Chapter 10: Assessment of the Northern Rockfish Stock in the Gulf of Alaska

by

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Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with new survey data. For Gulf of Alaska rockfish in alternate (even) years, we present only an executive summary to recommend harvest levels for the next (odd) year. For this on-cycle year, we update the 2007 assessment model with new data acquired since 2007. As in 2007, the general model structure is a separable age-structured model as used for Gulf of Alaska Pacific ocean perch, dusky rockfish, and rougheye/blackspotted rockfish.

Summary of Major Changes

Changes in input data

The input data were updated to include the 2009 trawl survey biomass estimate, updated catch for 2008, preliminary catch for 2009, survey age compositions for 2007, and fishery size compositions for 2007.

Changes in the assessment methodology

Two model configurations were considered. Model 1 is the base model from 2007 with updated data. This model has a mix of methods for assigning year specific likelihoods weights for fishery and survey age and size compositions. The main change for Model 2 is a consistent method of assigning year specific likelihood weights. This method combines both the number hauls and the number of samples such that the year specific likelihood weight is equal to the square root of the product of the number of hauls and the number samples scaled to a maximum of fifty for each data source.

We chose Model 2 to provide assessment advice for 2010. This model has an overall better balance in the fits to age and length compositions than Model 1 and a better fit to the survey biomass index.

Summary of results

The 2010 projected age 2+ biomass is 103,300 t. The recommended ABC for 2010 is 5,100 t, the maximum allowable ABC under Tier 3a. This ABC is 17% higher than the 2009 ABC. The OFL is 6,070 t. The corresponding reference values for northern rockfish recommended for this year and projected one additional year along with corresponding values from last year's SAFE are summarized in the table below. Northern rockfish is not subjected to overfishing, is not currently overfished, and is not approaching a condition of overfishing.

Summary	Last year's SAFE		2009 Projection	
	2009	**2010**	**2010**	**2011***
Total Biomass (t)	90,557	88,430	103,300	99,600
Female spawning biomass (t)	28,386	27,558	34,790	33,600
$B_{100\%}$ (t, female spawning biomass)	55,750	55,750	61,370	61,370
$B_{40\%}$ (t, female spawning biomass)	22,300	22,300	24,550	24,550
$B_{35\%}$ (t, female spawning biomass)	19,500	19,500	21,480	21,480
M	0.060	0.060	0.060	0.060
F_{ABC} $(=F_{40\%})$	0.061	0.061	0.059	0.059
F_{OFL} $(=F_{35\%})$	0.073	0.073	0.071	0.071
ABC	**4,362**	**4,174**	**5,100**	**4,810**
OFL	5,204	4,979	6,070	5,730

*Projected ABCs and OFLs are derived using an expected catch value of 4,436 t for 2010 based on recent ratios of catch to ABC (0.87). This calculation is in response to management requests to obtain a more accurate one-year projection.

The following table shows the recommended apportionment for 2010.

	Western	Central	Eastern*	Total
Area Apportionment	52.99%	46.96%	0.05%	100.00%
Area ABC (t)	**2,703**	**2,395**	**2**	**5,100**

*For management purposes the small ABC in the Eastern area is combined with other slope rockfish.

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Northern rockfish	2008	93,391	5,430	4,549	4,549	4,052
	2009	90,557	5,204	4,362	4,362	3,843
	2010	103,300	6,070	5,100		
	2011	99,600	5,730	4,810		

[1]Total biomass estimates from the age structured model.

Stock/ Assemblage	Area	2009 OFL	2009 ABC	2009 TAC	2009 Catch[2]	2010 OFL	2010 ABC	2011 OFL	2011 ABC
Northern rockfish	W		2,054	2,054	1,945		2,703		2,549
	C		2,308	2,308	1,898		2,395		2,259
	E*						2		2
	Total	5,204	4,362	4,362	3,843	6,070	5,100	5,730	4,810

[2]Current as of October 10, 2009 (http://www.fakr.noaa.gov)

* For management purposes, the small ABC for northern rockfish in the Eastern Gulf of Alaska is combined with other slope rockfish.

SSC Comments

"As recognized last year, the SSC again notes that the estimates of spawning biomass have low precision, as shown by the very wide confidence bounds around both the survey and model estimates (Figures 10.4 and 10.11). The SAFE authors recognize this in their remarks that the stratified random survey design does a poor job of assessing the stock, and that the issue of untrawlable survey grounds is an added concern. Given this imprecision, we suggested in our

minutes from December 2006 that an evaluation of the appropriate tier level may be needed. In response, the SAFE authors suggest that the model continues to improve as more data accumulates, and that tier 3a is appropriate. The SSC accepts this rationale and looks forward to future opportunities to evaluate the performance of the assessment."

We believe that Tier 3a is still appropriate for northern rockfish. The current model poorly fits the high and imprecise survey biomass estimates of 1999, 2001, 2005, and 2007 but reasonably fits the low but relatively precise biomass estimates of 1984-1996, 2003, and 2009. The current model indirectly accounts for northern rockfish often being found over untrawlable grounds by estimating a survey catchability coefficient of less than 1.0 (q = 0.74). We believe the current model is doing an adequate job of guiding stock assessment advice.

Introduction

The northern rockfish, *Sebastes polyspinis*, is a locally abundant and commercially valuable member of its genus in Alaskan waters. As implied by its common name, northern rockfish has one of the most northerly distributions among the 60+ species of *Sebastes* in the North Pacific Ocean. It ranges from extreme northern British Columbia around the northern Pacific Rim to eastern Kamchatka and the northern Kurile Islands and also north into the eastern Bering Sea (Allen and Smith 1988). Within this range, northern rockfish are most abundant in Alaska waters, from the western end of the Aleutian Islands to Portlock Bank in the central Gulf of Alaska (Clausen and Heifetz 2002).

Since 1988, the North Pacific Fishery Management Council (NPFMC) has managed northern rockfish in the Gulf of Alaska as part of the slope rockfish assemblage (Table 10.1). In 1991, the NPFMC divided the slope rockfish assemblage in the Gulf of Alaska into three management subgroups: Pacific ocean perch, shortraker/rougheye rockfish, and all other species of slope rockfish. In 1993, a fourth management subgroup, northern rockfish, was also created. In 2004, rougheye rockfish and shortraker rockfish were also split into separate species management. These subgroups were established to protect Pacific ocean perch, shortraker/rougheye, and northern rockfish (the four most sought-after commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual ABC (acceptable biological catch) and TAC (total allowable catch). Prior to 1991, an ABC and TAC were assigned to the entire assemblage. ABC and TAC for each subgroup, including northern rockfish, is apportioned to the three management areas of the Gulf of Alaska (Western, Central, and Eastern) based on a weighted average of the proportion of biomass by area from the three most recent Gulf of Alaska trawl surveys. Northern rockfish are scarce in the eastern Gulf of Alaska, and the ABC apportioned to the Eastern Gulf management area is small. This translates to a TAC that is too difficult to be managed effectively as a directed fishery. Since 1999, the ABC for northern rockfish apportioned to the Eastern Gulf management area is included in the West Yakutat ABC for "other slope rockfish."

Gulf of Alaska northern rockfish grow significantly faster and reach a larger maximum length than Aleutian Islands northern rockfish (Clausen and Heifetz 2002). Also, Aleutian Islands northern rockfish are older (maximum age 72) than Gulf of Alaska northern rockfish (maximum age 67). However, a genetic study of northern rockfish collected at three locations near the western Aleutian Islands, the western Gulf of Alaska, and Kodiak Island provided no evidence for genetically distinct stock structure within the sampled population (Gharrett et al. 2003). The genetic analysis was considered preliminary, and sample sizes were small. Consequently, the lack of evidence for stock structure does not necessarily confirm stock homogeneity and additional genetic studies are underway.

Little is known about the life history of northern rockfish. Northern rockfish are presumed to be viviparous with internal fertilization. There have been no studies on fecundity of northern rockfish. Observations during research surveys in the Gulf of Alaska indicate that parturition (larval release) occurs in the spring and is completed by summer. Larval northern rockfish cannot be unequivocally identified to species at this time, even using genetic techniques, so information on larval distribution and length of the larval stage is unknown. The larvae metamorphose to a pelagic juvenile stage, but there is no information on when these juveniles become demersal.

Little information is available on the habitat of juvenile northern rockfish. Studies in the eastern Gulf of Alaska and Southeast Alaska using trawls and submersibles have indicated that several species of juvenile (< 20 cm) red rockfish (*Sebastes spp.*) associate with benthic nearshore living and non-living structure and appear to use the structure as a refuge (Carlson and Straty 1981; Kreiger 1993). Freese and Wing (2003) also identified juvenile (5 to 10 cm) red rockfish (*Sebastes sp.*) associated with sponges (primarily *Aphrocallistes sp.)* attached to boulders 50 km offshore in the GOA at 148 m depth over a substrate that was primarily a sand and silt mixture. Only boulders with sponges harbored juvenile rockfish, and the juvenile red rockfish appeared to be using the sponges as shelter (Freese and Wing 2003). Although these studies did not specifically observe northern rockfish, it is likely that juvenile northern rockfish also utilize similar habitats. Length frequencies of northern rockfish captured in NMFS bottom trawl surveys and observed in commercial fishery bottom trawl catches indicate that older juveniles (>20 cm) are found on the continental shelf, generally at locations inshore of the adult habitat (Pers. comm. Dave Clausen).

Northern rockfish are generally planktivorous. They eat mainly euphausiids and calanoid copepods in both the GOA and the Aleutian Islands (Yang 1993; Yang 1996; Nelson and Yang 2000). There is no indication of a shift in diet over time or a difference in diet between the GOA and AI (Yang 1996, Yang and Nelson 2000). In the Aleutian Islands, calanoid copepods were the most important food of smaller-sized northern rockfish (< 25 cm), while euphausiids were the main food of larger sized fish (> 25 cm) (Yang 1996). The largest size group also consumed myctophids and squids (Yang 2003). Arrow worms, hermit crabs, and shrimp have also been noted as prey items in much smaller quantities (Yang 1993, 1996). Large offshore euphausiids are not directly associated with the bottom, but rather, are thought to be advected onshore near bottom at the upstream ends of underwater canyons where they become easy prey for planktivorous fishes (Brodeur 2001). Predators of northern rockfish are not well documented, but likely include larger fish, such as Pacific halibut, that are known to prey on other rockfish species.

Trawl surveys and commercial fishing data indicate that the preferred habitat of adult northern rockfish in the Gulf of Alaska is relatively shallow rises or banks on the outer continental shelf at depths of about 75-150 m (Clausen and Heifetz 2003). The highest concentrations of northern rockfish from NMFS trawl survey catches appear to be associated with relatively rough (variously defined as hard, steep, rocky or uneven) bottom on these banks (Clausen and Heifetz 2003). Heifetz (2002) identified rockfish (including *Sebastes spp.*) as among the most common commercial fish captured with gorgonian corals (primarily *Callogorgia, Primnoa, Paragorgia, Fanellia, Thouarella*, and *Arththrogorgia*) in NMFS trawl surveys of Gulf of Alaska and Aleutian waters. Krieger and Wing (2002) identified six rockfish species (*Sebastes spp.*) associated with gorgonian coral (*Primnoa spp.*) from a manned submersible in the eastern Gulf of Alaska. However, neither Heifetz (2002) nor Krieger and Wing (2002) specifically identified northern rockfish in their studies, and more research is required to determine if northern rockfish are associated with living structure, including corals, in the Gulf of Alaska, and the nature of those associations if they exist.

Results of an analysis of localized depletionbased on Leslie depletion estimators on targeted rockfish catches detected relatively few localized depletions for northern rockfish (Hanselman et al. 2007). Several significant depletions occurred in the early 1990s for northern rockfish, but were not detected again by the depletion analysis. However, when fishery and survey CPUEs were plotted over time for a geographic block of high rockfish fishing intensity that contained the "Snakehead", the results indicated there were year-after-year drops in both fishery and survey CPUE for northern rockfish. Presently, fishing for northern rockfish is nearly absent relative to previous effort in the area. The significance of these observations depend on the migratory and stock structure patterns of northern rockfish. If fine-scale stock structure is determined in northern rockfish, or if the area is essential to northern rockfish reproductive success, then these results would suggest that current apportionment of ABC may not be sufficient to protect northern rockfish from localized depletion.

Provisions to guard against serial depletion in northern rockfish should be examined in the Gulf of Alaska rockfish rationalization plan. The extension of the fishing season that has been implemented may spread out the fishery in time and space and reduce the risk of localized serial depletion on the “Snakehead” and other relatively shallow (75 – 150 m) offshore banks on the outer continental shelf where northern rockfish are concentrated.

If there is relatively small scale stock structure (120 km) in Gulf of Alaska northern rockfish, then recovery from localized depletion, as indicated above for a region known as the “Snakehead,” could be slow. Analysis of otolith microchemistry may provide a useful tool, in addition to genetic analysis, for identifying small scale (120 km) stock structure of northern rockfish relative to their overall range. Berkeley et al. (2004) suggests that, in addition to the maintenance of age structure, the maintenance of spatial distribution of recruitment is essential for long-term sustainability of exploited rockfish populations. In particular, Berkeley et al. (2004) outline Hedgecock's “sweepstakes hypothesis” to explain small-scale genetic heterogeneity observed in some widely distributed marine populations. According to Berkeley et al. (2004), "most spawners fail to produce surviving offspring because their reproductive activity is not matched in space and time to favorable oceanographic conditions for larval survival during a given season. As a result of this mismatch the surviving year class of new recruits is produced by only a small minority of adults that spawned within those restricted temporal and spatial oceanographic windows that offered good conditions for larval survival and subsequent recruitment" However, Miller and Shanks (2004) found limited larval dispersal (120 km) in black rockfish off the Pacific coast with an analysis of otolith microchemistry. In particular, these results suggest that black rockfish exhibit some degree of stock structure at very small scales (120 km) relative to their overall range. Localized genetic stocks of POP have also been found in northern B.C. (Withler et al. 2001). Limited larval dispersal contradicts Hedgecock's hypothesis and suggests that genetic heterogeneity in rockfish may be the result of stock structure rather than the result of the sweepstakes hypothesis.

Recent work on black rockfish (*Sebastes melanops*) has shown that larval survival may be higher from older female spawners (Berkeley et al. 2004). The black rockfish population has shown a distinct reduction in the proportion of older fish in recent fishery samples off the West Coast of North America, raising concerns if larval survival diminishes with spawner age. 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. However, relationships on fecundity or larval survival at age have not yet been evaluated for northern rockfish or other 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 the REFM Division to determine if this relationship occurs for Pacific ocean perch in the Central Gulf of Alaska.

Management measures

In 1991, the 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. 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 (acceptable biological catch) and TAC (total allowable catch), whereas prior to 1991, an 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 distribution of exploitable biomass.

Amendment 41, which took effect in 2000, prohibited trawling in the Eastern area east of 140 degrees W. longitude. However, trawling did not occur in this area starting in 1998. Since most slope rockfish, especially Pacific ocean perch, are caught exclusively with trawl gear, this amendment could have concentrated fishing effort for slope rockfish in the Eastern area in the relatively small area between 140 degrees and 147 degrees W. longitude that remained open to trawling. To ensure that such a geographic over-concentration of harvest would not occur, effective in 1999, the NPFMC divided the Eastern area into two smaller management areas: West Yakutat (area between 147 and 140 degrees W. longitude) and East Yakutat/Southeast Outside (area east of 140 degrees W. longitude). Separate ABC's and TAC's are assigned to each of these smaller areas for Pacific ocean perch. This should not have had a major effect on northern rockfish, though, as very few northern rockfish are found in the Eastern area.

In November, 2006, NMFS issued a final rule to implement Amendment 68 of the GOA groundfish Fishery Management Plan for 2007 through 2011. This action implemented the Central GOA Rockfish Pilot Program. The intention of this Program is to enhance resource conservation and improve economic efficiency for harvesters and processors in the rockfish fishery. An additional objective is to spread out the fishery in time and space, allowing for better prices for product and reducing the pressure of what was an approximately two week fishery in July. The primary rockfish management groups in this program are northern rockfish, Pacific ocean perch, and pelagic shelf rockfish. Potential effects of this program on northern rockfish include: 1) Extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA, 3) Improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, 4) a higher potential to harvest 100% of the TAC in the Central GOA region. The authors will pay close attention to the benefits and consequences of this action.

Fishery

Total commercial catch (t) of northern rockfish in the GOA for the years 1965-2009 is summarized by foreign, joint venture, and domestic fisheries (Table 10.1, Fig. 10.1).

Catches of GOA northern rockfish during the years 1961-1976 were estimated as 5% of the foreign GOA Pacific ocean perch catch in the same years. A Pacific ocean perch trawl fishery by the U.S.S.R. and Japan began in the Gulf of Alaska in the early 1960's. This fishery developed rapidly with massive efforts by the Soviet and Japanese fleets. Catches peaked in 1965 when a total of nearly 350,000 metric tons (t) was caught, but declined to 45.5 t by 1976 (Ito 1982). Some northern rockfish were likely taken in this fishery, but there are no available summaries of northern rockfish catches for this period. Foreign catches of all rockfish were often reported simply as "Pacific ocean perch," with no attempt to differentiate species. The only detailed analysis of bycatch in slope rockfish fisheries of the Gulf of Alaska is that of Ackley and Heifetz (2001) who examined data from the observer program for the years 1993-95. Consequently, our best estimate of northern rockfish catch from 1965-1976 comes from analysis of the ratio of northern rockfish catch to POP catch in the years 1993-1995. For hauls targeting on Pacific ocean perch, northern rockfish composed 5% of the catch (Ackley and Heifetz 2001).

Catches of GOA northern rockfish during the years 1977-1983 were available from NMFS foreign and joint venture fisheries observer data. With the advent of a NMFS observer program aboard foreign fishing vessels in 1977, enough information on species composition of rockfish catches was collected so that estimates of the northern rockfish catch were made for 1977-83 from extrapolation of catch compositions from the foreign observer program (Clausen and Heifetz 2002). The relatively large catch estimates for the foreign fishery in 1982-83 are an indication that at least some directed fishing for northern rockfish probably occurred in those years. Joint venture catches of northern rockfish, however, appear to have been relatively modest.

Catches of GOA northern rockfish during the years 1984-1989 were estimated as 8% of the domestic slope rockfish catch during the same years. A completely domestic trawl fishery for rockfish in the Gulf of Alaska began in 1984 but a domestic observer program was not implemented until 1990. Domestic catches of GOA northern rockfish during the years 1984-1989 were estimated from the ratio of domestic northern rockfish catch to domestic slope rockfish catch (8%) reported by the 1990 NMFS observer program:

$$\text{northern rockfish catch}_i = \frac{\text{northern rockfish catch}_{1990}}{\text{slope rockfish assemblage catch}_{1990}} * \text{ slope rockfish assemblage catch}_i$$

Catches of GOA northern rockfish during the years 1990-1992 were estimated from extrapolation of catch compositions from the domestic observer program (Clausen and Heifetz 2002). Catch estimates of northern rockfish increased greatly from about 1,700 t in 1990 to nearly 7,800 t in 1992. The increases for 1991 and 1992 can be explained by the removal of Pacific ocean perch and shortraker/rougheye rockfish from the slope rockfish management group. As a result of this removal, relatively low TAC's were adopted for these three species, and the rockfish fleet redirected more of its effort to northern rockfish in 1991 and 1992.

Catches of GOA northern rockfish during the years 1993-present were available directly from NMFS domestic fisheries observer data. Northern rockfish were removed from the slope rockfish assemblage and managed with an individual TAC beginning in 1993. As a consequence, directly reported catch for northern rockfish has been available since 1993. Catch of northern rockfish was reduced after the implementation of a northern specific TAC in 1993. Most of the catch since 1993 has been taken in the Central area, where the majority of the northern rockfish exploitable biomass is located. Gulfwide catches for the years 1993-2009 have ranged from 2,947 t to 5,968 tr. Annual ABCs and TACs have been relatively consistent during this period and have varied between 4,360 t and 5,760 t. In 2001, catch of northern rockfish was below TAC because the maximum allowable bycatch of Pacific halibut was reached in the central Gulf of Alaska for "deep water trawl species," which includes northern rockfish. Catches of northern rockfish have been near their TAC's in more recent years, 2003 - 2009.

Research catches of northern rockfish have been relatively small and are listed in Table 10.2.

In the Gulf of Alaska, northern rockfish are generally caught with bottom trawls identical to those used in the Pacific ocean perch fishery. Many of these nets are equipped with so-called "tire gear," in which automobile tires are attached to the footrope to facilitate towing over rough substrates. Most of the catch has been taken during July, as the directed rockfish trawl fishery in the Gulf of Alaska has traditionally opened around July 1. Rockfish trawlers usually direct their efforts first toward Pacific ocean perch because of its higher value relative to other rockfish species. After the TAC for Pacific ocean perch has been reached and NMFS closes directed fishing for this species, trawlers switch and target northern rockfish. With the implementation Central Gulf Rockfish Pilot Project in 2007, catches have been spread out more throughout the year.

Historically, bottom trawls have accounted for nearly all the commercial harvest of northern rockfish in the Gulf of Alaska. In the years 1990-98, bottom trawls took over 99% of the catch (Clausen and Heifetz 2002). Before 1996, most of the slope rockfish trawl catch (>90%) was taken by large factory-trawlers that processed the fish at sea. A significant change occurred in 1996, however, when smaller shore-based trawlers began taking a sizeable portion of the catch in the Central Gulf for delivery to processing plants in Kodiak. Factory trawlers continued to take nearly all the northern rockfish catch in the Western area during this period.

A study of the northern rockfish fishery for the period 1990-98 showed that 89% of northern rockfish catch was taken from just five relatively small fishing grounds: Portlock Bank, Albatross Bank, an unnamed bank south of Kodiak Island that fishermen commonly refer to as the "Snakehead," Shumagin Bank, and Davidson Bank (Clausen and Heifetz 2002). The Snakehead accounted for 46% of the northern rockfish catch during these years. All of these grounds can be characterized as relatively shallow (75–150 m) offshore banks on the outer continental shelf.

Data from the observer program for 1990-98 indicated that 82% of the northern rockfish catch during that period came from directed fishing for northern rockfish and 18% was taken as incidental catch in fisheries for other species (Clausen and Heifetz 2002).

Bycatch and discards

The only detailed analysis of incidental catch in slope rockfish fisheries of the Gulf of Alaska is that of Ackley and Heifetz (2001) who examined data from the observer program for the years 1993-95. For hauls targeting on northern rockfish, the predominant incidental species was dusky rockfish, distantly followed by "other slope rockfish," Pacific ocean perch, and arrowtooth flounder.

For the combined rockfish trawl fisheries during 1997-2004 the largest non-rockfish bycatch groups are Pacific cod (1,750 t/year), arrowtooth flounder (1,500 t/year), and sablefish (1,100 t/year) More recent data for 2005-2009 indicates an increase in the combined rockfish fisheries of bycatch of greenling/Atka mackerel (1,584 t/year) and walleye pollock (590 t/year), and decreases of arrowtooth flounder (565 t/year), sablefish (515 t/year), and Pacific cod (422 t/year).

Gulfwide discard rates (% discarded) for northern rockfish in the commercial fishery for 1997-2009 are as follows:

1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
27.8	18.3	11.1	8.7	17.5	9.8	9.3	7.8	4.3	9.2	2.6	4.9	2.8

These discard rates are generally similar to those in the Gulf of Alaska for Pacific ocean perch and dusky rockfish.

Data

The following table summarizes the data used in the stock assessment model for northern rockfish (bold denotes new data for this assessment):

Source	Data	Years
Fisheries	Catch	1961-**2009**
NMFS bottom trawl surveys	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, **2009**
NMFS bottom trawl surveys	Age	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, **2007**
U.S. trawl fisheries	Age	1998, 1999, 2000, 2001, 2002, 2004, 2005, 2006
U.S. trawl fisheries	Length	1990,1991,1992, 1993, 1994, 1995, 1996, 1997, 2003, **2007**

Fishery data

Observers aboard fishing vessels and at onshore processing facilities have provided data on size and age compositions of the commercial catch of northern rockfish and sample sizes are presented in Table 10.3. Length compositions are presented in Table 10.4 and Fig.10.3, and age compositions are presented in Table 10.5 and Fig.10.2. The fishery age compositions indicate that strong year-classes occurred around the year 1976 and 1984. The fishery age compositions from 2004 and 2006 also indicate that the 1993 and/or 1994 year-classes are strong. The clustering of several large year-classes in each period is most likely due to aging error.

Survey Data

Bottom trawl surveys were conducted in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, and 2009. The surveys provide an index of biomass, size and age composition data, and growth characteristics. The trawl surveys have used a stratified random design to sample fishing stations that cover all areas of the Gulf of Alaska out to a depth of 500 m (in some surveys to 1,000 m). Generally, attempts have been made through the years to standardize the survey design and the fishing nets used, but there have been some exceptions to this standardization. In particular, much of the survey effort 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 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 listed in this report, and the estimates are believed to be the best available. Even so, the use of Japanese vessels in 1984 and 1987 introduced an element of uncertainty as to the standardization of these two surveys. Also, a different survey design was used in the eastern Gulf of Alaska in 1984, and the eastern Gulf of Alaska was not covered by the 2001 survey. These data inconsistencies for the eastern Gulf of Alaska have had little effect on the survey results for northern rockfish, as relative abundance of northern rockfish is very low in the eastern Gulf of Alaska.

The trawl survey indices of biomass for northern rockfish have been highly variable from survey to survey (Table 10.6 and Fig. 10.2). In particular, the 2005 Gulfwide survey biomass estimate (359,026 t) was 82% higher than the 2003 biomass estimate (66,310 t). The 2003 survey biomass estimate (66,310 t) was 19% of the 2001 biomass estimate (343,731 t). The 2009 biomass estimate (89,896) was 40% of the 2007 estimate. Such large fluctuations in biomass do not seem reasonable given the long life, slow growth, low natural mortality, late maturity, and relatively modest level of commercial catch of northern rockfish.

The precision of some of the biomass estimates has been low and is reflected in the large 95% confidence intervals and high CVs associated with some survey biomass estimates of northern rockfish (Table 10.6 and Fig. 10.4). In both 1999 and 2001, a single very large survey haul of northern rockfish greatly increased the biomass estimates and resulted in wide confidence bounds. The haul in 2001 was the largest individual catch (14 t) of northern rockfish ever taken during a Gulf of Alaska survey. In contrast, the 2005 and 2007 survey had several large hauls of northern rockfish in the Central Gulf and confidence bounds were narrower (Figure 10.5). The 2009 survey did not have any very large hauls and the biomass estimate was lower and more precise than the 2005 and 2007 estimates. The highly variable biomass estimates for northern rockfish suggest that an alternative to the stratified random design may be needed to reduce the variability in biomass estimates.

Trawl surveys provide size composition data for northern rockfish but are not used directly in the current age structured assessment model (Table 10.7 and 10.8). They are, however, used to expand the length stratified survey age compositions to random samples of survey age composition for use in the model. The age samples are interpreted for age by the break and burn method and used to create age-length keys. These keys are then expanded by the survey length frequencies to compute survey estimates of numbers at age (Table 10.9, Fig. 10.3). These age compositions indicate that recruitment of northern rockfish is highly variable. Several surveys (1984, 1987, 1990, and 1996) show especially strong year-classes from the period around 1975-77, although they differ as to which specific years were greatest, likely due to age determination errors. The 1993, 1996, and 1999 age compositions also indicate that the 1983-85 year-classes may be stronger than average, which is in agreement with recent age compositions obtained from the commercial fishery described above.

Analytic Approach

Gulf of Alaska northern rockfish are assessed using an age-structured modeling approach.

Model structure

The basic model is described as a separable age-structured model (Box 1) and was implemented using AD Model Builder software (Otter Research Ltd 2000; Courtney et al. 2005, 2006). The assessment model is based on a generic rockfish model developed in a workshop held in February 2001 (Courtney et al. 2006) and follows closely the GOA Pacific ocean perch model. 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 (Fig. 10.7). The parameters, population dynamics, and equations of the model are in Box 1.

Key information sources are survey index of biomass, catch-at-age estimates, and survey numbers at age estimates. Length compositions are used for years when age estimates are not available. Error in the predicted catch is allowed by specifying the variance of the estimates. Similarly, the age and length composition data are weighted according to pre-specified sampling levels.

Penalties were added to the overall objective function in order to constrain parameter estimates to reasonable values and to speed model convergence. Parameter estimates for the key parameters of survey catchability (q), and natural mortality (M) were modeled with lognormal prior distributions. Arithmetic means and standard errors (μ, σ) for the lognormal distributions were provided as input to the model. The standard errors for selected model parameters were estimated based on multivariate normal approximation of the covariance matrix.

As with the model presented in 2007 the model configuration includes an estimation of catchability q using an assumed prior distribution with a mean of 1.0 and a *CV* of 45%. This is identical to that used in the Gulf of Alaska Pacific ocean perch and dusky rockfish assessments.

This year we also present a model configuration that uses a different method of assigning year specific likelihood weights (ψ_y^g: Box 1) for fishery and survey age and size compositions. Previously, different methods were used depending on the data source. Here we use a “hybrid” approach that is consistent for all data sets. This method combines both the number hauls and the number of samples such that the year specific likelihood weight is equal to the square root of the product of the number of hauls and the samples scaled to a maximum of fifty for each data source.

Parameters estimated independently

Age at 50% maturity (13 years) and size at 50% maturity (36.1 cm fork length) for northern rockfish in the Gulf of Alaska was estimated from a sample of 77 females in the central Gulf of Alaska1 (C. Lunsford pers. comm.. July 1997). Maximum reported age for Gulf of Alaska northern rockfish is 67 years from the survey and 51 years from the fishery. For modeling purposes, age at recruitment is set at 2 and ages past 22 are pooled into a plus group. We fix the variability of recruitment deviations (σ_r) at 1.5 which allows highly variable recruitment

Area	Size at 50% maturity	Age at 50% maturity	Sample size
Central Gulf of Alaska	36.1	12.8[3]	77

Recently, Chilton (2007) provided new estimates for female northern rockfish of age maturity. The new estimate of age of 50% maturity is 8 years which is considerably younger than that currently used in the assessment. Future analyses will evaluate the effects of this new estimate on the stock assessment. The $F_{40\%}$ reference value corresponding to this new estimate would be considerably higher than the value currently estimated for northern rockfish. Until we have a better understanding of the new data, we continue to assume an age at 50% of 12.8 years for GOA northern rockfish.

Length-weight coefficients for the formula $W=aL^b$, where W = weight in grams and L = length in mm, were estimated with available data from NMFS bottom trawl surveys (1984-2005).

Area	Sex	a	b	Sample size
Gulf of Alaska	combined	1.75×10^{-5}	2.98	3,193

The von Bertalanffy age-length relationship and resulting length-age transition matrix were based on the length-at-age data from NMFS bottom trawl surveys (1984-2005) (Fig. 10.8). Previous parameters are available from Heifetz and Clausen (1991), Courtney et al. (1999), and Malecha et al. (2007). The length-at-age transition matrix was constructed by adding normal error to the von Bertalanffy growth curve with standard deviation of length modeled as a linearly increasing function of survey age (e.g., Courtney et al. 1999). An aging error matrix was constructed by assuming that break and burn ages were unbiased with a normal error around each age and was not updated for this assessment (Courtney et al. 1999).

Parameters estimated conditionally

For the model presented in this assessment, 129 parameters were estimated conditionally: 1 survey catchability parameter, 1 natural mortality parameter, 69 initial age composition and subsequent recruitment parameters, 49 annual fishing mortality values, 4 selectivity-at-age parameters (2 each for the fishery and survey)

The estimates of natural mortality (*M*) and catchability (*q*) are estimated with the use of prior distributions as penalties. The prior mean for natural mortality of 0.06 is based the estimate provided by Heifetz and Clausen (1991) using the method of Alverson and Carney (1975). Natural mortality is notoriously a difficult parameter to estimate within the model so we assign a “tight” prior CV of 5%.

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%. This allows the parameter more freedom than that allowed to natural mortality.

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	1
Log-mean-recruitment	μ_r	1
Recruitment deviations	τ_y	69
Spawners-per-recruit levels	$F_{35\%}, F_{40\%}, F_{50\%}$	3
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	49
Logistic fishery selectivity	$a_{f50\%}, \delta_f$	2
Logistic survey selectivity	$a_{s50\%}, \delta_s$	2
Total		129

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 model presented in this SAFE report, the number of parameters estimated is 129. 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 2,000,000 iterations out of 10,000,000 and "thinned" the chain to one value out of every thousand, leaving a sample distribution of 4,000. Further assurance that the chain had converged was to compare the mean of the first half of the chain with the second half after removing the "burn-in" and "thinning". Because these two values were similar we concluded that convergence had been attained. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% confidence intervals for some parameters.

Box 1.

Notation	Description
y	Year, $y=1, 2,\ldots T$
T	Terminal year of the model
a	Model age class, $a = a_0, a_0+1, \ldots, a_+$
a_0	Age at recruitment to the model
a_+	Plus-group age class (oldest age considered plus all older ages)
l	Length class
Ω	Number of length bins (for length composition data)
g	Gear-type (g = survey or fishery)
x	Index for likelihood component
w_a	Average weight at age
φ_a	Mature female population proportion at age
μ_r	Average log-recruitment
μ_f	Average log-fishing mortality
ϕ_y	Annual fishing mortality deviation
τ_y	Annual recruitment deviation ~ (0, σ_r)
σ_r	Recruitment standard deviation
$N_{y,a}$	Numbers of fish at age a in year y
M	Natural mortality
s_a^g	Selectivities at age a for gear type g
δ_1^g, δ_2^g	Parameters for the logistic selectivity curve (if option selected) where δ_1^g is the age at 50% selected and δ_1^g represents the curvature for gear type g
$F_{y,a}$	Fishing mortality for year y and age class a ($=s_a^g \mu_f e^{\phi_y}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
R_y	Recruitment in year y
R_0	Unfished average recruitment
B_y	Spawning biomass in year y
B_0	Unfished average spawning biomass
ω	Set mean recruitment to average (=0) or to stock-recruitment curve (=1)
$\mathbf{A}$	Ageing-error matrix dimensioned $a_+ \times a_+$
$\mathbf{A}^l$	Age to length transition matrix dimensioned $a_+ \times \Omega$
$\rho_{y,a}^g$	Pearson residual of proportion at age (or length) a for gear g and year y
q	Survey catchability coefficient
λ_x	Statistical weight (penalty) for component x
$B_y^{Survey}, \hat{B}_y^{Survey}$	Observed and predicted survey index in year y
$P_{y,l}^g, \hat{P}_{y,l}^g$	Observed and predicted proportion at length l for gear g in year y
$P_{y,a}^g, \hat{P}_{y,a}^g$	Observed and predicted proportion at observed age a' for gear g in year y
ψ_y^g	Sample size assumed for gear g in year y (for multinomial likelihood)
n_g	Number of years that age (or length) composition is available for gear g
h_μ, σ_h	Prior mean, standard deviation for steepness (if stock-recruitment option selected)
q_μ, σ_q	Prior mean, standard deviation for catchability coefficient
M_μ, σ_M	Prior mean, standard deviation for natural mortality
$\sigma_{r_\mu}, \sigma_{\sigma_r}$	Prior mean, standard deviation for recruitment

Box 1. (continued)

Equations describing state dynamics | **Model Description** (continued)

$$N_{1,a} = \begin{cases} R_1, & a = a_0 \\ e^{\left(\mu_r + \tau_{a_0 - a + 1}\right)} e^{-(a-a_0)M}, & a_0 < a < a_+ \\ e^{(\mu_r)} e^{-(a-a_0)M} \left(1 - e^{-M}\right)^{-1}, & a = a_+ \end{cases}$$

Initial year recruitment and numbers at ages.

$$N_{y,a} = \begin{cases} R_y, & a = a_0 \\ N_{y-1,a-1} e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} e^{-Z_{y-1,a-1}} + N_{y-1,a} e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$$

Subsequent years recruitment and numbers at ages

$$R_y = \begin{cases} e^{\left(\mu_r + \tau_y\right)}, & \omega = 0 \\ \dfrac{B_{y-a_0} e^{\tau_y}}{\alpha + \beta B_{y-a_0}}, & \omega = 1 \end{cases}$$

Recruitment

where $\alpha = \frac{B_0}{R_0}\left(1 - \frac{h-2}{0.8h}\right),\ \beta = \frac{5h-1}{4hR_0}$,

$$B_0 = \sum_{a_0}^{a_+ - 1} R_0 e^{-(a-a_0)M} \varphi_a w_a + R_0 e^{-(a_+ - a_0)M} \varphi_{a_0} w_{a_0} \Big/ \left(1 - e^{-M}\right)$$

and $B_y = \begin{cases} B_0, & y = 1 \\ \sum_a \varphi_a w_a N_{y,a}, & y > 1 \end{cases}$.

Observation equations

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

Catch biomass in year *y*

$$s_a^g = \frac{1}{1 + e^{-2.944439\left(a - \delta_1^g\right)/\delta_2^g}}$$

Logistic selectivity

$$\hat{I}_y = q^g \sum_{a_0}^{a_+} N_{y,a} \frac{s_a^g}{\max\left(s_a^g\right)} w_a$$

Survey biomass index

$$\hat{P}_{y,\cdot}^g = N_y s^g \left(\sum_{a_0}^{a_+} N_{y,a} s_a^g\right)^{-1} \mathbf{A}$$

Vector of fishery or survey predicted proportions at age

$$\hat{P}_{y,\cdot}^g = N_y s^g \left(\sum_{a_0}^{a_+} N_{y,a} s_a^g\right)^{-1} \mathbf{A}^l$$

Vector of fishery or survey predicted proportions at length

Box 1. (continued)

Posterior distribution components	**Model Description** (continued)
$L_C = \lambda_c \sum_y \left(\ln C_y - \ln \hat{C}_y \right)^2 / \left(2\sigma_C^2 \right)$	Catch likelihood
$L_I = \lambda_I \sum_y \left(\ln B_y^{Survey} - \ln \hat{B}_y^{Survey} \right)^2 / \left(2\sigma_y^{Survey^2} \right)$	Survey biomass index likelihood
$L_{age} = \lambda_{age} \sum_{i=1}^{n_g} -\psi_y^g \sum_{a_0}^{a_+} \left(P_{i,a}^g + v \right) \ln \left(\hat{P}_{i,a}^g + v \right)$	Age composition likelihood
$L_{length} = \lambda_{length} \sum_{i=1}^{n_g} -\psi_y^g \sum_{l=1}^{\Omega} \left(P_{i,l}^g + v \right) \ln \left(\hat{P}_{i,l}^g + v \right)$	Length composition likelihood (ψ_y^g =sample size, n_g = number of years of data for gear *g*, *i* = year of data availability, *v* is a constant set at 0.01)
$L_h = \left(\ln \hat{h} - \ln h_\mu \right)^2 / 2\sigma_h^2$	Prior for stock-recruitment steepness, when estimated
$L_q = \left(\ln \hat{q}^g - \ln q_\mu^g \right)^2 / 2\sigma_q^2$	Prior on survey catchability coefficient for gear *g*
$L_M = \left(\ln \hat{M} - \ln M_\mu \right)^2 / 2\sigma_M^2$	Prior for natural mortality
$L_{\sigma_r} = \left(\ln \hat{\sigma}_r - \ln \sigma_{r_\mu} \right)^2 / 2\sigma_{\sigma_r}^2$	Prior distribution for σ_r (if estimated)
$L_\tau = \sum_{y=1}^{T} \frac{\tau_y^2}{2\hat{\sigma}_r^2} + \ln \hat{\sigma}_r$	Prior on recruitment deviations.
$L_f = \lambda_f \sum_{y=1}^{T} \phi_y^2$	Regularity penalty on fishing mortality
$L_s = \lambda_s \sum_{a_0+1}^{a_+} \mathrm{I} \left(s_a^g < s_{a-1}^g \right) \left(s_{a-1}^g - s_a^g \right)^2$	Selectivity non-decreasing penalty – "**I**" represents indicator function (1 if true, 0 if false). Only used if selected.
$L_{s_a} = \lambda_{s_a} \sum_{a_0}^{a_+-2} \left(s_{a+2}^g + s_a^g - 2s_{a+1}^g \right)^2$	Selectivity smoothness penalty (squared second differences). Only used if selected.
$L_{Total} = \sum_x L_x$	Total objective function value

Model Evaluation

We consider two model model configurations:

Model Number	Model Description
Model 1 (Base case)	• Model from Heifetz et al. (2007)
Model 2	• Update all data • Change method for year specific likelihood weights

Model 1 is the base model from 2007. Only changes that have occurred were appending new data. This data includes updated catch, 2007 survey age composition, 2009 biomass estimate, and the 2007 fishery length composition. This model had a mix of weighting methods depending on the data source. To make weighting methods more consistent Model 2 was developed.

Model 2 is structurally similar to Model 1. The main difference is the method of assigning year specific likelihood weights (ψ_y^g: Box 1) for fishery and survey age and size compositions. For Model 1 and previous assessments different methods were used depending on the data source. Here we use a “hybrid” approach that is consistent for all data sets. This method combines both the number hauls and the number of samples such that the year specific likelihood weight is equal to the square root of the product of the number of hauls and the samples scaled to a maximum of 50 for each data source. This change in the method of weighting results in a better balance in the influence that each data set has on assessment results. Previously survey age and fishery age were weighted considerably higher than fishery age data. This model also included some routine data maintenance. Some of the input data has changed because of database screening, strata area recalculation for the biomass index, or compositional data updates.

Comparison of likelihood values and estimated parameter values between models are shown in Table 10.10. Both models have similar properties compared to previous model results: Poor fit to the high survey biomass estimates of 1999, 2001, 2005, and 2007 and a reasonable fit to the low survey biomass estimates. When compared with the 2007 application of Model 1, the major change for the current application of Model 1 is the large reduction in the estimate of *q,* the survey catchability coefficient (previously 0.74 compared to 0.60; Table 10.10). This results in a considerably higher estimated stock level than that previously estimated. We are uncomfortable with the lower estimate of *q* for Model 1 because of its implication for a considerably higher stock biomass than previous estimates. Model 2 has an overall better balance in the fits to age and length composition data than Model 1 and a better fit to the survey biomass index (Table 10.10). Also the estimate of *q* is similar to the previous assessment. Therefore, we favor Model 2.

Model Results

Definitions

Spawning biomass is the biomass estimate of mature females. Total biomass is the biomass estimate of all northern rockfish age two and greater. Recruitment is measured as number of age two northern rockfish. Fishing mortality is fully-selected *F*, meaning the mortality at the age the fishery has fully selected the fish.

Parameter estimates from Model 2 were similar to the previous northern rockfish assessment (Table 10.10 and 10.11). The $F_{40\%}$ reference value changed slightly from 0.061 to 0.059 reflecting slight changes in the fishery selectivity estimates. Comparison of fishery selectivity between the previous and the current assessment:

	Age												
	2	3	4	5	6	7	8	9	10	11	12	13	14+
Previous assessment	0%	0%	0%	1%	3%	9%	27%	57%	83%	95%	99%	100%	100%
Current assessment	0%	0%	0%	1%	4%	12%	33%	65%	87%	96%	99%	100%	100%

The estimates of current population abundance indicate that it is dominated by older fish from the 1976 and 1984 year class, and the above average 1994 year-classes (Table 10.5). The fit to the survey biomass index fails to capture the apparent increase in northern rockfish indicated by point estimates of the 2005 and 2007 trawl surveys (Fig. 10.4). This is not surprising given the wide confidence intervals associated with these surveys. Fits to the fishery and survey age compositions were reasonable but the “plus group” (age 23 and older) were sometimes underestimated compared to the observed values (Fig. 10.2 and 10.6). The model did not fit the fishery size comps well in the 1990s but fits very well in the 2000s (Fig. 10.3)

Selectivity estimates for the fishery and the survey are similar, but with the survey being somewhat more gradual with age. Compared to the maturity at age curve that is used, selectivity occurs at slightly younger ages than the age of maturity (Fig. 10.9, Table 10.13).

Recruitment estimates for Model 2 show a high degree of uncertainty, but indicate 3 large year-classes (Table 10.5 and Fig. 10.10). The pattern of stock-recruitment suggest that environmental variability plays a large role in determining recruitment strengths. Overall, the current status of the stock appears to be reasonably healthy and about equal to stock levels estimated last year and for the late 1970s (Fig. 10.11). The trajectory of fishing mortality has remained below the $F_{40\%}$ level most of the time and below $F_{35\%}$ in all years except 1964-66 during the period of intense fishing for Pacific ocean perch (Fig. 10.12).

Model 2 implies a somewhat higher stock biomass than results from our previous full assessment of 2007. For example for 2010, total biomass for Model 2 is projected to be 103,300 t, whereas previously we had projected total biomass in 2010 of 88,430 t. The point estimate for the 2009 survey biomass index is much lower than the 2005 and 2007 estimates, which perhaps implies that stock levels are lower than in our previous assessment (Fig. 10.4). However the previous model was predicting an even lower biomass estimate of about 60,000 t for 2010 (Fig. 10.4). The 2009 survey estimate of 89,900 t was relatively precise and was considerably higher than the 2007 prediction. Therefore, the 2009 survey estimate suggests a higher stock biomass level than our previous assessment.

To more fully understand the influence of the 2009 survey we conducted an exploratory model run that essentially ignored the biomass estimate from the 2009 survey by increasing the standard error for this estimate. Results from this run were more in line with our previous assessment. For example 2010 total biomass from this run is 88,280 t, similar to the 2010 projection of 88,430 t from our previous model.

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. In the management path we plot the ratio of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to unfished biomass ($B_{100\%}$). Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The historical management path for northern rockfish has been above the F_{OFL} adjusted limit for only a few years in the 1960s. In recent years, northern rockfish have been above $B_{40\%}$ and below $F_{40\%}$ (Figure 10.12).

Uncertainty Distributions

From the MCMC chains described in the *uncertainty approach* section, we summarize the posterior densities of key parameters for the recommended model using histograms (Figure 10.13). We also use these posterior distributions to show uncertainty around time series estimates such as spawning biomass (Fig. 10.14). The distributions of $F_{40\%}$, *ABC*, total biomass, and spawning biomass are skewed, indicating there is a possibility of biomass being higher than model estimates.

Projections and Harvest Alternatives

Amendment 56 reference points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines "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. Estimates of reference points related to maximum sustainable yield (MSY) for GOA northern rockfish are currently available. Tier 3 proxies from Amendment 56 are therefore presented. The following values from Model 2 results were computed based on recruitment from post-1976 spawning event (in t of female spawning biomass):

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
61,370	24,550	21,480	0.059	0.071

Specification of OFL and maximum permissible ABC

The female spawning biomass for 2010 is estimated at 34,790 t. This is above the $B_{40\%}$ value of 24,550 t. Under Amendment 56, Tier 3, the maximum permissible fishing mortality for ABC is $F_{40\%}$ and fishing mortality for OFL is $F_{35\%}$. Applying these fishing mortality rates for 2010, yields the following ABC and OFL:

Year	OFL	Max ABC
2010	6,070	5,100
2011	5,730	4,810

The overfishing level is not apportioned by area for Gulf of Alaska northern rockfish.

ABC recommendation

Based on this year's recommended assessment model, the projected female spawning biomass in 2010 is 34,790 t. The value for $B_{35\%}$ is estimated at 21,480 t as determined from average recruitment of the 1977-2005 year-classes (recruits from years 1979 – 2007). While we believe there is some concern for this stock given the lack of strong recruitment in recent years, we continue to recommend that $F_{40\%}$ be used as the basis for ABC calculations. We recommend that the ABC for northern rockfish for the 2010 fishery in the Gulf of Alaska be set at 5,100 t. This ABC is a 17% increase over the 2009 ABC of 4,362.

Population projections

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

For each scenario, the projections begin with the vector of 2009 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2010 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2009. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch after 2009 is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2010, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the catch in 2009 to the ABC recommended in the assessment for 2009. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.) In this scenario we use the ratio of most recent catch to ABC, and apply it to estimated ABCs for 2010 and 2011 to determine the catch for 2010 and 2011, then maximum permissible thereafter. Projections incorporating estimated catches help produce more accurate projections for fisheries that do not utilize all of the TAC.
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2005-2009 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above 1) above its MSY level in 2009 or 2) above ½ of its MSY level in 2009 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2010 and 2011, F is set equal to *max* F_{ABC}, and in all subsequent years F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2022 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios (Table 10.14). The difference for this assessment for projections is in Scenario 2 (Author's F); we use pre-specified catches to increase accuracy of short-term projections in fisheries (such as sablefish) where the catch is usually less than the ABC. This was suggested to help management with setting preliminary ABCs and OFLs for 2010 and 2011. In this scenario we use the ratio of most recent catch to ABC, and apply it to estimated ABCs for 2010 and 2011 to determine the catch for 2010 and 2011, then set catch at maximum permissible thereafter.

Status determination

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2010, it does not provide the best estimate of OFL for 2011, because the mean 2010 catch under Scenario 6 is predicated on the 2010 catch being equal to the 2010 OFL, whereas the actual 2010 catch will likely be less than the 2009 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2008) is 4,052 t. This is less than the 2008 OFL of 5,430 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2009:
a. If spawning biomass for 2009 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2009 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2009 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 10.14). If the mean spawning biomass for 2019 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:
a. If the mean spawning biomass for 2012 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2012 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2012 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2022. If the mean spawning biomass for 2022 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 10.14, the stock is not overfished and is not approaching an overfished condition.

Alternate Projection

During the 2006 rockfish CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. We continue to present an alternative projection scenario using the uncertainty of the full assessment model, harvesting at *author's F* (0.87 maximum permissible based on recent ratios of catch to ABC). This is conservative relative to a maxABC or alternative 1 projection scenario. This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 10,000,000. The projection shows wide credibility intervals on future spawning biomass (Fig. 10.14). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1977-2005 year classes, and this projection predicts that the median spawning biomass will eventually dip near these reference points when harvesting at a proportion of 0.87 of $F_{40\%}$. Spawning biomass then begins to increase as average recruitment fills in for the recent low recruitments.

Apportionment of ABC

Since 1996 for slope rockfish including northern rockfish, the apportionment of ABC among areas has been determined from the weighted average of the proportion of exploitable biomass by area in the most recent three triennial trawl surveys. Assuming that survey error contributes 2/3 of the total variability in predicting the distribution of biomass, the weight of a prior survey should be 2/3 the weight of the preceding survey. This results in weights of 4:6:9 for the 2005, 2007, and 2009 surveys, respectively.

Based on the tables below area apportionments for Gulf of Alaska northern rockfish are 52.99% for the Western area, 46.96% for the Central area, and 0.05% for the Eastern area. Applying these apportionments to the recommended ABC for northern rockfish results in 2,703 t for the Western area, 2,395 t for the Central area, and 2 t for the Eastern area. For management purposes, the small ABC of northern rockfish in the Eastern area is combined with other slope rockfish.

Estimated trawl survey biomass by area for northern rockfish in the Gulf of Alaska.

	Western	Central		Eastern		
Year	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2005	231,138	102,605	25,123	160	0	359,026
2007	114,222	92,250	20,559	38	0	227,069
2009	44,693	8,842	36,290	70	0	89,896

Percentage of trawl survey biomass by area and 2010 apportionment of ABC for northern rockfish in the Gulf of Alaska.

		Western	Central		Eastern		
Year	Weights	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2005	4	64.38%	28.58%	7.00%	0.04%	0.00%	100%
2007	6	50.30%	40.63%	9.05%	0.02%	0.00%	100%
2009	9	49.72%	9.84%	40.37%	0.08%	0.00%	100%
Weighted average		52.99%	46.96%		0.05%		100.00%
Area ABC		**2,703**	**2,395**		**2**		**5,100**

Ecosystem Considerations

In general, a determination of ecosystem considerations for slope 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 10.15.

Ecosystem Effects on the Stock

Prey availability/abundance trends: Similar to many other rockfish species, stock condition of slope rockfish appears to be influenced by periodic abundant year-classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval northern 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 slope rockfish is difficult. Visual identification is not possible, though genetic techniques allow identification to species level for larval slope rockfish (Gharrett et al. 2001). Some juvenile rockfish found in inshore habitat feed on shrimp, amphipods, and other crustaceans, as well as some mollusk and fish (Byerly 2001). Adult slope rockfish such as Pacific ocean perch and northern rockfish feed on euphausiids. Adult rockfish such as shortraker and rougheye are probably opportunistic feeders with more mollusks and fish in their diet. Little if anything is known about abundance trends of likely rockfish prey items. Euphausiids are also a major item in the diet of walleye pollock. Changes in the abundance of walleye pollock could lead to a corollary change in the availability of euphausiids, which would then have an impact on Pacific ocean perch and northern rockfish.

Predator population trends: Rockfish are preyed on by a variety of other fish at all life stages and to some extent by marine mammals during late juvenile and adult stages. Whether or not 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 slope rockfish, but information on these life stages and their predators is nil.

Changes in physical environment: Strong year-classes corresponding to the period around 1977 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 slope rockfish. Pacific ocean perch appear to have had a strong 1986 or 1987 year-class, and northern rockfish appear to have had a strong 1984 year-class. There may be other years when environmental conditions were especially favorable for rockfish species. The environmental mechanism for this increased survival remains unknown. Changes in water temperature and currents could have effects 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. Submersible studies on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). The Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of groundfish is minimal or temporary based largely on the the criterion that groundfish stocks were above Minimum Stock Size Threshold (MSST). However, such criteria is inadequate to make such a conclusion (Drinkwater 2004). While proof of adverse effect on habitat would be difficult to obtain, the lack of an increasing trend in stock abundance and relatively low levels of recent recruitment are not supportive of the EIS conclusions.

Rockfish fishery effects on the ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the Gulf of Alaska, bottom trawl fisheries for pollock, deepwater flatfish, and Pacific ocean perch account for most of the observed bycatch of coral, while rockfish fisheries account for little of the bycatch of sea anemones, sea whips, and sea pens. The bottom trawl fisheries for Pacific ocean perch and Pacific cod and the pot fishery for Pacific cod account for most of the observed bycatch of sponges (Table 10.16).

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: The directed slope rockfish trawl fishery that begins in July is concentrated in known areas of abundance and typically lasts only a few weeks. The annual exploitation rates on rockfish are thought to be quite low. Insemination is likely in the fall or winter, and parturition is likely mostly in the spring. Hence, reproductive activities are probably not directly affected by the commercial fishery.

Fishery-specific effects on amount of large size target fish: No evidence for targeting large fish.

Fishery contribution to discards and offal production: Fishery discard rates of northern rockfish during 2002-2009 have been 2.8 - 9 .8%.

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

Fishery-specific effects on EFH living and non-living substrate: Unknown, but the heavy-duty "rockhopper" trawl gear commonly used in the fishery can disturb seafloor habitat. Table 10-16 shows the estimated bycatch of living structure such as benthic urochordates, corals, sponges, sea pens, and sea anemones by the GOA rockfish fisheries. The average bycatch of corals/bryozoans (1652 kg), sea anemones (1554 kg), and sponges (2473 kg) by rockfish fisheries in the GOA represented 61%, 8%, and 42% respectively of those species taken by all Gulfwide fisheries.

Data Gaps and Research Priorities

Life history and habitat utilization

There is little information on larval, post-larval, or early life history stages of northern 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 major fishing grounds, on what HAPC biota are found on these grounds, and on what impact bottom trawling may have on these biota.

Assessment Data

The highly variable biomass estimates for northern rockfish suggest that the stratified random design of the surveys does a relatively poor job of assessing stock condition of northern rockfish and that a different survey approach may be needed to reduce the variability in biomass estimates. In particular, the CIE review report recommended that assumptions about extending area-swept estimates of biomass in trawlable versus untrawlable may impact catchability assumptions. The AFSC is currently undertaking a study on habitat classifications so that assumptions about catchability can be more rigorously established. For northern rockfish and the other Gulf of Alaska rockfish assessed with age-structured models, we plan to focus on optimizing and taking a consistent approach to the methods we use for multinomial sample sizes, the way we choose our bins for age and length compositions, and to examine growth for changes over time.

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Table 10.1 Commercial catch (t) and management action for northern rockfish in the Gulf of Alaska, 1961-present. The *Fishery* Section describes procedures used to estimate catch during 1961-1993. Catch estimates for 1993-2009 are from NMFS Observer Program and Alaska Regional Office updated through October 3, 2009.

Year	Foreign	Joint venture	Domestic	Total	TAC	%TAC
1961	800	-	-	800	-	-
1962	3,250	-	-	3,250	-	-
1963	6,815	-	-	6,815	-	-
1964	12,170	-	-	12,170	-	-
1965	17,430	-	-	17,430	-	-
1966	10,040	-	-	10,040	-	-
1967	6,000	-	-	6,000	-	-
1968	5,010	-	-	5,010	-	-
1969	3,630	-	-	3,630	-	-
1970	2,245	-	-	2,245	-	-
1971	3,875	-	-	3,875	-	-
1972	3,880	-	-	3,880	-	-
1973	2,820	-	-	2,820	-	-
1974	2,550	-	-	2,550	-	-
1975	2,520	-	-	2,520	-	-
1976	2,275	-	-	2,275	-	-
1977	622	-	-	622	-	-
1978	553	-	-	554	-	-
1979	666	3	-	670	-	-
1980	809	tr	-	810	-	-
1981	1,469	-	-	1,477	-	-
1982	3,914	-	-	3,920	-	-
1983	2,705	911	-	3,618	-	-
1984	494	497	10	1,002	-	-
1985	tr	115	70	185	-	-
1986	tr	11	237	248	-	-
1987	-	56	427	483	-	-
1988[1]	-	tr	1,107	1,107	-	-
1989	-	-	1,527	1,527	-	-
1990	-	-	1,697	1,716	-	-
1991[2]	-	-	4,528	4,528	-	-
1992	-	-	7,770	7,770	-	-
1993[3]	-	-	4,825	4,846	5,760	84%
1994	-	-	5,968	5,968	5,760	104%
1995	-	-	5,634	5,634	5,270	107%
1996	-	-	3,343	3,356	5,270	63%
1997	-	-	2,947	2,947	5,000	59%
1998	-	-	3,055	3,058	5,000	61%
1999	-	-	5,399	5,412	4,990	108%
2000	-	-	3,325	3,325	5,120	65%
2001	-	-	3,127	3,150	4,880	64%
2002	-	-	3,337	3,337	4,770	70%
2003	-	-	5,349	5,349	5,530	97%
2004	-	-	4,806	4,806	4,870	98%
2005	-	-	4,806	4,806	5,091	94%
2006	-	-	4,956	4,956	5,091	93%
2007			4,187	4,187	4,938	85%
2008			4,052	4,052	4,549	89%
2009*			3,843	3,843	4,362	88%

[1] 1988 - Slope rockfish assemblage management implemented by NPFMC.

[2]1991 - Slope rockfish divided into 3 management subgroups: Pacific ocean perch, shortraker/ rougheye, and other slope rockfish.

[3]1993 A fourth management subgroup, northern rockfish was created.

[*] Central Gulf Rockfish Pilot Project implemented for rockfish fishery. *Catch as of 10/10/2009

Table 10.2 Catch (t) of northern rockfish taken during research cruises in the Gulf of Alaska, 1977-2009. (Tr.=trace)

Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Catch	Tr.	0.5	1	0.5	8.4	6.4	1.7	11.3	10.8	0.7	40.6	0	0.2	19.2	0	0
Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Catch	20.8	0	0	12.5	0	2.5	13.2	0	23.4	0	6.8	0	27.12	0	21.7	0
Year	2009															
Catch	7.2															

Table 10.3 Fishery length and age samples available for the northern rockfish assessment in the Gulf of Alaska.

	Length composition		Age composition	
Year	# Fish	# Hauls*	# Fish	# Hauls*
1990	4,909	53	0	0
1991	15,466	155	0	0
1992	15,207	125	0	0
1993	12,541	110	0	0
1994	8,905	98	0	0
1995	12,370	135	0	0
1996	12,496	176	0	0
1997	5,262	74	0	0
1998	10,615	137	498	51
1999	5,287	248	308	160
2000	3,898	280	585	187
2001	3,001	261	451	156
2002	3,802	283	616	187
2003	7,387	498	0	0
2004	5,403	370	746	270
2005	4,208	301	422	211
2006	4,769	317	500	206
2007	7,944	587		
2008	7,384	81		
2009	4,779	43		

* Note that the number of hauls includes the number of observed at-sea hauls plus the number of observed port samples from the commercial fishery.

Table 10.4 Fishery length (cm) compositions available for northern rockfish in the Gulf of Alaska (at-sea and port samples combined).

Length class (cm)	1990	1991	1992	1993	Year 1994	1995	1996	1997	1998	1999
15	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.005	0.001	0.000	0.000	0.000	0.000	0.001
22	0.000	0.001	0.000	0.005	0.001	0.001	0.000	0.000	0.000	0.000
23	0.002	0.002	0.000	0.006	0.001	0.001	0.000	0.000	0.001	0.001
24	0.004	0.002	0.000	0.008	0.001	0.002	0.001	0.002	0.001	0.001
25	0.006	0.002	0.000	0.008	0.002	0.004	0.002	0.006	0.000	0.002
26	0.005	0.004	0.000	0.007	0.006	0.007	0.006	0.014	0.001	0.003
27	0.011	0.005	0.000	0.008	0.008	0.011	0.007	0.020	0.001	0.005
28	0.016	0.008	0.001	0.012	0.013	0.011	0.005	0.021	0.002	0.004
29	0.023	0.011	0.003	0.015	0.013	0.013	0.007	0.021	0.003	0.007
30	0.026	0.023	0.006	0.018	0.016	0.017	0.011	0.019	0.007	0.011
31	0.029	0.041	0.015	0.028	0.025	0.021	0.010	0.014	0.010	0.021
32	0.039	0.071	0.032	0.046	0.038	0.029	0.019	0.015	0.018	0.028
33	0.049	0.122	0.053	0.074	0.070	0.049	0.036	0.029	0.028	0.039
34	0.075	0.179	0.094	0.100	0.111	0.085	0.061	0.054	0.046	0.051
35	0.122	0.194	0.139	0.140	0.161	0.126	0.109	0.115	0.084	0.063
36	0.173	0.144	0.157	0.148	0.183	0.151	0.151	0.159	0.137	0.104
37	0.159	0.090	0.154	0.113	0.157	0.156	0.169	0.173	0.178	0.137
38+	0.260	0.102	0.346	0.238	0.193	0.317	0.406	0.337	0.484	0.521
Sample size	4,909	15,466	15,207	12,541	8,905	12,370	12,496	5,262	10,615	5,287

Table 10.4 (continued) Fishery length (cm) compositions available for northern rockfish in the Gulf of Alaska (at-sea and port samples combined).

Length class (cm)	Year 2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
15	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.003	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.004	0.001	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000
22	0.004	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.004	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.005	0.001	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.001
25	0.003	0.000	0.005	0.001	0.001	0.001	0.001	0.001	0.000	0.000
26	0.005	0.003	0.003	0.004	0.003	0.000	0.002	0.001	0.001	0.000
27	0.006	0.006	0.010	0.006	0.005	0.003	0.004	0.002	0.001	0.001
28	0.012	0.009	0.011	0.007	0.009	0.006	0.008	0.003	0.002	0.002
29	0.013	0.024	0.022	0.016	0.011	0.009	0.012	0.006	0.004	0.001
30	0.016	0.032	0.039	0.027	0.017	0.017	0.022	0.012	0.010	0.006
31	0.022	0.037	0.055	0.044	0.026	0.030	0.038	0.016	0.019	0.010
32	0.035	0.042	0.087	0.064	0.042	0.043	0.051	0.033	0.028	0.016
33	0.041	0.047	0.088	0.083	0.055	0.072	0.065	0.046	0.039	0.028
34	0.055	0.057	0.074	0.083	0.077	0.098	0.078	0.065	0.059	0.046
35	0.069	0.069	0.061	0.085	0.078	0.118	0.097	0.088	0.076	0.085
36	0.094	0.085	0.066	0.072	0.089	0.123	0.101	0.104	0.096	0.106
37	0.116	0.118	0.084	0.076	0.089	0.097	0.092	0.118	0.099	0.114
38+	0.490	0.467	0.382	0.431	0.497	0.382	0.429	0.505	0.564	0.582
Sample size	3,898	3,001	3,802	7,387	5,403	4,208	4,769	7,944	7,384	4,779

Table 10.5 Fishery age compositions for northern rockfish in the Gulf of Alaska. All age compositions are based on "break and burn" reading of otoliths.

	Year							
Age	1998	1999	2000	2001	2002	2004	2005	2006
2	0.000	0.006	0.002	0.000	0.000	0.001	0.000	0.000
3	0.004	0.003	0.024	0.011	0.000	0.015	0.000	0.006
4	0.006	0.006	0.005	0.055	0.032	0.008	0.021	0.002
5	0.034	0.000	0.015	0.024	0.151	0.036	0.045	0.046
6	0.022	0.042	0.019	0.031	0.070	0.111	0.066	0.064
7	0.032	0.013	0.043	0.038	0.055	0.176	0.147	0.070
8	0.058	0.029	0.031	0.049	0.042	0.050	0.164	0.132
9	0.070	0.039	0.058	0.042	0.044	0.035	0.052	0.070
10	0.094	0.049	0.053	0.053	0.047	0.036	0.017	0.048
11	0.094	0.062	0.048	0.051	0.032	0.028	0.031	0.034
12	0.068	0.127	0.074	0.040	0.031	0.027	0.038	0.034
13	0.078	0.065	0.094	0.053	0.047	0.032	0.026	0.020
14	0.034	0.058	0.067	0.084	0.068	0.015	0.019	0.016
15	0.034	0.042	0.060	0.060	0.067	0.025	0.031	0.038
16	0.022	0.019	0.024	0.044	0.032	0.046	0.026	0.028
17	0.026	0.023	0.022	0.027	0.026	0.058	0.033	0.020
18	0.044	0.032	0.010	0.035	0.023	0.035	0.045	0.040
19	0.050	0.029	0.043	0.018	0.021	0.029	0.024	0.050
20	0.227	0.354	0.309	0.284	0.211	0.237	0.216	0.282
21	1998	1999	2000	2001	2002	2004	2005	2006
22	0.000	0.006	0.002	0.000	0.000	0.001	0.000	0.000
23+	0.004	0.003	0.024	0.011	0.000	0.015	0.000	0.006
Sample size	498	308	585	451	616	746	422	500

Table 10.6 Biomass estimates (t), by statistical area, for northern rockfish in the Gulf of Alaska based on triennial and biennial trawl surveys. Gulfwide CV's are also listed.

	Statistical areas						
Year	Shumagin	Chirikof	Kodiak	Yakutat	South-eastern	Total	CV
1984	27,716	5,165	6,448	5	0	39,334	29%
1987	45,038	13,794	77,084	500	0	136,417	29%
1990	32,898	5,792	68,044	343	0	107,076	42%
1993	13,995	40,446	49,998	41	0	104,480	35%
1996	28,114	40,447	30,212	192	0	98,965	27%
1999	45,457	29,946	166,665	118	0	242,187	61%
2001	93,291	24,490	225,833	117a	0a	343,731	60%
2003	9,146	49,793	7,336	5	0	66,310	48%
2005	231,138	102,605	25,123	160	0	359,026	37%
2007	114,222	92,250	20,559	38	0	227,069	38%
2009	44,693	8,842	36,290	70.2	0	89,896	32%

[a]Biomass estimates are not available for the Yakutat and Southeastern areas in 2001 because these areas were not sampled that year. Substitute values are listed in this table and were obtained by averaging the biomass estimates for each of these areas in the 1993, 1996, and 1999 surveys.

Table 10.7 Northern rockfish survey length and age samples available for the Gulf of Alaska.

	Length composition		Age composition	
Year	# Fish	# Hauls*	# Fish	# Hauls*
1984	4,235	50	356	6
1987	9,584	82	497	17
1990	3,091	48	331	12
1993	4,384	106	242	17
1996	4,239	131	462	19
1999	3,471	124	278	27
2001	3,810	106	466	85
2003	2,941	126	216	22
2005	4,556	147	417	72
2007	4,723	139	605	82
2009	2,849	132		

* Note that the number of hauls used for length composition in the current assessment is the number of hauls used to estimate population numbers at length from the NMFS bottom-trawl survey which are limited to good performance survey tows and which may be less than the number of hauls from which specimens were collected for age determination (e.g, 2001).

Table 10.8 Survey length (cm) compositions available for northern rockfish in the Gulf of Alaska, 1984-2009.

Length					Year					
class (cm)	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007
15	0.010	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.007	0.004	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
17	0.005	0.005	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000
18	0.008	0.004	0.000	0.001	0.001	0.000	0.003	0.000	0.000	0.000
19	0.006	0.005	0.001	0.001	0.001	0.001	0.002	0.001	0.000	0.000
20	0.005	0.008	0.001	0.000	0.001	0.001	0.002	0.001	0.000	0.000
21	0.003	0.009	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000
22	0.005	0.010	0.003	0.002	0.002	0.002	0.002	0.002	0.000	0.000
23	0.008	0.012	0.005	0.003	0.002	0.003	0.001	0.004	0.000	0.000
24	0.017	0.013	0.012	0.003	0.002	0.002	0.002	0.006	0.001	0.000
25	0.022	0.015	0.011	0.007	0.003	0.002	0.002	0.007	0.000	0.002
26	0.027	0.015	0.030	0.005	0.007	0.006	0.004	0.018	0.001	0.002
27	0.045	0.017	0.024	0.007	0.008	0.002	0.005	0.011	0.001	0.006
28	0.052	0.022	0.017	0.008	0.006	0.006	0.008	0.007	0.001	0.002
29	0.089	0.044	0.017	0.007	0.008	0.002	0.005	0.010	0.063	0.006
30	0.095	0.071	0.013	0.012	0.009	0.003	0.010	0.015	0.034	0.003
31	0.102	0.118	0.022	0.014	0.016	0.002	0.011	0.021	0.012	0.007
32	0.093	0.140	0.038	0.041	0.020	0.027	0.023	0.040	0.013	0.018
33	0.074	0.130	0.090	0.055	0.027	0.031	0.017	0.064	0.021	0.038
34	0.060	0.122	0.126	0.091	0.034	0.035	0.053	0.077	0.025	0.061
35	0.051	0.087	0.139	0.147	0.059	0.054	0.051	0.063	0.031	0.069
36	0.058	0.067	0.118	0.162	0.121	0.078	0.121	0.078	0.052	0.083
37	0.049	0.034	0.102	0.123	0.118	0.128	0.127	0.071	0.055	0.091
38+	0.110	0.044	0.229	0.311	0.552	0.614	0.549	0.503	0.686	0.609
Sample size	4,235	9,584	3,091	4,384	4,239	3,471	3,810	2,941	4,556	4,723

Table 10.8 (continued) Survey length (cm) compositions for northern rockfish in the Gulf of Alaska, 1984-2009.

Length class (cm)	Year 2009
15	0.001
16	0.001
17	0.000
18	0.001
19	0.001
20	0.001
21	0.001
22	0.001
23	0.001
24	0.000
25	0.001
26	0.001
27	0.003
28	0.002
29	0.002
30	0.008
31	0.006
32	0.013
33	0.012
34	0.032
35	0.040
36	0.056
37	0.082
38+	0.735
Sample size	2,849

Table 10.9 Survey age compositions for northern rockfish in the Gulf of Alaska. All age compositions are based on "break and burn" reading of otoliths.

	Year									
Age	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007
2	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000
3	0.000	0.003	0.001	0.003	0.002	0.000	0.005	0.001	0.000	0.000
4	0.000	0.018	0.002	0.003	0.001	0.002	0.003	0.001	0.001	0.000
5	0.014	0.055	0.029	0.009	0.002	0.011	0.006	0.035	0.001	0.001
6	0.040	0.041	0.054	0.011	0.011	0.003	0.013	0.021	0.014	0.007
7	0.091	0.030	0.027	0.011	0.006	0.009	0.041	0.014	0.037	0.004
8	0.191	0.003	0.041	0.063	0.021	0.009	0.016	0.096	0.052	0.029
9	0.112	0.029	0.054	0.120	0.041	0.042	0.038	0.126	0.047	0.090
10	0.051	0.101	0.045	0.065	0.053	0.028	0.072	0.056	0.061	0.057
11	0.046	0.112	0.058	0.103	0.085	0.079	0.061	0.036	0.047	0.073
12	0.026	0.112	0.035	0.044	0.076	0.069	0.040	0.029	0.033	0.063
13	0.071	0.034	0.054	0.049	0.077	0.054	0.063	0.021	0.011	0.082
14	0.067	0.043	0.082	0.040	0.040	0.056	0.049	0.051	0.021	0.031
15	0.063	0.014	0.097	0.024	0.033	0.078	0.050	0.033	0.012	0.017
16	0.040	0.037	0.051	0.052	0.039	0.092	0.054	0.043	0.020	0.026
17	0.019	0.103	0.051	0.031	0.017	0.016	0.045	0.000	0.032	0.020
18	0.019	0.041	0.007	0.040	0.034	0.072	0.058	0.018	0.031	0.010
19	0.006	0.080	0.011	0.028	0.054	0.019	0.029	0.030	0.008	0.020
20	0.007	0.027	0.066	0.004	0.088	0.013	0.022	0.061	0.039	0.028
21	0.003	0.026	0.066	0.023	0.028	0.030	0.017	0.012	0.046	0.033
22	0.010	0.007	0.046	0.034	0.031	0.022	0.012	0.021	0.019	0.038
23+	0.126	0.086	0.125	0.242	0.258	0.297	0.309	0.294	0.469	0.370
Sample size	356	497	331	242	462	278	466	216	417	605

Table 10.10 Summary results for GOA northern rockfish stock assessment model. SDNR stands for the standard deviation of normalized residuals—for specified variances to be consistent with the pattern of output residuals, these values should be 1.0. Model 2 is the authors recommended model.

	2007 model	Model 1	Model 2
Likelihood components			
Catch	0.03	0.03	0.04
Survey index	9.57	9.74	8.92
Fishery age data	16.15	18.92	22.36
Survey age data	45.46	48.66	33.91
Fishery size data	31.01	31.92	35.74
Recruit. variability	4.01	4.99	5.10
F penalty	3.96	3.93	3.94
q Prior	0.22	0.64	0.22
M prior	0.00	0.014	0.0002
Subtotal for data	102.23	109.26	100.97
Total	110.42	118.83	110.23
Goodness of fit			
Eff. N Fishery Age	82	70	79
N Input	22	23	66
SDNR	0.44	0.47	0.70
Eff. N Survey Age	40	60	56
N Input	26	38	50
SDNR	0.45	0.61	0.77
Eff. N Fishery Size	40	55	43
N Input	26	37	65
SDNR	0.92	0.54	0.81
Parameter estimates			
Natural Mortality	0.060	0.059	0.060
Survey q	0.744	0.600	0.740
(CV)	(24%)	(27%)	(27%)
2010 SSB	32,274	40,339	34,793
(CV)	(47%)	(41%)	(41%)
F40%	0.061	0.060	0.059

Table 10.11 Summary of results from 2009 compared with 2007 results

	2007	2009	
		BASE + 2009 data	Updated data and likelihood weights
Likelihoods	1	1	2
Catch	0.03	0.03	0.04
Survey Biomass	9.57	9.74	8.92
Fishery Ages	16.15	18.92	22.36
Survey Ages	45.46	48.66	33.91
Fishery Sizes	31.01	31.92	35.74
Data-Likelihood	102.23	109.26	100.97
Penalties/Priors			
Recruitment Devs	4.01	4.99	5.10
Fishery Selectivity	0	0	0
Survey Selectivity	0	0	0
Fish-Sel Domeshape	0	0	0
Survey-Sel Domeshape	0	0	0
Average Selectivity	0	0	0
F Regularity	3.96	3.93	3.94
σ_r prior	0	0	0
q prior	0.22	0.64	0.22
M prior	0.00	0.014	0.0002
Objective Fun Total	110.42	118.83	110.23
Parameter Estimates			
Active parameters			
q	0.744	0.600	0.740
M	0.060	0.059	0.060
σ_r	1.500	1.500	1.500
log-mean-recruitment		3.662	3.555
$F_{40\%}$	0.061	0.060	0.059
Total Biomass	93,391	115,867	103,299
Spawning Biomass	29,170	40,339	34,793
$B_{0\%}$	55,750	65,720	61,368
$B_{40\%}$	22,300	26,288	24,547
ABC ($F_{40\%}$)	4,550	5,770	**5,100**
$F_{35\%}$	0.073	0.071	0.071
OFL ($F_{35\%}$)	5,430	6,870	6,070

Table 10.12 Estimated time series of female spawning biomass, 95% confidence bounds on female spawning biomass, 6+ biomass (age 6 and greater), catch/(6+ biomass), and the number of age two recruits for northern rockfish in the Gulf of Alaska for this year's Model 2 results compared to 2007.

	Spawning Biomass (t)		SSB Confidence Bounds (Hessian)		6+ total biomass (t)		Catch / (6+ total biomass)		Age Two Recruits (millions)	
Year	Current	Previous	Lower	Upper	Current	Previous	Current	Previous	Current	Previous
1977	23,807	24,187	6,939	40,675	77,010	77,651	0.008	0.008	19.4	19.0
1978	24,069	24,441	7,697	40,441	78,168	78,713	0.007	0.007	99.3	87.5
1979	24,620	24,967	8,658	40,582	80,465	80,696	0.008	0.008	22.5	17.9
1980	25,410	25,712	9,759	41,061	82,786	82,791	0.010	0.01	22.0	24.8
1981	26,415	26,646	10,959	41,871	85,706	85,532	0.017	0.017	11.9	10.0
1982	27,419	27,547	12,045	42,793	105,144	102,341	0.037	0.038	20.3	18.2
1983	27,740	27,712	12,367	43,113	108,492	104,217	0.033	0.035	29.5	17.5
1984	28,374	28,147	12,857	43,891	111,761	107,539	0.009	0.009	42.3	37.5
1985	30,165	29,720	14,342	45,988	115,124	110,160	0.002	0.002	12.4	17.3
1986	32,506	31,802	16,260	48,752	120,267	114,558	0.002	0.002	56.1	49.7
1987	35,076	34,060	18,311	51,841	126,789	118,249	0.004	0.004	18.9	16.4
1988	37,767	36,392	20,387	55,147	135,662	125,513	0.008	0.009	13.0	12.2
1989	40,342	38,564	22,269	58,415	137,779	128,095	0.011	0.012	17.2	16.4
1990	42,735	40,526	23,919	61,551	148,025	136,735	0.012	0.013	18.2	13.7
1991	44,923	42,271	25,347	64,499	150,883	138,770	0.030	0.033	8.2	8.7
1992	45,899	42,780	25,588	66,210	149,015	136,520	0.052	0.057	16.4	17.4
1993	45,462	41,880	24,443	66,481	144,072	131,364	0.034	0.037	11.9	11.4
1994	45,827	41,860	24,104	67,550	141,844	128,229	0.042	0.047	11.2	9.4
1995	45,571	41,269	23,170	67,972	136,059	122,578	0.041	0.046	7.5	5.8
1996	45,197	40,619	22,145	68,249	131,852	118,751	0.025	0.028	58.2	42.2
1997	45,413	40,616	21,766	69,060	128,830	115,923	0.023	0.025	25.0	15.1
1998	45,529	40,558	21,366	69,692	125,829	112,886	0.024	0.027	16.1	10.3
1999	45,350	40,241	20,760	69,940	121,713	108,755	0.044	0.05	21.1	18.3
2000	43,946	38,729	19,044	68,848	125,827	109,785	0.026	0.03	26.9	26.5
2001	43,259	37,938	18,083	68,435	126,584	108,279	0.025	0.029	6.6	7.9
2002	42,608	37,152	17,163	68,053	125,868	105,957	0.027	0.031	6.3	7.9
2003	41,949	36,301	16,200	67,698	125,903	105,019	0.042	0.051	7.9	8.7
2004	40,649	34,716	14,538	66,760	125,179	103,979	0.038	0.046	7.9	9.5
2005	39,729	33,462	13,175	66,283	120,907	99,984	0.040	0.048	8.7	10.3
2006	38,910	32,274	11,838	65,982	116,015	95,701	0.043	0.052	10.0	11.2
2007	38,100	31,097	10,450	65,750	110,905	91,228	0.038	0.042	10.7	11.2
2008	37,516		9,302	65,730	106,253		0.038		11.4	
2009	37,516		8,796	66,236	101,719		0.038		11.4	
2010	34,793		6,749	62,836						

Table 10.13 Estimated numbers (thousands) in 2009, fishery selectivity, and survey selectivity of northern rockfish in the Gulf of Alaska based on Model 2. Also shown are schedules of age specific weight and female maturity.

	2009 numbers	Percent	Weight (g)	Fishery	Survey
2	11,361	1	63	0.000	0.009
3	10,706	2	103	0.001	0.020
4	9,458	3	153	0.003	0.040
5	8,329	4	210	0.010	0.081
6	6,845	6	273	0.035	0.157
7	5,858	9	336	0.118	0.281
8	5,505	13	399	0.332	0.452
9	4,030	18	458	0.648	0.635
10	3,883	25	512	0.872	0.785
11	14,322	33	561	0.962	0.885
12	10,143	43	603	0.989	0.942
13	6,963	52	641	0.997	0.972
14	9,702	62	672	0.999	0.986
15	20,367	71	699	1.000	0.993
16	2,371	78	722	1.000	0.997
17	3,236	84	740	1.000	0.999
18	3,107	89	756	1.000	0.999
19	3,902	92	769	1.000	1.000
20	1,778	95	780	1.000	1.000
21	3,591	96	788	1.000	1.000
22	3,084	97	795	1.000	1.000
23+	45,382	98	801	1.000	1.000

Table 10.14 Set of projections of spawning biomass and yield for northern rockfish in the Gulf of Alaska. This set of projections encompasses six harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For a description of scenarios see *Projections and Harvest Alternatives*. All units in t. $B_{40\%}$ = 24,550 t, $B_{35\%}$ = 21,480 t, $F_{40\%}$ = 0.059, and $F_{35\%}$ = 0.071.

Year	Maximum permissible F	Author's F* (prespecified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (t)				
2009	35,631	35,631	35,631	35,631	35,631	35,631	35,631
2010	34,696	34,790	35,035	34,862	35,381	34,563	34,696
2011	33,259	33,600	34,574	33,895	35,946	32,752	33,259
2012	31,743	31,987	33,954	32,805	36,333	30,908	31,621
2013	30,204	30,432	33,217	31,643	36,566	29,087	29,747
2014	28,695	28,906	32,412	30,460	36,679	27,343	27,947
2015	27,282	27,476	31,606	29,324	36,733	25,737	26,287
2016	26,019	26,196	30,853	28,295	36,788	24,325	24,817
2017	24,947	25,108	30,210	27,418	36,903	23,171	23,593
2018	24,069	24,211	29,671	26,690	37,074	22,288	22,639
2019	23,437	23,558	29,311	26,155	37,377	21,674	21,965
2020	23,038	23,141	29,126	25,813	37,834	21,299	21,539
2021	22,833	22,919	29,046	25,643	38,435	21,116	21,313
2022	22,778	22,850	29,110	25,612	39,159	21,081	21,240
			Fishing mortality				
2009	0.042	0.042	0.042	0.042	0.042	0.042	0.042
2010	0.059	0.052	0.030	0.045	-	0.071	0.071
2011	0.059	0.059	0.030	0.045	-	0.071	0.071
2012	0.059	0.059	0.030	0.045	-	0.071	0.071
2013	0.059	0.059	0.030	0.045	-	0.071	0.071
2014	0.059	0.059	0.030	0.045	-	0.071	0.071
2015	0.059	0.059	0.030	0.045	-	0.071	0.071
2016	0.059	0.059	0.030	0.045	-	0.070	0.070
2017	0.059	0.059	0.030	0.045	-	0.067	0.067
2018	0.058	0.058	0.030	0.045	-	0.064	0.064
2019	0.056	0.057	0.030	0.045	-	0.062	0.062
2020	0.055	0.056	0.030	0.045	-	0.061	0.061
2021	0.055	0.055	0.030	0.045	-	0.061	0.061
2022	0.055	0.055	0.030	0.045	-	0.061	0.061
			Yield (t)				
2009	3,843	3,843	3,843	3,843	3,843	3,843	3,843
2010	5,100	5,100	2,586	3,882	-	6,070	5,100
2011	4,777	4,810	2,493	3,688	-	5,730	4,777
2012	4,488	4,522	2,408	3,512	-	5,228	5,346
2013	4,237	4,268	2,334	3,358	-	4,885	4,991
2014	4,025	4,052	2,272	3,228	-	4,596	4,690
2015	3,853	3,877	2,224	3,123	-	4,363	4,446
2016	3,734	3,755	2,197	3,055	-	4,151	4,270
2017	3,674	3,695	2,197	3,030	-	3,880	4,011
2018	3,576	3,610	2,215	3,035	-	3,713	3,820
2019	3,499	3,529	2,242	3,054	-	3,625	3,712
2020	3,463	3,489	2,273	3,080	-	3,593	3,663
2021	3,460	3,481	2,305	3,108	-	3,600	3,657
2022	3,482	3,499	2,337	3,138	-	3,637	3,682

* Projected ABCs and OFLs for 2011 are derived using an expected catch value of 4,436 t for 2010 based on recent ratios of catch to ABC. This is shown in Scenario 2, Author's F.

Table 10.15 Analysis of ecosystem considerations for slope rockfish.

Indicator	*Observation*	*Interpretation*	*Evaluation*
Ecosystem effects on stock			
Prey availability or abundance trends	important for larval and post-larval survival, but no information known	may help to determine year-class strength	possible concern if some information available
Predator population trends	Unknown		little concern for adults
Changes in habitat quality	Variable	variable recruitment	possible concern
Fishery effects on ecosystem			
Fishery contribution to bycatch			
Prohibited species	unknown		
Forage (including herring, Atka mackerel, cod, and pollock)	unknown		
HAPC biota (seapens/whips, corals, sponges, anemones)	fishery disturbing hard-bottom biota, i.e., corals, sponges	could harm the ecosys- tem by reducing shelter for some species	concern
Marine mammals and birds	probably few taken		little concern
Sensitive non-target species	unknown		
Fishery concentration in space and time	little overlap be- tween fishery and reproductive activities	fishery does not hinder reproduction	little concern
Fishery effects on amount of large size target fish	no evidence for tar-geting large fish	large fish and small fish are both in population	little concern
Fishery contribution to discards and offal production	discard rates moderate to high for some species of slope rockfish	little unnatural input of food into the ecosystem	some concern
Fishery effects on age-at-maturity and fecundity	fishery is catching some immature fish	could reduce spawn- ing potential and yield	possible concern

Table 10.15 Estimated bycatch of nontarget species in targeted rockfish in the Gulf of Alaska 2003-2009.

	Estimated Catch (kg)						
Group Name	2003	2004	2005	2006	2007	2008	2009
Benthic urochordata	2	133		44	31	267	1
Birds	215				83	40	18
Brittle star unidentified	161	2	47	93	8	37	26
Corals Bryozoans	1,904	65	6,128	390	2,272	469	340
Eelpouts	30	222	9,604	32	123	376	5
Eulachon	11	205	79	299	51	7	25
Giant Grenadier	139,261	445	134,573	272,059	127,139	163,570	283,684
Greenlings	8,131	6,971	3,564	5,945	7,735	15,083	8,026
Grenadier	473,931	2,830,011	77,036	65,538	70,609	3,429	3,199
Hermit crab unidentified	13	10	40	56	5	6	12
Invertebrate unidentified	382	949	98	40	12	239	306
Large Sculpins	123	43,292	15,478	28,314	26,878	19,788	29,761
Misc crabs	28	342	742	406	135	66	98
Misc crustaceans		24					369
Octopus	654	425	194	468	58	2,893	1,144
Other osmerids	553	145	15	263	89	0	137
Other Sculpins	23,928	15,039	12,175	3,896	4,488	3,502	3,810
Pandalid shrimp	916	297	235	172	113	108	88
Scypho jellies	650	2,982	151	429	206	112	696
Sea anemone unidentified	2,892	2,965	298	619	205	690	3,206
Sea pens whips		2	44			19	14
Sea star	3,218	2,128	1,457	2,218	657	1,157	1,813
Shark, Other	208	221	178	1,614	397	37	5
Shark, pacific sleeper	275	753	150	386	39	1,110	274
Shark, salmon	12	120	500	620	492	722	381
Shark, spiny dogfish	35,460	2,296	2,812	2,002	6,216	4,785	1,350
Skate, Big		6,635	4,622	4,210	128	3,721	3,604
Skate, Longnose	864	16,417	8,941	8,093	15,035	10,863	13,228
Skate, Other	104,657	10,380	45,017	35,787	16,664	8,086	10,985
Snails	423	304	153	799	68	184	11,902
Sponge unidentified	3,815	1,141	1,138	956	646	2,970	6,642
Squid	9,139	11,940	1,525	10,226	3,052	5,235	13,875
urchins dollars cucumbers	353	616	162	298	168	258	660

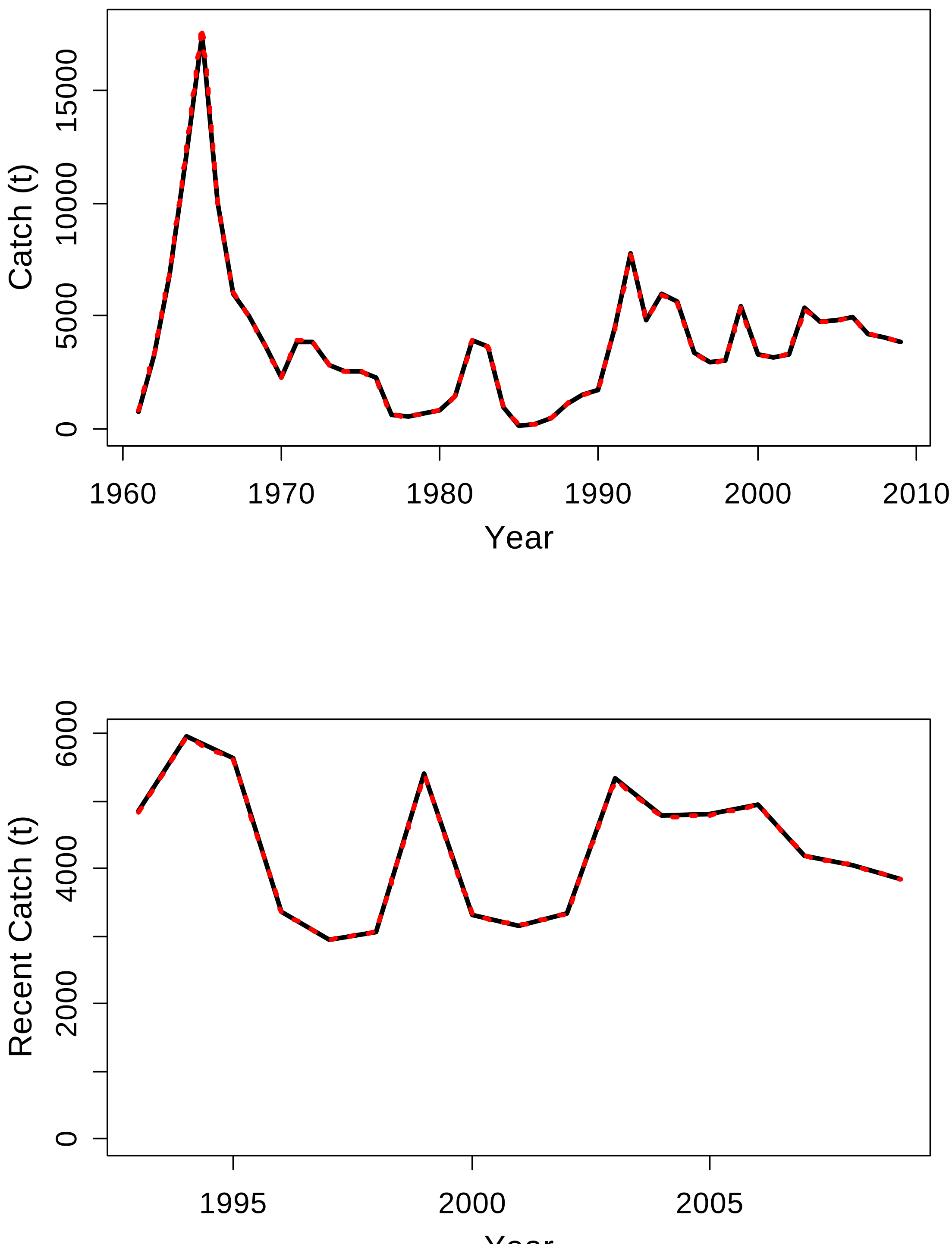


Figure 10.1 Estimated long-term and recent commercial catch of northern rockfish in the Gulf of Alaska. The *Fishery* section describes the procedures used to estimate catch for the years 1965-1993. Catch for the years 1993-2009 is from NMFS Observer Program and Alaska Regional Office.

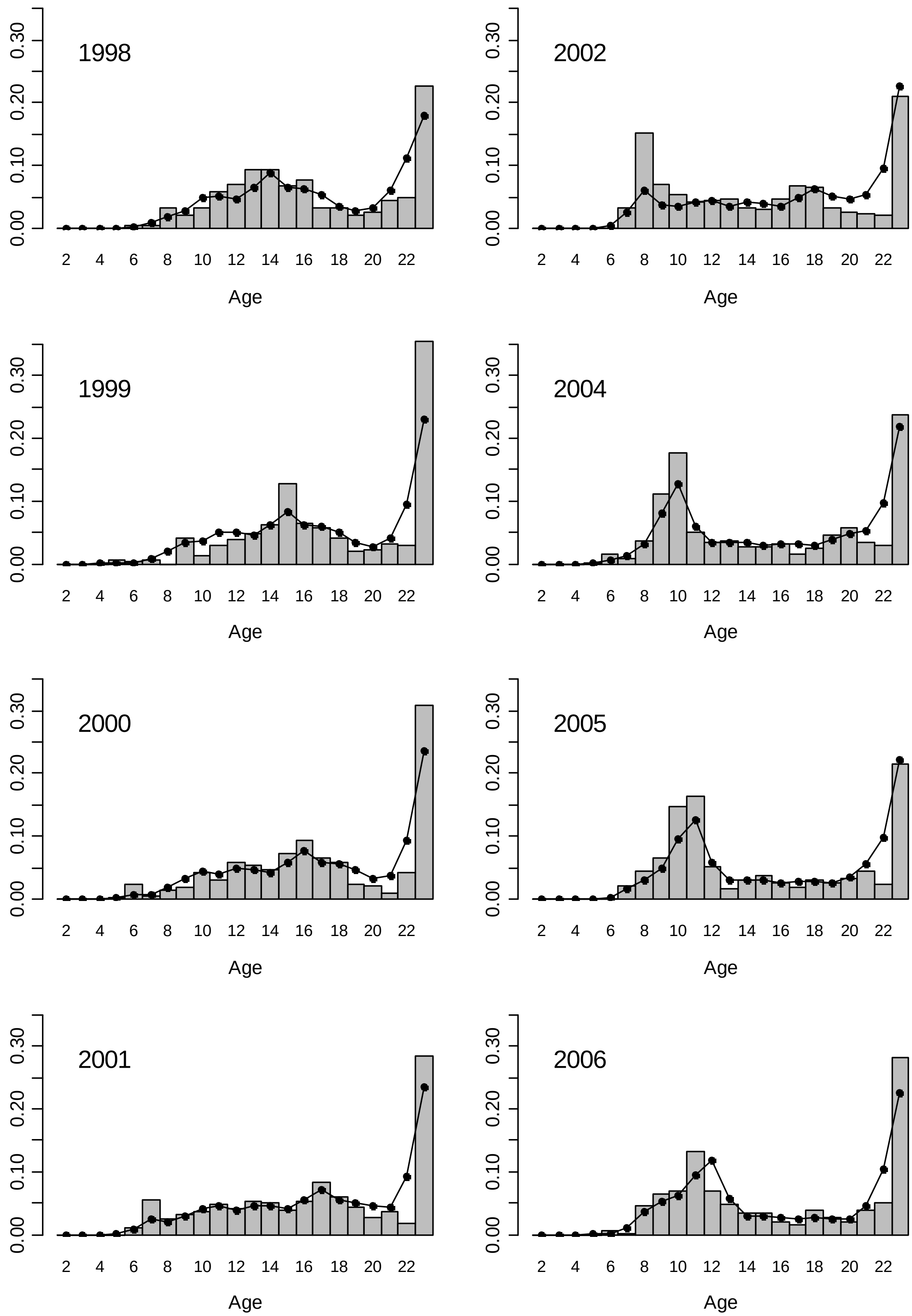


Figure 10.2 Fishery age compositions for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles .

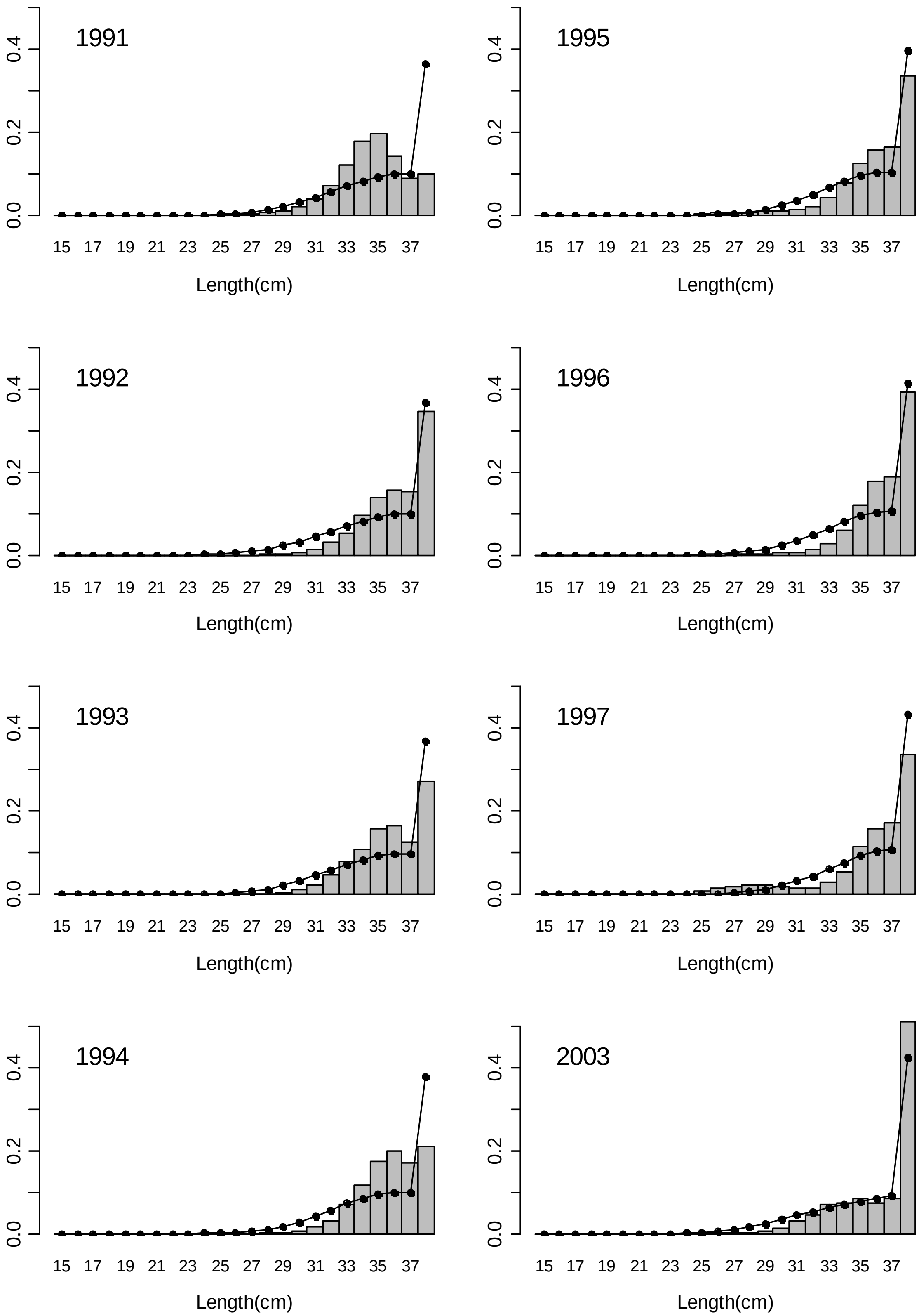


Figure 10.3 Fishery length compositions for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

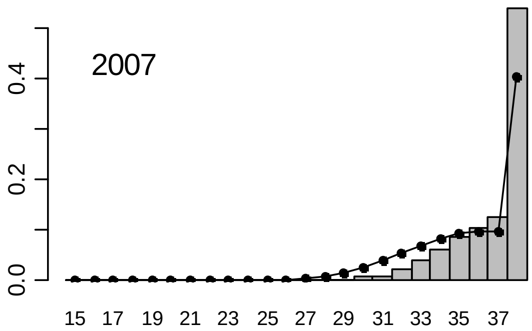


Figure 10.3 (continued) Fishery length compositions for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

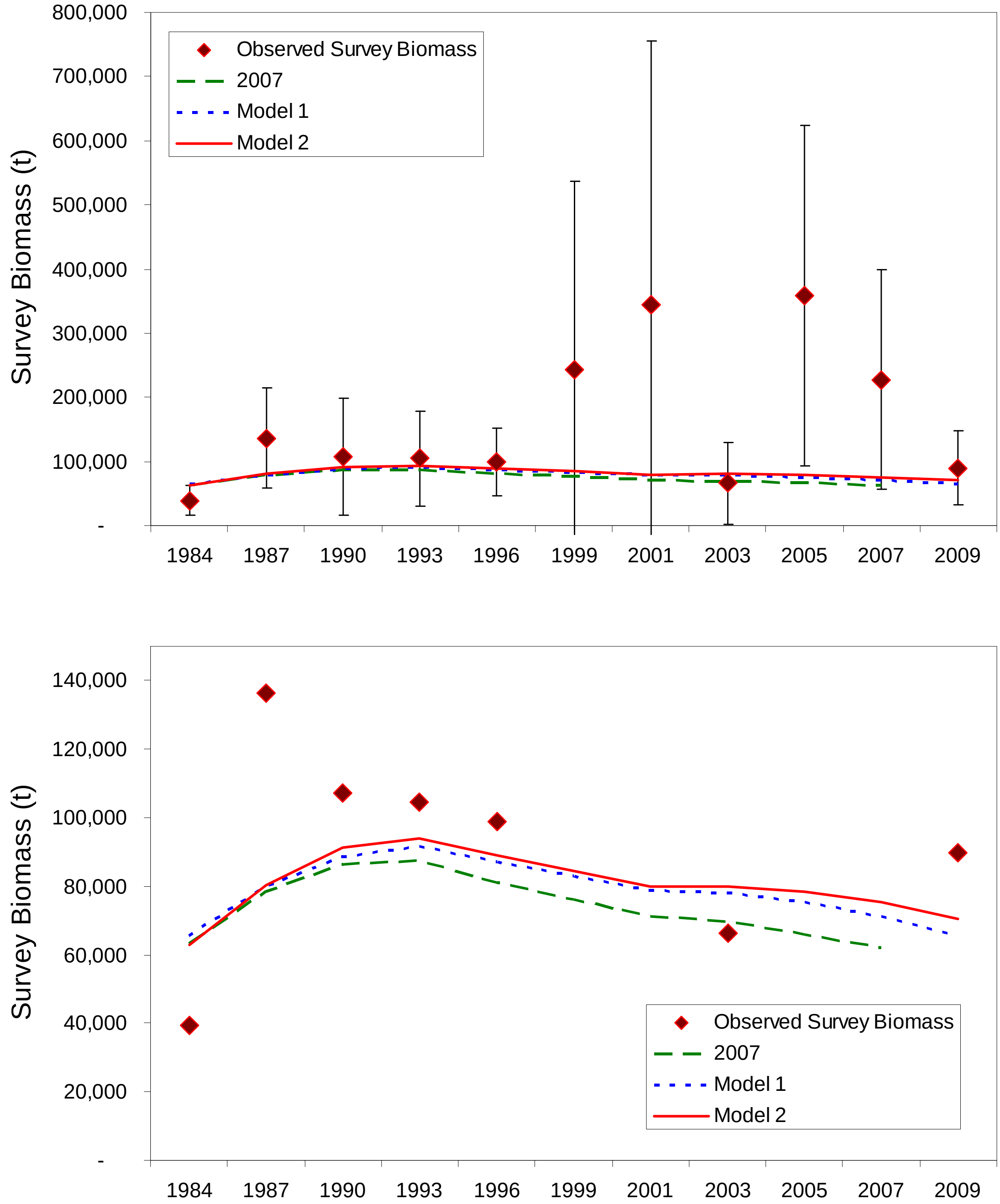


Figure 10.4 Upper panel is observed and predicted GOA northern rockfish trawl survey index of biomass. Observed biomass=circles with 95% confidence intervals of sampling error. Predictions are from 2007 model and this year's model. Recommended model is red solid line. Bottom panel is an expansion without confidence intervals and the high point estimates of 1999, 2001, 2005, and 2007 to look at the fit at a visible scale.

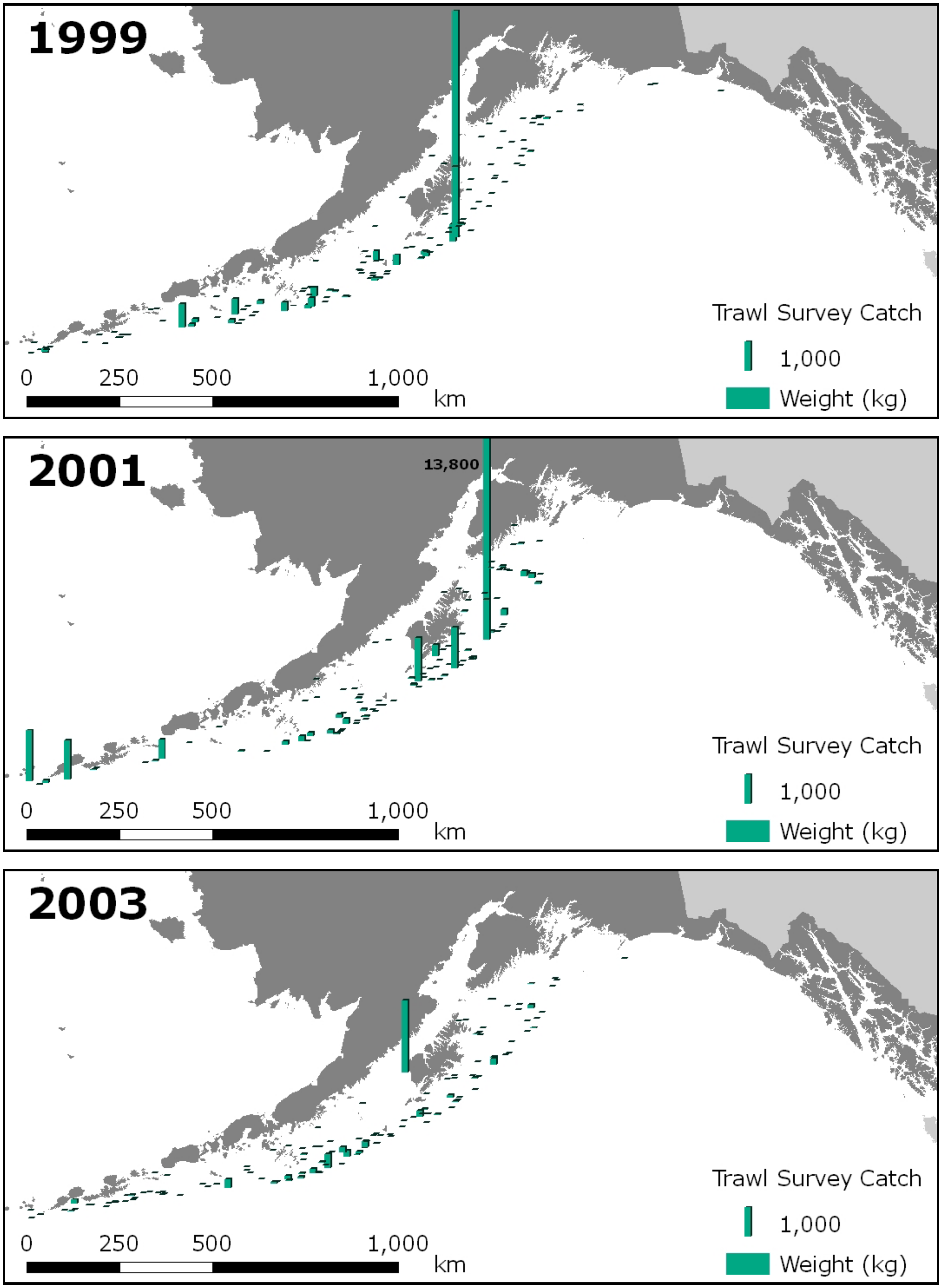


Figure 10.5. Spatial distribution of northern rockfish catch in the Gulf of Alaska during the 2001 - 2009 trawl surveys.

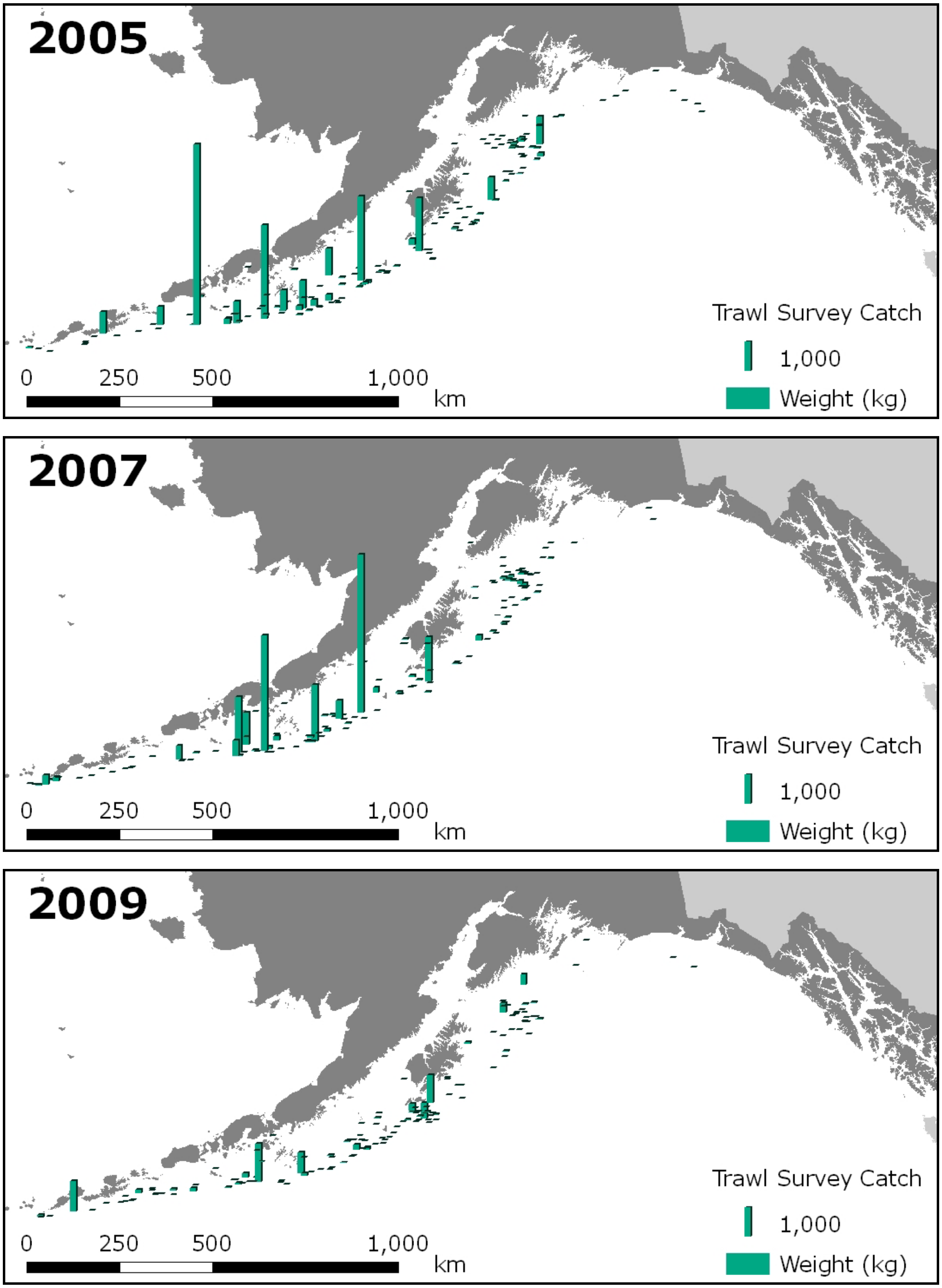


Figure 10.5. (continued) Spatial distribution of northern rockfish catch in the Gulf of Alaska during the 2001 -2009 trawl surveys.

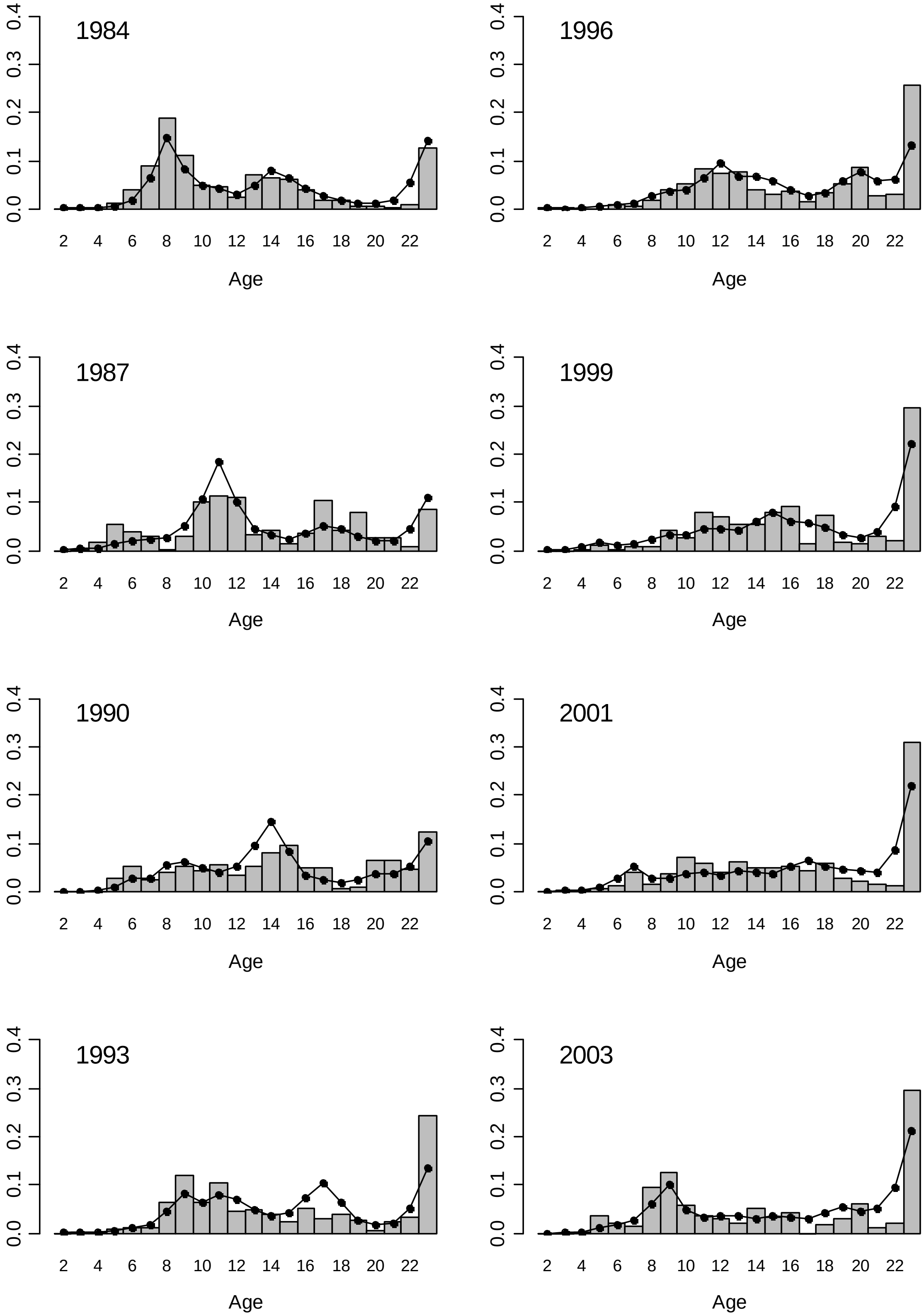


Figure 10.6 Trawl survey age composition by year for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

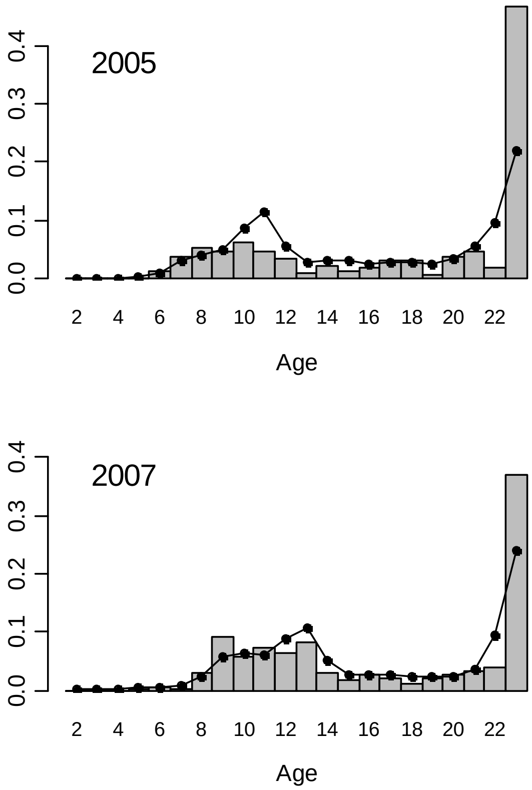


Figure 10.6 (continued). Trawl survey age composition by year for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

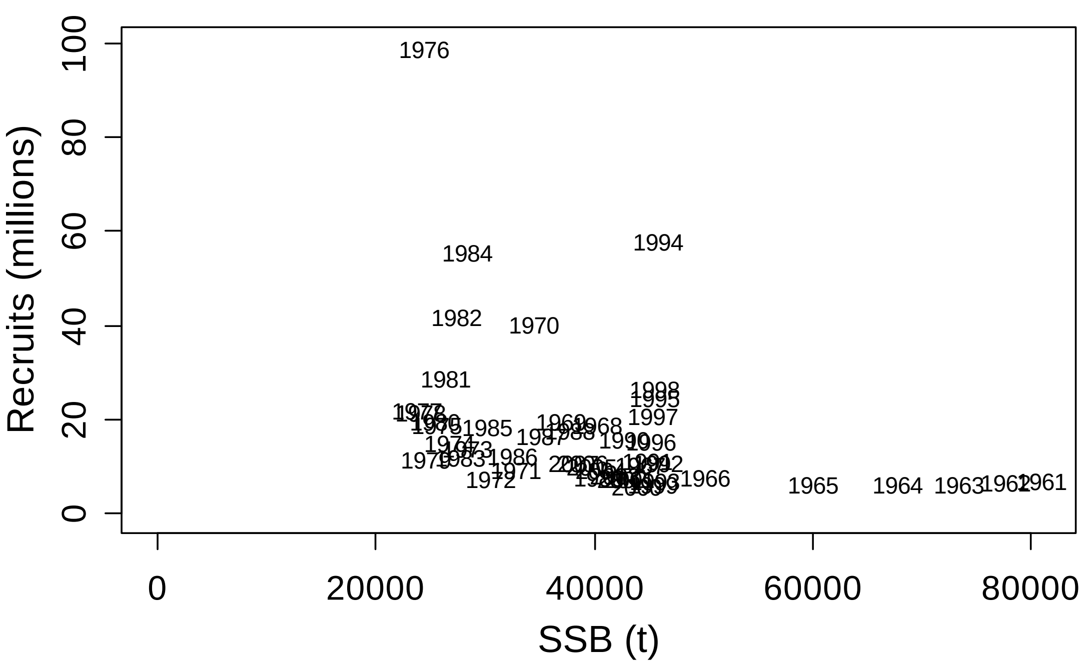


Figure 10.7. Relationship between female spawning stock biomass (SSB) and recruitment for GOA northern rockfish based on the authors recommended model.

Figure 10.8. Length-age transition matrix used for GOA northern rockfish. The matrix is based on Length at age data from trawl surveys.

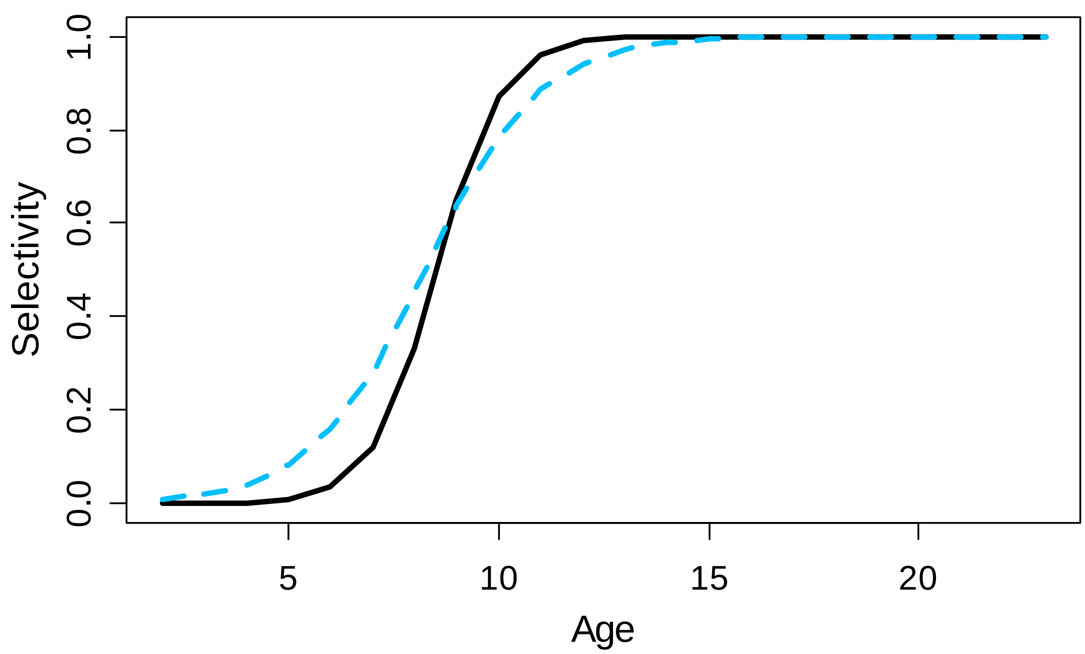


Figure 10.9. Fishery (solid line) and survey (dotted line) estimates of selectivity for GOA northern rockfish based on the authors recommended model.

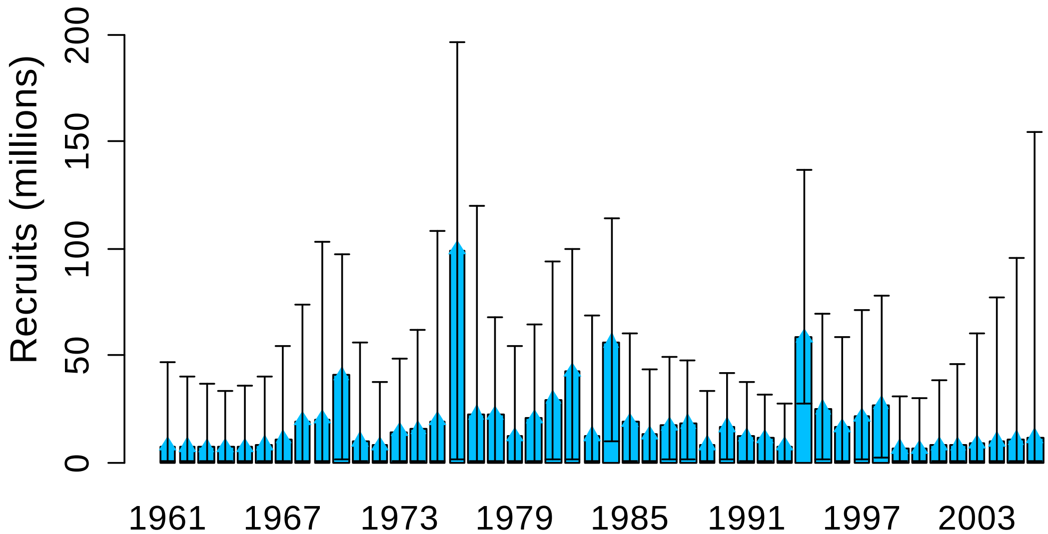
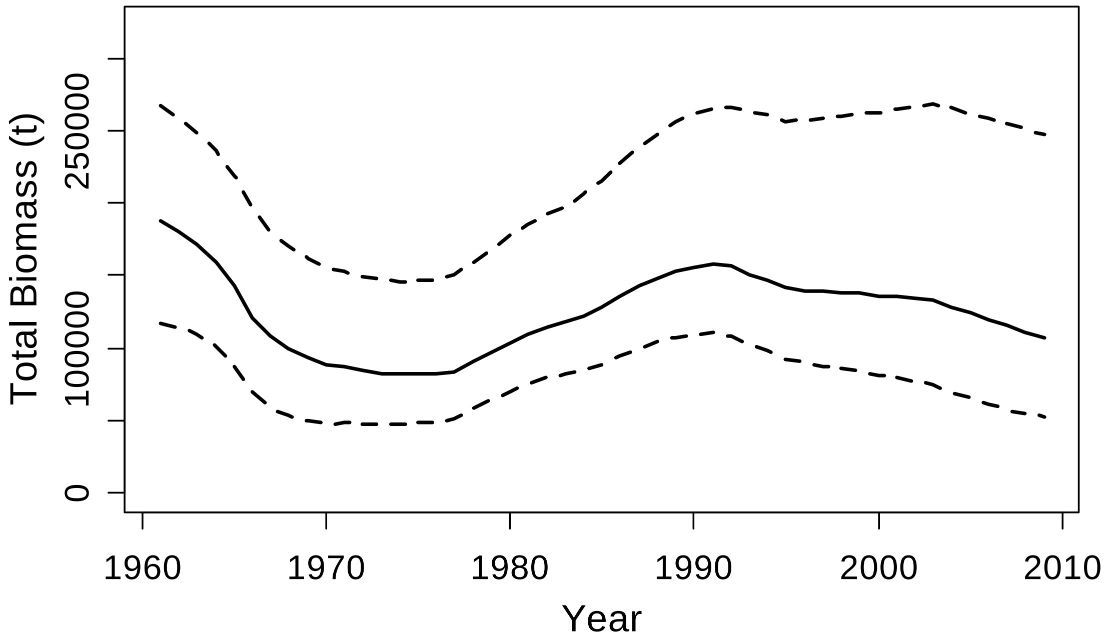


Figure 10.10. Estimates of year class strength and 95% confidence intervals for GOA northern rockfish based on the authors recommended model.



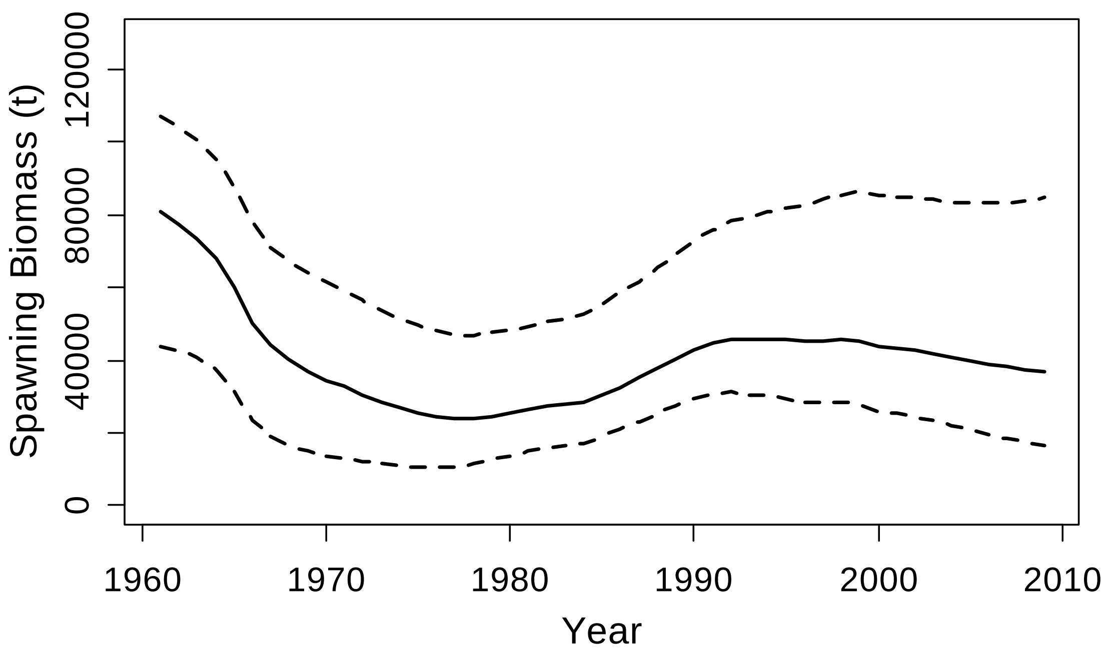
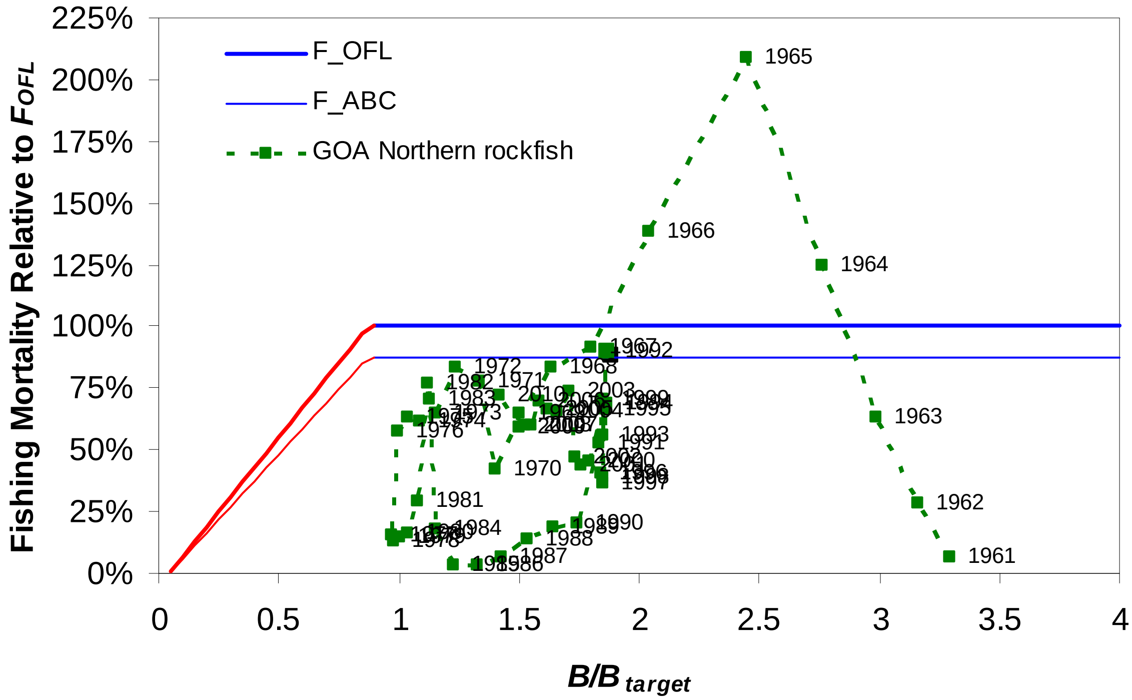


Figure 10.11. Model estimated total biomass and spawning biomass (solid lines) with 95% confidence intervals determined by MCMC (dashed line) for Gulf of Alaska northern rockfish.



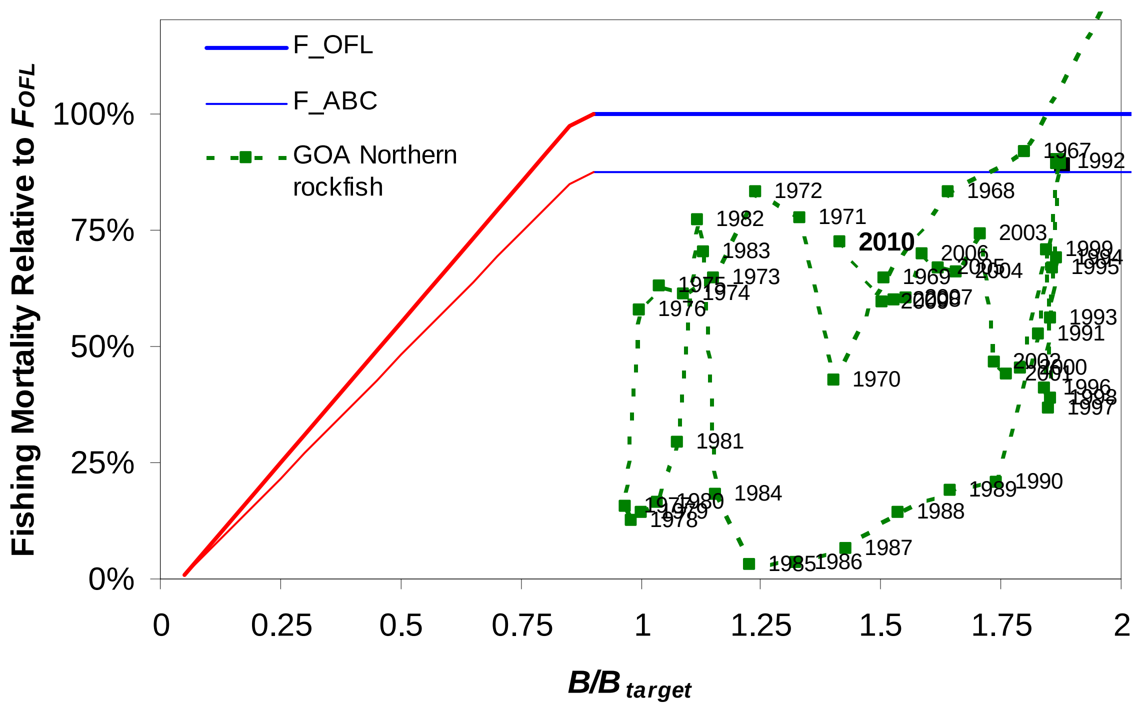


Figure 10.12. Time series of northern rockfish estimated spawning biomass relative to the target level and fishing mortality relative to F_{OFL} for author recommended model.

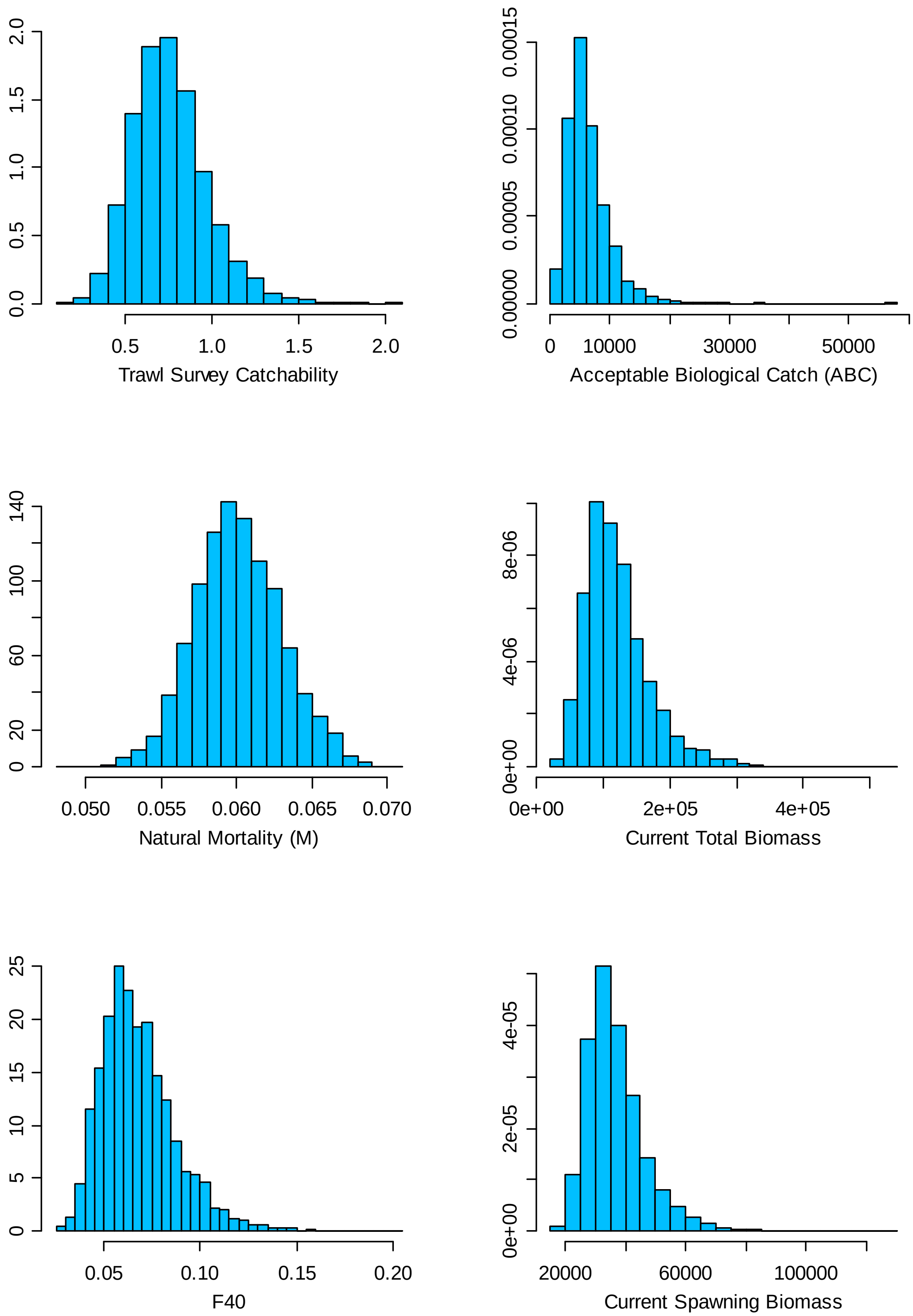


Figure 10.13. Histograms of estimated posterior distributions for key parameters derived from the MCMC for GOA northern rockfish.

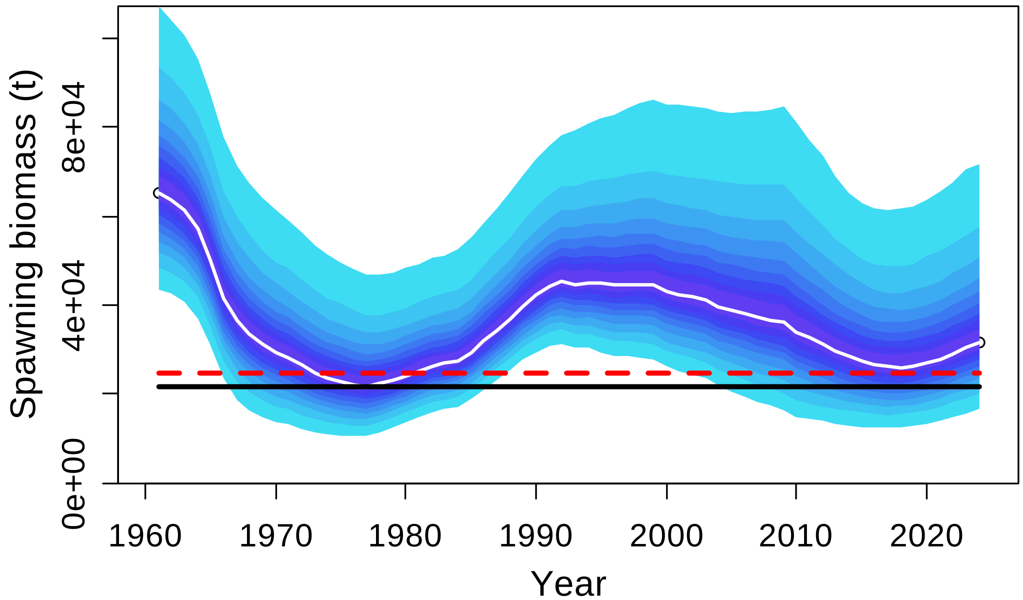


Figure 10.14. Bayesian credible intervals for entire spawning stock biomass series including projections through 2023. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1977-2005. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.