13. Pelagic Shelf Rockfish

Chris R. Lunsford, S. Kalei Shotwell, Dana H. Hanselman, and David M. Clausen
November 2007

Executive Summary

We continue to recommend using the average of exploitable biomass from the three most recent trawl surveys to determine the ABC's for dark, widow, and yellowtail rockfishes. For the three species, the average exploitable biomass from the 2003, 2005, and 2007 surveys was 9,682 mt (8,576 mt for dark rockfish, 132 mt for widow rockfish, and 974 mt for yellowtail rockfish). The 2008 recommended ABC for dark, widow, and yellowtail rockfish combined is 508 mt based on tier 5 calculations (F=0.75M). The 2008 OFL (F=M=0.07) for dark, widow, and yellowtail rockfish is 678 mt. Recommended area apportionments of ABC dark, widow, and yellowtail rockfish are 98 mt for the Western area, 353 mt for the Central area, 24 mt for the West Yakutat area, and 34 mt for the Southeast/Outside area.

In 2003 for dusky rockfish, the age-structured model was first accepted as an alternative to average trawl survey biomass estimates and was used to determine the ABC. We continue to 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. The maximum allowable ABC for 2008 is 4,719 mt based on tier 3 and derived from the recommended model. This ABC is 5% less than last year's ABC of 4,991 mt. The decrease in ABC is likely due to a 2.5 fold increase in survey biomass from 2003 to 2005 which inflated the 2006 and 2007 ABC's, followed by a decrease in survey biomass in 2007. The biomass for 2007 was similar to the 2003 survey biomass. The 2008 OFL for dusky rockfish is 5,722 mt. Recommended area apportionments of ABC are 905 mt for the Western area, 3,274 mt for the Central area, 227 mt for the West Yakutat area, and 313 mt for the Southeast/Outside area.

For the pelagic shelf rockfish assemblage, ABC and OFL for dusky rockfish are combined with ABC and OFL for dark, widow, and yellowtail rockfish. The 2008 recommended ABC for pelagic shelf rockfish is 5,227 mt with area apportionments of 1,003 mt for the Western area, 3,626 mt for the Central area, 251 mt for the West Yakutat area, and 347 mt for the Southeast/Outside area. The 2008 OFL for pelagic shelf rockfish is 6,400 mt. The stock is not overfished, nor is it approaching overfishing status. A summary table of exploitable biomass, exploitation rates, ABC, OFL, and natural mortality rate (*M*) for pelagic shelf rockfish is presented below:

Species	Other Pelagic Rockfish	Dusky Rockfish	Pelagic Shelf Rockfish Assemblage 2008	Pelagic Shelf Rockfish Assemblage 2009*
Exploitable Biomass (mt)	9,682	72,253	81,935	--
M	0.07	0.07	0.07	0.07
Maximum Allowable F_{ABC}	0.0525	0.088	--	--
Recommended F_{ABC}	0.0525	0.088	--	--
F_{OFL} (M, $F_{35\%}$)	0.07	0.108	--	--
ABC (mt, max allowable)	**508**	**4,719**	**5,227**	**5,140**
OFL (mt)	678	5,722	6,400	6,294

*The 2009 ABC and OFL for dusky rockfish were projected using an expected catch value of 3,081 mt for 2008, 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 13-9 in response to management requests for a more accurate one-year projection.

Summary of Major Changes to Model, Data, and Results

New data for 2007 includes updated 2006 fishery catch, estimated 2007 fishery catch, 2005 survey ages, and 2007 survey biomass estimates.

For dusky rockfish, the model used is the same as last year's author recommended 2005 model with updated fishery and survey data. This model incorporates a variety of changes from previous recommended models, such as: using an updated size-age matrix, removing fishery size compositions from 1990 (experimental year for Observer program), full estimation of the recruitment standard deviation and survey catchability, and modifying the natural mortality to be more in line with other similarly aged rockfish. We recommend the use of this model for determining ABC because it uses a more realistic estimate of natural mortality and has a better fit to available data including a reasonable fit to survey biomass estimates.

Previously, dark rockfish and dusky rockfish were considered one species and treated as a tier 4 species because of the information available for dusky rockfish. Since dusky rockfish now have an age-structured model and are managed as a tier 3 species, we now consider dark rockfish a tier 5 species along with widow and yellowtail rockfish. The exploitable biomass was substantially higher from 2005-2007 for dark rockfish because of an unusually high biomass estimate from the 2005 trawl survey. Conversely, yellowtail biomass estimates were much lower in 2005 and again in 2007 because the 1999 and 2001 survey estimates were exceptionally high and have been left out of the exploitable biomass calculations.

In March, 2007, the North Pacific Fishery Management Council took final action to remove dark rockfish from both the GOA FMP (PSR Complex) 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. At this time, the rules to implement these FMP amendments have not yet been finalized. Thus it is unlikely the effective date for Amendments 77/73 will occur before January, 2009. Therefore, it would not be until 2009 that dark rockfish would be removed from Federal management (including the associated contribution to OFLs and ABCs under the respective complexes in both regions) and full management authority would be turned over to the State. 2008 ABC's and OFLs presented in this assessment are for the PSR complex including dark rockfish but point estimates for individual species are included for comparative purposes.

Responses to SSC Comments Specific to the PSR Assessment

There were no SSC comments in 2005 or 2006 for pelagic shelf rockfish.

Responses to SSC Comments In General

"Phase-plane diagram. The SSC appreciates the addition of phase-plane diagrams to most stock assessments and reiterates interest in these diagrams for all stock assessments in which it is possible to do so using standardized axes (i.e., X axis of B/B_{target}; and Y axis of F_{catch}/F_{OFL}), formatted relative to harvest control rules. In addition, values from the most recent year should be provided annually by the assessment authors to the plan team. The plan teams are requested to provide a figure summarizing all stocks in the introduction section of the SAFE documents. This figure would show the most recent year's status for all stocks possible by plotting realized F relative to F_{OFL} versus biomass relative to target biomass. One point for each stock from the most recent year plotted relative to the harvest control rules would provide a snapshot of relative stock management performance for the group (see figure below as a

potential example). One option could be to plot the last two years values as a line with an arrow head to show the change in each stock's performance from the prior year."

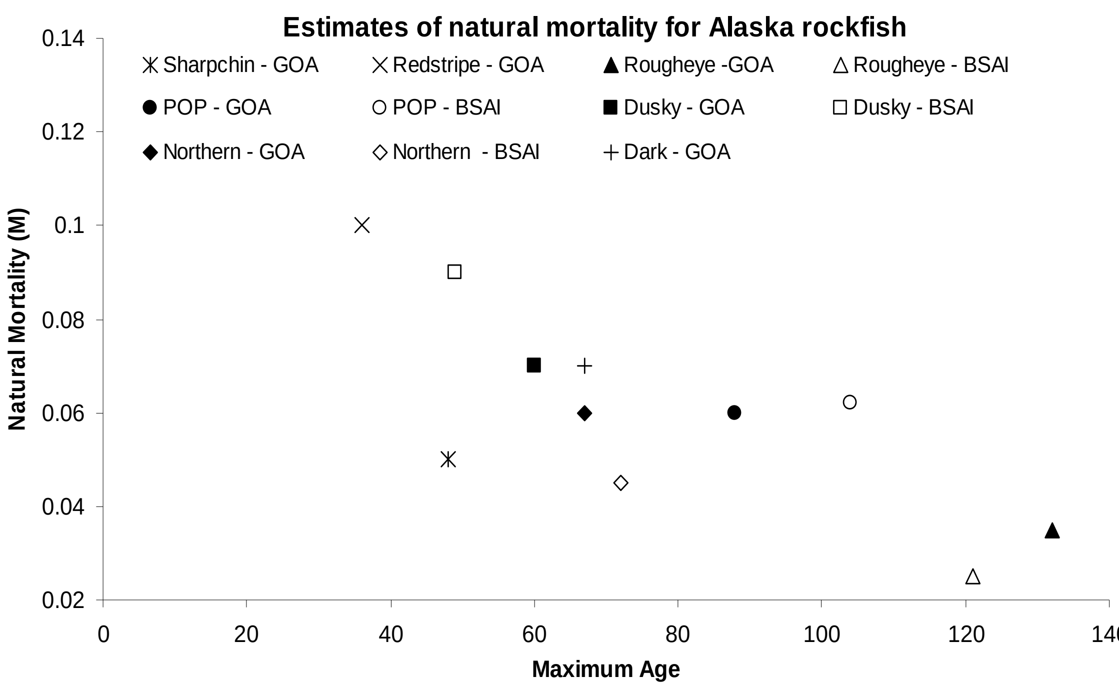
In this assessment we moved from the Goodman et al. (2002) style management path plot to one that incorporates the harvest control rules in Figure 13-12.

Responses to CIE Review

In June, 2006, the Alaska Fisheries Science Center (AFSC) arranged for a review of Alaska rockfish harvest strategies and stock assessment methods by the Center of Independent Experts (CIE). Three reviewers participated and each produced a separate review without collaboration with other panelists or NMFS staff. The reviews can be found at: http://www.afsc.noaa.gov/refm/docs/2006/rf_CIE.pdf. The AFSC prepared a draft response to the review and presented several discussion points at the February, 2007 SSC meeting. The draft response can be found at: ftp://ftp.afsc.noaa.gov/afsc/public/rockfish/RWG response to CIE review.pdf. The draft response focused on specific comments and recommendations regarding rockfish assessments in Alaska. Comments that pertained to pelagic shelf rockfish include:

"Estimation of M is problematic, whether it is via a maximum age assumption, an early catch-curve, or is estimated within a stock assessment model. However it is done, the objective should be to attain a "best" estimate of M – not a conservative estimate of M."

A description of methods available for estimating M is provided in the draft response to the CIE. Estimates of natural mortality currently in use for Alaska rockfish stock assessments have been derived from a variety of different literature references and vary among species and between areas.



The natural mortality value used for pelagic shelf rockfish in this assessment is 0.07. An overview of the methodology and justification for using this value of M is provided in *Analytical Approach* section of this document. The authors will monitor new research regarding maximum age of rockfish species and alternative methods for estimating natural mortality. We will also continue to experiment with model derived estimates of natural mortality as more data becomes available for use in the model.

"Trawl survey indices take no account of the proportion of untrawlable ground in each stratum (a particular problem for the GOA survey)."

A center-wide initiative is underway to estimate the effect of untrawlable areas on groundfish stock assessments. Retrospective studies of untrawlable stations during past surveys, development of split-beam acoustic methods to estimate untrawlable areas, analysis of existing echosounder data, and alternative methods to trawl surveys that will allow estimation of fish abundance in untrawlable areas are all being investigated to address the problem.

"Develop informative priors for the trawl q*'s. Changes in gear setup and operation (e.g., length of trawl, standardization of methods) should be considered for each time series. More than one q will probably be needed for each time series."*

Several simulations were presented in the draft response to the CIE which addressed how well standard stock assessment models estimate catchability under different scenarios. Another simulation was presented which modeled the trawl survey sampling and estimation procedures under a variety of situations. The question of trawl survey catchability is an important component to rockfish assessments and will likely be an ongoing research effort at the AFSC.

Introduction

Distribution and life history

The pelagic shelf rockfish assemblage in the Gulf of Alaska is comprised of four species: dusky rockfish (*Sebastes variabilis*), dark rockfish (*S. ciliatus*), 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, dark, 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[1]. A separate study counted eighty-two juvenile rockfish closely associated with boulders that had attached sponges. No rockfish were observed near boulders without sponges (Freese and Wing 2003). Another study using a submersible in the eastern GOA observed small dusky rockfish associated with *Primnoa* spp. corals (Krieger and Wing 2002).

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

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).

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, dark, 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.

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

For dusky rockfish, we continue to 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.

Fishery

Catch History

Fishery catch statistics for the pelagic shelf rockfish complex in the Gulf of Alaska are only available for the years 1988-2007 (Table 13-1a). Specific catches for dusky rockfish were estimated from the Regional Office blend estimates from 1977-2007 for input in the age-structured model (Table 13-1b). 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 mt 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 13-1a 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 13-1a 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 (mt)	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 13-1c.

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 1991-2006, based on data from the domestic observer program:

	Percent of assemblage catch			
Year	Dusky	Dark	Yellowtail	Widow
1991	93.5	0.2	5.1	1.2
1992	98.9	0.3	trace	0.8
1993	98.1	trace	0.5	1.4
1994	98.3	1.2	0.1	0.4
1995	99.2	trace	trace	0.8
1996	99.7	trace	trace	0.3
1997	99.9	trace	trace	0.1
1998	99.9	trace	trace	trace
1999	97.4	2.6	trace	trace
2000	99.2	0.6	0.1	0.2
2001	99.7	0.3	trace	trace
2002	99.4	0.5	trace	0.1
2003	98.8	0.8	trace	0.3
2004	95.5	0.4	trace	4.5
2005	98.7	1.1	0.2	trace
2006	99.4	0.6	trace	trace

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. Clearly, with the possible exception of 1991, 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[2]. 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.

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

[2]National Marine Fisheries Service, Alaska Region, Fishery Management Section, P.O. Box 21668, Juneau, AK 99802-1688. Data are from weekly production and observer reports through October 13, 2007.

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.

Discards
Gulf-wide discard rates (percent of the total catch discarded within management categories) of pelagic shelf rockfish are available for the years 1991-2007. Rates are listed in the following table and have been relatively low over time[3].

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

In contrast, discard rates in the fisheries for slope rockfish in the Gulf of Alaska have generally been much higher (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	1977-2007
U.S. trawl fisheries	Length	1990-1999, 2003, 2005
	Age	2000, 2001, 2002, 2004
Domestic trawl survey	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007
	Age	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005

Fishery Data

Catch
Catch estimates are a combination of foreign observer data, joint venture catch data, and NMFS Regional Office blend data (Table 13-1a, Table 13-1b, Figure 13-1). Catches range from 17 mt in 1986 to 4,538 mt 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.

[3]National Marine Fisheries Service, Alaska Region, P.O. 21668, Juneau, AK 99802. Data are from weekly production and observer reports through October 13, 2007.

Age and Size composition

In addition to the catch data listed in Table 13-1a and 13-1b, length frequency data for dusky rockfish in the commercial fishery are available for the years 1991-2007 (Table 13-2). 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 only in the 1999-2006 commercial fisheries. Aging has been completed for the 2000, 2001, 2002 and 2004 samples (Table 13-3). Similar to the fishery length data discussed in the preceding paragraph, the data in Table 13-3 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 four years accurately track the 1987 year class which shows up as 13 year olds in 2000 and the 1992 year class which is evident as eight year olds in 2000. This year class appears especially strong in the 2004 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 and 2007. The 2001 survey biomass is a weighted average of 1993-1999 biomass estimates, since the Eastern Gulf was not surveyed. The surveys provide estimates of biomass for pelagic shelf rockfish (Table 13-4a). 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 and dark rockfish biomass estimates were the highest ever recorded. The dark rockfish biomass was influenced by a large catch of 1154 kg in the Shumagin area. The next largest catch of dark rockfish was 167 kg. 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.

Comparison of Trawl Surveys

Comparative biomass estimates for the nine triennial surveys show wide fluctuations for dusky rockfish (Table 13-4a, Table 13-4b, Figure 13-2). 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 mt, and decreased in 2007 to a biomass 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 last three surveys are shown in Figure 13-2b. The magnitude of catch varies greatly with several large tows typically occurring in each survey. Highest catches occur in the Central and Western Gulfs, 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 1984-2007 (Table 13-5). 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 or 2007. 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 2005 trawl surveys (Table 13-6). 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 data showed some prominent younger ages which were dominated by the 1997 year class. This year class also appeared in the 2005 data. Additionally, the 2003 and 2005 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 dark, widow, and yellowtail rockfish.

Dark, Widow, and Yellowtail Rockfish

Assessment Parameters

Information on mortality rates and maximum age for three species of pelagic shelf rockfish is shown in Table 13-7. 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 complex 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 13-7). We suggest that the value of 0.07 which was recently computed for dark rockfish in the GOA[4] might be more appropriate for dark, 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 dark, widow, and yellowtail rockfish for the three most recent surveys (2003, 2005, and 2007) are 1,037 mt, 25,440 mt, and 2,570 mt respectively (Table 13-4a). Averaging these values yields a current exploitable biomass of 9,682 mt for dark, widow, and yellowtail rockfish. This estimate can be broken down into 8,576 mt for dark rockfish, 132 mt for widow rockfish, and 974 mt 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

[4] Chilton, L. *In Review*. Growth and natural mortality of dark rockfish (Sebastes ciliatus) in the western Gulf of Alaska. 23rd. Lowell Wakefield Fisheries Symposium on Biology, Assessment, and Management of North Pacific Rockfishes.

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 13-3). 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 x 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 estimated 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 13-7).

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 13-4). 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 1.7 with a CV of 45% (Figure 13-4).

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	47
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	31
Fishery selectivity coefficients	fs_a	8
Survey selectivity coefficients	ss_a	7
Total		100

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 50,000 iterations out of 5,000,000 and "thinned" the chain to one value out of every thousand, leaving a sample distribution of 4,950. 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% confidence intervals for some parameters.

BOX 1. AD Model Builder Model Description

Parameter definitions	
y	Year
a	Age classes
l	Length classes
w_a	Vector of estimated weight at age, $a_0 \rightarrow a_+$
m_a	Vector of estimated maturity at age, $a_0 \rightarrow a_+$
a_0	Age at first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
σ_r	Annual recruitment deviation
ϕ_y	Annual fishing mortality deviation
fs_a	Vector of selectivities at age for fishery, $a_0 \rightarrow a_+$
ss_a	Vector of selectivities at age for survey, $a_0 \rightarrow a_+$
M	Natural mortality, 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 (mt)

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

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

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

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

Equations describing population dynamics

Start year

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

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

This model is the author recommended model presented in the 2005 Pelagic Shelf Rockfish assessment which was accepted to determine the 2006 ABC (Lunsford et al. 2005). This model builds on previous assessments and a variety of changes were made to model parameters and available data in comparison to previous years. We used the updated size-age matrix and removed the fishery size compositions from 1990. This was the first year of the Observer Program and considered experimental in operation. The 1990 length compositions showed a large proportion of fish in the lowest pooled length bin, which has not been seen in any other length distribution. Therefore, we did not have much confidence in this first year of size compositions. Additionally, because of our lack of confidence in the catch data, we increased the fishing mortality regularity penalty to smooth the predicted catches. Finally, the estimate of natural mortality was lowered from 0.09 to 0.07, as described in the *parameters estimated independently* section.

Model Results

Table 13-8a summarizes the results from this year's recommended model and the 2005 model. The weighting structure is the same in both cases. In general, model predictions continue to fit the data well (Figures 13-2, 13-5, 13-6, and 13-7). As mentioned in the *fishery data* section, the catch data was estimated from a variety of sources and we do not have much confidence in this information; therefore, model fit to the catch data is moderate (Figure 13-1). The 2007 survey biomass estimate decreased from last year and is more in line with the 2003 survey estimate (Figure 13-2). Model fit to this data reveals a slightly more moderate increasing trend than last year. 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. The objective function value has increased slightly from last year's data, primarily due to the addition of new data.

Biomass and Exploitation Trends

Total biomass estimates indicate a moderately increasing trend over time with a slight dome shape in the most recent years (Figure 13-8), while spawning biomass estimates show a continuous linear increase throughout the time series (Figure 13-9). MCMC confidence intervals indicate that the historic low was more certain than the more recent increases, particularly when looking at the upper confidence intervals. The estimated selectivity curve for the fishery and survey data suggested a pattern similar to what we expected for dusky rockfish (Figure 13-10). 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 (Figure 13-11). This rise is likely 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 13-12).

Recruitment

Recruitment is highly variable throughout the time series (Figure 13-13), 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 13-3). The addition of new data in this year's model has decreased recruitment estimates for 1997 and 1998 and increased recruitment estimates for 1986, 1992, and 1995. Estimates for the most recent years are still fairly low. MCMC confidence bands for recruitment are fairly narrow in the some years; however, the confidence bands nearly contain zero for many years which indicates considerable uncertainty, particularly for the most recent years (Figure 13-13).

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 13-14). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass and recruitment (Figures 13-8, 13-9, and 13-13).

Table 13-8b 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 MLE 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*, current total biomass, 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 far out of the Bayesian confidence 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

Dark, 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 x M. We now recommend that ABC for these three fish be computed separately from dusky rockfish, and that the tier 5 formula be applied to dark, widow, and yellowtail rockfish. If we assume an M of 0.07 for the three species, F_{ABC} is then 0.75 x M, which equals 0.0525. Multiplying this value of F by the current exploitable biomass for dark, widow, and yellowtail rockfish (9,682 mt; see *analytical approach* section) yields an ABC of 508 mt for 2008. This estimate can be broken down into 450 mt for dark rockfish, 7 mt for widow rockfish, and 51 mt for yellowtail rockfish. This is approximately 40 mt lower than what was recommended in 2005 and 2006. This decrease is mostly because a large yellowtail biomass estimate from the 2001 survey is no longer used in the exploitable biomass computations.

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 1981-2005 (year classes between 1977 and 2001). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. 2008 estimates of these reference points are (in terms of female spawning biomass):

$B_{0\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
44,316	17,727	15,511	0.087	0.107

Specification of OFL and Maximum Permissible ABC

Dark, Widow, and Yellowtail

As described in the above section dark, widow and yellowtail rockfish fall into tier 5 of the overfishing definitions, in which estimates of biomass and natural rate of mortality (M) are the only parameters known. For tier 5 species, F_{OFL} is defined equal to M. This results into a 2008 Gulf-wide OFL of 678 mt. This estimate can be broken down into 599 mt for dark rockfish, 9 mt for widow rockfish, and 68 mt for yellowtail rockfish.

Dusky Rockfish

Female spawning biomass for 2008 is estimated at 23,486 mt. This is above the $B_{40\%}$ value of 17,727 mt. 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 2008, yields the following ABC and OFL:

$F_{40\%}$	0.087
ABC	4,719
$F_{35\%}$	0.107
OFL	5,722

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 as dark, widow, and yellowtail rockfish that are not modeled (tier 4 or higher), such projections are not possible, but yields for just the year 2008 can be computed for scenarios 1-5.

Dark, Widow, and Yellowtail
Scenario 1: In all future years, *F* is set equal to *max* F_{ABC}. (Rationale: For tier 5 species (dark, widow, yellowtail) F is set equal to *max* F_{ABC} = 0.75 x M (0.07), and the corresponding yield is 508 mt.)

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 2008 recommended in the assessment to the *max* F_{ABC} for 2008. (Rationale: For tier 5 species (dark, widow, yellowtail) F is set equal to the recommended F_{ABC} = 0.75 x M (0.07), and the corresponding yield is 508 mt.)

Scenario 3: In all future years, *F* is set equal to 50% of *max* F_{ABC}. (Rationale: For tier 5 species (dark, widow, yellowtail) F is set equal to 50% of max F_{ABC} = 50% of 0.75 x M (0.07), and the corresponding yield is 254 mt.)

Scenario 4: In all future years, *F* is set equal to the 2003-2007 average *F*. (Rationale: For tier 5 species (dark, widow, yellowtail) F is set equal to the average F for 2001-2005. The average F for 2003-2005 is 0.75 x M (0.09) and 0.75 x M (0.07) for the years 2006-2007, and the corresponding yield is 595 mt.)

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 2007 numbers-at-age estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2007. 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. For the first three years, an estimated catch is used that is equal to the current ratio of catch to TAC. In subsequent years, total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 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 2008, 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 F_{ABC} value for 2008 recommended in the assessment to the *max* F_{ABC} for 2008. (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 pre-specified catches for 2008 and 2009 to provide a more accurate short-term projection of spawning biomass and ABC for species such as dusky where much of the ABC goes unharvested.

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 2003-2007 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 2008 or 2) above ½ of its MSY level in 2008 and above its MSY level in 2018 under this scenario, then the stock is not overfished.)

Scenario 7: In 2008 and 2009, *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 2020 under this scenario, then the stock is not approaching an overfished condition.)

Status Determination (Dusky Rockfish only)

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 overfished? This depends on the stock's estimated spawning biomass in 2008:

a) If spawning biomass for 2008 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2008 is estimated to be above $B_{35\%}$, the stock is above its MSST.
c) If spawning biomass for 2008 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 13-9). If the mean spawning biomass for 2018 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 (Table 13-9):

a) If the mean spawning biomass for 2008 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2008 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2008 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2020. If the mean spawning biomass for 2020 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

A summary of the results of these scenarios for dusky rockfish is in Table 13-9. For dusky rockfish the stock is not overfished and is not approaching an overfished condition.

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 2003, 2005, and 2007 trawl surveys, the percent distribution of pelagic shelf rockfish biomass in the Gulf of Alaska is: Western area 20%; Central area 69%, and Eastern area 11%. Applying these percentages to the ABC of dark, widow, and yellowtail (508 mt) yields the following apportionments for the Gulf in 2008: Western area 98 mt; Central area 353 mt; and Eastern area 58 mt. Applying these percentages to the ABC of dusky rockfish (4,719 mt) yields the following apportionments for the Gulf in 2008: Western area, 905 mt; Central area, 3,274 mt; and Eastern area, 540 mt (Table 13-10). The total ABC apportionments for the pelagic shelf rockfish complex in 2008 are: Western area, 1,003 mt; Central area, 3,626 mt; and Eastern area, 598 mt.

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 0.420, so that the pelagic shelf rockfish complex ABC for West Yakutat would be 251 mt (24 mt for other pelagics and 227 mt for dusky rockfish), and the ABC for East Yakutat/Southeast Outside would be 347 mt (34 mt for other pelagics and 313 mt for dusky rockfish, Table 13-10).

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, and 2005 surveys showed the percentages in West Yakutat were 67.5, 43.8, 61.3 and 61.0, respectively. In 2007, West Yakutat comprised 52.0% 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., $F_{OFL} = F_{35\%}$=0.108), overfishing is set equal to 5,722 mt for dusky rockfish. For tier 5 species, F_{OFL} is defined to equal M, and F_{ABC} is <= 0.75 x M. This equates into a 2008 Gulfwide OFL of 678 mt for dark, widow, and yellowtail rockfish. The combined 2008 OFL for pelagic shelf rockfish is 6,400 mt (Table 13-10).

Other Considerations

Management Problems Involving Dark Rockfish

Although black and blue rockfish have been removed from the pelagic shelf assemblage, one management problem that remains is the taxonomic distinction between dusky rockfish and dark rockfish. We note that the two 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). *Sebastes 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 a common name dusky rockfish. The inshore habitat of dark rockfish is one that this variety shares with black and blue rockfish. This suggests that from a biological perspective, it may be more logical for dark rockfish to be grouped with the latter two species, rather than in the pelagic shelf assemblage. Moreover, information from ADF&G indicates that in past years a sizeable portion (perhaps 25%) of the fish reported as black rockfish in the Kenai Peninsula jig fishery may have actually been dark dusky rockfish.[5] Dark rockfish and black rockfish often co-occur in nearshore kelp beds of the Gulf of Alaska, and they are superficially similar in appearance, especially in body color, which leads to misidentification.

In 2003 we recommended removing dark rockfish from the pelagic shelf assemblage and transferring it to state jurisdiction when it was determined to be a valid species. This recommendation is similar to what has been done for black and blue rockfish. Since official recognition as a separate species, the GOA Plan Team has also endorsed removing dark rockfish from the FMP based on the following rationale: (1) separation at species level, (2) distribution of dark rockfish to nearshore habitats that are not specifically assessed by the GOA trawl survey, and (3) the risk of overfishing dark rockfish in local areas given the relatively high TAC for the pelagic shelf rockfish assemblage as a whole. In 2004, the SSC endorsed the rationale and agreed with the Plan Team’s recommendation of removing dark rockfish from the FMP.

In March, 2007, the North Pacific Fishery Management Council took final action to remove dark rockfish from both the GOA FMP (PSR Complex) 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. At this time, the rules to implement these FMP amendments have not yet been finalized. Thus it is unlikely the effective date for Amendments 77/73 will occur before January, 2009. Therefore, it would not be until 2009 that dark rockfish would be removed from Federal management (including the associated contribution to OFLs and ABCs under the respective complexes in both regions) and full management authority would be turned over to the State. 2008 ABC’s and OFLs presented in this assessment are for the PSR complex including dark rockfish but point estimates for individual species are included for comparative purposes.

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 13-11. Additionally, we include a summary of non-target species bycatch estimates and proportion of total catch for Gulf of Alaska rockfish targeted fisheries 2003-2005 (Table 13-12).

[5] W. Bechtol, Alaska Department of Fish and Game, 3298 Douglas St., Homer, AK 99603. Pers. commun. August 1995.

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. Adult dusky rockfish consume mostly euphausiids (Yang 1990). 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.

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.

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

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 13-2 (length frequency in the commercial fishery) and Table 13-5 (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 13-7 suggest that in the 1990's the fishery may have caught a sizeable number of immature fish.

Fishery-specific effects on EFH 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.

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 will change fishing patterns 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. We hope to explore different techniques and determine the most appropriate method for weighting sample sizes for use in rockfish models.

Summary

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

Dark, Widow, and Yellowtail	Last Year's Estimates[7]		This Year's Estimates:	
	2007	2008	**2008**	2009
Tier 5				
Exploitable Biomass (mt)	--	--	**9,628**	--
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 (mt, maximum allowable)	551	551	**508**	508
OFL (mt)	735	735	**678**	678
Dusky rockfish	**Last Year's Model Projection Not Updated**		**This Year's Projection Revised Model**	
	2007	2008	**2008**	2009*
Tier 3a				
Total Biomass (age 4+)			**68,253**	64,147
Exploitable Biomass	--	--	**72,253**	--
Female Spawning Biomass (mt)	26,401	27,023	**23,486**	22,796
$B_{0\%}$ (mt, female spawning)				
$B_{40\%}$ (mt)	--	--	**17,727**	--
$B_{35\%}$ (mt, female spawning)			**15,511**	--
M	0.07	0.07	**0.07**	0.07
F_{ABC} (maximum allowable = $F_{40\%}$)	0.088	0.088	**0.087**	0.087
F_{OFL} ($F_{35\%}$)	0.108	0.108	**0.107**	0.107
$ABC_{F40\%}$ (mt yield at $F_{40\%}=F_{max}$)	4,991	6,071	**4,719**	4,632
OFL (mt, yield at $F_{35\%}$)	5,723	7,451	**5,722**	5,616
Pelagic Shelf Rockfish Complex	**Last Year's Estimates:**		**This Year's Projection:**	
	2007	2008	**2008**	2009*
Exploitable Biomass	--	--	**81,935**	--
M	0.07	0.07	**0.07**	0.07
$ABC_{F40\%}$ (mt, maximum allowable)	5,436	5,530	**5,227**	5,140
OFL (mt, $F_{35\%}$)	6,662	6,779	**6,400**	6,294

*The 2009 ABC and OFL for dusky rockfish were projected using an expected catch value of 3,081 mt for 2008, 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 13-9 in response to management requests for a more accurate one-year projection.

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. We hope that we will be able to obtain larger sample sizes of age data in the future. This will allow us to develop an age error transition matrix applicable to dusky rockfish rather than assuming the same age determination error found for northern rockfish. The current

[7] 2006 Gulf of Alaska PSR SAFE, Executive Summary

sample sizes are too small to be precise for any ages away from the center of the distribution. 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.

Plan Team Summaries

Stock Assemblage	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Pelagic Shelf Rockfish	2006	97,386	6,662	5,436	5,436	2,446
	2007		6,458	5,542	5,542	3,278
	2008	70,823	6,400	5,227		
	2009		6,294	5,140		

[1]Total biomass from trawl survey estimates for dark, widow and yellowtail rockfish and age-structured model for dusky rockfish

Stock		2007				2008		2009	
Assemblage	Area	OFL	ABC	TAC	Catch[2]	OFL	ABC	OFL	ABC
Pelagic Shelf Rockfish	W		1,466		589		1,003		986
	C		3,325		2,395		3,626		3566
	WYAK		307		293		251		247
	EYAK/SEO		444		1		347		341
	Total	6,458	5,542		3,278	6,400	5,227	6,294	5,140

[2]Current as of October 3, 2007 (http://www.fakr.noaa.gov/2007/car110_goa.pdf)

Literature Cited

Ackley, D. R., and J. Heifetz. 2001. Fishing practices under maximum retainable bycatch rates in Alaska's groundfish fisheries. Alaska Fish. Res. Bull. 8(1): 22-44.

Archibald, C. P., W. Shaw, and B. M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B. C. coastal waters, 1977-79. Can. Tech. Rep. Fish. Aquat. Sci. 1048. 57p.

Berkeley, S. A., C. Chapman, and S. M. Sogard. 2004. Maternal age as a determinant of larval growth and survival in a marine fish, *Sebastes melanops*. Ecology 85(5):1258-1264.

Bobko, S.J. and S.A. Berkeley. 2004. Maturity, ovarian cycle, fecundity, and age-specific parturition of black rockfish (*Sebastes melanops*). Fisheries Bulletin 102:418-429.Chilton, D. E., and R. J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60: 102 p.

Clausen, D. M., and J. Heifetz. 1989. Pelagic shelf rockfish. In T. K. Wilderbuer (editor), Condition of groundfish resources of the Gulf of Alaska in 1988, p. 171-181. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-165.

Clausen, D. M., and J. Heifetz. 1991. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the 1992 Gulf of Alaska groundfish fishery, p. 7-1 - 7-12. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D. M., and J. Heifetz. 1993. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1994, p. 7-1 - 7-13. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D. M., and J. Heifetz. 1994. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1995, p. 7-1 - 7-15. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D. M., and J. Heifetz. 1995. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1996, p. 7-1 - 7-17. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D. M., and J. Heifetz. 1996. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 271-288. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D. M., and J. Heifetz. 1997. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 289-308. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D. M., and J. Heifetz. 1998. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 331-348. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D. M., and J. Heifetz. 1999. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 405-425. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D. M., and J. Heifetz. 2000. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 295-314. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D. M., and J. Heifetz. 2001. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 7-1 - 7-25. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D. M., C. R. Lunsford, and J. T. Fujioka. 2002. Pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 383-418. North Pacific Fishery Management Council, 605 W. 4th. Avenue, Suite 306, Anchorage, AK 99501-2252.

Clausen, D. M., J. T. Fujioka, and J. Heifetz. 2003. Shortraker/rougheye and other slope rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 531 – 572. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501.

Courtney, D.L., J. Heifetz, M. F. Sigler, and D. M. Clausen. 1999. An age structured model of northern rockfish, *Sebastes polyspinis*, recruitment and biomass in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2000, p. 361-404. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Courtney, D.L., J. N. Ianelli, D. Hanselman, and J. Heifetz. 2007. Extending statistical age-structured assessment approaches to Gulf of Alaska rockfish (*Sebastes* spp.). In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 429–449.

De Bruin, J., R. Gosden, C. Finch, and B. Leaman. 2004. Ovarian aging in two species of long-lived rockfish, *Sebastes aleutianus* and *S. alutus*. Biol. Reprod. 71:1036-1042.

Freese, J.L. and B.L. Wing. 2003. Juvenile red rockfish, *Sebastes* sp., associations with sponges in the Gulf of Alaska. Mar. Fish. Rev. 65:38-42.

Goodman, D., M. Mangel, G. Parkes, T.J. Quinn II, V. Restrepo, T. Smith, and K. Stokes. 2002. Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish Fishery Management Plans. Draft report. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hanselman, D., Spencer, P., Shotwell, K., and Reuter, R. 2007. Localized depletion of three Alaska rockfish species. In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 493 – 511.

Hoenig. J. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82:898-903.

Krieger, K.J., and B.L. Wing. 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the Gulf of Alaska. Hydrobiologia 471: 83-90.

Leaman, B. M. 1991. Reproductive styles and life history variables relative to exploitation and management of *Sebastes* stocks. Environmental Biology of Fishes 30: 253-271.

Leaman, B.M. and R.J. Beamish. 1984. Ecological and management implications of longevity in some Northeast Pacific groundfishes. Int. North Pac. Fish. Comm. Bull. 42:85-97.

Leaman, B.M. and D.A. Nagtegaal. 1987. Age validation and revised natural mortality rate for yellowtail rockfish. Trans. Am. Fish. Soc. 116:171-175.

Longhurst, A., 2002. Murphy's law revisited: longevity as a factor in recruitment to fish populations.. Fish. Res. 56:125-131.

Lunsford, C.R., S.K. Shotwell, D.H. Hanselman, D.M.Clausen, and D.L. Courtney. 2005. Gulf of Alaska pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 727-780, Appendix A. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501.

Malecha, P.W., and J. Heifetz. 2004. Growth and mortality of rockfish (Scorpaenidae) from Alaska waters. In Review, 39 p. Available from the Auke Bay Laboratory, NMFS, NOAA, 11305 Glacier Hwy, Juneau, AK 99801.

Martin, M. H. 1997. Data report: 1996 Gulf of Alaska bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-82. 235 p.

National Marine Fisheries Service. 2001. Alaska groundfish fisheries draft programmatic supplemental environmental impact statement. Available from Alaska Region, National Marine Fisheries Service, Box 21668, Juneau, AK 99802.

Orr, J. W., and J. E. Blackburn. 2004. The dusky rockfishes (Teleostei: Scorpaeniformes) of the North Pacific Ocean: resurrection of *Sebastes variabilis* (Pallas, 1814) and a redescription of *Sebastes ciliatus* (Tilesius, 1813). Fish. Bull., U.S. 102:328-348. Online. (.pdf, 569KB).

Reuter, R. F. 1999. Describing dusky rockfish (*Sebastes ciliatus*) habitat in the Gulf of Alaska using historical data. M.S. Thesis, California State University, Hayward CA. 83 p.

Seeb, L. W. 1986. Biochemical systematics and evolution of the Scorpaenid genus *Sebastes*. Ph.D. Thesis, Univ. Washington, Seattle, WA. 177 p.

Yang, M-S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-22. 150 p.

Table 13-1a. Commercial catch[a] (mt) 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, 1988-2007.

Year	Category[c]	Regulatory Area[b] 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[5f]	U.S.	589	2395	294	293	1	3,278	5,542	5,542

Management Actions

[1] Pelagic shelf rockfish complex 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 and separate ABCs and TACs assigned.

[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.

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 3, 2007.

Table 13-1b. Estimated catch (mt) history for dusky rockfish. Values from 1977-2007 are a combination of foreign observer data, joint venture catch data, and NMFS Regional Office blend 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	1017
1984	540
1985	34
1986	17
1987	19
1988	1067
1989	1707
1990	1612
1991	2190
1992	3565
1993	3132
1994	2938
1995	2868
1996	2289
1997	2626
1998	3110
1999	4538
2000	3701
2001	2999
2002	3305
2003	3020
2004	2553
2005	2207
2006	2428
2007[a]	3245

[a] Catch updated through 10/03/07.

Table 13-1c. Catch (mt) of pelagic shelf rockfish taken during research cruises in the Gulf of Alaska, 1977-2007. (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

Table 13-2. 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	2005	2006	2007
≤21	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0.001	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0.001	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0.002	0	0	0	0.003	0	0	0	0	0	0.000	0	0.001
28	0	0.002	0	0.002	0	0.003	0	0	0	0.001	0	0	0	0.001
29	0.001	0.003	0	0.001	0	0.011	0	0	0	0	0	0	0	0.001
30	0.003	0.005	0	0.002	0	0.017	0	0	0	0	0	0.000	0	0
31	0.003	0.012	0	0.001	0	0.008	0.001	0	0	0	0	0.000	0	0
32	0.003	0.013	0	0	0	0.006	0.002	0	0	0	0.001	0.001	0.002	0
33	0.005	0.016	0	0.002	0	0.019	0.004	0	0	0	0.001	0.000	0	0.003
34	0.008	0.019	0	0.001	0	0.011	0.009	0	0	0.001	0.001	0.001	0.005	0.003
35	0.025	0.019	0	0.004	0.003	0.006	0.021	0	0.002	0.003	0.003	0.003	0.004	0.004
36	0.029	0.015	0	0.004	0.005	0.014	0.028	0	0.002	0.006	0.005	0.005	0.006	0.005
37	0.019	0.016	0.001	0.003	0.004	0.011	0.045	0.001	0.001	0.008	0.004	0.003	0.012	0.012
38	0.024	0.027	0.001	0.009	0.003	0.003	0.044	0.005	0.004	0.013	0.014	0.013	0.022	0.015
39	0.069	0.037	0.006	0.004	0.012	0.008	0.036	0.009	0.006	0.02	0.022	0.016	0.039	0.016
40	0.084	0.111	0.02	0.019	0.016	0.033	0.04	0.023	0.011	0.029	0.036	0.034	0.039	0.034
41	0.134	0.121	0.046	0.041	0.029	0.053	0.065	0.051	0.028	0.052	0.052	0.052	0.06	0.057
42	0.145	0.127	0.103	0.074	0.046	0.069	0.096	0.104	0.079	0.088	0.088	0.084	0.083	0.073
43	0.14	0.115	0.145	0.076	0.077	0.092	0.117	0.146	0.115	0.112	0.106	0.105	0.106	0.097
44	0.136	0.115	0.2	0.146	0.087	0.108	0.123	0.175	0.164	0.145	0.147	0.148	0.123	0.109
45	0.086	0.099	0.197	0.171	0.124	0.128	0.13	0.167	0.181	0.139	0.149	0.152	0.142	0.122
46	0.057	0.071	0.151	0.176	0.136	0.136	0.103	0.125	0.149	0.135	0.137	0.141	0.127	0.131
47+	0.034	0.05	0.131	0.266	0.459	0.261	0.137	0.192	0.258	0.247	0.233	0.239	0.23	0.317
Sample size	582	1141	653	595	312	120	637	597	933	2046	1235	1517	1772	3481

Table 13-3. Fishery age compositions for dusky rockfish in the Gulf of Alaska. Ages 4 and below are pooled. Pooled age 21+ includes all fish 21 and older.

Age(yr)	2000	2001	2002	2004
≤4	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000
6	0.002	0.002	0.000	0.000
7	0.000	0.004	0.007	0.007
8	0.012	0.004	0.009	0.009
9	0.007	0.043	0.011	0.011
10	0.036	0.035	0.104	0.104
11	0.048	0.068	0.109	0.109
12	0.143	0.077	0.095	0.095
13	0.206	0.132	0.064	0.064
14	0.211	0.170	0.154	0.154
15	0.099	0.161	0.134	0.134
16	0.051	0.089	0.120	0.120
17	0.027	0.060	0.052	0.052
18	0.015	0.031	0.025	0.025
19	0.015	0.012	0.011	0.011
20	0.012	0.017	0.007	0.007
21+	0.116	0.097	0.098	0.098
Sample size	413	517	441	452

Table 13-4a. Biomass estimates (mt) 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
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 13-4a (continued). Biomass estimates (mt) 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

[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.

Table 13-4b. 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

Table 13-5. 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
≤21	0	0.002	0	0.005	0.003	0.001	0.007	0.001	0.004	0
22	0	0.001	0.008	0.002	0.002	0.001	0.002	0.004	0.001	0
23	0	0.001	0.004	0.004	0.004	0.001	0.003	0	0.001	0
24	0	0	0.002	0.007	0.003	0	0.005	0.001	0.002	0
25	0	0	0.006	0.002	0.003	0.002	0.003	0	0.002	0.001
26	0	0.001	0	0.015	0.001	0	0.004	0.004	0.001	0.001
27	0	0	0.007	0.018	0.001	0.001	0.006	0.017	0.001	0.001
28	0.002	0	0.006	0.023	0.001	0	0.002	0.024	0.001	0.001
29	0.001	0	0.007	0.021	0.005	0.001	0.022	0.027	0.004	0.001
30	0.004	0.002	0	0.03	0.002	0.002	0.024	0.044	0.005	0.003
31	0.009	0.001	0.001	0.039	0.002	0.006	0.029	0.027	0.010	0.001
32	0.014	0.005	0.007	0.051	0.002	0.008	0.033	0.031	0.014	0.004
33	0.016	0.002	0.001	0.043	0.007	0.008	0.026	0.053	0.016	0.003
34	0.037	0.018	0.003	0.04	0.003	0.013	0.03	0.008	0.019	0.010
35	0.051	0.041	0.001	0.046	0.006	0.015	0.026	0.011	0.021	0.013
36	0.07	0.066	0.002	0.053	0.001	0.015	0.042	0.013	0.046	0.013
37	0.066	0.1	0.004	0.037	0.009	0.016	0.039	0.043	0.026	0.017
38	0.092	0.089	0.006	0.048	0.009	0.019	0.04	0.077	0.052	0.024
39	0.129	0.079	0.019	0.051	0.016	0.016	0.059	0.072	0.031	0.049
40	0.136	0.108	0.017	0.051	0.036	0.03	0.061	0.066	0.042	0.070
41	0.129	0.139	0.077	0.035	0.08	0.035	0.071	0.050	0.046	0.077
42	0.101	0.114	0.125	0.044	0.065	0.075	0.06	0.050	0.072	0.110
43	0.061	0.109	0.115	0.061	0.127	0.103	0.064	0.065	0.092	0.106
44	0.036	0.059	0.153	0.064	0.133	0.114	0.058	0.070	0.101	0.115
45	0.021	0.027	0.175	0.073	0.111	0.15	0.083	0.065	0.100	0.098
46	0.012	0.018	0.151	0.065	0.113	0.141	0.076	0.062	0.100	0.098
47+	0.014	0.019	0.104	0.075	0.256	0.231	0.127	0.114	0.189	0.185
Sample Size	2055	2818	1182	2871	1632	1420	1297	1889	3606	1819

Table 13-6. Trawl survey age compositions for dusky rockfish in the Gulf of Alaska. Ages 4 and below are pooled. Pooled age 21+ includes all fish 21 and older.

Age (yr)	1984	1987	1990	1993	1996	1999	2001	2003	2005
≤4	0.000	0.000	0.008	0.004	0.013	0.001	0.014	0.002	0.006
5	0.000	0.000	0.005	0.058	0.007	0.001	0.006	0.072	0.008
6	0.000	0.000	0.003	0.094	0.014	0.001	0.081	0.114	0.029
7	0.067	0.192	0.001	0.193	0.004	0.056	0.074	0.011	0.060
8	0.258	0.003	0.001	0.088	0.025	0.013	0.052	0.288	0.063
9	0.108	0.047	0.007	0.119	0.049	0.047	0.188	0.073	0.038
10	0.142	0.155	0.115	0.031	0.188	0.033	0.095	0.019	0.100
11	0.155	0.213	0.134	0.032	0.111	0.113	0.093	0.064	0.088
12	0.129	0.109	0.086	0.020	0.148	0.271	0.037	0.037	0.058
13	0.058	0.057	0.114	0.048	0.045	0.121	0.066	0.035	0.150
14	0.015	0.034	0.171	0.022	0.030	0.065	0.099	0.019	0.064
15	0.048	0.043	0.139	0.039	0.033	0.025	0.061	0.044	0.034
16	0.007	0.014	0.043	0.045	0.015	0.015	0.034	0.066	0.037
17	0.000	0.027	0.015	0.042	0.018	0.001	0.013	0.033	0.034
18	0.000	0.012	0.055	0.016	0.052	0.021	0.009	0.016	0.035
19	0.000	0.019	0.035	0.016	0.041	0.025	0.007	0.020	0.055
20	0.004	0.010	0.009	0.010	0.045	0.048	0.008	0.004	0.038
21+	0.010	0.065	0.061	0.123	0.165	0.146	0.062	0.083	0.101
Sample size	161	386	145	508	652	184	718	276	475

Table 13-7. 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. *In Review*. Growth and natural mortality of dark rockfish (*Sebastes ciliatus*) in the western Gulf of Alaska. 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 13-8a. Likelihoods and estimates of key parameters with estimates of standard error (σ) derived from Hessian matrix for this and last year's model for GOA dusky rockfish.

	Author Recommended		*2005 Model*
Likelihoods	Value	Weight	
Catch	15.19	10	15.26
Trawl Biomass	35.08	5	31.40
Fishery Ages	19.31	1	18.59
Survey Ages	70.11	1	61.43
Fishery Sizes	79.73	1	57.99
Data-Likelihood	**219.42**		**184.66**
Penalties/Priors			
Recruitment Devs	30.68	1	32.66
Fishery Selectivity	2.17	1	1.90
Trawl Selectivity	0.57	1	0.83
Fish-Sel Domeshape	0.00	1	0.00
Survey-Sel Domeshape	0.00	1	0.00
Average Selectivity	0.00	1	0.00
F Regularity	70.85	2	71.68
σ_r prior	0.14		0.02
q-prior	0.0005		0.00
Objective Fun. Total	***323.83***		***256.31***

Parameter Estimates	Value	σ	
q-trawl	1.014	0.158	0.811
σ_r	1.180	0.155	1.256
Log-mean-rec	0.432	0.187	0.430
$F_{40\%}$	0.087	0.024	0.088
Total Biomass (mt) 2007	70,980	15,292	86,893
B_{2008} (mt)	23,486		24,733
$B_{0\%}$ (mt)	44,316		45,727
$B_{40\%}$ (mt)	17,727		18,291
$ABC_{F40\%}$ (mt)	**4,719**		**4,885**
$F_{50\%}$	0.059	0.016	0.060
$ABC_{F50\%}$ (mt)	3,210		3,320

Table 13-8b. Estimates of key parameters (μ) with Hessian estimates of standard deviation (σ), MCMC standard deviations (σ (MCMC)) and 95% Bayesian confidence intervals (BCI) derived from MCMC simulations.

Parameter	μ	σ	σ(MCMC)	BCI-Lower	BCI-Upper
q1, trawl survey	1.014	0.158	0.154	0.657	1.265
$F_{40\%}$	0.087	0.024	0.035	0.057	0.185
Total Biomass	70,980	15,292	23,780	56,238	141,105
Female Sp. Biomass	23,907	5,160	6,545	18,211	43,518
ABC	4,719	1,267	2,621	3,119	13,320
σ_r	1.18	0.155	0.343	1.515	2.85

Table 13-9. 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 mt. $B_{40\%}$ = 17,727 mt, $B_{35\%}$ = 15,511 mt, $F_{40\%}$ = 0.087, and $F_{35\%}$ = 0.107.

Year	Maximum permissible F	Author's F (pre-specified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
				Spawning Biomass (mt)			
2007	23,406	23,406	23,406	23,406	23,406	23,406	23,406
2008	23,486	23,602	23,645	23,619	23,812	23,414	23,486
2009	22,796	23,582	23,889	23,697	25,066	22,319	22,796
2010	21,773	23,079	23,745	23,398	25,974	20,934	21,704
2011	20,622	21,819	23,359	22,882	26,622	19,486	20,178
2012	19,416	20,494	22,762	22,199	27,004	18,055	18,666
2013	18,349	19,311	22,148	21,548	27,308	16,843	17,369
2014	17,439	18,275	21,481	20,920	27,474	15,922	16,339
2015	16,874	17,571	21,001	20,516	27,755	15,393	15,724
2016	16,603	17,178	20,715	20,339	28,213	15,157	15,421
2017	16,476	16,946	20,540	20,252	28,673	15,068	15,276
2018	16,552	16,937	20,635	20,371	29,353	15,164	15,327
2019	16,696	17,009	20,888	20,559	30,078	15,316	15,444
2020	16,860	17,114	21,088	20,768	30,796	15,479	15,579
				Fishing Mortality			
2007	0.063	0.063	0.063	0.063	0.063	0.063	0.063
2008	0.087	0.056	0.044	0.052	-	0.107	0.107
2009	0.087	0.056	0.044	0.052	-	0.107	0.107
2010	0.087	0.087	0.044	0.052	-	0.107	0.107
2011	0.087	0.087	0.044	0.052	-	0.107	0.107
2012	0.087	0.087	0.044	0.052	-	0.107	0.107
2013	0.087	0.087	0.044	0.052	-	0.101	0.101
2014	0.084	0.087	0.044	0.052	-	0.095	0.095
2015	0.081	0.084	0.044	0.052	-	0.091	0.091
2016	0.079	0.081	0.044	0.052	-	0.089	0.089
2017	0.078	0.080	0.044	0.052	-	0.088	0.088
2018	0.078	0.079	0.044	0.052	-	0.088	0.088
2019	0.078	0.079	0.044	0.052	-	0.089	0.089
2020	0.078	0.079	0.044	0.052	-	0.089	0.089
				Yield (mt)			
2007	3,245	3,245	3,245	3,245	3,245	3,245	3,245
2008	4,719	3,081	2,409	2,837	-	5,722	4,719
2009	4,632	3,081	2,461	2,877	-	5,518	4,632
2010	4,236	4,488	2,344	2,720	-	4,955	5,136
2011	3,852	4,073	2,218	2,555	-	4,427	4,583
2012	3,495	3,688	2,090	2,391	-	3,946	4,083
2013	3,166	3,338	1,966	2,234	-	3,335	3,532
2014	2,835	3,055	1,876	2,121	-	2,908	3,057
2015	2,776	2,967	1,909	2,153	-	2,863	2,976
2016	2,773	2,928	1,948	2,192	-	2,883	2,970
2017	2,768	2,892	1,972	2,215	-	2,899	2,965
2018	2,833	2,932	2,015	2,264	-	2,991	3,042
2019	2,887	2,965	2,047	2,301	-	3,063	3,103
2020	2,939	3,001	2,076	2,334	-	3,131	3,161

Table 13-10. Allocation of 2008 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 mt.

Year	Weights	Western Gulf	Central Gulf	West Yakutat	SE/ Outside	Total
2003	4	6	75	16	3	100%
2005	6	46	52	1	1	100%
2007	9	7	79	7	7	100%
Weighted Mean		19.2	69.3	7.3	4.2	100%
Area Allocation						100%
Area ABC Dark, Widow, Yellowtail		**98**	**353**	**24**	**34**	**508**
Area ABC Dusky (mt)		**905**	**3,274**	**227**	**313**	**4,719**
Area ABC Total Pelagic Shelf		**1,003**	**3,626**	**251**	**347**	**5,227**
OFL Dark, Widow, Yellowtail (mt)						**678**
OFL Dusky (mt)						**5,722**
OFL Total Pelagic Shelf						**6,400**

Table 13-11. Analysis of ecosystem considerations for pelagic shelf rockfish and the dusky rockfish fishery.

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

Table 13-12. Nontarget species bycatch estimates in kilograms for Gulf of Alaska rockfish targeted fisheries 2003-2007.

	Estimated Catch (kg)				
Group Name	2003	2004	2005	2006	2007
Benthic urochordata	2	130		44	30
Birds	215				82
Birds Total	215				82
Bivalves	5			6	
Brittle star unidentified	161	2	47	93	8
Corals Bryozoans	1,903	60	6,125	360	2,259
Red Tree Coral	0	5		44	
Corals Bryozoans Total	1,904	65	6,125	404	2,259
Eelpouts	30	222	11,406	32	121
Eulachon	11	197	87	321	21
Giant Grenadier	139,261	418	134,043	277,147	122,516
Greenlings	8,372	6,923	3,541	5,959	6,821
Grenadier	480,913	2,835,239	95,761	65,538	70,296
Grenadier Total	480,913	2,835,239	95,761	65,538	70,296
Hermit crab unidentified	13	10	40	49	5
Invertebrate unidentified	441	938	98	43	
Lanternfishes (myctophidae)		0			0
Large Sculpins	123	42,999	16,476	28,465	26,486
Misc crabs	28	338	705	414	104
Misc crustaceans		24			
Misc fish	145,399	116,116	117,541	182,333	175,303
Misc inverts (worms etc)				10	
Octopus	654	425	193	468	46
Other osmerids	553	141	15	268	83
Other Sculpins	24,076	15,019	14,506	3,904	4,315
Pandalid shrimp	916	293	261	175	96
Polychaete unidentified	4				
Scypho jellies	660	2,920	150	438	204
Sea anemone unidentified	3,304	2,940	296	622	195
Sea pens whips		2	43		
Sea star	3,306	2,102	1,467	2,231	477
Shark, Other	208	221	178	1,614	327
Shark, pacific sleeper	275	628	150	386	39
Shark, salmon	12	120	500	620	693
Shark, spiny dogfish	35,460	2,107	2,760	2,002	1,826
Skate, Big		6,635	4,622	4,210	111
Skate, Longnose	864	16,270	9,348	8,093	14,363
Skate, Other	106,607	10,380	45,017	35,787	16,166
Snails	423	302	157	801	65
Sponge unidentified	3,815	1,140	1,130	949	610
Squid	9,139	11,905	1,526	9,844	2,955
Stichaeidae				13	
urchins dollars cucumbers	353	606	160	306	139
Grand Total	967,508	3,077,777	468,351	633,590	446,762

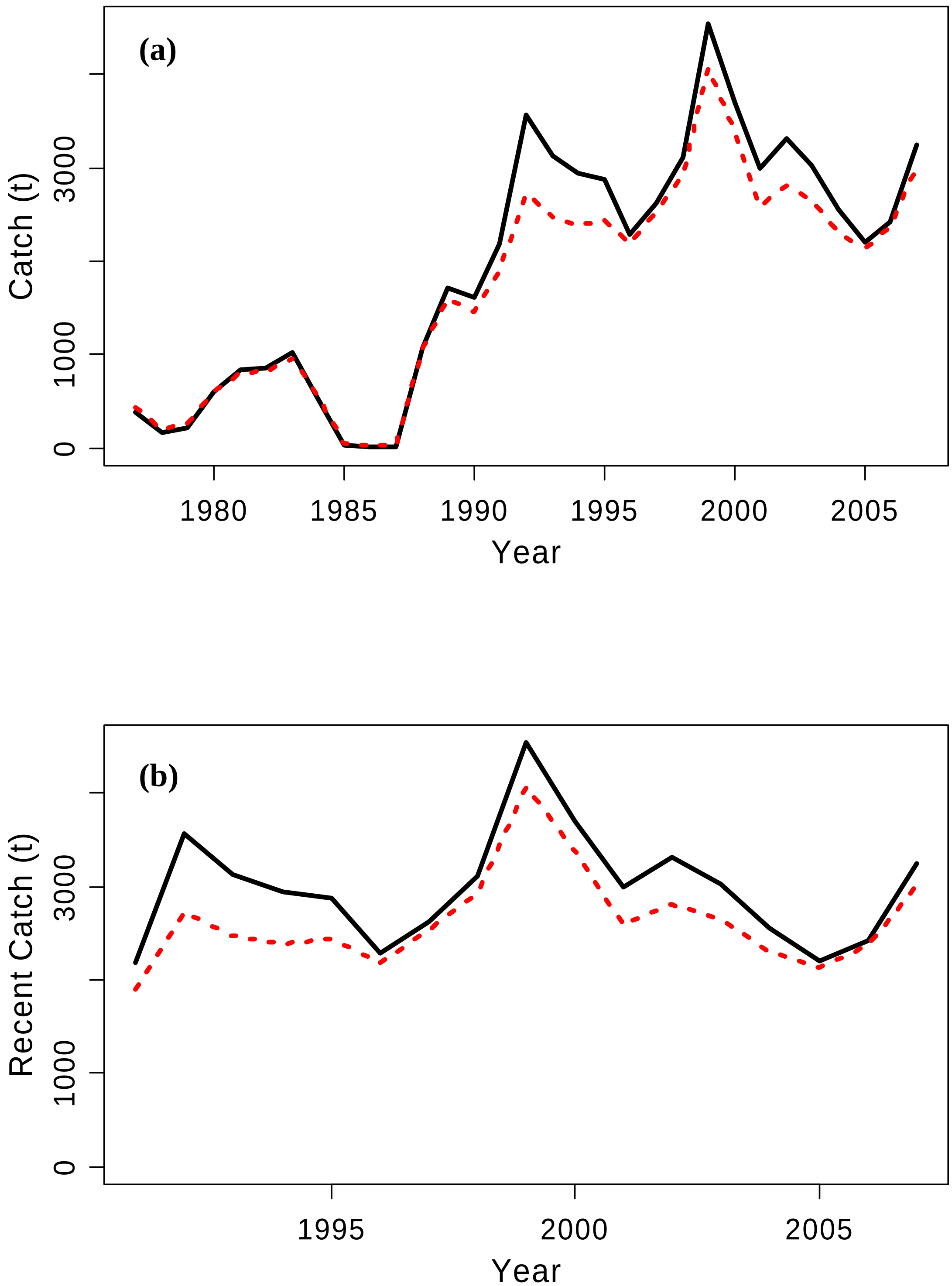


Figure 13-1. Estimated long-term (a) and short-term (b) commercial catches for GOA dusky rockfish. Observed is solid line, predicted author recommended model is dashed line.

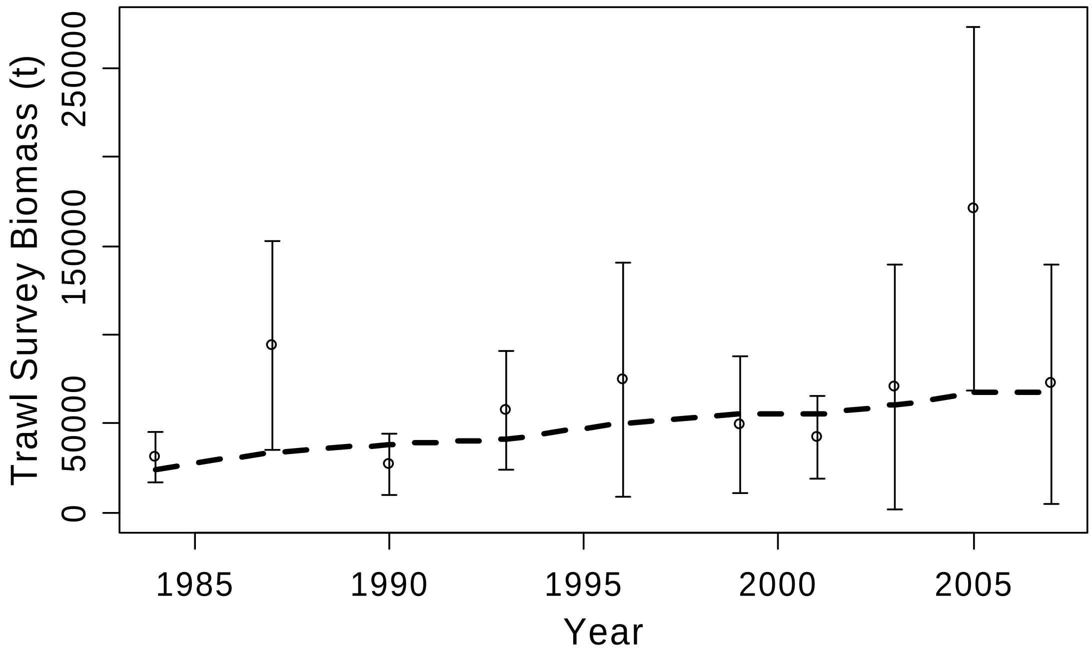


Figure 13-2a. Observed and predicted GOA dusky rockfish trawl survey biomass based on author recommended model. Observed biomass is circles with 95% confidence intervals of sampling error.

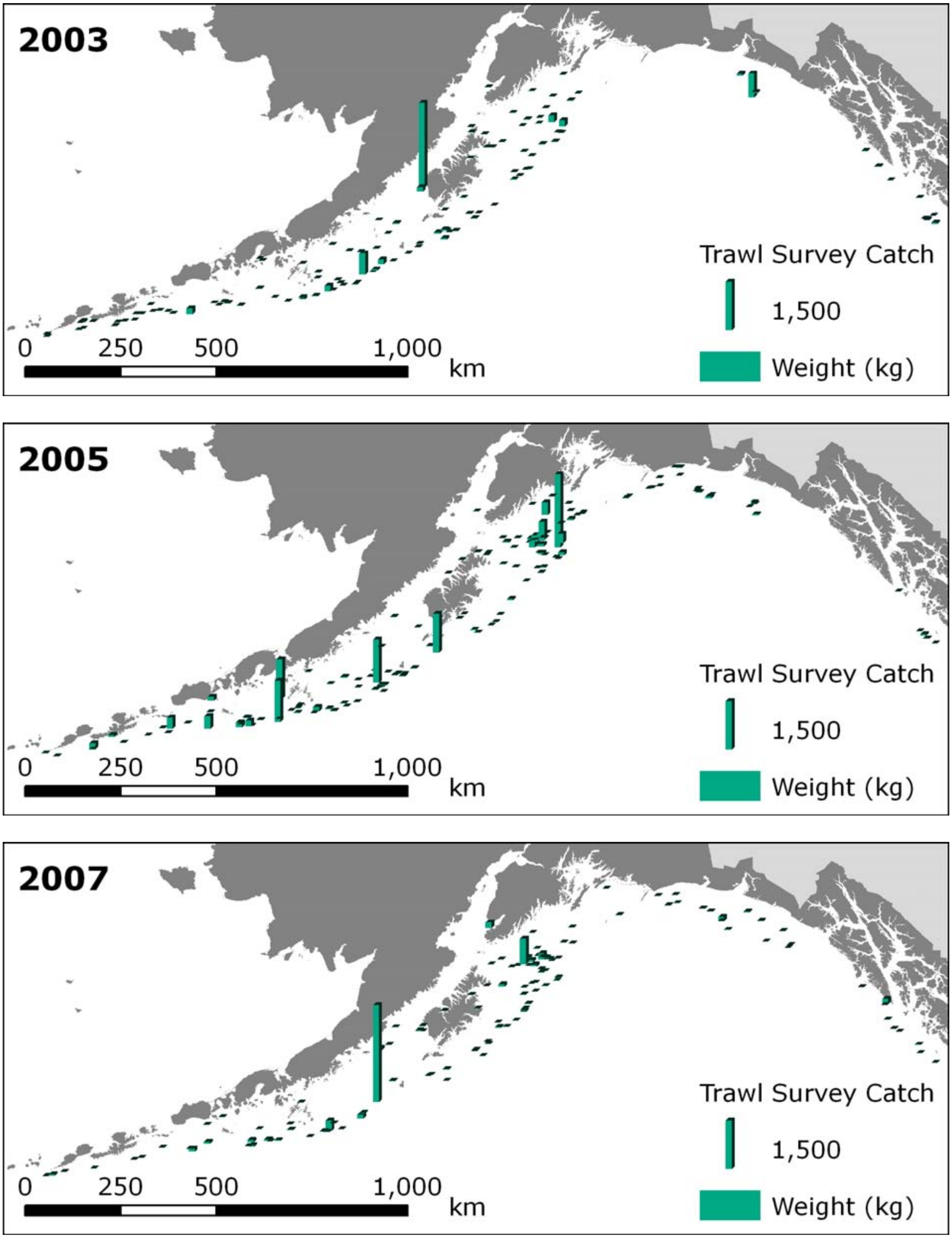


Figure 13-2b. Distribution of Gulf of Alaska dusky rockfish catches in the 2003, 2005, and 2007 NMFS groundfish trawl surveys.

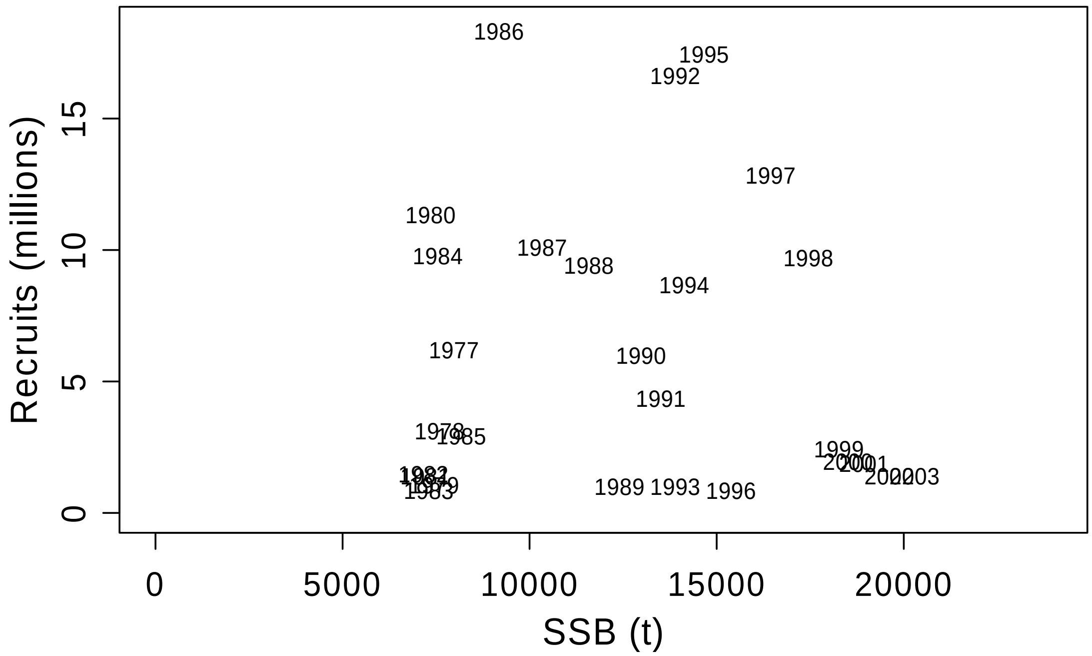


Figure 13-3. Scatterplot of spawner-recruit data for GOA dusky rockfish author recommended model. Label is year class of age 4 recruits. SSB = Spawning stock biomass in tons (t).

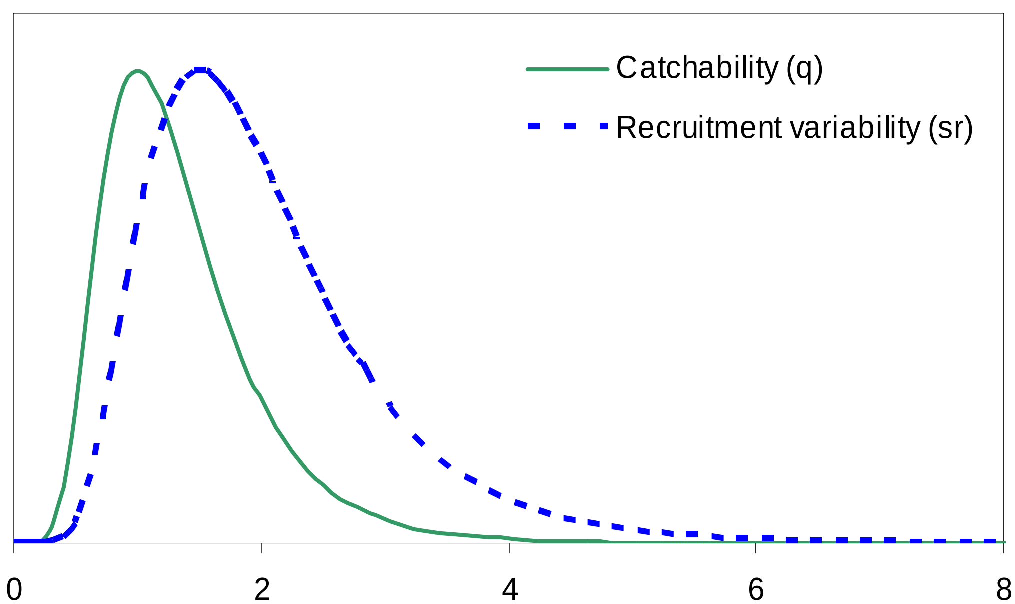


Figure 13-4. Prior distributions for catchability (q, μ=1, CV=45%) and recruitment variability (σ_r, μ=1.5, CV=45%) of GOA dusky rockfish, μ=0.05, CV=10%.

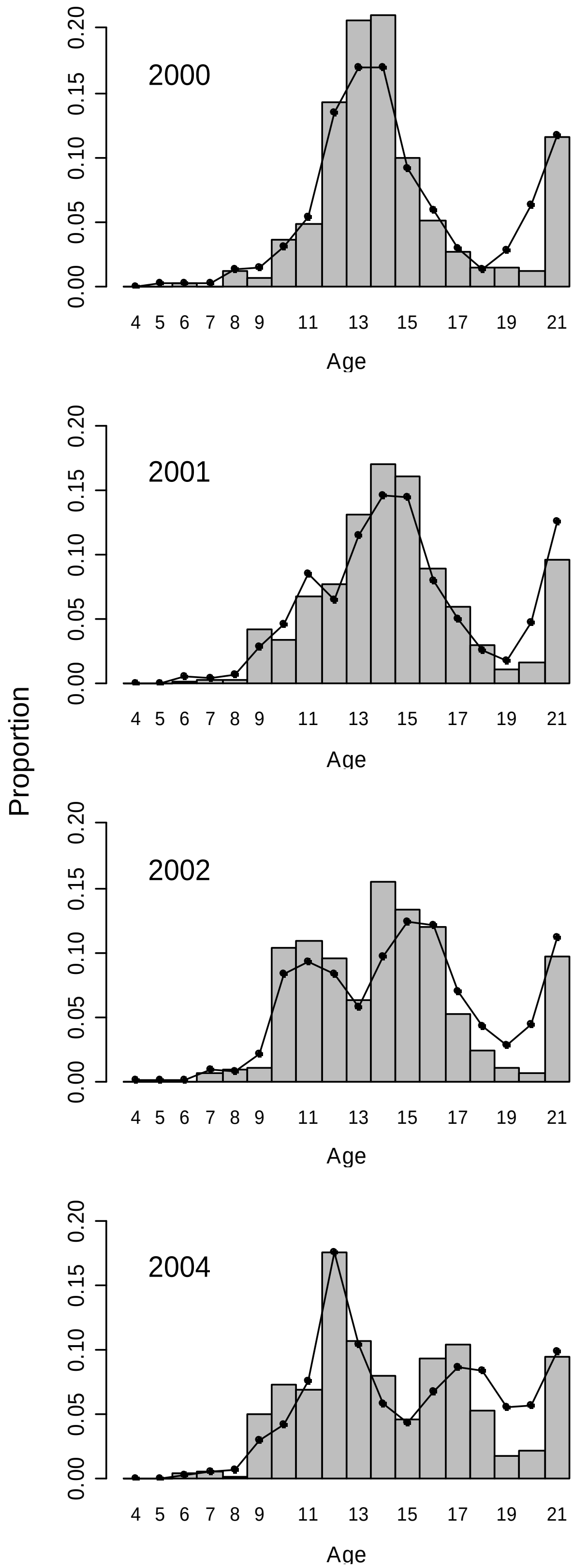


Figure 13-5. Fishery age compositions for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles.

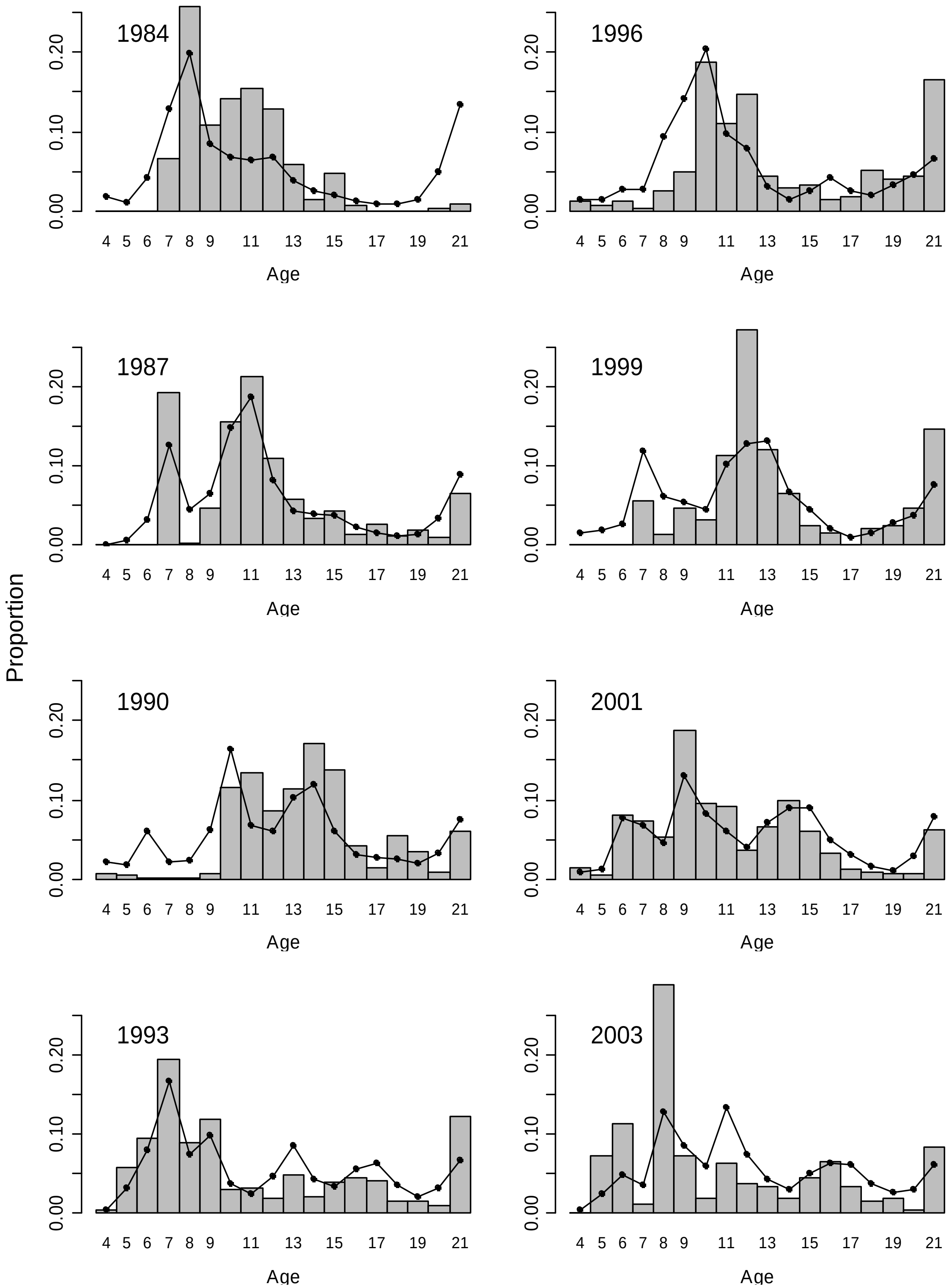


Figure 13-6. Trawl survey age composition by year for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles.

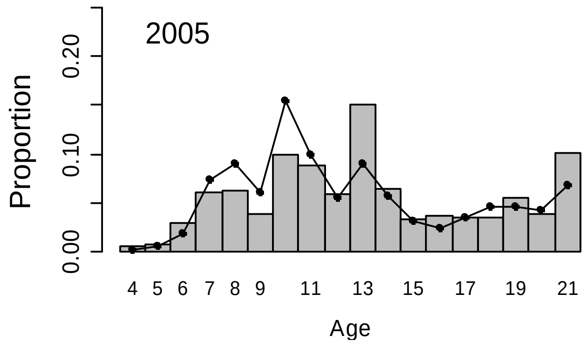


Figure 13-6 (continued). Trawl survey age composition by year for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles.

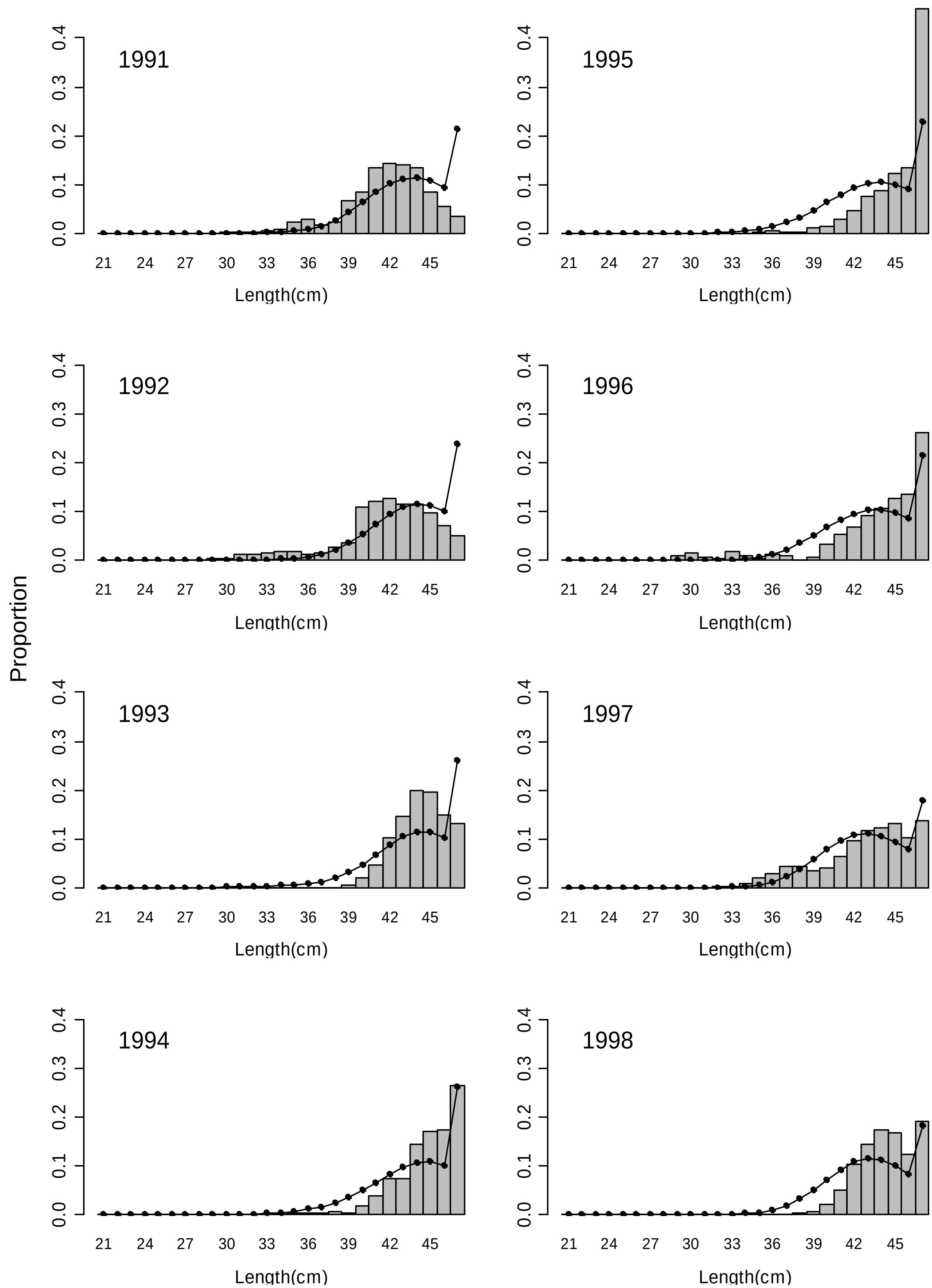


Figure 13-7. Fishery length compositions for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles.

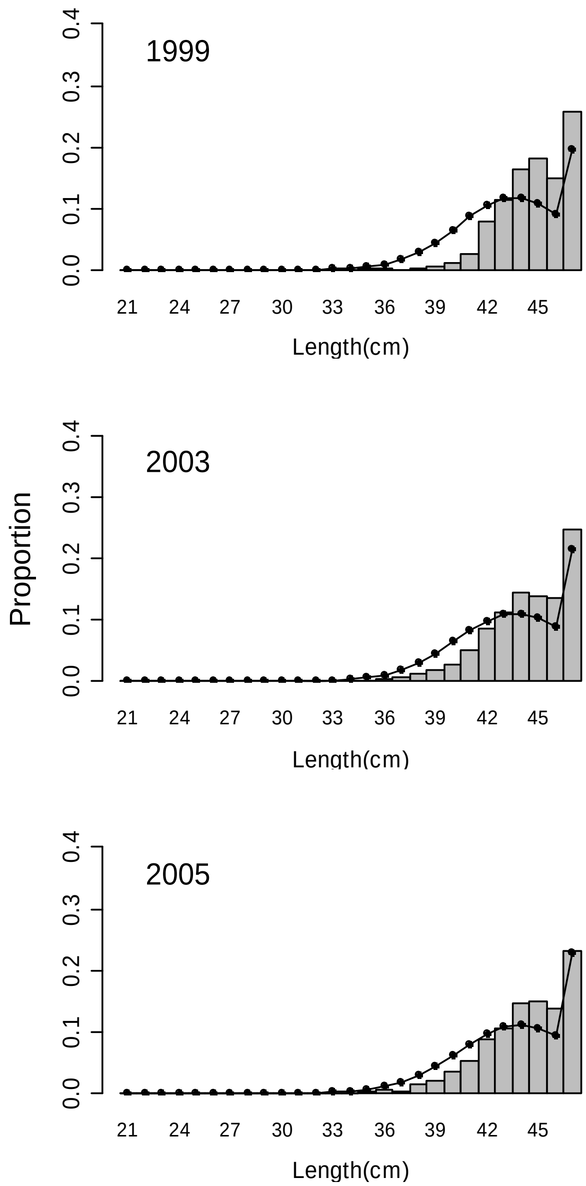


Figure 13-7 (continued). Fishery length compositions for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles.

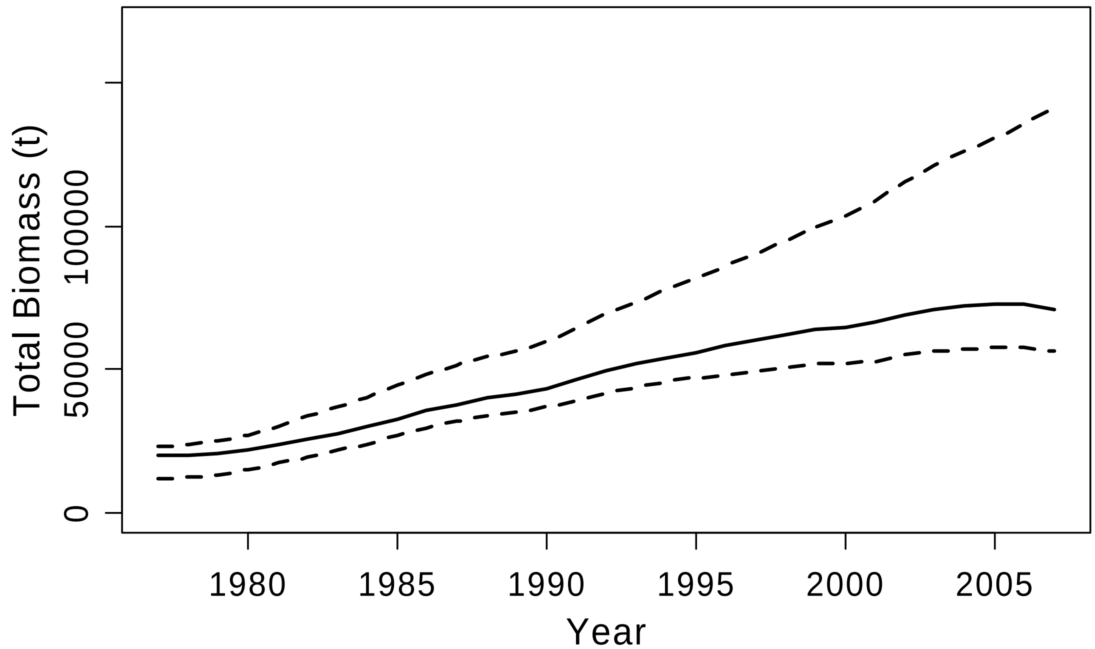


Figure 13-8. Time series of predicted total biomass of GOA dusky rockfish for author recommended model. Dashed lines represent 95% confidence intervals from 5 million MCMC runs.

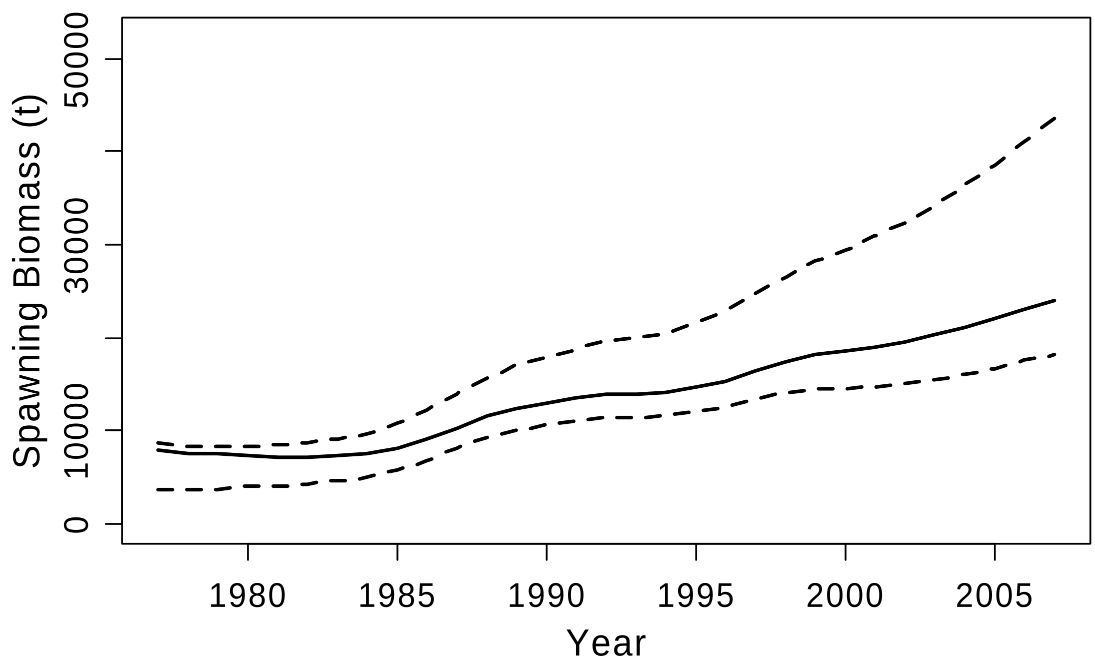


Figure 13-9. Time series of predicted spawning biomass of GOA dusky rockfish for author recommended model. Dashed lines represent 95% confidence intervals from 5 million MCMC runs.

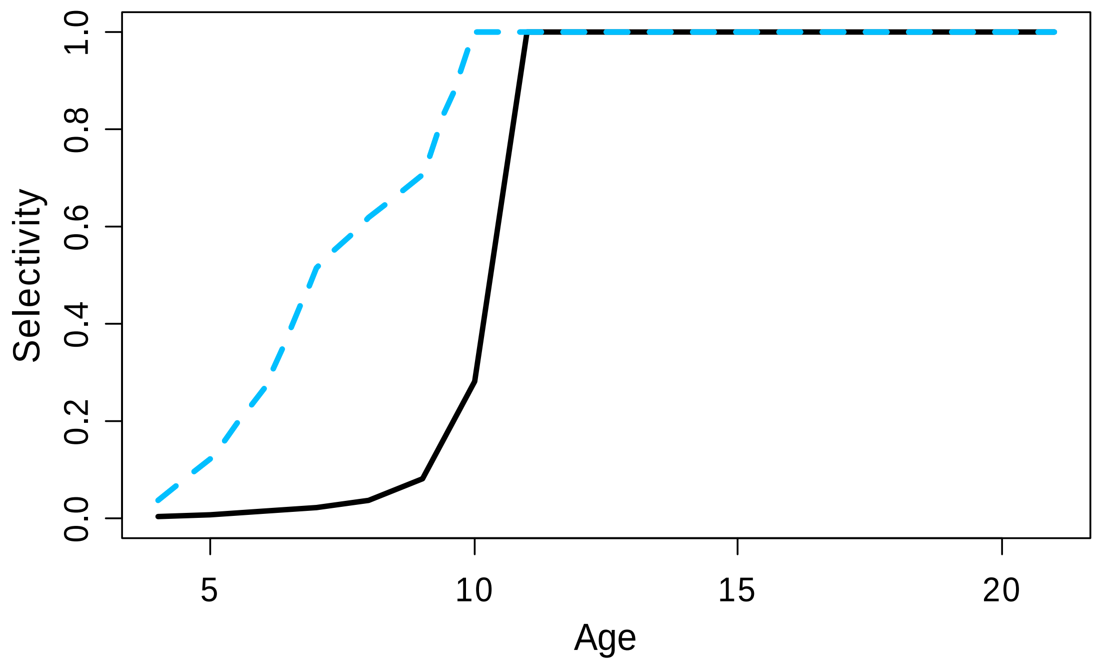


Figure 13-10. Estimated fishery and survey selectivity for GOA dusky rockfish from author recommended model. Dashed line is survey selectivity and solid line is fishery selectivity.

Figure 13-11. Time series of estimated fully selected fishing mortality for GOA dusky rockfish from author recommended model.

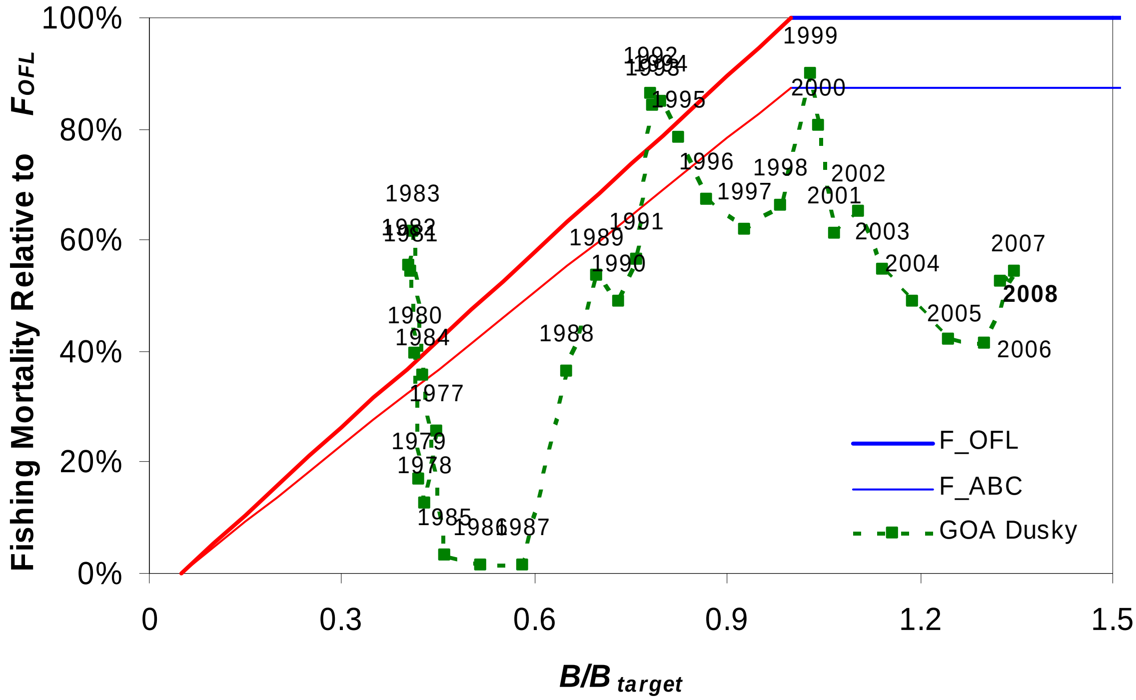


Figure 13-12. Time series of dusky rockfish estimated spawning biomass relative to the unfished level and fishing mortality relative to F_{OFL} for author recommended model.

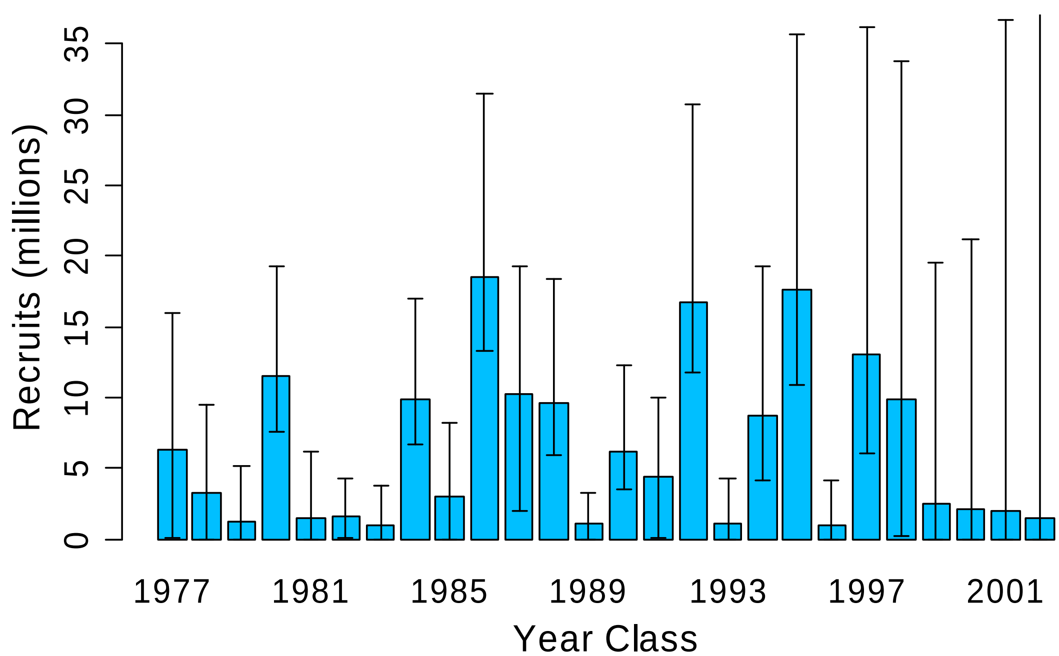


Figure 13-13. Estimated recruitments (age 4) for GOA dusky rockfish from author recommended model.

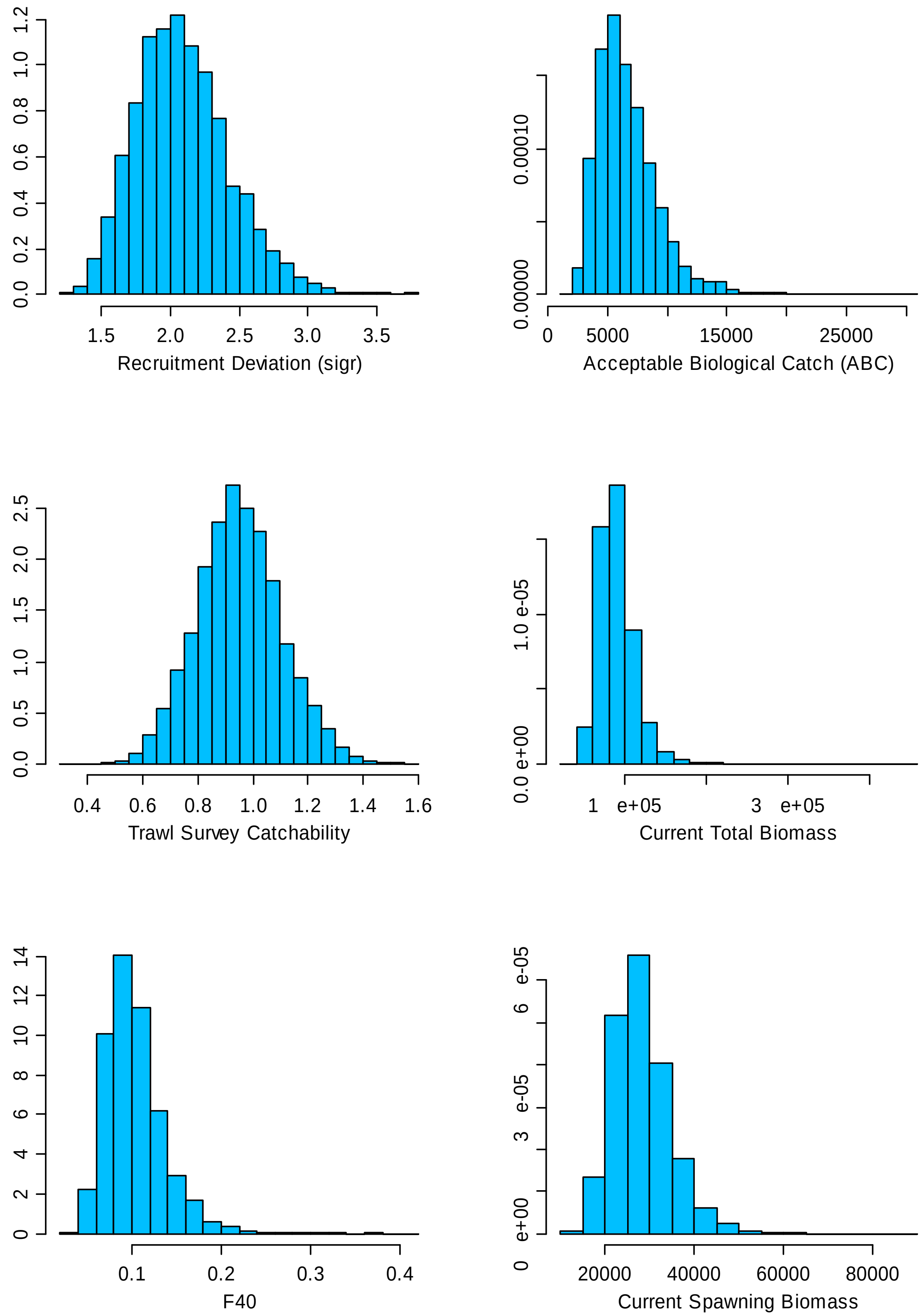


Figure 13-14: Histograms of estimated posterior distributions for key parameters derived from the MCMC for GOA dusky rockfish.

(This page intentionally left blank)