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

by

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Executive Summary

Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rockfish in on-cycle (odd) years, we present a full stock assessment document with updated assessment and projection model results.

As in 2013, 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 2013 assessment model with new data acquired since 2013 and present three new model improvements.

Summary of Changes in Assessment Inputs

Changes in input data: The input data were updated to include survey biomass estimates for 2015, survey age compositions for 2013, final catch for 2014 and preliminary catch for 2015, fishery age compositions from 2012, and fishery size compositions for 2013.

Changes in the assessment methodology: The assessment methodology has changed since the 2013 assessment and incorporates the following changes:

1. In the past trawl survey age samples were treated as if they were randomly collected when estimating growth. Growth is now estimated taking into account that ages are collected under a length-stratified sampling design.
2. The ageing error matrix was updated and extended to more appropriately model the ages at or near the plus age group. An ageing error matrix was constructed that extends the modeled ages compared to the ages fit in the data until >99.9% were in the plus age group of the data.
3. The plus age group has been set to 45+ to (1) ensure the plus age group proportion for all years is <10%, (2) ensure the plus age group proportion is less than the maximum proportion in the remainder of the age composition data, (3) minimizing age bins with zero samples, and (4) examining model fits and residuals.

Summary of Results

The 2016 projected age 2+ biomass is 77,596 t. The recommended ABC for 2016 is 4,008 t, the maximum allowable ABC under Tier 3a. This ABC is a 20% decrease compared to the 2014 ABC of 4,999 t and a 15% decrease from the projected 2016 ABC from last year. The OFL is 4,783 t. The corresponding reference values for northern rockfish recommended for this year and the following year are summarized in the table below along with corresponding values from last year's SAFE. Overfishing is not occurring, the stock is not overfished, and it is not approaching an overfished condition.

Quantity	As estimated or specified *last* year for: 2015	2016	As estimated or recommended *this* year for: 2016	2017[1]
M (natural mortality)	0.06	0.06	0.059	0.059
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	98,409	94,820	77,596	74,722
Projected Female spawning biomass	39,838	37,084	31,313	29,033
$B_{100\%}$	75,183	75,183	69,957	69,957
$B_{40\%}$	30,073	30,073	27,983	27,983
$B_{35\%}$	26,314	26,314	24,485	24,485
F_{OFL}	0.073	0.073	0.074	0.074
$maxF_{ABC}$	0.061	0.061	0.062	0.062
F_{ABC}	0.061	0.061	0.062	0.062
OFL (t)	5,961	5,631	**4,783**	4,501
maxABC (t)	4,999	4,722	4,008	3,772
ABC (t)	4,999	4,722	**4,008**	3,772
Status	As determined *last* year for: 2013	2014	As determined *this* year for: 2014	2015
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

[1]Projected ABCs and OFLs for 2016 and 2017 are derived using estimated catch of 4,223 for 2015, and projected catches of 3,576 t and 3,343 t for 2016 and 2017 based on realized catches from 2012-2014. This calculation is in response to management requests to obtain more accurate projections

The following table shows the recommended apportionment for 2016.

	Western	Central	Eastern*	Total
Area Apportionment	11.4%	88.5%	0.01%	100.00%
Area ABC (t)	**457**	**3,547**	**4**	**4,008**

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

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Northern rockfish	2014	102,893	6,349	5,324	5,324	4,277
	2015	98,409	5,961	4,999	4,999	3,848
	2016	77,596	4,783	4,008		
	2017	74,722	4,501	3,772		

Stock/ Assemblage	Area	2015 OFL	ABC	TAC	Catch[2]	2016 OFL	ABC	2017 OFL	ABC
Northern rockfish	W		1,226	1,226	977		457		430
	C		3,772	3,772	2,871		3,547		3,338
	E*						4		4
	Total	5,961	4,998	4,998	3,848	4,783	4,008	4,501	3,772

[1]Total biomass estimates from the age structured model.
[2]Current as of October 1, 2015 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 and is why this total differs from above.

SSC and Plan Team Comments on Assessments in General

"*The SSC requests that stock assessment authors utilize the following model naming conventions in SAFE chapters:*

- *Model 0: last years' model with no new data,*
- *Model 1: last years' model with updated data, and*
- *Model numbers higher than 1 are for proposed new models.*" (SSC, December 2014)

"*For this year's final assessments, the Teams recommend that each author of an age-structured assessment use one of the following model naming conventions ("TPA" represents the alternative described in the Team procedures document)…*" (Joint Plan Team, September 2015)

"*Of the options presented in the Joint Plan Teams minutes, the SSC agrees that that Option 4 has several advantages and recommends that this Option be advanced next year.*" (SSC, October 2015)

For this assessment, we will use the simplified convention suggested in the December SSC minutes and will investigate further detailed naming for the full next assessment cycle.

"The Team recommends using the random effects model, rather than the weighted survey average approach to the extent practical for POP and for rockfish in general [for apportionment]." (Plan Team, September 2014)

The SSC also requests that stock assessment authors utilize the random effects model for area apportionment of ABCs" (SSC, December 2014)

"*The Teams recommend that the random effects survey smoothing model be used as a default for determining current survey biomass and apportionment among areas.*" (Joint Plan Teams, September 2015)

For this assessment we are computing area apportionments following the recommended methodology of using the random effects smoothing model applied to the design-based survey biomass estimates. See the 'Area Apportionment of Harvests' section below for further details.

SSC and Plan Team Comments Specific to this Assessment

"For the GOA age-structured rockfish assessments, if length composition data are withheld, the Team recommends exploratory model runs to test sensitivity. This should include any year of fishery or survey length composition data which could serve as a proxy for the age composition, not simply the most recent survey year." (Plan Team, November 2013)

The GOA rockfish models do not utilize length frequency composition data from the trawl survey as an additional set of compositional data because it used in constructing the age composition data and the size-age conversion matrix. Other assessment authors use only the last year of survey size composition because ages are not yet available, and then remove them in the following assessment. An analysis including only the most recent year of the bottom trawl survey length composition data into the GOA rockfish assessment models was presented as Appendix 9B in the 2014 GOA Pacific ocean perch assessment (Hulson et al., 2014) and reviewed by the PT and SSC. Overall, the results of this analysis suggest that the usefulness of including the most recent year's bottom trawl survey length composition is case specific but does not significantly influence model performance in general. Unless we were to fit the entire series of survey length composition data in the model, we continue to support excluding the last year's length composition in isolation in the interest of model stability and consistency. Therefore, we recommend that the status quo assessment model that does not include the most recent year's survey length composition continue to be used for northern rockfish.

"For assessments involving age-structured models, this year's CIE review of BSAI and GOA rockfish assessments included three main recommendations for future research: Authors should consider: (1) development of alternative survey estimators, (2) evaluating selectivity and fits to the plus group, and (3) re-evaluating natural mortality rates. The SSC recommends that authors address the CIE review during full assessment updates scheduled in 2014." (SSC, December 2013)

An AFSC response to the rockfish CIE review was prepared that addresses some of their concerns. Please refer to the "Summary and response to the 2013 CIE review of the AFSC rockfish" document presented to the September 2013 Plan Team for further details (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/2013_Rockfish_CIE_Response.pdf). Specifically, in response to SSC comments above:

1. In this assessment we provide an additional model case that includes alternative methodology for computing survey biomass estimates based on a geostatistical generalized linear mixed model (presented in Appendix 12B of the GOA dusky rockfish SAFE). This approach provides an alternative methodology for estimating biomass from catch data than the traditional design-based estimates commonly used. This alternative estimator generates biomass estimates that are much more reasonable for a slow growing long lived species such as northern rockfish and results in improved model fits to this time series. We will investigate this approach further, including model changes that would need to be made prior to implementing a more precise index, and bring forth results in the next full assessment.

2. In September, 2015, three GOA rockfish modeling updates were presented: using a length-stratified design rather than random design for growth estimation, extending the ageing error matrix to more appropriately model the plus age group, and examining the best age for the plus group age bin. In this assessment we present alternative model runs and incorporate all of these changes in the recommended model.

3. Natural mortality for northern rockfish is estimated within the model.

"The Team asks the [rockfish] *authors to investigate whether the conversion matrix has changed over time. Additionally, the Team requests that the criteria for omitting data in stock assessment models be based upon the quality of the data (e.g. bias, sampling methods, information content, redundancy with other data, etc.) rather than the effect of the data on modeled quantities."* (Plan Team, November 2011)

In September, 2015, three GOA rockfish modeling updates were presented: using length-stratified methods rather than random methods for growth estimation, extending the ageing error matrix to more appropriately model the plus age group, and examining the best age for the plus group age bin. In this assessment we present alternative model runs incorporating all of these changes.

"The SSC also looks forward to an update of weight-at-age, length and age transition matrices, ageing error matrix, and length bins for fishery length compositions during the next assessment cycle." (SSC, December 2011)

In September, 2015, updates to the ageing error matrix and length-stratified methodology for growth estimation (including weight-at-age and the length and age transition matrices) were presented and are included in this year's recommended assessment model. No changes have been made to the fishery length bins at this time, but will be further investigated for the next full assessment for northern rockfish.

"The SSC recommends that the authors explore and evaluate alternative approaches to constructing the trawl survey biomass and consider recommendations from the survey averaging work group for apportionment. The SSC recommends including work on maturity for northern rockfish as a research priority." (SSC, December 2013)

In this year's assessment we provide an additional model run that utilizes a geostatistical estimator of the trawl survey biomass for comparison with the design-based trawl survey biomass that has been used in the northern rockfish assessment. We do not use this as our preferred model, however, due to a number of model changes that would be necessary to properly model a more precise index (more details provided below in the 'Results of Model Selection' section). We will be investigating the use of this estimator more thoroughly with the intention of using it in the next full assessment for northern rockfish. The random effects model recommended by the survey averaging working group has been used for apportionment in this year's assessment. We are currently working with AFSC RACE division members to construct a proposal that will sample northern rockfish maturity over several years which will enable us to investigate time-dependent changes in maturity for northern rockfish.

The Team recommends moving forward with these three improvements and encourages the authors to further examine choosing the appropriate plus age groups. To facilitate model evaluation, the Team recommends the authors present the two alternative models suggested. (Plan Team, September 2015)

The improvements identified by the Plan Team (length-stratified growth, ageing error matrix extension, and plus age group analysis) have been incorporated in the recommended model for this year's northern rockfish assessment.

The SSC suggests that Dr. Hulson should also explore the utility of delay-difference models as an alternative way to model the plus age group. Dr. Quinn and others have published on this approach. (SSC, October 2015)

The methodology suggested by Deriso and others to account for differing growth in the plus age group is analogous to the correction employed in previous rockfish models to set the weight at age of the plus group to 1/2 the difference between the age before the plus group and w_infinity. However, with the recommended increases in plus group, they are very near w_infinity, and these approximations are no longer necessary.

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 Kuril 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. Like other *Sebastes* species, northern rockfish are presumed to be ovoviviparous 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 as among the most common commercial fish captured with gorgonian corals (primarily *Callogorgia*, *Primnoa*, *Paragorgia*, *Fanellia*, *Thouarella*, and *Arthrogorgia*) in NMFS trawl surveys of Gulf of Alaska and

Aleutian waters. Krieger and Wing (2002) identified six rockfish species associated with gorgonian coral (*Primnoa spp.*) from a manned submersible in the eastern Gulf of Alaska. Research focusing on non-trawlable habitats found rockfish species often associate with biogenic structure (Du Preez et al., 2011, Laman et al., 2015). However, most of these studies did not specifically observe northern rockfish, 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. Some literature suggests that environmental factors may affect the condition of female rockfish that contributes to reproductive success (Hannah and Parker, 2007; Rodgveller et al. 2012; Beyer et al. 2015). 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 slightly older (maximum age 72) than Gulf of Alaska northern rockfish (maximum age 67), the difference in age could be due to sampling variability. There have been two studies on the genetic stock structure of northern rockfish. One study of northern rockfish provided no evidence for genetically distinct stock structure when comparing samples from near the western Aleutian Islands, the western Gulf of Alaska, and Kodiak Island (Gharrett et al. 2003). The results from that study were considered preliminary, and sample sizes were small. Consequently, the lack of evidence for stock structure did not necessarily confirm stock homogeneity. A more recent study did find spatial structure on a relatively small scale for northern rockfish sampled from several locations in the Aleutian Islands and Bering Sea (Gharrett et al. 2012).

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” area, the results indicated there were year-after-year drops in both fishery and survey CPUE for northern rockfish. 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), and Kamin et al. (2013) concluded that fine-scale genetic heterogeneity for Pacific ocean perch in Alaska was not the influence of a sweepstakes effect. 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

From 1988-1993, the North Pacific Fishery Management Council (NPFMC) 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 a complex of all other species of slope rockfish, including northern rockfish. In 1993, a fourth management subgroup, northern rockfish, was also created. In 2004, rougheye rockfish and shortraker rockfish were also split and managed separately. 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. In the assessments after 1991 and until this year’s assessment, 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. In this year’s assessment ABC and TAC is apportioned to the three management areas in the Gul of Alaska with the random effects model developed by the Plan Team survey averaging working group. 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 east of 140 degrees W. longitude in the Eastern GOA. 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. This probably does not have a major effect on northern rockfish populations because their abundance in the Eastern area is low.

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 was to enhance resource conservation and improve economic efficiency for harvesters and processors in the rockfish fishery. An additional objective was to spread out the fishery in time and space, allowing for enhanced market conditions 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, and 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 (see Figure 10.1in Hulson et al. 2013)). 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 implementation of the 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 1961-2015 is summarized by foreign, joint venture, and domestic fisheries (Table 10.2 and Figure 10.1).

Catches of GOA northern rockfish during the years 1961-1976 were estimated as 5% of the foreign GOA Pacific ocean perch catch in the same years. A Pacific ocean perch trawl fishery by the U.S.S.R. and Japan began in the Gulf of Alaska in the early 1960's. This fishery developed rapidly with massive efforts by the Soviet and Japanese fleets. Catches peaked in 1965 when a total of nearly 350,000 metric tons (t) were 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 1993-2015 have ranged from 2,935 t to 5,966 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 – 2015. 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 in the GOA rockfish fishery from 2010-2015 are shown in Table 10.3. For the GOA rockfish fishery during 2010-2015, the largest non-rockfish bycatch groups are Atka mackerel (1,218 t/year), walleye pollock (937 t/year), arrowtooth flounder (895 t/year), and Pacific cod (612 t/year). Non-FMP species catch in the rockfish target fisheries is dominated by giant grenadier and miscellaneous fish (Table 10.4). However, the amounts from hauls targeting northern rockfish are likely much lower as this includes all rockfish target hauls.

Prohibited species catch in the GOA rockfish fishery is generally low for most species. Catch of prohibitted and non-target species generally decreased with implementation of the Central GOA Rockfish Program (Hulson et al. 2013). The only increase of prohbited species catch observed in 2015 was in halibut catch, which was nearly 20 tons greater than the 2014 catch (Table 10.5). Chinook salmon catch was lower than the five year average in both 2014 and 2015.

Gulfwide discard rates (% discarded) for northern rockfish in the commercial fishery for 1993-2015 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
Year	2011	2012	2013	2014	2015				
% Discarded	3.9	2.5	4.1	3.9	4.1				

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-**2015**
NMFS bottom trawl surveys	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, **2015**
NMFS bottom trawl surveys	Age	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, **2013**
U.S. trawl fisheries	Age	1998, 1999, 2000, 2001, 2002, 2004, 2005, 2006, 2008, 2010, **2012**
U.S. trawl fisheries	Length	1990,1991,1992, 1993, 1994, 1995, 1996, 1997, 2003, 2007, 2009, 2011, **2013**

Fishery data

Catch

Catch of northern rockfish range from 185 t to 17,430 t during 1961 to 2015. Detailed description of catch is provided above (within the "*Description of the catch time series*" section) and in Table 10.2 and Figure 10.1.

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 10.2 and age compositions are presented in Table 10.7 and Figure 10.3; 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 were 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 – 2015. 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 10.4). 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). The 2013 biomass estimate (370,454 t) is the highest estimated biomass on record and is similar to the 2005 estimate. This increase is largely explained by a three-fold increase in the Chirikof region. The 2015 biomass estimate is the second lowest on record (48,933 t), however, and is 77% smaller than the 2013 estimate (Table 10.8). 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 10.4). In both 1999 and 2001, a single very large survey haul of northern rockfish greatly increased the biomass estimates and resulted in wide confidence bounds. The haul in 2001 was the largest individual catch (14 t) of northern rockfish ever taken during a Gulf of Alaska survey. In contrast, the 2005 and 2007 survey had several large hauls of northern rockfish in the Central Gulf and confidence bounds were narrower (Figure 10.4). 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 2013 survey had several large catches in the Chirikof region but relatively low catches in other areas resulting in a CV of 60% (Figure 10.5). The 2015 biomass estimate was much more precise and had a CV of 34%, similar to other low biomass estimates from past surveys. The highly variable biomass estimates for northern rockfish suggest that an alternative to the design-based estimators may be useful to reduce the variability in biomass estimates. Appendix 12B of the GOA dusky rockfish assessment describes an alternative geostatistical generalized linear mixed model (GLMM) presented in Thorson et al. (2015) to the standard design-based trawl survey biomass index. We do not used this model-based index in the recommended model for this year due to several issues that would need to be addressed within the model prior to its implementation (described in further detail below). However, we present some results in the following sections using this model-based trawl survey biomass index within the northern rockfish assessment model to show the potential improvements this index could have on the assessment.

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 10.6) 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, 2009 and 2011) 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 10.7). In years with age readings, trawl survey size composition data are multiplied by an age-length key (computed from length-stratified otolith collections) to obtain survey age compositions. 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); especially in recent years. Also similar to the fishery age compositions, the proportion of older fish older has been increasing since the mid to early 2000s.

Maturity Data

In previous stock assessments for northern rockfish, age at maturity was 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). A more recent study reevaluating maturity of northern rockfish (Chilton 2007, n=157) has been published, providing additional information for maturity-at-age. This study collected ovarian samples from female northern rockfish throughout the year in both 2000 and 2001. In a report submitted to the GOA Groundfish Plan Team in September 2010, the two studies were compared and the advantages and disadvantages of the different approaches for studying maturity (histology versus visual inspection) were discussed (Rodgveller et al. 2010). In this year's assessment, as in the 2011 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 (Figure 10.8). There could 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 (Fournier et al. 2012). 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 1961-2015. 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.

Model Selection

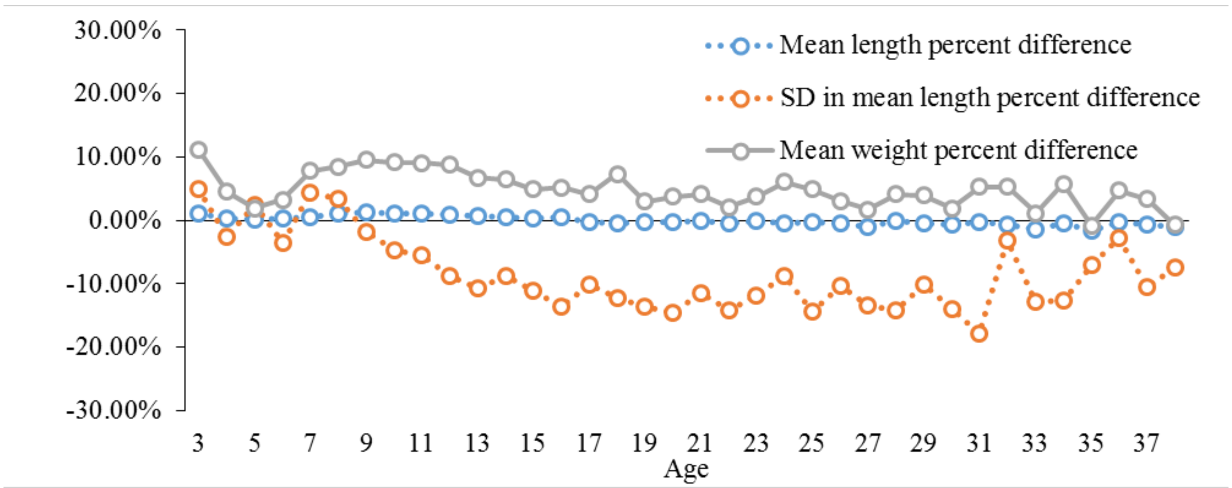
In total, three changes were made to input data and model configuration in this year's assessment compared to the 2013 assessment. We present these changes in a step-wise manner, building upon each previous model change to arrive at the preferred model for this year's assessment. The following table provides the model case name and description of the changes made to the model.

Model case	Description
M0	2013 model
M1	Same model as 2013, but with updated data
M2	Model M1, with length-stratified estimates of growth parameters for weight-at-age and size-age conversion matrix
M3	Model M2, with extension of the number of ages in the model compared to the number of ages in data within the ageing error matrix
M4	Model M3, with extension of the plus age group
Additional model run investigated	
M5	Model M4, with alternative model-based bottom trawl survey index

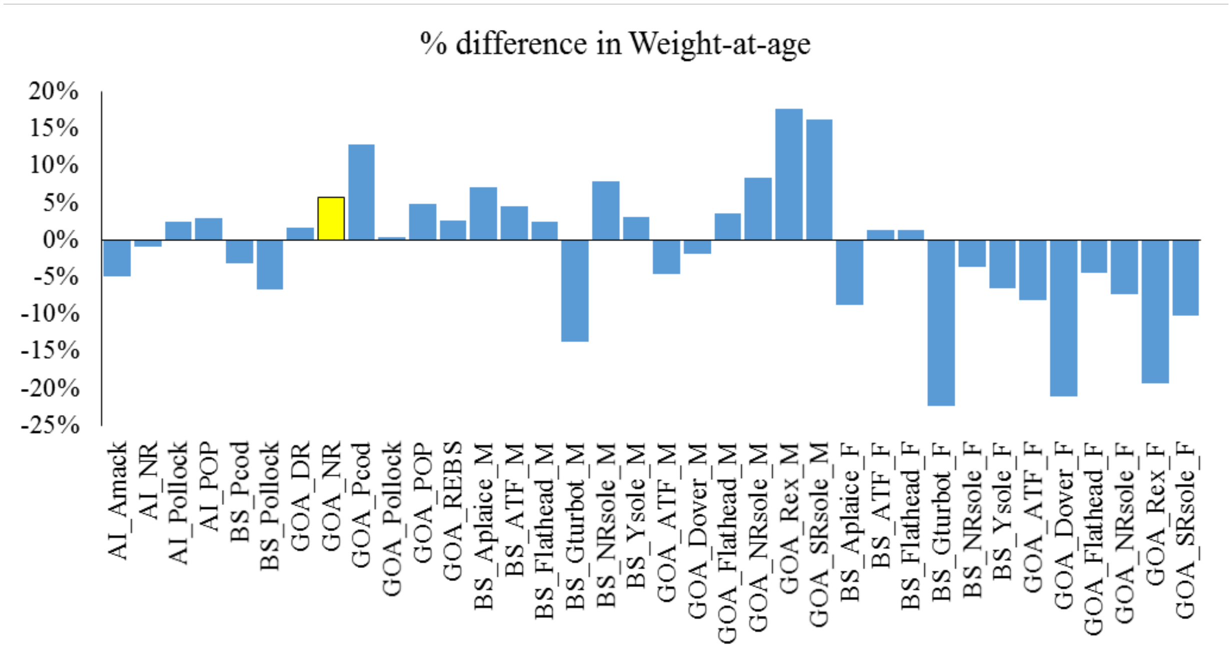
Note, each additional model case includes the changes made to the model in the previous model case. For example, model case M3 would also include length-stratified estimates of growth from model case M2 in addition to the extension of the ageing error matrix. A brief description of each model changed is provided below.

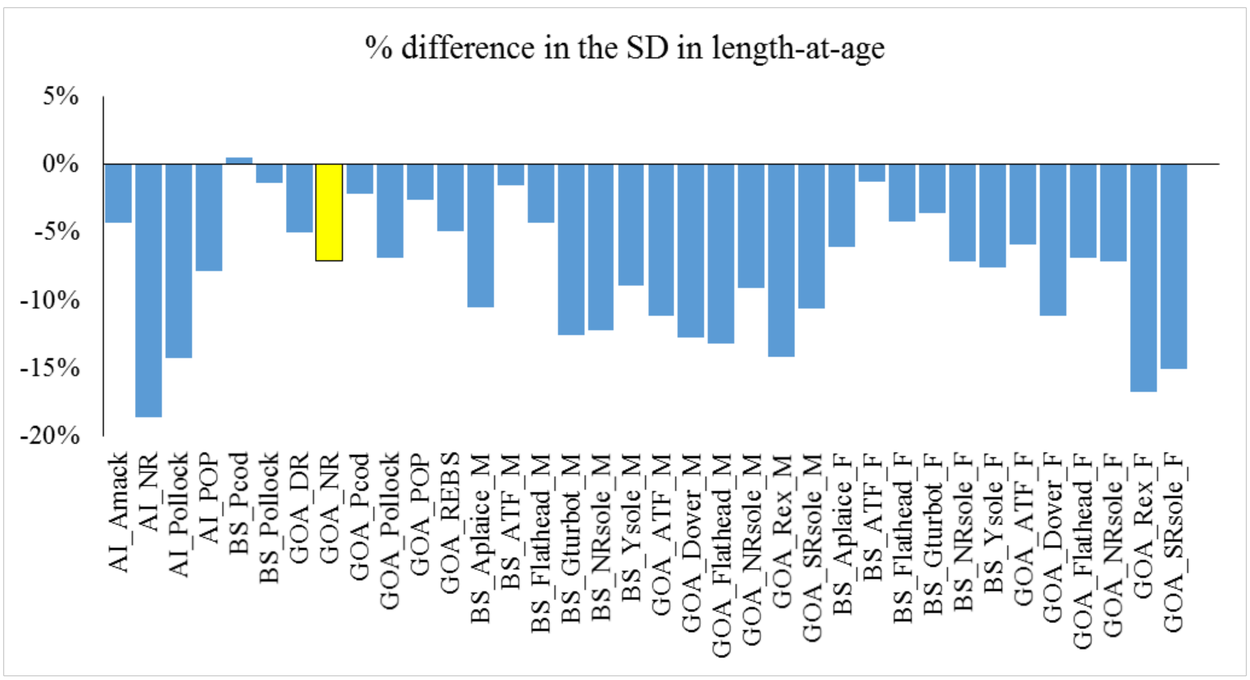
M2 – Length-stratified growth

Otolith collections for rockfish in the AFSC bottom trawl survey are done following a length-stratified design (i.e., a specified number of otoliths are collected for each length category). Corresponding growth estimates are then derived from these samples. In previous rockfish assessments growth observations have been treated as if they were collected randomly, rather than following the length-stratified sampling design of the survey. In this year's assessment we use new estimates of growth, for weight-at-age and the size-age conversion matrix used in the assessment model, based on length-stratified methods rather than random methods (Quinn and Deriso 1999, Bettoli and Miranda 2001). The following figure compares the percent difference between random and length-stratified mean length, standard deviation (SD) in mean length, and mean weight (positive values indicate that the mean value from random methods is larger than the mean value from length-stratified methods).



Overall, the differences in mean length were small between length-stratified and random methods. However, the SD in mean length was, on average, about 8% smaller from length-stratified methods compared to random methods and had the largest differences for ages greater than around 10. Mean weight was, on average, about 7% larger from length-stratified methods compared to random methods and for some ages could be upwards of 10% larger. These average percent differences between length-stratified methods and random methods in weight-at-age and the SD in length-at-age are not uncommon when investigating the differences for other species, however. The following plots show the average percent difference (across age) in weight-at-age and the SD in length-at-age across a number of the Tier 3 species at AFSC (GOA northern rockfish is highlighted in yellow).

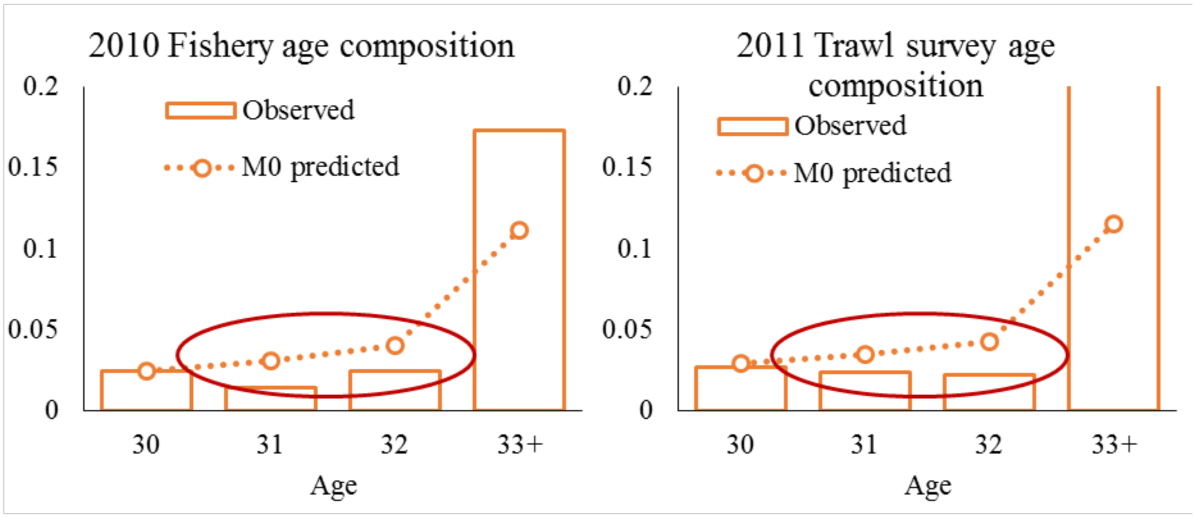




Compared with other species assessed at AFSC, the average percent difference in weight-at-age for northern rockfish is similar to most species with positive weight-at-age differences. The percent differences in the SD in mean length-at-age between length-stratified and random methods for northern rockfish is also similar to other species differences. In the following section, ‘Parameters Estimated Outside the Assessment Model’, the parameter estimates from the von Bertalanffy growth curve that are shown were obtained from length-stratified methods to determine mean length and weight. This data change is reflected in model case M2 and is used in all the following model cases M3 – M5.

M3 – Extension of ageing error matrix

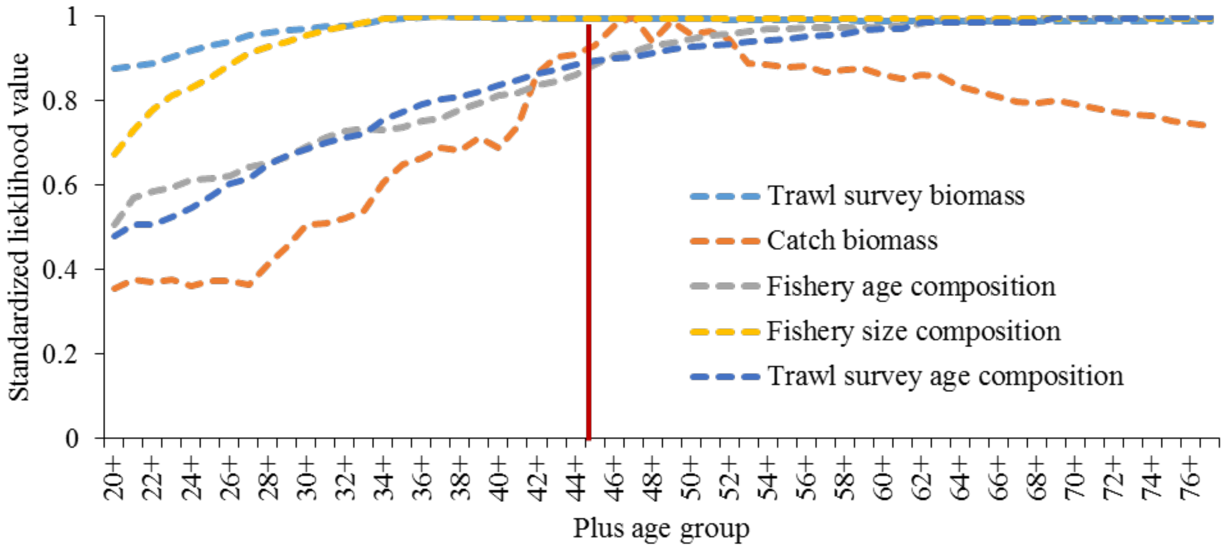
Previous assessments have noted that the model consistently over-estimated the proportions-at-age in the age classes adjacent to the plus age group in the bottom trawl survey and fishery age composition datasets. An example of the 2013 model fit to the most recent fishery and trawl survey age compositions is shown in the following figure (shown are the last 4 age classes for presentation, with circles identifying the ages with lack of fit from the model).



Further investigations revealed that this was due to the construction of the ageing error matrix. In its current form, the ageing error matrix distributes the fish in the plus age group based on the ageing error of the first age in the plus age group. For example, in the 2013 northern rockfish assessment the plus age group was started at age-33. Thus, the distribution of fish in the plus age group into age classes younger than the plus age group were based on the ageing error of age-33, rather than based on the ageing error of all the fish age-33 and older. This translates into a greater probability of fish in the plus age group being in the adjacent age classes that are younger than the plus age group than would be present for all fish older than the plus age group. This explains the consistent over estimation shown in the figures above. In model case M2 we provide an alternative ageing error matrix that extends the plus age group in the model compared to the plus age group in the data until 99.9% of the fish in the model's plus age group are within the plus age group of the data. Using this improved ageing error matrix vastly improves model fit to the age classes adjacent to the plus age group for both fishery and survey age compositions. This form of the ageing error matrix is also used in the following model cases M4 and M5.

M4 – Setting the plus age group

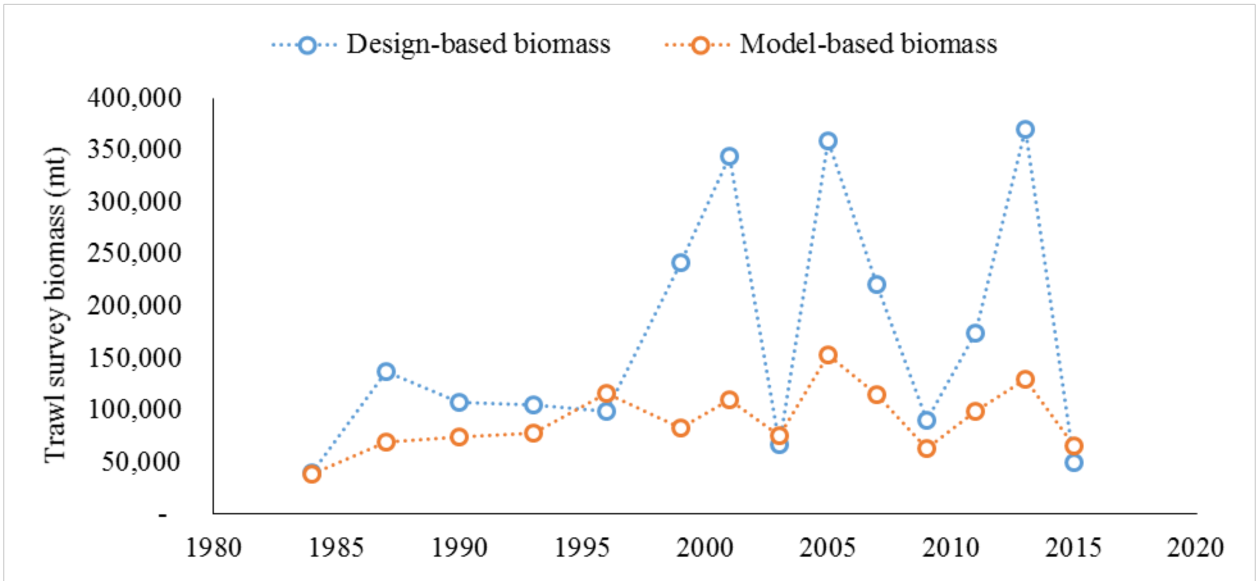
In both the GOA and BSAI rockfish assessments investigations have been devoted to determining the appropriate plus age group for the data fit by the assessment model (e.g., Hulson et al. 2011, Spencer and Ianelli 2012). These investigations evaluated the changes to the likelihood values of the fitted data in the model to determine the appropriate age group. Unfortunately, these investigations have not given clear guidance as to where to set the plus age group. Following SSC and Plan Team guidance, in model case M3 we extend the plus age group of the data until (1) <10% of the age composition is within the plus age group and (2) the proportion in the plus age group is less than the maximum proportion within the remainder of the age composition. For GOA northern rockfish this results in a plus age group starting at age-45. The following figure shows where this plus age group of 45+ is in relation to the standardized negative log-likelihood values for the fitted datasets when changing the plus age group from age-20+ to age-77+.



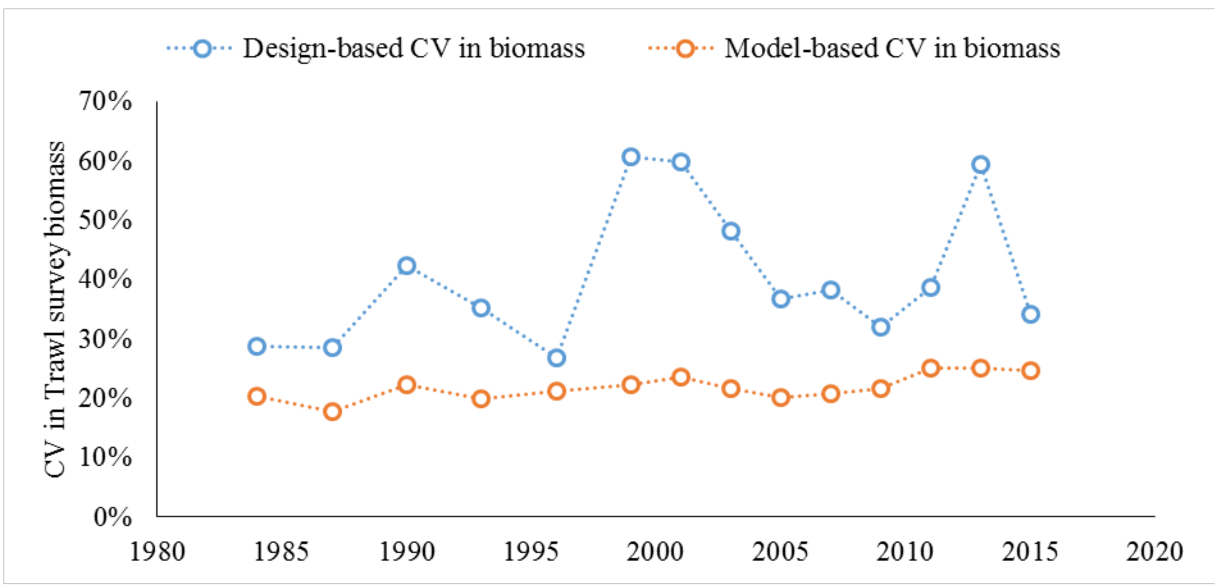
At a plus group of age-45+ the negative log-likelihoods for trawl survey biomass and fishery size have plateaued, indicating further changes to the plus age group to these negative log-likelihoods is negligible. At this plus age the catch negative log-likelihood is near its maximum. However, it should be noted that the catch negative log-likelihood value is very small in this model. The age composition's negative log-likelihoods for both the fishery and survey at this plus age are increasing, but more slowly than at younger plus age groups. In model case M4 we set the plus age at age-45+, and use this plus age group (along with the changes made in model cases M2 and M3) in the preferred assessment model for this year.

Additional model run: M5 – Alternative trawl survey biomass

As noted in the 'Data' section, the trawl survey estimates of biomass for northern rockfish are highly variable, both within and across years. As described in Appendix 12B of the dusky rockfish assessment (Lunsford et al. 2015), an alternative method to estimate the trawl survey biomass has been constructed based on a geostatistical estimator (e.g., Thorson et al. 2015). The following figure compares the biomass estimates from the design-based survey biomass, which is currently used in the northern rockfish assessment, and the alternative model-based biomass index.



The alternative model-based biomass reduces the inter-annual variability in the biomass estimates from the trawl survey compared to the design-based values by over 90%. Note that the years with extremely large biomass estimates from the design-based method (e.g., 1999, 2001, 2005, 2013) are in years where a small number of large catches in the trawl survey are extremely influential. However, the influence of these large catches is reduced in the model-based trawl survey biomass index, resulting in a more consistent time series of trawl survey biomass. The following figure compares the CVs in the design-based and modeled trawl survey biomass.



The average CV in trawl survey biomass from the design-based method across years is ~41% and can reach upwards of 60% in some years, whereas the average CV in biomass from the model-based index is ~22%. This results in a decrease of over 45% in the average trawl survey biomass CV.

One attribute of the northern rockfish assessment model that was applied in previous assessments, in order to accommodate the highly variable design-based trawl survey biomass estimates, is that the weight applied to the negative log-likelihoods of the age and length composition data were set at 0.5 in order for the model to more precisely fit the design-based biomass index. Upon applying the more precise alternative bottom trawl survey biomass index in model case M5 we also set the weighting for the age and length composition negative log-likelihoods to 1.

Parameters Estimated Outside the Assessment Model

A von Bertalanffy growth curve was fitted to survey size at age data from 1984-2013 using length-stratified methods (Quinn and Deriso 1999, Bettoli and Miranda 2001). Sexes were combined. An age to size conversion matrix was then constructed by adding normal error with a standard deviation equal to the survey data for the probability of different sizes for each age class. 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 from length-stratified methods are shown below:

L_∞=41.72 cm κ=0.16 t_0=-0.34

The previous assessments growth curve parameters were:

L_∞=39.9 cm κ=0.18 t_0=-0.22

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

W_∞=1124 g a=1.23 x 10^{-5} b=3.04

The previous assessments growth parameters for weight were:

W_∞=984 g a=9.16 x 10^{-6} b=3.09

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 between-reader percent agreement tests conducted at the AFSC Age and Growth lab. We fix the variability of recruitment deviations (σ_r) at 1.5 which allows highly variable recruitment.

Parameters Estimated Inside the Assessment Model

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 on 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-at-age is modeled with the logistic function, similar to selectivity-at-age for the survey and fishery. The fit to the two studies that have provided maturity data for northern rockfish from the model is shown in Figure 10.8.

The numbers of estimated parameters from the model 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	102
Spawners-per-recruit levels	$F_{35\%}, F_{40\%}, F_{50\%}$	3
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	55
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		170

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 170. 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 1,000,000 iterations out of 10,000,000 and “thinned” the chain to one value out of every four thousand, leaving a sample distribution of 4,500. 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
$\hat{I}_y = q * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$	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

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Formulae for likelihood components **<u>BOX 1 (Continued)</u>**

$L_1 = \lambda_1 \sum_y \left(\ln\left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$	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
$L_7 = \frac{1}{2\sigma_q^2}\left(\ln \left. q \middle/ q_{prior} \right. \right)^2$	Penalty on deviation from prior distribution of catchability coefficient
$L_8 = \frac{1}{2\sigma_{\sigma_r}^2}\left(\ln \left. \sigma_r \middle/ \sigma_{r(prior)} \right. \right)^2$	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

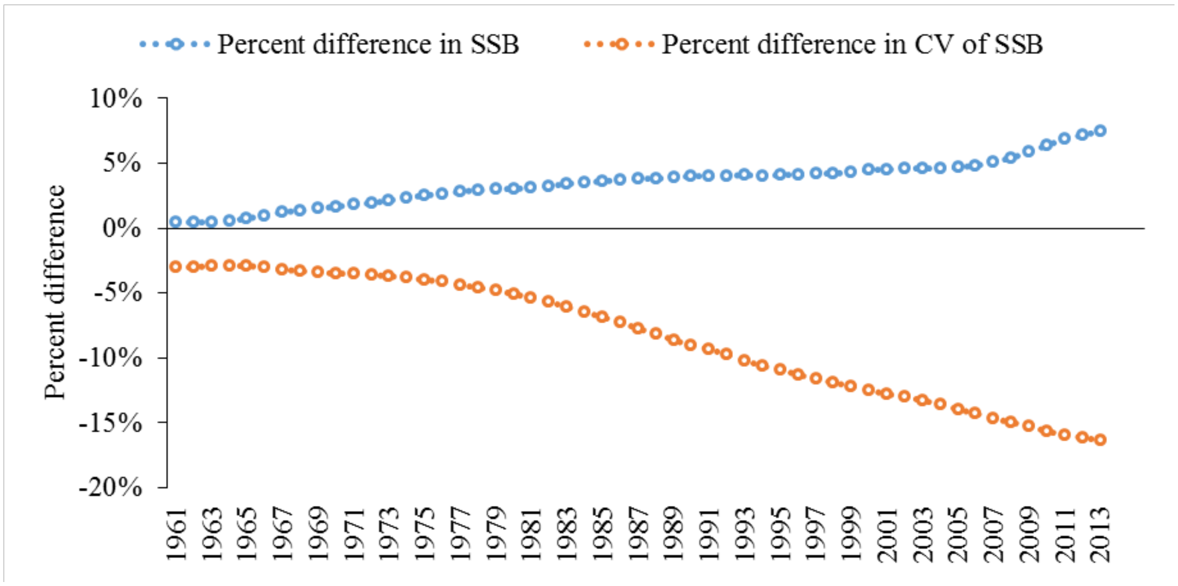
Results

Results of Model Selection

Before presenting the standard model results, in this section we will present the results of each of the alternative model cases in a stepwise manner, ultimately arriving at the recommended assessment model for this year. Results investigated include the changes in model results for each model case as well as the model output uncertainty and objective function values.

M1 – 2013 model with updated data

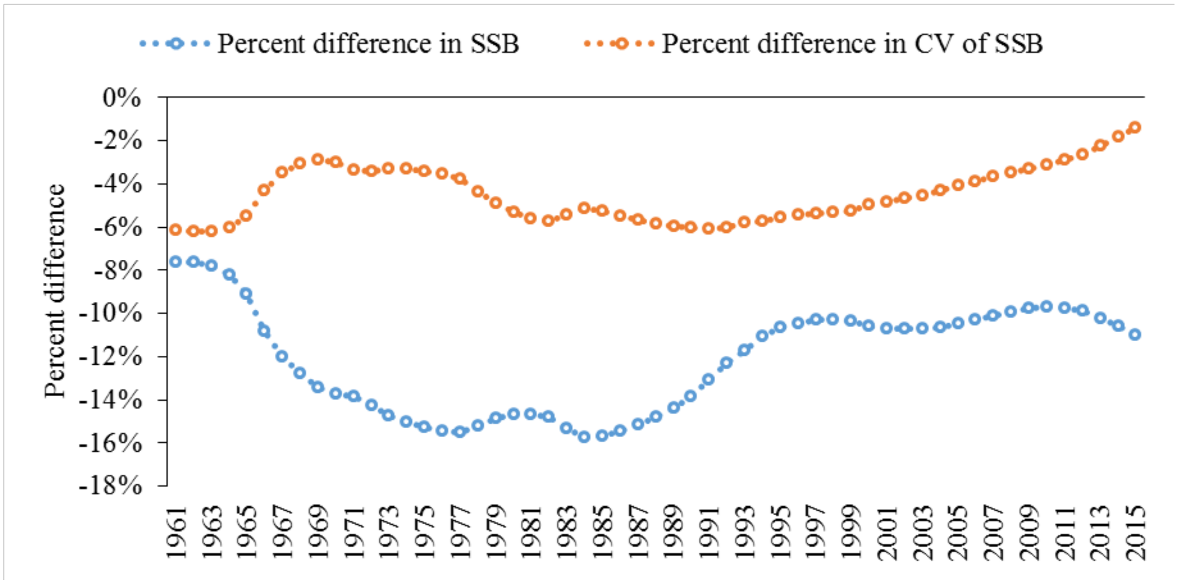
With the update of data to 2015 the overall objective function value increases, as would be expected with the additional data being fit by the model (Table 10.11). The catchability parameter decreases from the 2013 value of 0.60 to 0.57 with the additional 2015 design-based survey biomass estimate, and mean recruitment decreases from 17.27 million in 2013 to 16.98 million in 2015. The following figure shows the percent difference in spawning biomass and the CV in spawning biomass for model case M1 compared to M0 (negative values indicate estimates that are smaller in model case M1 compared to M0).



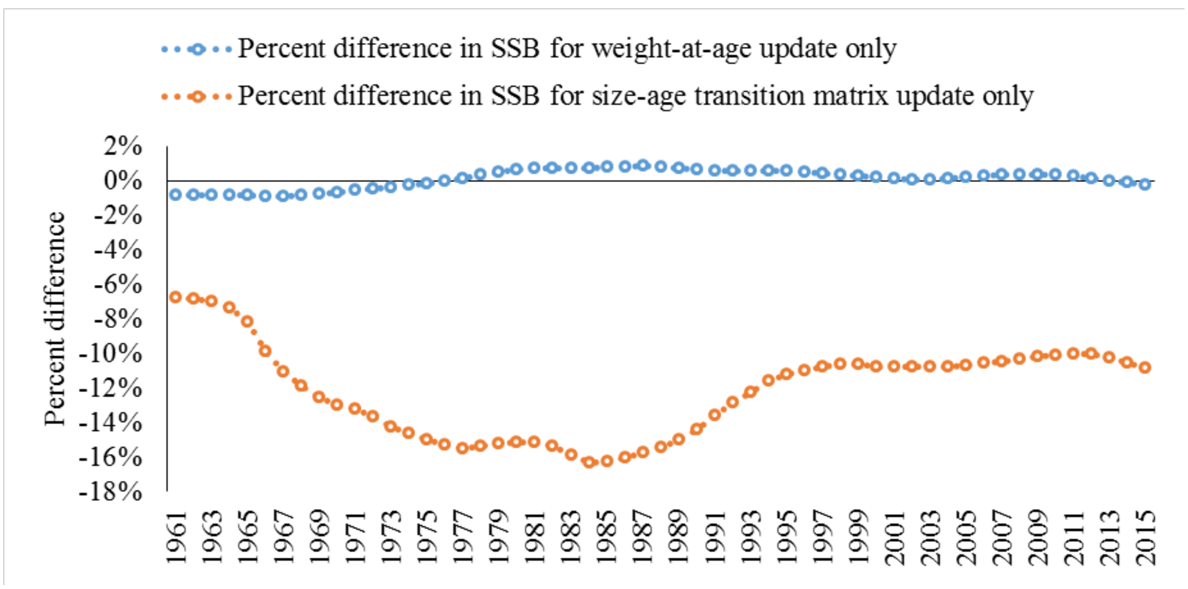
The average increase in spawning biomass from the 2013 assessment (model case M0) and the same model with updated data to 2015 (model case M1) was around 5%, reaching a maximum increase of 7% by 2013. The CV in spawning biomass also decreased compared to the 2013 assessment. This increase in estimated spawning biomass can be attributed to the decrease in the trawl survey catchability parameter.

M2 – Length-stratified growth

When length-stratified growth estimates are used in the assessment model for mean weight and the size-age transition matrix the overall data negative log-likelihood increases (Table 10.11). Decreases in the negative log-likelihood values compared to model case M1 (the same model as 2013 but with updated data) occurred for the trawl survey biomass and fishery age composition negative log-likelihoods, while increases occurred for the trawl survey age composition and fishery size composition negative log-likelihoods. The following figure shows the percent difference in spawning biomass and the CV in spawning biomass for model case M2 compared to M1 (negative values indicate estimates that are smaller in model case M2 compared to M1).



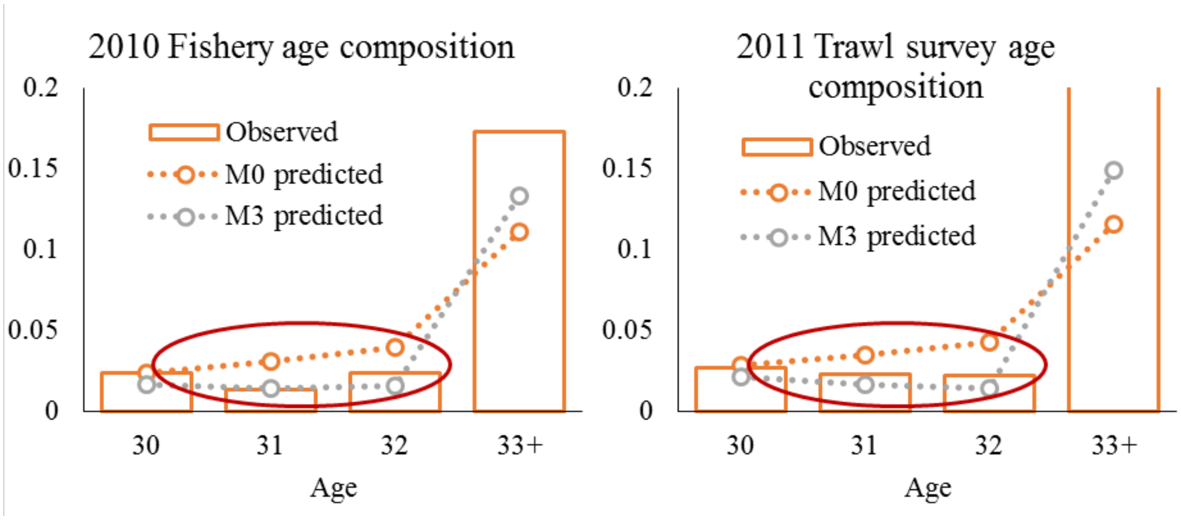
Overall, the spawning biomass in model case M2 compared to M1 decreases by about 12% across the time series, and the CV in spawning biomass is also smaller in model case M2 than model case M1 by around 5%. This decrease in spawning biomass resulting from model case M2 compared to model case M1 is due to the change in the SD's for mean length-at-age used in the size-age transition matrix. The following figure shows the percent difference in spawning biomass upon updating the mean weight only and updating the size-age transition matrix only.



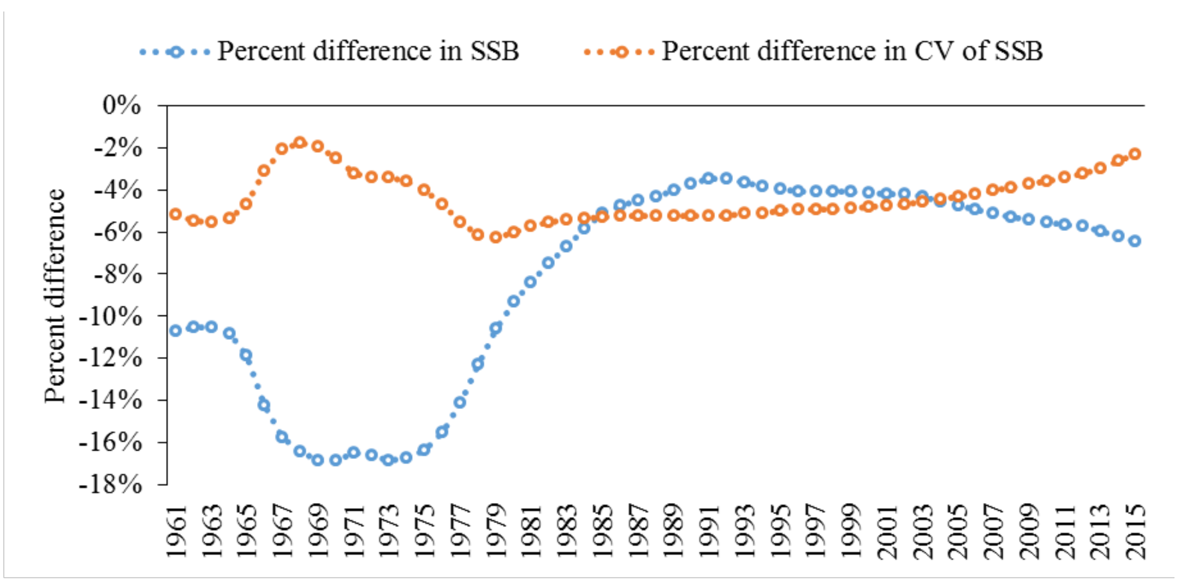
Updating the mean weight-at-age with length-stratified methods had a relatively small influence on the results of model case M2 compared to model case M1, whereas updating the size-age transition matrix with length-stratified methods had the largest influence on the model results when comparing between model case M2 and model case M1. The only length composition data that is fit in the assessment is from the fishery, and these results highlight the influence of this data on the model when the SD's in mean length are used from length-stratified methods compared to random methods. As it is more appropriate to model growth using the same methods as those used when collecting the data (length-stratified), we recommend that in this year's assessment and in future assessments growth be modeled using length-stratified methods. The results from the following model cases (M3 – M5) all use length-stratified estimates of growth.

M3 – Extension of ageing error matrix

When the extended ageing error matrix is utilized in model case M3 to more properly model the plus age group and the adjacent age classes the data negative log-likelihood decreases by around 8% in model case M3 compared to model case M2 (Table 10.11). This decrease is attributed to large decreases in the negative log-likelihoods of the age composition datasets, the fishery age composition negative log-likelihood decreases by 21% and the trawl survey age composition negative log-likelihood decreases by 18%. The following figures use the example age composition years for the fishery and trawl survey age composition shown above, with comparison to results from model case M3.



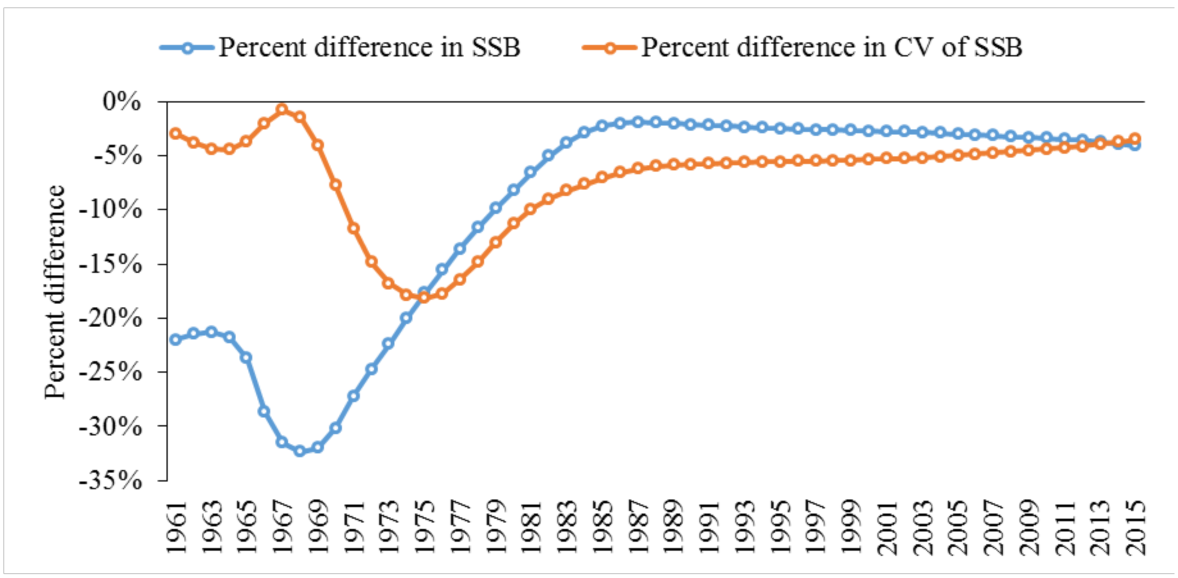
The large improvement in fit to the age composition data in model case M3 compared to M2 and M1 is due, in large part to fitting the adjacent age classes to the plus age group more precisely, it also improves the fit to the plus age group itself. The following figure shows the percent difference in spawning biomass and the CV in spawning biomass for model case M3 compared to M2 (negative values indicate estimates that are smaller in model case M3 compared to M2).



Overall, the spawning biomass in model case M3 compared to M2 decreases by about 8% across the time series, and the CV in spawning biomass is also smaller in model case M3 than model case M2 by around 4%. Due to the large improvement in fit to the age composition datasets, we recommend that in this year's assessment and in future assessments the extended ageing error matrix be utilized to fit the age composition datasets. The results from the following model cases (M4 – M5) all use the extended ageing error matrix presented in model case M3.

M4 – Setting the plus age group

When setting the plus age group to age-45+ in model case M4 to (1) ensure the plus age group proportion for all years is <10%, (2) the plus age group proportion is less than the maximum proportion in the remainder of the age composition data, (3) minimizing age bins with zero samples, and (4) examining model fits and residuals, there was an overall increase in the data negative log-likelihood value. This increase is attributed to increases in the negative log-likelihood values for the fishery and survey age composition, which is expected given the larger number of ages modeled. The negative log-likelihood values for the remaining datasets remain similar to the negative log-likelihoods from model case M3. The following figure shows the percent difference in spawning biomass and the CV in spawning biomass for model case M4 compared to M3 (negative values indicate estimates that are smaller in model case M4 compared to M3).

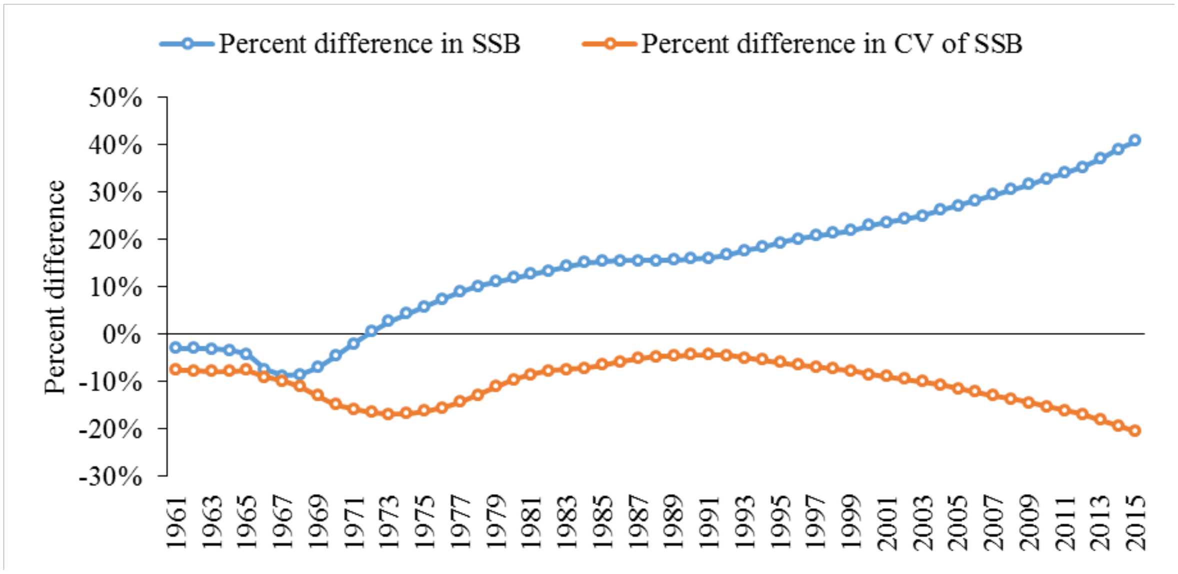


The largest differences in the spawning biomass and the CV in spawning biomass when comparing model case M4 with model case M3 occur at the beginning of the time series. Overall, model case M4 results in about a 4% decrease in the spawning biomass and CV in spawning biomass at the end of the time series. To ensure that the proportion of fish in the plus age group remains manageable in both the fishery and trawl survey age composition we recommend that in this year's assessment and in future assessments a plus age group of age-45+ be used.

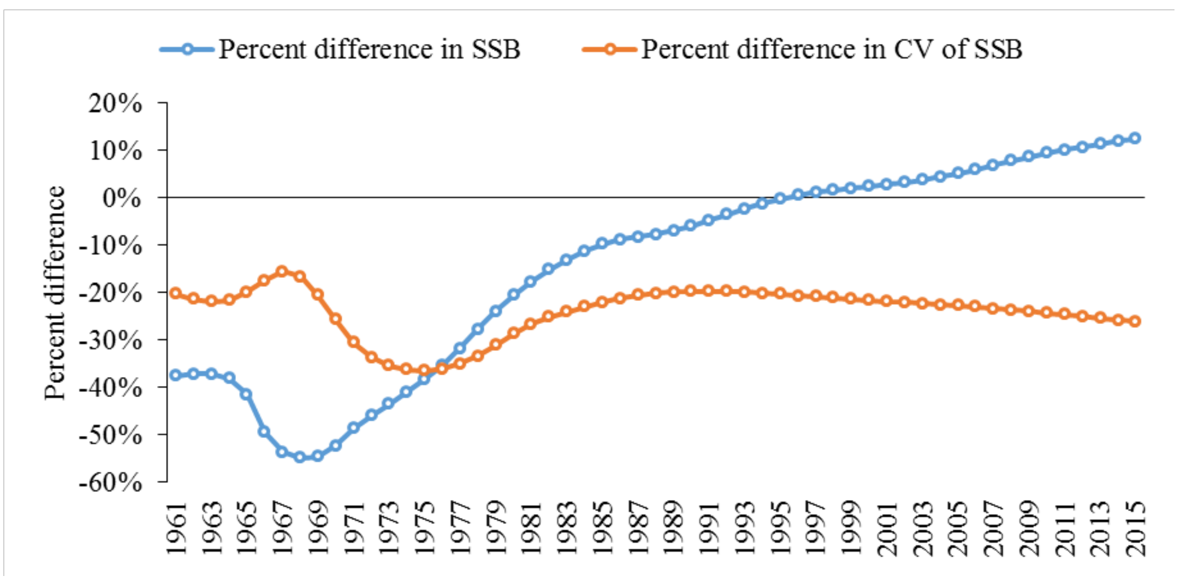
We recommend model case M4 as the preferred model for the 2015 northern rockfish assessment for the following reasons: (1) growth should be modeled based on the manner in which the observations were collected, (2) extending the ageing error matrix results in improvements to the fit of the age composition datasets, and (3) setting the plus age group to 45+ allows for a manageable proportion of fish within the plus age group to be modeled.

Additional model run: M5 – Alternative trawl survey biomass

The following figure shows the percent difference in spawning biomass and the CV in spawning biomass for model case M5 compared to M4 when utilizing the alternative model-based trawl survey biomass estimates (negative values indicate estimates that are smaller in model case M5 compared to M4).



After 1972 the spawning biomass estimated in model case M5 is larger compared to the spawning biomass estimated in model case M4. On average, the CV from model case M5 is 10% smaller than the average CV in spawning biomass from model case M4. The following figure shows the percent difference in spawning biomass and the CV in spawning biomass for model case M5 compared to M1, the base case model that is the same as the model used in 2013 but with updated data (negative values indicate estimates that are smaller in model case M5 compared to M1).



For much of the time series the spawning biomass estimated from model case M5 is smaller than the estimated spawning biomass from case M1, except at the end of the time series (after about 1995) when the spawning biomass estimated from model case M5 is larger than model case M1. The estimated CV in spawning biomass from model case M5 is, on average, 24% smaller than the estimated CV in spawning biomass from model case M1. The increase in spawning biomass resulting from model case M5 is due to a catchability parameter estimate that is smaller in case M5 (0.54) compared to model case M1 (0.57) or model case M4 (0.71).

Overall, the alternative model-based index for trawl survey biomass provides potential for substantial improvements to the uncertainty of modeled quantities obtained from the northern rockfish assessment. However, we do not recommend this model as the preferred assessment model for this year's assessment due to some outstanding issues that we feel should be resolved and/or investigated prior to its implementation. The primary issue is the relative weighting used between the new index and the other datasets used in the model, in particular, the relative weighting between the index and compositional data through the effective sample sizes chosen for the age and length composition data. When utilizing the model-based index that reduces inter-annual variability by over 90% large changes in the model occur, which we feel should be investigated more thoroughly prior to implementation. The alternative model-based index will be further explored in the next full assessment cycle with the intention of its inclusion in future assessments of northern rockfish.

Model Evaluation

The recommended changes to the model for this year's assessment were described in the previous section and our recommended model for this year is model case M4. When we present alternative model configurations, our usual criteria for choosing a superior model are: (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.

The model generally produces good visual fits to the data, and biologically reasonable patterns of recruitment, abundance, and selectivities. The 2015 model shows recent recruitment is low but stable, and there was a decrease in spawning and total biomass from previous projections. Therefore the, 2015 recommended model is utilizing the new information effectively, and we use it to recommend 2016 ABC and OFL.

Time Series Results

Key results have been summarized in Tables 10.11 to 10.15. Model predictions fitted the data well (Figures 10.1 to 10.4 and 10.6) and most parameter estimates have remained similar to the last assessment's 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.

Biomass and exploitation 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). Since the early 1990s the total biomass estimated in the model has been decreasing from a high of over 190,000 t in 1991. Similarly, the spawning biomass estimated in the model has also been decreasing since 1998. However, 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, 2011, and 2013 trawl surveys (Figure 10.4). This is not surprising given the wide confidence intervals associated with these surveys (the trawl survey biomass estimate in 2013 has a 60% coefficient of variation). Overall, the current status of the stock appears to be about equal to stock levels estimated last year and for the late 1970s (Figure 10.9 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 10.10).

Parameter estimates from this year’s model were similar to the previous northern rockfish assessment (Table 10.11). The trajectory of fishing mortality has remained below the $F_{40\%}$ level most of the time and below $F_{35\%}$ in all years except 1964-66 during the period of intense fishing for Pacific ocean perch (Figure 10.10). 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 10.11).

Recruitment

Recruitment estimates show a high degree of uncertainty, but indicate several large year-classes in the 1990s (Table 10.13 and 10.14 and Figure 10.12). Recent recruitment since 2001 have been considerably lower than the 1977 – 2000. Fits to the fishery and survey age compositions were reasonable with this year’s recommended model (Figures 10.3 and 10.6). The model did not fit the fishery size comps well in the 1990s but fits very well in the 2000s (Figure 10.2). The pattern of stock-recruitment suggests that environmental variability plays a large role in determining recruitment strengths (Figure 10.13).

Uncertainty results

From the MCMC chains described in the *Uncertainty Approach* section, we summarize the posterior densities of key parameters for the recommended model using histograms (Figure 10.14). We also use these posterior distributions to show uncertainty around time series estimates such as spawning biomass (Table 10.14 and Figures 10.9 and 10.15). 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.

Retrospective analysis

A within-model retrospective analysis of the recommended model was conducted for the last 10 years of the time-series by dropping data one year at a time. The revised Mohn’s “rho” statistic (Hanselman et al. 2013) in female spawning biomass was -0.14, indicating that the model increases the estimate of female spawning biomass in recent years as data is added to the assessment. The retrospective female spawning biomass and the relative difference in female spawning biomass from the model in the terminal year are shown in Figure 10.16 (with 95% credible intervals from MCMC). In general the relative difference in female spawning biomass in recent ranged from around -30% to around 10%, but there are some large changes (upwards of 100%) in the mid- to late-1970s.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Northern rockfish in the GOA are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$,,equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing.

Estimation of the $B_{40\%}$ reference point requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the average of age-2 recruitments between 1979 and 2013. Because of uncertainty in very recent recruitment estimates, we lag 2 years behind model estimates in our projection. Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. The 2015 estimates of these reference points are:

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
69,957	27,983	24,485	0.062	0.074

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2016 is estimated at 31,313 t. This is above the $B_{40\%}$ value of 27,983 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 2016, yields the following ABC and OFL:

$F_{40\%}$	0.062
ABC	4,008
$F_{35\%}$	0.074
OFL	4,783

Projections and Status Determination

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 2015 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2016 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2015. 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 2015 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 2016, 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 2016 and 2017, 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 2012-2014 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 catch to ABC will yield more realistic 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 2010-2014 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

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

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2015 or 2) above ½ of its MSY level in 2015 and above its MSY level in 2025 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2016 and 2017, F is set equal to *max* F_{ABC}, and in all subsequent years F is set to 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 2027 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 two-year ahead specifications.

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 2016, it does not provide the best estimate of OFL for 2017, because the mean 2016 catch under Scenario 6 is predicated on the 2016 catch being equal to the 2016 OFL, whereas the actual 2016 catch will likely be less than the 2016 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 (2014) is 4,277 t. This is less than the 2014 OFL of 6,349 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 2015:
a. If spawning biomass for 2015 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2015 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2015 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 2025 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 2017 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2017 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2017 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2027. If the mean spawning biomass for 2027 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. 2012-2014 for this year). For northern rockfish, the expansion factor for 2015 catch is 1.10.

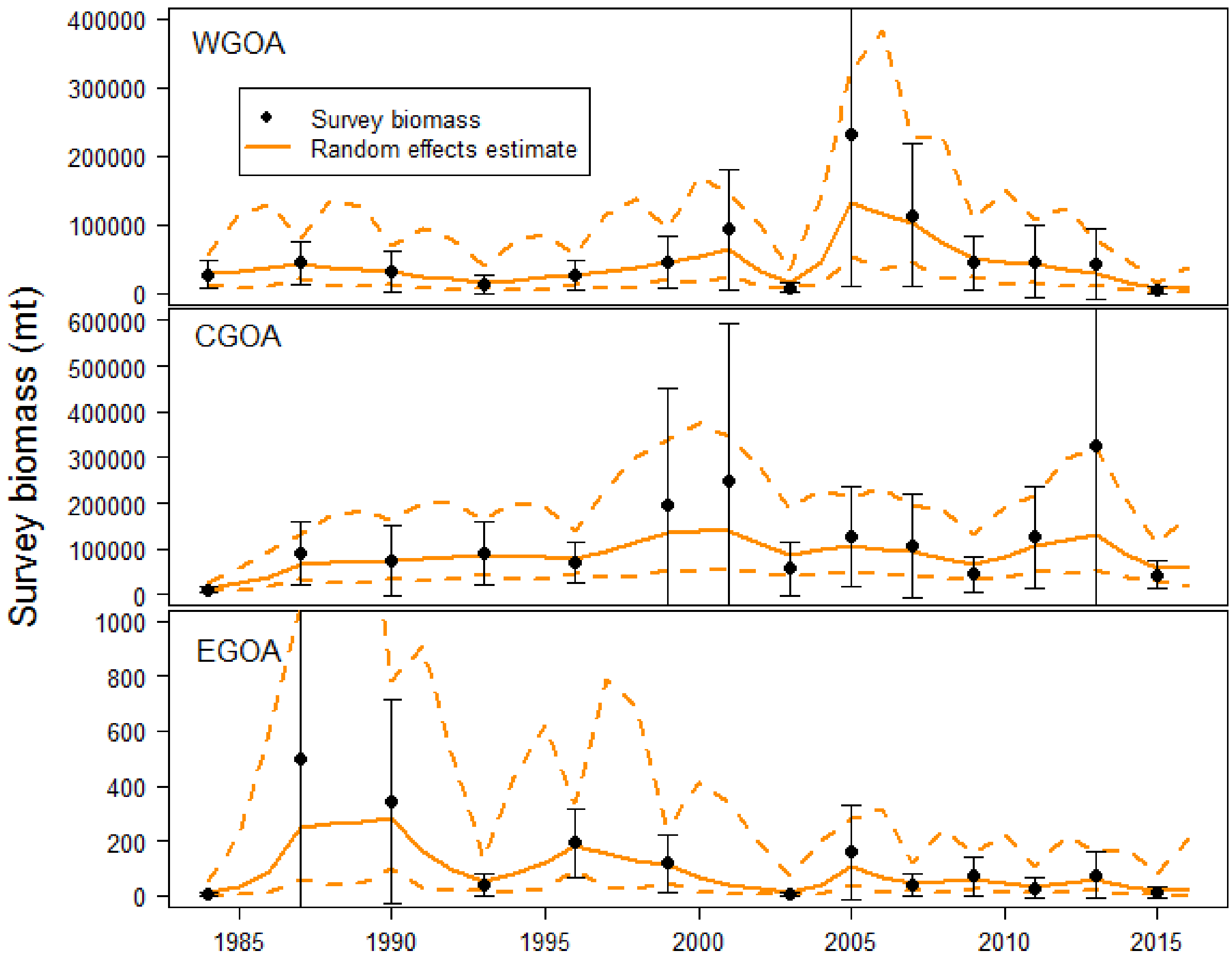
For catch projections into the next two years, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, 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 the same estimated yield ratio (0.89) as Scenario 2, except for all years instead of the next two. 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 10.15). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1977-2013 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

For this assessment the Plan Team and SSC requested that the random effects model proposed by the survey averaging working group be utilized for apportionment. The random effects model was fit to the survey biomass estimates (with associated variance) for the Western, Central, and Eastern Gulf of Alaska. The random effects model estimates a process error parameter (constraining the variability of the modeled estimates among years) and random effects parameters in each year modeled. The fit of the random effects model to survey biomass in each area is shown in the following figure. For illustration the 95% confidence intervals are shown for the survey biomass (error bars) and the random effects estimates of survey biomass (dashed lines).



In general the random effects model fits the area-specific survey biomass reasonably well. Based on the random effects estimates the area apportionments for Gulf of Alaska northern rockfish are 11.4% for the Western area (down from 24.5% in 2013), 88.5% for the Central area (up from 75.5% in 2013), and 0.01% for the Eastern area (down from 0.03% in 2013). Overall, the trawl survey biomass decreased in all three areas in 2015 compared to 2013 and in terms of apportionment, the decrease was upwards of 50% for the Western area. This was in response to the random effects model fitting the smallest trawl survey biomass observed in the Western area. In comparison to the 4:6:9 weighting method that was used in previous assessments, the weighted method results in 14.9% in the Western area, 85.0% in the Central area, and 0.1% in the Eastern area, still producing a nearly 40% decrease in apportionment for the Western area. Applying the random effect model apportionments to the recommended ABC for northern rockfish results in 457 t for the Western area, 3,547 t for the Central area, and 4 t for the Eastern area. For management purposes, the small ABC of northern rockfish in the Eastern area is combined with other rockfish.

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 are 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 effects 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.

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: 2015	2016	As estimated or recommended *this* year for: 2016	2017[1]
M (natural mortality)	0.06	0.06	0.059	0.059
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	98,409	94,820	77,596	74,722
Projected Female spawning biomass	39,838	37,084	31,313	29,033
$B_{100\%}$	75,183	75,183	69,957	69,957
$B_{40\%}$	30,073	30,073	27,983	27,983
$B_{35\%}$	26,314	26,314	24,485	24,485
F_{OFL}	0.073	0.073	0.074	0.074
$maxF_{ABC}$	0.061	0.061	0.062	0.062
F_{ABC}	0.061	0.061	0.062	0.062
OFL (t)	5,961	5,631	**4,783**	4,501
maxABC (t)	4,999	4,722	4,008	3,772
ABC (t)	4,999	4,722	**4,008**	3,772
Status	As determined *last* year for: 2013	2014	As determined *this* year for: 2014	2015
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

[1]Projected ABCs and OFLs for 2016 and 2017 are derived using estimated catch of 4,223 for 2015, and projected catches of 3,576 t and 3,343 t for 2016 and 2017 based on realized catches from 2012-2014. 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

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

Table 10.1. (continued) 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
2008	4,052	4,549	4,549		
2009	3,952	4,362	4,362		
2010	3,902	5,098	5,098		
2011	3,443	4,854	4,854		NPFMCs Central GOA Rockfish Program goes into effect starting with 2012 fishery
2012	5,077	5,507	5,507		
2013	4,879	5,130	5,130		
2014	4,277	5,324	5,324		
2015	3,848	4,999	4,999		

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 1993-2013 are from NMFS Observer Program and Alaska Regional Office updated through October 1, 2015.

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	-	-

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 1993-2013 are from NMFS Observer Program and Alaska Regional Office updated through October 1, 2015.

Year	Foreign	Joint venture	Domestic	Total	TAC	%TAC
1987	-	56	427	483	-	-
1988[1]	-	tr	1,107	1,107	-	-
1989	-	-	1,527	1,527	-	-
1990	-	-	1,697	1,716	-	-
1991[2]	-	-	4,528	4,528	-	-
1992	-	-	7,770	7,770	-	-
1993[3]	-	-	4,820	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	5,098	77%
2011	-	-	3,443	3,440	4,854	71%
2012	-	-	5,077	5,063	5,507	92%
2013	-	-	4,879	4,569	5,130	89%
2014	-	-	4,277	4,277	5,324	80%
2015*	-	-	3,848	3,848	4,999	77%

[1] 1988 - Slope rockfish assemblage management implemented by NPFMC.
[2] 1991 - Slope rockfish divided into 3 management subgroups: Pacific ocean perch, shortraker/ rougheye, and other slope rockfish.
[3] 1993 – A fourth management subgroup, northern rockfish, was created
[4] 2007 – Central Gulf Rockfish Pilot Project implemented for rockfish fishery.
* Catch as of 10/1/2015.

Table 10.3. FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2010-2015. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/15/2015.

	Estimated Catch (t)						
Group Name	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Average**
Pacific Ocean Perch	14,974	13,120	13,953	11,555	15,283	15,895	14,130
Northern Rockfish	3,833	3,164	4,883	4,527	3,650	3,600	3,943
Dusky Rockfish	2,953	2,315	3,642	2,870	2,752	2,480	2,835
Arrowtooth Flounder	706	340	764	766	1,425	1,370	895
Walleye Pollock	1,046	813	574	829	1,339	1,022	937
Atka Mackerel	2,148	1,404	1,173	1,162	446	973	1,218
Pacific cod	734	560	404	584	624	763	612
Harlequin Rockfish	462	350	603	305	437	565	454
Sablefish	388	440	470	495	527	410	455
Shortraker Rockfish	133	239	303	290	243	237	241
Rougheye Rockfish	180	286	219	274	359	223	257
Thornyhead Rockfish	106	161	130	104	243	216	160
Rex Sole	93	51	72	89	84	115	84
Yelloweye Rockfish	85	69	188	179	86	113	120
Sharpchin Rockfish	105	112	82	45	93	96	89
Flathead Sole	24	13	16	25	30	44	25
Sculpin	59	39	55	70	33	43	50
Redstripe Rockfish	60	67	54	22	70	42	53
Dover Sole	27	15	37	24	30	33	28
Longnose Skate	12	25	23	23	26	31	23
Silvergray Rockfish	26	57	28	14	25	30	30
Rock Sole	46	44	61	26	28	26	39
Redbanded Rockfish	19	25	14	14	31	24	21
Majestic Squid	4	12	15	10	19	23	14
Skate, Other	23	14	14	18	36	22	21

Table 10.4. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2010 - 2015. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/15/2015.

	Estimated Catch (t)					
Group Name	2010	2011	2012	2013	2014	2015
Benthic urochordata	0.08	Conf.	Conf.	Conf.	Conf.	Conf.
Birds	Conf.	Conf.	Conf.	Conf.	Conf.	Conf.
Bivalves	0.01	0.01	0.01	Conf.	0.01	Conf.
Brittle star unidentified	0.02	0.01	0.04	0.02	0.05	0.06
Capelin	-	-	-	0.02	-	-
Corals Bryozoans	0.06	0.11	Conf.	Conf.	Conf.	Conf.
Dark Rockfish	111.68	12.82	55.38	42.16	47.91	45.12
Eelpouts	0.05	Conf.	.30	.04	.13	Conf.
Eulachon	Conf.	Conf.	Conf.	0.07	0.02	0.03
Giant Grenadier	404.00	449.33	310.82	889.11	512.50	727.33
Greenlings	9.47	7.67	8.76	6.99	4.16	8.14
Pacific Grenadier	Conf.	-	-	-	-	-
Hermit crab unidentified	0.01	0.02	Conf.	0.03	.04	0.03
Invertebrate unidentified	5.05	0.35	3.85	0.18	Conf.	0.19
Lanternfishes	Conf.	-	-	Conf.	-	0.04
Misc crabs	0.07	0.04	0.04	0.01	0.04	Conf.
Misc crustaceans	.02	Conf.	-	Conf.	Conf.	Conf.
Misc deep fish	-	-	-	Conf.	-	-
Misc fish	163.87	129.52	151.71	159.64	124.55	142.73
Misc inverts (worms etc)	-	Conf.	-	-	-	-
Other osmerids	0.04	-	Conf.	0.02	Conf.	-
Pacific Sand lance	-	Conf.	-	-	-	-
Pandalid shrimp	0.20	0.06	0.06	0.06	0.10	0.05
Polychaete unidentified	-	-	-	Conf.	-	-
Scypho jellies	1.45	0.02	0.16	0.39	5.13	1.23
Sea anemone unidentified	1.51	4.07	6.27	4.02	2.15	1.12
Sea pens whips	0.01	0.04	-	0.04	0.06	-
Sea star	1.29	1.46	0.92	0.89	1.60	3.46
Snails	0.20	0.23	1.26	0.15	0.12	0.26
Sponge unidentified	3.63	3.95	1.37	1.28	1.81	5.45
Stichaeidae	-	-	-	Conf.	Conf.	Conf.
Urchins, dollars cucumbers	0.20	0.44	0.30	0.28	0.21	0.98

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, for the GOA rockfish fishery. Source: NMFS AKRO Blend/Catch Accounting System PSCNQ via AKFIN 10/15/2015.

Group Name	2010	2011	2012	2013	2014	2015	Average
Bairdi Crab	0.10	0.03	0.09	0.07	0.17	0.05	0.08
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chinook Salmon	1.57	1.01	1.58	2.32	1.25	0.88	1.44
Golden K. Crab	3.00	0.13	0.11	0.10	0.03	0.02	0.57
Halibut	140.81	121.70	109.22	112.95	126.99	144.46	126.02
Herring	0.15	0.00	0.00	0.00	0.00	0.00	0.03
Other Salmon	0.37	0.21	0.31	2.02	0.56	0.34	0.63
Opilio Crab	0.00	0.00	0.00	0.00	0.00	0.03	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 used in the assessment model for northern rockfish in the Gulf of Alaska (at-sea and port samples combined).

Length class (cm)	Year 1991	1992	1993	1994	1995	1996	1997	2003	2007	2009
15	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000
22	0.001	0.000	0.005	0.001	0.001	0.000	0.000	0.000	0.000	0.000
23	0.002	0.000	0.006	0.001	0.001	0.000	0.000	0.000	0.000	0.000
24	0.002	0.000	0.008	0.001	0.002	0.001	0.002	0.001	0.000	0.001
25	0.002	0.000	0.008	0.002	0.004	0.002	0.006	0.001	0.001	0.000
26	0.004	0.000	0.007	0.006	0.007	0.006	0.014	0.004	0.001	0.001
27	0.005	0.000	0.008	0.008	0.011	0.007	0.020	0.006	0.002	0.002
28	0.008	0.001	0.012	0.013	0.011	0.005	0.021	0.007	0.003	0.002
29	0.011	0.003	0.015	0.013	0.013	0.007	0.021	0.016	0.006	0.003
30	0.023	0.006	0.018	0.016	0.017	0.011	0.019	0.027	0.012	0.007
31	0.041	0.015	0.028	0.025	0.021	0.010	0.014	0.044	0.016	0.016
32	0.071	0.032	0.046	0.038	0.029	0.019	0.015	0.064	0.033	0.021
33	0.122	0.053	0.074	0.070	0.049	0.036	0.029	0.083	0.046	0.030
34	0.179	0.094	0.100	0.111	0.085	0.061	0.054	0.083	0.065	0.044
35	0.194	0.139	0.140	0.161	0.126	0.109	0.115	0.085	0.088	0.079
36	0.144	0.157	0.148	0.183	0.151	0.151	0.159	0.072	0.104	0.093
37	0.090	0.154	0.113	0.157	0.156	0.169	0.173	0.076	0.118	0.105
38+	0.102	0.346	0.238	0.193	0.317	0.406	0.337	0.431	0.505	0.595
Sample size	15,466	15,207	12,525	8,905	12,370	12,496	5,262	7,387	7,944	6,408
# Hauls	147	125	94	90	121	108	73	374	489	422

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

Length class (cm)	Year 2011	2013
15	0.000	0.000
16	0.000	0.000
17	0.000	0.000
18	0.000	0.000
19	0.000	0.000
20	0.000	0.000
21	0.000	0.000
22	0.000	0.000
23	0.000	0.000
24	0.000	0.001
25	0.000	0.001
26	0.000	0.001
27	0.000	0.001
28	0.000	0.002
29	0.001	0.003
30	0.001	0.003
31	0.002	0.006
32	0.005	0.004
33	0.011	0.009
34	0.023	0.019
35	0.051	0.036
36	0.076	0.066
37	0.103	0.099
38+	0.725	0.751
Sample size	5,121	6,418
# Hauls	403	500

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
2	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
4	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
6	0.004	0.003	0.024	0.011	0.000	0.015	0.000	0.006
7	0.006	0.006	0.005	0.055	0.032	0.008	0.021	0.002
8	0.034	0.000	0.015	0.024	0.151	0.036	0.045	0.046
9	0.022	0.042	0.019	0.031	0.070	0.111	0.066	0.064
10	0.032	0.013	0.043	0.038	0.055	0.176	0.147	0.070
11	0.058	0.029	0.031	0.049	0.042	0.050	0.164	0.132
12	0.070	0.039	0.058	0.042	0.044	0.035	0.052	0.070
13	0.094	0.049	0.053	0.053	0.047	0.036	0.017	0.048
14	0.094	0.062	0.048	0.051	0.032	0.028	0.031	0.034
15	0.068	0.127	0.074	0.040	0.031	0.027	0.038	0.034
16	0.078	0.065	0.094	0.053	0.047	0.032	0.026	0.020
17	0.034	0.058	0.067	0.084	0.068	0.015	0.019	0.016
18	0.034	0.042	0.060	0.060	0.067	0.025	0.031	0.038
19	0.022	0.019	0.024	0.044	0.032	0.046	0.026	0.028
20	0.026	0.023	0.022	0.027	0.026	0.058	0.033	0.020
21	0.044	0.032	0.010	0.035	0.023	0.035	0.045	0.040
22	0.050	0.029	0.043	0.018	0.021	0.029	0.024	0.050
23	0.036	0.075	0.034	0.033	0.013	0.023	0.026	0.036
24	0.030	0.042	0.046	0.033	0.029	0.011	0.009	0.024
25	0.022	0.010	0.022	0.044	0.044	0.012	0.009	0.010
26	0.024	0.026	0.029	0.042	0.028	0.021	0.005	0.012
27	0.012	0.016	0.014	0.013	0.011	0.039	0.026	0.018
28	0.010	0.042	0.021	0.020	0.008	0.029	0.031	0.018
29	0.026	0.036	0.024	0.009	0.010	0.012	0.024	0.034
30	0.020	0.023	0.041	0.018	0.011	0.017	0.028	0.032
31	0.006	0.029	0.019	0.020	0.011	0.011	0.007	0.022
32	0.010	0.013	0.014	0.013	0.011	0.008	0.002	0.006
33	0.012	0.003	0.010	0.009	0.010	0.009	0.007	0.006
34	0.000	0.006	0.002	0.004	0.005	0.007	0.017	0.012
35	0.002	0.006	0.003	0.002	0.000	0.009	0.005	0.012
36	0.000	0.000	0.003	0.002	0.003	0.009	0.005	0.020
37	0.002	0.006	0.002	0.011	0.005	0.003	0.002	0.008
38	0.006	0.003	0.002	0.007	0.000	0.003	0.002	0.000
39	0.002	0.003	0.005	0.000	0.002	0.001	0.005	0.002
40	0.004	0.003	0.007	0.002	0.005	0.001	0.000	0.002
41	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000
42	0.000	0.006	0.002	0.000	0.000	0.004	0.002	0.002
43	0.002	0.003	0.003	0.000	0.000	0.003	0.002	0.002
44	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.004
45+	0.000	0.000	0.003	0.000	0.003	0.004	0.000	0.000
Sample size	498	308	585	451	616	746	422	500
# Hauls	51	160	187	156	187	270	211	206

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		
	2009	2010	2012
2	0.000	0.000	0.000
3	0.000	0.000	0.000
4	0.000	0.000	0.000
5	0.000	0.000	0.002
6	0.000	0.000	0.000
7	0.006	0.000	0.007
8	0.020	0.012	0.000
9	0.026	0.024	0.003
10	0.078	0.032	0.022
11	0.068	0.060	0.041
12	0.048	0.115	0.027
13	0.093	0.072	0.094
14	0.076	0.052	0.105
15	0.030	0.068	0.077
16	0.022	0.052	0.057
17	0.012	0.028	0.089
18	0.006	0.018	0.048
19	0.012	0.016	0.022
20	0.022	0.024	0.026
21	0.020	0.022	0.012
22	0.016	0.032	0.010
23	0.038	0.014	0.009
24	0.050	0.014	0.024
25	0.028	0.034	0.021
26	0.030	0.030	0.024
27	0.022	0.016	0.033
28	0.006	0.020	0.038
29	0.014	0.014	0.010
30	0.026	0.024	0.024
31	0.028	0.014	0.012
32	0.034	0.024	0.010
33	0.032	0.028	0.015
34	0.018	0.038	0.015
35	0.018	0.020	0.019
36	0.006	0.004	0.022
37	0.018	0.008	0.014
38	0.018	0.010	0.014
39	0.012	0.012	0.010
40	0.006	0.014	0.012
41	0.002	0.010	0.005
42	0.008	0.004	0.002
43	0.004	0.002	0.003
44	0.000	0.010	0.002
45+	0.022	0.014	0.019
Sample size	497	503	583
# Hauls	311	311	420

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.

Year	Statistical areas					Total	CV
	Shumagin	Chirikof	Kodiak	Yakutat	South-eastern		
1984	27,716	5,165	6,448	5	0	39,334	29%
1987	45,038	13,794	77,084	500	0	136,417	29%
1990	32,898	5,792	68,044	343	0	107,076	42%
1993	13,995	40,446	49,998	41	0	104,480	35%
1996	28,114	40,447	30,212	192	0	98,965	27%
1999	45,457	29,946	166,665	118	0	242,187	61%
2001	93,291	24,490	225,833	117[a]	0[a]	343,731	60%
2003	9,146	49,793	7,336	5	0	66,310	48%
2005	231,110	102,605	25,123	160	0	358,998	37%
2007	114,222	92,250	20,559	38	0	227,069	38%
2009	44,693	8,842	36,290	70	0	89,896	32%
2011	47,082	91,774	34,757	28	0	173,641	39%
2013	42,936	304,516	22,927	76	0	370,454	60%
2015	5,680	36,356	6,885	12	0	48,933	34%

[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
2	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000
3	0.000	0.003	0.001	0.003	0.002	0.000	0.005	0.001
4	0.000	0.018	0.002	0.003	0.001	0.002	0.003	0.001
5	0.014	0.055	0.029	0.009	0.002	0.011	0.006	0.035
6	0.040	0.041	0.054	0.011	0.011	0.003	0.013	0.021
7	0.091	0.030	0.027	0.011	0.006	0.009	0.041	0.014
8	0.191	0.003	0.041	0.063	0.021	0.009	0.016	0.096
9	0.112	0.029	0.054	0.120	0.041	0.042	0.038	0.126
10	0.051	0.101	0.045	0.065	0.053	0.028	0.072	0.056
11	0.046	0.112	0.058	0.103	0.085	0.079	0.061	0.036
12	0.026	0.112	0.035	0.044	0.076	0.069	0.040	0.029
13	0.071	0.034	0.054	0.049	0.077	0.054	0.063	0.021
14	0.067	0.043	0.082	0.040	0.040	0.056	0.049	0.051
15	0.063	0.014	0.097	0.024	0.033	0.078	0.050	0.033
16	0.040	0.037	0.051	0.052	0.039	0.092	0.054	0.043
17	0.019	0.103	0.051	0.031	0.017	0.016	0.045	0.000
18	0.019	0.041	0.007	0.040	0.034	0.072	0.058	0.018
19	0.006	0.080	0.011	0.028	0.054	0.019	0.029	0.030
20	0.007	0.027	0.066	0.004	0.088	0.013	0.022	0.061
21	0.003	0.026	0.066	0.023	0.028	0.030	0.017	0.012
22	0.010	0.007	0.046	0.034	0.031	0.022	0.012	0.021
23	0.031	0.007	0.019	0.044	0.030	0.025	0.027	0.011
24	0.021	0.003	0.009	0.045	0.033	0.030	0.045	0.007
25	0.006	0.004	0.010	0.046	0.027	0.020	0.029	0.014
26	0.003	0.017	0.034	0.007	0.052	0.015	0.042	0.025
27	0.010	0.026	0.006	0.017	0.014	0.034	0.012	0.030
28	0.004	0.012	0.012	0.022	0.015	0.025	0.009	0.054
29	0.009	0.003	0.002	0.006	0.028	0.024	0.024	0.035
30	0.000	0.002	0.010	0.000	0.006	0.016	0.021	0.016
31	0.004	0.005	0.010	0.002	0.007	0.024	0.014	0.000
32	0.013	0.000	0.009	0.010	0.004	0.045	0.019	0.000
33	0.003	0.002	0.005	0.005	0.015	0.010	0.011	0.041
34	0.000	0.003	0.000	0.006	0.007	0.008	0.008	0.010
35	0.003	0.000	0.000	0.006	0.005	0.000	0.017	0.012
36	0.000	0.000	0.000	0.009	0.000	0.003	0.004	0.007
37	0.004	0.000	0.000	0.001	0.007	0.000	0.000	0.019
38	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	0.000	0.000	0.000	0.014	0.002	0.012	0.002	0.003
40	0.006	0.000	0.000	0.002	0.000	0.002	0.010	0.011
41	0.005	0.000	0.000	0.000	0.000	0.003	0.009	0.000
42	0.000	0.001	0.000	0.000	0.003	0.000	0.000	0.000
43	0.004	0.000	0.000	0.000	0.004	0.000	0.000	0.000
44	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45+	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000
Sample size	356	497	331	242	462	278	466	216
# Hauls	6	17	12	17	19	27	85	22

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				
	2005	2007	2009	2011	2013
2	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000
4	0.001	0.000	0.000	0.001	0.000
5	0.001	0.001	0.003	0.000	0.000
6	0.014	0.007	0.000	0.000	0.001
7	0.037	0.004	0.007	0.000	0.004
8	0.052	0.029	0.015	0.002	0.004
9	0.047	0.091	0.022	0.003	0.002
10	0.061	0.058	0.051	0.015	0.006
11	0.047	0.074	0.071	0.019	0.023
12	0.033	0.063	0.053	0.023	0.028
13	0.011	0.083	0.060	0.040	0.032
14	0.021	0.031	0.062	0.040	0.038
15	0.012	0.017	0.038	0.021	0.052
16	0.020	0.026	0.034	0.028	0.070
17	0.032	0.020	0.021	0.059	0.044
18	0.031	0.010	0.033	0.017	0.070
19	0.008	0.020	0.033	0.016	0.031
20	0.039	0.028	0.027	0.023	0.037
21	0.046	0.033	0.016	0.022	0.013
22	0.019	0.038	0.010	0.029	0.023
23	0.012	0.049	0.027	0.021	0.029
24	0.012	0.011	0.041	0.039	0.033
25	0.021	0.012	0.046	0.031	0.030
26	0.025	0.014	0.026	0.015	0.011
27	0.022	0.027	0.017	0.047	0.033
28	0.037	0.028	0.014	0.034	0.032
29	0.036	0.030	0.030	0.018	0.035
30	0.038	0.033	0.013	0.027	0.015
31	0.023	0.024	0.012	0.023	0.037
32	0.040	0.016	0.025	0.022	0.002
33	0.018	0.010	0.022	0.025	0.014
34	0.046	0.019	0.011	0.030	0.024
35	0.027	0.014	0.012	0.052	0.009
36	0.024	0.023	0.021	0.036	0.031
37	0.011	0.009	0.019	0.035	0.036
38	0.005	0.014	0.028	0.039	0.017
39	0.011	0.005	0.013	0.017	0.019
40	0.011	0.010	0.010	0.019	0.012
41	0.004	0.004	0.008	0.030	0.018
42	0.000	0.001	0.007	0.028	0.023
43	0.004	0.002	0.005	0.014	0.007
44	0.013	0.003	0.007	0.008	0.003
45+	0.026	0.010	0.029	0.030	0.052
Sample size	417	605	651	430	495
# Hauls	72	82	69	74	68

Table 10.10. Survey length (cm) compositions available for northern rockfish in the Gulf of Alaska, 1984-2015. (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 (cm)	Year										
	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009
15	0.010	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
16	0.007	0.004	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
17	0.005	0.005	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
18	0.008	0.004	0.000	0.001	0.001	0.000	0.003	0.000	0.000	0.000	0.001
19	0.006	0.005	0.001	0.001	0.001	0.001	0.002	0.001	0.000	0.000	0.001
20	0.005	0.008	0.001	0.000	0.001	0.001	0.002	0.001	0.000	0.000	0.001
21	0.003	0.009	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.001
22	0.005	0.010	0.003	0.002	0.002	0.002	0.002	0.002	0.000	0.000	0.001
23	0.008	0.012	0.005	0.003	0.002	0.003	0.001	0.004	0.000	0.000	0.001
24	0.017	0.013	0.012	0.003	0.002	0.002	0.002	0.006	0.001	0.000	0.000
25	0.022	0.015	0.011	0.007	0.003	0.002	0.002	0.007	0.000	0.002	0.001
26	0.027	0.015	0.030	0.005	0.007	0.006	0.004	0.018	0.001	0.002	0.001
27	0.045	0.017	0.024	0.007	0.008	0.002	0.005	0.011	0.001	0.006	0.003
28	0.052	0.022	0.017	0.008	0.006	0.006	0.008	0.007	0.001	0.002	0.002
29	0.089	0.044	0.017	0.007	0.008	0.002	0.005	0.010	0.063	0.006	0.002
30	0.095	0.071	0.013	0.012	0.009	0.003	0.010	0.015	0.034	0.003	0.008
31	0.102	0.118	0.022	0.014	0.016	0.002	0.011	0.021	0.012	0.007	0.006
32	0.093	0.140	0.038	0.041	0.020	0.027	0.023	0.040	0.013	0.018	0.013
33	0.074	0.130	0.090	0.055	0.027	0.031	0.017	0.064	0.021	0.038	0.012
34	0.060	0.122	0.126	0.091	0.034	0.035	0.053	0.077	0.025	0.061	0.032
35	0.051	0.087	0.139	0.147	0.059	0.054	0.051	0.063	0.031	0.069	0.040
36	0.058	0.067	0.118	0.162	0.121	0.078	0.121	0.078	0.052	0.083	0.056
37	0.049	0.034	0.102	0.123	0.118	0.128	0.127	0.071	0.055	0.091	0.082
38+	0.110	0.044	0.229	0.311	0.552	0.614	0.549	0.503	0.686	0.609	0.735
Sample size	4,235	9,584	3,091	4,384	4,239	3,471	3,810	2,941	4,556	4,723	2,849
# Hauls	50	82	48	106	131	124	106	126	147	139	132

Table 10.10 (continued) Survey length (cm) compositions available for northern rockfish in the Gulf of Alaska, 1984-2015. (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 (cm)	Year		
	2011	2013	2015
15	0.000	0.000	0.000
16	0.000	0.000	0.000
17	0.000	0.000	0.000
18	0.000	0.000	0.001
19	0.000	0.000	0.000
20	0.000	0.000	0.000
21	0.000	0.000	0.000
22	0.000	0.000	0.000
23	0.001	0.000	0.000
24	0.000	0.000	0.000
25	0.000	0.001	0.002
26	0.000	0.001	0.001
27	0.000	0.001	0.001
28	0.001	0.001	0.004
29	0.000	0.001	0.002
30	0.000	0.004	0.002
31	0.001	0.002	0.006
32	0.002	0.004	0.007
33	0.004	0.005	0.009
34	0.015	0.012	0.013
35	0.012	0.013	0.007
36	0.018	0.034	0.025
37	0.044	0.040	0.053
38+	0.900	0.880	0.867
Sample size	2,460	3,138	2,325
#	89	86	95

Table 10.11. Summary of results (including likelihood components and key parameter estimates) from the 2015 model cases investigated compared with 2013 results.

	M0-2013	M1-2015	M2-2015	M3-2015	M4-2015
Catch	0.04	0.04	0.04	0.06	0.09
Survey Biomass	11.10	10.82	10.14	10.10	10.14
Fishery Ages	25.53	29.78	29.35	23.06	28.52
Survey Ages	45.71	51.07	56.39	46.43	55.27
Fishery Sizes	41.59	43.84	50.58	50.54	50.59
Maturity Likelihood	70.20	70.20	70.20	70.20	70.20
Data-Likelihood	194.21	205.75	216.70	200.39	214.81
Penalties/Priors					
Recruitment Devs	7.38	8.54	8.18	8.12	8.12
F Regularity	4.67	4.76	4.70	4.94	5.55
q prior	0.66	0.76	0.42	0.33	0.28
M prior	0.04	0.06	0.02	0.02	0.02
Objective Fun Total	206.96	219.87	230.02	213.8	228.78
Parameter Estimates					
Active parameters					
q	0.60	0.57	0.66	0.70	0.71
M	0.06	0.06	0.06	0.06	0.06
σ_r	1.5	1.5	1.5	1.5	1.5
Mean recruitment (millions)	17.27	16.98	14.13	14.16	13.81
$F_{40\%}$	0.06	0.06	0.06	0.06	0.06
Total Biomass	102,893	95,634	85,757	80,518	77,574
Spawning Biomass	42,960	39,619	35,102	32,736	31,347
$B_{0\%}$	75,183	74,263	71,542	71,509	69,957
$B_{40\%}$	30,073	29,705	28,617	28,604	27,983
ABC ($F_{40\%}$)	5,324	4,933	4,475	4,184	**4,009**
$F_{35\%}$	0.07	0.07	0.07	0.07	0.07
OFL ($F_{35\%}$)	6,349	5,886	5,339	4,993	4,784

Table 10.12. Estimated numbers (thousands) in 2015, fishery selectivity, and survey selectivity of northern rockfish in the Gulf of Alaska based on the preferred model. Also shown are schedules of age specific weight and female maturity.

Age	2015 numbers (thousands)	Percent mature	Weight (g)	Fishery selectivity	Survey selectivity
2	8,588	0	24	0.000	0.010
3	8,091	1	76	0.000	0.020
4	7,014	1	152	0.001	0.041
5	6,169	3	243	0.006	0.081
6	4,983	5	341	0.032	0.153
7	4,014	9	438	0.155	0.272
8	3,506	16	531	0.508	0.436
9	2,354	26	616	0.853	0.615
10	1,590	40	692	0.970	0.767
11	873	56	760	0.995	0.872
12	689	71	818	0.999	0.934
13	1,174	83	868	1.000	0.967
14	2,059	90	911	1.000	0.984
15	1,715	95	947	1.000	0.992
16	2,444	97	977	1.000	0.996
17	6,729	98	1,002	1.000	0.998
18	4,079	99	1,023	1.000	0.999
19	2,933	100	1,041	1.000	1.000
20	4,754	100	1,055	1.000	1.000
21	6,951	100	1,067	1.000	1.000
22	1,257	100	1,077	1.000	1.000
23	1,432	100	1,086	1.000	1.000
24	1,346	100	1,092	1.000	1.000
25	1,796	100	1,098	1.000	1.000
26	881	100	1,103	1.000	1.000
27	1,761	100	1,106	1.000	1.000
28	1,424	100	1,109	1.000	1.000
29	1,039	100	1,112	1.000	1.000
30	1,959	100	1,114	1.000	1.000
31	3,521	100	1,116	1.000	1.000
32	1,075	100	1,117	1.000	1.000
33	2,212	100	1,118	1.000	1.000
34	1,271	100	1,119	1.000	1.000
35	1,119	100	1,120	1.000	1.000
36	574	100	1,121	1.000	1.000
37	770	100	1,121	1.000	1.000
38	1,562	100	1,122	1.000	1.000
39	1,758	100	1,122	1.000	1.000
40	959	100	1,122	1.000	1.000
41	355	100	1,123	1.000	1.000
42	579	100	1,123	1.000	1.000
43	304	100	1,123	1.000	1.000
44	463	100	1,123	1.000	1.000
45	1,036	100	1,123	1.000	1.000
46	266	100	1,123	1.000	1.000
47	418	100	1,123	1.000	1.000
48	202	100	1,123	1.000	1.000
49	158	100	1,123	1.000	1.000
50+	922	100	1,124	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 results compared to 2013.

	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	16,602	25,773	64,302	86,093	0.010	0.007	24.8	14.4
1978	18,587	27,485	69,317	90,413	0.008	0.006	41.7	101.3
1979	21,124	29,923	75,968	94,879	0.009	0.007	34.5	29.4
1980	24,070	32,911	80,255	98,947	0.010	0.008	15.9	19.2
1981	27,216	36,127	87,748	102,278	0.017	0.014	11.1	12.1
1982	30,114	38,991	99,383	123,823	0.039	0.032	20.3	17.8
1983	31,899	40,594	107,755	130,434	0.034	0.028	21.5	26.3
1984	33,764	42,319	111,972	134,821	0.009	0.007	34.7	46.1
1985	36,894	45,545	116,858	139,478	0.002	0.001	15.5	11.3
1986	40,707	49,712	124,049	145,100	0.002	0.002	46.0	68.0
1987	44,754	54,275	131,112	151,744	0.004	0.003	23.1	26.0
1988	48,659	58,629	141,191	162,216	0.008	0.007	11.1	10.7
1989	51,988	62,152	145,933	164,896	0.010	0.009	13.8	18.7
1990	54,798	64,884	157,706	178,667	0.011	0.010	15.6	19.5
1991	57,369	67,210	164,195	184,482	0.027	0.024	7.2	8.9
1992	58,779	68,306	164,135	183,489	0.047	0.042	13.4	17.9
1993	58,897	68,147	160,434	179,810	0.030	0.027	9.2	12.1
1994	60,165	69,266	159,439	178,648	0.037	0.033	8.9	9.8
1995	60,654	69,666	154,530	173,487	0.036	0.032	7.2	6.4
1996	60,715	69,666	150,819	169,853	0.022	0.020	36.3	57.0
1997	61,108	70,005	148,010	167,001	0.020	0.018	22.6	24.7
1998	61,066	69,894	145,096	163,613	0.021	0.019	12.6	12.2
1999	60,479	69,232	141,254	158,923	0.038	0.034	15.9	20.6
2000	58,494	67,161	142,577	162,664	0.023	0.020	23.8	27.9
2001	57,315	65,901	143,808	163,291	0.022	0.019	7.9	5.8
2002	56,291	64,798	143,022	161,555	0.023	0.021	5.0	5.6
2003	55,463	63,908	142,686	161,074	0.037	0.032	5.5	4.7
2004	54,231	62,629	142,531	160,287	0.034	0.030	2.8	2.9
2005	53,561	61,903	138,991	155,403	0.032	0.029	1.5	2.7
2006	53,164	61,394	134,442	150,111	0.037	0.033	1.7	4.1
2007	52,496	60,516	128,975	143,617	0.032	0.029	2.8	5.5
2008	51,882	59,608	123,140	137,022	0.033	0.029	3.7	7.2
2009	50,895	58,265	116,631	130,113	0.034	0.030	5.1	9.0
2010	49,421	56,402	109,901	123,314	0.035	0.032	5.4	9.6
2011	47,430	54,037	103,295	116,783	0.033	0.029	6.3	10.0
2012	45,197	51,492	97,360	111,153	0.052	0.045	7.4	10.6
2013	41,870	47,949	90,278	104,520	0.054	0.046	7.9	10.6
2014	38,495	-	83,786	-	0.051	-	8.6	-
2015	35,426	-	78,470	-	0.054	-	8.6	-

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 results.

	Recruits (Age 2)			Total Biomass			Spawning Biomass		
Year	Mean	2.50%	97.50%	Mean	2.50%	97.50%	Mean	2.50%	97.50%
1977	24,821	715	64,464	70,181	50,956	103,355	16,602	10,737	26,600
1978	41,684	415	95,935	77,172	56,348	112,449	18,587	12,385	29,207
1979	34,466	1,276	83,350	85,213	62,506	123,033	21,124	14,440	32,563
1980	15,927	482	48,641	93,793	69,365	133,809	24,070	16,718	36,419
1981	11,150	446	38,779	102,296	76,040	145,123	27,216	19,159	40,379
1982	20,324	800	50,517	109,842	81,774	155,586	30,114	21,380	44,408
1983	21,520	694	61,864	114,483	84,483	162,455	31,899	22,528	46,891
1984	34,740	1,288	69,035	119,377	87,829	170,125	33,764	23,643	49,636
1985	15,502	425	50,157	126,768	93,728	180,063	36,894	26,071	53,759
1986	46,044	14,209	86,290	135,355	100,658	190,913	40,707	29,140	58,828
1987	23,140	746	50,711	144,141	107,567	202,780	44,754	32,282	64,046
1988	11,110	580	33,435	152,492	113,974	213,200	48,659	35,358	69,263
1989	13,818	937	31,908	159,560	119,157	222,365	51,988	37,953	73,348
1990	15,582	1,924	33,081	165,286	123,208	229,967	54,798	40,099	77,140
1991	7,154	339	20,626	169,613	126,229	236,071	57,369	42,049	80,595
1992	13,400	3,197	28,112	169,890	125,387	237,335	58,779	42,834	82,894
1993	9,178	600	21,675	165,755	120,656	233,809	58,897	42,279	83,971
1994	8,918	1,207	21,084	163,579	117,876	232,167	60,165	42,871	86,169
1995	7,165	387	18,102	159,310	113,531	227,886	60,654	42,671	87,301
1996	36,270	19,525	63,336	155,291	108,685	223,892	60,715	42,125	87,787
1997	22,590	6,293	43,068	153,944	106,919	223,188	61,108	42,169	88,679
1998	12,639	1,551	30,497	153,378	105,936	223,280	61,066	41,961	88,640
1999	15,933	2,948	33,290	152,979	104,923	223,303	60,479	41,106	87,936
2000	23,826	10,406	46,892	150,605	101,349	221,797	58,494	39,023	85,816
2001	7,853	563	18,701	150,431	100,335	222,494	57,314	37,938	84,582
2002	5,006	478	13,827	150,166	98,903	224,548	56,291	36,834	83,493
2003	5,462	723	14,008	149,087	97,494	224,043	55,463	36,083	82,881
2004	2,828	213	8,089	145,266	93,331	219,641	54,231	34,635	81,979
2005	1,502	113	4,885	140,986	88,966	215,233	53,561	33,560	82,052
2006	1,713	124	5,966	136,085	84,636	209,898	53,164	32,755	82,330
2007	2,792	178	8,858	129,944	78,699	203,368	52,496	31,540	82,062
2008	3,711	202	14,214	123,968	73,408	195,716	51,882	30,554	81,721
2009	5,061	258	21,623	117,746	68,188	187,633	50,895	29,322	81,037
2010	5,412	218	30,296	111,465	62,977	179,651	49,421	27,733	79,619
2011	6,321	234	40,715	105,276	57,877	171,792	47,430	26,028	77,405
2012	7,372	249	48,939	99,754	53,634	164,075	45,197	24,079	74,690
2013	7,898	290	62,994	92,954	47,752	156,208	41,870	21,119	70,856
2014	8,586	260	107,545	86,844	42,790	150,154	38,495	18,313	66,291
2015	8,588	302	117,238	81,862	39,027	147,274	35,426	15,847	61,960
2016	13,809	293	75,503	77,574	35,443	144,835	31,347	12,998	55,953
2017	13,809	330	93,173	74,636	35,319	143,970	29,024	12,389	51,206

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	0.71	0.76	0.74	0.16	0.19	0.46	1.21
M	0.0593	0.0599	0.0598	0.0028	0.0029	0.0544	0.0658
$F_{40\%}$	0.0617	0.0708	0.0674	0.0160	0.0208	0.0405	0.1213
2016 SSB	31,347	30,156	28,492	10,651	11,180	12,998	55,953
2016 ABC	4,009	4,262	3,974	1,695	2,255	984	9,515

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. $B_{40\%}$ = 27,983 t, $B_{35\%}$ = 24,485 t, $F_{40\%}$ = 0.062, and $F_{35\%}$ = 0.074.

Year	Maximum permissible F	Author's F[1] (Estimated catches)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (mt)				
2015	34,045	34,045	34,045	34,045	34,045	34,045	34,045
2016	31,242	31,313	31,562	31,326	31,886	31,114	31,242
2017	28,770	29,033	29,958	29,081	31,198	28,307	28,770
2018	26,703	27,062	28,611	27,177	30,697	25,985	26,602
2019	25,081	25,390	27,540	25,614	30,410	24,200	24,720
2020	23,878	24,145	26,756	24,380	30,348	22,882	23,322
2021	23,045	23,275	26,245	23,461	30,518	21,966	22,339
2022	22,551	22,748	25,984	22,849	30,930	21,409	21,724
2023	22,371	22,539	25,962	22,539	31,598	21,179	21,444
2024	22,475	22,617	26,149	22,516	32,534	21,239	21,459
2025	22,811	22,931	26,551	22,743	33,724	21,530	21,712
2026	23,302	23,402	27,103	23,153	35,115	21,971	22,120
2027	23,865	23,948	27,847	23,669	36,632	22,479	22,599
2028	24,437	24,506	28,740	24,228	38,204	22,988	23,086
			Fishing mortality				
2015	0.060	0.060	0.060	0.060	0.060	0.060	0.060
2016	0.062	0.055	0.031	0.054	-	0.074	0.074
2017	0.062	0.055	0.031	0.054	-	0.074	0.074
2018	0.059	0.060	0.031	0.054	-	0.069	0.069
2019	0.055	0.056	0.030	0.054	-	0.064	0.064
2020	0.052	0.053	0.029	0.054	-	0.060	0.060
2021	0.050	0.051	0.029	0.054	-	0.057	0.057
2022	0.049	0.050	0.028	0.054	-	0.056	0.056
2023	0.049	0.049	0.028	0.054	-	0.055	0.055
2024	0.049	0.049	0.028	0.054	-	0.055	0.055
2025	0.050	0.050	0.029	0.054	-	0.056	0.056
2026	0.051	0.051	0.030	0.054	-	0.057	0.057
2027	0.052	0.052	0.030	0.054	-	0.059	0.059
2028	0.053	0.053	0.031	0.054	-	0.060	0.060
			Yield (mt)				
2015	4,223	4,223	4,223	4,223	4,223	4,223	4,223
2016	4,008	4,008	2,034	3,491	-	4,783	4,008
2017	3,747	3,772	1,959	3,289	-	4,419	3,747
2018	3,372	3,463	1,902	3,128	-	3,825	4,009
2019	3,023	3,097	1,813	3,003	-	3,373	3,518
2020	2,784	2,845	1,738	2,911	-	3,067	3,183
2021	2,639	2,690	1,702	2,854	-	2,878	2,973
2022	2,594	2,637	1,713	2,854	-	2,811	2,890
2023	2,638	2,675	1,769	2,903	-	2,848	2,914
2024	2,733	2,764	1,847	2,968	-	2,944	3,000
2025	2,860	2,886	1,932	3,038	-	3,079	3,125
2026	3,003	3,025	2,014	3,109	-	3,234	3,272
2027	3,142	3,160	2,090	3,176	-	3,387	3,417
2028	3,268	3,282	2,162	3,241	-	3,529	3,554

[1]Projected ABCs and OFLs for 2016 and 2017 are derived using estimated catch of 4,223 for 2015, and projected catches of 3,576 t and 3,343 t for 2016 and 2017 based on realized catches from 2012-2014. 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

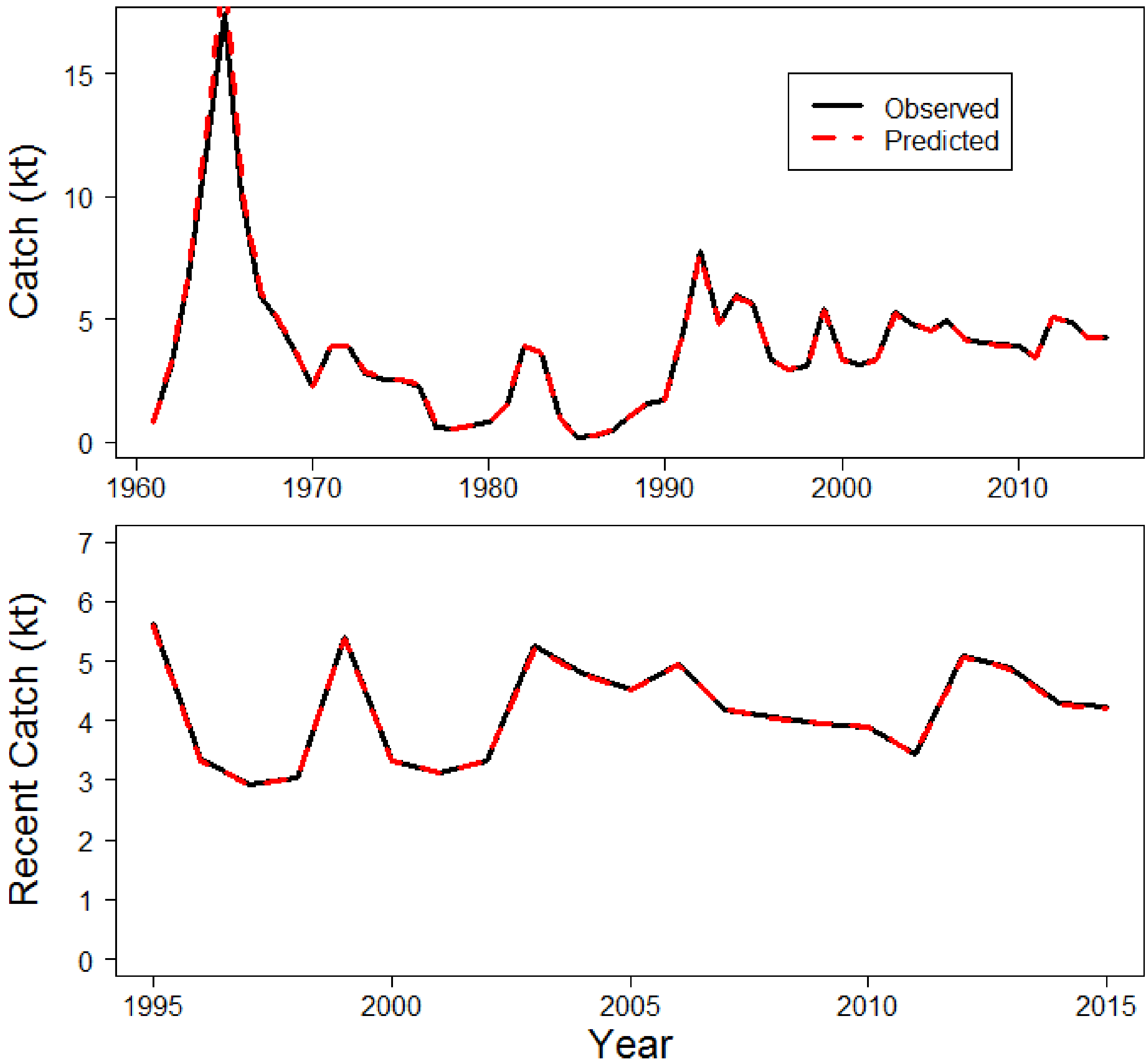

Figure 10.1. Estimated (red dashed lines) and observed (black solid lines) long-term and recent commercial catch of northern rockfish in the Gulf of Alaska. The *Description of the catch time series* section describes the procedures used to estimate catch for the years 1965-1993. Catch for the years 1993-2015 is from NMFS Observer Program and Alaska Regional Office.

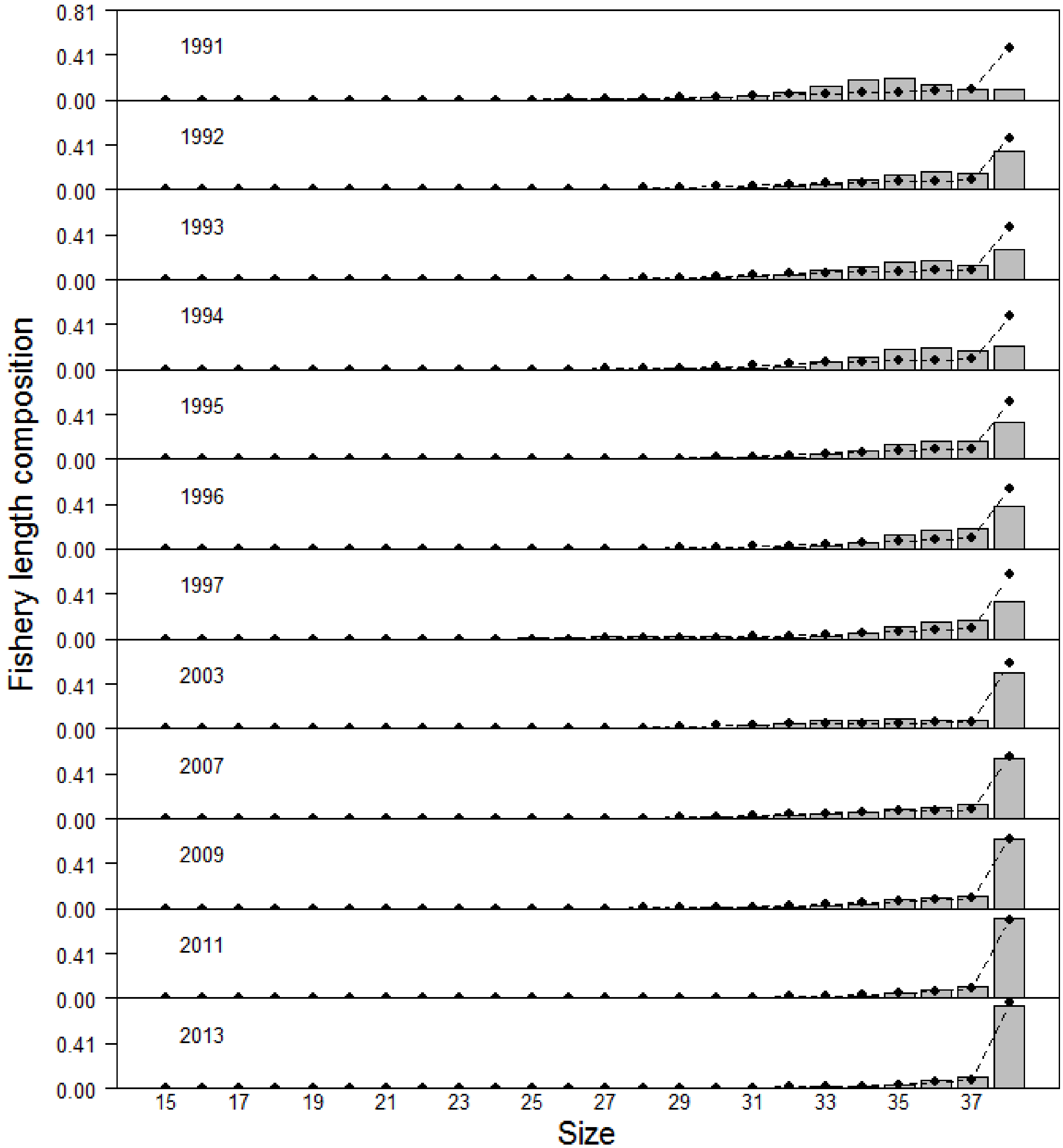

Figure 10.2. Fishery length compositions for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

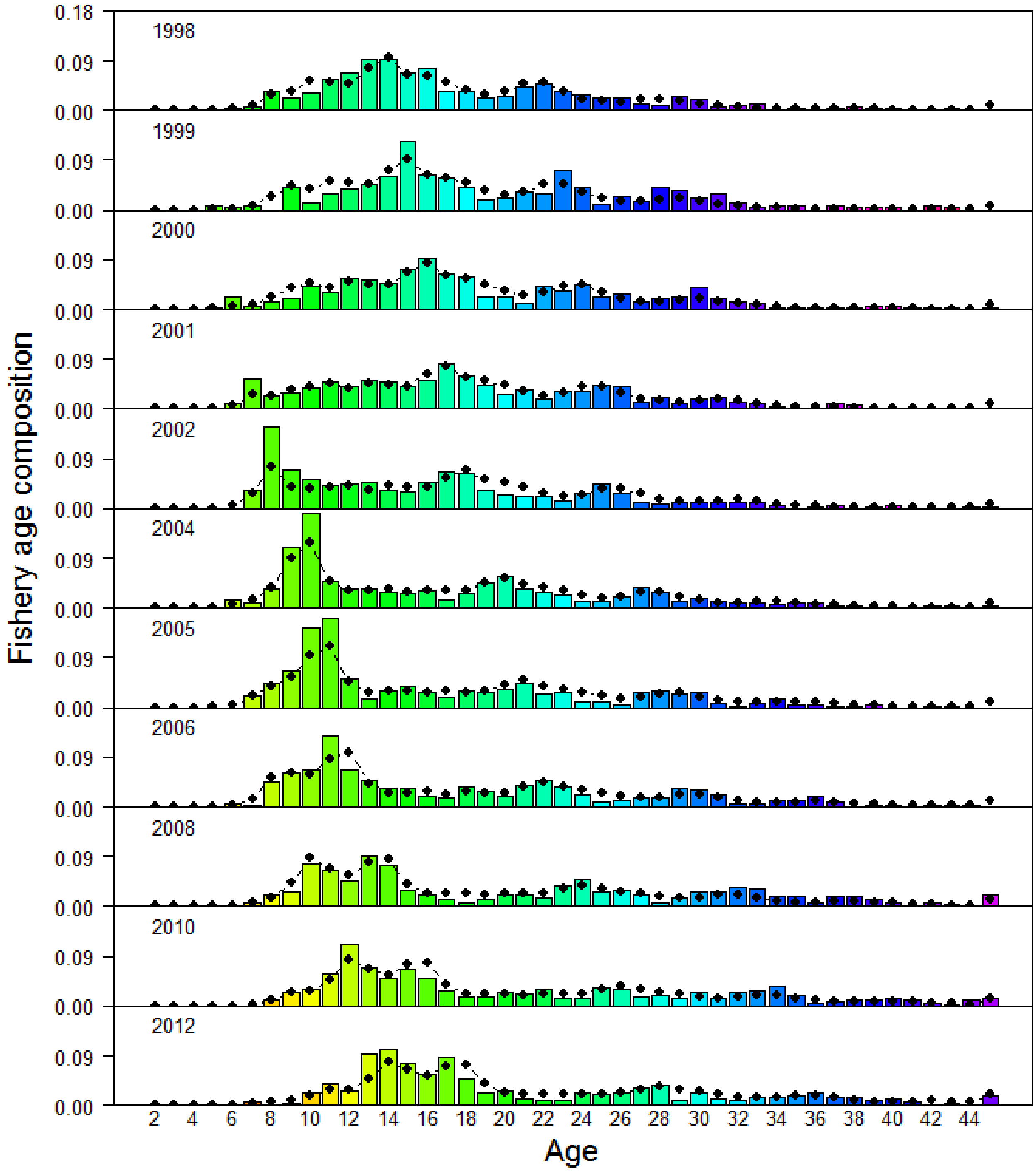

Figure 10.3. Fishery age compositions for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

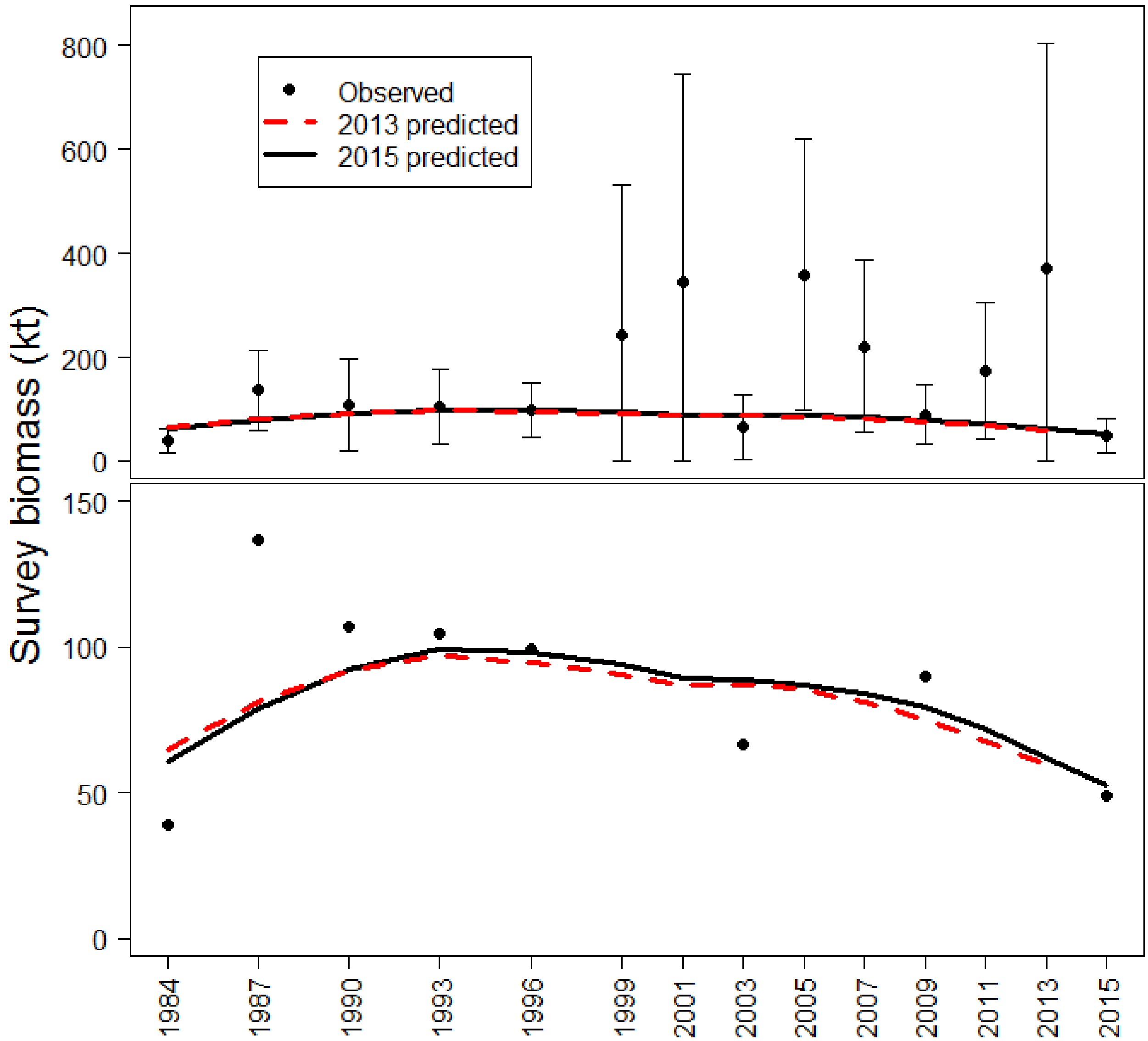

Figure 10.4. Upper panel is observed and predicted GOA northern rockfish trawl survey index of biomass (shown in units of kilotons). Observed biomass=circles with 95% confidence intervals of sampling error. Predictions are from 2011 model and this year's model configurations. Recommended model is black solid line. Bottom panel is an expansion without confidence intervals and the high point estimates of 1999, 2001, 2005, 2007, 2011, and 2013 to look at the fit at a visible scale.

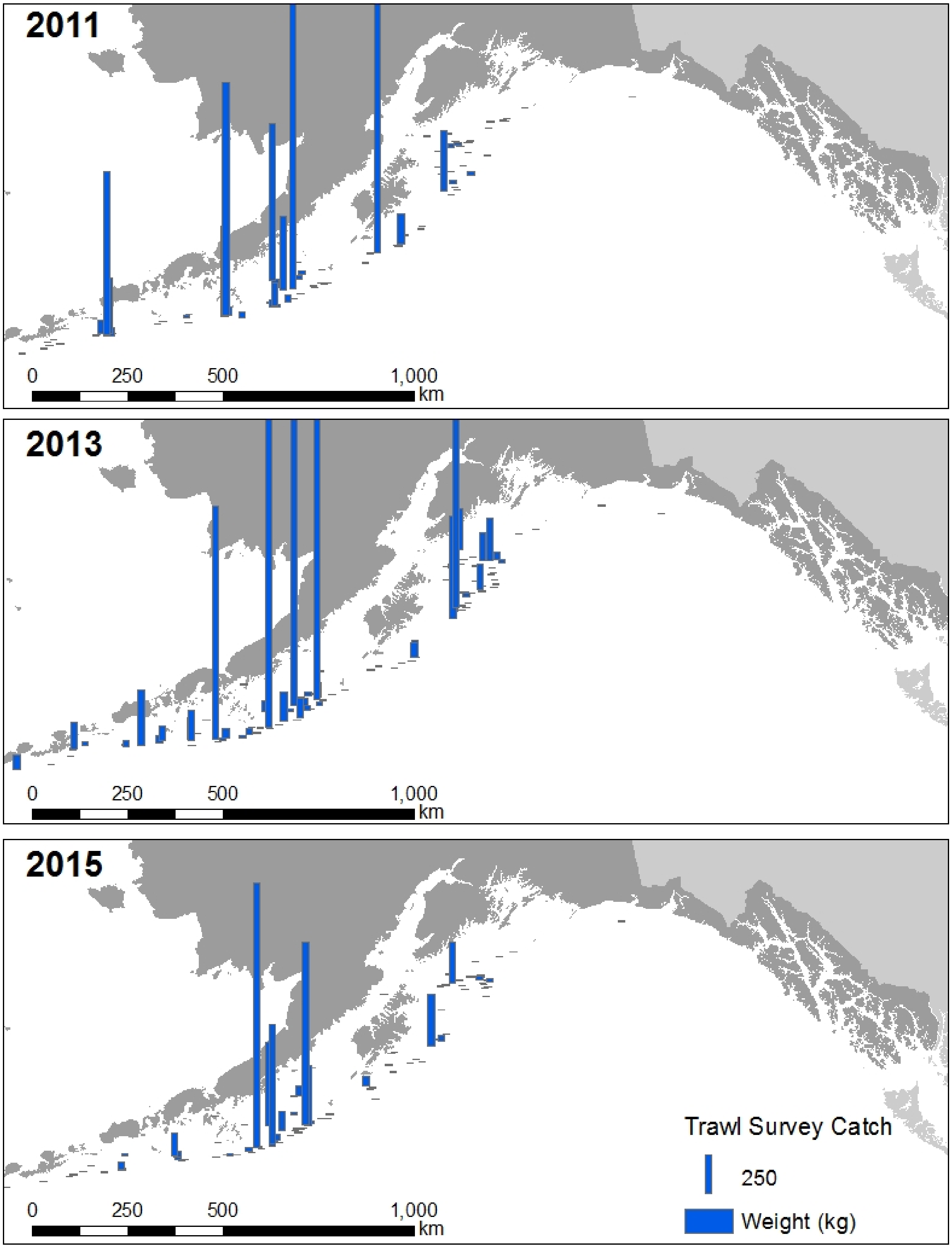

Figure 10.5. Spatial distribution of northern rockfish catch in the Gulf of Alaska during the trawl surveys.

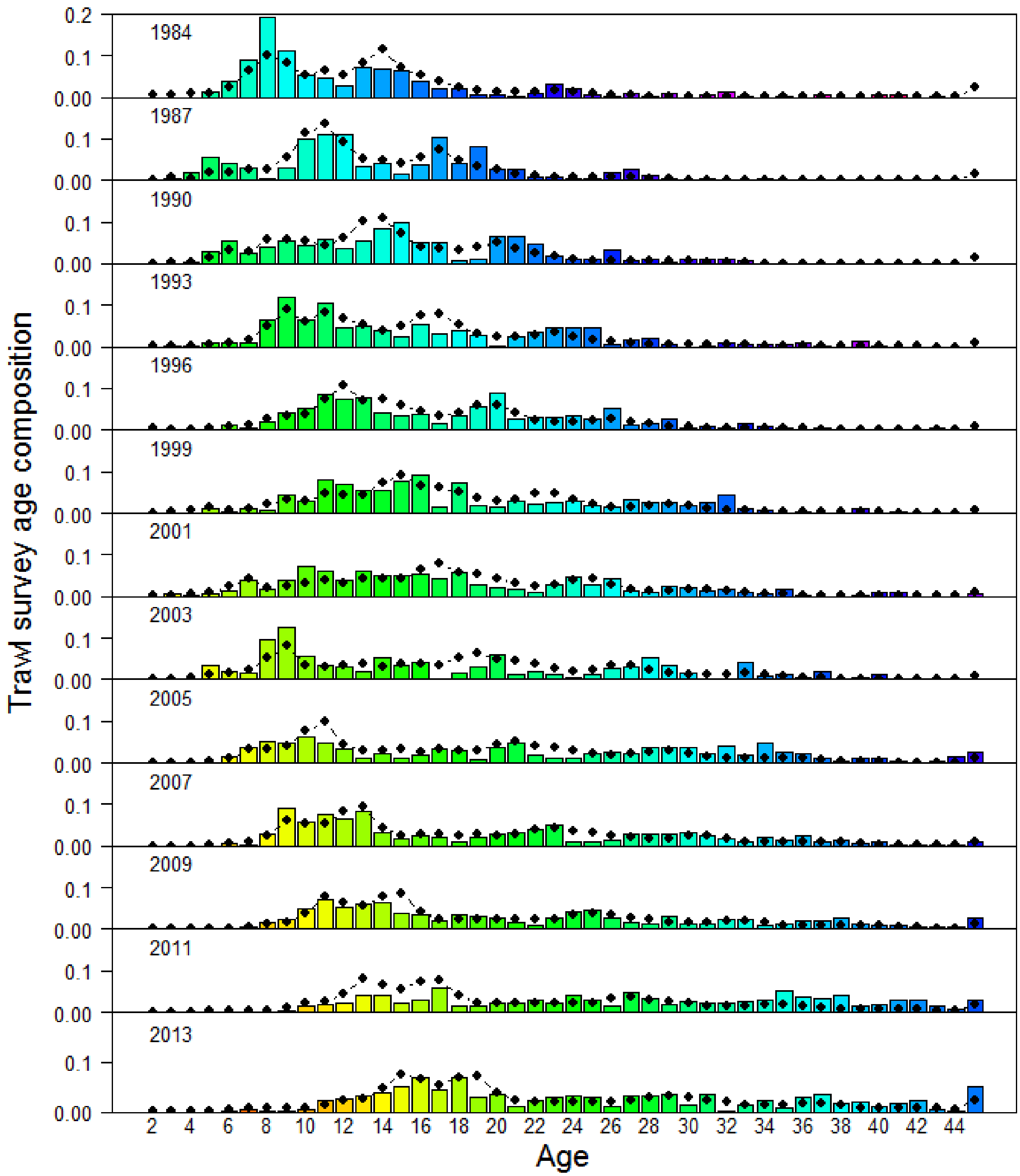

Figure 10.6. Trawl survey age composition by year for GOA northern rockfish. Observed = bars, predicted from author recommended model = line with circles.

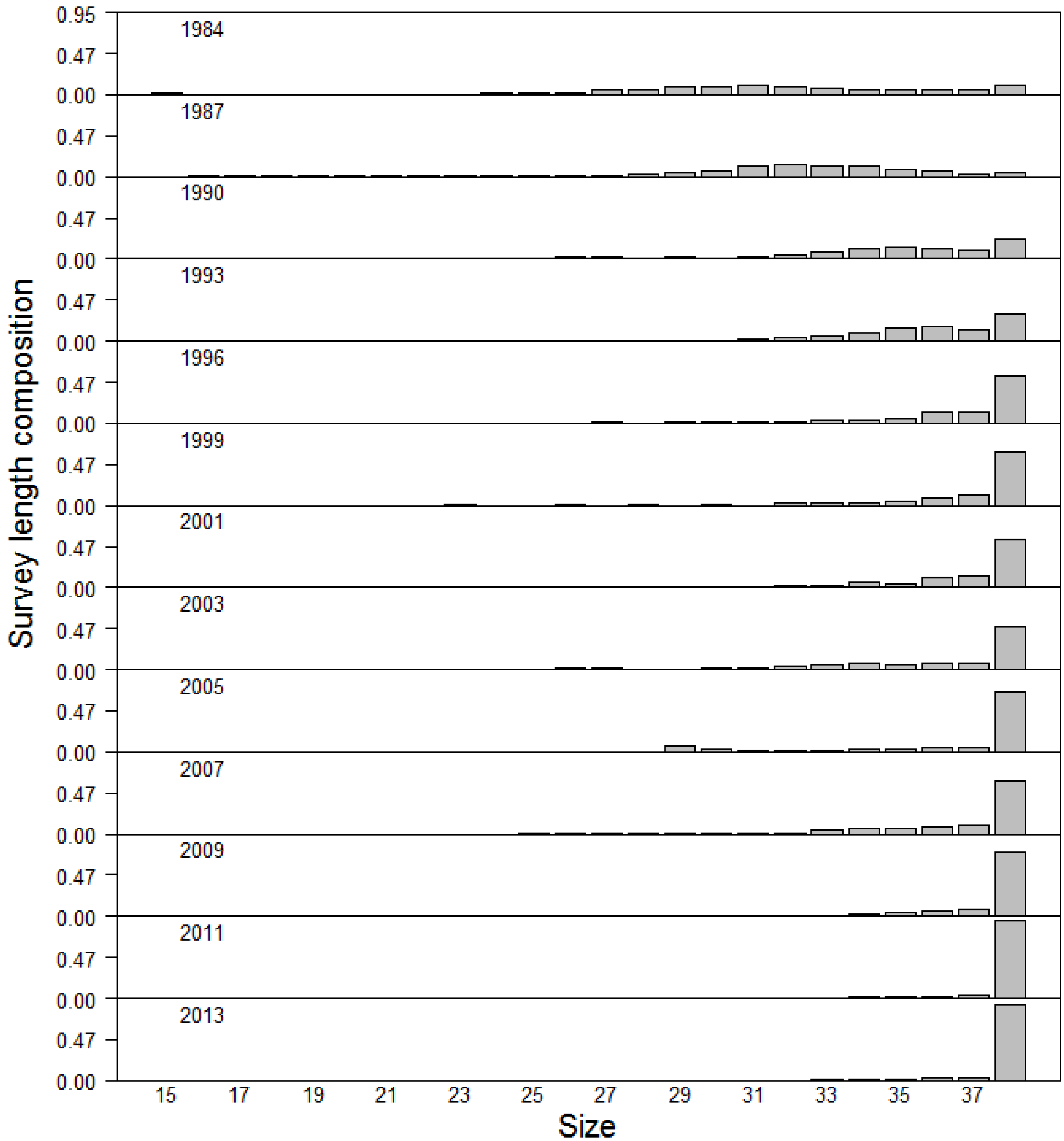

Figure 10.7. Groundfish survey length compositions for GOA northern rockfish. Observed = bars. Survey size distributions not used in the model because survey ages are available for these years.

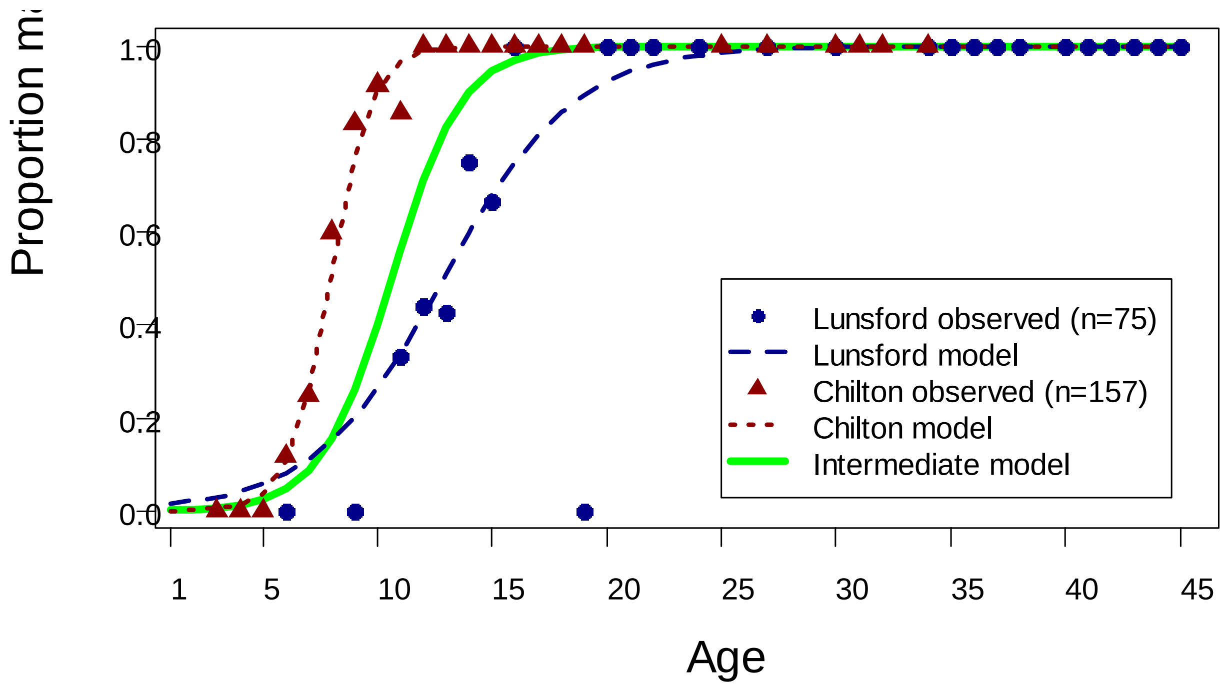

Figure 10.8. Intermediate model fit to combined female northern rockfish maturity data. Also shown are separate model fits to each dataset.

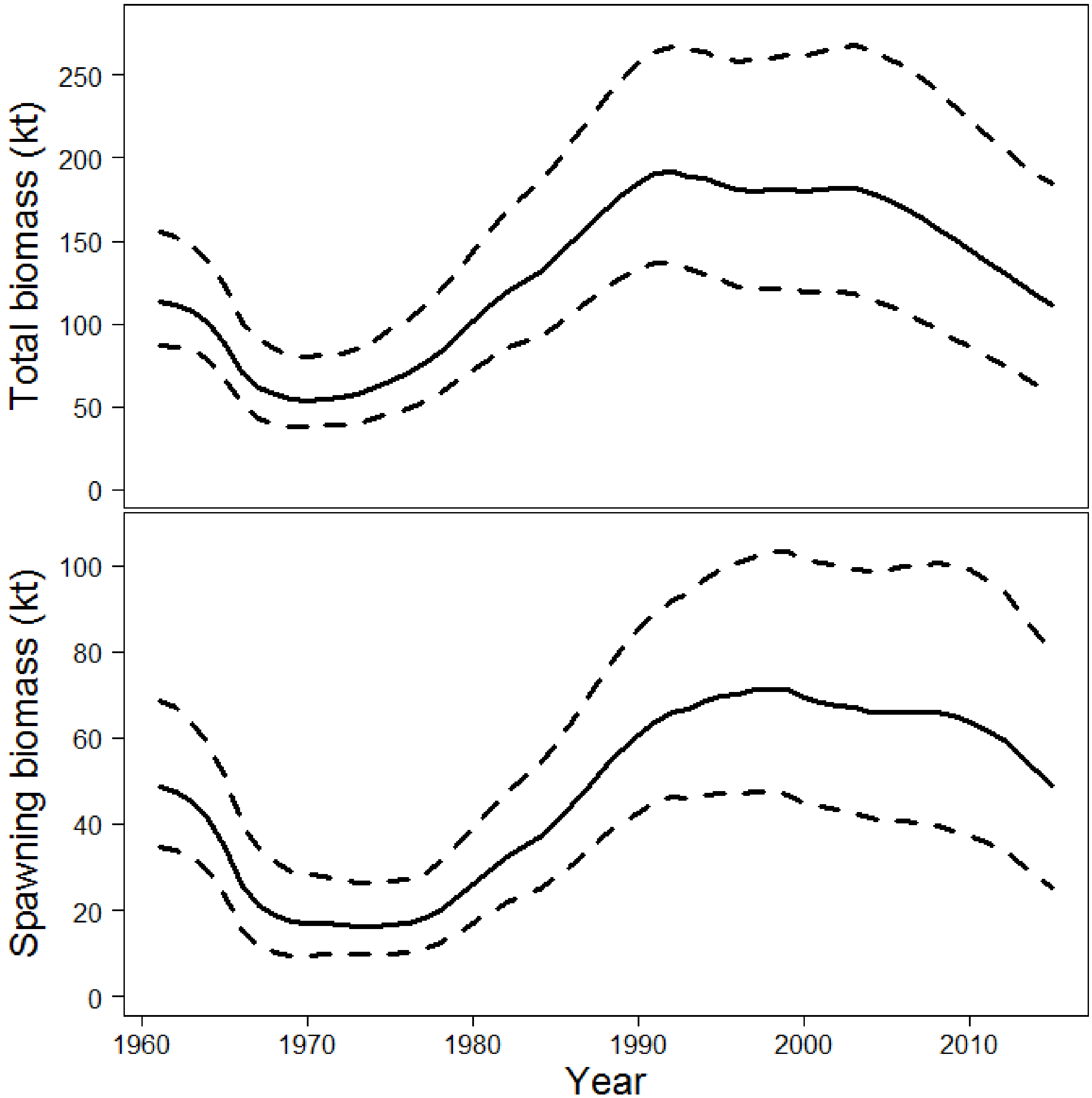

Figure 10.9. Model estimated total biomass and spawning biomass (solid lines) with 95% credible intervals determined by MCMC (dashed line) for Gulf of Alaska northern rockfish.

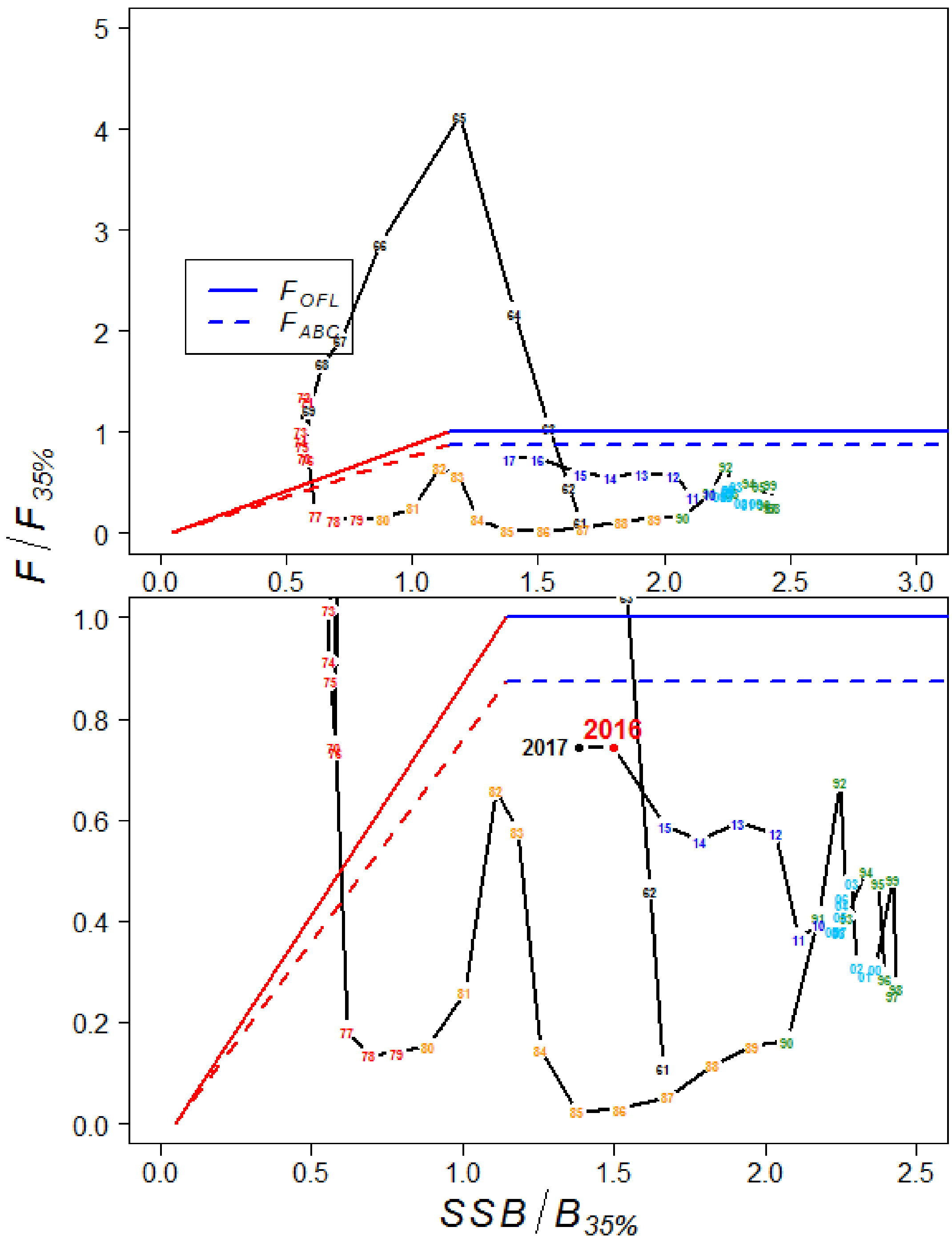

Figure 10.10. Time series of northern rockfish estimated spawning biomass (*SSB*) relative to $B_{35\%}$ and fishing mortality (*F*) relative to $F_{35\%}$ for author recommended model.

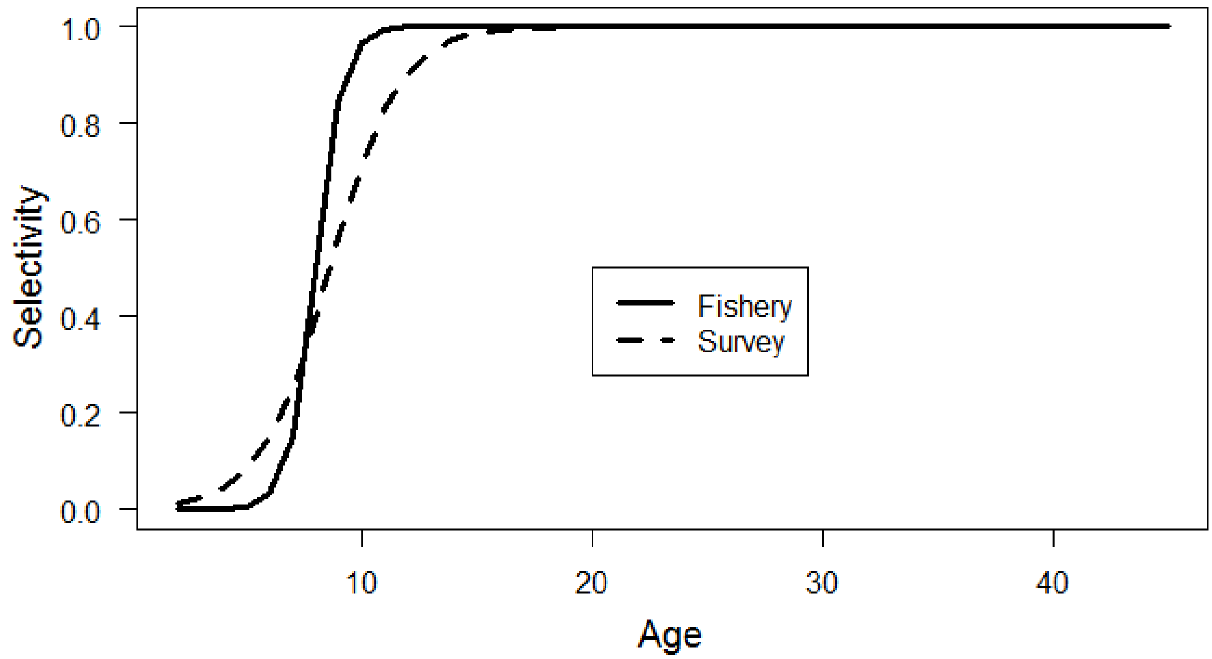

Figure 10.11. Fishery (solid line) and survey (dotted line) estimates of selectivity for GOA northern rockfish based on the authors recommended model.

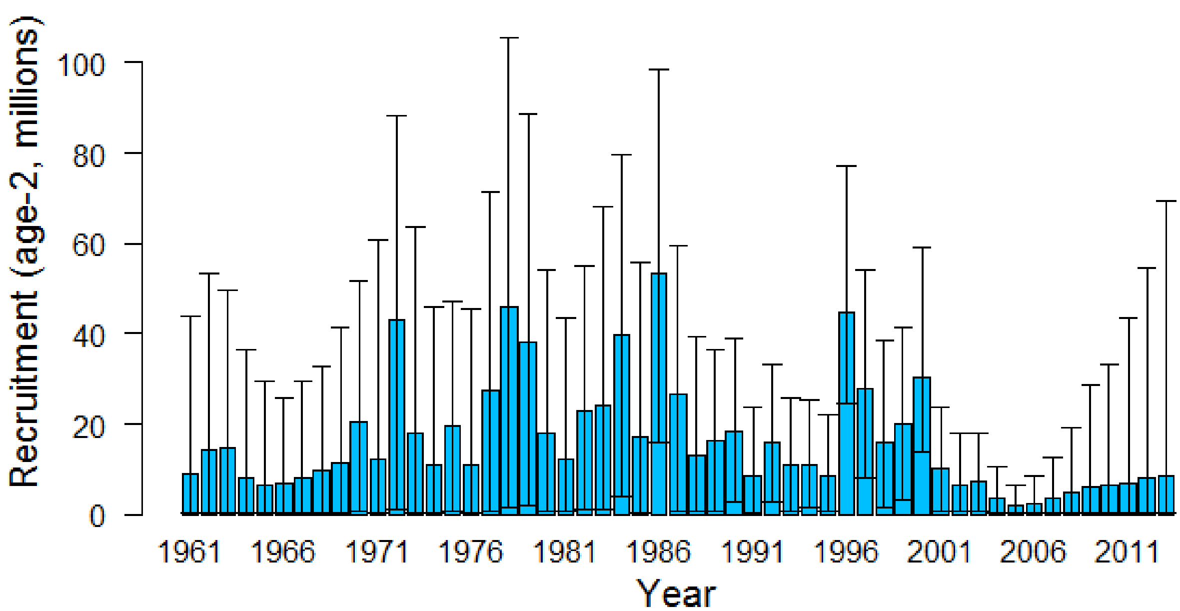

Figure 10.12. Estimates of recruitment (at age-2) and 95% credible intervals for GOA northern rockfish based on the 2015 model.

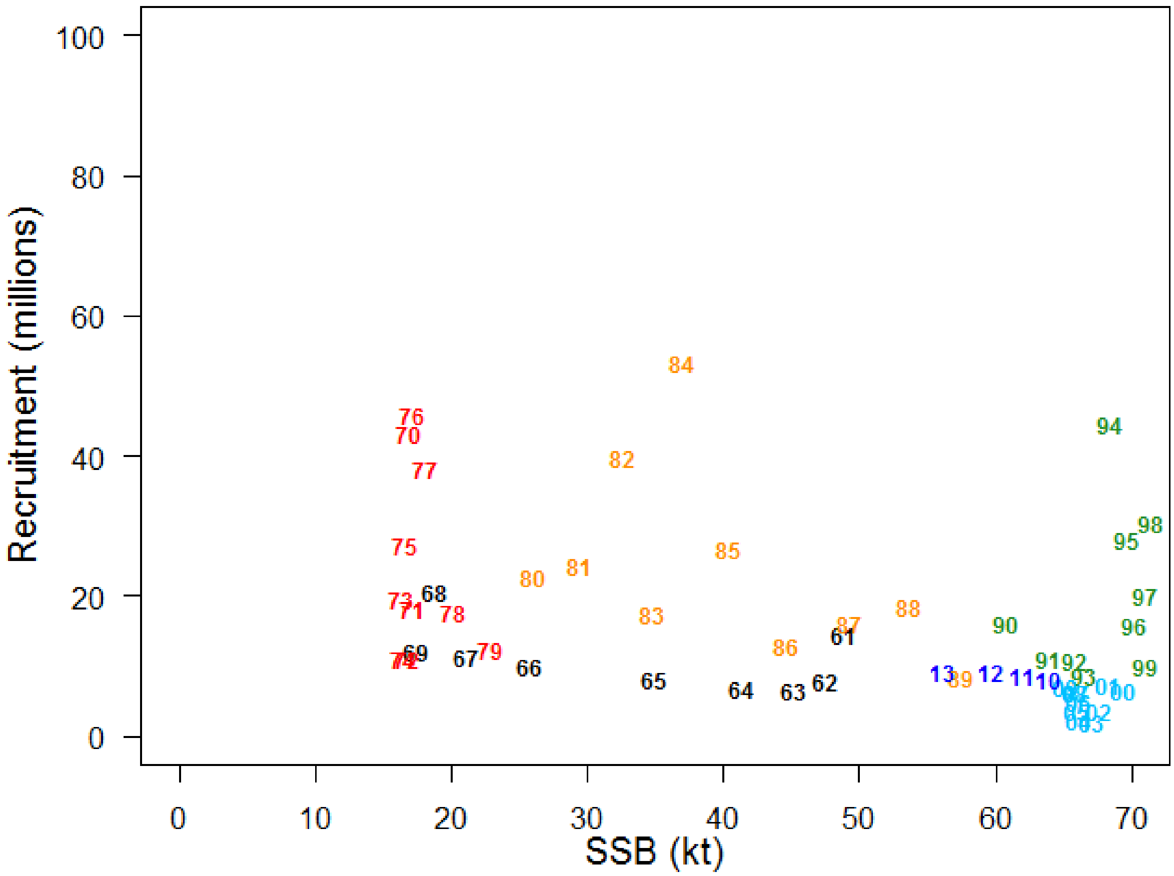

Figure 10.13. Relationship between female spawning stock biomass (SSB) and recruitment (by year class) for GOA northern rockfish based on the 2015 model.

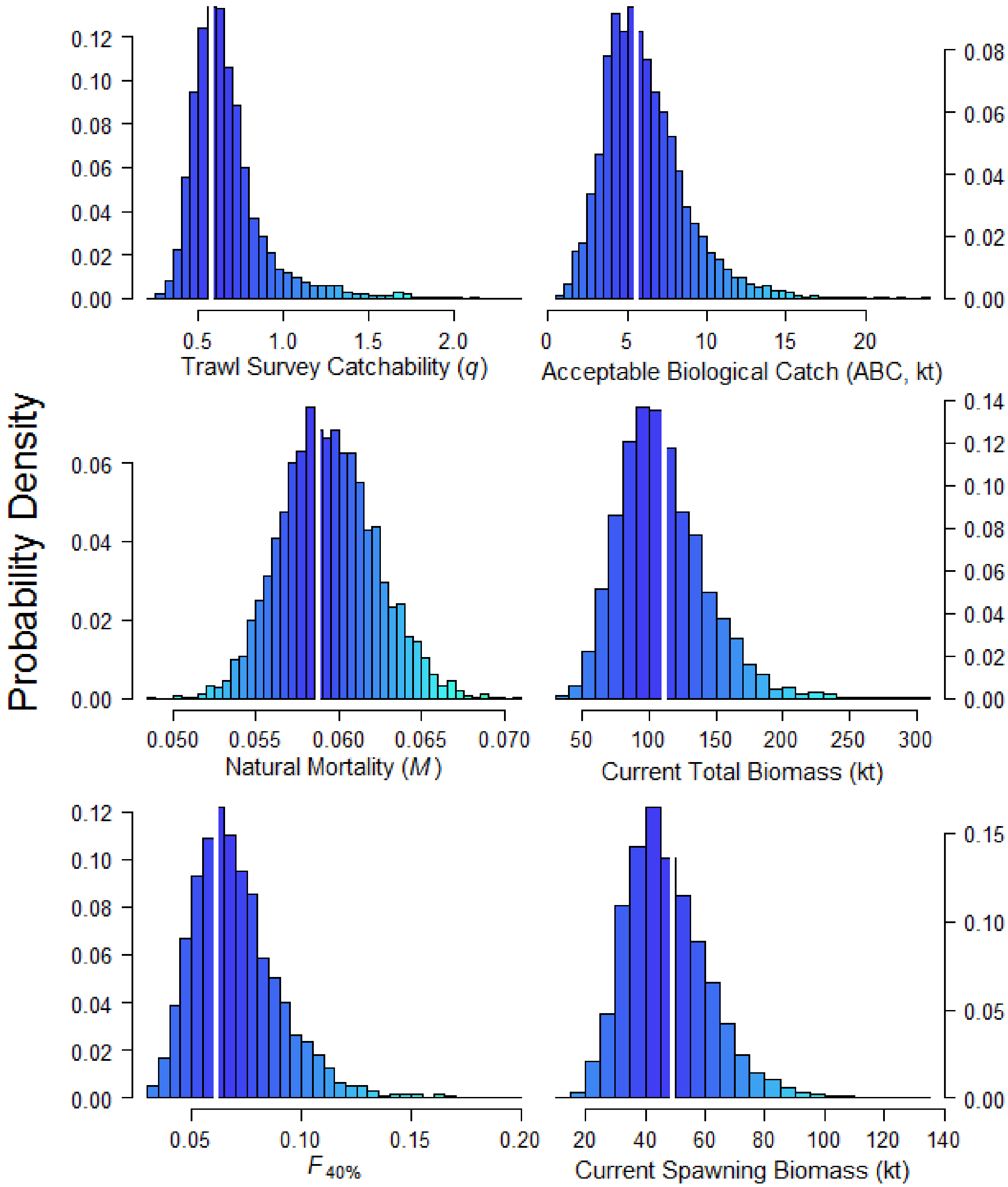

Figure 10.14. Histograms of estimated posterior distributions for key parameters derived from the MCMC for GOA northern rockfish. Vertical white lines represent the maximum likelihood estimate for comparison with the MCMC results.

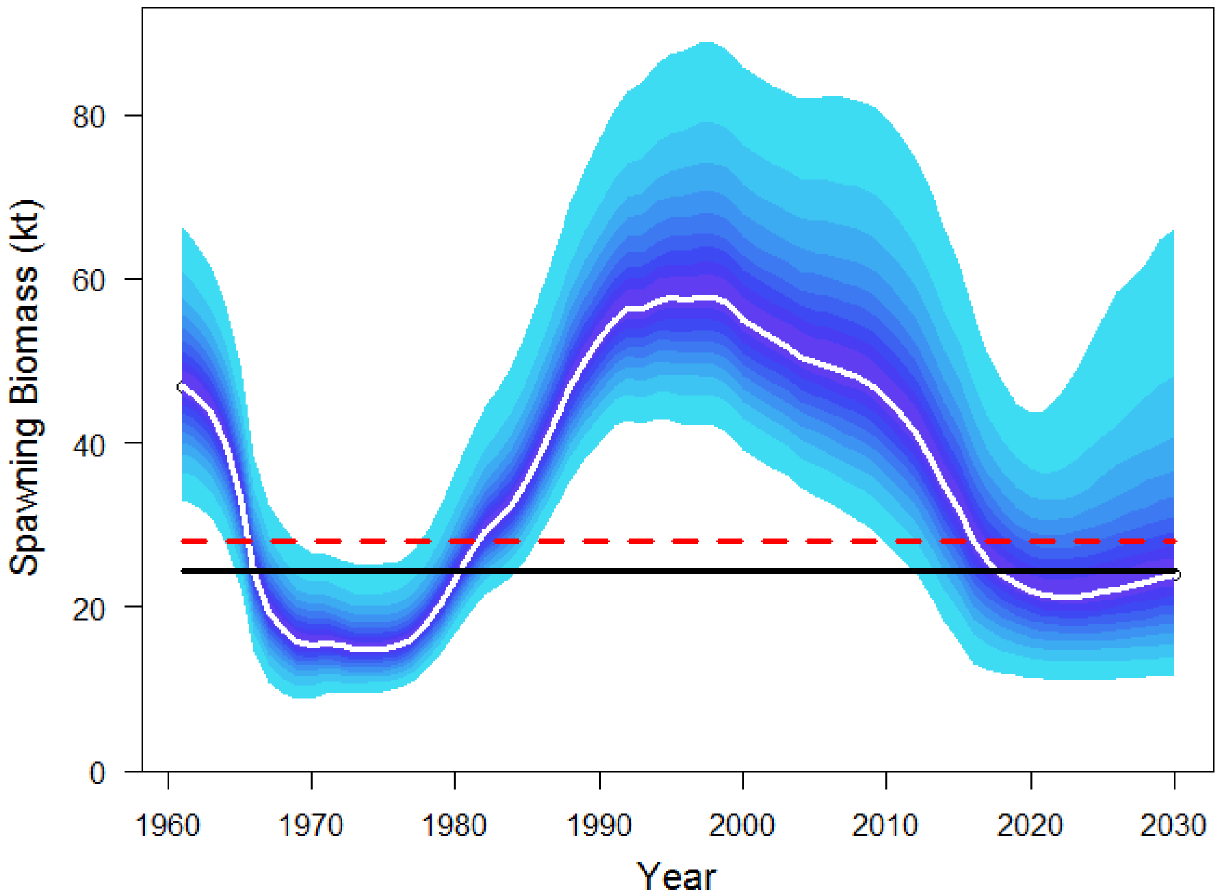

Figure 10.15. Bayesian credible intervals for entire spawning stock biomass series including projections through 2030. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1977-2013. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution

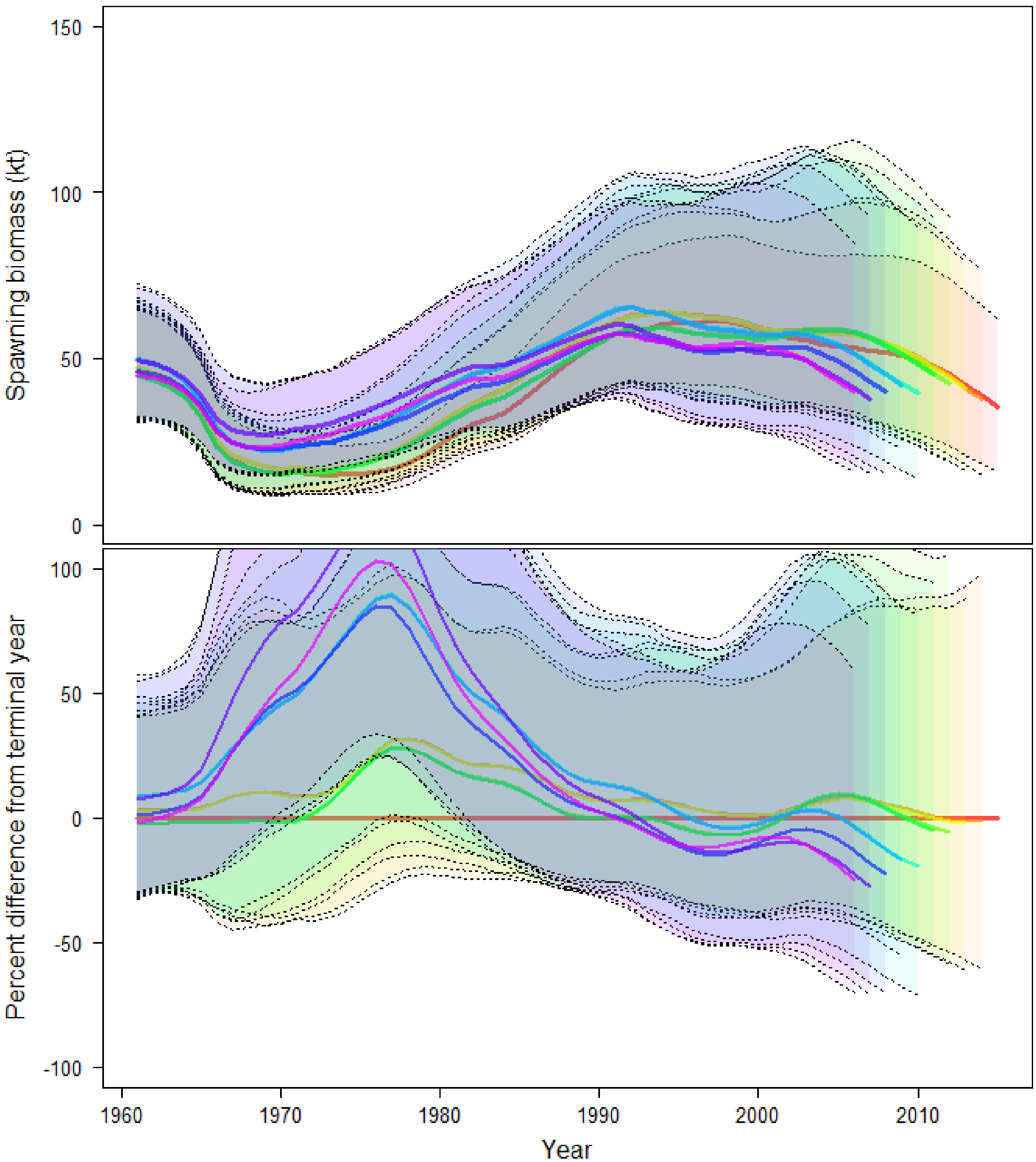

Figure 10.16 Retrospective peels of estimated female spawning biomass for the past 10 years from the recommended model with 95% credible intervals derived from MCMC (top), and the percent difference in female spawning biomass from the recommended model in the terminal year with 95% credible intervals from MCMC.

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 (CAS) estimates. For Gulf of Alaska (GOA) northern rockfish, these estimates can be compared to the research removals reported in previous assessments (Heifetz 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 recent years. Total removals from activities other than a directed fishery were less than 1 t in years when there is not a GOA bottom trawl survey. This represents approximately 0.02% of the recently recommended ABCs 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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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
2011		11	<1	11
2012		<1	<1	1
2013		18	<1	18
2014		<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.

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