Chapter 12: Assessment of Pelagic Shelf Rockfish in the Gulf of Alaska

Chris R. Lunsford, S. Kalei Shotwell, and Dana H. Hanselman
November 2009

Executive Summary

Gulf of Alaska rockfish are assessed on a biennial stock assessment schedule designed to coincide with new survey data. For pelagic shelf rockfish in alternate (even) years, we present an executive summary to recommend harvest levels for the next (odd) year. For this on-cycle year, we incorporate new survey biomass estimates to estimate exploitable biomass of Tier 5 species and for dusky rockfish (Tier 3) we update the 2007 assessment model estimates with new data and present one alternative model configuration.

Effective January 30, 2009, dark rockfish were removed from Federal management (including the associated contribution to OFLs and ABCs under the respective assemblages in both regions) and full management authority was turned over to the State of Alaska. ABCs and OFLs presented in this assessment for the pelagic shelf rockfish assemblage now exclude dark rockfish. This results in significantly lower exploitable biomass estimates and associated ABC/OFL recommendations for the Tier 5 species (widow and yellowtail rockfish) when compared to earlier assessment recommendations. The overall effect on the assemblage recommendations, however, is much less.

For widow and yellowtail rockfishes we continue to recommend using the average of exploitable biomass from the three most recent trawl surveys to determine ABCs. For dusky rockfish, we continue to use the age-structured model developed in a workshop held at the Auke Bay Laboratory in February 2001, and refined to its current configuration in 2004. The model was constructed with AD Model Builder software. The model is a separable age-structured model with allowance for size composition data that is adaptable to several rockfish species. The model's starting point is 1977 and contains all available data including catch, fishery age and size compositions, survey age and size compositions, and survey biomass estimates.

Summary of Changes in Assessment Inputs

Changes in the input data: New data for 2009 includes updated 2008 fishery catch, estimated 2009 fishery catch, three new years of fishery ages (2003, 2005, 2006), 2007 survey ages, and 2009 survey biomass.

Changes in the assessment methodology: For dusky rockfish, two alternative models are presented. Model 1 is the same as last year's author recommended 2007 model with updated fishery and survey data. Model 2 is presented this year as the recommended model. Model 2 is identical to the recommended 2007 model with one change. The fishery catch time series has been split into two time periods (1977-1990 and 1991-2009) and the weight on catch has been reduced for the earlier time period and increased for the most recent time period. Implementing this change resulted in an improved model fit to fishery catch.

Summary of Results

We continue to recommend using the average of exploitable biomass from the three most recent trawl surveys to determine the ABC's for widow and yellowtail rockfishes. For these two species, the average exploitable biomass from the 2005, 2007, and 2009 surveys was 1,724 t (158 t for widow rockfish and 1,566 t for yellowtail rockfish). The 2010 recommended ABC for widow and yellowtail rockfish combined is 91 t based on Tier 5 calculations (F=0.75M). The 2010 OFL (F=M=0.07) for widow and yellowtail rockfish is 121 t. Recommended area apportionments of ABC for widow and yellowtail rockfish are 12 t for the Western area, 58 t for the Central area, 7 t for the West Yakutat area, and 14 t for the Southeast/Outside area.

For dusky rockfish, the maximum allowable ABC for 2010 is 4,957 t based on Tier 3 and derived from the recommended model. This ABC is 5% more than last year's ABC of 4,723 t and nearly identical the 2005 recommended ABC. The slight changes in ABC are likely due to a 2.5 fold increase in survey biomass in 2005 compared to relatively stable biomass estimates in 2003, 2007, and 2009. The 2010 OFL for dusky rockfish is 6,006 t. Recommended area apportionments of ABC are 637 t for the Western area, 3,183 t for the Central area, 425 t for the West Yakutat area, and 712 t for the Southeast/Outside area.

For the pelagic shelf rockfish assemblage, ABC and OFL for dusky rockfish are combined with ABC and OFL for widow and yellowtail rockfish. The 2010 recommended ABC for pelagic shelf rockfish is 5,048 t with area apportionments of 649 t for the Western area, 3,241 t for the Central area, 432 t for the West Yakutat area, and 726 t for the Southeast/Outside area. The 2010 OFL for pelagic shelf rockfish is 6,127 t. The stock is not overfished, nor is it approaching overfishing status. Reference values for pelagic shelf rockfish are summarized in the following table with the recommended ABC and OFL values in bold.

Widow and Yellowtail	Last Year's Estimates[1]		This Year's Estimates:	
	2009	2010	**2010**	2011
Tier 5				
Total (Exploitable) Biomass (t)	1,106	1,106	1,724	1,724
M	0.07	0.07	0.07	0.07
F_{ABC} (maximum allowable = *0.75**M)	0.0525	0.0525	0.0525	0.0525
F_{OFL} (M)	0.07	0.07	0.07	0.07
ABC (t, maximum allowable)	58	58	**91**	91
OFL (t)	77	77	**121**	121

Dusky rockfish	Last Year's Model Projection Not Updated		This Year's Projection Revised Model	
	2009	2010	**2010**	2011*
Tier 3a				
Total (Exploitable) Biomass (age 4+)	65,271	62,574	67,685	64,242
Female Spawning Biomass (t)	23,332	22,657	25,800	24,861
$B_{100\%}$ (t, female spawning)	--	--	47,898	--
$B_{40\%}$ (t)	--	--	19,159	--
$B_{35\%}$ (t, female spawning)	--	--	16,764	--
M	0.07	0.07	0.07	0.07
F_{ABC} (maximum allowable = $F_{40\%}$)	0.087	0.087	0.087	0.087
F_{OFL} ($F_{35\%}$)	0.107	0.107	0.106	0.106
$ABC_{F40\%}$ (t yield at $F_{40\%}$=F_{max})	4,723	4,407	**4,957**	4,625
OFL (t, yield at $F_{35\%}$)	5,726	5,343	**6,006**	5,603

Pelagic Shelf Rockfish Assemblage	Last Year's Estimates:		This Year's Projection:	
	2009	2010	**2010**	2011*
Total (Exploitable) Biomass	66,377	63,680	69,409	65,966
M	0.07	0.07	0.07	0.07
$ABC_{F40\%}$ (t, maximum allowable)	4,781	4,465	**5,048**	4,716
OFL (t, $F_{35\%}$)	5,803	5,420	**6,127**	5,724

*The 2011 ABC and OFL for dusky rockfish were projected using an expected catch value of 3,408 t for 2010, based on recent ratios of catch to maximum permissible ABC. The projection results of this method are listed under the Author's F method in Table 12-9 in response to management requests for a more accurate one-year projection.

The following table shows the recommended apportionment for 2010.

	Western	Central	Eastern	Total
Area Apportionment	12.9%	64.2%	22.9%	100%
Area ABC (t)	**649**	**3,241**	**1,158**	**5,048**
OFL (t)				**6,127**

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 0.37 which is lower than the 0.42 value in 2007. This results in the following apportionment to the W. Yakutat area:

	W. Yakutat	E. Yakutat/Southeast
Area ABC (t)	**432**	**726**

Responses to SSC Comments Specific to the PSR Assessment

The December 2008 SSC minutes included the following comments:

"The Plan Team report indicates that species identification problems persist in the catch accounting for PSR. The State and Federal biologists plan to share techniques for identifying dark, dusky, northern, black and blue rockfish to reduce misidentifications. The SSC supports the technique-sharing activity described above and encourages the stock assessment authors to examine the implications of uncertainty in catch estimation on the dusky rockfish assessment."

Several efforts have occurred to help improve the identification of PSR species at Kodiak processing plants. ADF&G has collected data from federal rockfish deliveries in an attempt to understand how many fish are misidentified in respect to black and dark rockfish. This data is currently being collected but has not been analyzed at this time (N. Sagalkin, pers comm..). NMFS Alaska Region staff has distributed rockfish keys to processors and have helped train plant personnel at the start of the last several rockfish seasons (J. Bonney, pers comm.) Additionally, staff at the Fisheries Monitoring and Analysis Division at the AFSC have a draft manuscript in review regarding rockfish identification in Kodiak plants versus observer audit samples (C. Faunce, pers comm.). Results are not yet available but may provide some information on misidentification rates. In general, the rockfish identification at plants has improved in recent years.

In regards to the PSR assessment, catch of PSR species is dominated by dusky rockfish. We compute an annual catch value for dusky rockfish to be used as input to the model by analyzing the species composition of the PSR assemblage in observer sampled hauls. The total PSR catch estimated by the Catch Accounting System is then multiplied by the proportion of the PSR assemblage comprised of dusky rockfish sampled by observers in the fishery. We believe the misidentification of PSR species at plants is a minor concern in the estimated catch of dusky rockfish. This is because dusky rockfish dominate the catch of the PSR assemblage (>98%) and the species identification problems are usually associated with dark, blue, and black rockfish. The current perceived rates of misidentification are likely not substantial enough to have any major effect on the catch history of dusky rockfish used in the model. We will continue to monitor the problem and will report any rates that are available and if warranted, will explore the implications of uncertainty in the dusky catch history

Plan Team Summaries

Stock Assemblage	Year	Biomass	OFL	ABC	TAC	Catch[2]
Pelagic Shelf Rockfish	2008	77,935[1]	6,400	5,227	5,227	3,643
	2009	66,377[2]	5,803	4,781	4,781	2,995
	2010	69,409[3]	6,127	5,048		
	2011	65,966[3]	5,724	4,716		

[1]Total biomass estimates for pelagic shelf rockfish, including: dark, widow and yellowtail rockfish from 2007 trawl survey and age-structured model for dusky rockfish. Average exploitable biomass is not used.
[2]Total biomass estimates for pelagic shelf rockfish, including: widow, yellowtail rockfish (not dark) from 2003, 2005, 2007 average exploitable biomass and age-structured model for dusky rockfish.
[3]Total biomass estimates for pelagic shelf rockfish, including: widow, yellowtail rockfish (not dark) from 2005, 2007, 2009 average exploitable biomass and age-structured model for dusky rockfish.

Stock Assemblage	Area	2009 OFL	ABC	TAC	Catch[2]	2010 OFL	ABC	2011 OFL	*ABC*
Pelagic Shelf Rockfish	W		819	819	714		649		606
	C		3,404	3,404	2,122		3,241		3,028
	WYAK		234	234	158		432		404
	EYAK/SEO		324	324	1		726		678
	Total	5,803	4,781	4,781	2,995	6,127	5,048	5,724	4,716

[2]Current as of October 22, 2009 (http://www.fakr.noaa.gov/2009/car110_goa.pdf)

Introduction

Distribution and life history

The pelagic shelf rockfish assemblage in the Gulf of Alaska is comprised of three species: dusky rockfish (*Sebastes variabilis*), yellowtail rockfish (*S. flavidus*), and widow rockfish (*S. entomelas*). 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.

Gulf-wide, dusky rockfish are the most abundant species in the assemblage, whereas yellowtail, and widow rockfish make up a very small proportion of the biomass in Alaska waters. Dusky rockfish 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.

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[2]. 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).

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 Gulf of Alaska. 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 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 ruinous to a population with highly episodic recruitment like rockfish (Longhurst 2002). Recent 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.

Evidence of stock structure

No studies have been done to determine if the Gulf of Alaska population of dusky rockfish is one stock, or if subpopulations occur. No stock identification work has been done on yellowtail or widow rockfish as these species are generally considered minor species in Alaska waters.

In a recent 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. In general, however, there is little evidence for localized depletion of dusky rockfish in the Gulf of Alaska. Potential reasons for this may include: 1) the local populations may be large enough compared to the existing catch limits that significant depletions do not occur, 2) there is insufficient data for a less targeted species like dusky rockfish to detect real depletions that are happening, or 3) the data selection criteria were aimed at the complex of targeted rockfish. If the fishery concentrates on harvesting Pacific ocean perch until the catch limit is reached, then subsequently targets northern rockfish then dusky rockfish, depletion would be exaggerated for the first target and then underestimated for the final target.

The appropriate spatial and temporal scale at which localized depletion becomes important for rockfish is a subject for future research. Localized depletion becomes problematic if it diminishes the ability of rockfish to replenish fished areas and support localized spawning populations. Thus, evaluations of localized depletion for rockfish should reflect the spatial scale characterizing fish movement within a year and the location and spatial extent of spawning populations. This information can be obtained from research on early life history and genetic stock structure. From a management perspective, localized aggregations of rockfish are logical candidate areas for spatial management measures. Identification of such areas can be aided if rockfish are observed to associate with certain habitat features.

Management measures

This assemblage is one of three management groups for *Sebastes* in the Gulf which were implemented in 1988 by the North Pacific Fishery Management Council (NPFMC). Pelagic shelf rockfish can be 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.

Until 1998, black rockfish (*S. melanops*) and blue rockfish (*S. mystinus*) were also included in the assemblage. However, in April 1998, a NPFMC Gulf of Alaska Fishery Management Plan amendment went into effect that removed these two species from the federal management plan and transferred their jurisdiction to the state of Alaska.

For dusky rockfish, an age-structured model was first accepted in 2003 as an alternative to average trawl survey biomass estimates and was used to determine the ABC. For yellowtail and widow rockfishes, we recommend ABC using the average of exploitable biomass from the three most recent trawl surveys.

For dusky rockfish, we use the generic rockfish model as the primary assessment tool. This model was developed in a workshop held at the Auke Bay Laboratory in February 2001, and refined to its current configuration in 2004. The model was constructed with AD Model Builder software. The model is a separable age-structured model with allowance for size composition data that is adaptable to several rockfish species. The model's starting point is 1977 and contains all available data including catch, fishery age and size compositions, survey age and size compositions, and survey biomass estimates.

In 1998, Amendment 41 was passed (became effective in 2000), which prohibited trawling in the Eastern Gulf east of 140 degrees W. longitude. 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. 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). Separate ABCs and TACs are now assigned to each of these smaller areas for the pelagic shelf rockfish assemblage.

In 2007 the Central Gulf of Alaska Rockfish Pilot 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 is a five year 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. Potential effects of this program to pelagic shelf rockfish include: 1) Extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA, 3) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, and 4) a higher potential to harvest 100% of the TAC in the Central GOA region. Future analyses regarding the Pilot Project effects on pelagic shelf rockfish will be possible as more data becomes available.

In March, 2007, the North Pacific Fishery Management Council took final action to remove dark rockfish from both the GOA FMP (PSR Assemblage) and BSAI FMP (other rockfish complex). Removing the species from the Federal FMP serves to turn full management authority of the stock over to the State of Alaska in both regions. The rules to implement these FMP amendments were finalized in 2008 and the effective date for Amendments 77/73 was January 1, 2009. Therefore, effective January 30, 2009, dark rockfish were removed from Federal management (including the associated contribution to OFLs and ABCs under the respective assemblages in both regions) and full management authority was turned over to the State. ABC's and OFLs presented in this assessment for the PSR assemblage now exclude dark rockfish.

A summary of these management measures and a time series of catch, ABC and TAC are shown below.

Year	Catch (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.
1989	1,738	6,600	3,300		No reported foreign or joint venture catches of PSR
1990	1,647	8,200	8,200		
1991	2,342	4,800	4,800		
1992	3,605	6,886	6,886		
1993	3,193	6,740	6,740		

1994	2,989	6,890	6,890		
1995	2,891	5,190	5,190		
1996	2,296	5,190	5,190		
1997	2,629	5,140	5,140		
1998	3,113	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	4,659	4,880	4,880		Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	3,731	5,980	5,980		Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	3,008	5,980	5,980		Dusky rockfish treated as tier 4 species whereas dark, widow, and yellowtail broken out as tier 5 species
2002	3,322	5,490	5,490		
2003	2,975	5,490	5,490		Age structured model for dusky rockfish accepted to determine ABC and moved to Tier 3 status
2004	2,885	4,470	4,470		
2005	2,397	4,553	4,553		
2006	2,444	5,436	5,436		
2007	3,370	5,542	5,542		Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	3,447	5,227	5,227		
2009	2,821	4,781	4,781		Dark rockfish removed from PSR assemblage and federal management plan

Fishery

Catch History

Fishery catch statistics for the pelagic shelf rockfish assemblage in the Gulf of Alaska are only available for the years 1988-2009 (Table 12-1a). Specific catches for dusky rockfish were estimated from the Regional Office blend estimates from 1977-2009 for input in the age-structured model (Table 12-1b). 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 desirable slope rockfish species such as Pacific ocean perch, and there was less reason for fishermen to target a lower valued fish such as dusky rockfish. However, as TACs for slope rockfish became more restrictive in the early 1990's, 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. In following years, in-season management regulations have usually prevented any further increase in the dusky rockfish fishery, and have sometimes caused a decrease in catch. For example, in 1997-1998 and 2000-2006, the pelagic shelf rockfish trawl fishery in the Central area was closed with a substantial amount of un-harvested TAC remaining, either to ensure that catches did not exceed the TAC, or to prevent excessive bycatch of Pacific ocean perch or Pacific halibut.

Catches in Table 12-1a include black and blue rockfish for the years 1988-97, when these species were members of the pelagic shelf assemblage. A significant black rockfish jig fishery started in 1991 in the Gulf of Alaska, but precise catches of black rockfish for these years are not available. Clausen and Heifetz (1997) provided approximations of the Gulf-wide annual catches of black rockfish for the years 1991-97. The approximation for 1997 was later revised in the 1998 SAFE report (Clausen and Heifetz

1998). These approximations can be subtracted from the Gulf-wide totals in Table 12-1a to yield the following estimates of pelagic shelf rockfish catch for the three species that now comprise the assemblage:

Year	1991	1992	1993	1994	1995	1996	1997
Catch (t)	1,773	3,163	3,041	2,610	2,342	1,834	2,280

Catches of pelagic shelf rockfish from research cruises since 1977 are listed in Table 12-1c.

Description of the Fishery

Pelagic shelf rockfish (excluding the former members, black and blue rockfish) have been caught almost exclusively with bottom trawls. Species composition data for the present species in the assemblage are shown below for the fishery in the years 1991-2009, based on data from the domestic observer program:

Percent of Assemblage Catch

Year	Dusky	Dark[1]	Yellowtail	Widow
1991-1995	97.6	0.6	1.9	0.9
1996-2000	99.2	1.6	0.1	0.2
2001-2005	98.4	0.6	0.2	1.6
2006	99.4	0.6	trace	trace
2007	99.7	0.3	trace	trace
2008	99.3	0.5	0.1	0.1
2009	99.8		trace	0.2

[1]Dark rockfish removed from federal management plan in 2009

Although the vast majority of these catches come from bottom trawls, a small portion of the data may also come from longline vessels that carried observers, which could account for some of the yellowtail and dark rockfish listed. Removal of dark rockfish from the PSR assemblage does not significantly affect the proportion of catch since on average dark rockfish accounted for only 0.7 percent of the total PSR catch. Clearly, nearly all the catch consists of dusky rockfish.

The trawl fishery for dusky rockfish in the Gulf of Alaska in recent years occurred mostly in July, because management regulations did not allow rockfish trawling in the Gulf until the first week in July. The same trawlers that target Pacific ocean perch and northern rockfish also target dusky rockfish. Typically, these vessels filled the quota first for Pacific ocean perch, and after this fishery closed moved on to catch dusky and northern rockfish. 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. These shore-based trawlers have accounted for 18-74% of the trawl catch in the Central area in the years 1996-2006[3]. The Rockfish Pilot Project initiated in 2007 allocates the rockfish quota by sector so the percentage of 2007 catches by shore-based catcher vessels may differ in comparison to previous years. Additionally, the season will begin in May rather than July and fishing will be allowed until November 15. One benefit already realized from the Rockfish Pilot Project is increased observer coverage (see figure below). As more data becomes available we hope to analyze the potential biological effects that have occurred as a result of this change in the fishery.

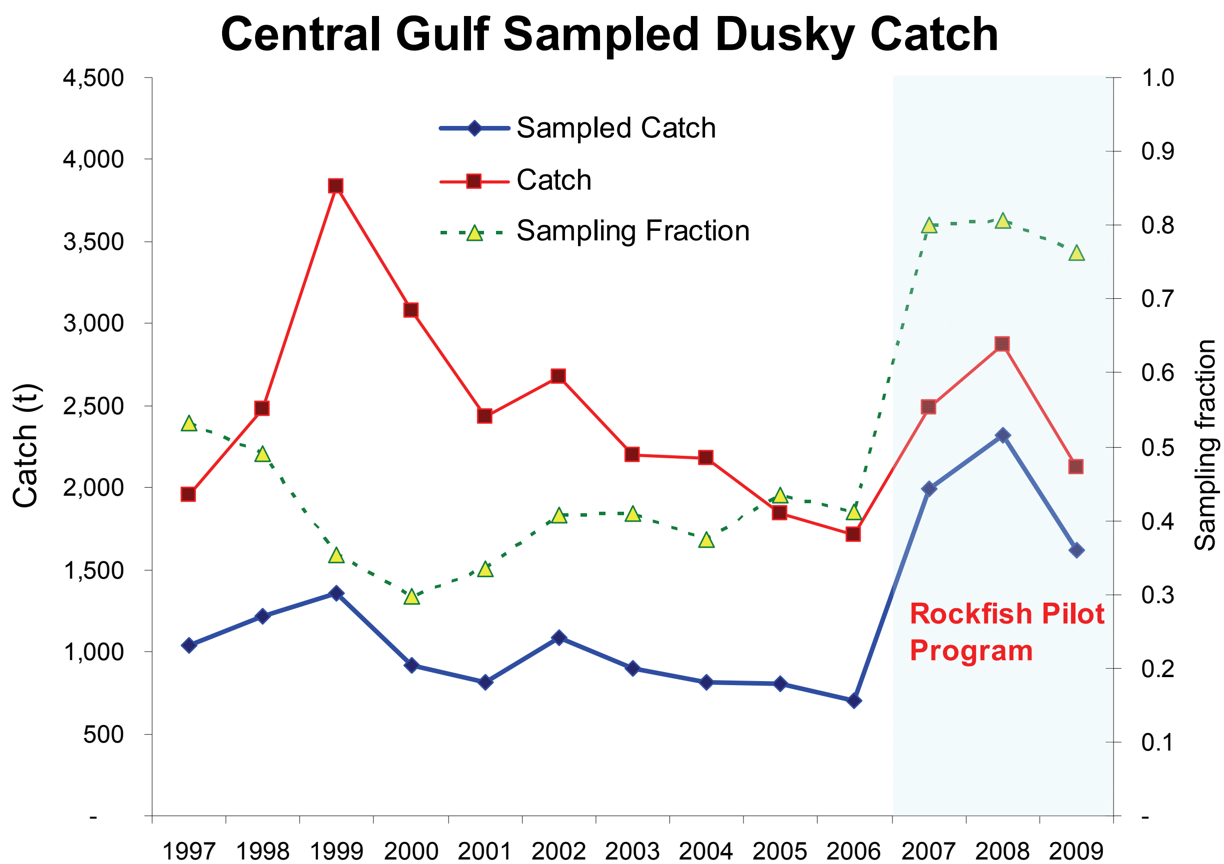

Figure. Increase in sampled catch by the Observer Program in the Central Gulf since the inception of the Rockfish Pilot Program. Sampling fraction is the proportion of total catch where the hauls were sampled by observers.

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 slope rockfish" species). There is no information on the bycatch of pelagic shelf rockfish in non-rockfish fisheries, but it is presumed to be small.

For rockfish fisheries in general, the largest non-rockfish bycatch groups in the combined rockfish trawl fishery during 1997-2004 are Pacific cod (1,750 t/year), arrowtooth flounder (1,500 t/year), and sablefish 1,100 t/year) (Hanselman et al. 2007). More recent data for 2007-2009 indicates an increase in all rockfish fisheries of bycatch of greenling/atka mackerel (1,584 t/year) and walleye pollock (590 t/year), and decreases of arrowtooth flounder (565 t/year), sablefish (515 t/year), and Pacific cod (422 t/year) (AKFIN data provided by T. Hiatt, Oct. 2009).

Discards
Gulf-wide discard rates (percent of the total catch discarded within management categories) of pelagic shelf rockfish are available for the years 1991-2009. Rates are listed in the following table and have been relatively low over time[4]. The lowest rates have occurred in 2008 and 2009 which may be a consequence of the Rockfish Pilot Project which was initiated in 2007.

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
% Discard	10.2	5.9	10.8	9.4	6.3	10.9	6.4	4.8	9.3	3.8
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	
% Discard	4.3	4.7	2.4	3.6	4.4	7.5	9.2	1.7	2.2	

In contrast, discard rates in the fisheries for slope rockfish in the Gulf of Alaska have generally been much higher until the implementation of the Rockfish Pilot Project (see chapters for Pacific ocean perch, northern rockfish, rougheye, and other slope rockfish).

Data

Data Summary
The following table summarizes the data available for this assessment:

Source	Data	Years
Fisheries	Catch	1977-2009
U.S. trawl fisheries	Length	1990-1999, 2007
	Age	2000, 2001, 2002, 2003, 2004, 2005, 2006
Domestic trawl survey	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009
	Age	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007

Fishery Data
Catch
Catch estimates are a combination of foreign observer data, joint venture catch data, and NMFS Regional Office blend data (Table 12-1a, Table 12-1b, Figure 12-1). 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 dusky model to account for this. 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
In addition to the catch data listed in Table 12-1a and 12-1b, length frequency data for dusky rockfish in the commercial fishery are available for the years 1991-2009 (Table 12-2). These data are the raw length frequencies for all dusky rockfish measured by observers. 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 1999-2009 commercial fisheries. Aging has been completed for the 2000 - 2006 samples (Table 12-3). Similar to the fishery length data discussed in the preceding paragraph, the data in Table 12-3 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. All years accurately track the 1987 year class which shows up as 13 year olds in 2000 and the 1992 year class which appears as eight year olds in 2000 and is especially strong in the 2003 – 2006 data.

Survey Data

Biomass Estimates from Trawl Surveys

Comprehensive trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and 1999, and these surveys became biennial in 2001, 2003, 2005, 2007, and 2009. The surveys provide estimates of biomass for pelagic shelf rockfish (Table 12-4a). 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.

The estimates for the 1984 through 1996 surveys showed that dusky rockfish comprised virtually all the biomass of the assemblage. In 1999, dusky rockfish again predominated, but a relatively large biomass of yellowtail rockfish was also seen in the Southeastern area. This yellowtail rockfish biomass can be mostly attributed to one relatively large catch in Dixon Entrance near the U.S./Canada boundary. In 2005, the dusky biomass estimates were the highest ever recorded. Five hauls caught more than 1000 kg of dusky rockfish in the western and central Gulfs which contributed to the high biomass estimate. Dusky rockfish were separated into “light” and “dark” varieties in surveys since 1996. 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 previous surveys also consisted of nearly all dusky rockfish (light dusky). On a geographic basis, the Kodiak statistical area has usually shown the highest biomass of dusky rockfish. Biomass estimates for the assemblage have been consistently lowest in the Southeastern area, with the exception of 1999 when the large catch of yellowtail rockfish was found in this area. In 2007 West Yakutat had the highest biomass ever recorded. This can be attributed to a couple of tows that caught high numbers of dusky rockfish.

Comparison of Trawl Surveys

Comparative biomass estimates for the nine triennial surveys show wide fluctuations for dusky rockfish (Table 12-4a, Table 12-4b, Figure 12-2a). 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, and decreased in 2007 and 2009 to estimates similar to 2003. Large confidence intervals are associated with all these biomass estimates, particularly in 1987, 1996, 2003, 2005, and 2007. This is an indication of the generally patchy and highly aggregated distribution of this species. The catches of dusky rockfish in the 2005, 2007, and 2009 surveys are shown in Figure 12-2b. The magnitude of catch varies greatly with several large tows typically occurring in each survey. Highest catches occur in the Central and Western Gulf, especially in 2005. 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. However, because of the apparently light fishing pressure on dusky rockfish during most of these years (catches have usually been much less than the ABC), and their relatively low rate of natural mortality, large and abrupt changes in abundance such as those shown by the trawl surveys seem unlikely. Surveys with the larger biomass estimates do not influence the model as much as lower, more precise estimates because of the high imprecision surrounding the larger biomass estimates.

Survey Size Compositions

Gulf-wide survey size compositions are available from 1984-2009 (Table 12-5). 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 2005, 2007 or 2009. 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 2007 trawl surveys (Table 12-6). Similar to the length data, these age data also indicate that recruitment is highly variable. 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 1984 survey. This year class is also prominent in the 1987 and 1990 age compositions. In 1987, just 4 year classes (1975, 1976, 1977, and 1980) comprised over 75% of the estimated population, and mean age was 10.5 years. The 1990 results showed no significant recruitment of young fish and appeared to merely reflect growth of the population that existed in 1987; mean age was 14.4 years. The 1993 age composition showed a very prominent 1986 year class. This year class is clearly associated with the large influx of small fish that was noted previously in the 1993 size compositions, and its presence likely explains much of the increase in dusky rockfish biomass that year. The existence of a strong 1986 year class was further confirmed by the 1996 age composition, in which this year class was again the most important. The 1996 results showed little evidence of recruitment of young fish <10 years old; accordingly, mean age of the population increased from 12.1 years in 1993 to 14.7 years in 1996. In 1999, fish <10 years old again comprised only a small part of the population, and fish aged 12, which would correspond to the 1987 year class, were very prominent. 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. The 2001 age compositions showed the

1986 year class as a distinct mode at age 15. The 2001 data also indicated a possibly strong 1992 year class which was evident in the 2003 data and even more so in the 2005 data. The 2003, 2005, and 2007 data indicate a strong 1995 year class and the 2005 and 2007 data indicate a prominent 1998 year class. Additionally, the 2003, 2005, and 2007 age compositions had increasing proportions of ages >16 years which may be the remnants of the 1986 year class which was evident in previous age compositions.

Analytical Approach

Due to the lack of biological information for dusky rockfish, assessments prior to 2003 used a biomass-based approach based on trawl survey data to calculate ABCs for pelagic shelf rockfish. We now provide an alternative approach for dusky rockfish that is based on age-structured modeling. However, we still apply the biomass-based approach to compute ABCs for widow and yellowtail rockfish.

Widow, and Yellowtail Rockfish

Assessment Parameters

Information on mortality rates and maximum age for three species of pelagic shelf rockfish and dark rockfish is shown in Table 12-7. These data are based on the currently accepted "break-and-burn" method of aging otoliths. The method used to determine the natural mortality rate for the pelagic shelf assemblage was described in Clausen and Heifetz (1991).The estimates range from 0.06-0.09 and were based on dusky rockfish samples. Mortality rates for older rockfish such as Pacific ocean perch and rougheye rockfish are estimated at 0.06 and 0.04, respectively (see specific chapters for these management categories for more information). The value of 0.09 has been used because pelagic shelf rockfish were typically younger than other long-lived rockfish. However, estimates of natural mortality for dark, yellowtail, and widow from different sources using a variety of techniques (e.g. catch curve analysis) indicate that 0.09 may be too high (Table 12-7). We suggest that the value of 0.07 which was recently computed for dark rockfish in the GOA[5] might be more appropriate for widow and yellowtail, and beginning with the 2005 assessment have used 0.07 as the best estimate for natural mortality.

Current Exploitable Biomass

Since 1994, current exploitable biomass for pelagic shelf rockfish was computed by averaging the Gulf-wide assemblage biomass in the most recent three trawl surveys (i.e., averaging the 1987, 1990, and 1993 surveys for the 1994 and 1995 reports, averaging the 1990, 1993, and 1996 surveys for the 1996, 1997, and 1998 reports, etc.) (Clausen and Heifetz, 1994). This averaging technique was used because of the uncertainty of the biomass estimates (discussed previously in *Comparison of Trawl Surveys* section), and the resultant desire to avoid placing too much emphasis on the results of an individual survey.

The Gulf-wide biomass estimates for widow and yellowtail rockfish for the three most recent surveys (2005, 2007, and 2009) are 1,249 t, 1,332 t, and 2,592 t respectively (Table 12-4a). Averaging these values yields a current exploitable biomass of 1,724 t for widow and yellowtail rockfish. This estimate can be broken down into 158 t for widow rockfish and 1,566 t for yellowtail rockfish.

Dusky Rockfish Model Structure

We present model results for dusky rockfish based on an age-structured model using AD Model Builder software (Otter Research Ltd 2000). In 2003, the stock assessment was first accepted as an alternative to trawl survey biomass estimates. 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. 2003). 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 is no information regarding situations with low spawners and low recruits (Figure 12-3). The main difference between the dusky model and the Pacific ocean perch model is that natural mortality is not estimated in the dusky rockfish model. The parameters, population dynamics, and equations of the model are in Box 1.

Parameters Estimated Independently

Life-history parameters including proportion mature-at-age and weight-at-age, were taken from the 2001 Pelagic Shelf Rockfish SAFE Document (Clausen and Heifetz 2001).

The best length-weight information for dusky rockfish comes from the 1996 triennial survey, in which motion-compensated electronic scales were used to weigh a relatively large sample of individual fish for this species. The length weight relationship for combined sexes, using the formula W = aLb, where W is weight in grams and L is fork length in mm, a = 3.28×10^{-5} and b = 2.90 (Martin 1997).

Size at 50% maturity for a relatively small sample (n=64) of female dusky rockfish in the Kodiak area has been estimated to be 42.8 cm fork length (Clausen and Heifetz 1997). Age data for these fish were analyzed using a logistic function, which provided an estimated age at 50% maturity of 11.3 years.

The size-age transition matrix was constructed from the Von Bertalanffy growth curve fit to length and age data collected from triennial trawl surveys from 1984-2003. 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_∞ = 46.6 cm, κ = 0.23, and t_0 =1.27.

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).

New estimates of natural mortality were calculated due to questions about the validity of the high natural mortality rate of dusky rockfish versus other similarly aged rockfish. The method used to determine the natural mortality rate for dusky rockfish was first described in Clausen and Heifetz (1991) and has been used for this assessment in the past. An updated estimate was calculated by Malecha et al. (2004). This estimate was based on the Hoenig (1983) empirical estimator for natural mortality based on maximum lifespan:

$$\frac{-\ln(0.01)}{t_{\max}}$$

This estimate was 0.08 and based on the highest age recorded in the trawl survey of 59. The highest recorded age in the fishery ages was 76, which equates to a Hoenig estimate of 0.06. Additionally, a natural mortality of 0.09 would correspond to a Hoenig maximum age estimate of 51. For this assessment we chose a value of 0.07, which corresponds to recent estimates of M for dark rockfish and is close to estimates for other pelagic rockfish (Table 12-7).

Parameters Estimated Conditionally

The estimates of catchability (q) and recruitment deviations (σ_r) are estimated with the use of prior distributions as penalties. Catchability is a parameter that is somewhat unknown for rockfish, so while we assign it a prior mean of 1 (assuming all fish in the area swept are captured, there is no herding of fish from outside the area swept, and that there is no effect of untrawlable grounds) we assign it a less precise CV of 45% (Figure 12-4). This allows the parameter more freedom than that allowed for natural mortality. Recruitment deviation is the amount of variability that the model assigns recruitment estimates.

Rockfish are thought to have highly variable recruitment, so we assign a high prior mean to this parameter of 1.5 with a CV of 45% (Figure 12-4).

Other parameters estimated conditionally include, but are not limited to: selectivity (up to full selectivity) for survey and fishery, mean recruitment, fishing mortality, and spawner per recruit levels. 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	49
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	33
Fishery selectivity coefficients	fs_a	8
Survey selectivity coefficients	ss_a	7
Total		104

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 100. In a low-dimensional model, an analytical solution might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, the chain will converge (Jones and Hobert 2001). The "burn-in" is a set of iterations removed at the beginning of the chain. This method is not strictly necessary but we use it as a precautionary measure. In our simulations we removed the first 4,000,000 iterations out of 20,000,000 and "thinned" the chain to one value out of every thousand, leaving a sample distribution of 4,000. Further assurance that the chain had converged was 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

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

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

$$L_7 = \frac{1}{2\sigma_q^2} \left(\ln q \big/ q_{prior} \right)^2$$

Penalty on deviation from prior distribution of catchability coefficient

$$L_8 = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln \sigma_r \big/ \sigma_{r(prior)} \right)^2$$

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

Model Evaluation

For this assessment, we present the 2007 model updated for 2009, and one new model that weights the fishery catch time series differently. The basic features of the two model runs are described in the following table:

Model Number	Model Description
Model 1 (Base Case)	• Model from Lunsford et al 2007, updated for 2009
Model 2	• Catch time series split into two time periods • Different weighting schemes applied to the two different time periods

A brief evaluation of the unique features of each model that we explored follows:

Model 1: This is the model presented in the 2007 Pelagic Shelf Rockfish assessment which was accepted by the Plan Team to determine the 2007 ABC (Lunsford et al. 2007). This model built on previous assessments and a variety of changes were made to model parameters and available data in comparison to previous years.

Model 2: This model is identical to the base model with new weighting schemes applied to fishery catch. Since the dusky rockfish model was first developed in 2001 fitting the fishery catch has been problematic. We believe this is likely due to several early years in the catch time series prior to accurate catch accounting when the reported catch dropped to suspiciously low levels (see *Fishery data* section). In response, beginning with the 2005 model less weight has been placed on the fishery catch. With the addition of new data in 2009 the model fit to fishery catch is adequate for the older data but has degraded for the more recent time period, the time period when catch estimates are more reliable. To improve model fit on the most recent years we separated the time series into two components and weighted them differently. In this model, there is a weight of 2 applied to the 1977-1990 catch and a weight of 50 applied to the 1991-2009 catch.

Model Comparison

Table 12-8a summarizes the results from the 2007 Model, Model 1, and this year's recommended Model 2.

The weighting structure is the same in the 2007 Model and Model 1. As mentioned earlier, however, the catch data was estimated from a variety of sources and we not have much confidence in this information; therefore Model 1 fit to the catch data is moderate, especially in recent years. (Figure 12-1a). When the catch time series is split into two periods and the older series is weighted less and the recent time series weighted higher, the model fit to the catch data is improved (Figure 12-1b). This results in slightly lower q and higher log mean recruitment. Total biomass increased and $B_{40\%}$ slightly decreased. We feel this is an improvement upon the 2007 model as recent catches are now being predicted more accurately and overall the model fit has improved.

Model Results

For conciseness, we only show the recommended Model 2 in most figures.

In general, model predictions continue to fit the data well (Figures 12-2, 12-5, 12-6, and 12-7). The model is producing stable results with minimal penalties and appears reasonable. Splitting the catch data into two time periods with different weighting schemes has improved model fit to catch substantially (Figure

12-1). The 2009 survey biomass estimate is very similar to the 2007 estimate and the model now tracks the 2003, 2007, and 2009 estimates well (Figure 12-2a). Model fit to this data reveals a fairly level curve throughout the recent time series with only a small increase in response to the 2005 biomass estimate. There is some lack of fit to the plus group in the fishery size compositions for 1991-1993. 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 fits to fishery age compositions have improved, likely due to the addition of three new years of data and the especially strong 1992 year class which is prevalent in most the recent age compositions. The survey age compositions also track the 1992 year class well and try to fit the 1995 year class, which appears strong in recent years.

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

Total biomass estimates indicate a moderately increasing trend over time with a slight dome shape in the years surrounding the exceptionally high 2003 survey biomass estimate (Figure 12-8), while spawning biomass estimates show a continuous linear increase throughout the time series flattening out in recent years (Figure 12-9). 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 12-10). 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 9, while fish are fully selected by the fishery at age 11.

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 (Figure 12-11). This rise may be due to the increase in catch from the implementation of the Central Gulf of Alaska Rockfish Pilot Program (see the *Management measures* and *Fishery* sections). Goodman et al. (2002) suggested that stock assessment authors use a “management path” graph as a way to evaluate management and assessment performance over time. In the management path we plot the ratio of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to the target level ($B_{40\%}$). Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The historical management path for dusky rockfish has been above the F_{OFL} 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 12-12).

Recruitment

Recruitment is highly variable throughout the time series (Figure 12-13), 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 is apparently unrelated to spawning stock biomass (Figure 12-3). The addition of new data in this year’s model has decreased recruitment estimates for 1997 but had little effect on other estimates. Estimates for the most recent years continue to be fairly low. MCMC credible bands 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 12-13).

Uncertainty Distributions

From the MCMC chains described in the *Uncertainty approach* section, we summarize the posterior densities of key parameters for the recommended model using histograms (Figure 12-14). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass and recruitment (Figures 12-8, 12-9, and 12-13).

Table 12-8b 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 $F_{40\%}$, σ_r (recruitment deviation), ABC, and female spawning biomass. These larger standard deviations indicate that these parameters are more uncertain than indicated by the standard estimates, especially in the case of σ_r in which the MLE estimate is out of the Bayesian credible intervals. This highlights a concern that σ_r requires a fairly informative prior distribution since it is confounded with available data on recruitment variability. To illustrate this problem, imagine a stock that truly has variable recruitment. If this stock lacks age data (or the data are very noisy), then the modal estimate of σ_r is near zero. As an alternative, we could run sensitivity analyses to determine an optimum value for σ_r and fix it at that value instead of estimating it within the model. The distributions of $F_{40\%}$, *ABC*, total biomass, and spawning biomass are skewed, indicating there is a possibility of biomass being higher than model estimates.

Projections and Harvest Alternatives

Amendment 56 Reference Points

Widow and Yellowtail

Before the November 2001 SAFE report, widow and yellowtail rockfish were always lumped with dusky (and dark) rockfish in the ABC computations. Exploitable biomass of widow and yellowtail rockfish was multiplied by 0.07 to determine ABC, identical to the procedure used for dusky rockfish. In effect, this meant that all three species were treated as Tier 4 species. According to the 1999 overfishing definitions, however, these species should be assigned to Tier 5, because $F_{35\%}$ and $F_{40\%}$ are unknown for these species in Alaska. In Tier 5, F_{ABC} is defined to be <=0.75 * M. We now recommend that ABC for widow and yellowtail rockfish be computed separately from dusky rockfish, and that the Tier 5 formula be applied to these two species. If we assume an M of 0.07 for the two species, F_{ABC} is then 0.75 * M, which equals 0.0525. Multiplying this value of F by the current exploitable biomass for widow and yellowtail rockfish (1,724 t; see *analytical approach* section) yields an ABC of 91 t for 2010. This estimate can be broken down into 8 t for widow rockfish and 83 t for yellowtail rockfish. This is approximately 33 t lower than what was recommended in 2007 and 2008. This decrease is because dark rockfish have been removed from the federal management plan and are no longer included in the exploitable biomass estimates. Overall, the proportion of ABC attributed to widow and yellowtail increased for both species from 2008 to 2009.

Dusky Rockfish

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). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. 2010 estimates of these reference points are (in terms of female spawning biomass):

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
47,898	19,159	16,764	0.087	0.106

Specification of OFL and Maximum Permissible ABC

Widow, and Yellowtail

As described in the above section widow and yellowtail rockfish fall into Tier 5 of the overfishing definitions, in which estimates of biomass and natural mortality (M) are the only parameters known. For Tier 5 species, F_{OFL} is defined equal to M. This results into a 2010 Gulf-wide OFL of 121 t. This estimate can be broken down into 11 t for widow rockfish, and 110 t for yellowtail rockfish.

Dusky Rockfish

Female spawning biomass for 2010 is estimated at 25,800 t. This is above the $B_{40\%}$ value of 19,159 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 2010 yields the following ABC and OFL:

$F_{40\%}$	0.087
ABC	4,957
$F_{35\%}$	0.106
OFL	6,006

Projections

To satisfy requirements of the NPFMC's Amendment 56, the National Environmental Policy Act (NEPA), and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), all stock assessments have been asked to provide a set of seven harvest scenarios for future years. For species that are assessed using an age/length-structured model (Tiers 1, 2, or 3 in the overfishing definitions), these scenarios can take the form of multi-year projections. For species such widow and yellowtail rockfish that are not modeled (Tier 4 or higher), such projections are not possible, but yields for just the year 2010 can be computed for scenarios 1-5.

Widow and Yellowtail

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: For Tier 5 species (widow, yellowtail) F is set equal to *max* F_{ABC} = 0.75 * M (0.07), and the corresponding yield is 91 t.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2010 recommended in the assessment to the *max* F_{ABC} for 2010. (Rationale: For Tier 5 species (widow, yellowtail) F is set equal to the recommended F_{ABC} = 0.75 * M

(0.07), and the corresponding yield is 91 t.)

Scenario 3: In all future years, *F* is set equal to 50% of *max* F_{ABC}. (Rationale: For Tier 5 species (widow, yellowtail) F is set equal to 50% of max F_{ABC} = 50% of 0.75 * M (0.07), and the corresponding yield is 46 t.)

Scenario 4: In all future years, *F* is set equal to the 2005-2009 average *F*. (Rationale: For Tier 5 species (widow, yellowtail) F is set equal to the average F for 2005-2009. The average F for 2005-2009 is 0.75 * M (0.07), and the corresponding yield is 91 t.)

Scenario 5: In all future years, *F* is set equal to zero. (Rationale: F equals 0, and the corresponding yield would be 0.)

Dusky Rockfish

For each scenario, the projections begin with the vector of 2009 numbers-at-age estimated in the assessment. This vector is then projected forward to the beginning of 2010 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2009. 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 2009 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 2010, are as follows ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

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

Scenario 2: In all future years, *F* is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the catch in 2009 to the ABC recommended in the assessment for 2009. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.) In this scenario we use the ratio of most recent catch to ABC, and apply it to estimated ABCs for 2010 and 2011 to determine the catch for 2010 and 2011, then maximum permissible thereafter. Projections incorporating estimated catches help produce more accurate projections for fisheries that do not utilize all of the TAC.

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 2005-2009 average *F*. (Rationale: For some stocks, TAC can be well below ABC, and recent average *F* may provide a better indicator of F_{TAC} than F_{ABC}.)

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

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

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2009 or 2) above ½ of its MSY level in 2009 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)

Scenario 7: In 2010 and 2011, 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 2022 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 12-9). 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 (such as sablefish) where the catch is usually less than the ABC. This was suggested to help management with setting preliminary ABCs and OFLs for 2010 and 2011. In this scenario we use the ratio of most recent catch to ABC, and apply it to estimated ABCs for 2010 and 2011 to determine the catch for 2010 and 2011, then set catch at maximum permissible thereafter.

Status Determination (Dusky Rockfish only)

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 2010, it does not provide the best estimate of OFL for 2011, because the mean 2010 catch under Scenario 6 is predicated on the 2010 catch being equal to the 2010 OFL, whereas the actual 2010 catch will likely be less than the 2009 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 (2008) is 3,423 t. This is less than the 2008 OFL of 5,752 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 2009:
a. If spawning biomass for 2009 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2009 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2009 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 12-9). If the mean spawning biomass for 2019 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 2012 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2012 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2012 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2022. If the mean spawning biomass for 2022 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 12-9, 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 *author's F* (0.6 maximum permissible based on recent ratios of catch to ABC). This is conservative relative to a max ABC or alternative 1 projection scenario. This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 20,000,000. The projection shows wide credibility intervals on future spawning biomass (Figure 12-15). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1981-2007 age-4 recruitments, and this projection predicts that the median spawning biomass will increase quickly once average recruitment is consistently applied and the low proportion of ABC is taken (0.6).

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 have continued to follow it. Therefore, based on a 4:6:9 weighting of the 2005, 2007, and 2009 trawl surveys, the percent distribution of pelagic shelf rockfish biomass in the Gulf of Alaska is: Western area 13%; Central area 64%, and Eastern area 23%. Applying these percentages to the ABC of widow and yellowtail (91 t) yields the following apportionments for the Gulf in 2010: Western area 12 t; Central area 58 t; and Eastern area 21 t. Applying these percentages to the ABC of dusky rockfish (4,957 t) yields the following apportionments for the Gulf in 2010: Western area, 637 t; Central area, 3,183 t; and Eastern area, 1137 t (Table 12-10). The total ABC apportionments for the pelagic shelf rockfish assemblage in 2010 are: Western area, 649 t; Central area, 3,241 t; and Eastern area, 1158 t.

Because the Eastern area is now divided into two management areas for pelagic shelf 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 0.373, so that the pelagic shelf rockfish assemblage ABC for West Yakutat would be 432 t (7 t for other pelagics and 425 t for dusky rockfish), and the ABC for East Yakutat/Southeast Outside would be 726 t (14 t for other pelagics and 712 t for dusky rockfish, Table 12-10).

One possible problem was mentioned in 2003 concerning the above apportionment scheme to determine the ABC in the West Yakutat and East Yakutat/Southeast Outside areas. Two recent trawl surveys of the eastern Gulf of Alaska in 1999 and 2003 found very low biomass estimates of pelagic shelf rockfish in the West Yakutat area. In these surveys, the biomass in West Yakutat only comprised 2.6% and 11.1%, respectively, of the total assemblage biomass in the Eastern Gulf. In contrast, the 1990, 1993, 1996, 2005, and 2007 surveys showed the percentages in West Yakutat were 67.5, 43.8, 61.3 61.0, and 52.0 respectively. In 2009, West Yakutat comprised 89.0% of the total assemblage biomass. The 1999 and 2003 estimates are likely due to sampling issues and do not reflect an actual downward shift in the proportion of biomass in West Yakutat. Therefore, we continue to use the current weighting scheme and the upper 95% confidence interval to determine this area's allocation.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.106), overfishing is set equal to 6,006 t for dusky rockfish. For Tier 5 species, F_{OFL} is defined to equal M, and F_{ABC} is <= 0.75 * M. This equates into a 2010 Gulfwide OFL of 121 t for widow and yellowtail rockfish. The combined 2010 OFL for pelagic shelf rockfish is 6,127 t (Table 12-10).

Other Considerations

Management Problems Involving PSR Rockfish

In March, 2007, the North Pacific Fishery Management Council took final action to remove dark rockfish from both the GOA FMP (PSR Assemblage) and BSAI FMP (other rockfish complex). Removing the species from the Federal FMP serves to turn full management authority of the stock over to the State of Alaska in both regions. The rules to implement these FMP amendments were finalized in 2008 and the effective date for Amendments 77/73 was January 30, 2009. Therefore, effective January 1, 2009, dark rockfish were removed from Federal management (including the associated contribution to OFLs and ABCs under the respective assemblages in both regions) and full management authority was turned over to the State. ABC's and OFLs presented in this assessment for the PSR assemblage now exclude dark rockfish.

Several efforts have occurred to help improve the identification of PSR species at Kodiak processing plants. ADF&G has collected data from federal rockfish deliveries in an attempt to understand how many fish are misidentified in respect to black and dark rockfish. This data is currently being collected but has not been analyzed at this time (N. Sagalkin, pers comm.). NMFS Alaska Region staff have distributed rockfish keys to processors and have helped train plant personnel at the start of the last several rockfish seasons (J. Bonney, pers comm.) Additionally, staff at the Fisheries Monitoring and Analysis Division at the AFSC have a draft manuscript in review regarding rockfish identification in Kodiak plants versus observer audit samples (C. Faunce, pers comm.). Results are not yet available but may provide some information on misidentification rates. In general, the rockfish identification at plants has improved in recent years but is an issue we are monitoring.

Ecosystem Considerations

In general, a determination of ecosystem considerations for pelagic shelf rockfish 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 12-11. Additionally, we include a summary of non-target species bycatch estimates and proportion of total catch for Gulf of Alaska rockfish targeted fisheries 2003-2009 (Table 12-12).

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.[6] 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 Pilot Project began which allowed fishing in the Central Gulf from May1 – 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 12-2 (length frequency in the commercial fishery) and Table 12-5 (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.

Fishery contribution to discards and offal production: fishery discard rates of pelagic shelf rockfish have been quite low in recent years, as they have averaged only about 6% in the period 1997-2007. The discard rate of species other than pelagic shelf rockfish in the dusky rockfish fishery is unknown.

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 12-7 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 pelagic shelf 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 12-12 shows the estimated bycatch of living structure such as benthic urochordates, corals, sponges, sea pens, and sea anemones by the GOA rockfish fisheries. The average bycatch of corals/bryozoans (1652 kg), sea anemones (1554 kg), and sponges (2473 kg) by rockfish fisheries in the GOA represented 61%, 8%, and 42% respectively of those species taken by all Gulfwide 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. 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 Pilot Project 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. Species identification of pelagic shelf species is easily confused with rockfish species managed by the State (dark, blue, black) and efforts are underway to explore the rates of misidentification. It is essential misidentification is minimized as accurate catch estimation is essential to successful management of the PSR assemblage.

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.

Summary

A summary of biomass levels, exploitation rates and recommended ABC and OFLs for the pelagic shelf rockfish assemblage is in the following table:

Widow and Yellowtail	Last Year's Estimates[7]		This Year's Estimates:	
	2009	2010	**2010**	2011
Tier 5				
Total (Exploitable) Biomass (t)	1,106	1,106	1,724	1,724
M	0.07	0.07	0.07	0.07
F_{ABC} (maximum allowable = *0.75**M)	0.0525	0.0525	0.0525	0.0525
F_{OFL} (M)	0.07	0.07	0.07	0.07
ABC (t, maximum allowable)	58	58	**91**	91
OFL (t)	77	77	**121**	121

Dusky rockfish	Last Year's Model Projection Not Updated		This Year's Projection Revised Model	
	2009	2010	**2010**	2011*
Tier 3a				
Total (Exploitable) Biomass (age 4+)	65,271	62,574	67,685	64,242
Female Spawning Biomass (t)	23,332	22,657	25,800	24,861
$B_{100\%}$ (t, female spawning)	--	--	47,898	--
$B_{40\%}$ (t)	--	--	19,159	--
$B_{35\%}$ (t, female spawning)	--	--	16,764	--
M	0.07	0.07	0.07	0.07
F_{ABC} (maximum allowable = $F_{40\%}$)	0.087	0.087	0.087	0.087
F_{OFL} ($F_{35\%}$)	0.107	0.107	0.106	0.106
$ABC_{F40\%}$ (t yield at $F_{40\%}$=F_{max})	4,723	4,407	**4,957**	4,625
OFL (t, yield at $F_{35\%}$)	5,726	5,343	**6,006**	5,603

Pelagic Shelf Rockfish Assemblage	Last Year's Estimates:		This Year's Projection:	
	2009	2010	**2010**	2011*
Total (Exploitable) Biomass	66,377	63,680	69,409	65,966
M	0.07	0.07	0.07	0.07
$ABC_{F40\%}$ (t, maximum allowable)	4,781	4,465	**5,048**	4,716
OFL (t, $F_{35\%}$)	5,803	5,420	**6,127**	5,724

*The 2011 ABC and OFL for dusky rockfish were projected using an expected catch value of 3,408 t for 2010, based on recent ratios of catch to maximum permissible ABC. The projection results of this method are listed under the Author's F method in Table 12-9 in response to management requests for a more accurate two-year projection.

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Table 12-1a. Commercial catch[a] (t) of fish in the pelagic shelf rockfish assemblage in the Gulf of Alaska, with Gulfwide values of acceptable biological catch (ABC), total allowable catch (TAC), and relevant management actions, 1988-2009.

		Regulatory Area[b]							
Year	Category[c]	Western	Central	Eastern	West Yakutat[d]	Southeast Outside[e]	Gulfwide Total	Gulfwide ABC	Gulfwide TAC
1988[1]	Foreign	0	0	0	-	-	0		
	U.S.	400	517	168	-	-	1,085		
	JV	Tr	1	0	-	-	1		
	Total	400	518	168	-	-	1,086	3,300	3,300
1989	U.S.	113	888	737	-	-	1,738	6,600	3,300
1990	U.S.	165	955	527	-	-	1,647	8,200	8,200
1991	U.S.	215	1,191	936	-	-	2,342	4,800	4,800
1992	U.S.	105	2,622	887	-	-	3,605	6,886	6,886
1993	U.S.	238	2,061	894	-	-	3,193	6,740	6,740
1994	U.S.	290	1,702	997	-	-	2,989	6,890	6,890
1995	U.S.	108	2,247	536	471	64	2,891	5,190	5,190
1996	U.S.	182	1,849	265	190	75	2,296	5,190	5,190
1997	U.S.	96	1,959	574	536	38	2,629	5,140	5,140
1998[2]	U.S.	60	2,477	576	553	22	3,113	4,880	4,880
1999[3]	U.S.	130	3,835	694	672	22	4,659	4,880	4,880
2000[4]	U.S.	190	3,074	467	445	22	3,731	5,980	5,980
2001	U.S.	121	2,436	451	439	12	3,008	5,980	5,980
2002	U.S.	185	2,680	457	448	9	3,322	5,490	5,490
2003	U.S.	164	2,194	617	607	10	2,975	5,490	5,490
2004	U.S.	281	2,182	211	199	12	2,885	4,470	4,470
2005	U.S.	118	1,843	218	215	3	2,397	4,553	4,553
2006	U.S.	557	1713	174	173	1	2,444	5,436	5,436
2007[5]	U.S.	595	2,485	294	293	4	3,374	5,542	5,542
2008	U.S.	577	2,870	196	195	1	3,643	5,227	5,227
2009[6]	U.S.	714	2,122	159	158	1	2,995	4,781	4,781

Management Actions

[1] Pelagic shelf rockfish assemblage management action implemented by North Pacific Fishery Management Council as one of three management groups of *Sebastes* in the GOA.

[2] Black and blue rockfish removed from federal management plan.

[3] Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside, separate ABCs and TACs.

[4] Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.

[5] Central Gulf Rockfish Pilot Project implemented for rockfish fishery.

[6]Dark rockfish removed from federal management plan.

Catch Accounting Notes

[a]Catches for 1988-97 include black rockfish and blue rockfish, which were members of the assemblage during those years.

[b]Catches for West Yakutat and Southeast Outside areas are not available for years before 1996. Eastern area is comprised of the West Yakutat and Southeast Outside areas combined.

[c] JV = joint venture production; U.S. = domestic annual production.

[d]West Yakutat area is comprised of statistical areas 640 and 649.

[e]Southeast Outside area is comprised of statistical areas 650 and 659.

[f]Catch updated through October 22, 2009.

Table 12-1b. Estimated catch (t) history for dusky rockfish. Values from 1977-2009 are a combination of foreign observer data, joint venture catch data, and NMFS Regional Office Catch Accounting System data. Values are used in age-structured model for dusky rockfish.

Year	Catch
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
1989	1,707
1990	1,612
1991	2,190
1992	3,565
1993	3,132
1994	2,938
1995	2,868
1996	2,289
1997	2,626
1998	3,110
1999	4,538
2000	3,701
2001	2,999
2002	3,305
2003	3,020
2004	2,553
2005	2,207
2006	2,428
2007	3,366
2008	3,618
2009[a]	2,935

[a] Catch updated through 10/22/09.

Table 12-1c. Catch (t) of pelagic shelf rockfish taken during research cruises in the Gulf of Alaska, 1977-2009. (Catches before 2002 do not include longline surveys; tr=trace)

Year	Catch
1977	0.4
1978	0.5
1979	0.9
1980	0.2
1981	7.4
1982	1.0
1983	0.5
1984	6.5
1985	6.8
1986	0.3
1987	34.4
1988	0.0
1989	0.1
1990	4.8
1991	0.0
1992	tr
1993	6.8
1994	0.0
1995	0.0
1996	7.4
1997	0.0
1998	2.5
1999	6.7
2000	0.0
2001	2.7
2002	tr
2003	5.9
2004	tr
2005	13.7
2006	tr
2007	7.4
2008	tr
2009	5.5

Table 12-2. 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	2003	2004
≤21	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
23	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
25	0.000	0.001	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
27	0.000	0.002	0.000	0.000	0.000	0.002	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	0.000	0.000
29	0.000	0.003	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.001
30	0.002	0.005	0.000	0.002	0.000	0.012	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	0.001	0.000
32	0.003	0.012	0.000	0.000	0.000	0.004	0.001	0.000	0.000	0.001	0.000
33	0.004	0.015	0.000	0.002	0.000	0.014	0.004	0.001	0.000	0.001	0.001
34	0.007	0.019	0.000	0.001	0.001	0.008	0.008	0.001	0.000	0.001	0.001
35	0.025	0.019	0.000	0.004	0.002	0.004	0.019	0.000	0.002	0.002	0.001
36	0.029	0.015	0.000	0.004	0.005	0.010	0.026	0.001	0.002	0.005	0.003
37	0.019	0.017	0.001	0.003	0.004	0.008	0.042	0.003	0.001	0.006	0.006
38	0.024	0.027	0.001	0.009	0.007	0.002	0.041	0.006	0.004	0.006	0.010
39	0.069	0.036	0.006	0.004	0.020	0.010	0.034	0.012	0.006	0.006	0.020
40	0.084	0.108	0.020	0.019	0.028	0.033	0.041	0.027	0.011	0.015	0.027
41	0.134	0.117	0.046	0.041	0.045	0.052	0.060	0.059	0.028	0.015	0.038
42	0.145	0.125	0.103	0.074	0.059	0.082	0.088	0.099	0.079	0.039	0.053
43	0.140	0.114	0.145	0.076	0.084	0.093	0.106	0.147	0.116	0.094	0.081
44	0.136	0.117	0.200	0.146	0.098	0.120	0.112	0.170	0.164	0.156	0.129
45	0.085	0.100	0.197	0.171	0.124	0.128	0.119	0.163	0.182	0.180	0.166
46	0.057	0.073	0.151	0.176	0.126	0.126	0.097	0.126	0.148	0.163	0.160
47+	0.034	0.060	0.131	0.266	0.397	0.278	0.199	0.185	0.257	0.310	0.301
Sample size	2012	5495	3659	2117	1794	515	3090	2565	1684	2748	1826

Table 12-2 continued. 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)	2005	2006	2007	2008	2009
≤21	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000	0.000
25	0.000	0.000	0.001	0.000	0.000
26	0.000	0.000	0.002	0.000	0.000
27	0.000	0.000	0.000	0.000	0.000
28	0.000	0.000	0.001	0.000	0.000
29	0.000	0.000	0.001	0.000	0.000
30	0.001	0.000	0.002	0.000	0.000
31	0.000	0.000	0.002	0.000	0.000
32	0.001	0.000	0.003	0.001	0.002
33	0.001	0.000	0.003	0.000	0.000
34	0.002	0.001	0.002	0.001	0.003
35	0.002	0.002	0.002	0.003	0.002
36	0.004	0.004	0.004	0.005	0.005
37	0.007	0.006	0.007	0.003	0.009
38	0.009	0.010	0.012	0.013	0.016
39	0.011	0.017	0.021	0.016	0.032
40	0.019	0.024	0.032	0.034	0.043
41	0.039	0.048	0.054	0.052	0.063
42	0.064	0.082	0.072	0.084	0.085
43	0.099	0.110	0.100	0.105	0.110
44	0.122	0.149	0.129	0.148	0.128
45	0.135	0.146	0.128	0.152	0.147
46	0.145	0.147	0.136	0.141	0.117
47+	0.339	0.253	0.286	0.239	0.238
Sample size	2314	1770	4590	6600	3644

Table 12-3. 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
4	0.000	0.000	0.000	0.000	0.002	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.002	0.002	0.000	0.002	0.005	0.000	0.000
7	0.000	0.004	0.007	0.000	0.007	0.002	0.006
8	0.012	0.004	0.009	0.019	0.002	0.005	0.026
9	0.007	0.043	0.011	0.030	0.055	0.014	0.036
10	0.034	0.035	0.104	0.046	0.069	0.092	0.078
11	0.049	0.068	0.109	0.177	0.066	0.104	0.146
12	0.141	0.077	0.095	0.102	0.182	0.079	0.097
13	0.207	0.132	0.063	0.091	0.114	0.191	0.074
14	0.212	0.170	0.154	0.038	0.083	0.099	0.113
15	0.100	0.161	0.134	0.073	0.040	0.061	0.071
16	0.051	0.089	0.120	0.127	0.076	0.038	0.052
17	0.027	0.060	0.052	0.097	0.104	0.061	0.039
18	0.015	0.031	0.025	0.062	0.055	0.061	0.071
19	0.015	0.012	0.011	0.018	0.019	0.063	0.036
20	0.012	0.017	0.007	0.014	0.021	0.038	0.049
21+	0.117	0.097	0.098	0.104	0.100	0.092	0.107
Sample size	411	517	441	628	422	444	309

Table 12-4a. Biomass estimates (t) for species in the pelagic shelf rockfish assemblage in the Gulf of Alaska, based on results of bottom trawl surveys from 1984 through 2009.

	Statistical Area					
Species	Shumagin	Chirikof	Kodiak	Yakutat	South-eastern	Total
1984						
Dusky rockfish	3,843	7,462	4,329	15,126	307	31,068
Yellowtail rockfish	0	0	0	17	454	471
Total, all species	3,843	7,462	4,329	15,143	761	31,539
1987						
Dusky rockfish	12,011	4,036	46,005	18,346	1,097	81,494
Widow rockfish	0	0	0	51	96	147
Total, all species	12,011	4,036	46,005	18,397	1,193	81,641
1990						
Dusky rockfish	2,963	1,233	16,779	5,808	953	27,735
Widow rockfish	0	0	0	285	0	285
Total, all species	2,963	1,233	16,779	6,093	953	28,020
1993						
Dusky rockfish	11,450	12,880	23,780	7,481	1,626	57,217
Total, all species	11,450	12,880	23,780	7,481	1,626	57,217
1996						
Light dusky rockfish	3,553	19,217	36,037	14,193	1,480	74,480
Dark dusky rockfish	152	139	59	0	0	350
Widow rockfish	0	10	0	0	919	929
Yellowtail rockfish	0	0	20	0	65	85
Total, all species	3,704	19,366	36,116	14,193	2,464	75,843
1999						
Light dusky rockfish	2,538	9,157	33,729	2,097	2,108	49,628
Dark dusky rockfish	2,130	31	49	0	0	2,211
Widow rockfish	0	0	69	0	115	184
Yellowtail rockfish	0	0	0	162	12,509	12,671
Total, all species	4,668	9,188	33,847	2,259	14,732	64,694

(Table continued on next page.)

Table 12-4a (continued). Biomass estimates (t) for species in the pelagic shelf rockfish assemblage in the Gulf of Alaska, based on results of bottom trawl surveys from 1984 through 2007.

	Statistical Area					
Species	Shumagin	Chirikof	Kodiak	Yakutat	South-eastern	Total
2001						
Light dusky rockfish	5,352	2,062	23,590	7,924[a]	1,738[a]	40,667[a]
Dark dusky rockfish	362	15	36	0[a]	0[a]	413[a]
Widow rockfish	0	0	0	0[a]	345[a]	345[a]
Yellowtail rockfish	0	0	0	54[a]	4,192[a]	4,245[a]
Total, all species	5,714	2,077	23,626	7,978[a]	6,275[a]	45,670[a]
2003						
Light dusky rockfish	4,039	46,729	7,198	11,519	1,377	70,862
Dark dusky rockfish	235	49	16	0	0	300
Widow rockfish	0	0	0	0	32	32
Yellowtail rockfish	0	0	0	71	635	705
Total, all species	4,274	46,778	7,214	11,590	2,044	71,899
2005						
Dusky rockfish	69,295	38,216	60,097	2,488	389	170,484
Dark rockfish	21,454	389	2,348	0	0	24,191
Widow rockfish	0	0	51	0	77	128
Yellowtail rockfish	0	0	0	0	1,121	1,121
Total, all species	90,749	38,605	62,445	2,448	1,587	195,924
2007						
Dusky rockfish	4,985	38,350	19,482	5,579	3,857	72,253
Dark rockfish	240	60	938	0	0	1,238
Widow rockfish	0	0	16	0	220	236
Yellowtail rockfish	0	17	0	0	1,079	1,096
Total, all species	5,225	38,427	20,436	5,579	5,156	74,823
2009[1]						
Dusky rockfish	1,404	4,075	40,836	25,082	726	72,123
Widow rockfish	0	0	18	78	14	110
Yellowtail rockfish	0	0	30	33	2,419	2,482
Total, all species	1,404	4,075	40,884	25,193	3,159	74,715

[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] Dark rockfish removed from federal management plan in 2009.

Table 12-4b. GOA dusky rockfish biomass estimates, standard errors, lower confidence intervals, and upper confidence intervals from NMFS triennial/biennial trawl surveys in the Gulf of Alaska.

Year	Biomass	Standard Error	Lower CI	Upper CI
1984	31,068	7,146	16,776	45,360
1987	94,212	29,391	35,430	152,994
1990	26,827	8,635	9,557	44,097
1993	57,217	16,590	24,037	90,397
1996	74,480	32,851	8,778	140,182
1999	49,540	19,193	11,154	87,926
2001	41,905	11,634	18,637	65,173
2003	70,862	34,352	2,158	139,566
2005	170,484	51,657	68,202	272,766
2007	72,253	34,369	4,890	139,616
2009	72,123	24,687	23,735	120,510

Table 12-5. NMFS trawl survey length compositions for dusky rockfish in the Gulf of Alaska. Lengths below 21 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	2009
≤21	0.000	0.000	0.000	0.001	0.003	0.001	0.003	0.000	0.001	0.000	0.003
22	0.000	0.001	0.008	0.002	0.001	0.001	0.002	0.004	0.001	0.000	0.006
23	0.000	0.001	0.004	0.004	0.004	0.001	0.003	0.000	0.001	0.000	0.011
24	0.000	0.000	0.002	0.007	0.003	0.000	0.005	0.001	0.002	0.000	0.012
25	0.000	0.000	0.006	0.002	0.003	0.002	0.003	0.000	0.002	0.001	0.005
26	0.000	0.001	0.000	0.015	0.001	0.000	0.004	0.004	0.001	0.001	0.009
27	0.000	0.000	0.006	0.018	0.001	0.001	0.006	0.017	0.001	0.001	0.005
28	0.002	0.000	0.006	0.023	0.001	0.000	0.002	0.024	0.001	0.001	0.006
29	0.001	0.000	0.007	0.021	0.005	0.001	0.022	0.027	0.004	0.001	0.007
30	0.004	0.001	0.000	0.030	0.002	0.002	0.024	0.044	0.005	0.003	0.010
31	0.009	0.001	0.001	0.039	0.002	0.006	0.029	0.027	0.010	0.001	0.008
32	0.015	0.004	0.007	0.051	0.002	0.008	0.033	0.031	0.014	0.004	0.010
33	0.014	0.002	0.001	0.043	0.007	0.008	0.026	0.053	0.016	0.003	0.005
34	0.036	0.018	0.003	0.040	0.003	0.013	0.030	0.008	0.019	0.010	0.007
35	0.048	0.039	0.001	0.046	0.006	0.015	0.026	0.011	0.021	0.013	0.007
36	0.061	0.061	0.002	0.053	0.001	0.015	0.042	0.013	0.046	0.013	0.008
37	0.066	0.093	0.004	0.037	0.009	0.016	0.039	0.043	0.027	0.017	0.006
38	0.090	0.084	0.006	0.049	0.009	0.019	0.040	0.077	0.053	0.024	0.011
39	0.131	0.080	0.019	0.051	0.016	0.016	0.059	0.072	0.031	0.049	0.011
40	0.139	0.109	0.017	0.051	0.036	0.031	0.061	0.066	0.042	0.070	0.020
41	0.134	0.142	0.077	0.035	0.080	0.035	0.071	0.050	0.046	0.077	0.031
42	0.105	0.121	0.125	0.044	0.065	0.072	0.061	0.050	0.072	0.110	0.036
43	0.061	0.112	0.115	0.061	0.127	0.104	0.064	0.065	0.092	0.106	0.073
44	0.037	0.062	0.153	0.064	0.133	0.115	0.058	0.070	0.101	0.115	0.069
45	0.022	0.028	0.175	0.073	0.111	0.150	0.083	0.065	0.100	0.098	0.105
46	0.013	0.019	0.151	0.065	0.113	0.141	0.076	0.062	0.101	0.099	0.154
47+	0.014	0.020	0.104	0.076	0.256	0.231	0.127	0.114	0.190	0.185	0.363
Sample Size	1881	2818	1113	2299	1478	1340	1255	1780	3383	1818	2024

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

Table 12-7. Instantaneous rate of natural mortality and maximum age for pelagic shelf rockfish, based on the break-and-burn method of aging otoliths. Area indicates location of study: Gulf of Alaska (GOA) or British Columbia (BC).

Species	Mortality Rate	Maximum Age	Area	Reference
Dusky Rockfish	0.09	59	GOA	1
	0.09	51	GOA	2
	0.08	59[b]	GOA	3
	0.06	76[c]	GOA	4
Dark Rockfish	0.07	75	GOA	5
Yellowtail Rockfish	0.07	53	BC	6
Widow Rockfish	0.05[a]	59	BC	7

[a]Instantaneous rate of total mortality (Z).
[b] Maximum survey age.
[C] Maximum fishery age.

References: 1) Clausen and Heifetz (1991); 2) Back-calculated maximum age using Hoenig (1983) (–ln(0.001)/*M*); 3) Malecha et al. (2004); 4) Calculated for this document using Hoenig (1983) (–ln(0.001)/t_m); 5) Chilton, L. Growth and natural mortality of dark rockfish (*Sebastes ciliatus*) in the western Gulf of Alaska. Poster. 23rd. Lowell Wakefield Fisheries Symposium on Biology, Assessment, and Management of North Pacific Rockfishes; 6) Leaman and Nagtegaal (1987); 7) Chilton and Beamish (1982).

Table 12-8a. Likelihoods and estimates of key parameters with estimates of standard error (σ) derived from Hessian matrix for last year's 2007 model, Model 1, and Model 2 (author recommended) for GOA dusky rockfish.

	2007 Model		***Model 1***		***Model 2 (Author Rec)***	
Likelihoods	Value	Weight	Value	Weight	Value	Weight
Catch (1977-2009)	15.19	10	15.04	10	27.31	2 (1977-1990) 50 (1991-2009)
Trawl Biomass	35.08	5	35.72	5	34.13	5
Fishery Ages	19.31	1	28.29	1	22.72	1
Survey Ages	70.11	1	74.70	1	68.38	1
Fishery Sizes	79.73	1	82.63	1	26.80	1
Data-Likelihood	**219.42**		**237.36**		**179.34**	
Penalties/Priors						
Recruitment Devs	30.68	1	31.65	1	27.65	1
Fishery Selectivity	2.17	1	2.08	1	1.52	1
Trawl Selectivity	0.57	1	0.61	1	0.64	1
Fish-Sel Domeshape	0.00	1	0.00	1	0.00	1
Survey-Sel	0.00	1	0.00	1	0.00	1
Average Selectivity	0.00	1	0.00	1	0.00	1
F Regularity	70.85	2	70.64	2	34.36	2
σ_r prior	0.14		0.15		0.26	
q-prior	0.0005		0.0018		0.02	
Objective Fun. Total	**323.83**		**342.50**		**243.79**	
Parameter Estimates	Value	σ	Value	σ	Value	σ
q-trawl	1.014	0.158	0.973	0.141	0.911	0.125
σ_r	1.180	0.155	1.172	0.147	1.084	0.143
Log-mean-rec	0.432	0.187	0.463	0.180	0.648	0.178
$F_{40\%}$	0.087	0.024	0.087	0.024	0.087	0.024
Total Biomass (t)	70,980	15,292	66,928	13,364	67,685	13,291
B_{2011} (t)	23,486		63,276		64,242	
$B_{100\%}$ (t)	44,316		46,464		47,898	
$B_{40\%}$ (t)	17,727		18,586		19,159	
$\boldsymbol{ABC_{F40\%}}$ ***(t)***	**4,719**		**4,979**		**4,957**	

Table 12-8b. 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	0.911	0.873	0.125	0.125	0.871	0.635	1.125
$F_{40\%}$	0.087	0.103	0.024	0.038	0.096	0.056	0.191
Female Sp. Biomass	25,800	29,472	5,249	6,251	28,858	19,346	43,954
ABC	4,957	6,589	1,662	2,638	6,124	3,102	12,984
σ_r	1.084	2.008	0.143	0.331	1.979	1.457	2.750

Table 12-9. 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 12.6.3. All units are in t. $B_{40\%}$ = 19,159 t, $B_{35\%}$ = 16,764 t, $F_{40\%}$ = 0.087, and $F_{35\%}$ = 0.106.

Year	Maximum permissible F	Author's F (pre-specified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning Biomass (t)				
2009	26,216	26,216	26,216	26,216	26,216	26,216	26,216
2010	25,683	25,800	25,861	25,842	26,049	25,602	25,683
2011	24,111	24,861	25,305	25,162	26,591	23,592	24,111
2012	22,401	22,999	24,470	24,226	26,816	21,524	22,331
2013	20,772	21,309	23,562	23,244	26,904	19,618	20,330
2014	19,220	19,692	22,541	22,190	26,783	17,889	18,498
2015	18,003	18,403	21,663	21,330	26,735	16,642	17,122
2016	17,227	17,554	20,996	20,744	26,854	15,880	16,260
2017	16,768	17,033	20,485	20,350	27,035	15,457	15,758
2018	16,657	16,873	20,258	20,274	27,515	15,372	15,611
2019	16,767	16,943	20,282	20,418	28,200	15,496	15,685
2020	16,988	17,131	20,427	20,673	28,967	15,721	15,868
2021	17,292	17,407	20,776	21,041	29,861	16,012	16,127
2022	17,622	17,714	21,312	21,461	30,819	16,317	16,406
			Fishing Mortality				
2009	0.048	0.048	0.048	0.048	0.048	0.048	0.048
2010	0.087	0.059	0.043	0.049	-	0.106	0.106
2011	0.087	0.087	0.043	0.049	-	0.106	0.106
2012	0.087	0.087	0.043	0.049	-	0.106	0.106
2013	0.087	0.087	0.043	0.049	-	0.106	0.106
2014	0.086	0.087	0.043	0.049	-	0.099	0.099
2015	0.081	0.083	0.043	0.049	-	0.091	0.091
2016	0.077	0.079	0.043	0.049	-	0.087	0.087
2017	0.075	0.076	0.043	0.049	-	0.084	0.084
2018	0.074	0.074	0.043	0.049	-	0.083	0.083
2019	0.073	0.074	0.043	0.049	-	0.084	0.084
2020	0.074	0.074	0.043	0.049	-	0.084	0.084
2021	0.074	0.075	0.043	0.049	-	0.086	0.086
2022	0.075	0.076	0.043	0.049	-	0.087	0.087
			Yield (t)				
2009	2,935	2,935	2,935	2,935	2,935	2,935	2,935
2010	4,957	**4,957***	2,531	2,846	-	6,006	4,957
2011	4,505	4,625	2,399	2,683	-	5,603	4,505
2012	4,063	4,171	2,254	2,508	-	4,744	4,922
2013	3,665	3,759	2,115	2,342	-	4,206	4,359
2014	3,284	3,391	1,983	2,185	-	3,485	3,723
2015	2,832	2,953	1,875	2,056	-	2,942	3,115
2016	2,559	2,653	1,808	1,977	-	2,646	2,774
2017	2,569	2,643	1,855	2,029	-	2,681	2,780
2018	2,636	2,694	1,900	2,090	-	2,777	2,854
2019	2,707	2,753	1,937	2,138	-	2,875	2,933
2020	2,824	2,860	1,995	2,206	-	3,020	3,065
2021	2,925	2,954	2,046	2,261	-	3,140	3,175
2022	3,022	3,045	2,098	2,313	-	3,254	3,281

*This projection was determined with a catch of 3,408 t.

Table 12-10. Allocation of 2010 ABC for pelagic shelf rockfish in the Gulf of Alaska. Apportionment is based on the weighted average of pelagic shelf rockfish assemblage 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.

Year	Weights	Western Gulf	Central Gulf	West Yakutat	SE/ Outside	Total
2005	4	46	52	1	1	100%
2007	6	7	79	7	7	100%
2009	9	2	60	34	4	100%
Weighted Mean		12.9	64.2	18.6	4.3	100%
Area Allocation						100%
Area ABC Widow, Yellowtail (t)		**12**	**58**	**7**	**14**	**91**
Area ABC Dusky (t)		**637**	**3,183**	**425**	**712**	**4,957**
Area ABC Total Pelagic Shelf (t)		**649**	**3,241**	**432**	**726**	**5,048**
OFL Widow, Yellowtail (t)						**121**
OFL Dusky (t)						**6,006**
OFL Total Pelagic Shelf (t)						**6,127**

Table 12-11. Analysis of ecosystem considerations for pelagic shelf rockfish and the dusky rockfish fishery.

Indicator	Observation	Interpretation	Evaluation
Ecosystem effects on *GOA pelagic shelf rockfish*			
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

Table 12-12. Nontarget species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2003-2009.

	Estimated Catch (t)						
Group Name	2003	2004	2005	2006	2007	2008	2009
Benthic urochordata	0.00	0.13	0.00	0.04	0.03	0.27	0.00
Birds	0.22	0.00	0.00	0.00	0.08	0.04	0.02
Brittle star unidentified	0.16	0.00	0.05	0.09	0.01	0.04	0.03
Corals Bryozoans	1.90	0.07	6.13	0.39	2.27	0.47	0.34
Eelpouts	0.03	0.22	9.60	0.03	0.12	0.38	0.01
Eulachon	0.01	0.21	0.08	0.30	0.05	0.01	0.03
Giant Grenadier	139.26	0.45	134.57	272.06	127.14	163.57	283.68
Greenlings	8.13	6.97	3.56	5.95	7.74	15.08	8.03
Grenadier	473.93	2,830.01	77.04	65.54	70.61	3.43	3.20
Hermit crab unidentified	0.01	0.01	0.04	0.06	0.01	0.01	0.01
Invertebrate unidentified	0.38	0.95	0.10	0.04	0.01	0.24	0.31
Large Sculpins	0.12	43.29	15.48	28.31	26.88	19.79	29.76
Misc crabs	0.03	0.34	0.74	0.41	0.14	0.07	0.10
Misc crustaceans	0.00	0.02	0.00	0.00	0.00	0.00	0.37
Octopus	0.65	0.43	0.19	0.47	0.06	2.89	1.14
Other osmerids	0.55	0.15	0.02	0.26	0.09	0.00	0.14
Other Sculpins	23.93	15.04	12.18	3.90	4.49	3.50	3.81
Pandalid shrimp	0.92	0.30	0.24	0.17	0.11	0.11	0.09
Scypho jellies	0.65	2.98	0.15	0.43	0.21	0.11	0.70
Sea anemone unidentified	2.89	2.97	0.30	0.62	0.21	0.69	3.21
Sea pens whips	0.00	0.00	0.04	0.00	0.00	0.02	0.01
Sea star	3.22	2.13	1.46	2.22	0.66	1.16	1.81
Shark, Other	0.21	0.22	0.18	1.61	0.40	0.04	0.01
Shark, pacific sleeper	0.28	0.75	0.15	0.39	0.04	1.11	0.27
Shark, salmon	0.01	0.12	0.50	0.62	0.49	0.72	0.38
Shark, spiny dogfish	35.46	2.30	2.81	2.00	6.22	4.79	1.35
Skate, Big	0.00	6.64	4.62	4.21	0.13	3.72	3.60
Skate, Longnose	0.86	16.42	8.94	8.09	15.04	10.86	13.23
Skate, Other	104.66	10.38	45.02	35.79	16.66	8.09	10.99
Snails	0.42	0.30	0.15	0.80	0.07	0.18	11.90
Sponge unidentified	3.82	1.14	1.14	0.96	0.65	2.97	6.64
Squid	9.14	11.94	1.53	10.23	3.05	5.24	13.88
urchins dollars cucumbers	0.35	0.62	0.16	0.30	0.17	0.26	0.66

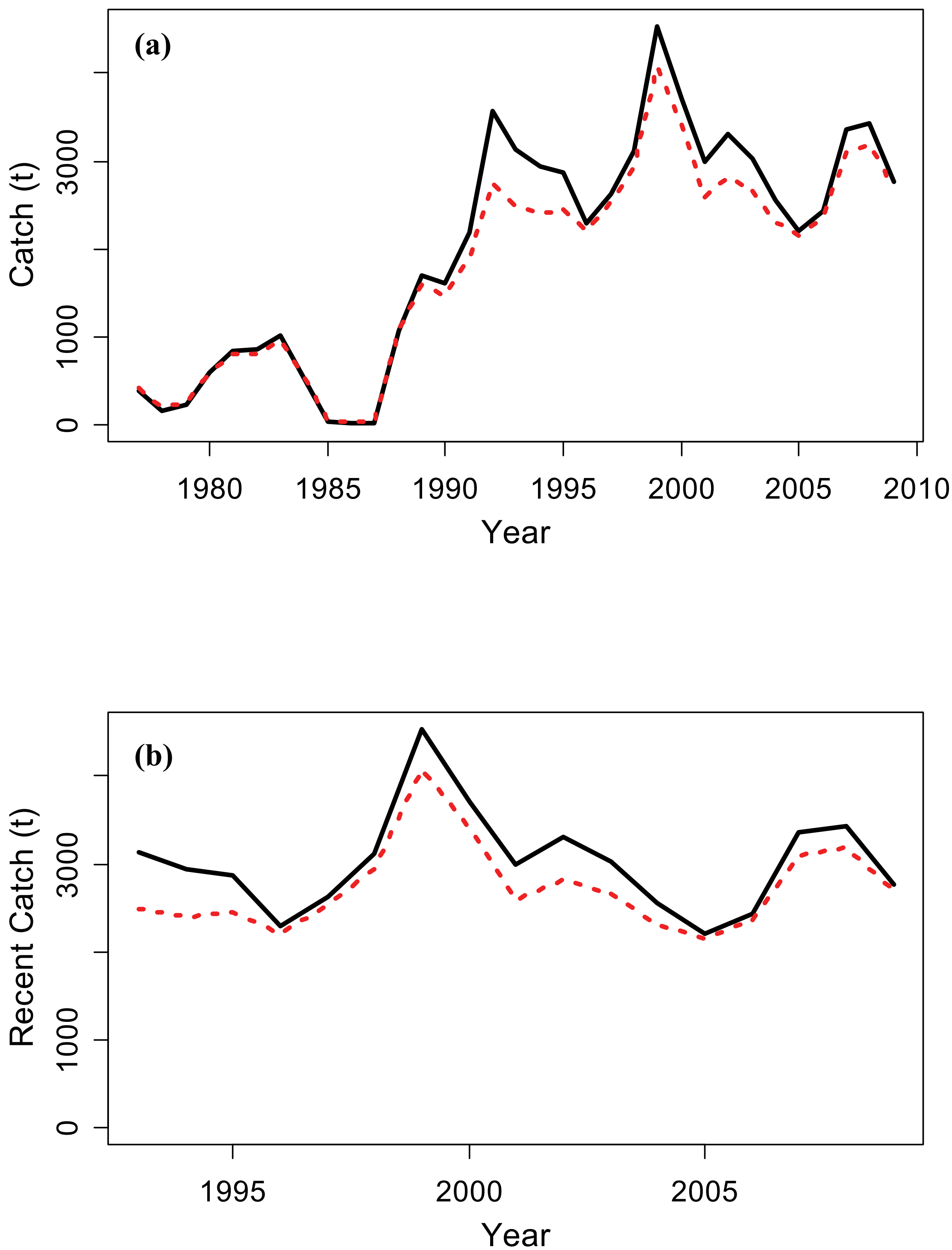

Figure 12-1a. Estimated long-term (a) and short-term (b) commercial catches for GOA dusky rockfish. Observed is solid line, predicted base model is dashed line.

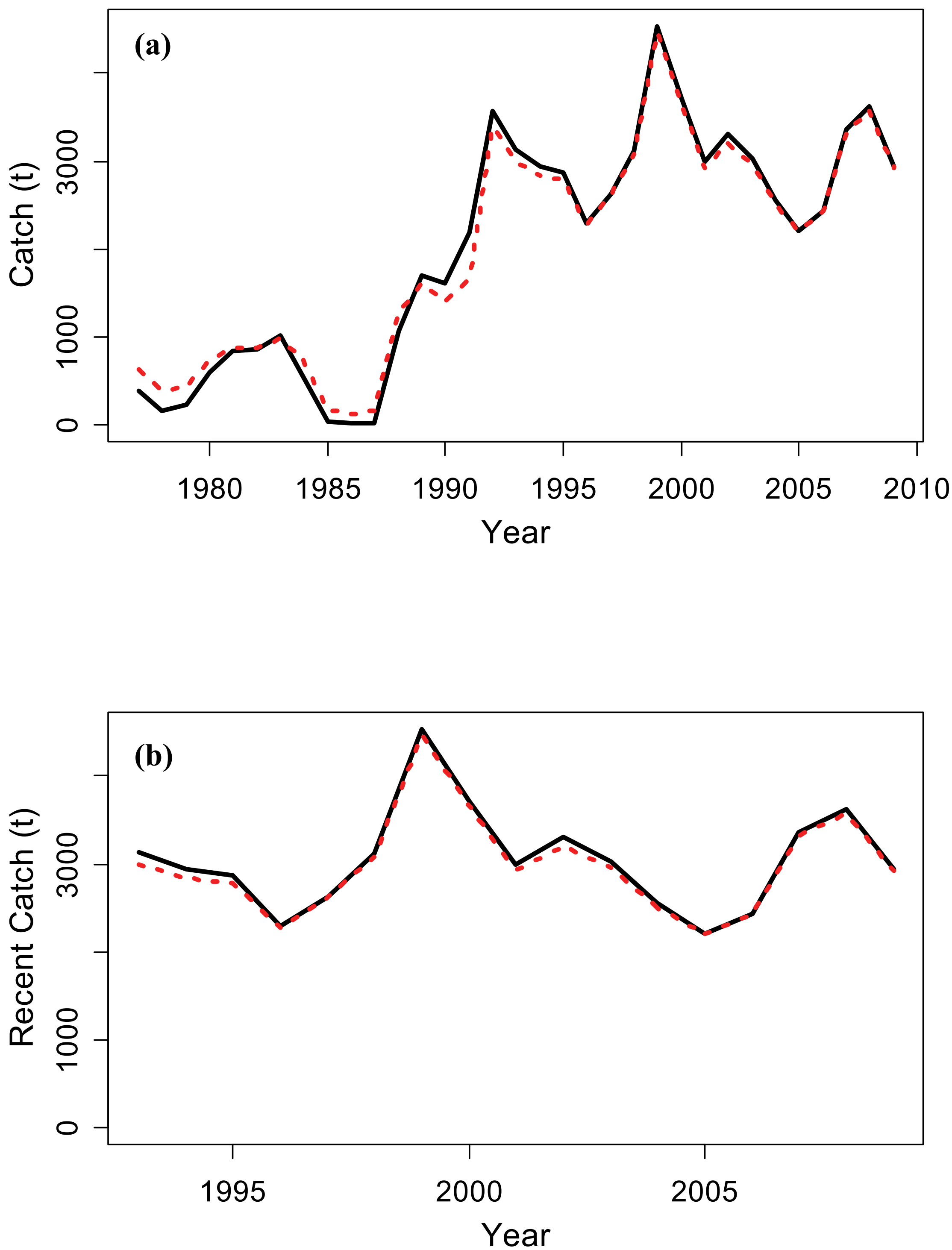

Figure 12-1b. Estimated long-term (a) and short-term (b) commercial catches for GOA dusky rockfish. Observed is solid line, predicted author recommended model (Model 2) is dashed line.

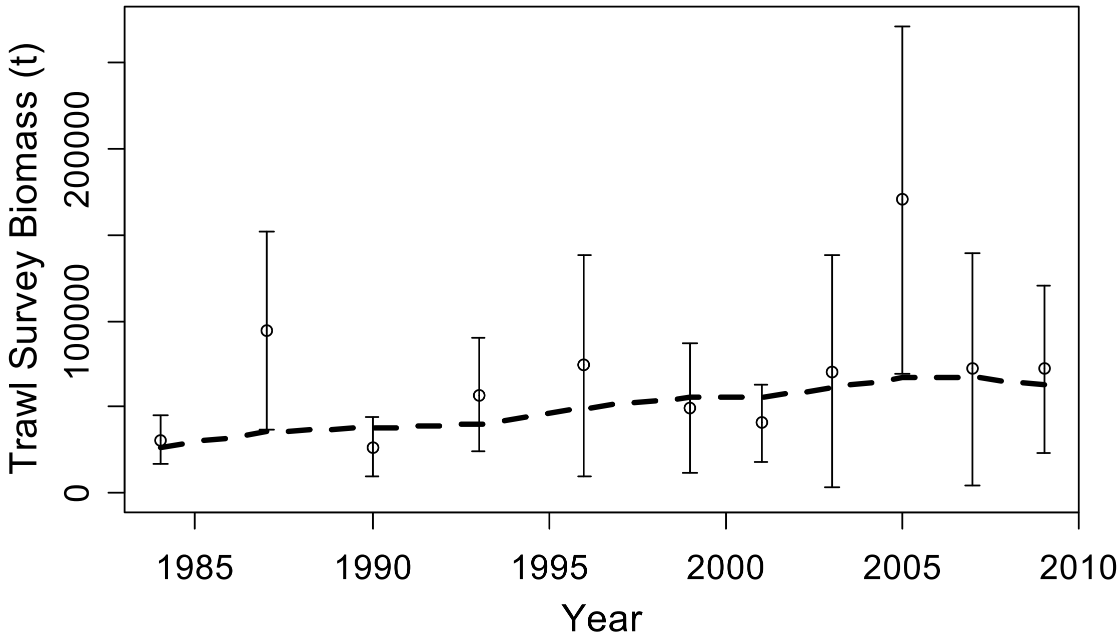

Figure 12-2a. Observed and predicted GOA dusky rockfish trawl survey biomass based on author recommended model. Observed biomass is circles with 95% confidence intervals of sampling error.

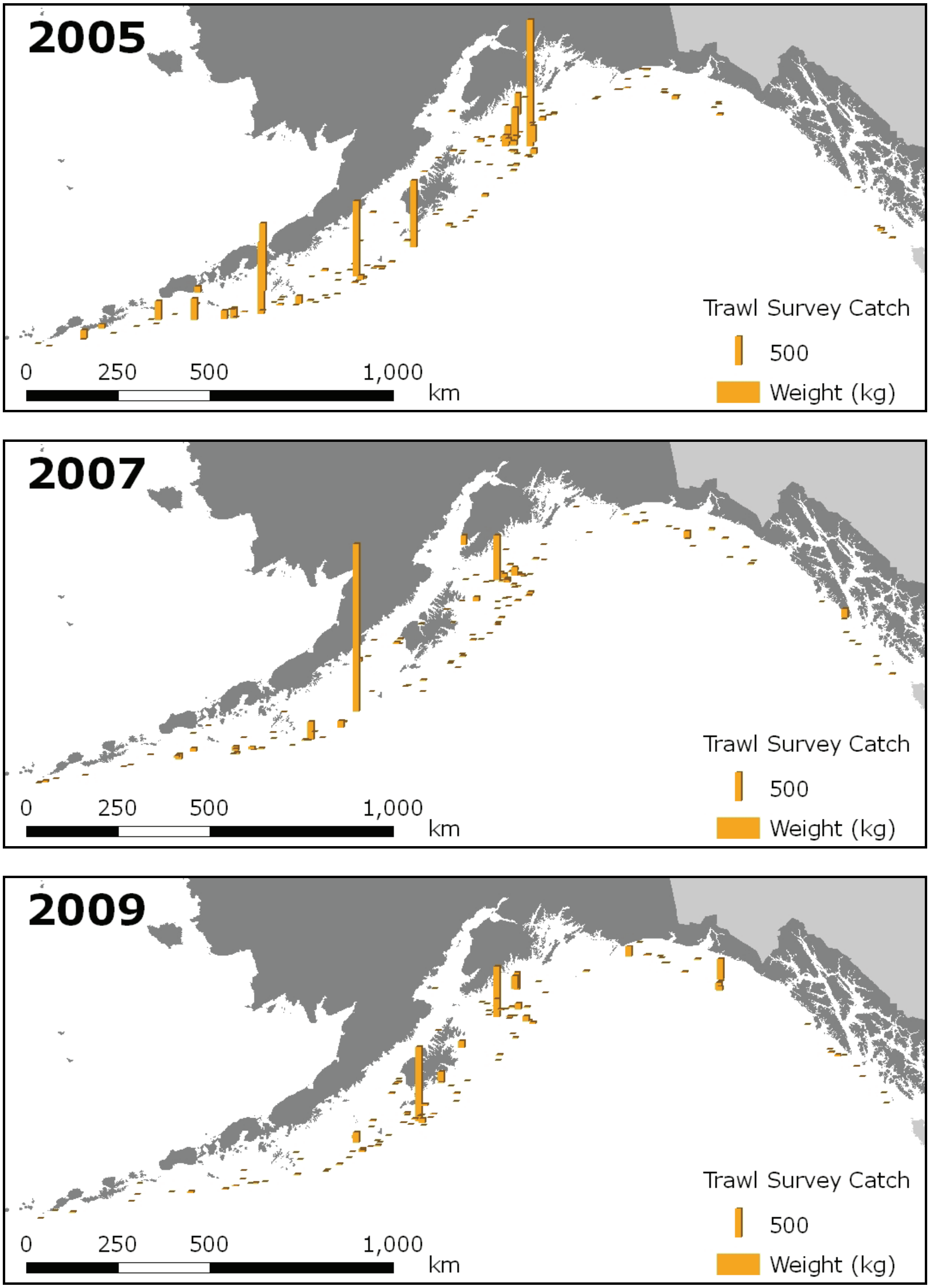

Figure 12-2b. Spatial distribution of dusky rockfish in the Gulf of Alaska during the 2005, 2007, and 2009 NMFS trawls surveys.

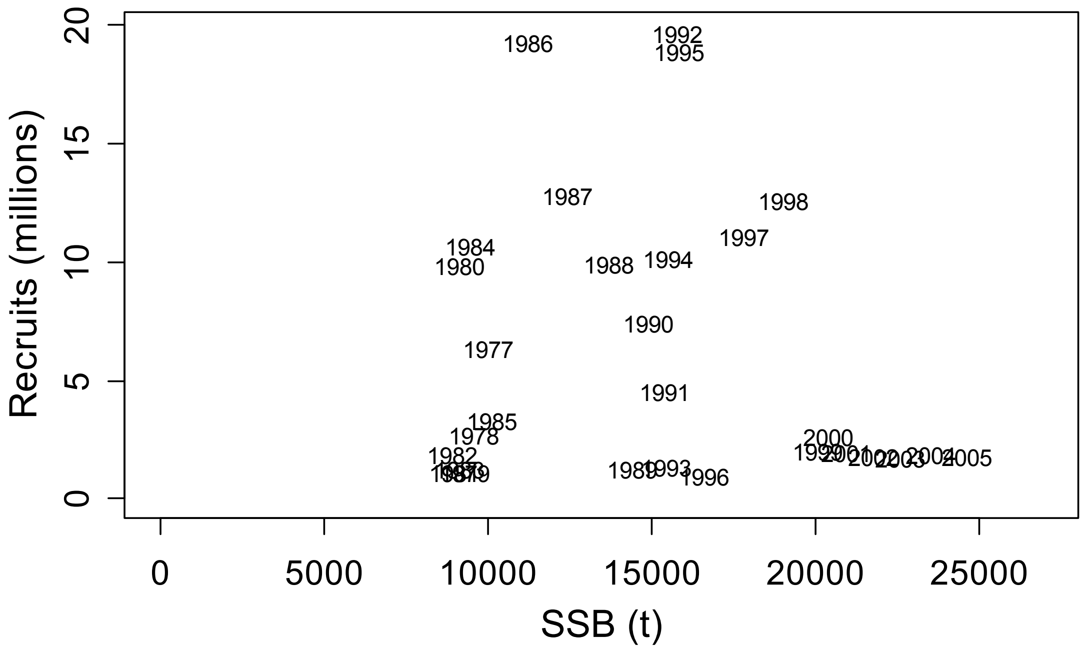

Figure 12-3. Scatterplot of spawner-recruit data for GOA dusky rockfish author recommended model. Label is year class of age 4 recruits. SSB = Spawning stock biomass in tons (t).

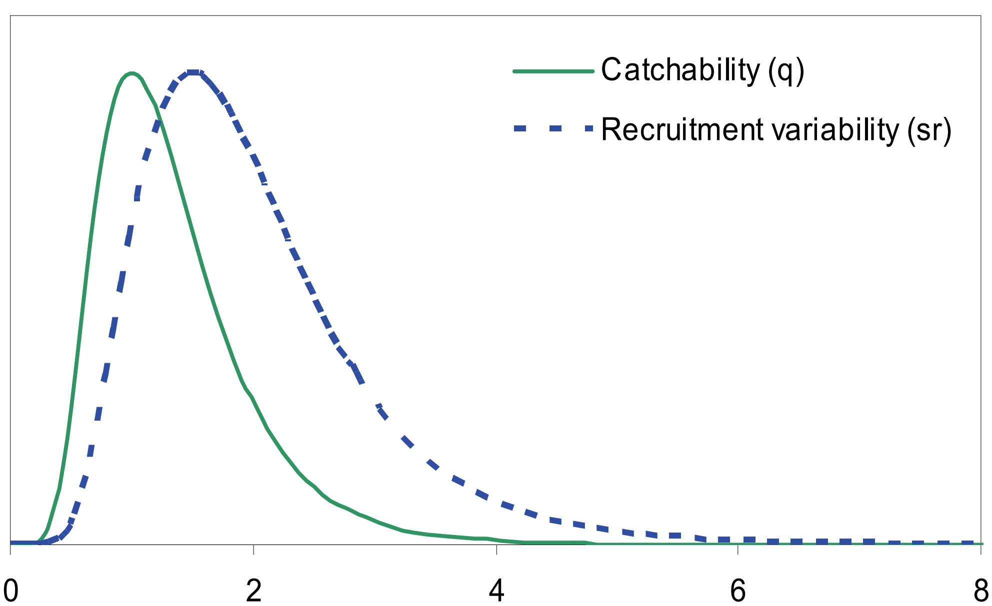

Figure 12-4. Prior distributions for catchability (*q*, μ=1, CV=45%) and recruitment variability (σ_r, μ=1.5, CV=45%) of GOA dusky rockfish.

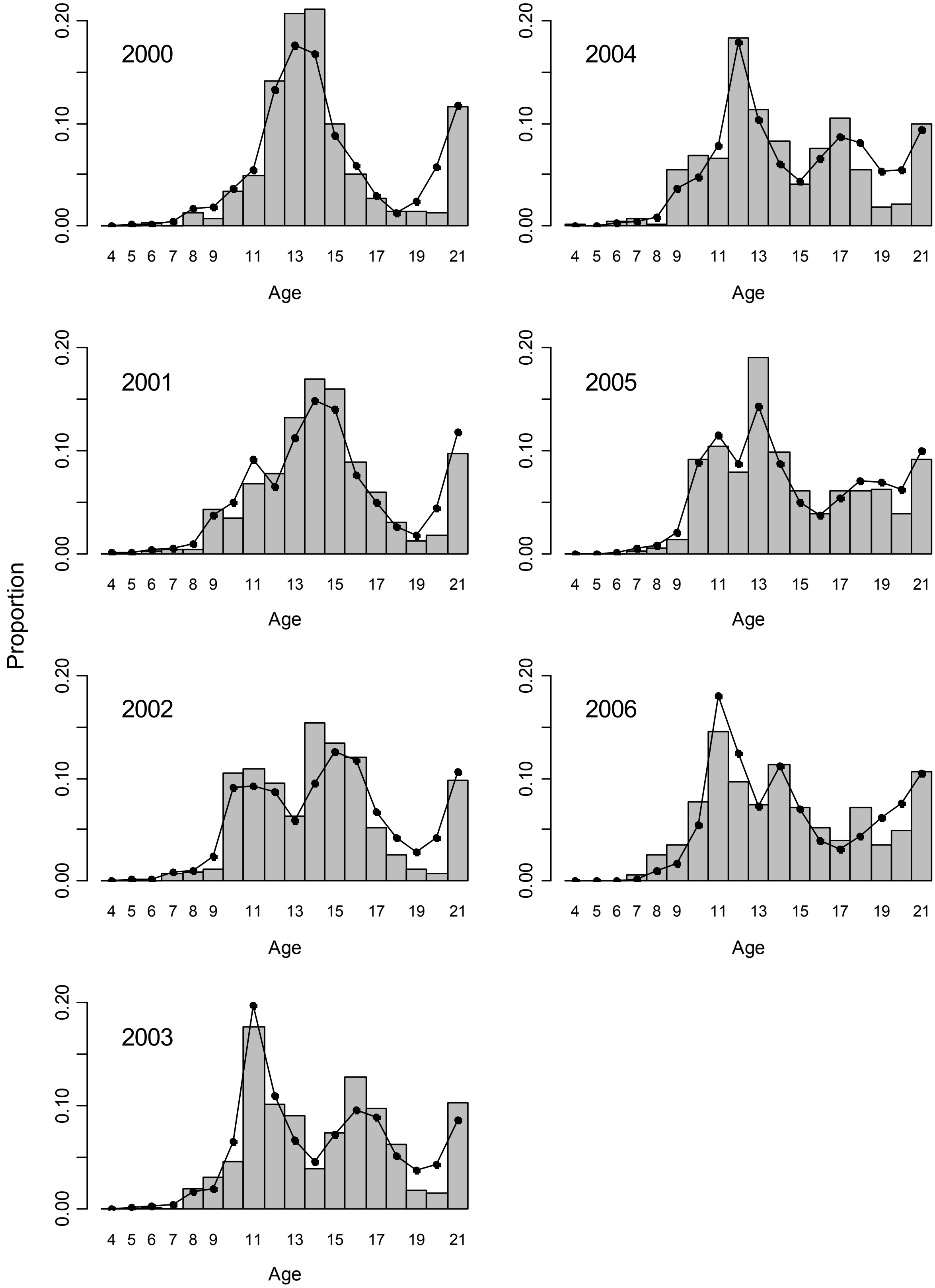

Figure 12-5. Fishery age compositions for GOA dusky rockfish. Observed is bars, author

recommended model predicted is line with circles.

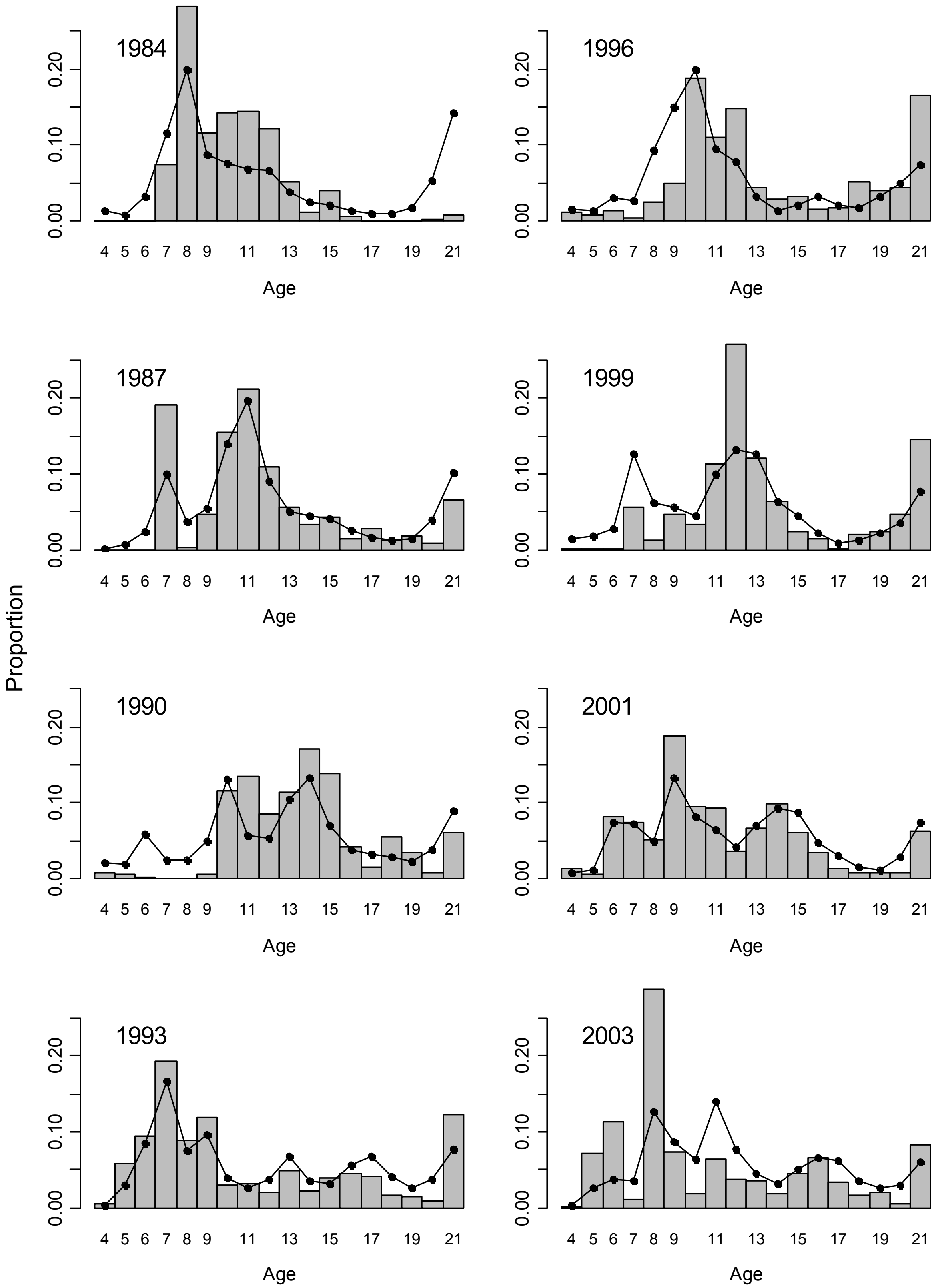

Figure 12-6. Trawl survey age composition by year for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles.

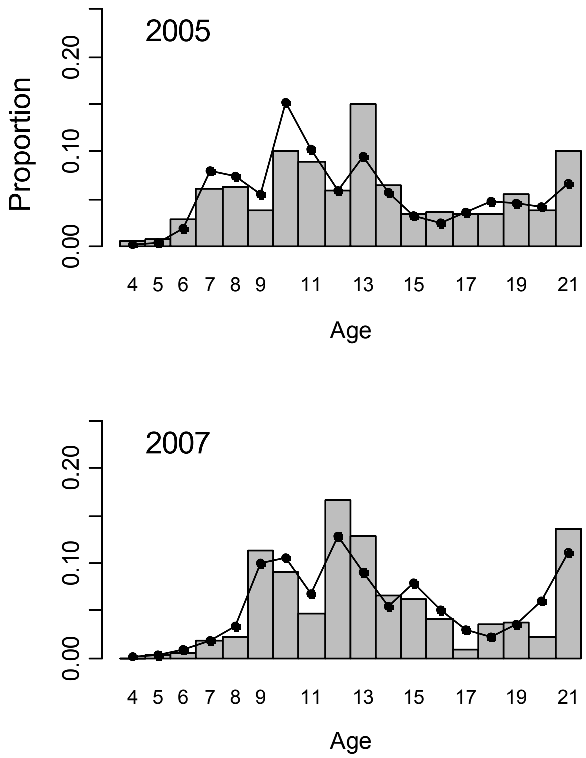

Figure 12-6 (continued). Trawl survey age composition by year for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles.

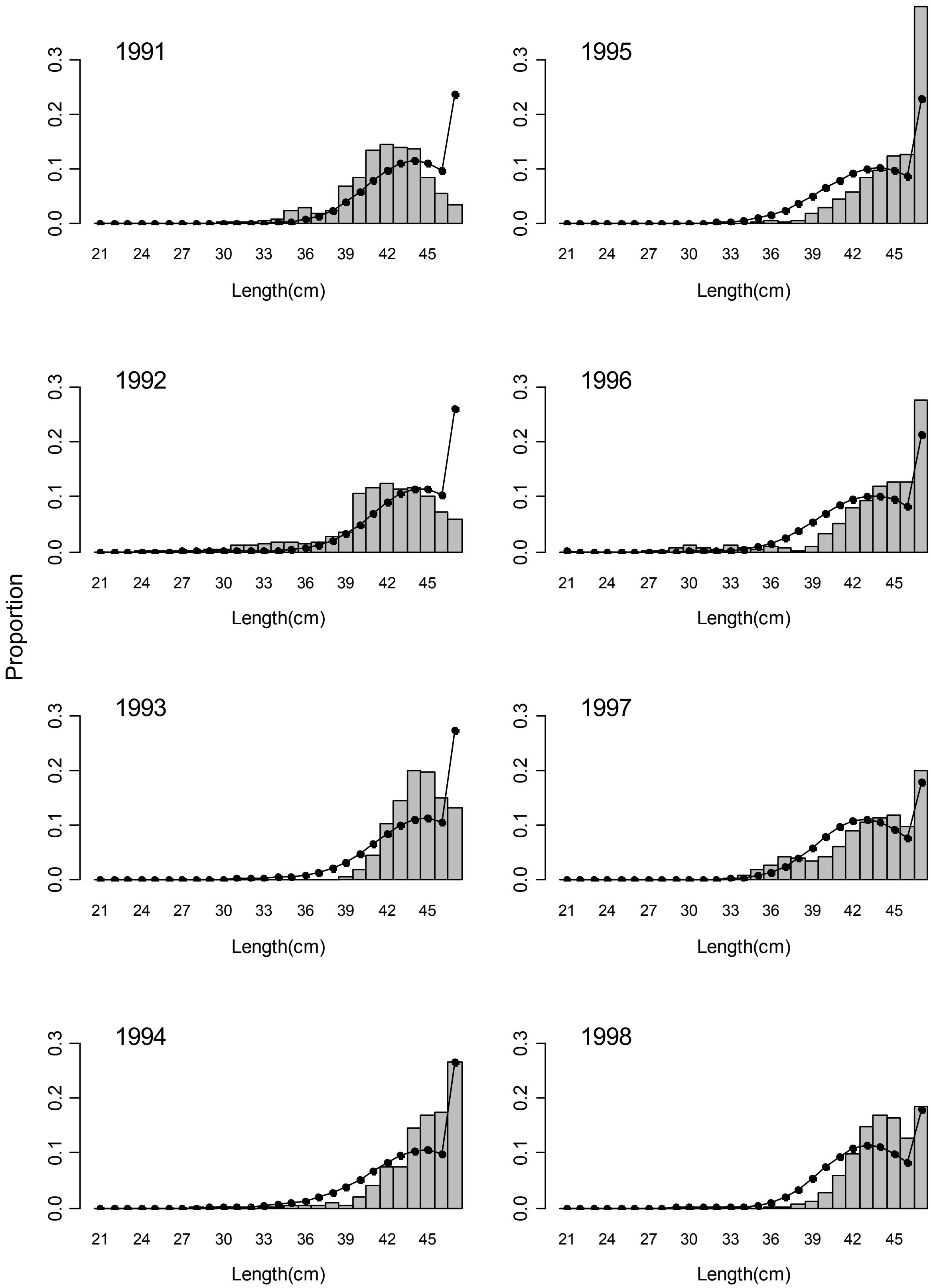

Figure 12-7. Fishery length compositions for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles.

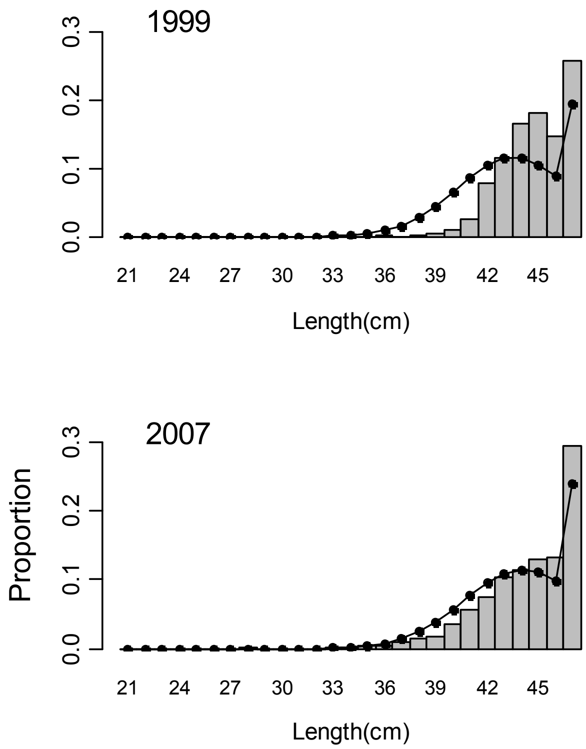

Figure 12-7 (continued). Fishery length compositions for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles.

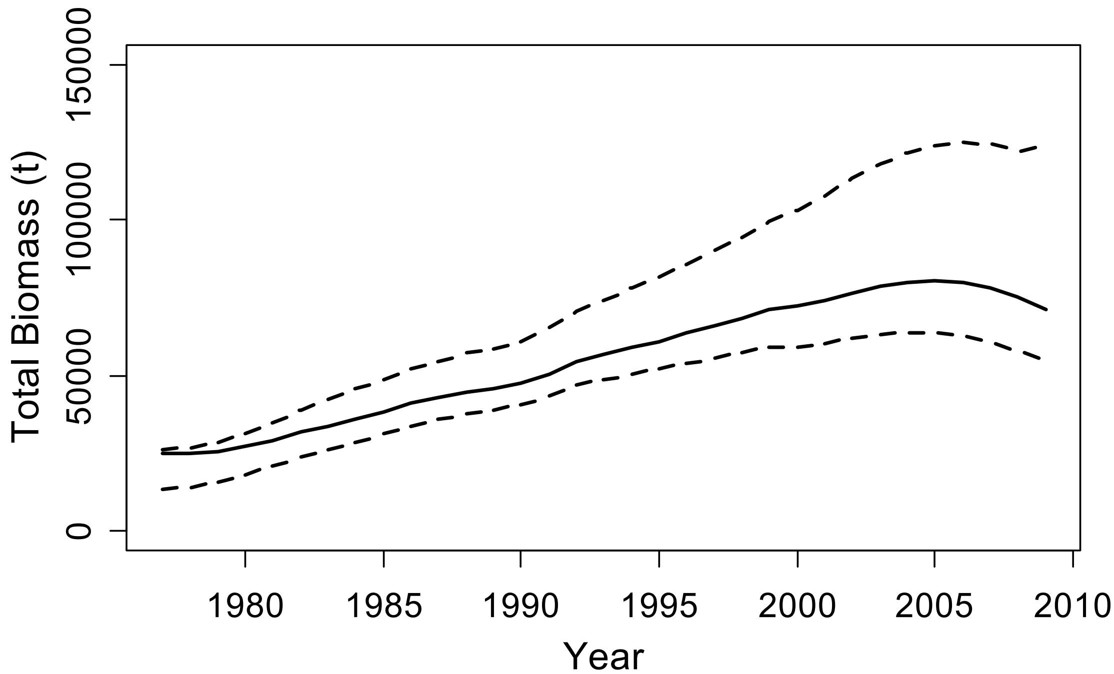

Figure 12-8. Time series of predicted total biomass of GOA dusky rockfish for author recommended model. Dashed lines represent 95% credible intervals from the MCMC runs.

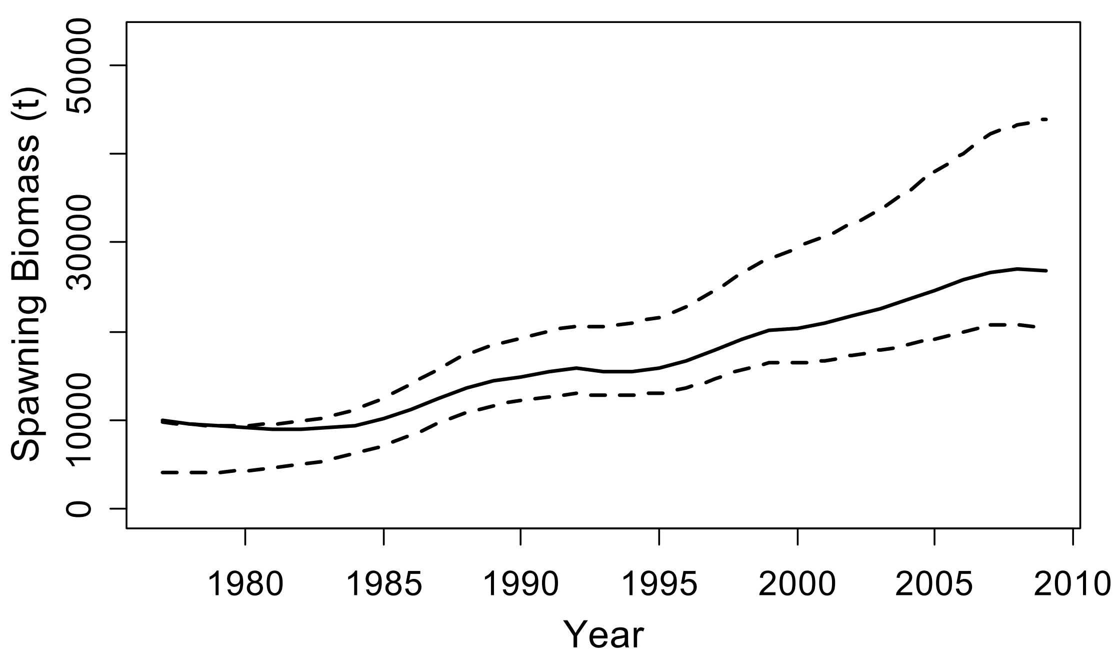

Figure 12-9. Time series of predicted spawning biomass of GOA dusky rockfish for author recommended model. Dashed lines represent 95% credible intervals from the MCMC runs.

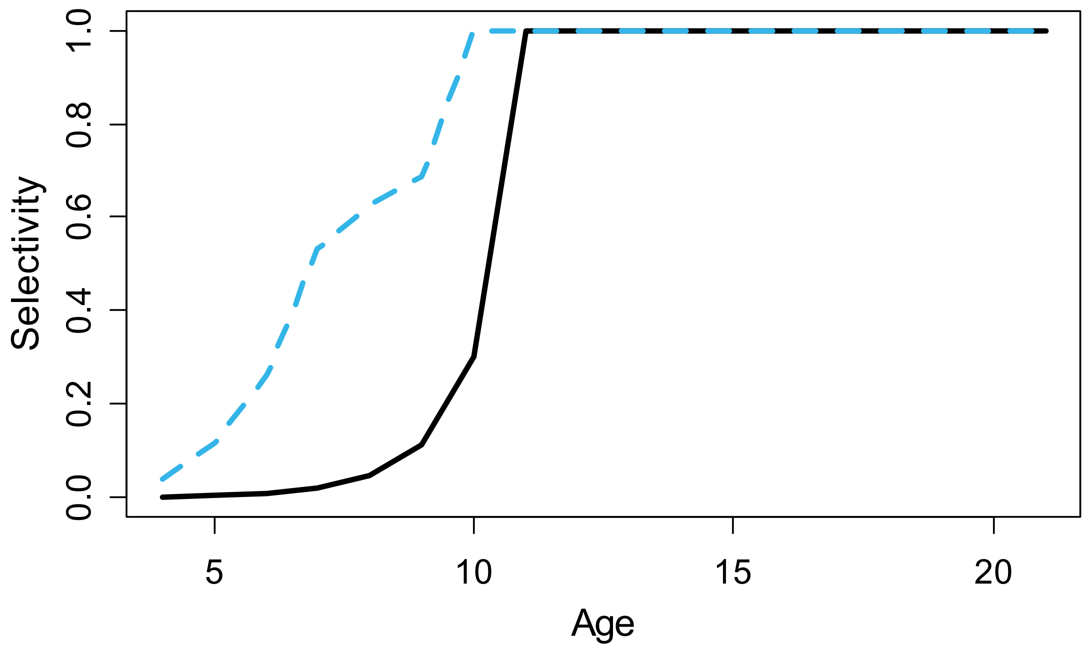

Figure 12-10. Estimated fishery and survey selectivity for GOA dusky rockfish from author recommended model. Dashed line is survey selectivity and solid line is fishery selectivity.

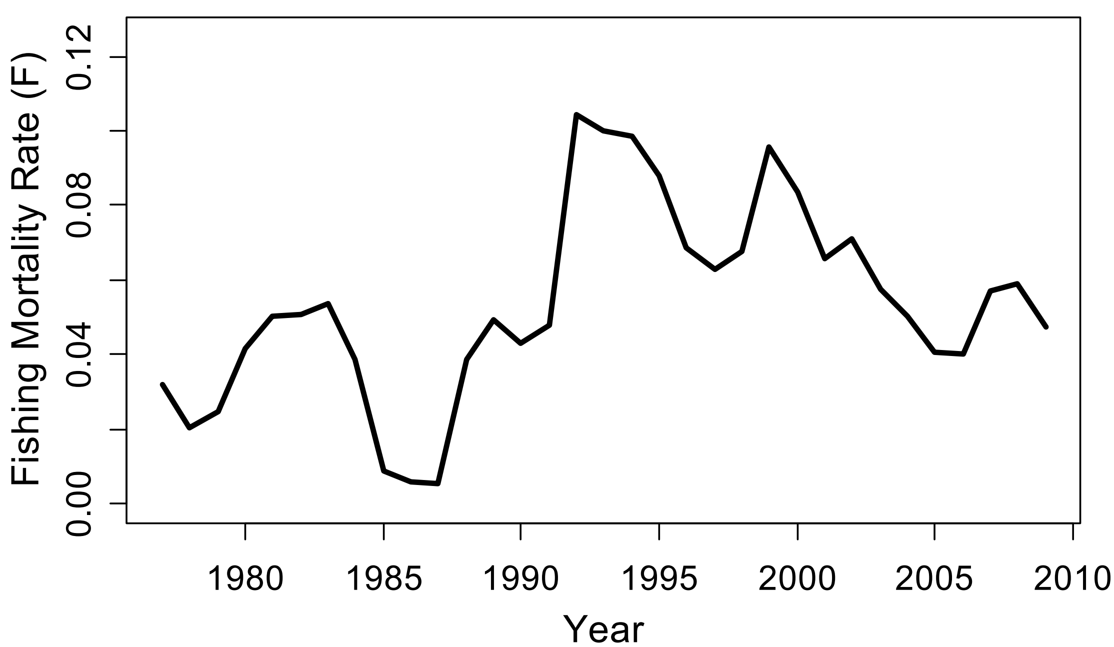

Figure 12-11. Time series of estimated fully selected fishing mortality for GOA dusky rockfish from author recommended model.

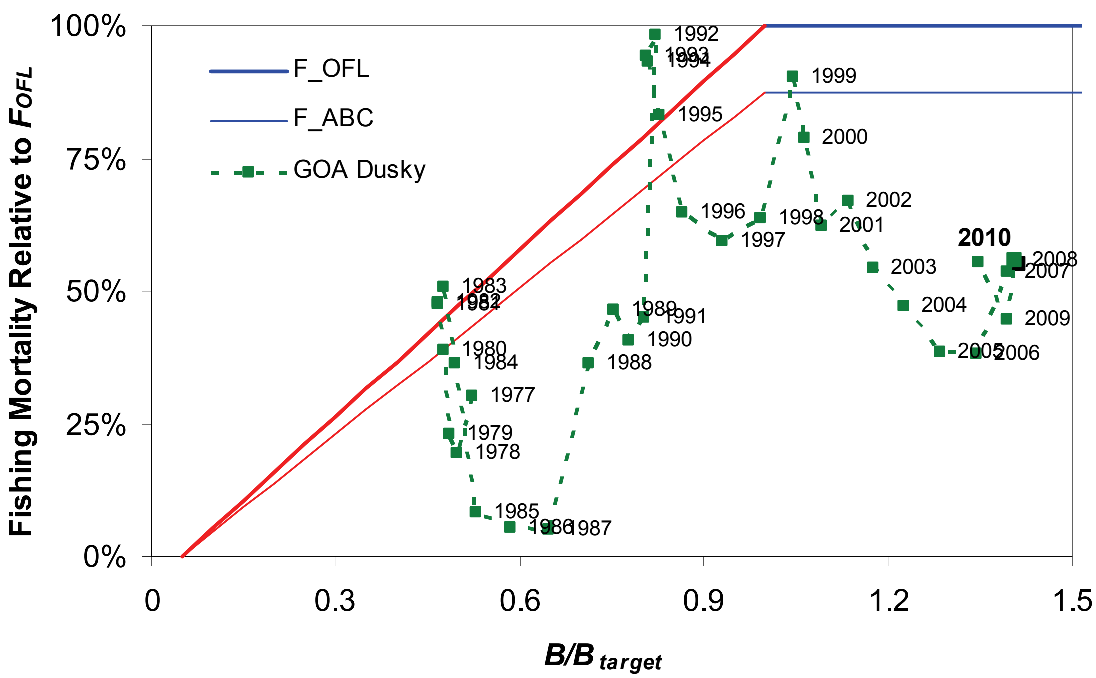

Figure 12-12. Time series of dusky rockfish estimated spawning biomass relative to the unfished level and fishing mortality relative to F_{OFL} for author recommended model.

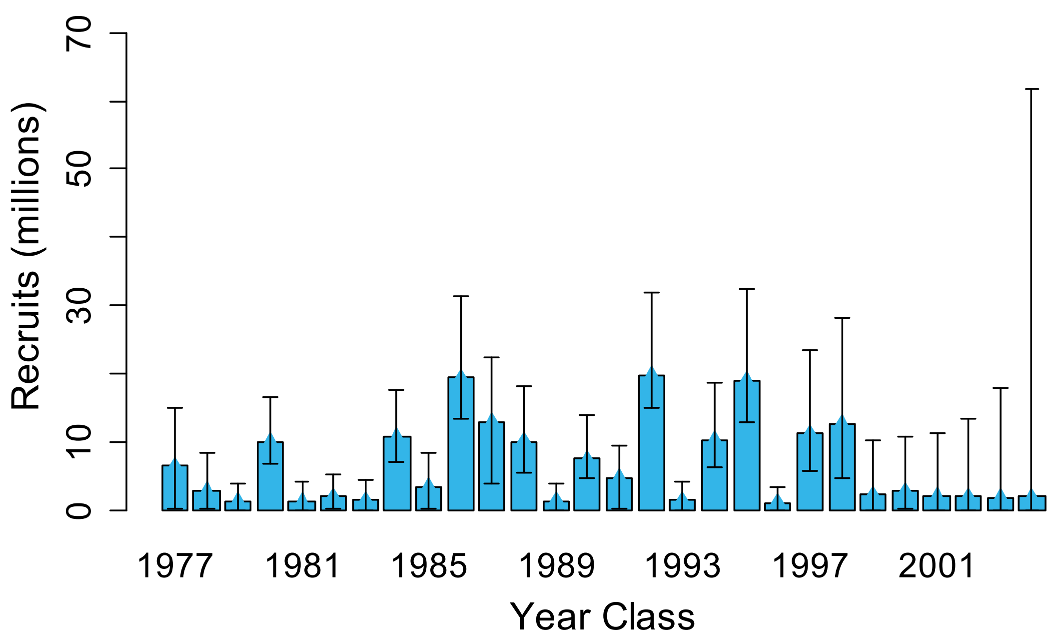

Figure 12-13. Estimated recruitments (age 4) for GOA dusky rockfish from author recommended model.

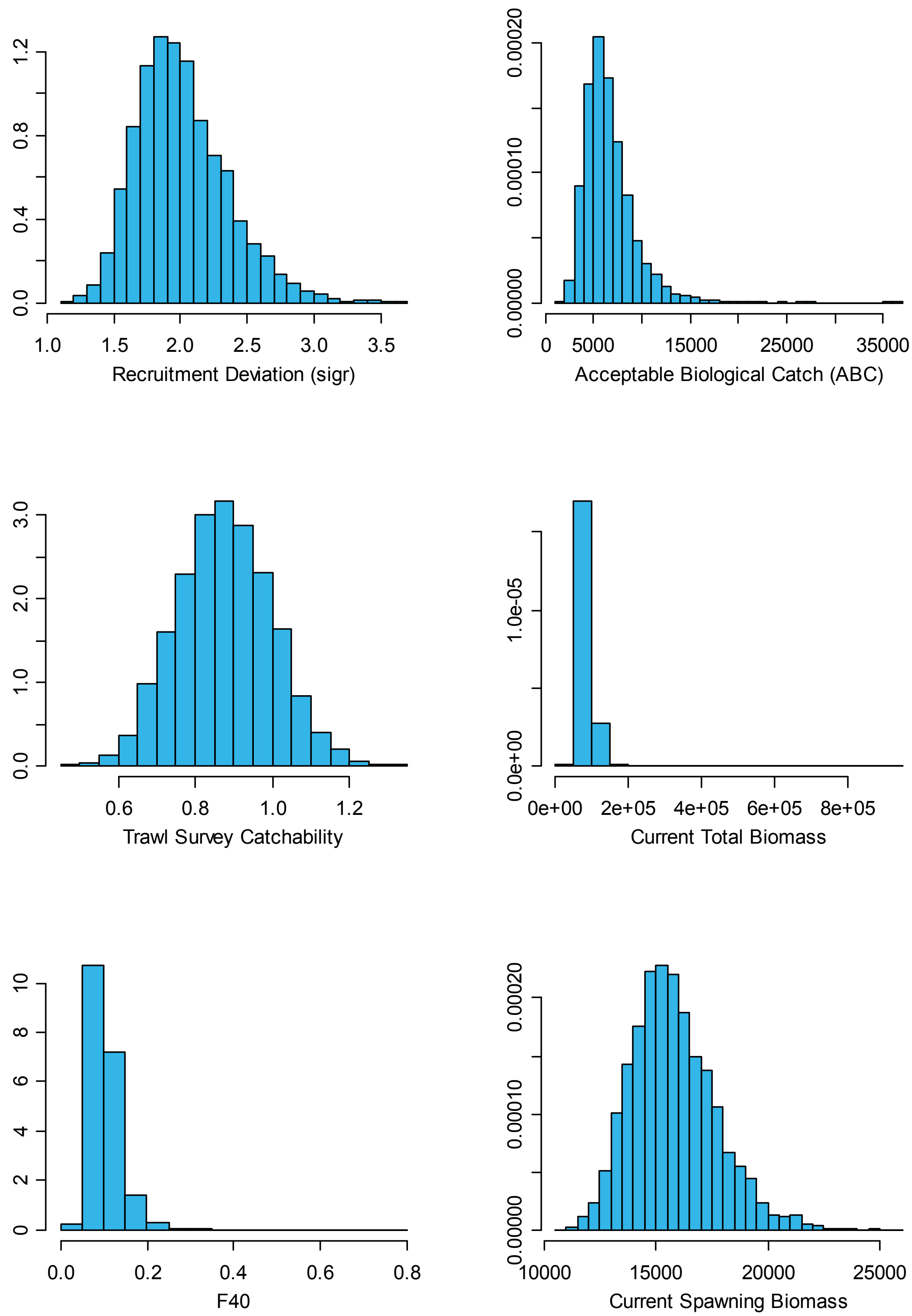

Figure 12-14: Histograms of estimated posterior distributions for key parameters derived from the MCMC for GOA dusky rockfish.

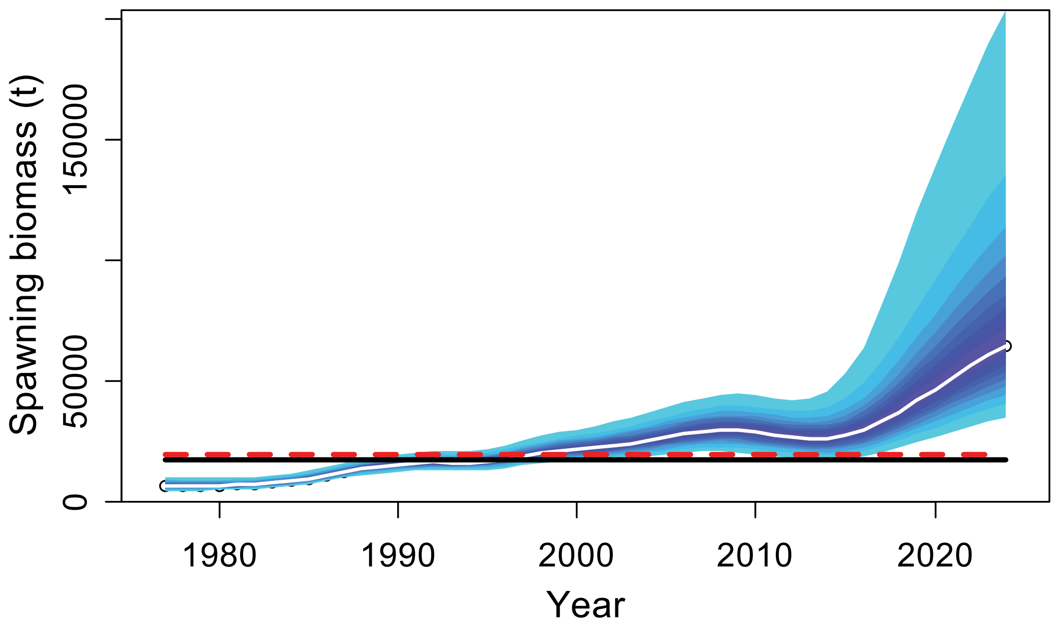

Figure 12-15. Bayesian credible intervals for entire spawning stock biomass series including projections through 2024. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1981-2007. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.