10. Assessment of the Northern Rockfish stock in the Gulf of Alaska

by

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Executive Summary

As in 2009, the general model structure for GOA northern rockfish is a separable age-structured model as used for Gulf of Alaska Pacific ocean perch, dusky rockfish, and rougheye/blackspotted rockfish. This consists of an assessment model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses results from the assessment model to predict future population estimates and recommended harvest levels. GOA rockfish are assessed on a biennial stock assessment schedule to coincide with new survey data. For Gulf of Alaska rockfish in alternate (even) years, we present only an executive summary to recommend harvest levels for the next (odd) year. For this on-cycle year, we update the 2009 assessment model with new data acquired since 2009.

Summary of Changes in Assessment Inputs

Changes in input data: The input data were updated to include the 2011 trawl survey biomass estimate, updated catch for 2010, preliminary catch for 2011, survey age compositions for 2009, fishery age compositions for 2008 and 2010, and fishery size compositions for 2009 and 2011.

Changes in the assessment methodology: Three model configurations are considered. Model 1 is the base model from 2009 with updated data. The main change for Model 2 compared to Model 1 is using an intermediate maturity curve with parameters estimated conditionally in the assessment model, fit to female northern rockfish maturity data used in previous assessments (C. Lunsford pers. comm. July 1997, Heifetz et al. 2009) and more recent data from Chilton (2007). Model 3 uses the same maturity estimation method as Model 2 with the addition of extending the plus age group for both fishery and survey age compositions from age 23+ to 33+. In both Model 2 and 3, identical maturity-at-age parameter estimates are obtained whether fitting the maturity data independently or conditionally, this is also true for the all the other parameters estimated in the model. Estimating maturity-at-age parameters conditionally influences the model only through the evaluation of uncertainty, as the MCMC procedure includes variability in the maturity parameters in conjunction with variability in all other parameters, rather than assuming the maturity parameters are fixed. We recommend Model 3 to provide assessment advice for 2012. This model results in an improvement of the model fit to both fishery and survey age compositions compared to Model 1 and 2, and utilizes new maturity information while providing a method to incorporate uncertainty in maturity parameters into the uncertainty in assessment model results.

Summary of Results

The 2012 projected age 2+ biomass is 104,155 t. The recommended ABC for 2012 is 5,509 t, the maximum allowable ABC under Tier 3a. This ABC is 13% higher than the 2011 ABC of 4,857 t. The OFL is 6,574 t. The corresponding reference values for northern rockfish recommended for this year and projected one additional year along with corresponding values from last year's SAFE are summarized in the table below. The GOA northern rockfish stock is not subjected to overfishing, is not currently overfished, and is not approaching a condition of overfishing.

Quantity	As estimated or *specified last* year for: 2011	2012	As estimated or *recommended this* year for: 2012*	2013
M (natural mortality rate)	0.06	0.06	0.06	0.06
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	100,463	97,767	104,155	99,449
Female spawning biomass (t)				
Projected	33,961	32,671	43,414	40,589
$B_{100\%}$	61,368	61,368	72,983	72,983
$B_{40\%}$	24,547	24,547	29,193	29,193
$B_{35\%}$	21,479	21,479	25,544	25,544
F_{OFL}	0.071	0.071	0.074	0.074
$maxF_{ABC}$	0.059	0.059	0.062	0.062
F_{ABC}	0.059	0.059	0.062	0.062
OFL (t)	5,784	5,498	**6,574**	6,152
maxABC (t)	4,857	4,616	**5,509**	5,155
ABC (t)	4,857	4,616	**5,509**	5,155
Status	As determined *last* year for: 2009	2010	As determined *this* year for: 2010	2011
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projected ABCs and OFLs for 2012 and 2013 are derived using expected catches of 3,590 and 4,683 t for 2011 and 2012 based on realized catches from 2008-2010. This calculation is in response to management requests to obtain more accurate projections.

The following table shows the recommended apportionment for 2012.

	Western	Central	Eastern*	Total
Area Apportionment	39.13%	60.83%	0.04%	100.00%
Area ABC (t)	**2,156**	**3,351**	**2**	**5,509**

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

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Northern rockfish	2010	113,200	6,070	5,100	5,100	3,902
	2011	108,298	5,784	4,857	4,857	3,341
	2012	104,155	6,574	5,509		
	2013	99,449	6,152	5,155		

Stock/ Assemblage	Area	2011 OFL	ABC	TAC	Catch[2]	2012 OFL	ABC	2013 OFL	ABC
Northern rockfish	W		2,573	2,573	1,741		2,156		2,017
	C		2,281	2,281	1,600		3,351		3,136
	E*						2		2
	Total	5,784	4,854	4,854	3,341	6,574	5,509	6,152	5,155

[1]Total biomass estimates from the age structured model.
[2]Current as of October 4, 2011 Source: NMFS Alaska Regional Office via the Alaska Fisheries Information Network (AKFIN).
* For management purposes, the small ABC for northern rockfish in the Eastern Gulf of Alaska is combined with other slope rockfish.

Responses to SSC Comments since the last full assessment

"The methods for area apportionment of the ABC that are used in the specific chapters are different from those given in the general introductory material to the SAFE on page 4. The SSC suggests that the table be updated. Also, a different number of years are used for various species (e.g., 5 years for sablefish, 4 years for pollock, 3 surveys, most recent survey). SSC members recall extensive discussions about these issues but the rationale for the decision is not given in the SAFE chapters. The SSC suggests that description of the apportionment rationale in each SAFE chapter of area-apportioned species would be helpful to the reader." (December, 2009)

The annual allocation of the Gulf-wide ABC for northern rockfish amongst the three regulatory areas in the Gulf has been based on the geographic distribution of biomass in the trawl surveys. Since the 1996 SAFE report, this distribution has been computed as a weighted average of the percent biomass distribution for each area in the three most recent trawl surveys. Details can be found in Section "*Area Allocation of Harvests*".

"The SSC looks forward to seeing the new maturity data that has recently become available for this species and the impact on incorporation of those data into the assessment model next year. The SSC agrees with the authors' suggestion to expand the plus group age category from 23 years to at least 30 years, noting that a substantial proportion of the assessed stock appears to be in the current plus age group." (December, 2009)

We incorporated the maturity data from Chilton (2007) into this stock assessment, and made comparisons to alternative models that do not use this information. Also, we provide rationale for extending the plus age group to age 33+. We recommend a model configuration in which maturity parameters are estimated conditionally in the model and fit to combined maturity data and the plus age group for the survey and fishery age compositions is extended to 33+.

"The SSC recommends that stock assessment authors and plan teams address this issue in the upcoming stock assessment cycle. Stock assessment authors should clearly lay out which sources of removals are currently included in the assessment, how removals from each source are estimated, and how they are being included in (A) and (B) above. To the extent possible, authors should discuss all known sources of mortality (including handling mortality, indirect mortality, subsistence, etc.) and which of these sources are considered in the assessment." (June 2011)

Estimates of non-commercial catch of northern rockfish are documented in Appendix 10-A.

Responses to GOA Plan Team Comments since the last full assessment

"Plan Team recommendations for the next assessment:

1.) The Plan Team supports the assessment authors' suggestion to change the plus group for age compositions from 23 to 30 years.

2.) The Plan Team also supports investigating a recent publication which suggests changes to the maturity curve for northern rockfish, which might be considered in an upcoming model.

3.) *The Plan Team encourages the authors to bring relevant age data analyses and maturity comparisons forward next September during the off year for this assessment." (November, 2009)*

In a report submitted to the GOA Groundfish Plan Team in September 2010 two maturity studies for northern rockfish were compared. In this year's assessment, we combine the data from both studies to estimate maturity of northern rockfish. We also provide rationale for extending the plus age group to age 33+.

"The Team discussed the different catch assumptions made across assessments. The Team noted that authors should be clear in how catch is projected and what assumptions are made to make the catch estimate for the projection." (November, 2010)

When making projections for northern rockfish we project a catch that is equivalent to the ratio of previous year's total catches to ABC, which is standard for all GOA rockfish projections. Refer to Section "*Projections and Harvest Alternatives*" for details.

Introduction

Biology and distribution

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).

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

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

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

Trawl surveys and commercial fishing data indicate that the preferred habitat of adult northern rockfish in the Gulf of Alaska is relatively shallow rises or banks on the outer continental shelf at depths of about 75-150 m (Clausen and Heifetz 2002). 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 2002). 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.

Recent work on black rockfish (*Sebastes melanops*) has shown that larval survival may be higher from older female spawners (Berkeley et al. 2004). The black rockfish population has shown a distinct reduction in the proportion of older fish in recent fishery samples off the West Coast of North America, raising concerns if larval survival diminishes with spawner age. De Bruin et al. (2004) examined Pacific ocean perch (*S. alutus*) and rougheye rockfish (*S. aleutianus*) for senescence in reproductive activity of older fish and found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. However, relationships on fecundity or larval survival at age have not yet been evaluated for northern rockfish or other rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age.

Evidence of stock structure

Gulf of Alaska northern rockfish grow significantly faster and reach a larger maximum length than Aleutian Islands northern rockfish (Clausen and Heifetz 2002). Also, Aleutian Islands northern rockfish are older (maximum age 72) than Gulf of Alaska northern rockfish (maximum age 67), the difference in age is possibly due to sampling variability. 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. A recent study that has been completed (Gharrett et al. in press) for northern rockfish sample from several locations in the Aleutian Islands and Bering Sea did find spatial structure on a relatively small scale.

Results of an analysis of localized depletion based on Leslie depletion estimators on targeted rockfish catches detected relatively few localized depletions for northern rockfish (Hanselman et al. 2007). Several significant depletions occurred in the early 1990s for northern rockfish, but were not detected again by the depletion analysis. However, when fishery and survey CPUEs were plotted over time for a geographic block of high rockfish fishing intensity that contained the "Snakehead", the results indicated there were year-after-year drops in both fishery and survey CPUE for northern rockfish. Presently, fishing for northern rockfish is nearly absent relative to previous effort in the area. The significance of these observations depends on the migratory and stock structure patterns of northern rockfish. If fine-scale stock structure is determined in northern rockfish, or if the area is essential to northern rockfish reproductive success, then these results would suggest that current apportionment of ABC may not be sufficient to protect northern rockfish from localized depletion. Provisions to guard against serial depletion in northern rockfish should be examined in the Gulf of Alaska rockfish rationalization plan. The extension of the fishing season that has been implemented may spread out the fishery in time and space and reduce the risk of localized serial depletion on the "Snakehead" and other relatively shallow (75 – 150 m) offshore banks on the outer continental shelf where northern rockfish are concentrated.

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

Description of management units/measures

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 a weighted average of the proportion of biomass by area from the three most recent Gulf of Alaska trawl surveys. Northern rockfish are scarce in the eastern Gulf of Alaska, and the ABC apportioned to the Eastern Gulf management area is small. This translates to a TAC that is too difficult to be managed effectively as a directed fishery. Since 1999, the ABC for northern rockfish apportioned to the Eastern Gulf management area is included in the West Yakutat ABC for “other slope rockfish.”

Amendment 41, which took effect in 2000, prohibited trawling in the Eastern area east of 140 degrees W. longitude. However, trawling did not occur in this area starting in 1998. Since most slope rockfish, especially Pacific ocean perch, are caught exclusively with trawl gear, this amendment could have concentrated fishing effort for slope rockfish in the Eastern area in the relatively small area between 140 degrees and 147 degrees W. longitude that remained open to trawling. However, this should not have a major effect on northern rockfish because of the low abundance in the Eastern area.

In November, 2006, NMFS issued a final rule to implement Amendment 68 of the GOA groundfish Fishery Management Plan for 2007 through 2011. This action implemented the Central GOA Rockfish Pilot Program (RPP). The intention of this Program is to enhance resource conservation and improve economic efficiency for harvesters and processors in the rockfish fishery. An additional objective is to spread out the fishery in time and space, allowing for better prices for product and reducing the pressure of what was an approximately two-week fishery in July. The primary rockfish management groups in this program are northern rockfish, Pacific ocean perch, and pelagic shelf rockfish. Potential effects of this program on northern rockfish include: 1) Extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA, 3) Improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, 4) a higher potential to harvest 100% of the TAC in the Central GOA region. In a comparison of catches in the four years before the RPP to the four years after, it appears that average catches have increased overall (although, this may be due to increased observer coverage) and have spread out spatially in the western and central Gulf (Figure 10.1). The authors will pay close attention to the benefits and consequences of this action.

A summary of key management measures and a time series of catch, ABC and TAC are provided in Table 10.1.

Fishery

Description of the directed fishery

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

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

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

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

Description of the catch time series

Total commercial catch (t) of northern rockfish in the GOA for the years 1961-2011 is summarized by foreign, joint venture, and domestic fisheries (Table 10.2 and Figure 10.2).

Catches of GOA northern rockfish during the years 1961-1976 were estimated as 5% of the foreign GOA Pacific ocean perch catch in the same years. A Pacific ocean perch trawl fishery by the U.S.S.R. and Japan began in the Gulf of Alaska in the early 1960's. This fishery developed rapidly with massive efforts by the Soviet and Japanese fleets. Catches peaked in 1965 when a total of nearly 350,000 metric tons (t) was caught, but declined to 45,500 t by 1976 (Ito 1982). Some northern rockfish were likely taken in this fishery, but there are no available summaries of northern rockfish catches for this period. Foreign catches of all rockfish were often reported simply as “Pacific ocean perch” with no attempt to differentiate species. The only detailed analysis of bycatch in slope rockfish fisheries of the Gulf of Alaska is that of Ackley and Heifetz (2001) who examined data from the observer program for the years 1993-95. Consequently, our best estimate of northern rockfish catch from 1961-1976 comes from analysis of the ratio of northern rockfish catch to Pacific ocean perch catch in the years 1993-1995. For hauls targeting on Pacific ocean perch, northern rockfish composed 5% of the catch (Ackley and Heifetz 2001).

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

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

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

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

Catches of GOA northern rockfish during the years 1993-present were available directly from NMFS domestic fisheries observer data. Northern rockfish were removed from the slope rockfish assemblage and managed with an individual TAC beginning in 1993. As a consequence, directly reported catch for northern rockfish has been available since 1993. Catch of northern rockfish was reduced after the implementation of a northern specific TAC in 1993. Most of the catch since 1993 has been taken in the Central area, where the majority of the northern rockfish exploitable biomass is located. Gulfwide catches for the years 1993-2011 have ranged from 2,935 t to 5,635 t. Annual ABCs and TACs have been relatively consistent during this period and have varied between 4,362 t and 5,760 t. In 2001, catch of northern rockfish was below TAC because the maximum allowable bycatch of Pacific halibut was reached in the central Gulf of Alaska for "deep water trawl species," which includes northern rockfish. Catches of northern rockfish have been near their TAC's in more recent years, 2003 - 2011.

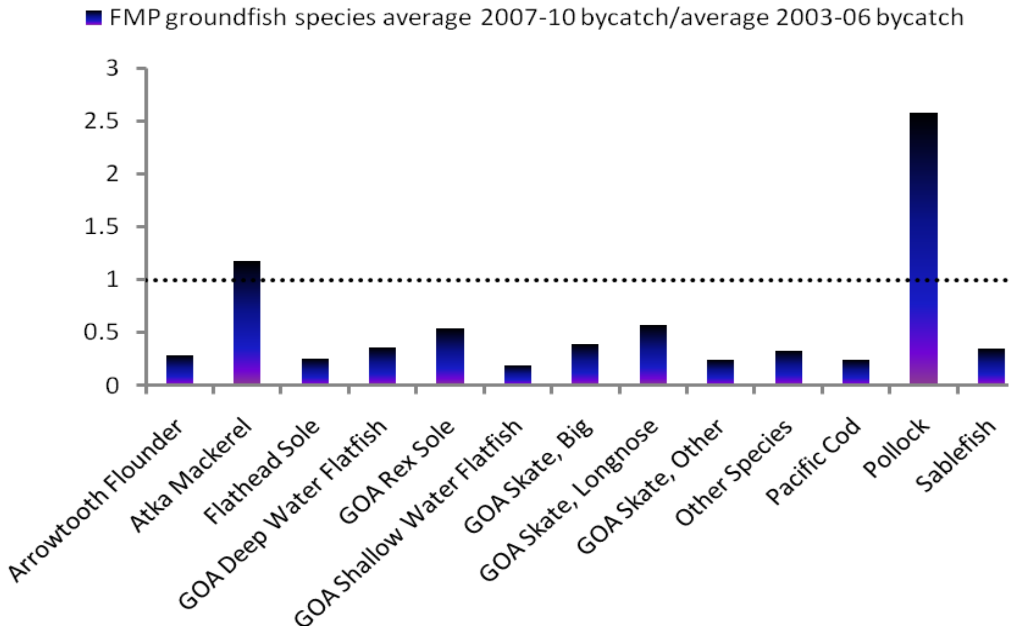
Research catches of northern rockfish have been relatively small and are listed in Table 10A.1 in Appendix 10A.

Bycatch and discards

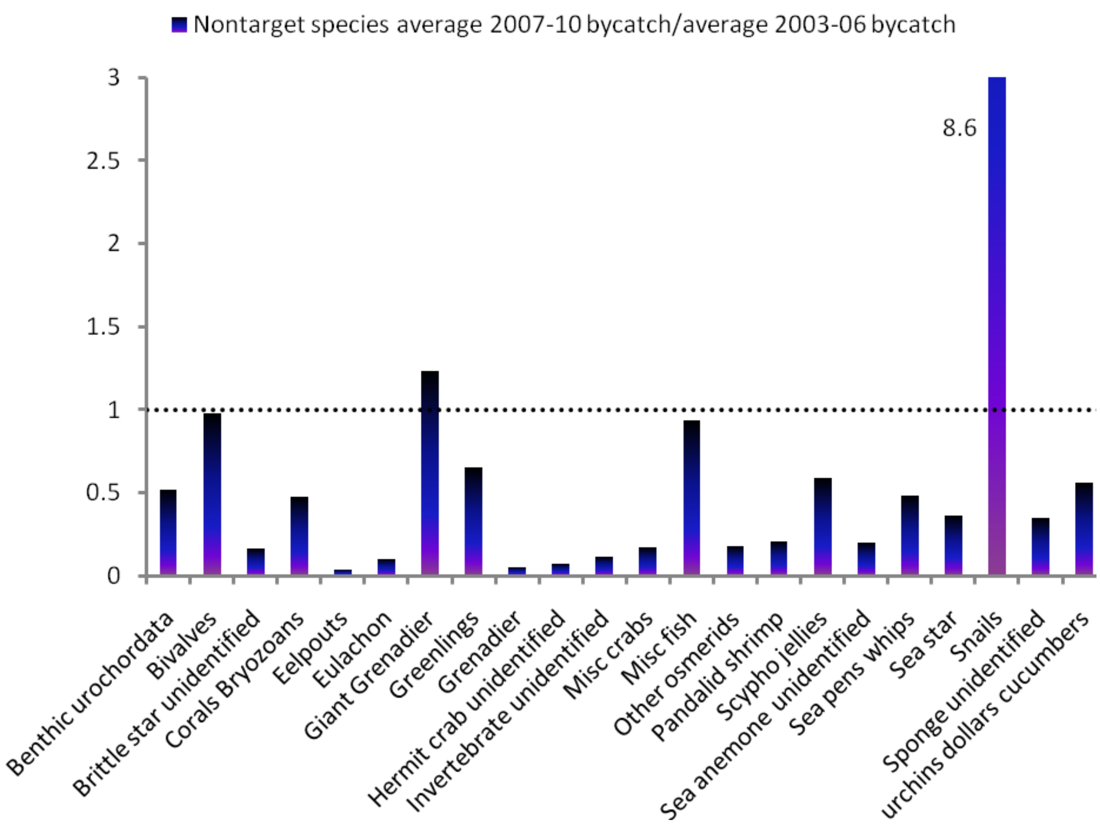
The only detailed analysis of incidental catch in slope rockfish fisheries of the Gulf of Alaska is that of Ackley and Heifetz (2001) who examined data from the observer program for the years 1993-95. For hauls targeting on northern rockfish, the predominant incidental species were dusky rockfish, distantly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

Total FMP groundfish catch estimates targeted in the GOA rockfish fishery from 2006-2010 are shown in Table 10.3. For the GOA rockfish fishery during 1991-2010 the largest non-rockfish bycatch groups are arrowtooth flounder (1,540 t/year), sablefish (948 t/year), Pacific cod (814 t/year), Atka mackerel (585 t/year) and walleye pollock (352 t/year).

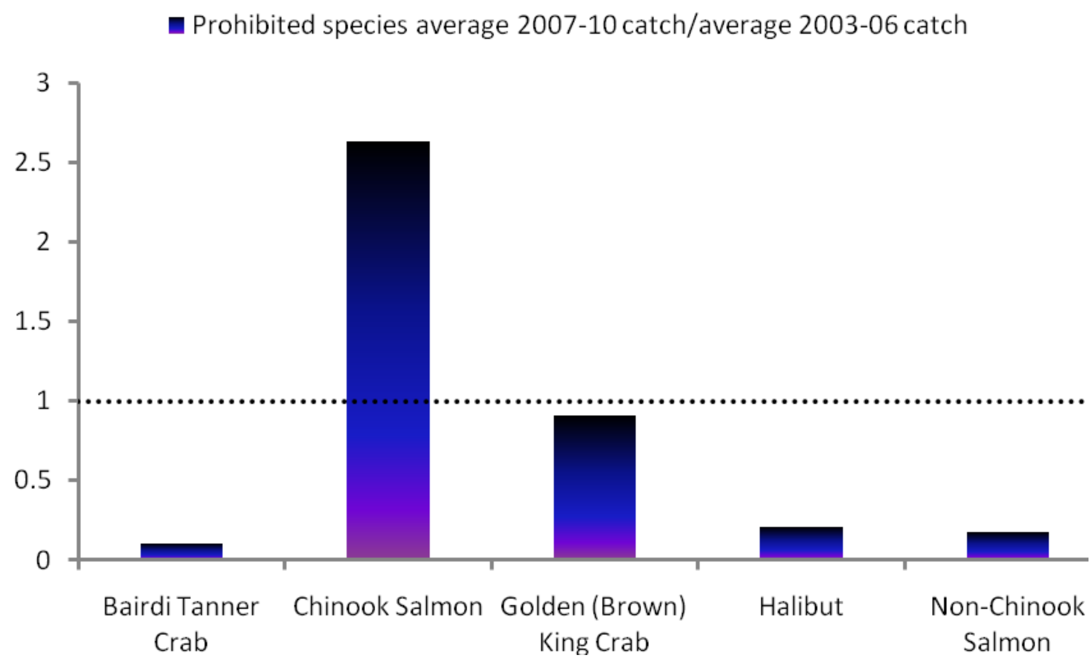
We compared bycatch in the central GOA from pre-2006 and post-2007 (the year of the Central GOA Rockfish Pilot Program implementation) for the rockfish fishery by dividing the average post-2007 bycatch (2007-2010) by the average pre-2006 bycatch (2003-2006) for non-rockfish species that had available information in both time periods. For the majority of FMP groundfish species bycatch in the central GOA has reduced since 2007, with the exception of Atka mackerel (214 t/year pre-2006 compared to 251 t/year post-2007) and walleye pollock (136 t/year pre-2006 compared to 352 t/year post-2007):



Non-FMP species bycatch in the GOA rockfish target fisheries is dominated by giant grenadier (127 – 423 t), miscellaneous fish (132 – 181 t), and ocassionally dark rockfish (recently removed from FMP to state management, 0 – 111 t) (Table 10.4). Only 2 of 23 nontarget species in the central GOA showed an increase in bycatch post-2007 compared to pre-2006, giant grenadier (127 t/year pre-2006 compared to 156 t/year post-2007) and snails (0.3 t/year pre-2006 compared to 2.6 t/year post-2007):



Pohibited species catch in the GOA rockfish fishery has been decreasing for all the major species with the exception of golden king crab which increased to over 3,000 animals in 2009 and 2010. Halibut catch during rockfish targeted hauls has declined since 2005 from 368 t to 142 t in 2010 (Table 10.5). Bycatch since 2007 in the central GOA rockfish fishery has decreased for all of the prohibited species, with the exception of chinook salmon (600 fish/year pre-2006 compared to 1,578 fish/year post-2007):



Gulfwide discard rates (% discarded) for northern rockfish in the commercial fishery for 1993-2010 are as follows:

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001
% Discarded	26.5	17.7	12.7	16.6	28	18.4	11.3	10	17.7
Year	2002	2003	2004	2005	2006	2007	2008	2009	2010
% Discarded	10	9.4	7.9	4.3	9.2	2.6	4.9	3.1	1.5

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

Data

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

Source	Data	Years
Fisheries	Catch	1961-**2011**
NMFS bottom trawl surveys	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, **2011**
NMFS bottom trawl surveys	Age	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, **2009**
U.S. trawl fisheries	Age	1998, 1999, 2000, 2001, 2002, 2004, 2005, 2006, **2008**, **2010**
U.S. trawl fisheries	Length	1990,1991,1992, 1993, 1994, 1995, 1996, 1997, 2003, 2007, **2009**, **2011**

Fishery data

Catch

Catch of northern rockfish range from 185 t to 17,430 t from 1961 to 2011. Detailed description of catch is provided above (within the "*Description of the catch time series*" section) and in Table 10.2 and Figure 10.2.

Age and Size composition

Observers aboard fishing vessels and at onshore processing facilities have provided data on length and age compositions of the commercial catch of northern rockfish. Length compositions are presented in Table 10.6 and Figure 10.3 and age compositions are presented in Table 10.7 and Figure 10.4; these tables also include associated annual sample sizes and number of hauls sampled for the age and length compositions. The fishery age compositions indicate that stronger than average year-classes occurred around the year 1976 and 1984. The fishery age compositions from 2004 and 2006 also indicate that the 1996-1998 year-classes are strong. The clustering of several large year-classes in each period is most likely due to aging error. Recent fishery length compositions (2003-present) indicate that a large proportion of the northern rockfish catch are found to be larger than 38 cm, which is the current plus length bin.

Survey Data

Biomass Estimates from Trawl Surveys

Bottom trawl surveys were conducted in the Gulf of Alaska triennially from 1984 – 1999 and biennially from 1999 – 2011. 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 1,000 m (in some surveys only to 500 m). Generally, attempts have been made through the years to standardize the survey design and the fishing nets used, but there have been some exceptions to this standardization. In particular, much of the survey effort in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (for a discussion see Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates listed in this report, and the estimates are believed to be the best available. Even so, the use of Japanese vessels in 1984 and 1987 introduced an element of uncertainty as to the standardization of these two surveys. Also, a different survey design was used in the eastern Gulf of Alaska in 1984, and the eastern Gulf of Alaska was not covered by the 2001 survey. These data inconsistencies for the eastern Gulf of Alaska have had little effect on the survey results for northern rockfish, as relative abundance of northern rockfish is very low in the eastern Gulf of Alaska.

The trawl survey indices of biomass for northern rockfish have been highly variable from survey to survey (Table 10.8 and Figure 10.5). In particular, the 2011 biomass estimate (173,642 t) was 93% larger than the 2009 estimate (89,896 t) while the 2009 biomass estimate was 60% smaller than the 2007 estimate (227,069 t).The 2007 biomass estimate was 36% smaller than the 2005 estimate (358,998 t), which was over 440% larger than the 2003 estimate (66,310 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 precision of some of the biomass estimates has been low and is reflected in the large 95% confidence intervals and high CVs associated with some survey biomass estimates of northern rockfish that are the result of few very large catches during the survey (Table 10.8 and Figure 10.5). In both 1999 and 2001, a single very large survey haul of northern rockfish greatly increased the biomass estimates and resulted in wide confidence bounds. The haul in 2001 was the largest individual catch (14 t) of northern rockfish ever taken during a Gulf of Alaska survey. In contrast, the 2005 and 2007 survey had several large hauls of northern rockfish in the Central Gulf and confidence bounds were narrower (Figures 10.5 and 10.6). The 2009 survey did not have any very large hauls and the biomass estimate was lower and more precise than the 2005 and 2007 estimates. The 2011 survey had several large hauls and the confidence bounds are comparable to 2007. The highly variable biomass estimates for northern rockfish suggest that an alternative to the stratified random design may be needed to reduce the variability in biomass estimates.

Age and Size composition

Ages for northern rockfish were determined from the break-and-burn method (Chilton and Beamish 1982). These age compositions (Table 10.9 and Figure 10.7) indicate that recruitment of northern rockfish is highly variable. Several surveys (1984, 1987, 1990, and 1996) show especially strong year-classes from the period around 1975-77; although they differ as to which specific years were greatest, likely due to age determination errors. The 1993, 1996, and 1999 age compositions also indicate that the 1983-85 year-classes may be stronger than average. Recent age compositions (2005, 2007, and 2009) indicate that the 1996-98 year-classes may also be stronger than average, which is in agreement with recent age compositions obtained from the commercial fishery described above. Trawl surveys provide size composition data for northern rockfish but are not used directly in the current age structured assessment model (Table 10.10 and Figure 10.8). In years with age readings, trawl survey size composition data are multiplied by an age-length key (computed from length-stratified otolith collections) to obtained survey age compositions (Figure 10.9). Similar to the fishery length compositions discussed above, a large proportion of northern rockfish lengths are greater than the current plus length bin (38 cm); including 90% of the lengths sampled in 2011.

Maturity Data

In previous stock assessments for northern rockfish, age at maturity has been based on a logistic curve fit to ovarian samples collected from female northern rockfish in the central Gulf of Alaska (GOA) in the spring of 1996 (n=75, C. Lunsford pers. comm. July 1997, Heifetz et al. 2009). More recently, a study reevaluating maturity for northern rockfish (Chilton 2007, n=157) has been published, providing additional information for maturity-at-age that can be used for stock assessment. This additional study collected ovarian samples for female northern rockfish throughout the year in both 2000 and 2001. In a report submitted to the GOA Groundfish Plan Team in September 2010 these two studies were compared, including presentation of the difficulties with conducting maturity studies and the advantages and disadvantages of different approaches for studying maturity (Rodgveller et al. 2010). In this year’s assessment, we combine the data from both studies to estimate maturity of northern rockfish. Due to the relatively small sample sizes for each study, the close proximity in time for each study (4 years apart compared to the 51 year time series used in this assessment), and the large difference in the age at 50% maturity (12.8 years used in previous assessments compared to 8 years obtained by Chilton 2007), we combine these data and estimate an intermediate maturity-at-age rather than consider time-dependent changes in maturity. There could possibly be time-dependent changes in maturity-at-age for northern rockfish, although, additional data would be necessary to evaluate this hypothesis.

Analytic Approach

Model structure

The basic model for Gulf of Alaska northern rockfish is described as a separable age-structured model (Box 1) and was implemented using AD Model Builder software (ADMB Project 2009). The assessment model is based on a generic rockfish model developed in a workshop held in February 2001 (Courtney et al. 2007) and follows closely the GOA Pacific ocean perch model. The northern rockfish model is fit to time series extending from 1961-2011. As with other rockfish age-structured models, this model does not attempt to fit a stock-recruitment relationship but estimates a mean recruitment, which is adjusted by estimated recruitment deviations for each year. The parameters, population dynamics, and equations of the model are shown in Box 1.

This year we present a method to incorporate recently obtained observations on female northern rockfish maturity-at-age (Chilton 2007) for which the logistic function parameters are estimated conditionally in the model (Models 2 and 3). Unlike the model in the 2009 assessment (Model 1), that estimates maturity-at-age independently, this method links uncertainty in maturity parameters to uncertainty in model results (i.e., ABC). We also present a model configuration that extends the plus age group for the survey and fishery age compositions from age 23+ to 33+ (Model 3). Compared to the previous model (Model 1) extending the plus age group results in an improvement of the model fit to survey and fishery age compositions. Rational behind selecting the plus age group to be 33+ in Model 3 is presented in the following section, *Age Composition Plus Age Group Evaluation*.

Age Composition Plus Age Group Evaluation

In the survey and fishery age compositions the plus age group is the maximum age fit in the model. Within the plus age group all other ages observed that are greater than or equal to the plus age are aggregated. In previous assessments for northern rockfish, and Model 1 presented here, the plus age group has been set at 23+; all ages observed in the fishery and survey that are equal to or greater than age 23 are combined in the last bin of the age compositions.

We approached the evaluation of the plus age group for age compositions fit in the northern rockfish model with two methods: (1) the survey age compositions are pooled across years and the plus age group proportion is calculated from age 23 to age 50, and (2) the assessment model is fit to fishery and survey age compositions in which the plus age group is incrementally extended from the current plus age group (age 23+) to age 50+, one age at a time.

To provide advice on the minimum age of the plus age group the survey age compositions were pooled across years and the proportion of the plus age group was calculated from age 23 – 50. The survey age compositions were pooled across years, rather than investigate the year-by-year plus age group proportions, so that a recommendation can be made that would influence all years in the survey (and fishery) age compositions similarly. We considered the appropriate plus age group to be the first age at which the plus age group proportion for the pooled survey age compositions dropped below 10%. From 1993 to 2009 the plus age group proportion for age 23+ in the survey age compositions ranges from 24% to 47%, for the pooled survey data the plus age group proportion for age 23+ is 30% (Figure 10.10). We selected 10% as an arbitrary threshold in an effort to reduce the plus age group proportions, as the northern rockfish model has not fit the plus age group in either the fishery or survey age compositions well in previous assessments (e.g., Heifetz et al 2009). The plus age group at age 33+ was the first age at which the plus age group proportion dropped below 10% upon pooling the survey age compositions (Figure 10.10).

Analysis of the plus age group for northern rockfish in the fishery and survey age compositions was also performed by incrementally extending the plus age group from the current plus age group (age 23+) to age 50+, one age at a time, and fitting the resulting age compositions in the assessment model. Overall, as the plus age group is extended in the fishery and survey age compositions, the total objective function value (including dataset fits and prior/penalty functions) decreases initially, reaches a minimum at age 33+, then increases as the plus age group is extended to 50+ (Figure 10.11). The decrease in the total objective function value is due to decreases in the negative log-likelihoods for both the fishery and survey age compositions; as the plus age group is extended beyond 23+ the model obtains a better fit to the age composition data. This result is somewhat counterintuitive, one would hypothesize that as the plus age group is extended the number of data points fit by the model would increase, thus, increasing the number of 'residuals' summed in the objective function. In this case, the fit to the survey and fishery age compositions improves because as the plus age group is extended (1) additional structure emerges from the age compositions that the model is more closely able to predict, and, (2) the model fit to the plus age group proportion itself improves as the proportion decreases.

We select age 33+ as the plus age group because (1) this is the first age at which the plus age group proportion is smaller than 10% in the pooled survey age compositions, and (2) the total objective function value reaches a minimum when setting the plus age group at age 33+ in the fishery and survey age compositions. We compare this model configuration (Model 3) with the previous model configurations (Model 1 and 2).

Parameters estimated independently

A von Bertalanffy growth curve was fitted to survey size at age data from 1984-2007. Sexes were combined. A size to age transition matrix was then constructed by adding normal error with a standard deviation equal to the survey data for the probability of different ages for each size class (Courtney et al. 1999, Figure 10.9). Previous parameters are available from Heifetz and Clausen (1991), Courtney et al. (1999), and Malecha et al. (2007). The estimated parameters for the growth curve are shown below:

L_∞=39.9 cm κ=0.18 t_0=-0.22 n=3870

Weight-at-age was constructed with weight at age data from the same data set as the length at age. The estimated growth parameters are shown below.

W_∞=984 g a=9.16 x 10^{-6} b=3.09 n=3432

Aging error matrices were constructed by assuming that the break-and-burn ages were unbiased but had a given amount of normal error around each age based on percent agreement tests conducted at the AFSC Age and Growth lab (Figure 10.12); the aging error matrix was not updated for this assessment, rather, extended to accommodate additional ages in the survey and fishery age compositions (Courtney et al. 1999). We fix the variability of recruitment deviations (σ_r) at 1.5 which allows highly variable recruitment.

Parameters estimated conditionally

The estimates of natural mortality (M) and catchability (q) are estimated with the use of lognormal prior distributions as penalties that are added to the overall objective function in order to constrain parameter estimates to reasonable values and to speed model convergence. Arithmetic means and standard errors (μ, σ) for the lognormal distributions were provided as input to the model. The standard errors for selected model parameters were estimated based on multivariate normal approximation of the covariance matrix. The prior mean for natural mortality of 0.06 is based the estimate provided by Heifetz and Clausen (1991) using the method of Alverson and Carney (1975). Natural mortality is notoriously a difficult parameter to estimate within the model so we assign a "tight" prior CV of 5%. Catchability is a parameter that is somewhat unknown for rockfish, so while we assign it a prior mean of 1 (assuming all fish in the area swept are captured and there is no herding of fish from outside the area swept, and that there is no effect of untrawlable grounds), we assign it a less precise CV of 45%. This allows the parameter more freedom than that allowed to natural mortality. This is identical to that used in the Gulf of Alaska Pacific ocean perch and dusky rockfish assessments.

Maturity

Maturity-at-age is modeled with the logistic function, similar to selectivity-at-age for the survey and fishery. In this year's assessment we present models (Model 2 and 3) that estimates logistic parameters for maturity-at-age conditionally. Parameter estimates for maturity-at-age are obtained by fitting both datasets collected on female northern rockfish maturity from Lunsford (pers. comm. July 1997) and Chilton (2007). The binomial likelihood is used in the assessment model as an additional component to the joint likelihood function to fit the combined observations of female northern rockfish maturity (e.g., Quinn and Deriso 1999). The binomial likelihood was selected because (1) the sample sizes for maturity are small and assuming convergence to the normal distribution may not be appropriate in this case, (2) the binomial likelihood inherently includes sample size as a weighting component, and, (3) resulting maturity-at-age from the normal likelihood (weighted by sample size) was very similar to maturity-at-age obtained with the binomial likelihood. Parameters for the logistic function describing maturity-at-age are estimated conditionally in the model so that uncertainty in model results (e.g., ABC) can be linked to uncertainty in maturity parameter estimates through the Markov Chain Monte Carlo (MCMC) procedure described below in the *Uncertainty approach* section. The fit to the combined observations of maturity-at-age obtained in the preferred assessment model (Model 3) is shown in Figure 10.13. In both Model 2 and 3, identical maturity-at-age parameter estimates are obtained whether fitting the maturity data independently or conditionally, this is also true for the all the other parameters estimated in the model. Estimating maturity-at-age parameters conditionally influences the model only through the evaluation of uncertainty, as the MCMC procedure includes variability in the maturity parameters in conjunction with variability in all other parameters, rather than assuming the maturity parameters are fixed.

The numbers of estimated parameters from the recommended model (Model 3) are shown below. Other derived parameters are described in Box 1.

Parameter name	Symbol	Number
Natural mortality	M	1
Catchability	q	1
Log-mean-recruitment	μ_r	1
Recruitment deviations	τ_y	81
Spawners-per-recruit levels	$F_{35\%}, F_{40\%}, F_{50\%}$	3
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	51
Logistic fishery selectivity	$a_{f50\%}, \delta_f$	2
Logistic survey selectivity	$a_{s50\%}, \delta_s$	2
Logistic maturity-at-age	$a_{m50\%}, \delta_m$	2
Total		145

Uncertainty approach

Evaluation of model uncertainty has recently become an integral part of the "precautionary approach" in fisheries management. In complex stock assessment models such as this model, evaluating the level of uncertainty is difficult. One way is to examine the standard errors of parameter estimates from the Maximum Likelihood (ML) approach derived from the Hessian matrix. While these standard errors give some measure of variability of individual parameters, they often underestimate their variance and assume that the joint distribution is multivariate normal. An alternative approach is to examine parameter distributions through Markov Chain Monte Carlo (MCMC) methods (Gelman et al. 1995). When treated this way, our stock assessment is a large Bayesian model, which includes informative (e.g., lognormal natural mortality with a small CV) and noninformative (or nearly so, such as a parameter bounded between 0 and 10) prior distributions. In the model presented in this SAFE report, the number of parameters estimated is 145. In a low-dimensional model, an analytical solution might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space, which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, the chain will converge (Jones and Hobert 2001). The "burn-in" is a set of iterations removed at the beginning of the chain. This method is not strictly necessary but we use it as a precautionary measure. In our simulations we removed the first 4,000,000 iterations out of 20,000,000 and "thinned" the chain to one value out of every thousand, leaving a sample distribution of 4,000. Further assurance that the chain had converged was to compare the mean of the first half of the chain with the second half after removing the "burn-in" and "thinning". Because these two values were similar we concluded that convergence had been attained. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% confidence intervals for some parameters.

BOX 1. AD Model Builder Model Description

Parameter definitions	
y	Year
a	Age classes
l	Length classes
w_a	Vector of estimated weight at age, $a_0 \rightarrow a_+$
m_a	Vector of estimated maturity at age, $a_0 \rightarrow a_+$
a_0	Age at first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
σ_r	Annual recruitment deviation
ϕ_y	Annual fishing mortality deviation
fs_a	Vector of selectivities at age for fishery, $a_0 \rightarrow a_+$
ss_a	Vector of selectivities at age for survey, $a_0 \rightarrow a_+$
M	Natural mortality
$F_{y,a}$	Fishing mortality for year y and age class a ($fs_a \mu_f e^{\varepsilon}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
$\varepsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length transition matrix
q	Survey catchability coefficient
SB_y	Spawning biomass in year y, ($=m_a\, w_a\, N_{y,a}$)
q_{prior}	Prior mean for catchability coefficient
$\sigma_{r(prior)}$	Prior mean for recruitment deviations
σ_q^2	Prior CV for catchability coefficient
$\sigma_{\sigma_r}^2$	Prior CV for recruitment deviations

BOX 1 (Continued)

Equations describing the observed data

$$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1 - e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$$ Catch equation

$$\hat{I}_y = q \ * \sum_a N_{y,a} * \frac{s_a}{\max\left(s_a\right)} * w_a$$ Survey biomass index (t)

$$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,a'}$$ Survey age distribution Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,l}$$ Survey length distribution Proportion at length

$$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$$ Fishery age composition Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$$ Fishery length composition Proportion at length

Equations describing population dynamics

Start year

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Formulae for likelihood components **BOX 1 (Continued)**

$L_1 = \lambda_1 \sum_y \left(\ln \left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$	Catch likelihood
$L_2 = \lambda_2 \sum_y \frac{\left(I_y - \hat{I}_y\right)^2}{2 * \hat{\sigma}^2 \left(I_y\right)}$	Survey biomass index likelihood
$L_3 = \lambda_3 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$	Fishery age composition likelihood
$L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$	Fishery length composition likelihood
$L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$	Survey age composition likelihood
$L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$	Survey size composition likelihood
$L_7 = \frac{1}{2\sigma_q^2} \left(\ln {q}/{q_{prior}} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient
$L_8 = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln {\sigma_r}/{\sigma_{r(prior)}} \right)^2$	Penalty on deviation from prior distribution of recruitment deviations
$L_9 = \lambda_9 \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln\left(\sigma_r\right) \right]$	Penalty on recruitment deviations
$L_{10} = \lambda_{10} \sum_y \phi_y^2$	Fishing mortality regularity penalty
$L_{11} = \lambda_{11} \bar{s}^2$	Average selectivity penalty (attempts to keep average selectivity near 1)
$L_{12} = \lambda_{12} \sum_{a_0}^{a_+} \left(s_i - s_{i+1}\right)^2$	Selectivity dome-shapedness penalty – only penalizes when the next age's selectivity is lower than the previous (penalizes a downward selectivity curve at older ages)
$L_{13} = \lambda_{13} \sum_{a_0}^{a_+} \left(FD(FD(s_i - s_{i+1})\right)^2$	Selectivity regularity penalty (penalizes large deviations from adjacent selectivities by adding the square of second differences)
$L_{total} = \sum_{i=1}^{13} L_i$	Total objective function value

Results

Model Evaluation

We consider three model configurations using the following criteria: (1) the best overall fit to the data (in terms of negative log-likelihood), (2) biologically reasonable patterns of estimated recruitment, catchabilities, and selectivities, (3) a good visual fit to length and age compositions, and (4) parsimony.

Model Number	Model Description
Model 1 (Base case)	• Model from Heifetz et al. (2009), updated for 2011
Model 2	• Incorporate new maturity data from Chilton (2007) and estimate logistic maturity-at-age parameters conditionally
Model 3	• Same as Model 2 with the extension of the plus age group for fishery and survey age compositions from 23+ to 33+

Model 1 is the base model from 2009. Only changes that have occurred were appending new data. This data includes updated catch, 2009 survey age compositions, 2011 biomass estimate, 2008 and 2010 fishery age compositions, and the 2009 and 2011 fishery length compositions. This model uses maturity-at-age from Lunsford (pers. comm. 1997) that is fit independently and sets the plus age group for the fishery and survey age compositions at age 23+.

Model 2 is structurally similar to Model 1. The main difference is that an intermediate maturity curve is estimated conditionally in the model by combining data from Lunsford (pers. comm. 1997) and Chilton (2007).

Model 3 is the same as Model 2, with the difference that the plus age group for fishery and survey age compositions is extended from age 23+ to age 33+.

Comparison of likelihood values and estimated parameter values among models are shown in Table 10.11. All three models considered have similar properties compared to previous model results: Poor fit to the high survey biomass estimates of 1999, 2001, 2005, 2007, and 2011 and a reasonable fit to the low survey biomass estimates (Figure 10.5). When compared with the 2009 application of Model 1, the major change for the current model configurations is the reduction in the estimate of *q,* the survey catchability coefficient (previously 0.74 compared to 0.66 from Model 1 and 2, and 0.67 from Model 3; Table 10.11). This result is due to the large survey biomass estimate in 2011. In comparison with Model 1 and 2, Model 3 results in an improved fit to the fishery and survey age compositions (36.23 compared to 24.87 for the fishery age compositions, 43.44 compared to 35.38 for the survey age compositions, Table 10.11). We do not select Model 1 due to the omission of recently obtained maturity data, or Model 2 due to the poorer fit to the age composition data compared to Model 3. Therefore, we favor Model 3 and present results only for Model 3.

Time Series Results

Definitions

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

Abundance trends

The estimates of current population abundance indicate that it is dominated by older fish from the 1976 and 1984 year class, and the above average 1993 and 1997 year-classes (Table 10.12). The fit to the survey biomass index fails to capture the apparent increase in northern rockfish abundance indicated by point estimates of the 2005, 2007, and 2011 trawl surveys (Figure 10.5). This is not surprising given the wide confidence intervals associated with these surveys.). Model 3 implies a slightly higher stock biomass since 1979 than results from our previous full assessment of 2009. For example for 2012, total biomass for Model 3 is projected to be 104,155 t, whereas previously we had projected total biomass in 2012 of 96,595 t. This is due to the higher survey biomass estimate of 2011 compared to 2009, in conjunction with a smaller survey catchability parameter estimate in Model 3 compared to the previous full assessment (Table 10.11). Overall, the current status of the stock appears to be reasonably healthy and about equal to stock levels estimated last year and for the late 1970s (Figure 10.14 and Table 10.13).

Goodman et al. (2002) suggested that stock assessment authors use a "management path" graph as a way to evaluate management and assessment performance over time. In the management path we plot the ratio of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to $B_{35\%}$. Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The historical management path for northern rockfish has been above the F_{OFL} adjusted limit for only a few years in the 1960s. In recent years, northern rockfish have been above $B_{35\%}$ and below $F_{35\%}$ (Figure 10.15).

Fishing mortality and selectivity

Parameter estimates from Model 3 were similar to the previous northern rockfish assessment (Table 10.11). The $F_{40\%}$ reference value changed slightly from 0.059 to 0.062 reflecting changes to the maturity-at-age parameter estimates. The trajectory of fishing mortality has remained below the $F_{40\%}$ level most of the time and below $F_{35\%}$ in all years except 1964-66 during the period of intense fishing for Pacific ocean perch (Figure 10.15). 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 estimated, selectivity occurs at slightly younger ages than the age of maturity (Table 10.12 and Figure 10.16).

Recruitment

Recruitment estimates for Model 3 show a high degree of uncertainty, but indicate several large year-classes (Table 10.13 and 10.14 and Figure 10.17). Fits to the fishery and survey age compositions were reasonable but the "plus group" (age 33 and older) remain underestimated in recent years compared to the observed values (Figures 10.4 and 10.7). The model did not fit the fishery size comps well in the 1990s but fits very well in the 2000s (Figure 10.3). The pattern of stock-recruitment suggests that environmental variability plays a large role in determining recruitment strengths (Figure 10.18).

Uncertainty Distributions

From the MCMC chains described in the *Uncertainty Approach* section, we summarize the posterior densities of key parameters for the recommended model using histograms (Figure 10.19). We also use these posterior distributions to show uncertainty around time series estimates such as spawning biomass (Table 10.14 and Figures 10.14 and 10.20). Table 10.15 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviations derived from the Hessian matrix compared to the standard deviations derived from MCMC methods. The Hessian and MCMC standard deviations are similar for q and M, but the MCMC standard deviations are larger for the estimates of $F_{40\%}$, ABC, and female spawning biomass. These larger standard deviations indicate that these parameters are more uncertain than indicated by the standard estimates. The distributions of $F_{40\%}$, *ABC*, total biomass, and spawning biomass are skewed, indicating there is a possibility of biomass being higher than model estimates.

Projections and Harvest Alternatives

Amendment 56 reference points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines “overfishing level” (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Estimates of reference points related to maximum sustainable yield (MSY) for GOA northern rockfish are currently available. Tier 3 proxies from Amendment 56 are therefore presented. The following values from Model 3 results were computed based on recruitment from post-1976 spawning event (in t of female spawning biomass):

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
72,983	29,193	25,544	0.062	0.074

Specification of OFL and maximum permissible ABC

The female spawning biomass for 2012 is estimated at 43,414 t. This is above the $B_{40\%}$ value of 29,193 t. Under Amendment 56, Tier 3, the maximum permissible fishing mortality for ABC is $F_{40\%}$ and fishing mortality for OFL is $F_{35\%}$. Applying these fishing mortality rates for 2012, yields the following ABC and OFL:

Year	OFL	Max ABC
2012	6,574	5,509
2013	6,152	5,155

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

ABC recommendation

Based on this year’s recommended assessment model, the projected female spawning biomass in 2012 is 43,414 t. The value for $B_{35\%}$ is estimated at 25,544 t as determined from average recruitment of the 1977-2007 year-classes (recruits from years 1979 – 2009). While we believe there is some concern for this stock given the lack of strong recruitment in recent years, we continue to recommend that $F_{40\%}$ be used as the basis for ABC calculations. We recommend that the ABC for northern rockfish for the 2012 fishery in the Gulf of Alaska be set at 5,509 t. This ABC is a 13% increase over the 2011 ABC of 4,857 t.

Population projections

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

For each scenario, the projections begin with the vector of 2011 numbers at age as estimated in the assessment (Table 10.12). This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2011. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment.

Total catch after 2011 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 2012, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In 2012 and 2013, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the realized catches in 2008-**Error! Reference source not found.** to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio of catch to ABC will yield more accurate projections.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2007-2011 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

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

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above 1) above its MSY level in 2011 or 2) above ½ of its MSY level in 2011 and above its MSY level in 2021 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2012 and 2013, 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 2024 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios (Table 10.16). The difference for this assessment for projections is in Scenario 2 (Author's F); we use pre-specified catches to increase accuracy of short-term projections in fisheries where the catch is usually less than the ABC. This was suggested to help management with setting preliminary ABCs and OFLs for 2012 and 2013. In this scenario we use the ratio of most recent catch to ABC, and apply it to estimated ABCs for 2012 and 2013 to determine the catch for 2012 and 2013, then set catch at maximum permissible thereafter.

Status determination

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2012, it does not provide the best estimate of OFL for 2013, because the mean 2012 catch under Scenario 6 is predicated on the 2012 catch being equal to the 2012 OFL, whereas the actual 2012 catch will likely be less than the 2011 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

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

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2010) is 3,902 t. This is less than the 2010 OFL of 6,070 t. Therefore, the stock is not being subjected to overfishing.

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

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2011:

a. If spawning biomass for 2011 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2011 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2011 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 10.16). If the mean spawning biomass for 2021 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:

a. If the mean spawning biomass for 2014 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2014 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2014 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2024. If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 10.16, the stock is not overfished and is not approaching an overfished condition.

Specified catch estimation

In response to Gulf of Alaska Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. In the past, two standard approaches in rockfish models have been employed; assume the full TAC will be taken, or use a certain date prior to publication of assessments as a final estimate of catch for that year. Both methods have disadvantages. If the author assumes the full TAC is taken every year, but it rarely is, the ABC will consistently be underestimated. Conversely, if the author assumes that the catch taken by around October is the final catch, and substantial catch is taken thereafter, ABC will consistently be overestimated. Therefore, going forward in the Gulf of Alaska rockfish assessments, for current year catch, we are applying an expansion factor to the official catch on or near October 1 by the 3-year average of catch taken between October 1 and December 31 in the last three complete catch years (e.g. 2008-2010 for this year, see example Figures below). For northern rockfish, the expansion factor for 2011 catch is 1.07.

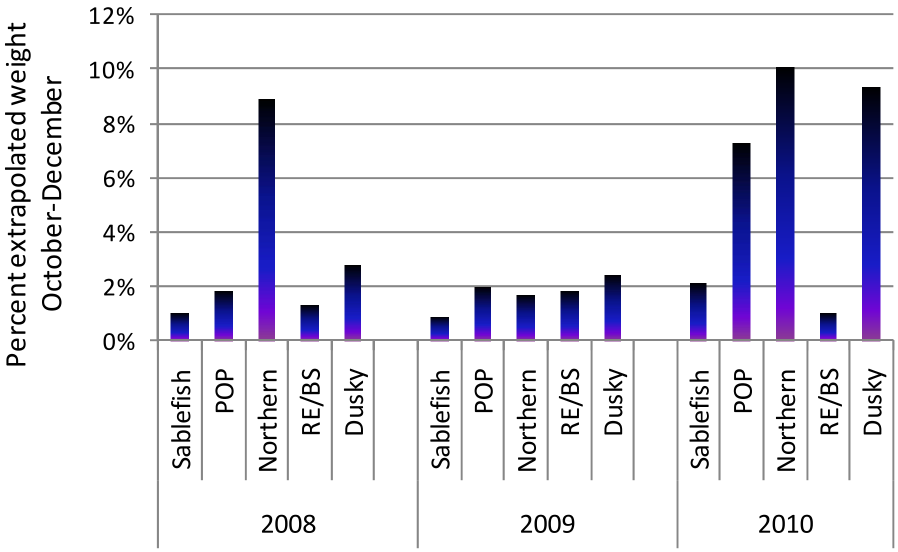


Figure. Extrapolated catch that occurs between October and December, 2008-2010.

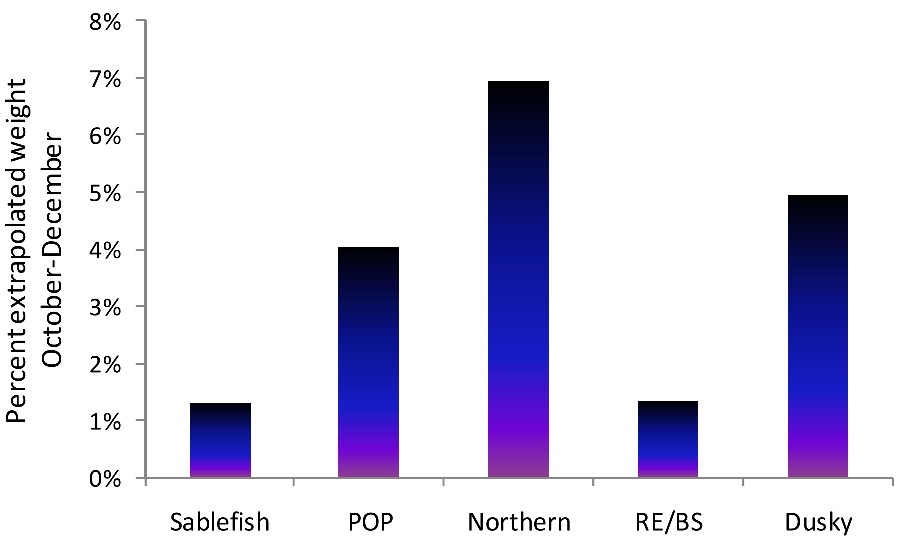


Figure. Examples of mean proportion of catch between October-December, 2008-2010.

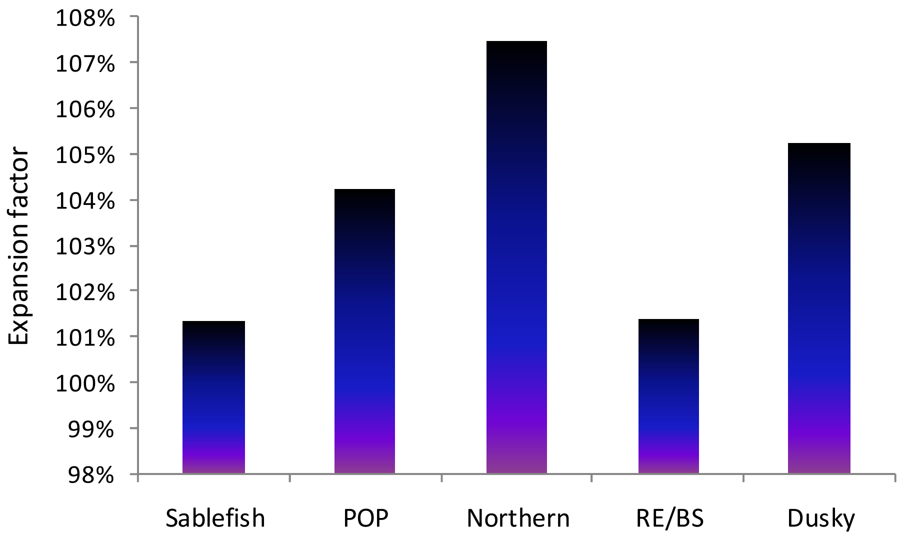


Figure. Expansion factor: $x = \sum_1^{12} C_y / \sum_1^{9} C_y$, where C_y is catch in month *y*.

For catch projections into the next two years, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, based on both the lower catch in the first year out, and based on the amount of catch taken before spawning in the projection two years out.

Alternate Projection

During the 2006 rockfish CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. We continue to present an alternative projection scenario using the uncertainty of the full assessment model, harvesting at maxABC which is analogous to Alternative 1. This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 10,000,000. The projection shows wide credibility intervals on future spawning biomass (Figure 10.20). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1977-2009 year classes, and this projection predicts that the median spawning biomass will eventually dip to $B_{35\%}$ harvesting at maxABC in future years.

Apportionment of ABC

Since 1996 for slope rockfish including northern rockfish, the apportionment of ABC among areas has been determined from the weighted average of the proportion of exploitable biomass by area in the most recent three triennial trawl surveys. Assuming that survey error contributes 2/3 of the total variability in predicting the distribution of biomass, the weight of a prior survey should be 2/3 the weight of the preceding survey. This results in weights of 4:6:9 for the 2007, 2009, and 2011 surveys, respectively.

Based on the tables below area apportionments for Gulf of Alaska northern rockfish are 39.13% for the Western area, 60.83% for the Central area, and 0.04% for the Eastern area. Applying these apportionments to the recommended ABC for northern rockfish results in 2,156 t for the Western area, 3,351 t for the Central area, and 2 t for the Eastern area. In comparison to the previous apportionments in 2009, the addition of the 2011 trawl biomass estimate results in an increase in apportionment for the

Central area and a decrease for the Western area. For management purposes, the small ABC of northern rockfish in the Eastern area is combined with other slope rockfish.

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

	Western	Central		Eastern		
Year	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2007	114,222	92,250	20,559	38	0	227,069
2009	44,693	8,842	36,290	70	0	89,896
2011	47,082	91,774	34,757	28	0	173,641

Percentage of trawl survey biomass by area and 2012 apportionment of ABC for northern rockfish in the Gulf of Alaska.

		Western	Central		Eastern		
Year	Weights	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2007	4	50.30%	40.63%	9.05%	0.02%	0.00%	100%
2009	6	49.72%	9.84%	40.37%	0.08%	0.00%	100%
2011	9	27.11%	52.85%	20.02%	0.02%	0.00%	100%
Weighted average		39.13%	60.83%		0.04%		100%
Area ABC		**2,156**	**3,351**		**2**		**5,509**

Ecosystem Considerations

In general, a determination of ecosystem considerations for slope rockfish is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 10.17.

Ecosystem Effects on the Stock

Prey availability/abundance trends: Similar to many other rockfish species, stock condition of slope rockfish appears to be influenced by periodic abundant year-classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval northern rockfish may be an important determining factor of year-class strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and year-class strength. Moreover, identification to the species level for field collected larval slope rockfish is difficult. Visual identification is not possible, though genetic techniques allow identification to species level for larval slope rockfish (Gharrett et al. 2001). Some juvenile rockfish found in inshore habitat feed on shrimp, amphipods, and other crustaceans, as well as some mollusk and fish (Byerly 2001). Adult slope rockfish such as Pacific ocean perch and northern rockfish feed on euphausiids. Adult rockfish such as shortraker and rougheye are probably opportunistic feeders with more mollusks and fish in their diet. Little if anything is known about abundance trends of likely rockfish prey items. Euphausiids are also a major item in the diet of walleye pollock. Changes in the abundance of walleye pollock could lead to a corollary change in the availability of euphausiids, which would then have an impact on Pacific ocean perch and northern rockfish.

Predator population trends: Rockfish are preyed on by a variety of other fish at all life stages and to some extent by marine mammals during late juvenile and adult stages. Whether or not the impact of any particular predator is significant or dominant is unknown. Predator effects would likely be more important on larval, post-larval, and small juvenile slope rockfish, but information on these life stages and their predators is nil.

Changes in physical environment: Strong year-classes corresponding to the period around 1977 have been reported for many species of groundfish in the Gulf of Alaska, including Pacific ocean perch, northern rockfish, sablefish, and Pacific cod. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including slope rockfish. Pacific ocean perch appear to have had a strong 1986 or 1987 year-class, and northern rockfish appear to have had a strong 1984 year-class. There may be other years when environmental conditions were especially favorable for rockfish species. The environmental mechanism for this increased survival remains unknown. Changes in water temperature and currents could have effects on prey item abundance and success of transition of rockfish from pelagic to demersal stage. Rockfish in early juvenile stage have been found in floating kelp patches which would be subject to ocean currents.

Changes in bottom habitat due to natural or anthropogenic causes could alter survival rates by altering available shelter, prey, or other functions. Submersible studies on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2003). The Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of groundfish is minimal or temporary based largely on the the criterion that groundfish stocks were above Minimum Stock Size Threshold (MSST). However, such criteria is inadequate to make such a conclusion (Drinkwater 2004). While proof of adverse effect on habitat would be difficult to obtain, the lack of an increasing trend in stock abundance and relatively low levels of recent recruitment are not supportive of the EIS conclusions.

Rockfish fishery effects on the ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the Gulf of Alaska, bottom trawl fisheries for pollock, deepwater flatfish, and Pacific ocean perch account for most of the observed bycatch of coral, while rockfish fisheries account for little of the bycatch of sea anemones, sea whips, and sea pens. The bottom trawl fisheries for Pacific ocean perch and Pacific cod and the pot fishery for Pacific cod account for most of the observed bycatch of sponges (Table 10.4).

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: The directed slope rockfish trawl fishery that begins in July is concentrated in known areas of abundance and typically lasts only a few weeks. The annual exploitation rates on rockfish are thought to be quite low. Insemination is likely in the fall or winter, and parturition is likely mostly in the spring. Hence, reproductive activities are probably not directly affected by the commercial fishery.

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

Fishery contribution to discards and offal production: Fishery discard rates of northern rockfish during 2002-2010 have been 1.5 – 10.0%.

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

Fishery-specific effects on EFH living and non-living substrate: Unknown, but the heavy-duty "rockhopper" trawl gear commonly used in the fishery can disturb seafloor habitat. Table 10.4 shows the estimated bycatch of living structure such as benthic urochordates, corals, sponges, sea pens, and sea anemones by the GOA rockfish fisheries. The average bycatch of corals/bryozoans (0.78 t), and sponges (2.98 t) by rockfish fisheries are a large proportion of the catch of those species taken by all Gulfwide fisheries.

Data Gaps and Research Priorities

Life history and habitat utilization

There is little information on larval, post-larval, or early life history stages of northern rockfish. Habitat requirements for larval, post-larval, and early stages are mostly unknown. Habitat requirements for later stage juvenile and adult fish are anecdotal or conjectural. Research needs to be done on the bottom habitat of the major fishing grounds, on what HAPC biota are found on these grounds, and on what impact bottom trawling may have on these biota.

Assessment Data

The highly variable biomass estimates for northern rockfish suggest that the stratified random design of the surveys does a relatively poor job of assessing stock condition of northern rockfish and that a different survey approach may be needed to reduce the variability in biomass estimates. In particular, the CIE review report recommended that assumptions about extending area-swept estimates of biomass in trawlable versus untrawlable grounds may impact catchability assumptions. The AFSC is currently undertaking a study on habitat classifications so that assumptions about catchability, in particular, time-dependent changes in catchability, can be more rigorously established.

Given the substantial influence of maturity-at-age on management quantities (i.e., ABC) we strongly suggest that continued research be devoted to collecting maturity-at-age data for northern and other Gulf of Alaska rockfish. A study is currently underway in which a larger sample size for northern rockfish has been collected compared to previous studies, with this additional study we intend to investigate possible time-dependent maturity. However, to fully understand changes in maturity over time, continued effort would be required to collect and analyze rockfish maturity samples.

For northern rockfish and the other Gulf of Alaska rockfish assessed with age-structured models, we plan to focus on optimizing and taking a consistent approach to the methods we use for multinomial sample sizes, the way we choose our bins for age and length compositions, and to examine growth for changes over time.

Summary

A summary of biomass levels, exploitation rates and recommended ABCs and OFLs for northern rockfish is in the following table:

Quantity	As estimated or *specified last* year for: 2011	2012	As estimated or *recommended this* year for: 2012*	2013
M (natural mortality rate)	0.06	0.06	0.06	0.06
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	100,463	97,767	104,155	99,449
Female spawning biomass (t)				
Projected	33,961	32,671	43,414	40,589
$B_{100\%}$	61,368	61,368	72,983	72,983
$B_{40\%}$	24,547	24,547	29,193	29,193
$B_{35\%}$	21,479	21,479	25,544	25,544
F_{OFL}	0.071	0.071	0.074	0.074
$maxF_{ABC}$	0.059	0.059	0.062	0.062
F_{ABC}	0.059	0.059	0.062	0.062
OFL (t)	5,784	5,498	**6,574**	6,152
maxABC (t)	4,857	4,616	**5,509**	5,155
ABC (t)	4,857	4,616	**5,509**	5,155
Status	As determined *last* year for: 2009	2010	As determined *this* year for: 2010	2011
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projected ABCs and OFLs for 2012 and 2013 are derived using expected catches of 3,590 and 4,683 t for 2011 and 2012 based on realized catches from 2008-2010. This calculation is in response to management requests to obtain more accurate projections.

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Table 10.1. A summary of key management measures and the time series of catch, ABC and TAC for northern rockfish in the Gulf of Alaska.

Year	Catch (t)	ABC	TAC		Management Measures
1988*	1,107				The slope rockfish assemblage, including northern rockfish, was one of three management groups for *Sebastes* implemented by the North Pacific Management Council. Previously, *Sebastes* in Alaska were managed as “Pacific ocean perch complex” or “other rockfish”
1989*	1,527				
1990*	1,716				
1991*	4,528				Slope assemblage split into three management subgroups with separate ABCs and TACs: Pacific ocean perch, shortraker/rougheye rockfish, and all other slope species
1992*	7,770				
1993	4,820	5,760	5,760		Northern rockfish designated as a subgroup of slope rockfish with separate ABC and TAC
1994	5,966	5,760	5,760		
1995	5,635	5,270	5,270		
1996	3,340	5,720	5,270		
1997	2,935	5,000	5,000		
1998	3,055	5,000	5,000		
1999	5,409	4,990	4,990		Eastern GOA divided into West Yakutat and East Yakutat/Southeast Outside in response to trawl closure in Eastern GOA. Because northern rockfish are scarce in Eastern GOA, the ABC and TAC for northern rockfish in Eastern GOA allocated to West Yakutat ABC as part of "other slope rockfish".
2000	3,333	5,120	5,120		Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W. Preliminary age-structured model results presented for northern rockfish.
2001	3,133	4,880	4,880		Assessment and harvest recommendations now based on using an age structured model constructed with AD Model Builder software.
2002	3,339	4,770	4,770		
2003	5,256	5,530	5,530		
2004	4,811	4,870	4,870		
2005	4,522	5,091	5,091		
2006	4,958	5,091	5,091		
2007	4,187	4,938	4,938		Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	4,052	4,549	4,549		
2009	3,952	4,362	4,362		
2010	3,902	5,100	5,100		
2011	3,341	4,857	4,857		

* Northern rockfish managed as part of the slope rockfish assemblage and not assigned separate ABC/TAC

Table 10.2. Commercial catch (t) and management action for northern rockfish in the Gulf of Alaska, 1961-present. The *Description of the catch time series* Section describes procedures used to estimate catch during 1961-1993. Catch estimates for 1993-2011 are from NMFS Observer Program and Alaska Regional Office updated through October 4, 2011.

Year	Foreign	Joint venture	Domestic	Total	TAC	%TAC
1961	800	-	-	800	-	-
1962	3,250	-	-	3,250	-	-
1963	6,815	-	-	6,815	-	-
1964	12,170	-	-	12,170	-	-
1965	17,430	-	-	17,430	-	-
1966	10,040	-	-	10,040	-	-
1967	6,000	-	-	6,000	-	-
1968	5,010	-	-	5,010	-	-
1969	3,630	-	-	3,630	-	-
1970	2,245	-	-	2,245	-	-
1971	3,875	-	-	3,875	-	-
1972	3,880	-	-	3,880	-	-
1973	2,820	-	-	2,820	-	-
1974	2,550	-	-	2,550	-	-
1975	2,520	-	-	2,520	-	-
1976	2,275	-	-	2,275	-	-
1977	622	-	-	622	-	-
1978	553	-	-	554	-	-
1979	666	3	-	670	-	-
1980	809	tr	-	810	-	-
1981	1,469	-	-	1,477	-	-
1982	3,914	-	-	3,920	-	-
1983	2,705	911	-	3,618	-	-
1984	494	497	10	1,002	-	-
1985	tr	115	70	185	-	-
1986	tr	11	237	248	-	-
1987	-	56	427	483	-	-
1988[1]	-	tr	1,107	1,107	-	-
1989	-	-	1,527	1,527	-	-
1990	-	-	1,697	1,716	-	-
1991[2]	-	-	4,528	4,528	-	-
1992	-	-	7,770	7,770	-	-

[1] 1988 - Slope rockfish assemblage management implemented by NPFMC.
[2] 1991 - Slope rockfish divided into 3 management subgroups: Pacific ocean perch, shortraker/ rougheye, and other slope rockfish.

Table 10.2 (continued). Commercial catch (t) and management action for northern rockfish in the Gulf of Alaska, 1961-present. The *Description of the catch time series* Section describes procedures used to estimate catch during 1961-1993. Catch estimates for 1993-2011 are from NMFS Observer Program and Alaska Regional Office updated through October 4, 2011.

Year	Foreign	Joint venture	Domestic	Total	TAC	%TAC
1993[3]	-	-	4,820	4,820	5,760	84%
1994	-	-	5,966	5,966	5,760	104%
1995	-	-	5,635	5,635	5,270	107%
1996	-	-	3,340	3,340	5,270	63%
1997	-	-	2,935	2,935	5,000	59%
1998	-	-	3,055	3,055	5,000	61%
1999	-	-	5,409	5,409	4,990	108%
2000	-	-	3,333	3,333	5,120	65%
2001	-	-	3,133	3,133	4,880	64%
2002	-	-	3,339	3,339	4,770	70%
2003	-	-	5,256	5,256	5,530	95%
2004	-	-	4,811	4,811	4,870	99%
2005	-	-	4,522	4,522	5,091	89%
2006	-	-	4,958	4,958	5,091	97%
2007[4]	-	-	4,187	4,187	4,938	85%
2008	-	-	4,052	4,052	4,549	89%
2009	-	-	3,952	3,952	4,362	91%
2010	-	-	3,902	3,902	5,100	77%
2011*	-	-	3,341	3,341	4,857	69%

[3] 1993 – A fourth management subgroup, northern rockfish, was created
[4] 2007 – Central Gulf Rockfish Pilot Project implemented for rockfish fishery.
* Catch as of 10/4/2011.

Table 10.3. FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2006-2011. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/10/2011.

	Estimated Catch (t)					
Group Name	2006	2007	2008	2009	2010	2011
Pacific Ocean Perch	13,104	12,641	12,136	12,397	14,974	12,669
Northern Rockfish	4,653	3,957	3,812	3,855	3,833	3,143
Pelagic Shelf Rockfish	2,243	3,113	3,515	2,950	2,958	2,308
Atka Mackerel	779	1,094	1,745	1,913	2,148	1,404
Pollock	351	124	390	1,280	1,046	787
Other Rockfish	742	492	629	733	734	656
Pacific Cod	521	250	445	630	731	545
Sablefish	856	641	503	404	388	435
Arrowtooth Flounder	1,085	688	517	502	706	319
Rougheye Rockfish	83	114	104	97	179	285
Shortraker Rockfish	273	291	231	247	134	237
Thornyhead Rockfish	312	300	248	185	106	160
Deep Water Flatfish	92	45	29	30	48	56
Rex Sole	98	52	67	83	93	50
Shallow Water Flatfish	45	22	71	53	47	47
Sculpin	0	0	0	0	0	37
Skate, Longnose	21	17	12	17	12	24
Skate, Other	49	20	10	13	28	14
Flathead Sole	25	18	19	32	24	13
Squid	0	0	0	0	0	12
Skate, Big	4	0	4	4	13	5
Shark	0	0	0	0	0	3
Demersal Shelf Rockfish	13	1	Conf.	Conf.	Conf.	Conf.
Octopus	0	0	0	0	0	1

Table 10.4. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2006 - 2011. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/10/2011.

			Estimated Catch (t)			
Group Name	2006	2007	2008	2009	2010	2011
Benthic urochordata	0.04	0.03	0.27	Conf.	0.08	Conf.
Birds	-	Conf.	Conf.	0.01	-	Conf.
Bivalves	0.01	-	0.00	Conf.	0.01	0.01
Brittle star unidentified	0.09	0.01	0.04	0.03	0.02	0.01
Capelin	-	-	-	0.00	-	-
Corals Bryozoans	0.39	2.27	0.47	0.36	0.42	0.38
Dark Rockfish	-	-	17.86	46.98	110.85	12.82
Eelpouts	0.03	0.12	0.35	0.00	0.05	Conf.
Eulachon	0.30	0.05	0.01	0.03	0.00	0.00
Giant Grenadier	272.06	127.14	161.30	298.50	374.15	423.43
Greenlings	5.94	7.74	14.77	8.10	9.52	7.34
Grenadier	65.54	70.61	3.43	3.11	34.94	110.64
Hermit crab unidentified	0.06	Conf.	0.01	0.01	0.01	0.02
Invertebrate unidentified	0.04	0.01	0.24	0.30	5.05	0.38
Lanternfishes	-	Conf.	-	0.00	Conf.	-
Misc crabs	0.41	0.13	0.07	0.10	0.07	0.04
Misc crustaceans	-	-	-	0.36	0.02	Conf.
Misc deep fish	-	-	0.00	-	-	-
Misc fish	180.74	186.07	195.90	134.74	167.24	132.49
Misc inverts (worms etc)	0.01	-	0.01	Conf.	-	Conf.
Other osmerids	0.26	0.09	Conf.	0.16	0.01	-
Pacific Sand lance	-	-	-	-	-	Conf.
Pandalid shrimp	0.17	0.11	0.11	0.09	0.22	0.06
Scypho jellies	0.43	0.21	0.11	0.70	1.89	0.00
Sea anemone unidentified	0.62	0.20	0.69	3.24	1.56	4.10
Sea pens whips	-	-	Conf.	0.01	0.01	0.04
Sea star	2.22	0.66	1.16	1.79	1.38	1.52
Snails	0.80	0.07	0.18	10.63	0.20	0.23
Sponge unidentified	0.96	0.65	2.97	6.65	3.66	4.41
Stichaeidae	0.01	-	-	0.01	-	-
Urchins, dollars cucumbers	0.30	0.17	0.26	0.66	0.22	0.44

Table 10.5. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and thousands of animals for crab and salmon, by year, and fisheries management plan area for the GOA rockfish fishery. Source: NMFS AKRO Blend/Catch Accounting System PSCNQ via AKFIN 10/10/2011.

Group Name	2005	2006	2007	2008	2009	2010	Average
Bairdi Crab	1.75	0.96	0.16	0.06	0.30	0.10	0.56
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chinook Salmon	0.45	0.26	2.04	2.28	1.39	1.60	1.34
Golden K. Crab	0.00	0.07	0.13	0.34	3.28	3.00	1.14
Halibut	368	254	137	160	110	142	195
Herring	0.00	0.00	0.02	0.04	0.00	0.15	0.04
Other Salmon	3.38	1.83	0.72	0.53	0.47	0.37	1.22
Opilio Crab	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Red King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10.6. Fishery length (cm) compositions available for northern rockfish in the Gulf of Alaska (at-sea and port samples combined).

Length class	Year								
(cm)	1990	1991	1992	1993	1994	1995	1996	1997	1998
15	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.005	0.001	0.000	0.000	0.000	0.000
22	0.000	0.001	0.000	0.005	0.001	0.001	0.000	0.000	0.000
23	0.002	0.002	0.000	0.006	0.001	0.001	0.000	0.000	0.001
24	0.004	0.002	0.000	0.008	0.001	0.002	0.001	0.002	0.001
25	0.006	0.002	0.000	0.008	0.002	0.004	0.002	0.006	0.000
26	0.005	0.004	0.000	0.007	0.006	0.007	0.006	0.014	0.001
27	0.011	0.005	0.000	0.008	0.008	0.011	0.007	0.020	0.001
28	0.016	0.008	0.001	0.012	0.013	0.011	0.005	0.021	0.002
29	0.023	0.011	0.003	0.015	0.013	0.013	0.007	0.021	0.003
30	0.026	0.023	0.006	0.018	0.016	0.017	0.011	0.019	0.007
31	0.029	0.041	0.015	0.028	0.025	0.021	0.010	0.014	0.010
32	0.039	0.071	0.032	0.046	0.038	0.029	0.019	0.015	0.018
33	0.049	0.122	0.053	0.074	0.070	0.049	0.036	0.029	0.028
34	0.075	0.179	0.094	0.100	0.111	0.085	0.061	0.054	0.046
35	0.122	0.194	0.139	0.140	0.161	0.126	0.109	0.115	0.084
36	0.173	0.144	0.157	0.148	0.183	0.151	0.151	0.159	0.137
37	0.159	0.090	0.154	0.113	0.157	0.156	0.169	0.173	0.178
38+	0.260	0.102	0.346	0.238	0.193	0.317	0.406	0.337	0.484
Sample size	4,909	15,466	15,207	12,525	8,905	12,370	12,496	5,262	10,615
# Hauls	42	147	125	94	90	121	108	73	123

Table 10.6 (continued). Fishery length (cm) compositions available for northern rockfish in the Gulf of Alaska (at-sea and port samples combined).

Length class (cm)	Year 1999	2000	2001	2002	2003	2004	2005	2006	2007
15	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000
19	0.000	0.003	0.000	0.001	0.000	0.000	0.000	0.000	0.000
20	0.000	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.000
21	0.001	0.004	0.001	0.002	0.000	0.001	0.000	0.000	0.000
22	0.000	0.004	0.000	0.002	0.000	0.000	0.000	0.000	0.000
23	0.001	0.004	0.000	0.002	0.000	0.000	0.000	0.000	0.000
24	0.001	0.005	0.001	0.004	0.001	0.000	0.000	0.000	0.000
25	0.002	0.003	0.000	0.005	0.001	0.001	0.001	0.001	0.001
26	0.003	0.005	0.003	0.003	0.004	0.003	0.000	0.002	0.001
27	0.005	0.006	0.006	0.010	0.006	0.005	0.003	0.004	0.002
28	0.004	0.012	0.009	0.011	0.007	0.009	0.006	0.008	0.003
29	0.007	0.013	0.024	0.022	0.016	0.011	0.009	0.012	0.006
30	0.011	0.016	0.032	0.039	0.027	0.017	0.017	0.022	0.012
31	0.021	0.022	0.037	0.055	0.044	0.026	0.030	0.038	0.016
32	0.028	0.035	0.042	0.087	0.064	0.042	0.043	0.051	0.033
33	0.039	0.041	0.047	0.088	0.083	0.055	0.072	0.065	0.046
34	0.051	0.055	0.057	0.074	0.083	0.077	0.098	0.078	0.065
35	0.063	0.069	0.069	0.061	0.085	0.078	0.118	0.097	0.088
36	0.104	0.094	0.085	0.066	0.072	0.089	0.123	0.101	0.104
37	0.137	0.116	0.118	0.084	0.076	0.089	0.097	0.092	0.118
38+	0.521	0.490	0.467	0.382	0.431	0.497	0.382	0.429	0.505
Sample size	5,287	3,898	3,001	3,802	7,387	5,403	4,208	4,769	7,944
# Hauls	206	211	191	215	374	292	254	240	489

Table 10.6 (continued). Fishery length (cm) compositions available for northern rockfish in the Gulf of Alaska (at-sea and port samples combined).

Length class (cm)	Year 2008	2009	2010	2011
15	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.001
21	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000
24	0.000	0.001	0.000	0.001
25	0.000	0.000	0.000	0.001
26	0.001	0.001	0.001	0.001
27	0.001	0.002	0.001	0.002
28	0.002	0.002	0.003	0.002
29	0.004	0.003	0.008	0.003
30	0.010	0.007	0.011	0.003
31	0.019	0.016	0.018	0.007
32	0.028	0.021	0.028	0.013
33	0.039	0.030	0.037	0.020
34	0.059	0.044	0.049	0.037
35	0.076	0.079	0.072	0.068
36	0.096	0.093	0.088	0.088
37	0.099	0.105	0.103	0.113
38+	0.564	0.595	0.580	0.642
Sample size	7,384	6,408	7,204	3,311
# Hauls	487	422	482	261

Table 10.7. Fishery age compositions for northern rockfish in the Gulf of Alaska. All age compositions are based on "break and burn" reading of otoliths.

Age	Year									
	1998	1999	2000	2001	2002	2004	2005	2006	2008	2010
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.006	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000
6	0.004	0.003	0.024	0.011	0.000	0.015	0.000	0.006	0.000	0.000
7	0.006	0.006	0.005	0.055	0.032	0.008	0.021	0.002	0.006	0.000
8	0.034	0.000	0.015	0.024	0.151	0.036	0.045	0.046	0.020	0.012
9	0.022	0.042	0.019	0.031	0.070	0.111	0.066	0.064	0.026	0.024
10	0.032	0.013	0.043	0.038	0.055	0.176	0.147	0.070	0.078	0.032
11	0.058	0.029	0.031	0.049	0.042	0.050	0.164	0.132	0.068	0.060
12	0.070	0.039	0.058	0.042	0.044	0.035	0.052	0.070	0.048	0.115
13	0.094	0.049	0.053	0.053	0.047	0.036	0.017	0.048	0.093	0.072
14	0.094	0.062	0.048	0.051	0.032	0.028	0.031	0.034	0.076	0.052
15	0.068	0.127	0.074	0.040	0.031	0.027	0.038	0.034	0.030	0.068
16	0.078	0.065	0.094	0.053	0.047	0.032	0.026	0.020	0.022	0.052
17	0.034	0.058	0.067	0.084	0.068	0.015	0.019	0.016	0.012	0.028
18	0.034	0.042	0.060	0.060	0.067	0.025	0.031	0.038	0.006	0.018
19	0.022	0.019	0.024	0.044	0.032	0.046	0.026	0.028	0.012	0.016
20	0.026	0.023	0.022	0.027	0.026	0.058	0.033	0.020	0.022	0.024
21	0.044	0.032	0.010	0.035	0.023	0.035	0.045	0.040	0.020	0.022
22	0.050	0.029	0.043	0.018	0.021	0.029	0.024	0.050	0.016	0.032
23	0.036	0.075	0.034	0.033	0.013	0.023	0.026	0.036	0.038	0.014
24	0.030	0.042	0.046	0.033	0.029	0.011	0.009	0.024	0.050	0.014
25	0.022	0.010	0.022	0.044	0.044	0.012	0.009	0.010	0.028	0.034
26	0.024	0.026	0.029	0.042	0.028	0.021	0.005	0.012	0.030	0.030
27	0.012	0.016	0.014	0.013	0.011	0.039	0.026	0.018	0.022	0.016
28	0.010	0.042	0.021	0.020	0.008	0.029	0.031	0.018	0.006	0.020
29	0.026	0.036	0.024	0.009	0.010	0.012	0.024	0.034	0.014	0.014
30	0.020	0.023	0.041	0.018	0.011	0.017	0.028	0.032	0.026	0.024
31	0.006	0.029	0.019	0.020	0.011	0.011	0.007	0.022	0.028	0.014
32	0.010	0.013	0.014	0.013	0.011	0.008	0.002	0.006	0.034	0.024
33+	0.030	0.042	0.046	0.038	0.034	0.054	0.047	0.070	0.165	0.173
Sample size	498	308	585	451	616	746	422	500	497	503
# Hauls	51	160	187	156	187	270	211	206	311	311

Table 10.8. Biomass estimates (t), by statistical area, for northern rockfish in the Gulf of Alaska based on triennial and biennial trawl surveys. Gulfwide CV's are also listed.

	Statistical areas						
Year	Shumagin	Chirikof	Kodiak	Yakutat	South-eastern	Total	CV
1984	27,716	5,165	6,448	5	0	39,334	29%
1987	45,038	13,794	77,084	500	0	136,417	29%
1990	32,898	5,792	68,044	343	0	107,076	42%
1993	13,995	40,446	49,998	41	0	104,480	35%
1996	28,114	40,447	30,212	192	0	98,965	27%
1999	45,457	29,946	166,665	118	0	242,187	61%
2001	93,291	24,490	225,833	117a	0[a]	343,731	60%
2003	9,146	49,793	7,336	5	0	66,310	48%
2005	231,138	102,605	25,123	160	0	359,026	37%
2007	114,222	92,250	20,559	38	0	227,069	38%
2009	44,693	8,842	36,290	70.2	0	89,896	32%
2011	47,082	91,774	34,757	28	0	173,641	39%

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

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

Age	Year								
	1984	1987	1990	1993	1996	1999	2001	2003	2005
2	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000
3	0.000	0.003	0.001	0.003	0.002	0.000	0.005	0.001	0.000
4	0.000	0.018	0.002	0.003	0.001	0.002	0.003	0.001	0.001
5	0.014	0.055	0.029	0.009	0.002	0.011	0.006	0.035	0.001
6	0.040	0.041	0.054	0.011	0.011	0.003	0.013	0.021	0.014
7	0.091	0.030	0.027	0.011	0.006	0.009	0.041	0.014	0.037
8	0.191	0.003	0.041	0.063	0.021	0.009	0.016	0.096	0.052
9	0.112	0.029	0.054	0.120	0.041	0.042	0.038	0.126	0.047
10	0.051	0.101	0.045	0.065	0.053	0.028	0.072	0.056	0.061
11	0.046	0.112	0.058	0.103	0.085	0.079	0.061	0.036	0.047
12	0.026	0.112	0.035	0.044	0.076	0.069	0.040	0.029	0.033
13	0.071	0.034	0.054	0.049	0.077	0.054	0.063	0.021	0.011
14	0.067	0.043	0.082	0.040	0.040	0.056	0.049	0.051	0.021
15	0.063	0.014	0.097	0.024	0.033	0.078	0.050	0.033	0.012
16	0.040	0.037	0.051	0.052	0.039	0.092	0.054	0.043	0.020
17	0.019	0.103	0.051	0.031	0.017	0.016	0.045	0.000	0.032
18	0.019	0.041	0.007	0.040	0.034	0.072	0.058	0.018	0.031
19	0.006	0.080	0.011	0.028	0.054	0.019	0.029	0.030	0.008
20	0.007	0.027	0.066	0.004	0.088	0.013	0.022	0.061	0.039
21	0.003	0.026	0.066	0.023	0.028	0.030	0.017	0.012	0.046
22	0.010	0.007	0.046	0.034	0.031	0.022	0.012	0.021	0.019
23	0.031	0.007	0.019	0.044	0.030	0.025	0.027	0.011	0.012
24	0.021	0.003	0.009	0.045	0.033	0.030	0.045	0.007	0.012
25	0.006	0.004	0.010	0.046	0.027	0.020	0.029	0.014	0.021
26	0.003	0.017	0.034	0.007	0.052	0.015	0.042	0.025	0.025
27	0.010	0.026	0.006	0.017	0.014	0.034	0.012	0.030	0.022
28	0.004	0.012	0.012	0.022	0.015	0.025	0.009	0.054	0.037
29	0.009	0.003	0.002	0.006	0.028	0.024	0.024	0.035	0.036
30	0.000	0.002	0.010	0.000	0.006	0.016	0.021	0.016	0.038
31	0.004	0.005	0.010	0.002	0.007	0.024	0.014	0.000	0.023
32	0.013	0.000	0.009	0.010	0.004	0.045	0.019	0.000	0.040
33+	0.024	0.007	0.005	0.043	0.042	0.038	0.068	0.104	0.202
Sample size	356	497	331	242	462	278	466	216	417
# Hauls	6	17	12	17	19	27	85	22	72

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

Age	Year 2007	2009
2	0.000	0.000
3	0.000	0.000
4	0.000	0.000
5	0.001	0.003
6	0.007	0.000
7	0.004	0.007
8	0.029	0.015
9	0.090	0.023
10	0.057	0.050
11	0.073	0.071
12	0.063	0.054
13	0.082	0.060
14	0.031	0.063
15	0.017	0.038
16	0.026	0.034
17	0.020	0.021
18	0.010	0.034
19	0.020	0.033
20	0.028	0.028
21	0.033	0.016
22	0.038	0.010
23	0.049	0.027
24	0.011	0.041
25	0.012	0.046
26	0.014	0.027
27	0.027	0.017
28	0.028	0.014
29	0.030	0.030
30	0.034	0.013
31	0.024	0.012
32	0.016	0.025
33+	0.125	0.187
Sample size	605	646
# Hauls	82	69

Table 10.10. Survey length (cm) compositions available for northern rockfish in the Gulf of Alaska, 1984-2011. (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).)

Length class	Year								
(cm)	1984	1987	1990	1993	1996	1999	2001	2003	2005
15	0.010	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000
16	0.007	0.004	0.000	0.000	0.000	0.000	0.001	0.000	0.000
17	0.005	0.005	0.000	0.001	0.001	0.000	0.000	0.000	0.000
18	0.008	0.004	0.000	0.001	0.001	0.000	0.003	0.000	0.000
19	0.006	0.005	0.001	0.001	0.001	0.001	0.002	0.001	0.000
20	0.005	0.008	0.001	0.000	0.001	0.001	0.002	0.001	0.000
21	0.003	0.009	0.001	0.001	0.001	0.001	0.001	0.001	0.000
22	0.005	0.010	0.003	0.002	0.002	0.002	0.002	0.002	0.000
23	0.008	0.012	0.005	0.003	0.002	0.003	0.001	0.004	0.000
24	0.017	0.013	0.012	0.003	0.002	0.002	0.002	0.006	0.001
25	0.022	0.015	0.011	0.007	0.003	0.002	0.002	0.007	0.000
26	0.027	0.015	0.030	0.005	0.007	0.006	0.004	0.018	0.001
27	0.045	0.017	0.024	0.007	0.008	0.002	0.005	0.011	0.001
28	0.052	0.022	0.017	0.008	0.006	0.006	0.008	0.007	0.001
29	0.089	0.044	0.017	0.007	0.008	0.002	0.005	0.010	0.063
30	0.095	0.071	0.013	0.012	0.009	0.003	0.010	0.015	0.034
31	0.102	0.118	0.022	0.014	0.016	0.002	0.011	0.021	0.012
32	0.093	0.140	0.038	0.041	0.020	0.027	0.023	0.040	0.013
33	0.074	0.130	0.090	0.055	0.027	0.031	0.017	0.064	0.021
34	0.060	0.122	0.126	0.091	0.034	0.035	0.053	0.077	0.025
35	0.051	0.087	0.139	0.147	0.059	0.054	0.051	0.063	0.031
36	0.058	0.067	0.118	0.162	0.121	0.078	0.121	0.078	0.052
37	0.049	0.034	0.102	0.123	0.118	0.128	0.127	0.071	0.055
38+	0.110	0.044	0.229	0.311	0.552	0.614	0.549	0.503	0.686
Sample size	4,235	9,584	3,091	4,384	4,239	3,471	3,810	2,941	4,556
# Hauls	50	82	48	106	131	124	106	126	147

Table 10.10 (continued). Survey length (cm) compositions for northern rockfish in the Gulf of Alaska, 1984-2011.

Length class (cm)	Year 2007	2009	2011
15	0.000	0.001	0.000
16	0.000	0.001	0.000
17	0.000	0.000	0.000
18	0.000	0.001	0.000
19	0.000	0.001	0.000
20	0.000	0.001	0.000
21	0.000	0.001	0.000
22	0.000	0.001	0.000
23	0.000	0.001	0.001
24	0.000	0.000	0.000
25	0.002	0.001	0.000
26	0.002	0.001	0.000
27	0.006	0.003	0.000
28	0.002	0.002	0.001
29	0.006	0.002	0.000
30	0.003	0.008	0.000
31	0.007	0.006	0.001
32	0.018	0.013	0.002
33	0.038	0.012	0.004
34	0.061	0.032	0.015
35	0.069	0.040	0.012
36	0.083	0.056	0.018
37	0.091	0.082	0.044
38+	0.609	0.735	0.900
Sample size	4,723	2,849	2,460
# Hauls	139	132	89

Table 10.11. Summary of results (including likelihood components and key parameter estimates) from the 2011 model configurations compared with 2009 results.

		2011		
	2009	Model 1	Model 2	Model 3
Catch	0.04	0.03	0.03	0.05
Survey Biomass	8.92	9.51	9.51	10.09
Fishery Ages	22.36	36.23	36.23	24.87
Survey Ages	33.91	43.44	43.44	35.38
Fishery Sizes	35.74	37.54	37.54	40.82
Maturity Likelihood	0	0	23.50	23.50
Data-Likelihood	100.97	126.74	150.24	134.70
Penalties/Priors				
Recruitment Devs	5.10	6.44	6.44	6.30
Fishery Selectivity	0	0	0	0
Survey Selectivity	0	0	0	0
Fish-Sel Domeshape	0	0	0	0
Survey-Sel Domeshape	0	0	0	0
Average Selectivity	0	0	0	0
F Regularity	3.94	3.88	3.88	4.50
σ_r prior	0	0	0	0
q prior	0.22	0.43	0.43	0.40
M prior	0.00	0.01	0.01	0.01
Objective Fun Total	110.23	137.49	160.99	145.91
Parameter Estimates				
Active parameters				
q	0.74	0.66	0.66	0.67
M	0.06	0.06	0.06	0.06
σ_r	1.5	1.5	1.5	1.5
Mean recruitment (millions)	18.79	17.91	17.91	16.92
$F_{40\%}$	0.06	0.05	0.06	0.06
Total Biomass	103,299	111,390	111,390	104,155
Spawning Biomass	34,793	42,932	46,617	43,414
$B_{0\%}$	61,368	68,513	75,665	72,983
$B_{40\%}$	24,547	27,405	30,266	29,193
ABC ($F_{40\%}$)	5,099	5,290	6,012	**5,509**
$F_{35\%}$	0.07	0.07	0.08	0.07
OFL ($F_{35\%}$)	6,072	6,259	7,174	6,574

Table 10.12. Estimated numbers (thousands) in 2011, fishery selectivity, and survey selectivity of northern rockfish in the Gulf of Alaska based on Model 3. Also shown are schedules of age specific weight and female maturity.

Age	2011 numbers (thousands)	Percent mature	Weight (g)	Fishery selectivity	Survey selectivity
2	10,292	0	29	0.000	0.008
3	9,713	1	74	0.000	0.018
4	8,683	1	134	0.001	0.039
5	7,628	3	205	0.006	0.083
6	6,130	5	281	0.031	0.167
7	4,451	9	358	0.141	0.308
8	2,573	16	433	0.455	0.497
9	2,344	26	502	0.810	0.687
10	3,000	40	566	0.956	0.829
11	2,983	56	624	0.991	0.915
12	2,850	71	675	0.998	0.960
13	12,061	83	720	1.000	0.981
14	7,837	90	759	1.000	0.992
15	4,486	95	793	1.000	0.996
16	7,750	97	822	1.000	0.998
17	15,940	98	847	1.000	0.999
18	1,717	99	868	1.000	1.000
19	2,309	100	886	1.000	1.000
20	2,537	100	902	1.000	1.000
21	3,330	100	915	1.000	1.000
22	1,578	100	926	1.000	1.000
23	3,070	100	935	1.000	1.000
24	2,663	100	943	1.000	1.000
25	1,466	100	950	1.000	1.000
26	3,079	100	955	1.000	1.000
27	7,517	100	960	1.000	1.000
28	1,149	100	964	1.000	1.000
29	4,053	100	967	1.000	1.000
30	2,467	100	970	1.000	1.000
31	1,428	100	972	1.000	1.000
32	925	100	974	1.000	1.000
33+	18,887	100	976	1.000	1.000

Table 10.13. Estimated time series of female spawning biomass, 95% confidence bounds on female spawning biomass, 6+ biomass (age 6 and greater), catch/(6+ biomass), and the number of age two recruits for northern rockfish in the Gulf of Alaska for this year's Model 3 results compared to 2009.

	Spawning Biomass (t)		6+ total biomass (t)		Catch / (6+ total biomass)		Age Two Recruits (millions)	
Year	Current	Previous	Current	Previous	Current	Previous	Current	Previous
1977	23,171	23,807	77,732	77,010	0.008	0.008	14.0	19.4
1978	24,731	24,069	81,652	78,168	0.007	0.007	87.8	99.3
1979	26,944	24,620	85,614	80,465	0.008	0.008	28.9	22.5
1980	29,637	25,410	89,213	82,786	0.009	0.01	14.2	22
1981	32,512	26,415	92,346	85,706	0.016	0.017	11.6	11.9
1982	35,028	27,419	110,854	105,144	0.035	0.037	16.7	20.3
1983	36,289	27,740	116,799	108,492	0.031	0.033	26.9	29.5
1984	37,656	28,374	119,681	111,761	0.008	0.009	41.0	42.3
1985	40,476	30,165	123,791	115,124	0.001	0.002	10.7	12.4
1986	44,167	32,506	128,903	120,267	0.002	0.002	63.2	56.1
1987	48,201	35,076	135,546	126,789	0.004	0.004	23.4	18.9
1988	52,042	37,767	144,928	135,662	0.008	0.008	10.1	13
1989	55,136	40,342	147,424	137,779	0.010	0.011	16.6	17.2
1990	57,548	42,735	160,186	148,025	0.011	0.012	17.5	18.2
1991	59,644	44,923	165,402	150,883	0.027	0.03	8.2	8.2
1992	60,555	45,899	164,277	149,015	0.047	0.052	16.0	16.4
1993	60,213	45,462	160,269	144,072	0.030	0.034	11.1	11.9
1994	61,145	45,827	158,829	141,844	0.038	0.042	9.2	11.2
1995	61,367	45,571	153,739	136,059	0.037	0.041	6.3	7.5
1996	61,215	45,197	149,981	131,852	0.022	0.025	53.4	58.2
1997	61,446	45,413	147,235	128,830	0.020	0.023	23.6	25
1998	61,280	45,529	144,099	125,829	0.021	0.024	12.4	16.1
1999	60,611	45,350	139,821	121,713	0.039	0.044	19.6	21.1
2000	58,574	43,946	143,257	125,827	0.023	0.026	27.3	26.9
2001	57,383	43,260	144,037	126,584	0.022	0.025	5.9	6.6
2002	56,374	42,608	142,772	125,868	0.023	0.026	5.6	6.3
2003	55,592	41,949	142,564	125,903	0.037	0.042	5.1	7.9
2004	54,428	40,649	142,159	125,179	0.034	0.038	3.6	7.9
2005	53,823	39,729	137,824	120,907	0.033	0.04	3.7	8.7
2006	53,446	38,910	133,089	116,015	0.037	0.043	6.0	10
2007	52,729	38,100	127,274	110,905	0.033	0.038	7.8	10.7
2008	52,018	37,516	121,480	106,253	0.033	0.038	9.1	11.4
2009	50,912	36,860	115,460	101,719	0.034	0.038	9.8	11.4
2010	49,330		109,798		0.036		10.3	
2011	47,293		104,552		0.032		10.3	

Table 10.14. Estimated time series of number of age 2 recruits (in thousands), total biomass, and female spawning biomass with 95% confidence bounds for northern rockfish in the Gulf of Alaska for this year's Model 3 results.

	Recruits (Age 2)			Total Biomass			Spawning Biomass		
Year	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%
1977	13,989	445	90,936	82,533	55,992	134,934	23,171	12,711	41,836
1978	87,814	2,276	172,434	89,086	61,566	144,637	24,731	14,407	43,591
1979	28,889	615	115,936	96,585	67,676	155,522	26,944	16,541	46,114
1980	14,157	439	53,995	104,486	73,965	166,708	29,637	18,911	49,567
1981	11,598	422	45,343	112,183	79,935	178,137	32,512	21,429	53,671
1982	16,750	448	57,678	118,794	84,814	187,724	35,028	23,596	57,302
1983	26,947	876	91,092	122,561	87,079	195,346	36,289	24,495	59,561
1984	41,026	820	90,760	126,737	89,392	202,979	37,656	25,383	61,781
1985	10,668	407	77,393	133,030	93,950	212,326	40,476	27,583	65,996
1986	63,212	3,159	127,629	141,008	100,104	223,557	44,167	30,431	71,605
1987	23,396	555	73,249	148,926	105,942	235,608	48,201	33,435	77,398
1988	10,088	444	41,928	156,202	111,280	245,517	52,042	36,340	83,011
1989	16,622	615	46,868	162,249	115,564	255,534	55,136	38,614	87,465
1990	17,490	705	43,905	167,069	118,399	263,479	57,548	40,418	91,433
1991	8,248	389	32,730	170,566	120,564	269,497	59,644	41,960	94,615
1992	15,972	995	37,159	170,253	119,082	271,559	60,555	42,193	96,959
1993	11,117	818	33,987	165,686	113,601	269,301	60,213	41,050	97,963
1994	9,238	549	24,675	163,188	110,486	267,947	61,145	41,233	100,557
1995	6,287	314	23,843	158,629	105,465	263,251	61,367	40,605	101,961
1996	53,364	24,653	103,246	154,991	101,299	260,897	61,215	39,768	102,981
1997	23,603	929	54,877	153,960	99,286	261,019	61,446	39,453	103,964
1998	12,385	666	44,971	153,530	98,059	261,497	61,280	38,889	104,402
1999	19,609	1,063	51,879	153,226	96,755	263,568	60,611	38,056	104,317
2000	27,346	4,362	62,448	150,944	93,018	264,110	58,574	35,940	102,357
2001	5,862	336	21,688	150,565	91,282	266,217	57,383	34,752	101,231
2002	5,573	374	17,804	149,964	89,516	267,275	56,374	33,651	100,163
2003	5,098	382	16,592	148,492	86,955	266,997	55,592	32,735	99,906
2004	3,642	251	14,207	144,289	82,447	263,372	54,428	31,199	99,154
2005	3,703	213	15,361	139,749	77,581	259,570	53,823	29,906	100,054
2006	6,002	263	27,509	134,830	72,986	254,333	53,446	28,806	101,146
2007	7,780	289	45,155	128,984	67,187	247,624	52,729	27,386	101,346
2008	9,120	336	67,058	123,637	62,601	240,683	52,018	26,186	101,387
2009	9,781	351	80,364	118,336	58,102	233,688	50,912	24,807	100,770
2010	10,308	357	124,374	113,200	53,788	227,645	49,330	23,074	99,306
2011	10,292	342	130,219	108,298	50,094	224,372	47,293	21,096	96,950
2012	16,922	375	104,406	104,155	47,635	222,998	43,414	18,524	90,228

Table 10.15. Estimates of key parameters with Hessian estimates of standard deviation (σ), MCMC standard deviations (σ(MCMC)) and 95% Bayesian credible intervals (BCI) derived from MCMC simulations.

Parameter	μ	μ (MCMC)	Median (MCMC)	σ	σ(MCMC)	BCI-Lower	BCI-Upper
q	0.67	0.68	0.67	0.16	0.17	0.39	1.05
M	0.06	0.06	0.06	0.003	0.003	0.054	0.065
$F_{40\%}$	0.062	0.071	0.068	0.016	0.021	0.04	0.12
2012 SSB	43,414	46,038	43,010	16,493	18,707	18,524	90,228
2012 ABC	5,509	6,658	5,958	2,522	3,441	2,017	15,345

Table 10.16. Set of projections of spawning biomass and yield for northern rockfish in the Gulf of Alaska. This set of projections encompasses six harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For a description of scenarios see *Projections and Harvest Alternatives*. All units in t. $B_{40\%}$ = 29,193 t, $B_{35\%}$ = 25,544 t, $F_{40\%}$ = 0.062, and $F_{35\%}$ = 0.074.

Year	Maximum permissible F	Author's F* (Estimated catches)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (mt)				
2011	45,791	45,791	45,791	45,791	45,791	45,791	45,791
2012	43,280	43,414	43,724	43,635	44,171	43,104	43,280
2013	40,098	40,589	41,757	41,421	43,485	39,452	40,098
2014	37,133	37,828	39,841	39,286	42,749	36,100	36,982
2015	34,487	35,121	38,093	37,346	42,084	33,141	33,935
2016	32,216	32,791	36,590	35,673	41,576	30,618	31,330
2017	30,337	30,857	35,369	34,302	41,276	28,551	29,173
2018	28,853	29,314	34,446	33,245	41,210	26,975	27,490
2019	27,784	28,178	33,832	32,511	41,402	25,891	26,316
2020	27,125	27,457	33,530	32,098	41,871	25,233	25,583
2021	26,812	27,090	33,519	31,981	42,612	24,923	25,210
2022	26,758	26,992	33,743	32,103	43,580	24,870	25,104
2023	26,875	27,071	34,129	32,389	44,710	24,980	25,169
2024	27,089	27,252	34,612	32,773	45,932	25,177	25,330
			Fishing mortality				
2011	0.037	0.037	0.037	0.037	0.037	0.037	0.037
2012	0.062	0.052	0.031	0.037	-	0.074	0.074
2013	0.062	0.052	0.031	0.037	-	0.074	0.074
2014	0.062	0.062	0.031	0.037	-	0.074	0.074
2015	0.062	0.062	0.031	0.037	-	0.074	0.074
2016	0.062	0.062	0.031	0.037	-	0.074	0.074
2017	0.062	0.062	0.031	0.037	-	0.072	0.072
2018	0.061	0.061	0.031	0.037	-	0.068	0.068
2019	0.058	0.059	0.031	0.037	-	0.065	0.065
2020	0.057	0.058	0.031	0.037	-	0.063	0.063
2021	0.056	0.057	0.031	0.037	-	0.062	0.062
2022	0.056	0.056	0.031	0.037	-	0.062	0.062
2023	0.056	0.056	0.031	0.037	-	0.062	0.062
2024	0.056	0.056	0.031	0.037	-	0.063	0.063
			Yield (mt)				
2011	3,590	3,590	3,590	3,590	3,590	3,590	3,590
2012	5,509	5,509	2,796	3,343	-	6,574	5,509
2013	5,109	5,155	2,671	3,175	-	6,024	5,109
2014	4,772	4,859	2,568	3,034	-	5,563	5,695
2015	4,491	4,569	2,483	2,918	-	5,179	5,297
2016	4,257	4,327	2,414	2,823	-	4,860	4,965
2017	4,071	4,134	2,363	2,750	-	4,502	4,686
2018	3,899	3,999	2,340	2,712	-	4,103	4,255
2019	3,714	3,811	2,347	2,712	-	3,888	4,009
2020	3,623	3,703	2,370	2,730	-	3,789	3,886
2021	3,597	3,662	2,400	2,757	-	3,766	3,844
2022	3,609	3,662	2,432	2,788	-	3,792	3,855
2023	3,642	3,685	2,465	2,820	-	3,840	3,890
2024	3,690	3,724	2,500	2,855	-	3,904	3,944

*Projected ABCs and OFLs for 2012 and 2013 are derived using expected catches of 3,590 and 4,683 t for 2011 and 2012 based on realized catches from 2008-2010. This calculation is in response to management requests to obtain more accurate projections.

Table 10.17. 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 ecosystem 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 between fishery and reproductive activities	fishery does not hinder reproduction	little concern
Fishery effects on amount of large size target fish	no evidence for targeting 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 spawning potential and yield	possible concern

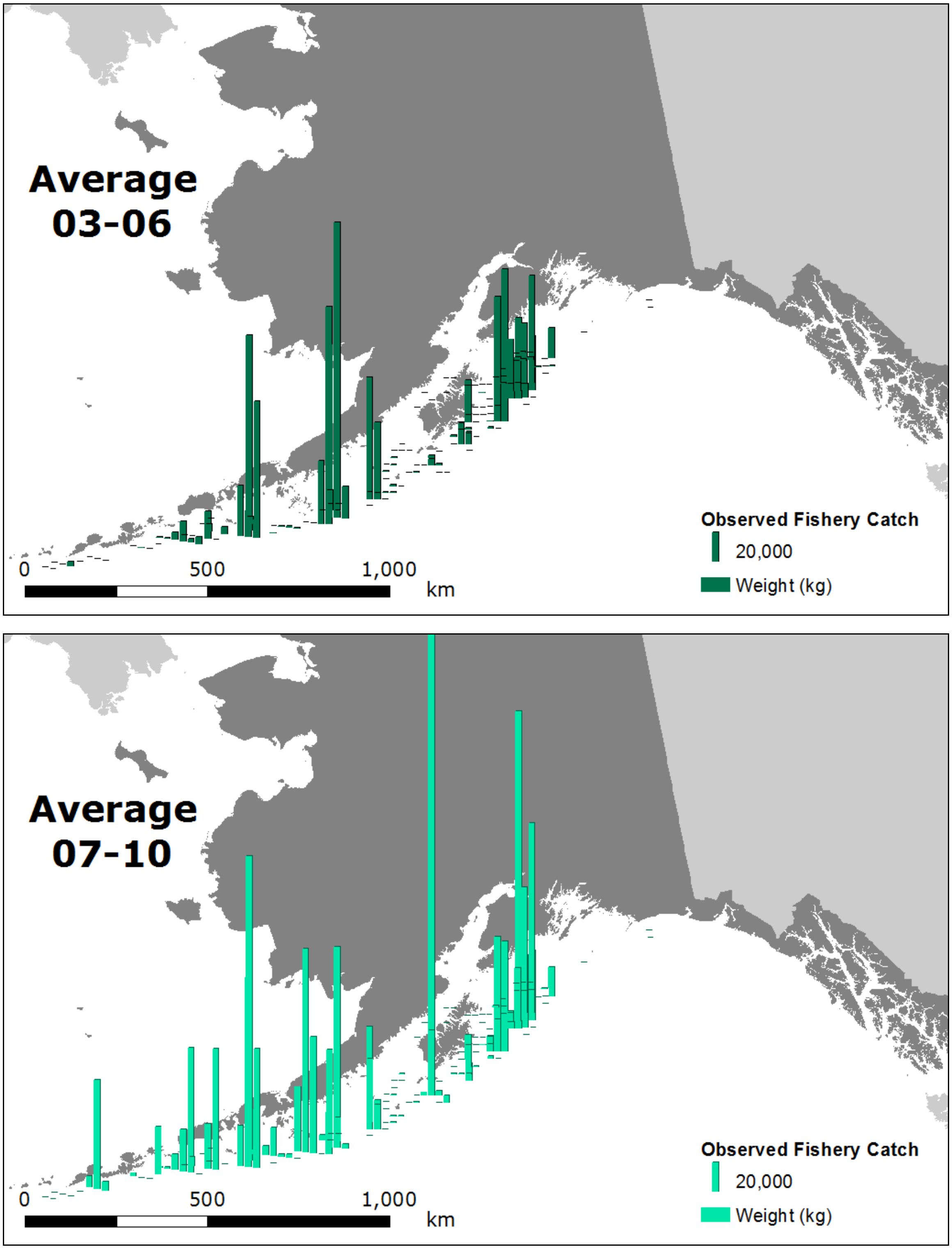

Figure 10.1. Spatial distribution of northern rockfish trawl fishery catch in the Gulf of Alaska (GOA) based on observer data aggregated by 400 km^2 blocks and averaged by (a) four years prior to central GOA Rockfish Pilot Program, 2003-2006, and (b) four years after implementation of program, 2007-2010.

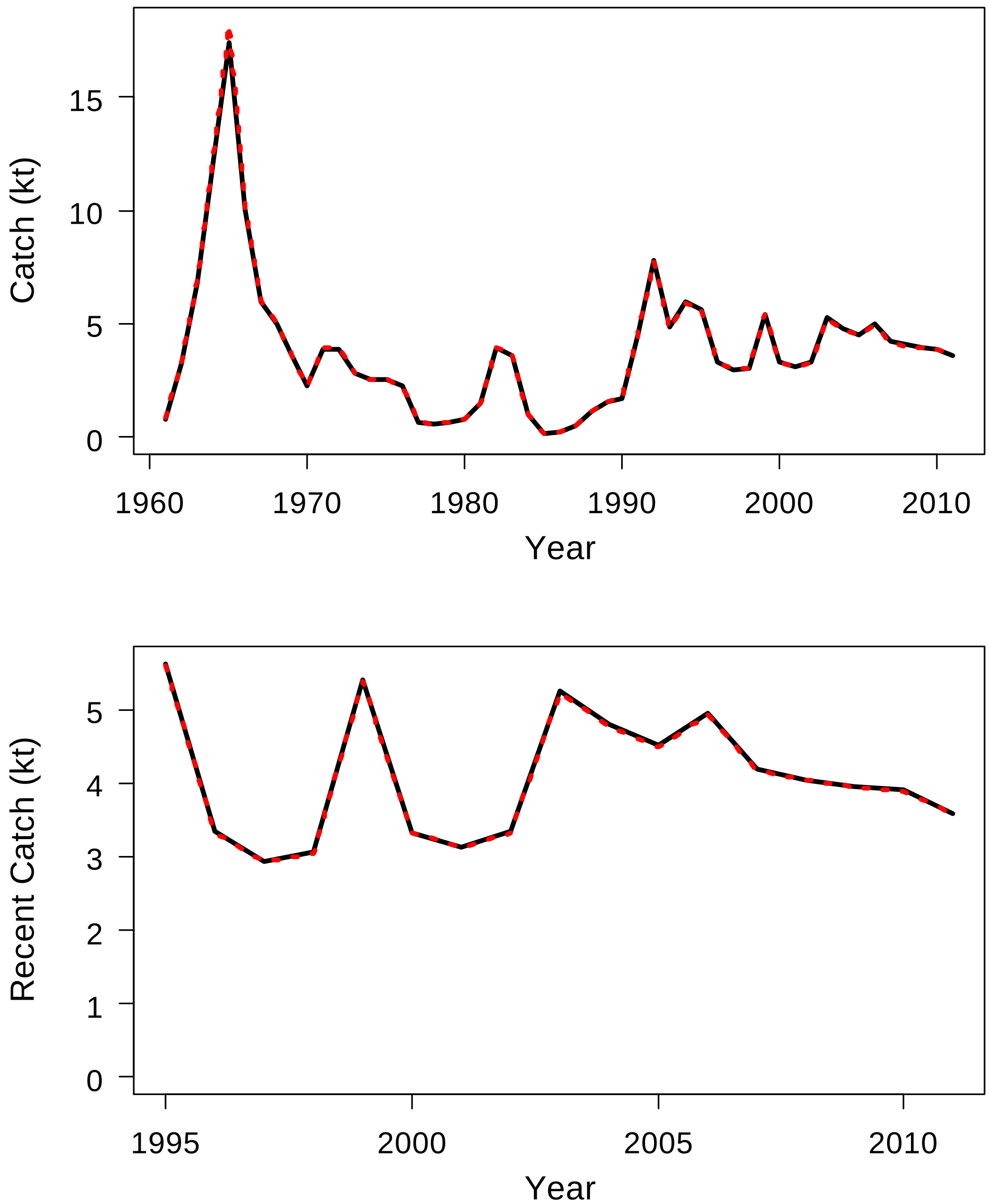

Figure 10.2. Estimated (red dashed lines) and observed (black solid lines) long-term and recent commercial catch of northern rockfish in the Gulf of Alaska. The *Description of the catch time series* section describes the procedures used to estimate catch for the years 1965-1993. Catch for the years 1993-2011 is from NMFS Observer Program and Alaska Regional Office.

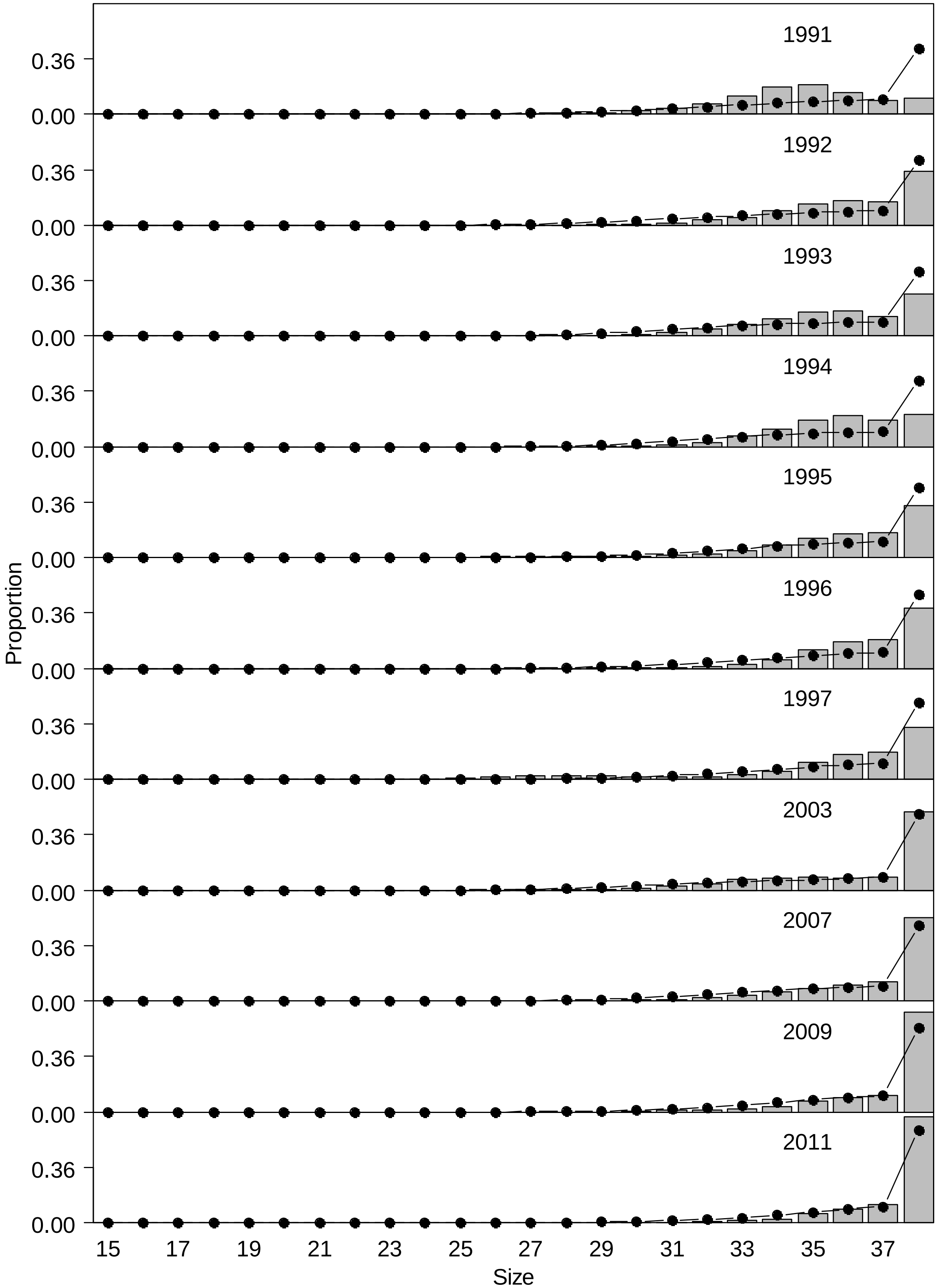

Figure 10.3. Fishery length compositions for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

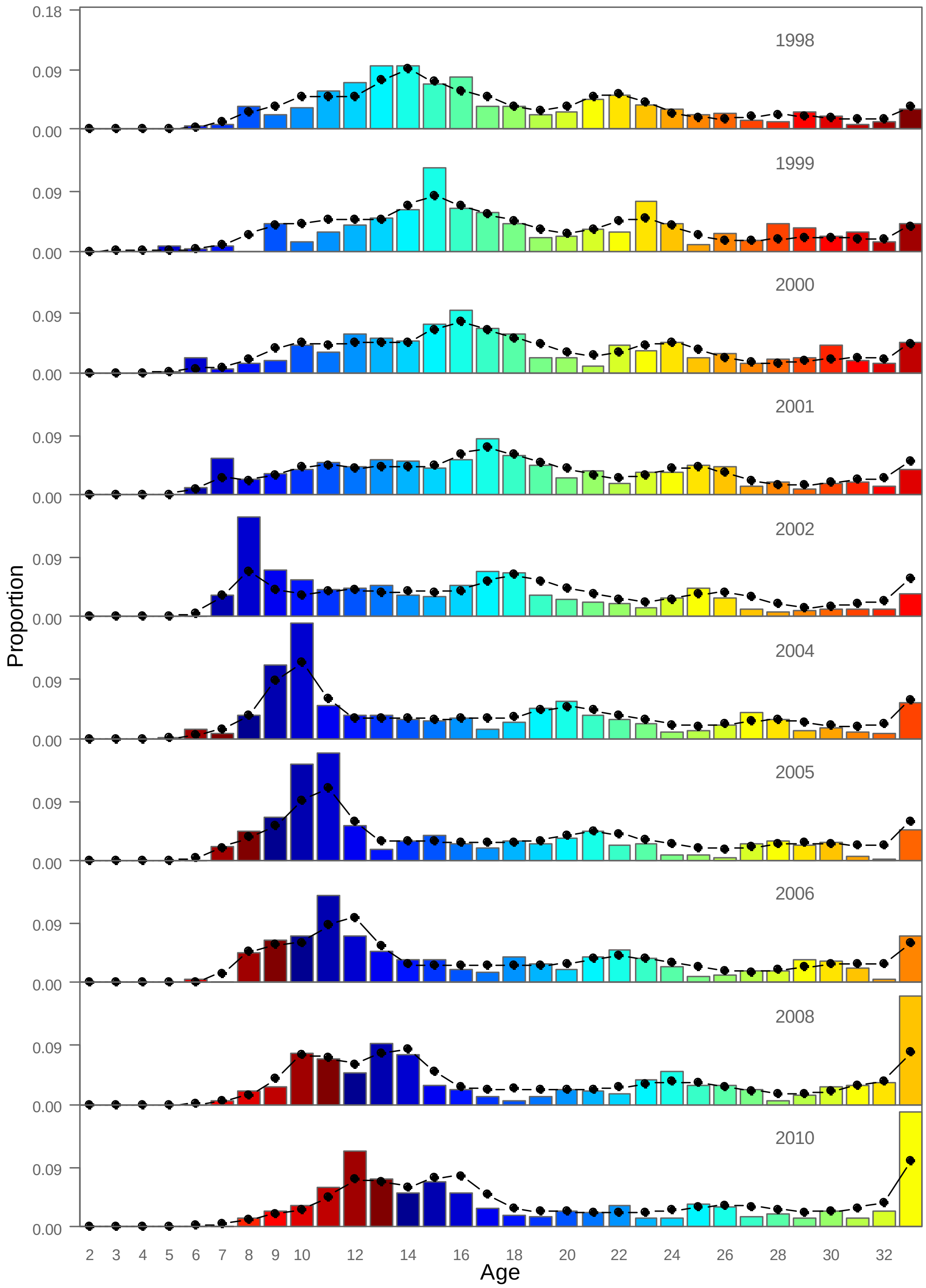

Figure 10.4. Fishery age compositions for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

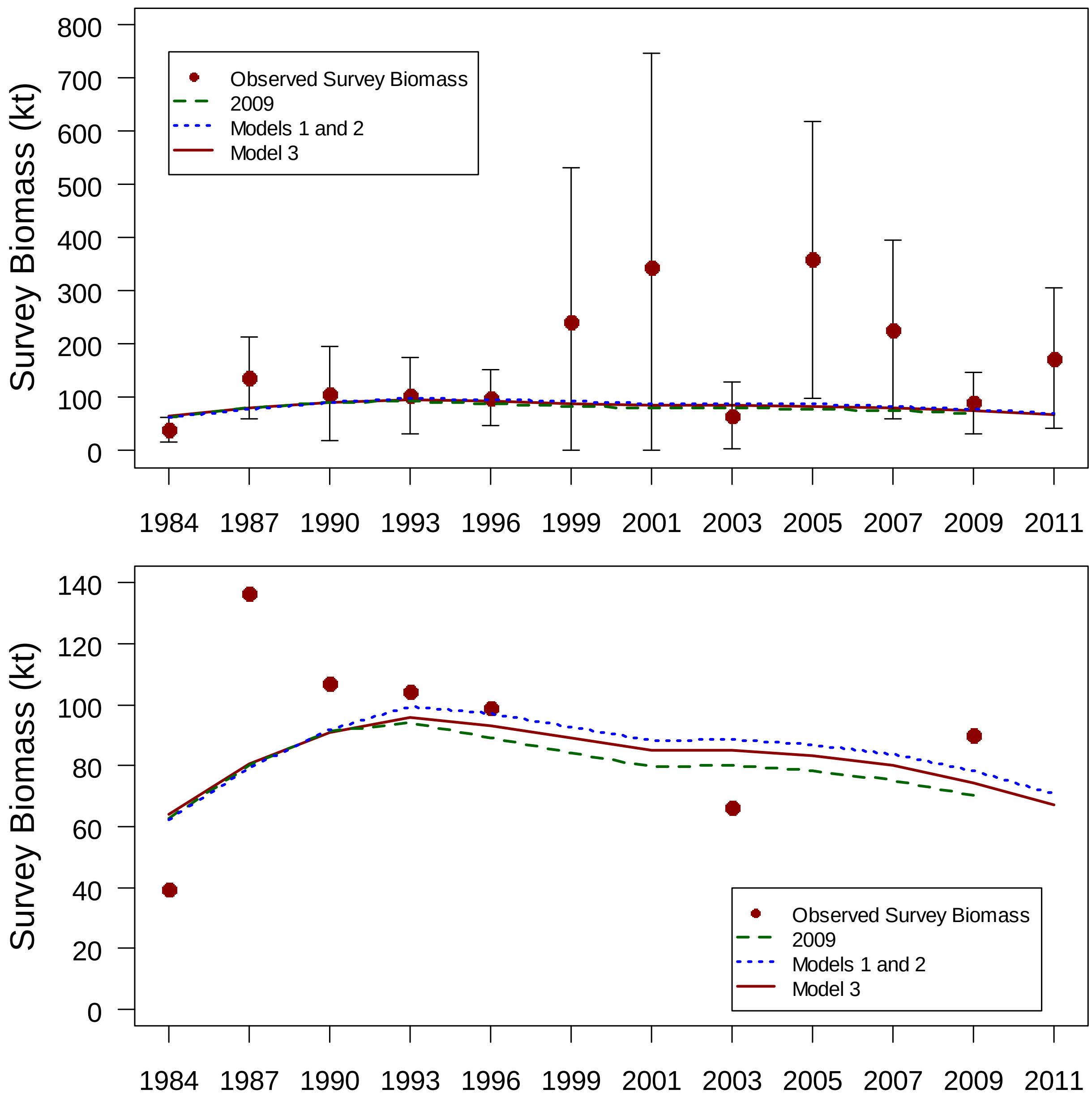

Figure 10.5. Upper panel is observed and predicted GOA northern rockfish trawl survey index of biomass (shown in units of kilotons). Observed biomass=circles with 95% confidence intervals of sampling error. Predictions are from 2009 model and this year's model configurations. Recommended model is red solid line. Bottom panel is an expansion without confidence intervals and the high point estimates of 1999, 2001, 2005, 2007, and 2011 to look at the fit at a visible scale.

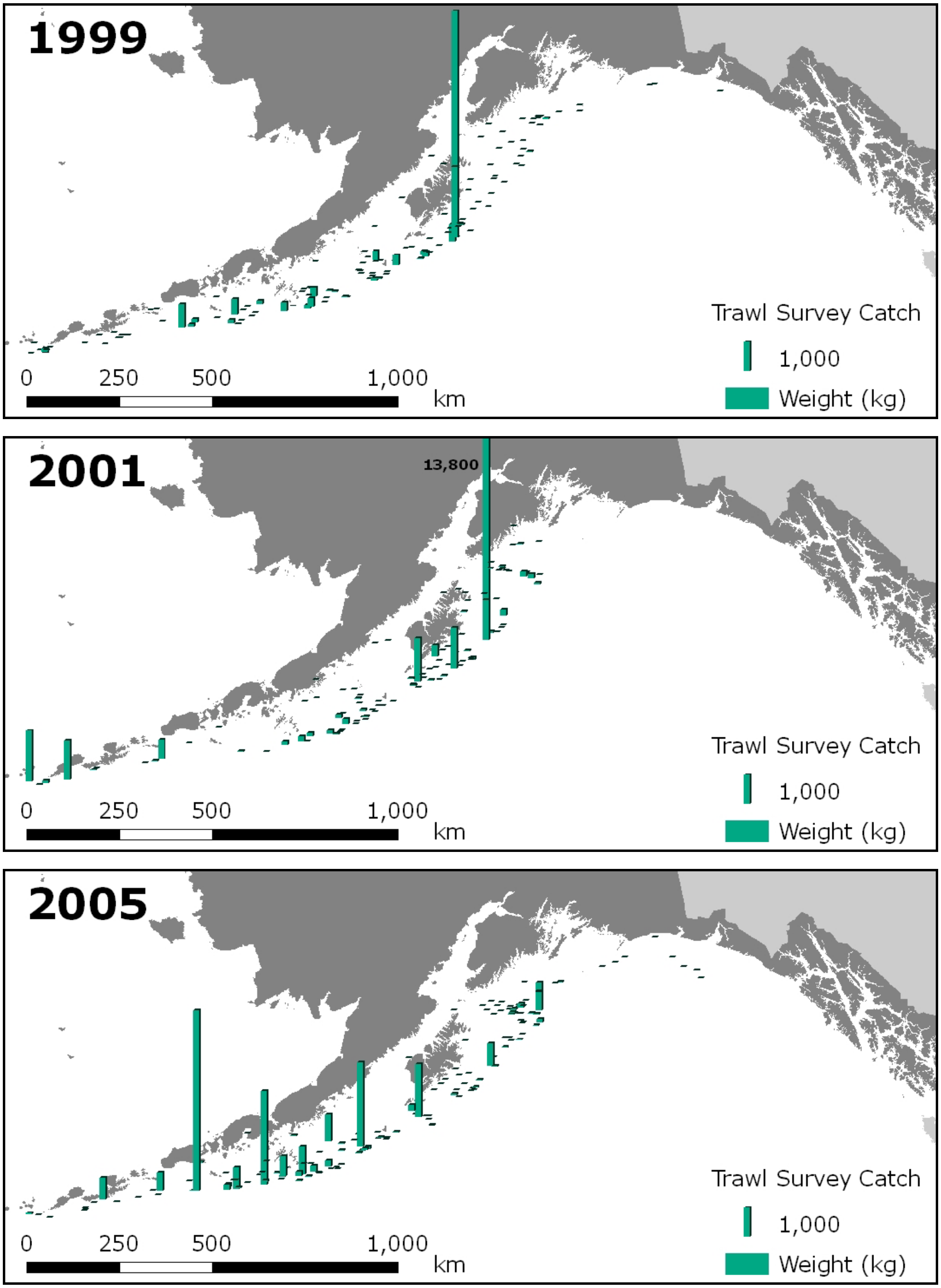

Figure 10.6. Spatial distribution of northern rockfish catch in the Gulf of Alaska during the trawl surveys.

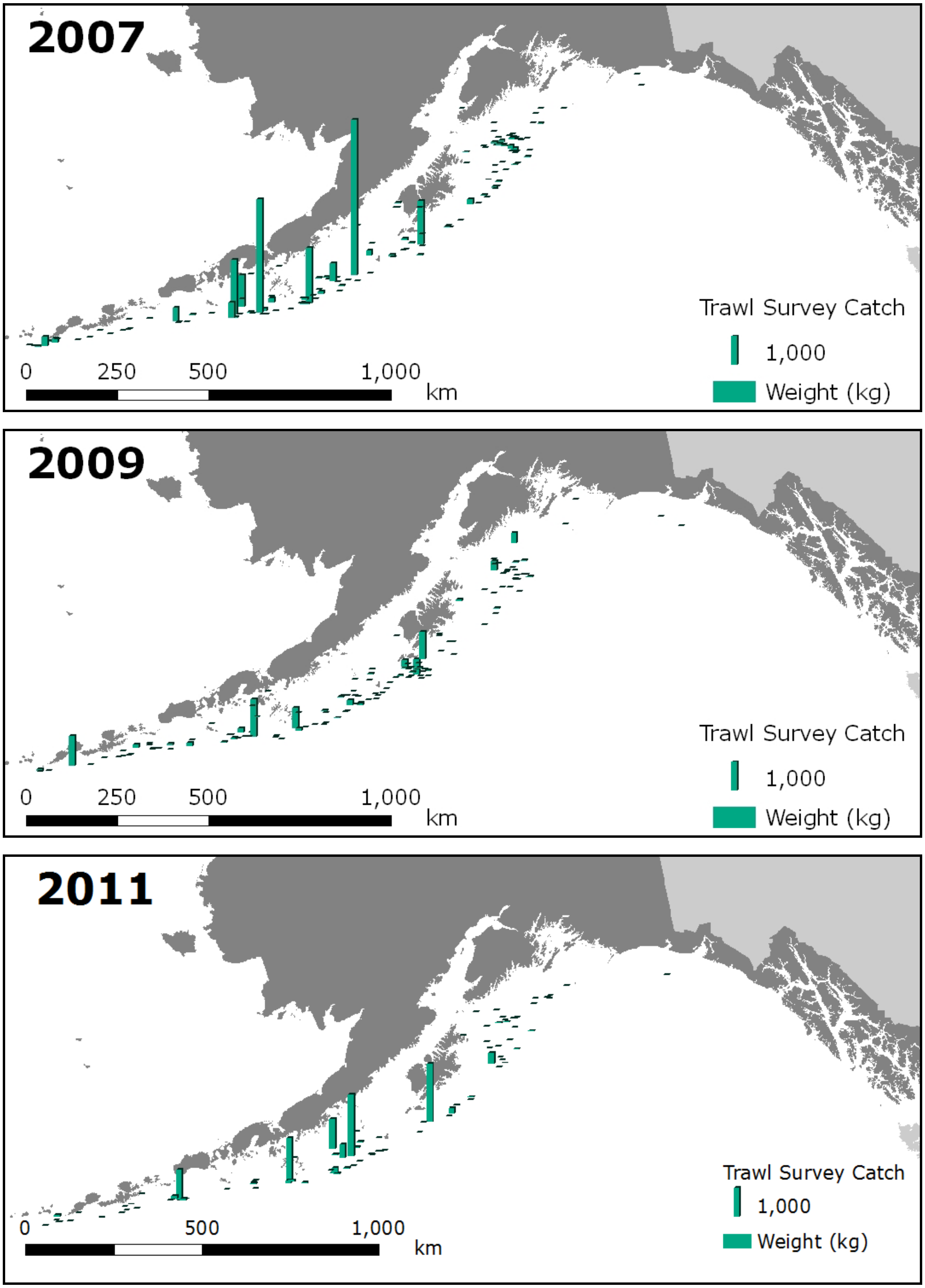

Figure 10.6. (continued) Spatial distribution of northern rockfish catch in the Gulf of Alaska during the trawl surveys.

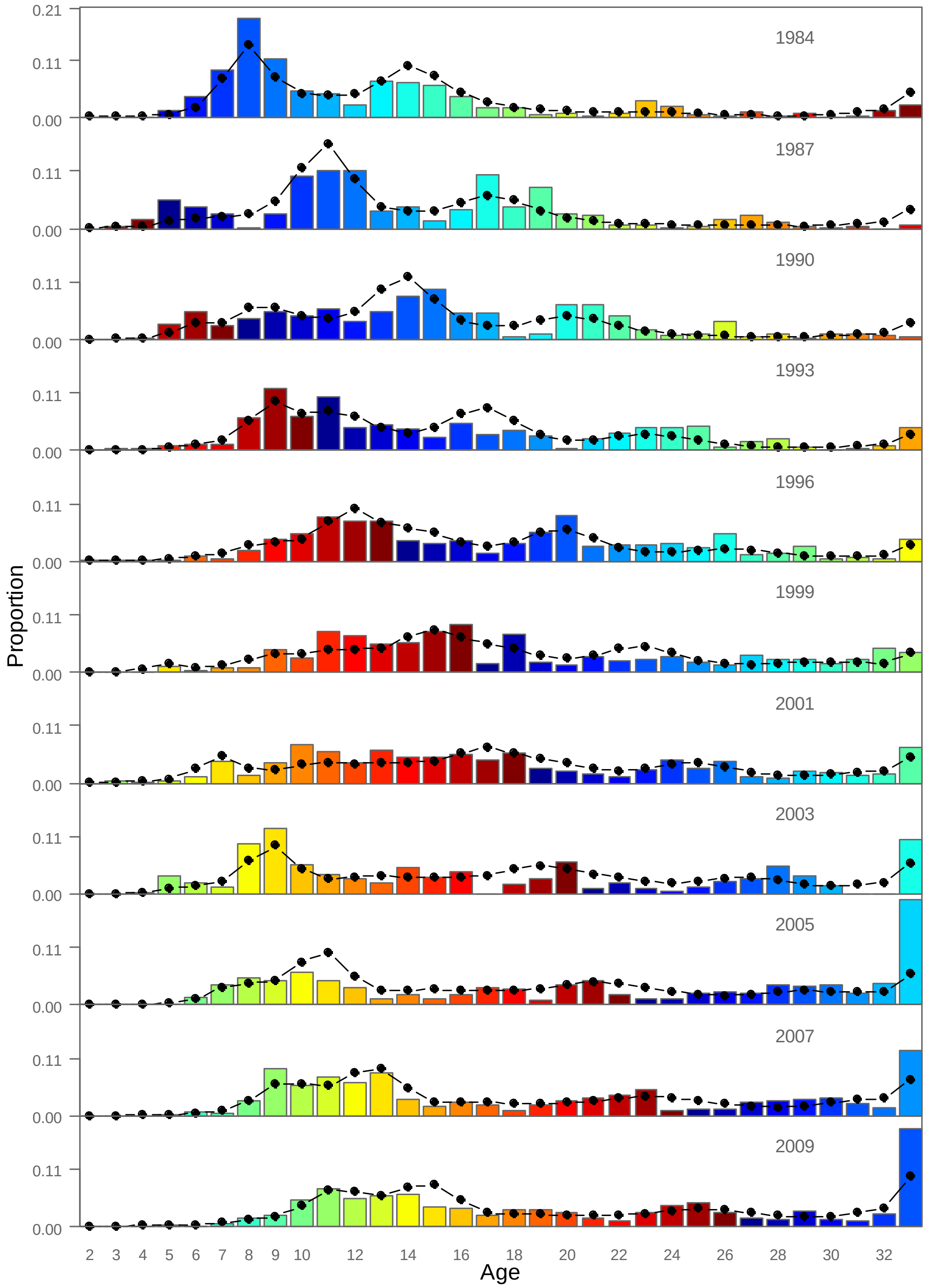

Figure 10.7. Trawl survey age composition by year for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

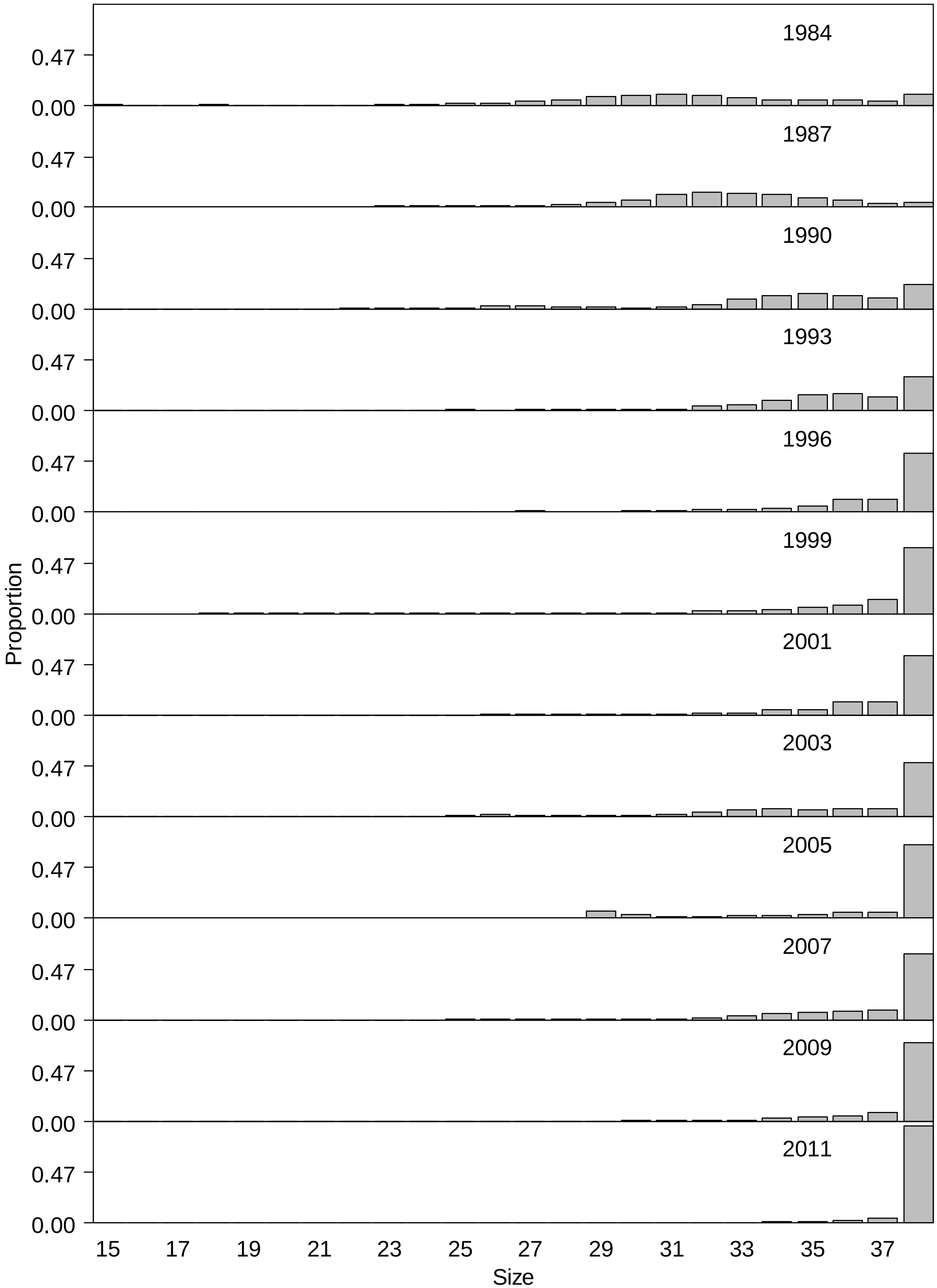

Figure 10.8. Groundfish survey length compositions for GOA northern rockfish. Observed = bars. Survey size distributions not used in the model because survey ages are available for these years.

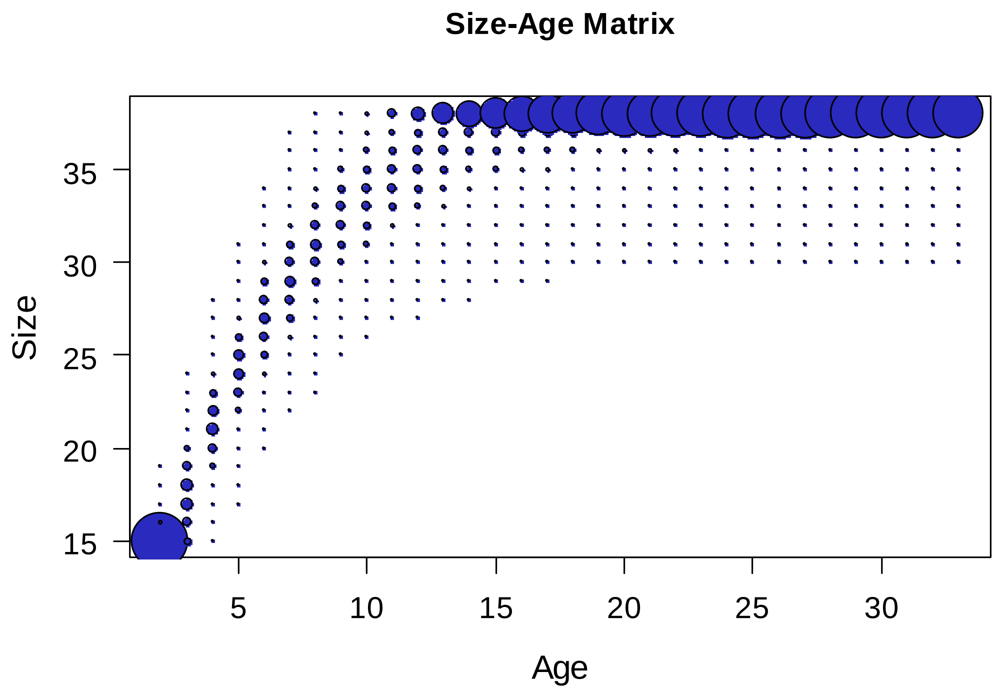

Figure 10.9. Length-age transition matrix used for GOA northern rockfish. The matrix is based on length at age data from trawl surveys.

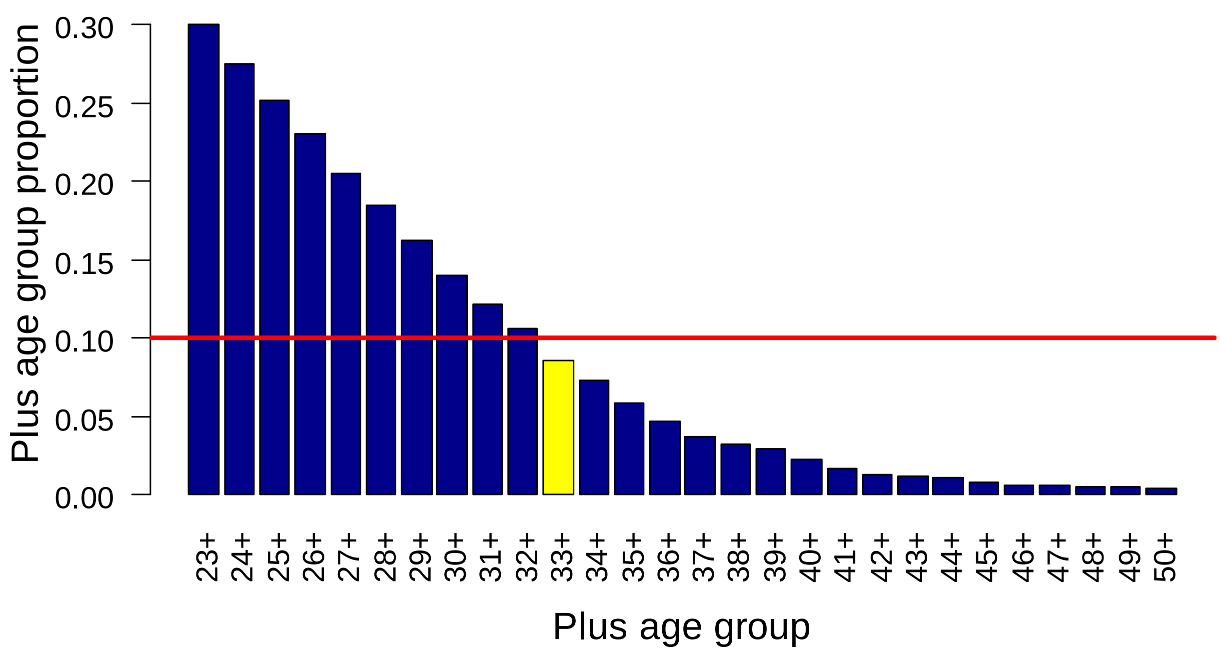

Figure 10.10. Plus age group proportions from age 23+ to 50+ obtained from the pooled survey age compositions. Age 33+ is highlighted as this is the first plus age group to fall below the 10% threshold.

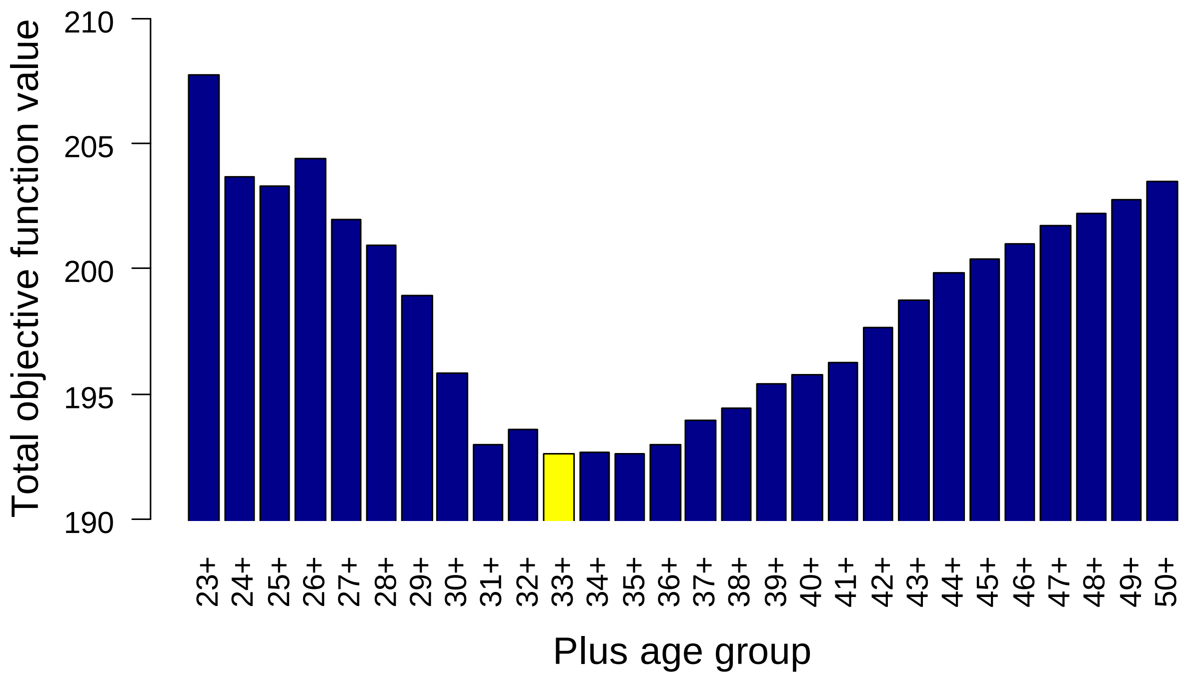

Figure 10.11. Total objective function value after fitting fishery and survey age compositions in which the plus age group is extended from age 23+ to 50+. Age 33+ is highlighted as this is the minimum total objective function value obtained.

Figure 10.12. Ageing error matrix used for GOA northern rockfish. The matrix is based on percent agreement tests conducted at the AFSC Age and Growth lab.

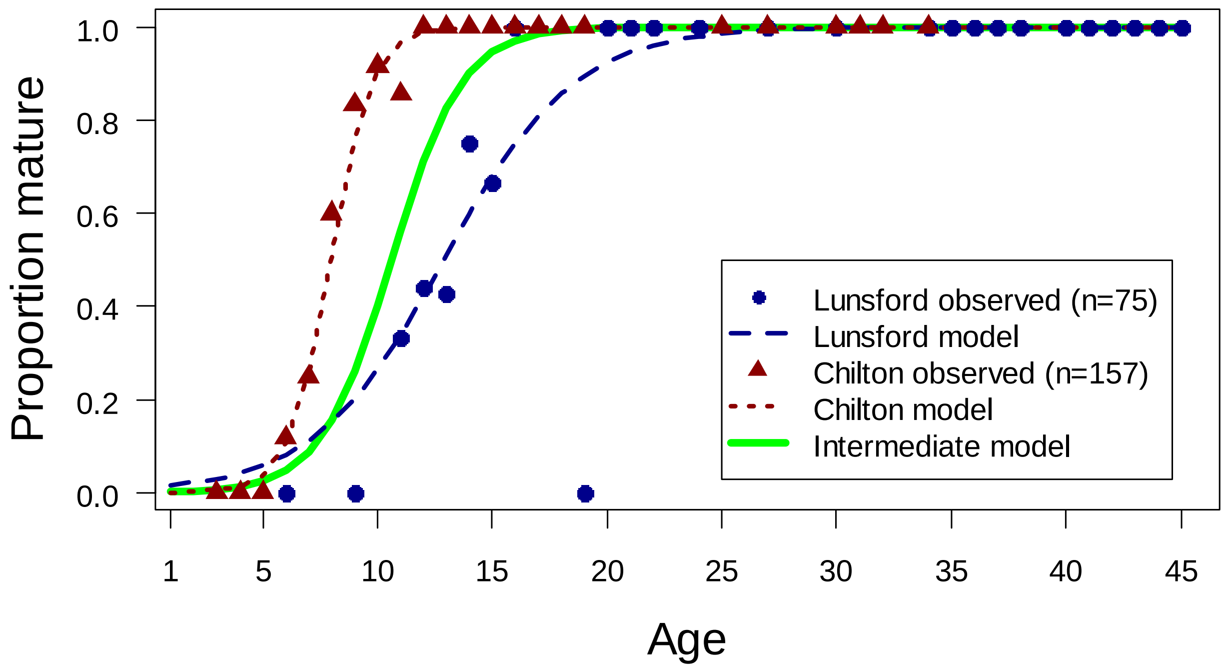

Figure 10.13. Intermediate model fit to combined female northern rockfish maturity data. Also shown are separate model fits to each dataset.

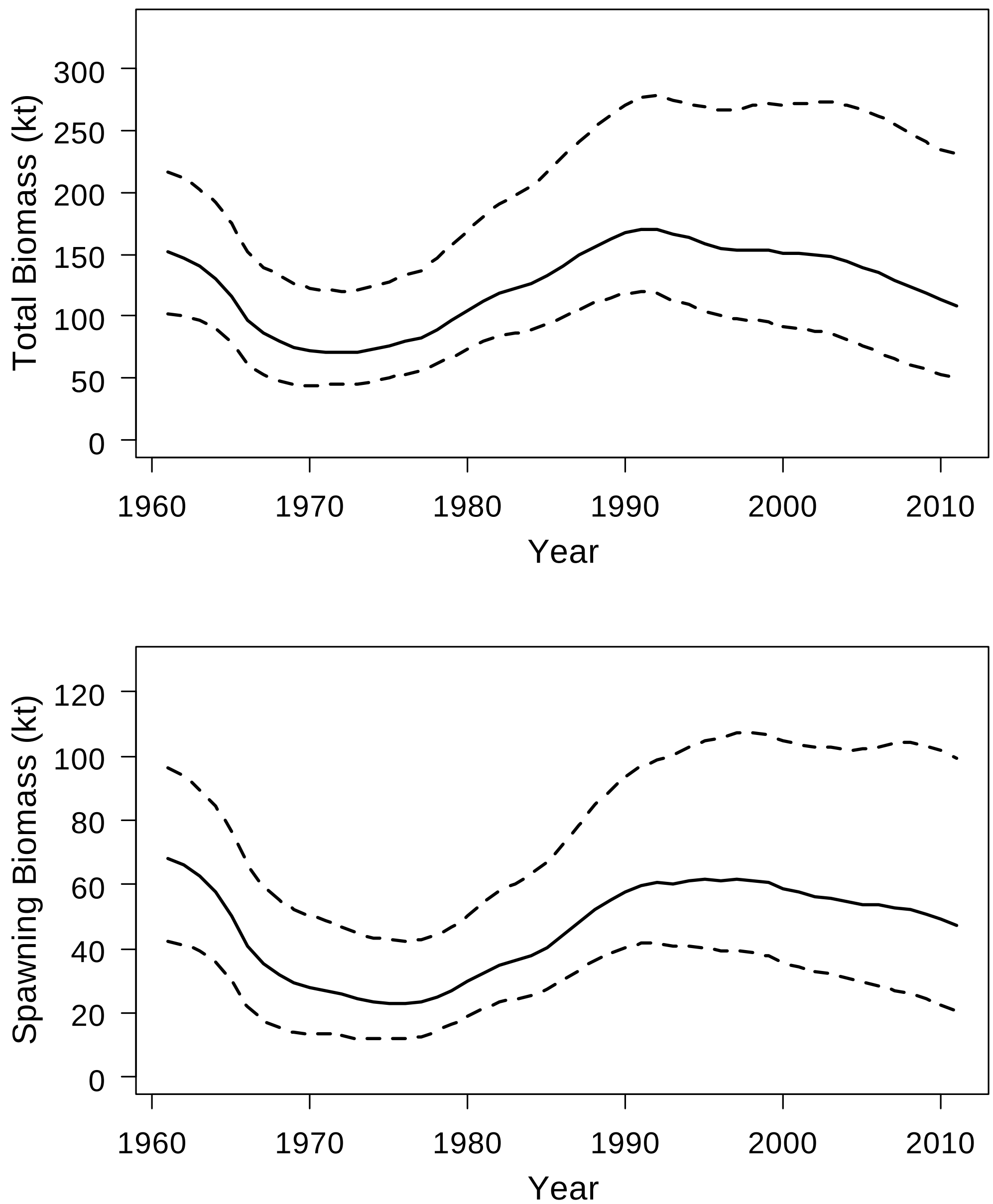

Figure 10.14. Model estimated total biomass and spawning biomass (solid lines) with 95% confidence intervals determined by MCMC (dashed line) for Gulf of Alaska northern rockfish.

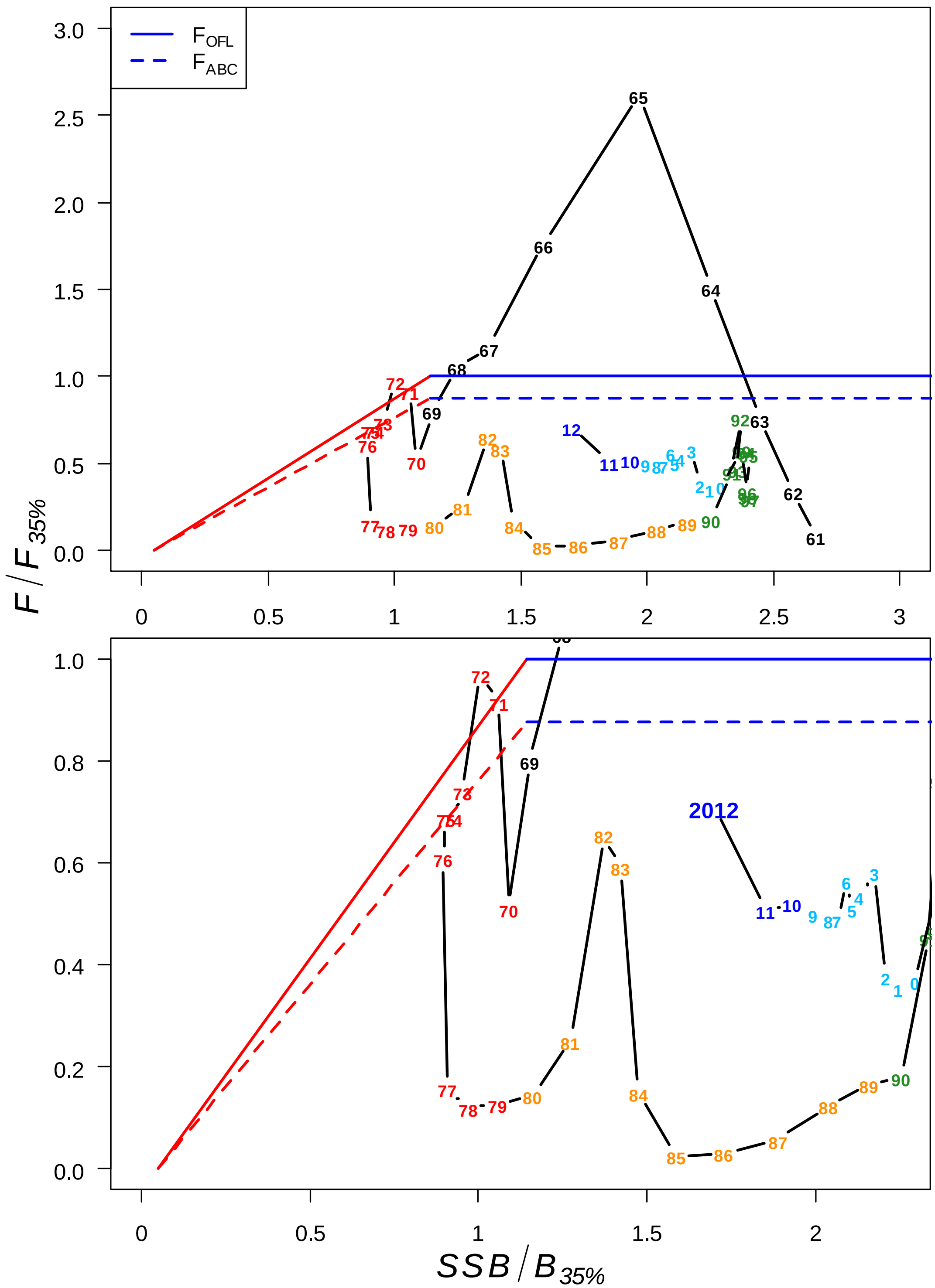

Figure 10.15. Time series of northern rockfish estimated spawning biomass (*SSB*) relative to $B_{35\%}$ and fishing mortality (*F*) relative to $F_{35\%}$ for author recommended model.

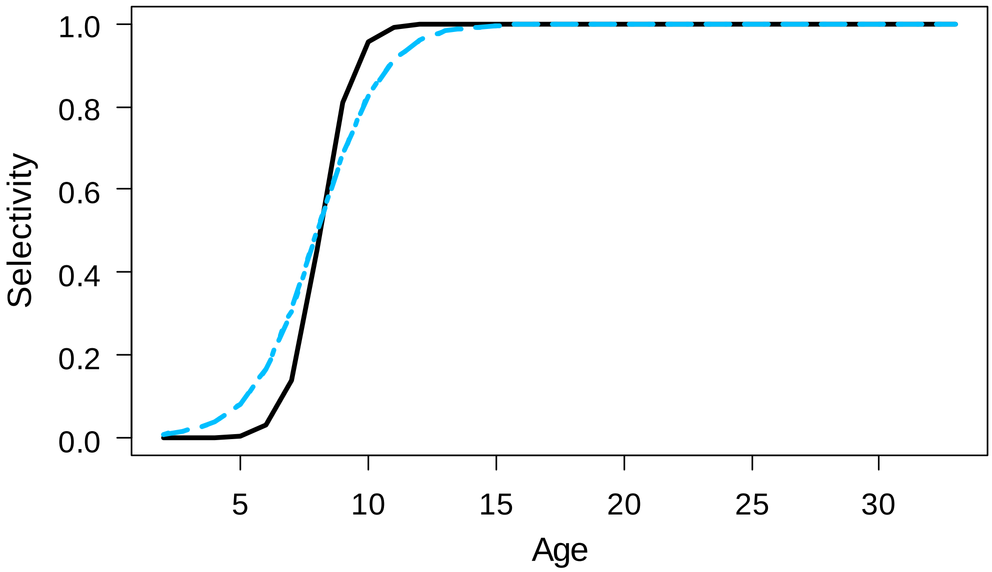

Figure 10.16. Fishery (solid line) and survey (dotted line) estimates of selectivity for GOA northern rockfish based on the authors recommended model.

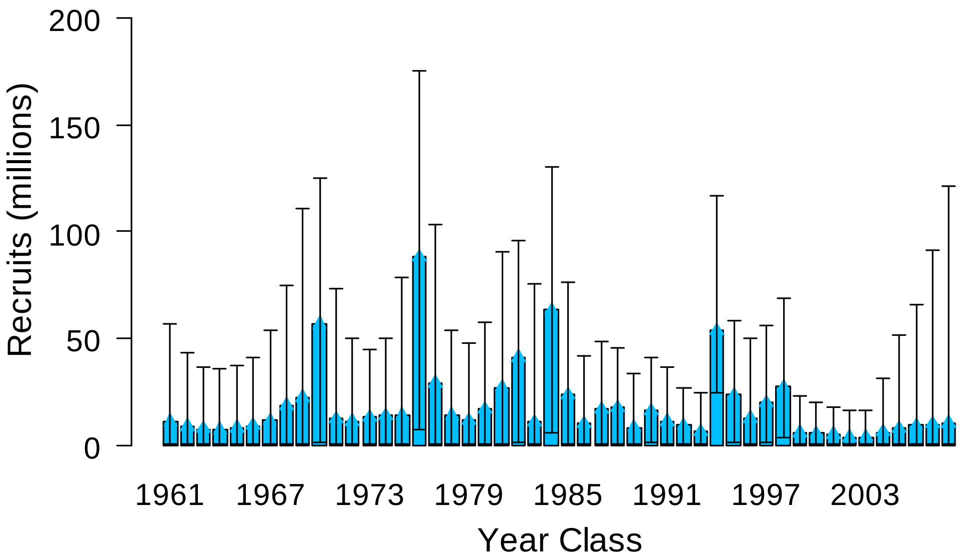

Figure 10.17. Estimates of year class strength and 95% confidence intervals for GOA northern rockfish based on the authors recommended model.

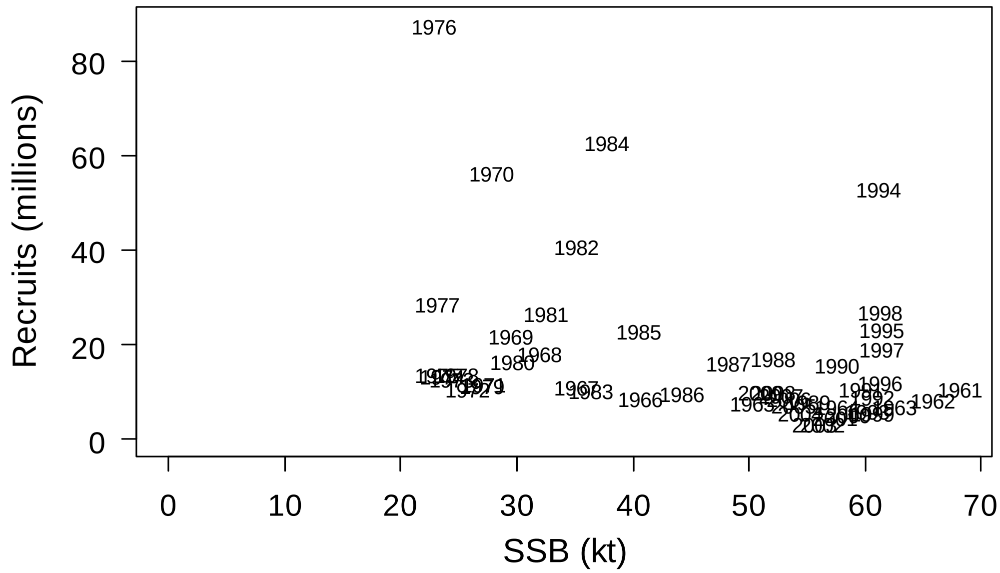

Figure 10.18. Relationship between female spawning stock biomass (SSB) and recruitment (by year class) for GOA northern rockfish based on the authors recommended model.

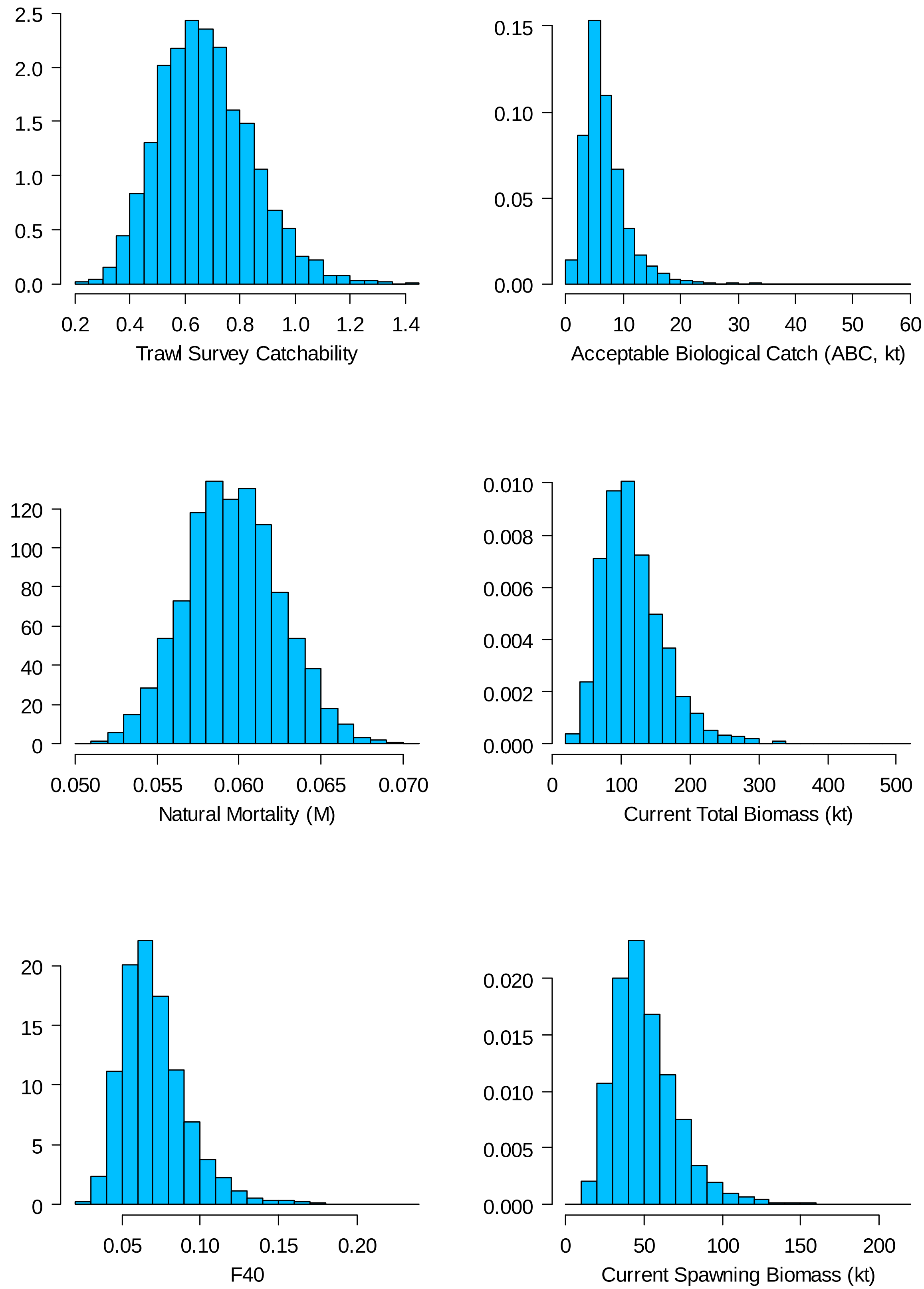

Figure 10.19. Histograms of estimated posterior distributions for key parameters derived from the MCMC for GOA northern rockfish.

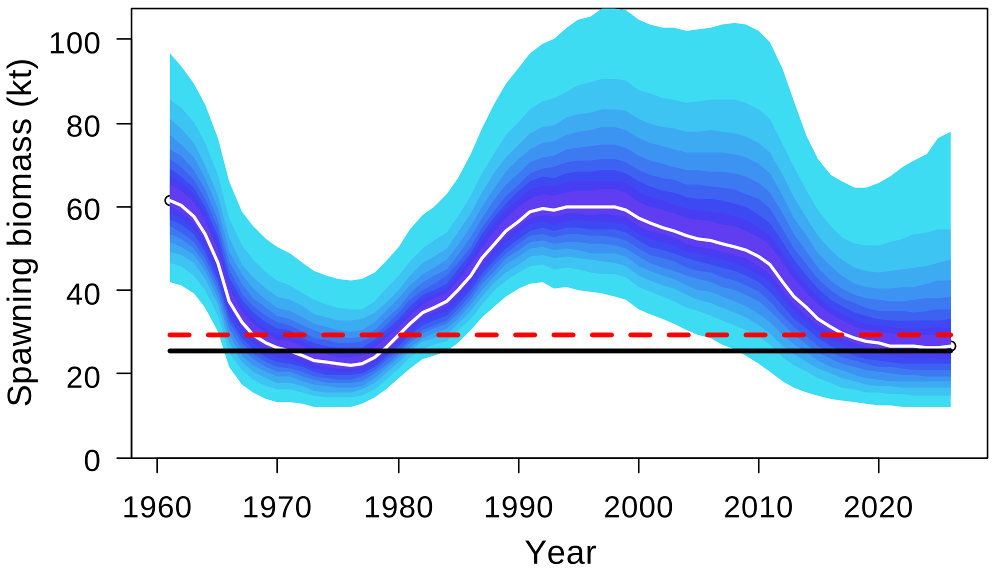

Figure 10.20. Bayesian credible intervals for entire spawning stock biomass series including projections through 2025. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1977-2009. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

Appendix 10A.—Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska.

The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities. This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For Gulf of Alaska (GOA) northern rockfish, these estimates can be compared to the research removals reported in previous assessments (Lunsford et al. 2009) (Table 10A.1). Northern rockfish research removals are minimal relative to the fishery catch and compared to the research removals for many other species. The majority of removals are taken by the Alaska Fisheries Science Center's (AFSC) biennial bottom trawl survey which is the primary research survey used for assessing the population status of northern rockfish in the GOA. Other research activities that harvest northern rockfish include other trawl research activities and minor catches occur in longline surveys conducted by the International Pacific Halibut Commission and the AFSC. There was no recorded recreational harvest or harvest that was non-research related of northern rockfish in 2010. Total removals from activities other than a directed fishery were less than 1 t in 2010. This is 0.02% of the 2011 recommended ABC of 4,857 t and represents a very low risk to the northern rockfish stock. Research harvests in recent years are higher in odd years due to the biennial cycle of the AFSC bottom trawl survey in the GOA. These catches vary greatly and in recent years have ranged from 7 – 27 t. Even research catches of this magnitude do not pose a significant risk to the northern rockfish stock in the GOA.

The second dataset, Halibut Fishery Incidental Catch Estimation (HFICE), is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011).

These estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between "retained" or "discarded" catch. These estimates should be considered a separate time series from the current CAS estimates of total catch. Because of potential overlaps HFICE removals should not be added to the CAS produced catch estimates. The overlap will apply when groundfish are retained or discarded during an IFQ halibut trip. IFQ halibut landings that also include landed groundfish are recorded as retained in eLandings and a discard amount for all groundfish is estimated for such landings in CAS. Discard amounts for groundfish are not currently estimated for IFQ halibut landings that do not also include landed groundfish. For example, catch information for a trip that includes both landed IFQ halibut and sablefish would contain the total amount of sablefish landed (reported in eLandings) and an estimate of discard based on at-sea observer information. Further, because a groundfish species was landed during the trip, catch accounting would also estimate discard for all groundfish species based on available observer information and following methods described in Cahalan et al. (2010). The HFICE method estimates all groundfish caught during a halibut IFQ trip and thus is an estimate of groundfish caught whether landed or discarded. This prevents simply adding the CAS total with the HFICE estimate because it would be analogous to counting both retained and discarded groundfish species twice. Further, there are situations where the HFICE estimate includes groundfish caught in State waters and this would need to be considered with respect to ACLs (e.g. Chatham Strait sablefish fisheries). Therefore, the HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery may become available following restructuring of the Observer Program in 2013.

The HFICE estimates of GOA northern rockfish catch are minimal indicating the halibut fishery does encounter northern rockfish but catches are likely low (Table 10A.2). The majority of catch likely occurs in the western and central GOA's as there is very little biomass of northern rockfish in the Eastern GOA. Estimated catches are near or below 1 t per year. Based on these estimates, the impact of the halibut fishery on northern rockfish stocks is minimal.

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Tribuzio, C.A., S. Gaichas, J. Gasper, H. Gilroy, T. Kong, O. Ormseth, J. Cahalan, J. DiCosimo, M. Furuness, H. Shen, K. Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams of the North Pacific Fishery Management Council.

Table 10A.1. Total removals of Gulf of Alaska northern rockfish (t) from activities not related to directed fishing, since 1977. Trawl survey sources are a combination of the NMFS echo-integration, small-mesh, and GOA bottom trawl surveys, and occasional short-term research projects. Other is longline, personal use, recreational, and subsistence harvest.

Year	Source	Trawl	Other	Total
1977	**Assessment of northern rockfish in the Gulf of Alaska (Heifetz et al. 2009)**	0		0
1978		1		1
1979		1		1
1980		1		1
1981		8		8
1982		6		6
1983		2		2
1984		11		11
1985		11		11
1986		1		1
1987		41		41
1988		0		0
1989		1		1
1990		19		19
1991		0		0
1992		0		0
1993		21		21
1994		0		0
1995		0		0
1996		13		13
1997		1		1
1998		2		2
1999		13		13
2000		0		0
2001		23		23
2002		0		0
2003		7		7
2004		0		0
2005		27		27
2006		0		0
2007		22		22
2008		0		0
2009		7		7
2010	AKRO	<1	<1	1

Table 10A.2. Estimates of Gulf of Alaska northern rockfish catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group. WGOA = Western Gulf of Alaska, CGOA = Central Gulf of Alaska, EGOA = Eastern Gulf of Alaska, PWS = Prince William Sound.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
WGOA	0	0	0	<1	0	0	0	0	0	0
CGOA-Shumagin	0	0	0	0	0	0	0	0	<1	0
CGOA-Kodiak	0	0	0	<1	0	0	0	0	0	0
EGOA-Yakutat/PWS*	0	0	0	0	0	0	0	0	0	0
EGOA-Southeast	0	0	0	0	0	0	0	0	0	0
Southeast Inside*	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	1	0	0	0	0	<1	0

*These areas include removals from the state of Alaska waters.