Section 9

9. Gulf of Alaska Northern Rockfish

by

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9.0 Executive Summary

Summary of Major Changes

For northern rockfish, the reference age-structured model (Model 1) is recommended 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. The reference model was reviewed at a rockfish modeling workshop held in Juneau in the spring of 2006. The reference model differs from last year's GOA northern rockfish model by removal of the stock recruitment relationship, and by modeling selectivity as a logistic rather than smoothed penalty function, and estimates natural mortality with a penalized prior distribution. The model differs from the last full assessment for GOA northern rockfish (SAFE 2003 for 2004) by estimating separate selectivities for the survey and fishery and by allowing estimation of natural mortality with an informative lognormal prior distribution.

Input data

The model was updated to include the 2005 survey biomass estimate, updated catch from 2004, final catch for 2005, preliminary catch for 2006, survey age composition from 2003 and 2005, fishery age compositions from 2004, and updated fishery age compositions from a backlog of available otoliths for the years 2000 – 2002. Fishery length compositions were not used for the years with fishery age compositions (1998-2002, and 2004). An estimate of historical catch is provided for the years 1961-1976 in order to examine model sensitivity to unreported catch in those years. Catch for the years 1961-1976 was estimated here as 5% of POP catch in the same years based on analysis of the ratio of northern rockfish catch to POP catch in the years 1993-1995 (Ackley and Heifetz, 2001). The LVB relationship and resulting age-length transition matrix were updated with the most recently available length-at-age data from NMFS bottom trawl surveys.

Assessment methodology

The assessment methodology this year focused on evaluating model fit to the survey biomass index. The standard deviation of normalized residuals for the fit to survey biomass was compared from 9 model runs designed to evaluate sensitivity to model assumptions and the relative contributions of different data components. The reference model (Model 1) simplified last year's GOA northern rockfish model (Model 2) by removal of the stock recruitment relationship, by modeling selectivity as a logistic rather than smoothed penalty function, and updated the LVB relationship and length-age transition matrix with most recently available data, and included estimates of historic catch from 1961-1977. Models 3 - 9 evaluated model sensitivity to model assumptions about survey catchability and the relative contributions of different data components. For comparing among model alternatives and sensitivities, a means to judge how well models fit data given the assumed component variances (and statistical weights, if any) was developed. The approach taken here was to standardize output variances and compare them with assumed input values (normalized residuals).

Assessment results

The recommended ABC for 2007 is 4,940 t. The corresponding reference values for northern rockfish recommended for this year and projected one additional year are summarized below:

Summary	2007	2008
6+ Total Biomass (t)	94,271	91,557
$B_{40\%}$ (t)	22,740	22,740
Female spawning biomass (t)	30,220	29,350
F_{ABC} $(=F_{40\%})$	0.062	0.062
F_{OFL} $(=F_{35\%})$	0.074	0.074
ABC	4,940	4,750
OFL	5,890	5,660

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

Response to SSC and Plan Team comments

Response to 2005 SSC Comments

There were no 2005 specific SSC comments to GOA northern rockfish assessment authors.

Response to 2005 GOA Plan Team Minutes

The Plan team recommended review of the GOA northern rockfish again in Sept 2006.

The Plan Team questioned the location of sampling for length and age data relative to where catch was taken. The fishery characteristics appear to be changing with more deliveries to Kodiak. In 2004 there were 942 fish aged from 308 hauls but the author did not have a breakdown of the number of fish from each of these hauls, thus there could be a disproportionate amount from certain hauls which could bias the data in the model.

Sample Sizes are given in tables 9.3 and 9.7.

The Plan Team discussed the M values used in the models. Bill Clark questioned the impacts of freeing M under this model.

Consensus at the 2006 rockfish modeling workshop was to acknowledge that there is error in estimation of natural mortality by assigning a relatively informative lognormal prior distribution. Prior and posterior distributions for natural mortality and survey catchability can then be compared e.g., Fig 9.17.

The Plan team noted that estimating a parameter for historical F appeared problematic and that other possible approaches for obtaining an historical F rate include either starting the model back further with an estimate of catch from those years or using two time series of catch (one estimated historical with less data, one more recent with better data).

The approach taken this year was to start the model in 1961 with an estimate of catch based upon the ratio of northern rockfish catch to Pacific ocean perch catch.

Some technical issues related to the model included negative recruitment likelihoods are in models 4 and 5, Table 9.8)

Negative recruitment likelihoods resulted from priors on recruitment deviations if stock-recruitment curve selected (Box 1). The model was simplified this year by removing estimation of the stock-recruitment curve from within the age-structured model

The Plan Team recommended model 4, but was uncomfortable with such a large increase in ABC resulting from the model. The Team thus accepts the model for the maximum permissible ABC level but chose the ABC from the past year as the ABC recommendation for 2006. The biological concerns noted above with respect to the actual status of the stock and model fits led the Team to recommend a lower ABC than the maximum permissible. The Plan Team and the stock assessment authors were concerned that Models 2-5 need additional validation to insure that results are reliable. In particular the effect of including historic fishing mortality on model results needs to be more fully explored. Thus, the Plan Team recommends that the ABC from 2005 be used for 2006. Since the model 4 maximum permissible values were accepted (but not recommended) the Team was comfortable with the OFLs for 2006 and 2007 as specified from model 4.

The Team notes the problems with new survey biomass estimates trending upwards while model results predict a decline. The assessment author was commended for examining these various models in an attempt to further evaluate this dichotomy in model versus survey trends. It was noted that next year there may be a new maturity schedule available for use in the assessment. This model should be presented again in September with new formulations and new information included.

The new maturity schedule is not available.

A plan team member commented that the model fit to survey data is problematic due to the high variability in survey biomass estimates and artificially forcing the model to fit the high points may be inappropriate. One problem is in the confidence intervals associated with the biomass estimates which is why the models have trouble fitting these survey estimates. The variance in the early surveys may also be artificially low.

During informal model evaluation, simultaneous removal of the 1984 and 2003 biomass estimates did not result in substantially different estimates of stock status.

The author noted further difficulties in assessing this stock is that northern rockfish are associated with hard to trawl areas. The Team discussed the issue of trawlable versus untrawlable grounds. It was noted that areas that are classified once as untrawlable for the survey are never sampled again. This clearly biases the estimates of certain fish on untrawlable grounds.

An example of trawlable VS untrawlable hauls is provided in Fig. 9.4. The 2006 CIE results also comment on the possible bias in survey biomass estimated from avoiding untrawlable grounds.

Members of the rockfish working group provided an update on some submersible work last year on the snakehead area. Using the submersible they evaluated an area that was thought to be trawlable and was then established as untrawlable for the survey. The Team discussed requesting the rockfish working group to report on survey issues related to rockfish possibly at the September 2006 meeting.

Kalei Shotwell presented an overview of the map grid of trawlable versus untrawlable grounds from the GOA survey. She noted that this grid is used to pick stations in the survey design. The Team discussed the methodology of picking stations and excluding those marked in red areas as untrawlable. It was noted that this methodology usually results in more trawling occurring in known areas than unknown due to efficiency requirements during the survey.

9.1 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. 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 the average distribution of exploitable biomass from the three most recent Gulf of Alaska trawl surveys. Exploitable biomass for slope rockfish apportionment is calculated as the average of the three most recent trawl survey biomass estimates for depths greater than 100 m. Northern rockfish are relatively scarce in the eastern Gulf of Alaska, and the ABC apportioned to the Eastern Gulf management area is small. This small ABC is generally 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).

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.

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.

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.

9.2 Fishery

Total commercial catch (mt) of northern rockfish in the GOA for the years 1965-2006 is summarized by foreign, joint venture, and domestic fisheries (Table 9.1, Fig. 9.1).

Catches of GOA northern rockfish during the years 1965-1976 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 1993-2005 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 - 2005.

Research catches of northern rockfish have been relatively small and are listed in Table 9.2.

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.

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 percent of the total catch of northern rockfish in the Central area that shore-based trawlers have taken since 1996.[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 an analysis of localized depletion of rockfish stocks were presented at the 2005 Lowell Wakefield symposium (Hanselman et al., 2006). Results of the 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. 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 bycatch in fisheries for other species (Clausen and Heifetz 2002).

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. For hauls targeting on northern rockfish, the predominant bycatch species was dusky rockfish, distantly followed by “other slope rockfish,” Pacific ocean perch, and arrowtooth flounder.

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[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.

Gulfwide discard rates[2] (% discarded) for northern rockfish in the commercial fishery for 1993-2002 are as follows:

1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
26.5	17.7	12.7	16.5	27.8	18.3	11.1	8.7	17.5	9.8

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.

9.3 Data

The following table summarizes the data used for this assessment:

Source	Data	Years
Fisheries	Catch	1961-2006
NMFS bottom trawl surveys	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005
NMFS bottom trawl surveys	Age	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003
U.S. trawl fisheries	Age	1998, 1999, 2000, 2001, 2002, 2004
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 9.3. Length compositions are presented in Table 9.4 and Fig. 9.2, and age compositions are presented in Table 9.5 and Fig. 9.3. The fishery length compositions indicate recent recruitment of smaller fish to the population during the years 2002 and 2003. The fishery age compositions indicate that strong year-classes occurred around the years 1976 and 1984. The fishery age compositions from 2004 also indicate that 1994 is emerging as a strong year-class. The sample size (942) for the at sea fishery age composition data in 2004 appears to be large enough to adequately resolve recent year-classes (Fig. 9.3). 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, and 2005. 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

2 Source: National Marine Fisheries Service, Alaska Region, Fishery Management Section, P.O. Box 21688, Juneau, AK 99802-1688. Data are from weekly production and observer reports through October 5, 2002.

low in the eastern Gulf of Alaska. The biomass estimates for northern rockfish have been highly variable from survey to survey (Table 9.6 and Fig. 9.4). 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 survey had several large hauls of northern rockfish in the Central Gulf and estimated variance was smaller (Attachment 9.2). 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. 9.5).

The Gulf of Alaska trawl surveys provide size composition data for northern rockfish population (Table 9.7, Fig 9.6). Generally, the northern rockfish size compositions have been unimodal, however the proportion of smaller fish increased slightly in the 2003 and 2005 and may suggest some recent strong recruitment. Survey size composition estimates (Table 9.8) are not used directly in the current age structured assessment model but are 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 population numbers at age (Table 9.9, Fig. 9.7). The age compositions from each survey 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, perhaps 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.

9.4 Analytic Approach

Gulf of Alaska northern rockfish are currently assessed using an age-structured modeling approach. This year some modifications to the models used in the past were made. These were done to easily evaluate alternative assumptions and the influence of individual data components. These modifications arose from an AFSC sponsored rockfish modeling workshop and resulted in an age structured model template for applications to rockfish species managed by the AFSC.

Model structure

The basic model is described as a separable age-structured model (Box 1) and was implemented using ADMB (Courtney et al. 2005, 2006). While the stock-recruitment relationships are built in to the model’s computer code, for the purposes of simplifying this assessment, these relationships were omitted from analyses. Key information sources are survey index of biomass, catch-at-age estimates, and survey population 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 and evaluated for sensitivity.

The standard errors for selected model parameters were estimated based on multivariate normal approximation of the covariance matrix. The marginal posterior distributions for parameters of interest (e.g., spawning biomass over time) are presented and compared to their approximation based on the delta-method and the estimated asymptotic multivariate normal covariance matrix. The MCMC simulations, the first 500,000 "burn-in" iterations were removed and each subsequent $1{,}000^{th}$ simulation was saved out of 5,000,000. Further tests that the chain had converged were done by comparing the mean of the first half of the chain with mean of the second half after removing the "burn-in" and "thinning." If these two values were similar then convergence to the posterior distribution is more likely (Gelman et al. 1995).

Parameters estimated independently

The natural mortality rate (*M*) for northern rockfish in the Gulf of Alaska is estimated to be 0.06. This estimate was determined by Heifetz and Clausen (1991) using the method of Alverson and Carney (1975). Maximum reported age for Gulf of Alaska northern rockfish is 67 years from the survey and 51 years from the fishery. Age at first recruitment to the commercial fishery is 5 years and to the survey is 2 years. For modeling purposes, age at recruitment is set at 2 and ages past 23 are pooled into a plus group.

Area	Mortality rate	Maximum age	Age of first recruitment
Gulf of Alaska	0.06	67	2 – 5

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].

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

Length-weight coefficients for the formula $W=aL^b$, where W = weight in grams and L = length in mm, were updated here with the most recently available length-at-age data from NMFS bottom trawl surveys (1984-2006). Previous parameters are available from Heifetz and Clausen (1989), Martin (1997), and Courtney et al. (1999).

Area	Sex	a	b	Sample size
Gulf of Alaska	combined	1.75 x 10-5	2.98	3,193

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

The LVB relationship and resulting age-length transition matrix were updated here with the most recently available length-at-age data from NMFS bottom trawl surveys (1984-2005) (Fig. 9. 8). Previous parameters are available from Heifetz and Clausen (1991), Courtney et al. (1999), and Malecha and Heifetz (2001). Figure 9.8 shows some difference in the LVB curves based on data from the previous time period (1984-1993). However, it was assumed that this is the result of the availability of more older and larger fish in the complete time series (1984-1993), rather than a change in growth over time and the use of separate size at age relationships for separate time periods was not evaluated.

The length-at-age transition matrix was constructed by adding normal error to the updated 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 all models presented in this assessment, 121 parameters were estimated conditionally: 68 initial age composition and subsequent recruitment parameters (number of years (46) + number of ages (21) + 1), 47 annual fishing mortality values, 4 selectivity-at-age parameters (2 each for the fishery and survey), 1 natural mortality parameter, and 1 survey catchability parameter.

For comparing among model alternatives and sensitivities, a means to judge how well models fit data given the assumed component variances (and statistical weights, if any) was developed (Courtney et al. 2006). The approach taken here was to standardize output variances and compare them with assumed input values. For survey indices, the normalized residuals are calculated as:

$$\rho_y^{Survey} = \frac{\left(B_y^{Survey} - \hat{B}_y^{Survey}\right)}{\sigma_y^{Survey}}$$

For age and length composition data, the standard deviations of Pearson (normalized) residuals were computed. The Pearson residuals are defined as

$$\rho_{y,a}^{g} = \frac{\left(P_{y,a}^{g} - \hat{P}_{y,a}^{g}\right)}{\sqrt{\hat{P}_{y,a}^{g}\left(1-\hat{P}_{y,a}^{g}\right)/\psi_y^g}}$$

where $P_{y,a}^g$ is the observed vector of proportions-at-age, $\hat{P}_{y,a}^g$ are the predicted values, and ψ_y^g denotes the assumed multinomial sample size corresponding to year y. Standard deviations of $\rho_{y,a}^g$ should be near 1.0 if the model is fitting the data according to the specified variances. Values greater than 1.0 suggest that the model is fitting poorly given the specified level of data precision. Values less than 1.0 indicate the model is fitting the data better than the magnitude of the variance (or sample size) specified would indicate.

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 is the number of years between 5% and 95% selection 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)

Initial year recruitment and numbers at ages.

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

Subsequent years recruitment and numbers at ages

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

Recruitment

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

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

$$B_0=\sum_{a_0}^{a_+-1}R_0e^{-(a-a_0)M}\varphi_a w_a+R_0e^{-(a_+-a_0)M}\varphi_{a_0}w_{a_0}\Big/\left(1-e^{-M}\right)$$

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

Observation equations

Catch biomass in year *y*

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

Logistic selectivity

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

Survey biomass index

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

Vector of fishery or survey predicted proportions at age

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

Vector of fishery or survey predicted proportions at length

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

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

9.5 Model Evaluation

The reference case model (Model 1) for this year's stock assessment for northern rockfish is based on a number of evaluations conducted during the past year. This includes 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. The primary differences from previous models include:

1) The model extends back to 1961 and uses historical fishing levels as tied (approximately) to the magnitude of Pacific ocean perch catches prior to 1977. This part of the catch time series is assumed to be highly uncertain compared to the recent period (CV of ~32% compared to CV of 10% for the recent period).

2) Assumptions about survey catchability are rationalized based on the characteristics of this species. For this assessment, a naive prior distribution with mean of 1.0 and CV of 15% was assumed.

3) The extents to which residual patterns conformed to their statistical expectations (based on input variances) are evaluated.

4) Stock-recruitment relationships are omitted. Given current developments on improving estimates of maturity at age for northern rockfish, including explicit stock-recruitment relationships in the model are considered premature. This was also done to simplify interpretation and influence of the actual data components.

5) Survey and fishery selectivity at age are modeled as asymptotic logistic functions rather than a non-parametric smoothed functions. Preliminary investigations revealed that the overall likelihood provided a better fit with fewer parameters in this configuration.

A large number of model sensitivities were conducted, primarily to evaluate assumptions and the relative contributions of different data sources. These models are presented as sensitivities rather than plausible model alternatives. Their intent is to provide insight on contributions of assumptions and different data sources. This analysis focused on a set of models encompassing nine sensitivity analyses: a new reference case (Model 1), a model with last year's estimated length-age transition matrix (Model 2), a diffuse prior distribution on survey catchability (Model 3, prior CV=30% instead of 15%), and four models with survey index, fishery age composition, survey age composition, and fishery size compositions each down-weighted in succession (Models 4-7). Finally Model 8 had all age and size composition down-weighted (to 1% of their original values) and Model 9 had these same data up-weighted by a factor of four. These alternatives can be summarized as follows:

Model 1	Reference case
Model 2	Previous year's growth curve
Model 3	Diffuse prior on survey catchability
Model 4	Down-weight survey index
Model 5	Down-weight fishery age data
Model 6	Down-weight survey Age
Model 7	Down-weight fishery Size
Model 8	Down-weight all size and age
Model 9	Up-weight all size and age

9.6 Results

Results from the new reference case (Model 1) were very similar to those from past northern rockfish assessments (Fig. 9.9). The reference case results in 2006 female spawning biomass levels that are lower or consistent with the model alternatives and that the fit to the survey index is reasonably good as measured by the value of the standard deviation of normalized residuals (Fig. 9.10; Table 9.10). Model 2 (using estimates of growth from previous assessments) fit the size composition data more poorly and showed greater inconsistency with other data suggesting that the new growth data more accurately reflects the average somatic growth conditions for northern rockfish (Table 9.10). Models 3 and 4 (more diffuse prior on survey catchability, and down-weight survey index) result in appreciably higher and more uncertain stock status. Models 5 and 7 (down-weight fishery age and fishery size) are similar to Model 1 in terms of stock status and fit consistency with the survey index. Models 6 and 8 had better performance in terms of consistency with the survey index but these models down-weighted the survey age composition data. However, the observed large fluctuations in biomass estimates between survey years do not seem reasonable given the long life, slow growth, and low natural mortality of northern rockfish and models with a better fit to age composition data are assumed to be more realistic for northern rockfish.

The new reference case (Model 1) is recommended for this year's assessment. This model has similar properties compared to previous model results (i.e., poor fit to increased trend in survey biomass) and seems to reflect the uncertain nature on the current stock size. Subsequent presentations are therefore based on this selected model.

Northern rockfish survey biomass estimates are assumed to be strongly affected by two very low and precise estimates (e.g, in 1984 and 2003, Fig. 9.11). However, during model evaluation, simultaneous removal of the 1984 and 2003 biomass estimates did not result in substantially different estimates of stock status.

The reference case estimates of current population abundance indicate that it is dominated by older fish from three strong year-classes: 1976, 1984, and 1994 (Table 9.11). The fit to the estimated catch was as precise as expected while the fit to the survey biomass index fails to capture the apparent increase in GOA northern rockfish (Fig. 9.11). Fits to the fishery age composition were reasonable but the "plus group" (age 23 and older) were underestimated compared to the observed values (Fig. 9.12). The model still seems to expect more old fish in the survey age comps from 1984-93 (Fig. 9.13), and more large fish in the fishery size comps (Fig. 9.14) than observed for the first 15 years of data (1990-95). This could be an indication of dome-shaped selectivities or of higher than estimated historic fishing mortality.

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 younger ages than the age of maturity (Fig. 9.15; Table 9.12).

Recruitment estimates for Model 1 show a high degree of uncertainty, but indicate 3 large year-classes (Fig. 9.16). 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 for the late 1970s (Fig. 9.17). The trajectory of fishing mortality shows that the stock has generally remained above the $B_{40\%}$ level for female spawning biomass and may have exceeded the OFL during the mid-1960s during the period of intense fishing for Pacific ocean perch (Fig. 9.18).

The posterior marginal Bayesian credibility bounds[1] showing the 5th and 95th percentiles for female spawning biomass compared well with the delta-method approximation (based on the inverse Hessian matrix) (Fig. 9.19). Note that these estimates ignore uncertainty due to independently estimated parameters such as maturity at age. The estimates of maturity at age are based on a small sample of fish (n=77) collected in one year, and the calculations of $F_{40\%}$ and $B_{40\%}$ depend on these estimates of maturity.

[1] Patrick Cordue of the 2006 rockfish CIE panel suggested that the term 'confidence interval' has a non-Bayesian definition – he suggested the term 'credibility bounds' for these kinds of plots showing the 5th and 95th percentiles of the MCMC marginal posterior distributions.

Posterior marginal distributions of survey catchability and natural mortality for Model 1 compared to Model 8 (where all size and age-composition data are down-weighted) show that when all data are down-weighted, the resulting key parameter estimates are uninformative (Fig. 9.20).

9.7 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):

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$
56,860	22,740	19,900

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 19,900 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
2007	5,890	4,940
2008	5,660	4,750

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

ABC recommendation

Based on this year's recommended assessment model (Model 1), the projected female spawning biomass in 2007 is 30,220 t. The value for B_{msy} (approximated by $B_{35\%}$) is estimated at 19,900 t as determined from average recruitment of the 1977-2002 year-classes (recruits from years 1979 – 2004). 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 2007 fishery in the Gulf of Alaska be set at 4,940 t. This ABC is down slightly from the previous analyses (ABC in 2006 was 5,090). Compared to sensitivities evaluated, this recommendation can be viewed as precautionary because: a conservative prior distribution on survey catchability was assumed (e.g., compared to Model 4), and that further efforts to fit the survey biomass increase (i.e., by ignoring the age and size composition data) would result in higher current stock size estimates, and that the maturity-at-age estimates are preliminary (and likely biased towards older age-at-maturity). The 1994 year-class is emerging as stronger than average. This strong recruitment, along with recent high survey biomass estimates, supports this relatively stable ABC. However, given the uncertainty in the recent biomass estimates, and evidence of localized depletion discussed above, caution is warranted for management of this stock.

Apportionment of ABC

The 2006 area apportionments for Gulf of Alaska northern rockfish are 29.12% for the Western area, 70.84% for the Central area, and 0.04% for the Eastern area. Applying these apportionments to the recommended ABC for northern rockfish results in 1,439 t for the Western area, 3,449 t for the Central area, and 2 t for the Eastern area. For management purposes, the small ABC of northern rockfish in the Eastern area is combined with other slope rockfish.

Prior to the 1996 fishery, the apportionment of ABC among areas was determined from distribution of biomass based on the average proportion of exploitable biomass by area in the most recent three triennial trawl surveys. For the 1996 fishery, an alternative method of apportionment was recommended by the Plan Team and accepted by the Council. Recognizing the uncertainty in estimation of biomass yet wanting to adapt to current information, the Plan Team chose to employ a method of weighting prior surveys based on the relative proportion of variability attributed to survey error. Assuming that survey error contributes 2/3 of the total variability in predicting the distribution of biomass, 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 2001, 2003, and 2005 surveys, respectively. Exploitable survey biomass is calculated as survey biomass for depths greater than 100 m. The percentage of exploitable survey biomass by area is averaged rather than the raw values. The eastern Gulf was not covered by the 2001 trawl survey. The 2001 Eastern Gulf exploitable survey biomass estimate is the average of 1993, 1996, and 1999 Eastern Gulf exploitable survey biomass estimates.

Percentage of survey biomass by region and resulting area apportionments follow:

Percentage of exploitable survey biomass estimates by Gulf of Alaska region			
	Western	Central	Eastern
2001 - Northern rockfish	26.18%	73.79%	0.03%
2003 - Northern rockfish	13.005%	86.973%	0.022%
2005 - Northern rockfish	41.2%	58.8%	0.1%
Apportionment (4:6:9) weighted average of 2001, 2003,2005 percent exploitable biomass			
	Western	Central	Eastern
Apportionment - Northern rockfish	29.12%	70.84%	0.04%

*bold values are proportions based on average of 93,96, 99 Eastern Gulf values

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 2006 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2007 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2006. 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 2007 and 2008, 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 2007 and 2008 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 2002-2006 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 2007 or 2) above ½ of its MSY level in 2007 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)

Scenario 7: In 2007 and 2008, 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 2019 under this scenario, then the stock is not approaching an overfished condition.)

For northern rockfish, projected B_{2007} (30,220 t) is greater than $B_{35\%}$, therefore the stock is not overfished nor is the stock approaching an overfished condition (Table 9.13). The projected catch and biomass trends show declines as the stock approaches the $B_{40\%}$ level (Fig. 9.21).

Summary

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

Summary	2007	2008
6+ Total Biomass (t)	94,271	91,557
$B_{40\%}$ (t)	22,740	22,740
Female spawning biomass (t)	30,220	29,350
F_{ABC} (=$F_{40\%}$)	0.062	0.062
F_{OFL} (=$F_{35\%}$)	0.074	0.074
ABC	4,940	4,750
OFL	5,890	5,660

9.8 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 9.14.

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 9.15).

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 slope rockfish during 2000-2002 have been 7-11% for Pacific ocean perch, 9-18% for northern rockfish, 21-30% for shortraker and rougheye rockfish, and 48-53% for other slope rockfish. The discard amount of species other than slope rockfish in the slope rockfish fishery has not been determined.

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

Fishery-specific effects on EFH non-living substrate: Unknown, but the heavy-duty "rockhopper" trawl gear commonly used in the fishery can move aroun

9.9 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.

Results of an analysis of localized depletion of rockfish stocks were presented at the 2005 Lowell Wakefield symposium (Hanselman etal. 2006). 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.

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.

9.10 References

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Tables

Table 9.1. Commercial catch (t) of northern rockfish in the Gulf of Alaska, 1961-present[1].

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	-	tr	1,107	1,107	-	-
1989	-	-	1,527	1,527	-	-
1990	-	-	1,697	1,716	-	-
1991	-	-	4,528	4,528	-	-
1992	-	-	7,770	7,770	-	-
1993	-	-	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	-	-	5,343	5,349	5,530	97%
2004	-	-	4,783	4,783	4,870	98%
2005	-	-	4,783	4,806	5,091	94%
2006	-	-	5,002	5,002	5,091	93%

[1]Section 9.2 describes the procedures used to estimate catch for the years 1961-1993. Catch estimates for the years 1993-2006 are from NMFS Observer Program and Alaska Regional Office.

Table 9.2. 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
Catch	0	20.8	0	0	12.5	0	2.5	13.2	0	23.4	0	5.6	0	23.2	0

Table 9.3. Northern rockfish fishery sampling levels for length and age data in the Gulf of Alaska.

	Length composition		Age composition	
Year	# Fish	# Hauls*	# Fish	# Hauls*
1990	4,909	53	0	0
1991	15,466	155	0	0
1992	15,207	125	0	0
1993	12,541	110	0	0
1994	8,905	98	0	0
1995	12,370	135	0	0
1996	12,496	176	0	0
1997	5,262	74	0	0
1998	10,615	137	498	51
1999	5,287	248	308	160
2000	3,898	280	585	187
2001	3,001	261	451	156
2002	3,802	283	616	187
2003	7,387	498	0	0
2004	5,403	370	746	270
2005	4,208	301	0	0
2006	691	62	0	0

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

Table 9.4. Fishery length (cm) compositions for northern rockfish in the Gulf of Alaska (at-sea and port samples combined).

Length							Year										
class (cm)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2005
15-24	0.18	0.14	-	0.02	0.01	0.36	0.03	0.15	0.22	0.21	0.45	0.04	0.14	0.07	0.02	-	-
25	0.18	0.20	0.01	0.04	-	0.42	0.03	0.65	0.04	0.14	0.21	-	-	0.08	0.02	0.05	-
26	0.09	0.30	0.02	0.09	0.01	0.68	-	1.39	0.08	0.37	0.34	0.21	0.07	0.13	0.11	-	-
27	0.42	0.35	0.03	0.10	0.06	0.92	0.11	2.01	0.10	0.34	0.28	0.51	0.31	0.22	0.31	0.21	0.18
28	0.80	0.73	0.11	0.21	0.17	0.80	0.16	2.11	0.16	0.18	0.90	0.90	0.58	0.25	0.48	0.45	0.18
29	1.64	1.03	0.28	0.53	0.36	1.02	0.28	2.11	0.21	0.21	0.86	2.09	1.41	0.68	0.53	0.64	1.28
30	1.84	2.29	0.63	1.04	0.70	1.28	0.67	1.92	0.46	0.41	0.69	2.65	3.12	1.16	0.96	1.50	1.46
31	2.22	4.08	1.50	2.37	1.66	1.53	0.62	1.44	0.65	0.62	1.07	2.78	4.50	3.05	1.43	2.46	4.19
32	3.48	7.17	3.21	4.59	3.02	2.13	1.32	1.50	1.26	1.10	1.07	2.52	7.52	4.53	2.83	3.66	3.83
33	4.84	12.32	5.27	7.90	6.98	4.33	2.81	2.91	2.08	2.11	1.58	2.74	7.07	7.05	4.52	6.36	7.83
34	7.77	18.03	9.38	10.86	11.62	8.08	5.83	5.42	4.14	3.55	2.76	3.50	6.49	7.49	7.26	9.49	10.93
35	12.85	19.55	13.91	15.63	17.46	12.74	12.20	11.48	8.29	4.83	5.72	5.73	5.80	8.41	7.70	11.60	17.12
36	18.60	14.51	15.68	16.58	19.94	15.64	17.69	15.91	14.02	10.25	9.47	8.16	6.80	7.52	9.12	12.69	13.11
37	17.11	9.07	15.42	12.74	17.09	16.43	18.91	17.34	18.32	14.87	13.61	12.65	10.06	8.33	9.41	10.02	12.57
38	12.61	4.67	13.12	10.04	9.97	13.51	14.95	14.98	16.97	17.94	17.98	14.70	11.12	10.17	8.75	8.69	7.83
39	8.26	2.28	9.48	6.79	5.30	8.57	10.26	9.12	13.47	15.63	16.98	13.29	10.95	11.05	9.73	9.41	7.10
40	3.77	1.16	6.12	4.79	2.49	3.99	6.60	5.21	9.10	11.97	12.44	10.56	8.93	9.51	9.93	8.23	4.92
41	1.75	0.74	3.30	3.35	1.18	2.05	3.70	2.36	5.02	7.44	6.99	5.90	6.28	7.85	9.82	6.04	3.10
42	0.84	0.27	1.30	1.76	0.68	1.52	1.79	1.18	2.78	3.57	3.34	4.27	3.98	5.74	6.53	4.41	0.91
43	0.40	0.33	0.45	0.46	0.47	1.12	0.82	0.51	1.55	2.01	1.31	2.44	2.64	3.87	4.65	2.03	1.28
44	0.18	0.21	0.36	0.08	0.34	0.84	0.37	0.21	0.70	0.87	1.10	1.79	1.03	1.59	2.83	1.26	1.64
45	0.04	0.22	0.34	0.03	0.31	0.77	0.29	0.06	0.30	0.64	0.48	0.51	0.79	0.83	1.36	0.24	0.36
46	0.02	0.23	0.01	-	0.11	0.62	0.16	0.02	0.05	0.27	0.07	0.64	0.31	0.15	1.01	0.27	0.18
47-52	0.11	0.12	0.09	-	0.06	0.64	0.42	0.02	0.03	0.48	0.31	1.41	0.10	0.25	0.70	0.29	-

Table 9.5. 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 class	**1998**	**1999**	**2000**	**2001**	**2002**	**2004**
2	-	-	-	-	-	-
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	0.65	0.17	-	-	0.13
6	0.4	0.32	2.39	1.11	-	1.47
7	0.6	0.65	0.51	5.54	3.25	0.8
8	3.41	-	1.54	2.44	15.1	3.62
9	2.21	4.22	1.88	3.1	6.98	11.13
10	3.21	1.3	4.27	3.77	5.52	17.56
11	5.82	2.92	3.08	4.88	4.22	4.96
12	7.03	3.9	5.81	4.21	4.38	3.49
13	9.44	4.87	5.3	5.32	4.71	3.62
14	9.44	6.17	4.79	5.1	3.25	2.82
15	6.83	12.66	7.35	3.99	3.08	2.68
16	7.83	6.49	9.4	5.32	4.71	3.22
17	3.41	5.84	6.67	8.43	6.82	1.47
18	3.41	4.22	5.98	5.99	6.66	2.55
19	2.21	1.95	2.39	4.43	3.25	4.56
20	2.61	2.27	2.22	2.66	2.6	5.76
21	4.42	3.25	1.03	3.55	2.27	3.49
22	5.02	2.92	4.27	1.77	2.11	2.95
23	3.61	7.47	3.42	3.33	1.3	2.28
24	3.01	4.22	4.62	3.33	2.92	1.07
25	2.21	0.97	2.22	4.43	4.38	1.21
26	2.41	2.6	2.91	4.21	2.76	2.14
27	1.2	1.62	1.37	1.33	1.14	3.89
28	1	4.22	2.05	2	0.81	2.95
29	2.61	3.57	2.39	0.89	0.97	1.21
30	2.01	2.27	4.1	1.77	1.14	1.74
31	0.6	2.92	1.88	2	1.14	1.07
32	1	1.3	1.37	1.33	1.14	0.8
33-51	3.01	4.22	4.62	3.77	3.41	5.36

Table 9.6. 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%

[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 9.7. Northern rockfish survey sampling levels for length and age data in the Gulf of Alaska.

	Length composition		Age composition	
Year	# Fish	# Hauls*	# Fish	# Hauls
1984	3,518	43	356	6
1987	6,010	36	497	17
1990	2,381	40	442	14
1993	3,736	95	354	20
1996	3,147	115	462	19
1999	2,738	105	293	29
2001	2,629	87	533	95
2003	2,684	113	272	26
2005	3,537	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 9.8. Survey length (cm) compositions for northern rockfish in the Gulf of Alaska, 1984-2005.

Length class (cm)	Year 1984	1987	1990	1993	1996	1999	2001	2003	2005
5-15	1.52	0.68	0.07	0.01	0.49	0.11	1.21	0.07	0.01
16	0.72	0.38	-	0.03	0.03	0.02	0.07	-	0.01
17	0.51	0.48	0.02	0.07	0.08	0.01	0.04	0.02	0.02
18	0.81	0.43	-	0.11	0.10	0.05	0.27	-	0.00
19	0.58	0.49	0.06	0.06	0.05	0.07	0.24	0.05	0.00
20	0.46	0.80	0.07	0.05	0.09	0.08	0.15	0.11	0.02
21	0.28	0.94	0.13	0.07	0.07	0.12	0.15	0.13	0.02
22	0.53	0.99	0.34	0.15	0.21	0.17	0.16	0.25	0.03
23	0.77	1.16	0.55	0.26	0.23	0.34	0.12	0.38	0.01
24	1.67	1.30	1.18	0.33	0.20	0.18	0.20	0.58	0.15
25	2.22	1.50	1.13	0.66	0.31	0.22	0.19	0.70	0.04
26	2.65	1.50	2.97	0.53	0.70	0.61	0.39	1.81	0.08
27	4.49	1.73	2.43	0.68	0.82	0.20	0.49	1.12	0.12
28	5.16	2.24	1.66	0.77	0.55	0.56	0.79	0.72	0.13
29	8.89	4.36	1.71	0.69	0.80	0.18	0.51	0.99	6.35
30	9.46	7.12	1.28	1.21	0.90	0.26	0.94	1.48	3.41
31	10.16	11.74	2.24	1.45	1.59	0.23	1.04	2.07	1.17
32	9.25	13.93	3.82	4.07	2.02	2.68	2.29	3.96	1.31
33	7.41	13.00	9.00	5.50	2.66	3.09	1.70	6.41	2.11
34	5.92	12.13	12.56	9.07	3.40	3.54	5.24	7.67	2.55
35	5.06	8.63	13.89	14.67	5.92	5.38	5.04	6.30	3.15
36	5.76	6.73	11.82	16.15	12.07	7.77	11.99	7.82	5.20
37	4.84	3.41	10.16	12.32	11.73	12.81	12.54	7.06	5.54
38	3.43	2.23	7.47	10.47	13.45	18.37	16.49	9.94	8.90
39	2.30	1.21	6.17	6.51	11.80	12.66	10.49	9.48	10.70
40	1.71	0.54	2.95	5.34	9.45	11.00	11.43	8.16	11.70
41	1.84	0.26	2.72	3.85	9.22	9.36	5.48	6.98	10.80
42	0.82	0.06	1.73	2.32	5.20	4.72	6.17	4.87	8.07
43	0.45	0.03	0.69	1.23	3.17	3.80	1.79	4.83	7.69
44	0.26	0.02	0.56	0.82	1.84	1.13	0.87	1.42	7.67
45	-	-	0.52	0.43	0.63	0.18	0.50	1.72	2.32
46	0.09	-	0.11	0.08	0.21	0.11	0.63	1.73	0.41
47-50	-	-	-	0.07	0.01	0.01	0.41	1.15	0.29

Table 9.9. Survey age compositions for northern rockfish in the Gulf of Alaska. All age compositions are based on "break and burn" reading of otoliths.

Age Class	Year 1984	1987	1990	1993	1996	1999	2001	2003	2005
2	-	-	-	0.03	0.28	-	0.02	-	-
3	-	0.37	0.06	0.28	0.30	0.03	0.62	0.07	0.01
4	-	1.78	0.19	0.31	0.13	0.16	0.08	0.15	0.11
5	1.48	5.53	2.91	0.85	0.21	1.05	0.44	3.46	0.14
6	4.10	4.05	5.42	1.07	1.13	0.27	1.25	2.11	1.44
7	8.91	2.96	2.65	1.09	0.58	0.94	5.05	1.45	3.70
8	18.34	0.28	4.08	6.34	2.07	0.89	0.71	9.64	5.19
9	10.83	2.88	5.38	11.98	4.10	4.23	3.72	12.63	4.67
10	5.08	10.10	4.47	6.53	5.31	2.77	6.97	5.65	6.11
11	4.63	11.21	5.77	10.31	8.52	7.92	8.23	3.60	4.65
12	2.59	11.15	3.52	4.44	7.58	6.92	4.68	2.92	3.33
13	7.23	3.43	5.36	4.90	7.72	5.42	3.40	2.13	1.11
14	6.81	4.28	8.24	4.02	4.02	5.62	4.60	5.13	2.09
15	6.35	1.40	9.71	2.44	3.29	7.82	5.53	3.33	1.19
16	4.05	3.66	5.08	5.19	3.87	9.16	5.22	4.27	1.97
17	1.98	10.31	5.08	3.14	1.65	1.56	6.75	-	3.21
18	1.90	4.09	0.67	3.97	3.41	7.21	7.77	1.76	3.06
19	0.59	7.98	1.12	2.81	5.44	1.88	1.76	2.96	0.81
20	0.76	2.72	6.56	0.40	8.78	1.30	0.95	6.10	3.87
21	0.32	2.55	6.63	2.32	2.77	3.00	0.89	1.19	4.64
22	1.01	0.70	4.58	3.41	3.06	2.19	1.99	2.05	1.86
23	3.25	0.65	1.92	4.45	3.02	2.51	2.24	1.06	1.25
24	2.16	0.29	0.89	4.46	3.33	3.03	6.27	0.66	1.17
25	0.66	0.39	0.97	4.64	2.68	1.96	2.23	1.35	2.12
26	0.33	1.74	3.37	0.69	5.22	1.50	2.92	2.53	2.52
27	1.06	2.58	0.64	1.68	1.36	3.35	1.66	2.99	2.17
28	0.37	1.20	1.17	2.22	1.47	2.48	0.86	5.39	3.74
29	0.94	0.31	0.18	0.57	2.75	2.40	0.90	3.45	3.58
30	-	0.23	0.98	-	0.57	1.65	2.22	1.56	3.83
31	0.42	0.52	0.96	0.24	0.75	2.39	2.12	-	2.31
32	1.40	-	0.90	0.95	0.42	4.54	0.86	-	3.98
33-67	2.45	0.65	0.54	4.26	4.20	3.85	7.08	10.42	20.19

Table 9.10. Summary results for alternative models for GOA northern rockfish. Shaded cells represent likelihood components that were down-weighted while boxed cells indicate data components that were up-weighted. SDNR stands for the standard deviation of normalized residuals—for specified variances to be consistent with the pattern of output residuals, these values should be 1.0.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Likelihood components									
Catch	0.09	0.08	0.05	0.02	0.11	0.05	0.08	0.05	0.16
Survey index	8.64	9.42	8.16	0.56	8.24	4.57	9.71	5.60	9.31
Fishery age data	58.86	61.74	58.76	58.68	1.86	57.72	56.81	1.03	232.28
Survey age data	50.76	50.67	50.04	48.92	46.93	1.35	49.13	1.03	193.07
Fishery size data	38.61	51.09	39.01	40.14	26.58	35.57	0.45	0.31	156.97
Recruit. variability	4.54	4.42	4.50	4.21	3.84	5.63	4.29	3.25	7.07
F penalty	3.95	4.00	3.86	3.86	3.80	3.58	4.08	3.51	4.21
q Prior	0.97	1.27	1.46	0.03	0.90	0.21	1.21	0.26	1.29
M prior	0.37	0.24	0.35	0.37	0.44	0.69	0.24	0.55	0.41
Subtotal for data	156.95	173.01	156.01	148.32	83.72	99.25	116.17	8.02	591.77
Total	169.33	185.40	167.56	157.23	95.18	111.30	128.42	17.23	608.38
Goodness of fit	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**
Eff. N **Fishery Age**	115	114	119	128	69	111	134	74	121
N Input	174	174	174	174	174	174	174	174	174
SDNR	1.00	0.98	1.00	1.00	2.13	0.92	0.94	1.26	0.99
Eff. N **Survey Age**	54	62	59	58	48	14	59	23	59
N Input	20	20	20	20	20	20	20	20	20
SDNR	0.55	0.56	0.55	0.55	0.57	3.15	0.54	2.10	0.54
Eff. N **Fishery Size**	41	41	40	39	40	43	41	48	40
N Input	26	26	26	26	26	26	26	26	26
SDNR	0.50	0.54	0.51	0.53	0.46	0.47	0.55	0.43	0.51
SDNR **Survey index**.	1.39	1.45	1.31	3.22	1.36	1.02	1.46	1.12	1.45
Parameter estimates	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**
Natural Mortality	0.063	0.062	0.063	0.063	0.063	0.064	0.062	0.063	0.063
(CV)	(4%)	(4%)	(4%)	(4%)	(4%)	(5%)	(4%)	(5%)	(4%)
Survey q	0.812	0.788	0.599	0.963	0.818	0.907	0.792	0.898	0.786
(CV)	(13%)	(13%)	(21%)	(15%)	(13%)	(14%)	(13%)	(14%)	(13%)
1961 SSB	94,869	97,459	107,570	125,440	94,307	97,912	97,850	102,470	85,973
(CV)	(14%)	(14%)	(16%)	(19%)	(13%)	(15%)	(14%)	(15%)	(12%)
2006 SSB	31,108	30,761	45,294	60,881	29,087	42,202	29,006	34,445	30,118
(CV)	(29%)	(29%)	(33%)	(39%)	(29%)	(27%)	(30%)	(31%)	(27%)
Ratio 1961/2006 SSB	0.33	0.32	0.42	0.49	0.31	0.43	0.30	0.34	0.35
1994 Year class	59,395	60,149	80,294	100,920	31,692	99,107	51,869	40,214	57,149
(CV)	(30%)	(32%)	(34%)	(39%)	(45%)	(33%)	(30%)	(152%)	(24%)

Table 9.11. 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. 2005.

	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	28,490	15,628	75,749	44,022	92,354	70,949	0.007	0.009	22,161	21,411
1978	28,357	17,362	78,463	49,670	92,666	74,990	0.006	0.007	112,452	75,597
1979	28,457	19,313	81,672	56,252	93,945	79,406	0.007	0.008	11,747	19,809
1980	28,764	21,418	84,057	64,005	95,568	83,589	0.008	0.010	14,397	13,782
1981	29,204	23,633	85,565	71,816	98,133	88,400	0.015	0.017	11,164	12,052
1982	29,409	25,726	86,810	74,419	119,331	104,229	0.033	0.038	10,527	14,953
1983	29,286	26,975	87,653	74,770	119,903	107,312	0.030	0.034	21,848	14,885
1984	29,786	28,262	92,251	76,812	120,637	108,980	0.008	0.009	33,308	18,192
1985	31,225	30,475	101,677	81,150	122,665	112,261	0.002	0.002	11,234	17,719
1986	33,092	33,025	110,149	89,841	124,555	116,252	0.002	0.002	65,601	38,001
1987	35,121	35,580	115,041	103,754	127,986	119,556	0.004	0.004	23,307	17,053
1988	37,153	38,055	117,353	107,140	133,302	122,847	0.008	0.009	14,595	12,207
1989	38,997	40,190	118,374	108,351	133,449	125,029	0.011	0.012	17,335	14,472
1990	40,596	41,964	119,585	108,841	144,093	130,923	0.012	0.013	14,617	12,020
1991	41,604	43,405	121,684	109,605	146,902	132,601	0.031	0.034	8,188	11,113
1992	41,305	43,441	122,246	107,904	144,736	130,104	0.054	0.060	19,012	14,836
1993	40,407	41,911	120,594	103,281	139,374	124,513	0.035	0.039	6,641	11,404
1994	39,944	41,342	120,920	102,399	136,053	121,149	0.044	0.049	12,115	9,523
1995	39,169	40,216	118,283	102,323	129,886	116,226	0.043	0.048	7,762	9,698
1996	38,661	39,187	114,501	98,653	125,902	112,285	0.027	0.030	63,579	78,548
1997	38,612	38,957	112,018	96,491	121,607	109,901	0.024	0.027	23,692	27,173
1998	38,483	38,796	109,366	94,933	118,491	107,384	0.026	0.028	11,459	18,460
1999	37,822	38,516	106,360	92,798	114,227	104,642	0.047	0.052	14,248	19,265
2000	36,606	37,184	100,976	88,659	119,192	114,407	0.028	0.029	33,950	36,121
2001	35,867	36,755	98,461	87,768	119,672	117,591	0.026	0.027	7,654	16,801
2002	35,141	36,547	98,073	87,666	117,938	119,331	0.028	0.028	8,208	19,917
2003	34,188	36,479	99,547	86,929	116,313	120,844	0.046	0.044	10,449	19,917
2004	32,955	35,884	99,120	88,451	116,657	123,799	0.041	0.039	12,221	19,917
2005	32,002	35,866	97,966	98,758	112,523	123,532	0.043	0.039	13,846	19,917
2006	34,195	36,061	96,076	99,554	108,038	122,591	0.047	0.05	15,744	19,917

Table 9.12. Estimated numbers (thousands) in 2006, fishery selectivity, and survey selectivity of northern rockfish in the Gulf of Alaska based on Model 5. Also shown are schedules of age specific weight and female maturity.

Age	2006 numbers (1000's)	Percent mature	Weight (g)	Fishery selectivity	Survey selectivity
2	15,744	1	63	0.001	0.008
3	13,003	2	103	0.002	0.016
4	10,778	3	153	0.007	0.034
5	8,652	4	210	0.020	0.070
6	6,375	6	273	0.059	0.138
7	5,567	9	336	0.157	0.254
8	23,004	13	399	0.358	0.420
9	8,902	18	458	0.626	0.606
10	6,514	25	512	0.833	0.766
11	12,136	33	561	0.937	0.874
12	29,274	43	603	0.978	0.936
13	3,220	52	641	0.993	0.969
14	4,539	62	672	0.998	0.985
15	2,248	71	699	0.999	0.993
16	5,816	78	722	1.000	0.997
17	2,268	84	740	1.000	0.998
18	3,672	89	756	1.000	0.999
19	3,937	92	769	1.000	1.000
20	2,983	95	780	1.000	1.000
21	4,272	96	788	1.000	1.000
22	10,769	97	795	1.000	1.000
23+	38,382	98	801	1.000	1.000

Table 9.13. Northern rockfish spawning biomass, fishing mortality, and yield for seven harvest scenarios based on Model 1.

	$B_{100\%}$	$B_{40\%}$	$B_{35\%}$				
	56,860	22,740	19,900				
Catch (ABC)	Max. perm. ABC	Author's F	5-year average F	$F_{75\%}$	No fishing	Overfished	Approaching overfished?
2006	5,090	5,090	5,090	5,090	5,090	5,090	5,090
2007	4,940	4,940	4,410	1,290	0	5,890	4,940
2008	4,750	4,750	4,270	1,290	0	5,600	4,750
2009	4,530	4,530	4,090	1,290	0	5,270	5,390
2010	4,310	4,310	3,910	1,270	0	4,960	5,070
2011	4,120	4,120	3,760	1,260	0	4,700	4,790
2012	3,970	3,970	3,640	1,260	0	4,490	4,570
2013	3,870	3,870	3,570	1,260	0	4,340	4,420
2014	3,810	3,810	3,520	1,280	0	4,170	4,290
2015	3,780	3,780	3,510	1,290	0	4,000	4,110
2016	3,720	3,720	3,500	1,310	0	3,880	3,970
2017	3,670	3,670	3,500	1,330	0	3,800	3,880
2018	3,630	3,630	3,500	1,350	0	3,760	3,820
2019	3,610	3,610	3,510	1,370	0	3,750	3,800
Spawning Biomass							
2006	31,110	31,110	31,110	31,110	31,110	31,110	31,110
2007	30,220	30,220	30,290	30,670	30,830	30,100	30,220
2008	29,350	29,350	29,610	31,140	31,770	28,890	29,350
2009	28,480	28,480	28,920	31,560	32,690	27,720	28,370
2010	27,590	27,590	28,200	31,900	33,540	26,560	27,170
2011	26,690	26,690	27,440	32,150	34,280	25,410	25,970
2012	25,790	25,790	26,660	32,310	34,920	24,300	24,820
2013	24,930	24,930	25,910	32,400	35,480	23,270	23,750
2014	24,140	24,140	25,220	32,470	36,000	22,360	22,780
2015	23,470	23,470	24,630	32,560	36,510	21,620	21,980
2016	22,940	22,940	24,150	32,700	37,060	21,070	21,370
2017	22,550	22,550	23,800	32,920	37,660	20,690	20,940
2018	22,280	22,280	23,540	33,180	38,290	20,440	20,640
2019	22,120	22,120	23,390	33,510	38,980	20,310	20,470
Fishing mortality							
2006	0.062	0.062	0.062	0.062	0.062	0.062	0.062
2007	0.062	0.062	0.055	0.016	0.000	0.074	0.062
2008	0.062	0.062	0.055	0.016	0.000	0.074	0.062
2009	0.062	0.062	0.055	0.016	0.000	0.074	0.074
2010	0.062	0.062	0.055	0.016	0.000	0.074	0.074
2011	0.062	0.062	0.055	0.016	0.000	0.074	0.074
2012	0.062	0.062	0.055	0.016	0.000	0.074	0.074
2013	0.062	0.062	0.055	0.016	0.000	0.074	0.074
2014	0.062	0.062	0.055	0.016	0.000	0.072	0.073
2015	0.062	0.062	0.055	0.016	0.000	0.070	0.071
2016	0.061	0.061	0.055	0.016	0.000	0.068	0.069
2017	0.060	0.060	0.055	0.016	0.000	0.067	0.068
2018	0.059	0.059	0.055	0.016	0.000	0.066	0.066
2019	0.059	0.059	0.055	0.016	0.000	0.065	0.066

Table 9.14. 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

Table 9.15. Average bycatch (kg) and bycatch rates during 1997 - 99 of living substrates in the Gulf of Alaska; POT - pot gear; BTR - bottom trawl; HAL - Hook and line (source - Draft Programmatic SEIS).

		Bycatch (kg)				Target catch (t)	Bycatch rate (kg/t target)			
Target fishery	Gear	Coral	Anemone	Sea whips	Sponge		Coral	Anemone	Sea whips	Sponge
Arrowtooth flounder	POT	0	0	0	0	4	0.0000	0.0000	0.0000	0.0000
Arrowtooth flounder	BTR	58	99	13	24	2,097	0.0276	0.0474	0.0060	0.0112
Deep water flatfish	BTR	1,626	481	5	733	2,001	0.8124	0.2404	0.0024	0.3663
Rex sole	BTR	321	306	11	317	2,157	0.1488	0.1417	0.0053	0.1468
Shallow water flatfish	POT	0	0	0	0	5	0.0000	0.0000	0.0000	0.0000
Shallow water flatfish	BTR	53	4,741	115	403	2,024	0.0261	2.3420	0.0567	0.1993
Flathead sole	BTR	3	267	1	136	484	0.0071	0.5522	0.0019	0.2806
Pacific cod	HAL	28	4,419	961	33	10,765	0.0026	0.4105	0.0893	0.0030
Pacific cod	POT	0	14	0	1,724	12,863	0.0000	0.0011	0.0000	0.1340
Pacific cod	BTR	34	5,767	895	788	37,926	0.0009	0.1521	0.0236	0.0208
Pollock	BTR	1,153	55	0	23	2,465	0.4676	0.0222	0.0000	0.0092
Pollock	PTR	41	110	0	0	97,171	0.0004	0.0011	0.0000	0.0000
Demersal shelf rockfish	HAL	0	0	0	141	226	0.0000	0.0000	0.0000	0.6241
Northern rockfish	BTR	25	90	0	103	1,938	0.0127	0.0464	0.0000	0.0532
Other slope rockfish	HAL	0	0	0	0	14	0.0000	0.0000	0.0000	0.0000
Other slope rockfish	BTR	0	0	0	0	193	0.0000	0.0000	0.0000	0.0000
Pelagic shelf rockfish	HAL	0	0	0	0	203	0.0000	0.0000	0.0000	0.0000
Pelagic shelf rockfish	BTR	324	176	3	245	1,812	0.1788	0.0969	0.0017	0.1353
Pacific ocean perch	BTR	549	90	5	1,968	6,564	0.0837	0.0136	0.0007	0.2999
Pacific ocean perch	PTR	7	0	0	55	1,320	0.0052	0.0000	0.0000	0.0416
Shortraker/rougheye	HAL	6	0	0	0	19	0.3055	0.0000	0.0000	0.0000
Shortraker/rougheye	BTR	0	18	0	0	21	0.0000	0.8642	0.0000	0.0000
Sablefish	HAL	156	154	68	27	11,143	0.0140	0.0138	0.0061	0.0025
Sablefish	BTR	0	0	0	0	27	0.0000	0.0000	0.0000	0.0000
Shortspine thornyhead	HAL	0	0	0	0	2	0.0000	0.0000	0.0000	0.0000
Shortspine thornyhead	BTR	0	9	0	1	2	0.0000	4.8175	0.0000	0.4069

Figures

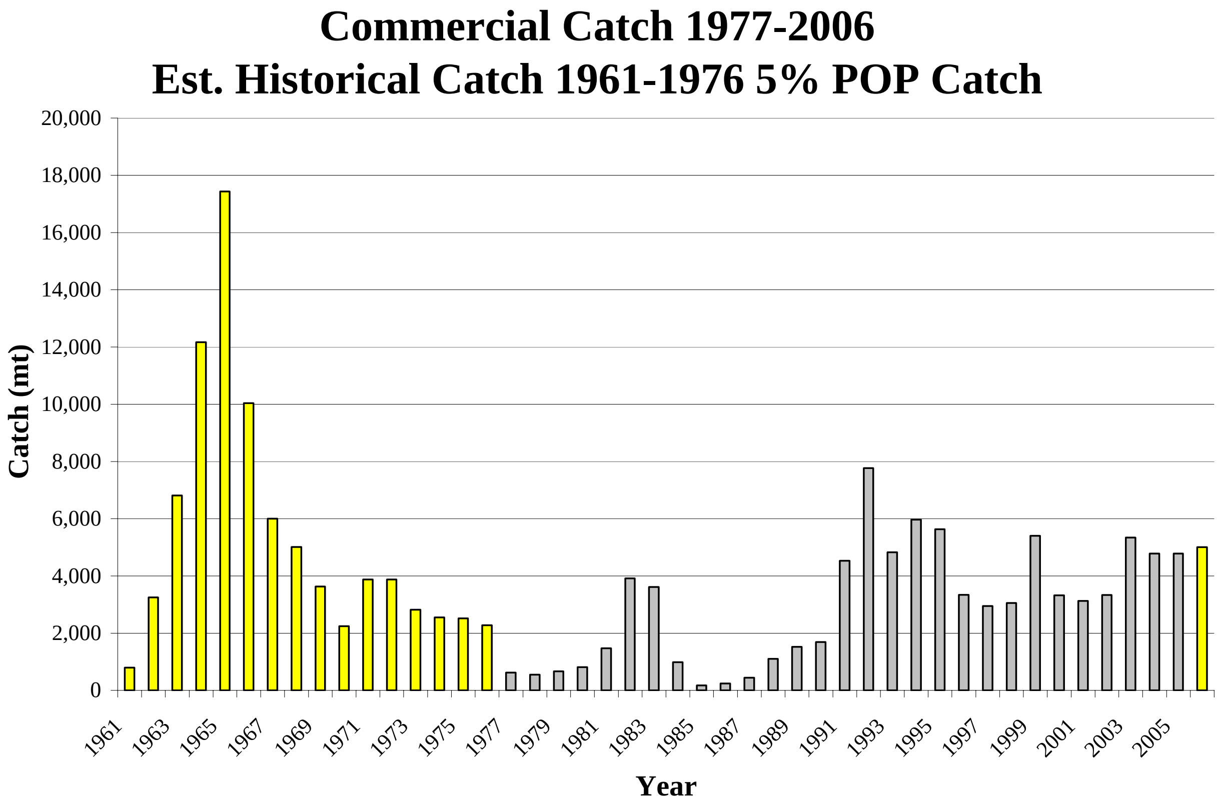


Figure 9.1. Commercial catch for northern rockfish in the Gulf of Alaska.

[1]Section 9.2 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.

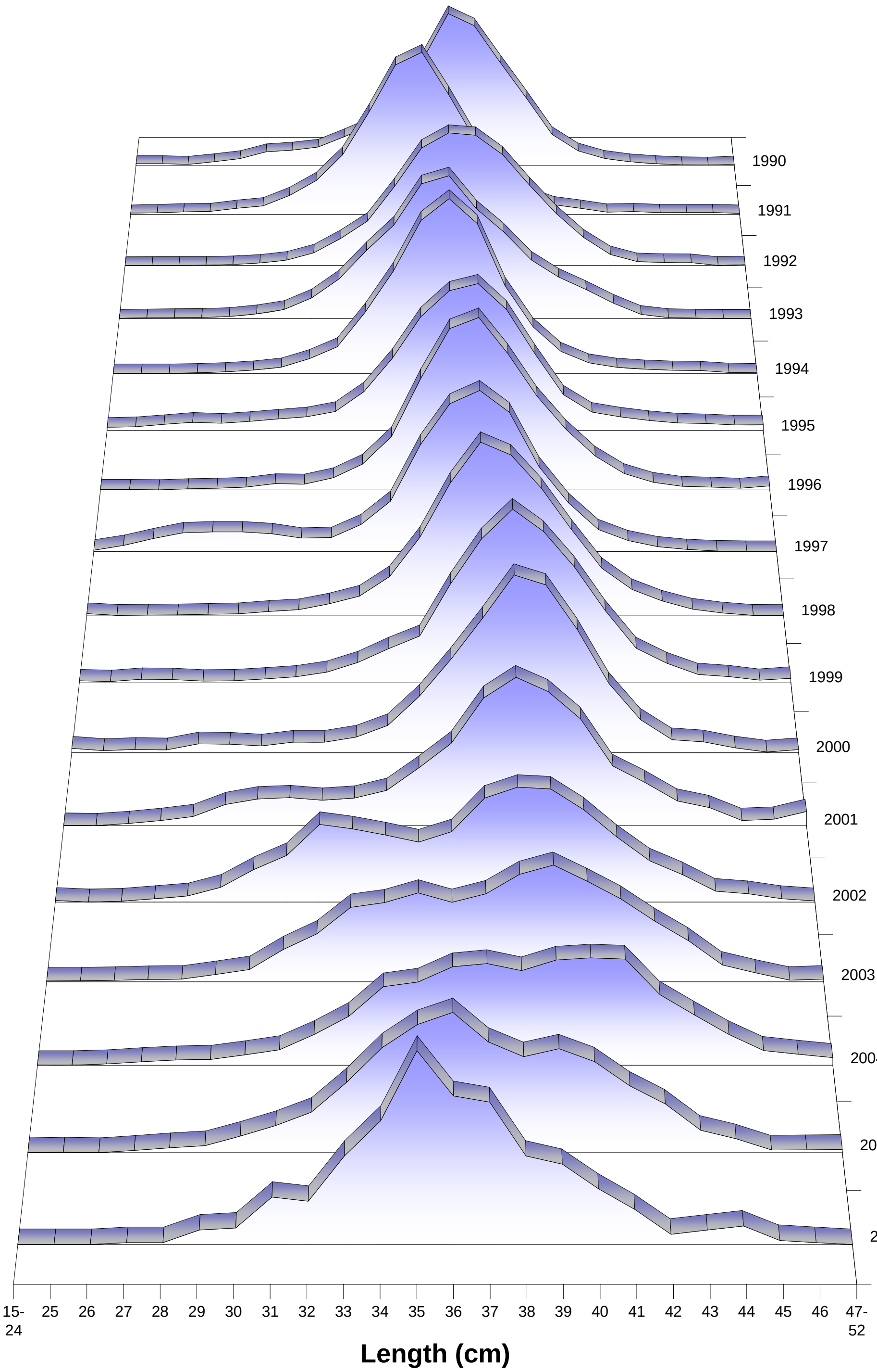


Figure 9.2. Fishery length (cm) compositions for northern rockfish in the Gulf of Alaska.

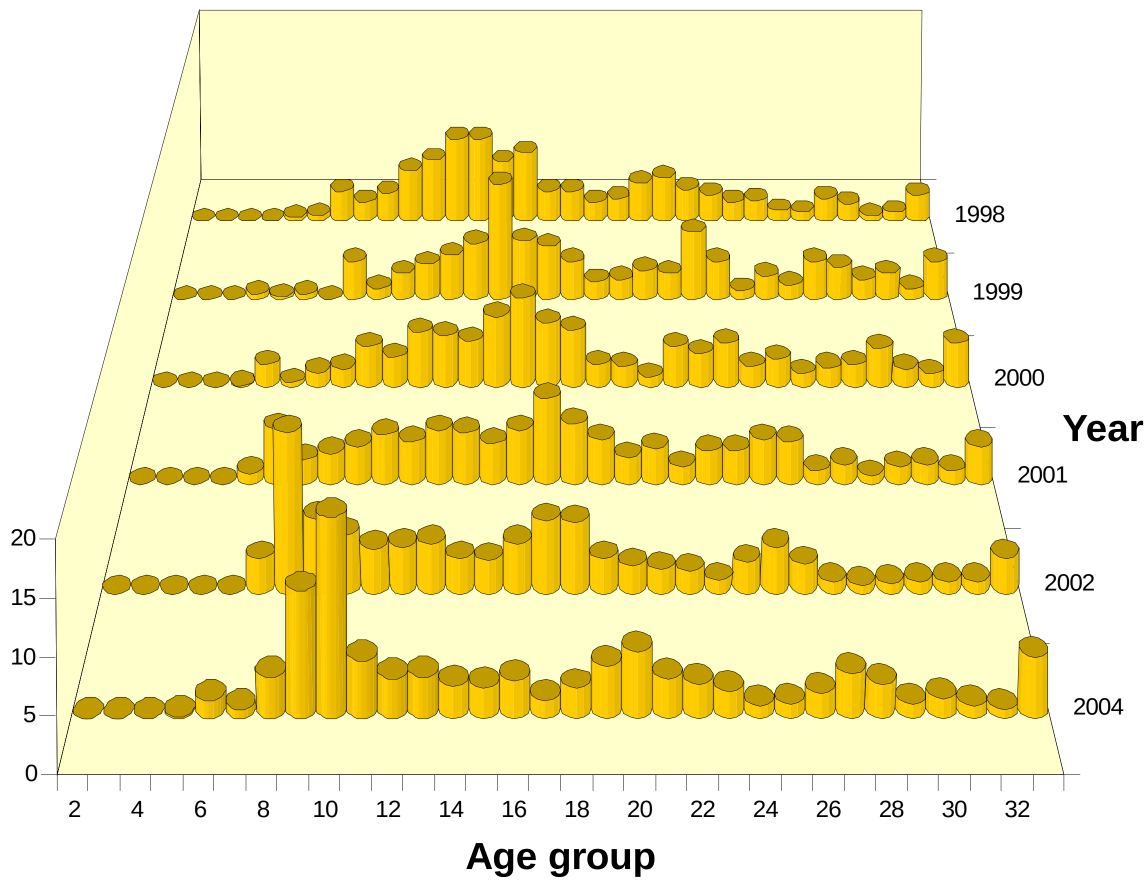


Figure 9.3. Fishery age compositions for northern rockfish in the Gulf of Alaska. Age structures were collected in 2003, but were not aged.

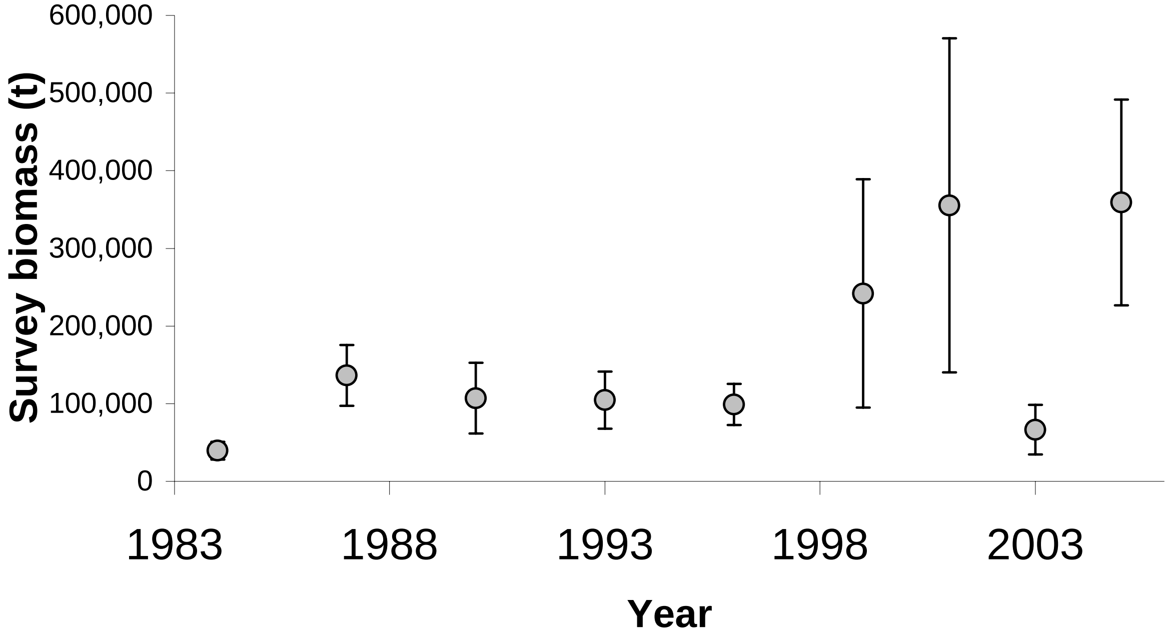


Figure 9.4. Estimated biomass of northern rockfish in the Gulf of Alaska based on trawl surveys from 1984 to 2005. Vertical bars represent one ± standard error based on the sampling distribution.

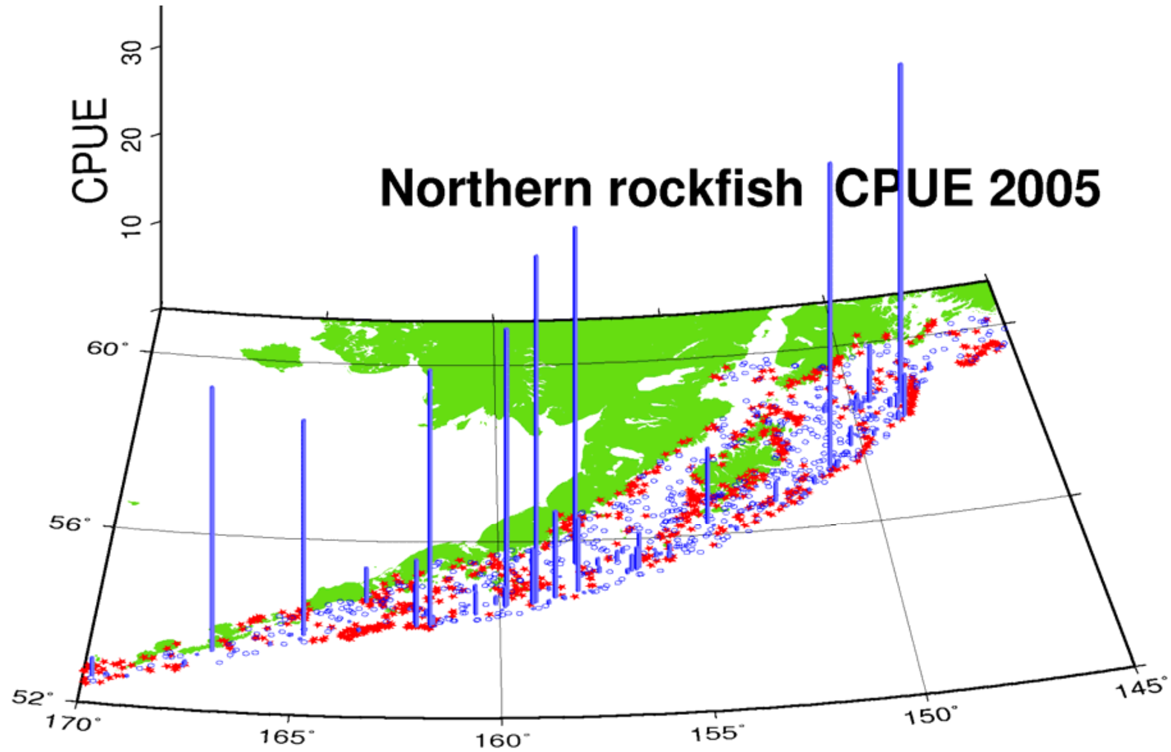


Figure 9.5. Survey trawl CPUE for 2005 showing locations where stations were omitted due to untrawlable grounds (red stars). Vertical bars represent the relative magnitude of northern rockfish trawl CPUE while open circles represent successful tows but no catch of northern rockfish.

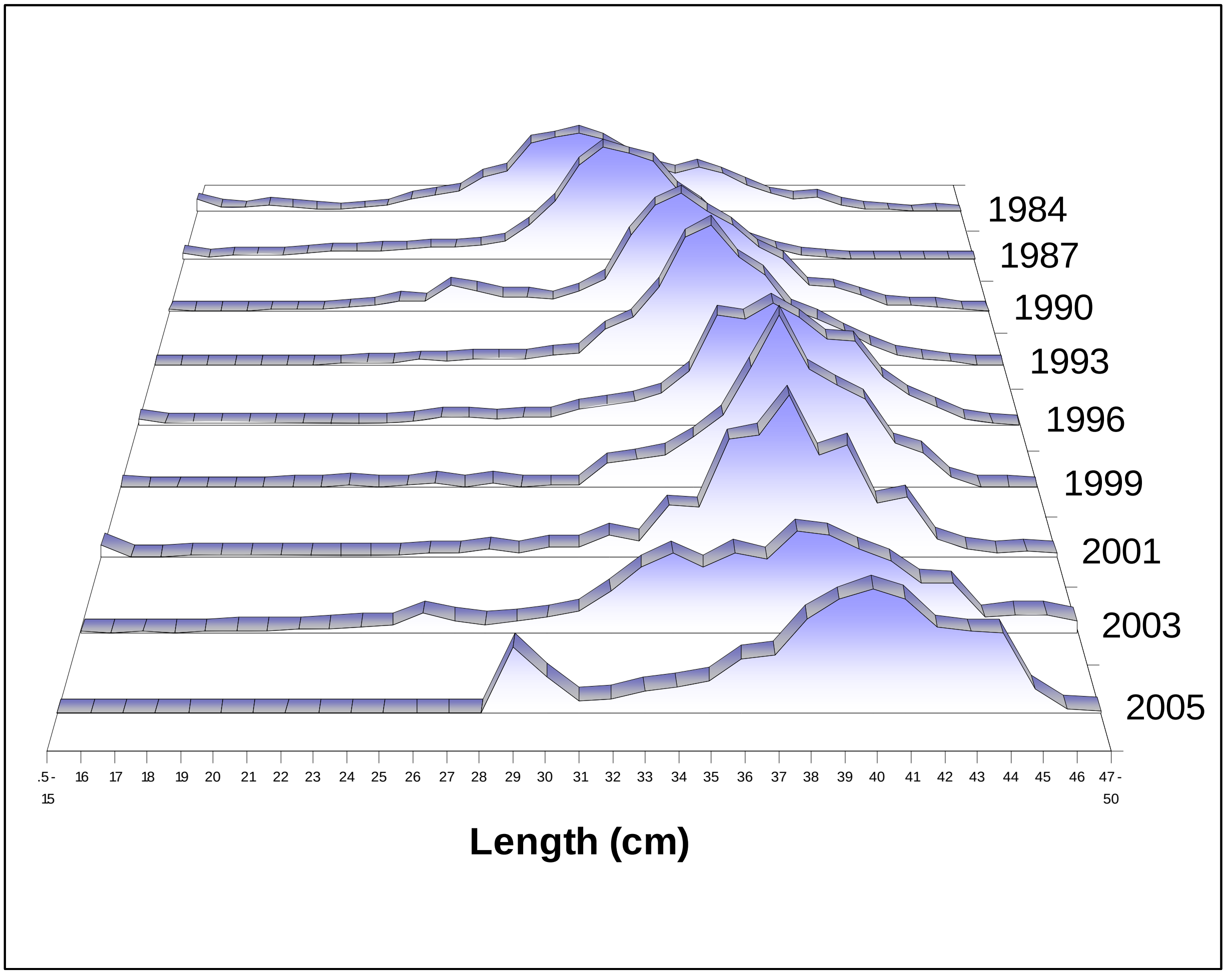


Figure 9.6. Survey size compositions (estimated population in millions) for northern rockfish in the Gulf of Alaska.

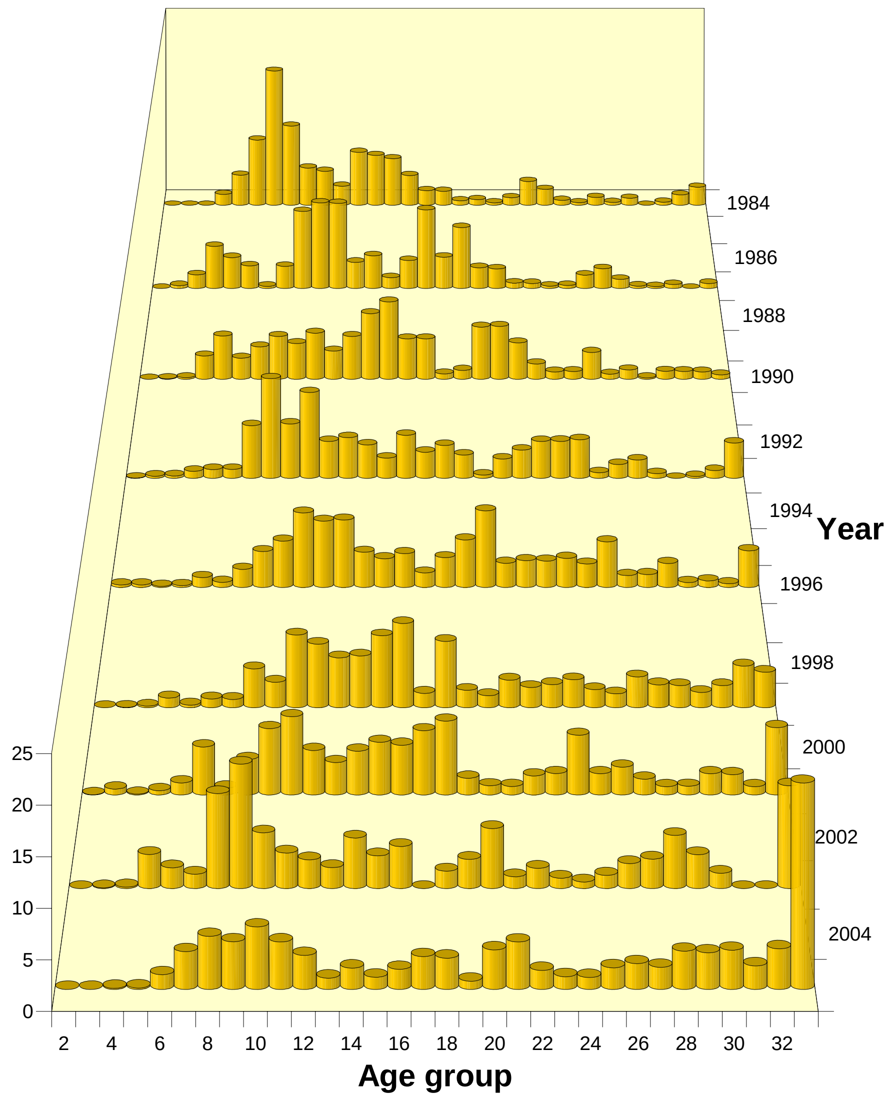


Figure 9.7. Survey age compositions (estimated population in millions) for northern rockfish in the Gulf of Alaska.

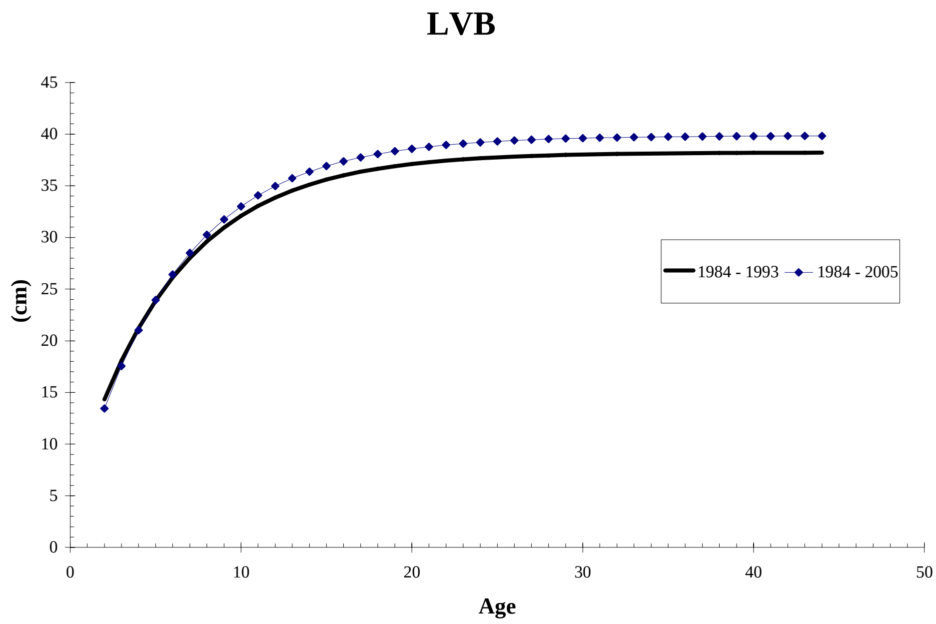


Figure 9.8. Length at age (LVB) from past assessments (1984-1993 length-at-age data) and updated for this assessment (1984-1995 length-at-age data).

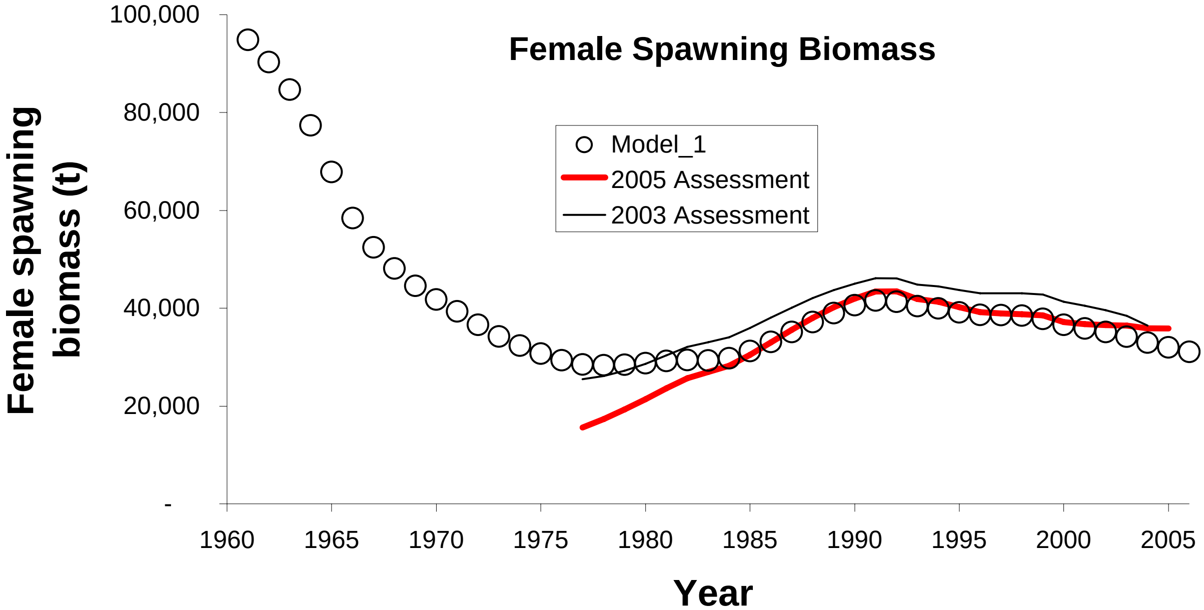


Figure 9.9. Comparison of female spawning biomass for Model 1 (current assessment) and recent years results for GOA northern rockfish, 1961-2006.

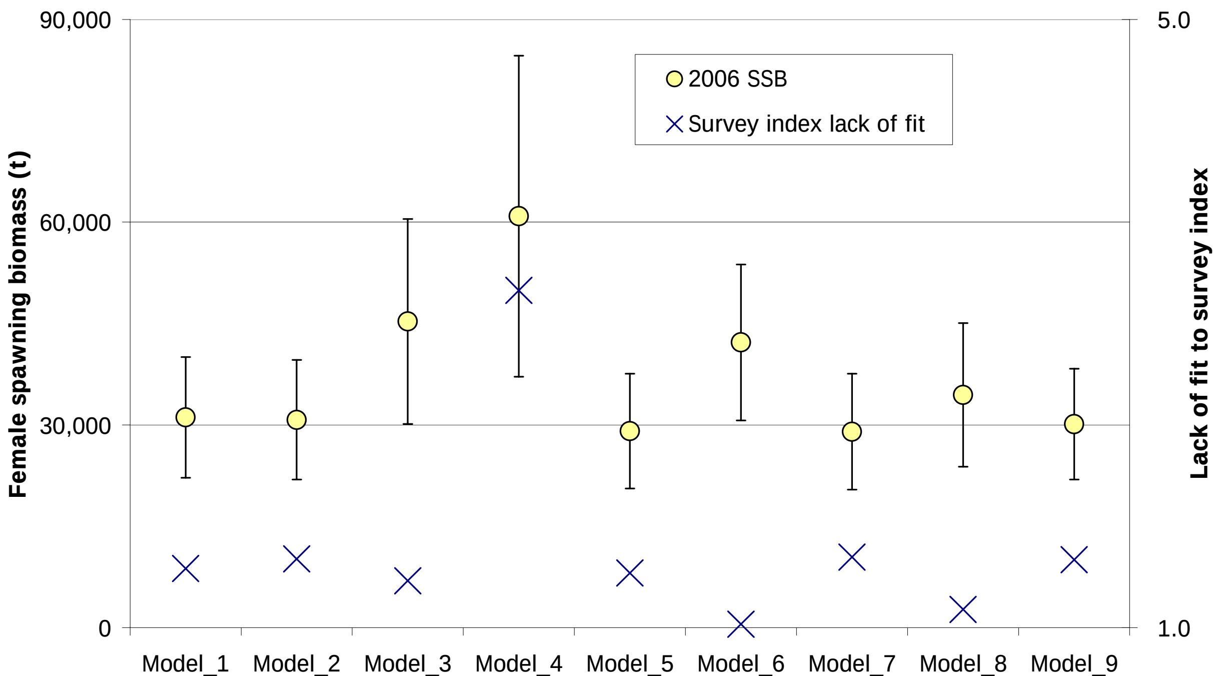


Figure 9.10. Model comparisons for estimates of 2006 GOA northern rockfish female spawning biomass and relative lack of fit (the standardized deviations of normalized residuals) to the survey index (lower values mean a better fit). Vertical bars represent ±1 standard deviation in female spawning biomass.

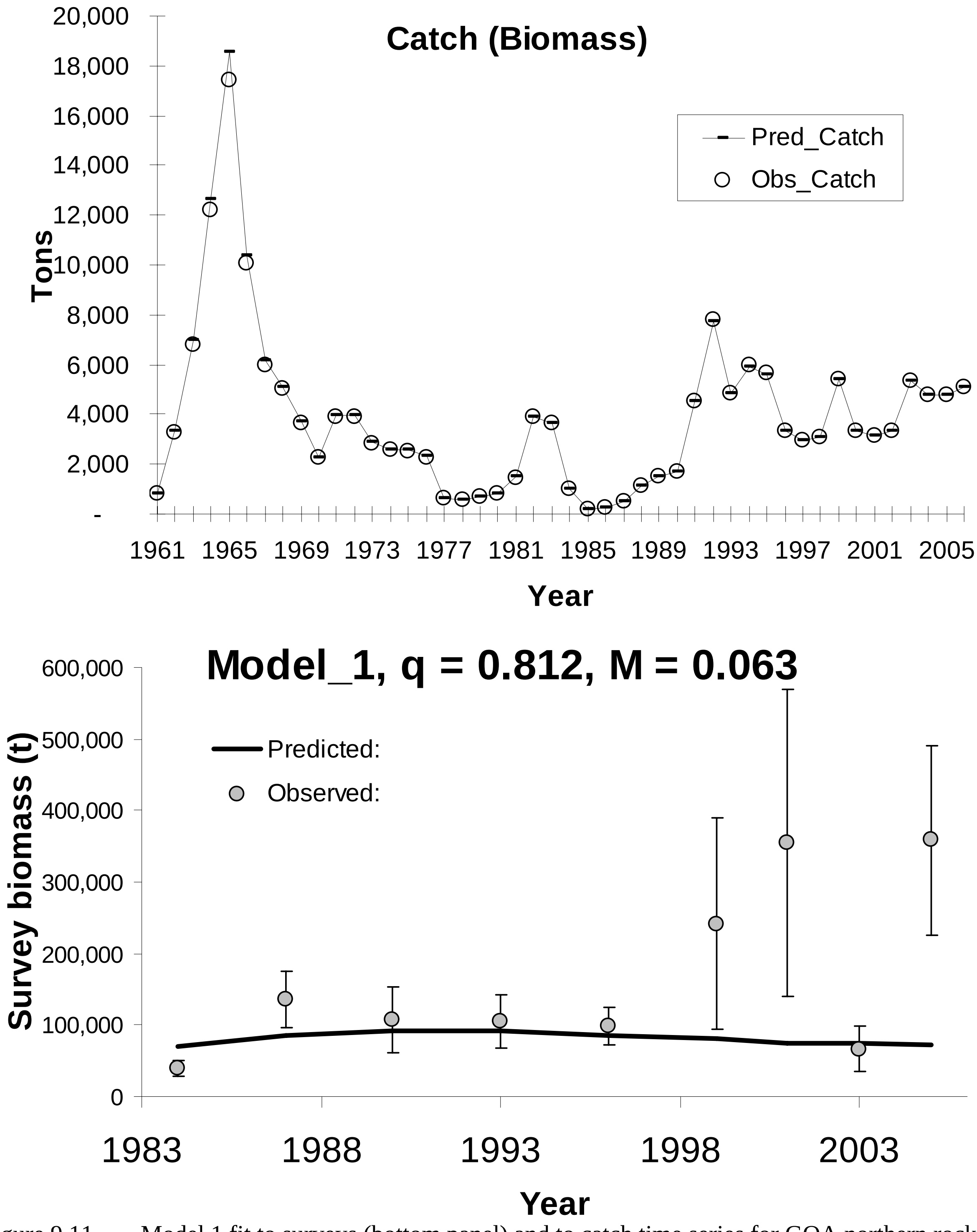


Figure 9.11. Model 1 fit to surveys (bottom panel) and to catch time series for GOA northern rockfish. Note that during the period 1961-1976 the catch estimates are treated as being relatively uncertainty (CV input ~32% compared to 10% for the period since 1977).

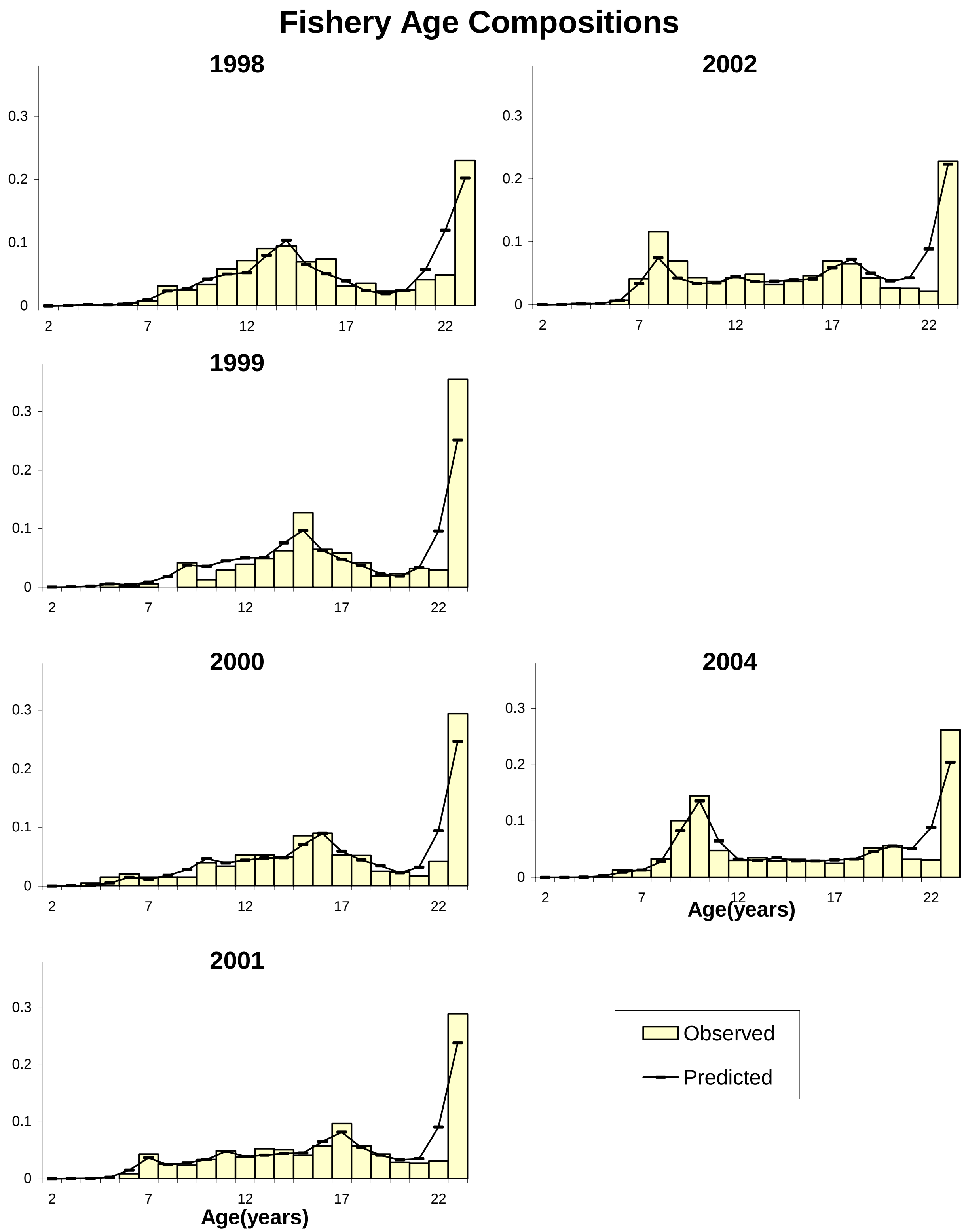


Figure 9.12. Observed and predicted Model 1 fishery age compositions for GOA northern rockfish.

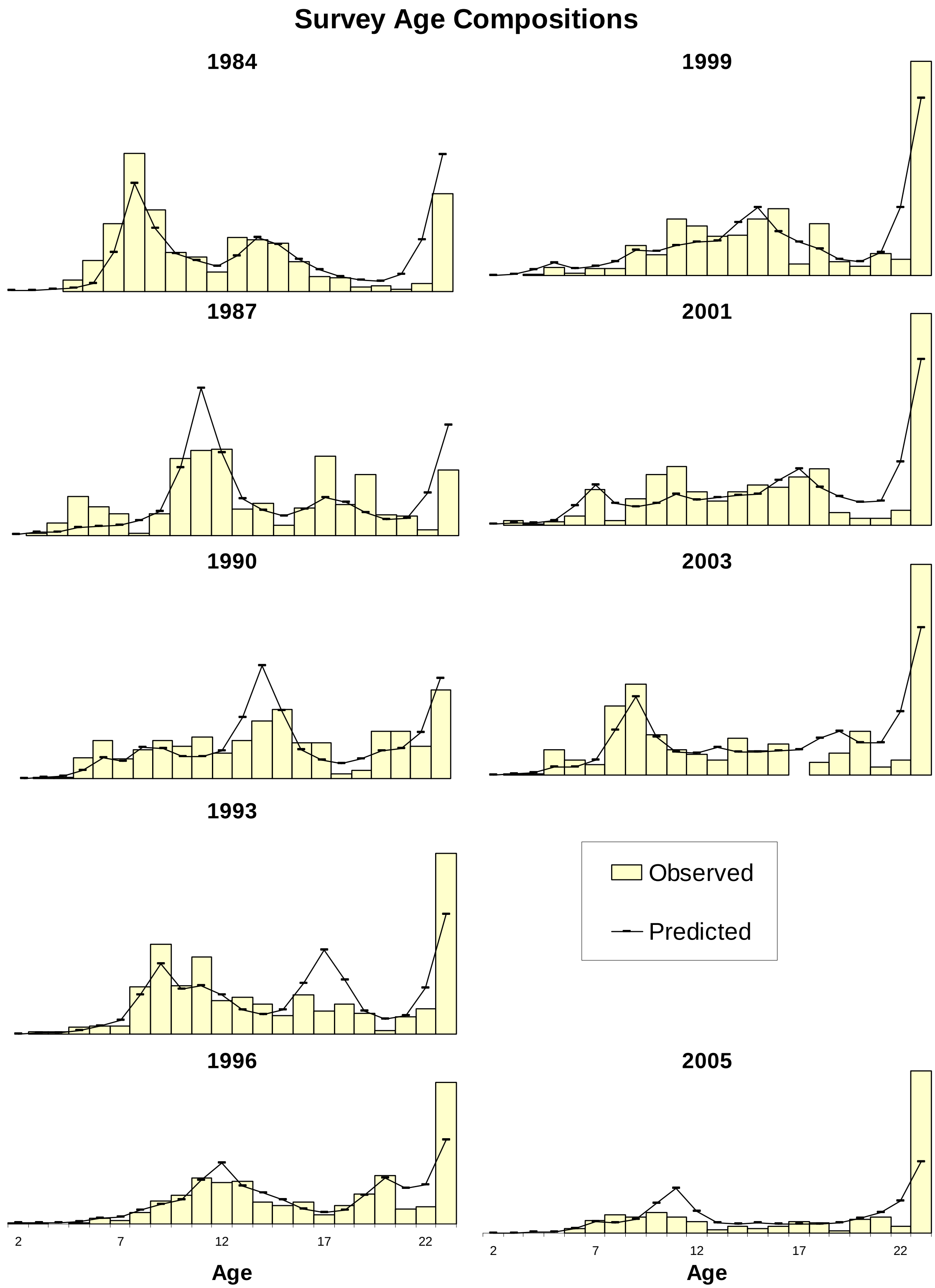


Figure 9.13. Observed and predicted Model 1 survey age compositions for GOA northern rockfish.

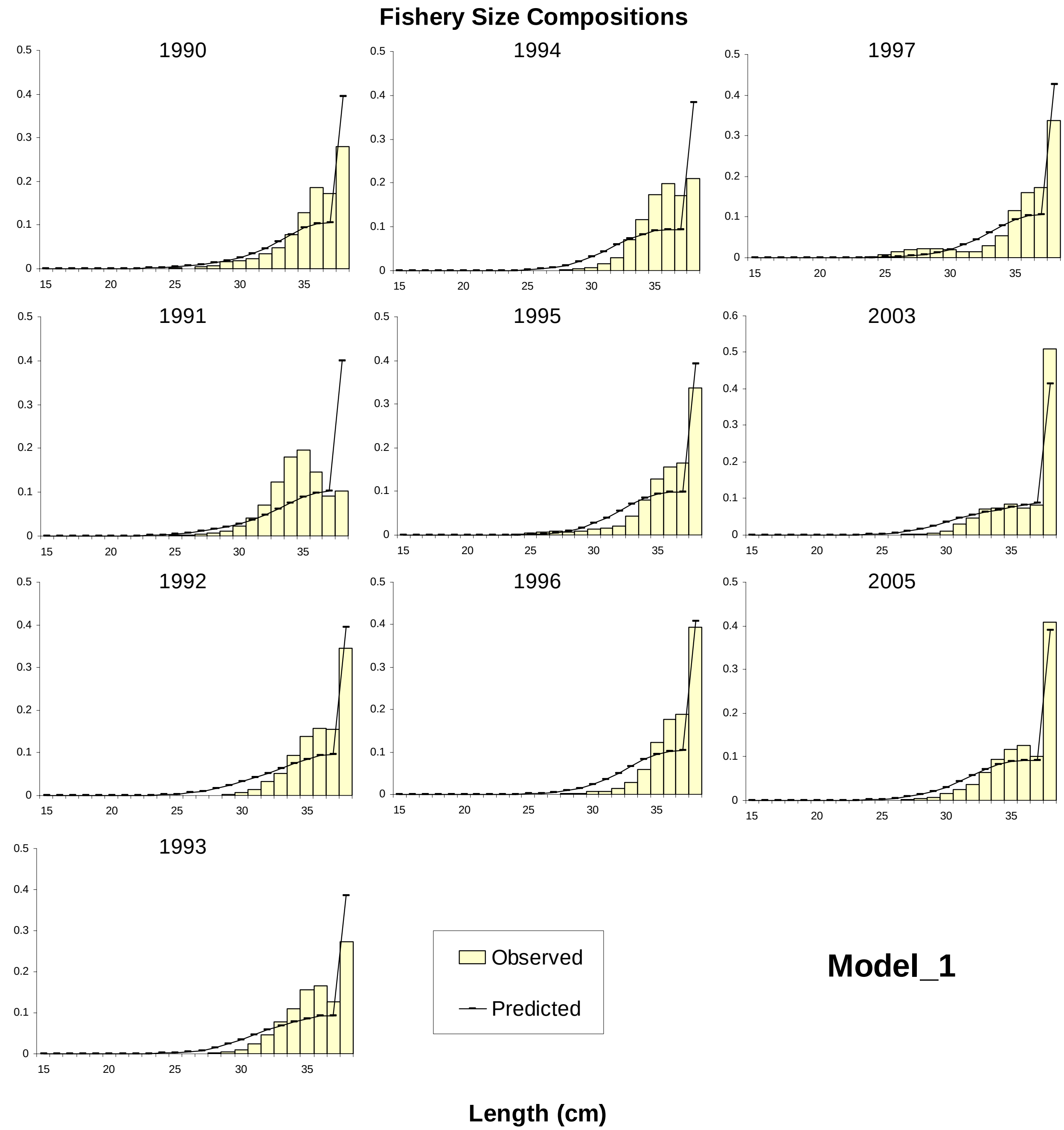


Figure 9.14. Observed and predicted fishery size compositions for GOA northern rockfish, Model 1.

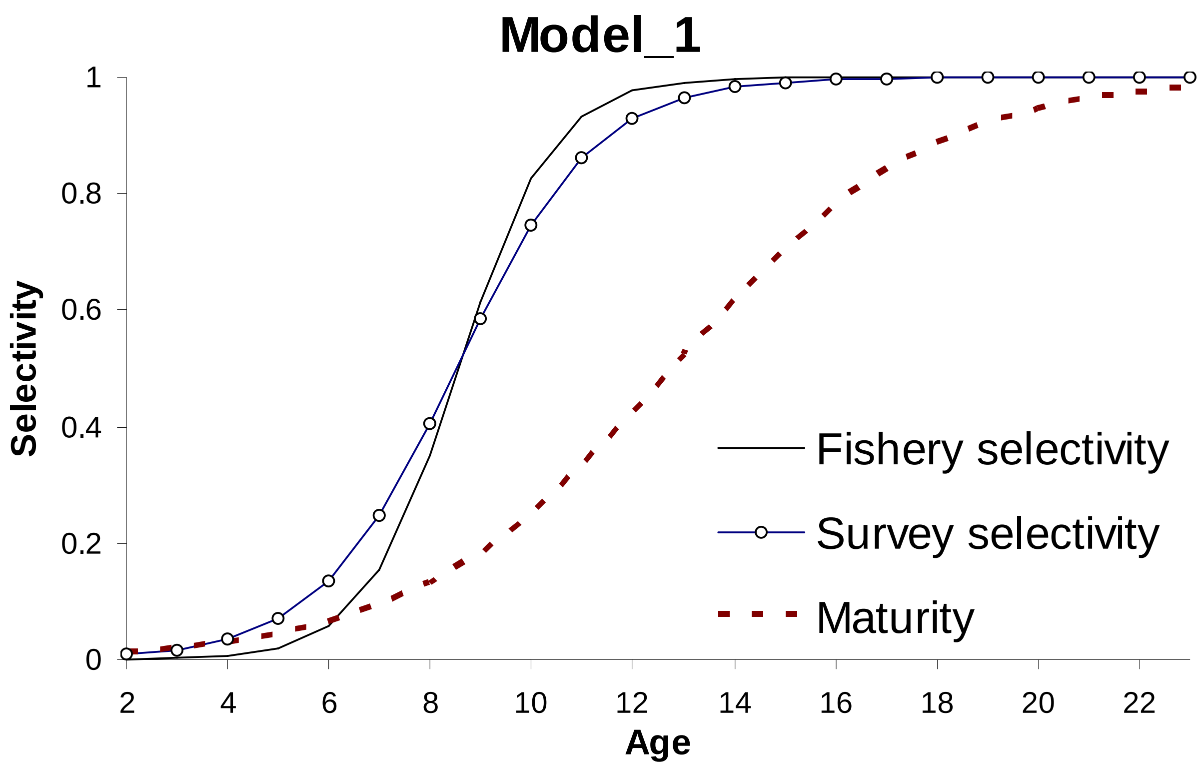
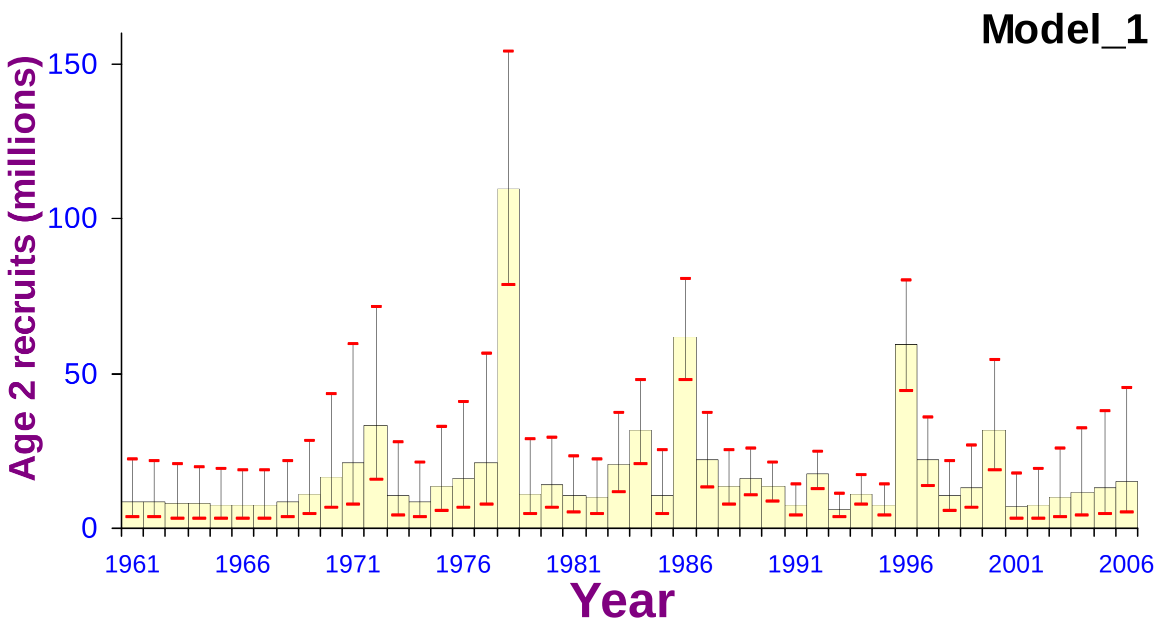


Figure 9.15. Estimates of survey and fishery selectivity at age compared to input maturity at age for GOA northern rockfish. Note that only 77 samples were used to estimate the maturity schedule.



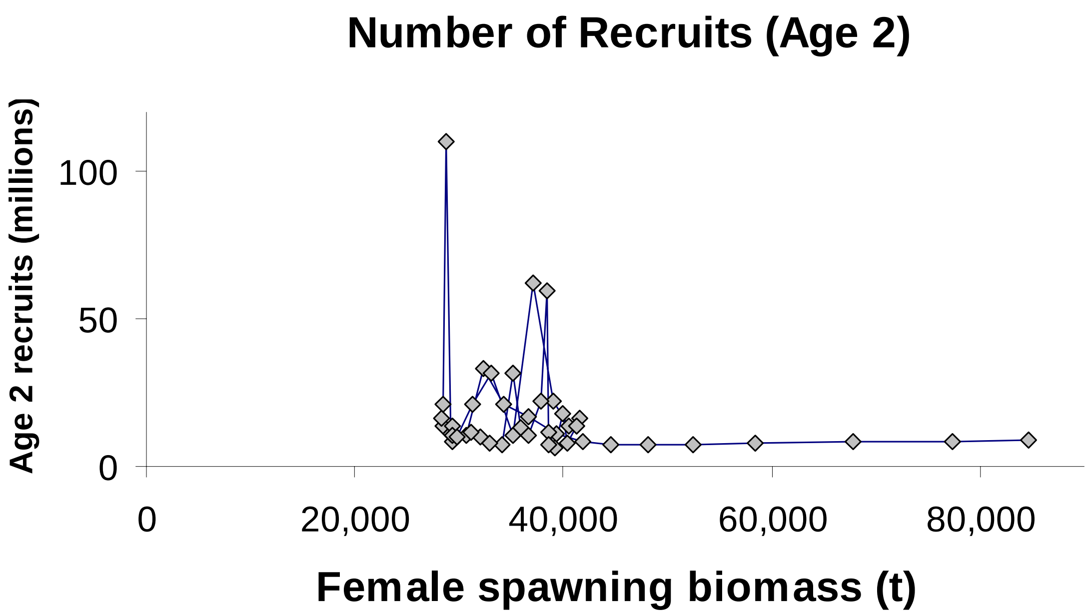


Figure 9.16. Stock-recruitment (bottom panel) and estimates of recruitment (top panel) for GOA northern rockfish, 1961-2006.

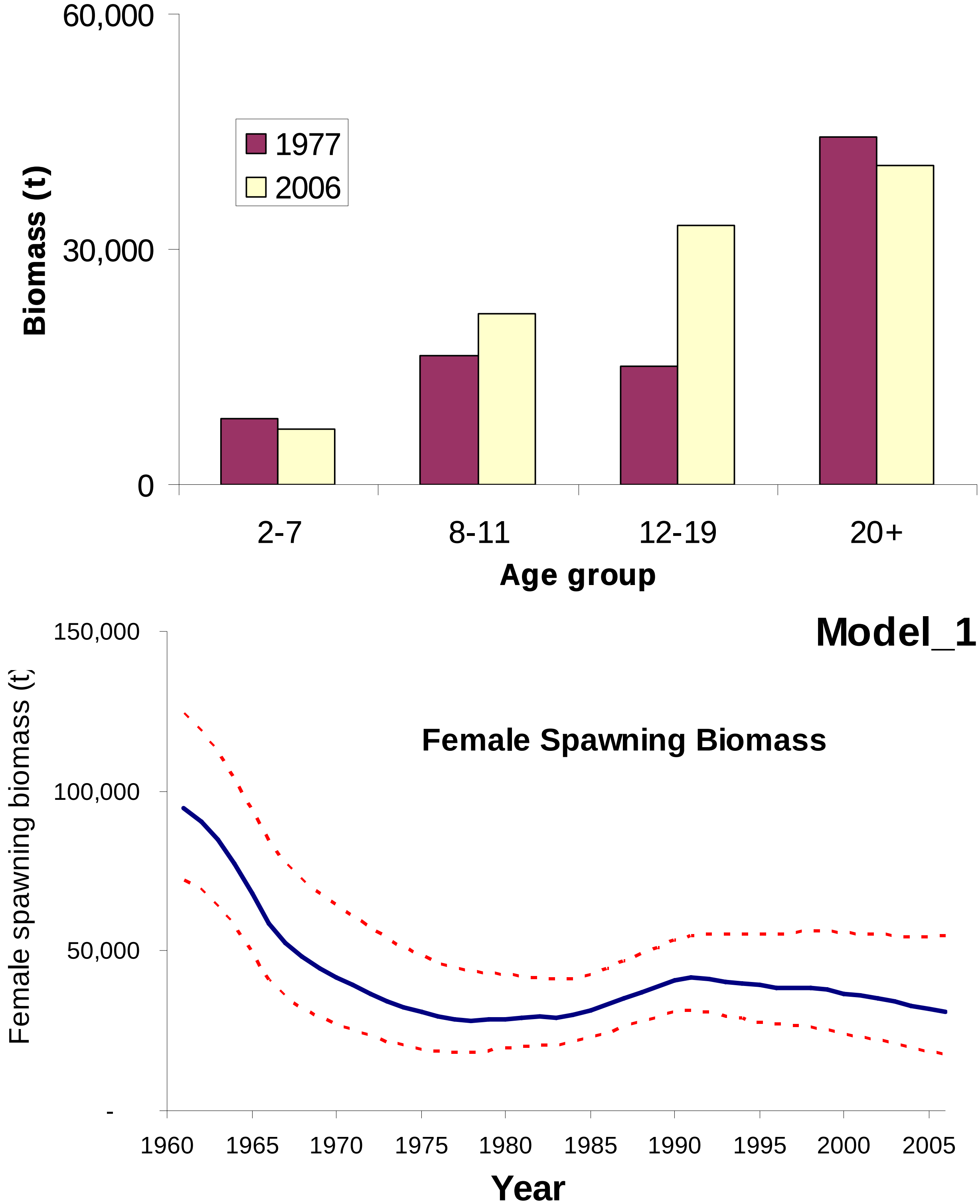


Figure 9.17. Estimated biomass by age group for 1977 and 2006 (top panel) and the estimated female spawning biomass trend (with approximate 95% confidence bands) from 1961-2006 for GOA northern rockfish.

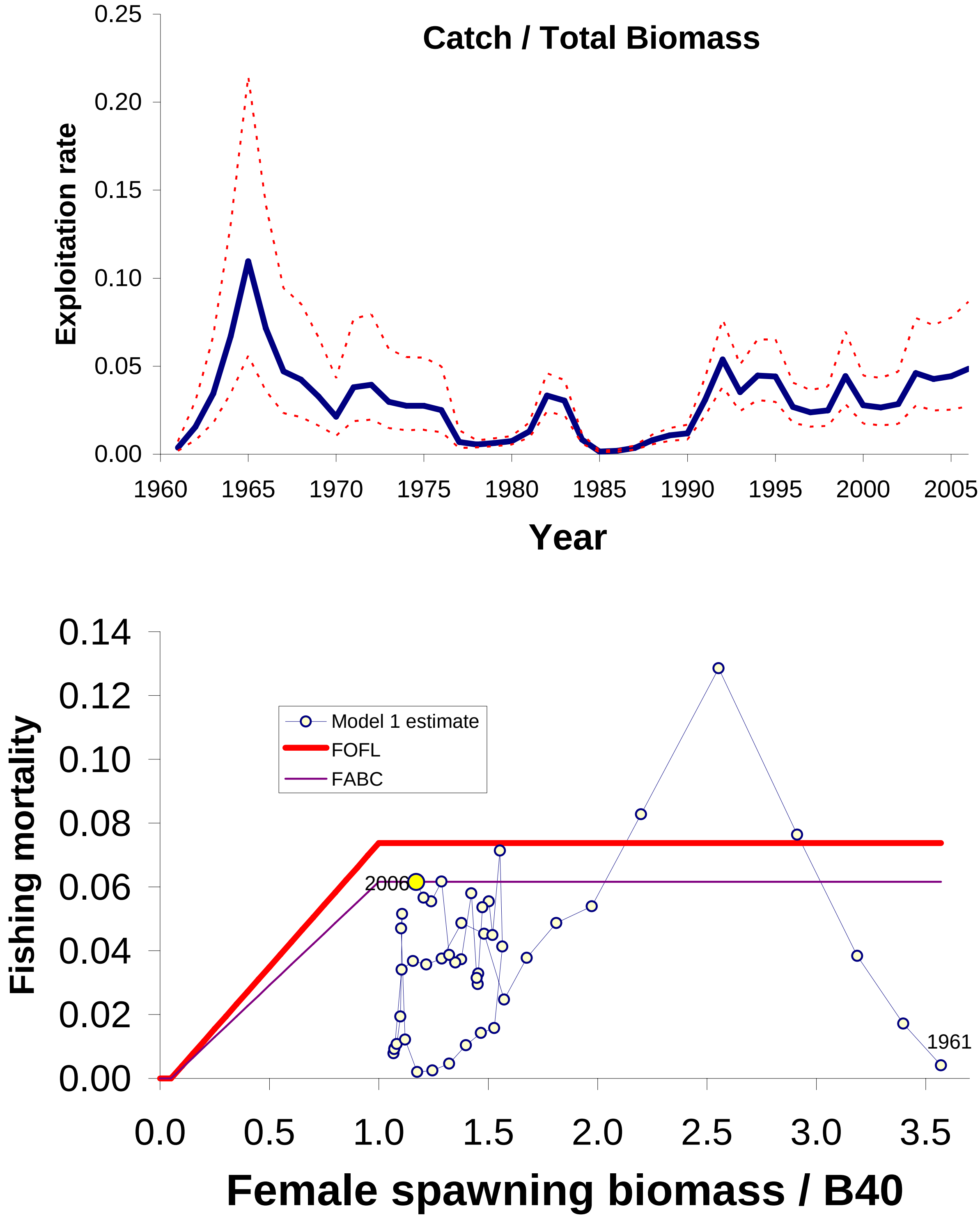


Figure 9.18. Time series of exploitation rate (catch over total age 2+ biomass; top panel) and phase plot of historical fishing mortality relative to spawning biomass (bottom panel) for GOA northern rockfish based on Model 1. The larger circle on the bottom panel is the estimated value for 2006.

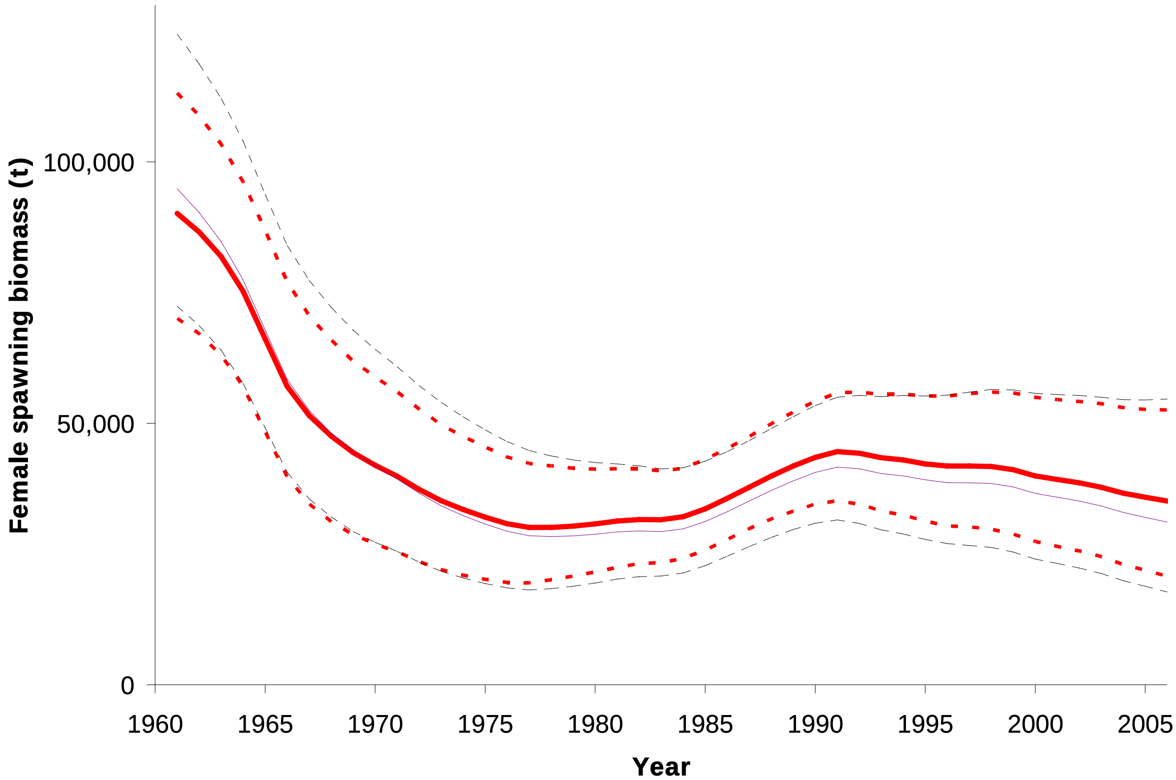


Figure 9.19. Posterior marginal distribution of female spawning biomass based on the MCMC integration (thick solid and dashed lines) and from the posterior mode and delta method approximation of 95% confidence bands (thin solid and dashed lines) for GOA northern rockfish 1961-2006.

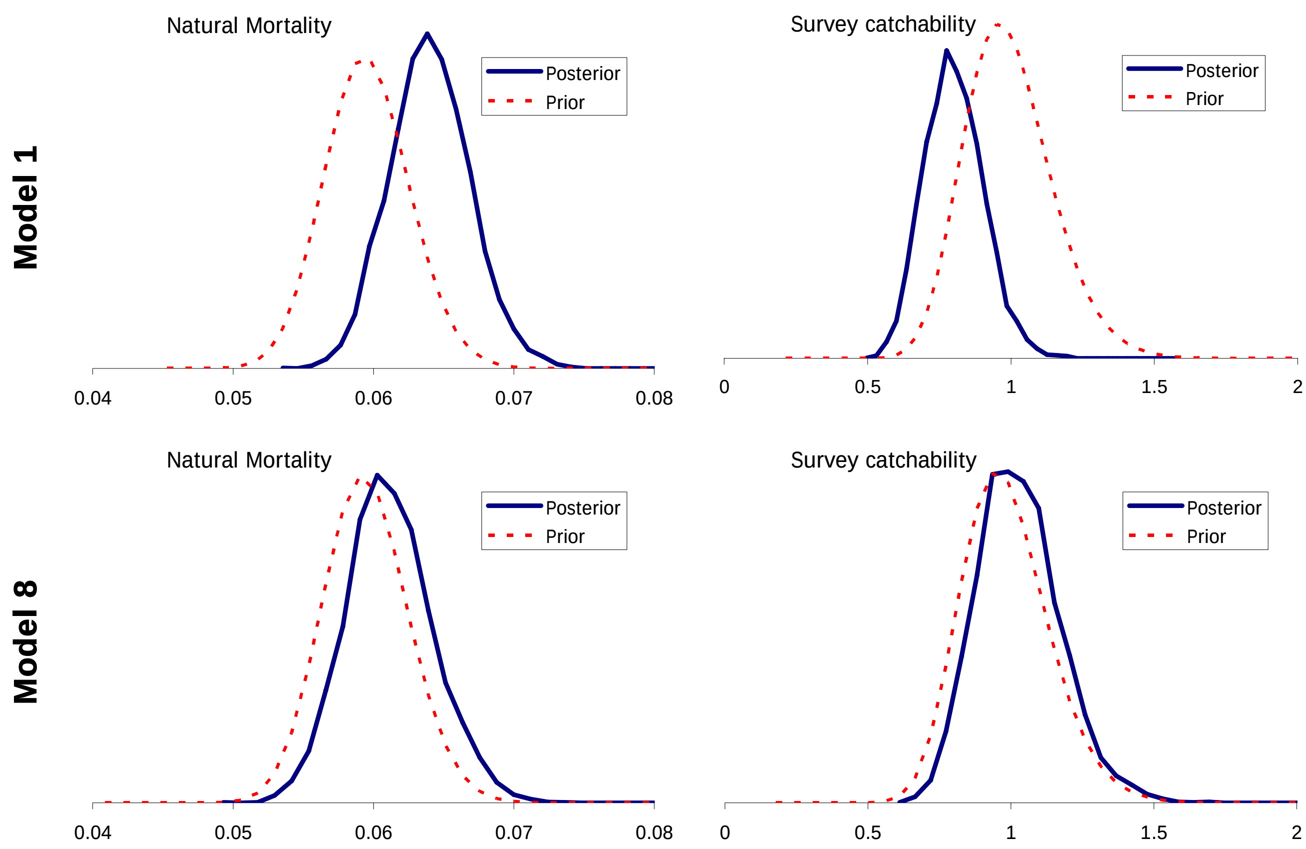


Figure 9.20. GOA northern rockfish.MCMC marginal posterior distributions (and priors in dashed lines) for natural mortality (left panels) and survey catchability (right panels) for Models 1 and 8 respectively.

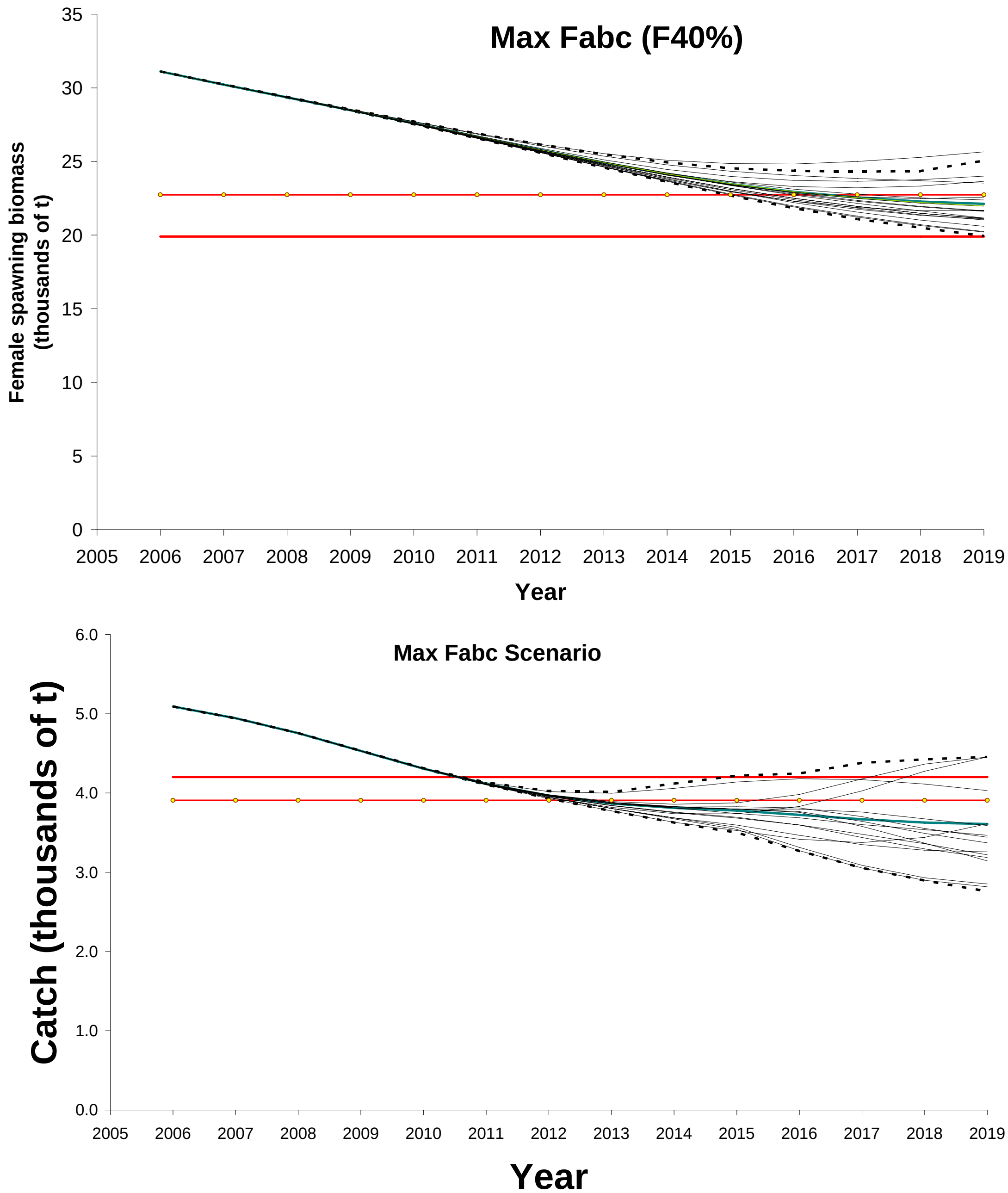


Figure 9.21. GOA northern rockfish.projections under the F_{ABC} policy showing expected female spawning biomass (top panel) and catch (bottom panel) levels. Horizontal lines without dots are the equilibrium $F_{40\%}$ levels and those with dots are the F_{msy} (=$F_{35\%}$) levels.

Attachment 9.1. Response to past SSC and Plan Team comments

Response to 2004 SSC Comments

SSC Comments to the Assessment Authors: Regarding the contribution of older females to stock productivity, the SSC requests that the SAFE authors examine the consequences for rockfish management in both the BSAI and GOA if it is true that older females have a disproportionate large contribution to stock productivity and are also disproportionately harvested due to their size. We request that this type of management strategy evaluation be done for those species for which loss of older females is most prevalent or suspected. We also request that an evaluation of the actual degree of loss of older aged females be provided, including an evaluation of how to adjust for early fishery data where there may have been intense fishing prior to historic age collections. We encourage comparison of BSAI and GOA results.

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 (See section 9.1.4).

A parameter was added to this year's assessment model to estimate average historic fishing mortality in computations of initial numbers at age in 1977. Incorporating historic fishing mortality results in a better fit to recent high biomass estimates (See section 9.7). However, an evaluation of the actual degree of loss of older aged females, including an evaluation of how to adjust for early fishery data where there may have been intense fishing prior to historic age, was not conducted for northern rockfish.

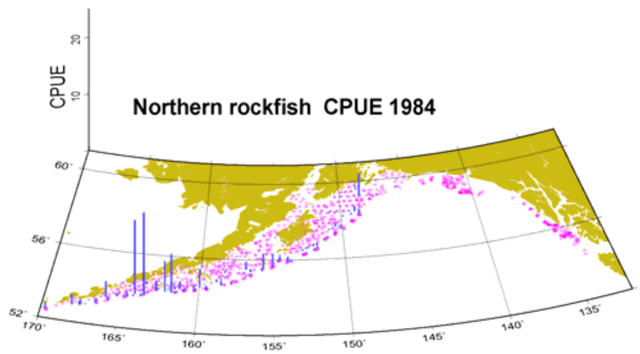
Response to 2003 SSC Comments on Northern Rockfish Depletion

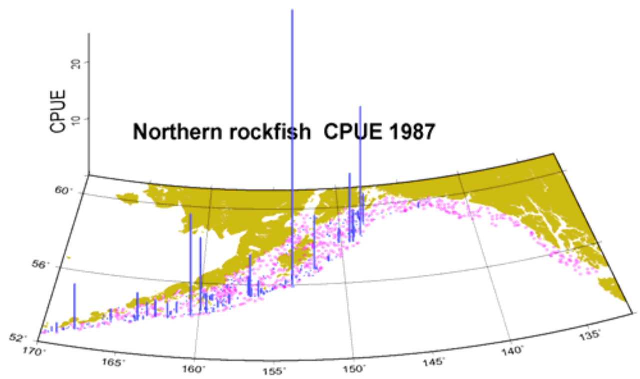
In the SAFE the stock assessment authors indicates that a study of the northern rockfish fishery for the period 1990-98 showed that an estimated 89% of the catch was taken from just five relatively small fishing grounds: Portlock Bank, Albatross Bank, an unnamed bank south of Kodiak Island that fishermen commonly refer to as the "Snakehead", Shumagin Bank, and Davidson Bank. In particular, Snakehead was the most important fishing ground, as it accounted for 46% of the catch during these years. The SSC requested examination of this fishery feature to determine if there is any biological significance.

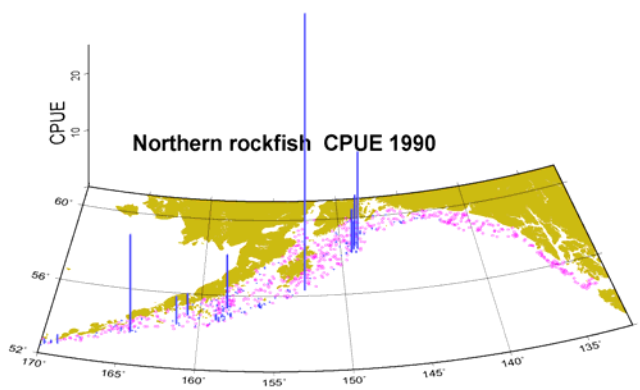
Results of an analysis of localized depletion of rockfish stocks were presented at the 2005 Lowell Wakefield symposium. The use of Leslie depletion estimators on targeted rockfish catches detected relatively few localized depletions for northern rockfish. Several significant depletions occurred in the 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.

Attachment 9.2. Survey CPUE Patterns

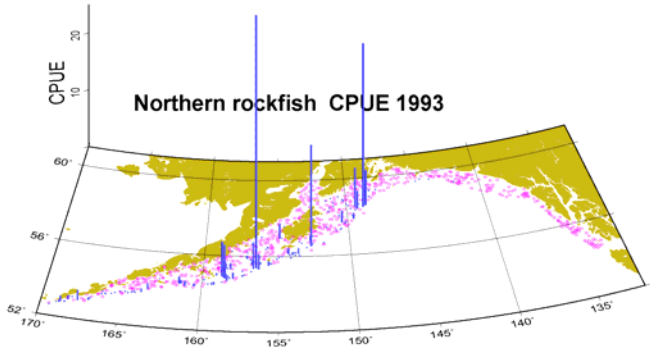
Survey CPUE

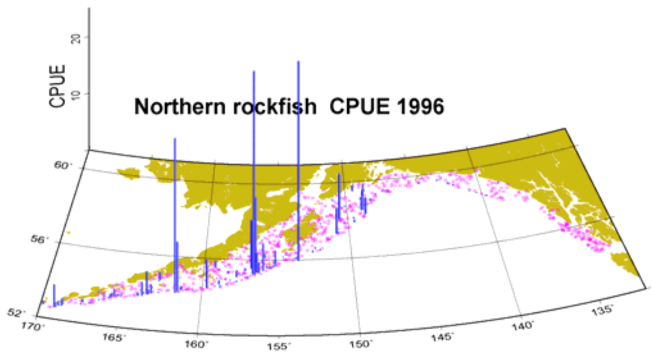


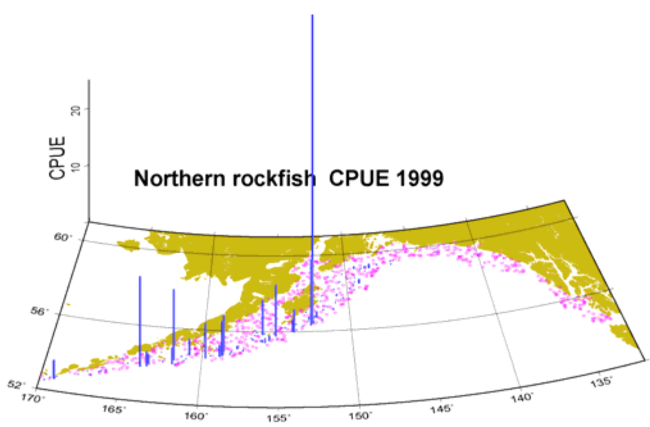




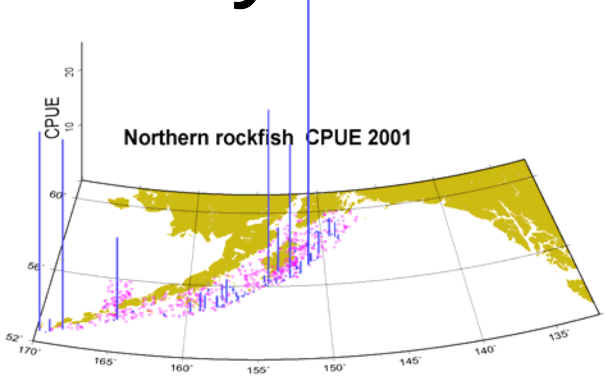
Survey CPUE

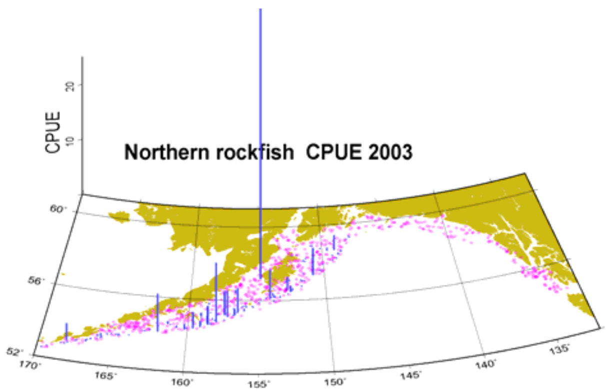

CPUE
Northern rockfish CPUE 1993


CPUE
Northern rockfish CPUE 1996


CPUE
Northern rockfish CPUE 1999

Survey CPUE


CPUE
20
10
Northern rockfish CPUE 2001
60°
56°
52°
170°
165°
160°
155°
150°
145°
140°
135°


CPUE
20
10
Northern rockfish CPUE 2003
60°
56°
52°
170°
165°
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155°
150°
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140°
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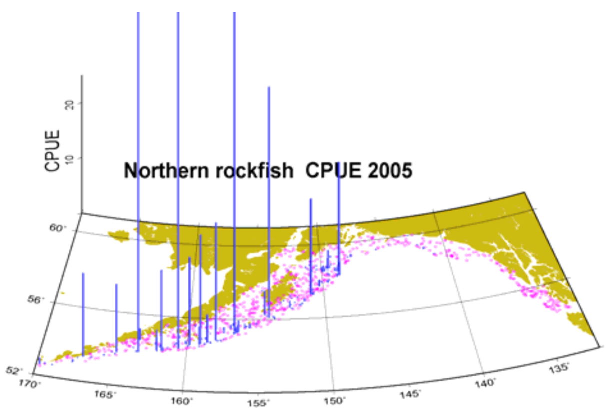
CPUE
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Northern rockfish CPUE 2005
60°
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