams can recommend incorporation of these estimates in their OFL/ABC recommendations.

For November, several components are recommended to be included in a table in an appendix in each assessment chapter:

1.) *The 2010 total catch removal estimates along with research catch estimates reported in previous assessments. The major sources of removals should be noted along with any large deviations in total catch between previously used research catches and the new estimates.*
2.) *HFICE estimates should be tabulated for the years 2001-2010 (from Cindy Tribuzio). Comparisons should be made to the corresponding CAS estimates from the AKRO. The impacts of including HFICE estimates on the total catch estimates currently used in the assessments should be discussed and the implications of these estimates on the ABC and OFL recommendations should be explored."*

(September 2011)

Estimates of non-commercial catch and HFICE estimates of rougheye and blackspotted rockfish are documented in Appendix 13A.

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 is quite extensive (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 both expensive and 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 a few post-larval RE/BS rockfish from samples collected 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 fish become demersal. Juvenile rougheye rockfish (15- to 30-cm fork length) have been frequently taken in Gulf of Alaska bottom trawl surveys, implying the use of low relief, trawlable bottom substrates. They are generally found at shallower, more inshore areas than adults and have been taken in variety of locations, ranging from inshore fiords to offshore waters of the continental shelf. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981, Straty 1987, Krieger 1993). Another submersible study on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). Although these studies did not specifically identify rougheye rockfish, it is reasonable to suspect that juvenile rougheye rockfish may be among the species that utilize this habitat as refuge during their juvenile stage.

Adult rougheye and blackspotted rockfish are demersal and are known to inhabit particularly steep, rocky areas of the continental slope, with highest catch rates generally at depths of 300 to 400 m in longline surveys (Zenger and Sigler 1992) and at depths of 300 to 500 m in bottom trawl surveys and in the commercial trawl fishery (Ito 1999). Observations from a manned submersible in this habitat indicate that the fish prefer steep slopes and are often associated with boulders and sometimes with *Primnoa* spp. coral (Krieger and Ito 1999, Krieger and Wing 2002). Within this habitat, rougheye rockfish tend to have a relatively even distribution when compared with the highly aggregated and patchy distribution of other rockfish such as Pacific ocean perch (*Sebastes alutus*) (Clausen and Fujioka, 2007).

Food habit studies in Alaska indicate that the diet of rougheye and blackspotted rockfish is primarily shrimp (especially pandalids) and that various 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 be dramatically higher from older female spawners (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. de Bruin et al. (2004) examined Pacific ocean perch (*S. alutus*) and rougheye/blackspotted rockfish for senescence in reproductive activity of older fish and found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. Such relationships have not yet been determined to exist for rougheye and blackspotted rockfish or other rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. However, in a recent study on Pacific ocean perch, Spencer et al. (2007) showed that the effects of enhanced larval survival from older mothers decreased estimated F_{msy} (the fishing rate that produces maximum sustainable yield) by 3% to 9%, and larger decreases in stock productivity were associated at higher fishing mortality rates that produced reduced age compositions.

Evidence of stock structure

In December 2007 the SSC requested that the GOA rougheye and blackspotted rockfish authors *"work to bring forward a rationale for decisions regarding assessment of mixed species groups with attention to the potential for overfishing the weaker stock."* In December 2008 the SSC endorsed the preparation of a new field identification pamphlet and stated that *"identification of rockfish to species is a high research priority"*. We responded to the 2007 comment in the **Responses to Council, SSC, and Plan Team Comments** section of the 2008 GOA Rougheye and Blackspotted Rockfish Executive Summary. We elaborated on this response in the 2009 GOA Rougheye and Blackspotted Rockfish SAFE report in the **Evidence of Stock Structure** section of the **Introduction**. This section included a summary of the recent studies on the genetic and phenotypic differences between rougheye and blackspotted rockfish and a discussion of the current research regarding high at-sea misidentification rates and understanding species specific life history characteristics. Finally, we completed a full stock structure evaluation of rougheye and blackspotted rockfish following the template provided by the Stock Structure Working Group (SSWG) in 2009 (Spencer et al. 2010). This evaluation is provided in **Appendix A** of the 2010 GOA rougheye and blackspotted rockfish executive summary SAFE report (Shotwell et. al 2010). Brief summaries of rougheye and blackspotted rockfish speciation, the stock structure template, and current research are provided below.

Rougheye and Blackspotted Speciation

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

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). The overlap is quite extensive (Gharrett et al. 2006, 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.

Non-genetic information suggests population structure by large management areas of eastern, central, and western GOA. This is evident in opposite trajectories for population trends by area, significantly different age, length, and growth parameters by area, and significant differences in parasite prevalence and intensity by area. Genetic studies have generally been focused on the speciation of the RE/BS complex; however, consistencies between the two species also suggest population structure by management area. Tests of homogeneity and adjacency show genetic structure consistent with a neighborhood model of dispersion. Dispersal distance for rougheye and blackspotted was consistent with management areas; however, rougheye in the eastern GOA may exhibit finer scale population structure (Gharrett et al. 2007).

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 on average low area-specific harvest rates, we continue to recommend the current management specifications for RE/BS rockfish.

Current Research

At present there is difficulty in accurate at-sea field identification between the two species. Several recent studies have found that on average, when compared to genetic identifications, field scientists had a misidentification rate of approximately 46% (samples in eastern GOA near Yakutat) and 51% (samples in British Columbia), while the expert (Jay Orr) had misidentification rates of 9% (Shotwell et al. 2009). There is also no information on whether the two species have significantly different life history traits (e.g. age of maturity, growth). If differences in growth and maturity exist, disproportionate harvest rates could result. This may be particularly true in areas where the two species are caught together in the same haul such as in central and eastern GOA (Gharrett et al. 2005).

In response to these concerns, a special project was initiated during the 2009 AFSC GOA bottom trawl survey. The goal of this study was to collect relevant biological and genetic data to improve at-sea identification and examine differences in life history characteristics between the two species. Field scientists collected length, weight, and muscle tissue from all rougheye and blackspotted rockfish being sampled for otoliths. Additionally, all unknown rougheye/blackspotted specimens were sampled for otoliths. For the whole survey, 934 otoliths and tissue samples were collected. Of these 420 were blackspotted, 495 were rougheye, and 19 were unidentified blackspotted/rougheye. During the summer of 2010, half of the otolith samples for this study were aged by the AFSC Age and Growth Lab and the genetic samples were analyzed by scientists at Auke Bay Laboratories. Preliminary analysis of these samples suggested similar misidentification rates to the previous exercises on the longline survey (J. Heifetz, *personal communication*). In order to more fully examine potential age and growth differences, a 2011 request to the AFSC Age and Growth Lab was initiated to complete the aging of the remaining otolith samples.

The high misidentification rates preclude the development of separate models for rougheye and blackspotted rockfish in the GOA at this time. Scientists and observers are currently evaluating new techniques to determine whether rapid and accurate field identification can occur; however, until reliable identification of both species can occur, we must continue to manage rougheye and blackspotted rockfish as a complex. The special project on the 2009 GOA trawl survey will enhance training and field identification guides, allow for accurately specifying misidentification rates, and begin estimating biological parameters such as growth and distribution by species. Additionally, recently developed techniques utilizing diagnostic single-nucleotide polymorphisms (SNPs) for rougheye and blackspotted rockfish may reduce the cost and processing time for genetic identification of large sample sizes (Garvin et al. 2011). In the future, we plan to extend this sampling to commercial fisheries as a special project requested of the Observer Program. When combined with accurate species-specific catch and survey data, such information will help determine the utility of separate species models for examining if one species is a weaker stock and may be at greater risk to overfishing.

Management measures

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

In November, 2006, NMFS issued a final rule to implement Amendment 68 of the GOA groundfish Fishery Management Plan for 2007 through 2011. This action initiated the Central Gulf of Alaska Rockfish Pilot Program. The intention of this Program is to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central Gulf of Alaska rockfish fishery. This is a five year rationalization program that establishes cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish management groups. This implementation impacts primary management groups but will also affect secondary groups with a maximum retained allowance (MRA). The primary rockfish management groups are Pacific ocean perch, northern rockfish, and pelagic shelf rockfish, while the secondary species include rougheye and shortraker rockfish. The program should spread out the fishery in time and space, allowing for better prices for product and reducing the pressure of what was an approximately two week fishery in July. The authors will pay close attention to the benefits and consequences of this action.

Management measures since the creation of the slope rockfish assemblage in 1988 and a time series of catch, ABC, and TAC are shown in Table 13-2.

Fishery

Historical Background

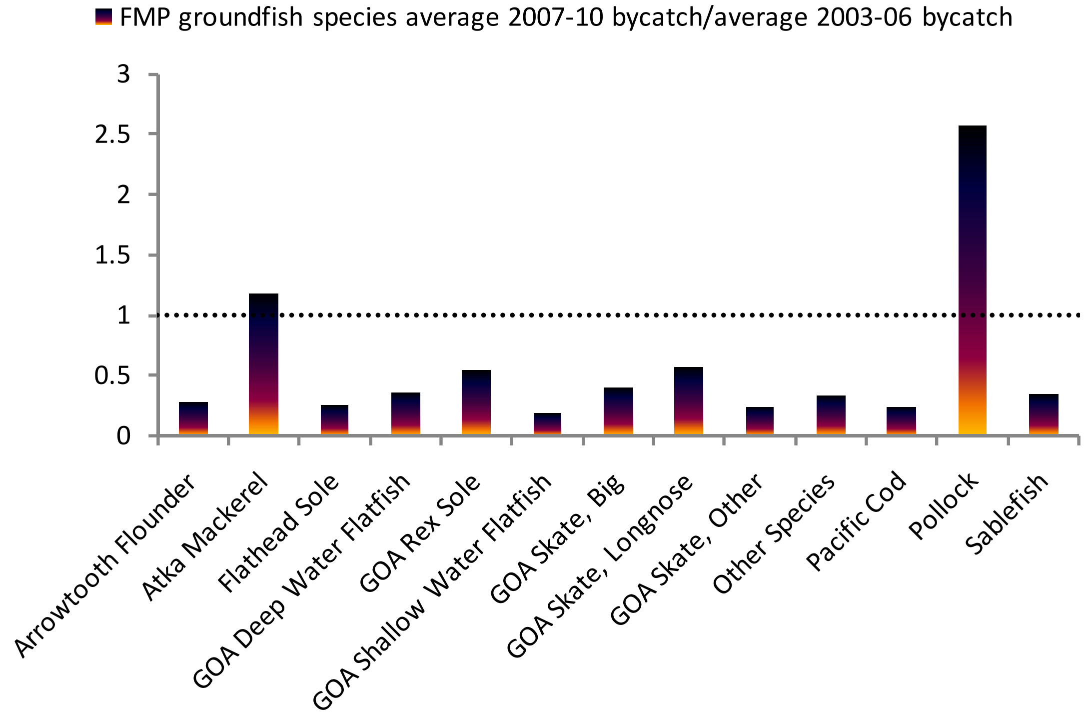
Rougheye and blackspotted rockfish have been managed as "bycatch" only species since the creation of the shortraker/rougheye rockfish management subgroup in the Gulf of Alaska in 1991. Historically, Gulf-wide catches of the rougheye and blackspotted rockfish have been between 130-2,418 t (Table 13-3). Catches peaked in the late 80s and early 90s and have been steadily declining since with a small increase recently. RE/BS rockfish are generally caught in either bottom trawls or with longline gear. In 2011, 65% of the catch was from bottom trawls, 29% from longline, and 6% from pelagic trawls. Approximately 83% of this bottom trawl catch was taken in the rockfish fishery while, 17% was taken in the flatfish fisheries. The amount of catch taken in the rockfish fishery has more than doubled in the past two years, probably due to increased Pacific ocean perch ABC allocated to the central GOA. For longline gear, nearly all the RE/BS catch appears to come as "true" bycatch in the sablefish or halibut longline fisheries, with 77% of the 2011 catch taken in the sablefish fishery and 23% in the halibut fishery (Table 13-4). Since catch accounting was established separately for RE/BS rockfish in 2005, the TACs for RE/BS rockfish are not fully taken, and are generally between 30-40% of potential quota (Table 13-3).

In 2007, the Central Gulf of Alaska Rockfish Pilot Program was implemented. Potential effects of this program to rougheye and blackspotted rockfish include: 1) an extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA, 3) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, and 4) a higher potential to harvest 100% of the TAC in the Central GOA region. Recent data show that the Pilot project has resulted in much higher observer coverage of catch in the Central GOA (Figure 13-1).

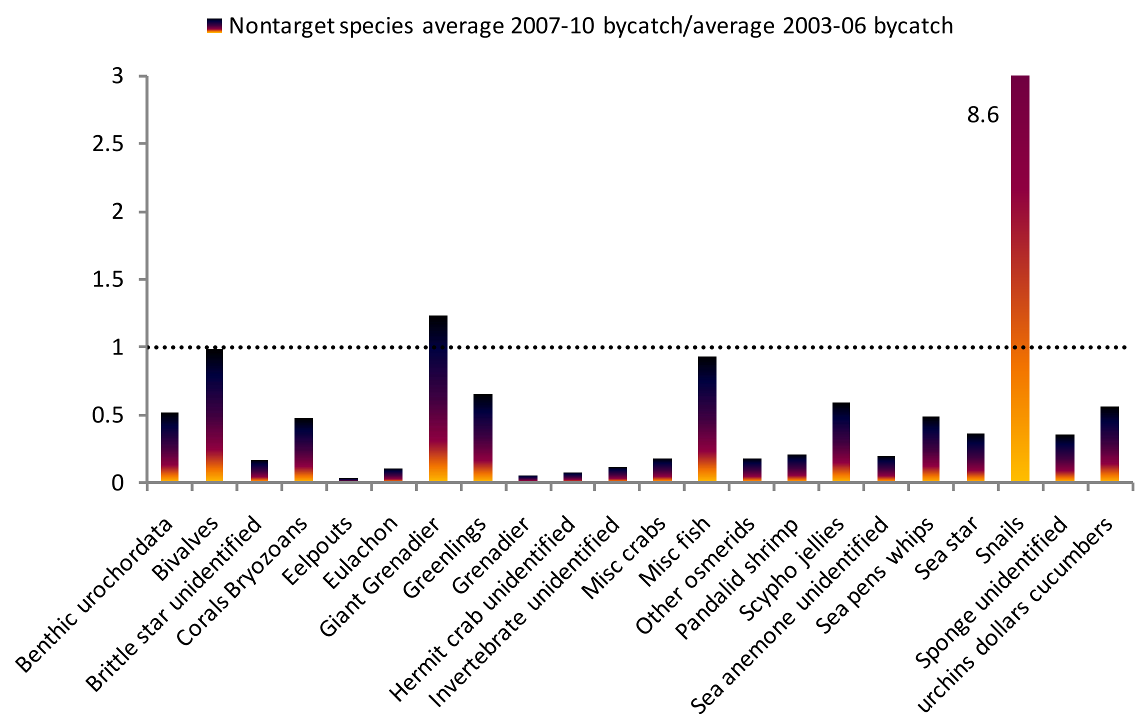
Bycatch

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 (Table 13-4). For the combined rockfish trawl fisheries during 1991-2010 for the GOA the largest non-rockfish bycatch groups are arrowtooth flounder (1,540 t/year), sablefish (948 t/year), Pacific cod (814 t/year), Atka mackerel (585 t/year) and walleye pollock (352 t/year). Total FMP groundfish species catch estimates targeted in the rockfish fishery from 2006-2010 are shown in Table 13-5.

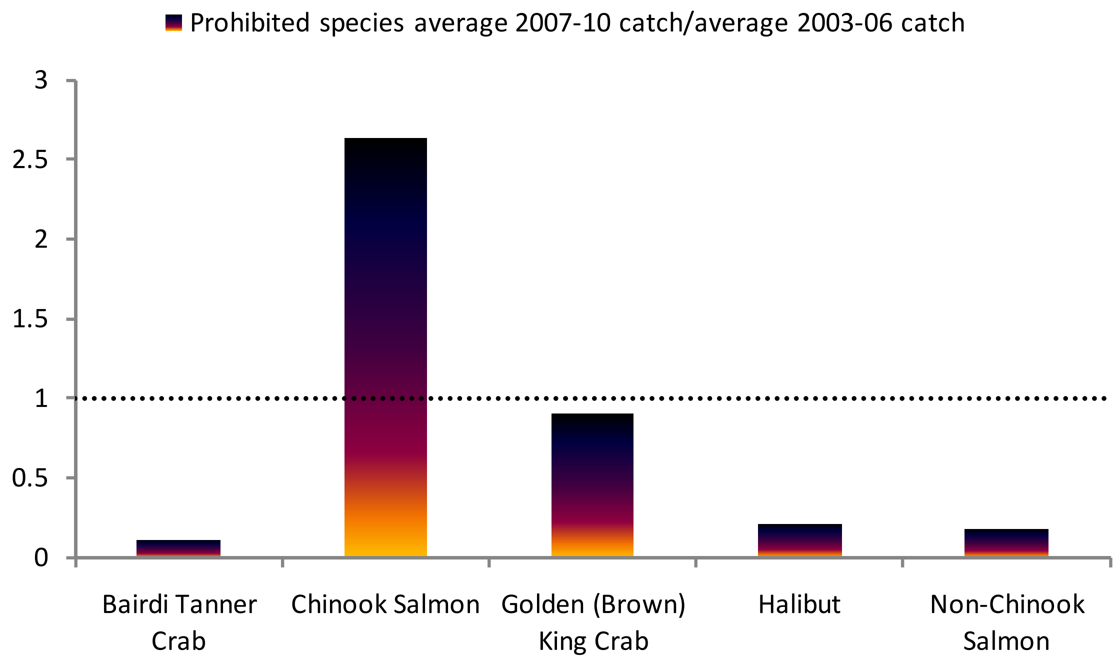
We compared bycatch for the combined rockfish fisheries in the central GOA from several years before and after 2007 to determine impact of the Central GOA Rockfish Pilot Program implementation. We divided the average post-2006 bycatch (2007-2010) by the average pre-2007 bycatch (2003-2006) for non-rockfish species that had available information in both time periods. For the majority of FMP groundfish species, bycatch in the central GOA has reduced since 2007, with the exception of Atka mackerel (214 t/year pre-2007 compared to 251 t/year post-2006) and walleye pollock (136 t/year pre-2007 compared to 352 t/year post-2006, see figure below):



Non-FMP species catch in the rockfish target fisheries is dominated by giant grenadier (127 – 423 t), miscellaneous fish (132 – 181 t), and ocassionally dark rockfish (recently removed from FMP to state management, 0 – 111 t) (Table 13-6). Only 2 of 23 nontarget species for which bycatch data were available for the two time periods resulted in an increase in bycatch post-2006 compared to pre-2007, giant grenadier and snails (see figure below):



Prohibited species catch in the GOA rockfish fishery has been decreasing for all the major species with the exception of golden king crab which increased to over 3,000 crabs in 2009 and 2010. Halibut catch during rockfish targeted hauls has declined since 2006 from 254 t to 108 t in 2011 (Table 13-7). Catch of prohibited species for which data were available in the two time periods in the combined rockfish trawl fisheries has decreased since 2007 for 4 of 5 groups, with the exception of chinook salmon (see figure below):



Discards

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

Shortraker / Rougheye / Blackspotted Complex

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

Rougheye / Blackspotted Complex

Year	2005	2006	2007	2008	2009	2010	2011
% Discards	19.5	27.6	38.0	29.3	20.9	23.2	16.6

The above table indicates that discards of rougheye and blackspotted have ranged from approximately 19% to 38% with an average of 25%. These values are relatively high when compared to other *Sebastes* species in the Gulf of Alaska.

[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 24, 2011 (http://www.akfin.org)

Data

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

Source	Data	Years
Fisheries	Catch	1977-**2011**
	Age	**1990**, 2004, 2006, **2008**
	Length	1991-1992, 2002-2003, 2005, 2007
NMFS trawl survey	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, **2011**
	Age	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, **2009**
AFSC longline survey	Relative Population Weight (RPW)	1990-**2010**, **2011**
	Length	1990-**2010**, **2011**

Fishery Data

Catch

Catches of rougheye and blackspotted rockfish range during 130 t to 2,418 t from 1977 to 2011. The catches from 1977-1992 were from Soh (1998). Catches from 1993-2004 were available as the shortraker/rougheye subgroup from the NMFS Alaska Regional Office. Originally we used information from a document presented to the NPFMC in 2003 to determine the proportion of rougheye rockfish in this catch (Ianelli 2003). This proportion was based on the NMFS Regional Office catch accounting system ("blend estimates"). The SSC recommended using the average of the values provided in the document, 0.43. In 2004 another method was developed for determining the proportion of rougheye/blackspotted in the catch based on data from the NMFS Groundfish Observer Program (Clausen et al. 2004, Appendix A). Catches were available from the observer 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 rougheye (Figure 13-2, Table 13-3).

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

Age composition

Rougheye and blackspotted rockfish appear to be among the longest-lived of all *Sebastes* species (Chilton and Beamish 1982, Munk 2001). Interpretation of annuli on otoliths is extremely difficult; however, recently NMFS age readers determined that aging of RE/BS rockfish could be moved into a production mode. Ages were determined from the break-and-burn method (Chilton and Beamish 1982). Rougheye and blackspotted rockfish otolith samples from onshore processing facilities have recently been aged. The sample sizes from onshore processing facilities are generally low and the distribution of ages is quite different from the at-sea samples. Therefore, we do not use these samples in calculating the fishery age compositions. The NMFS Observer Program began in 1990 and although this first year was considered preliminary, the 1990 ages are the only age compositions we have from the fishery prior to 2004. We, therefore, utilize this data in the model since it is considered important for estimating catch at age in the early 1990s. Table 13-8 summarizes the newly available fishery age compositions from 1990, 2004, 2006, and 2008. Sample sizes are similar to those taken in the trawl survey. The mean ages are relatively old at 30-37 for each year when compared to other aged rockfish species. Ages 25 and greater are pooled into a plus (+) group that is quite substantial in both years. This may imply that our age bins are somewhat restrictive for this extremely long-lived species. Future analysis will consider the potential for increasing the number of age bins to include several older age groups following the analysis that was recently completed for northern rockfish (Hulson et al. 2011).

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 1991-2007. Samples from 1993-2001 were limited for RE/BS rockfish. In general, we do not use size compositions in the model when age compositions are available. Given the arduous task of otolith interpretation for long-live rockfish such as rougheye and blackspotted rockfish, we generally request fishery ages only for years that do not overlap with a NMFS trawl survey. Since we anticipate fishery ages for non-trawl survey years, we do not include the size compositions for off-cycle years in the model. 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. Given the relatively short delay on receiving off-cycle fishery ages, we determined that the potential for model instability from adding size composition data that would simply be taken out in the next assessment cycle was not beneficial. We, therefore, use data from 1991-1992, 2002-2003, 2005, and 2007. Length samples from onshore processing facilities also exist for RE/BS rockfish; however, the distribution between onshore and at-sea lengths differ dramatically and the samples sizes are quite low. Therefore, as with age samples, we do not use these onshore length samples in calculating the fishery size compositions. Lengths were binned into 2 cm categories to obtain better sample sizes per bin from 20-60+ with the (+) group containing all the fish 60 cm and larger. On average, approximately 54% of the lengths are taken from the trawl fishery and 46% from the longline fishery for at-sea samples. This percentage is consistent for the data used in the model with 56% of lengths from the trawl fishery and 44% from the longline fishery. The mode of lengths for the 1991-1992 samples is approximately 45 cm and from 2002-2007 has steadily increased from 46 to 48 cm. Moderate presence of fish smaller than 40 cm is present in most years, particularly 1992.

NMFS Bottom Trawl Survey

Biomass Estimates

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

Summaries of biomass estimates from the 1984-2011 surveys are provided in Table 13-10. Trawl survey biomass estimates are shown in Figure 13-3. Historically estimates by region indicate that the western and eastern GOA time series of biomass tended to be in opposite phase (Table 13-10). From 2003-2007, the central and eastern GOA estimates increased, while the western GOA decreased. In 2009, all regions decreased and in 2011 both the eastern and central GOA decreased while the western GOA slightly increased. Given that the regional patterns are quite different and that the 2001 survey did not sample the Eastern Gulf, omitting this survey estimate from the model is reasonable. Additionally, data for 2001 are available from the longline survey.

The 1984 and 1987 survey results should be treated with some caution. A different survey design was used in the eastern Gulf of Alaska in 1984; furthermore, much of the survey effort in the western and central Gulf of Alaska 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 (for a discussion see Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates discussed here, and the estimates are believed to be the best available. Even so, the reader should be aware that an element of uncertainty exists as to the standardization of the 1984 and 1987 surveys.

The biomass estimates for rougheye and blackspotted rockfish have been relatively constant among the surveys, with the possible exception of 1993 and 2007. Generally, inter-survey changes in biomass are not statistically significant from each other (Table 13-10; Figure 13-3). Compared with other species of *Sebastes*, the biomass estimates for rougheye and blackspotted rockfish show relatively tight confidence intervals and low coefficients of variations (CV), ranging between 11% and 23%. The low CVs are an indication of the rather uniform distribution for this species compared with other slope rockfish (discussed previously in *Biology and Distribution* of the ***Introduction***). Despite this precision, however, trawl surveys are believed to do a relatively poor job of assessing abundance of adult rougheye 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 rougheye 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 rougheye rockfish are mostly based on the relatively few hauls in gully entrances, and they may not indicate a true picture of the abundance trends. However, the utilization of both the trawl and longline (which can sample where survey trawls cannot) biomass estimates should alleviate some of this concern.

In 2007, the trawl survey began separating rougheye rockfish from blackspotted rockfish using a species key developed by J. Orr (Orr and Hawkins, 2008). Biomass estimates by region of the two species somewhat support the broad southern and northern distribution of rougheye versus blackspotted rockfish in that blackspotted estimates were higher in the western GOA and rougheye estimates were higher in the eastern GOA (discussed previously in *Evidence of stock structure* under the ***Introduction*** section). However, both species were identified in all regions, implying some overlap throughout the GOA. Over all areas, more blackspotted rockfish were identified than rougheye in 2007 (56% versus 44%), while in 2009 and 2011 the reverse occurred (36% versus 64% and 35% versus 65%, respectively). Given the preliminary results from current research of high misidentification rates at-sea between the two species, we will continue to combine all survey data for both species until more information regarding species' specific life history characteristics is determined.

Age Compositions

The 2009 ages were added this year resulting in a total of ten years of survey age compositions with a total sample size of 4,824 ages. We now have survey age compositions corresponding to all survey biomass estimates used in the model except 2011. 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 show especially prominent modes in the younger ages, suggesting periods of large year classes from the mid to late 1970s, early 1980s and then again in the late 1980s early 1990s. In 2003, 2005, 2007, and 2009 compositions are spread relatively 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. Survey ages for 2007 and 2009 were split by rougheye and blackspotted rockfish. Rougheye compositions tend to be spread evenly across ages, while blackspotted tend to be much older. Mean age of rougheye was 15 and 18 in 2007 and 2009, respectively, while mean age for blackspotted in those years was 24 and 22, respectively. This may be due to a high at-sea misidentification rate or a true difference in age distribution between species. We combine these two age compositions for 2007 and 2009 in the stock assessment model. The mean age for the combined compositions was 19 for both years. Ages 25 and greater are pooled into a plus (+) group that is fairly substantial in nearly all years, particularly the 1984 compositions. As with the fishery ages, this may imply that our age bins are somewhat restrictive for this extremely long-lived species. Future analysis may consider the potential for increasing the number of age bins to include several older age groups following the analysis that was recently completed for northern rockfish (Hulson et al. 2011).

Survey Size Compositions

Gulf-wide population size compositions for rougheye rockfish are in Table 13-12. The size composition of rougheye rockfish in the 1984 survey indicated that a sizeable portion of the population was >40 cm in length. This is consistent with the presence of a large plus group in the age composition of this survey. In the 1996 through 2011 surveys there is a substantial increase in compositions of fish <30 cm in length suggesting that at least a moderate level of recruitment has been occurring throughout these years or there are fewer larger fish in the population. Compositions from all surveys (with the possible exception of 1990) were all skewed to the right, with a mode of about 43-45 cm. The 1990 size composition appears somewhat bimodal. The average length steadily decreased from 1984-1999, ranging from 41 to 35 cm. After this the mean length remained relatively steady between 36-38 cm. In the 2007, 2009, and 2011 survey rougheye and blackspotted rockfish lengths were split. Rougheye have an average length of 35 cm while blackspotted have an average of 41 cm. Rougheye have a much broader range of lengths from 15-53 cm, while blackspotted tend to be more confined to the 35-50 cm range. Again, this may be indicative of misidentification or a true difference in size distribution between species. Future analysis of the 2009 trawl survey experiment will aid in understanding some of these differences. Trawl survey size data are used in constructing the size-age transition matrix, but not used as data to be fit in the stock assessment model since survey ages for most years were available.

AFSC Longline Survey

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 NMFS trawl surveys (Rodgveller et al. 2011).

Abundance Index

Longline data were expressed as a relative population weight (RPW) and used as a second biomass index in the model. The standard deviation of the time series was used to approximate the standard error of the individual estimates. We use 20.6% as the CV for this index. The index values along with confidence intervals are provided in Table 13-13 and graphed in Figure 13-4. Longline survey RPW estimates for rougheye have been relatively constant since 1990, with the exception of large increases in 1997 and again in 2000. A sharp decline occurred in 2005 and estimates increased until 2007, declined again through 2009 and then increased by 27 % in 2010 and 12 % in 2011. The present value is approximately 30% above average for the time series.

As mentioned in the previous section, the trawl survey is not typically capable of sampling the deeper depths and high relief habitat of rougheye and blackspotted rockfish. This is not the case with the longline survey which can sample a large variety of habitats. One drawback, however, is that juvenile fish are not susceptible to longline gear. Subsequently, the longline survey does not provide much information on recruitment. 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). Incorporating both longline and trawl survey estimates in the model should remedy some of these issues.

Survey Size Compositions

Large samples of lengths were collected Gulf-wide for rougheye rockfish from 1990 through 2005. Efficiency improved in recent surveys and lengths are now collected for nearly all rougheye and blackspotted rockfish caught. The influence of such large sample sizes in the stock assessment model are somewhat remedied by taking the square root of sample size relative to the max of the series and scaling to 100 to determine the weight for each year. However, the implications of these assumptions toward weighting of samples sizes should be addressed and is a likely area for future research.

Since the longline survey does not sample in proportion to area, we used area weighted longline survey size compositions instead of compositions based on raw sample size. The longline survey size compositions show that small fish were rarely caught in the longline survey and that the length distribution was fairly stable through time (Table 13-14). Compositions for all years were normally distributed with a mode between 45 and 47 cm in length.

Comparison of NMFS Trawl and AFSC Longline Surveys

The spatial distribution of numbers of rougheye and blackspotted rockfish caught in the 2007, 2009, and 2011 trawl and longline surveys is depicted in Figure 13-5a. The trawl survey samples more of the continental shelf than the longline survey due to differences in survey design. However, the trawl survey tends to catch more RE/BS rockfish in the central GOA, while the longline survey catches more RE/BS rockfish in the eastern and western GOA. This can be seen in the 2007 and 2011 surveys, particularly in the eastern GOA. In 2009, both estimates decreased from the previous survey. The number of fish caught for both surveys is also more evenly distributed across areas rather than the large hauls in the 2007 and 2011 surveys in the eastern and western GOA.

Rougheye and blackspotted rockfish were identified separately in the 2007, 2009, and 2011 trawl surveys. The spatial distribution of the two species somewhat reflects the area differences seen in the trawl survey biomass estimates (discussed previously in *Biomass Estimates* under ***NMFS Bottom Trawl Survey Data*** section); however, the difference seems to be more slope versus continental shelf oriented (Figure 13-5b). In general, more rougheye are identified in the shallower depths than blackspotted. The east-west trend seems to be more prevalent in the 2007 survey than the 2009 and 2011 surveys where catches in the central GOA were dominated by rougheye. The changes in spatial distribution of the two species over time may be an area of future research when determining differences in life history characteristics.

Sensitivity analysis results

As per 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 Survey

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 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 survey; however, lengths of RE/BS rockfish are not taken on the IPHC survey.

For comparison to the AFSC survey, IPHC relative population numbers (RPN) were calculated similar to the AFSC survey, the only difference being the depth stratum increments. First, catch was calculated as the extrapolated number of fish caught per set (only 20% of hooks are counted). Data were also screened for ineffective hooks and sets that may have biased catch rates (e.g. whale depredation). Then an average catch per unit of effort (CPUE) was calculated by depth stratum for each region. The CPUE was then multiplied by the area size of that stratum. A region RPN was calculated by summing the RPNs for all strata in the region. Area sizes used to calculate biomass in the RACE trawl surveys were utilized for IPHC RPN calculations.

We computed Student's t normalized residuals for all areas combined to compare between the IPHC longline, AFSC longline, and NMFS trawl surveys (Figure below). 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 rougheye/blackspotted 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 NMFS trawl survey. This is the case for all years except 2007 where the NMFS trawl survey is increasing while the IPHC survey is decreasing. We will continue to examine trends in each region and at each depth interval for evidence of recruiting year classes and for comparison to the AFSC longline survey. There is some effort in depths shallower than 200 meters on the AFSC survey, and we will compute RPNs for these depths for future comparisons with the IPHC RPNs.

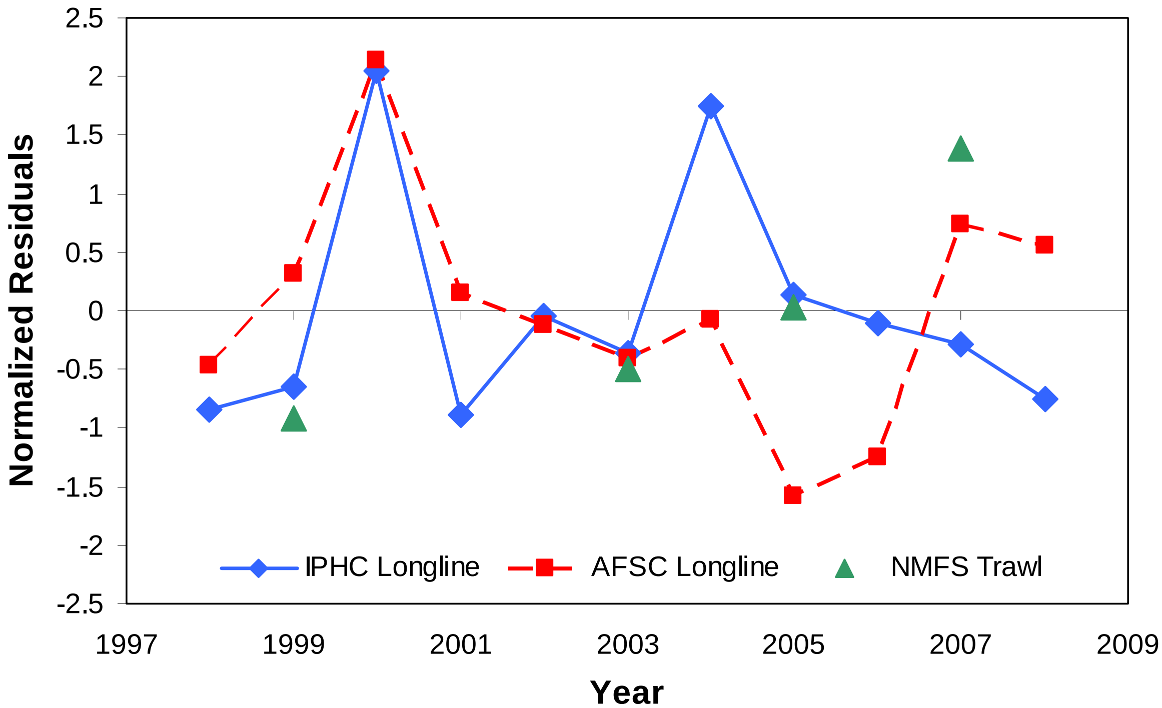


Figure: Comparison of IPHC longline (blue solid line with diamonds), AFSC longline (red dashed line with squares), and NMFS trawl surveys (green triangles) from 1997-2008.

Analytic Approach

Model Structure

We present model results for the rougheye/blackspotted rockfish complex based on an age-structured model using AD Model Builder software (ADMB Project 2009). This consists of an assessment model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model which uses result from the assessment model to predict future population estimates and recommended harvest levels. The GOA rougheye/blackspotted 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 is no information on low spawners and low recruits (Figure 13-6). The main difference between the rougheye/blackspotted model and the Pacific ocean perch model is the addition of data from the sablefish longline survey. Unlike the Pacific ocean perch model, the starting point for the rougheye/blackspotted model is 1977, so the population at the starting point has already sustained significant fishing pressure. The parameters, population dynamics and equations of the model are described in Box 1. The model has been in its current configuration since 2005. In 2009, further modifications were made to accommodate MCMC projections that use a pre-specified proportion of ABC for annual catch.

Parameters Estimated Independently

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 von Bertalanffy growth curve was fitted to survey size-at-age data from 1990 and 1999. Sexes were combined. A size-at-age transition matrix was then constructed by adding normal error with a standard deviation equal to the standard deviation of survey ages for each size class. The estimated parameters for the growth curve are shown below:

L_∞=51.2 cm κ=0.08 t_0=-1.15 n=866

Weight-at-age was constructed with weight-at-age data from the same data set as the size-at-age. The estimated growth parameters are shown below. A correction of $(W_\infty - W_{25})/2$ was used for the weight of the pooled ages (Schnute et al. 2001).

W_∞=2311 g κ=0.05 t_0=1.68 β=1.712 n=735

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 rougheye/blackspotted assessment. Age agreement tests were run on the 1990, 1999, and 2003 rougheye age samples, which were 2409 specimens and 1044 tests. We then estimated a new age error structure based on the percent agreement for each age from these tests.

The 430 specimens of rougheye/blackspotted rockfish used to derive the estimates of 50% maturity-at-age were recently aged and we now have ten years of trawl survey ages. In the future we plan to update the 50% maturity estimates, size-age matrix, weight-age series, and age error matrix with the McDermott (1994) maturity collection and the complete historical time series of trawl survey ages. We will follow the methods that were recently developed and completed for northern and dusky rockfish (Hulson et al. 2011, Lunsford et al. 2011). 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.

Parameters estimated conditionally

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 rougheye/blackspotted 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 “tight” prior CV of 10% (Figure 13-7).

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

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

The Hoenig (1983) methods based on longevity and the "rule-of-thumb" approach both produce natural mortality estimates similar to McDermott (1994). Catch-curve analysis produced an estimate of Z=0.094 and average fishing mortality (0.022) is subtracted to yield a natural mortality 0.072 which is the highest estimate. The Alverson and Carney (1975) estimate was much lower. Several assumptions of catch-curve analysis must be met before this method can be considered viable, and there is a likely time trend in recruitment for Gulf of Alaska 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 unknown 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 RPWs for rougheye and blackspotted rockfish are of the same magnitude as the trawl survey estimates we deemed this a logical starting point. We also assume a lognormal distribution to bind the minimum at zero. Without utilizing empirical data to assign a CV to the catchability prior we assign it a relatively imprecise prior CV of 45% to allow the data to influence the catchability estimate. This is a better assumption than fixing the trawl survey catchability at 1 or an arbitrary value near 1. In the future, we will consider using more informative priors for the trawl survey that are based on empirical observations from submersibles and the untrawlable/trawlable work currently underway. For the longline survey, we assign a very broad CV of 100% which essentially mimics a uniform prior with a lower bound of zero (Figure 13-8). These prior distributions allow the catchability parameters more freedom than that allowed to natural mortality.

Recruitment deviation is the amount of variability that the model assigns recruitment estimates. Rougheye and blackspotted rockfish are likely the longest-lived rockfish and information on recruitment is quite limited, but is expected to be episodic similar to Pacific ocean perch. Therefore, we assign a relatively high prior mean to this parameter of 1.1 with a "tight" CV of 6% to allow recruitments to be potentially variable (Figure 13-8).

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

Parameter name	Symbol	Number
Natural mortality	M	1
Catchability	q	2
Log-mean-recruitment	μ_r	1
Recruitment variability	σ_r	1
Fishing mortality rates	$F_{35\%}$, $F_{40\%}$, $F_{50\%}$	3
Recruitment deviations	τ_v	56
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_v	35
Fishery selectivity coefficients	fs_a	14
Survey selectivity coefficients	ss_a	25
Total		139

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 large 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 139. In a low-dimensional model, an analytical solution 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 four thousand, leaving a sample distribution of 4,000. Further assurance that the chain had converged was to compare the mean of the first half of the chain with the second half after removing the "burn-in" and "thinning". Because these two values were similar we concluded that convergence had been attained. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% credible intervals for some parameters.

BOX 1. AD Model Builder Rougheye Model Description

Parameter definitions	
y	Year
a	Age classes
l	Length classes
w_a	Vector of estimated weight at age, $a_0 \rightarrow a_+$
m_a	Vector of estimated maturity at age, $a_0 \rightarrow a_+$
a_0	Age it first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
ϕ_y	Annual fishing mortality deviation
τ_y	Annual recruitment deviation
σ_r	Recruitment standard deviation
fs_a	Vector of selectivities at age for fishery, $a_0 \rightarrow a_+$
ss_a	Vector of selectivities at age for survey, $a_0 \rightarrow a_+$
M	Natural mortality, log-scale estimation
$F_{y,a}$	Fishing mortality for year y and age class a ($fs_a \mu_f e^{\varepsilon}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
$\varepsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length transition 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 (mt)

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

Longline survey biomass index (mt)

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

Survey age distribution
Proportion at age

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

Survey length distribution
Proportion at length

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

Fishery age composition
Proportion at age

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

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

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

Number at age of recruitment
Number at ages between recruitment and pooled age class
Number in pooled age class

Formulae for likelihood components	**BOX 1 (Continued)**
$L_1 = \lambda_1 \sum_y \left(\ln\left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$	Catch likelihood
$L_2 = \lambda_2 \sum_y \frac{\left(I_{1y} - \hat{I}_{1y}\right)^2}{2 * \hat{\sigma}^2\left(I_{1y}\right)}$	Trawl survey biomass index likelihood
$L_3 = \lambda_3 \sum_y \frac{\left(I_{2y} - \hat{I}_{2y}\right)^2}{2 * \hat{\sigma}^2\left(I_{2y}\right)}$	Longline survey biomass index 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
$L_9 = \frac{1}{2\sigma_{q_1}^2} \left(\ln \frac{q_1}{q_{1\,prior}} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for trawl survey
$L_{10} = \frac{1}{2\sigma_{q_2}^2} \left(\ln \frac{q_2}{q_{2\,prior}} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for longline survey
$L_{11} = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln \frac{\sigma_r}{\sigma_{r(prior)}} \right)^2$	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
$L_{14} = \lambda_{14} \overline{s}^2$	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

This model is the same model accepted in 2009 with additional data. Estimated numbers in 2011, fishery selectivity, trawl and longline survey selectivity and schedules of age specific weight and female maturity are provided in Table 13-15 for reference.

Time Series Results

Tables 13-16 through 13-19 summarize the updated model results. Model predictions fit the age and size data relatively well (Figures 13-9, 13-10, 13-11 and 13-13). Trawl survey size compositions are provided for reference (Figure 13-12). Parameter estimates are similar to the 2009 estimates, with very similar trawl survey catchability, slightly higher longline survey catchability, and lower mean recruitment (Tables 13-16, 13-18). This is likely due to the discrepancy between the two survey trajectories and the increase in small fish for the more recent longline survey size compositions. Projected total and spawning biomass decreased. Estimates continue to track the influx of new recruits from the early 2000s. Catchability, selectivity, and recruitment are all somewhat confounded within the model. As the surveys estimate fewer fish, and age compositions suggest less recruitment, catchability estimates tend to increase so that large swings in biomass do not occur. This seems reasonable for long-lived fish such as rougheye and blackspotted rockfish.

Model predictions fit the data relatively well for the updated model. Model fits to trawl survey biomass and longline survey relative population weights (RPW) were fairly consistent over time with a steady value for the trawl survey estimate and a slight increase in the 2010 and 2011 longline survey estimate. Predicted values for the longline survey do not capture the spikes of 1997 and 2000, nor the lows of 2005 and 2006. Average longline RPWs surrounding these years combined with average trawl survey biomass estimates for 1996, 1999, and 2005 likely restrict the model from large swings in predictions for the longline RPWs. Fit to the fishery age compositions is marginal but likely hindered by an extremely large plus group (Figure 13-9). This may be improved by increasing the age bins or allowing selectivity for older aged fish more flexibility. Fit to the fishery size compositions are slightly flattened (Figure 13-10) particularly in 1991. This may be due to the slight right or left skew in most years. Fit to the trawl survey age compositions are generally very good with some over- or underestimation of the plus group in all years except 1987 and 1990 (Figure 13-11). Fit to the longline survey size compositions are similar to the fishery size compositions with slightly flattened peaks in most years (Figure 13-13).

The consistent patterns of positive residuals in the fishery and survey size compositions could be due to a variety of confounding issues between selectivity, growth, and ageing. In the future we may consider applying different shaped selectivity curves and updating the growth parameters with more years of size and age data. Additionally, we may experiment with increasing the age bins to reduce the influence of the large plus group during estimation.

Definitions

Spawning biomass is the 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.

Biomass and Exploitation Trends

Estimates of total biomass are relatively steady, decreasing slightly from the beginning of the time series until 1991 and increasing slightly to the most current estimate (Figure 13-14). Spawning biomass estimates are very similar to total biomass with a slightly steeper decreasing slope to 1991 and slightly steeper increasing slope to present (Figure 13-15). Fairly wide credible intervals result from the MCMC simulation for biomass estimates, with decreasing certainty in the more recent estimates, particularly the upper credible intervals. Estimated selectivity curves were similar to expected (Figure 13-16). The commercial fishery should target larger and subsequently older fish and the trawl survey should sample a larger range of ages. The longline survey samples deeper depths and small fish are not susceptible to the gear. The fishery selectivity curve should fall somewhere between the longline and trawl selectivity curves. The trawl survey is somewhat dome-shaped for older fish since adult habitat is typically in rocky areas along the shelf break where the trawl survey gear may have difficulty sampling. This dome-shape has relaxed somewhat from the 2009 model estimates.

Fully selected fishing mortality increased in the late 1980s and early 1990s and returned to relatively low levels from 1993 to present (Figure 13-17). The spike may be due to the management of rougheye/blackspotted rockfish in the slope rockfish complex prior to 1991 and the disproportionate harvest on shortraker due to their high value. Rougheye would also be caught as they often co-occur with shortraker. In general, fishing mortality is relatively low because historically most of the available TAC has not been caught. 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 rougheye/blackspotted rockfish has been above the F_{OFL} adjusted limit for only three years in the late 1980s and 1990 (Figure 13-18). Since 1990, spawning biomass of rougheye/blackspotted rockfish has been above $B_{40\%}$ and fishing mortality has been below $F_{40\%}$.

Recruitment

MCMC credible intervals for recruitment have continued to narrow with the addition of more age data (Figure 13-19). All CI bands do not contain zero, indicating more information is available for these estimates. This is particularly true for the 1990 year class, which exists as a large proportion in the age compositions. In general, though recruitment is highly variable, particularly in the most recent years where very little information exists on this part of the population. There also does not seem to be a clear spawner-recruit relationship for rougheye and blackspotted rockfish as recruitment is apparently unrelated to spawning stock biomass and there is little contrast in spawning stock biomass (Figure 13-6).

Uncertainty results

From the MCMC chains described previously in *Uncertainty* under the ***Analytical Approach*** section, we summarize the posterior densities of key parameters for the author recommended model using histograms (Figure 13-20) and credible intervals (Table 13-17). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass and recruitment (Figures 13-14, 13-15, 13-19, Table 13-19).

Table 13-17 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviation derived from the Hessian matrix. Also shown are the MCMC standard deviation and the corresponding Bayesian 95% credible intervals (BCI). The MLE and MCMC standard deviations are similar for q_1 (trawl survey catchability), q_2 (longline survey catchability), and M, but the MCMC standard deviations are larger for the estimates of $F_{40\%}$, projected female spawning biomass, ABC, and σ_r (recruitment deviation). The larger standard deviations indicate that these parameters are more uncertain than indicated by the standard modeling, especially in the case of σ_r in which the MLE estimate is slightly out of the Bayesian credible intervals. This highlights a concern that σ_r requires a fairly informative prior distribution since it is confounded with available data on recruitment variability. To illustrate this problem, imagine a stock that truly has variable recruitment. If this stock lacks age data (or the data are very noisy), then the modal estimate of σ_r is near zero. As an alternative, we could run sensitivity analyses to determine an optimum value for σ_r and fix it at that value instead of estimating it within the model. In contrast the Hessian standard deviation was larger for the estimate of q_2 (longline survey catchability), which may imply that this parameter is well estimated in the model. This is possibly due to the large amount of longline survey data in the model relative to other indices. The MCMC distribution of ABC, current total biomass, and current spawning biomass are skewed (Figure 13-20) indicating potential for higher biomass estimates (see also Figure 13-14 and Figure 13-15).

Projections and Harvest Alternatives

Amendment 56 Reference Points

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 1980-2009 (i.e. the 1977-2006 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 2011 estimates of these reference points are in the following table. Biomass estimates are for female spawning biomass.

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
24,329 (t)	9,732 (t)	8,515 (t)	0.039	0.047

Specification of OFL and Maximum Permissible ABC

Estimated female spawning biomass for 2012 is 12,610 t. This is above the $B_{40\%}$ value of 9,732 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 2012 yields the following *ABC* and *OFL*:

$F_{40\%}$	0.039
ABC (t)	1,223
$F_{35\%}$	0.047
OFL (t)	1,472

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 2011 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2011. 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 2011 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 2012, 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 2012 and 2013, 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 2008-2010 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 2007-2011 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 2011 or 2) above ½ of its MSY level in 2011 and above its MSY level in 2021 under this scenario, then the stock is not overfished.)

Scenario 7: In 2012 and 2013, 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 expected to be above its MSY level in 2024 under this scenario, then the stock is not approaching an overfished condition.)

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

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 2012, it does not provide the best estimate of OFL for 2013, because the mean 2012 catch under Scenario 6 is predicated on the 2012 catch being equal to the 2012 OFL, whereas the actual 2012 catch will likely be less than the 2012 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 (2010) is 450 t. This is less than the 2010 OFL of 1,568 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 2011:

a) If spawning biomass for 2011 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2011 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c) If spawning biomass for 2011 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 2021 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 2014 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2014 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c) If the mean spawning biomass for 2014 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2024. If the mean spawning biomass for 2022 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

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

Specified catch estimation

In response to Gulf of Alaska Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. In the past, two standard approaches in rockfish models have been employed; assume the full TAC will be taken, or use a certain date prior to publication of assessments as a final estimate of catch for that year. Both methods have disadvantages. If the author assumes the full TAC is taken every year, but it rarely is, the ABC will consistently be underestimated. Conversely, if the author assumes that the catch taken by around October 2011 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. 2008-2010 for this year, see example figures below). For rougheye and blackspotted rockfish, the expansion factor for 2011 catch is 1.014.

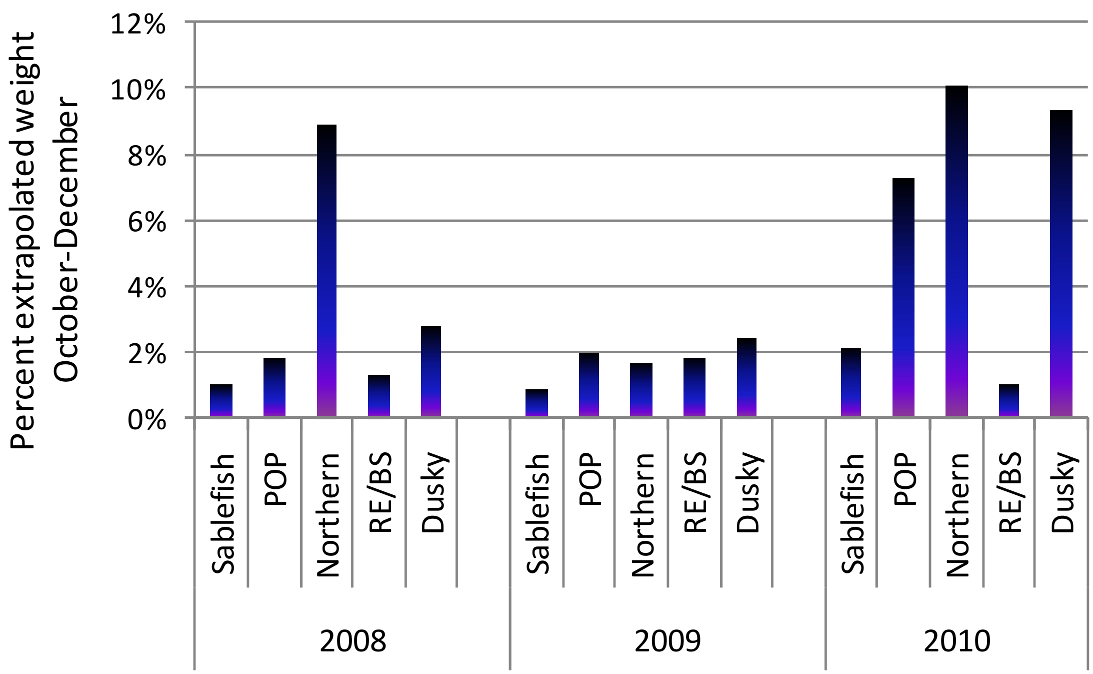


Figure. Extrapolated catch that occurs between October and December, 2008-2010.

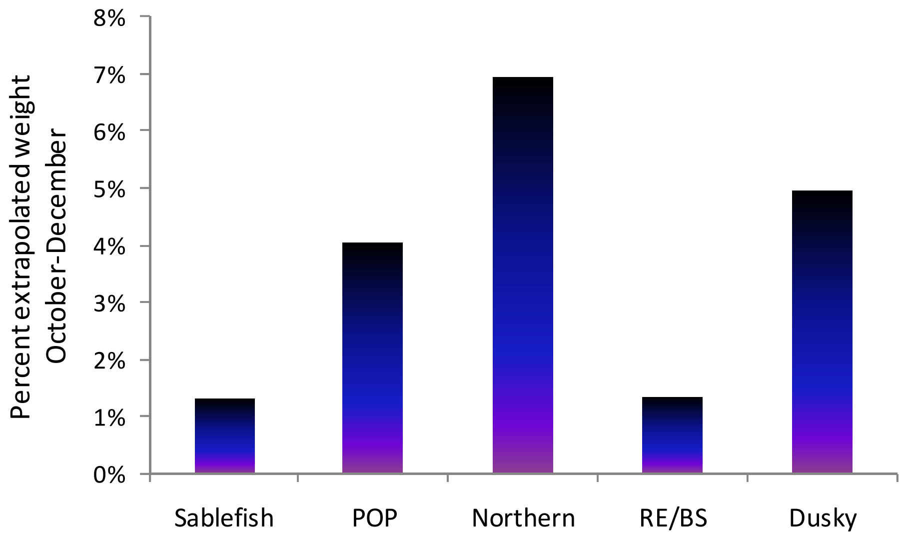


Figure. Examples of mean proportion of catch between October-December, 2008-2010.

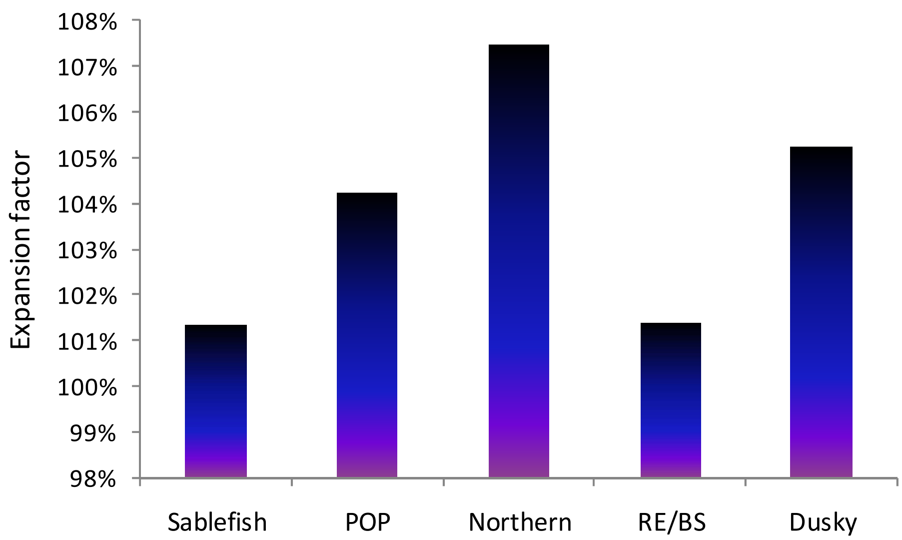


Figure. Expansion factor: $x = \sum_1^{12} C_y \,/\, \sum_1^{9} C_y$, where C_y is catch in month *y*.

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.

Alternate 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 1980-2007 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 (0.29).

Area Allocation of Harvests

We determine apportionment of ABC among areas utilizing a method that incorporates current survey information and recognizes the uncertainty in the estimation of biomass. This method was recommended by the Plan Team and accepted by the Council in 1996 and weights prior surveys based on the relative proportion of variability attributed to survey error. Assuming that survey error contributes 2/3rd of the total variability in predicting the distribution of biomass (a reasonable assumption), the weight of a prior survey should be 2/3rd the weight of the preceding survey. This resulted in weights of 4:6:9 for the 2007, 2009, and 2011 surveys, respectively and apportionments for rougheye and blackspotted rockfish of 6.60% for the Western area, 69.46% for the Central area, and 23.94% for the Eastern area (Table 13-21). Applying these percentages to the ABC for rougheye and blackspotted rockfish (1,223 t) yields the following apportionments for Gulf of Alaska 2012: 80 t for the Western area, 850 t for the Central area, and 293 t for the Eastern area.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.047), overfishing is set equal to 1,472 t for rougheye and blackspotted rockfish.

Ecosystem Considerations

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

Ecosystem Effects on the Stock

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

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

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

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

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

Effects of Rougheye/Blackspotted Fishery 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 2000-2004 have been 21-30 % for the shortraker/rougheye rockfish complex. The discard amount of species other than shortraker and RE/BS rockfish in hauls targeting these fish is unknown.

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. The average bycatch of corals/bryozoans (0.78 t) and sponges (2.98 t) by rockfish fisheries are a large proportion of the catch of those species taken by all Gulfwide fisheries.

Data Gaps and Research Priorities

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. Studies to improve our understanding of RE/BS density between trawlable and untrawlable grounds would help in our determination of catchability parameters. Future assessment priorities include:

1.) Information on the life history characteristics of blackspotted versus rougheye rockfish
2.) Update growth data for all rockfish, including age-age and age-length transition matrices
3.) Conduct sensitivity with respect to optimum plus groups for age compositions
4.) Explore different selectivity patterns to resolve marginal fit in fishery age compositions
5.) Synthesize previous studies on rockfish catchability with submersibles into informative prior distributions on catchability in the model
6.) Increase analysis of fishery spatial patterns and behavior

Summary

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

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:*	
	2011	2012	2012	2013
M (natural mortality)	0.034	0.034	0.034	0.034
Tier	3a	3a	3a	3a
Projected total (ages 3+) biomass (t)	45,907	46,154	42,856	43,085
Female spawning biomass (t)				
Projected	13,720	13,684	12,610	12,877
$B_{100\%}$	25,463	25,463	24,329	24,329
$B_{40\%}$	10,185	10,185	9,732	9,732
$B_{35\%}$	8,912	8,912	8,515	8,515
F_{OFL}	0.048	0.048	0.047	0.047
$maxF_{ABC}$	0.040	0.040	0.039	0.039
F_{ABC}	0.040	0.040	0.039	0.039
OFL (t)	1,579	1,579	**1,472**	1,492
maxABC (t)				
ABC (t)	1,312	1,312	**1,223**	1,240
Status	As determined *last* year for:		As determined *this* year for?	
	2009	2010	2010	2011
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projected ABCs and OFLs for 2012 and 2013 are derived using estimated catch of 525 t for 2011 and projected catch of 355 t for 2012 based on realized catches from 2008-2010. This calculation is in response to management requests to obtain more accurate projections.

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

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

Table 13-2. History of management measures and a time series of catch, ABC, and TAC for GOA RE/BS rockfish.

Year	Catch (t)*	ABC	TAC	Management Measures
1988	1,621	16,800	16,800	The slope rockfish assemblage, including rougheye, is one of three management groups for Sebastes implemented by the North Pacific Management Council. Previously, Sebastes in Alaska were managed as “Pacific ocean perch complex” (rougheye included) or “other rockfish”
1989	2,185	20,000	20,000	
1990	2,418	17,700	17,700	
1991	350	2,000	2,000	Slope assemblage split into three management subgroups with separate ABCs and TACs: Pacific ocean perch, shortraker/rougheye rockfish, and all other slope species
1992	1,127	1,960	1,960	
1993	583	1,960	1,764	
1994	579	1,960	1,960	
1995	704	1,910	1,910	
1996	558	1,910	1,910	
1997	545	1,590	1,590	
1998	665	1,590	1,590	
1999	320	1,590	1,590	Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	530	1,730	1,730	Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	591	1,730	1,730	
2002	273	1,620	1,620	
2003	394	1,620	1,620	
2004	301	1,318	1,318	Shortraker and rougheye rockfish divided into separate subgroups and assigned individual ABCs and TACs
2005	293	1,007	1,007	Rougheye managed separately from shortraker as age structured model accepted to determine ABC and moved to Tier 3 status
2006	358	983	983	
2007	422	988	988	Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	392	1,286	1,286	Rougheye and blackspotted formally verified as separate species so assessment now called the rougheye/blackspotted rockfish complex
2009	282	1,284	1,284	
2010	450	1,302	1,302	

*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 13-3. Estimated commercial catch[a] (t) for GOA RE/BS rockfish, with Gulfwide values of acceptable biological catch (ABC) and fishing quotas[b] (t), 1991-present.

Year	Catch (t)				ABC	TAC
	Commercial	Western GOA	Central GOA	Eastern GOA		
1977	1443					
1978	568					
1979	645					
1980	1353					
1981	719					
1982	569					
1983	628					
1984	760					
1985	130					
1986	438					
1987	525					
1988	1621					
1989	2185					
1990	2418					
1991	350				2,000	2,000
1992	1127				1,960	1,960
1993	583				1,960	1,764
1994	579				1,960	1,960
1995	704				1,910	1,910
1996	558				1,910	1,910
1997	545				1,590	1,590
1998	665				1,590	1,590
1999	320				1,590	1,590
2000	530				1,730	1,730
2001	591				1,730	1,730
2002	273				1,620	1,620
2003	394				1,620	1,620
2004	301				1,318	1,318
2005	293	53	126	115	1,007	1,007
2006	358	58	138	162	983	983
2007	422	71	194	157	988	988
2008	392	78	193	121	1,286	1,286
2009	282	80	101	101	1,284	1,284
2010	450	91	219	139	1,302	1,302

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

Table 13-4. Catch (t) of RE/BS rockfish as bycatch in other fisheries from 2006-2011. Other fisheries category not included due to confidentiality (# vessels or # processors is fewer than or equal to 2). Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/24/2011.

Year	Flatfish	Halibut	P. Cod	Pollock	Rockfish	Sablefish
2006	40	43	2	23	83	167
2007	90	60	1	28	114	129
2008	57	61	9	41	104	120
2009	34	45	7	11	97	87
2010	64	44	7	30	179	125
2011	58	36	2	34	285	119
Average	57	48	5	28	144	125

Table 13-5. FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2006-2011. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/24/2011.

	Estimated Catch (t)					
Group Name	2006	2007	2008	2009	2010	2011
Pacific Ocean Perch	13,104	12,641	12,136	12,397	14,974	12,754
Northern Rockfish	4,653	3,957	3,812	3,855	3,833	3,142
Pelagic Shelf Rockfish	2,243	3,113	3,515	2,950	2,958	2,308
Atka Mackerel	779	1,094	1,745	1,913	2,148	1,404
Pollock	351	124	390	1,280	1,046	794
Other Rockfish	742	492	629	733	734	656
Pacific Cod	521	250	445	630	731	546
Sablefish	856	641	503	404	388	435
Arrowtooth Flounder	1,085	688	517	502	706	319
Rougheye Rockfish	83	114	104	97	179	285
Shortraker Rockfish	273	291	231	247	134	237
Thornyhead Rockfish	312	300	248	185	106	160
Deep Water Flatfish	92	45	29	30	48	56
Rex Sole	98	52	67	83	93	50
Shallow Water Flatfish	45	22	71	53	47	47
Skate, Longnose	21	17	12	17	12	24
Skate, Other	49	20	10	13	28	14
Flathead Sole	25	18	19	32	24	13
Skate, Big	4	0	4	4	13	5
Demersal Shelf Rockfish	13	1	Conf.	Conf.	Conf.	Conf.
Other Species	55	42	39	57	74	
Sculpin						37
Squid						12
Shark						3
Octopus						1

Table 13-6. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2006 - 2011. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/24/2011.

			Estimated Catch (t)			
Group Name	2006	2007	2008	2009	2010	2011
Benthic urochordata	0.04	0.03	0.27	Conf.	0.08	Conf.
Birds	-	Conf.	Conf.	0.01	-	0.03
Bivalves	0.01	-	0.00	Conf.	0.01	0.01
Brittle star unidentified	0.09	0.01	0.04	0.03	0.02	0.01
Capelin	-	-	-	0.00	-	-
Corals Bryozoans	0.39	2.27	0.47	0.36	0.42	0.39
Dark Rockfish	-	-	17.86	46.98	110.85	12.88
Eelpouts	0.03	0.12	0.35	0.00	0.05	Conf.
Eulachon	0.30	0.05	0.01	0.03	0.00	0.00
Giant Grenadier	272.06	127.14	161.30	298.50	374.15	424.97
Greenlings	5.94	7.74	14.77	8.10	9.52	7.37
Grenadier	65.54	70.61	3.43	3.11	34.94	111.16
Hermit crab unidentified	0.06	Conf.	0.01	0.01	0.01	0.02
Invertebrate unidentified	0.04	0.01	0.24	0.30	5.05	0.38
Lanternfishes	-	Conf.	-	0.00	Conf.	-
Misc crabs	0.41	0.13	0.07	0.10	0.07	0.04
Misc crustaceans	-	-	-	0.36	0.02	Conf.
Misc deep fish	-	-	0.00	-	-	-
Misc fish	180.74	186.07	195.90	134.74	167.24	133.06
Misc inverts (worms etc)	0.01	-	0.01	Conf.	-	0.00
Other osmerids	0.26	0.09	Conf.	0.16	0.01	-
Pacific Sand lance	-	-	-	-	-	Conf.
Pandalid shrimp	0.17	0.11	0.11	0.09	0.22	0.06
Scypho jellies	0.43	0.21	0.11	0.70	1.89	0.00
Sea anemone unidentified	0.62	0.20	0.69	3.24	1.56	4.12
Sea pens whips	-	-	Conf.	0.01	0.01	0.04
Sea star	2.22	0.66	1.16	1.79	1.38	1.53
Snails	0.80	0.07	0.18	10.63	0.20	0.23
Sponge unidentified	0.96	0.65	2.97	6.65	3.66	4.43
Stichaeidae	0.01	-	-	0.01	-	-
Urchins, dollars, cucumbers	0.30	0.17	0.26	0.66	0.22	0.44

Table 13-7. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and thousands of animals for crab and salmon, by year, for the GOA rockfish fishery 2006-2011. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/24/2011.

Group Name	2006	2007	2008	2009	2010	2011
Bairdi Tanner Crab	0.96	0.16	0.06	0.30	0.10	0.04
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00
Chinook Salmon	0.26	2.04	2.28	1.39	1.60	1.02
Golden King Crab	0.07	0.13	0.34	3.28	3.00	0.13
Halibut	254.43	136.99	160.12	109.52	141.52	107.56
Herring	0.00	0.02	0.04	0.00	0.15	0.00
Other Salmon	1.83	0.72	0.53	0.47	0.37	0.21
Opilio Tanner Crab	0.00	0.00	0.00	0.02	0.00	0.00
Red King Crab	0.00	0.00	0.00	0.00	0.00	0.00

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

Age (years)	1990	2004	2006	2008
3	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000
7	0.0033	0.0000	0.0000	0.0000
8	0.0033	0.0000	0.0000	0.0034
9	0.0266	0.0000	0.0028	0.0103
10	0.0498	0.0049	0.0000	0.0103
11	0.0332	0.0000	0.0000	0.0069
12	0.0266	0.0000	0.0083	0.0069
13	0.0166	0.0049	0.0055	0.0172
14	0.0365	0.0049	0.0083	0.0172
15	0.0100	0.0171	0.0193	0.0137
16	0.0066	0.0098	0.0193	0.0241
17	0.0166	0.0122	0.0138	0.0412
18	0.0033	0.0073	0.0055	0.0344
19	0.0166	0.0196	0.0110	0.0515
20	0.0133	0.0416	0.0110	0.0928
21	0.0133	0.0391	0.0138	0.0275
22	0.0133	0.0440	0.0303	0.0412
23	0.0100	0.0465	0.0331	0.0206
24	0.0199	0.0367	0.0441	0.0206
25+	0.6811	0.7115	0.7741	0.5601
Sample size	301	409	363	291

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

Length (cm)	1991	1992	2002	2003	2005	2007
21	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000
23	0.0000	0.0056	0.0087	0.0000	0.0007	0.0007
25	0.0010	0.0065	0.0058	0.0012	0.0013	0.0007
27	0.0021	0.0084	0.0087	0.0020	0.0013	0.0048
29	0.0063	0.0130	0.0029	0.0040	0.0047	0.0054
31	0.0042	0.0297	0.0058	0.0032	0.0074	0.0122
33	0.0094	0.0270	0.0058	0.0064	0.0067	0.0115
35	0.0125	0.0362	0.0145	0.0095	0.0134	0.0258
37	0.0104	0.0455	0.0174	0.0139	0.0315	0.0326
39	0.0261	0.0660	0.0378	0.0382	0.0308	0.0605
41	0.0396	0.1004	0.0494	0.0545	0.0455	0.0713
43	0.1585	0.1087	0.1453	0.1010	0.0717	0.0965
45	0.2857	0.1645	0.1657	0.1427	0.1165	0.1209
47	0.2221	0.1292	0.1948	0.1924	0.1514	0.1461
49	0.1512	0.0790	0.1395	0.1717	0.1541	0.1352
51	0.0448	0.0465	0.1134	0.1125	0.1306	0.1175
53	0.0136	0.0344	0.0465	0.0719	0.0884	0.0822
55	0.0042	0.0362	0.0145	0.0322	0.0583	0.0299
57	0.0063	0.0251	0.0116	0.0199	0.0275	0.0190
59	0.0010	0.0167	0.0058	0.0079	0.0221	0.0129
60+	0.0010	0.0214	0.0058	0.0147	0.0362	0.0143
Sample size	959	1077	344	2516	1493	1472

Table 13-10. GOA RE/BS rockfish biomass estimates from NMFS triennial/biennial trawl surveys in the Gulf of Alaska. S.E. = Standard error. We exclude the 2001 survey because no sampling was performed in the Eastern Gulf. LCI and UCI are the lower and upper 95% confidence intervals respectively.

Year	Western	Central	Eastern	Biomass	S.E.	LCI	UCI	CV (%)
1984	8,779	32,416	3,896	45,091	7,313	30,758	59,425	16
1987	2,737	21,881	19,063	43,681	4,897	34,083	53,278	11
1990	1,329	35,467	8,041	44,837	9,296	26,617	63,057	21
1993	10,889	41,616	9,358	61,863	14,415	33,610	90,115	23
1996	3,449	28,396	14,067	45,913	7,432	31,346	60,481	16
1999	6,156	20,781	12,622	39,560	5,793	28,206	50,913	15
2003	8,921	24,610	9,670	43,202	6,724	30,024	56,380	16
2005	3,621	32,898	11,343	47,862	8,618	30,971	64,754	18
2007	3,773	39,410	16,697	59,880	10,380	39,536	80,225	17
2009	2,765	33,154	14,855	50,774	8,297	34,512	67,035	16
2011	3,305	32,583	8,228	44,115	7,126	30,149	58,082	16

Table 13-11. GOA RE/BS rockfish trawl survey age compositions extrapolated to population. Pooled age 25+ includes all fish 25 and older.

Age (yr)	1984	1987	1990	1993	1996	1999	2003	2005	2007
3	0.0000	0.0000	0.0011	0.0342	0.0023	0.0000	0.0285	0.0375	0.0065
4	0.0005	0.0006	0.0025	0.0122	0.0003	0.0247	0.0184	0.0468	0.0093
5	0.0000	0.0061	0.0058	0.0108	0.0204	0.0518	0.0669	0.0844	0.0331
6	0.0000	0.0652	0.0105	0.0237	0.1446	0.0251	0.0466	0.0385	0.0794
7	0.0035	0.0460	0.0395	0.0155	0.0173	0.0327	0.0275	0.0652	0.0429
8	0.0892	0.0249	0.0503	0.0211	0.0201	0.0587	0.0554	0.0510	0.0130
9	0.0338	0.0401	0.1100	0.0492	0.0321	0.1376	0.0509	0.0532	0.0465
10	0.0215	0.0533	0.1684	0.0727	0.0232	0.0505	0.0233	0.0791	0.0331
11	0.0075	0.1381	0.0918	0.0665	0.0246	0.0434	0.0203	0.0339	0.0220
12	0.0255	0.0959	0.0231	0.0898	0.0458	0.0186	0.0376	0.0504	0.0318
13	0.0100	0.0474	0.0548	0.0755	0.0410	0.0433	0.0387	0.0178	0.0480
14	0.0310	0.0445	0.0876	0.0571	0.0710	0.0442	0.0427	0.0403	0.0150
15	0.0747	0.0445	0.0285	0.0486	0.0698	0.0451	0.0136	0.0513	0.0273
16	0.0938	0.0156	0.0132	0.0633	0.0682	0.0546	0.0309	0.0327	0.0362
17	0.0400	0.0171	0.0075	0.0457	0.0517	0.0463	0.0254	0.0339	0.0411
18	0.0280	0.0149	0.0036	0.0229	0.0277	0.0565	0.0169	0.0226	0.0349
19	0.0120	0.0078	0.0206	0.0244	0.0353	0.0298	0.0195	0.0205	0.0315
20	0.0036	0.0038	0.0073	0.0242	0.0387	0.0362	0.0466	0.0315	0.0282
21	0.0094	0.0257	0.0088	0.0235	0.0212	0.0188	0.0312	0.0108	0.0308
22	0.0083	0.0070	0.0074	0.0114	0.0200	0.0192	0.0396	0.0179	0.0572
23	0.0113	0.0246	0.0098	0.0221	0.0187	0.0175	0.0396	0.0117	0.0344
24	0.0160	0.0117	0.0211	0.0098	0.0116	0.0130	0.0246	0.0116	0.0107
25+	0.4803	0.2652	0.2267	0.1758	0.1944	0.1326	0.2554	0.1574	0.2870
Sample size	369	348	194	775	701	617	488	424	435

Table 13-11 (continued). GOA RE/BS rockfish trawl survey age compositions extrapolated to population. Pooled age 25+ includes all fish 25 and older.

Age (yr)	2009
3	0.0129
4	0.0093
5	0.0176
6	0.0373
7	0.0422
8	0.0583
9	0.0454
10	0.0342
11	0.0432
12	0.0401
13	0.0487
14	0.0359
15	0.0688
16	0.0442
17	0.0439
18	0.0287
19	0.0238
20	0.0337
21	0.0199
22	0.0253
23	0.0249
24	0.0206
25+	0.2411
Sample size	473

Table 13-12. NMFS 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)	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007
21	0.0068	0.0143	0.0133	0.0158	0.0380	0.0751	0.0223	0.0602	0.0481	0.0399
23	0.0162	0.0328	0.0173	0.0176	0.0509	0.0625	0.0360	0.0579	0.0523	0.0393
25	0.0258	0.0314	0.0244	0.0236	0.0540	0.0501	0.0421	0.0437	0.0548	0.0488
27	0.0236	0.0294	0.0271	0.0288	0.0485	0.0416	0.0498	0.0423	0.0636	0.0443
29	0.0190	0.0286	0.0428	0.0341	0.0382	0.0552	0.0594	0.0484	0.0667	0.0420
31	0.0331	0.0404	0.0626	0.0472	0.0511	0.0699	0.0517	0.0570	0.0652	0.0470
33	0.0369	0.0515	0.0854	0.0519	0.0509	0.0642	0.0448	0.0579	0.0589	0.0462
35	0.0449	0.0572	0.1022	0.0692	0.0463	0.0685	0.0614	0.0473	0.0659	0.0469
37	0.0562	0.0727	0.1201	0.0772	0.0623	0.0621	0.0706	0.0418	0.0603	0.0558
39	0.0578	0.0721	0.0869	0.1069	0.0639	0.0720	0.0884	0.0525	0.0701	0.0804
41	0.0841	0.0817	0.0695	0.1240	0.0858	0.0788	0.0970	0.0680	0.0781	0.0874
43	0.1448	0.0858	0.0622	0.1337	0.1158	0.0821	0.1341	0.1003	0.0835	0.1063
45	0.1660	0.1147	0.0938	0.1259	0.1117	0.0802	0.0965	0.1146	0.0791	0.1160
47	0.1200	0.1120	0.0820	0.0764	0.0816	0.0614	0.0668	0.0963	0.0480	0.0794
49	0.0773	0.0872	0.0464	0.0323	0.0464	0.0369	0.0410	0.0598	0.0319	0.0520
51	0.0398	0.0418	0.0225	0.0116	0.0236	0.0220	0.0164	0.0261	0.0272	0.0332
53	0.0191	0.0223	0.0101	0.0067	0.0149	0.0076	0.0085	0.0099	0.0140	0.0167
55	0.0094	0.0080	0.0094	0.0036	0.0053	0.0033	0.0028	0.0069	0.0087	0.0096
57	0.0057	0.0054	0.0073	0.0034	0.0061	0.0017	0.0052	0.0029	0.0070	0.0036
59	0.0044	0.0034	0.0052	0.0031	0.0025	0.0023	0.0018	0.0022	0.0045	0.0022
60+	0.0090	0.0073	0.0096	0.0070	0.0024	0.0027	0.0034	0.0040	0.0121	0.0031
Sample size	4,701	3,994	3,522	5,639	3,943	3,758	1,959	2,924	4,089	4,252

Table 13-12 (continued). NMFS 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
21	0.0402	0.0364
23	0.0545	0.0507
25	0.0593	0.0522
27	0.0690	0.0596
29	0.0552	0.0569
31	0.0598	0.0704
33	0.0440	0.0543
35	0.0425	0.0627
37	0.0466	0.0602
39	0.0527	0.0638
41	0.0691	0.0825
43	0.0798	0.0992
45	0.0904	0.0867
47	0.0880	0.0603
49	0.0662	0.0480
51	0.0406	0.0251
53	0.0240	0.0111
55	0.0090	0.0098
57	0.0041	0.0034
59	0.0026	0.0017
60+	0.0024	0.0049
Sample size	4,155	2,475

Table 13-13. GOA RE/BS rockfish relative population weights (RPW) estimated from annual AFSC longline survey. S.E. = Standard Error. LCI and UCI are the lower and upper 95% confidence intervals respectively. CV for time series is approximately 20.6%.

Year	RPW	S.E.	LCI	UCI
1990	26,202	5,240	15,931	36,473
1991	33,341	6,668	20,271	46,410
1992	24,418	5,054	14,513	34,323
1993	28,752	5,950	17,089	40,415
1994	29,185	6,040	17,347	41,024
1995	33,663	6,967	20,008	47,318
1996	31,992	6,621	19,015	44,970
1997	46,889	9,704	27,869	65,909
1998	32,284	6,681	19,188	45,379
1999	35,298	7,305	20,980	49,617
2000	50,073	10,363	29,761	70,384
2001	35,267	7,299	20,961	49,572
2002	33,622	6,958	19,983	47,260
2003	33,611	6,956	19,977	47,244
2004	31,269	6,472	18,585	43,954
2005	22,342	4,624	13,279	31,404
2006	25,722	5,323	15,288	36,156
2007	38,233	7,913	22,724	53,742
2008	37,542	7,770	22,313	52,771
2009	30,993	6,414	18,421	43,565
2010	39,246	8,122	23,326	55,166
2011	43,843	9,074	26,058	61,627

Table 13-14. Size compositions for GOA RE/BS rockfish from the annual longline survey. Lengths are area-weighted and are binned in adjacent pairs and pooled at 60 and greater cm.

Length (cm)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
21	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
23	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
25	0.0000	0.0000	0.0011	0.0012	0.0002	0.0000	0.0000	0.0001	0.0000	0.0014
27	0.0016	0.0006	0.0004	0.0081	0.0009	0.0028	0.0001	0.0009	0.0005	0.0030
29	0.0006	0.0037	0.0037	0.0067	0.0045	0.0045	0.0030	0.0038	0.0026	0.0068
31	0.0071	0.0081	0.0108	0.0143	0.0057	0.0095	0.0098	0.0055	0.0144	0.0112
33	0.0163	0.0147	0.0214	0.0289	0.0125	0.0227	0.0140	0.0112	0.0198	0.0159
35	0.0203	0.0262	0.0335	0.0525	0.0165	0.0258	0.0286	0.0193	0.0313	0.0370
37	0.0350	0.0298	0.0476	0.0558	0.0345	0.0311	0.0452	0.0382	0.0434	0.0503
39	0.0468	0.0426	0.0682	0.0696	0.0447	0.0517	0.0672	0.0527	0.0552	0.0598
41	0.0676	0.0580	0.0983	0.0916	0.0669	0.0896	0.0913	0.0687	0.0666	0.0839
43	0.1180	0.1050	0.1367	0.1096	0.0903	0.1172	0.1181	0.1041	0.0944	0.1058
45	0.1652	0.1493	0.1610	0.1308	0.1183	0.1297	0.1366	0.1365	0.1394	0.1518
47	0.1715	0.1841	0.1325	0.1504	0.1697	0.1639	0.1549	0.1700	0.1634	0.1707
49	0.1407	0.1712	0.1209	0.1036	0.1613	0.1268	0.1424	0.1497	0.1529	0.1337
51	0.0962	0.1014	0.0678	0.0815	0.1088	0.1021	0.0931	0.1053	0.1010	0.0865
53	0.0442	0.0432	0.0415	0.0435	0.0754	0.0541	0.0413	0.0533	0.0525	0.0469
55	0.0254	0.0256	0.0167	0.0209	0.0357	0.0256	0.0250	0.0292	0.0220	0.0160
57	0.0206	0.0112	0.0115	0.0132	0.0182	0.0204	0.0139	0.0143	0.0158	0.0048
59	0.0058	0.0083	0.0091	0.0046	0.0139	0.0107	0.0057	0.0094	0.0093	0.0029
60+	0.0169	0.0169	0.0172	0.0131	0.0222	0.0117	0.0098	0.0277	0.0157	0.0118
Sample size	7,691	7,988	6,783	6,832	8,023	5,470	6,365	6,260	6,014	6,396

Table 13-14 (continued). Size compositions for GOA RE/BS rockfish from annual longline survey. Lengths are area-weighted and are binned in adjacent pairs and pooled at 60 and greater cm.

Length (cm)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
21	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
23	0.0000	0.0004	0.0003	0.0000	0.0000	0.0000	0.0009	0.0000	0.0004	0.0002
25	0.0003	0.0027	0.0013	0.0008	0.0001	0.0011	0.0002	0.0007	0.0004	0.0021
27	0.0013	0.0037	0.0028	0.0010	0.0038	0.0035	0.0025	0.0026	0.0018	0.0018
29	0.0025	0.0039	0.0060	0.0090	0.0136	0.0125	0.0123	0.0015	0.0067	0.0084
31	0.0084	0.0122	0.0106	0.0072	0.0259	0.0256	0.0077	0.0098	0.0181	0.0345
33	0.0149	0.0179	0.0189	0.0121	0.0203	0.0316	0.0182	0.0185	0.0281	0.0250
35	0.0286	0.0395	0.0268	0.0114	0.0361	0.0347	0.0241	0.0365	0.0416	0.0314
37	0.0587	0.0458	0.0390	0.0212	0.0595	0.0399	0.0366	0.0486	0.0535	0.0518
39	0.0764	0.0647	0.0597	0.0376	0.0840	0.0528	0.0454	0.0649	0.0616	0.0797
41	0.0905	0.0820	0.0740	0.0738	0.0904	0.0675	0.0820	0.1001	0.0726	0.1110
43	0.1017	0.1000	0.1268	0.1161	0.1046	0.1199	0.1183	0.1236	0.1073	0.1247
45	0.1335	0.1404	0.1561	0.1519	0.1339	0.1563	0.1493	0.1559	0.1307	0.1436
47	0.1359	0.1456	0.1530	0.1821	0.1495	0.1576	0.1614	0.1563	0.1383	0.1264
49	0.1417	0.1427	0.1365	0.1621	0.1213	0.1331	0.1531	0.1199	0.1302	0.1137
51	0.0889	0.0920	0.0844	0.0957	0.0753	0.0673	0.0869	0.0733	0.1009	0.0680
53	0.0540	0.0474	0.0518	0.0505	0.0392	0.0387	0.0474	0.0391	0.0555	0.0336
55	0.0271	0.0238	0.0194	0.0181	0.0153	0.0232	0.0237	0.0156	0.0227	0.0263
57	0.0145	0.0117	0.0127	0.0149	0.0127	0.0127	0.0122	0.0149	0.0096	0.0092
59	0.0058	0.0052	0.0092	0.0097	0.0081	0.0090	0.0083	0.0048	0.0102	0.0045
60+	0.0152	0.0183	0.0109	0.0246	0.0061	0.0130	0.0095	0.0134	0.0097	0.0042
Sample size	8,923	5,218	6,334	5,083	6,408	4,514	7,134	7,037	7,082	5,166

Table 13-14 (continued). Size compositions for GOA RE/BS rockfish from annual longline survey. Lengths are area-weighted and are binned in adjacent pairs and pooled at 60 and greater cm.

Length (cm)	2010	2011
21	0.0000	0.0000
23	0.0003	0.0003
25	0.0008	0.0019
27	0.0074	0.0061
29	0.0148	0.0122
31	0.0309	0.0275
33	0.0514	0.0403
35	0.0589	0.0573
37	0.0664	0.0727
39	0.0799	0.0907
41	0.0928	0.1082
43	0.1138	0.1240
45	0.1285	0.1217
47	0.1185	0.0995
49	0.0907	0.0938
51	0.0594	0.0575
53	0.0279	0.0318
55	0.0135	0.0153
57	0.0102	0.0112
59	0.0089	0.0051
60+	0.0250	0.0226
Sample size	5,949	5,778

Table 13-15. Estimated numbers (thousands) in 2011, fishery selectivity, trawl and longline survey selectivity of rougheye/blackspotted rockfish in the GOA. Also shown are schedules of age specific weight and female maturity.

Age	Numbers in 2011 (1000s)	Percent Mature	Weight (g)	Fishery Selectivity	Trawl Survey Selectivity	LL Survey Selectivity
3	1,082	0	156	0	16	0
4	1,041	0	268	0	26	0
5	1,084	0	373	0	45	0
6	942	0	473	0	70	0
7	913	0	568	1	74	0
8	949	0	659	1	79	0
9	1,369	0	744	2	93	0
10	1,801	1	825	3	100	0
11	1,766	2	902	3	98	0
12	808	5	975	3	81	0
13	1,507	8	1,044	4	81	2
14	1,102	14	1,109	9	81	6
15	723	22	1,172	26	81	21
16	1,044	31	1,230	100	81	60
17	3,027	40	1,286	100	81	100
18	791	50	1,339	100	81	100
19	651	59	1,390	100	81	100
20	585	66	1,437	100	81	100
21	2,001	72	1,482	100	81	100
22	369	77	1,525	100	81	100
23	400	81	1,566	100	81	100
24	310	84	1,604	100	81	100
25+	9,732	92	1,976	100	81	100

Table 13-16. Likelihoods and MLE estimates of key parameters with estimates of standard error (σ) derived from Hessian matrix for GOA RE/BS rockfish models.

	2009 Model		***2011 Updated***	
Likelihoods	Value	Weight	Value	Weight
Catch	0.054	5/50*	0.074	5/50*
Trawl Biomass	2.412	1	2.738	1
Longline Biomass	7.678	1	8.160	1
Fishery Ages	11.242	1	25.090	1
Trawl Survey Ages	31.794	1	35.247	1
Fishery Sizes	48.207	1	50.104	1
Trawl Survey Sizes	0	0	0	0
Longline Survey Sizes	93.382	1	104.519	1
Data-Likelihood	194.769		225.932	
Penalties/Priors				
Recruit Deviations	2.515	1	2.534	1
Fishery Selectivity	2.075	1	2.433	1
Trawl Selectivity	0.396	1	0.272	1
Longline Selectivity	0.808	1	0.586	1
Fish-Sel Domeshape	0	1	0	1
Survey-Sel Domeshp	0.087	1	0.038	1
LL-Sel Domeshape	0	1	0	1
Average Selectivity	0	0.1	0	0.1
F Regularity	1.225	0.1	1.193	0.1
σ_r prior	3.426		3.620	
q-trawl	0.381		0.310	
q-longline	0.001		0.013	
M	0.898		0.767	
Total penalties/priors	11.809		11.765	
Objective Fun. Total	206.578		237.697	

Parameter Estimates	Value	σ	Value	σ
q-trawl	1.478	0.464	1.422	0.431
q-longline	1.036	0.334	1.173	0.348
M	0.034	0.003	0.034	0.003
σ_r	0.932	0.058	0.928	0.058
Mean Recruitment (millions)	1.696		1.599	
$F_{40\%}$	0.040	0.011	0.039	0.011
Total Biomass (t)	45,751	14,185	42,856	12,143
Spawning Biomass (t)	13,638	4,475	12,610	3,791
$B_{100\%}$ (t)	25,463		24,329	
$B_{40\%}$ (t)	10,185	3,103	9,732	2,731
ABC$_{F40\%}$ (t)	**1,302**	572	1,223	511

*Values are weights on the catch series before the catch reliability penalty (1977-1992) and after (1993-2011).

Table 13-17. Estimates of key parameters (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.

	μ		σ		MCMC		
Parameter	Hessian	MCMC	Hessian	MCMC	Median	BCI-Lower	BCI-Upper
q_1, trawl survey	1.4220	1.5008	0.4314	0.4327	1.4595	0.7840	2.4689
q_2, longline survey	1.1734	1.0701	0.3479	0.3175	1.0533	0.5197	1.7603
M	0.0340	0.0340	0.0030	0.0031	0.0338	0.0283	0.0405
$F_{40\%}$	0.0392	0.0449	0.0107	0.0138	0.0428	0.0247	0.0791
Female Sp. Biomass	12,610	15,601	3,791	5,391	14,367	8,528	29,390
ABC	1,223	1,732	511	851	1,561	634	3,907
σ_r	0.9279	1.0785	0.0576	0.0666	1.0769	0.9551	1.2180

Table 13-18. Estimated time series of female spawning biomass, 6+ biomass (age 6 and greater), catch/6 + biomass, and number of age three recruits for RE/BS rockfish in the Gulf of Alaska. Estimates are shown for the current assessment model and from the previous assessment model.

	Spawning Biomass (t)		6+ Biomass (t)		Catch/6+ Biomass		Age 3 Recruits (1000's)	
Year	Previous	Current	Previous	Curren	Previous	Curre	Previous	Current
1977	16,928	16,232	46,573	43,850	0.031	0.033	857	729
1978	16,201	15,522	45,223	42,367	0.013	0.013	967	882
1979	15,871	15,203	44,661	41,706	0.014	0.015	4,542	3,952
1980	15,523	14,860	43,986	40,941	0.031	0.033	911	900
1981	14,886	14,223	42,633	39,523	0.017	0.018	993	885
1982	14,569	13,891	43,469	40,084	0.013	0.014	1,087	986
1983	14,359	13,651	43,156	39,714	0.015	0.016	3,027	3,070
1984	14,167	13,413	42,784	39,260	0.018	0.019	2,082	1,647
1985	13,951	13,138	42,286	38,693	0.003	0.003	1,653	1,353
1986	14,026	13,147	43,237	39,644	0.010	0.011	1,544	1,371
1987	13,988	13,039	43,589	39,808	0.012	0.013	1,092	900
1988	13,922	12,905	43,716	39,788	0.037	0.041	952	737
1989	13,422	12,336	42,744	38,714	0.051	0.056	770	635
1990	12,708	11,558	41,060	36,919	0.059	0.065	830	709
1991	11,979	10,787	39,216	34,991	0.009	0.010	889	869
1992	12,098	10,850	39,211	34,898	0.029	0.032	796	765
1993	12,006	10,697	38,539	34,140	0.015	0.017	4,598	3,963
1994	12,202	10,789	38,492	33,971	0.015	0.017	1,261	1,106
1995	12,259	10,817	38,124	33,606	0.018	0.021	1,249	1,172
1996	12,276	10,805	39,218	34,456	0.014	0.016	1,127	1,358
1997	12,372	10,865	39,284	34,441	0.014	0.016	2,133	4,970
1998	12,451	10,913	39,301	34,429	0.017	0.019	1,868	1,635
1999	12,463	10,893	39,126	34,364	0.008	0.009	1,144	1,091
2000	12,607	11,007	39,723	36,221	0.013	0.015	1,591	1,604
2001	12,907	11,236	40,500	37,075	0.015	0.016	2,267	2,121
2002	12,837	11,154	40,400	37,188	0.007	0.007	1,214	1,098
2003	12,910	11,208	40,796	37,793	0.010	0.010	2,842	2,320
2004	12,952	11,238	41,375	38,501	0.007	0.008	2,610	2,285
2005	13,210	11,500	41,909	39,170	0.007	0.007	1,819	1,679
2006	13,395	11,666	42,951	40,093	0.008	0.009	1,133	1,125
2007	13,536	11,825	43,838	40,926	0.010	0.010	1,157	1,046
2008	13,657	12,001	44,362	41,465	0.009	0.009	1,159	1,043
2009	13,757	12,188	44,545	41,713	0.006	0.007	1,157	1,160
2010		12,444		41,965		0.011		1,076
2011		12,653		41,984		0.013		1,082

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

	Recruits (Age 3)			Total Biomass			Spawning Biomass		
Year	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%
1977	729	158	7,538	44,512	32,681	79,472	16,232	11,258	27,725
1978	882	111	4,436	42,968	31,422	78,464	15,522	10,685	27,168
1979	3,952	105	3,722	42,806	31,335	78,783	15,203	10,544	27,082
1980	900	118	3,379	42,411	31,110	79,575	14,860	10,349	26,884
1981	885	102	2,668	41,272	30,026	78,216	14,223	9,831	26,509
1982	986	105	2,407	40,781	29,656	77,821	13,891	9,634	26,165
1983	3,070	118	3,844	40,757	29,623	78,452	13,651	9,586	25,947
1984	1,647	966	8,000	40,655	29,594	79,073	13,413	9,458	25,895
1985	1,353	107	3,836	40,401	29,416	79,218	13,138	9,250	25,615
1986	1,371	117	3,118	40,783	29,714	79,887	13,147	9,300	25,784
1987	900	120	3,762	40,775	29,736	79,997	13,039	9,266	25,808
1988	737	377	7,237	40,615	29,593	79,986	12,905	9,161	25,738
1989	635	198	5,765	39,318	28,489	78,924	12,336	8,721	24,988
1990	709	153	4,623	37,451	26,760	77,208	11,558	8,043	24,382
1991	869	192	3,946	35,532	25,050	75,550	10,787	7,342	23,638
1992	765	133	2,798	35,490	24,887	75,486	10,850	7,396	23,955
1993	3,963	113	2,311	35,260	24,553	75,729	10,697	7,238	23,948
1994	1,106	105	1,865	35,436	24,643	76,043	10,789	7,328	24,042
1995	1,172	129	2,219	35,458	24,647	76,682	10,817	7,342	24,364
1996	1,358	129	2,598	35,357	24,480	77,313	10,805	7,283	24,445
1997	4,970	106	2,776	35,977	24,860	79,319	10,865	7,303	24,667
1998	1,635	1,765	8,342	36,443	25,136	80,552	10,913	7,336	24,801
1999	1,091	124	4,137	36,691	25,252	81,780	10,893	7,270	24,844
2000	1,604	138	4,217	37,324	25,725	83,358	11,007	7,362	25,285
2001	2,121	159	6,439	38,202	26,427	84,792	11,236	7,502	25,719
2002	1,098	498	11,290	38,468	26,623	86,150	11,154	7,431	25,806
2003	2,320	174	7,013	39,179	27,184	87,702	11,208	7,457	25,898
2004	2,285	130	4,353	39,841	27,779	89,170	11,238	7,467	25,996
2005	1,679	207	5,928	40,832	28,730	91,454	11,500	7,628	26,482
2006	1,125	302	6,725	41,500	29,398	93,144	11,666	7,762	26,893
2007	1,046	135	4,492	41,965	29,930	94,185	11,825	7,881	27,277
2008	1,043	385	7,843	42,291	30,231	95,190	12,001	8,001	27,839
2009	1,160	300	8,418	42,528	30,256	96,083	12,188	8,169	28,285
2010	1,076	196	6,688	42,797	30,661	96,768	12,444	8,354	28,763
2011	1,082	146	5,165	42,836	30,744	98,318	12,653	8,527	29,418
2012	1,613	139	8,438	42,856	30,744	98,318	12,610	8,529	29,390

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 *Projections and Harvest Alternatives* section. Spawning biomass and yield are in t. $B_{40\%}$ = 9,732 t, $B_{35\%}$ = 8,515 t, $F_{40\%}$ = 0.039 and $F_{35\%}$ = 0.047.

Year	Maximum permissible F	Author's F*	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning Biomass (t)				
2011	12,391	12,391	12,391	12,391	12,391	12,391	12,391
2012	12,468	12,610	12,568	12,597	12,668	12,426	12,468
2013	12,395	12,877	12,732	12,833	13,079	12,258	12,395
2014	12,308	12,983	12,879	13,051	13,478	12,079	12,267
2015	12,448	13,115	13,263	13,512	14,134	12,125	12,310
2016	12,324	12,966	13,363	13,684	14,494	11,917	12,094
2017	12,195	12,811	13,452	13,845	14,846	11,711	11,879
2018	12,064	12,653	13,533	13,997	15,192	11,505	11,664
2019	12,146	12,720	13,854	14,400	15,819	11,504	11,658
2020	11,937	12,480	13,836	14,450	16,060	11,231	11,376
2021	11,683	12,194	13,755	14,432	16,223	10,924	11,059
2022	11,467	11,947	13,704	14,443	16,416	10,657	10,783
2023	11,288	11,737	13,683	14,482	16,635	10,432	10,549
2024	11,054	11,471	13,578	14,429	16,743	10,162	10,269
			Fishing Mortality				
2011	0.017	0.017	0.017	0.017	0.017	0.017	0.017
2012	0.039	0.011	0.020	0.014	-	0.047	0.047
2013	0.039	0.011	0.020	0.014	-	0.047	0.047
2014	0.039	0.039	0.020	0.014	-	0.047	0.047
2015	0.039	0.039	0.020	0.014	-	0.047	0.047
2016	0.039	0.039	0.020	0.014	-	0.047	0.047
2017	0.039	0.039	0.020	0.014	-	0.047	0.047
2018	0.039	0.039	0.020	0.014	-	0.047	0.047
2019	0.039	0.039	0.020	0.014	-	0.047	0.047
2020	0.039	0.039	0.020	0.014	-	0.047	0.047
2021	0.039	0.039	0.020	0.014	-	0.047	0.047
2022	0.039	0.039	0.020	0.014	-	0.047	0.047
2023	0.039	0.039	0.020	0.014	-	0.047	0.047
2024	0.039	0.039	0.020	0.014	-	0.047	0.047
			Yield (t)				
2011	525	525	525	525	525	525	525
2012	1,223	1,223*	618	438	-	1,472	1,223
2013	1,208	1,240*	621	443	-	1,441	1,208
2014	1,200	1,264	628	451	-	1,421	1,443
2015	1,192	1,253	635	458	-	1,402	1,422
2016	1,194	1,252	646	468	-	1,395	1,414
2017	1,192	1,246	655	476	-	1,384	1,402
2018	1,175	1,226	655	479	-	1,356	1,373
2019	1,162	1,212	659	484	-	1,332	1,349
2020	1,131	1,178	652	481	-	1,289	1,304
2021	1,100	1,144	643	477	-	1,246	1,260
2022	1,075	1,116	638	475	-	1,211	1,224
2023	1,053	1,091	633	473	-	1,179	1,191
2024	1,030	1,065	627	470	-	1,148	1,159

*Projected ABCs and OFLs for 2012 and 2013 are derived using estimated catch of 525 t for 2011 and projected catch of 355 t for 2012 based on realized catches from 2008-2010. This calculation is in response to management requests to obtain more accurate projections.

Table 13-21. Allocation of ABC and OFL for 2008 GOA RE/BS rockfish.

Year	Weights	Western Gulf	Central Gulf	Eastern Gulf	Total
2007	4	6%	66%	28%	100%
2009	6	6%	65%	29%	100%
2011	9	7%	74%	19%	100%
Weighted Mean	19				
Area Allocation		6.60%	69.46%	23.94%	100%
Area ABC (t)		**80**	**850**	**293**	**1,223**
OFL (t)					**1,472**

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

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

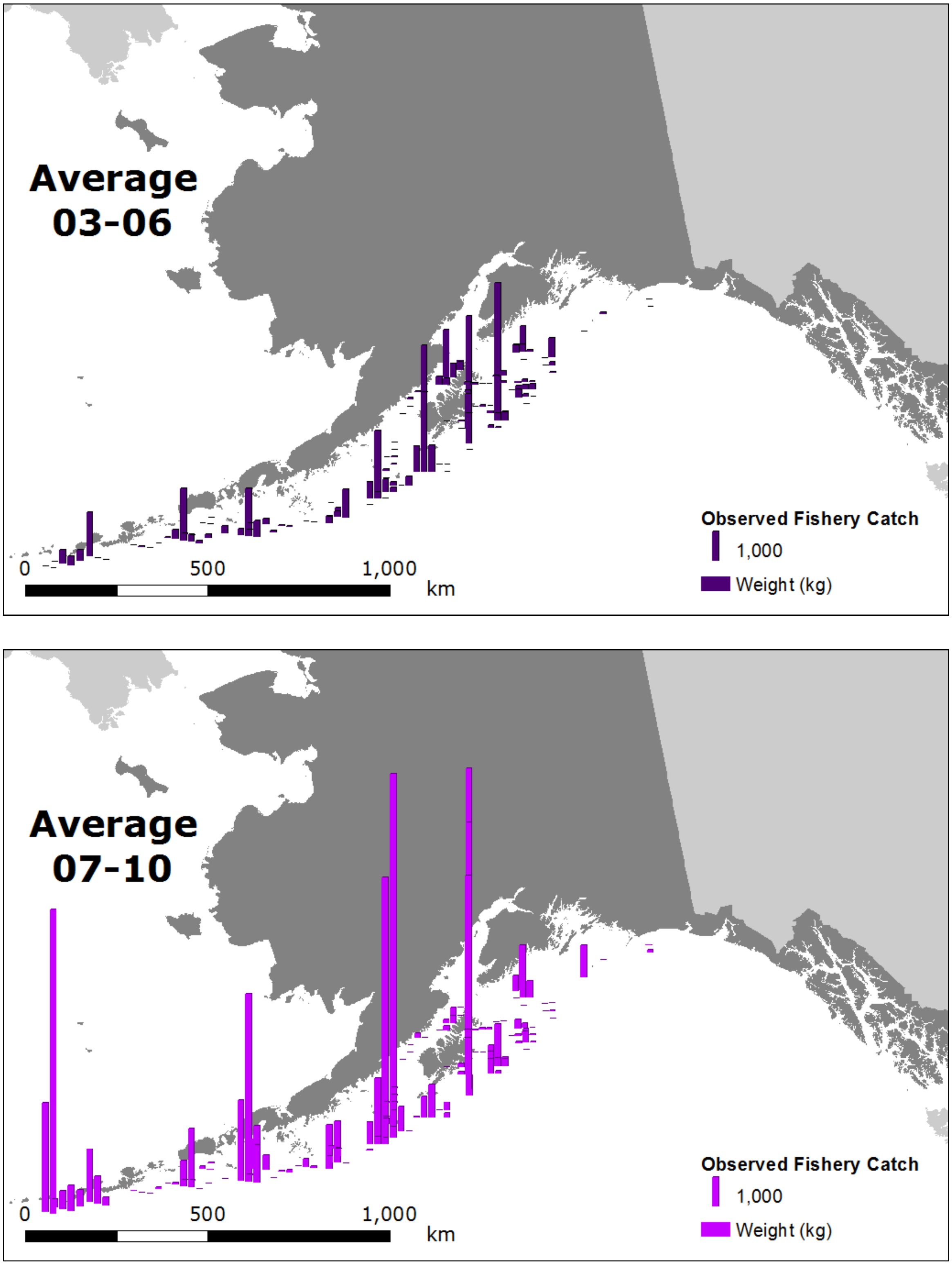
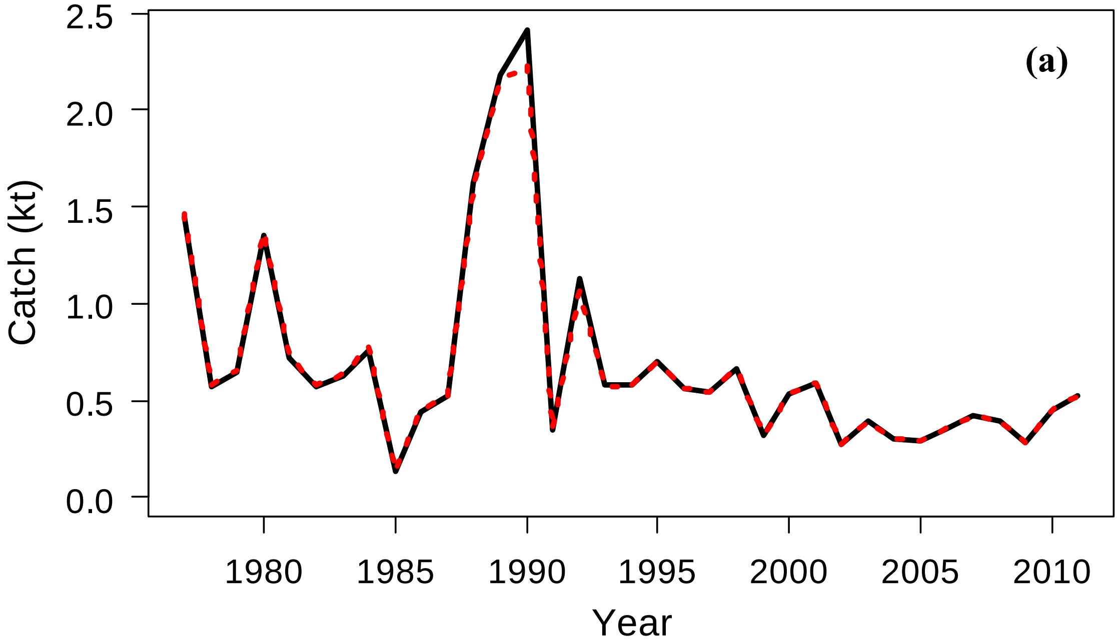


Figure 13-1. Spatial distribution of observed rougheye and blackspotted rockfish trawl fishery catch in the Gulf of Alaska (GOA) based on observer data aggregated by 400 km^2 blocks and averaged by (a) four years prior to central GOA Rockfish Pilot Program, 2003-2006, and (b) four years after implementation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



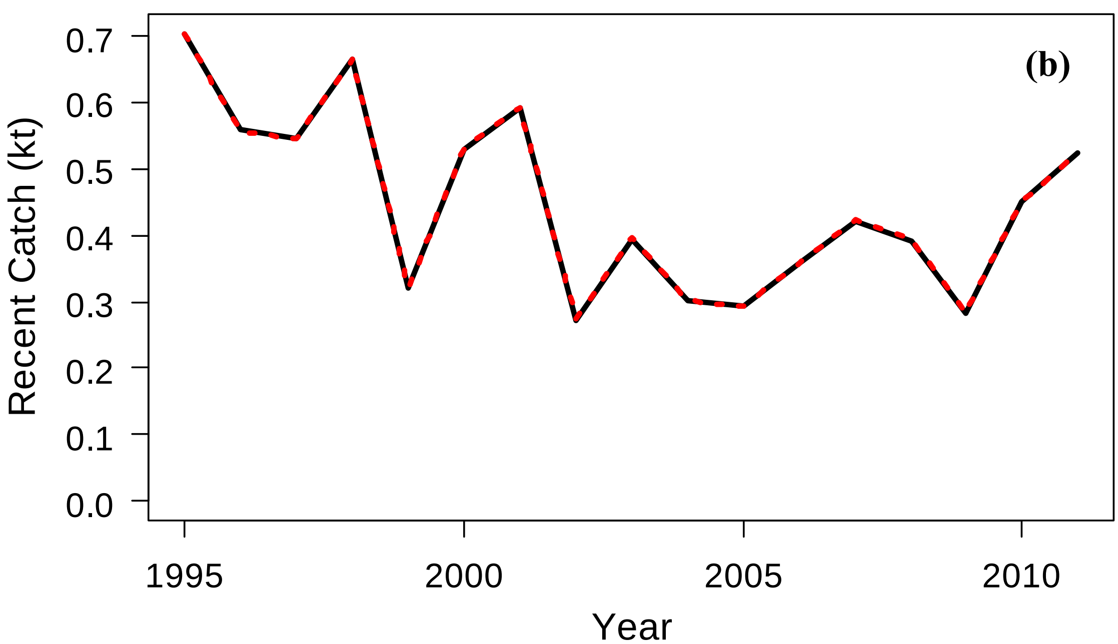


Figure 13-2. Estimated long-term (a) and short-term (b) commercial catches for Gulf of Alaska RE/BS rockfish. Solid line is observed catch and red dashed line is predicted from author recommended model.

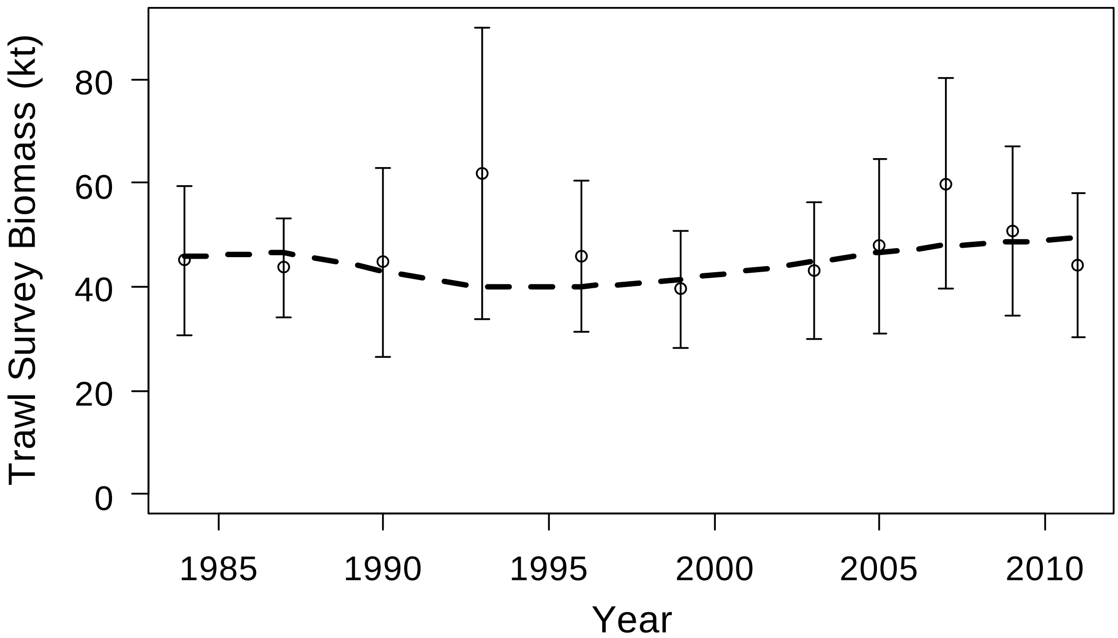


Figure 13-3. Observed (open circles) and predicted (dashed line) GOA RE/BS rockfish NMFS trawl survey biomass. Observed biomass presented with 95% confidence intervals of sampling error.

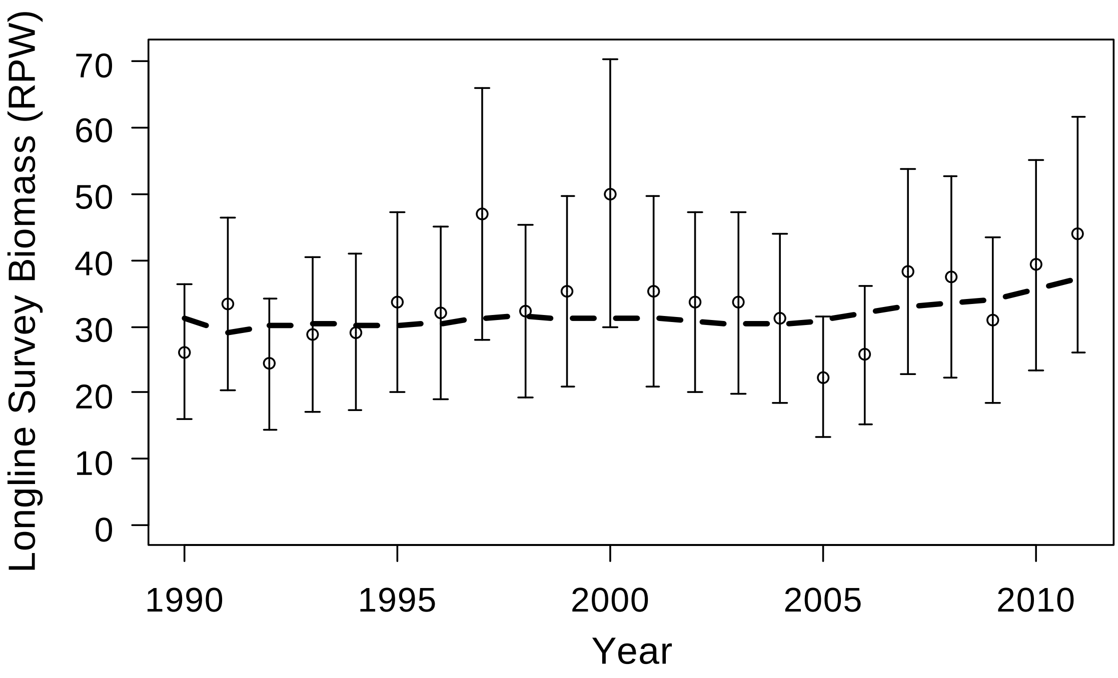
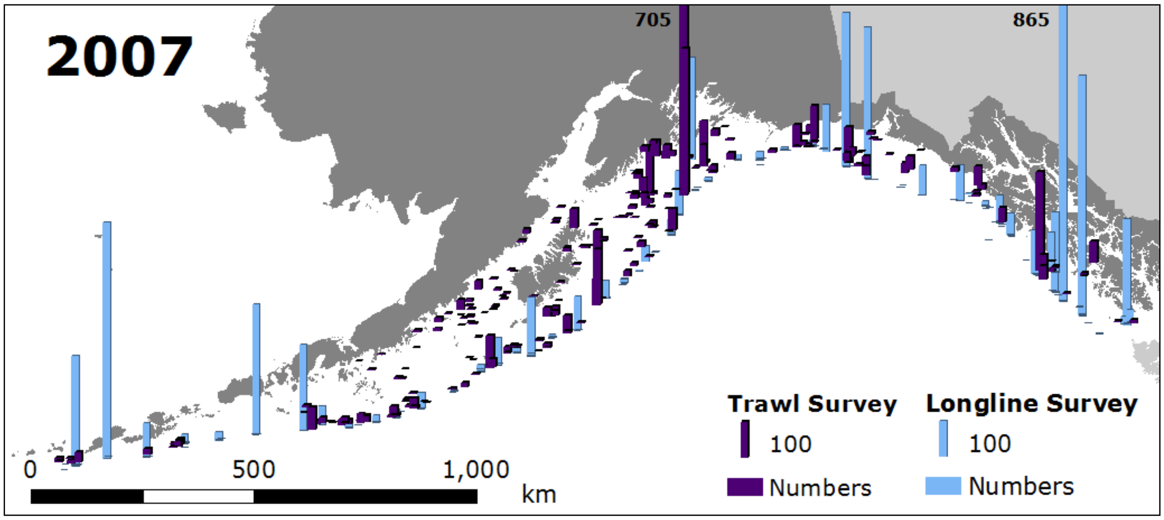
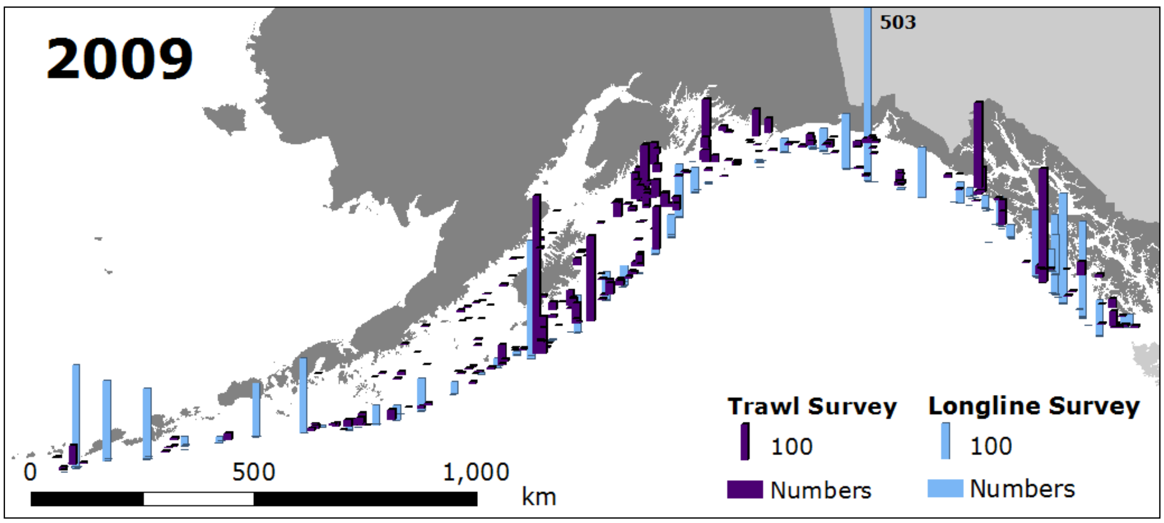


Figure 13-4. Observed (open circles) and predicted (dashed line) GOA RE/BS rockfish AFSC longline survey relative population weight (RPW in thousands). Observed biomass presented with 95% confidence intervals of sampling error.





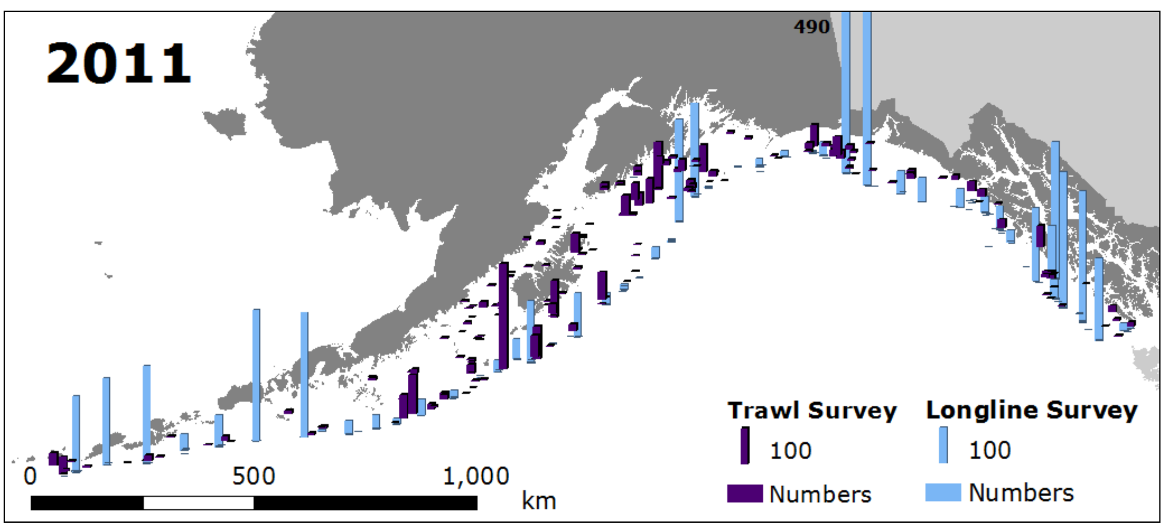


Figure 13-5a. Spatial distribution of rougheye and blackspotted rockfish in the Gulf of Alaska during the 2007, 2009, and 2011 AFSC trawl (dark purple) and AFSC longline (blue) surveys.

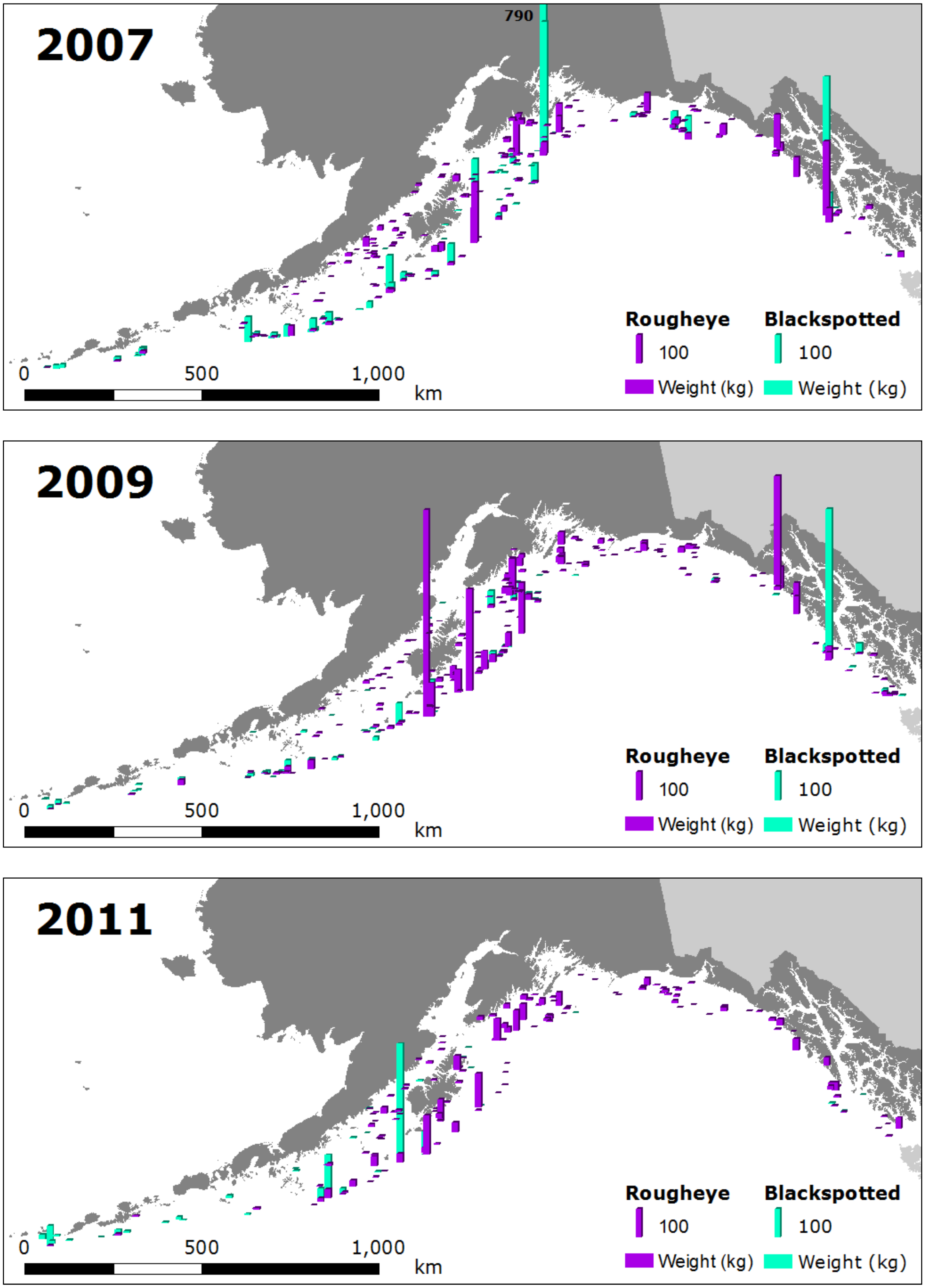


Figure 13-5b. Comparison of the spatial distribution between rougheye (purple) and blackspotted (green) rockfish in the Gulf of Alaska during the 2007, 2009, 2011 AFSC trawl surveys.

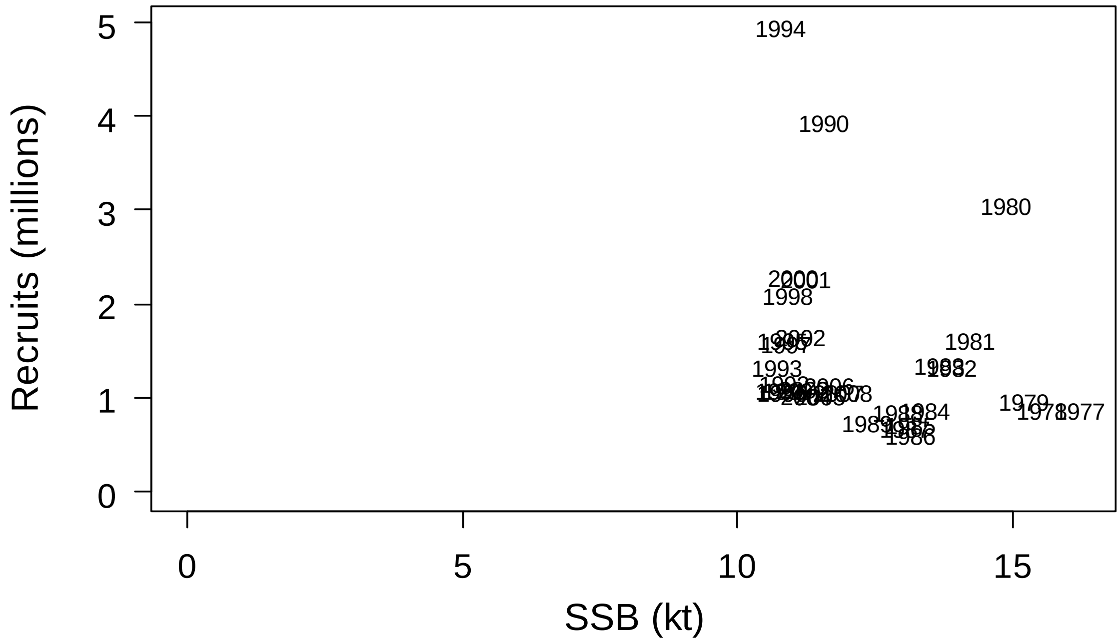


Figure 13-6. Scatterplot of spawner-recruit data for GOA RE/BS rockfish author recommended model. Label is year class of age 3 recruits. Recruits are in millions and SSB = Spawning stock biomass in tons.

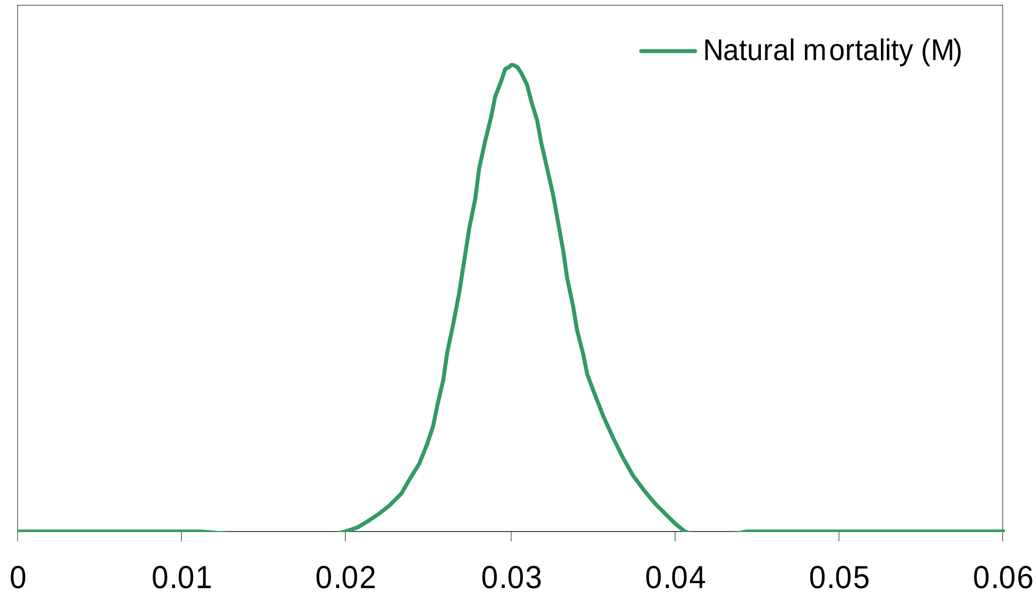


Figure 13-7. Prior distribution for natural mortality (M, μ=0.03, CV=10%) of GOA RE/BS rockfish.

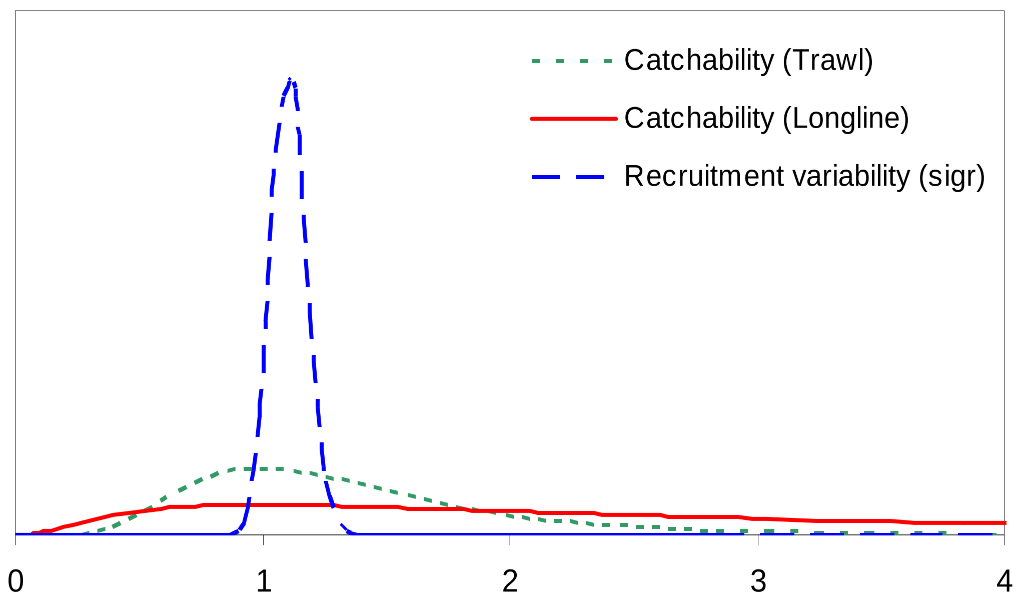


Figure 13-8. Prior distributions for NMFS trawl survey catchability ($q1$, μ=1, CV=45%), AFSC longline survey catchability ($q2$, μ=1, CV=100%), and recruitment variability (σ_r, μ=1.1, CV=6%) of GOA RE/BS rockfish.

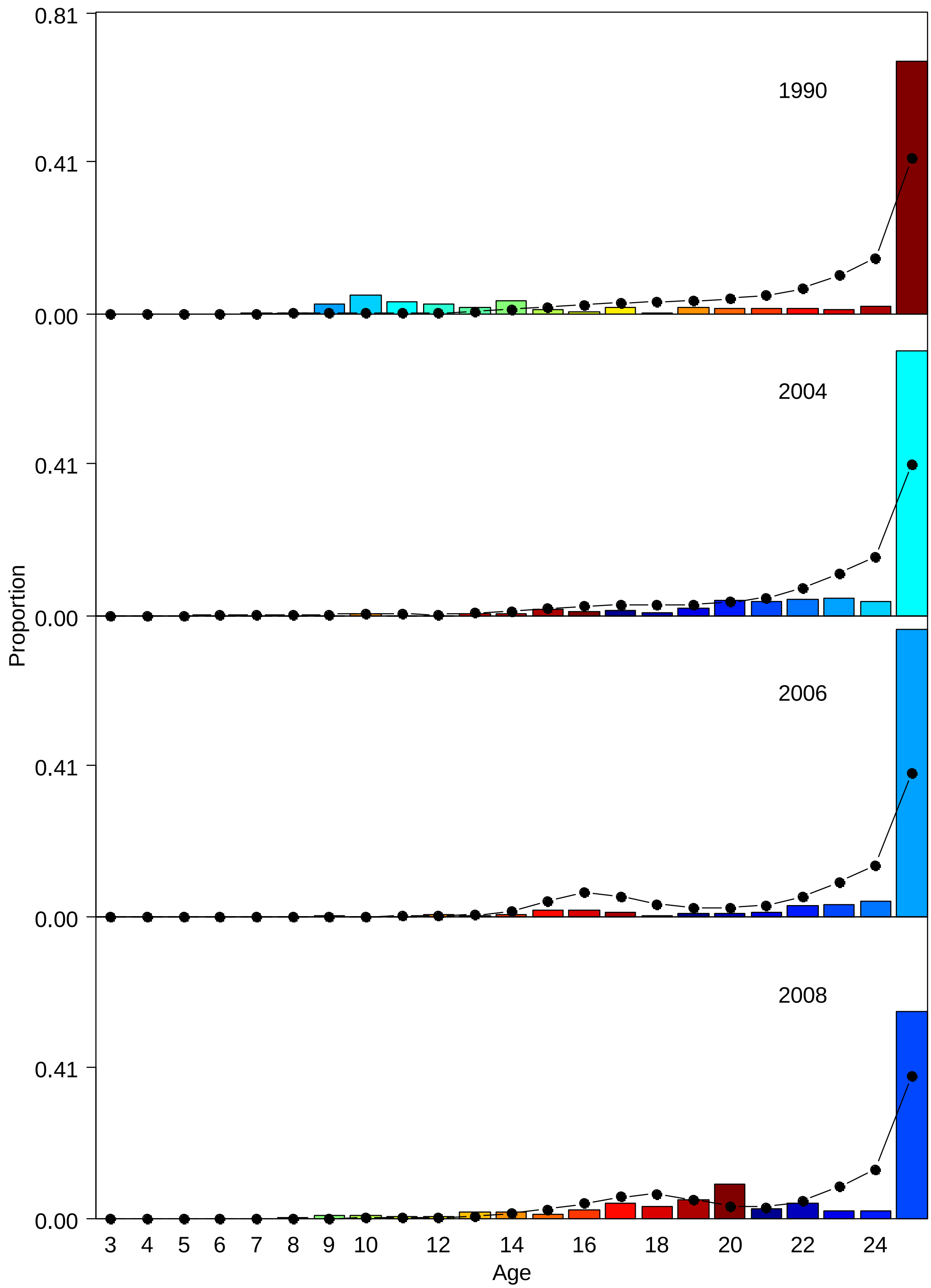


Figure 13-9. Fishery age compositions for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

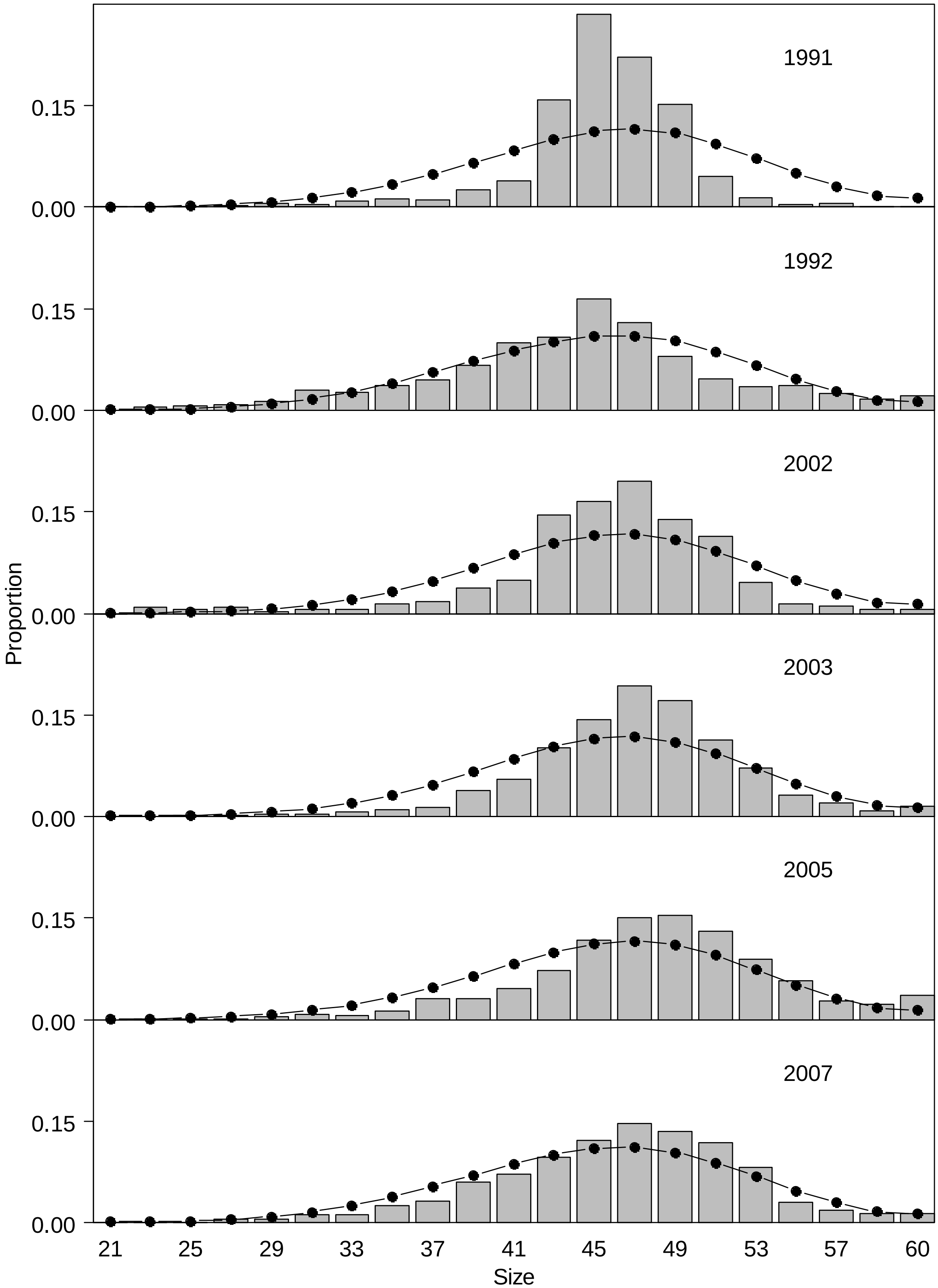


Figure 13-10. Fishery length compositions for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

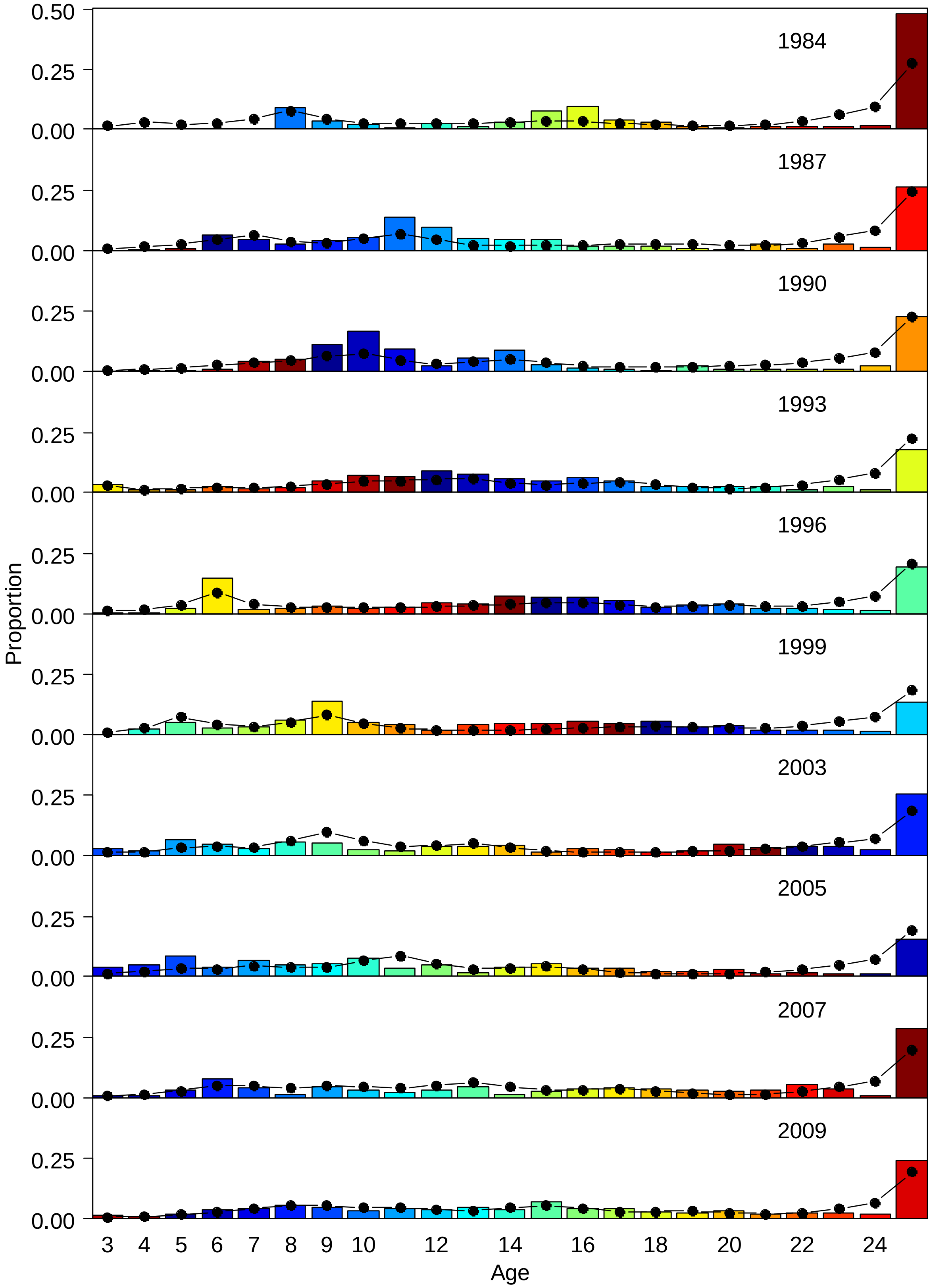


Figure 13-11. NMFS trawl survey age composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

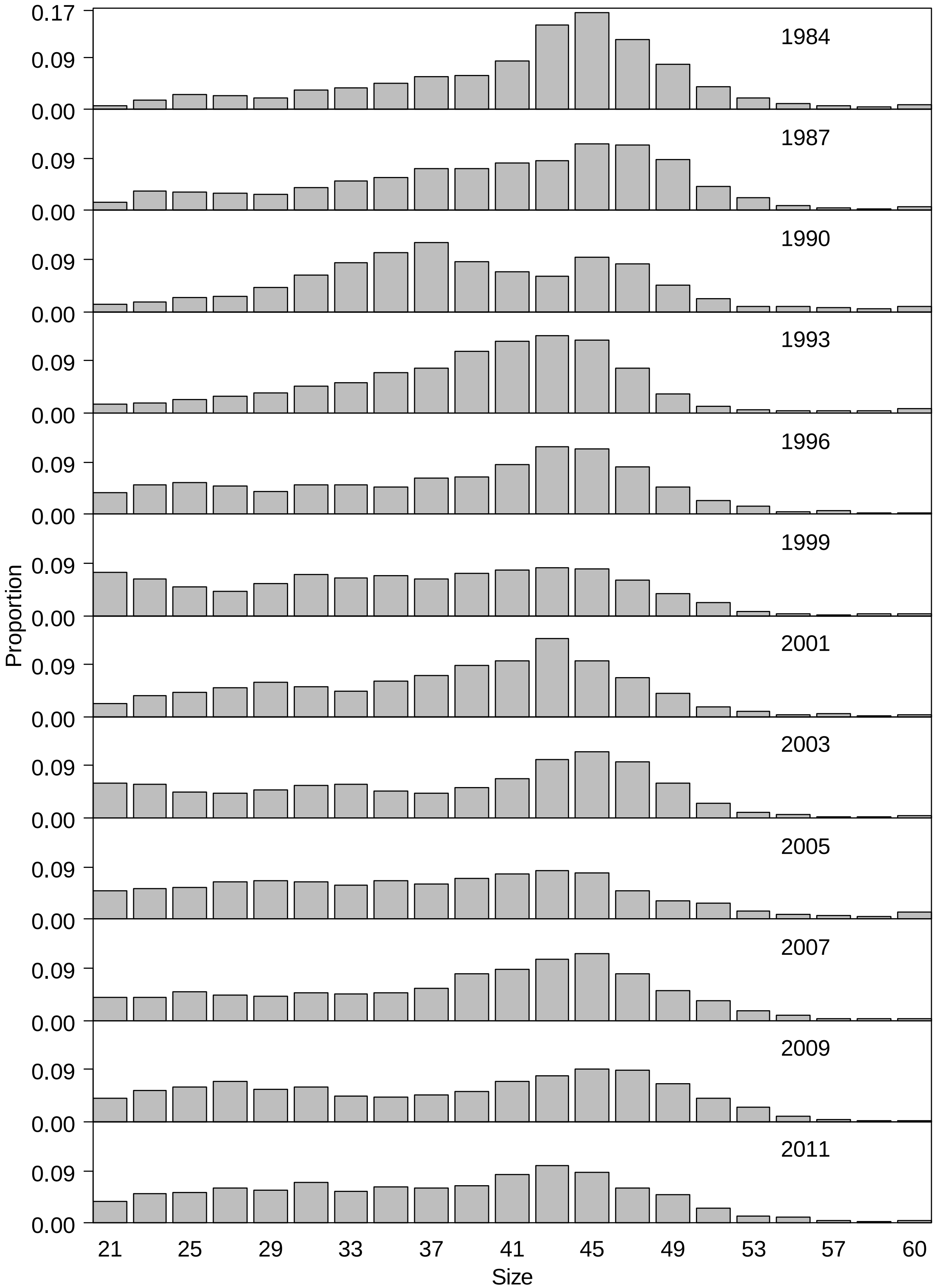


Figure 13-12. NMFS trawl survey length composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in model.

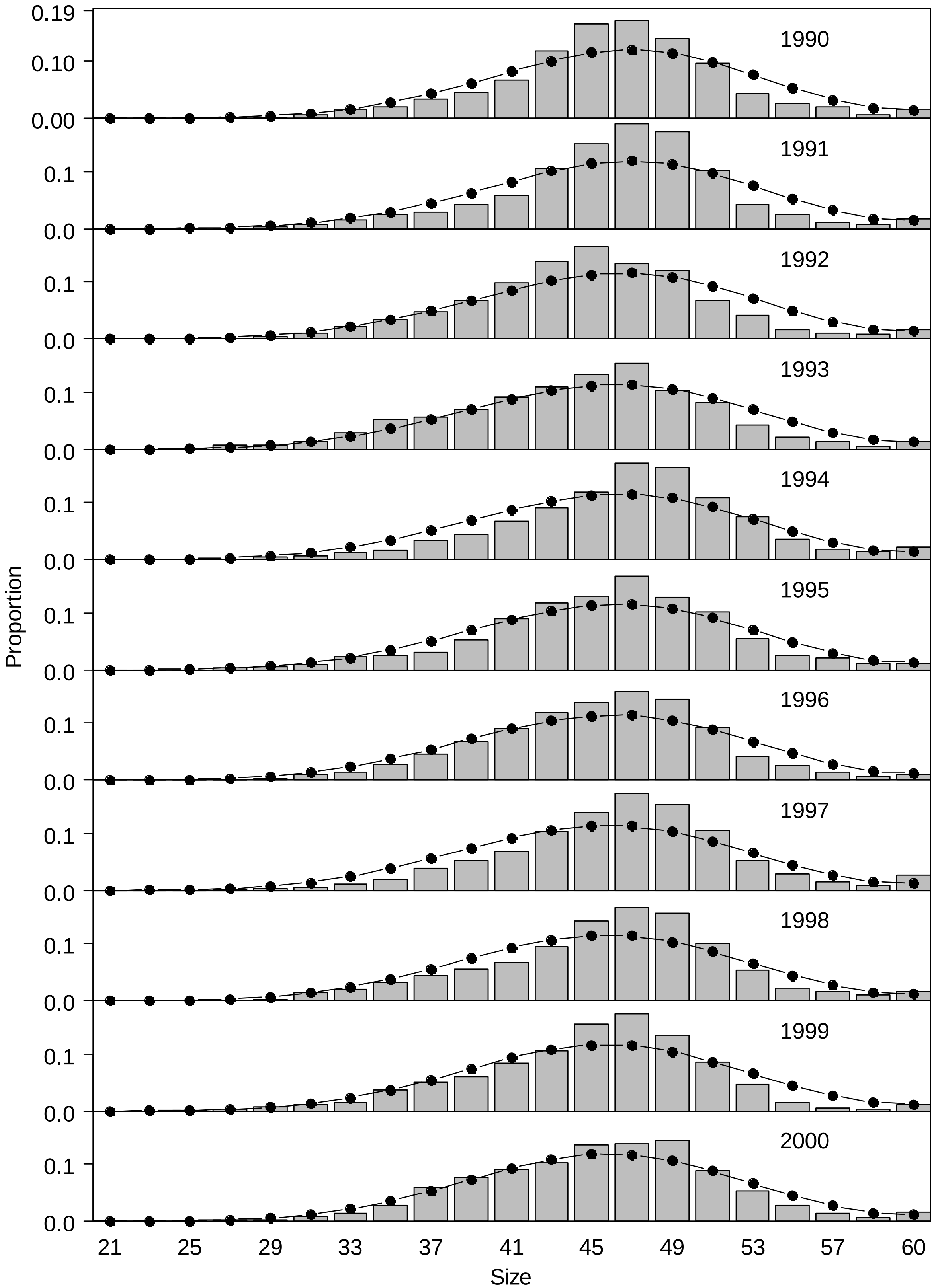


Figure 13-13. AFSC longline survey length composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

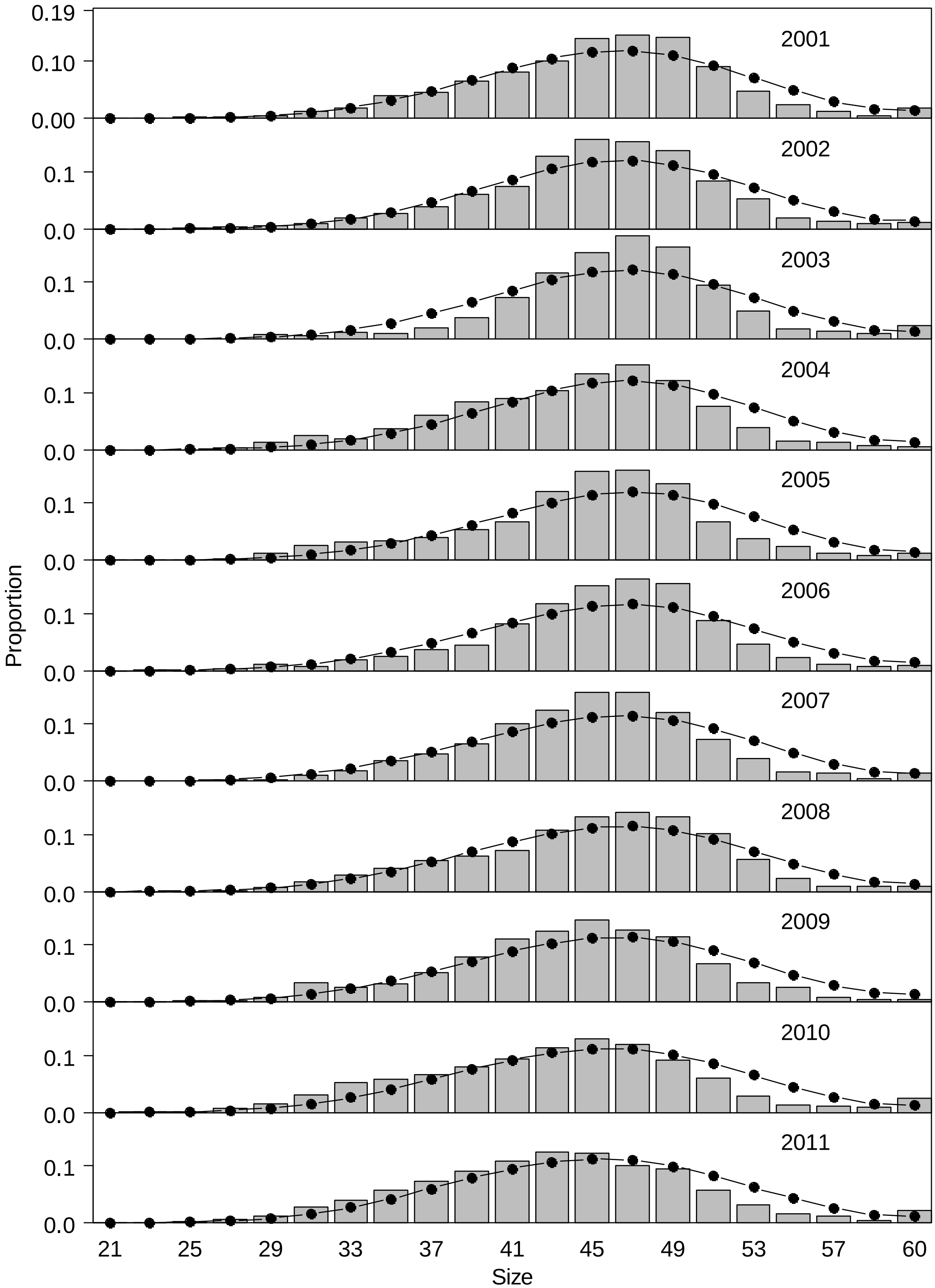


Figure 13-13 (continued). AFSC longline survey length composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

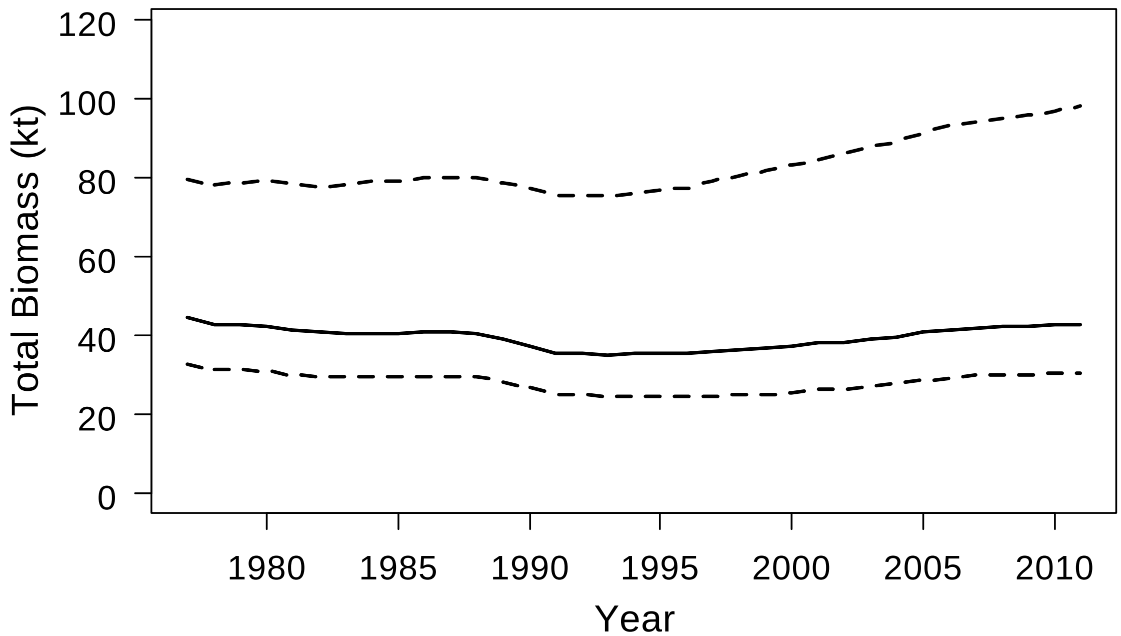


Figure 13-14. Time series of predicted total biomass for GOA RE/BS rockfish for author recommended model**.** Dashed lines = 95% credible intervals from 20 million MCMC runs.

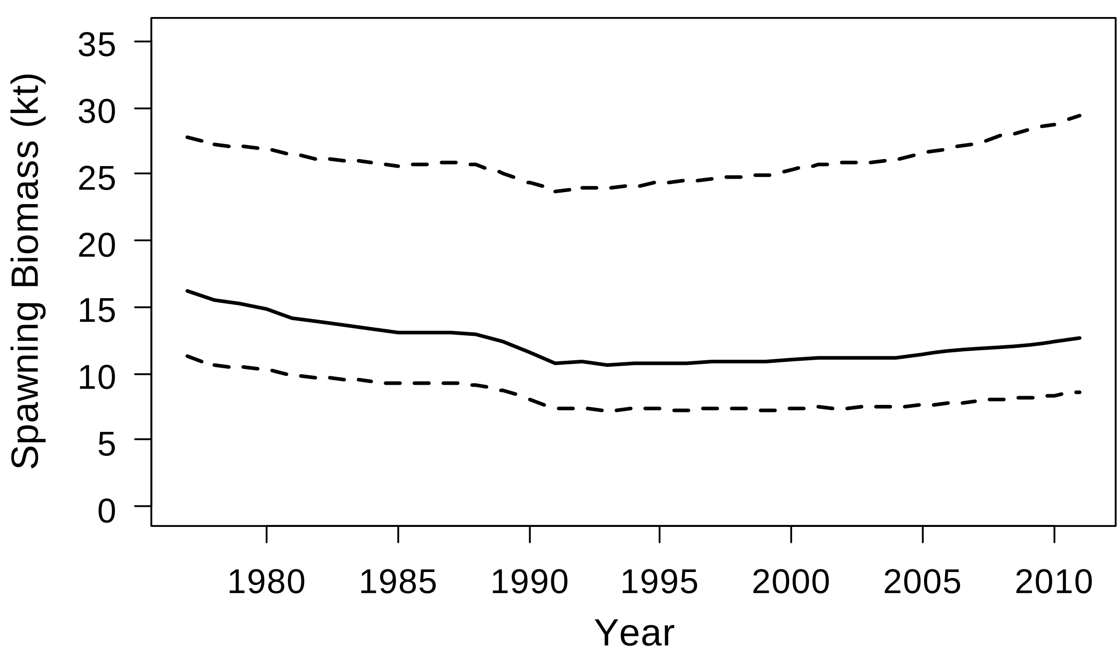


Figure 13-15. Time series of predicted spawning biomass of GOA RE/BS rockfish for author recommended model. Dashed lines = 95% credible intervals from 20 million MCMC runs.

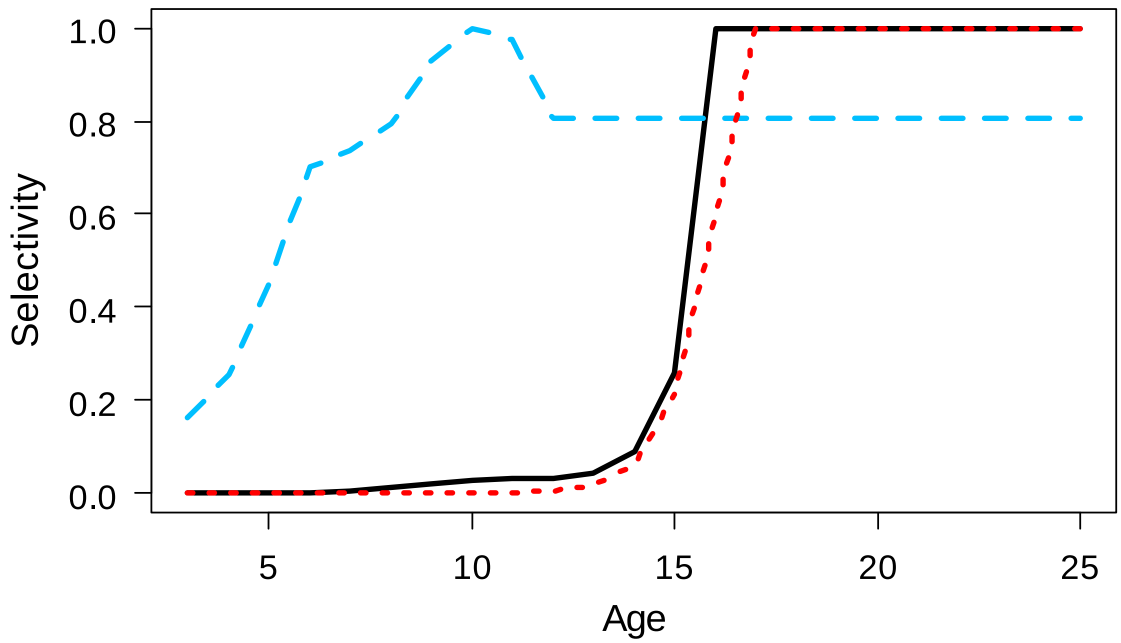


Figure 13-16. Estimated selectivity curves for GOA RE/BS rockfish from author recommended model. Dashed blue line = NMFS trawl survey selectivity, dotted red line = AFSC longline survey selectivity, and solid black line = combined fishery selectivity.

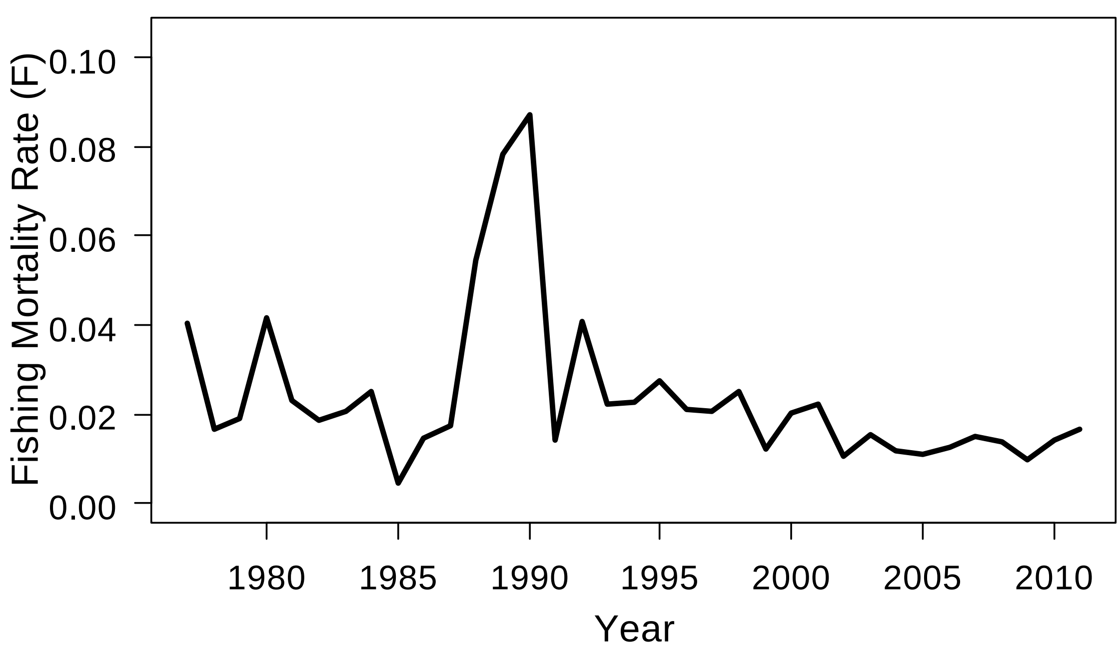


Figure 13-17. Time series of estimated fully selected fishing mortality for GOA RE/BS rockfish from author recommended model.

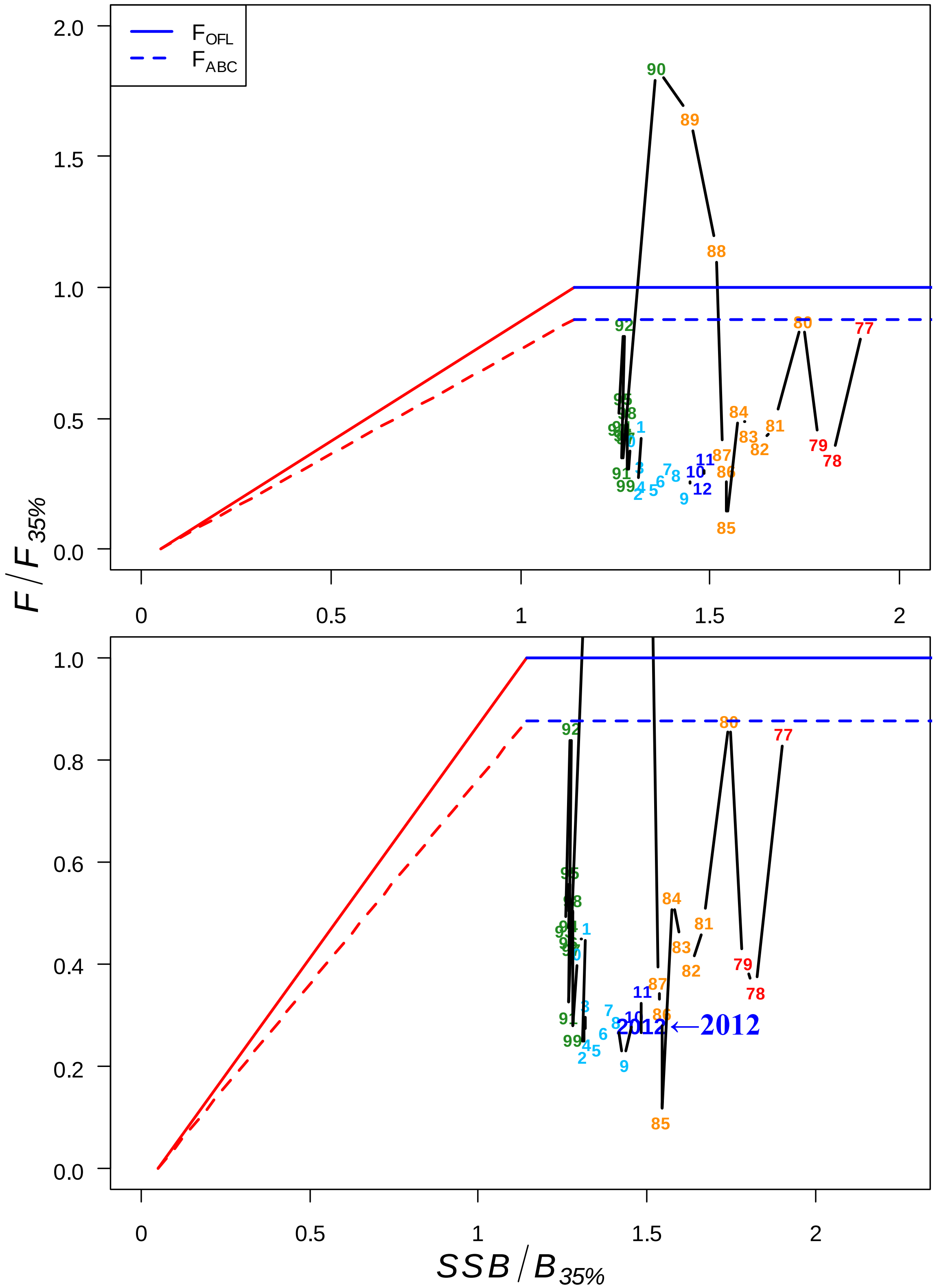


Figure 13-18. Time series of GOA RE/BS rockfish estimated spawning biomass relative to the $B_{35\%}$ and fishing mortality relative to F_{OFL} for author recommended model.

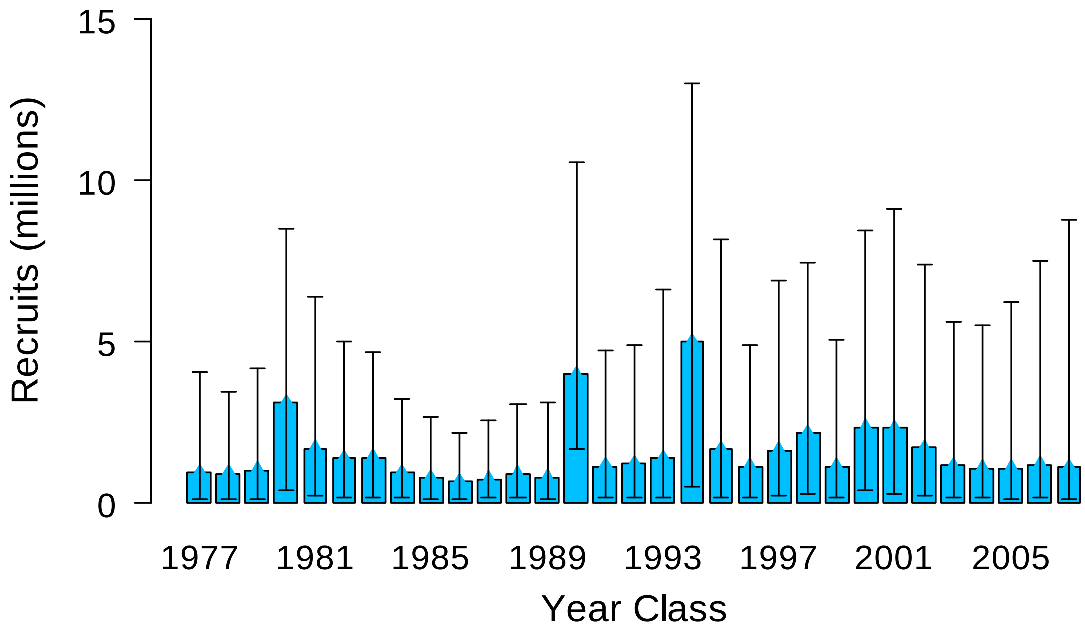


Figure 13-19. Estimated recruitments (age 3) for GOA RE/BS rockfish from author recommended model.

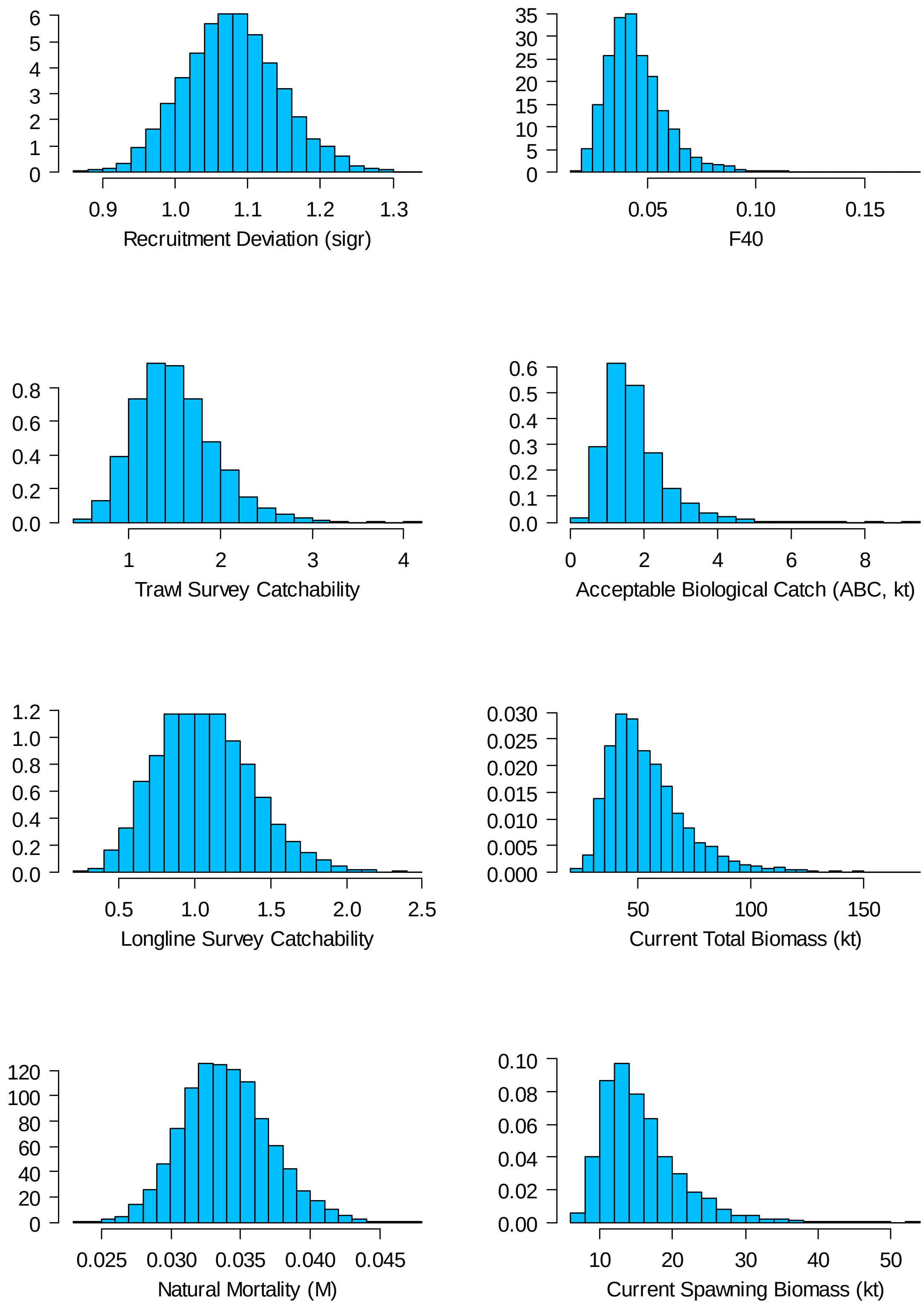


Figure 13-20: Histograms of estimated posterior distributions for key parameters derived from the 20 million MCMC runs for GOA RE/BS rockfish.

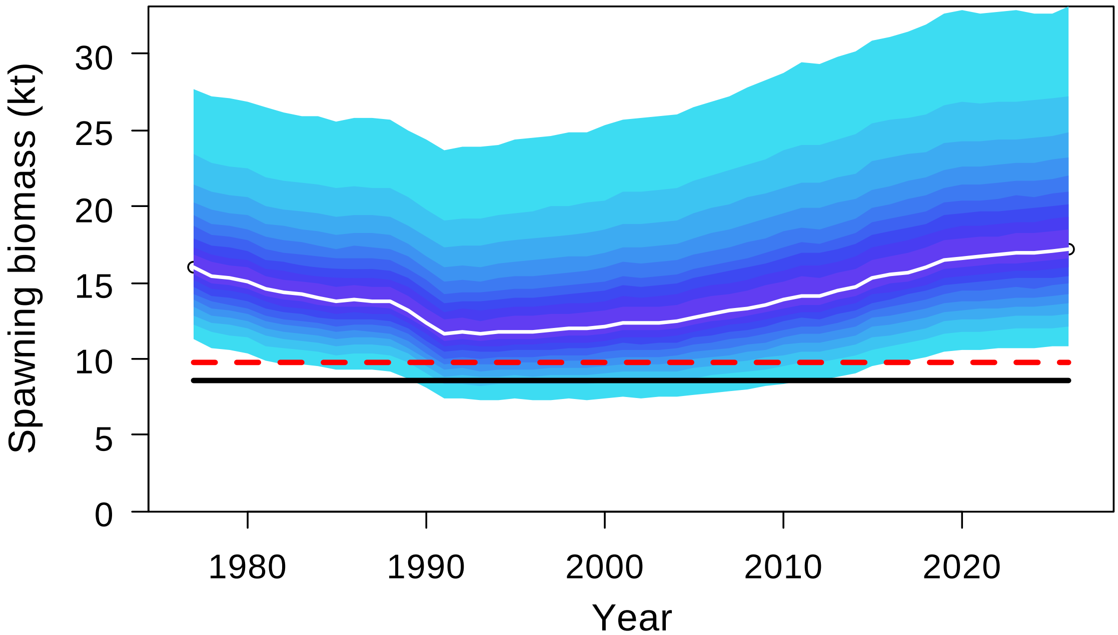


Figure 13-21: Bayesian credible intervals for entire spawning stock biomass series including projections through 2024. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1980-2009. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

Appendix 13A. Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska. The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities (Table 13A-1). This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For Gulf of Alaska (GOA) rougheye and blackspotted (RE/BS) rockfish stock, these estimates can be compared to the research removals reported in previous assessments (Shotwell et al. 2009). 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 longline survey. Other research activities that harvest RE/BS rockfish are minor but include other trawl research activities, scallop dredge, and recreational harvests.

Although data are not available for a complete accounting of all research catches, the values in Table 13A-1 indicate that generally RE/BS stock research removals have been modest relative to the fishery catch and compared to the research removals for many other species. The exceptions are in 1998 and 1999 where a total of 52 and 36 t, respectively were taken, mostly by research trawling. However, because commercial catches for the shortraker/rougheye rockfish complex during these years were below ABC (please refer to Table 13-2 in the main document), this relatively large catch was not a conservation concern. Total removals from activities other than a directed fishery were 9 t in 2010. This is 0.7% of the 2011 recommended ABC of 1,312 t and represents a low risk to the RE/BS stock. Research harvests dominate this with three major surveys taking significant amounts of RE/BS rockfish. Even research catches of this magnitude, however, do not pose a significant risk to the RE/BS stock in the GOA.

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

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

HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery will become available following restructuring of the Observer Program in 2013. At this time all vessels greater than 25 ft will be monitored for groundfish catch.

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

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

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

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.