11. Gulf of Alaska Rougheye Rockfish

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Executive Summary

We use a modified version of the generic rockfish model developed in a workshop at Auke Bay Laboratory in February 2001 as the primary assessment tool for rougheye rockfish (Courtney et al. 2007). The model was constructed with AD Model Builder software, and is a separable age-structured model with allowance for size composition data that is adaptable to several rockfish species. The data sets used include total catch biomass, fishery size compositions, trawl and longline survey biomass estimates, trawl survey age compositions, and longline survey size compositions. The projected ABC derived from the recommended model for 2008 is 1,286 t which is about 30% higher than last year's ABC of 988 t. The increase in ABC is likely due to the large amount of new data added to the model, particularly the historic trawl survey ages which allowed for more reliable estimate of mean recruitment. The catchability for both surveys decreased, resulting in an overall increase in the biomass time series. Additionally, the trawl survey catchability is more inline with other estimates of rougheye catchability based on empirical observations. This increase is also supported by the above average most recent trawl and longline survey biomass estimates. Recommended ABCs from area apportionments are 125 t for the Western area, 834 t for the Central area, and 327 t for the Eastern area. Reference values for rougheye rockfish are summarized below. The stock is not overfished, nor is it approaching overfishing status.

Summary	2008	2009*
Tier	3a	3a
Total Biomass (Age 3+)	46,121	46,266
Female Spawning Biomass (t)	13,882	13,980
$B_{0\%}$	24,839	
$B_{40\%}$ (t) (female spawning biomass)	9,935	-
$B_{35\%}$	8,694	
M	0.034	0.034
$F_{40\%}$	0.039	0.039
F_{ABC} (maximum allowable)	0.039	0.039
ABC (t; maximum allowable)	**1,286**	**1,279**
F_{OFL}	0.047	0.047
OFL (t)	1,548	1,540

*__Projected *ABC*s and *OFL*s for 2009 are derived using an expected catch value of 517 t for 2008 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 of this method are listed under the Author's F alternative in Table 11-10.

Summary of Major Changes to Model, Data, and Results

The assessment methodology is the same as the author recommended model in 2005 which utilizes the age error structure based on rougheye rockfish and the more accurate estimates of historical rougheye rockfish catch. New data added to this model were the updated estimates of 2006 and 2007 fishery catch, 2002 and 2006 fishery length compositions, 2007 trawl survey biomass estimate, 1984, 1993, 1996, and 2005 trawl survey age compositions, 2006-2007 longline survey relative population weights, and 2006-2007 longline survey size compositions. Since the longline survey does not sample in proportion to area, we used the now available area weighted longline survey size compositions instead of raw size compositions. We provide results from the 2005 model and the updated 2007 model. The trawl survey estimate increased by 25% from 2005, while the longline survey relative population weight increased by 15% in 2006 and another 50% in 2007. Estimates of catchability for both surveys decreased, resulting in an overall increase in the biomass time series. Trawl survey catchability is more inline with other estimates of rougheye catchability based on empirical observations. Model estimates result in a 30% increase in ABC. The addition of four years of trawl survey age data, particularly historic ages, confirmed several large recruitment years in the past, and increased the estimate of mean recruitment. This increase was also supported by recent increases in both survey biomass estimates. Potential higher recruitments are estimated for recent years; however, these estimates are highly uncertain given the lack of information on recent year classes. Female spawning biomass is well above $B_{40\%}$, with projected biomass stable.

Responses to SSC Comments

The SSC December 2005 minutes included the following comments concerning rougheye rockfish:

"The SSC requests that the authors provide a sensitivity analyses on the relative weighting between surveys to explore model fit to the data. This may provide some insight into the model trade offs of incorporating both surveys."

In 2006 we responded to this comment with a preliminary sensitivity analysis of the two survey indices (Shotwell et al. 2006). Data for the rougheye model has substantially increased this year and we have performed 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. Results of this analysis are in Appendix 11A of this document.

The SSC December 2006 minutes include the following comments concerning all fish stocks:

"The SSC appreciates the addition of phase-plane diagrams to most stock assessments and reiterates interest in these diagrams for all stock assessments in which it is possible to do so using standardized axes (i.e., X axis of B/B_{target}; and Y axis of F_{catch}/F_{OFL}), formatted relative to harvest control rules. In addition, values from the most recent year should be provided annually by the assessment authors to the plan team. The plan teams are requested to provide a figure summarizing all stocks in the introduction section of the SAFE documents. This figure would show the most recent year's status for all stocks possible by plotting realized F relative to F_{OFL} versus biomass relative to target biomass. One point for each stock from the most recent year plotted relative to the harvest control rules would provide a snapshot of relative stock management performance for the group… One option could be to plot the last two years values as a line with an arrow head to show the change in each stock's performance from the prior year."

In this assessment we moved from the Goodman et al. (2002) style management path to one that incorporates the harvest control rules in the phase-plane diagram (see *Model Results* section).

Responses to Rockfish CIE Review

In June, 2006, the Alaska Fisheries Science Center (AFSC) arranged for a review of Alaska rockfish harvest strategies and stock assessment methods by the Center of Independent Experts (CIE). Three reviewers participated and each produced a separate review without collaboration with other panelists or NMFS staff. The reviews can be found at: http://www.afsc.noaa.gov/refm/docs/2006/rf_CIE.pdf. The AFSC prepared a draft response to the review and presented several discussion points at the February, 2007 SSC meeting. The draft response can be found at: ftp://ftp.afsc.noaa.gov/afsc/public/rockfish/RWG response to CIE review.pdf. The draft response focused on specific comments and recommendations regarding rockfish assessments in Alaska. Comments that pertained to rougheye rockfish include:

"Estimation of M is problematic, whether it is via a maximum age assumption, an early catch-curve, or is estimated within a stock assessment model. However it is done, the objective should be to attain a "best" estimate of M – not a conservative estimate of M."

A description of methods available for estimating M is provided in the draft response to the CIE. Estimates of natural mortality currently in use for Alaska rockfish stock assessments have been derived from a variety of different literature references and vary among species and between areas. In general, estimates of natural mortality decrease with increasing maximum age. The natural mortality value used for rougheye rockfish in this assessment is 0.034. An overview of the methodology and justification for using this value of M is provided in *Parameters estimated conditionally* under the *Analytical Approach* section of this document. The authors will monitor new research regarding maximum age of rockfish species and alternative methods for estimating natural mortality. We will also continue to experiment with model derived estimates of natural mortality as more data becomes available for use in the model.

"Trawl survey indices take no account of the proportion of untrawlable ground in each stratum (a particular problem for the GOA survey)."

A center-wide initiative is underway to estimate the effect of untrawlable areas on groundfish stock assessments. Retrospective studies of untrawlable stations during past surveys, development of split-beam acoustic methods to estimate untrawlable areas, analysis of existing echosounder data, and alternative methods to trawl surveys that will allow estimation of fish abundance in untrawlable areas are all being investigated to address the problem.

"Develop informative priors for the trawl surveys. Changes in gear setup and operation (e.g., length of trawl, standardization of methods) should be considered for each time series. More than one q will probably be needed for each time series."

Several simulations were presented in the draft response to the CIE which addressed how well standard stock assessment models estimate catchability under different scenarios. Another simulation was presented which modeled the trawl survey sampling and estimation procedures under a variety of situations. The question of trawl survey catchability is an important component to rockfish assessments and will likely be an ongoing research effort at the AFSC.

Plan Team Summaries

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Rougheye rockfish	2006	37,449	1,180	983	983	351
	2007	39,506	1,148	988	988	397
	2008	46,121	1,548	1,286		
	2009	46,266	1,540	1,279		

[1]Total biomass from the age-structured model

Stock/		2007				2008		2009	
Assemblage	Area	OFL	ABC	TAC	Catch[2]	OFL	ABC	OFL	ABC
Rougheye rockfish	W		136	136	69		125		124
	C		611	611	180		834		830
	E		241	241	148		327		325
	Total	1,148	988	988	397	1,548	1,286	1,540	1,279

[2]Current as of October 3, 2007 (http://www.fakr.noaa.gov)

Introduction

Biology and Distribution

Rougheye rockfish (*Sebastes aleutianus*) 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). This species often co-occurs with shortraker rockfish (*Sebastes borealis*) in trawl or longline hauls.

Little is known about the biology and life history of rougheye rockfish, but the fish appear to be long-lived, with late maturation and slow growth. As with other *Sebastes* species, rougheye 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 rougheye 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). 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 rougheye 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.

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

Food habit studies in Alaska indicate that the diet of rougheye 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 rougheye 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). Predators of rougheye 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). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. De Bruin et al. (2004) examined Pacific ocean perch (*S. alutus*) and rougheye 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 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 now proposed as *S. aleutianus* or rougheye rockfish proposed 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). This species is typically lighter in coloration with spots absent from the spinous dorsal fin and possibly has mottling on the body. The northern species of rougheye rockfish now 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). This species is often darker in body coloration with distinct spots 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; however a potential difference in depth distribution may 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 with associated photos of 150 fish and observer identification based on the features in a pamphlet distributed by J. Orr. Genetic analysis of these samples is in progress. Preliminary discussions with researchers from this experiment suggest that identification of each species was difficult due to the range of coloration and spotting between individuals.

At present there appears to be difficulty in accurate field identification between the two species. Methods should be developed and tested that would enable rapid and accurate field identification of the two species by observers and scientists so that population estimates and catch accounting can occur. In addition studies should be undertaken that assess whether the two species have significantly different life history traits (i.e. age of maturity and growth). Until such information and studies occur it will be difficult to undertake distinct population assessments. Ongoing research in this area may determine particular habitat preference that might be useful for separating the species, and phenotypic research may determine a distinct combination of characters for onboard identification.

Management measures

In 1991, the North Pacific Fishery Management Council (NPFMC) divided the slope assemblage in the Gulf of Alaska into three management subgroups: Pacific ocean perch, shortraker/rougheye rockfish, and all other species of slope rockfish. Although each management subgroup was assigned its own value of ABC (acceptable biological catch) and TAC (total allowable catch), shortraker/rougheye rockfish and other slope rockfish were discussed in the same SAFE chapter because all species in these groups were classified into tiers 4 or lower in the overfishing definitions. This resulted in an assessment approach based primarily on survey biomass estimates rather than age-structured modeling. In 1993, a fourth management subgroup, northern rockfish, 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.

As of October 3, 2007, about 75% of the current catch of rougheye rockfish in the Central GOA was taken in March through May, suggesting that some spreading of harvest is occurring earlier in the season but not later. These are preliminary estimates and may change as the season progresses. The authors will pay close attention to the benefits and consequences of this action. Future analyses regarding the Pilot Project effects on rougheye rockfish will be possible as more data becomes available.

Fishery

Historical Background

Rougheye 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 shortraker/rougheye subgroup have been consistently around 1,500-2,000 t in the years since 1992 (Table 11-1a). Annual TAC's have been the major determining factor of these catch amounts, as TAC's have also ranged between ~1,500-2,000 t over these years. Rougheye are caught in either bottom trawls or with longline gear, and about half came from each gear type in 2007. Nearly all the longline catch of rougheye appears to come as "true" bycatch in the sablefish or halibut longline fisheries. However, in rockfish trawl fisheries some of the rougheye is 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 rougheye rockfish appear to take place in the Pacific ocean perch trawl fishery, especially because shortraker rockfish is the most valuable species of *Sebastes* in terms of landed price and rougheye often co-occur with shortraker in the trawl or longline hauls.

Catches of rougheye rockfish from research cruises since 1977 are listed in Table 11-1b. Preliminary estimates of longline survey catches were available from 1996-2007 and are included in the total research catch of rougheye.

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.

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 should be reported separately.

Shortraker/ Rougheye Subgroup

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

Year	2005	2006	2007
Discards	20.3	25.6	38.3

The above table indicates that discards of shortraker/rougheye have ranged from approximately 21% to 45% with an average of 28%. These values are relatively high when compared to other *Sebastes* species in the Gulf of Alaska.

[1] National Marine Fisheries Service, Alaska Region, P.O. 21668, Juneau, AK 99802. Data are from weekly production and observer reports through October 3, 2007.

Data

The following table summarizes the data used for this assessment:

Source	Data	Years
Fisheries	Catch	1977-2007
U.S. trawl fisheries	Length	1991-1992, 2002-2006
Domestic trawl survey	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007
	Age	1984, 1990, 1993, 1996, 1999, 2003, 2005
Sablefish longline survey	Biomass index	1990-2007
	Length	1990-2007

Fishery Data

Catch

Catches of rougheye rockfish range from 130 mt to 2,418 mt from 1977 to 2007. 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 in the catch based on data from the NMFS Groundfish Observer Program (Clausen et al. 2004, Appendix A). Catches were available from the observer database by area, gear, and species for hauls sampled by observers. This information was used to calculate proportions of rougheye 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 11-1, Table 11-1a).

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 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 rougheye 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 rougheye and shortraker since 2005.

Size composition

Observers aboard fishing vessels and at onshore processing facilities have provided data on size composition of the commercial catch of rougheye rockfish. Table 11-2 summarizes the available size compositions from 1991-2006. 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 rougheye. We use data from 1991-1992, and 2002-2006. Port length samples for rougheye also exist; however, the distribution of sampled lengths is generally choppy and sample sizes are typically low. We do not incorporate the port samples into the 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. Approximately 80% of the lengths are from the trawl fishery and 20% are from the longline fishery. The mode of length for the 1991-1992 samples is approximately 45 cm and from 2002-2006 has steadily increased from 46 to 49 cm. Moderate presence of fish smaller than 40 cm is present in most years, particularly 1992 and 2006.

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 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. We use data from the triennial surveys and the 2003-2007 biennial surveys.

Summaries of biomass estimates from the 1984-2007 surveys are provided in Table 11-3. Trawl survey biomass estimates are shown in Figure 11-2. Estimates by region indicate that the western and central GOA time series of biomass are relatively similar, while the eastern GOA tends to be the converse. This pattern has somewhat altered in the 2005 and 2007 surveys where the central and eastern GOA estimates are increasing 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, we do not use this estimate in this model. However, 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 have been relatively constant among the surveys, with the possible exception of 1993 and 2007. Confidence intervals overlap in all the surveys (Table 11-3; Figure 11-2) which indicate that none of the changes in biomass are statistically significant. Compared with other species of *Sebastes*, the biomass estimates for rougheye 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, the trawl surveys are believed to do a relatively poor job of assessing abundance of adult rougheye rockfish. Nearly all the catch of these fish is found on the upper continental slope 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. Overall, more blackspotted rockfish were identified than rougheye. This was particularly true in the central GOA where blackspotted rockfish estimates were 20% higher than rougheye rockfish estimates.

Age Compositions

Age determination for rougheye rockfish is problematic. This species appear to be among the longest-lived of all rockfish species, and 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). Four new years of age composition were added this year, 1984, 1993, 1996, and 2005. Samples for the 1987 trawl survey are currently being aged, and were not available for this year. We now have seven years of survey age compositions, with sample size total of 3,816 ages. Although rougheye rockfish have been reported to be greater than 200 years old (Munk 2001), the highest age collected over these survey years was 132. The average age was ranged from 15 to 23 over all survey years available (Table 11-4). Compositions from 1984, 1990, 1996, and 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 and 2005, compositions are spread relatively evenly across age groups 3-15 corresponding to the strong year classes of the early 1990s and potentially another period of increased recruitment in the early 2000s. Ages 25 and greater are pooled into a plus (+) group that is fairly substantial in some years, particularly the 1984 compositions. 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 11-5. 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 2007 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 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. 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.

Sablefish Longline Survey Data

Biomass Estimates

Catch, effort, and length data were collected during sablefish longline surveys for rougheye rockfish.

Rougheye data were collected outside of the SR/RE 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 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 11-6 and graphed in Figure 11-3. 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 have steadily increased to the present value which is approximately 16% above 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 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. Sample size increased in 2006 and 2007 as efficiency improved and observers now collect lengths for nearly all rougheye rockfish caught. The influence of such sample size differences in the stock assessment model are somewhat remedied by taking the square root of sample size 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 the now available area weighted longline survey size compositions instead of raw size compositions. 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 11-7). 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 rockfish caught in the 2005 and 2007 trawl and longline surveys is depicted in Figure 11-4. 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 rougheye rockfish in the central GOA, while the longline survey catches more rougheye in the eastern and western GOA. This is more evident in the 2005 surveys than in 2007. 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. The changes in spatial distribution of trawl and longline survey catches over time may be an area of future research when determining life history differences between blackspotted and rougheye rockfish.

Analytic Approach

Model Structure

We present model results for rougheye rockfish based on an age-structured model using AD Model Builder software (Otter Research Ltd 2000). Previously, the rougheye rockfish stock assessment was based solely on trawl survey biomass estimates. The assessment model is now based on a generic rockfish model developed in a workshop held in February 2001 (Courtney et al. 2007). This generic rockfish 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 11-5). The main difference between the rougheye 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 model was 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 length-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 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 rockfish used to derive the estimates of 50% maturity-at-age were recently aged and the historical 1987 age sample is currently being aged. 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 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 (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 11-6).

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 rockfish. 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 rockfish (Malecha et al. 2007). McDermott (1994) collected 430 samples of rougheye rockfish from across the Pacific Northwest to the Bering Sea, providing a representative sample of rougheye 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 rougheye rockfish, we feel that this is the most suitable estimate for a prior.

Catchability is a parameter that is somewhat unknown for rockfish, so while we assign it a prior mean of 1 (assuming all fish in the area swept are captured and there is no herding of fish from outside the area swept, and that there is no effect of untrawlable grounds), we assign it a less precise CV of 45% for the trawl survey and 100% for the longline survey (Figure 11-7). This allows the parameter more freedom than that allowed to natural mortality. Recruitment deviation is the amount of variability that the model assigns recruitment estimates. Rougheye 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 11-7).

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_y	52
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	31
Fishery selectivity coefficients	fs_a	14
Survey selectivity coefficients	ss_a	25
Total		131

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 131. 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 100,000 iterations out of 10,000,000 and "thinned" the chain to one value out of every two thousand, leaving a sample distribution of 4,950. 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% confidence 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^2_M	Prior CV for natural mortality
σ^2_q	Prior CV for catchability coefficient
$\sigma^2_{\sigma_r}$	Prior CV for recruitment deviations

BOX 1 (Continued)

Equations describing the observed data

$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1 - e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$	Catch equation
$\hat{I}_{1y} = q_1 * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$	Trawl survey biomass index (mt)
$\hat{I}_{2y} = q_2 * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$	Longline survey biomass index (mt)
$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,a'}$	Survey age distribution Proportion at age
$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,l}$	Survey length distribution Proportion at length
$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$	Fishery age composition Proportion at age
$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$	Fishery length composition Proportion at length

Equations describing population dynamics

Start year

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

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

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
$L_9 = \frac{1}{2\sigma_{q_1}^2} \left(\ln {}^{q_1}\!/\!{}_{q_{1\,prior}} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for trawl survey
$L_{10} = \frac{1}{2\sigma_{q_2}^2} \left(\ln {}^{q_2}\!/\!{}_{q_{2\,prior}} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for longline survey
$L_{11} = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln {}^{\sigma_r}\!/\!{}_{\sigma_{r(prior)}} \right)^2$	Penalty on deviation from prior distribution of recruitment deviations
$L_{12} = \lambda_{12} \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln \left(\sigma_r \right) \right]$	Penalty on recruitment deviations
$L_{13} = \lambda_{13} \sum_y \varepsilon_y^2$	Fishing mortality regularity penalty
$L_{14} = \lambda_{14} \bar{s}^2$	Average selectivity penalty (attempts to keep average selectivity near 1)
$L_{15} = \lambda_{15} \sum_{a_0}^{a_+} \left(s_i - s_{i+1} \right)^2$	Selectivity dome-shapedness penalty – only penalizes when the next age's selectivity is lower than the previous (penalizes a downward selectivity curve at older ages)
$L_{16} = \lambda_{16} \sum_{a_0}^{a_+} \left(FD(FD(s_i - s_{i+1}) \right)^2$	Selectivity regularity penalty (penalizes large deviations from adjacent selectivities by adding the square of second differences)
$L_{total} = \sum_{i=1}^{16} L_i$	Total objective function value

Model Evaluation

This model is the updated version of the accepted author recommended model presented in the 2005 GOA Rougheye Rockfish assessment. This model utilizes the age error matrix based on rougheye rockfish and the more accurate observer estimates of historical rougheye rockfish catch. An extensive amount of new data was added to the model including updated estimates of 2006 and 2007 fishery catch, 2002 and 2006 fishery length compositions, 2007 trawl survey biomass estimate, 1984, 1993, 1996, and 2005 trawl survey age compositions, 2006-2007 longline survey relative population weights, and 2006-2007 longline survey size compositions. At this time modifications to the model structure do not appear to be necessary. However, in the advent of a completed historical time series of age data, we plan to update estimates of 50% age-at-maturity, size-age matrix, weight-age vector, and age-error matrix. Ongoing research into model assumptions and performance as well as rougheye rockfish life history may result in future changes to the model.

Model Results

Table 11-8 summarizes the results from this year's author recommended model and the 2005 model. In general, parameter estimates are similar to the 2005 values with the exception of catchability for the trawl and longline surveys and mean recruitment. Estimates of catchability in both surveys decreased while the estimate of mean recruitment increased. The new estimate of trawl survey catchability is more inline with recent empirical observations of rougheye catchability. This is likely due to the newly available age data in the model and the increase in the biomass estimates from both surveys. In contrast, only three years of age data were available in 2005, and the 2005 trawl survey biomass estimates had increased while the longline survey estimate decreased to an all time low. With the addition of age data in the updated 2007 model, the influx of new recruits could be tracked from year to year producing a more reliable estimate of mean recruitment. The increase in both survey biomass estimates suggests the presence of more rougheye. Catchability, selectivity, and recruitment are all somewhat confounded within the model. As the surveys estimate more fish, and age compositions suggest better recruitment, catchability estimates tend to drop so that large swings in biomass do not occur. This seems reasonable for long-lived fish such as rougheye.

Model predictions fit the data well for the updated 2007 model. Fits to historical catch were fair over time with the exception of the peak in 1990 (Figures 11-1a), and recent catch fits are very close (Figure 11-1b). This is expected since estimates of historical rougheye catch were from a variety of sources and typically mixed with shortraker rockfish. Only since 2005 were rougheye split out from shortraker in the catch accounting system. Model fits to trawl survey biomass and longline survey relative population weights (RPW) were fairly consistent over time with a slight increase in the 2007 estimate. All predicted values fall within the 95% confidence intervals of the survey point estimates (Figures 11-2 and 11-3). However, predicted values for the longline survey do not capture the spikes of 1997 and 2000. Average longline RPWs surrounding these two year 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 size compositions are slightly flattened (Figure 11-8). 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 11-9). Fit to the longline survey size compositions is also very good with distributions slightly flattened from the peak in the most years (Figure 11-10).

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 11-11). 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 11-12). Fairly wide confidence bands result from the MCMC simulation for biomass estimates, with decreasing certainty in the more recent estimates, particularly the upper confidence intervals. Estimated selectivity curves were similar to expected (Figure 11-13). 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.

Fully selected fishing mortality increased in the late 1980s and early 1990s and returned to relatively low levels from 1993 to present (Figure 11-14). The spike may be due to the management of rougheye 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 rockfish has been above the F_{OFL} adjusted limit for only three years in the late 1980s and 1990 (Figure 11-15). Since 1990, rougheye rockfish have been above $B_{40\%}$ and below $F_{40\%}$.

Recruitment

MCMC confidence bands for recruitment have narrowed with the addition of several years of age compositions (Figure 11-16). Nearly half 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 11-5).

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 11-17) and confidence intervals (Table 11-9). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass and recruitment (Figures 11-10, 11-11, 11-15).

Table 11-9 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% confidence intervals (BCI). The MLE and MCMC standard deviations are similar for q_1 (trawl survey catchability), and M, but the MCMC standard deviations are larger for the estimates of current total biomass, current female spawning biomass, *ABC* and to a lesser extent $F_{40\%}$ 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 far out of the Bayesian confidence 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 11-16) indicating potential for higher biomass estimates (also see Figure 11-11).

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 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 1980-2005 (year classes between 1977 and 2002). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. The 2007 estimates of these reference points are in the following table. Biomass estimates are for female spawning biomass.

$B_{0\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
24,839 (t)	9,935 (t)	8,694 (t)	0.039	0.047

Specification of OFL and Maximum Permissible ABC

Estimated female spawning biomass for 2008 is 13,882 t. This is above the $B_{40\%}$ value of 9,935 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 2008 yields the following *ABC* and *OFL*:

$F_{40\%}$	0.039
ABC (mt)	1,286
$F_{35\%}$	0.047
OFL (mt)	1,548

Projections

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3. This set of projections that encompasses seven harvest scenarios is designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2007 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2007. 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. For the first three years, an estimated catch is used that is equal to the current ratio of catch to TAC. In subsequent years, total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 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 2008, are as follows ("*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 F_{ABC} value for 2008 recommended in the assessment to the *max* F_{ABC} for 2008. (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 pre-specified catch for 2008 to provide a more accurate short-term projection of spawning biomass and ABC for species such as rougheye where much of the ABC goes unharvested.

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 2003-2007 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 follows (for Tier 3 stocks, the MSY level is defined as *B35%*):

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 2008 or 2) above ½ of its MSY level in 2008 and above its MSY level in 2018 under this scenario, then the stock is not overfished.)

Scenario 7: In 2008 and 2009, 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 2020 under this scenario, then the stock is not approaching an overfished condition.)

Status Determination

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 overfished? This depends on the stock's estimated spawning biomass in 2008:

a) If spawning biomass for 2008 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2008 is estimated to be above $B_{35\%}$, the stock is above its MSST.
c) If spawning biomass for 2008 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 11-10). If the mean spawning biomass for 2018 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 (Table 11-10):

a) If the mean spawning biomass for 2008 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2008 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2008 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2020. If the mean spawning biomass for 2020 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

A summary of the results of these scenarios for rougheye rockfish is in Table 11-10. For rougheye rockfish the stock is not overfished and is not approaching an overfished condition.

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 (2003, 2005, and 2007). 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 2003, 2005, and 2007 surveys, respectively and apportionments for rougheye rockfish of 10% for the Western area, 65% for the Central area, and 25% for the Eastern area (Table 11-11). Applying these percentages to the ABC for rougheye rockfish (1,286 t) yields the following apportionments for Gulf of Alaska 2008: 125 t for the Western area, 834 t for the Central area, and 327 t for the Eastern area.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.047), overfishing is set equal to 1,548 mt for rougheye rockfish.

Ecosystem Considerations

In general, a determination of ecosystem considerations for rougheye rockfish is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 11-12. Additionally, we include a summary of nontarget species bycatch estimates and proportion of total catch for Gulf of Alaska rockfish targeted fisheries 2003-2007 (Table 11-13).

Ecosystem Effects on the Stock

Prey availability/abundance trends: similar to many other rockfish species, stock condition of rougheye 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 rougheye rockfish is difficult. Visual identification is not possible though genetic techniques allow identification to species level for larval rougheye rockfish (Gharrett et. al 2001). Food habit studies in Alaska indicate that the diet of rougheye rockfish is primarily shrimp (especially pandalids) and that various fish species such as myctophids are also consumed (Yang and Nelson 2000, Yang 2003). Juvenile rougheye rockfish in the GOA also consume a substantial amount of smaller invertebrates such as amphipods, mysids, and isopods (Yang and Nelson 2000). 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 rougheye 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 rougheye 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. Changes in bottom habitat due to natural or anthropogenic causes could alter survival rates by altering available shelter, prey, or other functions.

Fishery Effects on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the Gulf of Alaska, bottom trawl fisheries for rougheye rockfish account for very little bycatch of HAPC biota. This low bycatch may be explained by the fact that little targeted fishing exists for these fish.

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 rougheye 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 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.

Data Gaps and Research Priorities

There is little information on larval, post-larval, or early stage juveniles of rougheye rockfish. Habitat requirements for larval, post-larval, and early stages are mostly unknown. Habitat requirements for later stage juvenile and adult fish are 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.

Summary

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

Rougheye Rockfish Summary Table	Last year's projection: Not Updated		This year's projection Revised Model	
Tier 3a	2007	2008	2008	2009*
Total Biomass (ages 3+)			**46,121**	46,266
Female Spawning Biomass (t)	10,008	9,937	**13,882**	13,980
$B_{0\%}$ (t) (female spawning biomass)			**24,839**	
$B_{40\%}$ (t) (female spawning biomass)			**9,935**	
$B_{35\%}$ (t) (female spawning biomass)			**8,694**	
M	0.035	0.035	**0.034**	
$F_{50\%}$	0.027	0.027	**0.027**	0.027
F_{ABC} (maximum allowable = $F_{40\%}$)	0.039	0.039	**0.039**	0.039
F_{ABC} (author recommended)	0.039	0.039	**0.039**	0.039
F_{OFL}	0.047	0.047	**0.047**	0.047
$ABC_{F50\%}$			**890**	885
$ABC_{F40\%}$ (t, maximum allowable)	988	993	**1,286**	1,279
ABC (t, author recommended)	988	993	**1,286**	1,279
OFL (mt)	1,148	1,197	**1,548**	1,540

****Projected ABCs and OFLs for 2009 are derived using an expected catch value of 517 t for 2008 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 11-10.

In the future we may begin collecting ages from the longline survey and examine splitting the fishery data into trawl and longline fisheries. We may also examine the utility of applying depth stratification to the likelihood weighting on trawl and longline survey biomass estimates. Once the historical time series of age data is completed, we hope to update estimates of 50% age-at-maturity, size-age matrix, weight-age vector, and age-error matrix. Otoliths collected for the McDermott 1994 study were recently aged, and we may use these ages to estimate age-at-maturity directly instead of through the size-age matrix. Research on model assumptions and performance may result from these potential updates. 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.

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Table 11-1a. Estimated catch history for GOA rougheye rockfish. Values from 1977-1992 are from Soh (1998). Values from 1993-2004 are from either the observer program or NPFMC, and NMFS regional office "blend estimates." ABC and TAC were available for the shortraker/rougheye rockfish complex from 1991-2004. Separate ABCs and catch accounting were established for each species since 2005, and these values are provided for rougheye only.

Year	Catch (mt)		ABC	TAC
1977	1443			
1978	568			
1979	645			
1980	1353			
1981	719			
1982	569			
1983	628			
1984	760			
1985	130			
1986	438			
1987	525			
1988	1621			
1989	2185			
1990	2418		Shortraker / Rougheye Complex	
1991	350		2,000	2,000
1992	1127		1,960	1,960
	Observer Estimates	Blend estimates		
1993	583	830	1,960	1,764
1994	579	788	1,960	1,960
1995	704	968	1,910	1,910
1996	558	714	1,910	1,910
1997	545	692	1,590	1,590
1998	665	747	1,590	1,590
1999	320	564	1,590	1,590
2000	530	750	1,730	1,730
2001	591	850	1,730	1,730
2002	273	569	1,620	1,620
2003	394	603	1,620	1,620
2004	301	429	1,318	1,318
		Rougheye Only		
2005	289	289	1,007	1,007
2006	351	351	983	983
2007	397	397	988	988

Table 11-1b. Catch (t) of rougheye rockfish taken during research cruises in the Gulf of Alaska, 1977-2007 (Catches after 1996 include estimates of longline surveys catch).

Year	Research Catch
1977	0.6
1978	2.2
1979	1.4
1980	0.9
1981	6.3
1982	3.0
1983	3.0
1984	16.9
1985	7.0
1986	1.7
1987	12.6
1988	0.0
1989	0.5
1990	5.2
1991	0
1992	0
1993	9.8
1994	0
1995	0
1996	12.9
1997	15.5
1998	51.7
1999	35.8
2000	9.8
2001	8.8
2002	5.3
2003	8.7
2004	5.1
2005	8.3
2006	4.5
2007	15.1

Table 11-2. Fishery size compositions for GOA rougheye 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	2004	2005	2006
21	0.0000	0.0000	0.0000	0.0004	0.0008	0.0000	0.0007
23	0.0000	0.0056	0.0087	0.0000	0.0000	0.0007	0.0000
25	0.0010	0.0065	0.0058	0.0012	0.0017	0.0013	0.0000
27	0.0021	0.0084	0.0087	0.0020	0.0008	0.0013	0.0028
29	0.0063	0.0130	0.0029	0.0040	0.0059	0.0047	0.0035
31	0.0042	0.0297	0.0058	0.0032	0.0067	0.0074	0.0120
33	0.0094	0.0270	0.0058	0.0064	0.0093	0.0067	0.0127
35	0.0125	0.0362	0.0145	0.0095	0.0105	0.0134	0.0162
37	0.0104	0.0455	0.0174	0.0139	0.0215	0.0315	0.0268
39	0.0261	0.0660	0.0378	0.0382	0.0240	0.0308	0.0275
41	0.0396	0.1004	0.0494	0.0545	0.0434	0.0455	0.0444
43	0.1585	0.1087	0.1453	0.1010	0.0699	0.0717	0.0684
45	0.2857	0.1645	0.1657	0.1427	0.1166	0.1165	0.1298
47	0.2221	0.1292	0.1948	0.1924	0.1641	0.1514	0.1453
49	0.1512	0.0790	0.1395	0.1717	0.1641	0.1541	0.1622
51	0.0448	0.0465	0.1134	0.1125	0.1410	0.1306	0.1502
53	0.0136	0.0344	0.0465	0.0719	0.0997	0.0884	0.0867
55	0.0042	0.0362	0.0145	0.0322	0.0551	0.0583	0.0472
57	0.0063	0.0251	0.0116	0.0199	0.0278	0.0275	0.0226
59	0.0010	0.0167	0.0058	0.0079	0.0160	0.0221	0.0205
60+	0.0010	0.0214	0.0058	0.0147	0.0210	0.0362	0.0205
Sample size	959	1077	344	2516	2376	1493	1418

Table 11-3. GOA rougheye 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	1984	1987	1990	1993	1996	1999	2003	2005	2007
Biomass	45,091	43,681	44,837	61,863	45,913	39,560	43,202	47,862	59,880
S.E.	7,313	4,897	9,296	14,415	7,432	5,793	6,724	8,618	10,380
LCI	30,758	34,083	26,616	33,610	31,346	28,206	30,024	30,970	39,535
UCI	59,425	53,278	63,057	90,115	60,481	50,913	56,380	64,754	80,225

Table 11-4. GOA Rougheye rockfish trawl survey age compositions extrapolated to population. Pooled age 25+ includes all fish 25 and older.

Age (yr)	1984	1990	1993	1996	1999	2003	2005
3	0.0000	0.0011	0.0342	0.0023	0.0000	0.0285	0.0385
4	0.0005	0.0025	0.0122	0.0003	0.0267	0.0184	0.0478
5	0.0000	0.0058	0.0108	0.0204	0.0532	0.0669	0.0848
6	0.0000	0.0105	0.0237	0.1446	0.0251	0.0466	0.0384
7	0.0036	0.0395	0.0155	0.0173	0.0325	0.0275	0.0651
8	0.0916	0.0503	0.0211	0.0201	0.0585	0.0554	0.0508
9	0.0338	0.1100	0.0492	0.0321	0.1371	0.0509	0.0531
10	0.0215	0.1684	0.0727	0.0232	0.0504	0.0233	0.0789
11	0.0076	0.0918	0.0665	0.0246	0.0432	0.0203	0.0338
12	0.0261	0.0231	0.0898	0.0458	0.0186	0.0376	0.0502
13	0.0103	0.0548	0.0755	0.0410	0.0431	0.0387	0.0178
14	0.0311	0.0876	0.0571	0.0710	0.0440	0.0427	0.0402
15	0.0748	0.0285	0.0486	0.0698	0.0449	0.0136	0.0512
16	0.0934	0.0132	0.0633	0.0682	0.0543	0.0309	0.0326
17	0.0401	0.0075	0.0457	0.0517	0.0461	0.0254	0.0338
18	0.0280	0.0036	0.0229	0.0277	0.0563	0.0169	0.0225
19	0.0121	0.0206	0.0244	0.0353	0.0296	0.0195	0.0204
20	0.0035	0.0073	0.0242	0.0387	0.0360	0.0466	0.0314
21	0.0093	0.0088	0.0235	0.0212	0.0187	0.0312	0.0108
22	0.0081	0.0074	0.0114	0.0200	0.0191	0.0396	0.0178
23	0.0112	0.0098	0.0221	0.0187	0.0174	0.0396	0.0117
24	0.0159	0.0211	0.0098	0.0116	0.0129	0.0246	0.0116
25+	0.4775	0.2267	0.1758	0.1944	0.1320	0.2554	0.1569
Sample size	369	216	876	770	650	510	425

Table 11-5. NMFS trawl survey length compositions for GOA rougheye 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	0.020	0.047	0.027	0.078	0.079	0.159	0.110	0.156	0.188	0.040
23	0.016	0.032	0.017	0.017	0.049	0.057	0.033	0.052	0.045	0.039
25	0.026	0.030	0.024	0.022	0.052	0.046	0.038	0.039	0.047	0.049
27	0.023	0.028	0.027	0.027	0.046	0.038	0.045	0.038	0.054	0.044
29	0.019	0.028	0.042	0.032	0.037	0.050	0.054	0.043	0.057	0.042
31	0.033	0.039	0.062	0.044	0.049	0.064	0.047	0.051	0.056	0.047
33	0.036	0.050	0.084	0.049	0.049	0.058	0.041	0.052	0.050	0.046
35	0.044	0.055	0.101	0.065	0.044	0.062	0.056	0.042	0.056	0.047
37	0.055	0.070	0.118	0.072	0.060	0.057	0.064	0.038	0.051	0.056
39	0.057	0.070	0.086	0.100	0.061	0.066	0.080	0.047	0.060	0.080
41	0.083	0.079	0.069	0.116	0.082	0.072	0.088	0.061	0.067	0.087
43	0.143	0.083	0.061	0.125	0.111	0.075	0.122	0.090	0.071	0.106
45	0.164	0.111	0.092	0.118	0.107	0.073	0.088	0.103	0.067	0.116
47	0.118	0.108	0.081	0.072	0.078	0.056	0.061	0.086	0.041	0.079
49	0.076	0.084	0.046	0.030	0.044	0.034	0.037	0.054	0.027	0.052
51	0.039	0.040	0.022	0.011	0.023	0.020	0.015	0.023	0.023	0.033
53	0.019	0.022	0.010	0.006	0.014	0.007	0.008	0.009	0.012	0.017
55	0.009	0.008	0.009	0.003	0.005	0.003	0.003	0.006	0.007	0.010
57	0.006	0.005	0.007	0.003	0.006	0.002	0.005	0.003	0.006	0.004
59	0.004	0.003	0.005	0.003	0.002	0.002	0.002	0.002	0.004	0.002
60+	0.009	0.007	0.009	0.007	0.002	0.002	0.003	0.004	0.010	0.003
Sample size	5,205	4,511	3,522	5,818	4,427	7,602	2,191	3,030	4,092	4,253

Table 11-6. GOA rougheye rockfish relative population weights (RPW) estimated from annual Gulf of Alaska 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

Table 11-7. Size compositions for GOA rougheye 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	2000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000
27	0.002	0.001	0.000	0.008	0.001	0.003	0.000	0.001	0.001	0.003	0.001
29	0.001	0.004	0.004	0.007	0.005	0.005	0.003	0.004	0.003	0.007	0.002
31	0.007	0.008	0.011	0.014	0.006	0.009	0.010	0.005	0.014	0.011	0.008
33	0.016	0.015	0.021	0.029	0.012	0.023	0.014	0.011	0.020	0.016	0.015
35	0.020	0.026	0.033	0.053	0.016	0.026	0.029	0.019	0.031	0.037	0.029
37	0.035	0.030	0.048	0.056	0.035	0.031	0.045	0.038	0.043	0.050	0.059
39	0.047	0.043	0.068	0.070	0.045	0.052	0.067	0.053	0.055	0.060	0.076
41	0.068	0.058	0.098	0.092	0.067	0.090	0.091	0.069	0.067	0.084	0.090
43	0.118	0.105	0.137	0.110	0.090	0.117	0.118	0.104	0.094	0.106	0.102
45	0.165	0.149	0.161	0.131	0.118	0.130	0.137	0.136	0.139	0.152	0.133
47	0.171	0.184	0.133	0.150	0.170	0.164	0.155	0.170	0.163	0.171	0.136
49	0.141	0.171	0.121	0.104	0.161	0.127	0.142	0.150	0.153	0.134	0.142
51	0.096	0.101	0.068	0.081	0.109	0.102	0.093	0.105	0.101	0.086	0.089
53	0.044	0.043	0.042	0.043	0.075	0.054	0.041	0.053	0.052	0.047	0.054
55	0.025	0.026	0.017	0.021	0.036	0.026	0.025	0.029	0.022	0.016	0.027
57	0.021	0.011	0.011	0.013	0.018	0.020	0.014	0.014	0.016	0.005	0.014
59	0.006	0.008	0.009	0.005	0.014	0.011	0.006	0.009	0.009	0.003	0.006
60	0.017	0.017	0.017	0.013	0.022	0.012	0.010	0.028	0.016	0.012	0.015
Sample size	5,748	7,328	6,032	4,523	7,170	5,025	5,288	5,417	4,139	5,498	6,593

Table 11-7 (continued). Size compositions for GOA rougheye rockfish from annual longline survey. Lengths are area-weighted and are binned in adjacent pairs and pooled at 60 and greater cm.

Length (cm)	2001	2002	2003	2004	2005	2006	2007
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.001	0.000
25	0.003	0.001	0.001	0.000	0.001	0.000	0.001
27	0.004	0.003	0.001	0.004	0.003	0.003	0.003
29	0.004	0.006	0.009	0.014	0.013	0.012	0.002
31	0.012	0.011	0.007	0.026	0.026	0.008	0.010
33	0.018	0.019	0.012	0.020	0.032	0.018	0.019
35	0.039	0.027	0.011	0.036	0.035	0.024	0.036
37	0.046	0.039	0.021	0.060	0.040	0.037	0.049
39	0.065	0.060	0.038	0.084	0.053	0.045	0.065
41	0.082	0.074	0.074	0.090	0.067	0.082	0.100
43	0.100	0.127	0.116	0.105	0.120	0.118	0.124
45	0.140	0.156	0.152	0.134	0.156	0.149	0.156
47	0.146	0.153	0.182	0.150	0.158	0.161	0.156
49	0.143	0.136	0.162	0.121	0.133	0.153	0.120
51	0.092	0.084	0.096	0.075	0.067	0.087	0.073
53	0.047	0.052	0.051	0.039	0.039	0.047	0.039
55	0.024	0.019	0.018	0.015	0.023	0.024	0.016
57	0.012	0.013	0.015	0.013	0.013	0.012	0.015
59	0.005	0.009	0.010	0.008	0.009	0.008	0.005
60	0.018	0.011	0.025	0.006	0.013	0.009	0.013
Sample size	3,929	4,202	3,866	4,266	3,388	7,134	7,037

Table 11-8. Likelihoods and MLE estimates of key parameters with estimates of standard error (σ) derived from Hessian matrix for GOA rougheye rockfish models.

	2005 Model		*2007 Updated Model*	
Likelihoods	Value	Weight	Value	Weight
Catch	0.512	1	0.232	1
Trawl Biomass	1.703	1	2.316	1
Longline Biomass	7.280	1	7.121	1
Trawl Survey Ages	23.600	1	26.138	1
Trawl Fishery Sizes	39.476	1	30.419	1
Trawl Survey Sizes	42.859	1	0	1
Longline Survey Sizes	44.334	1	31.459	1
Data-Likelihood	**159.764**		**97.684**	
Penalties/Priors				
Recruit Deviations	4.589	1	1.956	1
Fishery Selectivity	1.147	1	1.412	1
Trawl Selectivity	0.711	1	0.295	1
Longline Selectivity	1.722	1	0.757	1
Fish-Sel Domeshape	0.002	1	0.000	1
Survey-Sel Domeshp	0.035	1	0.094	1
LL-Sel Domeshape	0.000	1	0.000	1
Average Selectivity	0.000	0	0.000	0
F Regularity	0.978	0.1	1.005	0.1
σ_r prior	2.588		3.355	
q-trawl	0.630		0.429	
q-longline	0.048		0.000	
M	1.082		0.667	
Total	13.532		9.969	
Objective Fun. Total	**173.707**		**107.653**	
Parameter Estimates	Value	σ	Value	σ
q-trawl	1.652	0.490	1.513	0.502
q-longline	1.363	0.454	0.977	0.382
M	0.035	0.003	0.034	0.003
σ_r	0.953	0.060	0.934	0.059
Log-mean-rec	0.032	0.312	0.166	0.351
$F_{40\%}$	0.039	0.008	0.039	0.011
Total Biomass (t)	37,449	12,209	45,752	17,046
Current Female Spawning Biomass (t)	9,976	3,466	13,882	5,692
$B_{0\%}$ (t)	20,997		24,839	
$B_{40\%}$ (t)	8,399		9,935	
$\boldsymbol{ABC_{F40\%}}$ **(t)**	**983**		**1286**	
$F_{50\%}$	0.027	0.005	0.027	0.007
$ABC_{F50\%}$ (t)	683		890	

Table 11-9. Estimates of key parameters (μ) with Hessian estimates of standard deviation (σ), MCMC standard deviations (σ (MCMC)) and 95% Bayesian confidence intervals (BCI) derived from MCMC simulations.

Parameter	μ	σ	σ(MCMC)	BCI-Lower	BCI-Upper
q1, trawl survey	1.513	0.502	0.459	0.683	2.466
q2, longline survey	0.977	0.382	0.309	0.341	1.528
M	0.034	0.003	0.003	0.028	0.040
$F_{40\%}$	0.039	0.011	0.014	0.024	0.078
Total Biomass	45,752	17,046	27,229	31,677	131,320
Female Sp. Biomass	14,243	5,691	8,813	8,927	41,538
ABC	1,286	345	1,131	726	4,900
σ_r	0.934	0.059	0.067	0.966	1.228

Table 11-10. Set of projections of spawning biomass (SB) and yield for GOA rougheye 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. $B_{40\%}$ = 9,935 t, $B_{35\%}$ = 8,694 t, $F_{40\%}$ = 0.039, and $F_{35\%}$ = 0.047.

Year	Maximum permissible F	Author's F (pre-specified catch)*	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
				Spawning Biomass (mt)			
2007	13,976	13,976	13,976	13,976	13,976	13,976	13,976
2008	13,882	14,017	13,994	14,040	14,107	13,836	13,882
2009	13,532	13,980	13,903	14,059	14,284	13,381	13,532
2010	13,199	13,810	13,815	14,077	14,460	12,950	13,155
2011	12,899	13,483	13,748	14,114	14,655	12,561	12,755
2012	12,642	13,199	13,712	14,181	14,878	12,222	12,405
2013	12,425	12,953	13,704	14,271	15,124	11,930	12,102
2014	12,256	12,756	13,735	14,399	15,406	11,690	11,852
2015	12,320	12,802	14,021	14,795	15,979	11,678	11,833
2016	12,180	12,635	14,064	14,933	16,272	11,478	11,623
2017	12,045	12,471	14,102	15,064	16,558	11,286	11,421
2018	11,922	12,321	14,146	15,200	16,849	11,111	11,237
2019	11,854	12,227	14,246	15,398	17,208	10,991	11,107
2020	11,771	12,117	14,316	15,563	17,531	10,860	10,967
				Fishing Mortality			
2007	0.012	0.012	0.012	0.012	0.012	0.012	0.012
2008	0.039	0.016	0.020	0.012	-	0.047	0.047
2009	0.039	0.016	0.020	0.012	-	0.047	0.047
2010	0.039	0.039	0.020	0.012	-	0.047	0.047
2011	0.039	0.039	0.020	0.012	-	0.047	0.047
2012	0.039	0.039	0.020	0.012	-	0.047	0.047
2013	0.039	0.039	0.020	0.012	-	0.047	0.047
2014	0.039	0.039	0.020	0.012	-	0.047	0.047
2015	0.039	0.039	0.020	0.012	-	0.047	0.047
2016	0.039	0.039	0.020	0.012	-	0.047	0.047
2017	0.039	0.039	0.020	0.012	-	0.047	0.047
2018	0.039	0.039	0.020	0.012	-	0.047	0.047
2019	0.039	0.039	0.020	0.012	-	0.047	0.047
2020	0.039	0.039	0.020	0.012	-	0.047	0.047
				Yield (mt)			
2007	397	397	397	397	397	397	397
2008	1,286	517	649	383	-	1,548	1,286
2009	1,250	517	643	383	-	1,493	1,250
2010	1,232	1,287	645	387	-	1,460	1,482
2011	1,210	1,262	645	389	-	1,424	1,445
2012	1,182	1,231	641	389	-	1,381	1,401
2013	1,171	1,217	644	394	-	1,359	1,378
2014	1,172	1,216	654	402	-	1,354	1,371
2015	1,175	1,216	665	411	-	1,349	1,366
2016	1,190	1,229	681	423	-	1,361	1,376
2017	1,179	1,216	683	427	-	1,342	1,356
2018	1,165	1,199	683	429	-	1,319	1,332
2019	1,142	1,174	679	429	-	1,286	1,298
2020	1,123	1,152	676	430	-	1,258	1,269

*The 2009 ABC was projected using an expected catch value of 517 t for 2007. 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 11-11. Allocation of ABC and OFL for 2008 GOA rougheye rockfish.

Year	Weights	Western Gulf	Central Gulf	Eastern Gulf	Total
2003	4	21%	57%	22%	100%
2005	6	8%	68%	24%	100%
2007	9	6%	66%	28%	100%
Weighted Mean	19	10%	65%	25%	100%
Area Allocation		10%	65%	25%	100%
Area ABC (mt)		**125**	**834**	**327**	**1,286**
OFL (mt)					**1,548**

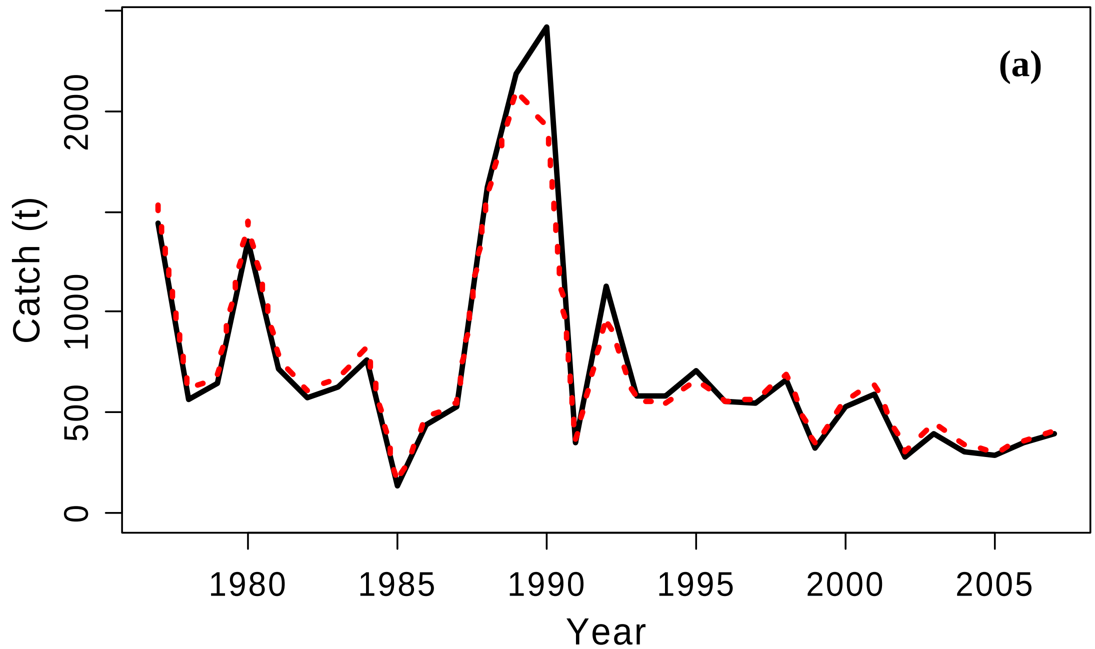
Table 11-12: Analysis of ecosystem considerations for GOA rougheye rockfish.

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 11-13: Nontarget species bycatch estimates in kilograms and proportion of total catch for Gulf of Alaska rockfish targeted fisheries 2003-2007.

	Estimated Catch (kg)				
Group Name	**2003**	**2004**	**2005**	**2006**	**2007**
Benthic urochordata	2	130		44	30
Birds	215				82
Birds Total	215				82
Bivalves	5			6	
Brittle star unidentified	161	2	47	93	8
Corals Bryozoans	1,903	60	6,125	360	2,259
Red Tree Coral	0	5		44	
Corals Bryozoans Total	1,904	65	6,125	404	2,259
Eelpouts	30	222	11,406	32	121
Eulachon	11	197	87	321	21
Giant Grenadier	139,261	418	134,043	277,147	122,516
Greenlings	8,372	6,923	3,541	5,959	6,821
Grenadier	480,913	2,835,239	95,761	65,538	70,296
Grenadier Total	480,913	2,835,239	95,761	65,538	70,296
Hermit crab unidentified	13	10	40	49	5
Invertebrate unidentified	441	938	98	43	
Lanternfishes (myctophidae)		0			0
Large Sculpins	123	42,999	16,476	28,465	26,486
Misc crabs	28	338	705	414	104
Misc crustaceans		24			
Misc fish	145,399	116,116	117,541	182,333	175,303
Misc inverts (worms etc)				10	
Octopus	654	425	193	468	46
Other osmerids	553	141	15	268	83
Other Sculpins	24,076	15,019	14,506	3,904	4,315
Pandalid shrimp	916	293	261	175	96
Polychaete unidentified	4				
Scypho jellies	660	2,920	150	438	204
Sea anemone unidentified	3,304	2,940	296	622	195
Sea pens whips		2	43		
Sea star	3,306	2,102	1,467	2,231	477
Shark, Other	208	221	178	1,614	327
Shark, pacific sleeper	275	628	150	386	39
Shark, salmon	12	120	500	620	693
Shark, spiny dogfish	35,460	2,107	2,760	2,002	1,826
Skate, Big		6,635	4,622	4,210	111
Skate, Longnose	864	16,270	9,348	8,093	14,363
Skate, Other	106,607	10,380	45,017	35,787	16,166
Snails	423	302	157	801	65
Sponge unidentified	3,815	1,140	1,130	949	610
Squid	9,139	11,905	1,526	9,844	2,955
Stichaeidae				13	
urchins dollars cucumbers	353	606	160	306	139
Grand Total	967,508	3,077,777	468,351	633,590	446,762



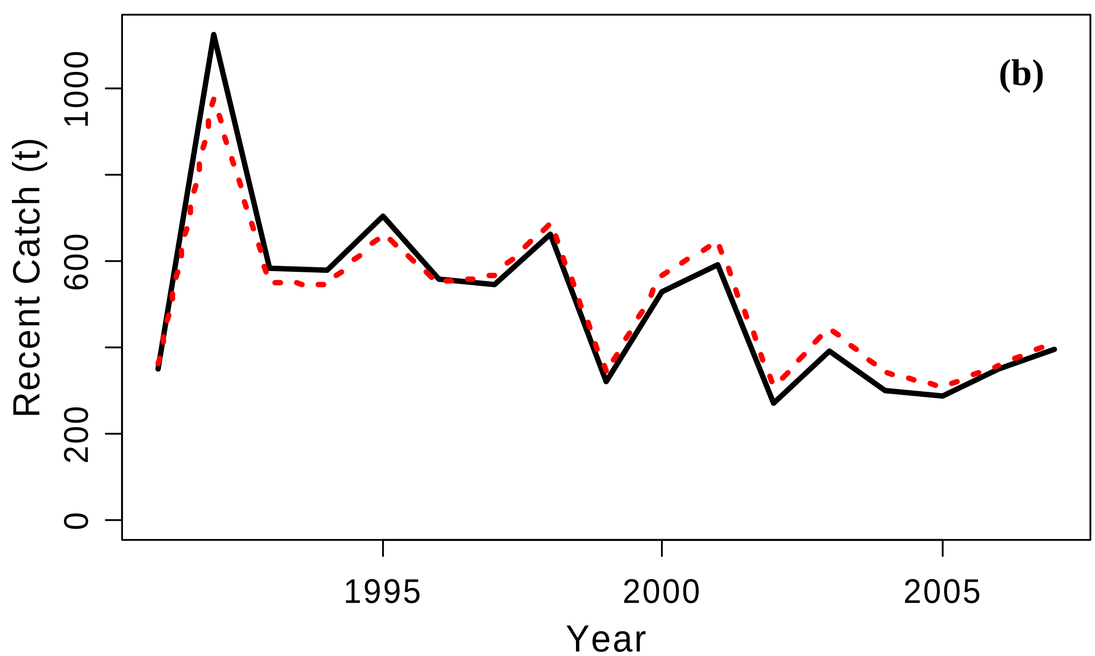


Figure 11-1. Estimated long-term (a) and short-term (b) commercial catches for Gulf of Alaska rougheye rockfish using data from Soh (1998) and NMFS Alaska Regional Office. Observer proportions used to determine proportion of rougheye catch from 1993-2004.

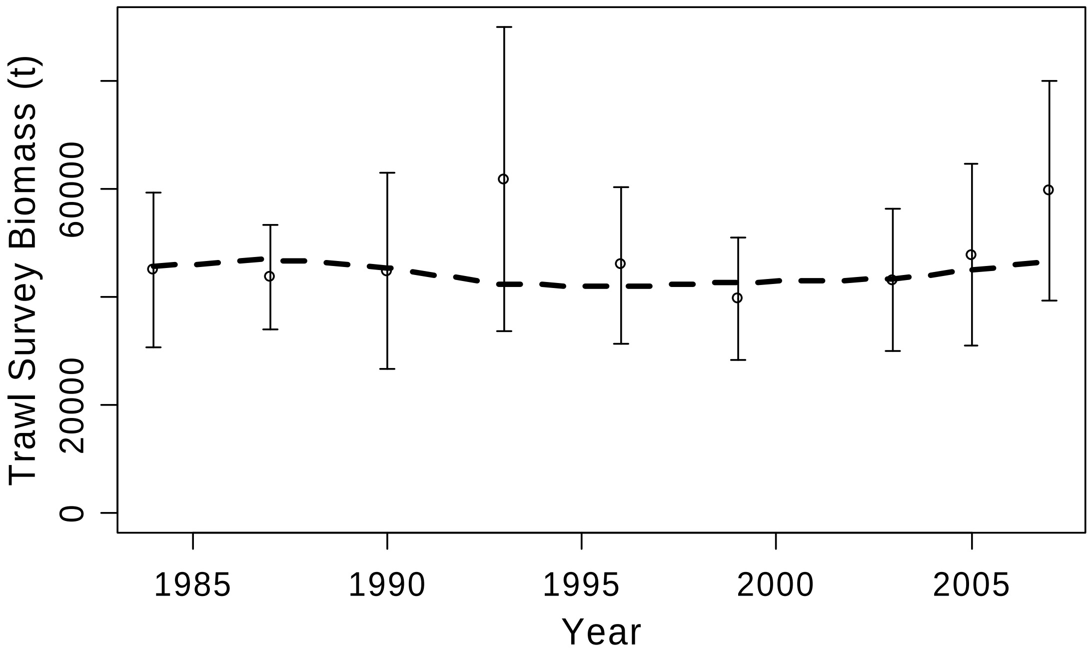


Figure 11-2. Observed (open circles) and predicted (dashed line) GOA rougheye rockfish trawl survey biomass. Observed biomass presented with 95% confidence intervals of sampling error.

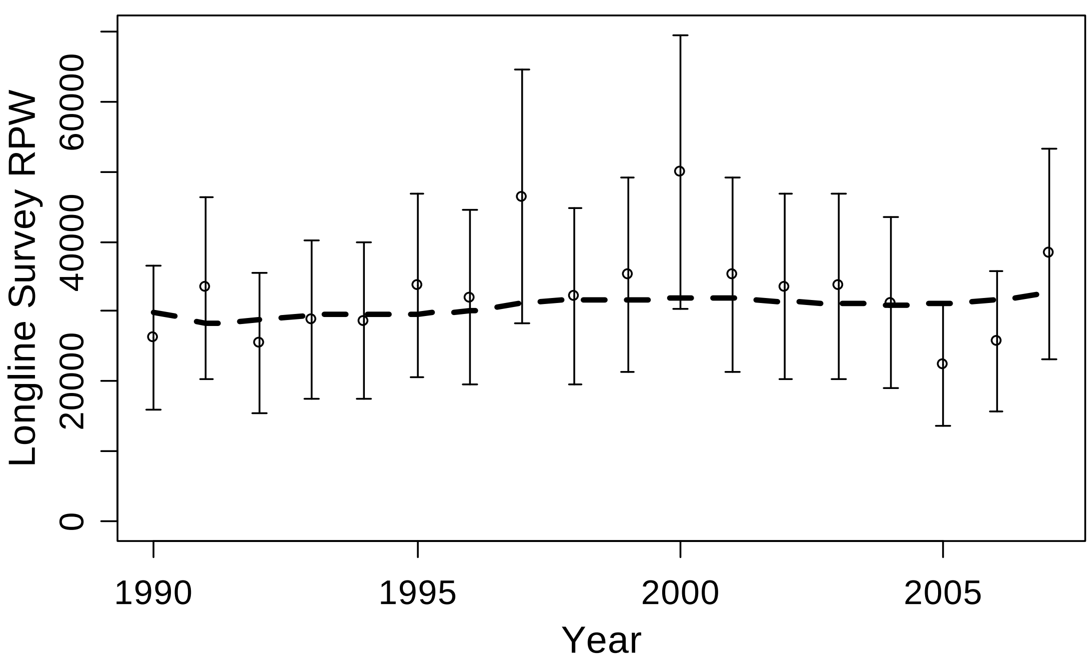


Figure 11-3. Observed (open circles) and predicted (dashed line) GOA rougheye rockfish longline survey relative population weight (RPW). Observed biomass presented with 95% confidence intervals of sampling error.

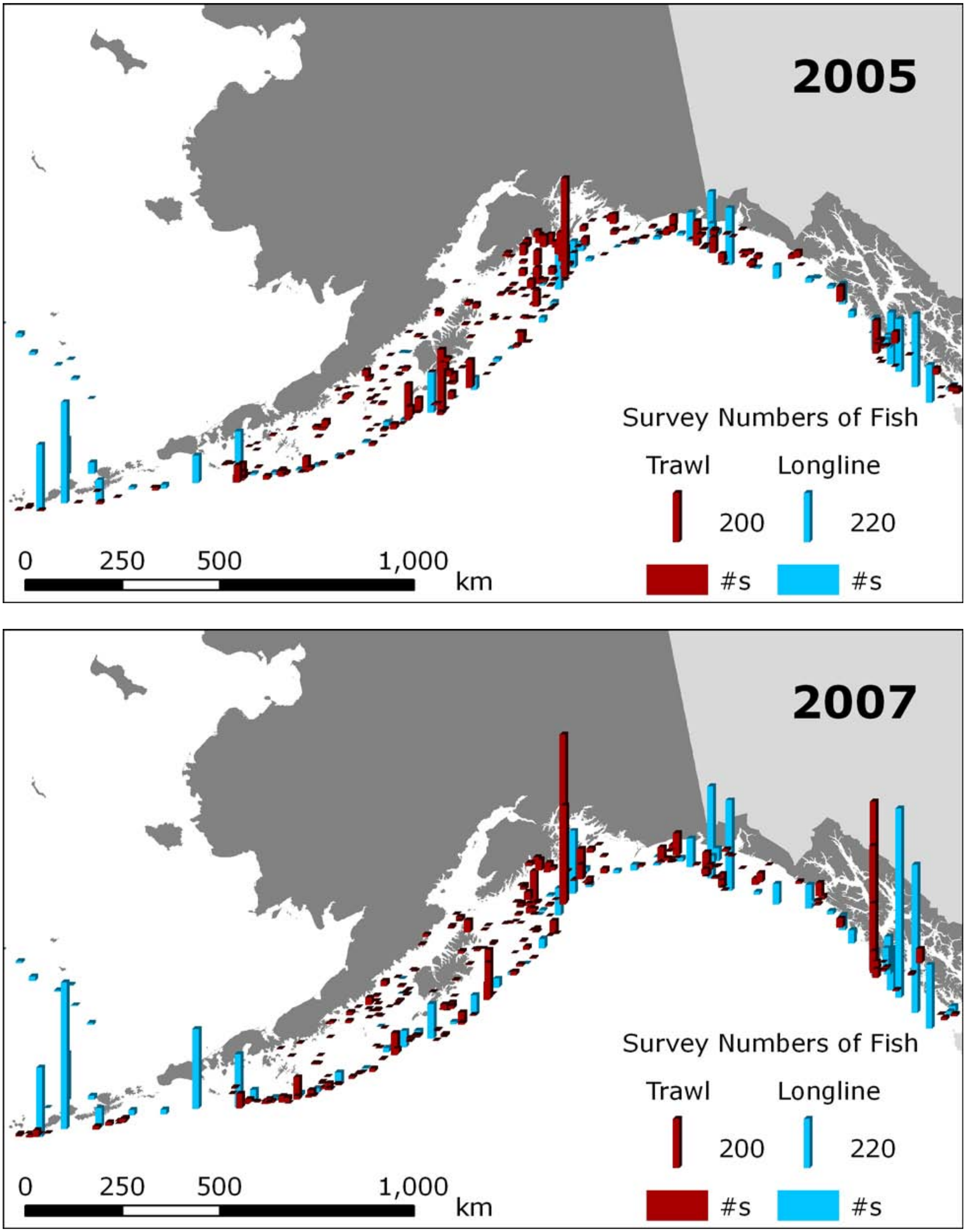


Figure 11-4. Distribution of Gulf of Alaska rougheye rockfish numbers of fish in the 2005 and 2007 NMFS trawl and longline survey.

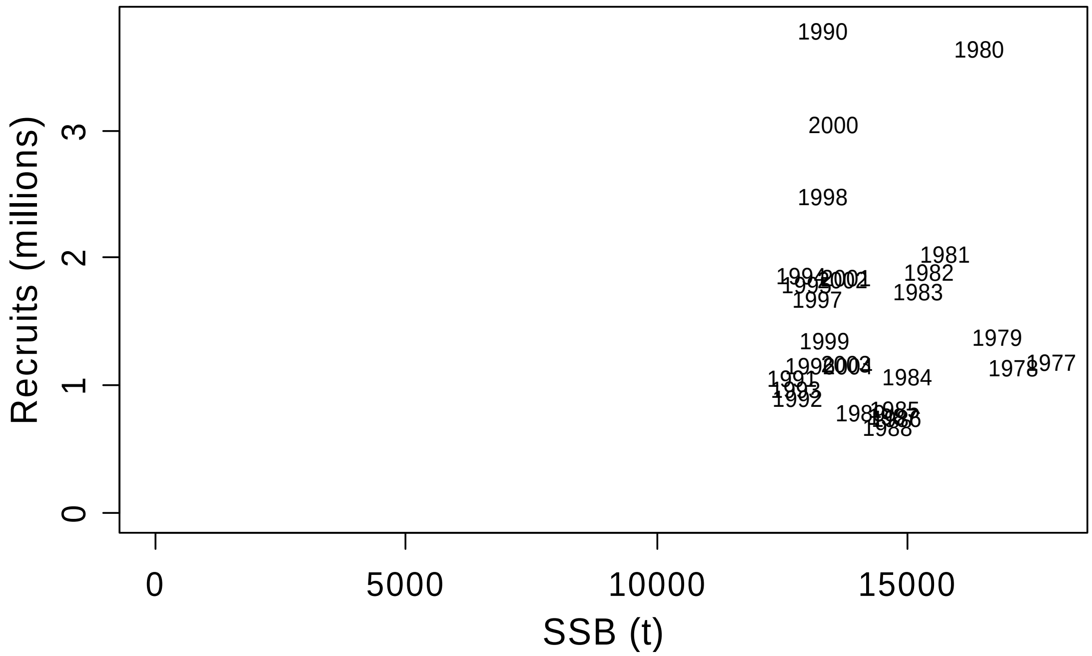


Figure 11-5. Scatterplot of spawner-recruit data for GOA rougheye rockfish author recommended model. Label is year class of age 3 recruits. SSB = Spawning stock biomass in tons.

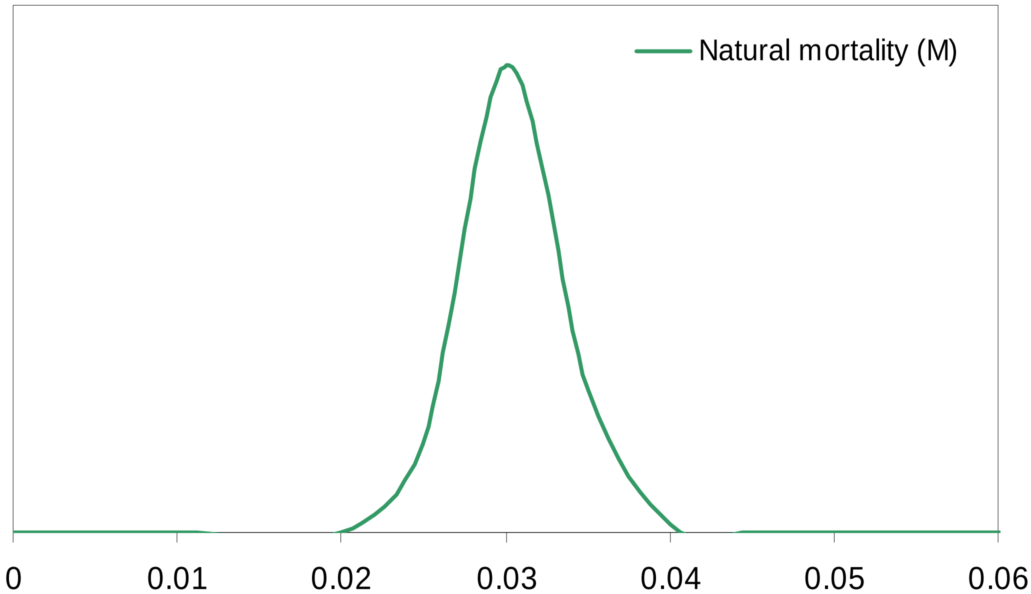


Figure 11-6. Prior distribution for natural mortality (*M*, μ=0.03, CV=10%) of GOA rougheye rockfish.

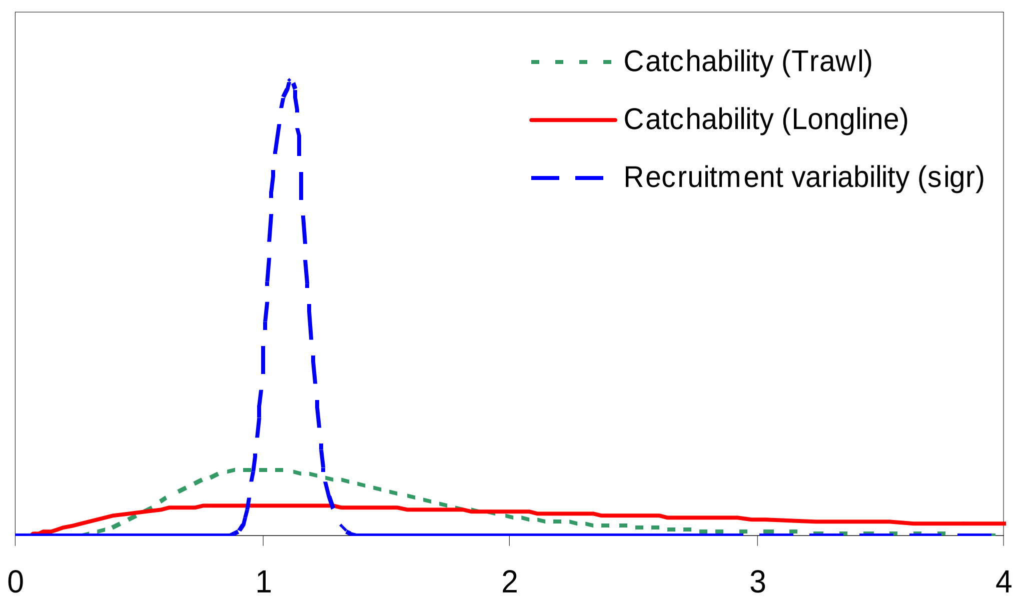


Figure 11-7. Prior distributions for trawl survey catchability (*q*1, μ=1, CV=45%), longline survey catchability (*q*2, μ=1, CV=100%), and recruitment variability (σ_r, μ=1.1, CV=6%) of GOA rougheye rockfish.

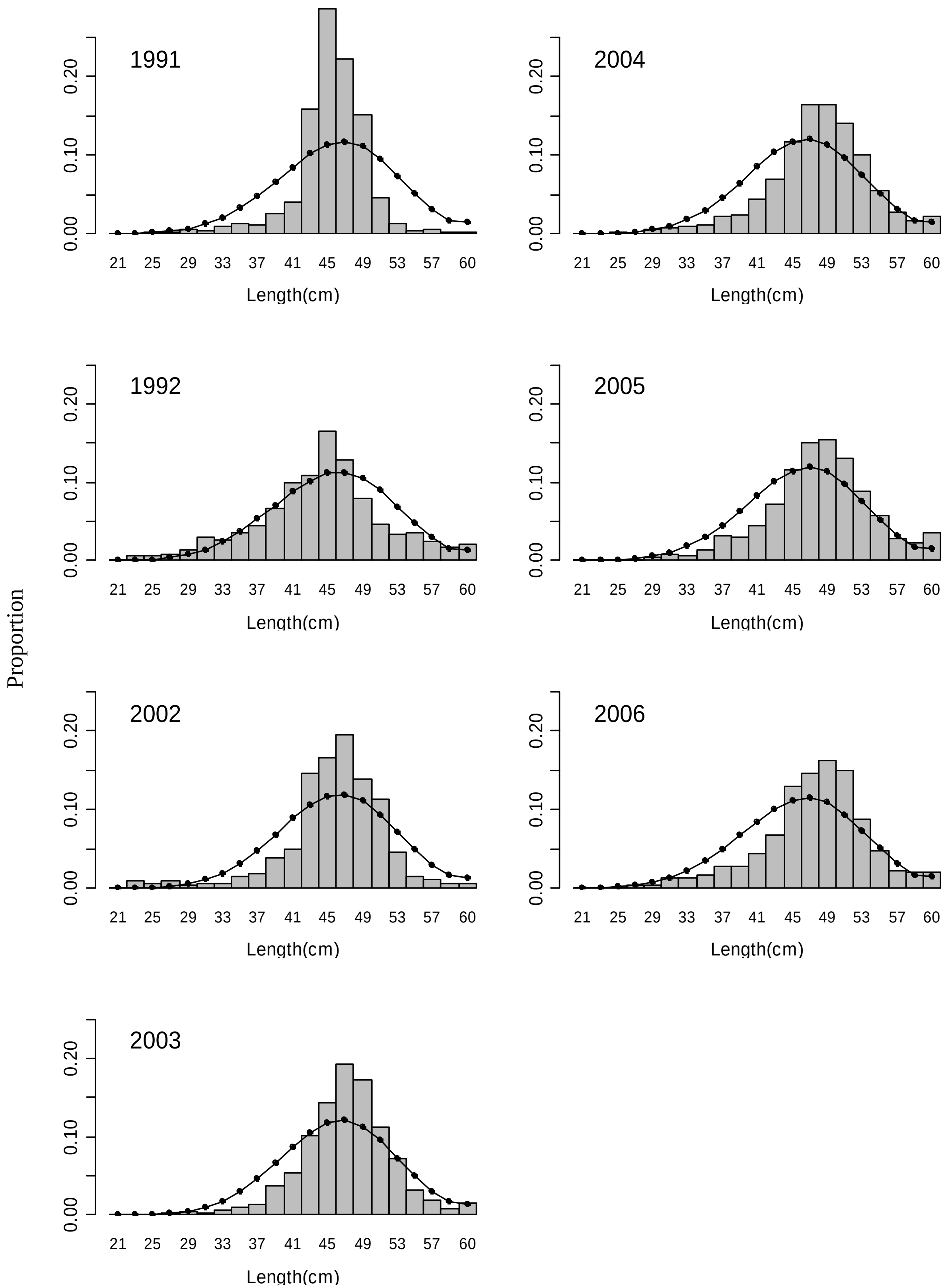


Figure 11-8. Fishery length compositions for GOA rougheye rockfish. Observed = bars, predicted from author recommended model = lines with circles.

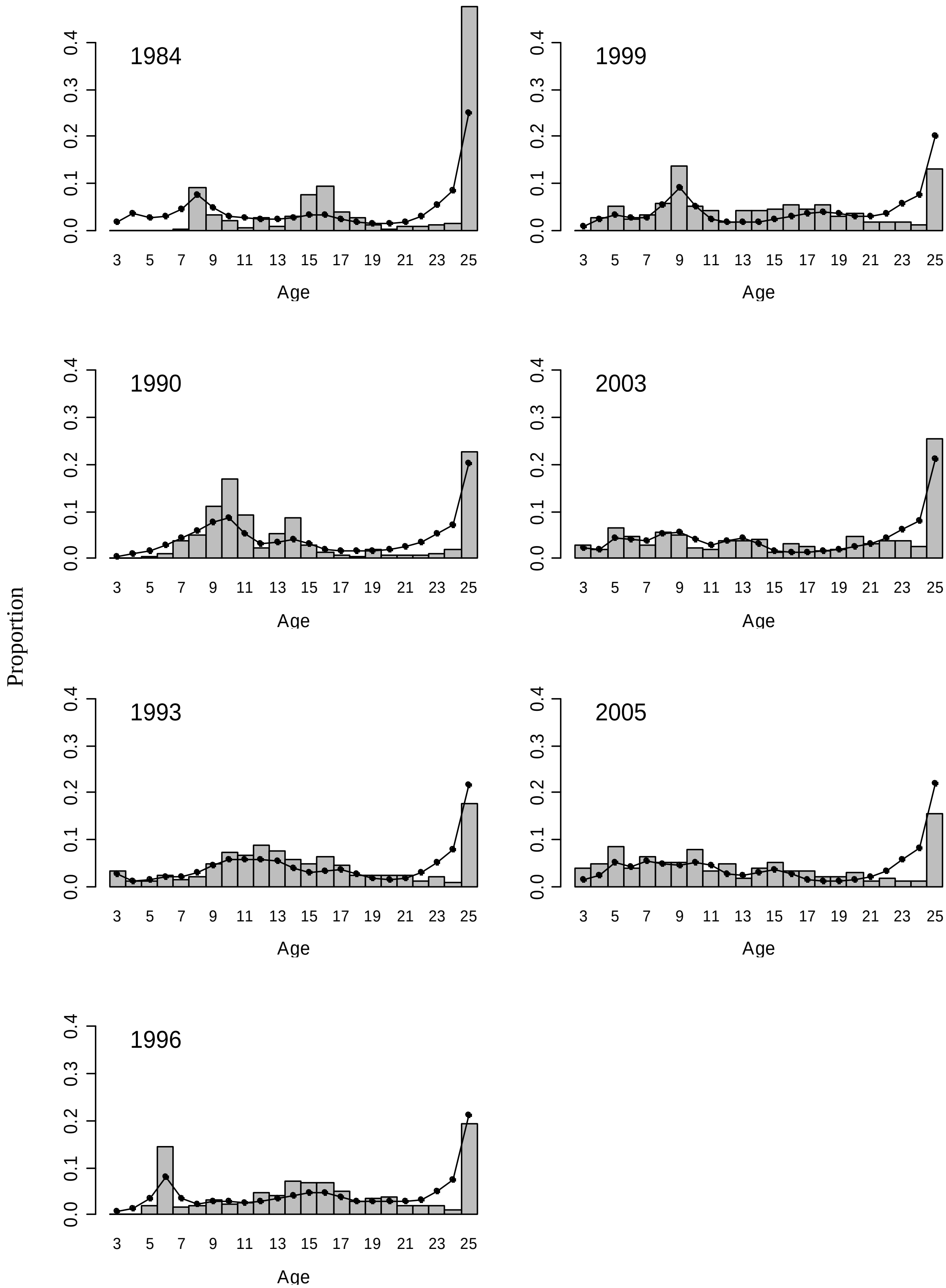


Figure 11-9. Trawl survey age composition by year for GOA rougheye rockfish. Observed = bars, predicted from author recommended model = lines with circles.

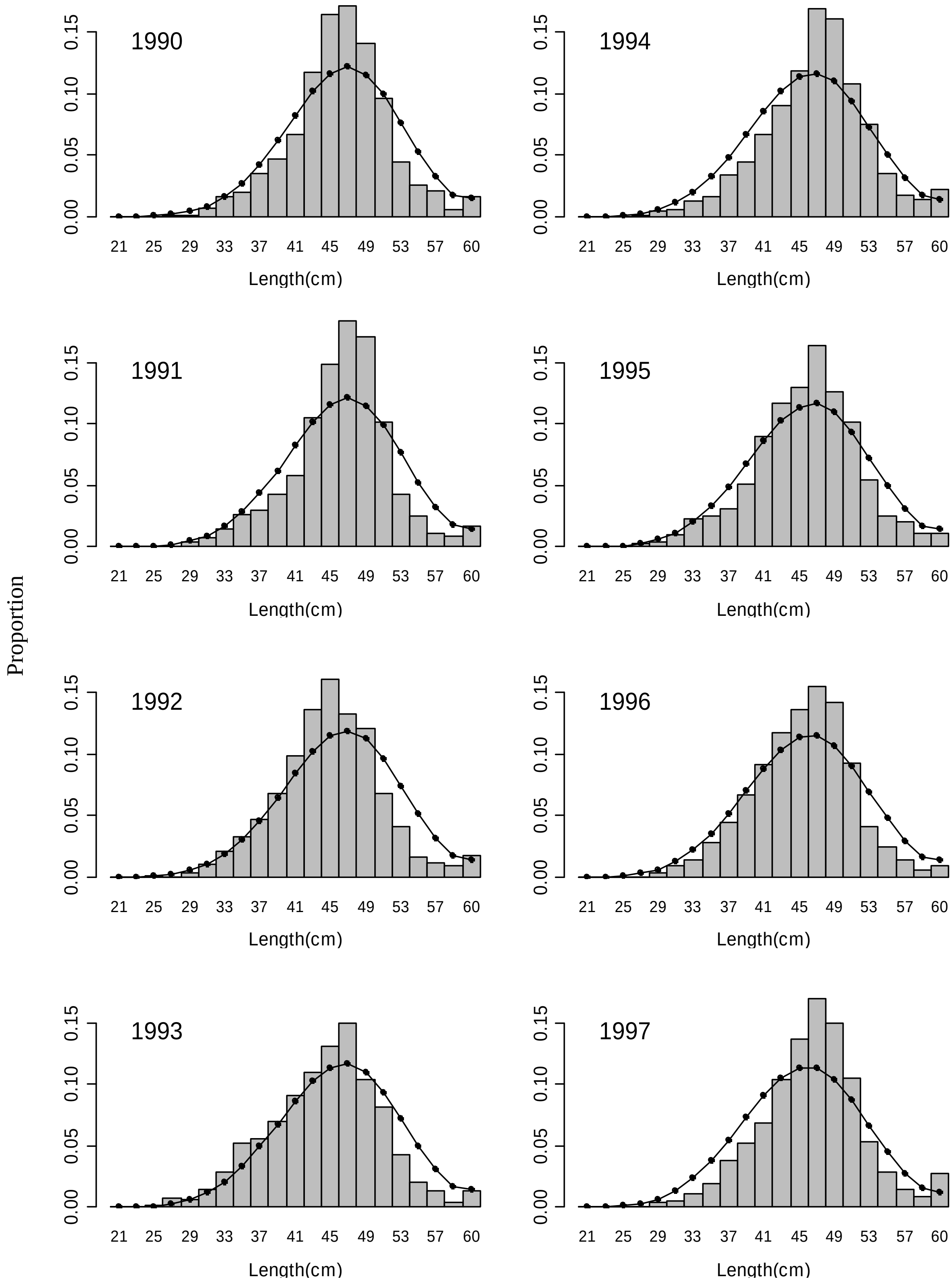


Figure 11-10. Longline survey length composition by year for GOA rougheye rockfish. Observed = bars, predicted from author recommended model = lines with circles.

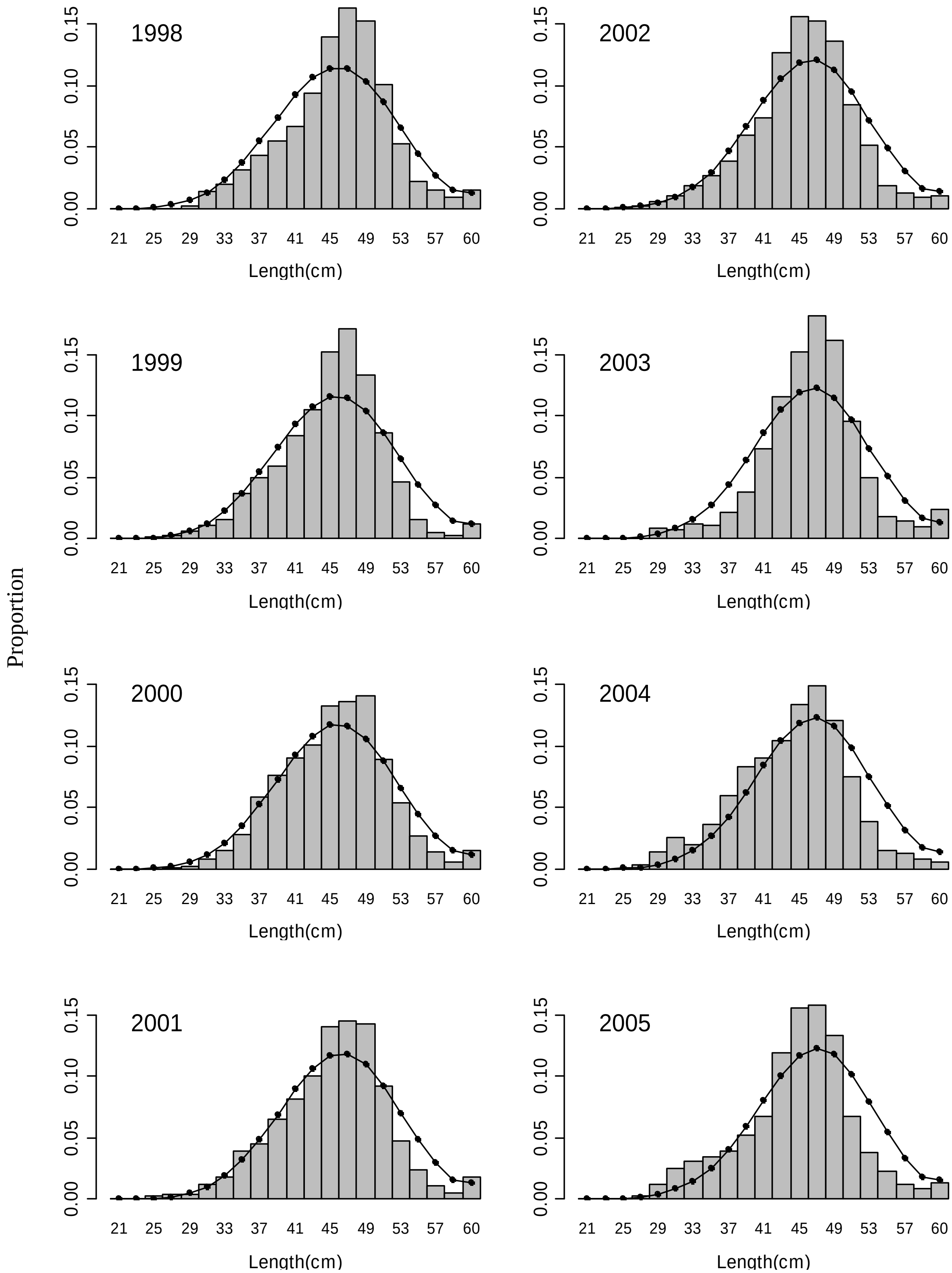


Figure 11-10 (continued). Longline survey length composition by year for GOA rougheye rockfish. Observed = bars, predicted from author recommended model = lines with circles.

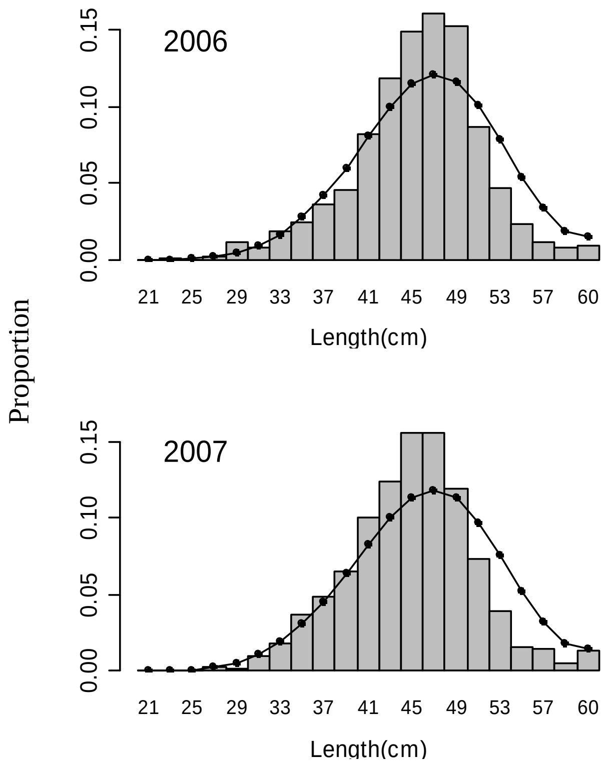


Figure 11-10 (continued). Longline survey length composition for GOA rougheye rockfish. Observed = bars, predicted from author recommended model = lines with circles.

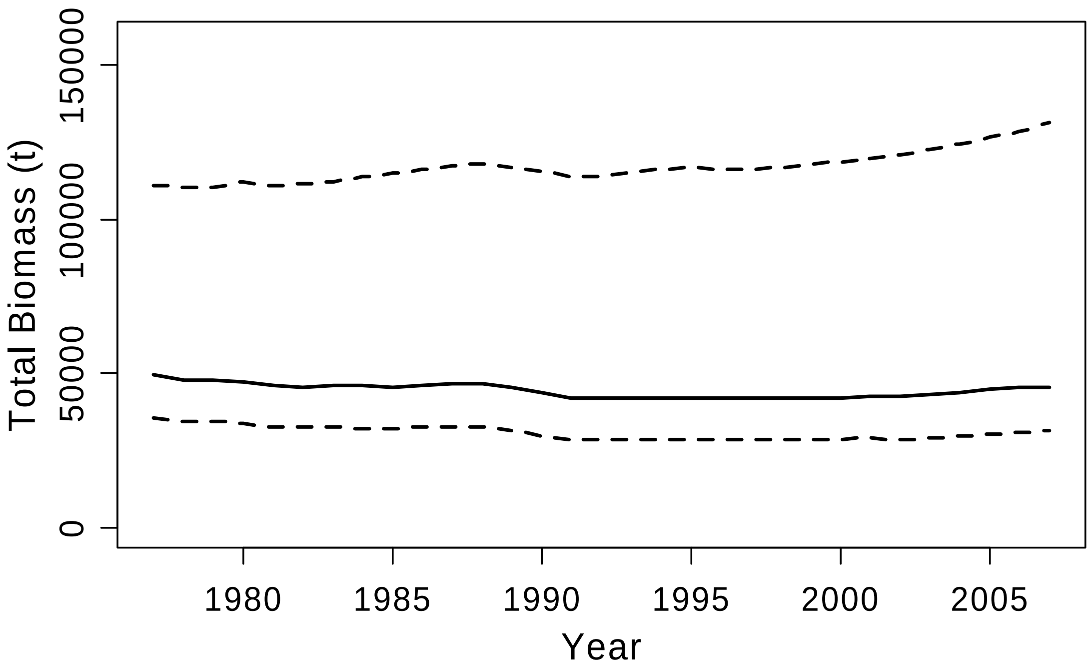


Figure 11-11. Time series of predicted total biomass for GOA rougheye rockfish for author recommended model. Dashed lines = 95% confidence intervals from 10 million MCMC runs.

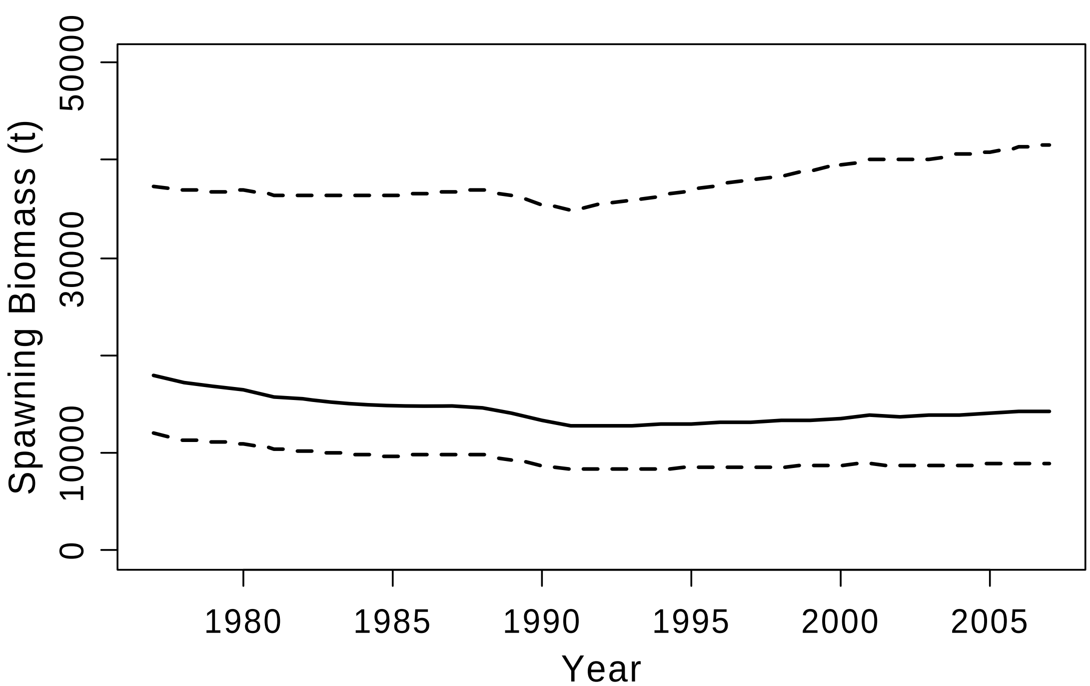


Figure 11-12. Time series of predicted spawning biomass of GOA rougheye rockfish for author recommended model. Dashed lines = 95% confidence intervals from 10 million MCMC runs.

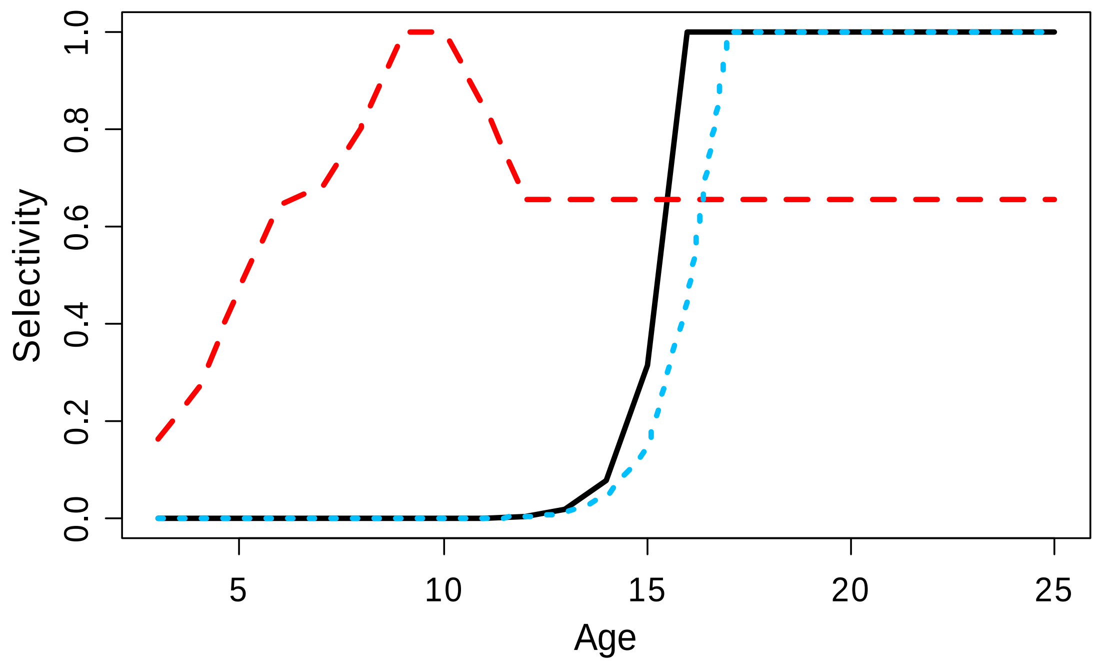


Figure 11-13. Estimated selectivity curves for GOA rougheye rockfish from author recommended model. Dashed red line = Trawl survey selectivity, dotted blue line = Longline survey selectivity, and solid black line = Combined fishery selectivity.

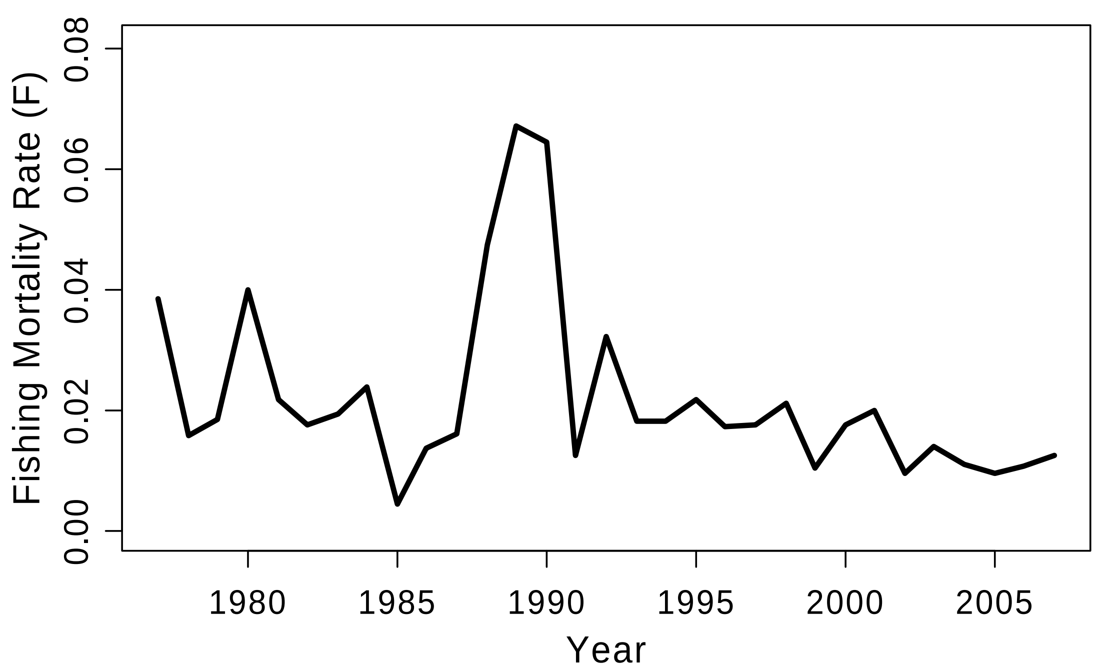


Figure 11-14. Time series of estimated fully selected fishing mortality for GOA rougheye rockfish from author recommended model.

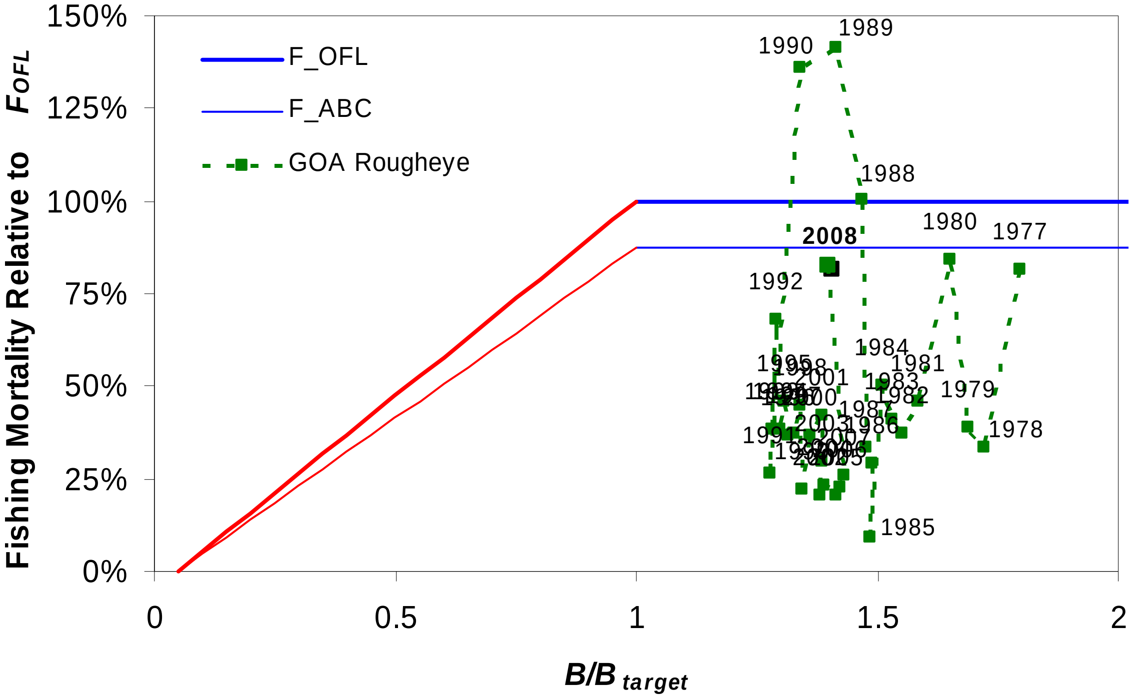


Figure 11-15. Time series of GOA rougheye rockfish estimated spawning biomass relative to the unfished level and fishing mortality relative to F_{OFL} for author recommended model.

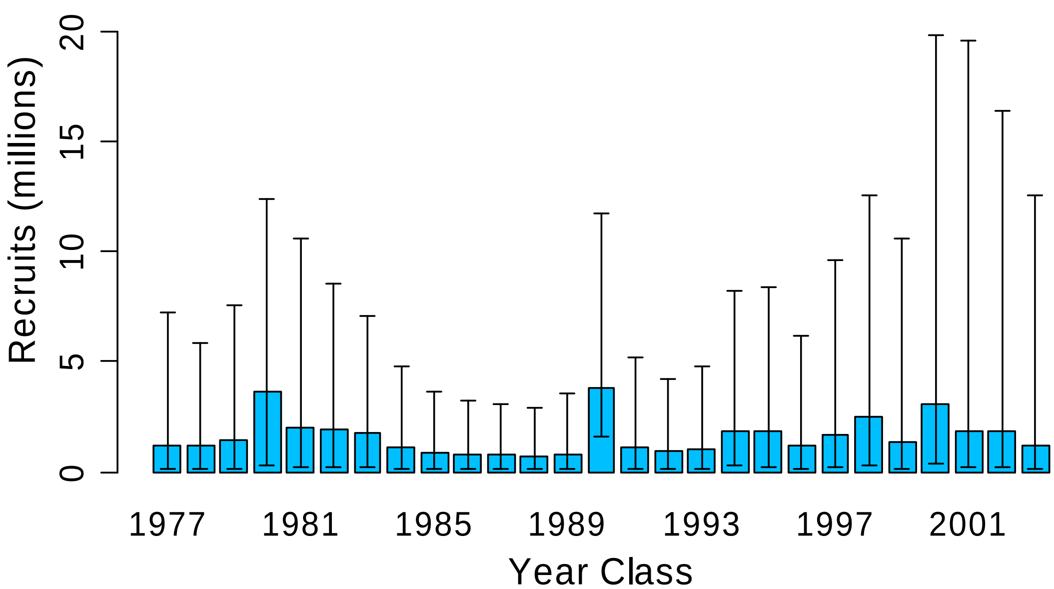


Figure 11-16. Estimated recruitments (age 3) for GOA rougheye rockfish from author recommended model.

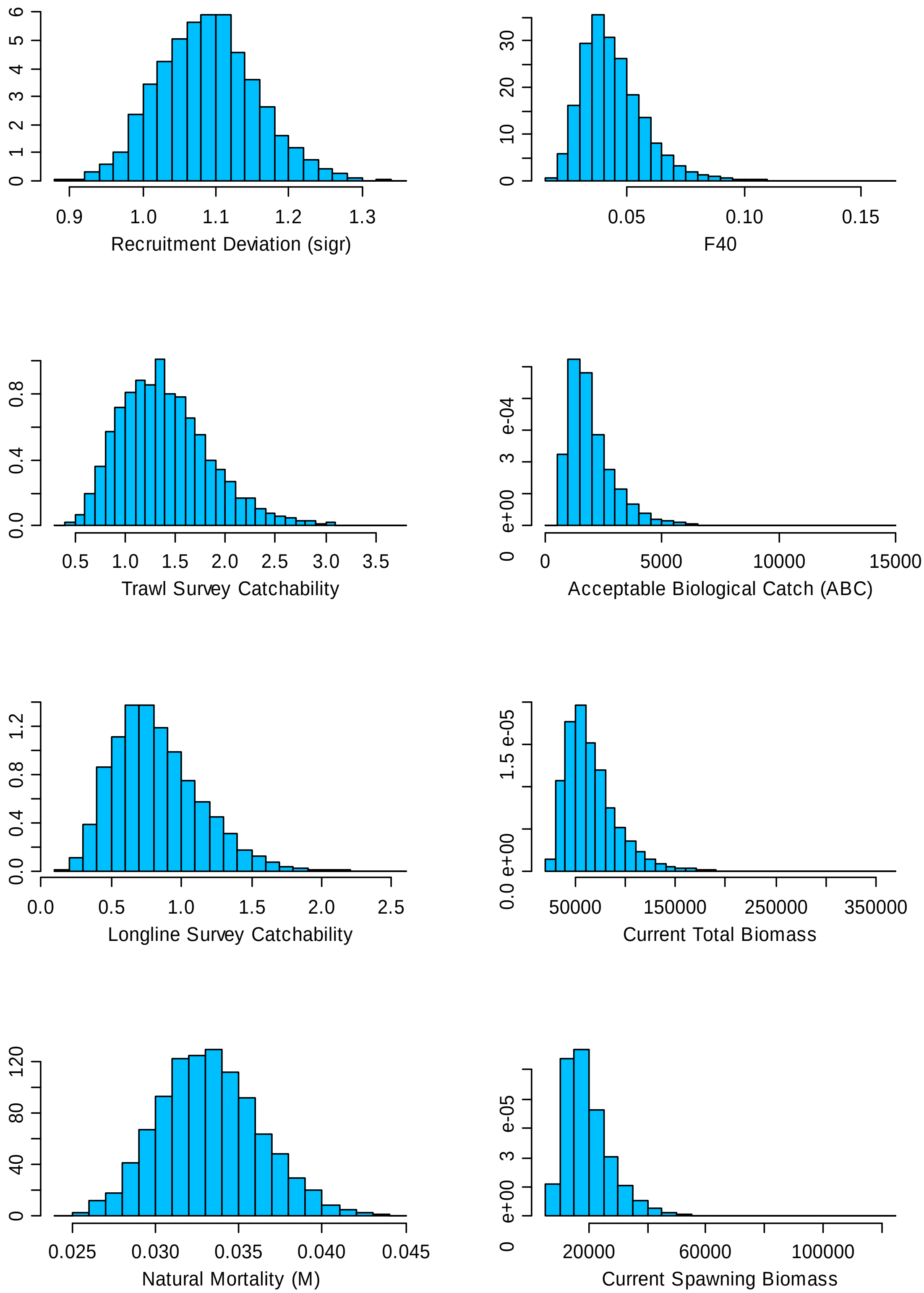


Figure 11-17: Histograms of estimated posterior distributions for key parameters derived from the 10 million MCMC runs for GOA rougheye rockfish.

Appendix A: Sensitivity of GOA rougheye rockfish stock assessment results to Trawl and Longline survey data

S. Kalei Shotwell and Dana Hanselman
Draft October 2007

Analytical Approach

In 2006, we performed a preliminary sensitivity analysis of rougheye rockfish stock assessment results to the trawl and longline survey biomass indices using 2005 model estimates. We revisit this analysis using the updated 2007 model which contains the updated estimates of 2006 and 2007 fishery catch, 2002 and 2006 fishery length compositions, 2007 trawl survey biomass estimate, 1984, 1993, 1996, and 2005 trawl survey age compositions, 2006-2007 longline survey biomass relative population weights, and 2006-2007 longline survey size compositions. The sampling precision for the two surveys biomass indices is approximately CV = 0.20. Therefore, we consider a wide range of error assumptions (CV = 0.05 to 0.4) about these values and apply this to the trawl and longline survey abundance indices, individually and then in concert. We then considered altering the precision on the trawl survey age and longline survey size compositions, by increasing or decreasing the weight on each index (0.5 to 2, effectively half to double precision). Finally, a range of different combinations of precision changes was explored over the two survey biomass indices combined with their respective age/length compositions. We report on differences between these sensitivity model runs and the author recommended model presented in the main text of the 2007 GOA Rougheye Rockfish SAFE.

Sensitivity Results

Estimates for projected female spawning biomass (B_{2008}), $B_{40\%}$, and ABC fluctuate over all model runs by 25-30%, while estimates of trawl survey catchability (q_1) change by about 17%, and estimates of longline survey catchability (q_2) change by about 41%. However, nearly half of the models considered are within 10% of the author recommended ABC from the 2007 updated model. The trajectory of female spawning biomass (SSB) over all models is relatively similar. It is the overall magnitude of SSB that depends on the precision configuration (Figure 11A-1). 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 weight on the trawl survey age compositions. In several scenarios, B_{2008} fell below $B_{40\%}$. This occurred with very high precision on only the longline survey or very high precision on the trawl survey biomass combined with very high weight on the trawl survey age compositions. We concentrate on potential sources of the latter sensitivity where B_{2008} fell below $B_{40\%}$ for this analysis.

The prior on the longline survey catchability is uninformative (CV=100%), centered about a mean of 1. When the precision is very high on the longline survey biomass index, the model essentially treats this abundance index as the true biomass. The relative population weights from the longline survey are considerably lower than the trawl survey biomass estimates ($\mu_{Longline}$=33,000; μ_{Trawl}=48,000); therefore, overall estimates of biomass will decrease. Additionally, estimates of survey catchability (q_1 and q_2) are above 2, suggesting that there are more fish caught by either survey than actually exist. The model reduces the overall biomass trajectory to account for the increased catchability estimates. The predicted values of the longline survey index follow the observed estimates very well and capture the most recent drop and steady increase from 2005-2007. Fish are not selected by the longline survey until ages 11-16, so little information on young fish is available from this survey. The model has information on older fish and some information on recruitment in the past and must fit a recent large drop and then increasing biomass trend of the longline survey. The catch index has a very low relative weight and if free to predict very high values and produce a fairly low fit to the catch data. Estimates of predicted catch do not follow the observed values and predict extremely anomalous values in more recent years (Figure 11.A-2), effectively capturing the trend of the longline survey index with no recruitment. The estimation of $B_{40\%}$ requires an assumption regarding the equilibrium level of recruitment. In the rougheye model this equilibrium level is equal to the average of age 3 recruits from 1980-2005. The estimate of $B_{40\%}$ is then based on an average that includes the recent years where there is no information on recruitment from the longline survey. These fish would not be included in the estimate of SSB for next year (B_{2008}). The $B_{40\%}$ estimate is inflated by several years of recruitment that are not captured in the estimate of B_{2008}; therefore B_{2008} falls below $B_{40\%}$.

In the cases where the combination of very high precision on the trawl survey biomass and very high weight on the trawl survey age compositions results in B_{2008} falling below $B_{40\%}$., the trawl survey selectivity curve shifts to the right and the estimate of trawl survey catchability is near 2. The sensitivity may be due to the relatively high proportions of age 4 and 5 year olds in the 2005 trawl survey age compositions combined with an increasing trend in trawl survey biomass estimates from 2003-2007. The shift to the right in the trawl survey selectivity curve allows for a very high estimate of recruitment in 2001 where there is very little other data in the model to constrain this value. We do not use the 2001 trawl survey data in the model because the survey did not sample the eastern GOA. The total area under the selectivity curve decreases with a right shift; therefore, the model increases the trawl survey catchability estimates to compensate for this loss. Again, an increase in catchability suggests the presence of more fish caught by the survey than actually exist and the model must reduce the overall biomass trajectory to account for the increased catchability estimate. The presence of a massive amount of recent recruits allows the model to fit the increasing trend in recent biomass. However, the estimate of $B_{40\%}$ is also based on an average that includes the massive 2001 estimate of recruitment. These fish are not mature and would not be included in the estimate of B_{2008}. In this case, the $B_{40\%}$ estimate is inflated by an anomalously large 2001 recruitment estimate and B_{2008} falls below $B_{40\%}$.

Distinct breaks can be seen in the parameter estimates over all model scenarios that represent these two main areas of model sensitivity (Figure 11.A-3, red circles). Catchability is not well estimated in most of these sensitive runs. The relatively low weighting on the catch index allows for the prediction of many extreme values and fairly poor fit to the catch data. This can drastically increase or decrease the biomass estimates in the model because the model is interpreting a drop in survey biomass in one year as a large harvest event. The existence of a large plus group may also be restricting the fit of the age compositions. The age compositions are a simple proportion for any given year. Poor fit in a plus group will result in an opposing poor fit in the younger ages as the proportions must sum to one. A preliminary analysis of fitting updated size-at-age and weight-at-age curves suggests that rougheye rockfish are slower growing than other deep water rockfish species and may not reach maximum size at 25 years. This would suggest the need for more age bins and may allow for a better fit to the age compositions.

Summary

Most of the outlier results where B_{2008} fell below $B_{40\%}$ were removed by performing the same sensitivity analysis as presented but increasing the weight on the catch data index. The model was not allowed to compensate for one low survey index estimate with a large increase in catch. In the future we may consider increasing the weight on the catch index to increase robustness of the model to weighting sensitivity. 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 rockfish population.

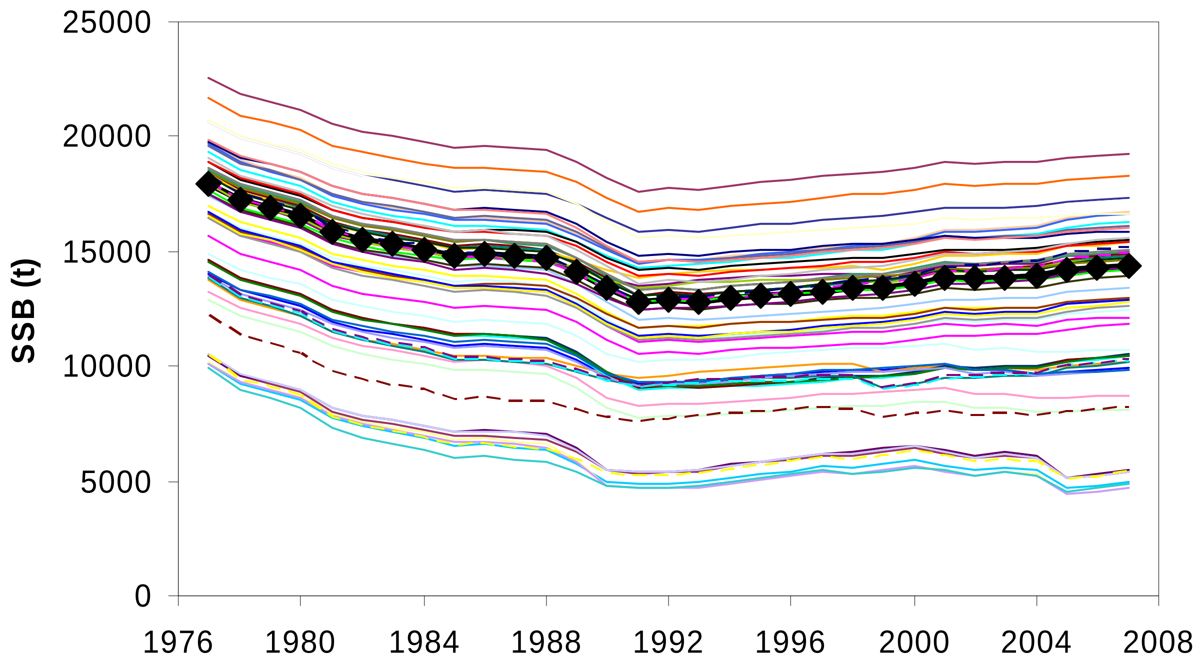


Figure 11A-1: Trajectories of spawning biomass for each combination of CVs over all model trials. Base model (black diamond) is from author recommended model in 2007 GOA Rougheye SAFE.

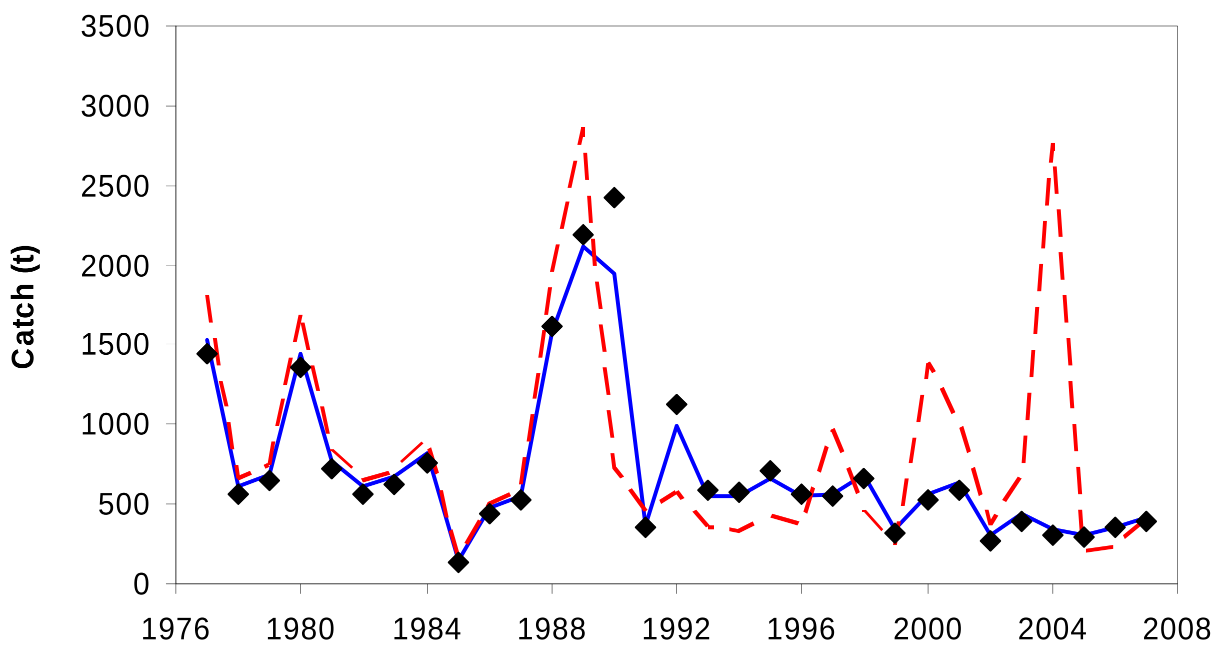


Figure 11A-2: Trajectories of observed and predicted rougheye rockfish catch. Observed values (black diamonds) and base model (blue line) are from author recommended model in 2007 GOA Rougheye SAFE. Red dash represents predicted catch for models with very high precision on longline survey biomass.

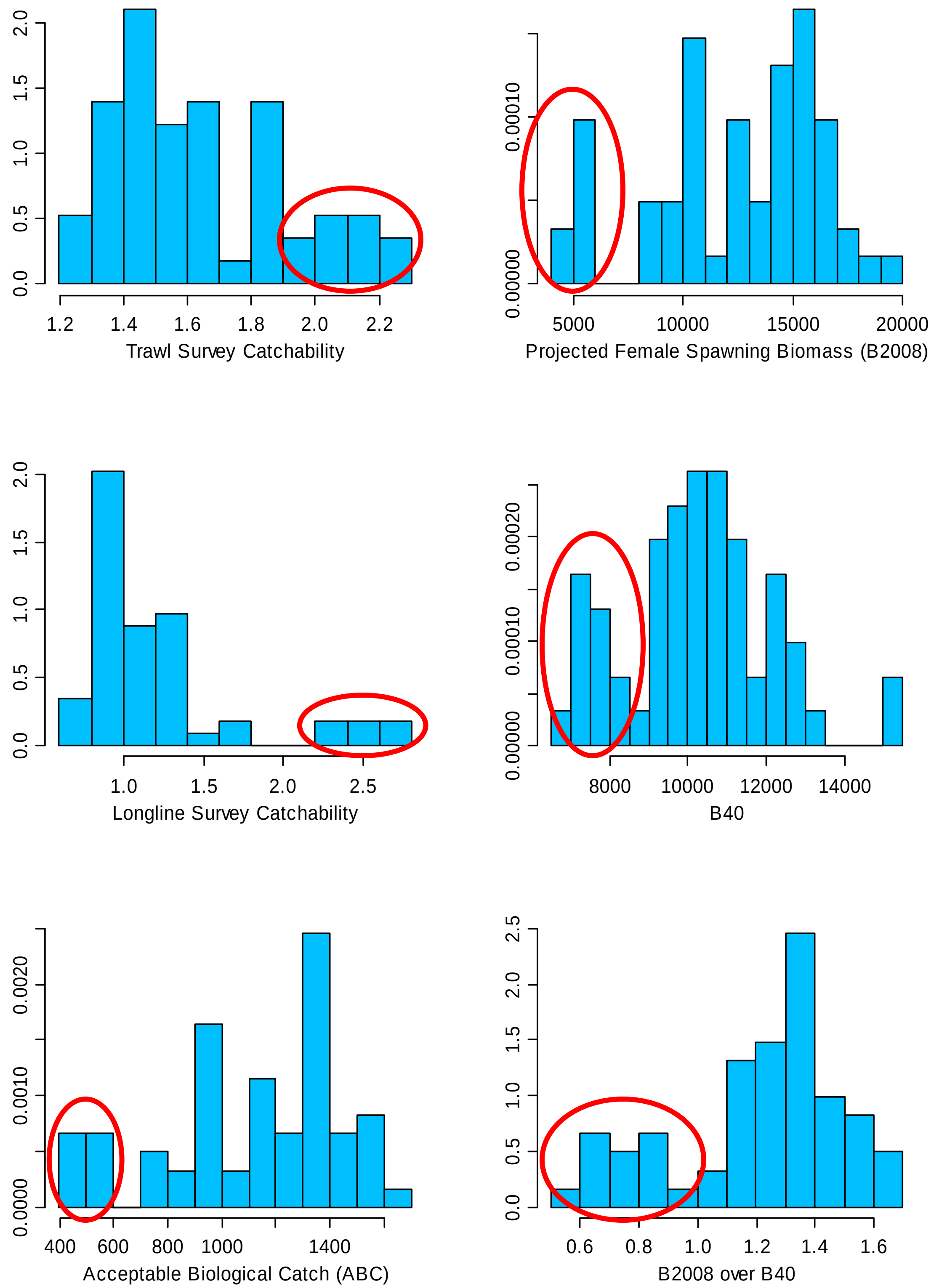


Figure 11A-3: Histograms of estimated parameters over all models from the sensitivity analysis. Red circles indicate areas of distinct breaks in parameter estimates where model sensitivity occurs.