Chapter 13: Assessment of Rougheye and Blackspotted Rockfish in the Gulf of Alaska

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Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with new survey data. We use a separable age-structured model as the primary assessment tool for Gulf of Alaska rougheye and blackspotted rockfish. The model consists of an assessment, which uses survey and fishery data to generate a historical time series of population estimates, and a projection which uses results from the assessment model to predict future population estimates and recommended harvest levels. The model was constructed with AD Model Builder software and allows for size composition data that is adaptable to several rockfish species. The data sets used in this assessment include total catch biomass, fishery size compositions, trawl and longline survey biomass estimates, trawl survey age compositions, and longline survey size compositions. Orr and Hawkins (2008) formally verified the presence of two species, rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*), in what was once considered a single variable species with light and dark color morphs. Hereafter we refer to these two species together as the rougheye/blackspotted rockfish complex or RE/BS rockfish.

Changes in the input data: New data added to this model were the updated estimates of 2007-2009 fishery catch, 2004 and 2006 fishery ages, 2007 fishery length compositions, 2009 trawl survey biomass estimate, 1987 and 2007 trawl survey age compositions, 2008-2009 longline survey relative population weights, and 2008-2009 longline survey size compositions.

Changes in the assessment methodology: The assessment methodology is very similar to the 2007 model which utilized the age error structure based on rougheye/blackspotted rockfish and the more accurate estimates of historical rougheye/blackspotted catch for 1993-2004. Additionally, we decreased the CV on the catch time series and utilized the catch reliability penalty in 1993. A CV of approximately 30% is implemented for the earlier part of the catch time series (1977-1992) where catches are not as well known, while a CV of 5% was used for the rest of the time series. As determined in the 2007 SAFE appendix analysis, the increased weight on the catch time series allows for increased robustness of the model to weighting sensitivity.

We provide results from the 2007 model, the updated 2009 model (base, Model 1), and the author recommended model with increased weight on the catch time series (Model 2). The trawl survey estimate decreased by 15% from 2007 and is now about 5% above the long term average for the time series. The longline survey relative population weight decreased by 2% in 2008 and another 17% in 2009. The current estimate is about 6% below the long term average. Estimates of catchability for both surveys are very similar to the 2007 estimates.

For the 2010 fishery, we recommended the maximum allowable ABC of 1,302 t from the author-recommended model (Model 2). This is a 1.4 % increase from last year's ABC of 1,284 t. Recommended ABCs from area apportionments are 80 t for the Western area, 862 t for the Central area, and 360 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 overfished, nor is it approaching overfishing status.

Rougheye Rockfish Summary Table	2009 projection: Not Updated		2010 projection Author recommended	
Tier 3a	2009	2010	2010	2011*
Total Biomass (ages 3+)	46,385	46,637	45,751	45,935
Female Spawning Biomass (t)	14,055	13,919	13,638	13,729
$B_{100\%}$ (t) (female spawning biomass)	-	-	25,463	-
$B_{40\%}$ (t) (female spawning biomass)	-	-	10,185	-
$B_{35\%}$ (t) (female spawning biomass)	-	-	8,912	-
M	0.034	0.034	0.034	0.034
F_{ABC} (maximum allowable = F40%)	0.039	0.039	0.040	0.040
F_{ABC} (author recommended)	0.039	0.039	0.040	0.040
F_{OFL}	0.047	0.047	0.048	0.048
$ABC_{F40\%}$ (t, maximum allowable)	1,284	1,297	1,302	1,313
ABC (t, author recommended)	1,284	1,297	**1,302**	1,313
OFL (t)	1,545	1,562	**1,568**	1,581

[*] **Projected ABCs and OFLs for 2011 are derived using an expected catch value of 400 t for 2010 based on recent ratios of catch to ABC.** This calculation is in response to management requests to obtain a more accurate one-year projection. Results for this method are listed under the Author's F alternative in Table 13-14.

Area Apportionment

The apportionment percentages have changed with the addition of the 2009 survey biomass. The following table shows the recommended apportionment for 2010.

Year	Western Gulf	Central Gulf	Eastern Gulf	Total
Area Allocation	6.16%	66.18%	27.65%	100%
Area ABC (t)	80	862	360	1,302
OFL (t)				1,568

Responses to Council, SSC, and Plan Team Comments

The 2007 SSC December minutes included the following comments concerning GOA RE/BS rockfish:

"The SSC requests that the assessment 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."

Please refer to the *Evidence of stock structure* section in the *Introduction* of this year's stock assessment for a discussion on this topic and the ongoing research in support of determining a rationale for decisions regarding mixed species groups.

Additionally the SSC encouraged including plots of the spatial distribution of catch in future assessments for several species of rockfish. Please refer to last year's stock assessment *Responses to SSC Comments* for a discussion of these plots pertaining to rougheye/blackspotted rockfish.

No comments in the 2008 SSC or Plan Team minutes were pertinent to GOA RE/BS rockfish.

Research Priorities

There is little information on larval, post-larval, or early stage juveniles of rougheye and blackspotted rockfish. Habitat requirements for larval, post-larval, and early stages are mostly unknown. Habitat requirements for later stage juvenile and adult fish are mostly anecdotal or conjectural. Research needs to be done on the bottom habitat of the fishing grounds, on what HAPC biota are found on these grounds, and on what impact bottom trawling has on these. Additionally, rougheye and blackspotted rockfish are undersampled by the current survey design. The stock assessment would benefit from additional survey effort on the continental slope. Further research on trawl catchability and trawlable/untrawlable grounds would be very useful. For rougheye/blackspotted rockfish and the other Gulf of Alaska rockfish assessed with age-structured models, we plan to focus on optimizing and making consistent the methods we use for multinomial sample sizes, the way we choose our bins for age and length compositions, and examine growth for changes over time. Information on the life history characteristics of blackspotted versus rougheye rockfish may also be useful for defining potential population parameter differences or differences in habitat preference.

Summaries for Plan Team

Species	**Year**	**Biomass[1]**	**OFL**	**ABC**	**TAC**	**Catch[2]**
Rougheye rockfish complex	2008	46,121	1,548	1,286	1,286	389
	2009	46,385	1,545	1,284	1,284	278
	2010	45,751	1,568	1,302		
	2011	45,935	1,581	1,313		

[1] Total biomass from the age-structured model

Stock/ Assemblage	**Area**	**2009 OFL**	**ABC**	**TAC**	**Catch[2]**	**2010 OFL**	**ABC**	**2011 OFL**	**ABC**
Rougheye rockfish complex	W		125	125	79		80		81
	C		833	833	99		862		869
	E		326	326	100		360		363
	Total	1,545	1,284	1,284	278	1,568	1,302	1,581	1,313

[2] Current as of October 24, 2009 (http://www.fakr.noaa.gov)

Introduction

Biology 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 center of abundance 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*) in trawl or longline hauls.

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 presumed to be viviparous, 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 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 ruinous 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). De Bruin et al. (2004) examined Pacific ocean perch (*S. alutus*) and rougheye/blackspotted rockfish (*S. aleutianus*) 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. In a study on Pacific ocean perch, Spencer et al. (2007) found that the effects of enhanced larval survival from older mothers on biological reference points produced ambiguous results. Reduced survival of larvae from younger females resulted in reduced reproductive potential per recruit for a given level of fishing mortality. However, this also increased estimated resiliency, which results from the estimated recruitments being associated with a reduced measure of reproductive potential. The two effects nearly counteract each other. Such relationships have not yet been determined to exist for rougheye and blackspotted rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. The AFSC has funded a project to determine if this relationship occurs for similar slope rockfish in the Central Gulf of Alaska.

Evidence of stock structure

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). The proposed speciation was initiated by Tsuyuki and Westrheim (1970) after electrophoretic studies of hemoglobin resolved three distinct banding patterns in what were later described as rougheye (Type A and B) and shortraker (Type C) rockfish. In this study, the two rougheye blood types detected in samples (n = 313) taken off the coast of Vancouver Island, British Columbia were predominant with a relatively rare presumed hybrid. However, they were unable to distinguish any patterns in meristics or morphometrics between the two types. Seeb (1986) again proposed two species of rougheye in an allozyme-based phylogenetic survey where clear isolation occurred between samples of rougheye (n = 47) into two types. The "*aleutianus*" type was represented by pink/red coloration with suborbital spines (n = 24), whereas the "*aleutianus* unknown" type had considerable blackness around the mouth and jaw with suborbital spines often lacking (n = 23). In 1997, Hawkins et al. initiated another allozyme-based study analyzing a large sample (n=750) of rougheye rockfish collected by bottom trawl and longline in the Gulf of Alaska and Bering Sea using starch gel electrophoresis. They describe two types that were separated out by five distinguishable loci, an Aleutian type and a Southeast type. Distributions of each type were somewhat distinct, although several areas of overlap existed. The Aleutian type was completely dominant in the western Aleutian Islands. In 2005, the published extension of this study (Hawkins et al. 2005) included more samples of rougheye (n=1027) and again demonstrated the two genetically distinct types of rougheye as *Sebastes aleutianus* and *S*. sp. cf. *aleutianus*. Both types are found in the Gulf of Alaska and occur in sympatry (overlapping distribution without interbreeding), although samples with depth information demonstrated a significantly deeper depth for *S*. sp. cf. *aleutianus*. Deep samples taken near Washington State indicate that the *S*. sp. cf. *aleutianus* type may diminish in the southern ranges while the *S. aleutianus* does not extend past the western Aleutian Islands. Finally, Gharrett et al. (2005) analyzed the variation in mitochondrial DNA and eight microsatellite loci in samples (n = 698) taken at 84 sites from Oregon to the western edge of the Aleutian Islands. They also determined two distinct types of rougheye, I and II, with a nearly fixed difference at one microsatellite loci and relatively little hybridization. The fixed difference is reflective of advanced lineage sorting and arguably results from speciation. Based on calculations of divergence time for lineage sorting, the authors suggest that divergence likely took place between several hundred thousand and one million years ago, making speciation an unlikely result of the last two glaciations. Samples in the Aleutian Islands and Bering Sea were predominantly Type I and many hauls throughout the sampling area were typically one type or the other. Additionally, for some genetically analyzed samples in which coloration was noted, dark morphs were predominant in the western Gulf of Alaska while samples in the eastern Gulf near Yakutat consisted of light, dark, and sometimes intermediate.

In a study on phenotypic differences, Gharrett et al. 2006 compared meristic characters and morphometric dimensions (35 reported) to genetically determined species. Samples were analyzed from eight of the 84 locations described in Gharrett et al. (2005) where coloration was recorded. Distributions of all the phenotypic parameters overlapped; however, Type II rougheye had slightly fewer and shorter gill rakers and deeper bodies. Upon examination of coloration, Type II were predominantly light colored, while Type I fish were either light or dark and the proportion of either color varied geographically. Orr and Hawkins (2006) discuss preliminary results of a fairly extensive study on the recognition, identification, and nomenclature of the two types of rougheye rockfish. They recognized the two species as *Sebastes aleutianus* (originally described by Jordon and Evermann 1898) and *Sebastes melanostictus* (described previously by Matsubara 1934). They defined *S. aleutianus* or rougheye rockfish as the southern species, ranging from California to the southern Bering Sea and eastern Aleutian Islands and *S. melanostictus* or the blackspotted rockfish as the northern species, ranging from the western Aleutian Islands and Bering Sea to Washington State. The blackspotted rockfish was distinguished primarily by a darker body color, discrete spotting on the dorsal fin and body, longer fin spines, longer gill rakers, and a narrower body depth at the anal-fin origin; although the morphometric differences were slight. Additionally, the blackspotted rockfish tend to be caught at deeper depths than rougheye in locations were both species were caught. However, both species were abundant at similar depths (200-350 m) and their distributions overlap extensively (Gulf of Alaska, southern Bering Sea, and eastern Aleutians).

In summary, the southern species of rougheye rockfish proposed as *S. aleutianus* or rougheye rockfish by Orr and Hawkins (2006) is likely similar to the Type II proposed by Gharrett et al. (2005 and 2006), the *S. aleutianus* proposed by Hawkins et al. (2005), the Southeast type proposed by Hawkins et al. (1997), the "*aleutianus*" proposed by Seeb (1986), and the B blood type proposed by Tsuyuki and Westrheim (1970). The northern species of rougheye rockfish proposed as *S. melanostictus* or blackspotted rockfish by Orr and Hawkins (2006) is likely similar to the Type I proposed by Gharrett et al. (2005 and 2006), the *S.* sp. cf. *aleutianus* proposed by Hawkins et al. 2005, the Aleutian type proposed by Hawkins et al. (1997), the "*aleutianus* unknown" proposed by Seeb (1986), and the A blood type proposed by Tsuyuki and Westrheim (1970). In 2008, Orr and Hawkins (2008) formally verified the presence of the two species. They used combined genetic analyses of 339 specimens from Oregon to Alaska to identify the two species and formulated general distribution and morphological characteristics for each. Rougheye rockfish is typically pale with spots absent from the spinous dorsal fin and possibly has mottling on the body. Blackspotted rockfish is darker with spotting almost always present on the dorsal fin and body. The two species occur in sympatric distribution with rougheye extending farther south along the Pacific Rim and blackspotted extending into the western Aleutian Islands. The overlap is quite extensive (Gharrett et al. 2005, 2006).

At present there appears to be difficulty in accurate at-sea field identification between the two species. Scientists and observers are currently evaluating new techniques to determine whether rapid and accurate field identification can occur. In 2005 and 2006, the sablefish longline survey conducted two-day sampling experiments in the eastern Gulf near Yakutat Bay to collect detailed depth information associated with the longline catch of rougheye and blackspotted rockfish. New GPS and sonar technology on board combined with numerous time-depth recorders along the groundline were used to determine accurate depth and GPS coordinates of the groundline as it fished. Approximately 250 rougheye and blackspotted rockfish were collected across a depth range of 200-400 m. Fish were visually identified to species in the field using a pamphlet distributed by Jay Orr. Tissue samples were taken for later positive identification by genetics and associated photographs were also taken for expert visual identification by Jay Orr. When compared to the genetic identifications, field scientists had a misidentification rate of 46%. Based on the photographs taken of sampled fish, Orr's misidentification rate was 29%. However, following the publication of the Orr and Hawkins 2008 paper, a re-examination of the samples by Orr reduced his misidentification rate to 9%. There were several other features not specified in the original pamphlet that may be important for correctly identifying blackspotted rockfish (J. Orr, personal communication). In 2008, samples collected in British Columbia were analyzed in a similar fashion. In this case, the field misidentification rate was 51%, while Orr's rate was again 9%.

The results from these identification exercises have led AFSC scientists to be concerned about their ability to accurately distinguish between the two species during surveys. Additionally, there is 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. In response to these concerns, a special project was initiated during the 2009 Gulf of Alaska RACE bottom trawl survey. The purpose 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 maturity, length, weight, and muscle tissue from all rougheye and blackspotted rockfish being sampled for otoliths. The genetic analysis of these samples will be conducted by Dr. Anthony Gharrett of the University of Alaska Fairbanks (UAF) when sufficient funding becomes available.

In addition to enhancing training and field identification guides, this sampling plan will allow for accurately specifying misidentification rates and estimating biological parameters such as growth, maturity, and distribution by species. 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 whether one species is a weaker stock and is at greater risk of 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 a weighted average of recent survey estimates of exploitable biomass distribution.

In November, 2006, NMFS issued a final rule to implement Amendment 68 of the GOA groundfish Fishery Management Plan to implement the Central Gulf of Alaska Rockfish Pilot Program in 2007. 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 effect secondary groups with a maximum retained allowance (MRA). The primary rockfish management groups are northern, Pacific ocean perch, and pelagic shelf rockfish, while the secondary species include rougheye and shortraker rockfish. Potential effects of this program to rougheye rockfish include: 1) changes in spatial distribution of fishing effort within the Central GOA, 2) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, 3) a higher potential to harvest 100% of the TAC in the Central GOA region, and 4) an extended fishing season lasting from May 1 – November 15. This 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. Future analyses regarding the Pilot Project effects on rougheye and blackspotted rockfish will be possible as more data becomes available. A summary of these management measures and a time series of catch, ABC and TAC are shown in Table 13-1.

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 13-2). RE/BS rockfish are caught in either bottom trawls or with longline gear, and about half came from each gear type in 2009. Nearly all the longline catch of RE/BS appears to come as "true" bycatch in the sablefish or halibut longline fisheries. However, in rockfish trawl fisheries some of the RE/BS rockfish are taken by actual targeting that some fishermen call "topping off" (Ackley and Heifetz 2001). Fishery managers assign all vessels in a directed fishery a maximum retainable bycatch rate for certain species that may be encountered as bycatch. If a vessel manages to not catch this bycatch limit during the course of a directed fishing trip, or the bycatch rate is set unnaturally high (as data presented in Ackley and Heifetz (2001) suggest), before returning to port the vessel may be able to make some target hauls on the bycatch species and still not exceed its bycatch limit. Such instances of "topping off" for RE/BS rockfish appear to take place in the Pacific ocean perch trawl fishery, especially because shortraker rockfish is the most valuable trawl-caught species of *Sebastes* in terms of landed price and RE/BS often co-occur with shortraker in the hauls. Estimates of rougheye and blackspotted rockfish bycatch were available from the International Pacific Halibut Commission (IPHC) for 1998-2008 and are listed in Table 13-2.

Catches of rougheye rockfish from research cruises are also listed in Table 13-2. Estimates were available from the NMFS bottom trawl survey for 1977-2009. Preliminary estimates of longline survey catches were available from 1996-2009.

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.

For rockfish fisheries in general, the largest non-rockfish bycatch groups in the combined rockfish trawl fishery during 1997-2004 are Pacific cod (1,750 t/year), arrowtooth flounder (1500 t/year), and sablefish 1100 t/year) (Hanselman et al. 2007). More recent data for 2007-2009 indicates an increase in all rockfish fisheries of bycatch of greenling/atka mackerel (1,584 t/year) and walleye pollock (590 t/year), and decreases of arrowtooth flounder (565 t/year), sablefish (515 t/year), and Pacific cod (422 t/year) (AKFIN data provided by T. Hiatt, Oct. 2009).

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 rockfish were reported separately.

Shortraker / Rougheye 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
Discards	20.3	25.6	38.3	28.2	19.0

The above table indicates that discards of rougheye and blackspotted have ranged from approximately 19% to 38% with an average of 26%. These values are relatively high when compared to other *Sebastes* species in the Gulf of Alaska.

Data

The following table summarizes the data used for this assessment:

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

Fishery Data

Catch

Catches of rougheye and blackspotted rockfish range from 130 t to 2,418 t from 1977 to 2009. 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

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[1] National Marine Fisheries Service, Alaska Region, P.O. 21668, Juneau, AK 99802. Data are from weekly production and observer reports through October 2009.

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 13-1, Table 13-2).

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

Age determination for rougheye and blackspotted rockfish is problematic. These species appear to be among the longest-lived of all *Sebastes* species (Chilton and Beamish 1982). Interpretation of annuli on otoliths is extremely difficult; however, recently NMFS age readers determined that aging of rougheye rockfish could be moved into a production mode. Ages were determined from the break-and-burn method (Chilton and Beamish 1982). Otolith samples taken by observers aboard fishing vessels and at onshore processing facilities have recently been aged for rougheye rockfish. Samples taken at 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 compositions. Table 13-3 summarizes the newly available fishery age compositions from 2004 and 2006. Sample sizes are comparable to those taken in the trawl survey. The mean ages are relatively old at 34 and 37 for 2004 and 2006 respectively 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 may consider the potential for increasing the number of age bins to include several older age groups.

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 13-4 summarizes the available size compositions from 1991-2007. The NMFS Observer Program began in 1990; however, this year was considered experimental in operation. We, therefore, consider size compositions prior to 1991 preliminary. Samples from 1993-2001 were also 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 Data

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 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 1984-2009 surveys are provided in Table 13-5. Trawl survey biomass estimates are shown in Figure 13-2. Historically estimates by region suggested that the western and eastern GOA time series of biomass tended to be in opposite phase. Since 2003, the central and eastern GOA estimates have increased, while the western GOA has decreased and remained relatively low. 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 in the estimates 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. Confidence intervals overlap in all the surveys (Table 13-5; Figure 13-2) which indicate that none of the changes in biomass are statistically significant. 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 such as northern rockfish (discussed previously in *Biology and Distribution* under the *Introduction* section). 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, 2006). 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 the reverse occurred (36% versus 64%). This was particularly true in the western GOA. 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

Two new years of age composition were added this year, 1987 and 2007. We now have nine years of survey age compositions, with sample size total of 4,351 ages. 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 132 (AFSC 2006). The average age ranged from 15 to 23 over all survey years available (Table 13-6). 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 and then again in the late 1980s early 1990s. In 2003, 2005, and 2007 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 were split by rougheye and blackspotted rockfish. Rougheye compositions tend to be spread evenly across ages, while blackspotted tend to be much older, with a mean age of 15 and 24 for rougheye and blackspotted, 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 in the stock assessment model. The mean age for the combined compositions was 20. 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.

Survey Size Compositions

Gulf-wide population size compositions for rougheye rockfish are in Table 13-7. 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 2009 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 has steadily decreased over time, ranging from 41 to 34 cm. In the 2007 and 2009 survey blackspotted and rougheye rockfish lengths were split. Rougheye have an average length of 34 cm while blackspotted have an average of 40 cm. Rougheye have a much broader range of lengths from 15-53 cm, while blackspotted tend to be more confined to the 37-50 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 Sablefish Longline Survey Data

Biomass Estimates

Catch, effort, and length data were collected during sablefish longline surveys for rougheye and blackspotted rockfish. Data were collected for RE/BS rockfish outside of the shortraker/rougheye complex 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.

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% as the CV for this index. The index values along with confidence intervals are provided in Table 13-8 and graphed in Figure 13-3. 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 by 2 % in 2008 and 17 % in 2009. The present value is approximately 5% below average for the time series. Confidence intervals overlap in all surveys indicating that none of the changes in RPW are statistically significant.

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. Incorporating both longline and trawl survey estimates in the model should remedy some of these issues.

Survey Size Compositions

Large subsamples 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 13-9). Compositions for all years were normal with a mode between 45 and 47 cm in length.

Comparison of Trawl and Longline Surveys

The spatial distribution of numbers of rougheye and blackspotted rockfish caught in the 2005, 2007, and 2009 trawl and longline surveys is depicted in Figure 13-4a. The trawl survey samples more of the continental shelf than the longline survey due to differences in survey design. However, the trawl survey tends to catch more RE/BS rockfish in the central GOA, while the longline survey catches more RE/BS rockfish in the eastern and western GOA. This is more evident in the 2005 and 2007 surveys than in 2009. The longline survey estimate in 2005 decreased from the previous year while the trawl survey estimate was near average. In 2007, both survey estimates increased from the previous survey. This can be seen in the increased number of fish caught in most areas, particularly 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 survey.

Rougheye and blackspotted rockfish were identified separately in the 2007 and 2009 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 13-4b). 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 survey 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 rougheye rockfish assessment. Data for the rougheye model substantially increased for the 2007 assessment; therefore, we included a more thorough sensitivity analysis on the relative influence of the trawl and longline survey estimates as well as 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 Data

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 (Table 13-10). 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 (r=0.9) 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.

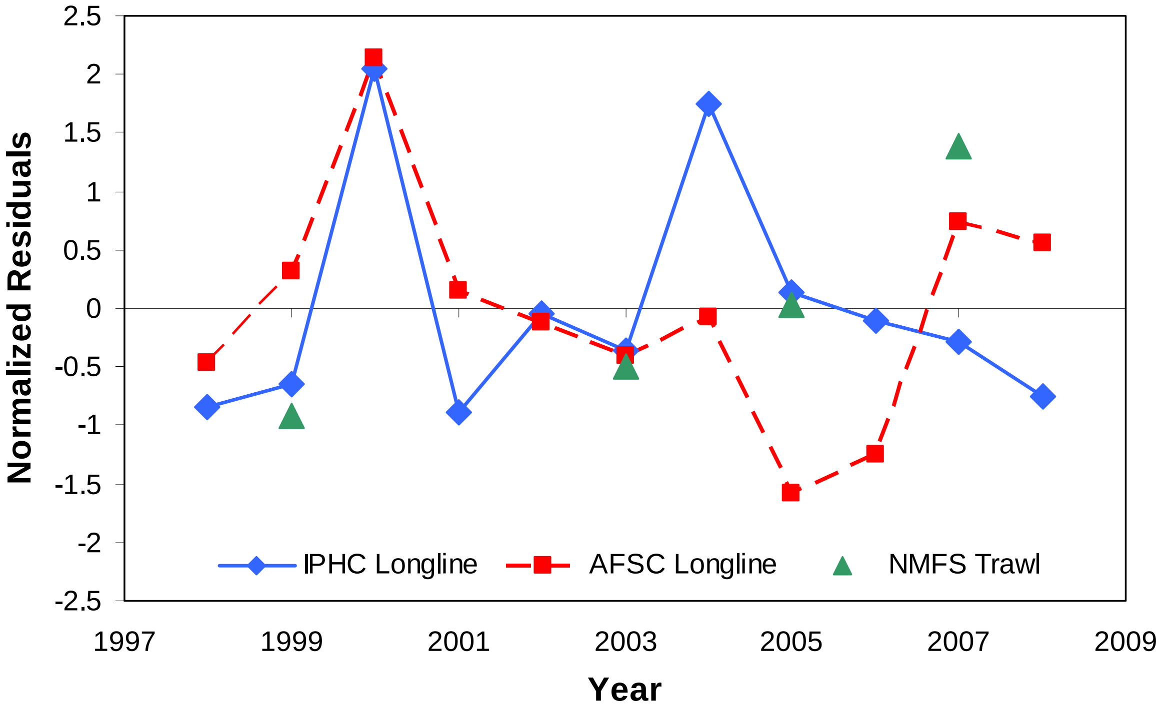

Figure: Comparison of IPHC longline (blue solid line with diamonds), AFSC longline (red dashed line with squares), and NMFS trawl surveys (green triangles) from 1998-2008.

Analytic Approach

Model Structure

We present model results for the rougheye/blackspotted rockfish complex based on a separable age-structured model using AD Model Builder software (Otter Research Ltd 2000) which allows for size composition data that is adaptable to several rockfish species. 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). 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 13-5). 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.

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 nine 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 special maturity collection and the complete historical time series of trawl survey ages. 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 13-6).

Several other alternatives to estimating natural mortality for rockfish are available such as catch-curve analysis, empirical life history relationships, and simplified maximum age equations (Malecha et al. 2007). Each of these methodologies was detailed in the draft response of the Rockfish Working Group to the center 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. These area-swept 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 13-7). These prior distributions allow the catchability parameters more freedom than that allowed to natural mortality. Recruitment deviation is the amount of variability that the model assigns recruitment estimates. Rougheye and blackspotted rockfish are likely the longest-lived rockfish and information on recruitment is quite limited, but is expected to be episodic. 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 13-7).

Other parameters estimated conditionally include, but are not limited to: selectivity (up to full selectivity) for surveys and fishery, mean recruitment, fishing mortality, and spawners per recruit levels. The numbers of estimated parameters 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
Spawners-per-recruit levels	F_{35}, F_{40}, F_{50}	3
Recruitment deviations	τ_v	54
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_v	33
Fishery selectivity coefficients	fs_a	14
Survey selectivity coefficients	ss_a	25
Total		135

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 135. 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

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

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
$L_8=\frac{1}{2\sigma_M^2}\left(\ln M/M_{prior}\right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_9=\frac{1}{2\sigma_{q_1}^2}\left(\ln q_1/q_{1prior}\right)^2$	Penalty on deviation from prior distribution of catchability coefficient for trawl survey
$L_{10}=\frac{1}{2\sigma_{q_2}^2}\left(\ln q_2/q_{2prior}\right)^2$	Penalty on deviation from prior distribution of catchability coefficient for longline survey
$L_{11}=\frac{1}{2\sigma_{\sigma_r}^2}\left(\ln \sigma_r/\sigma_{r(prior)}\right)^2$	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

Model Evaluation

This model is the updated version of the model accepted in the 2007 assessment. For the 2009 assessment we present two alternative models based on routine maintenance (data updates) and decreasing the CV on the catch time series in response to the sensitivity analysis results from 2007. The two models are identical in all aspects except the weighting on the catch time series. Our criteria for choosing a superior model are: (1) the best overall fit to the data (in terms of negative log-likelihood), (2) biologically reasonable patterns of estimated recruitment, catchabilities, and selectivities, (3) a good visual fit to length and age compositions, and (4) parsimony. The basic features of the model runs presented in this document are described in the following table:

Model Number	**Model Description**
Model 1 (Base Case)	• Base model from Shotwell et al. 2007, with appended 2009 data
Model 2	• Catch time series split into two time periods (1977-1992; 1993-2009) • Different weighting schemes applied to the two different time periods

Model 1 (Base Case): is the base model from 2007 where the only changes that occurred were appending new data. This includes updated 2007-2008 fishery catch, new estimate of 2009 fishery catch, 2004 and 2006 fishery age compositions, 2007 fishery size compositions, 2009 trawl survey biomass estimate, 1987 and 2007 trawl survey age compositions, 2008-2009 longline survey relative population weights, and 2008-2009 longline survey size compositions. When compared with 2007, the fits and results are very similar and the catch is not well estimated (Figure 13-1a).

Model 2: is identical to Model 1 with a decreased CV on the catch time series and utilizing the catch reliability penalty to split the catch time series into two periods of different reliability. A CV of approximately 30% is implemented for the earlier part of the catch time series (1977-1992) where catches are not as well known (Soh 1998), while a CV of 5% was used for the rest of the time series when observer data was available. When compared with 2007 and Model 1, the fits and results are also quite similar except the fit to the catch time series has dramatically improved (Figure 13-1b).

Given the improved fit to the catch time series which according to the sensitivity analysis should increase the robustness of the model to the assumed specification of precision, we recommend Model 2 to estimate management quantities for 2010 and discuss results of this model in the following section. Estimated numbers in 2009, fishery selectivity, trawl and longline survey selectivity and schedules of age specific weight and female maturity are provided in Table 13-11 for reference.

Model Results

Table 13-12 summarizes the results from the 2007 model, the base case (Model 1), and this year's author recommended model (Model 2) for comparison. Model predictions fit the age and size data relatively well (Figures 13-8, 13-9, 13-10 and 13-12). Trawl survey size compositions are provided for reference (Figure 13-11). Parameter estimates are nearly identical to the 2007 estimates, with slightly lower trawl survey catchability, slightly higher longline survey catchability, slightly lower mean recruitment. Projected total and spawning biomass are very similar. 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 well for the recommended model. Fits to historical catch are much improved from the 2007 model. The use of the catch reliability penalty allows for less fit on the earlier part of the time series. We can see this in the estimate for the very large 1990 catch (Figure 13-1b). Model fits to trawl survey biomass and longline survey relative population weights (RPW) were fairly consistent over time with a slight increase in the 2009 estimate. All predicted values fall within the 95% confidence intervals of the survey point estimates (Figures 13-2 and 13-3). However, predicted values for the longline survey do not capture the spikes of 1997 and 2000. Average longline RPWs surrounding these two years combined with average trawl survey biomass estimates for 1996 and 2000 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 13-8). This may be improved by increasing the age bins. Fit to the fishery size compositions are slightly flattened (Figure 13-9) particularly in 1991. This may be due to the slight right or left skew in most years. Fit to the trawl survey age compositions are generally very good with some over- or underestimation of the plus group in all years except 1990 (Figure 13-10). Fit to the longline survey size compositions are similar to the fishery size compositions with slightly flattened peaks in most years (Figure 13-12).

The 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 13-13). 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 13-14). Fairly wide credible bands 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 13-15). 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 2007 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 13-16). The spike may be due to the management of rougheye/blackspotted rockfish in the slope rockfish complex prior to 1991 and the disproportionate harvest on shortraker due to their high value. Rougheye would also be caught as they often co-occur with shortraker. In general, fishing mortality is relatively low because historically most of the available TAC has not been caught. 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 the target level ($B_{40\%}$). 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 13-17). Since 1990, rougheye/blackspotted rockfish have been above $B_{40\%}$ and below $F_{40\%}$.

Recruitment

MCMC credible bands for recruitment have continued to narrow with the addition of more age data (Figure 13-18). Almost 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 for 1993, 1996, 1999 and to a lesser extent 2003 and 2005. 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 rockfish as recruitment is apparently unrelated to spawning stock biomass and there is little contrast in spawning stock biomass (Figure 13-5).

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 13-19) and credible intervals (Table 13-13). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass and recruitment (Figures 13-13, 13-14, 13-18).

Table 13-13 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviation derived from the Hessian matrix. Also shown are the MCMC standard deviation and the corresponding Bayesian 95% credible intervals (BCI). The MLE and MCMC standard deviations are similar for q_1 (trawl survey catchability), q_2 (longline survey catchability), and M, but the MCMC standard deviations are larger for the estimates of projected female spawning biomass, $F_{40\%}$ 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 13-19) indicating potential for higher biomass estimates (see also Figure 13-13 and Figure 13-14).

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 1980-2007 (year classes between 1977 and 2004). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. The 2009 estimates of these reference points are in the following table. Biomass estimates are for female spawning biomass.

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
25,463 (t)	10,185 (t)	8,912 (t)	0.040	0.048

Specification of OFL and Maximum Permissible ABC

Estimated female spawning biomass for 2010 is 13,638 t. This is above the $B_{40\%}$ value of 10,185 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 2010 yields the following *ABC* and *OFL*:

$F_{40\%}$	0.040
ABC (t)	1,302
$F_{35\%}$	0.048
OFL (t)	1,568

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 2009 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2010 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2009. 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 2009 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 2010, 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 all future years, *F* is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the catch in 2009 to the ABC recommended in the assessment for 2009. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.) In this scenario we use the ratio of most recent catch to ABC, and apply it to estimated ABCs for 2010 and 2011 to determine the catch for 2010 and 2011, then maximum permissible thereafter. Projections incorporating estimated catches help produce more accurate projections for fisheries that do not utilize all of the TAC.

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 2005-2009 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 2009 or 2) above ½ of its MSY level in 2009 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)

Scenario 7: In 2010 and 2011, *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 2022 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 13-14). 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 2010 and 2011. In this scenario we use the average of the ratio of most recent catch to ABC for the past three years, and apply it to estimated ABCs for 2010 and 2011 to determine the catch for 2010 and 2011, then set catch at maximum permissible thereafter.

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 2010, it does not provide the best estimate of OFL for 2011, because the mean 2010 catch under Scenario 6 is predicated on the 2010 catch being equal to the 2010 OFL, whereas the actual 2010 catch will likely be less than the 2009 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 (2008) is 389 t. This is less than the 2008 OFL of 1,548 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 2009:

a) If spawning biomass for 2009 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2009 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c) If spawning biomass for 2009 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 13-14). If the mean spawning biomass for 2019 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 2012 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2012 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2012 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2022. 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 13-14, the stock is not overfished and is not approaching an overfished condition.

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 13-20). 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 (0.3).

Area Allocation of Harvests

Prior to the 1996 fishery, the apportionment of ABC among areas was determined from distribution of biomass based on the average proportion of exploitable biomass by area in the most recent three triennial trawl surveys (2005, 2007, and 2009). In the past, exploitable biomass for rougheye rockfish was estimated by the unweighted average biomass of the most recent three trawl surveys, excluding the estimated biomass in the 1-100 m depth stratum. The 1-100 m depth stratum was removed from the estimate because it was thought that most rockfish in this stratum were small juvenile fish younger than the age of recruitment, and thus were not considered exploitable. However, the difference between keeping this stratum and removing it was found to be negligible; therefore, we no longer exclude the 1-100 m depth stratum for estimating exploitable biomass. For the 1996 fishery, an alternative method of apportionment was recommended by the Plan Team and accepted by the Council. Recognizing the uncertainty in estimation of biomass yet wanting to adapt to current information, the Plan Team chose to employ a method of weighting prior surveys based on the relative proportion of variability attributed to survey error. Assuming that survey error contributes 2/3 of the total variability in predicting the distribution of biomass (a reasonable assumption), the weight of a prior survey should be 2/3 the weight of the preceding survey. This resulted in weights of 4:6:9 for the 2005, 2007, and 2009 surveys, respectively and apportionments for rougheye and blackspotted rockfish of 6.16% for the Western area, 66.18% for the Central area, and 27.65% for the Eastern area (Table 13-15). Applying these percentages to the ABC for rougheye and blackspotted rockfish (1,302 t) yields the following apportionments for Gulf of Alaska 2010: 80 t for the Western area, 862 t for the Central area, and 360 t for the Eastern area.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.048), overfishing is set equal to 1,568 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 13-16. Additionally, we include a summary of nontarget species bycatch estimates and proportion of total catch for Gulf of Alaska rockfish targeted fisheries 2003-2009 (Table 13-17).

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. While rougheye and blackspotted rockfish are not considered to be taken as a target species, "topping off" for rougheye and blackspotted rockfish appears to take place in the Pacific ocean perch trawl fishery. Table 13-17 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 (1.652 t), sea anemones (1.554 t), and sponges (2.473 t) by rockfish fisheries in the GOA represented 61%, 8%, and 42% respectively of those species taken by all Gulfwide fisheries.

Data Gaps and Research Priorities

There is little information on larval, post-larval, or early stage juveniles of rougheye and blackspotted rockfish. Habitat requirements for larval, post-larval, and early stages are mostly unknown. Habitat requirements for later stage juvenile and adult fish are mostly anecdotal or conjectural. Research needs to be done on the bottom habitat of the fishing grounds, on what HAPC biota are found on these grounds, and on what impact bottom trawling has on these. Additionally, rougheye and blackspotted rockfish are undersampled by the current survey design. The stock assessment would benefit from additional survey effort on the continental slope. Further research on trawl catchability and trawlable/untrawlable grounds would be very useful. For rougheye/blackspotted rockfish and the other Gulf of Alaska rockfish assessed with age-structured models, we plan to focus on optimizing and making consistent the methods we use for multinomial sample sizes, the way we choose our bins for age and length compositions, and examine growth for changes over time. Information on the life history characteristics of blackspotted versus rougheye rockfish may also be useful for defining potential population parameter differences or differences in habitat preference.

Summary

A summary of the primary reference values (i.e. biomass levels, exploitation rates, author recommended ABCs and OFLs) for rougheye and blackspotted rockfish, along with projection values for next year are provided in the following table. Recommended values are in bold.

Rougheye Rockfish Summary Table	2009 projection: Not Updated		2010 projection Author recommended	
Tier 3a	2009	2010	2010	2011[*]
Total Biomass (ages 3+)	46,385	46,637	45,751	45,935
Female Spawning Biomass (t)	14,055	13,919	13,638	13,729
$B_{100\%}$ (t) (female spawning biomass)	-	-	25,463	-
$B_{40\%}$ (t) (female spawning biomass)	-	-	10,185	-
$B_{35\%}$ (t) (female spawning biomass)	-	-	8,912	-
M	0.034	0.034	0.034	0.034
F_{ABC} (maximum allowable = $F_{40\%}$)	0.039	0.039	0.040	0.040
F_{ABC} (author recommended)	0.039	0.039	0.040	0.040
F_{OFL}	0.047	0.047	0.048	0.048
ABC$_{F40\%}$ (t, maximum allowable)	1,284	1,297	1,302	1,313
ABC (t, author recommended)	1,284	1,297	**1,302**	1,313
OFL (t)	1,545	1,562	**1,568**	1,581

[*] **Projected ABCs and OFLs for 2011 are derived using an expected catch value of 416 t for 2010 based on recent ratios of catch to ABC.** This calculation is in response to management requests to obtain a more accurate one-year projection. Results for this method are listed under the Author's F alternative in Table 13-14.

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Table 13-1. 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	289	1,007	1,007	Rougheye managed separately from shortraker as age structured model accepted to determine ABC and moved to Tier 3 status
2006	351	983	983	
2007	417	988	988	Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	389	1,286	1,286	Rougheye and blackspotted formally verified as separate species so assessment now called the rougheye/blackspotted rockfish complex
2009	278[*]	1,284	1,284	

[*] Current as of October 24, 2009 (http://www.fakr.noaa.gov)

Table 13-2. Estimated catch history for GOA RE/BS rockfish. Commercial values from 1977-1992 are from Soh (1998). Values from 1993-2004 are from the observer program. IPHC bycatch estimates were available from 1998-present. Research catches were available from NMFS trawl survey and AFSC longline survey. 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.

Year	Catch (t)							ABC	TAC
	Commercial	Western GOA	Central GOA	Eastern GOA	IPHC Bycatch	NMFS Trawl Survey	AFSC Longline Survey		
1977	1443					1			
1978	568					2			
1979	645					1			
1980	1353					1			
1981	719					6			
1982	569					3			
1983	628					3			
1984	760					17			
1985	130					7			
1986	438					2			
1987	525					13			
1988	1621					0			
1989	2185					1			
1990	2418					5			
1991	350							2,000	2,000
1992	1127							1,960	1,960
1993	583					10		1,960	1,764
1994	579							1,960	1,960
1995	704							1,910	1,910
1996	558					5	7.9	1,910	1,910
1997	545					0	15.5	1,590	1,590
1998	665				0.25	45	6.7	1,590	1,590
1999	320				0.33	28	7.8	1,590	1,590
2000	530				0.67		9.8	1,730	1,730
2001	591				0.18	2	6.8	1,730	1,730
2002	273				0.25		5.3	1,620	1,620
2003	394				0.29	3	5.7	1,620	1,620
2004	301				0.47		5.1	1,318	1,318
2005	294	53	126	115	0.36	5	3.3	1,007	1,007
2006	358	58	138	162	0.29		4.5	983	983
2007	417	71	187	159	0.24	8	7.1	988	988
2008	389	78	190	121	0.22		10.9	1,286	1,286
2009	278*	79	99	100		6	9.1	1,284	1,284

*Current as of October 24, 2009 (http://www.fakr.noaa.gov)

Table 13-3. Fishery age compositions for GOA RE/BS rockfish and sample sizes by year. Pooled age 25+ includes all fish 25 and older.

Age (years)	2004	2006
3	0.0000	0.0000
4	0.0000	0.0000
5	0.0000	0.0000
6	0.0000	0.0000
7	0.0000	0.0000
8	0.0000	0.0000
9	0.0000	0.0028
10	0.0049	0.0000
11	0.0000	0.0000
12	0.0000	0.0083
13	0.0049	0.0055
14	0.0049	0.0083
15	0.0171	0.0193
16	0.0098	0.0193
17	0.0122	0.0138
18	0.0073	0.0055
19	0.0195	0.0110
20	0.0415	0.0110
21	0.0390	0.0138
22	0.0439	0.0303
23	0.0463	0.0331
24	0.0366	0.0441
25+	0.7122	0.7741
Sample size	410	363

Table 13-4. Fishery size compositions for GOA RE/BS rockfish and sample size by year and pooled pairs of adjacent lengths. Data before 1991 is considered experimental, and little data exists for 1993-2001.

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 13-5. 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	Biomass	S.E.	LCI	UCI
1984	45,091	7,313	30,758	59,425
1987	43,681	4,897	34,083	53,278
1990	44,837	9,296	26,616	63,057
1993	61,863	14,415	33,610	90,115
1996	45,913	7,432	31,346	60,481
1999	39,560	5,793	28,206	50,913
2003	43,202	6,724	30,024	56,380
2005	47,862	8,618	30,970	64,754
2007	59,880	10,380	39,535	80,225
2009	50,774	8,297	34,512	67,035

Table 13-6. GOA RE/BS rockfish trawl survey age compositions extrapolated to population. Samples sizes from survey only ages. Pooled age 25+ includes all fish 25 and older.

Age (yr)	1984	1984	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 13-7. 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 13-7 (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
21	0.0402
23	0.0545
25	0.0593
27	0.0690
29	0.0552
31	0.0598
33	0.0440
35	0.0425
37	0.0466
39	0.0527
41	0.0691
43	0.0798
45	0.0904
47	0.0880
49	0.0662
51	0.0406
53	0.0240
55	0.0090
57	0.0041
59	0.0026
60+	0.0024
Sample size	4,155

Table 13-8. 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.

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	25,534	5,107	15,525	35,544
1993	28,782	5,756	17,499	40,064
1994	28,622	5,724	17,402	39,842
1995	33,663	6,733	20,467	46,858
1996	32,002	6,400	19,457	44,547
1997	46,456	9,291	28,245	64,666
1998	32,247	6,449	19,606	44,888
1999	35,299	7,060	21,462	49,136
2000	49,935	9,987	30,361	69,510
2001	35,267	7,053	21,442	49,091
2002	33,582	6,716	20,418	46,747
2003	33,611	6,722	20,435	46,786
2004	31,270	6,254	19,012	43,527
2005	22,342	4,468	13,584	31,099
2006	25,722	5,144	15,639	35,805
2007	38,233	7,647	23,246	53,220
2008	37,542	7,508	22,826	52,259
2009	31,311	6,262	19,037	43,585

Table 13-9. 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 13-9 (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 13-10. Relative population numbers of RE/BS rockfish based on IPHC catch data and estimated area sizes from NMFS trawl survey.

Year	Western Gulf	Central Gulf	Eastern Gulf	Gulf-wide
1998	5	17	95	118
1999	14	73	41	128
2000	19	92	169	279
2001	21	22	73	115
2002	28	33	101	162
2003	28	47	69	144
2004	35	50	178	262
2005	37	28	108	173
2006	27	72	60	159
2007	32	36	80	148
2008	27	43	52	123

Table 13-11. Estimated numbers (thousands) in 2009, 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 2009 (1000s)	Percent Mature	Weight (g)	Fishery Selectivity	Trawl Survey Selectivity	LL Survey Selectivity
3	1,157	0	156	0	14	0
4	1,120	0	268	0	24	0
5	1,081	0	373	0	45	0
6	1,022	0	473	0	64	0
7	1,586	0	568	0	65	0
8	2,199	0	659	0	73	0
9	2,314	0	744	0	94	0
10	955	1	825	0	100	0
11	1,723	2	902	0	94	0
12	1,168	5	975	1	71	0
13	812	8	1,044	2	71	1
14	1,280	14	1,109	6	71	4
15	1,412	22	1,172	25	71	14
16	719	31	1,230	100	71	43
17	760	40	1,286	100	71	100
18	733	50	1,339	100	71	100
19	2,553	59	1,390	100	71	100
20	423	66	1,437	100	71	100
21	451	72	1,482	100	71	100
22	402	77	1,525	100	71	100
23	356	81	1,566	100	71	100
24	418	84	1,604	100	71	100
25+	11,680	92	1,976	100	71	100

Table 13-12. Likelihoods and MLE estimates of key parameters with estimates of standard error (σ) derived from Hessian matrix for GOA RE/BS rockfish models.

	2007 Model		***2009 Updated***		***2009 Catch Weight***	
Likelihoods	Value	Weight	Value	Weight	Value	Weight
Catch	0.232	1	0.321	1	0.054	**5/50***
Trawl Biomass	2.316	1	2.377	1	2.412	1
Longline Biomass	7.121	1	7.425	1	7.678	1
Fishery Ages			11.317	1	11.242	1
Trawl Survey Ages	26.138	1	31.718	1	31.794	1
Fishery Sizes	30.419	1	48.329	1	48.207	1
Trawl Survey Sizes	0	1	0	0	0	0
Longline Survey Sizes	31.459	1	93.193	1	93.382	1
Data-Likelihood	97.684		194.680		194.769	
Penalties/Priors						
Recruit Deviations	1.956	1	2.458	1	2.515	1
Fishery Selectivity	1.412	1	2.091	1	2.075	1
Trawl Selectivity	0.295	1	0.387	1	0.396	1
Longline Selectivity	0.757	1	0.832	1	0.808	1
Fish-Sel Domeshape	0	1	0	1	0	1
Survey-Sel Domeshp	0.094	1	0.080	1	0.087	1
LL-Sel Domeshape	0	1	0	1	0	1
Average Selectivity	0.000	0	0.000	0.1	0.000	0.1
F Regularity	1.005	0.1	1.037	0.1	1.225	0.1
σ_r prior	3.355		3.439		3.426	
q-trawl	0.429		0.465		0.381	
q-longline	0.000		0.005		0.001	
M	0.667		0.809		0.898	
Total	9.969		11.602		11.809	
Objective Fun. Total	107.653		206.283		206.578	

Parameter Estimates	Value	σ	Value	σ	Value	σ
q-trawl	1.513	0.502	1.539	0.501	1.478	0.464
q-longline	0.977	0.382	1.107	0.384	1.036	0.334
M	0.034	0.003	0.034	0.003	0.034	0.003
σ_r	0.934	0.059	0.932	0.058	0.932	0.058
Log-mean-rec	0.166	0.351	0.089	0.330	0.144	0.312
$F_{40\%}$	0.039	0.011	0.040	0.011	0.040	0.011
Total Biomass (t)	45,752	17,046	42,770	14,388	45,751	14,185
Spawning Biomass (t)	13,882	5,692	12,674	4,527	13,638	4,475
$B_{100\%}$ (t)	24,839		24,296		25,463	
$B_{40\%}$ (t)	9,935		9,718	3,156	10,185	3,103
ABC**$_{F40\%}$ **(t)	1286		1,205	558	**1,302**	572

***Values are weights on the catch series before the catch reliability penalty (1977-1992) and after (1993-2009).**

Table 13-13. 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 RE/BS rockfish.

	μ		σ		MCMC		
Parameter	Hessian	MCMC	Hessian	MCMC	Median	BCI-Lower	BCI-Upper
q_1, trawl survey	1.4776	1.5282	0.4639	0.4667	1.4843	0.7527	2.5973
q_2, longline survey	1.0359	0.9348	0.3337	0.3065	0.9090	0.4182	1.6171
M	0.0343	0.0342	0.0031	0.0031	0.0340	0.0284	0.0406
$F_{40\%}$	0.0400	0.0459	0.0110	0.0148	0.0435	0.0250	0.0816
Female Sp. Biomass	13,638	17,367	4,475	6,912	15,851	8,743	34,562
ABC	1,302	1,899	572	1,031	1,662	659	4,547
σ_r	0.9322	1.0821	0.0585	0.0660	1.0804	0.9583	1.2166

Table 13-14. 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. All units in mt. $B_{40\%}$ = 10,185 t, $B_{35\%}$ = 8,912 t, $F_{40\%}$ = 0.40 and $F_{35\%}$ = 0.048.

Year	Maximum permissible F	Author's F[*]	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
Spawning Biomass (t)							
2009	13,515	13,515	13,515	13,515	13,515	13,515	13,515
2010	13,486	13,638	13,596	13,647	13,707	13,440	13,486
2011	13,217	13,729	13,585	13,756	13,964	13,066	13,217
2012	12,977	13,325	13,594	13,884	14,240	12,729	12,933
2013	12,770	13,104	13,624	14,033	14,538	12,430	12,626
2014	12,583	12,901	13,664	14,188	14,844	12,159	12,344
2015	12,686	12,996	14,014	14,667	15,491	12,172	12,351
2016	12,521	12,815	14,059	14,825	15,801	11,934	12,102
2017	12,366	12,643	14,105	14,983	16,112	11,710	11,868
2018	12,203	12,464	14,134	15,123	16,404	11,484	11,632
2019	12,096	12,343	14,223	15,327	16,769	11,313	11,452
2020	11,954	12,184	14,258	15,472	17,070	11,115	11,244
2021	11,758	11,971	14,215	15,532	17,273	10,872	10,991
2022	11,598	11,797	14,199	15,619	17,505	10,669	10,779
Fishing Mortality							
2009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
2010	0.040	0.012	0.020	0.011	-	0.048	0.048
2011	0.040	0.040	0.020	0.011	-	0.048	0.048
2012	0.040	0.040	0.020	0.011	-	0.048	0.048
2013	0.040	0.040	0.020	0.011	-	0.048	0.048
2014	0.040	0.040	0.020	0.011	-	0.048	0.048
2015	0.040	0.040	0.020	0.011	-	0.048	0.048
2016	0.040	0.040	0.020	0.011	-	0.048	0.048
2017	0.040	0.040	0.020	0.011	-	0.048	0.048
2018	0.040	0.040	0.020	0.011	-	0.048	0.048
2019	0.040	0.040	0.020	0.011	-	0.048	0.048
2020	0.040	0.040	0.020	0.011	-	0.048	0.048
2021	0.040	0.040	0.020	0.011	-	0.048	0.048
2022	0.040	0.040	0.020	0.011	-	0.048	0.048
Yield (t)							
2009	278	278	278	278	278	278	278
2010	1,302	1,302*	658	360	-	1,568	1,302
2011	1,279	1,313	658	364	-	1,581	1,279
2012	1,245	1,277	653	363	-	1,475	1,498
2013	1,225	1,256	654	367	-	1,441	1,463
2014	1,218	1,247	661	374	-	1,424	1,444
2015	1,215	1,243	670	382	-	1,411	1,430
2016	1,229	1,255	686	394	-	1,419	1,437
2017	1,233	1,257	697	402	-	1,416	1,433
2018	1,214	1,237	697	405	-	1,387	1,402
2019	1,186	1,207	691	404	-	1,346	1,360
2020	1,158	1,178	685	403	-	1,306	1,320
2021	1,129	1,147	677	401	-	1,267	1,279
2022	1,107	1,124	672	401	-	1,235	1,247

[*] The 2011 ABC was projected using an expected catch value of 400 t for 2010. This estimate is based on recent ratios of catch to maximum permissible ABC. This is in response to management requests for a more accurate one-year projection.

Table 13-15. Allocation of ABC and OFL for 2008 GOA RE/BS rockfish.

Year	Weights	Western Gulf	Central Gulf	Eastern Gulf	Total
2005	4	8%	69%	24%	100%
2007	6	6%	66%	28%	100%
2009	9	5%	65%	29%	100%
Weighted Mean	19				
Area Allocation		6.16%	66.18%	27.65%	100%
Area ABC (t)		**80**	**862**	**360**	**1,302**
OFL (t)					**1,568**

Table 13-16: 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

Table 13-17: Nontarget species bycatch estimates in tons and proportion of total catch for Gulf of Alaska rockfish targeted fisheries 2003-2009.

Estimated Catch (t)

Group Name	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Benthic urochordata	0.00	0.13	0.04	0.03	0.27	0.00	
Birds	0.22	0.08	0.04	0.02			
Brittle star unidentified	0.16	0.00	0.05	0.09	0.01	0.04	0.03
Corals Bryozoans	1.90	0.07	6.13	0.39	2.27	0.47	0.34
Eelpouts	0.03	0.22	9.60	0.03	0.12	0.38	0.01
Eulachon	0.01	0.21	0.08	0.30	0.05	0.01	0.03
Giant Grenadier	139.26	0.45	134.57	272.06	127.14	163.57	283.68
Greenlings	8.13	6.97	3.56	5.95	7.74	15.08	8.03
Grenadier	473.93	2,830.01	77.04	65.54	70.61	3.43	3.20
Hermit crab unidentified	0.01	0.01	0.04	0.06	0.01	0.01	0.01
Invertebrate unidentified	0.38	0.95	0.10	0.04	0.01	0.24	0.31
Large Sculpins	0.12	43.29	15.48	28.31	26.88	19.79	29.76
Misc crabs	0.03	0.34	0.74	0.41	0.14	0.07	0.10
Misc crustaceans		0.02	0.37				
Octopus	0.65	0.43	0.19	0.47	0.06	2.89	1.14
Other osmerids	0.55	0.15	0.02	0.26	0.09	-	0.14
Other Sculpins	23.93	15.04	12.18	3.90	4.49	3.50	3.81
Pandalid shrimp	0.92	0.30	0.24	0.17	0.11	0.11	0.09
Scypho jellies	0.65	2.98	0.15	0.43	0.21	0.11	0.70
Sea anemone unidentified	2.89	2.97	0.30	0.62	0.21	0.69	3.21
Sea pens whips		0.00	0.04	0.02	0.01		
Sea star	3.22	2.13	1.46	2.22	0.66	1.16	1.81
Shark, Other	0.21	0.22	0.18	1.61	0.40	0.04	0.01
Shark, pacific sleeper	0.28	0.75	0.15	0.39	0.04	1.11	0.27
Shark, salmon	0.01	0.12	0.50	0.62	0.49	0.72	0.38
Shark, spiny dogfish	35.46	2.30	2.81	2.00	6.22	4.79	1.35
Skate, Big		6.64	4.62	4.21	0.13	3.72	3.60
Skate, Longnose	0.86	16.42	8.94	8.09	15.04	10.86	13.23
Skate, Other	104.66	10.38	45.02	35.79	16.66	8.09	10.99
Snails	0.42	0.30	0.15	0.80	0.07	0.18	11.90
Sponge unidentified	3.82	1.14	1.14	0.96	0.65	2.97	6.64
Squid	9.14	11.94	1.53	10.23	3.05	5.24	13.88
urchins dollars cucumbers	0.35	0.62	0.16	0.30	0.17	0.26	0.66
Grand Total	812.21	2,957.56	327.61	446.30	283.97	249.50	399.28

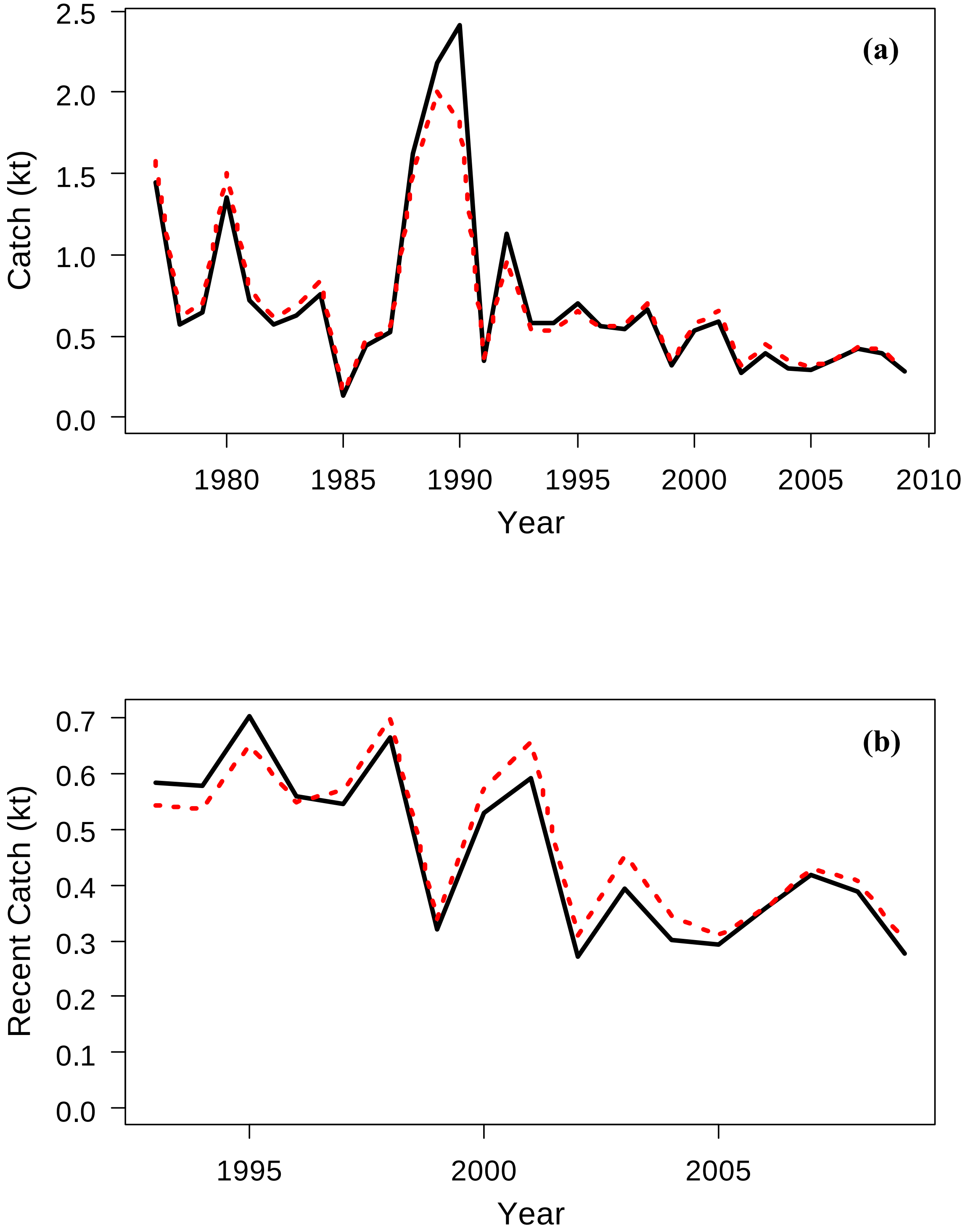


Figure 13-1a. Estimated long-term (a) and short-term (b) commercial catches for Gulf of Alaska RE/BS rockfish. Solid line is observed catch and red dashed line is predicted from base model (Model 1).

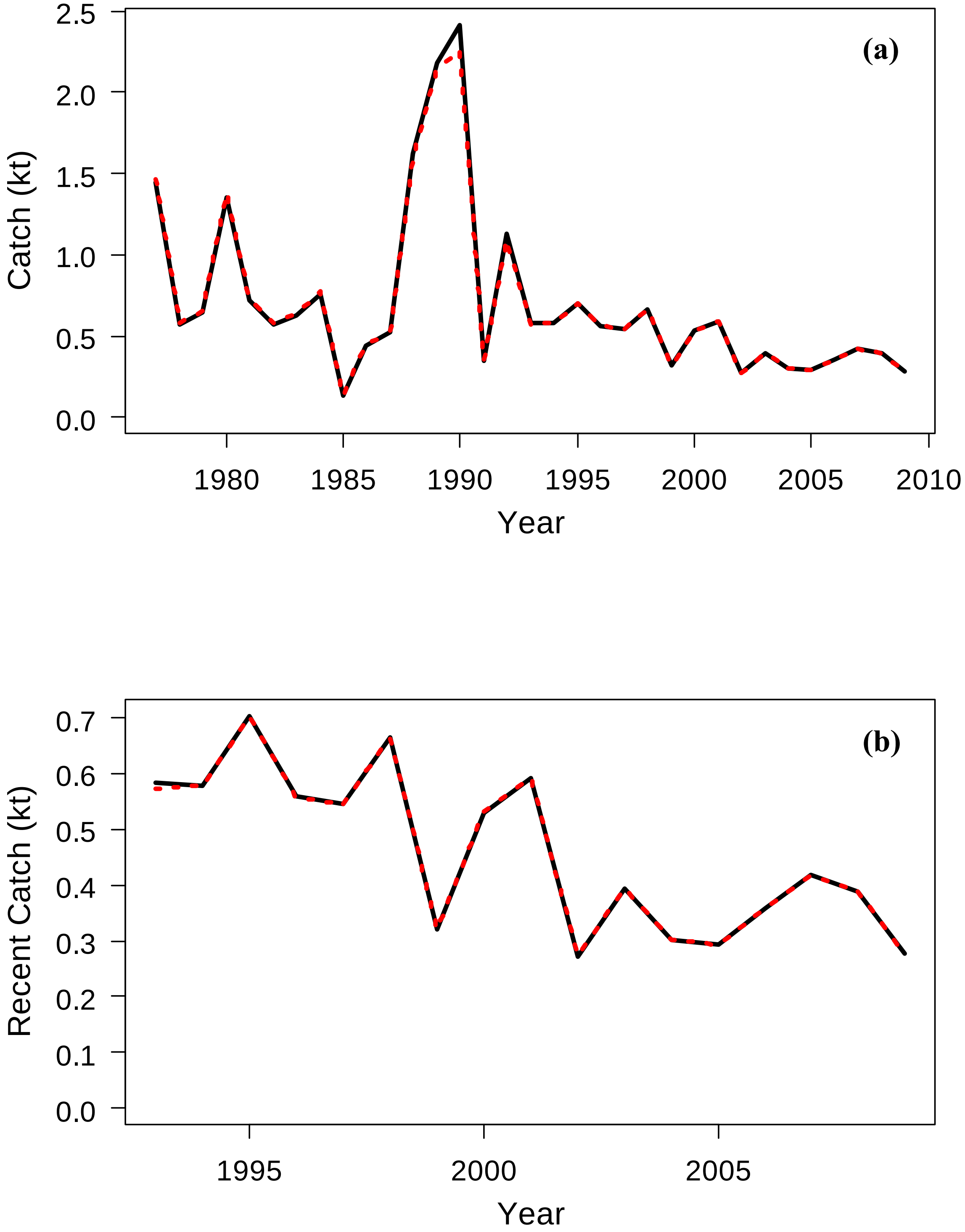


Figure 13-1b. Estimated long-term (a) and short-term (b) commercial catches for Gulf of Alaska RE/BS rockfish. Solid line is observed catch and red dashed is predicted from author recommended model (Model 2).

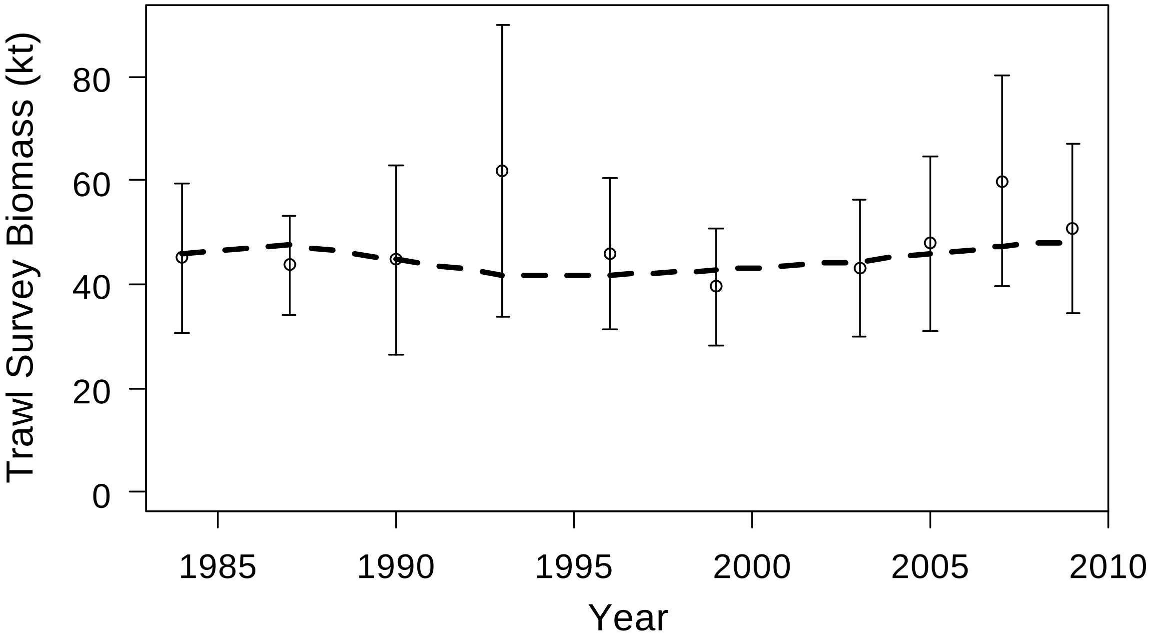


Figure 13-2. Observed (open circles) and predicted (dashed line) GOA RE/BS rockfish NMFS trawl survey biomass. Observed biomass presented with 95% confidence intervals of sampling error.

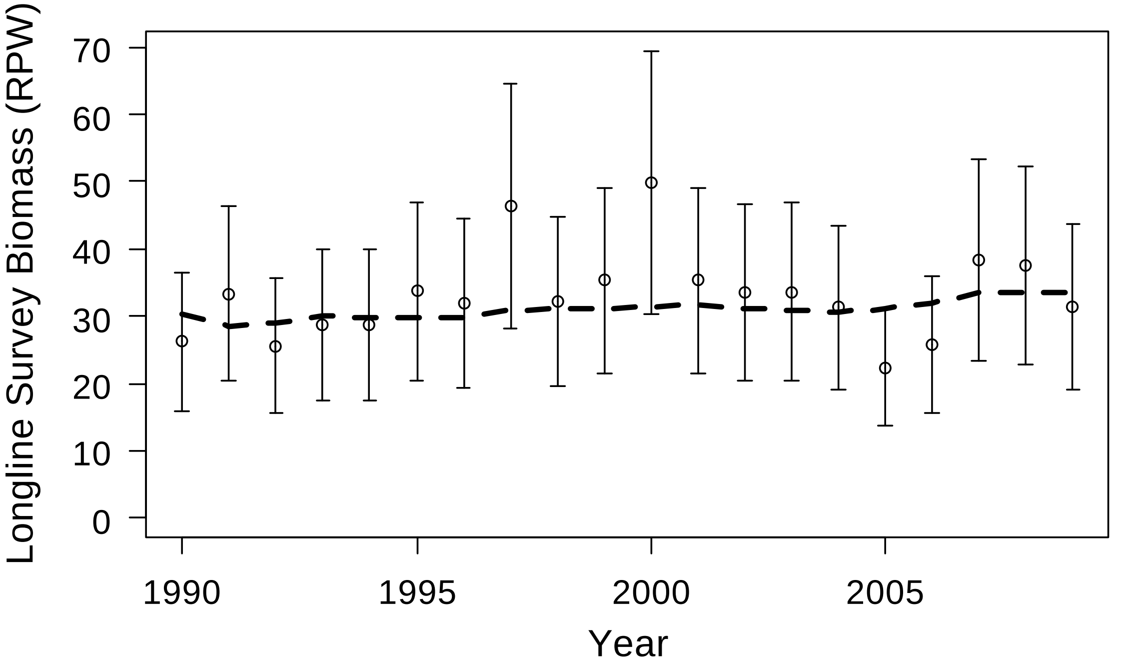


Figure 13-3. Observed (open circles) and predicted (dashed line) GOA RE/BS rockfish AFSC longline survey relative population weight (RPW in thousands). Observed biomass presented with 95% confidence intervals of sampling error.

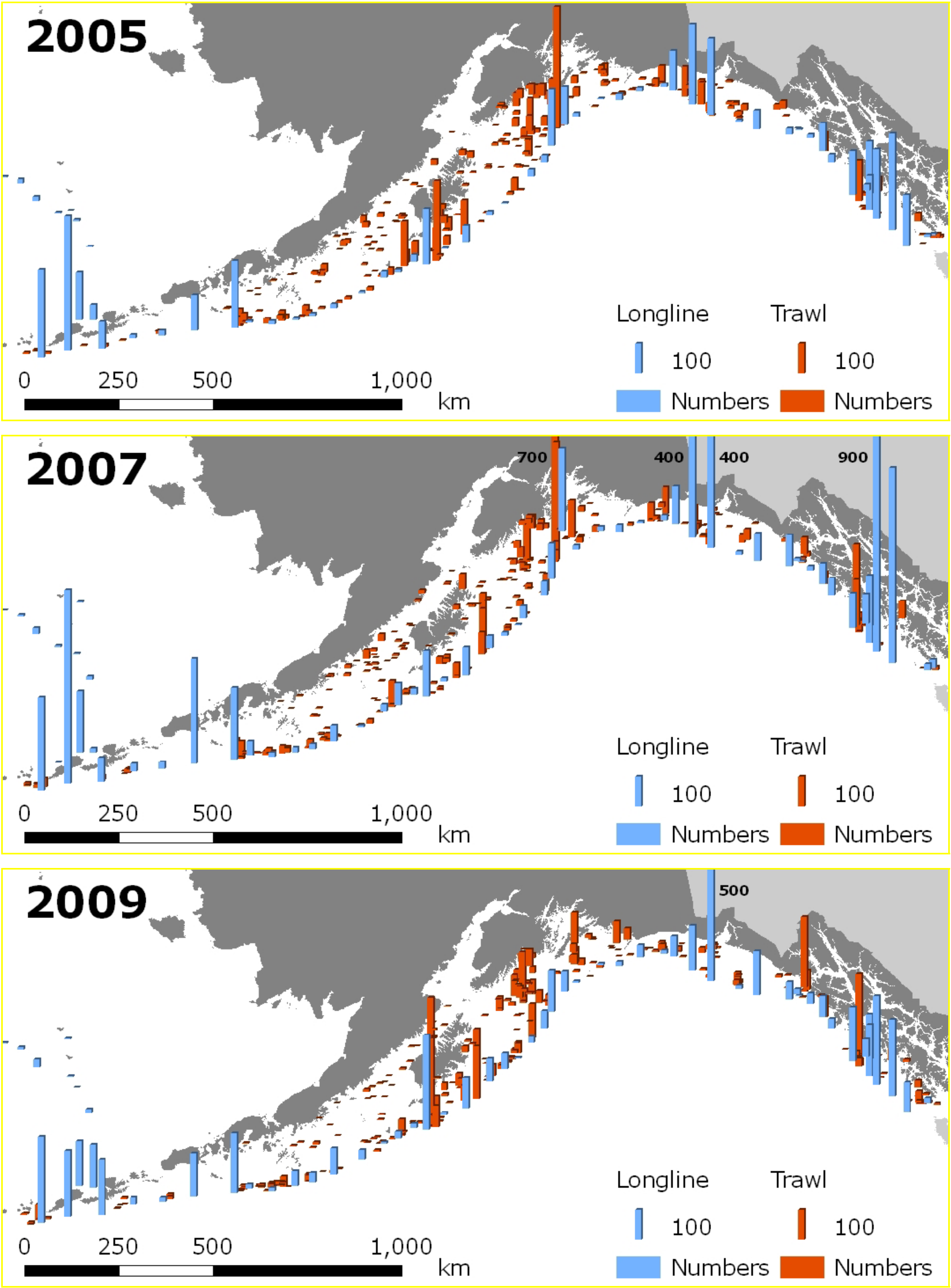
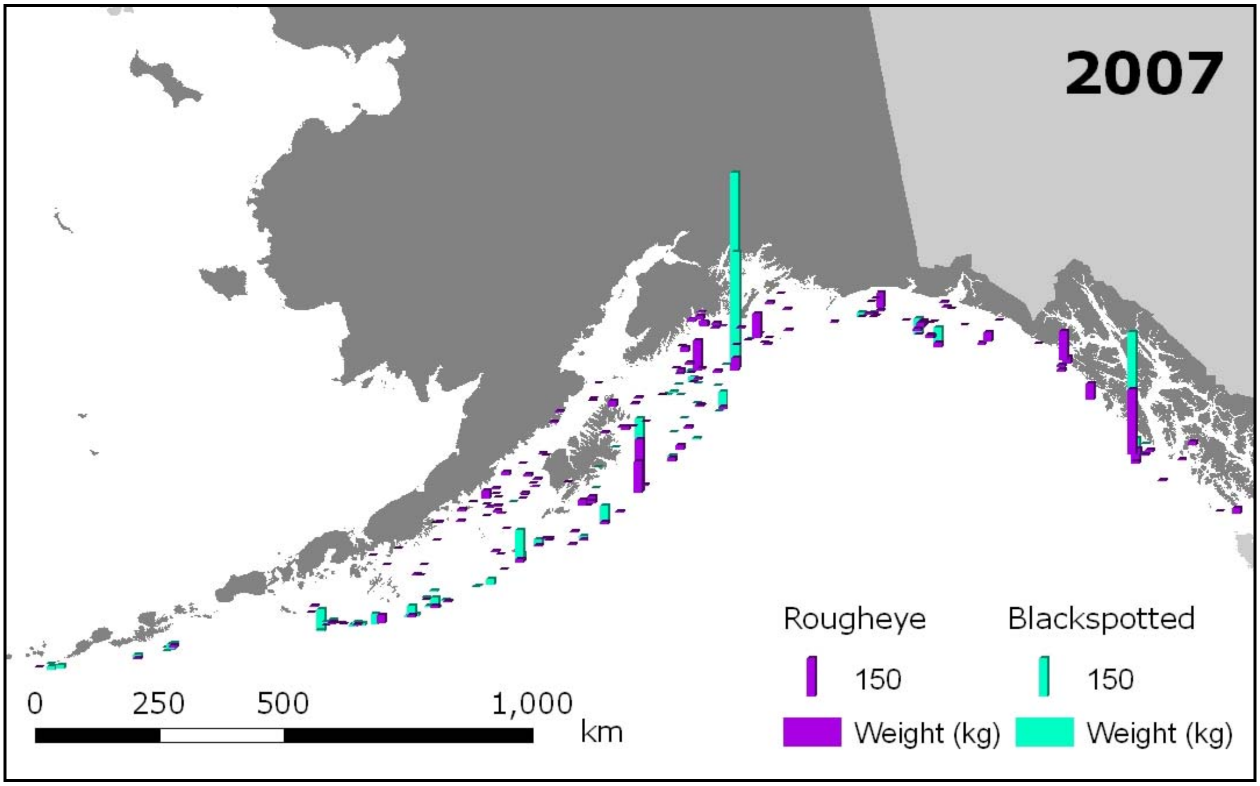


Figure 13-4a. Spatial distribution of rougheye and blackspotted rockfish in the Gulf of Alaska during the 2005, 2007, and 2009 NMFS trawl (red) and AFSC longline (blue) surveys.



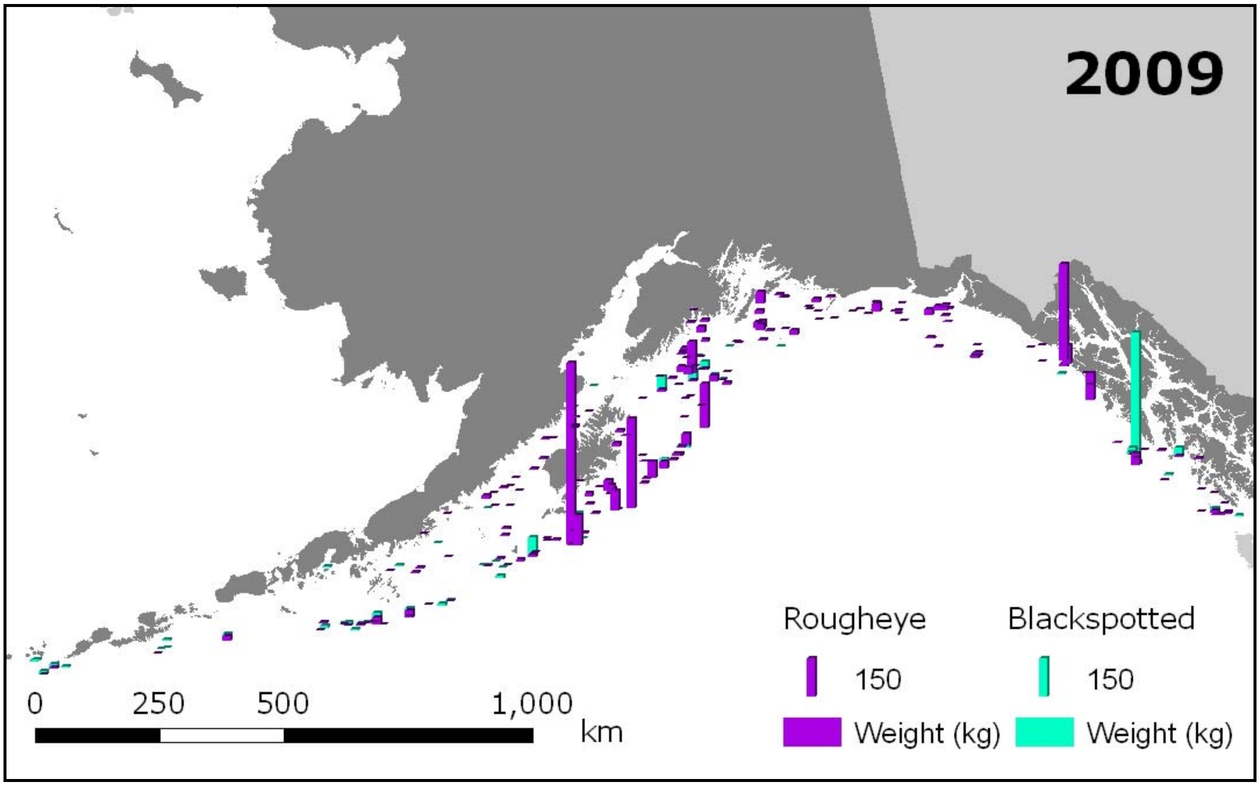


Figure 13-4b. Comparison of the spatial distribution between rougheye (purple) and blackspotted (green) rockfish in the Gulf of Alaska during the 2007 and 2009 NMFS trawl surveys.

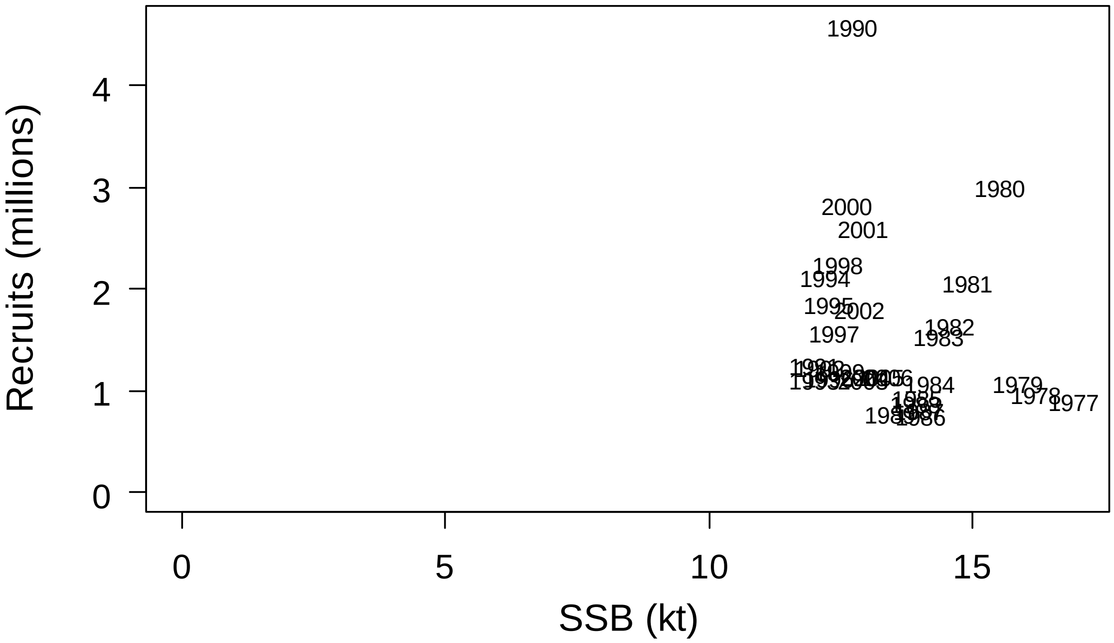


Figure 13-5. Scatterplot of spawner-recruit data for GOA RE/BS rockfish author recommended model. Label is year class of age 3 recruits. Recruits are in millions and SSB = Spawning stock biomass in tons.

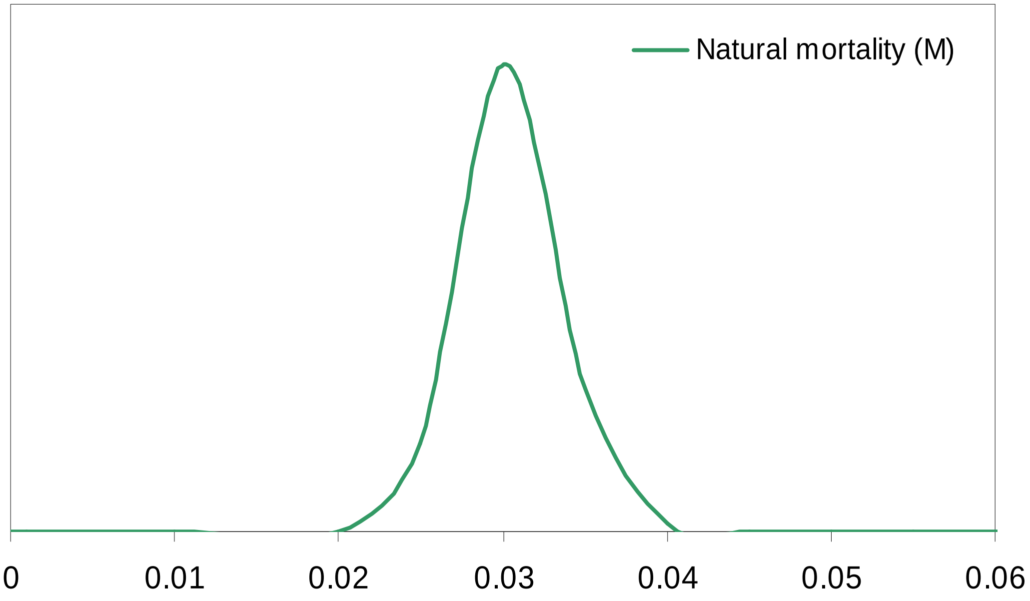


Figure 13-6. Prior distribution for natural mortality (M, μ=0.03, CV=10%) of GOA RE/BS rockfish.

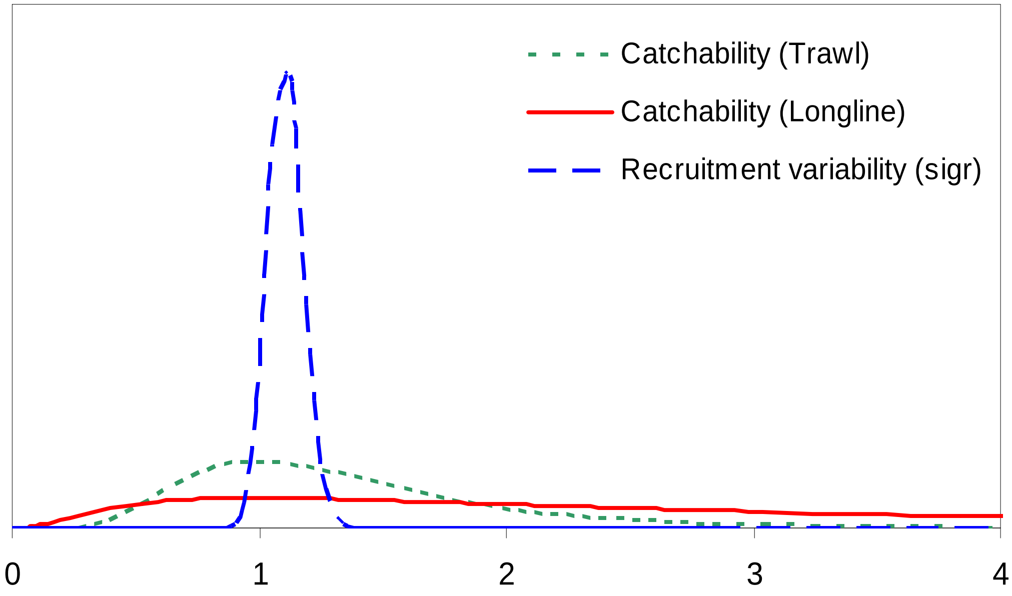


Figure 13-7. Prior distributions for NMFS trawl survey catchability ($q1$, μ=1, CV=45%), AFSC longline survey catchability ($q2$, μ=1, CV=100%), and recruitment variability (σ_r, μ=1.1, CV=6%) of GOA RE/BS rockfish.

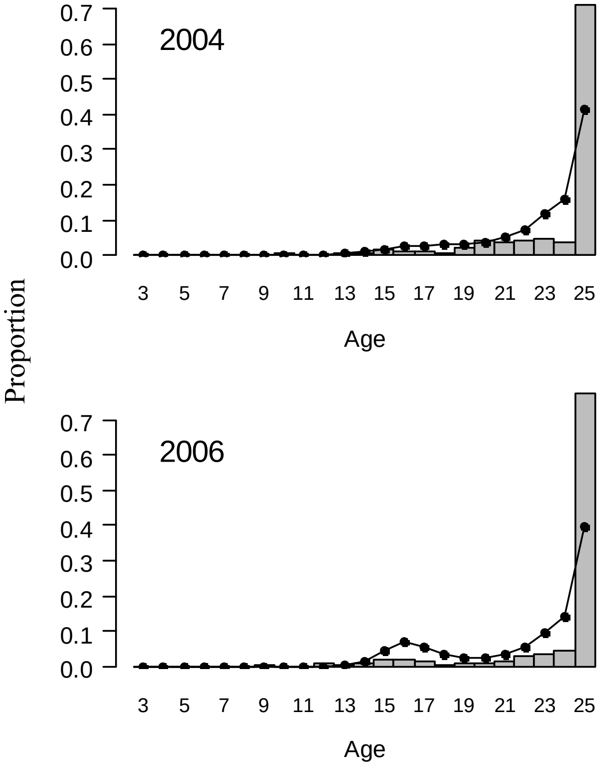


Figure 13-8. Fishery age compositions for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

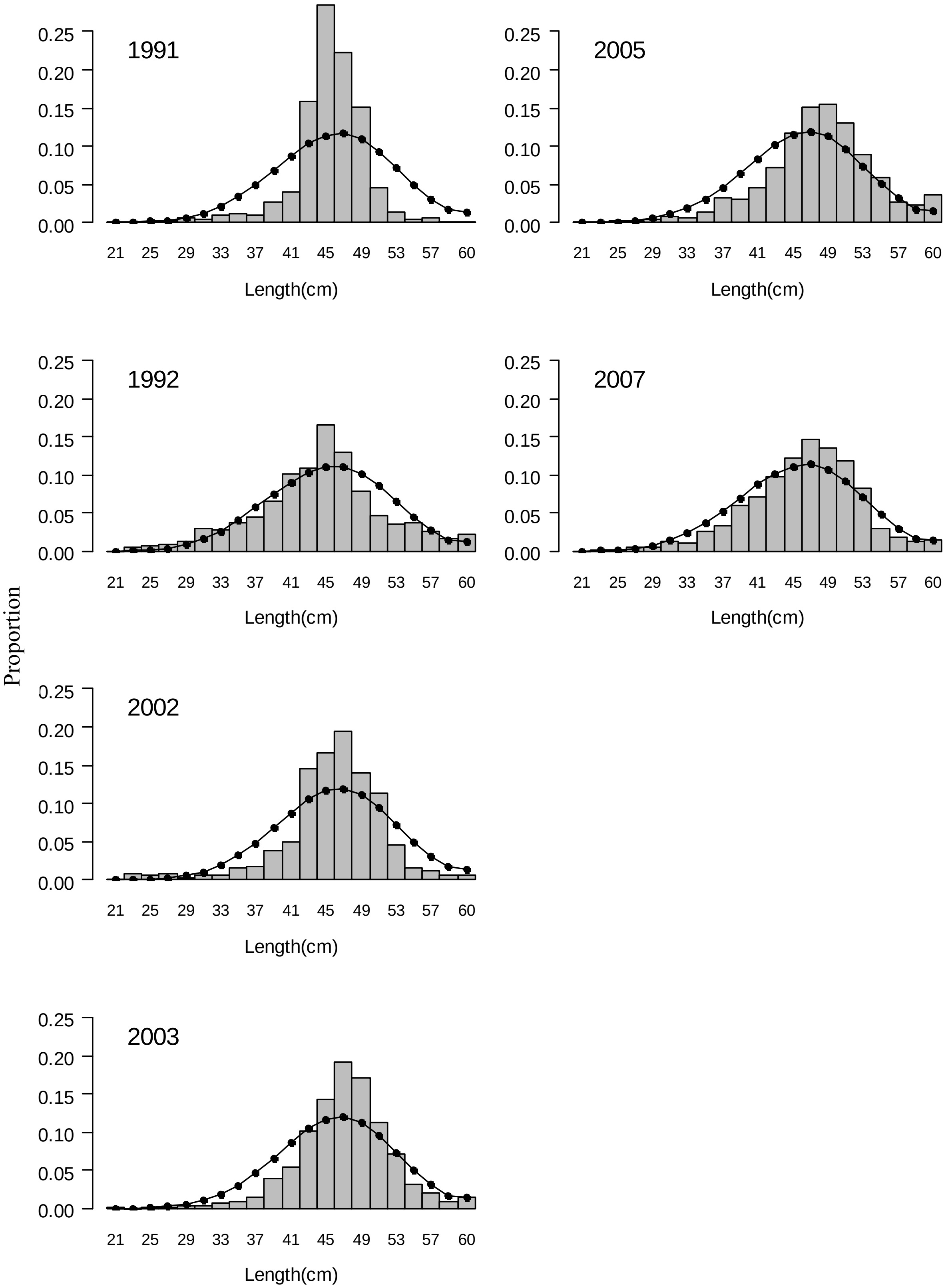


Figure 13-9. Fishery length compositions for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

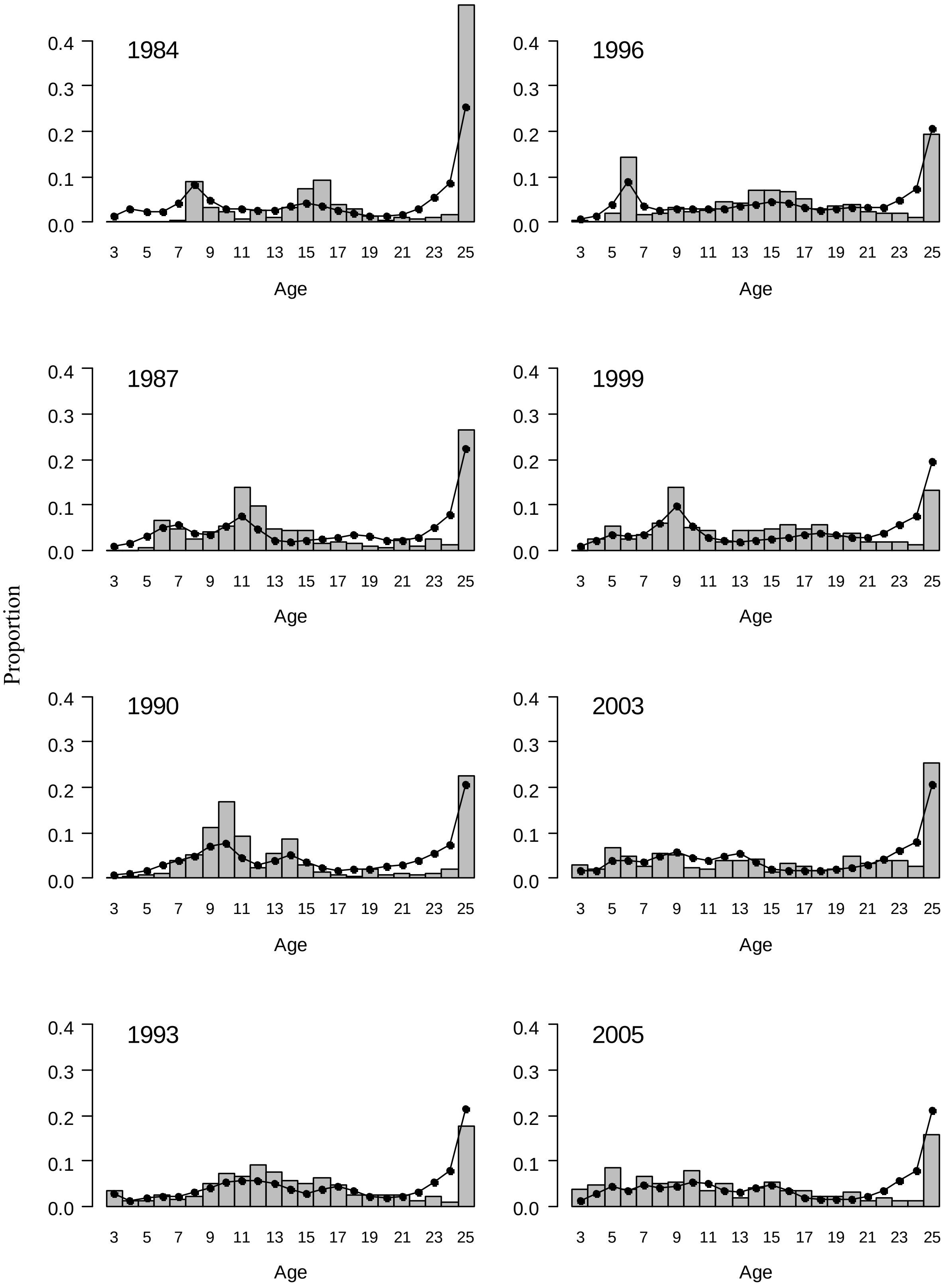


Figure 13-10. NMFS trawl survey age composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

Figure 13-10 (continued). NMFS trawl survey age composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

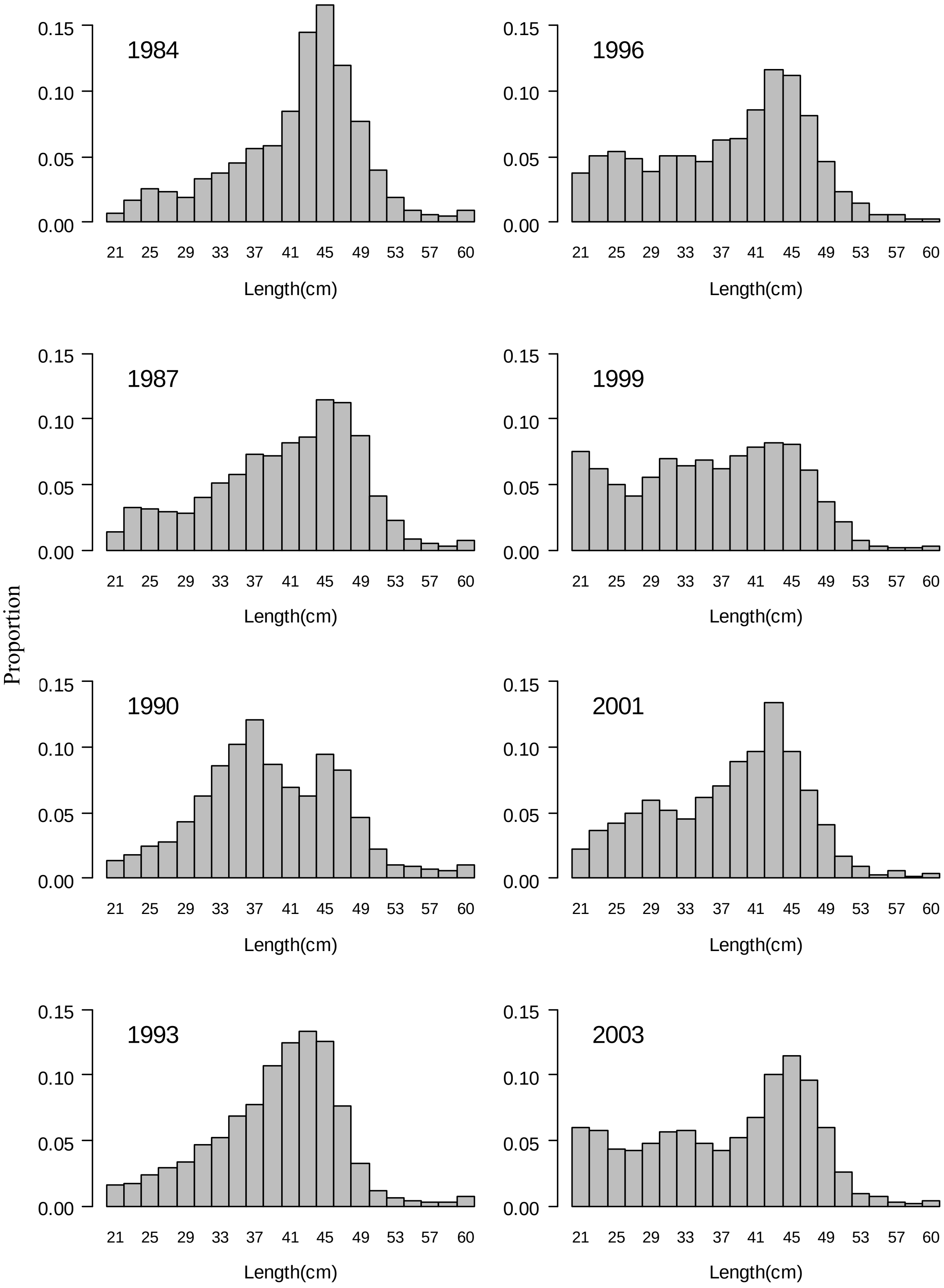


Figure 13-11. NMFS trawl survey length composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in model.

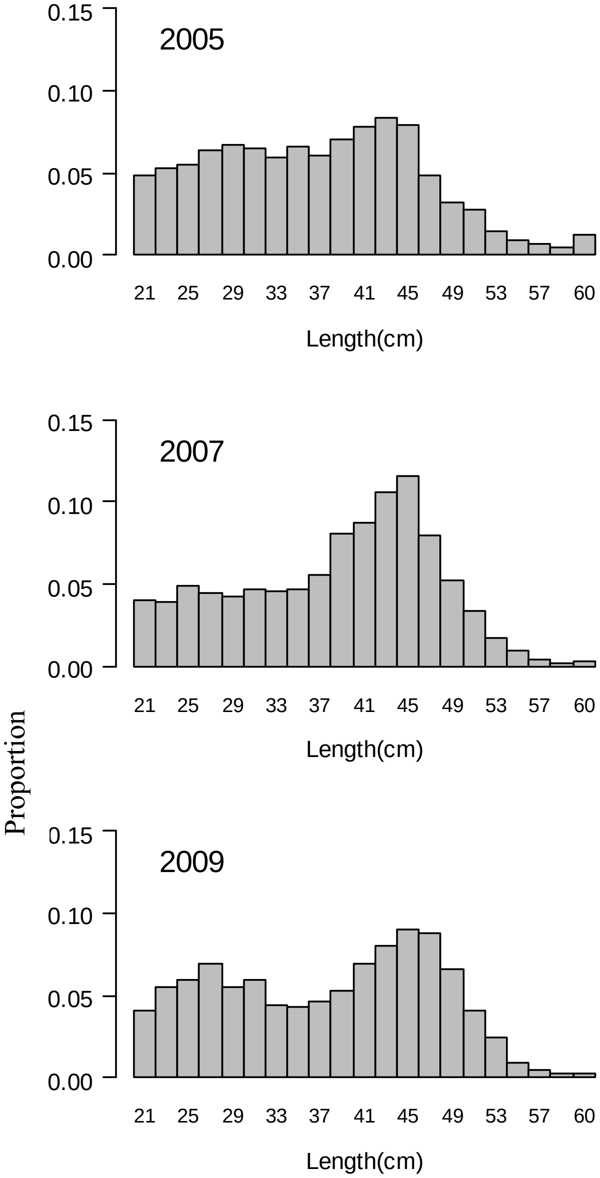


Figure 13-11 (continued). NMFS trawl survey length composition by year for GOA RE/BS rockfish. Observed = bars, data is used to determine size-age matrix, but not fit in model.

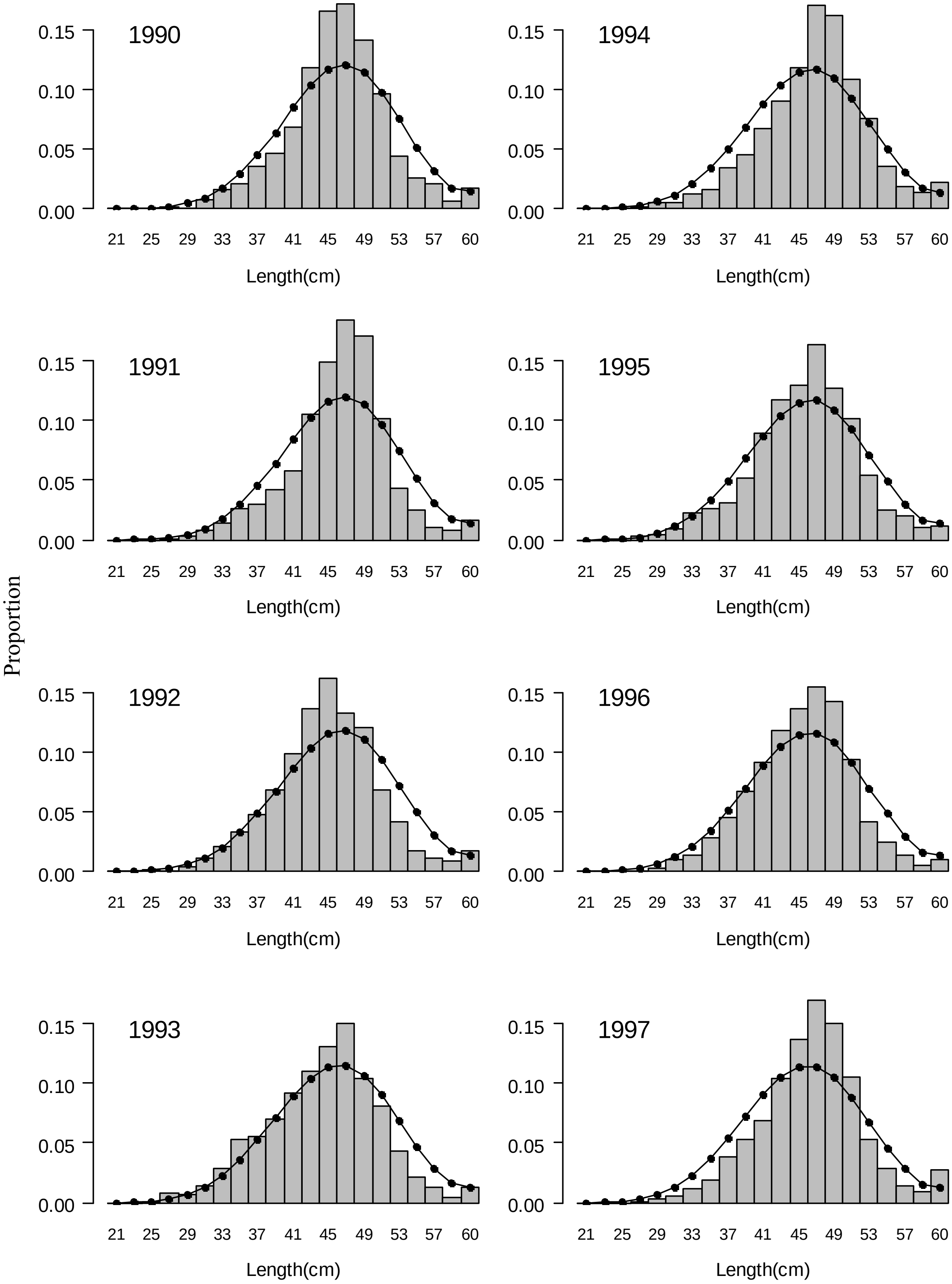


Figure 13-12. AFSC longline survey length composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

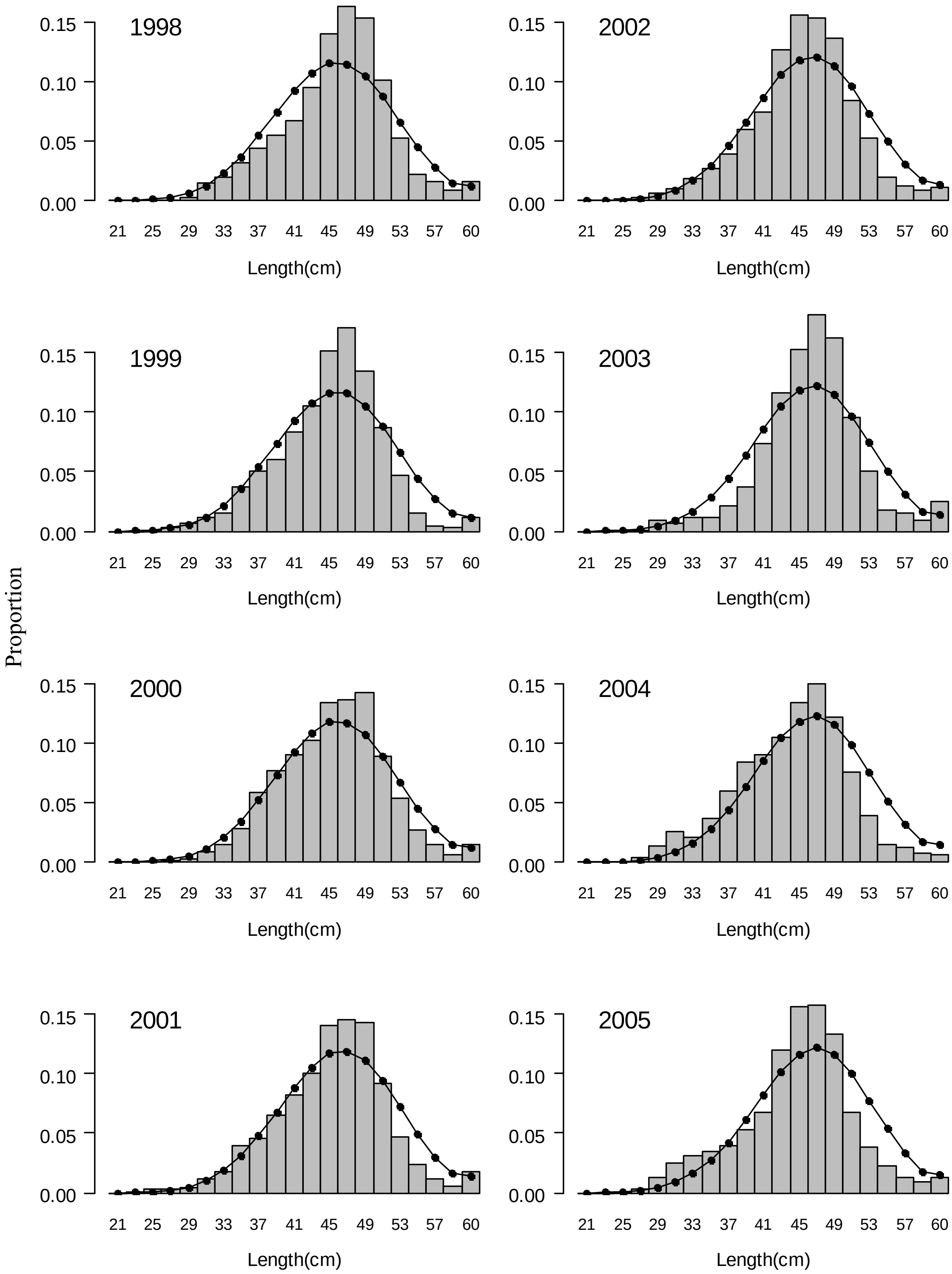


Figure 13-12 (continued). AFSC longline survey length composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

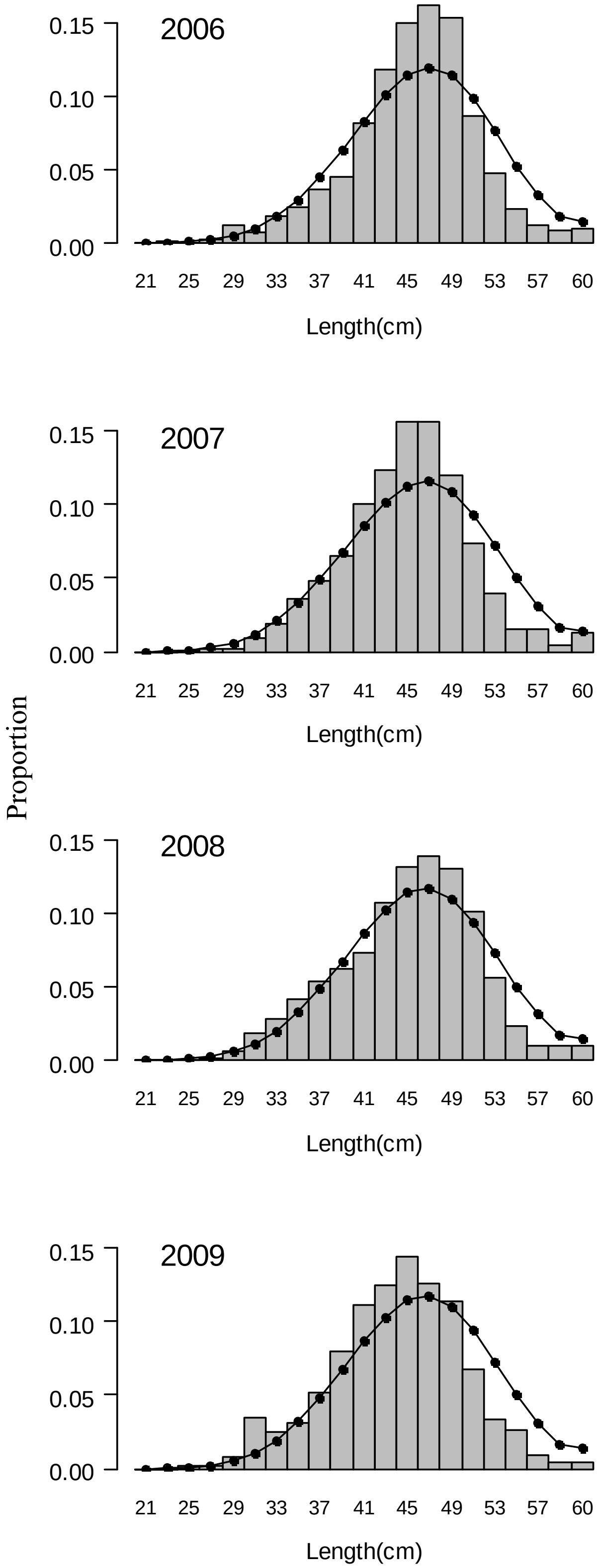


Figure 13-12 (continued). AFSC longline survey length composition by year for GOA RE/BS rockfish. Observed = bars, predicted from author recommended model = lines with circles.

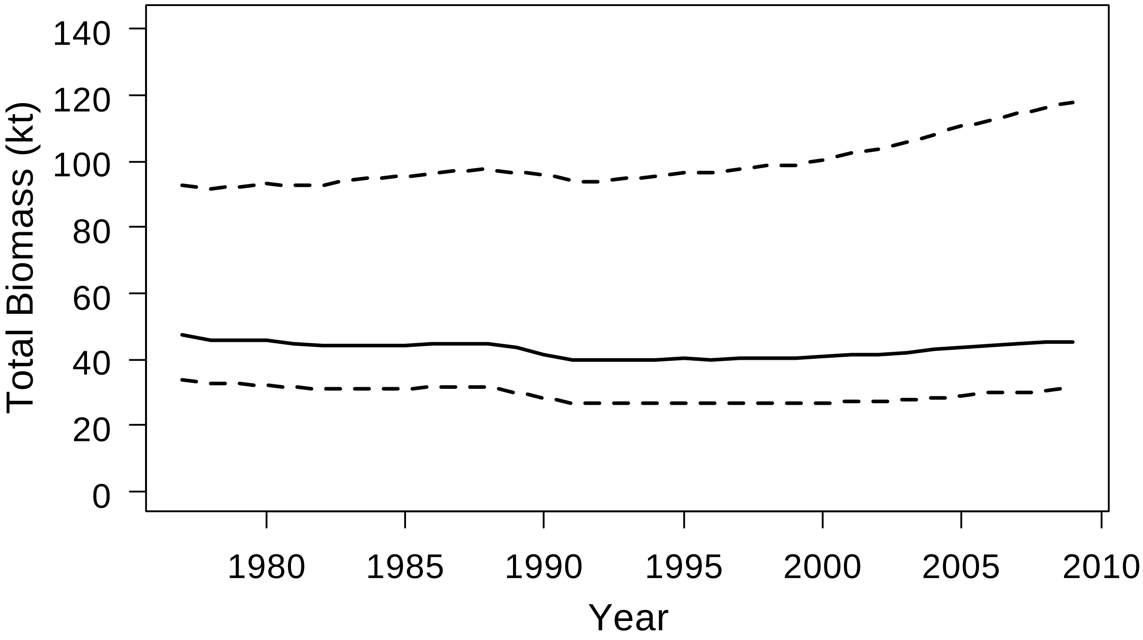


Figure 13-13. Time series of predicted total biomass for GOA RE/BS rockfish for author recommended model. Dashed lines = 95% credible intervals from 20 million MCMC runs.

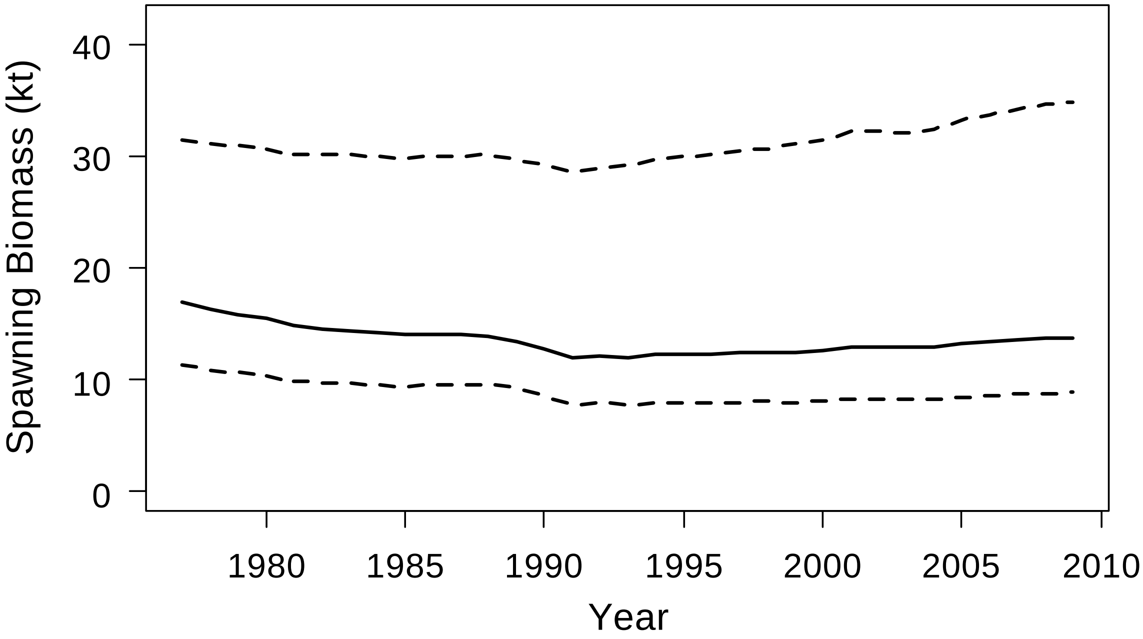


Figure 13-14. Time series of predicted spawning biomass of GOA RE/BS rockfish for author recommended model. Dashed lines = 95% credible intervals from 20 million MCMC runs.

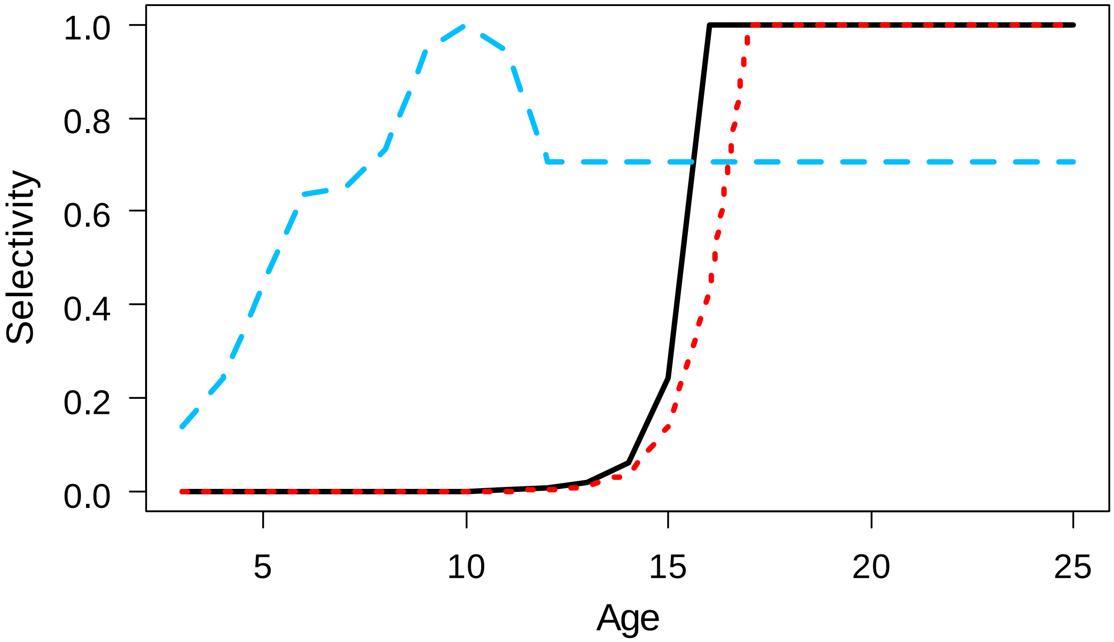


Figure 13-15. Estimated selectivity curves for GOA RE/BS rockfish from author recommended model. Dashed blue line = NMFS trawl survey selectivity, dotted red line = AFSC longline survey selectivity, and solid black line = combined fishery selectivity.

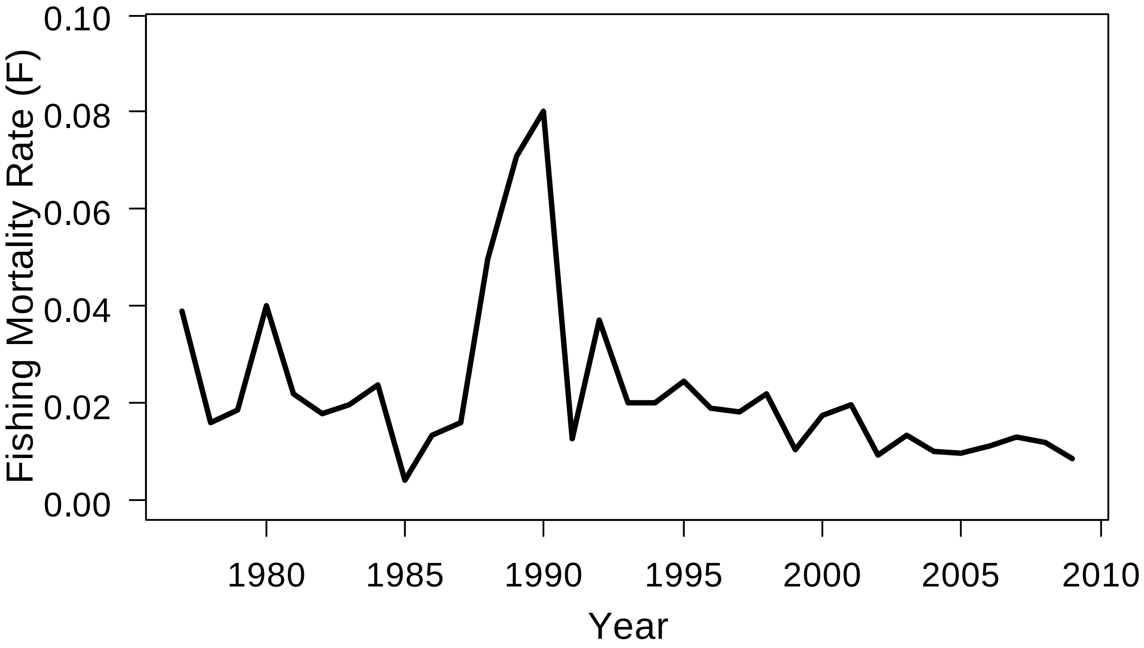


Figure 13-16. Time series of estimated fully selected fishing mortality for GOA RE/BS rockfish from author recommended model.

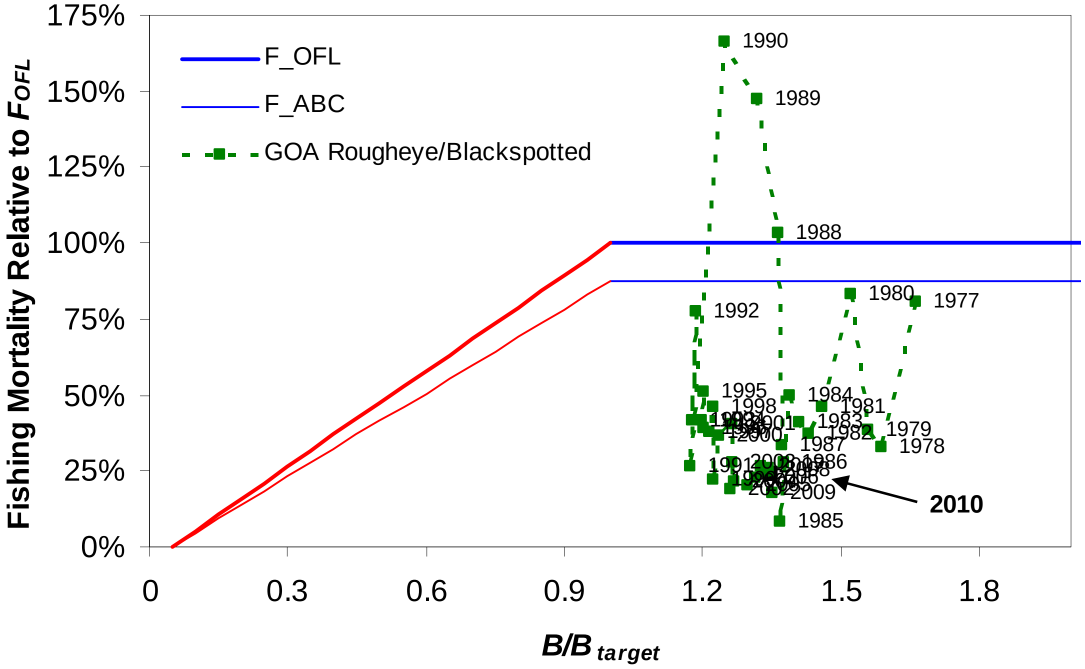


Figure 13-17. Time series of GOA RE/BS rockfish estimated spawning biomass relative to the unfished level and fishing mortality relative to F_{OFL} for author recommended model.

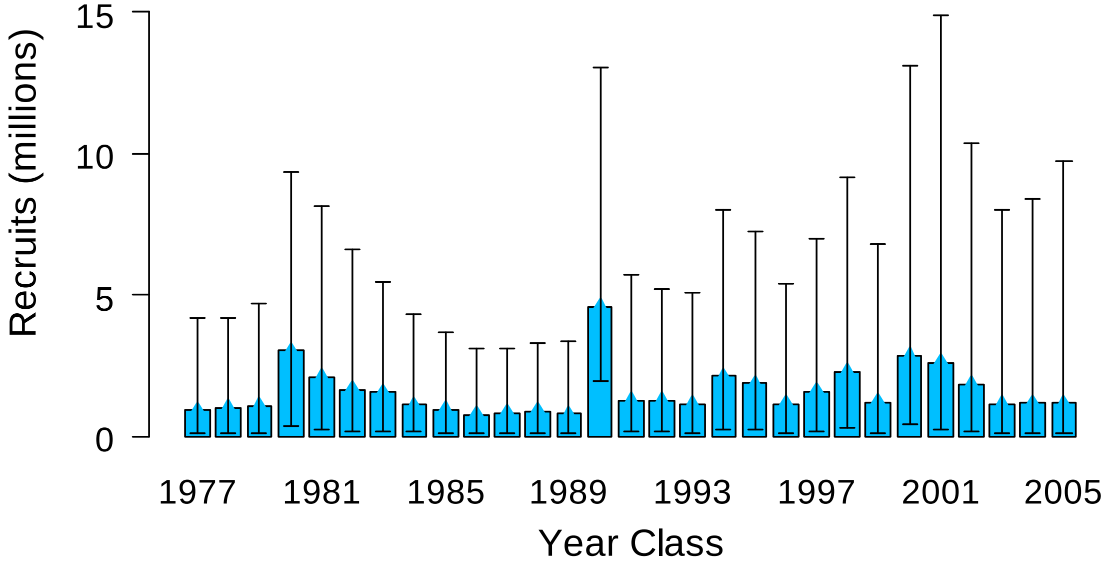


Figure 13-18. Estimated recruitments (age 3) for GOA RE/BS rockfish from author recommended model.

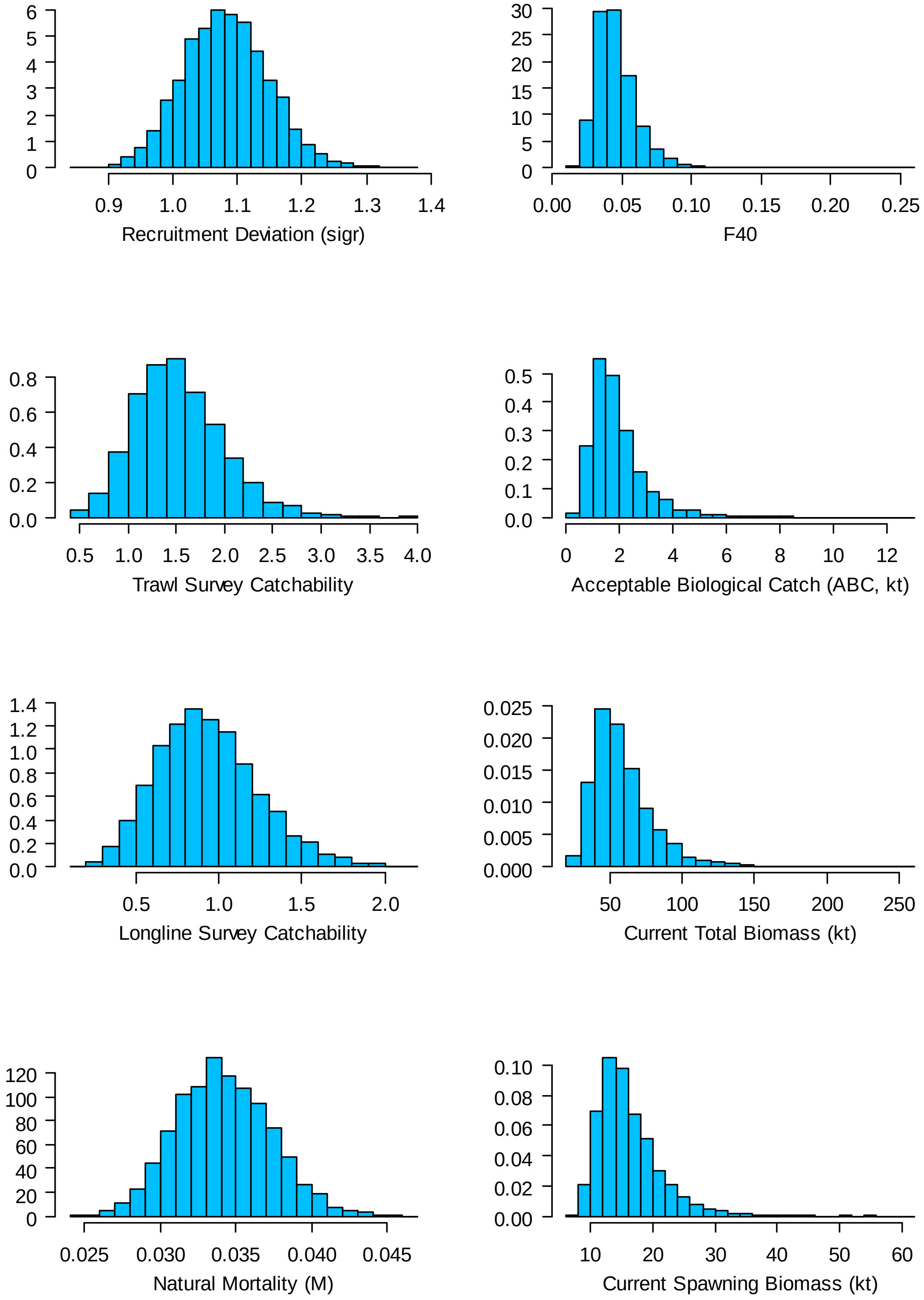


Figure 13-19: Histograms of estimated posterior distributions for key parameters derived from the 20 million MCMC runs for GOA RE/BS rockfish.

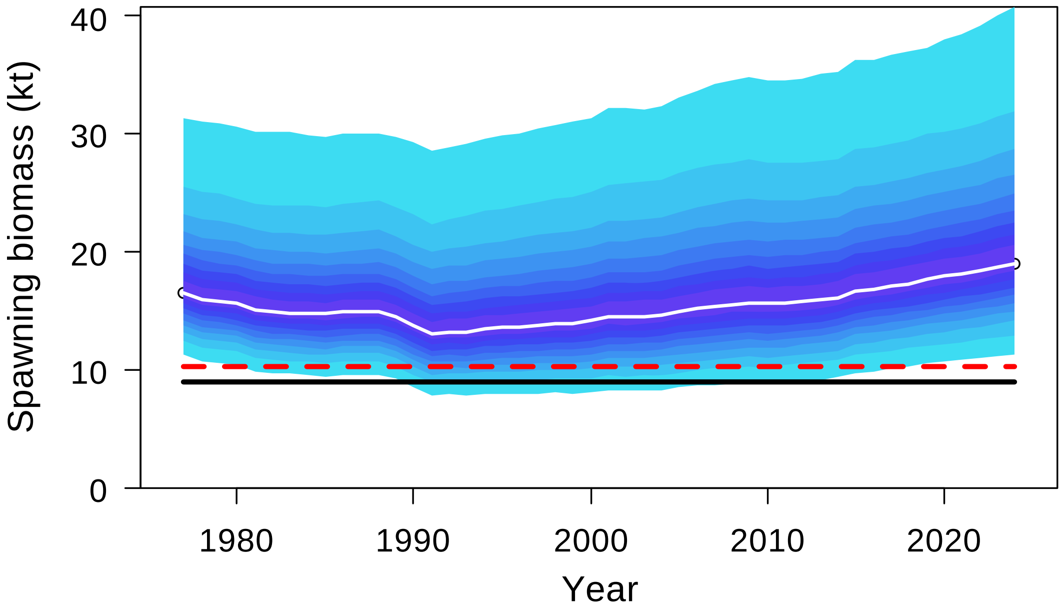


Figure 13-20: Bayesian credible intervals for entire spawning stock biomass series including projections through 2024. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1980-2007. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

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