10. Gulf of Alaska Northern Rockfish

by

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Executive Summary

Summary of Major Changes

Unlike other GOA rockfish a complete assessment was performed last year for northern rockfish. We use the reference age-structured model from last year (Model 1) for this year with updated data. This is the same model that is used for the GOA Pacific ocean perch, dusky rockfish, and rougheye rockfish assessments.

Input data

The data was updated to include the 2007 trawl survey biomass estimate, updated catch for 2006, preliminary catch for 2007, and fishery age compositions from 2006.

Assessment methodology

For model 1 the only major change to the model configuration relative to last year was that the CV for the prior on survey catchability *q* was changed from 15% to 45 % which is identical to that used in the GOA Pacific ocean perch, and dusky rockfish assessments. The outcome from this change did not substantially change stock assessment results relative to last year.

Assessment results

The recommended ABC for 2008 is 4,550 t. The corresponding reference values for northern rockfish recommended for this year and projected one additional year are summarized below:

Summary	2008	2009
Total Biomass (t)	93,391	90,672
$B_{40\%}$ (t)	22,300	22,300
Female spawning biomass (t)	29,170	28,180
F_{ABC} (=$F_{40\%}$)	0.061	0.061
F_{OFL} (=$F_{35\%}$)	0.073	0.073
ABC	**4,550**	**4,350**
OFL	5,430	5,120

The recommended Tier 3 ABC is similar to results from earlier assessments.

Response to SSC comments

"The SSC notes that there is a tradeoff in fits to different data. The SSC encourages efforts to explore the implications regarding the emphasis on survey biomass estimates for northern rockfish. Changing the relative emphasis of data sources has notable implications on assessment results. For example, the SSC notes that the estimate of 2006 spawning biomass doubles from the base case when survey biomass is downweighted (see comparison of Models 1 and 4)."

We agree with the SSC that the model is sensitive to changes in data weighting. While the survey biomass is appropriately weighted, the length and age compositions may be overweighted, due to the choice of sample size per year. In the future, we will evaluate effective sample size and standardized residuals to determine more appropriate values to assume for the sample size for annual age/length compositions. Lowering these values would lessen the emphasis on the compositions, and by extension, provide a better fit to survey biomass.

"The SSC accepts the Plan Team's recommendation to continue under Tier 3a this year, with female spawning biomass approximately 33% higher than $B_{40\%}$. However, the SSC notes that with the application of the new model, there have been large changes in $B_{40\%}$ and in estimates of biomass, perhaps more than would be expected for a long-lived species and given the nearly flat biomass trajectory in Figure 9.11. That figure also shows large fluctuations in survey biomass estimates. These fluctuations in model estimates and survey estimates, coupled with potential biases due to the problem of untrawlable grounds, suggest that an evaluation of the appropriate tier level may be in order for the future."

We believe that the model continues to improve as more data is accumulated, and that northern rockfish should remain in Tier 3a. Also, it is our opinion that a detailed discussion on Tier recommendations may be beyond the scope of this assessment. If a discussion is truly needed on the appropriate tier for northern rockfish, it might be better for the Plan Team or Council to address this issue.

Responses to SSC Comments In General

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

In this assessment we moved from the Goodman et al. (2002) style management path plot to one that incorporates the harvest control rules in Figure 10.12.

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 small ABC 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). Aleutian Islands northern rockfish can also be 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 Haight 1976, Carlson and Straty 1981, Straty 1987, and 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, 1996, 2003). There is no indication of a shift in diet over time or a difference in diet between the GOA and AI (Yang 1996, 2003). 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 ~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 depletion of rockfish stocks were presented at the 2005 Lowell Wakefield symposium (Hanselman et al. 2007). The use of Leslie depletion estimators on targeted rockfish catches detected relatively few localized depletions for northern rockfish. 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 block of high rockfish fishing intensity that contained the "Snakehead", the results indicated there were year-over-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. Under current management, the fishing season for slope rockfish in the Gulf of Alaska has been relatively short-lasting only a few weeks in July each year, which tends to concentrate the fishery in time and space. A pilot Gulf of Alaska rockfish rationalization fishery is planned for 2006. If the fishing season is extended under Gulf Rationalization pilot project, then the fishery may spread out 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 were northern rockfish are concentrated.

Historically, bottom trawls have accounted for nearly all the commercial harvest of northern rockfish in the Gulf of Alaska. 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 area for delivery to processing plants in Kodiak. Factory trawlers continued to take nearly all the northern rockfish catch in the Western area. Provisions to guard against localized depletion in northern rockfish should also insure adequate observer coverage on smaller shore based trawler vessels in the Central Gulf.

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, Bobko and Berkeley 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.

Fishery

Total commercial catch (mt) of northern rockfish in the GOA for the years 1965-2007 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 (mt) was caught, but declined to 45.5 mt 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 here 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 ~1,700 mt in 1990 to nearly 7,800 mt 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 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 1993-2006 have ranged from 2,947 mt to 5,968 mt, depending on the year. Annual ABC's and TAC's have been relatively consistent during this period and have varied between 4,870 mt and 5,760 mt. Catches of northern rockfish were below their TAC's in 2000 and 2002 as a conservative measure to ensure the TAC was not exceeded. 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 - 2006.

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. The following table shows the change from 1996 to 2002 in the percent of the total catch of northern rockfish in the Central area taken by shore-based trawlers.[1]

Percent of catch taken by shore-based trawlers in the Central Gulf area

	1996	1997	1998	1999	2000	2001	2002
Northern rockfish	32	32	53	44	73	57	73

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). In particular, 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.

Results of a depletion study indicated that targeted hauls for some slope rockfish species in the Gulf of Alaska showed a short term decline (a period of weeks) in CPUE during the fishing season and a rebound in CPUE by the next year (Hanselman et al. 2006). These results suggest that there is evidence of short term localized depletion for some slope rockfish species in the Gulf of Alaska, but depletion is not serial (i.e. the stock rebounded from year to year). One exception was that year-over-year localized depletion occurred in northern rockfish CPUE in the "Snakehead" area of the Gulf of Alaska. Significant depletion in northern rockfish CPUE was detected in one year (1994) over a period of a few weeks. Following 1994, fishery and survey CPUE did not rebound, indicating year-over-year localized depletion. Some depletion of dusky rockfish appeared to occur in the same area and year, but the depletion was not as severe. The "Snakehead" was fished heavily for northern rockfish in the 1990's, but is now only lightly fished. The change in fishery effort may have been due this depletion event in the 1990s.

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).

The only detailed analysis of incidental 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.

Gulfwide discard rates (% discarded) for northern rockfish in the commercial fishery for 1993-2006 are as follows:

1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
26.5	17.7	12.7	16.5	27.8	18.3	11.1	8.7	17.5	9.8	9.3	7.8	3.8	9.1

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

[1]National Marine Fisheries Service, Alaska Region, Fishery Management Section, P.O. Box 21668, Juneau, AK 99802-1688. Data are from weekly production and observer reports through October 5, 2002.

Data

The following table summarizes the data used for this assessment:

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

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. 10.2, and age compositions are presented in Table 10.5 and Fig.10.3. The fishery age compositions indicate that strong year-classes occurred around the years 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 and 2007. 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. 10.4). In particular, the 2005 Gulfwide survey biomass estimate (359,026 t) was 82% higher than the 2003 biomass estimate (66,368 t). The 2003 survey biomass estimate (66,368 t) was 18% of the 2001 biomass estimate (355,275 t). 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 variance of individual biomass estimates has also been high and is reflected in the large 95% confidence intervals associated with recent survey biomass estimates of northern rockfish. In both 1999 and 2001, a single very large survey haul of northern rockfish greatly increased the biomass estimates and resulting estimate of biomass variance. 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 estimated variance was smaller (Figure

10.5a). 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. This is particularly important in comparing “trawlable” versus untrawlable locales within the current survey design (Fig. 10.5b).

Trawl surveys provide size composition data for northern rockfish but are not used directly in the current age structured assessment model (Table 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. 10.6). 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. Mean age of northern rockfish in the surveys has increased from 13.1 years in 1984 to 18.6 years in 1999 and come down slightly to 18.15 years in 2001.

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. 2007) 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 (Figure 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.

A substantial difference between this year’s model configuration and last years is that for survey catchability q a prior distribution with a mean of 1.0 and a CV of 45% was assumed. This is identical to that used in the Gulf of Alaska Pacific ocean perch and dusky rockfish assessments. In last year’s assessment the CV on the prior on q was set to 15%. Preliminary evaluations of outcomes from this change showed that stock status did not substantially change relative to last year. For example, the estimate of female spawning stock biomass (SSB) for 2006 based on last years assessment was 34,200 t, and the 2006 SSB is 32,300 t based on this year’s assessment.

Another difference in this years model configuration is that the year specific likelihood weights (ψ_y^g : Box 1) for the fishery age composition likelihood was changed from the relative number of hauls to the square root of the number of fish aged each year. The Pacific ocean perch assessment uses the square root of the number of fish aged each year. The only new age composition data obtained this year for northern rockfish was from the fishery thus we only made this change for these data. Preliminary models with and without this change showed that stock status did not substantially change. In future assessments we plan to more fully examine the sensitivities of assessment outcomes to alternative sample size configurations used for all of the age and length composition data.

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 Alaska[3]. 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

Length-weight coefficients for the formula $W=aL^b$, where W = weight in grams and L = length in mm, were based on 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 LVB relationship and resulting length-age transition matrix were based on the most recently available 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 (Age 1 = 3, Age A = 40, N = 2, sigma 1 = 0.41, sigma A = 1.27, likelihood = 1335.40, AIC = 1339.40; Courtney et al. 1999).

Parameters estimated conditionally

For the model presented in this assessment, 126 parameters were estimated conditionally: 1 survey catchability parameter, 1 natural mortality parameter, 68 initial age composition and subsequent recruitment parameters, 47 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

[3] C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801. Pers. Comm. July, 1997.

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	68
Spawners-per-recruit levels	F_{35}, F_{40}, F_{50}	3
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	47
Logistic fishery selectivity	$a_{f50\%}, \delta_f$	2
Logistic survey selectivity	$a_{s50\%}, \delta_s$	2
Total		126

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 126. 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 50,000 iterations out of 5,000,000 and "thinned" the chain to one value out of every thousand, leaving a sample distribution of 4,950. Further assurance that the chain had converged was to compare the mean of the first half of the chain with the second half after removing the "burn-in" and "thinning". Because these two values were similar we concluded that convergence had been attained. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% confidence intervals for some parameters.

Box 1.

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 $\alpha=\dfrac{B_0}{R_0}\left(1-\dfrac{h-2}{0.8h}\right),\ \beta=\dfrac{5h-1}{4hR_0}$,	
$B_0=\sum_{a_0}^{a_+-1}R_0e^{-(a-a_0)M}\varphi_a w_a+R_0e^{-(a_+-a_0)M}\varphi_{a_0}w_{a_0}\Big/\left(1-e^{-M}\right)$	
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*
$s_a^g=\dfrac{1}{1+e^{-2.944439\left(a-\delta_1^g\right)/\delta_2^g}}$	Logistic selectivity
$\hat{I}_y=q^g\sum_{a_0}^{a_+}N_{y,a}\dfrac{s_a^g}{\max\left(s_a^g\right)}w_a$	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

The recommended model configuration (Model 1) is essentially the same as that recommended by the author and accepted by the Plan Team and SSC for the 2007 ABC determination (Courtney et al. 2006). This model has similar properties compared to previous model results (i.e., poor fit to recent survey biomass estimates) and seems to reflect the uncertain nature on the current stock size. Subsequent presentations are therefore based on this model.

Last year a number of model configurations were evaluated based on comments from the Council's Plan Team and SSC, in addition to discussions during the rockfish stock assessment workshop held in Juneau in May 2006. A large number of model sensitivities were conducted, primarily to evaluate assumptions and the relative contributions of different data sources. For this years stock assessment we do not conduct any further model evaluations but update the model with updated data.

Results

Parameter estimates and stock status from Model 1 were similar to last years' northern rockfish assessment (Table 10.10 and 10.11; Fig. 10.10b). The $F_{40\%}$ reference changed slightly from 0.062 to 0.061 reflecting the change the in natural mortality from 0.063 to 0.060. Some of effects of the change in natural mortality were offset by a shift towards older ages in the estimates of fishery selectivity. This shift in selectivity would tend to raise F40% values.

Comparison of fishery selectivity between last years and the current assessment:

	Age												
	2	3	4	5	6	7	8	9	10	11	12	13	14+
Last year	0%	0%	1%	2%	6%	16%	36%	63%	83%	94%	98%	99%	100%
This year	0%	0%	0%	1%	3%	9%	27%	57%	83%	95%	99%	100%	100%

The estimates of current population abundance indicate that it is dominated by older fish, and several recent above average year-classes: 1994, 1997, and 1998 (Table 10.12). The fit to the survey biomass index fails to capture the apparent increase in GOA northern rockfish indicated from trawl surveys (Fig. 10.4). 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)

In general the model appears to fit the data better this year relative to last year (Table 10.1). Perhaps this is due to the CV on the prior on *q* being changed this year. Note in Table 10.1 the large change in the likelihood component value associated with the fishery age composition data (58.7 in last year's model to 16.15 in this year's model). This reflects the change in sample size associated with fishery age composition data as presented above not a better fit to this data.

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 10.12).

Recruitment estimates for Model 1 show a high degree of uncertainty, but indicate 3 large year-classes (Fig. 10.10a). 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 (10.10b) 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).

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 the target level ($B_{40\%}$). Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The 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 10.13).

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 10.14). We also use these posterior distributions to show uncertainty around time series estimates such as spawning biomass (Figure 10.11). 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 1 results were computed based on recruitment from post-1976 spawning event (in t of female spawning biomass):

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$
55,750	22,300	19,500

Specification of OFL and maximum permissible ABC

For Model 1, the year 2007 spawning biomass is estimated to be 30,220 t (at the time of spawning, assuming the stock is fished at F_{ABC}). This is above the B_{msy} value of 19,500 t. Under Amendment 56, the 2008 estimate (assuming Tier 3 catch levels) is 29,350 t. The OFL's and maximum permissible ABC values are thus:

Year	OFL	Max ABC
2008	5,430	4,550
2009	5,120	4,350

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 2008 is 29,170 t. The value for B_{msy} (approximated by $B_{35\%}$) is estimated at 19,500 t as determined from average recruitment of the 1977-2003 year-classes (recruits from years 1979 – 2005). As in last year's assessment, we recommend that $F_{40\%}$ be used as the basis for ABC calculations. We recommend that the ABC for northern rockfish for the 2008 fishery in the Gulf of Alaska be set at 4,550 t. This ABC is down slightly from last year (ABC in 2007 was 4,940).

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 2003, 2005, and 2007 surveys, respectively.

The proportion of exploitable biomass has been calculated based on survey biomass for depths greater than 100 m. The original rationale for the exclusion of 1 - 100 depth strata dates to the 1988 assessment (Clausen and Heifetz 1989) when all slope rockfish were grouped together as a single management category. There was concern that Pacific ocean perch (POP) were being overexploited within this category, and it was noted that according to the trawl survey results, most POP in the 1-100 m stratum were small juvenile fish less than the age of recruitment and thus should not be included in calculation of exploitable biomass. Therefore, to help constrain the POP catch, it was decided to exclude the 1-100 m stratum from the calculations of exploitable biomass for slope rockfish.

Excluding the 1-100 m stratum does not appear to be justifiable in the calculation of areal distribution of exploitable biomass for northern rockfish. Although a considerable portion of the biomass of northern rockfish resides in the 1 - 100 m depth stratum, these fish are about the same size as those from deeper stratum (Martin and Clausen 1995; Martin 1997; Britt and Martin 2001). Thus the rational for excluding these fish because they are small juvenile fish is not justifiable for northern rockfish. Hence, there is not a convincing argument for excluding the shallow stratum as part of the exploitable biomass. It is recommended that this procedure be dropped starting with the present assessment.

Estimated trawl survey biomass by area and comparison of apportionment excluding the 1-100 m stratum and including this stratum are shown below. Including the 1-100 m stratum results in higher apportionment to the Western GOA because a considerable portion of the estimated biomass resides in the 1-100 m stratum in the Western GOA. Using the new apportionment methodology results in area apportionments for Gulf of Alaska northern rockfish of 47.06% for the Western area, 52.91% for the Central area, and 0.02% for the Eastern area. Applying these apportionments to the recommended ABC for northern rockfish results in 2,141 t for the Western area, 2,408 t for the Central area, and 1 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 (mt) by area for northern rockfish in the Gulf of Alaska.

	Western	Central		Eastern		
Year	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2003	9,146	49,793	7,336	5	0	66,280
2005	231,138	102,605	25,123	160	0	359,026
2007	114,222	92,250	20,559	38	0	227,069

Percentage of trawl survey biomass by area and comparison of previous apportionment methodology with new methodology for northern rockfish in the Gulf of Alaska.

Year	Weights	Western	Central	Eastern	Total
		Previous apportionment excludes 1-100 m depth			
2003	4	13.0%	87.0%	0.0%	100%
2005	6	41.2%	58.8%	0.1%	100%
2007	9	41.7%	58.3%	0.0%	100%
	Weighted average	35.5%	64.5%	0.0%	100%
		1,615	**2,934**	**1**	4,550
		New apportionment includes 1-100 depth			
2003	4	13.8%	86.2%	0.0%	100%
2005	6	64.4%	35.6%	0.0%	100%
2007	9	50.3%	49.7%	0.0%	100%
	Weighted average	47.1%	52.9%	0.0%	
		2,141	**2,408**	**1**	4,550

Standard harvest scenarios and projection methodology

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 2007 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2007. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch 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 2008 and 2009, are as follows (A "*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, *F* is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, *F* is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2008 and 2009 recommended in the assessment to the *max* F_{ABC} for 2007. (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.)

Scenario 3: In all future years, *F* is set equal to the 2003-2007 average *F*. (Rationale: For some stocks, TAC can be well below ABC, and recent average *F* may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 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 5: In all future years, *F* is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

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

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2008 or 2) above ½ of its MSY level in 2008 and above its MSY level in 2018 under this scenario, then the stock is not overfished.)

Scenario 7: In 2008 and 2009, *F* is set equal to *max* F_{ABC}, and in all subsequent years, *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2020 under this scenario, then the stock is not approaching an overfished condition.)

For northern rockfish, projected B_{2008} (29,170 t) is greater than $B_{35\%}$ (19,500 t) therefore the stock is not overfished nor is the stock approaching an overfished condition (Table 10.13). The projected catch and biomass trends show declines as the stock approaches the $B_{40\%}$ level.

Summary

The corresponding reference values for northern rockfish recommended for this year and projected one additional year are summarized below:

Summary	2008	2009
Total Biomass (t)	93,391	90,672
$B_{40\%}$ (t)	22,300	22,300
Female spawning biomass (t)	29,170	28,180
F_{ABC} (=$F_{40\%}$)	0.061	0.061
F_{OFL} (=$F_{35\%}$)	0.073	0.073
ABC	4,550	4,350
OFL	5,430	5,120

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 10.14.

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.

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 10.15).

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 2002-2006 have been 3.8 -9 .8%.

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

Fishery-specific effects on EFH non-living substrate: Unknown, but the heavy-duty “rockhopper” trawl gear commonly used in the fishery can disturb seafloor habitat

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.

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Table 10.1. Commercial catch (t) and management acition 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 1993-2007 are from NMFS Observer Program and Alaska Regional Office updated through October 3, 2007.

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]			3,866	3,866*	4,938	78%

Management Actions

[1] 1988 - Slope rockfish assemblage management implemented by NPFMC as one of three management groups of *Sebastes* in the GOA.

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

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

[4] Central Gulf Rockfish Pilot Project implemented for rockfish fishery. *Catch as of 10/1/2007

Table 10.2. Catch (t) of northern rockfish taken during research cruises in the Gulf of Alaska, 1977-2006. (Tr.=trace)

Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	
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	
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Catch	0	20.8	0	0	12.5	0	2.5	13.2	0	23.4	0	5.6	0	23.2	0	21.7

Table10.3. 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	56
1999	5,287	248	308	160
2000	3,898	280	585	236
2001	3,001	261	451	214
2002	3,802	283	616	247
2003	7,387	498	0	110
2004	5,403	370	746	339
2005	4,208	301	0	44
2006	3,874	317	500	206

* 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.

Table10.4. Fishery length (cm) compositions for northern rockfish in the Gulf of Alaska (at-sea and port samples combined).

Length class (cm)	Year 1990	1991	1992	1993	1994	1995	1996	1997	1998
15-Jan	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
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
24	0.001	0.001	0.000	0.000	0.000	0.002	0.000	0.002	0.001
25	0.002	0.002	0.000	0.000	0.000	0.004	0.000	0.006	0.000
26	0.001	0.003	0.000	0.001	0.000	0.007	0.000	0.014	0.001
27	0.004	0.004	0.000	0.001	0.001	0.009	0.001	0.020	0.001
28	0.008	0.007	0.001	0.002	0.002	0.008	0.002	0.021	0.002
29	0.016	0.010	0.003	0.005	0.004	0.010	0.003	0.021	0.002
30	0.018	0.023	0.006	0.010	0.007	0.013	0.007	0.019	0.005
31	0.022	0.041	0.015	0.024	0.017	0.015	0.006	0.014	0.006
32	0.035	0.072	0.032	0.046	0.030	0.021	0.013	0.015	0.013
33	0.048	0.123	0.053	0.079	0.070	0.043	0.028	0.029	0.021
34	0.078	0.180	0.094	0.109	0.116	0.081	0.058	0.054	0.041
35	0.128	0.196	0.139	0.156	0.175	0.127	0.122	0.115	0.083
36	0.186	0.145	0.157	0.166	0.199	0.156	0.177	0.159	0.140
37	0.171	0.091	0.154	0.127	0.171	0.164	0.189	0.173	0.183
38+	0.280	0.102	0.346	0.273	0.209	0.336	0.393	0.337	0.500
Sample size	4506	15321	15207	10732	8138	11537	7942	5261	10072

Length class (cm)	Year 1999	2000	2001	2002	2003	2004	2005	2006	2007
15-Jan	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
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
24	0.001	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000
25	0.001	0.002	0.000	0.000	0.001	0.000	0.001	0.000	0.000
26	0.004	0.003	0.002	0.001	0.001	0.001	0.000	0.000	0.001
27	0.003	0.003	0.005	0.003	0.002	0.003	0.002	0.001	0.001
28	0.002	0.009	0.009	0.006	0.002	0.005	0.005	0.003	0.002
29	0.002	0.009	0.021	0.014	0.007	0.005	0.006	0.006	0.003
30	0.004	0.007	0.026	0.031	0.012	0.010	0.015	0.010	0.009
31	0.006	0.011	0.028	0.045	0.031	0.014	0.025	0.026	0.009
32	0.011	0.011	0.025	0.075	0.045	0.028	0.037	0.039	0.027
33	0.021	0.016	0.027	0.071	0.071	0.045	0.064	0.050	0.037
34	0.035	0.028	0.035	0.065	0.075	0.073	0.095	0.067	0.059
35	0.048	0.057	0.057	0.058	0.084	0.077	0.116	0.097	0.078
36	0.103	0.095	0.082	0.068	0.075	0.091	0.127	0.106	0.102
37	0.149	0.136	0.126	0.101	0.083	0.094	0.100	0.099	0.117
38+	0.608	0.610	0.555	0.461	0.510	0.553	0.409	0.495	0.555
Sample size	4370	2903	2340	2913	6025	4561	3742	3874	5404

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	2006
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.006	0.002	0.000	0.000	0.001	0.000
6	0.004	0.003	0.024	0.011	0.000	0.015	0.006
7	0.006	0.006	0.005	0.055	0.032	0.008	0.002
8	0.034	0.000	0.015	0.024	0.151	0.036	0.046
9	0.022	0.042	0.019	0.031	0.070	0.111	0.064
10	0.032	0.013	0.043	0.038	0.055	0.176	0.070
11	0.058	0.029	0.031	0.049	0.042	0.050	0.132
12	0.070	0.039	0.058	0.042	0.044	0.035	0.070
13	0.094	0.049	0.053	0.053	0.047	0.036	0.048
14	0.094	0.062	0.048	0.051	0.032	0.028	0.034
15	0.068	0.127	0.074	0.040	0.031	0.027	0.034
16	0.078	0.065	0.094	0.053	0.047	0.032	0.020
17	0.034	0.058	0.067	0.084	0.068	0.015	0.016
18	0.034	0.042	0.060	0.060	0.067	0.025	0.038
19	0.022	0.019	0.024	0.044	0.032	0.046	0.028
20	0.026	0.023	0.022	0.027	0.026	0.058	0.020
21	0.044	0.032	0.010	0.035	0.023	0.035	0.040
22	0.050	0.029	0.043	0.018	0.021	0.029	0.050
23+	0.227	0.354	0.309	0.284	0.211	0.237	0.282
Sample size	498	308	585	451	616	746	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	117[a]	0[a]	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%

[a]Biomass estimates are not available for the Yakutat and Southeastern areas in 2001because 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 in the Gulf of Alaska.

	Length composition		Age composition	
Year	# Fish	# Hauls*	# Fish	# Hauls
1984	4,312	43	356	6
1987	9,584	36	497	17
1990	3,490	40	442	14
1993	5,306	95	354	20
1996	4,502	115	462	19
1999	3,602	105	293	29
2001	4,278	87	533	95
2003	3,185	113	272	26
2005	4,868	123	421	73

* 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 for northern rockfish in the Gulf of Alaska, 1984-2005.

Length					Year					
class (cm)	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007
15-Jan	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	4312	9584	3490	5306	4502	3602	4278	3185	4868	4725

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
2	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000
3	0.000	0.004	0.001	0.003	0.003	0.000	0.005	0.001	0.000
4	0.000	0.018	0.002	0.003	0.001	0.002	0.003	0.001	0.001
5	0.014	0.055	0.029	0.009	0.002	0.011	0.006	0.035	0.001
6	0.040	0.040	0.054	0.011	0.011	0.003	0.013	0.021	0.014
7	0.091	0.030	0.027	0.011	0.006	0.009	0.041	0.014	0.037
8	0.191	0.003	0.041	0.063	0.021	0.009	0.016	0.096	0.052
9	0.112	0.029	0.054	0.120	0.041	0.042	0.038	0.126	0.047
10	0.051	0.101	0.045	0.065	0.053	0.028	0.072	0.056	0.061
11	0.046	0.112	0.058	0.103	0.085	0.079	0.061	0.036	0.047
12	0.026	0.112	0.035	0.044	0.076	0.069	0.040	0.029	0.033
13	0.071	0.034	0.054	0.049	0.077	0.054	0.063	0.021	0.011
14	0.067	0.043	0.082	0.040	0.040	0.056	0.049	0.051	0.021
15	0.063	0.014	0.097	0.024	0.033	0.078	0.050	0.033	0.012
16	0.040	0.037	0.051	0.052	0.039	0.092	0.054	0.043	0.020
17	0.019	0.103	0.051	0.031	0.017	0.016	0.045	0.000	0.032
18	0.019	0.041	0.007	0.040	0.034	0.072	0.058	0.018	0.031
19	0.006	0.080	0.011	0.028	0.054	0.019	0.029	0.030	0.008
20	0.007	0.027	0.066	0.004	0.088	0.013	0.022	0.061	0.039
21	0.003	0.026	0.066	0.023	0.028	0.030	0.017	0.012	0.046
22	0.010	0.007	0.046	0.034	0.031	0.022	0.012	0.021	0.019
23+	0.126	0.086	0.125	0.242	0.258	0.297	0.309	0.294	0.469
Sample size	356	497	442	354	462	293	533	272	421

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.

	Last years model	**Model 1**
Likelihood components		
Catch	0.09	0.03
Survey index	8.64	9.57
Fishery age data	58.86	16.15
Survey age data	50.76	45.46
Fishery size data	38.61	31.01
Recruit. variability	4.54	4.01
F penalty	3.95	3.96
q Prior	0.97	0.22
M prior	0.37	0.00
Subtotal for data	156.95	110.42
Total	169.33	102.23
Goodness of fit		
Eff. N **Fishery Age**	115	82
N Input	174	22
SDNR	1.00	0.44
Eff. N **Survey Age**	54	40
N Input	20	26
SDNR	0.55	0.45
Eff. N **Fishery Size**	41	40
N Input	26	26
SDNR	0.50	0.92
Parameter estimates		
Natural Mortality	0.063	0.060
Survey *q*	0.812	0.744
(CV)	(13%)	(24%)
1961 SSB	94,869	80,449
(CV)	(14%)	(22%)
2006 SSB	31,108	32,274
(CV)	(29%)	(47%)
Ratio 1961/2006 SSB	0.33	0.40
1994 Year class	59,395	42,174
(CV)	(30%)	(42%)
F40%	0.062	0.061

Table 10.11. Estimated time series of female spawning biomass, total exploitable 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 1 results compared to Courtney et al. (2006).

	Spawning Biomass (t)		Exploitable Biomass (t)		6+ total biomass (t)		Catch / (6+ total biomass)		Age Two Recruits (1000's)	
Year	Current	Previous	Current	Previous	Current	Previous	Current	Previous	Current	Previous
1977	24,187	28,490	59,485	75,749	77,651	92,354	0.008	0.007	19,024	22,161
1978	24,441	28,357	63,056	78,463	78,713	92,666	0.007	0.006	**87,472**	**112,452**
1979	24,967	28,457	67,677	81,672	80,696	93,945	0.008	0.007	17,911	11,747
1980	25,712	28,764	71,310	84,057	82,791	95,568	0.010	0.008	24,764	14,397
1981	26,646	29,204	73,262	85,565	85,532	98,133	0.017	0.015	9,986	11,164
1982	27,547	29,409	74,244	86,810	102,341	119,331	0.038	0.033	18,184	10,527
1983	27,712	29,286	74,027	87,653	104,217	119,903	0.035	0.030	17,465	21,848
1984	28,147	29,786	77,112	92,251	107,539	120,637	0.009	0.008	**37,462**	**33,308**
1985	29,720	31,225	86,281	101,677	110,160	122,665	0.002	0.002	17,278	11,234
1986	31,802	33,092	96,024	110,149	114,558	124,555	0.002	0.002	**49,656**	**65,601**
1987	34,060	35,121	102,676	115,041	118,249	127,986	0.004	0.004	16,404	23,307
1988	36,392	37,153	106,636	117,353	125,513	133,302	0.009	0.008	12,173	14,595
1989	38,564	38,997	108,967	118,374	128,095	133,449	0.012	0.011	16,437	17,335
1990	40,526	40,596	111,255	119,585	136,735	144,093	0.013	0.012	13,692	14,617
1991	42,271	41,604	114,416	121,684	138,770	146,902	0.033	0.031	8,713	8,188
1992	42,780	41,305	115,589	122,246	136,520	144,736	0.057	0.054	17,420	19,012
1993	41,880	40,407	113,977	120,594	131,364	139,374	0.037	0.035	11,379	6,641
1994	41,860	39,944	114,055	120,920	128,229	136,053	0.047	0.044	9,396	12,115
1995	41,269	39,169	111,030	118,283	122,578	129,886	0.046	0.043	5,764	7,762
1996	40,619	38,661	107,151	114,501	118,751	125,902	0.028	0.027	**42,174**	**63,579**
1997	40,616	38,612	104,900	112,018	115,923	121,607	0.025	0.024	15,149	23,692
1998	40,558	38,483	102,621	109,366	112,886	118,491	0.027	0.026	10,339	11,459
1999	40,241	37,822	100,147	106,360	108,755	114,227	0.050	0.047	18,320	14,248
2000	38,729	36,606	95,210	100,976	109,785	119,192	0.030	0.028	26,465	**33,950**
2001	37,938	35,867	92,279	98,461	108,279	119,672	0.029	0.026	7,890	7,654
2002	37,152	35,141	90,315	98,073	105,957	117,938	0.031	0.028	7,905	8,208
2003	36,301	34,188	89,891	99,547	105,019	116,313	0.051	0.046	8,678	10,449
2004	34,716	32,955	87,963	99,120	103,979	116,657	0.046	0.041	9,489	12,221
2005	33,462	32,002	85,839	97,966	99,984	112,523	0.048	0.043	10,272	13,846
2006	32,274	34,195	83,625	96,076	95,701	108,038	0.052	0.047	11,246	15,744
2007	31,097		81,473		91,228		0.042		11,246	

Table 10.12. Estimated numbers (thousands) in 2007, fishery selectivity, and survey selectivity of northern rockfish in the Gulf of Alaska based on Model 1. Also shown are schedules of age specific weight and female maturity.

Age	2007 numbers (1000's)	Percent mature	Weight (g)	Fishery selectivity	Survey selectivity
2	11,246	1	63	0.000	0.007
3	10,592	2	103	0.001	0.016
4	9,111	3	153	0.002	0.036
5	7,926	4	210	0.007	0.077
6	6,824	6	273	0.027	0.160
7	5,845	9	336	0.091	0.301
8	5,464	13	399	0.266	0.493
9	16,983	18	458	0.569	0.688
10	10,696	25	512	0.828	0.833
11	5,412	33	561	0.946	0.919
12	7,072	43	603	0.985	0.962
13	17,578	52	641	0.996	0.983
14	2,158	62	672	0.999	0.992
15	3,175	71	699	1.000	0.997
16	3,476	78	722	1.000	0.999
17	4,807	84	740	1.000	0.999
18	2,178	89	756	1.000	1.000
19	3,108	92	769	1.000	1.000
20	3,382	95	780	1.000	1.000
21	2,257	96	788	1.000	1.000
22	2,727	97	795	1.000	1.000
23+	41,253	98	801	1.000	1.000

Table 10.13. Northern rockfish spawning biomass, fishing mortality, and yield for seven harvest scenarios based on Model 1.

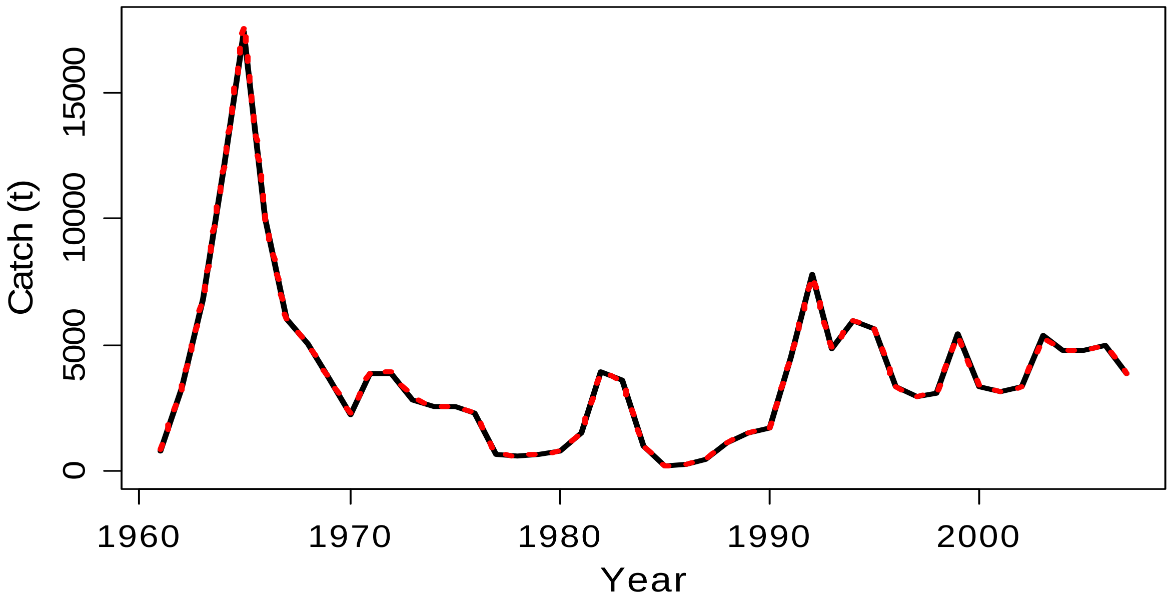
	$B_{100\%}$	$B_{40\%}$	$B_{35\%}$				
	55,750	22,300	19,500				
Year	Maximum permissible F	Author's F (Estimated catches)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
Spawning biomass (mt)							
2007	29,991	29,991	29,991	29,991	29,991	29,991	29,991
2008	29,170	29,229	29,458	29,191	29,752	29,055	29,170
2009	28,183	28,414	29,308	28,265	30,482	27,746	28,183
2010	27,213	27,548	29,125	27,349	31,183	26,485	27,106
2011	26,243	26,560	28,885	26,430	31,820	25,257	25,837
2012	25,283	25,580	28,587	25,514	32,376	24,073	24,610
2013	24,357	24,633	28,250	24,625	32,860	22,958	23,451
2014	23,493	23,747	27,897	23,793	33,286	21,946	22,387
2015	22,729	22,961	27,564	23,056	33,697	21,098	21,474
2016	22,100	22,308	27,303	22,443	34,132	20,449	20,763
2017	21,635	21,815	27,161	21,970	34,627	19,990	20,251
2018	21,315	21,468	27,081	21,621	35,172	19,687	19,902
2019	21,142	21,272	27,146	21,405	35,807	19,533	19,708
2020	21,091	21,200	27,233	21,304	36,531	19,497	19,638
Fishing mortality							
2007	0.050	0.050	0.050	0.050	0.050	0.050	0.050
2008	0.061	0.054	0.030	0.058	-	0.073	0.073
2009	0.061	0.054	0.030	0.058	-	0.073	0.073
2010	0.061	0.061	0.030	0.058	-	0.073	0.073
2011	0.061	0.061	0.030	0.058	-	0.073	0.073
2012	0.061	0.061	0.030	0.058	-	0.073	0.073
2013	0.061	0.061	0.030	0.058	-	0.073	0.073
2014	0.061	0.061	0.030	0.058	-	0.072	0.072
2015	0.061	0.061	0.030	0.058	-	0.069	0.069
2016	0.060	0.060	0.030	0.058	-	0.066	0.066
2017	0.059	0.059	0.030	0.058	-	0.065	0.065
2018	0.058	0.058	0.030	0.058	-	0.064	0.064
2019	0.057	0.057	0.030	0.058	-	0.063	0.063
2020	0.057	0.057	0.030	0.058	-	0.063	0.063
Yield (mt)							
2007	3,866	3,866	3,866	3,866	3,866	3,866	3,866
2008	4,553	**4,098**	2,310	4,390	-	5,431	4,553
2009	4,345	**3,910**	2,268	4,198	-	5,123	4,345
2010	4,123	4,172	2,213	3,992	-	4,808	4,917
2011	3,917	3,962	2,159	3,800	-	4,520	4,619
2012	3,738	3,779	2,112	3,633	-	4,272	4,361
2013	3,592	3,629	2,076	3,497	-	4,070	4,148
2014	3,486	3,519	2,055	3,398	-	3,855	3,982
2015	3,429	3,460	2,054	3,347	-	3,630	3,750
2016	3,365	3,411	2,072	3,334	-	3,497	3,595
2017	3,307	3,352	2,096	3,339	-	3,427	3,506
2018	3,275	3,314	2,123	3,350	-	3,396	3,461
2019	3,269	3,301	2,151	3,366	-	3,398	3,450
2020	3,282	3,308	2,179	3,384	-	3,423	3,465

Table 10.14. 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

Table10.15. Average bycatch (kg) and bycatch rates during of living substrates in the Gulf of Alaska; Source: Alaska Regional Office, data prepared by Olav Orsmeth.

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



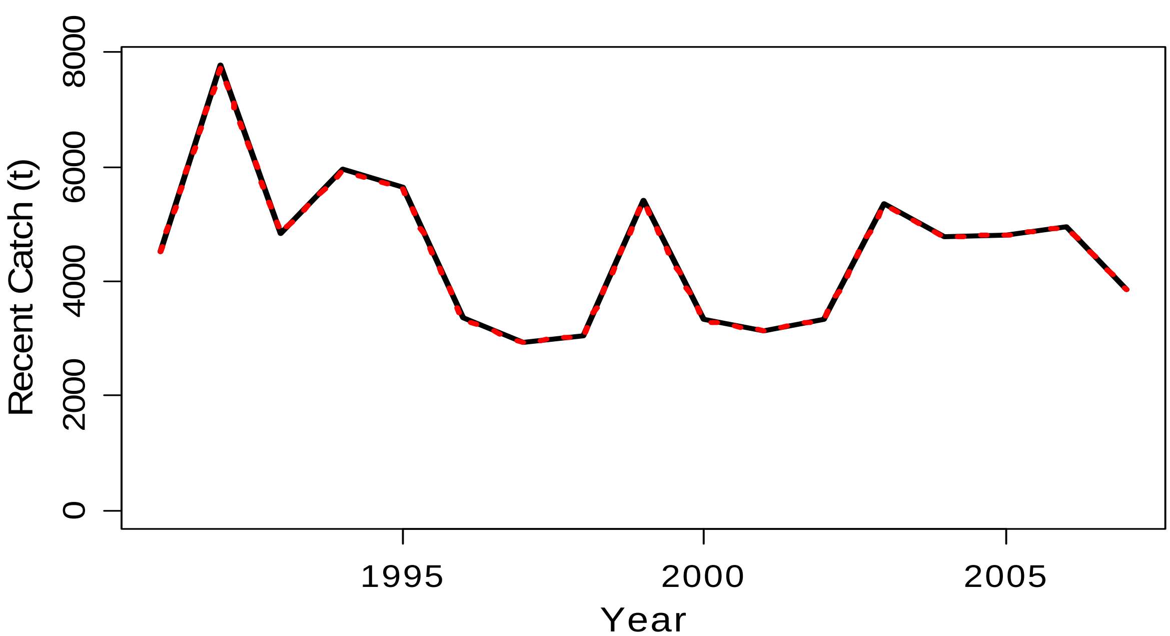


Figure 10.1. Estimated long-term and recent commercial catch of northern rockfish in the Gulf of Alaska. The *Fishery* section describes the procedures used to estimate catch for the years 1965-1993. Catch for the years 1993-2006 is from NMFS Observer Program and Alaska Regional Office.

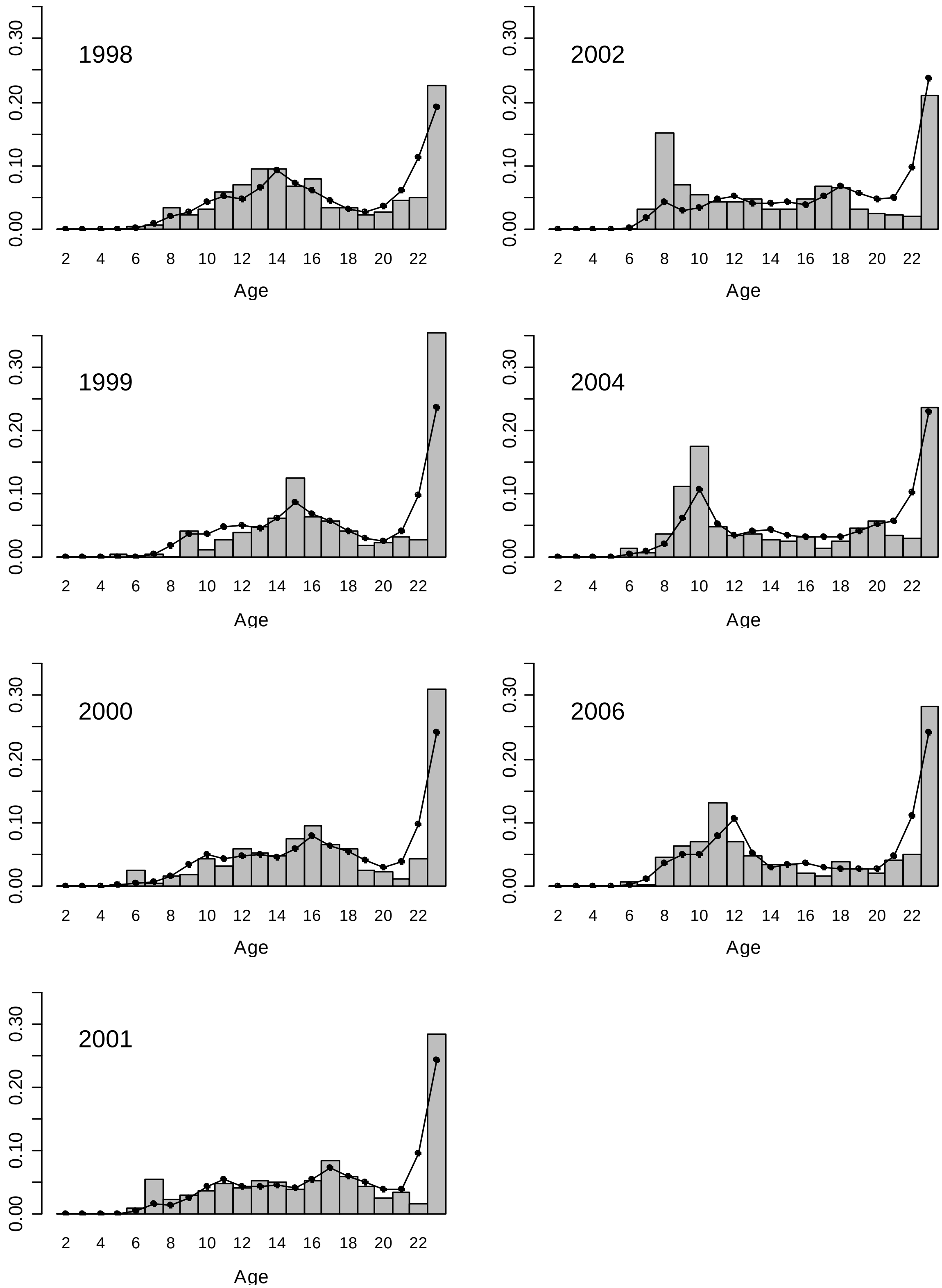


Figure 10.2. Fishery age compositions for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles .

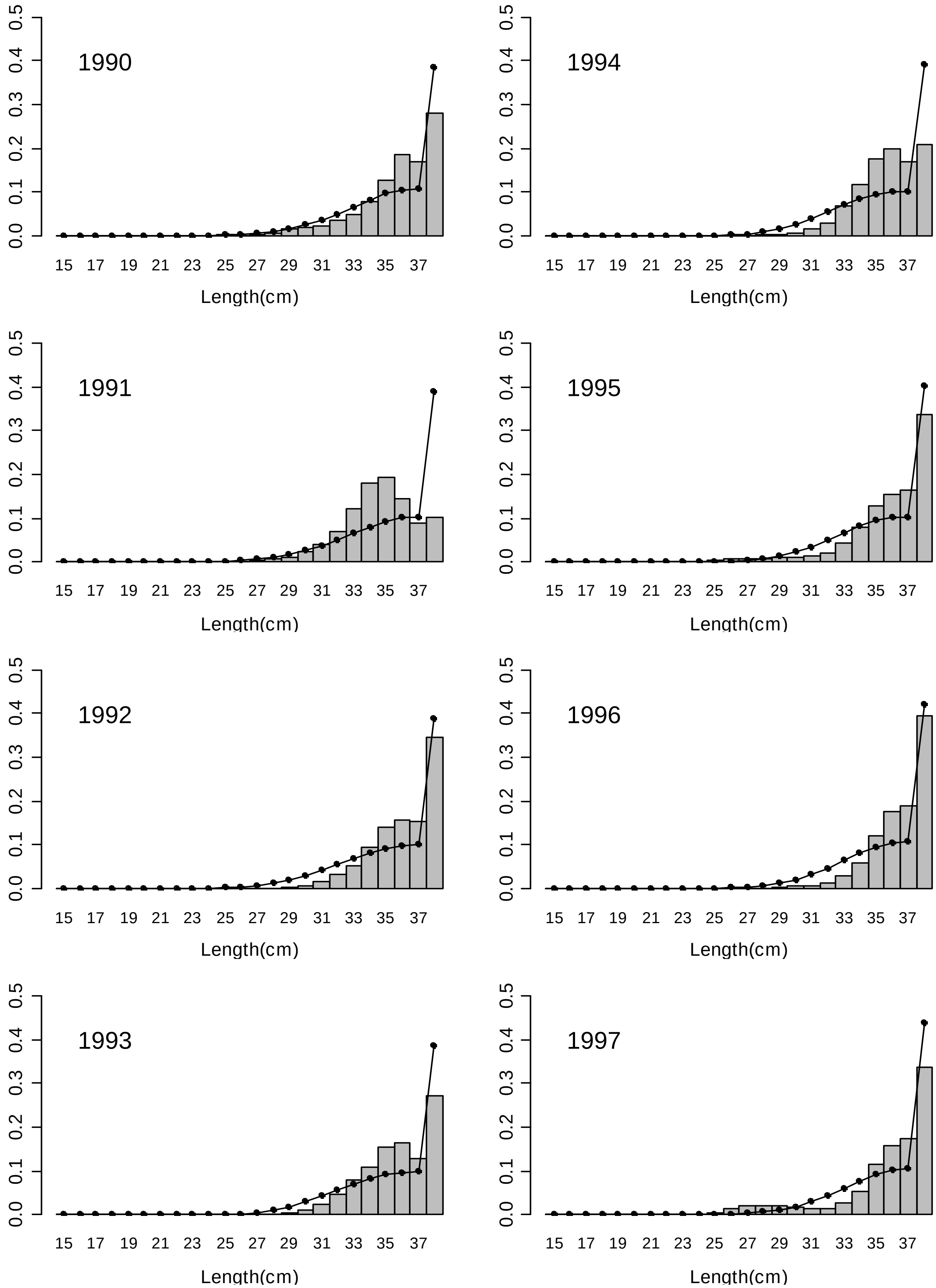


Figure 10.3. Fishery length compositions for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

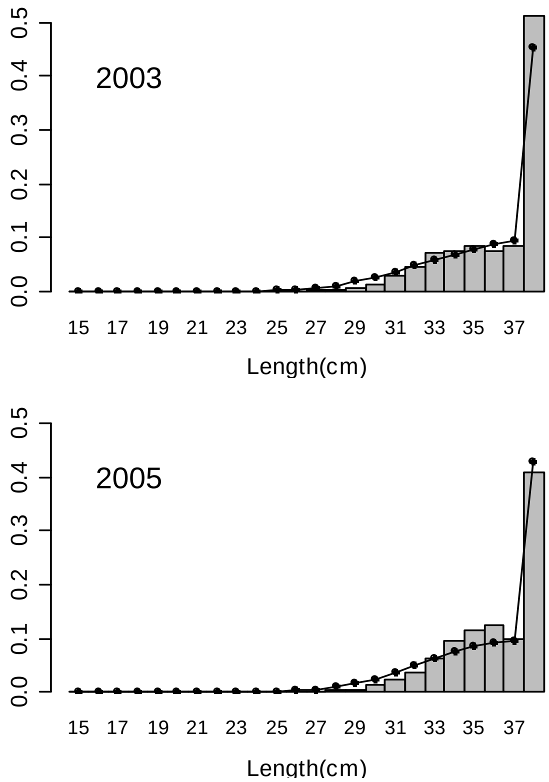


Figure 10.3 (continued) Fishery length compositions for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

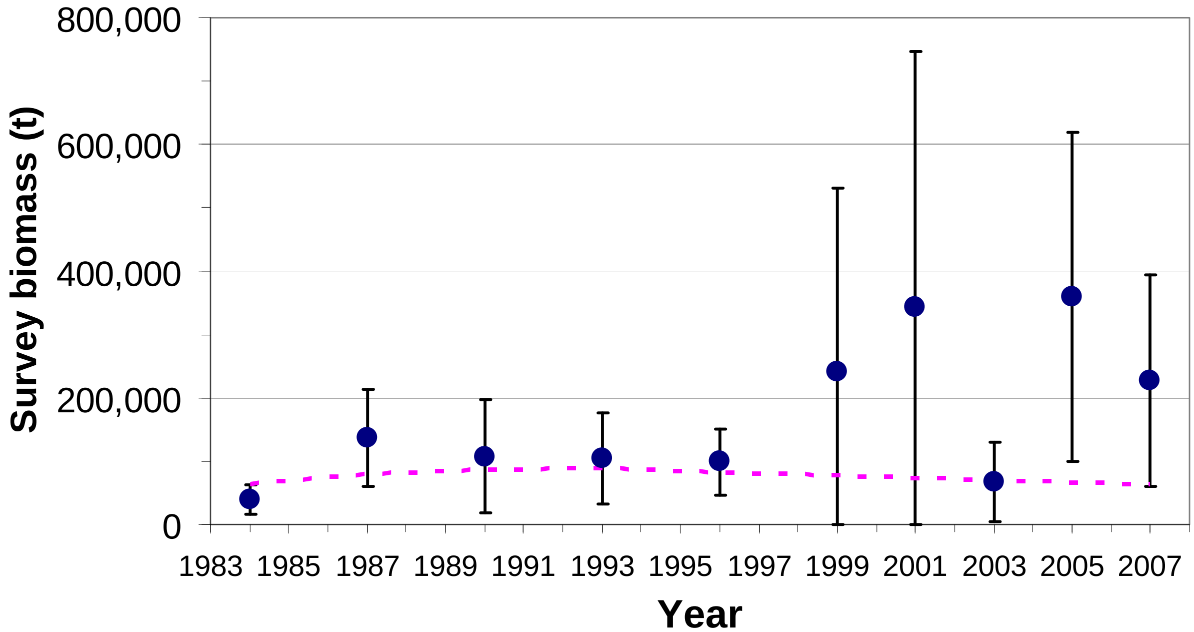


Figure 10.4. Observed and predicted GOA northern rockfish trawl survey index of biomass. Observed biomass=circles with 95% confidence intervals of sampling error. Predicted is based on authors recommended model.

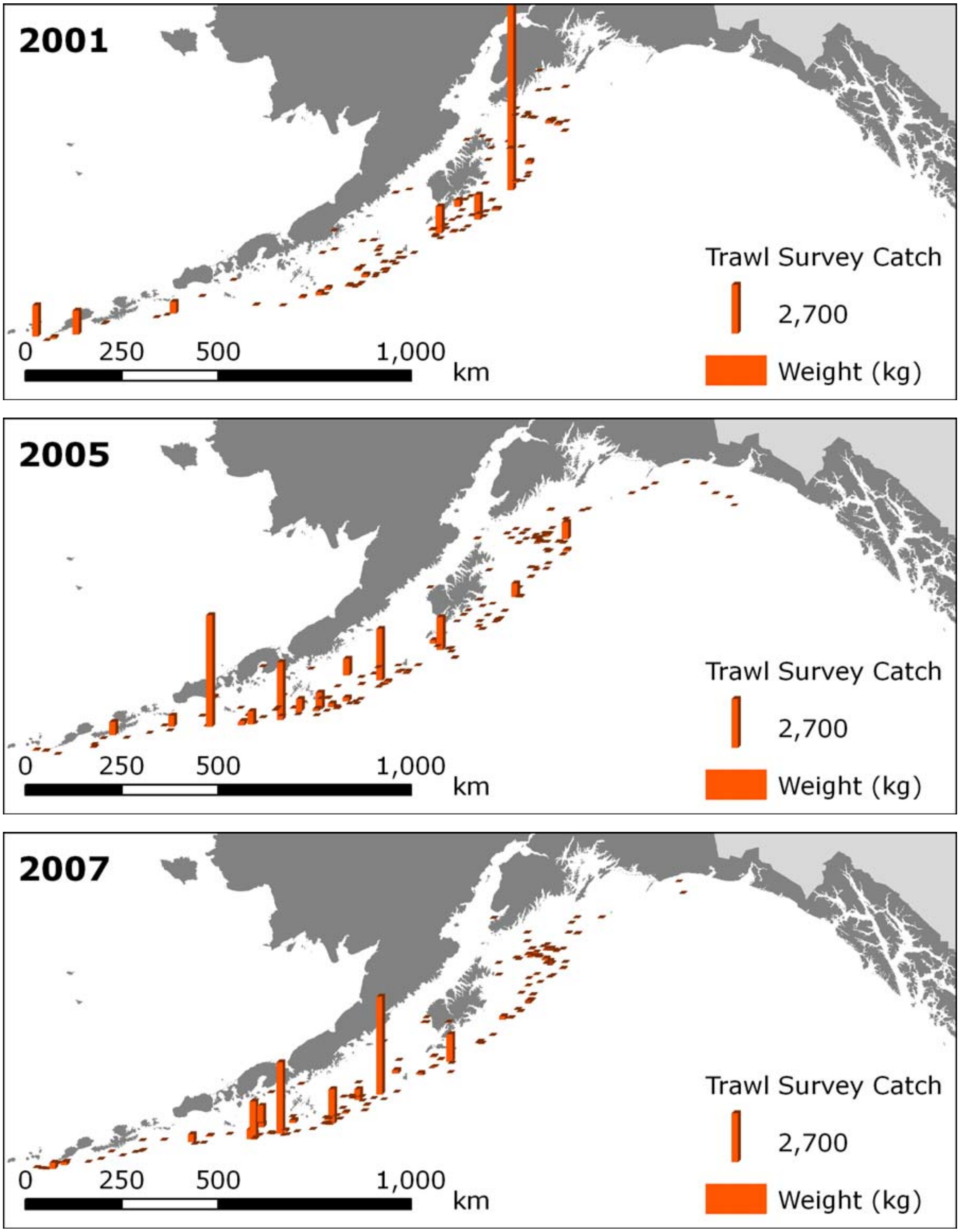


Figure 10.5a. Trawl survey catches of northern rockfish for 2001, 2005, and 2007.

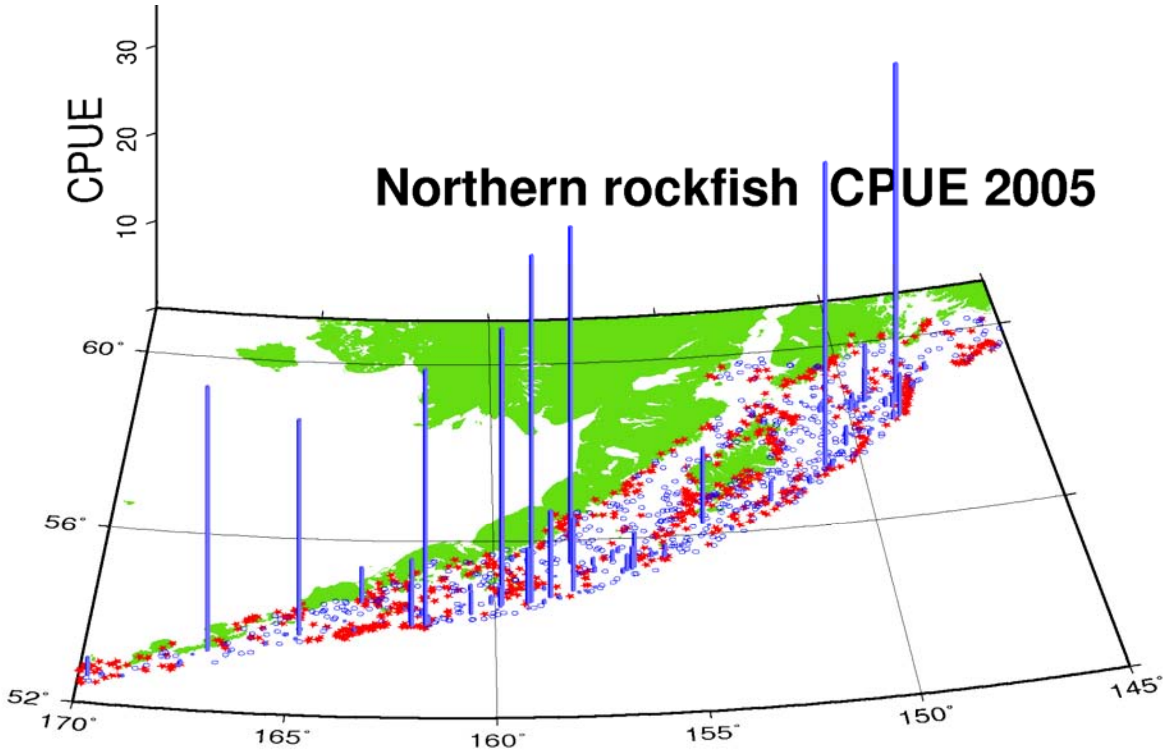


Figure 10.5b. Survey trawl CPUE for 2005 showing locations where stations were omitted due to untrawlable grounds (red stars). Vertical bars represent the relative magnitude of northern rockfish trawl CPUE while open circles represent successful tows but no catch of northern rockfish.

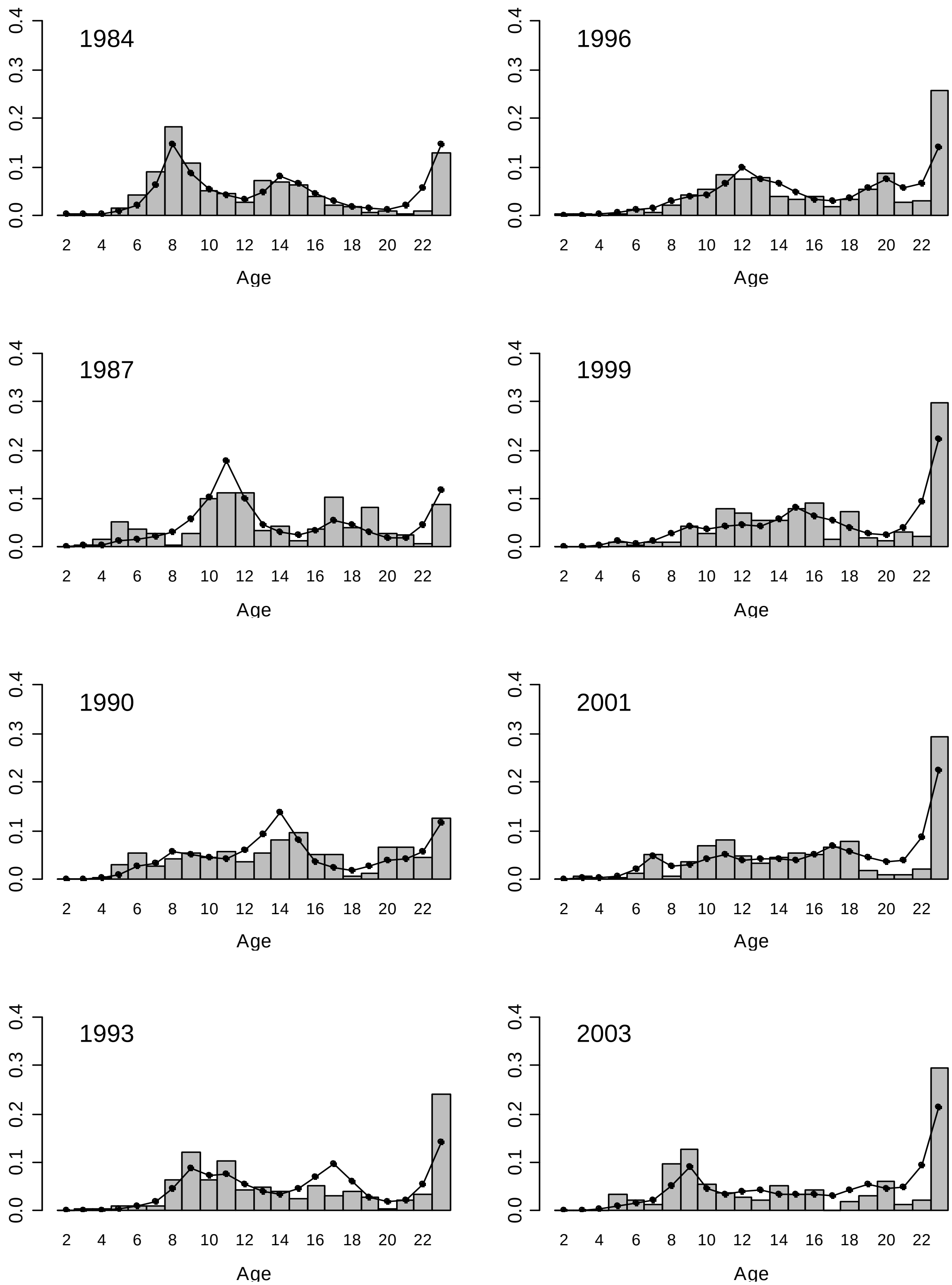


Figure 10.6. Trawl survey age composition by year for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

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

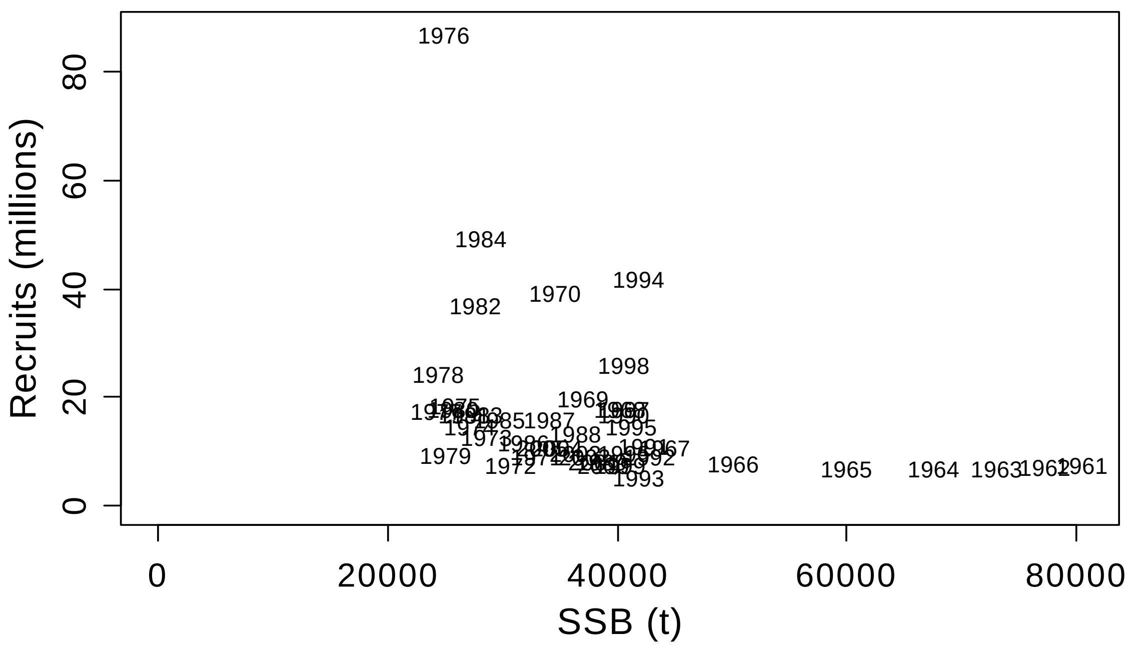


Figure 10.7. Relationship between female spawning stock biomass and recruitment for GOA northern rockfish based on the authors recommended model.

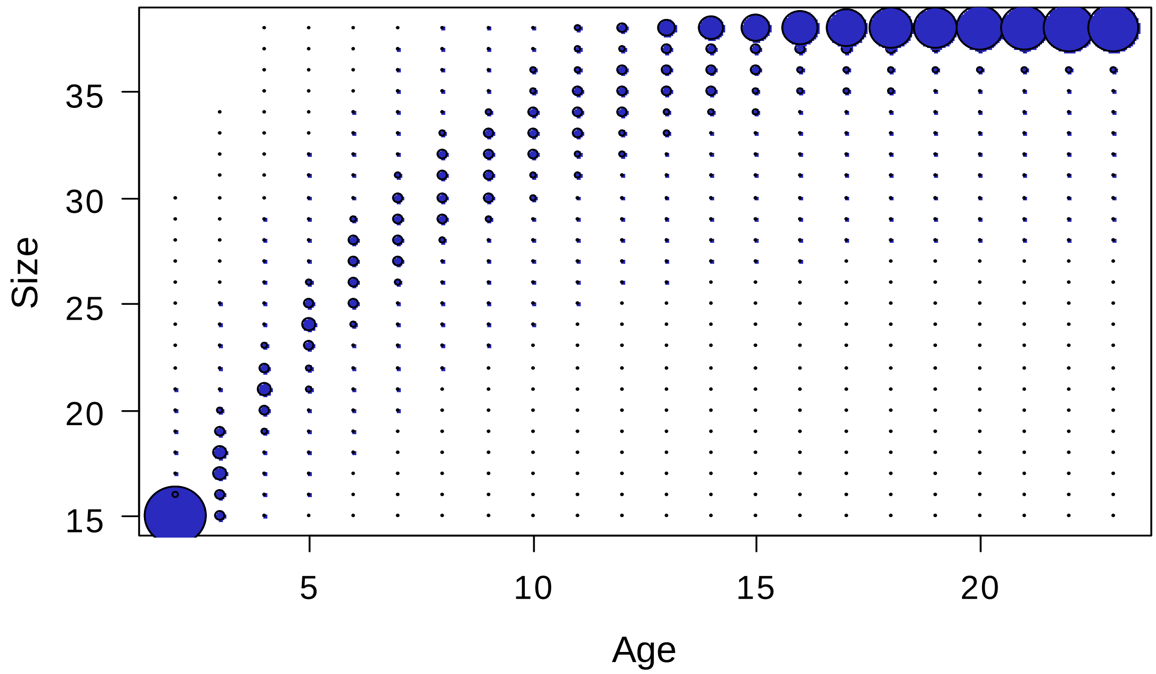


Figure 10.8. Length-age transition matrix used for GOA northern rockfish. The matrix is based on Length at age data from trawl surveys.

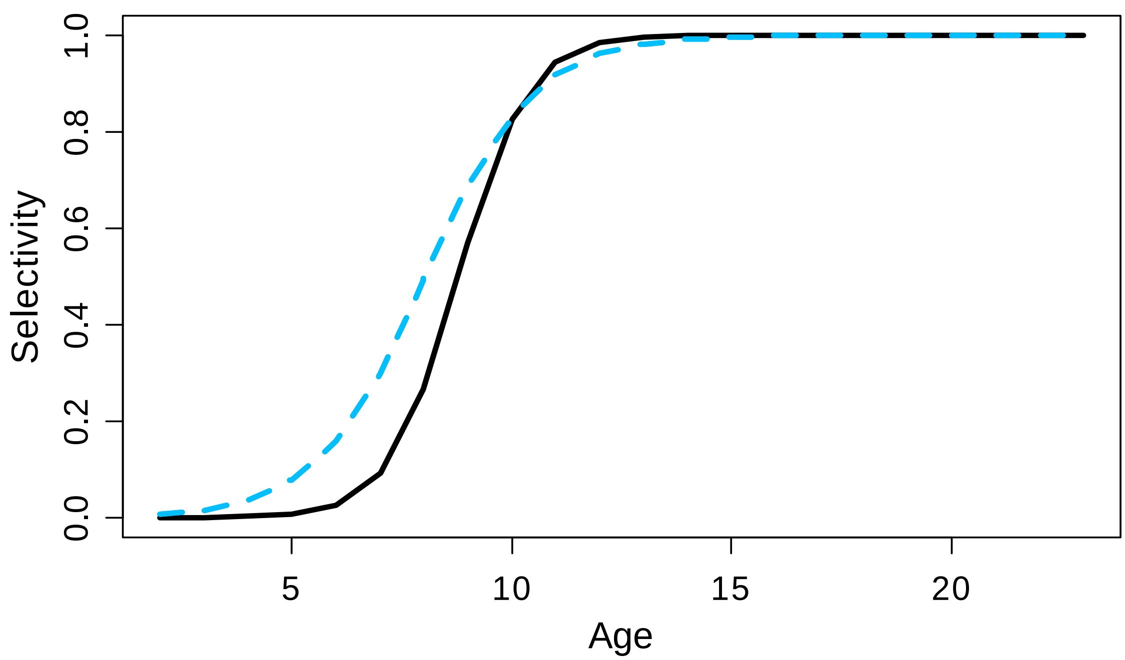


Figure 10.9. Fishery (solid line) and survey (dotted line) estimates of selectivity for GOA northern rockfish based on the authors recommended model.

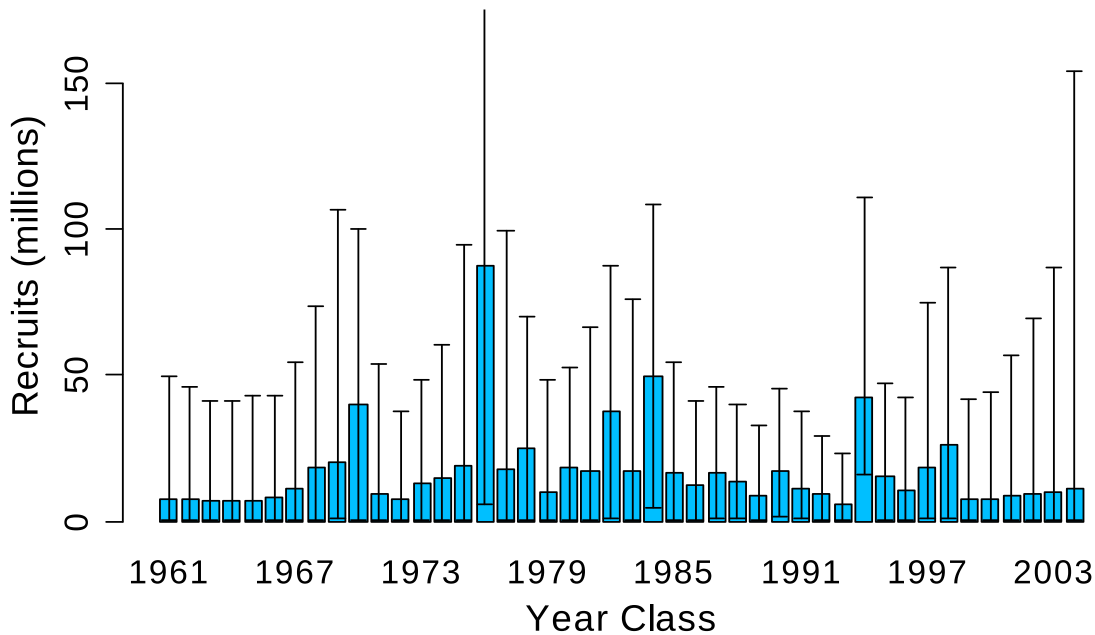


Figure 10.10a. Estimates of year class strength and 95% confidence intervals for GOA northern rockfish based on the authors recommended model.

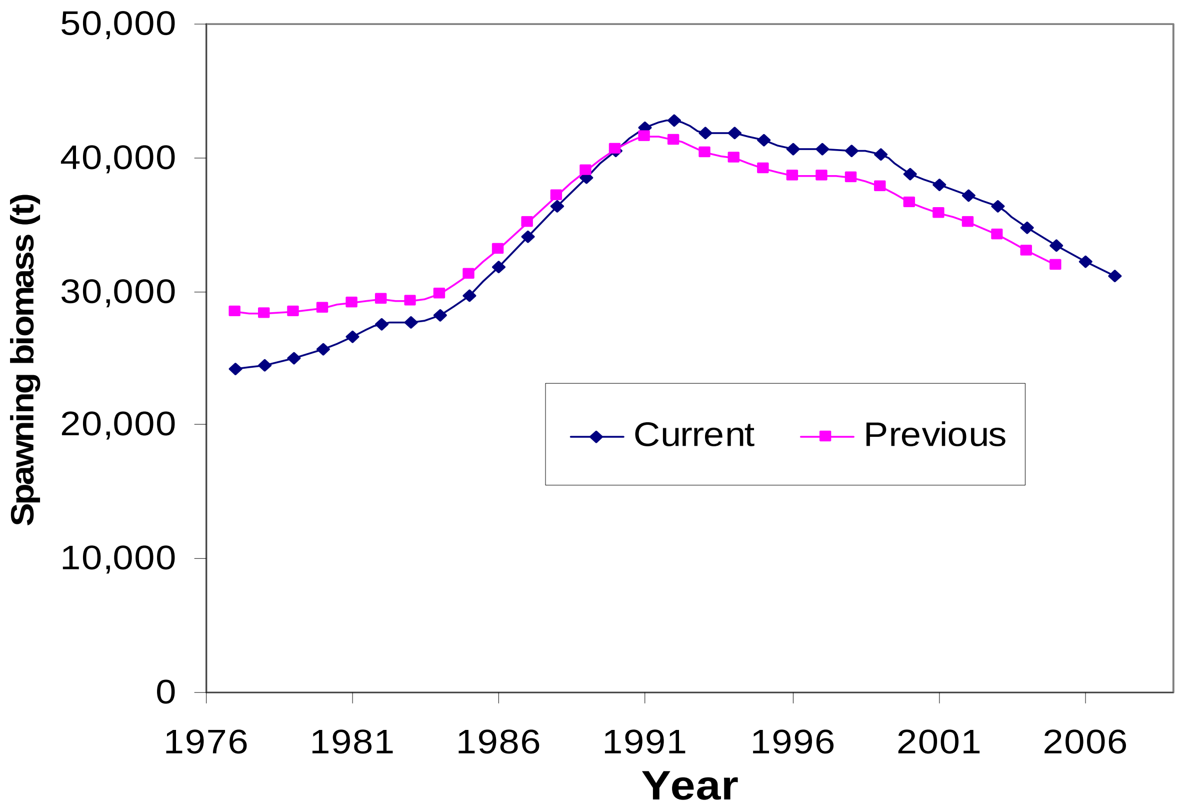


Figure 10.10b. Recent trend in female spawning biomass based on the current assessment and the previous assessment as reported in Courtney et al (2006).

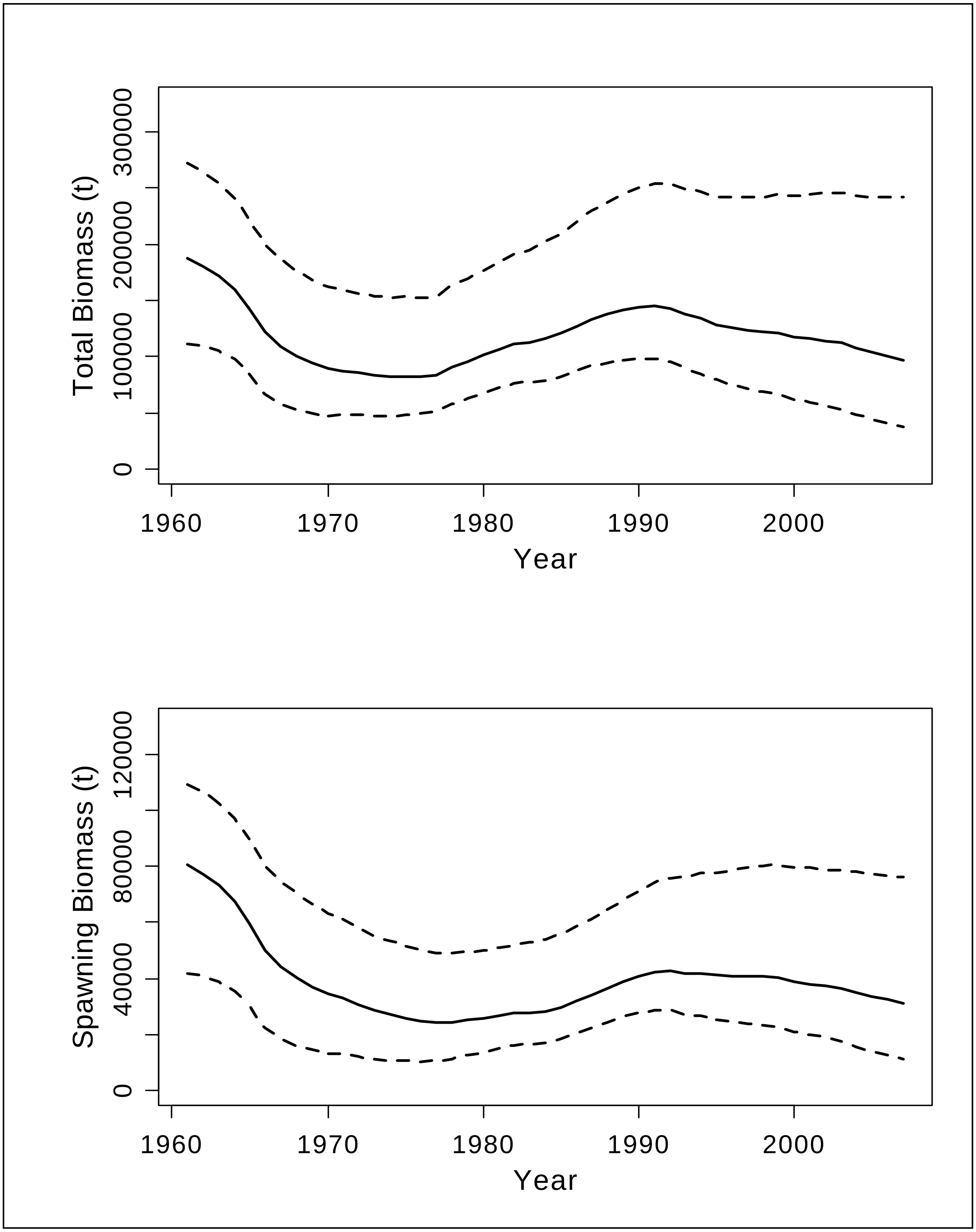


Figure 10.11. Model estimated total biomass and spawning biomass (solid lines) with 95% confidence intervals determined by MCMC (dashed line) for Gulf of Alaska northern rockfish.

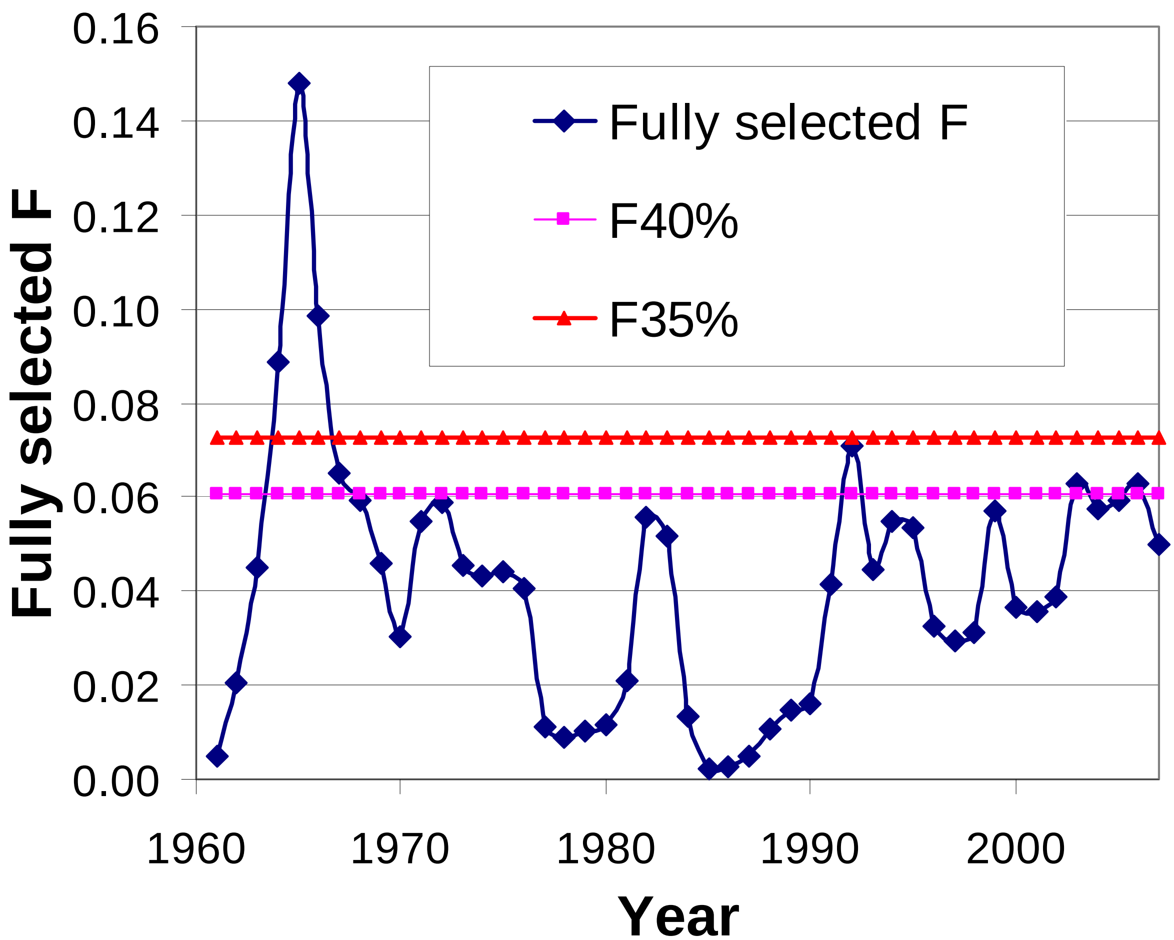


Figure 10.12. Model estimates of fishing mortality relative to $F_{40\%}$ and $F_{35\%}$ levels for GOA northern rockfish.

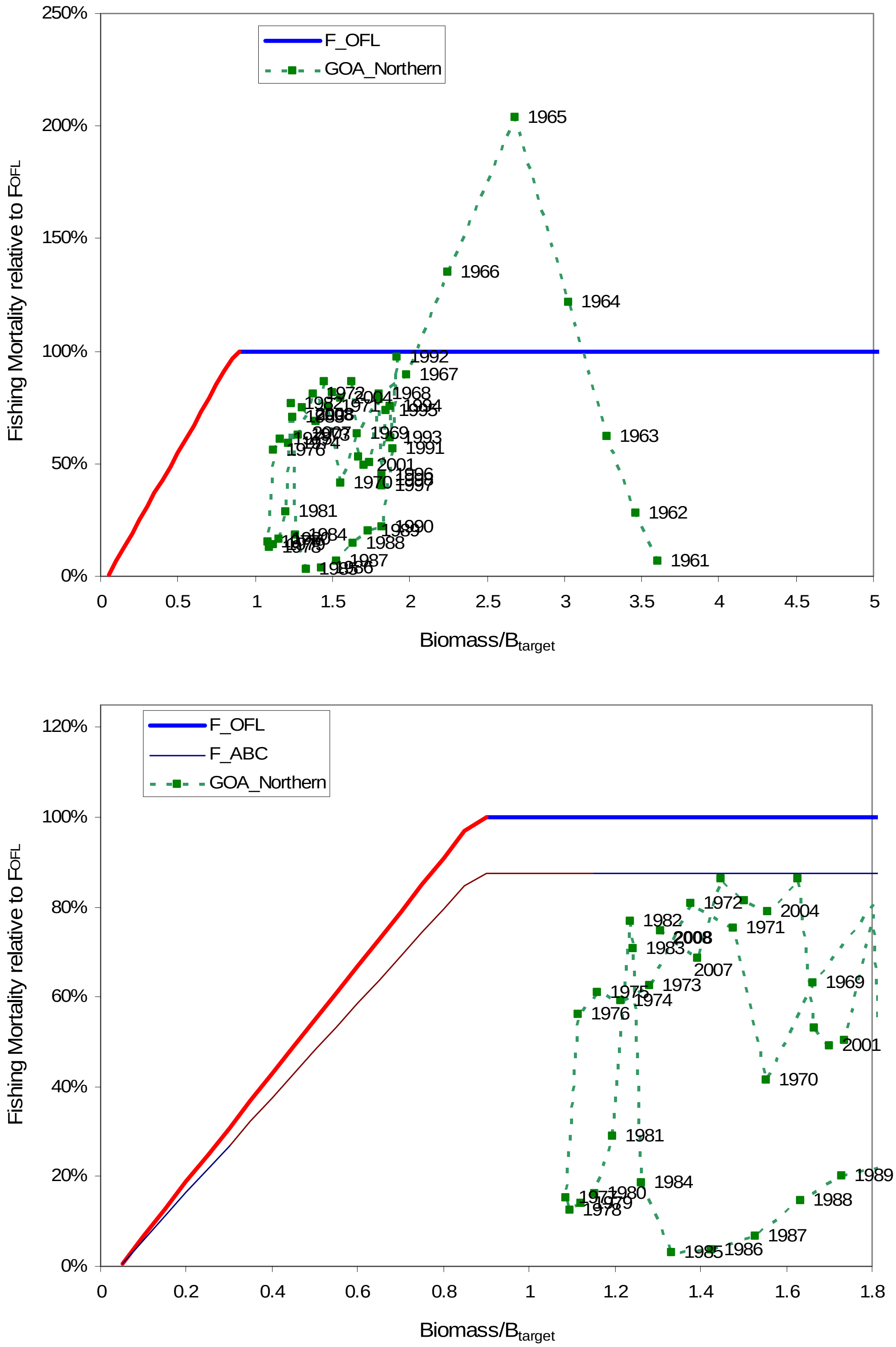


Figure 10.13. Time series of northern rockfish estimated spawning biomass relative to the target level and fishing mortality relative to F_{OFL} for author recommended model.

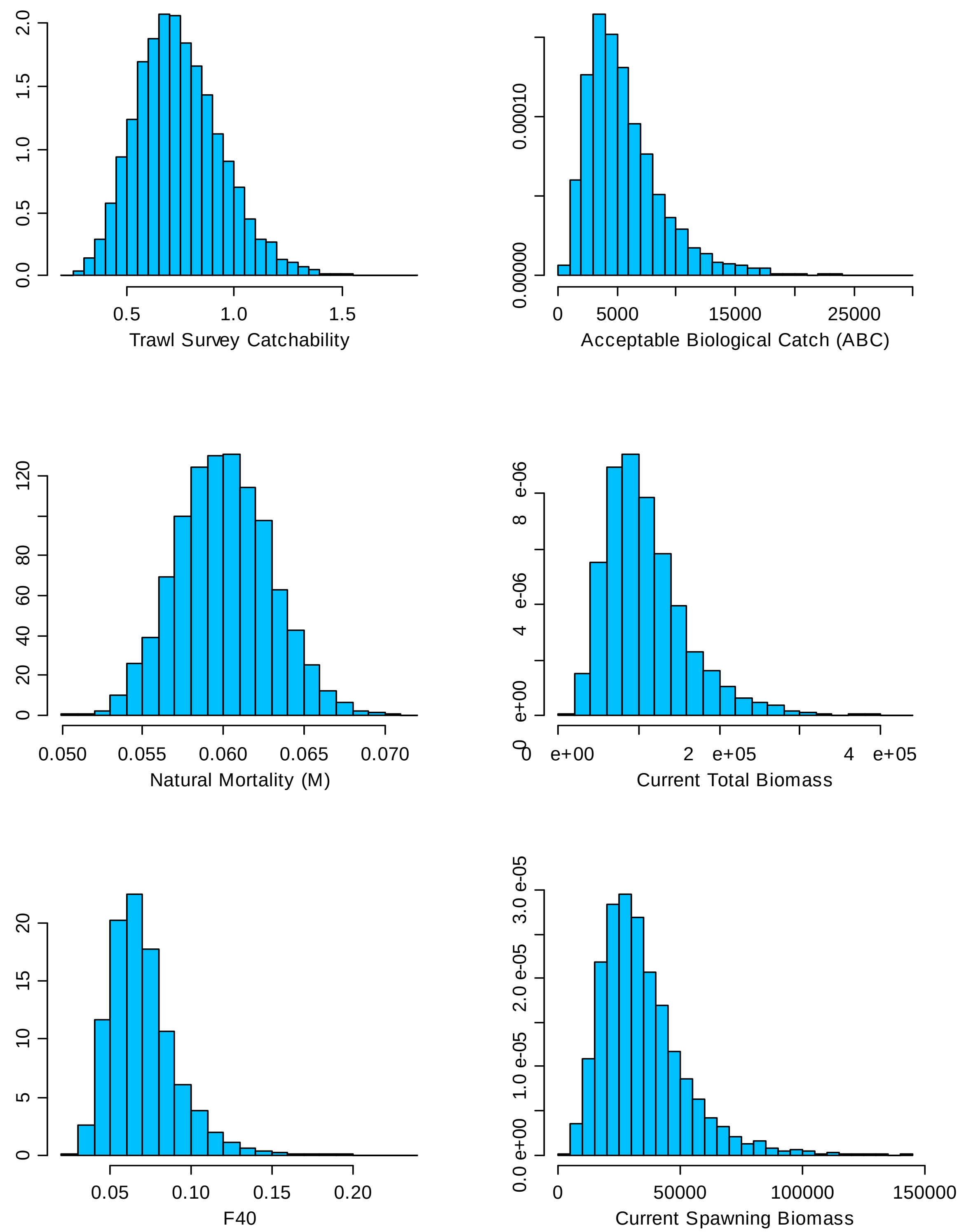


Figure 10.14. Histograms of estimated posterior distributions for key parameters derived from the MCMC for GOA northern rockfish.