12. Assessment of the Dusky Rockfish stock in the Gulf of Alaska

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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. However, due to the 2013 government shutdown, we do not present alternative model configurations in this year's assessment. Additionally, some sections may not have been fully updated from the 2011 assessment document.

We use a statistical age-structured model as the primary assessment tool for Gulf of Alaska dusky rockfish which qualifies as a Tier 3 stock. This assessment consists of a population 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 population model to predict future population estimates and recommended harvest levels. For this on-cycle year, we update the 2011 assessment model estimates with new data collected since the last full assessment.

Summary of Changes in Assessment Inputs

Changes in input data: The input data were updated to include the 2013 trawl survey biomass estimate, final catch for 2012, preliminary catch for 2013, survey age compositions for 2011, and final fishery length compositions for 2011.

Changes in the assessment methodology: The assessment methodology is the same as the 2011 assessment and uses the 2011 base model configuration with updated input data.

Summary of Results

The following results are based on the author recommended base model. The maximum allowable ABC for 2014 is 5,486 t based on Tier 3 status for dusky rockfish. This ABC is 17% more than last year's ABC of 4,700 t. The increase in ABC is attributable to a 19% increase in the trawl survey biomass estimate in 2013 from 2011. This is the second highest survey biomass estimate recorded and is 36% greater than the mean biomass estimate of the time series. The 2014 Gulf-wide OFL for dusky rockfish is 6,708 t. Recommended area apportionments of ABC are 317 t for the Western area, 3,584 t for the Central area, 1,384 t for the West Yakutat area, and 201 t for the Southeast/Outside area. This represents a large ABC increase in the West Yakutat area in comparison to previous years. This is attributable to the highest ever biomass recorded in this area in the 2013 survey which encountered large numbers of dusky rockfish in two hauls. The corresponding reference values for dusky rockfish are summarized in the following table, with the recommended ABC and OFL values in bold. 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: 2013	2014	As estimated or *recommended this* year for: 2014[1]	2015[1]
M (natural mortality rate)	0.07	0.07	0.07	0.07
Tier	3a	3a	3a	3a
Projected total (age 4+) biomass (t)	63,515	61,938	69,371	66,104
Female spawning biomass (t)				
Upper 95% confidence interval[2]			44,553	40,797
Point estimate	25,337	23,874	29,256	27,200
Lower 95% confidence interval[2]			19,848	18,116
$B_{100\%}$	49,683	49,683	52,264	52,264
$B_{40\%}$	19,873	19,873	20,906	20,906
$B_{35\%}$	17,389	17,389	18,292	18,292
F_{OFL}	0.122	0.122	0.122	0.122
$maxF_{ABC}$	0.098	0.098	0.098	0.098
F_{ABC}	0.098	0.098	0.098	0.098
OFL (t)	5,746	5,395	**6,708**	6,213
maxABC (t)	4,700	4,413	5,486	5,081
ABC (t)	4,700	4,413	**5,486**	5,081
Status	As determined *last* year for: 2011	2012	As determined *this* year for: 2012	2013
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 2014 and 2015 are derived using estimated catch of 2,993 for 2013, and projected catches of 3,530 t and 3,270 t for 2014 and 2015 based on realized catches from 2010-2012.This calculation is in response to management requests to obtain more accurate projections.
[2]Projected upper and lower 95% confidence intervals for female spawning biomass are derived from the MCMC estimated posterior distribution as presented in Table 12-15.

The following table shows the recommended apportionment for 2014.

	Western	Central	Eastern	Total
Area Apportionment	5.8%	65.3%	28.9%	100%
Area ABC (t)	**317**	**3,584**	**1,585**	**5,486**
OFL (t)				**6,708**

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of biomass still obtainable in the W. Yakutat area (between 147° W and 140° W) is 0.87. This results in the following apportionment to the W. Yakutat area:

	W. Yakutat	E. Yakutat/Southeast
Area ABC (t)	**1,384**	**201**

Plan Team Summaries

Stock/Assemblage	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
	2012	66,771	6,257	5,118	5,118	4,012
	2013	63,515	5,746	4,700	4,700	2,886[2]
	2014	69,371	6,708	5,486		
	2015	66,104	6,213	5,081		

Stock/		2013				2014		2015	
Assemblage	Area	OFL	ABC	TAC	Catch[2]	OFL	ABC	OFL	*ABC*
Dusky Rockfish	W		377	377	215		317		294
	C		3,533	3,533	2,660		3,584		3,319
	WYAK		495	495	3		1,384		1,282
	EYAK/SEO		295	295	8		201		186
	Total	5,746	4,700	4,700	2,886	6,708	5,486	6,213	5,081

[1]Total biomass (age 4+) estimates from age-structured model
[2]Current as of October 5, 2013

Responses to SSC and Plan Team Comments on Assessments in General

Because of the government shutdown, there was only sufficient time to compile SSC and Plan Team comments. For the next full assessment, we will respond to all previous comments.

"The SSC is pleased to see that many assessment authors have examined retrospective bias in the assessment and encourages the authors and Plan Teams to determine guidelines for how to best evaluate and present retrospective patterns associated with estimates of biomass and recruitment. We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments." (SSC, December 2011)

"The SSC concurs with the Plan Teams' recommendation that the authors consider issues for sablefish where there may be overlap between the catch-in-areas and halibut fishery incidental catch estimation (HFICE) estimates. In general, for all species, it would be good to understand the unaccounted for catches and the degree of overlap between the CAS and HFICE estimates, and to discuss these at the Plan Team meetings next September." (SSC, December 2011)

"The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented. The Teams recommend that the "other" removals data set continue to be compiled, and expanded to include all sources of removal." (Plan Team, September 2012)

"For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years."
(Plan Team, September 2012)

"The Teams recommend that the whole time series of each category of 'other' catches be made available on the NMFS "dashboard," so that they may be listed in all SAFE chapters."

(Plan Team, November 2012)

"The SSC recommends that the authors consider whether it is possible to estimate M with at least two significant digits in all future stock assessments to increase validity of the estimated OFL."
(SSC, December 2012)

SSC and Plan Team Comments Specific to this Assessment

"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)

"The Team noted the low recruitment estimates (with high uncertainty) for recent year classes, and requests a retrospective analysis to evaluate how changes in available data affect estimated year-class strength." (Plan Team, November 2011)

"Results from model 3 showed the age at 50% maturity from model 3 was approximately 10 years, a decline from the value of approximately 11 years used in previous assessments. This resulted in an increase in the recommended F_{OFL} *and* F_{ABC}*. The SSC asks the author to consider whether this downward adjustment in the age at 50% maturity is warranted."* (SSC, December 2011)

"The authors noted that if area specific OFLs were in place they would have been exceeded in the western GOA. The SSC encourages the authors to continue to track this in future years." (SSC, December 2012)

Introduction

Biology and Distribution

Dusky rockfish (*Sebastes variabilis*) have one of the most northerly distributions of all rockfish species in the Pacific. They range from southern British Columbia north to the Bering Sea and west to Hokkaido Is., Japan, but appear to be abundant only in the Gulf of Alaska (GOA). The forms of dusky rockfish commonly recognized as "light dusky rockfish" and "dark dusky rockfish" are now officially recognized as two species (Orr and Blackburn 2004). *S. ciliatus* applies to the dark shallow-water species with a common name dark rockfish, and *S. variabilis* applies to variably colored deeper-water species with the common name dusky rockfish.

Adult dusky rockfish are concentrated on offshore banks and near gullies on the outer continental shelf at depths of 100 to 200 m (Reuter 1999). Anecdotal evidence from fishermen and from biologists on trawl surveys suggests that dusky rockfish are often caught in association with a hard, rocky bottom on these banks or gullies. Also, during submersible dives on the outer shelf of the eastern GOA, dusky rockfish were observed in association with rocky habitats and in areas with extensive sponge beds, where adults were seen resting in large vase sponges[1]. A separate study counted eighty-two juvenile rockfish closely associated with boulders that had attached sponges. No rockfish were observed near boulders without sponges (Freese and Wing 2003). Another study using a submersible in the eastern GOA observed small dusky rockfish associated with *Primnoa* spp. corals (Krieger and Wing 2002).

Management Units

Dusky rockfish are managed as a separate stock in the GOA Federal Management Plan (FMP). There are three management areas in the GOA: Western, Central, and Eastern. The Eastern area is further divided into West Yakutat and East Yakutat/Southeast Outside management units. This is done to account for the trawl prohibition in the East Yakutat/Southeast Outside area (east of 140 degree W. longitude) created by Amendment 41.

Stock structure

A review of dusky rockfish stock structure was presented to the GOA Plan Team in September, 2011, and was presented as an Appendix to the 2012 assessment document. In summary, available data suggests lack of significant stock structure; therefore, the current resolution of spatial management is likely adequate and consistent with management goals (Lunsford et al. 2012). It is evident from this evaluation that life history focused research is warranted and will help in evaluating dusky rockfish stock structure in the GOA.

Life history

Parturition is believed to occur in the spring, based on observation of ripe females sampled on a research cruise in April 2001 in the central GOA. Similar to all other species of *Sebastes*, dusky rockfish are ovoviviparous with fertilization, embryonic development, and larval hatching occurring inside the mother. After extrusion, larvae are pelagic, but larval studies are hindered because they can only be positively identified by genetic analysis. Post-larval dusky rockfish have not been identified; however, the post-larval stage for other *Sebastes* is pelagic, so it is also likely to be pelagic for dusky rockfish. The habitat of young juveniles is completely unknown. At some point they are assumed to migrate to the bottom and take up a demersal existence, juveniles less than 25 cm fork length are infrequently caught in bottom trawl surveys (Clausen et al. 2002) or with other sampling gear. Older juveniles have been taken only infrequently in the trawl surveys, but when caught are often found at more inshore and shallower locations that adults. The major prey of adult dusky rockfish appears to be euphausiids, based on the

[1]V.M. O'Connell, Alaska Dept. of Fish and Game, 304 Lake St., Sitka, AK 99835. Pers. commun. July 1997.

limited food information available for this species (Yang 1993). In a more recent study, Yang et al. (2006) found that Pacific sandlance along with euphausiids were the most common prey item of dusky rockfish, comprising 82% and 17% , respectively, of total stomach contents by weight.

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-truncation could be deleterious to a population with highly episodic recruitment like rockfish (Longhurst 2002). Work on black rockfish (*S. melanops*) has shown that larval survival may be dramatically higher from older female spawners (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. 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. Such relationships have not yet been determined to exist for dusky rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age.

Fishery

Description of Directed Fishery

Dusky rockfish are caught almost exclusively with bottom trawls in the central and western areas of the GOA. Catches of dusky rockfish are concentrated at a number of relatively shallow, offshore banks of the outer continental shelf, especially the “W” grounds west of Yakutat, Portlock Bank northeast of Kodiak Island, and around Albatross Bank south of Kodiak Island. Highest catch-per-unit-effort in the commercial fishery is generally at depths of 100-149 m (Reuter 1999). During the period 1988-95, almost all the catch of dusky rockfish (>95%) was taken by large factory trawlers that processed the fish at sea. This changed starting in 1996, when smaller shore-based trawlers also began taking a sizeable portion of the catch in the Central Gulf area for delivery to processing plants in Kodiak.

The Rockfish Program in the Central GOA initiated in 2007 allocated the rockfish quota by sector so the percentage of 2007-present catches by shore-based catcher vessels differs in comparison to previous years. One benefit realized from the Rockfish Program is increased observer coverage and sampled catch for trips that target dusky rockfish (Lunsford et al. 2009). Since the majority of dusky rockfish catch comes from the Central GOA, the effects of the Rockfish Program has implications on the spatial distribution of dusky rockfish catch. In a study on localized depletion of Alaskan rockfish, Hanselman et al. (2007) found that dusky rockfish were rarely depleted in areas 5,000-10,000 km^2, except during 1994 in one area known as the “Snakehead” outside Kodiak Island in the Gulf of Alaska. This area was heavily fished for northern rockfish in the 1990s and both fishery and survey catch-per-unit-effort have consistently declined in this area since 1994. Comparison of spatial distribution of the dusky rockfish catch before and after the Rockfish Program began does not show major changes in catch distribution (Figure 12-1). Due to the increased observer coverage associated with the Program, however, it’s difficult to discern from examining catch levels whether areas are fished more or if it’s due to increased monitoring. Analysis of this data will help to understand how the extended season and spatial distribution of effort has changed in response to this management action.

Catch History

Catch reconstruction for dusky rockfish is difficult because in past years dusky rockfish were managed as part of the pelagic shelf rockfish assemblage (Table 12-1). Fishery catch statistics specific to dusky rockfish in the Gulf of Alaska are available for the years 1977-2013 (Table 12-2). Generally, annual catches increased from 1988 to 1992, and have fluctuated in the years following. This pattern is largely explained by management actions that have affected rockfish during this period. In the years before 1991, TACs were relatively large for more abundant slope rockfish species such as Pacific ocean perch, and there was less reason for fishermen to target dusky rockfish. However, as TACs for slope rockfish became more restrictive in the early 1990's and markets changed, there was a greater economic incentive for taking dusky rockfish. As a result, catches of the pelagic shelf assemblage increased, reaching 3,605 t Gulf-wide in 1992. However, a substantial amount of unharvested TAC generally remains each year in this fishery. This is largely due to in-season management regulations which close the rockfish fishery to ensure other species such as Pacific ocean perch do not exceed TAC, or to prevent excess bycatch of Pacific halibut.

In response to Annual Catch Limits (ACLs) requirements, assessments now document all removals including catch that is not associated with a directed fishery. Research catches of pelagic shelf rockfish have been reported in previous stock assessments (Lunsford et al. 2009). For this year, estimates of all removals not associated with a directed fishery including research catches are available and are presented in Appendix 12.A. In summary, research removals have typically been less than 10 t and some harvest occurs in the recreational fishery. These levels likely do not pose a significant risk to the dusky rockfish stock in the GOA.

Bycatch

Ackley and Heifetz (2001) examined bycatch of Gulf of Alaska rockfish fisheries using data from the observer program for the years 1994-96. For hauls targeting pelagic shelf rockfish, the major bycatch species were northern rockfish and fish in the “other slope rockfish” management category, followed by Pacific ocean perch. Similarly, dusky rockfish was the major bycatch species for hauls targeting northern rockfish. These conclusions are supported by another study (Reuter 1999), in which catch data from the observer program showed dusky rockfish were most commonly associated with northern rockfish, Pacific ocean perch, and harlequin rockfish (the latter is one of the “other rockfish” species).

Total FMP groundfish catch estimates targeted in the GOA rockfish fishery from 2008-2013 are shown in Table 12-3. For the GOA rockfish fishery during 2008-2013, the largest non-rockfish bycatch groups are Atka mackerel (1,591 t/year), pollock (818 t/year), arrowtooth flounder (581 t/year), and Pacific cod (558 t/year). Non-FMP species catch in the rockfish target fisheries is dominated by giant grenadier (161 – 836 t), miscellaneous fish (135 – 196 t), and ocassionally dark rockfish (recently removed from FMP to state management, 13 – 112 t) (Table 12-4). However, the amounts from dusky only targeted hauls are likely much lower as this includes all rockfish target hauls.

Prohibited species catch in the GOA rockfish fishery has been lower than average in 2011 and 2012 for all major species. The catch of golden king crab drecreased dramatically, from over 3,000 animals in 2009 and 2010, to just over 100 in 2011 and 2012 (Table 12-5).

We compared bycatch from pre-2007 and post-2006 in the central GOA for the combined rockfish fisheries to determine impact of the Central GOA Rockfish Program implementation (Figure 12-2). We divided the average post-2006 bycatch (2007-2010) by the average pre-2007 bycatch (2003-2006) for non-rockfish species that had available information in both time periods. For the majority of FMP groundfish species, bycatch in the central GOA has been reduced since 2007, with the exception of Atka mackerel and walleye pollock (Figure 12-2a). Nontarget species bycatch has also been lower since 2007 with the exception of snails and giant grenadier (Figure 12-2b). Bycatch of chinook salmon was much higher in 2007-2010 but other prohibited species catches were lower, including halibut (Figure 12-2c).

In summary, dusky rockfish are most likely to be associated with other rockfish species in fisheries and the bycatch of non-rockfish species in the dusky fishery are likely low but the only data available is for all rockfish targeted hauls. The only significant prohibited species that are encountered are Pacific halibut and chinook salmon. Bycatch estimates decreased for the majority of species in the Central GOA following the implementation of the Rockfish Pilot Program.

Discards

Gulf-wide discard rates (percent of the total catch discarded within management categories) of dusky rockfish are available from 1991-2012. Rates are listed in the following table and have ranged from less than one to ten percent of the total dusky catch over time. The lowest rates have been near one percent during 2007 – 2011 and are likely are a consequence of the Rockfish Pilot Project. In 2012 there was an increase to 4.0%, the highest since 2006 (5.0%). The cause for this is not known, but we will continue to monitor it in the future.

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
% Discard	9.8	5.6	10.5	9.2	6.1	5.0	6.1	1.8	1.3	0.9
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
% Discard	1.7	4.3	1.7	1.8	0.9	5.0	0.7	0.7	1.5	1.0
Year	2011	2012								
% Discard	1.8	4.0								

Management History

Sebastes rockfish species in Federal waters of the Gulf of Alaska (GOA) were first split into three broad management assemblages by the North Pacific Fishery Management Council (NPFMC) in 1988: slope rockfish, pelagic shelf rockfish, and demersal shelf rockfish. Species in each group were thought to share a somewhat similar habitat as adults, and separate "Stock Assessment and Fishery Evaluation" (SAFE) reports were prepared for each assemblage. Dusky rockfish were included in the pelagic shelf rockfish complex, defined as those species of *Sebastes* that inhabit waters of the continental shelf of the Gulf of Alaska, and that typically exhibit midwater, schooling behavior. In 1998 a GOA FMP amendment went into effect that removed black rockfish (*S. melanops*) and blue rockfish (*S. mystinus*) from the assemblage. In 2009 a similar amendment removed dark rockfish from the assemblage. Management authority of these three species was transferred to the State of Alaska.

Beginning in 2009 the pelagic shelf rockfish assemblage consisted of just three species, dusky, widow, and yellowtail rockfish. The validity of this management group became questionable as the group was dominated by dusky rockfish, which has a large biomass in the GOA and supports a valuable directed fishery, especially in the central GOA. In contrast, yellowtail and widow rockfish have a relatively low abundance in the GOA and are only taken commercially in very small amounts as bycatch. Moreover, since 2003, dusky rockfish has been assessed by an age-structured model and is considered a "Tier 3" species in the North Pacific Fishery Management Council's (NPFMC) harvest policy definitions, while yellowtail and widow rockfish remained "Tier 5" species in which the assessment is based on simple estimates of biomass and natural mortality.

Following recommendations by the authors, the GOA Groundfish Plan Team, and the NPFMC's Science and Statistical Committee, dusky rockfish were assessed separately starting in 2012 and are now presented as a stand-alone species in this document; widow and yellowtail rockfish have been included in the *Other Rockfish* stock assessment (see Appendix 12B, Lunsford et al 2011). Beginning in 2012 ABCs, TACs, and OFLs specific to dusky rockfish have been assigned.

Management Measures
In 1998, trawling in the Eastern Gulf east of 140 degrees W. longitude was prohibited through Amendment 41 (officially recognized in 2000). This had important management concerns for most rockfish species, including the pelagic shelf management assemblage, because the majority of the quota is caught by the trawl fishery. In response to this action, since 1999 the NPFMC has divided the Eastern Gulf management area into two smaller areas: West Yakutat (area between 140 and 147 degrees W. longitude) and East Yakutat/Southeast Outside (area east of 140 degrees W. longitude). ABC and TAC recommendations for dusky rockfish are generated for both West Yakutat and East Yakutat/Southeast Outside areas to account for the trawling ban in the Eastern area.

In 2007 the Central Gulf of Alaska Rockfish Program was implemented to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central Gulf of Alaska rockfish fishery. This rationalization program that establishes cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish species. The primary rockfish management groups are northern, Pacific ocean perch, and pelagic shelf rockfish (changed to dusky rockfish only in 2012). Potential effects of this program on the dusky rockfish fishery 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. We continue to monitor available fishery data to help understand effects the Rockfish Project may have on the dusky rockfish stock in the Central GOA.

Within the GOA, separate ABCs and TACs for dusky rockfish are assigned to smaller geographical areas that correspond to NMFS management areas. These include the Western GOA, Central GOA, and Eastern GOA. In response to Amendment 41 which prohibited bottom trawling east of 140 degrees W. longitude, the Eastern GOA management area was further divided into two smaller areas. These areas, West Yakutat and East Yakutat/Southeast Outside, are now assigned separate ABCs and TACs. OFLs for dusky rockfish are defined on a GOA-wide basis.

A summary of key management measures, a time series of catch, ABC, and TAC are provided in Table 12-1.

Data

Data Summary
The following table summarizes the data available for this assessment (bold denotes new data for this assessment):

Source	Data	Years
Fisheries	Catch	1977-**2013**
NMFS bottom trawl surveys	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, **2013**
NMFS bottom trawl surveys	Age	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, **2011**
U.S. trawl fisheries	Age	2000, 2001, 2002, 2003, 2004, 2005, 2006, 2008, **2010**
U.S. trawl fisheries	Length	1990-1999, 2007, 2009, 2011

Fishery Data
Catch

Catch estimates are a combination of foreign observer data, joint venture catch data, and NMFS Regional Office blend data. Catch estimates for dusky rockfish are available 1977-2013 (Table 12-2, Figure 12-3). Catches range from 17 t in 1986 to 4,538 t in 1999. We are skeptical of the low catches that occurred prior to 1988 and believe the catches for years 1985-1987 are likely underestimated. Since some of the catch data is of marginal quality prior to 1990, we make adjustments in the assessment model to account for this by reducing the model weighting of catch prior to 1991. These catches occurred during the end of the joint venture years and prior to accurate catch accounting of the newly formed domestic fishery.

Age and Size Composition

Length frequency data for dusky rockfish in the commercial fishery are available for the years 1991-2013 but are only used in the model when age compositions are not expected to be available for that year (Table 12-6). These data are the raw length frequencies for all dusky rockfish measured by observers in a given year. Since there was no attempt to collect or analyze these data systematically, some biases may be expected, especially for 1995 and 1996 when sample sizes were relatively small. Generally, however, these lengths were taken from hauls in which dusky rockfish were either the target or a dominant species, and they provide an indication of the trend in size composition for the fishery. Size of fish taken by the fishery generally appears to have increased after 1992; in particular, the mode increased from 42 cm in 1991-92 to 44-47 cm in 1993-97. The mode then decreased to 42 cm in 1998, and rose back to 45 cm in 1999-2002. Fish smaller than 40 cm are seen in moderate numbers in certain years (1991-92 and 1996-98), but it is unknown if this is an artifact of observer sampling patterns, or if it shows true influxes of younger fish.

Age samples for dusky rockfish have been collected by observers in the 1999-2013 commercial fisheries. Aging has been completed for the 2000-2010 samples (Table 12-7). Similar to the fishery length data discussed in the preceding paragraph, the data in Table 12-7 depicts the raw age distribution of the samples, and we did not attempt any further analysis to estimate a more comprehensive age composition. However, the samples were randomly collected from fish in over 100 hauls that had large catches of dusky rockfish, so the raw distribution is probably representative of the true age composition of the fishery. Fish ranged in age from 4 to 76 years. Several large and relatively steady year classes are evident through the time series including 1986, 1992, and 1995 (Figure 12-4).

Survey Data

Trawl Survey Biomass Estimates

Comprehensive trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and 1999, and biennially in 2001, 2003, 2005, 2007, 2009, 2011 and 2013. The surveys provide estimates of biomass for dusky rockfish (Table 12-8). Dusky rockfish were separated into “light” and “dark” varieties in surveys since 1996 and in 2004 further separated to dusky and dark rockfish. Each of these surveys has shown that dusky rockfish (light dusky) overwhelmingly predominate and that dark rockfish (dark dusky) are caught in only small quantities. Presumably, the dusky rockfish biomass in surveys previous to 1996 consisted of nearly all dusky rockfish.

The 1984 and 1987 survey results should be treated with some caution. A different survey design was used in the eastern Gulf of Alaska in 1984; furthermore, much of the survey effort in the western and central Gulf of Alaska 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 latter 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 discussed here, and the estimates are believed to be the best available. Even so, the reader should be aware that an element of uncertainty exists as to the standardization of the 1984 and 1987 surveys. Also, the 2001 survey biomass is a weighted average of 1993-1999 biomass estimates, since the Eastern Gulf was not surveyed in 2001.

Comparative biomass estimates for the trawl surveys show wide fluctuations for dusky rockfish (Table 12-8, Table 12-9, Figure 12-5). Total estimated biomass increased substantially between 1984 and 1987, dropped by over 50% in 1990, rebounded in 1993 and 1996, and decreased again in 1999 and 2001 (in areas that were sampled in 2001), increased in 2003, increased 2.5 fold in 2005 to 170,484 t, decreased in 2007 and 2009 to estimates similar to 2003, and increased again in 2011 and 2013. Large confidence intervals are associated with all these biomass estimates, particularly in 1987, 1996, 2003, 2005, 2007, and 2011. This is an indication of the generally patchy and highly aggregated distribution of this species. The 2013 survey biomass was 19% higher than the 2011 estimate and was 36% greater than the mean of the time series. The spatial distribution of the catches of dusky rockfish in the 2009, 2011, and 2013 surveys are shown in Figure 12-6. The magnitude of catch varies greatly with several large tows typically occurring in each survey. It is unknown whether these fluctuations indicate true changes in abundance, temporal changes in the availability of dusky rockfish to the survey gear, or are an artifact of the imprecision of the survey for this species. Despite the reduction of survey effort in 2013, the uncertainty of the biomass estimate did not increase substantially relative to previous surveys. A shift in biomass by management area did occur in the 2013 survey, with the largest biomass ever recorded occurring in the West Yakutat area (Table 12-8). This is likely attributable to two survey hauls that caught large amounts of dusky rockfish (Figure 12-6).

Survey Size Compositions
Gulf-wide survey size compositions are available from 1984-2013 (Table 12-10). Survey size compositions suggest that recruitment of dusky rockfish is a relatively infrequent event, as only two surveys, 1993 and 2003, showed evidence of substantial recruitment. Mean population length increased from 39.8 cm in 1987 to 43.1 cm in 1990. In 1993, however, a large number of small fish (~27-35 cm long) appeared which formed a sizeable percentage of the population, and this recruitment decreased the mean length to 38.3 cm. In the 1996 and 1999 surveys, the length frequency distribution was similar to that of 1990, with very few small fish, and both years had a mean population length of 43.9 cm. The 2001 size composition, although not directly comparable to previous years because the eastern Gulf of Alaska was not sampled, shows modest recruitment of fish <40 cm. In 2003, a distinct mode of fish is seen at ~30 cm that suggests relatively strong recruitment may have occurred. In 2005 mean population length increased to 42.2 cm and there is no evidence of recruitment of small fish in recent surveys. Survey size compositions are not used in the model because survey ages are available from those same years and are used in the model.

Survey Age Compositions
Gulf-wide age composition data for dusky rockfish are available for the 1984 through 2011 trawl surveys (Table 12-11). Similar to the length data, these age data also indicate that recruitment is infrequent. For each survey, ages were determined using the “break-and-burn” method of aging otoliths, and a Gulf-wide age-length key was developed. The key was then used to estimate age composition of the dusky rockfish population in the Gulf of Alaska. The 1976 year class appeared to be abundant in the early surveys, especially 1984 (Figure 12-7). The 1986 year class appeared strong in the 1993, 1996, and perhaps the 1999 surveys. Because rockfish are difficult to age, especially as the fish grow older, one possibility is that some of the fish aged 12 in 1999 were actually age 13 (members of the 1986 year class), which would agree more with the 1993 and 1996 age results. Little recruitment occurred in the years following until the 1992 and 1995 year classes appeared. The 2005-2011 data indicate a prominent 1995 year class but no large year classes are evident after 1995. The 2011 age composition is dominated by fish greater than 9 years old.

Other Time Series Data Used in the Assessment
Biological data used in this assessment does not vary through time as most estimates are derived by pooling data over time. Therefore, no biological data time series are presented here. Parameters estimated independent of the model are described below.

Analytical Approach

Model Structure

We present model results for dusky rockfish based on an age-structured model 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 and northern rockfish models (Courtney et al. 1999, Hanselman et al. 2007). In 2003, biomass estimates from an age-structured assessment model were first accepted as an alternative to trawl survey biomass estimates. As with other rockfish age-structured models, this model does not attempt to fit a stock-recruitment relationship but estimates a mean recruitment, which is adjusted by estimated recruitment deviations for each year. We do this because there does not appear to be an obvious stock-recruitment relationship in the model estimates, and there have been very high recruitments at low stock size (Figure 12-8). The parameters, population dynamics, and equations of the model are in Box 1.

Parameters Estimated Outside the Assessment Model

Parameters fit outside the assessment model include the life-history parameters for weight-at-age, age error matrices, and natural mortality. For dusky rockfish, these values were previously taken from the 2001 Pelagic Shelf Rockfish SAFE Document (Clausen and Heifetz 2001). Length-weight information for dusky rockfish is derived from data collected from GOA trawl surveys from 1984-2007, with a total sample size of 3,316. The length weight relationship for combined sexes, using the formula $W = aL^b$, where W is weight in grams and L is fork length in mm, $a = 8.17 \times 10^{-6}$ and $b = 3.12$.

The size-age transition matrix was constructed from the Von Bertalanffy growth curve fit to length and age data collected from GOA trawl surveys from 1984-2007. The transition matrix was constructed by adding normal error with a standard deviation equal to the standard deviation of survey ages for each size class. Estimated parameters are: $L_\infty = 47.5$ cm, $\kappa = 0.20$, and $t_0 = 0.65$.

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. The age error transition matrix was constructed by assuming the same age determination error used for northern rockfish (Courtney et al. 1999).

Prior to 2007 the natural mortality rate used for dusky rockfish was 0.09. Questions about the validity of the high natural mortality rate of dusky rockfish versus other similarly aged rockfish were raised in previous stock assessments (Lunsford et al. 2007). In 2007, the natural mortality rate was changed to 0.07 based on an estimate calculated by Malecha et al. (2004) using updated data. This method used the Hoenig (1983) empirical estimator for natural mortality based on maximum lifespan. Based on the highest age recorded in the trawl survey of 59 this estimate is 0.08. The highest recorded age in the fishery ages was 76, which equates to a Hoenig estimate of 0.06. The current natural morality estimate used in this assessment (0.07) is comparable to other similarly aged rockfish in the GOA.

Parameters Estimated Inside the Assessment Model

Maturity-at-age is modeled with the logistic function which estimates logistic parameters for maturity-at-age conditionally. Parameter estimates for maturity-at-age are obtained by combining data collected on female dusky rockfish maturity from Lunsford (pers. comm. July 1997) and Chilton (2010). The binomial likelihood is used in the assessment model as an additional component to the joint likelihood function to fit the combined observations of female dusky rockfish maturity (e.g., Quinn and Deriso, 1999). The binomial likelihood was selected because (1) the sample sizes for maturity are small and assuming convergence to the normal distribution may not be appropriate in this case, (2) the binomial likelihood inherently includes sample size as a weighting component, and, (3) resulting maturity-at-age from the normal likelihood (weighted by sample size) was very similar to maturity-at-age obtained with the binomial likelihood.

The fit to the combined observations of maturity-at-age obtained in the preferred assessment model (Model 3) is shown in Figure 12-9. Parameters for the logistic function describing maturity-at-age estimated conditionally in the model, as well as all other parameters estimated conditionally, were identical to estimating maturity-at-age independently. Estimating maturity-at-age parameters conditionally influences the model only through the evaluation of uncertainty, as the MCMC procedure includes variability in the maturity parameters in conjunction with variability in all other parameters, rather than assuming the maturity parameters are fixed. Thus, estimation of maturity-at-age within the assessment model allows for uncertainty in maturation to be incorporated into uncertainty for key model results (e.g., ABC) (described below in the *Uncertainty approach* section).

Other parameters estimated conditionally in the current model include, but are not limited to: logistic parameters for selectivity for survey and fishery, mean recruitment, fishing mortality, spawner per recruit levels, and logistic parameters for maturity. The numbers of estimated parameters are shown below. Other derived parameters are described in Box 1.

Parameter name	Symbol	Number
Catchability	q	1
Log-mean-recruitment	μ_r	1
Recruitment variability	σ_r	1
Spawners-per-recruit levels	$F_{35\%}, F_{40\%}, F_{50\%}$	3
Recruitment deviations	τ_y	53
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	37
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		103

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 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 non-informative (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 103. 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 two thousand, leaving a sample distribution of 4,500. Further assurance that the chain had converged was attained by comparing 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 of the parameters presented here, including 95% credible 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, fixed
$F_{y,a}$	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 **BOX 1 (Continued)**

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

Results

Model Evaluation

This model is identical in all aspects to the model accepted in 2011 except for inclusion of new and additional data. 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. Because the 2011 and 2013 models are identical and we are not providing alternative model configurations for comparison with the current model, we will only evaluate the 2013 model based on changes in results from 2011.

The model generally produces good visual fits to the data, and biologically reasonable patterns of recruitment, abundance, and selectivities. The model does not fit the 2013 survey estimate well, likely due to the increase in this estimate, with associated large uncertainty. Such an increase is difficult to explain for a long-lived species with our current model configuration. This year's model results in a slight increase in spawning and total biomass from previous projections. Therefore the, 2013 model is utilizing the new information effectively, and we use it to recommend 2014 ABC and OFL.

Time Series Results

Key results have been summarized in Tables 12-12 – 12-15. In general, model predictions continue to fit the data well (Figures 12-4, 12-5, 12-7, and 12-10).

Definitions

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

Biomass and Exploitation Trends

In general, model predictions continue to fit the data well (Figures 12-4, 12-5, 12-7, and 12-10). The predicted survey biomass estimate from the model is still lower than the 2011 observed value despite a modest increase in the observed 2013 survey biomass. The model tracks the 2003, 2007, and 2009 estimates well, although the 2005, 2011, and 2013 estimates are lower than the observed values (Figure 12-5). Total biomass estimates (age 4+) indicate a moderately increasing trend over time with a slight dome shape in the years surrounding the exceptionally high 2005 survey biomass estimate and a decrease thereafter, while spawning biomass estimates show a continuous linear increase throughout the time series and is also slightly dome shaped in recent years (Figure 12-11). MCMC credible intervals indicate that the historic low was more certain than the more recent increases, particularly when looking at the upper credible interval.

The estimated selectivity curve for the fishery and survey data suggested a pattern similar to what we expected for dusky rockfish (Figure 12-12). The commercial fishery should target larger and subsequently older fish and the survey should sample a larger range of ages. Fish are fully selected by the survey by age 13, while fish are fully selected by the fishery at age 15.

The fully-selected fishing mortality time series indicates a rise in fishing mortality from late 1980's through the late 1990's and has declined since with a small increase in 2007 and 2008 and an increase in 2012 (Figure 12-13). This rise may be due to harvest exceeding TAC in the Western GOA in 2012, which occurred in all rockfish fisheries in response to a delayed closing of the fishery. 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. We use a phase-plane plot of the ratio of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to the target level ($B_{35\%}$). Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. In the 2013 model the historical management path for dusky rockfish has been above the FOFL adjusted limit for only a few years in the early 1980's and early 1990's. Since 2000, dusky rockfish have been above $B_{40\%}$ and well below $F_{40\%}$ (Figure 12-14).

Recruitment

There is some lack of fit to the plus group in the fishery size compositions for 1991-1993 (Figure 12-10). This may be due to the increase in size of fish taken by the fishery in those years as mentioned in the Fishery data section. In general, the model fits the fishery age compositions well, likely due to the addition of data and the especially strong 1992 and 1995 year classes which are prevalent throughout the fishery age compositions (Figure 12-4). The survey age compositions also track the 1992 year class well and try to fit the 1995 year class, which appears strong in recent surveys (Figure 12-7).

Recruitment (age 4) is highly variable throughout the time series (Figure 12-15), particularly the most recent years, where typically very little information is known about the strength of incoming year classes. There also does not seem to be a clear spawner recruit relationship for dusky rockfish as recruitment appears unrelated to spawning stock biomass (Figure 12-8). The addition of new data in this year's model has increased recruitment estimates for several of the recent year classes, but had little effect on other estimates. MCMC credible bars for recruitment are fairly narrow in some years; however, the credible bands nearly contain zero for many years which indicates considerable uncertainty, particularly for the most recent years (Figure 12-15).

Retrospective Analysis

Within-model retrospective analysis was not conducted for this stock assessment. An in-depth retrospective analysis will be included in the next full stock assessment consistent with the template developed by the Plan Team's retrospective analysis group recommendations.

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 12-16) and credible intervals (Table 12-15). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass and recruitment (Figures 12-11, 12-15).

Table 12-13 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, 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. However, all estimates fall within the Bayesian credible intervals.

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, dusky rockfish in the GOA are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, which is equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing, $F_{35\%}$ which is ,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 $F_{40\%}$, which is 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 4 recruits from 1981-2009 (year classes between 1977 and 2005). Because of uncertainty in very recent recruitment estimates, we lag 4 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 2013 estimates of these female spawning biomass reference points are:

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
52,264	20,906	18,292	0.098	0.122

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2014 is estimated at 29,256 t. This is above the $B_{40\%}$ value of 20,906 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 2014, yields the following ABC and OFL:

$F_{40\%}$	0.098
ABC	5,486
$F_{35\%}$	0.122
OFL	6,708

Population Projections

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

For each scenario, the projections begin with the vector of 2013 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2014 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2013. 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 2013 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 2014, 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 2014 and 2015, *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 2010-2012 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 2009-2013 average *F*. (Rationale: For some stocks, TAC can be well below ABC, and recent average *F* may provide a better indicator of F_{TAC} than F_{ABC}.)
Scenario 5: In all future years, *F* is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):
Scenario 6: In all future years, *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above 1) above its MSY level in 2013 or 2) above ½ of its MSY level in 2013 and above its MSY level in 2023 under this scenario, then the stock is not overfished.)
Scenario 7: In 2014 and 2015, *F* is set equal to *max* F_{ABC}, and in all subsequent years *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2026 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 12-16). 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 2014, it does not provide the best estimate of OFL for 2015, because the mean 2014 catch under Scenario 6 is predicated on the 2014 catch being equal to the 2014 OFL, whereas the actual 2014 catch will likely be less than the 2014 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 (2012) is 4,012 t. This is less than the 2012 OFL of 6,257 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 2013:
a. If spawning biomass for 2013 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2013 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2013 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 12-16). If the mean spawning biomass for 2023 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 2016 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2016 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2016 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2026. If the mean spawning biomass for 2026 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 12-16, the stock is not overfished and is not approaching an overfished condition.

Alternate Projection

During the 2006 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 max ABC which is analogous to the Alternative 1 projection scenario. This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 10,000,000. The projection shows wide credibility intervals on future spawning biomass (Figure 12-17). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1981-2009 age-4 recruitments, and this projection predicts that the median spawning biomass will decrease quickly until average recruitment is attained and the low proportion of ABC is taken (0.65).

Area Allocation of Harvests

In all previous years, annual allocation of the Gulf-wide ABC for pelagic shelf rockfish amongst the three regulatory areas in the Gulf has been based on the geographic distribution of pelagic shelf rockfish biomass in the trawl surveys. Since the 1996 SAFE report, this distribution has been computed as a weighted average of the percent biomass distribution for each area in the three most recent trawl surveys. In the computations, each successive survey is given a progressively heavier weighting using factors of 4, 6, and 9, respectively. This 4:6:9 weighting scheme was originally recommended by the Gulf of Alaska Groundfish Plan Team, and had already been used for 1996 Pacific ocean perch stock assessment. The Plan Team believed that for consistency among the rockfish assessments, the same weighting should be applied to pelagic shelf rockfish. The Plan Team's scheme was adopted for the 1997 fishery, and we continue to follow it for dusky rockfish. Therefore, based on a 4:6:9 weighting of the 2009, 2011, and 2013 trawl surveys, the percent distribution of dusky rockfish biomass in the Gulf of Alaska is: Western area 5.8%; Central area 65.3%, and Eastern area 28.9%. Applying these percentages to the ABC of dusky rockfish (5,486 t) yields the following apportionments for the Gulf in 2014: Western area, 317 t; Central area, 3,584 t; and Eastern area, 1,585 t (Table 12-17).

Because the Eastern area is now divided into two management areas dusky rockfish, i.e., the West Yakutat area (area between 147 degrees W. longitude and 140 degrees W. longitude) and the East Yakutat/Southeast Outside area (area east of 140 degrees W. longitude), the ABC for this management group in the Eastern area must be further apportioned between these two smaller areas. The weighted average method described above results in a point estimate with considerable uncertainty. In an effort to balance this uncertainty with associated costs to the fishing industry, the Gulf of Alaska Plan Team has recommended that apportionment to the two smaller areas in the eastern Gulf be based on the upper 95% confidence limit of the weighted average of the estimates of the eastern Gulf biomass proportion that is in the West Yakutat area. The upper 95% confidence interval of this proportion is 0.87, so that the dusky rockfish ABC for West Yakutat would be 1,384 t, and the ABC for East Yakutat/Southeast Outside would be 201 t (Table 12-17). This represents a large increase in ABC to the West Yakutat area over previous years. This is attributable to the highest ever biomass recorded in this area in the 2013 survey which encountered large numbers of dusky rockfish in two hauls.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.122), the 2014 overfishing (OFL) is set equal to 6,708 t for dusky rockfish in the GOA (Table 12-17).

Ecosystem Considerations

In general, a determination of ecosystem considerations is hampered by the lack of biological and habitat information for dusky rockfish. A summary of the ecosystem considerations presented in this section is listed in Table 12-18. Additionally, we provide information regarding the FMP, non-FMP, and prohibited species caught in rockfish target fisheries to help understand ecosystem impacts by the dusky fishery (Tables 12-3, 12-4, 12-5).

Ecosystem Effects on the Stock

Prey availability/abundance trends: similar to many other rockfish species, stock condition of dusky rockfish appears to be greatly influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval dusky 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, field-collected larval dusky rockfish at present cannot even be visually identified to species. Yang (1993) reported that adult dusky rockfish consume mostly euphausiids. Yang et al. (2006) reports Pacific sandlance *Ammodytes hexapterus* and euphausiids as the most common prey item of dusky rockfish with Pacific sandlance comprising 82% of stomach content weight . Euphausiids are also a major item in the diet of walleye pollock, Pacific ocean perch, and northern rockfish. Changes in the abundance of these three species could lead to a corollary change in the availability of euphausiids, which would then have an impact on dusky rockfish.

Predator population trends: there is no documentation of predation on dusky rockfish. Larger fish such as Pacific halibut that are known to prey on other rockfish may also prey on adult dusky rockfish, but such predation probably does not have a substantial impact on stock condition. Predator effects would likely be more important on larval, post-larval, and small juvenile dusky rockfish, but information on these life stages and their predators is nil.

Changes in physical environment: strong year classes corresponding to the period 1976-77 have been reported for many species of groundfish in the Gulf of Alaska, including walleye pollock, Pacific ocean perch, northern rockfish, sablefish, and Pacific cod. As discussed in the *survey data* section, age data for dusky rockfish indicates that the 1976 and/or 1977 year classes were also unusually strong for this species. 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 dusky rockfish. The environmental mechanism for this increased survival of dusky rockfish, however, remains unknown. Pacific ocean perch and dusky rockfish both appeared to have strong 1986 year classes, and this may be another year when environmental conditions were especially favorable for rockfish species.

Changes in bottom habitat due to natural or anthropogenic causes could alter survival rates by altering available shelter, prey, or other functions. Associations of juvenile rockfish with biotic and abiotic structure have been noted by Carlson and Straty (1981), Pearcy et al. (1989), and Love et al. (1991). However, the Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of groundfish are minimal or temporary. The long-term upward trend in abundance suggests that at current levels of abundance and exploitation, habitat effects from fishing is not limiting this stock.

Fishery Effects on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: there is limited habitat information on adult dusky rockfish, especially regarding the habitat of the major fishing grounds for this species in the Gulf of Alaska. Nearly all the catch of dusky rockfish, however, is taken by bottom trawls, so the fishery potentially could affect HAPC biota such as corals or sponges if it occurred in localities inhabited by that biota. Corals and sponges are usually found on hard, rocky substrates, and there is some evidence that dusky rockfish may be found in such habitats. On submersible dives on the outer continental shelf of the eastern Gulf of Alaska, light dusky rockfish were observed in association with rocky habitats and in areas with extensive sponge beds, where the fish were observed resting in large vase-type sponges.[2] Also, dusky rockfish often co-occur and are caught with northern rockfish in the commercial fishery and in trawl surveys (Reuter 1999) and catches of northern rockfish have been associated with a rocky or rough bottom habitat (Clausen and Heifetz 2002). Based on this indirect evidence, it can be surmised that dusky rockfish are likely also associated with a rocky substrate. An analysis of bycatch of HAPC biota in commercial fisheries in the Gulf of Alaska in 1997-99 indicated that the dusky rockfish trawl fishery ranked fourth among all fisheries in the amount of corals taken as bycatch and sixth in the amount of sponges taken (National Marine Fisheries Service 2001). Little is known, however, about the extent of these HAPC biota and whether the bycatch is detrimental.

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 dusky rockfish trawl fishery in the Gulf of Alaska previously started in July and usually lasted only a few weeks. As mentioned previously in the *fishery* section, the fishery is concentrated at a number of offshore banks on the outer continental shelf. Beginning in 2007 the Rockfish Program began which allowed fishing in the Central Gulf from May 1 – November 15. There is no published information on time of year of insemination or parturition (larval release), but insemination is likely in the fall or winter, and anecdotal observations indicate parturition is mostly in the spring. Hence, reproductive activities are probably not directly affected by the commercial fishery. However, there may be some interaction in the Central Gulf if parturition is delayed until May 1.

Fishery-specific effects on amount of large size target fish: a comparison between Table 12-6 (length frequency in the commercial fishery) and Table 12-10 (size composition in the trawl surveys) suggests that although the fishery does not catch many small fish <40 cm length the fishery also does not target on very large fish.

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[2]V.M. O=Connell, Alaska Dept. of Fish and Game, 304 Lake St., Sitka, AK 99835. Pers. commun. July 1997.

Fishery contribution to discards and offal production: fishery discard rates of dusky rockfish have been quite low in recent years, especially after formation of the Rockfish Program. The discard rate of in the dusky rockfish fishery is unknown as discards are grouped as rockfish fishery target and are not available for just the dusky fishery.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: the fishery effects on age-at-maturity and fecundity are unknown, but based on the size of 50% maturity of female dusky rockfish reported in this document (42.8 cm), the fishery length frequency distributions in Figure 12-10 suggest that in the 1990's the fishery may have caught a sizeable number of immature fish.

Fishery-specific effects on EFH living and non-living substrate: effects of the dusky rockfish fishery on non-living substrate is unknown, but the heavy-duty rockhopper trawl gear commonly used in the fishery can move around rocks and boulders on the bottom. Table 12-4 shows the estimated bycatch of living structure such as benthic urochordates, corals, sponges, sea pens, and sea anemones by the GOA rockfish fisheries.

Data Gaps and Research Priorities

There is no information on larval, post-larval, or early stage juvenile dusky rockfish. Larval dusky rockfish can only be identified with genetic techniques, which are very high in cost and manpower. Analysis of stock structure through the stock structure template illustrates the need for a large scale genetic study to investigate stock structure of dusky rockfish in the GOA. Habitat requirements for larval, post-larval, and early stage juvenile dusky rockfish are completely unknown. Habitat requirements for later stage juvenile and adult fish are anecdotal or conjectural. Research needs to be done to identify the HAPC biota on the bottom habitat of the major fishing grounds and what impact bottom trawling has on these biota. The Rockfish Program has changed fishing patterns and harvest levels in the Central Gulf which may affect pelagic shelf rockfish. Available data should be analyzed in the coming years to determine the effects of this change in management. Several different techniques are used by stock assessors to weight length and age sample sizes in models. Research is currently being conducted to determine the best technique for weighting sample sizes and results should help us in choosing appropriate rationale for weighting. Prior to the next assessment cycle we hope to explore different techniques and determine the most appropriate method for weighting sample sizes for use in rockfish models.

Continued work will be done to improve and refine the dusky age-structured model. Dusky rockfish now have more data available for an age-structured assessment, which should allow for some relaxation of previous restrictions on model parameters. With the addition of new age data we should be able to develop an age error transition matrix applicable to dusky rockfish rather than assuming the same age determination error found for northern rockfish. Improving the data may allow the model to estimate parameters such as natural mortality and recruitment more effectively. MCMC simulations will continue to be used to explore parameter interactions and the distributions of key parameters.

We plan to follow the recommendations listed in the various working group reports (e.g. the methods for averaging surveys report) submitted to the Plan Team in September 2012. In addition, we anticipate that many of the comments specific to the dusky rockfish assessment during the 2013 Center for Independent Experts (CIE) Alaska rockfish scientific peer review will be incorporated. Please refer to the Summary and response to the 2013 CIE review of AFSC rockfish document presented to the September 2013 Plan Team for further details.

Summary

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

Quantity	As estimated or *specified last* year for: 2013	2014	As estimated or *recommended this* year for: 2014[1]	2015[1]
M (natural mortality rate)	0.07	0.07	0.07	0.07
Tier	3a	3a	3a	3a
Projected total (age 4+) biomass (t)	63,515	61,938	69,371	66,104
Female spawning biomass (t)				
Upper 95% confidence interval[2]			44,553	40,797
Point estimate	25,337	23,874	29,256	27,200
Lower 95% confidence interval[2]			19,848	18,116
$B_{100\%}$	49,683	49,683	52,264	52,264
$B_{40\%}$	19,873	19,873	20,906	20,906
$B_{35\%}$	17,389	17,389	18,292	18,292
F_{OFL}	0.122	0.122	0.122	0.122
$maxF_{ABC}$	0.098	0.098	0.098	0.098
F_{ABC}	0.098	0.098	0.098	0.098
OFL (t)	5,746	5,395	6,708	6,213
maxABC (t)	4,700	4,413	5,486	5,081
ABC (t)	4,700	4,413	**5,486**	5,081
Status	As determined *last* year for: 2011	2012	As determined *this* year for: 2012	2013
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 2014 and 2015 are derived using estimated catch of 2,993 for 2013, and projected catches of 3,530 t and 3,270 t for 2014 and 2015 based on realized catches from 2010-2012. This calculation is in response to management requests to obtain more accurate projections.

[2]Projected upper and lower 95% confidence intervals for female spawning biomass are derived from the MCMC estimated posterior distribution as presented in Table 12-15.

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Table 12-1. A summary of key management measures and the time series of catch, ABC and TAC for pelagic shelf rockfish and dusky rockfish in the Gulf of Alaska.

Year	Catch[1] (t)	ABC	TAC		Management Measures
1988	1,086	3,300	3,300		Pelagic shelf rockfish assemblage 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" which included PSR species. Apportionment and biomass determined from average percent biomass of most recent trawl surveys
1989	1,738	6,600	3,300		No reported foreign or joint venture catches of PSR
1990	1,647	8,200	8,200		
1991	2,187	4,800	4,800		
1992	3,532	6,886	6,886		
1993	3,182	6,740	6,740		
1994	2,980	6,890	6,890		
1995	2,882	5,190	5,190		
1996	2,290	5,190	5,190		Area apportionment based on 4:6:9 weighting scheme of 3 most recent survey biomass estimates rather than average percent biomass
1997	2,467	5,140	5,140		
1998	3,109	4,880	4,880		Black and blue rockfish removed from PSR assemblage and federal management plan Trawling prohibited in Eastern Gulf east of 140 degrees W.
1999	4,658	4,880	4,880		Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	3,728	5,980	5,980		Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	3,006	5,980	5,980		Dusky rockfish treated as tier 4 species whereas dark, widow, and yellowtail broken out as tier 5 species
2002	3,321	5,490	5,490		
2003	3,056	5,490	5,490		Age structured model for dusky rockfish accepted to determine ABC and moved to Tier 3 status
2004	2,688	4,470	4,470		
2005	2,236	4,553	4,553		
2006	2,452	5,436	5,436		
2007	3,383	5,542	5,542		Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	3,657	5,227	5,227		
2009	3,075	4,781	4,781		Dark rockfish removed from PSR assemblage and federal management plan
2010	3,119	5,059	5,509		
2011	2,538	4,754	4,754		Dusky rockfish broken out as stand-alone species for 2012. Widow and yellowtail rockfish included in other rockfish assemblage.
2012	4,012	5,118	5,118		
2013	2,886[2]	4,700	4,700		

[1] Catch is for entire pelagic shelf rockfish assemblage
[2] Catch is for dusky rockfish only, updated through October 5, 2013. Source: AKFIN.

Table 12-2. Commercial catch (t) of dusky rockfish in the Gulf of Alaska, with Gulf-wide values of acceptable biological catch (ABC), total allowable catch (TAC), and percent TAC harvested (% TAC). Values are a combination of foreign observer data, joint venture catch data, and NMFS Regional Office Catch Accounting System data.

Year	Catch	ABC[1]	TAC[1]	% TAC
1977	388	-	-	-
1978	162	-	-	-
1979	224	-	-	-
1980	597	-	-	-
1981	845	-	-	-
1982	852	-	-	-
1983	1,017	-	-	-
1984	540	-	-	-
1985	34	-	-	-
1986	17	-	-	-
1987	19	-	-	-
1988	1,067	3,300	3,300	32%
1989	1,707	6,600	3,300	52%
1990	1,612	8,200	8,200	20%
1991	2,035	4,800	4,800	41%
1992	3,443	6,886	6,886	50%
1993	3,119	6,740	6,740	46%
1994	2,913	6,890	6,890	42%
1995	2,836	5,190	5,190	55%
1996	2,275	5,190	5,190	44%
1997	2,464	5,140	5,140	48%
1998	3,107	4,880	4,880	64%
1999	4,535	4,880	4,880	93%
2000	3,699	5,980	5,980	62%
2001	2,997	5,980	5,980	50%
2002	3,301	5,490	5,490	60%
2003	3,020	5,490	5,490	55%
2004	2,557	4,470	4,470	57%
2005	2,209	4,553	4,553	49%
2006	2,436	5,436	5,436	45%
2007	3,372	5,542	5,542	61%
2008	3,631	5,227	5,227	69%
2009	3,069	4,781	4,781	64%
2010	3,109	5,059	5,059	61%
2011	2,529	4,754	4,754	53%
2012	4,012	5,118	5,118	78%
2013[a]	2,886	4,700	4,700	61%

[1] ABC and TAC are for the pelagic shelf rockfish assemblage which dusky rockfish was a member of until 2011. Individual ABCs and TACs were assigned to dusky rockfish starting in 2012.
[a] Catch updated through October 5, 2013. Source: AKFIN.

Table 12-3. FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2008-2013. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 11/7/2013.

	Estimated Catch (t)					
Group Name	2008	2009	2010	2011	2012	2013
Pacific Ocean Perch	12,135	12,397	14,974	13,120	13,953	10,969
Northern Rockfish	3,805	3,855	3,833	3,163	4,883	4,365
Pelagic Shelf Rockfish	3,521	2,956	2,965	2,324	-	-
Dusky Rockfish	-	-	-	-	3,642	2,711
Atka Mackerel	1,744	1,913	2,148	1,404	1,173	1,161
Pollock	390	1,280	1,046	811	574	806
Arrowtooth Flounder	517	502	706	340	763	659
Pacific Cod	445	631	734	560	404	573
Other Rockfish	632	736	737	657	889	473
Sablefish	503	404	388	440	469	448
Rougheye Rockfish	104	97	179	286	219	269
Shortraker Rockfish	231	247	134	239	303	263
Demersal Shelf Rockfish	43	72	30	26	110	135
Thornyhead Rockfish	248	185	106	161	130	94
Shark	0	0	0	5	5	88
Rex Sole	67	83	93	51	72	83
Sculpin	0	0	0	39	55	69
Shallow Water Flatfish	71	53	47	48	65	26
Deep Water Flatfish	29	30	48	57	54	24
Flathead Sole	19	32	24	13	16	24
Skate, Longnose	12	17	12	25	23	20
Skate, Other	10	14	28	14	20	19
Squid	0	0	0	12	15	9
Skate, Big	4	4	14	8	13	2
Octopus	0	0	0	1	1	1

Table 12-4. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2008 - 2013. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 11/7/2013.

	Estimated Catch (t)					
Group Name	2008	2009	2010	2011	2012	2013
Benthic urochordata	0.27	Conf.	0.08	Conf.	Conf.	Conf.
Birds	Conf.	0.03	-	Conf.	Conf.	6.48
Bivalves	0.00	Conf.	0.01	0.01	0.01	Conf.
Brittle star unidentified	0.04	0.03	0.02	0.01	0.03	0.03
Capelin	-	0.00	-	-	-	0.02
Corals Bryozoans	0.47	0.59	0.42	0.38	0.59	0.2
Dark Rockfish	17.86	46.98	112.03	12.82	59.03	42.28
Eelpouts	0.35	0.00	0.05	Conf.	0.3	Conf.
Eulachon	0.01	0.03	0.00	0.00	0.01	0.13
Giant Grenadier	161.3	684.57	539.49	418.91	347.87	836.31
Greenlings	14.73	8.1	9.52	7.91	9.05	7.35
Grenadier	3.43	3.11	34.94	110.49	89.67	9.00
Hermit crab unidentified	0.01	0.01	0.01	0.02	Conf.	0.03
Invertebrate unidentified	0.24	0.30	5.05	0.36	3.86	0.18
Lanternfishes	-	0.00	Conf.	-	-	Conf.
Misc crabs	0.07	0.10	0.07	0.04	0.05	0.01
Misc crustaceans	-	1.74	0.02	Conf.	-	Conf.
Misc deep fish	0.00	-	-	-	-	Conf.
Misc fish	195.64	134.74	167.1	133.25	156.73	160.98
Misc inverts (worms etc)	0.01	Conf.	-	Conf.	-	-
Other osmerids	Conf.	0.16	0.00	-	Conf.	0.00
Pacific Sand lance	-	-	-	Conf.	-	-
Pandalid shrimp	0.11	0.09	0.22	0.06	0.06	0.04
Polychaete unidentified	-	-	-	-	-	Conf.
Scypho jellies	0.11	0.70	1.87	0.00	0.16	0.47
Sea anemone unidentified	0.69	3.24	1.56	4.10	6.33	4.01
Sea pens whips	Conf.	0.01	0.01	0.04	-	0.02
Sea star	1.16	1.86	1.38	1.53	0.98	0.89
Snails	0.18	10.63	0.20	0.23	1.26	0.15
Sponge unidentified	2.97	6.65	3.66	4.41	1.39	1.32
Stichaeidae	-	0.01	-	-	-	Conf.
Urchins, dollars cucumbers	0.26	1.53	0.22	0.44	0.31	0.25

Table 12-5. 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 11/7/2013.

Group Name	2007	2008	2009	2010	2011	2012	Average
Bairdi Crab	0.16	0.06	0.62	0.10	0.03	0.09	0.18
Blue King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chinook Salmon	2.03	2.28	1.39	1.57	1.02	1.60	1.65
Golden K. Crab	0.13	0.34	3.28	3.00	0.13	0.11	1.17
Halibut	137	160	112	141	108	109	128
Herring	0.02	0.04	0.00	0.15	0.00	0.00	0.04
Other Salmon	0.72	0.50	0.47	0.37	0.21	0.31	0.43
Opilio Crab	0.00	0.00	0.14	0.00	0.00	0.00	0.02
Red King Crab	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 12-6. Fishery size compositions and sample size by year for dusky rockfish in the Gulf of Alaska. Lengths below 21 are pooled and lengths greater than 47 are pooled.

Length (cm)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2007	2009	2011
≤21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.000	0.002	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
28	0.000	0.002	0.000	0.002	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000
29	0.000	0.003	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.000
30	0.002	0.005	0.000	0.002	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000
31	0.002	0.011	0.000	0.000	0.001	0.006	0.001	0.000	0.000	0.000	0.001	0.000
32	0.003	0.012	0.000	0.000	0.000	0.004	0.001	0.000	0.000	0.000	0.000	0.001
33	0.004	0.015	0.000	0.002	0.000	0.014	0.004	0.001	0.000	0.002	0.002	0.001
34	0.007	0.019	0.000	0.001	0.001	0.008	0.008	0.001	0.000	0.003	0.004	0.001
35	0.025	0.019	0.000	0.004	0.002	0.004	0.019	0.000	0.002	0.003	0.006	0.001
36	0.029	0.015	0.000	0.004	0.005	0.010	0.026	0.001	0.002	0.005	0.010	0.001
37	0.019	0.017	0.001	0.003	0.004	0.008	0.042	0.003	0.001	0.010	0.013	0.002
38	0.024	0.027	0.001	0.009	0.007	0.002	0.041	0.006	0.004	0.014	0.021	0.007
39	0.069	0.036	0.006	0.004	0.020	0.010	0.034	0.012	0.006	0.019	0.027	0.014
40	0.084	0.108	0.020	0.019	0.028	0.033	0.041	0.027	0.011	0.035	0.043	0.026
41	0.134	0.117	0.046	0.041	0.045	0.052	0.060	0.059	0.028	0.057	0.049	0.044
42	0.145	0.125	0.103	0.074	0.059	0.082	0.088	0.099	0.079	0.075	0.070	0.077
43	0.140	0.114	0.145	0.076	0.084	0.093	0.106	0.147	0.116	0.103	0.086	0.107
44	0.136	0.117	0.200	0.146	0.098	0.120	0.112	0.170	0.164	0.115	0.104	0.121
45	0.085	0.100	0.197	0.171	0.124	0.128	0.119	0.163	0.182	0.131	0.121	0.137
46	0.057	0.073	0.151	0.176	0.126	0.126	0.097	0.126	0.148	0.132	0.123	0.128
47+	0.034	0.060	0.131	0.266	0.397	0.278	0.199	0.185	0.257	0.295	0.319	0.332
Sample size	2012	5495	3659	2117	1794	515	3090	2565	1684	4599	4843	3550

Table 12-7. Fishery age compositions for dusky rockfish in the Gulf of Alaska. Pooled age 21+ includes all fish 21 and older.

Age(yr)	2000	2001	2002	2003	2004	2005	2006	2008	2010
4	0	0	0	0	0.002	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0.002	0.002	0	0.002	0.005	0	0	0	0
7	0	0.004	0.007	0	0.007	0.002	0.006	0.007	0
8	0.012	0.004	0.009	0.019	0.002	0.005	0.026	0.007	0.006
9	0.007	0.043	0.011	0.030	0.055	0.014	0.036	0.038	0.033
10	0.034	0.035	0.104	0.046	0.069	0.092	0.078	0.086	0.054
11	0.049	0.068	0.109	0.177	0.066	0.104	0.146	0.109	0.069
12	0.141	0.077	0.095	0.102	0.182	0.079	0.097	0.065	0.151
13	0.207	0.132	0.063	0.091	0.114	0.191	0.074	0.164	0.105
14	0.212	0.170	0.154	0.038	0.083	0.099	0.113	0.076	0.048
15	0.100	0.161	0.134	0.073	0.040	0.061	0.071	0.060	0.133
16	0.051	0.089	0.120	0.127	0.076	0.038	0.052	0.058	0.066
17	0.027	0.060	0.052	0.097	0.104	0.061	0.039	0.045	0.027
18	0.015	0.031	0.025	0.062	0.055	0.061	0.071	0.041	0.045
19	0.015	0.012	0.011	0.018	0.019	0.063	0.036	0.043	0.042
20	0.012	0.017	0.007	0.014	0.021	0.038	0.049	0.050	0.018
21+	0.117	0.097	0.098	0.104	0.100	0.092	0.107	0.152	0.202
Sample size	411	517	441	628	422	444	309	604	332

Table 12-8. Biomass estimates (t) for dusky rockfish in the Gulf of Alaska by statistical area, based on results of NMFS bottom trawl surveys.

Year	Species[1]	Statistical Areas					Total
		Shumagin	Chirikof	Kodiak	Yakutat	Southeastern	
1984	Dusky Unident.	3,843	7,462	4,329	15,126	307	31,068
1987	Dusky Unident.	12,753	4,222	49,560	26,562	1,115	94,212
1990	Dusky Unident.	2,854	1,189	16,153	5,664	967	26,827
	Dusky	-	-	-	-	68	68
1993	Dusky Unident.	11,450	12,880	23,780	7,481	1,626	57,217
1996	Dusky	3,553	19,217	36,037	14,193	1,480	74,480
1999	Dusky	2,538	9,157	33,729	2,097	2,108	49,628
2001[a]	Dusky	5,351	2,062	23,590	7,924	1,738	40,665
2003	Dusky	4,039	46,729	7,198	11,519	1,377	70,856
2005	Dusky	69,295	38,216	60,097	2,488	389	170,484
2007	Dusky	4,985	38,350	19,482	5,579	3,857	72,253
2009	Dusky	1,404	4,075	40,836	25,082	726	72,123
2011	Dusky	10,473	5,169	62,893	4,103	768	83,407
2013	Dusky	2,950	19,123	36,238	40,685	174	99,170

[a]Note: The Yakutat and Southeastern areas were not sampled in the 2001 survey. Estimates of biomass for these two areas in 2001 were obtained by averaging the corresponding area biomasses in the 1993, 1996, and 1999 surveys.

[1] Dusky rockfish included in dusky unidentified rockfish, which included "light" and "dark" dusky combined, until 1996. In 1990 the first instance of dusky rockfish as a separate species occurred.

Table 12-9. GOA dusky rockfish biomass estimates, standard errors, lower confidence intervals, and upper confidence intervals, based on results of NMFS bottom trawl surveys.

Year	Biomass	Standard Error	Lower CI	Upper CI
1984	31,068	7,147	17,060	45,076
1987	94,212	29,391	36,606	151,818
1990	26,895	8,635	9,970	43,820
1993	57,217	16,590	24,701	89,733
1996	74,480	32,851	10,092	138,868
1999	49,628	19,194	12,008	87,248
2001	40,665	11,628	17,874	63,456
2003	70,856	34,352	3,526	138,186
2005	170,484	51,658	69,234	271,734
2007	72,253	34,369	4,890	139,616
2009	72,123	24,687	23,736	120,510
2011	83,407	36,806	11,267	155,547
2013	99,170	35,767	29,067	169,273

Table 12-10. NMFS trawl survey length compositions for dusky rockfish in the Gulf of Alaska. Lengths below 22 are pooled and lengths greater than 47 are pooled. Survey size compositions are not used in model.

Length (cm)	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007
≤21	0.000	0.000	0.000	0.001	0.003	0.001	0.003	0.000	0.001	0.000
22	0.000	0.001	0.008	0.002	0.001	0.001	0.002	0.004	0.001	0.000
23	0.000	0.001	0.004	0.004	0.004	0.001	0.003	0.000	0.001	0.000
24	0.000	0.000	0.002	0.007	0.003	0.000	0.005	0.001	0.002	0.000
25	0.000	0.000	0.006	0.002	0.003	0.002	0.003	0.000	0.002	0.001
26	0.000	0.001	0.000	0.015	0.001	0.000	0.004	0.004	0.001	0.001
27	0.000	0.000	0.006	0.018	0.001	0.001	0.006	0.017	0.001	0.001
28	0.002	0.000	0.006	0.023	0.001	0.000	0.002	0.024	0.001	0.001
29	0.001	0.000	0.007	0.021	0.005	0.001	0.022	0.027	0.004	0.001
30	0.004	0.001	0.000	0.030	0.002	0.002	0.024	0.044	0.005	0.003
31	0.009	0.001	0.001	0.039	0.002	0.006	0.029	0.027	0.010	0.001
32	0.015	0.004	0.007	0.051	0.002	0.008	0.033	0.031	0.014	0.004
33	0.014	0.002	0.001	0.043	0.007	0.008	0.026	0.053	0.016	0.003
34	0.036	0.018	0.003	0.040	0.003	0.013	0.030	0.008	0.019	0.010
35	0.048	0.039	0.001	0.046	0.006	0.015	0.026	0.011	0.021	0.013
36	0.061	0.061	0.002	0.053	0.001	0.015	0.042	0.013	0.046	0.013
37	0.066	0.093	0.004	0.037	0.009	0.016	0.039	0.043	0.027	0.017
38	0.090	0.084	0.006	0.049	0.009	0.019	0.040	0.077	0.053	0.024
39	0.131	0.080	0.019	0.051	0.016	0.016	0.059	0.072	0.031	0.049
40	0.139	0.109	0.017	0.051	0.036	0.031	0.061	0.066	0.042	0.070
41	0.134	0.142	0.077	0.035	0.080	0.035	0.071	0.050	0.046	0.077
42	0.105	0.121	0.125	0.044	0.065	0.072	0.061	0.050	0.072	0.110
43	0.061	0.112	0.115	0.061	0.127	0.104	0.064	0.065	0.092	0.106
44	0.037	0.062	0.153	0.064	0.133	0.115	0.058	0.070	0.101	0.115
45	0.022	0.028	0.175	0.073	0.111	0.150	0.083	0.065	0.100	0.098
46	0.013	0.019	0.151	0.065	0.113	0.141	0.076	0.062	0.101	0.099
47+	0.014	0.020	0.104	0.076	0.256	0.231	0.127	0.114	0.190	0.185
Sample Size	1881	2818	1113	2299	1478	1340	1255	1780	3383	1818

Table 12-10 (continued). NMFS trawl survey length compositions for dusky rockfish in the Gulf of Alaska. Lengths below 22 are pooled and lengths greater than 47 are pooled. Survey size compositions are not used in model.

Length (cm)	2009	2011	2013
≤21	0.003	0.001	0.000
22	0.006	0.000	0.001
23	0.011	0.000	0.000
24	0.012	0.000	0.000
25	0.005	0.000	0.001
26	0.009	0.000	0.002
27	0.005	0.000	0.001
28	0.006	0.000	0.001
29	0.007	0.000	0.002
30	0.010	0.002	0.003
31	0.008	0.002	0.004
32	0.010	0.002	0.003
33	0.005	0.003	0.005
34	0.007	0.005	0.003
35	0.007	0.006	0.005
36	0.008	0.015	0.007
37	0.006	0.019	0.011
38	0.011	0.017	0.012
39	0.011	0.036	0.011
40	0.020	0.042	0.009
41	0.031	0.058	0.021
42	0.036	0.091	0.043
43	0.073	0.135	0.101
44	0.069	0.114	0.112
45	0.105	0.109	0.179
46	0.154	0.103	0.153
47+	0.363	0.238	0.307
Sample Size	2024	1410	1889

Table 12-11. NMFS trawl survey age compositions for dusky rockfish in the Gulf of Alaska. Pooled age 21+ includes all fish 21 and older.

Age (yr)	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011
4	0.000	0.000	0.007	0.004	0.013	0.001	0.014	0.002	0.006	0.000	0.004	0.000
5	0.000	0.000	0.005	0.058	0.007	0.001	0.006	0.072	0.008	0.003	0.022	0.000
6	0.000	0.000	0.003	0.094	0.013	0.001	0.081	0.114	0.029	0.005	0.009	0.005
7	0.075	0.192	0.001	0.193	0.004	0.056	0.074	0.011	0.060	0.019	0.026	0.004
8	0.284	0.003	0.001	0.088	0.025	0.013	0.052	0.288	0.063	0.022	0.013	0.023
9	0.115	0.047	0.007	0.118	0.049	0.047	0.188	0.073	0.038	0.112	0.022	0.018
10	0.142	0.155	0.115	0.031	0.188	0.033	0.095	0.019	0.100	0.091	0.037	0.095
11	0.145	0.213	0.134	0.032	0.111	0.113	0.093	0.064	0.089	0.046	0.068	0.092
12	0.121	0.109	0.086	0.020	0.148	0.270	0.037	0.037	0.058	0.166	0.058	0.072
13	0.052	0.057	0.113	0.048	0.045	0.121	0.066	0.035	0.150	0.128	0.051	0.119
14	0.011	0.034	0.171	0.022	0.029	0.064	0.099	0.019	0.064	0.067	0.134	0.112
15	0.040	0.043	0.139	0.039	0.033	0.025	0.061	0.044	0.034	0.062	0.058	0.066
16	0.006	0.014	0.042	0.045	0.015	0.015	0.034	0.066	0.037	0.041	0.069	0.080
17	0.000	0.027	0.015	0.042	0.018	0.001	0.013	0.033	0.034	0.009	0.074	0.040
18	0.000	0.012	0.055	0.016	0.052	0.020	0.009	0.016	0.035	0.036	0.024	0.037
19	0.000	0.018	0.035	0.016	0.041	0.025	0.007	0.020	0.055	0.036	0.024	0.039
20	0.002	0.010	0.009	0.010	0.045	0.048	0.008	0.004	0.038	0.023	0.055	0.016
21+	0.008	0.065	0.061	0.123	0.165	0.146	0.062	0.083	0.101	0.135	0.252	0.182
Sample size	161	446	94	445	554	174	676	195	461	490	495	427

Table 12-12. Likelihood values and estimates of key parameters for 2011 model and this year's 2013 model for GOA dusky rockfish.

Likelihoods	*2011 Model*	*2013 Model*
Catch	27.19	27.14
Survey Biomass	36.74	38.84
Fishery Ages	27.11	30.23
Survey Ages	74.07	85.83
Fishery Sizes	50.78	49.93
Maturity Likelihood	65.00	65.00
Data-Likelihood	**280.89**	**296.97**
Penalties/Priors		
Recruitment Devs	24.39	25.83
Fishery Selectivity	0.00	0.00
Survey Selectivity	0.00	0.00
Fish-Sel Domeshape	0.00	0.00
Survey-Sel Domeshape	0.00	0.00
Average Selectivity	0.00	0.00
F Regularity	33.68	33.75
σ_r prior	0.41	0.40
q prior	0.03	0.03
Objective Fun. Total	**339.40**	**356.98**
Parameter Estimates		
Number parameters estimated	99	103
q-trawl	0.896	0.896
σ_r	0.998	1.006
Mean Recruitment since 1977 (millions)	6.68	7.08
$F_{40\%}$	0.098	0.098
Projected Total Biomass (t)	66,771	69,371
End year female spawning biomass (t)	29,205	31,574
$B_{0\%}$ (t)	49,683	52,264
$B_{40\%}$ (t)	19,873	20,906
ABC ($F_{40\%}$) (t)	**5,118**	**5,486**

Table 12-13. Estimates of key parameters (μ) 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	σ	σ MCMC	Median MCMC	BCI Lower	BCI Upper
q	0.896	0.897	0.125	0.127	0.892	0.657	1.158
$F_{40\%}$	0.098	0.121	0.029	0.045	0.112	0.063	0.234
2014 Female SSB	29,256	30,368	5,817	6,238	29,682	19,848	44,553
ABC	5,486	6,854	1,877	2,801	6,343	3,173	13,734

Table 12-14. Estimated time series of female spawning biomass, 6+ biomass (age 6 and greater), catch/6 + biomass, and number of age four recruits for dusky rockfish in the Gulf of Alaska. Estimates are shown for the current assessment and from the previous SAFE.

Year	Spawning biomass (t)		6+ Biomass (t)		Catch/6+ biomass		Age 4 recruits (1000's)	
	Previous	Current	Previous	Current	Previous	Current	Previous	Current
1977	11,927	12,365	27,488	28,423	0.025	0.024	2,255	2,277
1978	11,358	11,775	27,127	28,018	0.015	0.015	2,483	2,492
1979	10,997	11,395	27,031	27,885	0.018	0.017	3,065	3,113
1980	10,714	11,093	27,099	27,914	0.029	0.028	11,669	11,614
1981	10,416	10,778	27,249	28,042	0.034	0.033	6,132	6,132
1982	10,221	10,567	31,222	31,953	0.029	0.029	3,584	3,612
1983	10,242	10,571	33,807	34,493	0.030	0.029	1,861	1,926
1984	10,488	10,802	35,429	36,085	0.021	0.021	10,992	11,097
1985	11,157	11,456	36,425	37,073	0.005	0.005	1,539	1,577
1986	12,378	12,665	41,660	42,327	0.003	0.003	2,216	2,267
1987	13,807	14,083	43,389	44,057	0.003	0.003	1,504	1,548
1988	15,261	15,531	44,875	45,551	0.028	0.027	9,634	9,911
1989	16,130	16,398	44,549	45,233	0.036	0.036	3,221	3,341
1990	16,701	16,973	47,035	47,828	0.030	0.030	19,663	20,420
1991	17,241	17,523	47,443	48,299	0.033	0.033	11,111	11,557
1992	17,649	17,936	54,741	55,912	0.060	0.059	9,937	10,430
1993	17,314	17,643	58,088	59,558	0.052	0.050	1,467	1,552
1994	17,420	17,802	61,636	63,429	0.046	0.044	7,951	8,381
1995	18,081	18,542	61,742	63,699	0.045	0.043	3,561	3,586
1996	19,267	19,835	63,864	66,109	0.036	0.034	19,884	20,675
1997	20,957	21,647	64,433	66,786	0.038	0.037	1,456	1,515
1998	22,540	23,353	71,404	74,148	0.043	0.042	10,028	10,452
1999	23,602	24,534	70,848	73,708	0.063	0.061	19,753	21,771
2000	23,776	24,817	71,780	74,872	0.051	0.049	1,140	1,188
2001	24,256	25,404	77,986	82,013	0.037	0.036	10,303	11,799
2002	25,198	26,468	77,857	82,122	0.041	0.039	11,789	15,478
2003	26,182	27,603	80,412	85,477	0.037	0.034	2,369	2,969
2004	27,392	29,013	83,906	90,817	0.030	0.028	2,713	6,394
2005	28,809	30,702	83,831	91,513	0.026	0.024	2,014	5,619
2006	30,236	32,483	83,294	93,003	0.029	0.026	2,657	2,431
2007	31,276	33,975	81,489	93,404	0.041	0.036	1,936	2,412
2008	31,478	34,717	78,383	90,952	0.045	0.039	4,883	3,228
2009	31,069	34,918	74,325	87,539	0.041	0.035	2,194	2,015
2010	30,371	34,844	71,765	84,485	0.043	0.037	2,094	1,771
2011	29,205	34,240	68,115	80,591	0.038	0.031	2,078	1,936
2012		33,428		76,840		0.051		2,189
2013		31,574		71,561		0.042		2,173

Table 12-15. Estimated time series of recruitment, female spawning biomass, and total biomass (4+) for dusky rockfish in the Gulf of Alaska. Columns headed with 2.5% and 97.5% represent the lower and upper 95% credible intervals from the MCMC estimated posterior distribution.

	Recruits (Age 4)			Total Biomass			Spawning Biomass		
Year	Mean	2.50%	97.50%	Mean	2.50%	97.50%	Mean	2.50%	97.50%
1977	2,277	340	6,799	29,771	22,192	38,562	12,365	8,784	16,009
1978	2,492	355	6,679	29,244	22,011	37,954	11,774	8,317	15,417
1979	3,113	361	9,658	29,304	22,169	38,061	11,395	8,103	14,967
1980	11,614	3,261	20,734	31,222	24,356	40,256	11,093	7,979	14,637
1981	6,132	674	14,897	32,990	26,061	42,289	10,778	7,791	14,241
1982	3,612	456	9,409	34,639	27,602	44,311	10,567	7,713	13,986
1983	1,926	257	7,396	36,036	29,062	46,164	10,571	7,730	14,016
1984	11,097	5,604	16,712	38,909	31,664	49,292	10,802	7,998	14,271
1985	1,577	243	5,189	40,950	33,682	51,807	11,456	8,633	15,166
1986	2,267	371	5,221	43,284	35,968	54,546	12,665	9,772	16,649
1987	1,548	232	4,828	45,092	37,760	56,450	14,083	11,101	18,381
1988	9,911	5,276	14,938	48,018	40,612	59,712	15,531	12,460	20,127
1989	3,341	339	9,342	49,080	41,508	61,190	16,398	13,251	21,148
1990	20,420	13,356	29,280	52,960	45,172	65,733	16,973	13,799	21,836
1991	11,557	4,068	19,994	57,153	48,772	70,925	17,523	14,323	22,398
1992	10,430	5,100	16,391	61,696	52,541	76,463	17,936	14,795	22,828
1993	1,552	235	4,771	63,216	53,610	79,104	17,643	14,438	22,637
1994	8,381	4,920	13,187	65,594	55,265	82,475	17,802	14,499	23,066
1995	3,586	485	7,775	67,102	56,230	85,043	18,542	15,068	24,238
1996	20,675	15,281	29,214	71,369	59,369	91,044	19,835	16,003	26,130
1997	1,515	227	4,738	73,726	60,926	94,589	21,647	17,465	28,550
1998	10,452	5,733	16,296	76,712	62,979	99,018	23,353	18,814	30,874
1999	21,771	15,320	31,977	81,391	66,135	106,240	24,534	19,675	32,534
2000	1,188	192	3,735	82,099	65,938	108,542	24,817	19,696	33,458
2001	11,799	6,779	18,498	84,740	67,157	113,489	25,404	19,911	34,715
2002	15,478	9,116	25,498	88,987	70,021	120,146	26,468	20,521	36,475
2003	2,969	376	7,933	91,037	70,904	124,155	27,602	21,137	38,303
2004	6,394	1,867	13,068	93,041	71,784	127,632	29,013	22,081	40,621
2005	5,619	1093	12,293	94,683	72,607	130,645	30,702	23,244	43,199
2006	2,431	331	7,405	95,290	72,440	131,941	32,483	24,463	45,914
2007	2,412	357	7,028	94,664	71,513	131,931	33,975	25,407	48,163
2008	3,228	456	9,528	92,368	69,190	130,314	34,717	25,644	49,713
2009	2,015	287	7,661	88,975	65,633	126,949	34,918	25,458	50,290
2010	1,771	226	7,706	85,484	62,254	122,747	34,844	25,096	50,522
2011	1,936	248	10,178	81,544	58,750	118,690	34,240	24,402	49,917
2012	2,189	268	15,164	77,897	55,594	115,391	33,428	23,574	49,207
2013	2,173	277	14,540	72,696	51,036	110,131	31,574	21,794	47,258
2014	7,079	324	33,665	69,371	48,138	107,225	29,256	19,848	44,553
2015	7,079	317	36,474	66,104	-	-	27,200	18,116	40,797

Table 12-16. Set of projections of spawning biomass (SB) and yield for dusky rockfish in the Gulf of Alaska. Six harvest scenarios designed to satisfy the requirements of Amendment 56, NEPA, and MSFCMA. For a description of scenarios see section *Harvest Recommendations*. All units are in t. $B_{40\%}$ = 20,906 t, $B_{35\%}$ = 18,292 t, $F_{40\%}$ = 0.098, and $F_{35\%}$ = 0.122.

Year	Maximum permissible F	Author's F (pre-specified catch)[1]	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning Biomass (t)				
2013	30,962	30,962	30,962	30,962	30,962	30,962	30,962
2014	29,086	29,256	29,317	29,323	29,549	28,977	29,086
2015	26,163	27,200	27,624	27,663	29,170	25,501	26,163
2016	23,504	25,138	25,959	26,026	28,684	22,430	23,417
2017	21,178	22,593	24,408	24,499	28,167	19,836	20,655
2018	19,329	20,529	23,120	23,230	27,774	17,906	18,522
2019	18,108	19,052	22,187	22,311	27,602	16,692	17,162
2020	17,491	18,237	21,682	21,816	27,745	16,108	16,470
2021	17,390	17,983	21,630	21,761	28,255	16,045	16,325
2022	17,630	18,102	21,923	22,041	29,068	16,310	16,527
2023	18,045	18,420	22,425	22,529	30,086	16,729	16,895
2024	18,522	18,820	23,032	23,123	31,223	17,187	17,314
2025	18,992	19,229	23,669	23,753	32,406	17,621	17,718
2026	19,420	19,608	24,294	24,374	33,591	18,002	18,076
			Fishing Mortality				
2013	0.049	0.049	0.049	0.049	0.049	0.049	0.049
2014	0.098	0.062	0.049	0.048	-	0.122	0.122
2015	0.098	0.062	0.049	0.048	-	0.122	0.122
2016	0.098	0.098	0.049	0.048	-	0.122	0.122
2017	0.098	0.098	0.049	0.048	-	0.115	0.115
2018	0.091	0.096	0.049	0.048	-	0.103	0.103
2019	0.085	0.089	0.049	0.048	-	0.096	0.096
2020	0.081	0.085	0.049	0.048	-	0.092	0.092
2021	0.080	0.083	0.048	0.048	-	0.092	0.092
2022	0.081	0.083	0.048	0.048	-	0.093	0.093
2023	0.082	0.084	0.048	0.048	-	0.095	0.095
2024	0.084	0.085	0.048	0.048	-	0.097	0.097
2025	0.085	0.086	0.048	0.048	-	0.099	0.099
2026	0.086	0.087	0.048	0.048	-	0.101	0.101
			Yield (t)				
2013	2,993	2,993	2,993	2,993	2,993	2,993	2,993
2014	5,486	5,486	2,807	2,736	-	6,708	5,486
2015	4,913	5,081	2,636	2,572	-	5,876	4,913
2016	4,389	4,698	2,464	2,408	-	5,137	5,366
2017	3,917	4,183	2,298	2,248	-	4,262	4,622
2018	3,251	3,666	2,152	2,107	-	3,413	3,659
2019	2,803	3,110	2,038	1,998	-	2,911	3,083
2020	2,596	2,826	1,957	1,942	-	2,692	2,819
2021	2,591	2,767	1,940	1,948	-	2,709	2,805
2022	2,695	2,831	1,977	1,994	-	2,851	2,925
2023	2,834	2,940	2,040	2,054	-	3,031	3,087
2024	2,978	3,061	2,111	2,118	-	3,204	3,247
2025	3,113	3,178	2,181	2,181	-	3,361	3,393
2026	3,232	3,283	2,249	2,240	-	3,492	3,517

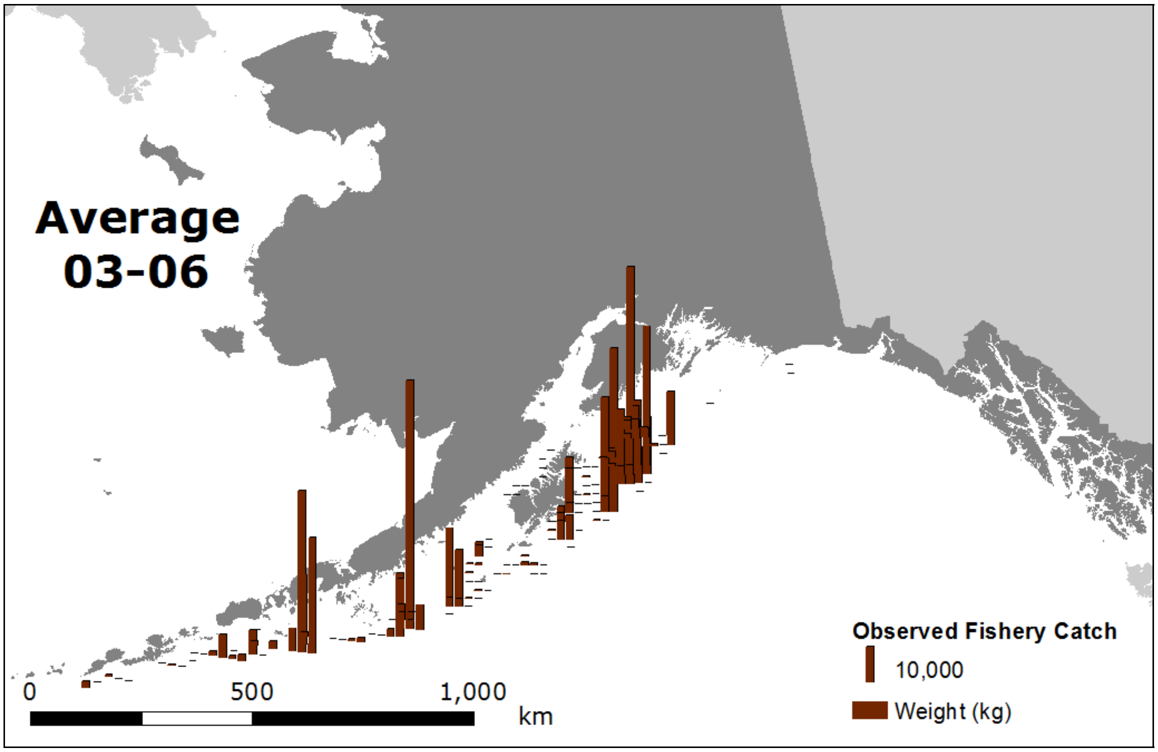
[1]Projected ABCs and OFLs for 2014 and 2015 are derived using estimated catch of 2,993 for 2013, and projected catches of 3,530 t and 3,270 t for 2014 and 2015 based on realized catches from 2010-2012.

Table 12-17. Allocation of 2014 ABC for dusky rockfish in the Gulf of Alaska. Apportionment is based on the weighted average of dusky rockfish biomass estimates in last three trawl surveys. Allocation for West Yakutat and SE/Outside is equal to the upper 95% confidence interval of the ratio of biomass in West Yakutat area to SE/Outside area. All units are in t.

		Western	Central		Eastern		
Year	Weights	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2009	4	2%	6%	57%	35%	1%	100%
2011	6	13%	6%	75%	5%	1%	100%
2013	9	3%	19%	37%	41%	0%	100%
Weighted Mean		6%	12%	53%	28%	1%	100%
Area Apportionment		5.8%	65.3%		28.9%		100%
Area ABC (t)		**317**	**3,584**		**1,585**		**5,486**
Yak/SE ABC (t)					**1,384**	**201**	
OFL (t)							**6,708**

Table 12-18. Analysis of ecosystem considerations for pelagic shelf rockfish and the dusky rockfish fishery.

Ecosystem effects on GOA *pelagic shelf rockfish*			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Phytoplankton and Zooplankton	Important for larval and post-larval survival but no information known	May help determine year class strength, no time series	Possible concern if some information available
Predator population trends			
Marine mammals	Not commonly eaten by marine mammals	No effect	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Halibut, arrowtooth, lingcod)	Arrowtooth have increased, others stable	More predation on juvenile rockfish	Possible concern
Changes in habitat quality			
Temperature regime	Higher recruitment after 1977 regime shift	Contributed to rapid stock recovery	No concern
Winter-spring environmental conditions	Affects pre-recruit survival	Different phytoplankton bloom timing	Causes natural variability, rockfish have varying larval release to compensate
Production	Relaxed downwelling in summer brings in nutrients to Gulf shelf	Some years are highly variable, like El Nino 1998	Probably no concern, contributes to high variability of rockfish recruitment
GOA pelagic rockfish fishery effects on ecosystem			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored (P. cod most common)	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Medium bycatch levels of sponge and corals	Bycatch levels small relative to total HAPC biota, but can be large in specific areas	Probably no concern
Marine mammals and birds	Very minor take of marine mammals, trawlers overall cause some bird mortality	Rockfish fishery is short compared to other fisheries	No concern
Sensitive non-target species	Likely minor impact on non-target rockfish	Data limited, likely to be harvested in proportion to their abundance	Probably no concern
Fishery concentration in space and time	Duration is short and in patchy areas	Not a major prey species for marine mammals	No concern, fishery is being extended for several months starting 2006
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Probably no concern
Fishery contribution to discards and offal production	Decreasing	Improving, but data limited	Possible concern with non-target rockfish
Fishery effects on age-at-maturity and fecundity	Black rockfish show older fish have more viable larvae	Inshore rockfish results may not apply to longer-lived slope rockfish	Definite concern, studies being initiated in 2005



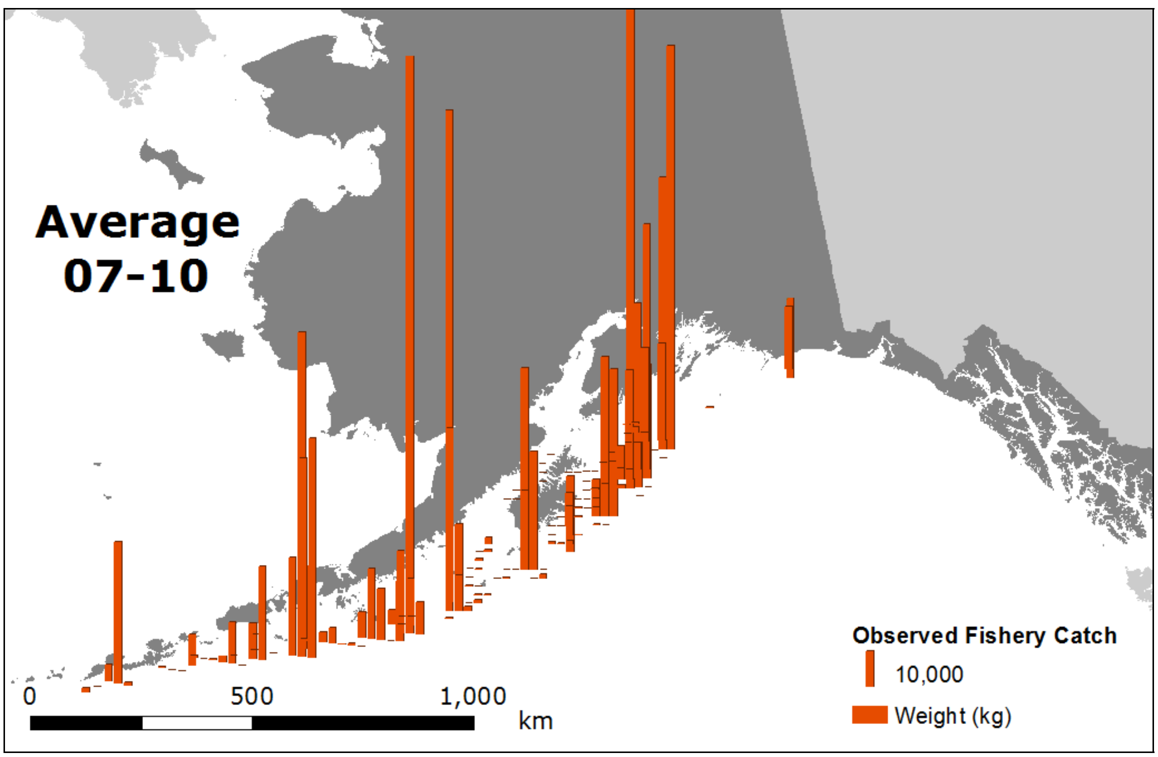


Figure 12-1. Spatial distribution of dusky rockfish fishery catch in the Gulf of Alaska (GOA) based on observer data aggregated by 400 km^2 blocks and averaged by (a) four years prior to central GOA Rockfish Program, 2003-2006, and (b) four years after implementation of program, 2007-2010.

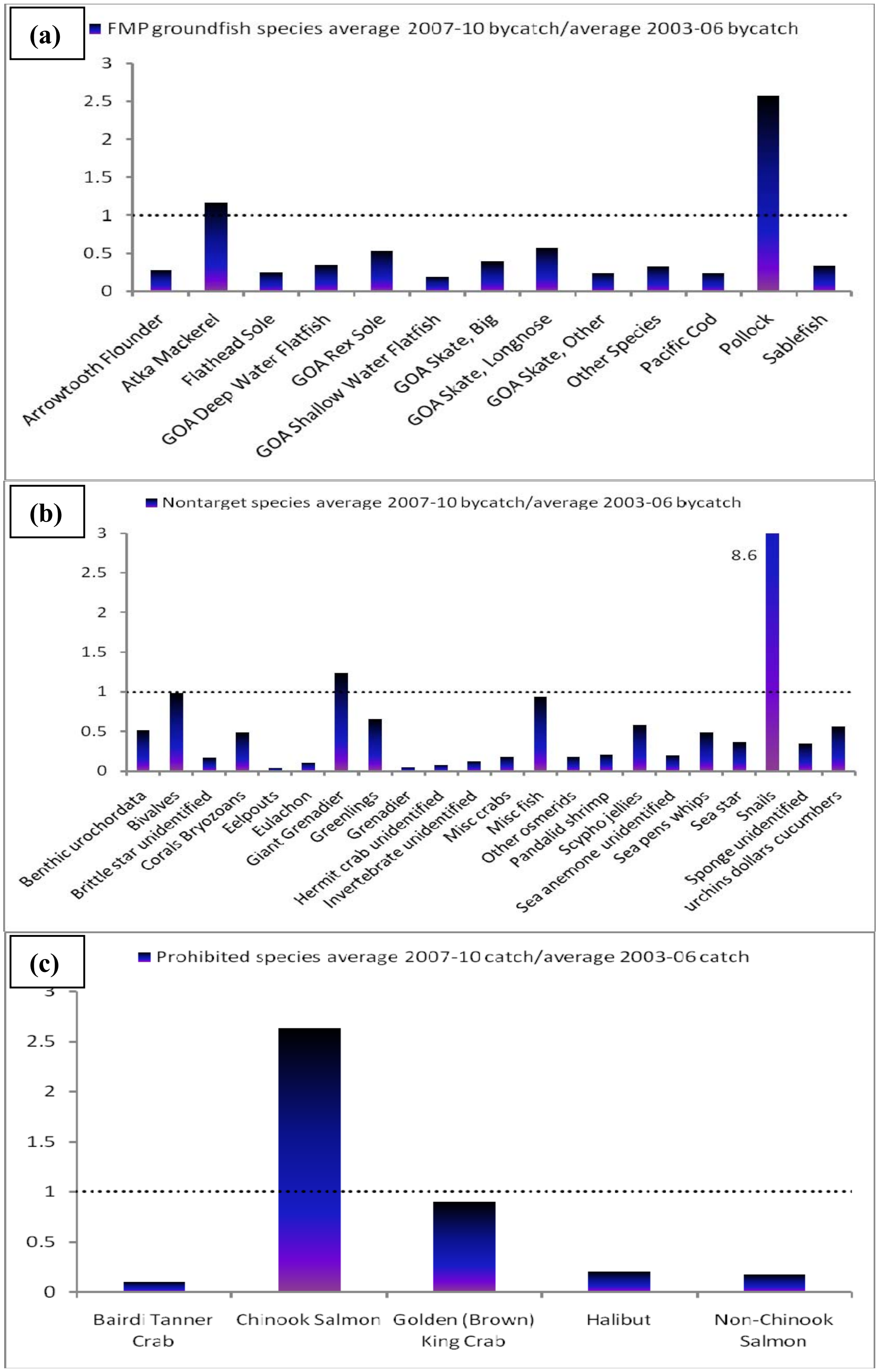


Figure 12-2. Comparison of bycatch of prohibited species in the Central Gulf of Alaska rockfish fishery before the Rockfish Program (2003-2006) and after (2007-2010). Values represent the average of the 2007-2010 catches divided by the average of the 2003-2006 catches for GOA FMP groundfish species (a), GOA nontarget species (b), and GOA prohibited species (c).

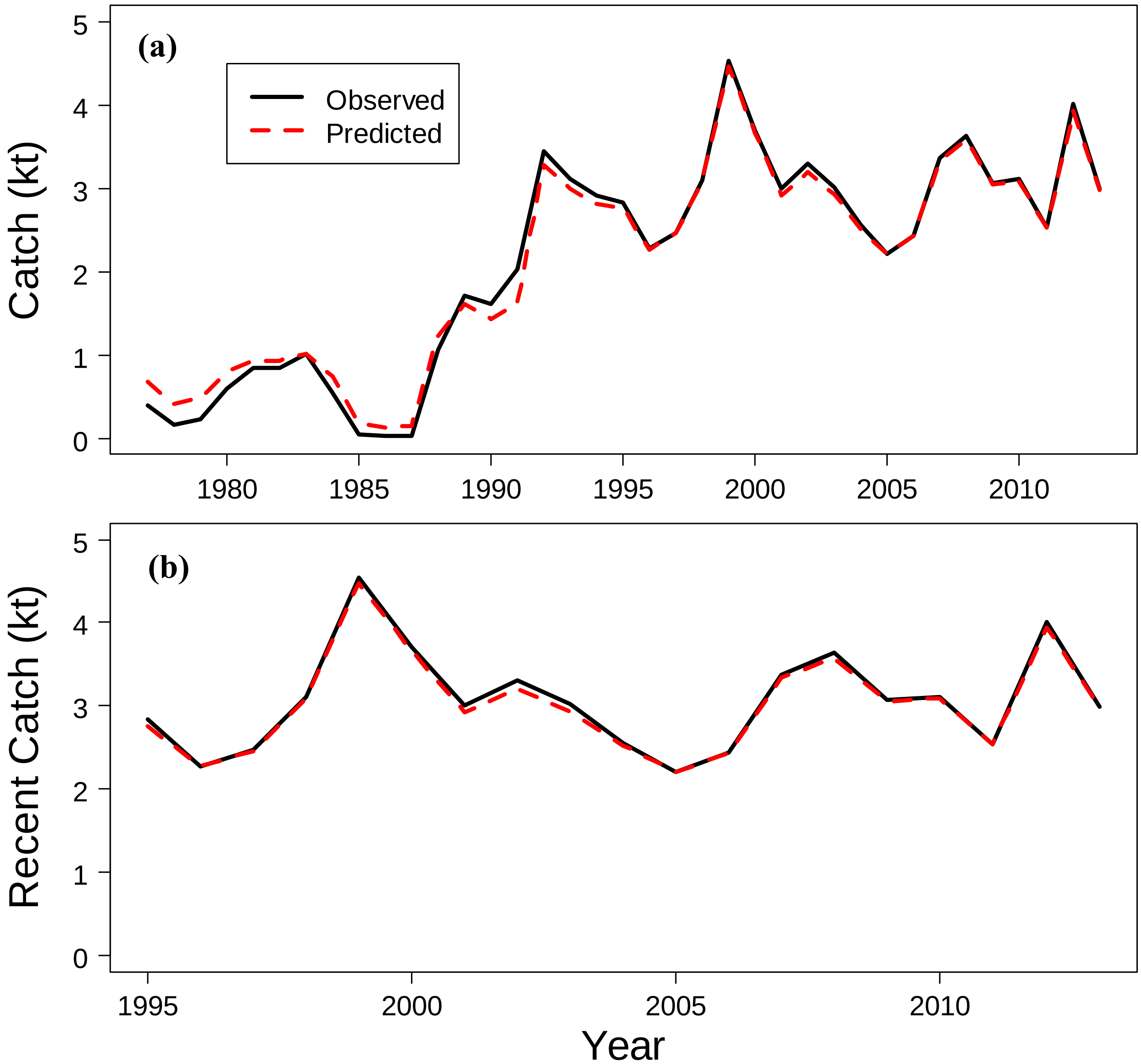


Figure 12-3. Estimated long-term (a) and short-term (b) commercial catches for GOA dusky rockfish. Observed is solid black line, predicted is dashed red line.

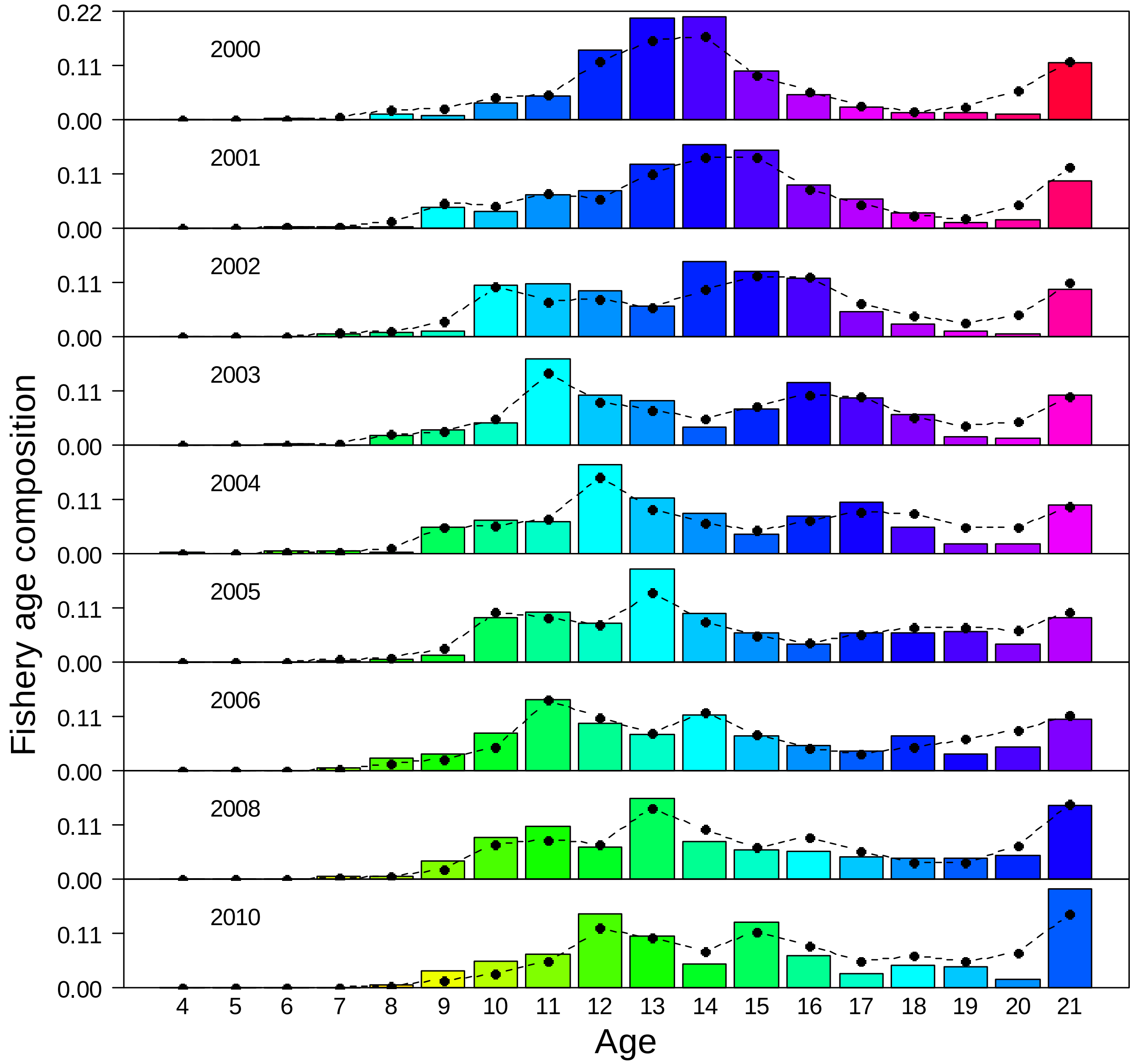


Figure 12-4. Fishery age compositions for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles. Colors correspond to individual year classes.

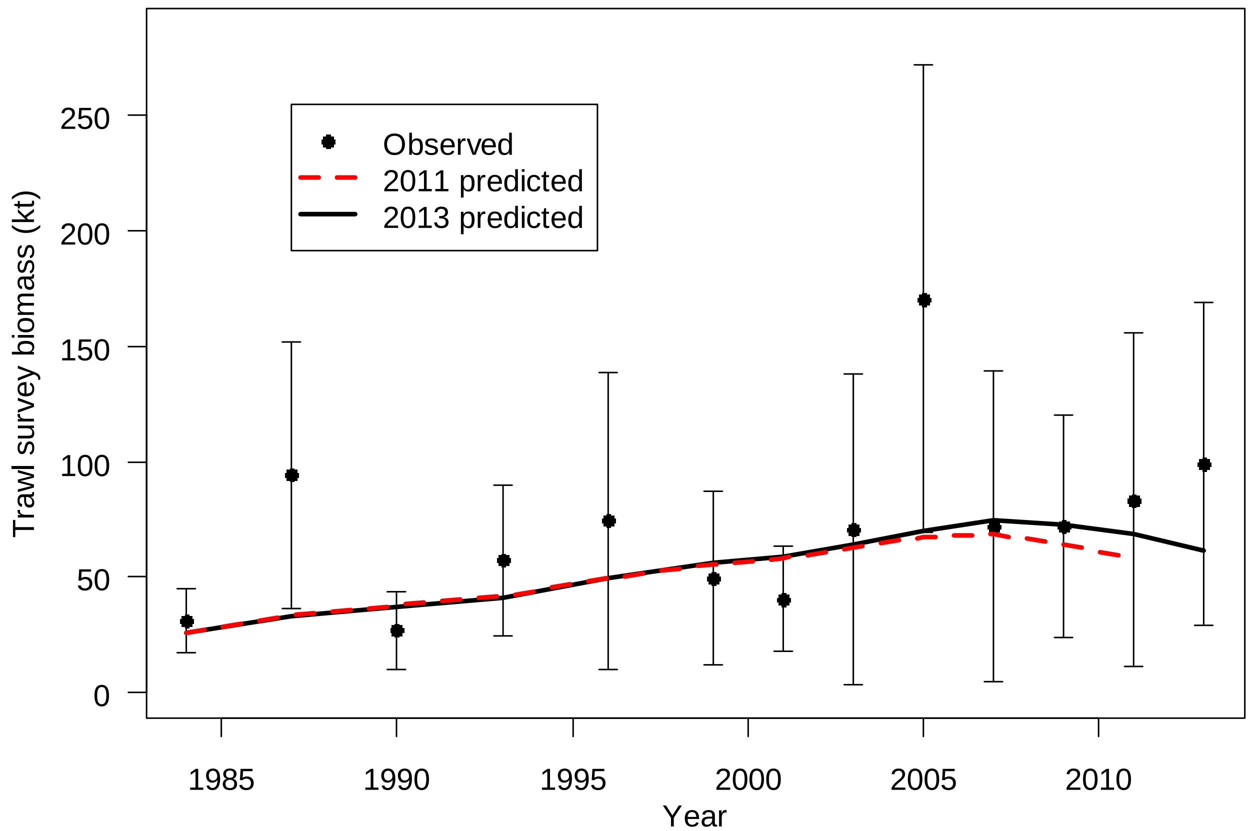


Figure 12-5. Observed and predicted GOA dusky rockfish trawl survey biomass based on the 2011 and 2013 models. Observed biomass is circles with 95% confidence intervals of sampling error.

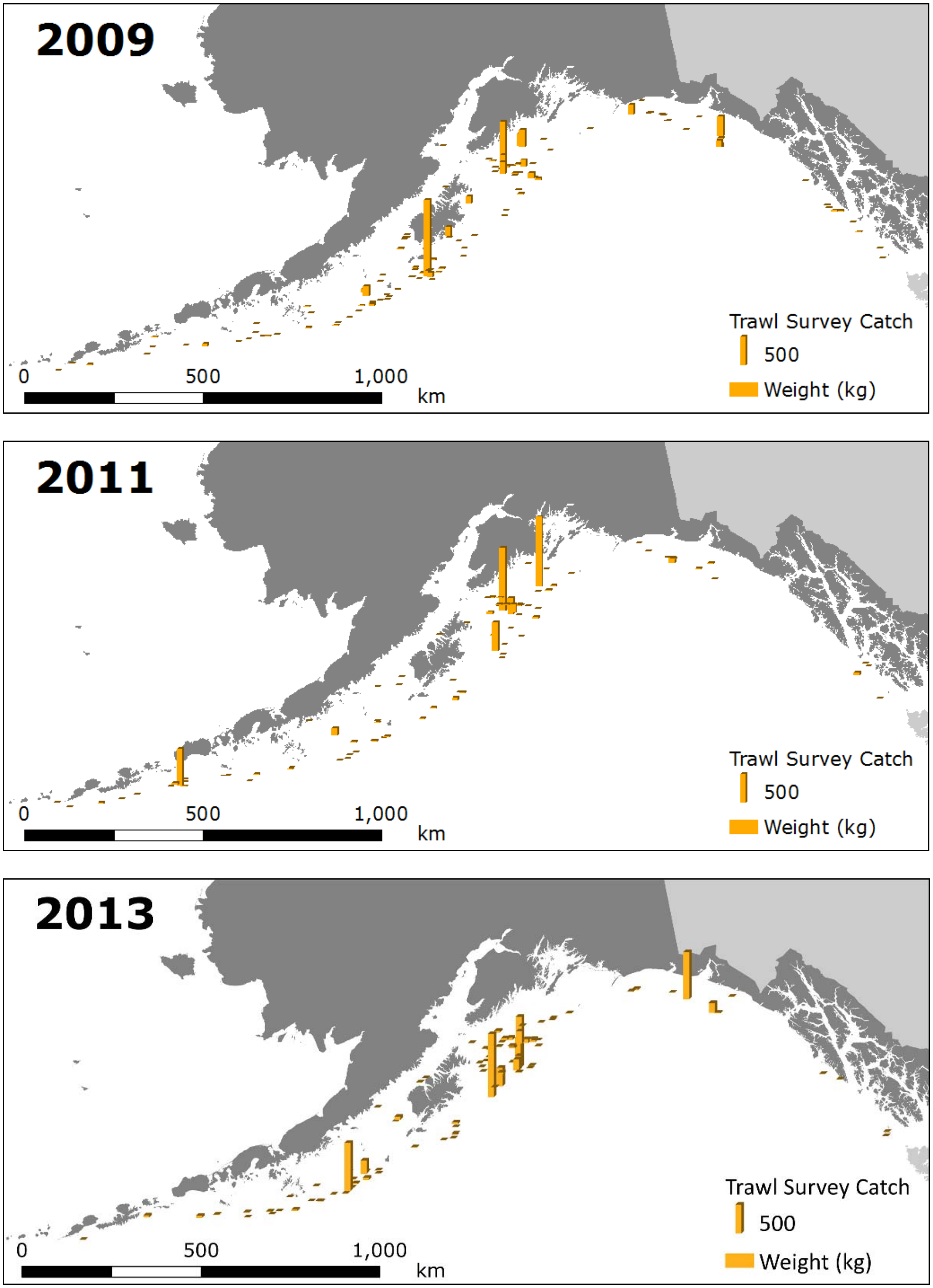


Figure 12-6. Spatial distribution of dusky rockfish in the Gulf of Alaska during the 2009, 2011, and 2013 NMFS trawls surveys.

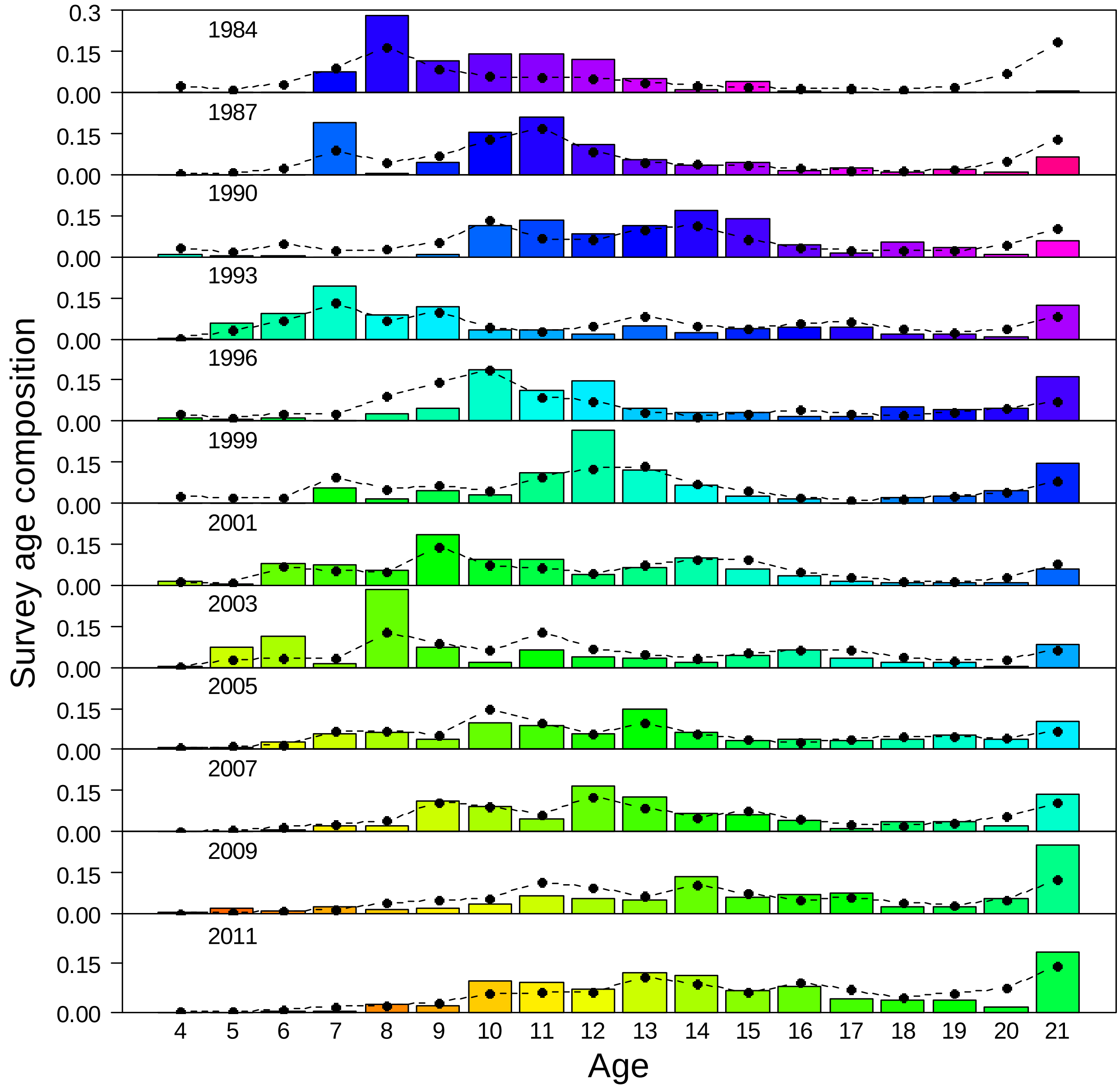


Figure 12-7. Trawl survey age composition by year for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles. Colors correspond to individual year classes.

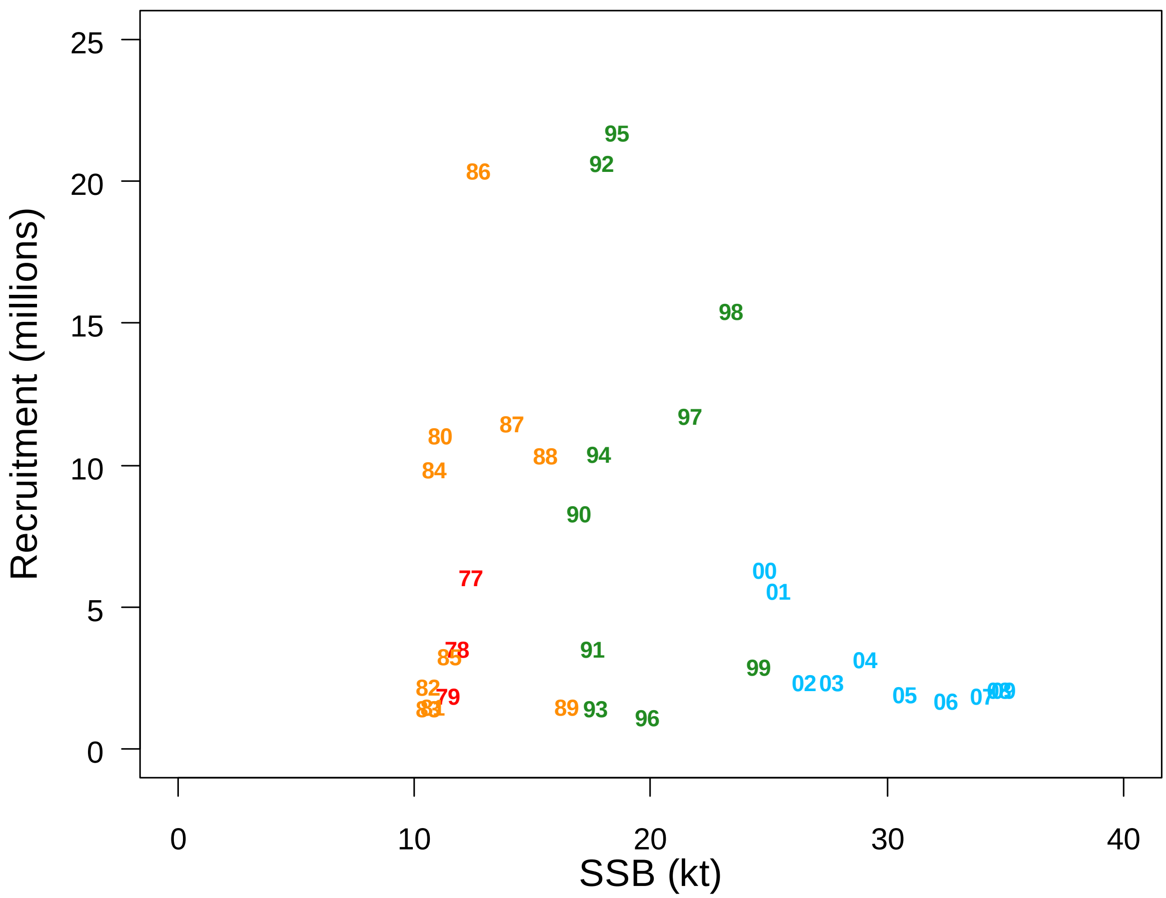


Figure 12-8. Scatterplot of spawner-recruit data for GOA dusky rockfish author recommended model. Label is year class of age 4 recruits. SSB = Spawning stock biomass in kilo tons (kt).

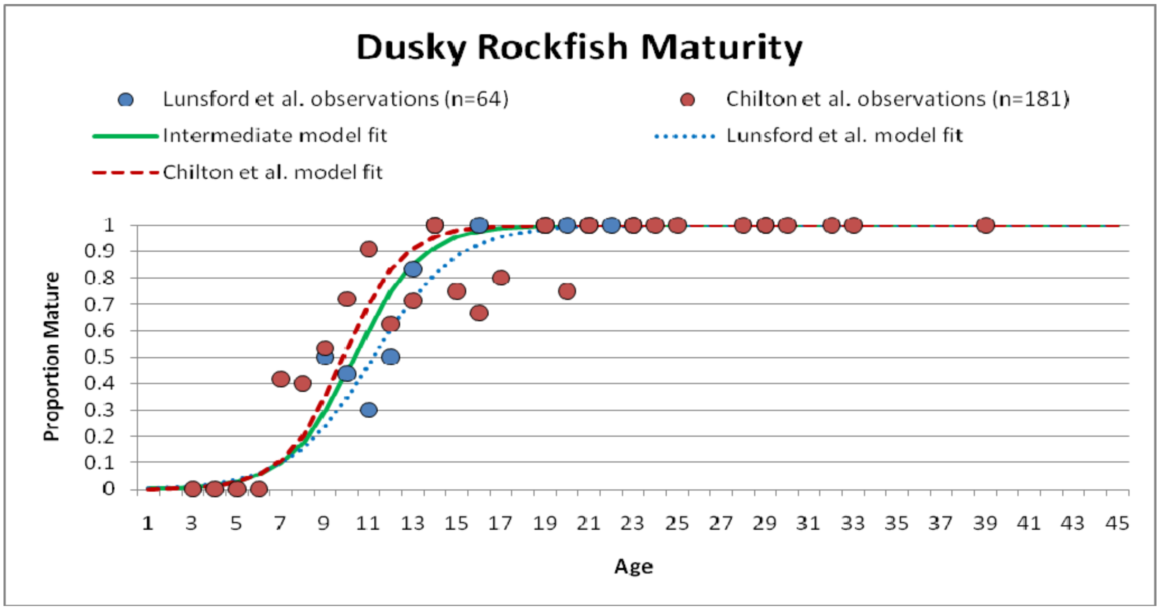


Figure 12-9. Comparison of maturity curves including intermediate curve used in determining Gulf of Alaska dusky rockfish 50% age at maturity.

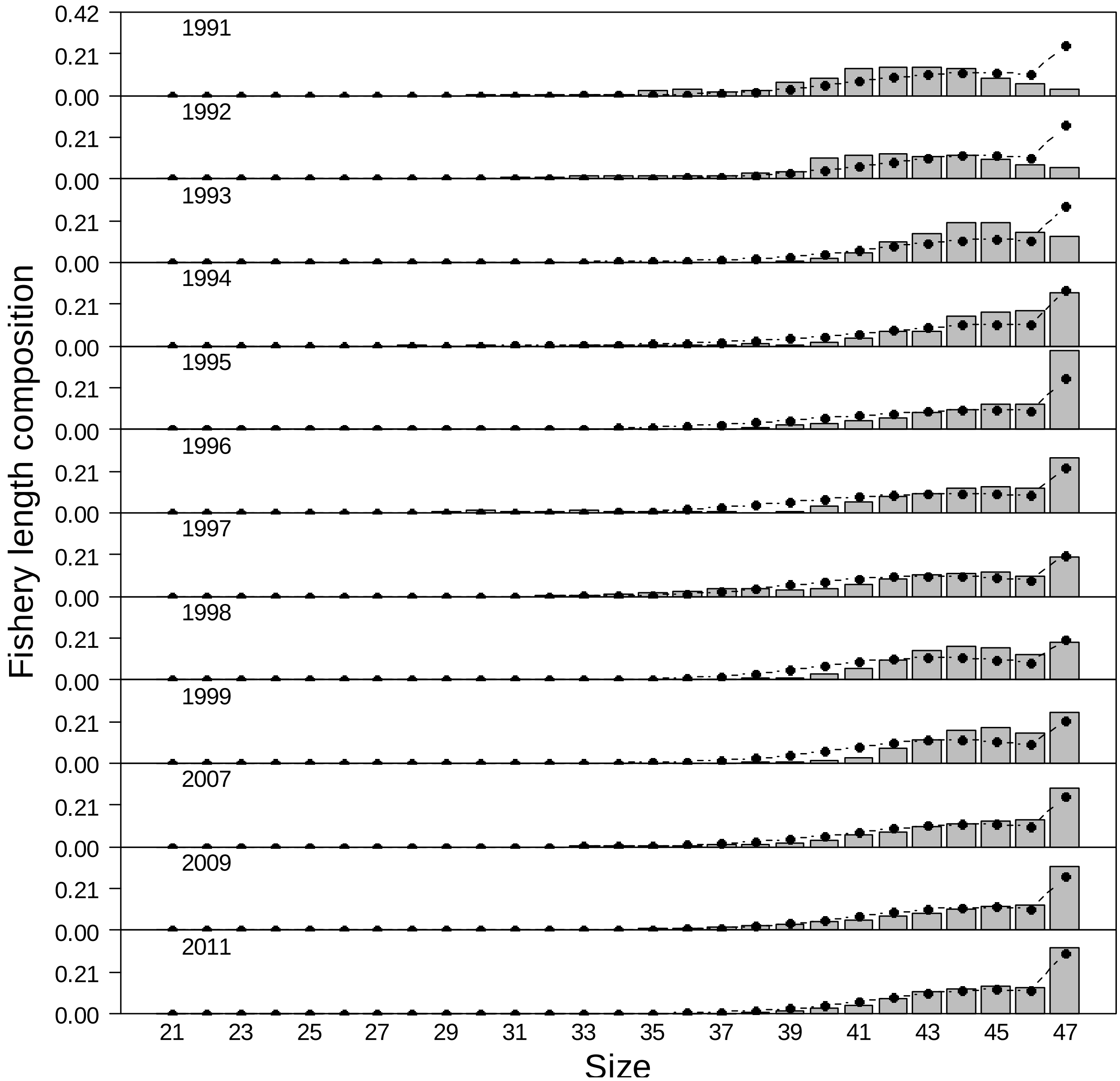


Figure 12-10. Fishery length compositions for GOA dusky rockfish. Observed is bars, 2013 model predicted is line with circles.

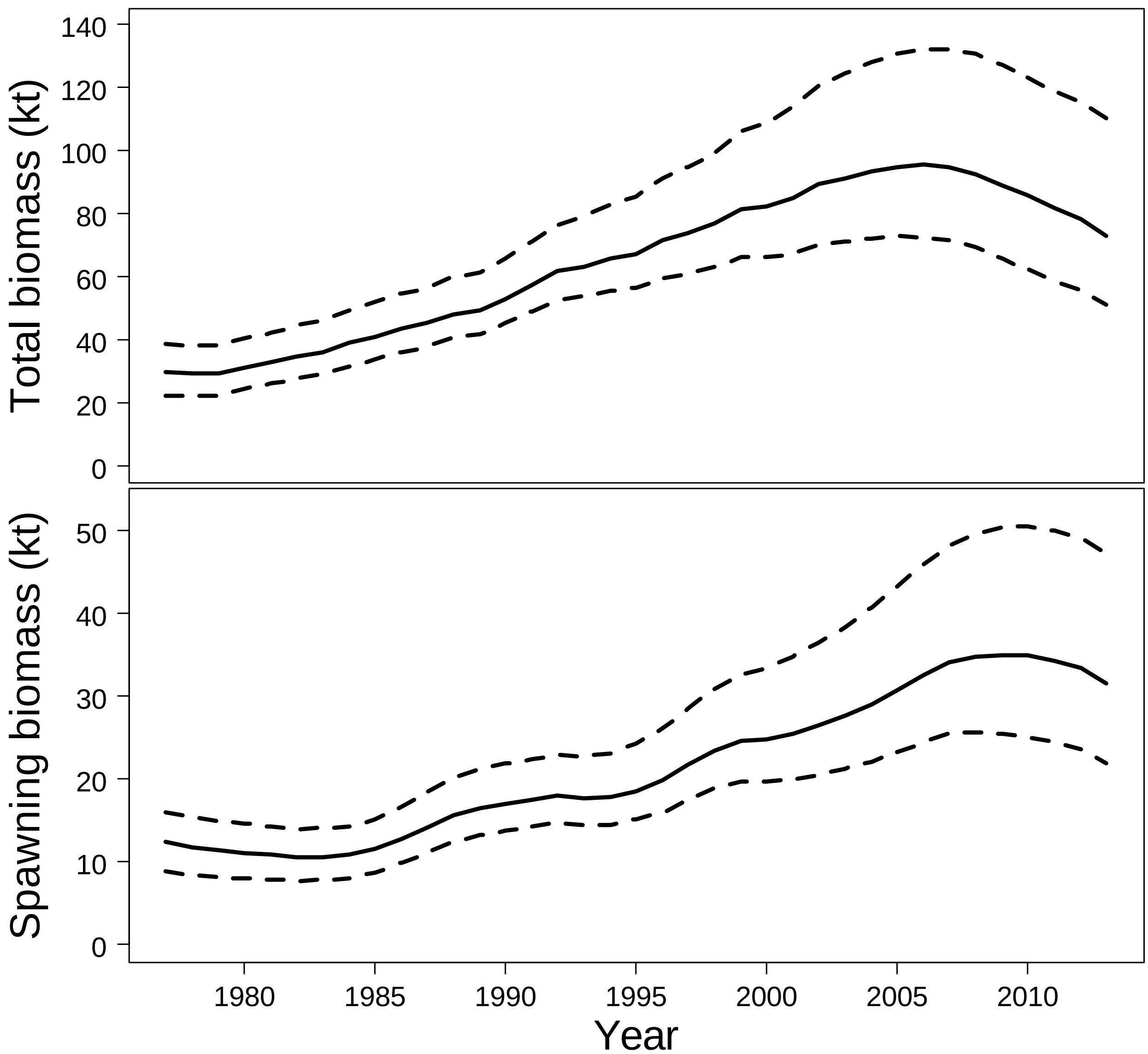


Figure 12-11. Time series of predicted total biomass and spawning biomass of GOA dusky rockfish for 2013 model. Dashed lines represent 95% credible intervals from 10 million MCMC runs.

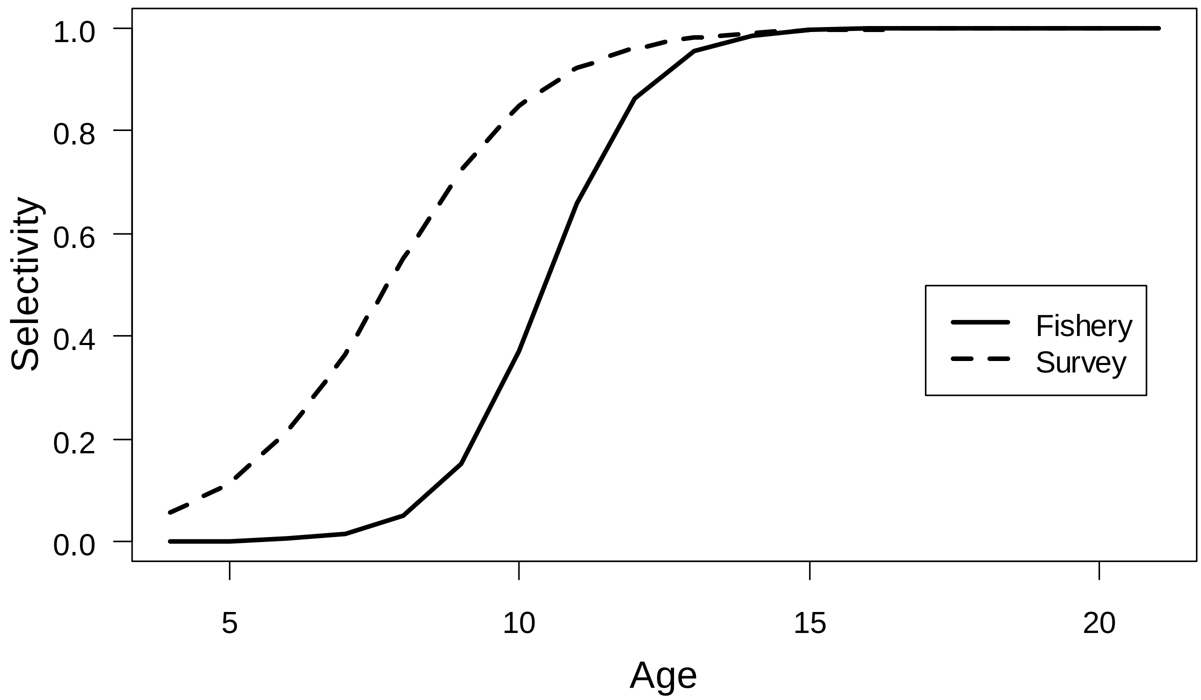


Figure 12-12. Estimated fishery and survey selectivity for GOA dusky rockfish from the 2013 model. Dashed line is survey selectivity and solid line is fishery selectivity.

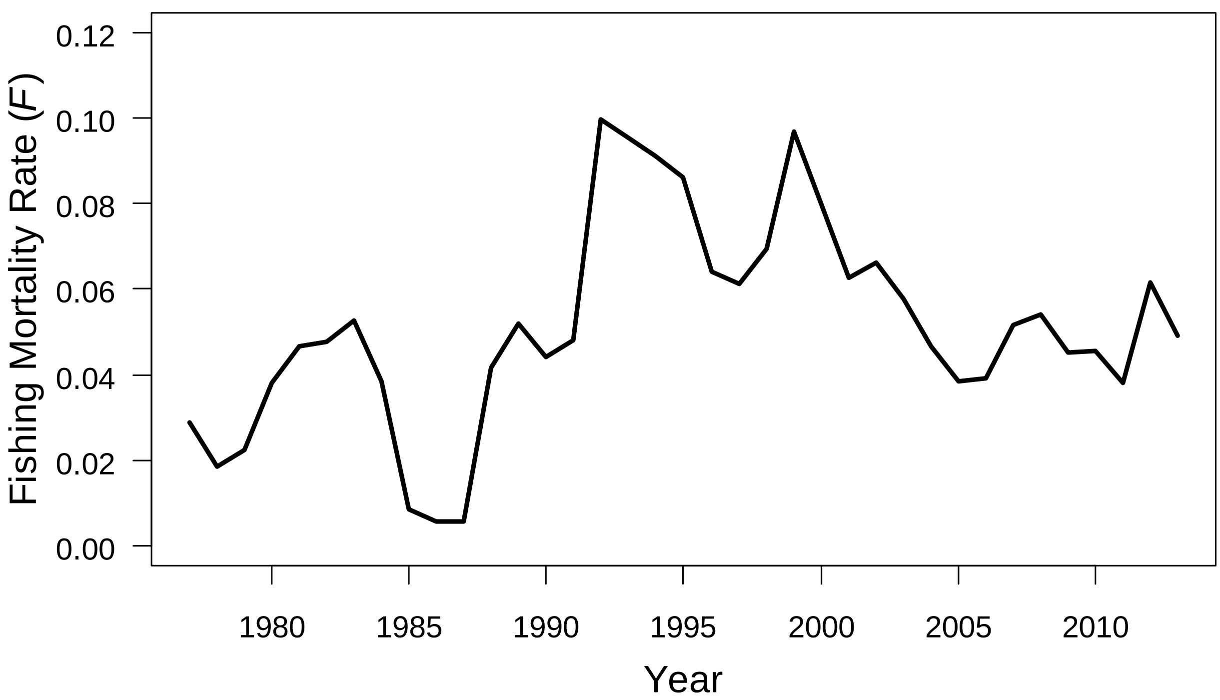


Figure 12-13. Time series of estimated fully selected fishing mortality for GOA dusky rockfish from the 2013 model.

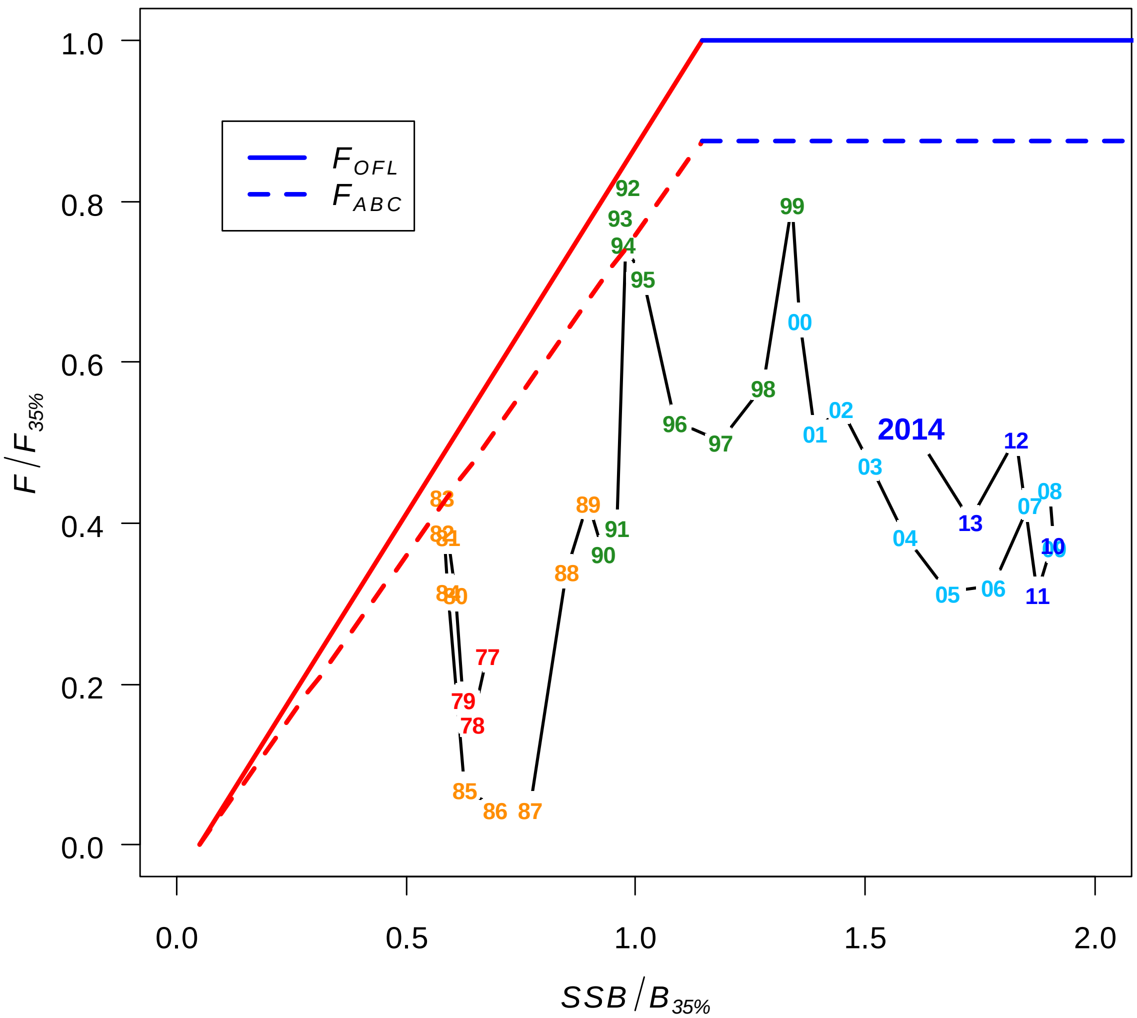


Figure 12-14. Time series of dusky rockfish estimated spawning biomass relative to the unfished level and fishing mortality relative to F_{OFL} for the 2013 model.

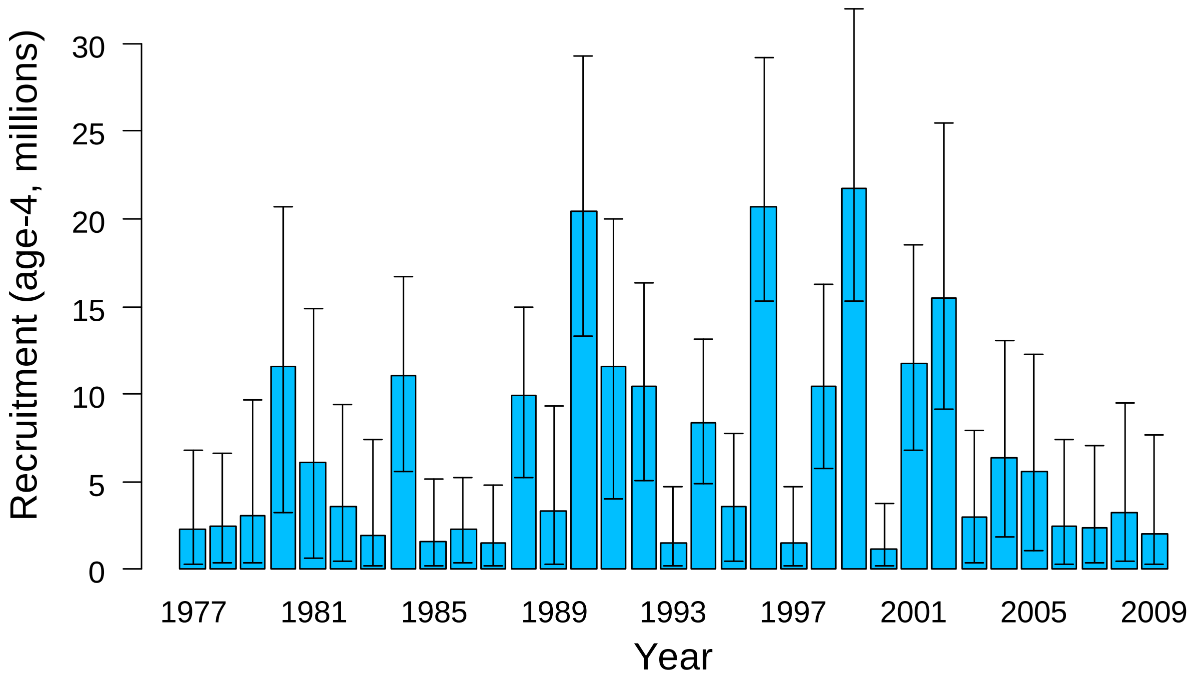


Figure 12-15. Estimated recruitments (age 4) for GOA dusky rockfish from the 2013 model.

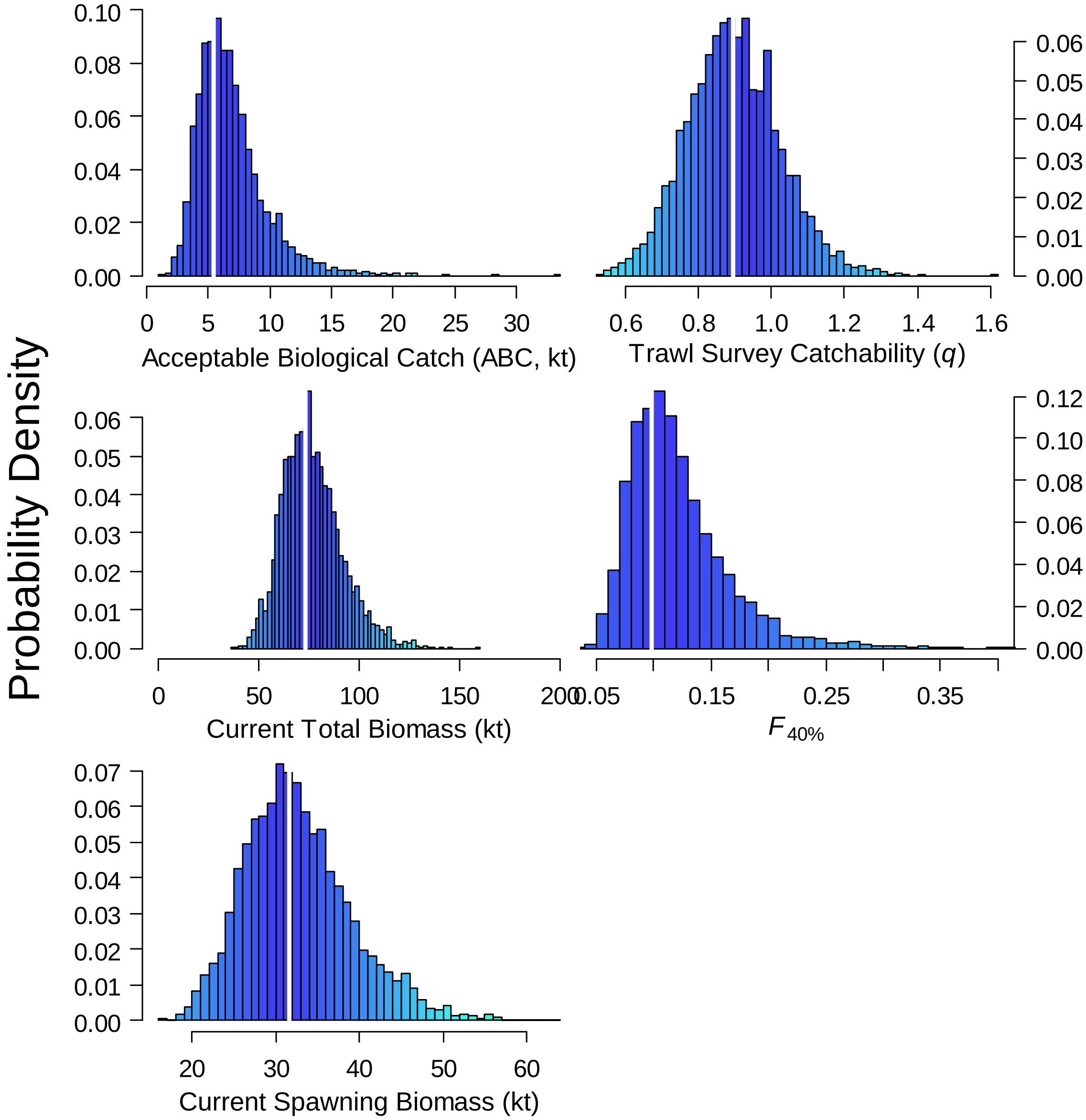


Figure 12-16. Histograms of estimated posterior distributions for key parameters derived from the MCMC for GOA dusky rockfish. Vertical white lines represent the maximum likelihood estimate for comparison with the MCMC results.

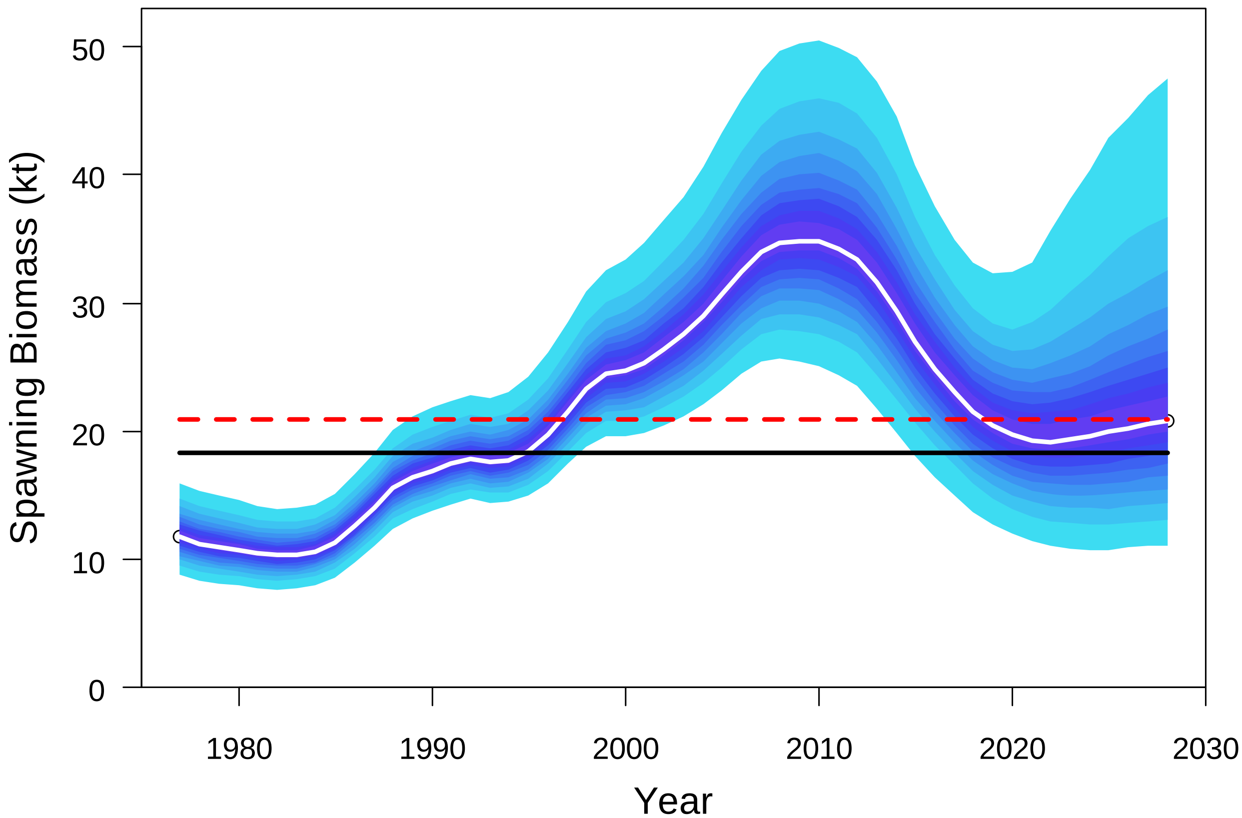


Figure 12-17. Bayesian credible intervals for entire spawning stock biomass series including projections through 2028. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1981-2009. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

Appendix 12A

Total Catch Accounting Data

In order to comply with the Annual Catch Limit (ACL) requirements, a new dataset has been generated to help estimate total catch and removals from NMFS stocks in Alaska. This dataset estimates total removals that do not occur during directed groundfish fishing activities. This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For Gulf of Alaska (GOA) dusky rockfish, these estimates can be compared to the research removals reported in previous assessments (Lunsford et al. 2009) (Table 12A-1). Dusky 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 dusky rockfish in the GOA. Other research activities that harvest dusky rockfish include longline surveys by the International Pacific Halibut Commission and the AFSC and the State of Alaska's small mesh trawl surveys. Recreational harvest of dusky rockfish does occur and in recent years has been between 5 t and 9 t. This indicates that annually the level of recreational harvest of dusky rockfish is comparable to the research harvest. Total removals from activities other than a directed fishery have been near 10 t since 2010. This is <1% of the 2013 recommended ABC of 6,436 t and represents a very low risk to the dusky 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 and have been less than 10 t except in 2005 when 13 t were removed. Even when accounting for recreational harvest, the estimated removals would generally be less than than 20 t, which do not pose a significant risk to the dusky rockfish stock in the GOA.

References:

Lunsford, C., S.K. Shotwell, and D. Hanselman. Gulf of Alaska pelagic shelf rockfish. 2009. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2010. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 9950. pp. 925-992.

Table 12A-1 Total removals of Gulf of Alaska dusky rockfish (t) from activities not related to directed fishing, since 1977. Trawl survey sources are a combination of the NMFS echo-integration, State of Alaska small-mesh, GOA bottom trawl surveys, and occasional short-term research projects. Other is longline, personal use, scallop dredge, and subsistence harvest.

Year	Source	Trawl	Recreational	Other	Total
1977*		1			1
1978*		1			1
1979*		1			1
1980*		1			1
1981*		6			6
1982*		1			1
1983*		1			1
1984*		5			5
1985*		7			7
1986*		1			1
1987*		35			35
1988*		1			1
1989*		1			1
1990*		5			5
1991*	**Assessment of Pelagic shelf rockfish in the Gulf of Alaska (Lunsford et al. 2009)**	0			0
1992*		0			0
1993*		7			7
1994*		0			0
1995*		0			0
1996		7			7
1997		1			1
1998		8			8
1999		6			6
2000		0			0
2001		3			3
2002		0			0
2003		6			6
2004		0			0
2005		13			13
2006		0			0
2007		7			7
2008		0			0
2009		5			5
2010	AKRO	<1	9	<1	10
2011	AKRO	5	5	<1	11
2012	AKRO	<1	8	<1	9

*May include catch of dark rockfish.

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