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

Chris R. Lunsford, S. Kalei Shotwell, Peter-John F. Hulson, and Dana H. Hanselman
November 2011

Executive Summary

Gulf of Alaska rockfish are assessed on a biennial stock assessment schedule designed to coincide with new data from the Gulf of Alaska bottom trawl survey.

For 2012, widow and yellowtail rockfish are removed from the pelagic shelf rockfish complex effectively leaving dusky rockfish as a stand-alone species. For this on-cycle year, we incorporate new survey biomass to update the 2009 dusky rockfish assessment model estimates with new data and present two alternative model configurations. Recommendations presented here will be for dusky rockfish only. Refer to *Chapter 16: Other Rockfish* for 2012 widow and yellowtail rockfish recommendations.

For this assessment, we continue to use the age-structured model first introduced in 2004. The model uses all available data from 1977-2011, utilizing catch, fishery age and size compositions, survey age and size compositions, and survey biomass estimates.

Summary of Changes in Assessment Inputs

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

Changes in the assessment methodology: Three model configurations are considered to incorporate recently published maturity data for dusky rockfish and to examine alternative estimation methods for fishery and survey selectivities. All three models incorporate updated catch, fishery, and survey data. Model 1 is the base model from the 2009 assessment. Model 2 utilizes an intermediate maturity curve with parameters estimated conditionally in the assessment model that is fitted to combined female dusky rockfish maturity data used in previous assessments (C. Lunsford pers. comm. July 1997, Lunsford et al. 2009) and data recently collected by Chilton (2010). Model 3 uses the same maturity estimation method as Model 2 with the addition of estimating logistic parameters for the survey and fishery selectivity rather than selectivity coefficients by age. Both Model 2 and Model 3 allow uncertainty in maturity to be incorporated into uncertainty in assessment model estimates. We recommend Model 3 to provide assessment advice for 2012. Model 3 has comparable model fits to datasets as Model's 1 and 2 while requiring fewer estimated parameters.

Summary of Results

The following results are based on author recommended Model 3. The maximum allowable ABC for 2012 is 5,118 t based on Tier 3 status for dusky rockfish. This ABC is 10% more than last year's ABC of 4,663 t. The increase in ABC is attributable to both changes in age at maturity estimates and to a 15% increase in the trawl survey biomass estimate in 2011 from 2009. The 2012 Gulf-wide OFL for dusky rockfish is 6,257 t. Recommended area apportionments of ABC are 409 t for the Western area, 3,849 t for the Central area, 542 t for the West Yakutat area, and 318 t for the Southeast/Outside area. The corresponding reference values for dusky rockfish are summarized in the following table, with the recommended ABC and OFL values in bold. The stock is not overfished, nor is it approaching overfishing status.

Quantity	As estimated or *specified last* year for: 2011	2012	As estimated or *recommended this* year for: 2012*	2013
M (natural mortality rate)	0.07	0.07	0.07	0.07
Tier	3a	3a	3a	3a
Projected total (age 4+) biomass (t)	64,774	62,584	66,771	64,064
Female spawning biomass (t)				
Projected	25,099	23,964	27,357	25,643
$B_{100\%}$	47,898	47,898	49,683	49,683
$B_{40\%}$	19,159	19,159	19,873	19,873
$B_{35\%}$	16,764	16,764	17,389	17,389
F_{OFL}	0.106	0.106	0.122	0.122
$maxF_{ABC}$	0.087	0.087	0.098	0.098
F_{ABC}	0.087	0.087	0.098	0.098
OFL (t)	5,649	5,266	**6,257**	5,822
maxABC (t)	4,663	4,347	**5,118**	4,762
ABC (t)	4,663	4,347	**5,118**	4,762
Status	As determined *last* year for: 2009	2010	As determined *this* year for: 2010	2011
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projected ABCs and OFLs for 2012 and 2013 are derived using expected catches of 2,601 and 3,327 t for 2011 and 2012 based on realized catches from 2008-2010. This calculation is in response to management requests to obtain more accurate projections.

The following table shows the recommended apportionment for 2012.

	Western	Central	Eastern	Total
Area Apportionment	8.0%	75.2%	16.8%	100%
Area ABC (t)	**409**	**3,849**	**860**	**5,118**
OFL (t)				**6,257**

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of biomass still obtainable in the W. Yakutat area (between 147° W and 140° W) is 0.63. This results in the following apportionment to the W. Yakutat area:

	W. Yakutat	E. Yakutat/Southeast
Area ABC (t)	**542**	**318**

Plan Team Summaries

Stock/Assemblage	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
	2010	67,685	6,006	4,957	4,957	3,101
	2011	64,774	5,649	4,663	4,663	2,472[2]
	2012	66,771	6,257	5,118	5,118	
	2013	64,064	5,822	4,762	4,762	

[1]Total biomass (age 4+) estimates from age-structured model

Stock/ Assemblage	Area	2011 OFL	ABC	TAC	Catch[2]	2012 OFL	ABC	2013 OFL	*ABC*
Dusky Rockfish	W		602	602	365		409		381
	C		2,993	2,993	2,048		3,849		3,581
	WYAK		398	398	58		542		504
	EYAK/SEO		670	670	1		318		296
	Total	5,649	4,663	4,663	2,472	6,257	5,118	5,822	4,762

[2]Current as of October 10, 2011

Responses to SSC Comments since the last full assessment

"The authors continue to use the 1996 length weight data in the dusky rockfish assessment. The SSC requests that the authors examine length weight from more recent surveys to determine whether additional information could be added to the assessment." (December, 2009)

Two input data updates were made for dusky rockfish in this stock assessment. Weight-at-age and size-age matrices were updated with bottom trawl survey data through 2007. For details, see Section *"Analytical Approach"*.

"The SSC notes that the author plans to address our request for options regarding reorganization of the PSR assessment and management. The GOA Plan Team minutes described a suggestion to break dusky rockfish from the pelagic shelf rockfish complex. The SSC agrees that this alternative should be explored." (December, 2010)

At the August, 2011, GOA Plan Team meeting a presentation and document explaining the rationale for reorganizing the pelagic shelf rockfish assemblage was presented. In response, dusky rockfish are now assessed separately and presented here in a stand-alone document. Details regarding the rationale and approach for reorganizing GOA rockfish can be found in Appendix 12.A.

"The SSC appreciates the responsiveness of the author to our comments and suggestions. In particular, the work of the author to address unobserved incidental catch in the IFQ halibut fishery will improve the assessment. The SSC looks forward to hearing more about the activities of the non-target catch estimation working group." (December, 2010)

Estimates of dusky rockfish catch in the IFQ halibut fishery are available and presented in Appendix 12.C.

"The methods for area apportionment of the ABC that are used in the specific chapters are different from those given in the general introductory material to the SAFE on page 4. The SSC suggests that the table be updated. Also, a different number of years are used for various species (e.g., 5 years for sablefish, 4 years for pollock, 3 surveys, most recent survey). SSC members recall extensive discussions about these

issues but the rationale for the decision is not given in the SAFE chapters. The SSC suggests that description of the apportionment rationale in each SAFE chapter of area-apportioned species would be helpful to the reader." (December, 2009)

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

"The SSC notes that the MCMC estimate of trawl survey q for the rougheye complex (0.381) is considerably different from the q for dusky rockfish (0.911). It would be useful to compare the model estimates of q for different species of rockfish and consider whether the estimates are reasonable. (December, 2009)

In this comment, the SSC was referring to the contribution of the prior distribution on trawl survey *q* to the objective function for GOA rougheye and blackspotted rockfish, not the point estimate. The catchability estimate for the RE/BS is 1.42, which is higher than northerns and dusky (0.67 and 0.90), but lower than Pacific ocean perch (2.03). These estimates at least relative to each other correspond with our perception from submersible studies on how the species range from untrawlable to trawlable habitat. Pacific ocean perch has been the subject of three studies which all yielded catchabilities above 1 (2.1, 1.3, and 2.1). Rougheye catches were compared with submersible observations in a 2006 analysis and yielded a catchability of 0.85. No studies have specifically looked at dusky rockfish catchability. In the future we hope to utilize any results of studies for other rockfish species to help derive informative prior distributions for our catchability estimates.

Responses to GOA Plan Team Comments since the last full assessment

"Applying the stock structure template to rockfish species was discussed and the Team encouraged rockfish authors to use the template for at least one GOA rockfish species (and also one flatfish species). The Team noted that Dusky rockfish would be a good candidate for GOA rockfish and either flathead sole or rocksole as a candidate for GOA Flatfish." (November, 2010)

At the August, 2011, GOA Plan Team meeting a presentation and document explaining the results of applying the stock structure template to dusky rockfish was presented. This document is provided in Appendix 12.B.

"The Team also recommends that the rockfish authors bring back in September a vulnerability assessment to go along with the revised complex management concepts. Consideration of potential new rockfish species complexes should be accompanied by a Productivity-Susceptibility Analysis to evaluate whether individual species in management complexes share similar productivity and vulnerability to fishing pressure." (November, 2010)

Approval of the newly reorganized rockfish groupings in the GOA occurred in the fall of 2011. In response, the Other Rockfish authors will provide a vulnerability assessment for species now in the Other Rockfish complex at the September, 2012, Plan Team meetings.

"Some rockfish assessments may have revised maturity estimates and the Team would like to review comparisons of these studies in September 2010. In particular, locations and timing of samples, and recommendations from assessment authors for approaches to modifying assessments." (November, 2009)

A report on incorporating revised rockfish maturity estimates in the Gulf of Alaska was presented at the September 2011 Plan Team meeting. New maturity data have been included in this assessment and are used in the author recommended model.

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

We discuss a modified methodology for estimating full-year catch for the current year and for projecting future catches for the two year projection of ABC and OFL in subsection *Specified catch estimation* in the *Projections and Harvest Alternatives* section.

Introduction

Distribution and Life History

Dusky rockfish (*Sebastes variabilis*) prior to 2012 were managed as a component of the pelagic shelf rockfish complex comprised of three species: dusky rockfish, 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.

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).

Parturition is believed to occur in the spring, based on observation of ripe females sampled on a research cruise in April 2001 in the central Gulf of Alaska. Similar to all other species of *Sebastes*, dusky rockfish are ovoviviparous with fertilization, embryonic development, and larval hatching occurring inside the mother. After extrusion, larvae are pelagic, but larval studies are hindered because they can only be positively identified by genetic analysis. Post-larval dusky rockfish have not been identified; however, the post-larval stage for other *Sebastes* is pelagic, so it is also likely to be pelagic for dusky rockfish. The habitat of young juveniles is completely unknown. At some point they are assumed to migrate to the bottom and take up a demersal existence, juveniles less than 25 cm fork length are infrequently caught in bottom trawl surveys (Clausen et al. 2002) or with other sampling gear. Older juveniles have been taken only infrequently in the trawl surveys, but when caught are often found at more inshore and shallower locations that adults. The major prey of adult dusky rockfish appears to be euphausiids, based on the limited food information available for this species (Yang 1993). In a more recent study, Yang et al. (2006) found that Pacific sandlance along with euphausiids were the most common prey item of dusky rockfish, comprising 82% and 17% , respectively, of total stomach contents by weight.

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-truncation could be deleterious to a population with highly episodic recruitment like rockfish (Longhurst 2002). Work on black rockfish (*S. melanops*) has shown that larval survival may be dramatically higher from older female spawners (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. De Bruin et al. (2004) examined Pacific ocean perch (*S. alutus*) and

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

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

A review of dusky rockfish stock structure was presented to the GOA Plan Team in September, 2011, and is presented in this document in Appendix 12.A. In summary, available data suggests lack of significant stock structure; therefore, the current resolution of spatial management is likely adequate and consistent with management goals (Appendix 12.A). It is evident from this evaluation that life history focused research is warranted and will help in evaluating dusky rockfish stock structure in the GOA.

Management Units/Measures

Sebastes rockfish species in Federal waters of the Gulf of Alaska (GOA) were first split into three broad management assemblages by the North Pacific Fishery Management Council (NPFMC) in 1988: slope rockfish, pelagic shelf rockfish, and demersal shelf rockfish. Species in each group were thought to share a somewhat similar habitat as adults, and separate "Stock Assessment and Fishery Evaluation" (SAFE) reports were prepared for each assemblage. Pelagic shelf rockfish were defined as those species of *Sebastes* that inhabit waters of the continental shelf of the Gulf of Alaska, and that typically exhibit midwater, schooling behavior.

In 1998, trawling in the Eastern Gulf east of 140 degrees W. longitude was prohibited through Amendment 41 (officially recognized in 2000). This had important management concerns for most rockfish species, including the pelagic shelf management assemblage, because the majority of the quota is caught by the trawl fishery. 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).

Until 1998, black rockfish (*S. melanops*) and blue rockfish (*S. mystinus*) were 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 March, 2007, the NPFMC took final action to remove dark rockfish from both the GOA FMP (PSR Assemblage) and BSAI FMP (other rockfish complex). Effective January 30, 2009, under Amendments 77/73 dark rockfish were removed from Federal management and full management authority was turned over to the State of Alaska.

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

GOA rockfish assessment authors began informally discussing that it made sense for dusky rockfish to have its own SAFE report and to be separated from the other two species. Changing to a stand-alone assessment for dusky rockfish would make it analogous to the other GOA rockfish that are currently assessed with age-structured models (Pacific ocean perch, northern rockfish, and rougheye/blackspotted rockfish), each of which has its own SAFE chapter. These discussions were formalized by recommendations of the GOA Groundfish Plan Team in 2009 and 2010, and presented to the GOA Groundfish Plan Team and the NPFMC's Science and Statistical Committee for approval in fall of 2011. Rationale for this action is presented in Appendix 12.B. Following agreement by both groups, dusky rockfish are now assessed separately and presented as a stand-alone species in this document; widow and yellowtail rockfish have been included in the *Other Rockfish* stock assessment. Beginning in 2012 ABCs, TACs, and OFLs specific to dusky rockfish will be assigned.

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 (changed to dusky rockfish only in 2012). Potential effects of this program on the dusky rockfish fishery include: 1) Extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA, 3) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, and 4) a higher potential to harvest 100% of the TAC in the Central GOA region. We continue to monitor available fishery data to help understand effects the Pilot Project may have on the dusky rockfish stock in the Central GOA.

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

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

Fishery

Catch History

Fishery catch statistics for dusky rockfish in the Gulf of Alaska are available for the years 1988-2011 (Table 12-2). Catch reconstruction for dusky rockfish is difficult because in past years dusky rockfish have been managed as part of the pelagic shelf rockfish assemblage (Lunsford et al. 2009). Generally, annual catches increased from 1988 to 1992, and have fluctuated in the years following. This pattern is largely explained by management actions that have affected rockfish during this period. In the years before 1991, TACs were relatively large for more abundant slope rockfish species such as Pacific ocean perch, and there was less reason for fishermen to target dusky rockfish. However, as TACs for slope rockfish became more restrictive in the early 1990's and markets changed, there was a greater economic incentive for taking dusky rockfish. As a result, catches of the pelagic shelf assemblage increased, reaching 3,605 t Gulf-wide in 1992. However, a substantial amount of unharvested TAC generally remains each year in this fishery. This is largely due to in-season management regulations which close the rockfish fishery to ensure other species such as Pacific ocean perch do not exceed TAC, or to prevent excess bycatch of Pacific halibut.

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

Description of Fishery

Dusky rockfish are caught almost exclusively with bottom trawls. Dusky rockfish have dominated the catch in the pelagic shelf assemblage and on average represent near 99% of the total pelagic shelf catch (Lunsford et al 2009). Although the vast majority of these catches come from bottom trawls, a small portion of the data may also come from longline vessels that carried observers.

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 accounted for 18-74% of the trawl catch in the Central area in the years 1996-2006[2].

The Rockfish Pilot Project in the Central GOA initiated in 2007 allocated the rockfish quota by sector so the percentage of 2007-present catches by shore-based catcher vessels differs in comparison to previous years. One benefit already realized from the Rockfish Pilot Project is increased observer coverage and sampled catch for trips that target dusky rockfish (Lunsford et al. 2009). Since the majority of dusky rockfish catch comes from the Central GOA the effects of the Rockfish Pilot Project has implications on the spatial distribution of dusky rockfish catch. 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. Comparison of spatial distribution of the dusky rockfish catch before and after the Rockfish Pilot Project began does not show major changes in catch distribution (Figure 12-1). Due to the increased observer coverage associated with the Pilot Project, however, it’s difficult to discern from examining catch levels whether areas are fished more or if it’s due to increased monitoring. Analysis of this data will help to understand how the extended season and spatial distribution of effort has changed in response to this management action.

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

[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.

species were northern rockfish and fish in the "other slope rockfish" management category, followed by Pacific ocean perch. Similarly, dusky rockfish was the major bycatch species for hauls targeting northern rockfish. These conclusions are supported by another study (Reuter 1999), in which catch data from the observer program showed dusky rockfish were most commonly associated with northern rockfish, Pacific ocean perch, and harlequin rockfish (the latter is one of the "other rockfish" species).

Bycatch estimates of all species caught in the GOA rockfish fishery are available. For groundfish species in the GOA Federal Management Plan (FMP) the highest non-rockfish catches in the years 2006-2011 are Atka Mackerel (*Pleurogrammus monopterygius*), walleye pollock (*Theragra chalcogramma*), and Pacific cod (*Gadus marcrocephalus*) (Table 12-3).

Bycatch estimates of species that are not in the GOA FMP caught in the GOA rockfish fishery are available in the years 2006-2011 (Table 12-4). Significant amounts of grenadier and greenling sp. are caught as well as some benthic fauna such as sponges. However, the amounts from dusky only targeted hauls are likely much lower as this includes all rockfish target hauls.

Bycatch estimates of prohibited species are minor with the exception of halibut, which has averaged 195 t in recent years (Table 12-5).

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

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

Discards

Gulf-wide discard rates (percent of the total catch discarded within management categories) of dusky rockfish are available from 1991-2010. Rates are listed in the following table and have ranged from less than one to ten percent of the total dusky catch over time[3]. The lowest rates have been since 2007 and are near one percent which likely are a consequence of the Rockfish Pilot Project.

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

[3]National Marine Fisheries Service, Alaska Region, P.O. 21668, Juneau, AK 99802. Data are from weekly production and observer reports through October 10, 2011 reported in AKFIN.

Data

Data Summary

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

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

Fishery Data

Catch

Catch estimates are a combination of foreign observer data, joint venture catch data, and NMFS Regional Office blend data. Catch estimates for dusky rockfish are available 1977-2011 (Table 12-2, Figure 12-3). Catches range from 17 t in 1986 to 4,538 t in 1999. We are skeptical of the low catches that occurred prior to 1988 and believe the catches for years 1985-1987 are likely underestimated. Since some of the catch data is of marginal quality prior to 1990, we make adjustments in the assessment model to account for this. These catches occurred during the end of the joint venture years and prior to accurate catch accounting of the newly formed domestic fishery.

Age and Size composition

Length frequency data for dusky rockfish in the commercial fishery are available for the years 1991-2011 (Table 12-6). These data are the raw length frequencies for all dusky rockfish measured by observers in a given year. Since there was no attempt to collect or analyze these data systematically, some biases may be expected, especially for 1995 and 1996 when sample sizes were relatively small. Generally, however, these lengths were taken from hauls in which dusky rockfish were either the target or a dominant species, and they provide an indication of the trend in size composition for the fishery. Size of fish taken by the fishery generally appears to have increased after 1992; in particular, the mode increased from 42 cm in 1991-92 to 44-47 cm in 1993-97. The mode then decreased to 42 cm in 1998, and rose back to 45 cm in 1999-2002. Fish smaller than 40 cm are seen in moderate numbers in certain years (1991-92 and 1996-98), but it is unknown if this is an artifact of observer sampling patterns, or if it shows true influxes of younger fish.

Age samples for dusky rockfish have been collected by observers in the 1999-2011 commercial fisheries. Aging has been completed for the 2000-2008 samples (Table 12-7). Similar to the fishery length data discussed in the preceding paragraph, the data in Table 12-8 depicts the raw age distribution of the samples, and we did not attempt any further analysis to estimate a more comprehensive age composition. However, the samples were randomly collected from fish in over 100 hauls that had large catches of dusky rockfish, so the raw distribution is probably representative of the true age composition of the fishery. Fish ranged in age from 4 to 76 years. Several large and relatively steady year classes are evident through the time series including 1987, 1992, and 1995 (Figure 12-4).

Survey Data

Trawl Survey Biomasss Estimates

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

The 1984 and 1987 survey results should be treated with some caution. A different survey design was used in the eastern Gulf of Alaska in 1984; furthermore, much of the survey effort in the western and central Gulf of Alaska in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this latter problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (for a discussion see Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates discussed here, and the estimates are believed to be the best available. Even so, the reader should be aware that an element of uncertainty exists as to the standardization of the 1984 and 1987 surveys. Also, the 2001 survey biomass is a weighted average of 1993-1999 biomass estimates, since the Eastern Gulf was not surveyed in 2001.

Comparative biomass estimates for the trawl surveys show wide fluctuations for dusky rockfish (Table 12-8, Table 12-9, Figure 12-5). Total estimated biomass increased substantially between 1984 and 1987, dropped by over 50% in 1990, rebounded in 1993 and 1996, and decreased again in 1999 and 2001 (in areas that were sampled in 2001), increased in 2003, increased 2.5 fold in 2005 to 170,484 t, decreased in 2007 and 2009 to estimates similar to 2003, and increased again in 2011. Large confidence intervals are associated with all these biomass estimates, particularly in 1987, 1996, 2003, 2005, 2007, and 2011. This is an indication of the generally patchy and highly aggregated distribution of this species. The catches of dusky rockfish in the 2007, 2009 and 2011 surveys are shown in Figure 12-6. The magnitude of catch varies greatly with several large tows typically occurring in each survey. It is unknown whether these fluctuations indicate true changes in abundance, temporal changes in the availability of dusky rockfish to the survey gear, or are an artifact of the imprecision of the survey for this species. 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 1984-2011 (Table 12-10) Survey size compositions suggest that recruitment of dusky rockfish is a relatively infrequent event, as only two surveys, 1993 and 2003, showed evidence of substantial recruitment. Mean population length increased from 39.8 cm in 1987 to 43.1 cm in 1990. In 1993, however, a large number of small fish (~27-35 cm long) appeared which formed a sizeable percentage of the population, and this recruitment decreased the mean length to 38.3 cm. In the 1996 and 1999 surveys, the length frequency distribution was similar to that of 1990, with very few small fish, and both years had a mean population length of 43.9 cm. The 2001 size composition, although not directly comparable to previous years because the eastern Gulf of Alaska was not sampled, shows modest recruitment of fish <40 cm. In 2003, a distinct mode of fish is seen at ~30 cm that suggests relatively strong recruitment may have occurred. In 2005 mean population length increased to 42.2 cm and there is no evidence of recruitment of small fish in 2005, 2007, 2009 or 2011. 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 2009 trawl surveys (Table 12-11). Similar to the length data, these age data also indicate that recruitment is infrequent. For each survey, ages were determined using the “break-and-burn” method of aging otoliths, and a Gulf-wide age-length key was developed. The key was then used to estimate age composition of the dusky rockfish population in the Gulf of Alaska. The 1976 year class appeared to be abundant in the early surveys, especially 1984 (Figure 12-7). The 1986 year class appeared strong in the 1993, 1996, and perhaps the 1999 surveys. Because rockfish are difficult to age, especially as the fish grow older, one possibility is that some of the fish aged 12 in 1999 were actually age 13 (members of the 1986 year class), which would agree more with the 1993 and 1996 age results. Little recruitment occurred in the years following until the 1992 and 1995 year classes appeared. The 2005 and 2007 data indicate a prominent 1998 year class but does not appear as strong in 2009. The 2009 age distribution is dispersed with only the 1995 year class being prominent.

Analytical Approach

Model Structure

We present model results for dusky rockfish based on an age-structured model using AD Model Builder software (ADMB Project 2009). In 2003, biomass estimates from an age-structured assessment model were first accepted as an alternative to trawl survey biomass estimates. The assessment model is based on a generic rockfish model developed in a workshop held in February 2001 (Courtney et al. 2007) and follows closely the GOA Pacific ocean perch and northern rockfish models (Courtney et al. 1999, Hanselman et al. 2007). As with other rockfish age-structured models, this model does not attempt to fit a stock-recruitment relationship but estimates a mean recruitment, which is adjusted by estimated recruitment deviations for each year. We do this because there does not appear to be an obvious stock-recruitment relationship in the model estimates, and there have been very high recruitments at low stock size (Figure 12-8). The main difference between the dusky rockfish 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

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

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

Aging error matrices were constructed by assuming that the break-and-burn ages were unbiased but had a given amount of normal error around each age. The age error transition matrix was constructed by assuming the same age determination error used for northern rockfish (Courtney et al. 1999).

Questions about the validity of the high natural mortality rate of dusky rockfish versus other similarly aged rockfish were raised in previous stock assessments (Lunsford et al. 2007). An updated estimate that was calculated by Malecha et al. (2004) has been used since 2007. This estimate was based on the Hoenig (1983) empirical estimator for natural mortality based on maximum lifespan. 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. For this assessment we use a value of 0.07, which is comparable to other similarly aged rockfish in the GOA.

Parameters Estimated Conditionally

Maturity at age

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

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

Other parameters

Other parameters estimated conditionally in the preferred model, Model 3, include, but are not limited to: logistic parameters for 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	51
Average fishing mortality	μ_f	1
Fishing mortality deviations	ϕ_y	35
Logistic fishery selectivity	$a_{f50\%}, \delta_f$	2
Logistic survey selectivity	$a_{s50\%}, \delta_s$	2
Logistic maturity-at-age	$a_{m50\%}, \delta_m$	2
Total		99

Uncertainty approach

Evaluation of model uncertainty has recently become an integral part of the “precautionary approach” in fisheries management. In complex stock assessment models such as this model, evaluating the level of uncertainty is difficult. One way is to examine the standard errors of parameter estimates from the Maximum Likelihood approach derived from the Hessian matrix. While these standard errors give some measure of variability of individual parameters, they often underestimate their variance and assume that the joint distribution is multivariate normal. An alternative approach is to examine parameter distributions through Markov Chain Monte Carlo (MCMC) methods (Gelman et al. 1995). When treated this way, our stock assessment is a large Bayesian model, which includes informative (e.g., lognormal natural mortality with a small CV) and non-informative (or nearly so, such as a parameter bounded between 0 and 10) prior distributions. In the model presented in this SAFE report, the number of parameters estimated is 100. In a low-dimensional model, an analytical solution might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, the chain will converge (Jones and Hobert 2001). The "burn-in" is a set of iterations removed at the beginning of the chain. This method is not strictly necessary but we use it as a precautionary measure. In our simulations we removed the first 4,000,000 iterations out of 20,000,000 and "thinned" the chain to one value out of every thousand, leaving a sample distribution of 4,000. Further assurance that the chain had converged was attained by comparing the mean of the first half of the chain with the second half after removing the "burn-in" and "thinning". Because these two values were similar we concluded that convergence had been attained. We use these MCMC methods to provide further evaluation of uncertainty of the parameters presented here, including 95% credible intervals for some parameters.

BOX 1. AD Model Builder Model Description

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

BOX 1 (Continued)

Equations describing the observed data

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

Catch equation

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

Survey biomass index (t)

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

Survey age distribution
Proportion at age

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

Survey length distribution
Proportion at length

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

Fishery age composition
Proportion at age

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

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

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

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

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

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

Results

Model Evaluation

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

Model Number	Model Description
Model 1 (Base case)	• Model from Lunsford et al. (2009), updated for 2011
Model 2	• Incorporate new maturity data from Chilton (2010) and estimate logistic maturity-at-age parameters conditionally
Model 3	• Same as Model 2, conditionally estimate selectivity for the survey and fishery with the logistic function

Model 1: This is the model presented in the 2009 Pelagic Shelf Rockfish assessment. Only changes that have occurred were appending new data. This data includes updated catch, 2009 survey age compositions, 2011 biomass estimate, 2008 fishery age compositions, and the 2009, 2010, and 2011 fishery length compositions. This model uses maturity-at-age from Lunsford (pers. comm. 1997) and estimates selectivity coefficient parameters by age for the survey and fishery. To evaluate incorporation of recently obtained data for maturity of dusky rockfish from Chilton (2010) Model 2 was developed. To investigate logistic selectivity rather than coefficients by age for the survey and fishery Model 3 was developed.

Model 2: This model is structurally similar to Model 1. The main difference is that an intermediate maturity curve is estimated conditionally in the model by combining data from Lunsford (pers. comm. 1997) and Chilton (2010).

Model 3: This model is the same as Model 2, with the difference that survey and fishery selectivity is estimated with the logistic function rather than coefficients by age.

Model Comparison

Table 12-12 summarizes the results from the 2009 Model, Model 1 and 2, and this year's recommended Model 3.

When compared with the 2009 application of Model 1, the major change for the current application of Model 1 is the reduction in the estimate of q, the survey catchability coefficient (previously 0.91 compared to 0.81; Table 12-12). This results in a higher estimated stock level than that previously estimated. We are uncomfortable with the large change in q from Models 1 and 2, and Model 3 has a similar q as 2009. Model 3 has overall similar fits to the observed data (slightly better fit to the fishery age composition) compared to Models 1 and 2 and reduces the number of estimated parameters by 9 compared to Model 1, and 11 compared to Model 2 (Table 12-12) giving it an advantage in terms of our parsimony criterion. The likelihood values for Models 2 and 3 are not superior to Model 1, but using the new maturity information in the model was a priority. Therefore, we do not select Model 1 due to the omission of recently obtained maturity data, or Model 2 due to the larger number of parameters estimated compared to Model 3. Therefore, we recommend Model 3.

Model Results

For conciseness, we only show the recommended Model 3 in most figures.

Key results have been summarized in Tables 12-12 – 12-15. In general, model predictions continue to fit the data well (Figures 12-4, 12-5, 12-7, and 12-10). The model is producing stable results with minimal penalties and appears reasonable. The 2011 survey biomass estimate is slightly larger than the 2009 and 2007 estimates and the model tracks the 2003, 2007, and 2009 estimates well, although the 2005 estimate is much higher (Figure 12-5). Model fit to this data reveals a fairly level curve throughout the recent time series with only a small increase in response to the 2005 biomass estimate. There is some lack of fit to the plus group in the fishery size compositions for 1991-1993 (Figure 12-10). This may be due to the increase in size of fish taken by the fishery in those years as mentioned in the Fishery data section. In general, the model fits the fishery age compositions well, likely due to the addition of data and the especially strong 1992 year class which is prevalent in most the recent age compositions (Figure 12-4). The survey age compositions also track the 1992 year class well and try to fit the 1995 year class, which appears strong in recent years (Figure 12-7).

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

Time Series Results

Biomass and Exploitation Trends
Total biomass estimates indicate a moderately increasing trend over time with a slight dome shape in the years surrounding the exceptionally high 2005 survey biomass estimate, while spawning biomass estimates show a continuous linear increase throughout the time series and is also slightly dome shaped in recent years (Figure 12-11). MCMC credible intervals indicate that the historic low was more certain than the more recent increases, particularly when looking at the upper credible interval. The model estimate crosses the MCMC upper interval in the beginning of the time series. This may be due to the uncertainty in data from this time period coupled with the uncertainty in estimating recruitment. The estimated selectivity curve for the fishery and survey data suggested a pattern similar to what we expected for dusky rockfish (Figure 12-12). The commercial fishery should target larger and subsequently older fish and the survey should sample a larger range of ages. Fish are fully selected by the survey by age 13, while fish are fully selected by the fishery at age 15.

The fully-selected fishing mortality time series indicates a rise in fishing mortality from late 1980's through the late 1990's and has declined since with a small increase in 2007 and 2008 (Figure 12-13). This rise may be due to the increase in catch from the implementation of the Central Gulf of Alaska Rockfish Pilot Program (see the Management measures and Fishery sections). Goodman et al. (2002) suggested that stock assessment authors use a "management path" graph as a way to evaluate management and assessment performance over time. We use a phase-plane plot of the ratio of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to the target level ($B_{35\%}$). Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The historical management path for dusky rockfish has been above the FOFL adjusted limit for only a few years in the early 1980's and early 1990's. Since 2000, dusky rockfish have been above $B_{40\%}$ and well below $F_{40\%}$ (Figure 12-14).

Recruitment
Recruitment is highly variable throughout the time series (Figure 12-15), particularly the most recent years, where typically very little information is known about the strength of incoming year classes. There also does not seem to be a clear spawner recruit relationship for dusky rockfish as recruitment appears unrelated to spawning stock biomass (Figure 12-8). The addition of new data in this year's model has increased recruitment estimates for 2006 and 2008 but had little effect on other estimates. MCMC

credible bands for recruitment are fairly narrow in some years; however, the credible bands nearly contain zero for many years which indicates considerable uncertainty, particularly for the most recent years (Figure 12-16).

Uncertainty Distributions

From the MCMC chains described in the *Uncertainty approach* section, we summarize the posterior densities of key parameters for the recommended model using histograms (Figure 12-16) and credible intervals (Table 9-15). We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass and recruitment (Figures 12-11, 12-15).

Table 12-13 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviations derived from the Hessian matrix compared to the standard deviations derived from MCMC methods. The Hessian and MCMC standard deviations are similar for q , but the MCMC standard deviations are larger for the estimates of $F_{40\%}$, σ_r (recruitment deviation), ABC, and female spawning biomass. These larger standard deviations indicate that these parameters are more uncertain than indicated by the standard estimates. However, all estimates fall within the Bayesian credible intervals.

Projections and Harvest Alternatives

Amendment 56 Reference Points

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

Estimation of the $B_{40\%}$ reference point requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the average of age 4 recruits from 1981-2009 (year classes between 1977 and 2005). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. 2010 estimates of these reference points are (in terms of female spawning biomass):

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
49,683	19,873	17,389	0.098	0.122

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2012 is estimated at 27,357 t. This is above the $B_{40\%}$ value of 19,873 t. Under Amendment 56, Tier 3, the maximum permissible fishing mortality for ABC is $F_{40\%}$ and fishing mortality for OFL is $F_{35\%}$. Applying these fishing mortality rates for 2010 yields the following ABC and OFL:

$F_{40\%}$	0.098
ABC	5,118

$F_{35\%}$	0.122
OFL	6,257

Population 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 each scenario, the projections begin with the vector of 2011 numbers-at-age estimated in the assessment. This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2011. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch after 2011 is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2012, are as 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 2012 and 2013, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the realized catches in 2008-2010 to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio of catch to ABC will yield more accurate projections.)

Scenario 3: In all future years, F is set equal to 50% of *max* F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 2007-2011 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

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

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as 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 2011 or 2) above ½ of its MSY level in 2011 and above its MSY level in 2021 under this scenario, then the stock is not overfished.)

Scenario 7: In 2012 and 2013, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2024 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios (Table 12-16). For catch projections into the next two years in Scenario 2, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, based on both the lower catch in the first year out, and based on the amount of catch taken before spawning in the projection two years out.

Status Determination

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

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

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2009) is 3,101 t. This is less than the 2010 OFL of 5,649 t. Therefore, the stock is not being subjected to overfishing.

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

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2011:
a. If spawning biomass for 2011 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2011 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2011 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 12-13). If the mean spawning biomass for 2021 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:
a. If the mean spawning biomass for 2014 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2014 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2014 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2024. If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition. Based on the above criteria and Table 12-15, the stock is not overfished and is not approaching an overfished condition.

Alternate Projection
During the 2006 CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. We continue to present an alternative projection scenario using the uncertainty of the full assessment model harvesting at max ABC which is analogous to the Alternative 1 projection scenario. This projection propagates uncertainty throughout the entire assessment procedure and is based on an MCMC chain of 10,000,000. The projection shows wide credibility intervals on future spawning biomass (Figure 12-17). The $B_{35\%}$ and $B_{40\%}$ reference points are based on the 1981-2009 age-4 recruitments, and this projection predicts that the median spawning biomass will decrease quickly until average recruitment is attained and the low proportion of ABC is taken (0.65).

Area Allocation of Harvests

In all previous years, annual allocation of the Gulf-wide ABC for pelagic shelf rockfish amongst the three regulatory areas in the Gulf has been based on the geographic distribution of pelagic shelf rockfish biomass in the trawl surveys. Since the 1996 SAFE report, this distribution has been computed as a weighted average of the percent biomass distribution for each area in the three most recent trawl surveys. In the computations, each successive survey is given a progressively heavier weighting using factors of 4, 6, and 9, respectively. This 4:6:9 weighting scheme was originally recommended by the Gulf of Alaska Groundfish Plan Team, and had already been used for 1996 Pacific ocean perch stock assessment. The Plan Team believed that for consistency among the rockfish assessments, the same weighting should be applied to pelagic shelf rockfish. The Plan Team's scheme was adopted for the 1997 fishery, and we continue to follow it for dusky rockfish. Therefore, based on a 4:6:9 weighting of the 2007, 2009, and 2011 trawl surveys, the percent distribution of dusky rockfish biomass in the Gulf of Alaska is: Western area 8.0%; Central area 75.2%, and Eastern area 16.8%. Applying these percentages to the ABC of dusky rockfish (5,118 t) yields the following apportionments for the Gulf in 2012: Western area, 409 t; Central area, 3,849 t; and Eastern area, 860 t (Table 12-17).

Because the Eastern area is now divided into two management areas dusky rockfish, i.e., the West Yakutat area (area between 147 degrees W. longitude and 140 degrees W. longitude) and the East Yakutat/Southeast Outside area (area east of 140 degrees W. longitude), the ABC for this management group in the Eastern area must be further apportioned between these two smaller areas. The weighted average method described above results in a point estimate with considerable uncertainty. In an effort to balance this uncertainty with associated costs to the fishing industry, the Gulf of Alaska Plan Team has recommended that apportionment to the two smaller areas in the eastern Gulf be based on the upper 95% confidence limit of the weighted average of the estimates of the eastern Gulf biomass proportion that is in the West Yakutat area. The upper 95% confidence interval of this proportion is 0.63, so that the dusky rockfish ABC for West Yakutat would be 542 t, and the ABC for East Yakutat/Southeast Outside would be 318 t (Table 12-17). This proportion (0.63) is higher than what was used in the 2010 assessment (0.37) which is due to the removal of widow and yellowtail rockfish biomass in the calculation. The result is a higher ABC in the West Yakutat region.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.122), the 2012 overfishing (OFL) is set equal to 6,257 t for dusky rockfish (Table 12-17).

Ecosystem Considerations

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

Ecosystem Effects on the Stock

Prey availability/abundance trends: similar to many other rockfish species, stock condition of dusky rockfish appears to be greatly influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval dusky rockfish may be an important determining factor of year class strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and year class strength; moreover, field-collected larval dusky rockfish at present cannot even be visually identified to species. Yang (1993) reported that adult dusky rockfish consume mostly euphausiids. Yang et al. (2006) reports Pacific sandlance *Ammodytes hexapterus* and euphausiids as the most common prey item of dusky rockfish with Pacific sandlance comprising 82% of stomach content weight . Euphausiids are also a major item in the diet of walleye pollock, Pacific ocean perch, and northern rockfish. Changes in the abundance of these three species could lead to a corollary change in the availability of euphausiids, which would then have an impact on dusky rockfish.

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

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

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

Fishery Effects on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: there is limited habitat information on adult dusky rockfish, especially regarding the habitat of the major fishing grounds for this species in the Gulf of Alaska. Nearly all the catch of dusky rockfish, however, is taken by bottom trawls, so the fishery potentially could affect HAPC biota such as corals or sponges if it occurred in localities inhabited by that biota. Corals and sponges are usually found on hard, rocky substrates, and there is some evidence that dusky rockfish may be found in such habitats. On submersible dives on the outer continental shelf of the eastern Gulf of Alaska, light dusky rockfish were observed in association with rocky habitats and in areas with extensive sponge beds, where the fish were observed resting in large vase-type sponges.[4] Also, dusky rockfish often co-occur and are caught with northern rockfish in the commercial fishery and in trawl surveys (Reuter 1999) and catches of northern rockfish have been associated with a rocky or rough bottom habitat (Clausen and Heifetz 2002). Based on this indirect evidence, it can be surmised that dusky rockfish are likely also associated with a rocky substrate. An analysis of bycatch of HAPC biota in commercial fisheries in the Gulf of Alaska in 1997-99 indicated that the dusky rockfish trawl fishery ranked fourth among all fisheries in the amount of corals taken as bycatch and sixth in the amount of sponges taken (National Marine Fisheries Service 2001). Little is known, however, about the extent of these HAPC biota and whether the bycatch is detrimental.

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

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

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

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

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

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

Data Gaps and Research Priorities

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

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

Summary

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

Quantity	As estimated or *specified last* year for: 2011	2012	As estimated or *recommended this* year for: 2012*	2013
M (natural mortality rate)	0.07	0.07	0.07	0.07
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	64,774	62,584	66,771	64,064
Female spawning biomass (t)				
Projected	25,099	23,964	27,357	25,643
$B_{100\%}$	47,898	47,898	49,683	49,683
$B_{40\%}$	19,159	19,159	19,873	19,873
$B_{35\%}$	16,764	16,764	17,389	17,389
F_{OFL}	0.106	0.106	0.122	0.122
$maxF_{ABC}$	0.087	0.087	0.098	0.098
F_{ABC}	0.087	0.087	0.098	0.098
OFL (t)	5,649	5,266	**6,257**	5,822
maxABC (t)	4,663	4,347	**5,118**	4,762
ABC (t)	4,663	4,347	**5,118**	4,762
Status	As determined *last* year for: 2009	2010	As determined *this* year for: 2010	2011
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projected ABCs and OFLs are derived using an expected catch value of 2,601 t for 2011 based on recent ratios of catch to ABC (0.65). This calculation is in response to management requests to obtain a more accurate one-year projection.

Plan Team Summaries

Stock/Assemblage	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
	2010	67,685	6,006	4,957	4,957	3,101
	2011	64,774	5,649	4,663	4,663	2,472[2]
	2012	66,771	6,257	5,118	5,118	
	2013	64,064	5,822	4,762	4,762	

[1]Total biomass (age 4+) estimates from age-structured model

Stock/ Assemblage	Area	2011 OFL	ABC	TAC	Catch[2]	2012 OFL	ABC	2013 OFL	*ABC*
Dusky Rockfish	W		602	602	365		409		381
	C		2,993	2,993	2,048		3,849		3,581
	WYAK		398	398	58		542		504
	EYAK/SEO		670	670	1		318		296
	Total	5,649	4,663	4,663	2,472	6,257	5,118	5,822	4,762

[2]Current as of October 10, 2011

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.

ADMB Project. 2009. AD Model Builder: automatic differentiation model builder. Developed by David Fournier and freely available from admb-project.org.

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.

Carlson, H. R., and R. R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of Southeastern Alaska. Mar. Fish. Rev. 43: 13-19.

Chilton, E.A. 2010. Maturity and growth of female dusky rockfish (*Sebastes variabilis*) in the central Gulf of Alaska. Fish. Bull. 108:70-78.

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., and J. Heifetz. 2002. The northern rockfish, *Sebastes polyspinis*, in Alaska: Commercial fishery, distribution, and biology. Mar. Fish. Rev. 64(4):1-28.

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.

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., Heifetz, J., Fujioka, J. T., Shotwell, S. K., and Ianelli, J. N. 2007. Pacific ocean perch. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. 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.

Love, M.S., M.H. Carr, and L.J. Haldorson. 1991. The ecology of substrate-associated juveniles of the genus Sebastes. Environmental Biology of Fishes 30:225-243.

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

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.

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).

Pearcy, W. G., D. L. Stein, M. A. Hixon, E. K. Pikitch, W. H. Barss, and R. M. Starr. 1989. Submersible observations of deep-reef fishes of Heceta Bank, Oregon. Fishery Bulletin 87:955-965.

Quinn II, T.J., and Deriso, R.B. 1999. Quantitative fish dynamics. Oxford University Press, New York. 542 pp.

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.

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.

Yang, M-S., K. Dodd, R. Hibpshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-164, 199 p.

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

Year	Catch[1] (t)	ABC	TAC		Management Measures
1988	1,086	3,300	3,300		Pelagic shelf rockfish assemblage was one of three management groups for *Sebastes* implemented by the North Pacific Management Council. Previously, *Sebastes* in Alaska were managed as "Pacific ocean perch complex" or "other rockfish" which included PSR species. Apportionment and biomass determined from average percent biomass of most recent trawl surveys
1989	1,738	6,600	3,300		No reported foreign or joint venture catches of PSR
1990	1,647	8,200	8,200		
1991	2,342	4,800	4,800		
1992	3,605	6,886	6,886		
1993	3,193	6,740	6,740		
1994	2,989	6,890	6,890		
1995	2,891	5,190	5,190		
1996	2,296	5,190	5,190		Area apportionment based on 4:6:9 weighting scheme of 3 most recent survey biomass estimates rather than average percent biomass
1997	2,629	5,140	5,140		
1998	3,113	4,880	4,880		Black and blue rockfish removed from PSR assemblage and federal management plan Trawling prohibited in Eastern Gulf east of 140 degrees W.
1999	4,659	4,880	4,880		Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	3,731	5,980	5,980		Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	3,008	5,980	5,980		Dusky rockfish treated as tier 4 species whereas dark, widow, and yellowtail broken out as tier 5 species
2002	3,322	5,490	5,490		
2003	2,975	5,490	5,490		Age structured model for dusky rockfish accepted to determine ABC and moved to Tier 3 status
2004	2,885	4,470	4,470		
2005	2,397	4,553	4,553		
2006	2,444	5,436	5,436		
2007	3,374	5,542	5,542		Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	3,643	5,227	5,227		
2009	2,995	4,781	4,781		Dark rockfish removed from PSR assemblage and federal management plan
2010	3,110	5,059	5,509		
2011	2,472[2]	4,754	4,754		Dusky rockfish broken out as stand-alone species for 2012. Widow and yellowtail rockfish included in other rockfish assemblage.

[1] Catch is for entire pelagic shelf rockfish assemblage

[2] Catch is for dusky rockfish only, updated through October 10, 2011. Source: AKFIN.

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

Year	Catch	ABC[1]	TAC[1]	% TAC
1977	388	-	-	-
1978	162	-	-	-
1979	224	-	-	-
1980	597	-	-	-
1981	845	-	-	-
1982	852	-	-	-
1983	1,017	-	-	-
1984	540	-	-	-
1985	34	-	-	-
1986	17	-	-	-
1987	19	-	-	-
1988	1,067	3,300	3,300	32%
1989	1,707	6,600	3,300	52%
1990	1,612	8,200	8,200	20%
1991	1,965	4,800	4,800	41%
1992	3,468	6,886	6,886	50%
1993	3,122	6,740	6,740	46%
1994	2,918	6,890	6,890	42%
1995	2,849	5,190	5,190	55%
1996	2,281	5,190	5,190	44%
1997	2,460	5,140	5,140	48%
1998	3,107	4,880	4,880	64%
1999	4,535	4,880	4,880	93%
2000	3,699	5,980	5,980	62%
2001	2,997	5,980	5,980	50%
2002	3,301	5,490	5,490	60%
2003	3,020	5,490	5,490	55%
2004	2,557	4,470	4,470	57%
2005	2,209	4,553	4,553	49%
2006	2,434	5,436	5,436	45%
2007	3,366	5,542	5,542	61%
2008	3,619	5,227	5,227	69%
2009	3,061	4,781	4,781	64%
2010	3,101	5,059	5,059	61%
2011[a]	2,472			

[1] ABC and TAC are for the pelagic shelf rockfish assemblage which dusky rockfish were a member of until 2011. Individual ABCs and TACs were not assigned to individual species.
[a] Catch updated through October 10, 2011. Source: AKFIN.

Table 12-3. FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska from 2006-2011. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/10/2011.

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

Table 12-4. Non-FMP species bycatch estimates in tons for Gulf of Alaska rockfish targeted fisheries 2006 - 2011. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/10/2011.

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

Table 12-5. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and thousands of animals for crab and salmon, by year, and fisheries management plan area for the GOA rockfish fishery. Source: NMFS AKRO Blend/Catch Accounting System PSCNQ via AKFIN 10/10/2011.

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

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

Length (cm)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2007	2009	2010	2011
≤21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
26	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000
27	0.000	0.002	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	0.000	0.002	0.000	0.002	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000
29	0.000	0.003	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.001	0.000	0.000	0.000
30	0.002	0.005	0.000	0.002	0.000	0.012	0.000	0.000	0.000	0.002	0.000	0.000	0.000
31	0.002	0.011	0.000	0.000	0.001	0.006	0.001	0.000	0.000	0.002	0.000	0.000	0.000
32	0.003	0.012	0.000	0.000	0.000	0.004	0.001	0.000	0.000	0.003	0.002	0.000	0.000
33	0.004	0.015	0.000	0.002	0.000	0.014	0.004	0.001	0.000	0.003	0.000	0.001	0.001
34	0.007	0.019	0.000	0.001	0.001	0.008	0.008	0.001	0.000	0.002	0.003	0.001	0.001
35	0.025	0.019	0.000	0.004	0.002	0.004	0.019	0.000	0.002	0.002	0.002	0.002	0.001
36	0.029	0.015	0.000	0.004	0.005	0.010	0.026	0.001	0.002	0.004	0.005	0.003	0.001
37	0.019	0.017	0.001	0.003	0.004	0.008	0.042	0.003	0.001	0.007	0.009	0.006	0.002
38	0.024	0.027	0.001	0.009	0.007	0.002	0.041	0.006	0.004	0.012	0.016	0.013	0.005
39	0.069	0.036	0.006	0.004	0.020	0.010	0.034	0.012	0.006	0.021	0.032	0.018	0.013
40	0.084	0.108	0.020	0.019	0.028	0.033	0.041	0.027	0.011	0.032	0.043	0.030	0.026
41	0.134	0.117	0.046	0.041	0.045	0.052	0.060	0.059	0.028	0.054	0.063	0.055	0.041
42	0.145	0.125	0.103	0.074	0.059	0.082	0.088	0.099	0.079	0.072	0.085	0.082	0.071
43	0.140	0.114	0.145	0.076	0.084	0.093	0.106	0.147	0.116	0.100	0.110	0.111	0.103
44	0.136	0.117	0.200	0.146	0.098	0.120	0.112	0.170	0.164	0.129	0.128	0.122	0.117
45	0.085	0.100	0.197	0.171	0.124	0.128	0.119	0.163	0.182	0.128	0.147	0.148	0.136
46	0.057	0.073	0.151	0.176	0.126	0.126	0.097	0.126	0.148	0.136	0.117	0.126	0.133
47+	0.034	0.060	0.131	0.266	0.397	0.278	0.199	0.185	0.257	0.286	0.238	0.281	0.349
Sample size	2012	5495	3659	2117	1794	515	3090	2565	1684	4599	4432	4320	2684

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

Age(yr)	2000	2001	2002	2003	2004	2005	2006	2008
4	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.002	0.002	0.000	0.002	0.005	0.000	0.000	0.000
7	0.000	0.004	0.007	0.000	0.007	0.002	0.006	0.007
8	0.012	0.004	0.009	0.019	0.002	0.005	0.026	0.007
9	0.007	0.043	0.011	0.030	0.055	0.014	0.036	0.038
10	0.034	0.035	0.104	0.046	0.069	0.092	0.078	0.086
11	0.049	0.068	0.109	0.177	0.066	0.104	0.146	0.109
12	0.141	0.077	0.095	0.102	0.182	0.079	0.097	0.065
13	0.207	0.132	0.063	0.091	0.114	0.191	0.074	0.164
14	0.212	0.170	0.154	0.038	0.083	0.099	0.113	0.076
15	0.100	0.161	0.134	0.073	0.040	0.061	0.071	0.060
16	0.051	0.089	0.120	0.127	0.076	0.038	0.052	0.058
17	0.027	0.060	0.052	0.097	0.104	0.061	0.039	0.045
18	0.015	0.031	0.025	0.062	0.055	0.061	0.071	0.041
19	0.015	0.012	0.011	0.018	0.019	0.063	0.036	0.043
20	0.012	0.017	0.007	0.014	0.021	0.038	0.049	0.050
21+	0.117	0.097	0.098	0.104	0.100	0.092	0.107	0.152
Sample size	411	517	441	628	422	444	309	604

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

		Statistical Areas					
Year	Species	Shumagin	Chirikof	Kodiak	Yakutat	Southeastern	Total
1984[1]	Dusky Unident.	3,843	7,462	4,329	15,126	307	31,068
1987[1]	Dusky Unident.	12,011	4,036	46,005	18,346	1,097	81,494
1990[1]	Dusky Unident.	2,963	1,233	16,779	5,808	953	27,735
1993[1]	Dusky Unident.	11,450	12,880	23,780	7,481	1,626	52,217
1996[2]	Light dusky	3,553	19,217	36,037	14,193	1,480	74,480
	Dark dusky	152	139	59	-	-	350
1999[2]	Light dusky	2,538	9,157	33,729	2,097	2,108	49,628
	Dark dusky	2,130	31	49	-	-	2,211
2001[2a]	Light dusky	5,352	2,062	23,590	7,924	1,738	40,667
	Dark dusky	362	15	36	-	-	413
2003[2]	Light dusky	4,039	46,729	7,198	11,519	1,377	70,862
	Dark dusky	235	49	16	-	-	300
2005[3]	Dusky	69,295	38,216	60,097	2,488	389	170,484
2007[3]	Dusky	4,985	38,350	19,482	5,579	3,857	72,253
2009[3]	Dusky	1,404	4,075	40,836	25,082	726	72,123
2011[3]	Dusky	10,473	5,169	62,893	4,103	768	83,407

[1] Identification of dusky rockfish included "light" and "dark" dusky combined
[2] Identification of dusky rockfish separated "light" and "dark" dusky
[3] "Dark" dusky rockfish officially recognized as separate species (dark rockfish) and no longer classified as a form of dusky rockfish
[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 12-9. GOA dusky rockfish biomass estimates, standard errors, lower confidence intervals, and upper confidence intervals, based on results of NMFS bottom trawl surveys.

Year	Biomass	Standard Error	Lower CI	Upper CI
1984	31,068	7,146	16,776	45,360
1987	81,494	29,391	35,430	152,994
1990	27,735	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	49,628	19,193	11,154	87,926
2001	40,667	11,634	18,637	65,173
2003	70,862	34,352	2,158	139,566
2005	170,484	51,657	68,202	272,766
2007	72,253	34,369	4,890	139,616
2009	72,123	24,687	23,736	120,510
2011	83,407	36,806	11,267	155,547

Table 12-10. NMFS trawl survey length compositions for dusky rockfish in the Gulf of Alaska. Lengths below 21 are pooled and lengths greater than 47 are pooled. Survey size compositions are not used in model.

Length (cm)	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011
≤21	0.000	0.000	0.000	0.001	0.003	0.001	0.003	0.000	0.001	0.000	0.003	0.001
22	0.000	0.001	0.008	0.002	0.001	0.001	0.002	0.004	0.001	0.000	0.006	0.000
23	0.000	0.001	0.004	0.004	0.004	0.001	0.003	0.000	0.001	0.000	0.011	0.000
24	0.000	0.000	0.002	0.007	0.003	0.000	0.005	0.001	0.002	0.000	0.012	0.000
25	0.000	0.000	0.006	0.002	0.003	0.002	0.003	0.000	0.002	0.001	0.005	0.000
26	0.000	0.001	0.000	0.015	0.001	0.000	0.004	0.004	0.001	0.001	0.009	0.000
27	0.000	0.000	0.006	0.018	0.001	0.001	0.006	0.017	0.001	0.001	0.005	0.000
28	0.002	0.000	0.006	0.023	0.001	0.000	0.002	0.024	0.001	0.001	0.006	0.000
29	0.001	0.000	0.007	0.021	0.005	0.001	0.022	0.027	0.004	0.001	0.007	0.000
30	0.004	0.001	0.000	0.030	0.002	0.002	0.024	0.044	0.005	0.003	0.010	0.002
31	0.009	0.001	0.001	0.039	0.002	0.006	0.029	0.027	0.010	0.001	0.008	0.002
32	0.015	0.004	0.007	0.051	0.002	0.008	0.033	0.031	0.014	0.004	0.010	0.002
33	0.014	0.002	0.001	0.043	0.007	0.008	0.026	0.053	0.016	0.003	0.005	0.003
34	0.036	0.018	0.003	0.040	0.003	0.013	0.030	0.008	0.019	0.010	0.007	0.005
35	0.048	0.039	0.001	0.046	0.006	0.015	0.026	0.011	0.021	0.013	0.007	0.006
36	0.061	0.061	0.002	0.053	0.001	0.015	0.042	0.013	0.046	0.013	0.008	0.015
37	0.066	0.093	0.004	0.037	0.009	0.016	0.039	0.043	0.027	0.017	0.006	0.019
38	0.090	0.084	0.006	0.049	0.009	0.019	0.040	0.077	0.053	0.024	0.011	0.017
39	0.131	0.080	0.019	0.051	0.016	0.016	0.059	0.072	0.031	0.049	0.011	0.036
40	0.139	0.109	0.017	0.051	0.036	0.031	0.061	0.066	0.042	0.070	0.020	0.042
41	0.134	0.142	0.077	0.035	0.080	0.035	0.071	0.050	0.046	0.077	0.031	0.058
42	0.105	0.121	0.125	0.044	0.065	0.072	0.061	0.050	0.072	0.110	0.036	0.091
43	0.061	0.112	0.115	0.061	0.127	0.104	0.064	0.065	0.092	0.106	0.073	0.135
44	0.037	0.062	0.153	0.064	0.133	0.115	0.058	0.070	0.101	0.115	0.069	0.114
45	0.022	0.028	0.175	0.073	0.111	0.150	0.083	0.065	0.100	0.098	0.105	0.109
46	0.013	0.019	0.151	0.065	0.113	0.141	0.076	0.062	0.101	0.099	0.154	0.103
47+	0.014	0.020	0.104	0.076	0.256	0.231	0.127	0.114	0.190	0.185	0.363	0.238
Sample Size	1881	2818	1113	2299	1478	1340	1255	1780	3383	1818	2024	1410

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

Age (yr)	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009
4	0.000	0.000	0.007	0.004	0.013	0.001	0.014	0.002	0.006	0.000	0.004
5	0.000	0.000	0.005	0.058	0.007	0.001	0.006	0.072	0.008	0.003	0.022
6	0.000	0.000	0.003	0.094	0.013	0.001	0.081	0.114	0.029	0.005	0.009
7	0.075	0.192	0.001	0.193	0.004	0.056	0.074	0.011	0.060	0.019	0.026
8	0.284	0.003	0.001	0.088	0.025	0.013	0.052	0.288	0.063	0.022	0.013
9	0.115	0.047	0.007	0.118	0.049	0.047	0.188	0.073	0.038	0.112	0.022
10	0.142	0.155	0.115	0.031	0.188	0.033	0.095	0.019	0.100	0.091	0.037
11	0.145	0.213	0.134	0.032	0.111	0.113	0.093	0.064	0.089	0.046	0.068
12	0.121	0.109	0.086	0.020	0.148	0.270	0.037	0.037	0.058	0.166	0.058
13	0.052	0.057	0.113	0.048	0.045	0.121	0.066	0.035	0.150	0.128	0.051
14	0.011	0.034	0.171	0.022	0.029	0.064	0.099	0.019	0.064	0.067	0.134
15	0.040	0.043	0.139	0.039	0.033	0.025	0.061	0.044	0.034	0.062	0.058
16	0.006	0.014	0.042	0.045	0.015	0.015	0.034	0.066	0.037	0.041	0.069
17	0.000	0.027	0.015	0.042	0.018	0.001	0.013	0.033	0.034	0.009	0.074
18	0.000	0.012	0.055	0.016	0.052	0.020	0.009	0.016	0.035	0.036	0.024
19	0.000	0.018	0.035	0.016	0.041	0.025	0.007	0.020	0.055	0.036	0.024
20	0.002	0.010	0.009	0.010	0.045	0.048	0.008	0.004	0.038	0.023	0.055
21+	0.008	0.065	0.061	0.123	0.165	0.146	0.062	0.083	0.101	0.135	0.252
Sample size	161	446	94	445	554	174	676	195	461	490	494

Table 12-12. Likelihood values and estimates of key parameters for last year's 2009 model, Model 1, and Model 2, and Model 3 (author recommended) for GOA dusky rockfish.

Likelihoods	*2009 Model*	*Model 1*	*Model 2*	*Model 3 (Author Rec)*
Catch	27.31	26.97	26.97	27.19
Survey Biomass	34.13	36.29	36.29	36.74
Fishery Ages	22.72	27.76	27.76	27.11
Survey Ages	68.38	73.28	73.28	74.07
Fishery Sizes	26.80	48.91	48.91	50.78
Maturity Likelihood	0.00	0.00	65.00	65.00
Data-Likelihood	**179.34**	**213.20**	**278.20**	**280.89**
Penalties/Priors				
Recruitment Devs	27.65	23.25	23.25	24.39
Fishery Selectivity	1.52	1.19	1.19	0.00
Survey Selectivity	0.64	0.57	0.57	0.00
Fish-Sel Domeshape	0.00	0.00	0.00	0.00
Survey-Sel Domeshape	0.00	0.00	0.00	0.00
Average Selectivity	0.00	0.00	0.00	0.00
F Regularity	34.36	33.73	33.73	33.68
σ_r prior	0.26	0.46	0.46	0.41
q prior	0.02	0.11	0.11	0.03
Objective Fun. Total	**243.79**	**272.50**	**337.50**	**339.40**
Parameter Estimates				
Number parameters estimated	104	108	110	99
q-trawl	0.911	0.813	0.813	0.896
σ_r	1.084	0.977	0.977	0.998
Mean Recruitment (millions)	7.196	7.103	7.103	6.729
$F_{40\%}$	0.087	0.086	0.092	0.098
Total Biomass (t)	67,685	72,347	72,347	66,771
B_{2011} (t)	64,242	69,604	69,382	64,064
$B_{0\%}$ (t)	47,898	50,091	52,443	49,683
$B_{40\%}$ (t)	19,159	20,036	20,977	19,873
ABC ($F_{40\%}$) (t)	**4,957**	**5,003**	**5,339**	**5,118**

Table 12-13. Estimates of key parameters (μ) with Hessian estimates of standard deviation (σ), MCMC standard deviations (σ (MCMC)) and 95% Bayesian credible intervals (BCI) derived from MCMC simulations.

Parameter	μ	μ MCMC	σ	σ MCMC	Median MCMC	BCI Lower	BCI Upper
q	0.896	0.889	0.125	0.128	0.884	0.646	1.154
$F_{40\%}$	0.098	0.122	0.029	0.044	0.113	0.063	0.234
Female Sp. Biomass	27,357	30,325	5,508	6,328	29,613	20,212	45,184
ABC	5,118	6,861	1,759	2,795	6,272	3,226	13,915

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

	Spawning biomass (t)		6+ Biomass (t)		Catch/6+ biomass		Age 2 recruits (1000's)	
Year	Previous	Current	Previous	Current	Previous	Current	Previous	Current
1977	10,030	11,927	23,973	27,488	0.016	0.014	2,659	2,255
1978	9,557	11,358	24,206	27,127	0.016	0.014	3,532	2,483
1979	9,289	10,997	24,574	27,031	0.016	0.014	2,818	3,065
1980	9,115	10,714	25,327	27,099	0.015	0.014	14,332	11,669
1981	8,959	10,416	25,753	27,249	0.015	0.014	6,434	6,132
1982	8,927	10,221	30,076	31,222	0.013	0.012	2,819	3,584
1983	9,100	10,242	33,174	33,807	0.012	0.011	1,210	1,861
1984	9,458	10,488	35,128	35,429	0.011	0.011	9,949	10,992
1985	10,130	11,157	36,375	36,425	0.011	0.011	1,205	1,539
1986	11,209	12,378	40,568	41,660	0.010	0.009	1,946	2,216
1987	12,421	13,807	42,331	43,389	0.009	0.009	1,364	1,504
1988	13,670	15,261	43,661	44,875	0.009	0.009	10,772	9,634
1989	14,412	16,130	43,139	44,549	0.009	0.009	3,373	3,221
1990	14,904	16,701	45,084	47,035	0.009	0.008	19,399	19,663
1991	15,386	17,241	45,561	47,443	0.009	0.008	12,931	11,111
1992	15,763	17,649	51,100	54,741	0.008	0.007	10,047	9,937
1993	15,455	17,314	54,541	58,088	0.007	0.007	1,315	1,467
1994	15,476	17,420	58,139	61,636	0.007	0.006	7,502	7,951
1995	15,850	18,081	59,008	61,742	0.007	0.006	4,624	3,561
1996	16,594	19,267	60,901	63,864	0.006	0.006	19,758	19,884
1997	17,816	20,957	62,078	64,433	0.006	0.006	1,398	1,456
1998	19,035	22,540	67,489	71,404	0.006	0.005	10,270	10,028
1999	20,038	23,602	67,527	70,848	0.006	0.005	19,011	19,753
2000	20,389	23,776	68,167	71,780	0.006	0.005	1,076	1,140
2001	20,949	24,256	72,843	77,986	0.005	0.005	11,159	10,303
2002	21,780	25,198	73,346	77,857	0.005	0.005	12,695	11,789
2003	22,552	26,182	75,758	80,412	0.005	0.005	2,146	2,369
2004	23,503	27,392	79,085	83,906	0.005	0.005	2,700	2,713
2005	24,614	28,809	79,572	83,831	0.005	0.005	2,048	2,014
2006	25,764	30,236	79,394	83,294	0.005	0.005	1,892	2,657
2007	26,714	31,276	77,912	81,489	0.005	0.005	1,799	1,936
2008	26,946	31,478	74,649	78,383	0.005	0.005	1,920	4,883
2009	26,731	31,069	70,521	74,325	0.006	0.005	1,913	2,194
2010		30,371		71,765		0.005		2,094
2011		29,205		68,115		0.006		2,078

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

	Recruits (Age 4)			Total Biomass			Spawning Biomass		
Year	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%
1977	2,255	38	10,638	28,828	14,238	29,264	11,927	4,557	11,481
1978	2,483	45	9,529	28,344	14,876	29,402	11,358	4,468	11,070
1979	3,065	39	13,418	28,437	15,945	30,257	10,997	4,571	10,857
1980	11,669	2,385	33,325	30,403	19,030	33,573	10,714	4,787	10,804
1981	6,132	97	21,191	32,215	21,705	36,947	10,416	4,999	10,781
1982	3,584	61	13,114	33,904	24,222	40,033	10,221	5,289	10,953
1983	1,861	19	7,304	35,327	26,248	42,613	10,242	5,757	11,392
1984	10,992	5,396	25,970	38,211	29,688	46,799	10,488	6,413	12,145
1985	1,539	20	5,430	40,261	32,057	49,982	11,157	7,365	13,348
1986	2,216	63	6,537	42,595	34,682	53,138	12,378	8,757	15,202
1987	1,504	19	4,658	44,400	36,592	55,515	13,807	10,283	17,287
1988	9,634	5,114	22,542	47,273	39,812	59,264	15,261	11,833	19,319
1989	3,221	32	8,405	48,283	40,697	60,553	16,130	12,740	20,596
1990	19,663	11,193	42,718	51,977	44,220	65,763	16,701	13,406	21,456
1991	11,111	2,678	23,255	55,965	47,763	70,794	17,241	14,029	22,184
1992	9,937	4,939	22,673	60,284	51,636	76,870	17,649	14,519	22,728
1993	1,467	17	3,632	61,571	52,456	79,328	17,314	14,229	22,666
1994	7,951	4,527	18,910	63,687	54,125	83,204	17,420	14,246	23,096
1995	3,561	53	7,814	65,003	54,847	85,590	18,081	14,749	24,235
1996	19,884	12,668	42,846	68,959	58,054	91,774	19,267	15,677	26,028
1997	1,456	18	3,660	71,107	59,527	95,271	20,957	17,046	28,438
1998	10,028	5,185	22,509	73,864	61,545	99,965	22,540	18,340	30,771
1999	19,753	12,015	41,765	77,995	64,553	107,301	23,602	19,159	32,594
2000	1,140	14	3,043	78,349	64,100	109,778	23,776	19,076	33,285
2001	10,303	5,516	23,740	80,400	65,212	114,613	24,256	19,297	34,468
2002	11,789	6,041	28,849	83,509	67,489	120,798	25,198	19,846	36,282
2003	2,369	30	7,854	84,668	68,022	124,120	26,182	20,537	38,287
2004	2,713	181	9,606	85,206	68,045	126,765	27,393	21,393	40,532
2005	2,014	45	7,941	85,102	67,707	127,955	28,809	22,427	43,150
2006	2,657	93	10,316	84,469	66,675	128,274	30,236	23,543	45,829
2007	1,936	25	9,994	82,727	64,988	126,800	31,276	24,265	47,998
2008	4,883	269	31,408	79,975	62,536	125,244	31,478	24,237	49,057
2009	2,194	24	15,916	76,329	59,105	122,315	31,069	23,645	49,335
2010	2,094	24	45,363	72,886	55,986	121,516	30,371	22,896	48,992
2011	2,078	25	51,501	69,200	52,661	123,535	29,205	21,771	48,021
2012	6,729	28	44,158	66,771	50,102	127,894	27,357	20,169	45,561

Table 12-16. Set of projections of spawning biomass (SB) and yield for dusky rockfish in the Gulf of Alaska. Six harvest scenarios designed to satisfy the requirements of Amendment 56, NEPA, and MSFCMA. For a description of scenarios see section 12.6.3. All units are in t. $B_{40\%}$ = 19,873 t, $B_{35\%}$ = 17,389 t, $F_{40\%}$ = 0.098, and $F_{35\%}$ = 0.122.

Year	Maximum permissible F	Author's F (pre-specified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning Biomass (t)				
2011	28,654	28,654	28,654	28,654	28,654	28,654	28,654
2012	27,206	27,357	27,420	27,406	27,637	27,105	27,206
2013	24,697	23,939	26,060	25,964	27,503	24,079	24,697
2014	22,439	23,939	24,736	24,570	27,284	21,435	22,357
2015	20,508	21,811	23,549	23,324	27,084	19,237	20,008
2016	18,927	20,036	22,535	22,262	26,946	17,538	18,126
2017	17,802	18,682	21,759	21,446	26,933	16,410	16,857
2018	17,199	17,894	21,334	20,989	27,177	15,832	16,175
2019	17,039	17,590	21,264	20,890	27,697	15,705	15,968
2020	17,188	17,625	21,485	21,078	28,457	15,876	16,078
2021	17,512	17,860	21,904	21,461	29,404	16,204	16,359
2022	17,904	18,180	22,423	21,942	30,453	16,579	16,697
2023	18,297	18,516	22,973	22,456	31,543	16,941	17,031
2024	18,658	18,832	23,515	22,963	32,630	17,260	17,328
			Fishing Mortality				
2011	0.046	0.046	0.046	0.046	0.046	0.046	0.046
2012	0.098	0.063	0.049	0.053	-	0.122	0.122
2013	0.098	0.063	0.049	0.053	-	0.122	0.122
2014	0.098	0.098	0.049	0.053	-	0.122	0.122
2015	0.098	0.098	0.049	0.053	-	0.118	0.118
2016	0.093	0.098	0.049	0.053	-	0.107	0.107
2017	0.087	0.092	0.049	0.053	-	0.099	0.099
2018	0.084	0.088	0.049	0.053	-	0.095	0.095
2019	0.083	0.085	0.049	0.053	-	0.094	0.094
2020	0.083	0.085	0.048	0.053	-	0.095	0.095
2021	0.084	0.085	0.048	0.053	-	0.097	0.097
2022	0.085	0.086	0.048	0.053	-	0.098	0.098
2023	0.086	0.087	0.048	0.053	-	0.100	0.100
2024	0.087	0.088	0.048	0.053	-	0.101	0.101
			Yield (t)				
2009	2,601	2,601	2,601	2,601	2,601	2,601	2,601
2010	5,118	5,118	2,619	2,795	-	6,257	5,118
2011	4,609	4,762	2,471	2,629	-	5,512	4,609
2012	4,170	4,454	2,337	2,479	-	4,885	5,099
2013	3,801	4,046	2,221	2,348	-	4,227	4,546
2014	3,304	3,671	2,110	2,226	-	3,474	3,715
2015	2,875	3,168	2,013	2,118	-	2,988	3,157
2016	2,657	2,876	1,957	2,057	-	2,756	2,880
2017	2,620	2,785	1,939	2,054	-	2,738	2,830
2018	2,687	2,814	1,964	2,090	-	2,840	2,910
2019	2,794	2,892	2,012	2,143	-	2,983	3,035
2020	2,911	2,987	2,070	2,201	-	3,126	3,165
2021	3,024	3,084	2,128	2,258	-	3,257	3,287
2022	3,124	3,171	2,184	2,312	-	3,368	3,391

*Scenarios 2 projections are derived using expected catches of 2,601 and 3,327 t for 2011 and 2012 based on realized catches from 2008-2010. This calculation is in response to management requests to obtain more accurate projections.

Table 12-17. Allocation of 2012 ABC for dusky rockfish in the Gulf of Alaska. Apportionment is based on the weighted average of dusky rockfish biomass estimates in last three trawl surveys. Allocation for West Yakutat and SE/Outside is equal to the upper 95% confidence interval of the ratio of biomass in West Yakutat area to SE/Outside area. All units are in t.

		Western	Central		Eastern		
Year	Weights	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total
2007	4	7%	53%	27%	8%	5%	100%
2009	6	2%	6%	57%	35%	1%	100%
2011	9	13%	6%	75%	5%	1%	100%
Weighted Mean		8	16	59	15	2	100%
Area Apportionment		8.02	75.17		16.81		100%
Area ABC (t)		**409**	**3,849**		**860**		**5,118**
Yak/SE ABC (t)					**542**	**318**	
OFL (t)							**6,257**

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

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

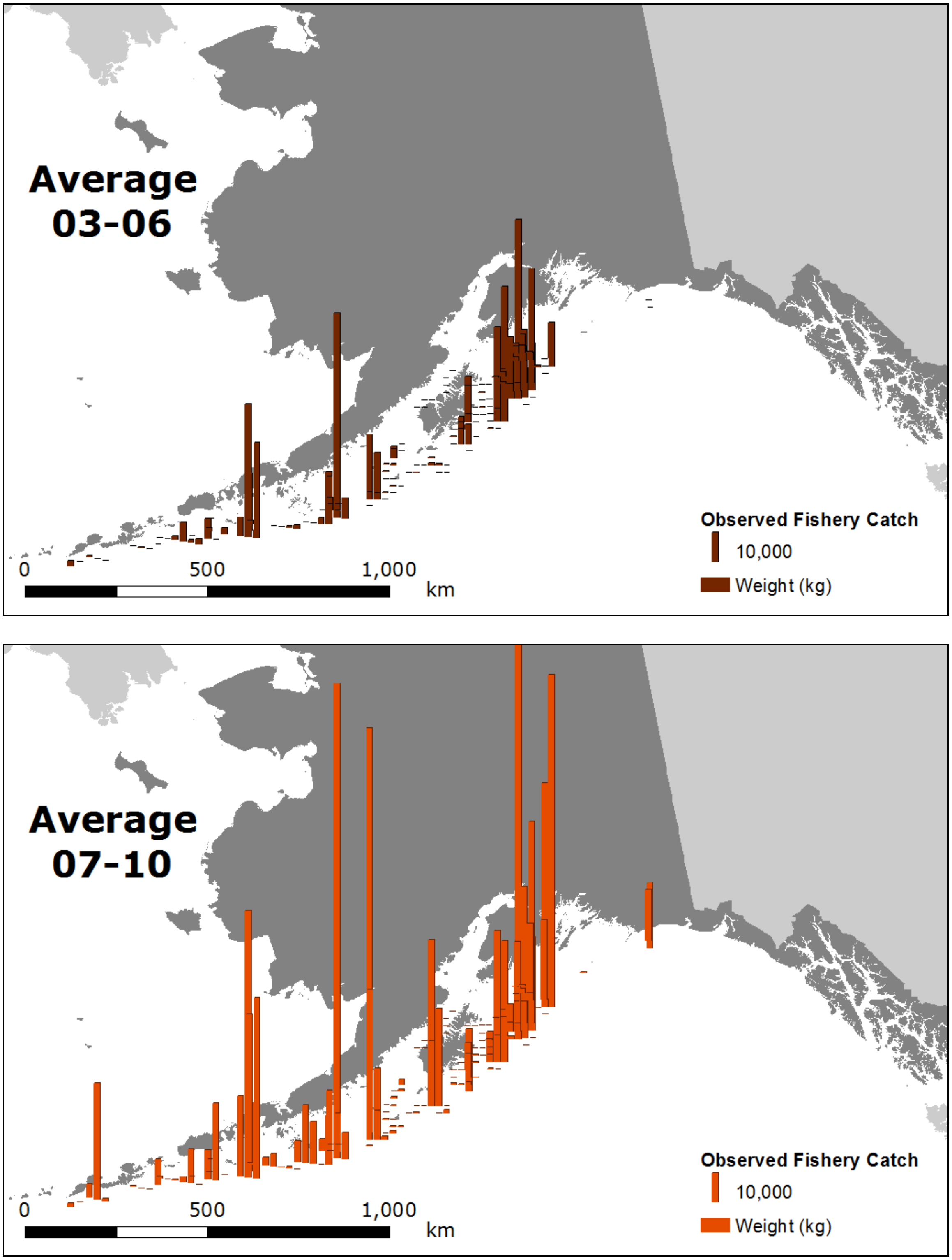


Figure 12-1. Spatial distribution of dusky rockfish fishery catch in the Gulf of Alaska (GOA) based on observer data aggregated by 400 km^2 blocks and averaged by (a) four years prior to central GOA Rockfish Pilot Program, 2003-2006, and (b) four years after implementation of program, 2007-2010.

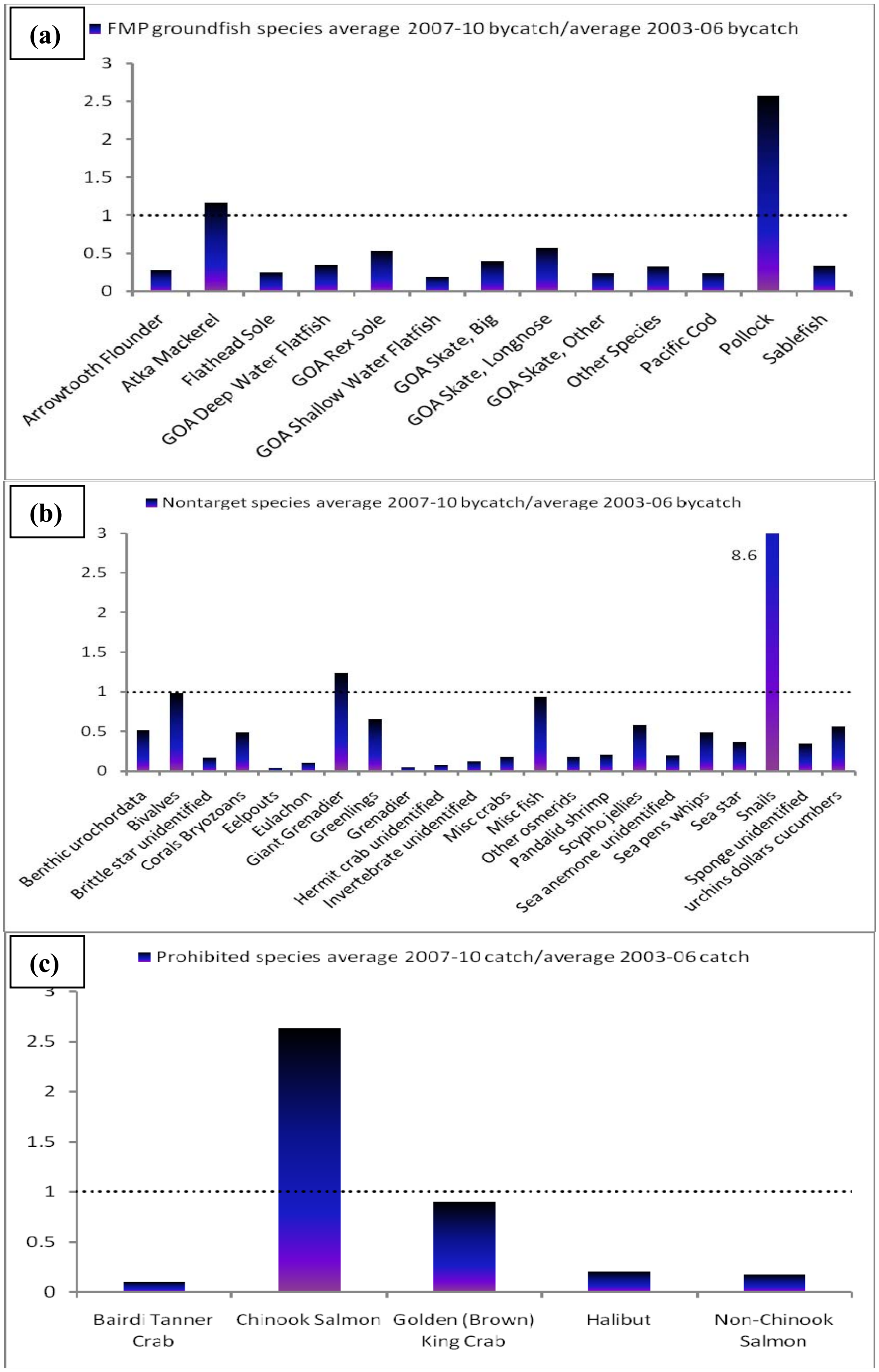
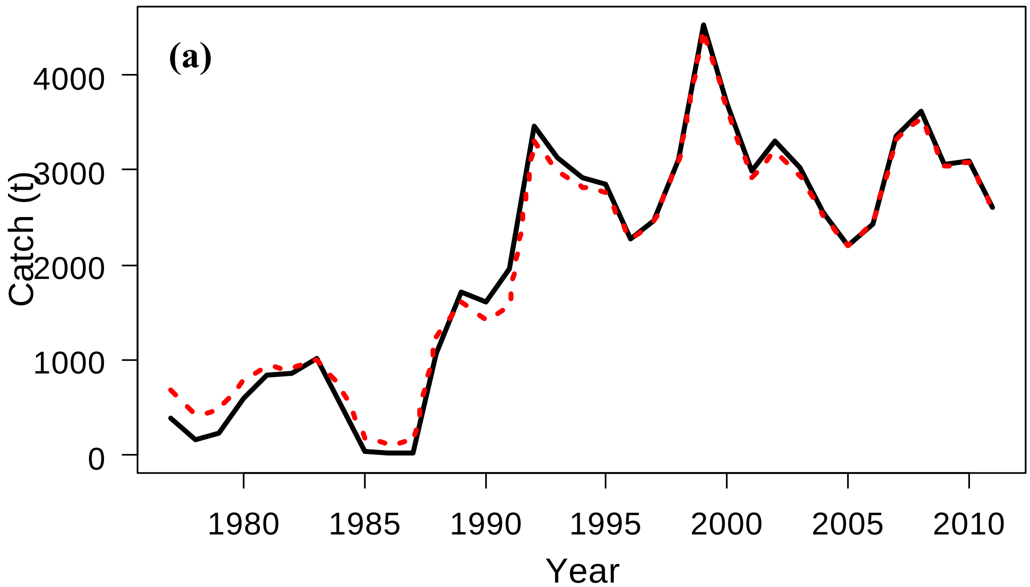


Figure 12-2. Comparison of bycatch of prohibited species in the Central Gulf of Alaska rockfish fishery before the Rockfish Pilot Program (2003-2006) and after (2007-2010). Values represent the average of the 2007-2010 catches divided by the average of the 2003-2006 catches for GOA FMP groundfish species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



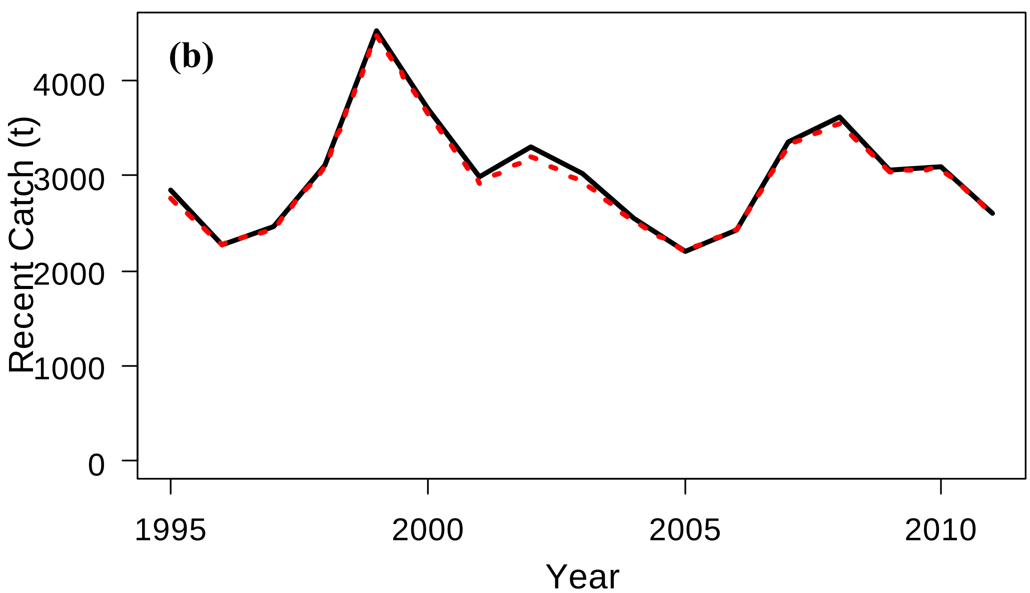


Figure 12-3. Estimated long-term (a) and short-term (b) commercial catches for GOA dusky rockfish. Observed is solid line, predicted author recommended model (Model 2) is dashed line.

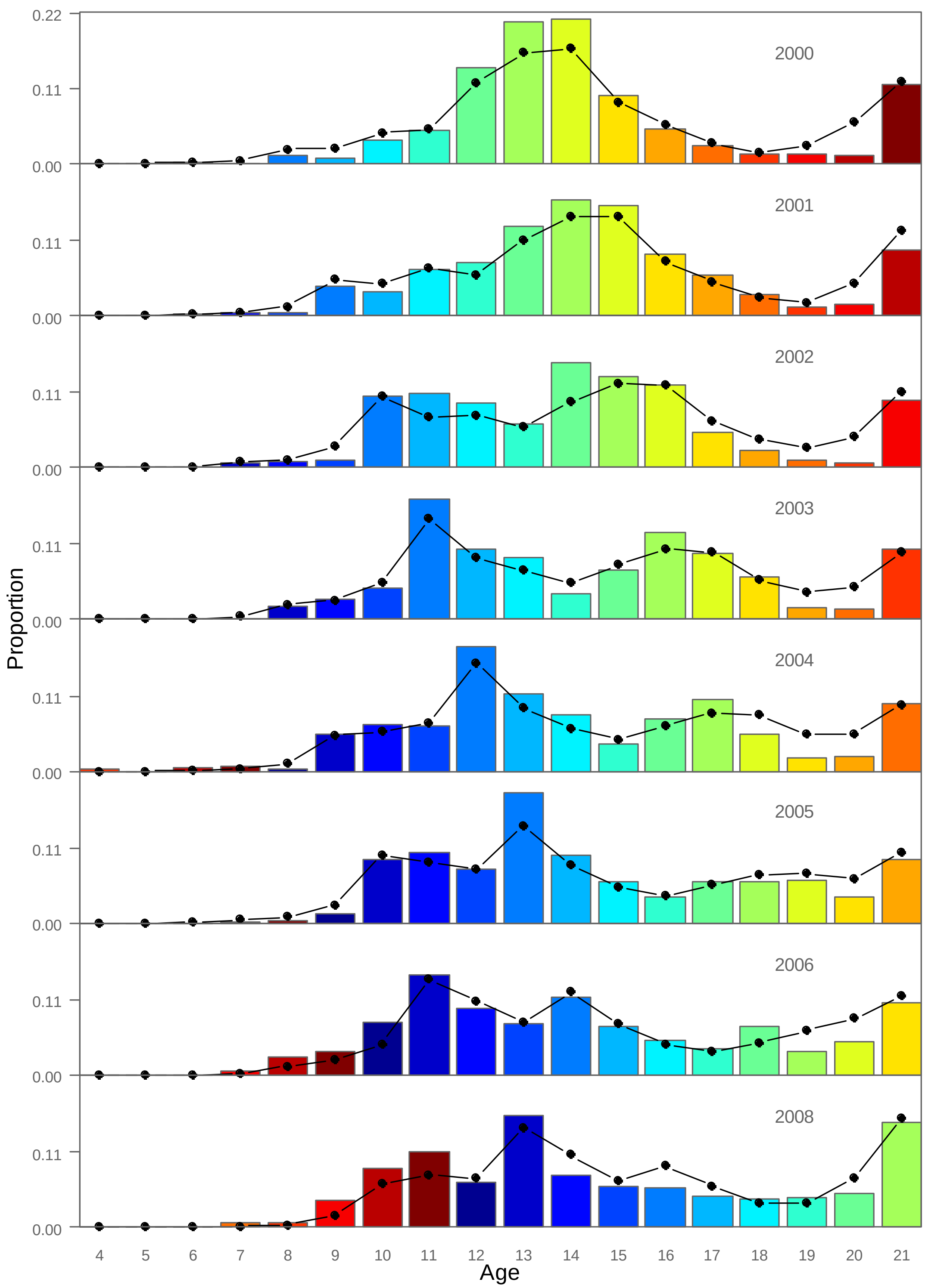


Figure 12-4. Fishery age compositions for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles. Colors correspond to individual year classes.

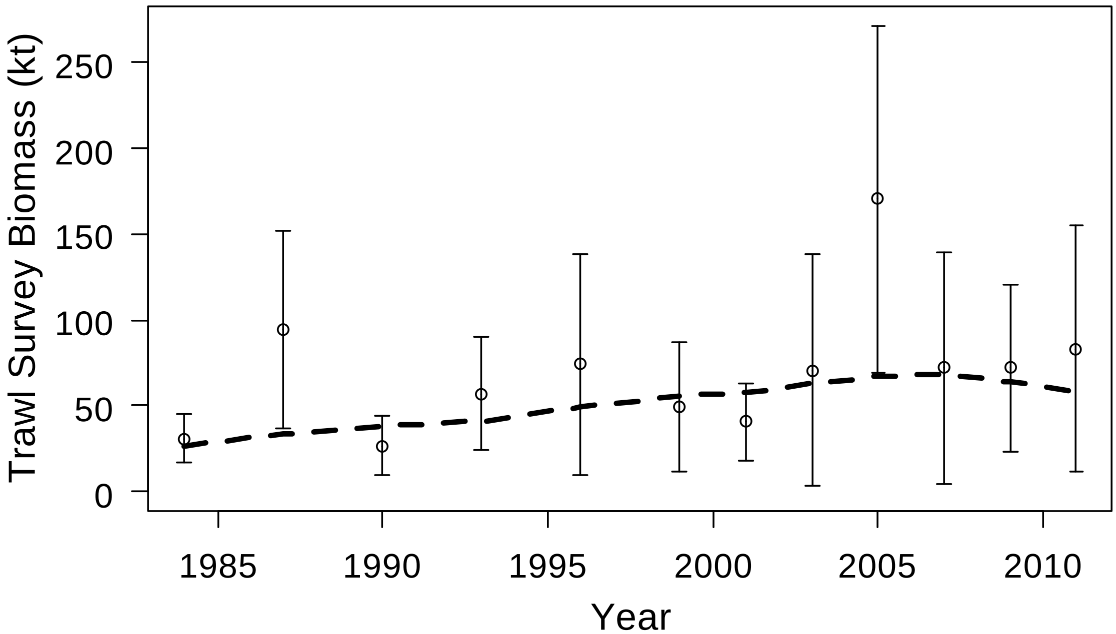


Figure 12-5. Observed and predicted GOA dusky rockfish trawl survey biomass based on author recommended model. Observed biomass is circles with 95% confidence intervals of sampling error.

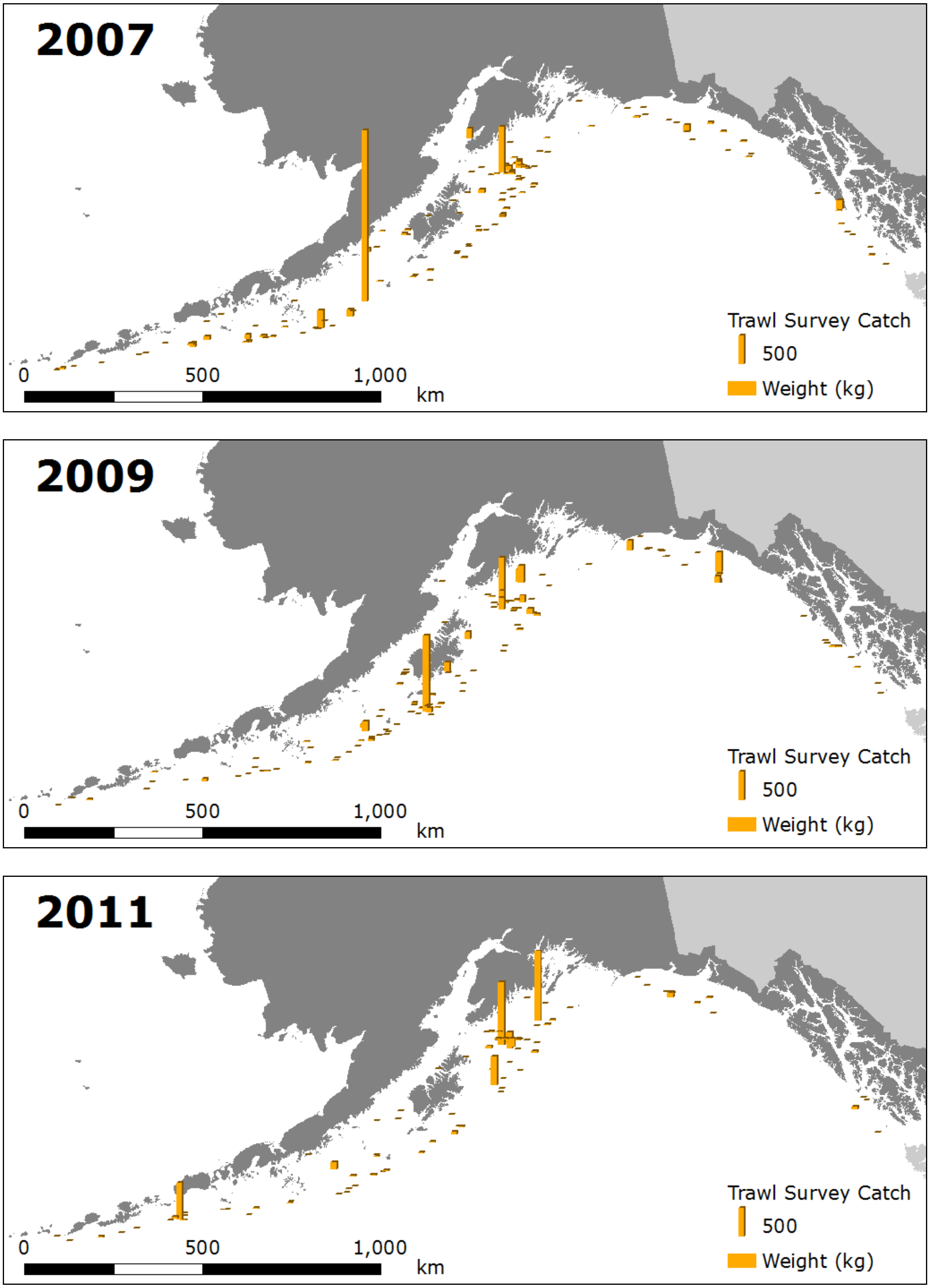


Figure12-6. Spatial distribution of dusky rockfish in the Gulf of Alaska during the 2007, 2009, and 2011 NMFS trawls surveys.

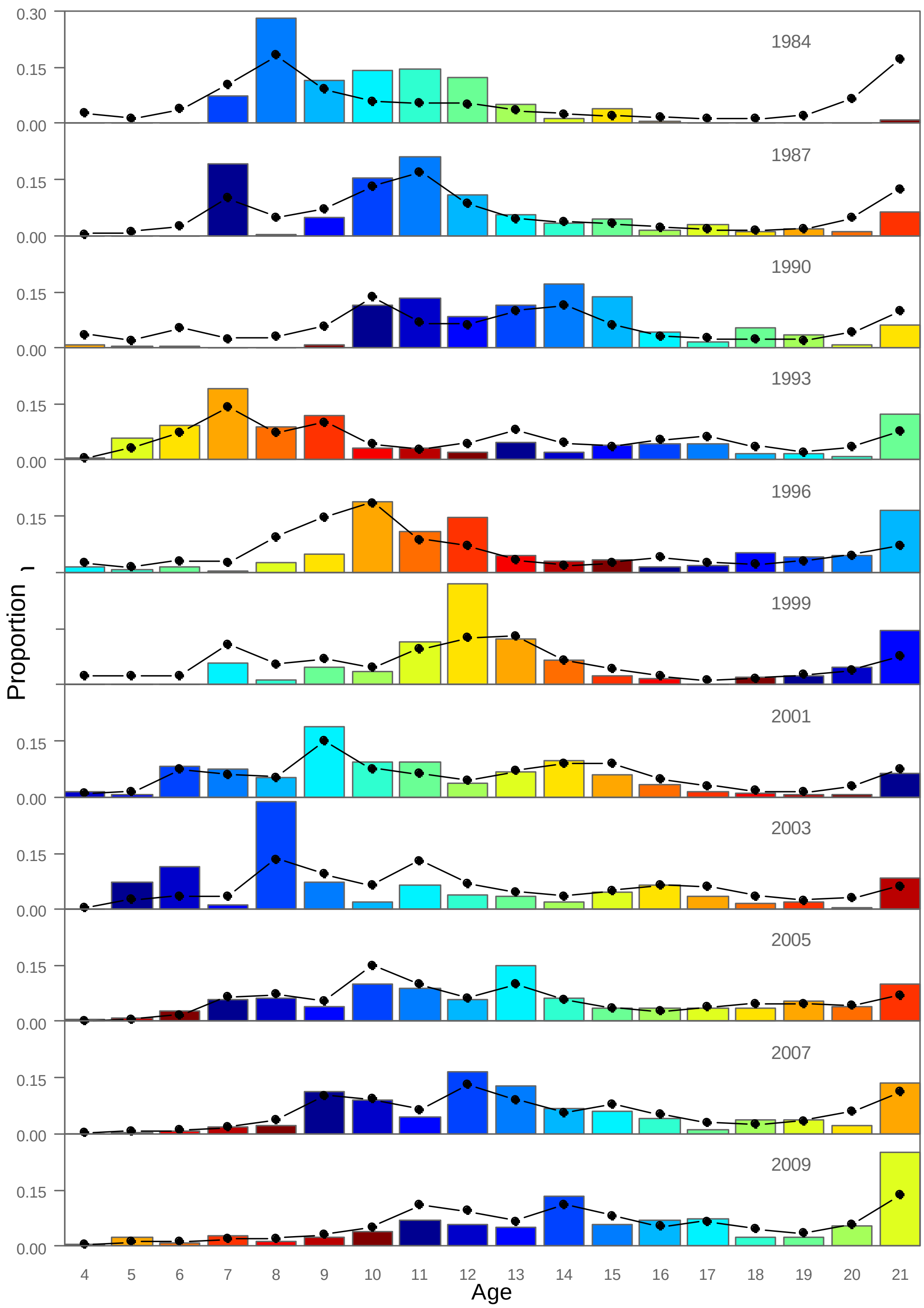


Figure 12-7. Trawl survey age composition by year for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles. Colors correspond to individual year classes.

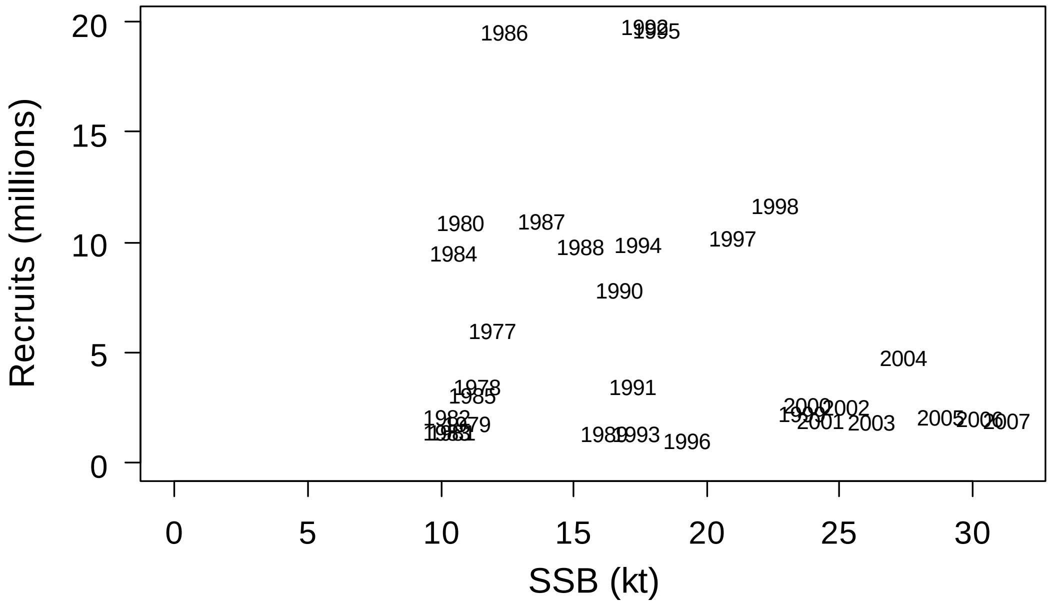


Figure 12-8. Scatterplot of spawner-recruit data for GOA dusky rockfish author recommended model. Label is year class of age 4 recruits. SSB = Spawning stock biomass in kilo tons (kt).

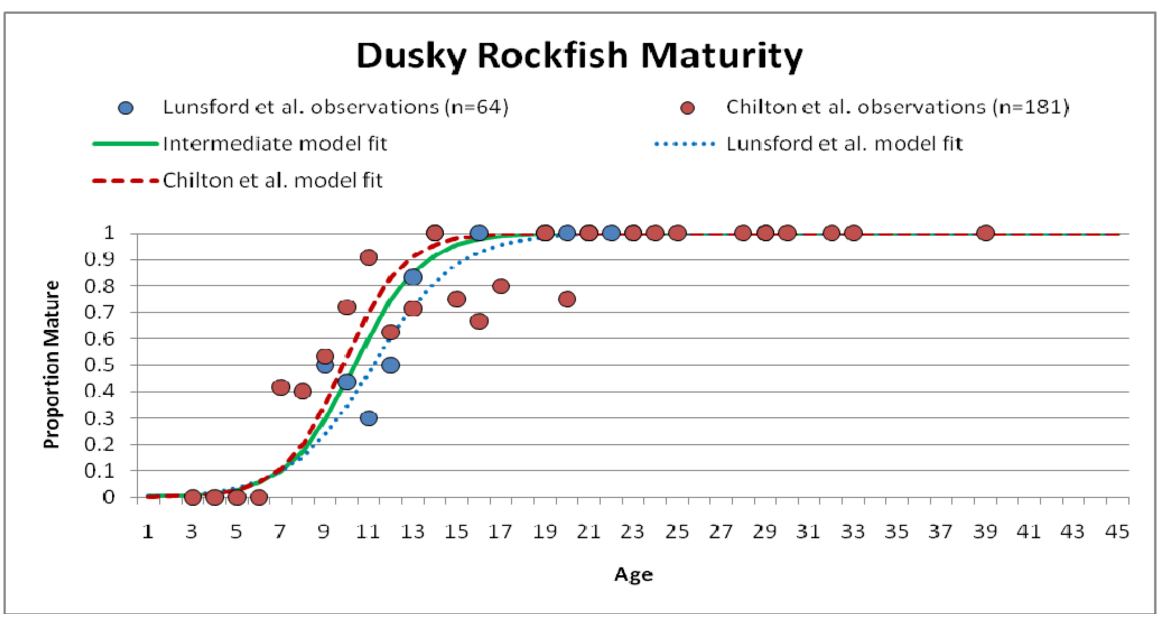


Figure 12-9. Comparison of maturity curves including intermediate curve used in determining Gulf of Alaska dusky rockfish 50% age at maturity.

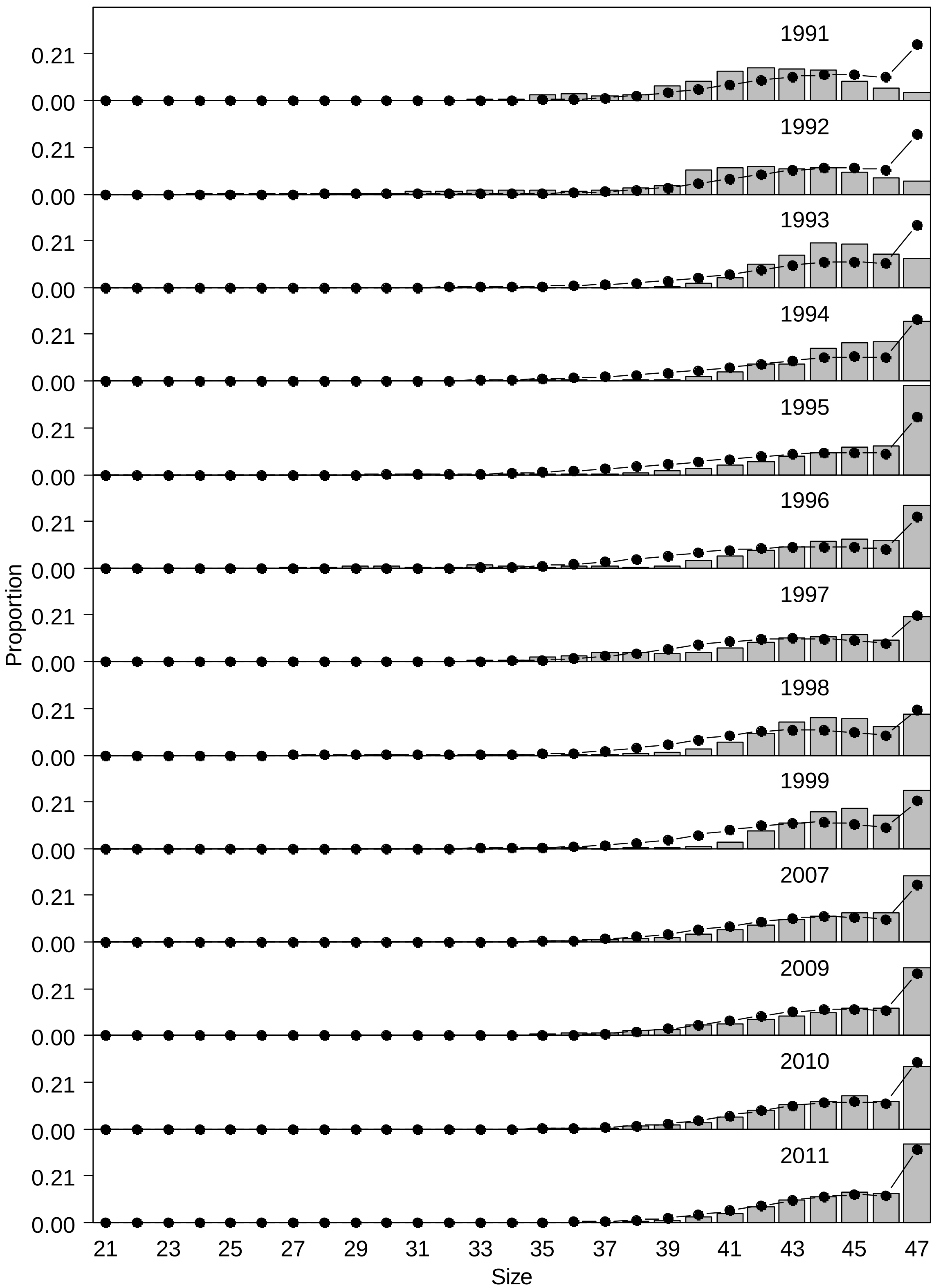
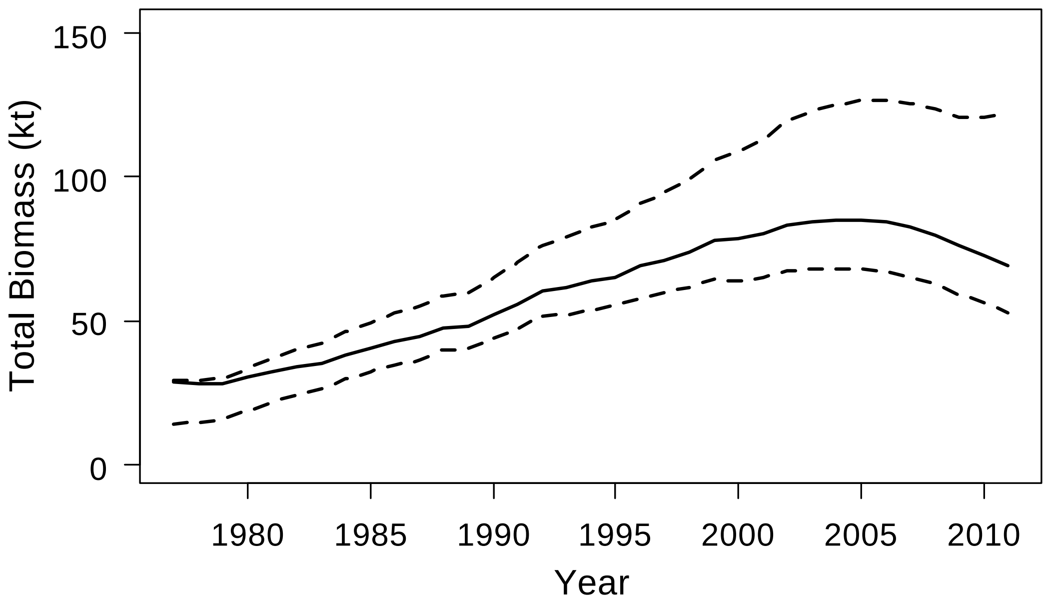


Figure 12-10. Fishery length compositions for GOA dusky rockfish. Observed is bars, author recommended model predicted is line with circles



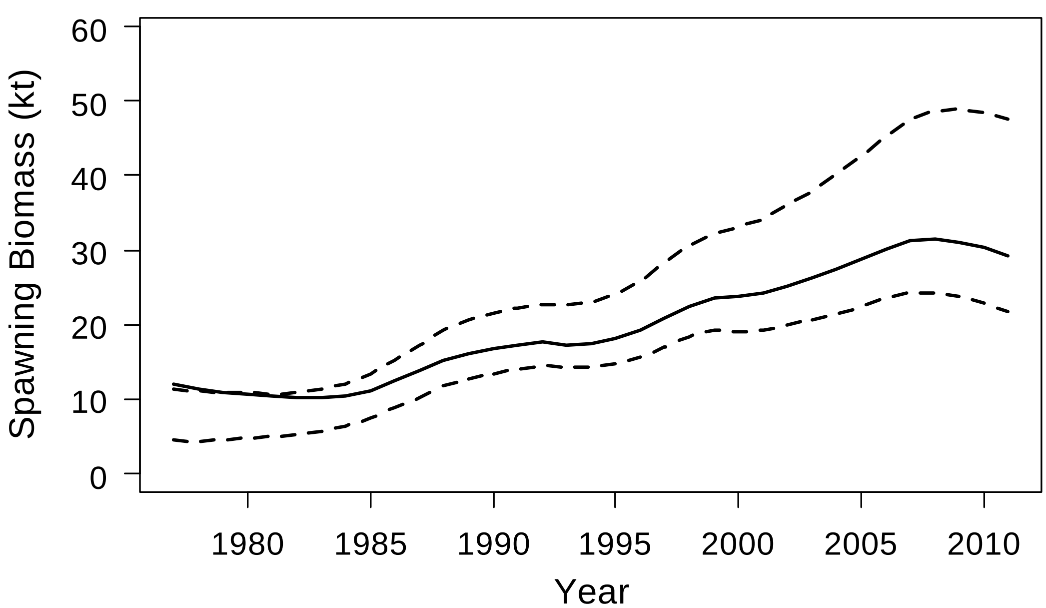


Figure 12-11. Time series of predicted total biomass and spawning biomass of GOA dusky rockfish for author recommended model. Dashed lines represent 95% credible intervals from 5 million MCMC runs.

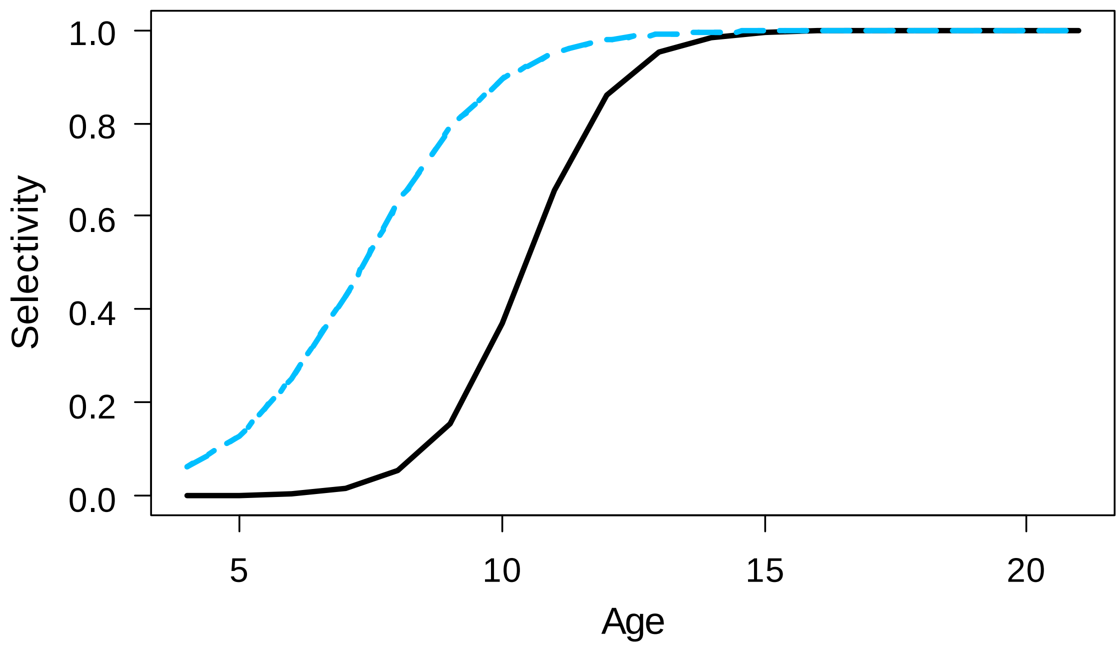


Figure 12-12. Estimated fishery and survey selectivity for GOA dusky rockfish from author recommended model. Dashed line is survey selectivity and solid line is fishery selectivity.

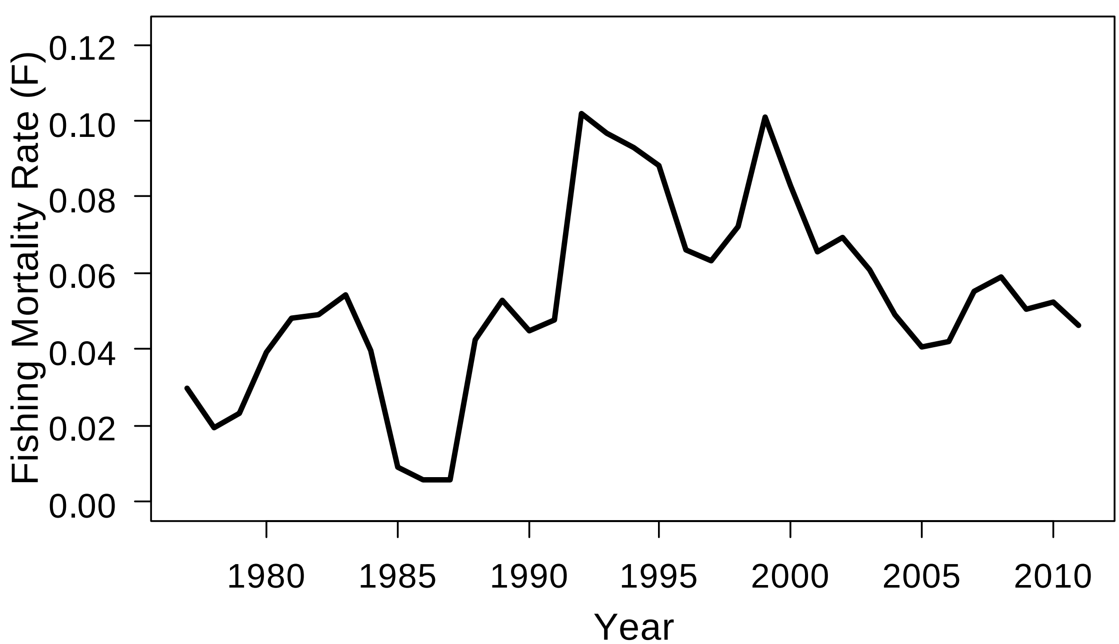


Figure 12-13. Time series of estimated fully selected fishing mortality for GOA dusky rockfish from author recommended model.

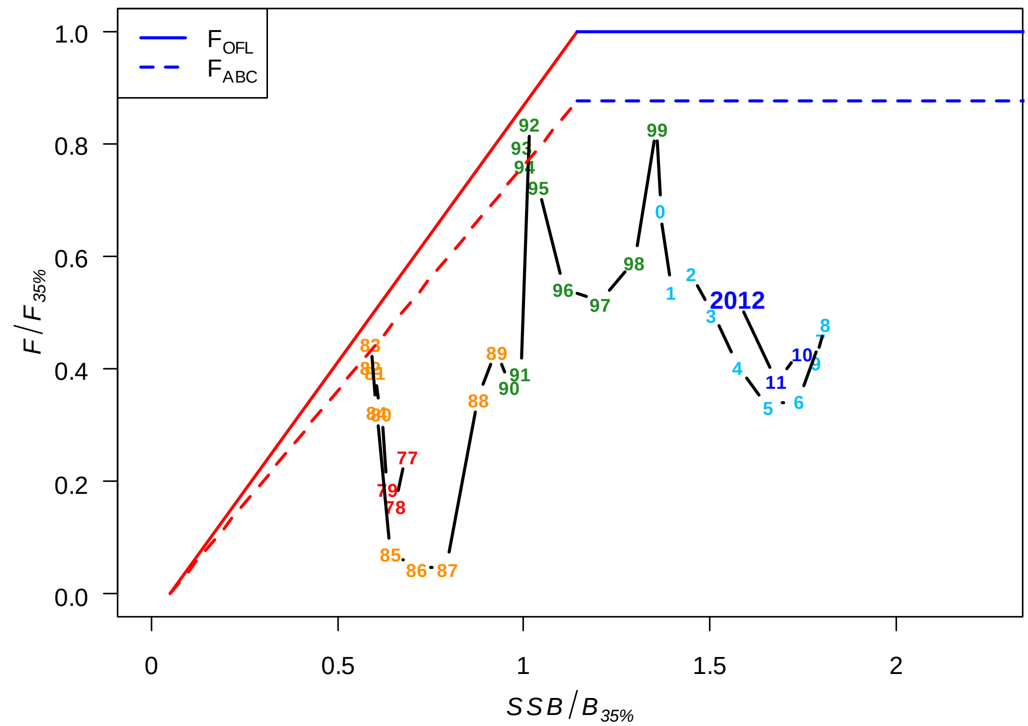


Figure 12-14. Time series of dusky rockfish estimated spawning biomass relative to the unfished level and fishing mortality relative to F_{OFL} for author recommended model.

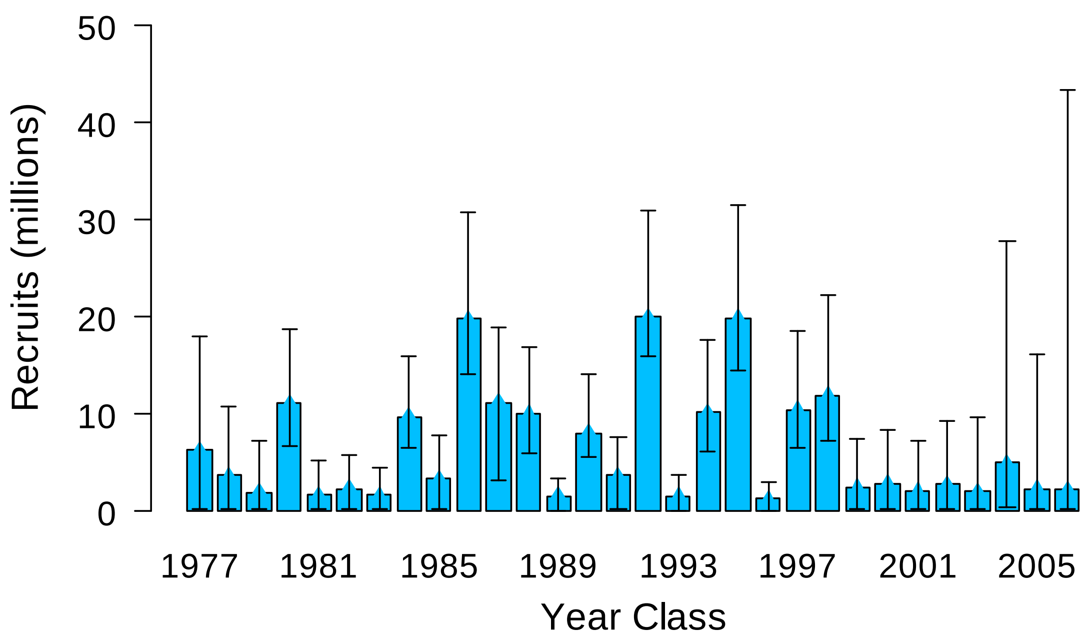


Figure 12-15. Estimated recruitments (age 4) for GOA dusky rockfish from author recommended model.

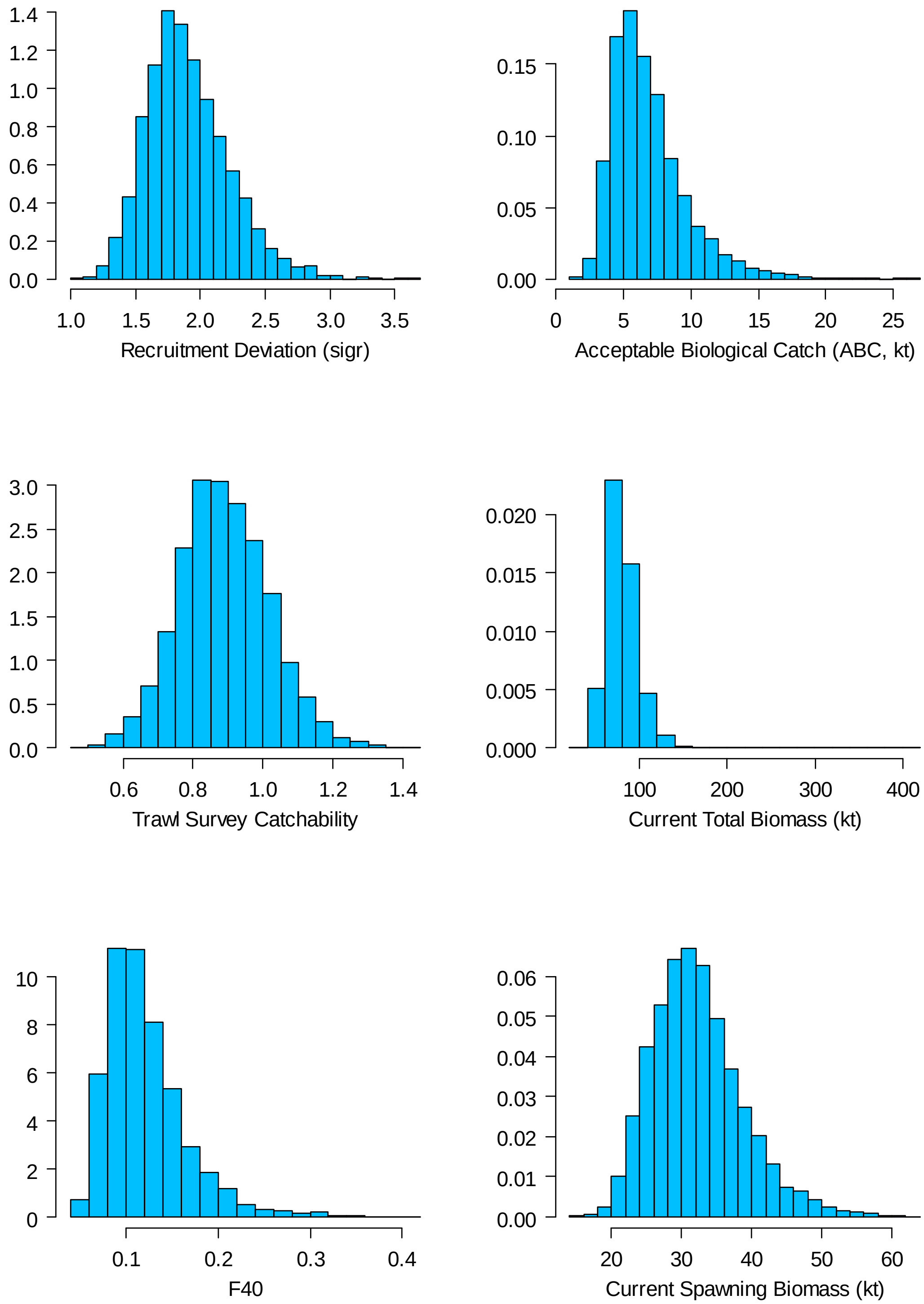


Figure 12-16. Histograms of estimated posterior distributions for key parameters derived from the MCMC for GOA dusky rockfish.

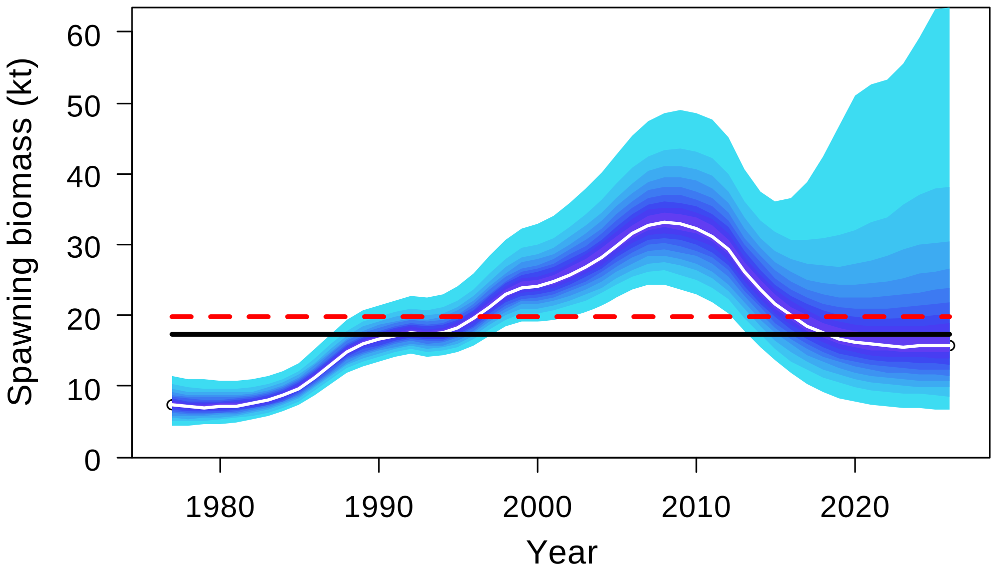


Figure 12-17. Bayesian credible intervals for entire spawning stock biomass series including projections through 2024. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1981-2007. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

Appendix 12.A

Evaluation of stock structure for Gulf of Alaska Dusky Rockfish

Chris Lunsford, Pete Hulson, and S.Kalei Shotwell

Executive Summary

We present various types of information on Gulf of Alaska (GOA) dusky rockfish to evaluate potential stock structure for this species. We follow the stock structure template recommended by the Stock Structure Working Group (SSWG) and elaborate on each category within this framework. Available data are consistent with population structure by large management areas of Eastern, Central, and Western GOA defined by fishery and survey sampling. Harvest and trend data indicate population levels are stable and that fishing effort appears consistent with abundance distribution. Dusky rockfish are long-lived but have a lower generation time than many other deep-water rockfish. The distribution is extremely patchy and highly aggregated but there is little information regarding spawning, reproduction, larval dispersal, behavior, or movement. Growth differences among regions in the GOA are minimal. No genetic information is available to infer any genetic stock structure components that might exist.

Currently, GOA dusky rockfish is managed as a Tier 3a species with area-specific Acceptable Biological Catch (ABC) and gulf-wide Overfishing Level (OFL). Given that localized depletion occurs infrequently in the GOA and that dusky rockfish catches are near 60% of maximum permissible ABC, the risk of overfishing is low. We continue to recommend the current management specifications for dusky rockfish.

Introduction

The Stock Structure Working Group (SSWG) was formed in 2009 to develop a set of guidelines to assist stock assessment authors in providing recommendations on stock structure for Alaska stocks. The framework was presented at the September 2009 joint Groundfish Plan Team and a report was drafted shortly thereafter that included a template for presenting various scientific data for inferring stock structure. In November, 2010, The Gulf of Alaska Groundfish Plan Team (GOA GPT) discussed the advantages of having all stock assessment authors evaluate stock structure characteristics of specific stocks. Subsequently, the GOA GPT recommended that the pelagic shelf rockfish (PSR) complex be used as a test example in the stock structure evaluation template.

Sebastes rockfish species in Federal waters of the Gulf of Alaska (GOA) were first split into three broad management assemblages by the North Pacific Fishery Management Council (NPFMC) in 1988: slope rockfish, PSR, and demersal shelf rockfish. Since 1988, major modifications have occurred to break out these broad groupings into finer scale assemblages. In the PSR assemblage, black and blue rockfish were removed from the group in 1998 and dark rockfish removed in 2009; management responsibilities for each of these species were transferred to the Alaska Department of Fish & Game. The other three species of PSR, dusky rockfish (*Sebastes variabilis*), yellowtail rockfish (*S. flavidus*), and widow rockfish (*S. entomelas*), have remained in the assemblage since its inception. In 2011, the GOA GPT recommended to the authors to reorganize the PSR assessment and management such that separate specifications would be established for dusky rockfish and specifications for the widow and yellowtail would be included in the “Other slope” species grouping. This was based on several reasons. First, the group is dominated by dusky rockfish which supports a valuable directed fishery whereas yellowtail and widow rockfish have a relatively low abundance in the GOA. Secondly, since 2003 dusky rockfish has been assessed by an age-structured model and is considered Tier 3 under NPFMC harvest policy definitions. Yellowtail and widow rockfish have remained Tier 5 species in which the assessment is based on simple estimates of biomass and natural mortality. Finally, extensive survey data and other information exists which indicate dusky rockfish do not generally share the same geographic distribution and habitat with the other two PSR species. Therefore, in this document we present specific information regarding stock structure characteristics of dusky rockfish in the GOA consistent with the expected breakout of dusky rockfish to its own specifications.

Dusky rockfish is managed as a Tier 3 species with area-specific Acceptable Biological Catch (ABC) and gulf-wide Overfishing Level (OFL) recommendations. Included here is a summary of what is known regarding the population of dusky rockfish in the GOA relevant to stock structure concerns along with an evaluation of the stock structure template, author recommendations, and potential management implications to be considered. The majority of this information is excerpted from the most recent full stock assessment and can be found in more detail there (Lunsford et al., 2009).

Distribution

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.

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. Within the GOA, the majority of dusky rockfish abundance occurs in the Central and Western Gulf.

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. On a finer spatial scale, submersible dives have observed dusky rockfish in association with rocky habitats and in areas with extensive sponge beds and coral colonies.

Life History

Dusky rockfish have been aged up to 76 years old. Little is known regarding the larval or juvenile life stages. 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, since juveniles less than 25 cm fork length are infrequently caught in bottom trawl surveys (Clausen et al. 2002) or with other sampling gear. Older juveniles have been taken only infrequently in the trawl surveys, but when caught are often found at more inshore and shallower locations that adults. The major prey of adult dusky rockfish appears to be euphausiids, based on the limited food information available for this species (Yang 1993). In a more recent study, Yang et al (2006) found that Pacific sandlance along with euphausiids were the most common prey item of dusky rockfish, comprising 82% and 17% , respectively, of total stomach contents by weight.

Fishery

Fishery catch statistics for the pelagic shelf rockfish complex are available from the Alaska Regional Office blend estimates and catch accounting system. Specific catches for dusky rockfish have been estimated for input in the age-structured model (Lunsford et al. 2009). Generally, annual catches of dusky rockfish increased from 1988 to 1992, and have fluctuated in the years following (Figure 12A-1). Catch is typically below ABC and TAC levels. Dusky rockfish are commonly caught in association with other slope rockfish species, mainly northern rockfish, which may constrain dusky rockfish catch due to over-harvest concerns for those species. Bycatch of dusky rockfish in other fisheries is presumed to be small in fisheries other than slope rockfish. Discard rates of dusky rockfish are relatively low and in recent years have decreased as a consequence of the Rockfish Pilot Project.

The majority of dusky rockfish are harvested in the Central and Western areas. Catches 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. In 1998, Amendment 41 was passed which had important management concerns for dusky rockfish as it prohibited trawling in the Eastern GOA east of 140 degrees W. longitude. This effectively reduced the commercial harvest of dusky rockfish to zero in the East Yakutat/Southeast Outside area. The Rockfish Pilot Project initiated in 2007 allocates the rockfish quota by sector which is intended to enhance resource conservation and improve economic efficiency. The program may affect the spatial distribution of fishing effort within the Central GOA since the extended fishing season lasts from May 1 through November 15 instead of an approximate two week fishery in July that had existed previously. This should spread the fishery out in space and time, but also has the potential to harvest up to 100% of the Central GOA TAC which has previously not been done. However, since 2007, gulf-wide catches have been near sixty percent of total TAC.

Survey

Standard bottom trawl surveys in the GOA provide the most comprehensive data on dusky rockfish. The trawl survey is based on a stratified random sampling design but is designed as a multi-species survey. There is high variability in survey catches of dusky rockfish because it is difficult to sample high relief habitat inhabited by dusky rockfish and this species is thought to be patchily distributed and highly aggregated., (Figure 12A-2). However, other available surveys, such as longline, do not effectively sample dusky rockfish. Comparative biomass estimates for the eleven bottom trawl surveys conducted show wide biomass fluctuations for dusky rockfish along with large confidence intervals (Figure 12A-3). Coefficient of variations (CVs) for biomass estimates range between 30% and 48%, similar to CVs for slope rockfish species. On a geographical basis, the Central Gulf region has the highest biomass of dusky rockfish whereas the lowest estimates are in the Eastern Gulf region.

Management
An age-structured model was first accepted in 2003 as an alternative to average trawl survey biomass estimates and was used to determine the ABC (Acceptable Biological Catch). ABC and TAC (Total Allowable Catch) are currently calculated for dusky rockfish under Tier 3 definitions and are apportioned to the three management areas of the GOA (Western, Central, Eastern). The apportionment is based on a weighted average of recent trawl survey estimates. The OFL (Overfishing Limit) is not apportioned to area but instead set at a gulf-wide level.

Application of Stock Structure Template
To address stock structure concerns, we utilize the existing framework for defining spatial management units introduced by Spencer et al. (2010) (Table 12A-1). In the following sections, we elaborate on the available information used to respond to specific factors and criterion for defining dusky rockfish stock structure.

<u>Harvest and trends</u>
Fishing mortality
The fully-selected fishing mortality time series indicates a rise in fishing mortality from late 1980's through the late 1990's and has declined since with a small increase in 2007 and 2008 (Figure 12A-4). Since 2000, these levels have been well below F40%, the maximum permissible fishing mortality for ABC.
Spatial concentration of fishery relative to abundance
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.
Population trends
NMFS trawl surveys have been conducted in the GOA since 1984. Despite high variability in survey catches and biomass estimates, the biomass trend of dusky rockfish population levels have been relatively stable (Figure 12A-3). Model predicted total biomass estimates indicate a moderately increasing trend over time (Figure 12A- 5). Population trends within regions are similar to overall trend and driven by the highly variable survey catch rates.
Spatial overlap of fishery and survey data
We utilized the observed fishery catch and trawl survey data to generate a series of spatial distribution maps of dusky rockfish concentrations. We developed maps of mean conditions to identify long-term patterns in dusky rockfish distribution (Figure 12A-6). In order to compare the trawl survey and the fishery data on the same map, we created an interpolated raster image of the

trawl survey data from 1984-2009 (Figure 12A-6a). The trawl survey provided the most complete spatial coverage and weight estimates were available by haul. Prior to the 1996 survey, dusky rockfish were not split from dark rockfish and were combined as a "dusky and dark rockfish unidentified" species code. However, the survey estimates are considered to be dominated by dusky rockfish (Lunsford et al. 2009) and we included these earlier survey estimates in the calculation of the survey raster. Based on this survey data, dusky rockfish are patchily distributed with high aggregations in the Amatuli Gully (shelf region southwest of Prince William Sound) and Yakutat region. We then calculated mean fishery catches by aggregating the observed fishery data in a raster image and converting the centroids of each raster cell to points. Observed fishery data was available from 1993-2009. In general, the mean catches for the observed fishery are distributed similarly to the trawl survey (Figure 12A-6b). The exception is the Eastern Gulf area where we see the impact of Amendment 41 prohibiting trawling east of the 140^{o}W line. This essentially splits the Yakutat region into two smaller areas and could serve to protect a section of the dusky population in the Eastern Gulf region.

<u>Barriers and phenotypic characters</u>

Generation time

Rockfish in the GOA are typically slow growing and long-lived. The maximum age of dusky rockfish in the GOA is 59 years from the survey and 76 years from the fishery. Estimates of natural mortality range from 0.06 to 0.09. We estimated generation time for dusky rockfish at 23 years following the methods described in Restrepo et al. 1998 and using the estimates available from the dusky age-structured model (Lunsford et al. 2009). Two studies have estimated the age at 50% maturity of dusky rockfish in the GOA and range from 9.2 years to 11.3 years. In comparison to other rockfish in the GOA, these values indicate dusky rockfish have a lower generation time, likely due to the higher natural mortality and earlier maturity.

Physical limitations

General circulation patterns of the GOA are well documented. However, how these interact on small spatial scales in association with bathymetric features is largely unknown. In addition, larval and post-larval distribution of dusky rockfish is poorly understood so interpreting physical limitations are difficult. Abundance of dusky rockfish is lowest in the Eastern GOA, and highest in the Central GOA followed by the Western GOA but what determines these abundances is unknown in regards to physical limitations.

Growth differences

To evaluate growth differences in dusky rockfish in the GOA, von Bertalanffy growth curves were fit to bottom trawl survey mean length-at-age and weight-at-age data by management region (Figure 12A-7). Overall, data from the Eastern GOA indicate the length and weight of younger aged fish in this region are greater than the other two regions. Yet for older fish in this region, the length and weight are less than fish from the Central and Western regions. This region represents the lowest abundance of dusky rockfish in the GOA which is reflected in the number of samples collected for this analysis. We believe the lack of smaller fish sampled in the Eastern GOA is responsible for the differences seen in growth curves among regions rather than true differences in length- and weight-at-age (Figure 12A-8). In addition, little difference is seen between the Western and Central regions, the areas of highest abundance and regions where nearly all commercial harvest occurs.

Age/size structure

The best available knowledge on the age and size structure of dusky rockfish in the GOA comes from bottom trawl survey data. Survey size and age compositions suggest that recruitment of dusky rockfish is a relatively infrequent event and highly variable with magnitudes of difference large enough to drive the composition of the population. Mean population length over time has ranged from 39.8 cm to 43.9 cm. The mean population age has fluctuated between 10.5 years and 14.7. There are no evident differences in size or age compositions among different regions in the GOA or in time apart from recruitment events. Due to the high variability in recruitment events it is uncertain if there has been size or age truncation in this population or if there are significant differences among regions.

Spawning time differences

Fertilized ova and eyed embryos have been observed from February to April. Parturition is believed to occur in the spring. 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. Therefore, recognizing differences in spawning times is not likely.

Maturity-at age/length differences

Two studies have estimated 50% maturity at age. Estimates range from 9.2 to 11.3 years. Both studies sampled areas in the Central Gulf of Alaska. Sufficient data for comparison of maturity at age or length among regions or through time is not available.

Morphometrics

Dusky rockfish were formally described in 2004 as a separate species from dark rockfish in Orr and Blackburn (2004). For both species, no significant regional variation was observed in morphometric measurements.

Meristics

Dusky rockfish were found to have a lower range and mode of meristic counts when compared to dark rockfish (Orr and Blackburn, 2004). Slight clinal variation was evident for lateral-line pores in dusky rockfish between southeast Alaska collections and northern GOA collections. However, further work specific to dusky rockfish would be needed to accurately address meristic differences.

<u>Behavior and movement</u>

Spawning site fidelity

Little is known regarding the spawning habits of dusky rockfish in the GOA. There is no information as to when insemination occurs or if migrations occur for breeding or spawning. Harvest or catch data from this time period (fall/winter) is sparse from fisheries or surveys so annual distribution changes are difficult to detect.

Mark-recapture data

Because rockfish are physoclistic and subject to barotrauma there is little information regarding movement studies of deep-water rockfish. It is unlikely that mark-recapture studies would be successful because dusky rockfish inhabit deep depths and are typically caught with trawl nets .

Natural tags

No studies have addressed otolith microchemistry of dusky rockfish in the GOA. Parasite infestation has been used as a natural occurring tag in some rockfish species in the GOA (Moles et al. 1998). However, no studies have addressed parasite tags in dusky rockfish.

<u>Genetics</u>

No studies have been done to determine if the Gulf of Alaska population of dusky rockfish is one stock, or if subpopulations occur. Because of the lack of genetic data analyses, evidence of genetic population structure or genetic variation in the dusky rockfish population is unknown.

Factors and criterion specific to genetics of dusky rockfish are:

Isolation by distance
Not Available
Dispersal distance
Not Available
Pairwise genetic differences
Not Available

Summary, Implications, and Recommendations

We summarize the available information on stock structure for dusky rockfish in the GOA in Table 12A-2. Harvest and trend data indicate population levels are stable or slightly increasing and that fishing mortality in recent years is below maximum permissible F. Fishing is focused in smaller spatial areas but distribution of effort appears to be consistent with abundance. Typical of *Sebastes* species, dusky rockfish are long-lived and have a long generation time but likely have a lower generation time than many other deep-water *Sebastes*. Little information is available regarding reproduction and mechanisms responsible for larval dispersion but dusky rockfish are found throughout the GOA in varying levels of abundance. Growth differences among regions in the GOA are minimal. Behavior and movement information for most *Sebastes* species is lacking in the GOA. No information is available regarding spawning movements or inter-annual movement. No genetic information is available to infer any genetic stock structure components that might exist.

The current management regime apportions the stock and catch into three large geographical regions. Survey and fishery information indicates that abundance levels differ among the regions. Commercial harvest in the Eastern GOA where dusky rockfish abundance is lowest is extremely low due to trawl fishery restrictions in that region. Because dusky rockfish are patchily distributed and tend to be concentrated in small spatial areas of high relief there is concern for localized depletion. However, available data indicate localized depletion has occurred infrequently in the GOA. Mixing and dispersal of fish among areas is unknown; therefore the capacity of the population for repopulating small spatial areas is unknown. With the lack of available data on fine scale genetic population structure, it is difficult to determine if current management practices effectively protect dusky rockfish populations from disproportionate harvest in certain areas. Dusky rockfish are of concern due to their apparent concentration in narrow depth bands along offshore banks and gullies, but no available data indicates that stock structure is at risk under the current management regime. Current management practices apportion ABC by management area but use a gulf-wide OFL. Dusky rockfish catches in the GOA are near 60% of maximum permissible and risk of overfishing is low. Based on available data, initiating area-specific OFL's is not recommended as there are multiple levels of precaution built into the current management recommendations and overharvest is unlikely. Given the available evidence on GOA dusky rockfish stock structure, the current resolution of spatial management is likely adequate and consistent with management goals.

Literature Cited

Carlson, H. R., and R. R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of Southeastern Alaska. Mar. Fish. Rev. 43: 13-19.

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.

Lunsford, C.R., S.K. Shotwell, and D.H. Hanselman. 2009. Gulf of Alaska pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 925-992, Appendix A. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501.

Moles. A., J. Heifetz, and D.C. Love. 1998. Metazoan parasites as potential markers for selected Gulf of Alaska rockfishes. Fish. Bull 96: 912-916.

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).

Restrepo, V. R., G. G. Thompson, P. M. Mace, W. L. Gabriel, L. L. Low, A. D. MacCall, R. D. Methot, J. E. Powers, B. L. Taylor, P. R. Wade, and J. F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing national standard 1 of the Magnuson–Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-31.

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.

Spencer, P., M. Canino, J. DiCosimo, M. Dorn, A.J. Gharrett, D. Hanselman, K. Palof, and M. Sigler. 2010. Guidelines for determination of spatial management units for exploited populations in Alaskan fishery groundfish management plans. Paper prepared for the September 2010 NPFMC Plan Team meeting.

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.

Yang, M-S., K. Dodd, R. Hibpshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-164, 199 p.

Table 12A-1. Framework of types of information to consider when defining spatial management units (from Spencer et al. 2010).

Factor and criterion	Justification
Harvest and trends	
Fishing mortality (5-year average percent of F_{abc} or F_{ofl})	If this value is low, then conservation concern is low
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	If fishing is focused on very small areas due to patchiness or convenience, localized depletion could be a problem.
Population trends (Different areas show different trend directions)	Differing population trends reflect demographic independence that could be caused by different productivities, adaptive selection, differing fishing pressure, or better recruitment conditions
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	If generation time is long, the population recovery from overharvest will be increased.
Physical limitations (Clear physical inhibitors to movement)	Sessile organism; physical barriers to dispersal such as strong oceanographic currents or fjord stocks
Growth differences (Significantly different LAA, WAA, or LW parameters)	Temporally stable differences in growth could be a result of either short term genetic selection from fishing, local environmental influences, or longer-term adaptive genetic change.
Age/size-structure (Significantly different size/age compositions)	Differing recruitment by area could manifest in different age/size compositions. This could be caused by different spawning times, local conditions, or a phenotypic response to genetic adaptation.
Spawning time differences (Significantly different mean time of spawning)	Differences in spawning time could be a result of local environmental conditions, but indicate isolated spawning stocks.
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Temporally stable differences in maturity-at-age could be a result of fishing mortality, environmental conditions, or adaptive genetic change.
Morphometrics (Field identifiable characters)	Identifiable physical attributes may indicate underlying genotypic variation or adaptive selection. Mixed stocks w/ different reproductive timing would need to be field identified to quantify abundance and catch
Meristics (Minimally overlapping differences in counts)	Differences in counts such as gillrakers suggest different environments during early life stages.
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Primary indicator of limited dispersal or homing
Mark-recapture data (Tagging data may show limited movement)	If tag returns indicate large movements and spawning of fish among spawning grounds, this would suggest panmixia
Natural tags (Acquired tags may show movement smaller than management areas)	Otolith microchemistry and parasites can indicate natal origins, showing amount of dispersal
Genetics	
Isolation by distance (Significant regression)	Indicator of limited dispersal within a continuous population
Dispersal distance (<<Management areas)	Genetic data can be used to corroborate or refute movement from tagging data. If conflicting, resolution between sources is needed.
Pairwise genetic differences (Significant differences between geographically distinct collections)	Indicates reproductive isolation.

Table 12A-2. Summary of available data on stock structure evaluation of GOA dusky rockfish. Template from Spencer et al. 2010.

Factor and criterion	Justification
Harvest and trends	
Fishing mortality (5-year average percent of F_{abc} or F_{ofl})	Recent years have low fishing mortality rates and catches are below ABC.
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	Fishing appears to be distributed similar to to survey abundance and distribution. Recent study found minimal localized depletion (Hanselman et al., 2007).
Population trends (Different areas show different trend directions)	Overall population trend is relatively stable or increasing. No major differences within regions. Changes in biomass by region due to high variability of survey.
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	Generation time is long (>10 years) but less than many deep-water *Sebastes* species.
Physical limitations (Clear physical inhibitors to movement)	No physical limitations known, but larval dispersal poorly understood.
Growth differences (Significantly different LAA, WAA, or LW parameters)	No major differences in growth among the Eastern GOA, Central GOA, and Western GOA.
Age/size-structure (Significantly different size/age compositions)	Age and size structures driven by major recruitment events. No major differences among regions in the GOA.
Spawning time differences (Significantly different mean time of spawning)	Unknown
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Unknown
Morphometrics (Field identifiable characters)	No significant regional variation.
Meristics (Minimally overlapping differences in counts)	Slight differences among southeast and the Northern GOA but more work needed to address for dusky rockfish.
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Unknown
Mark-recapture data (Tagging data may show limited movement)	Mark-recapture data unavailable.
Natural tags (Acquired tags may show movement smaller than management areas)	Unknown
Genetics	
Isolation by distance (Significant regression)	Unknown
Dispersal distance (<<Management areas)	Unknown
Pairwise genetic differences (Significant differences between geographically distinct collections)	Unknown

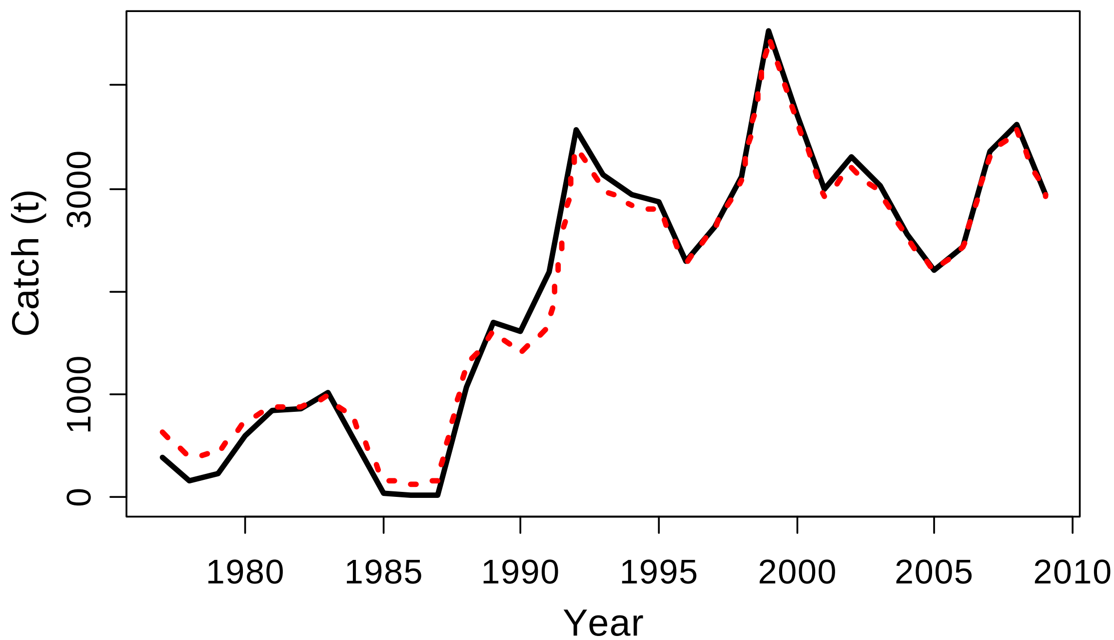


Figure 12A-1. Estimated commercial catches for GOA dusky rockfish. Observed is solid line, model estimated is dashed line (from Lunsford et al. 2009).

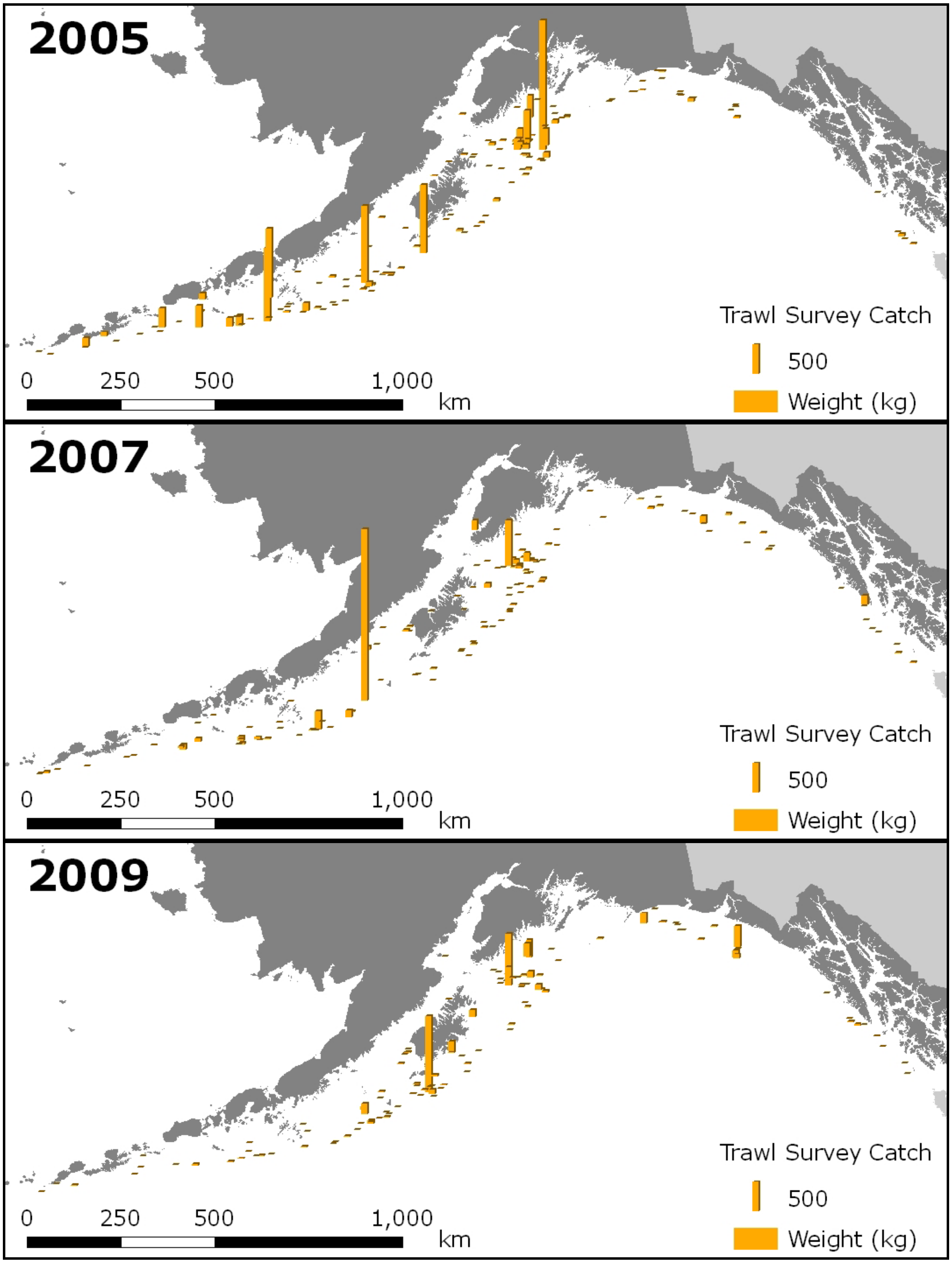


Figure 12A-2. Spatial distribution of dusky rockfish in the Gulf of Alaska during the 2005, 2007, and 2009 NMFS trawls surveys.

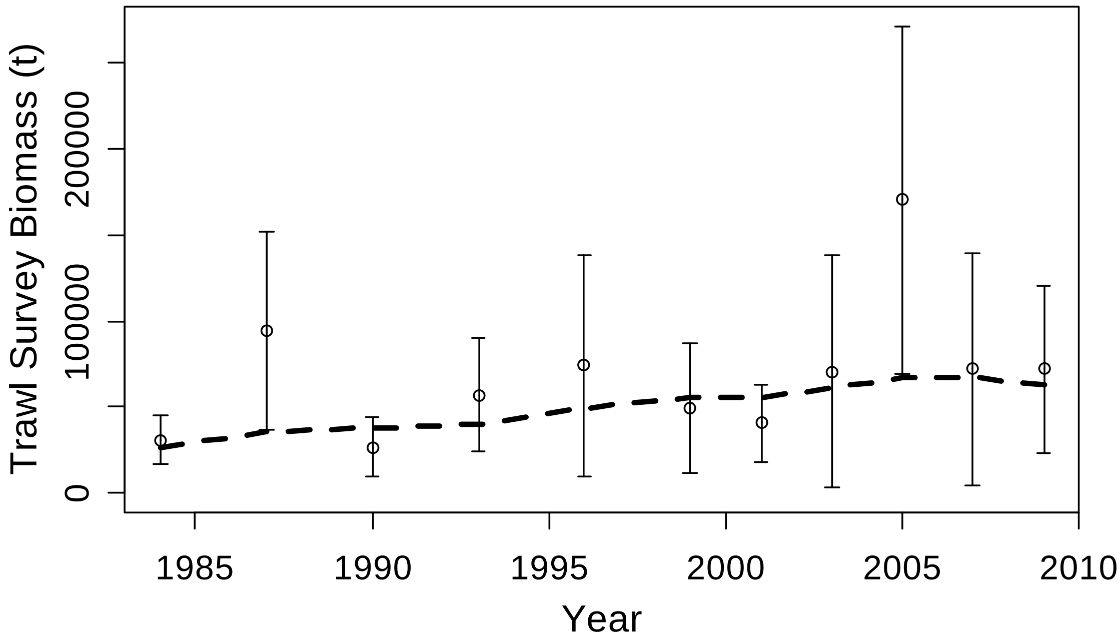


Figure 12A-3. Observed and model predicted GOA dusky rockfish trawl survey biomass. Observed biomass is circles with 95% confidence intervals of sampling error (from Lunsford et al. 2009).

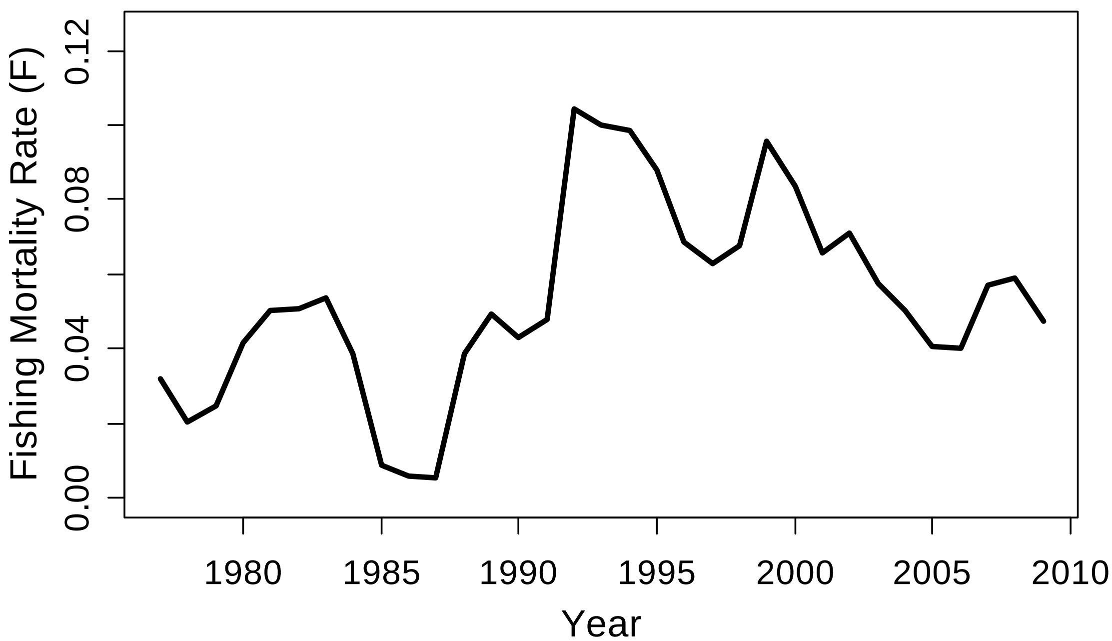


Figure 12A-4. Time series of estimated fully selected fishing mortality for GOA dusky rockfish (from Lunsford et al. 2009).

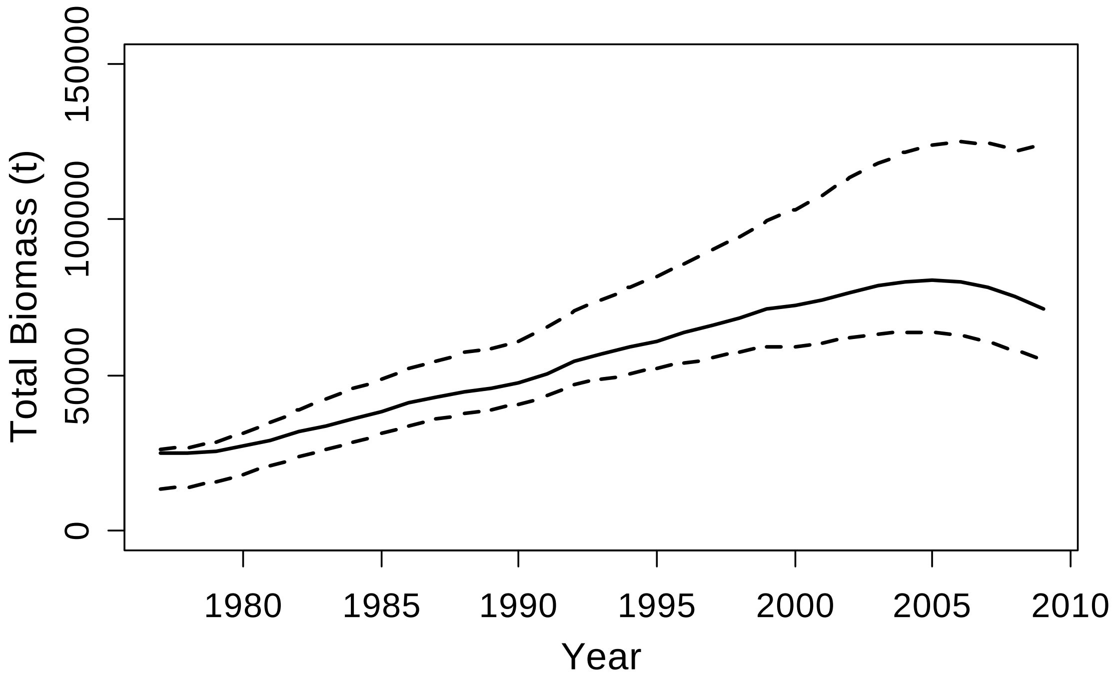
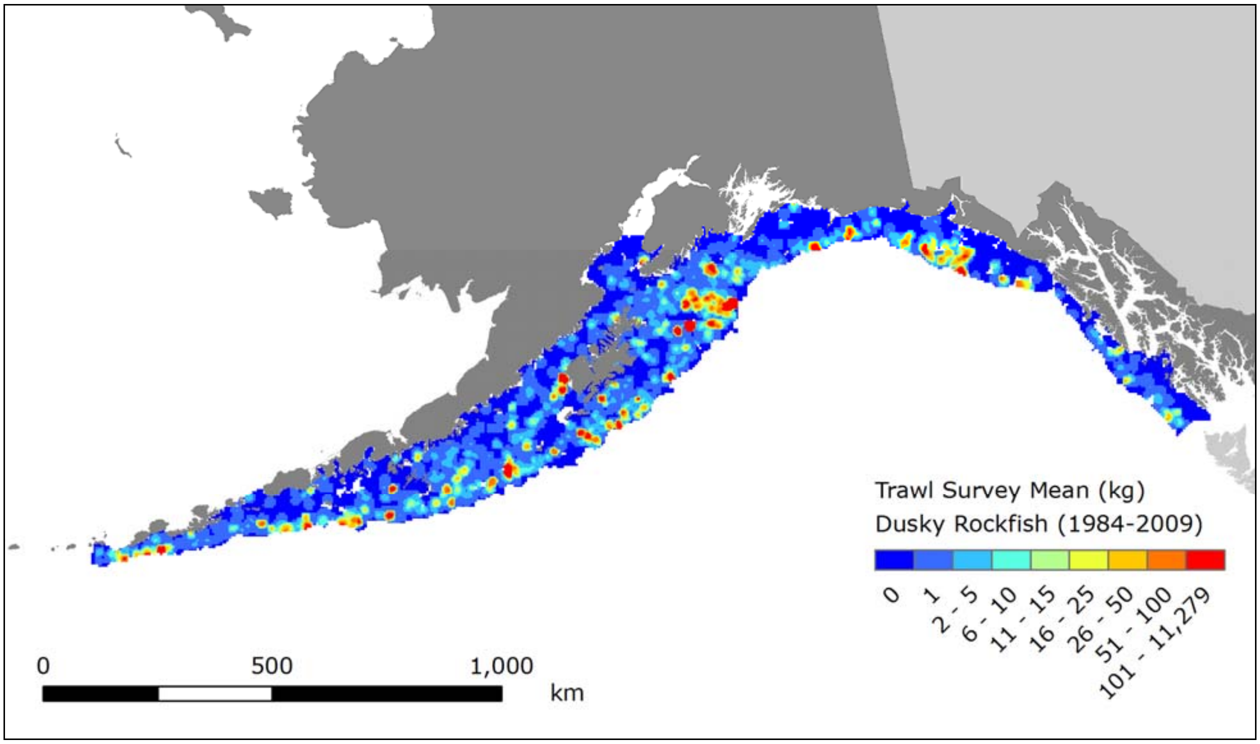


Figure 12A-5. Time series of predicted total biomass of GOA dusky rockfish for author recommended model. Dashed lines represent 95% credible intervals from 5 million MCMC runs (from Lunsford et al. 2009).



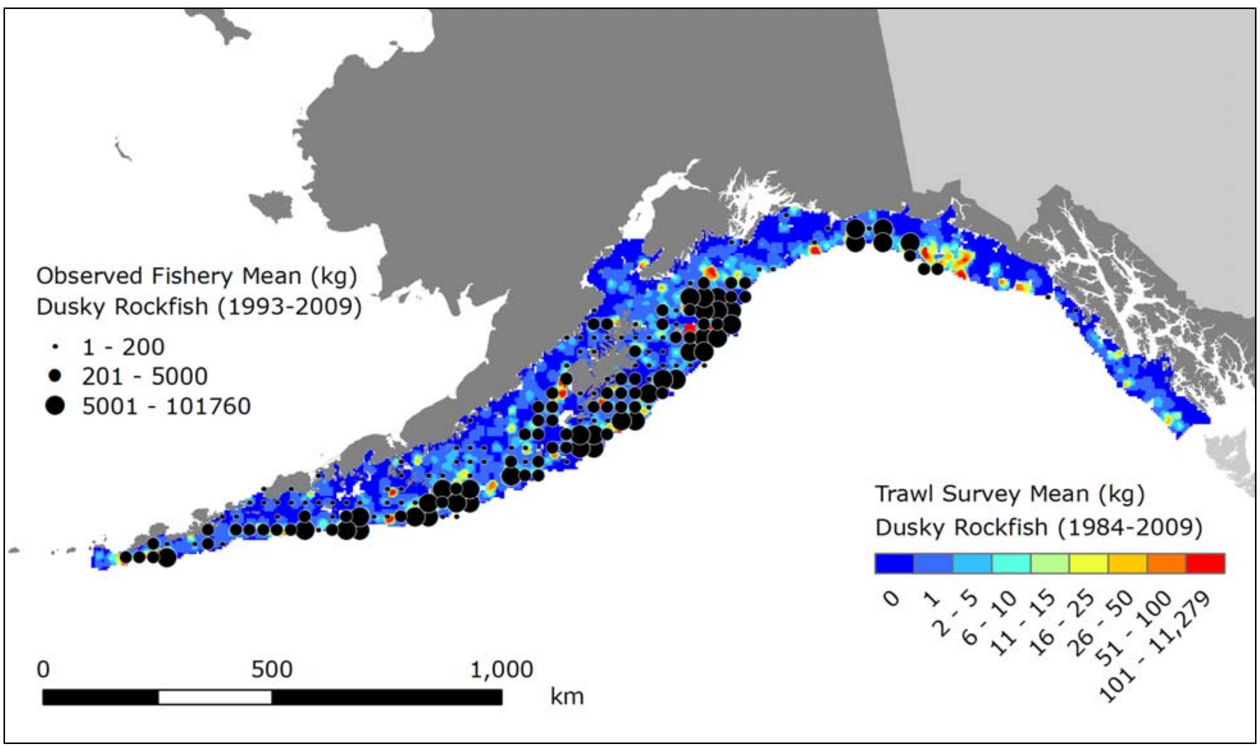


Figure 12A-6. Distribution maps of dusky rockfish for trawl survey mean conditions from 1984-2009 (a) and observed fishery catch mean (1993-2009) with trawl survey mean conditions (b).

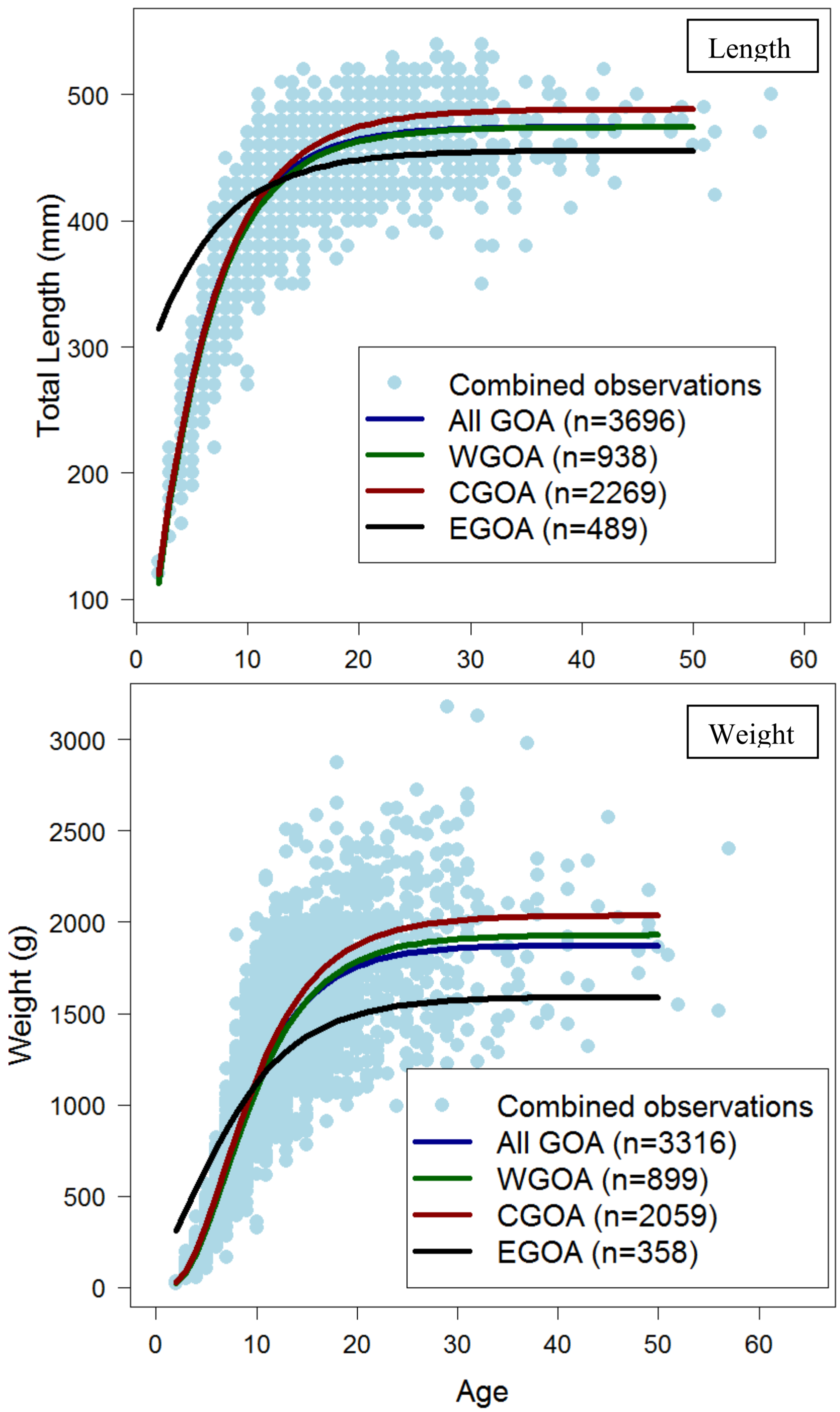


Figure 12A-7. Mean length-at-age and mean weight-at-age and fitted von Bertalanffy growth curves for dusky rockfish rockfish in the GOA using bottom trawl survey data for the Western GOA, Central GOA, Eastern GOA, and all GOA combined.

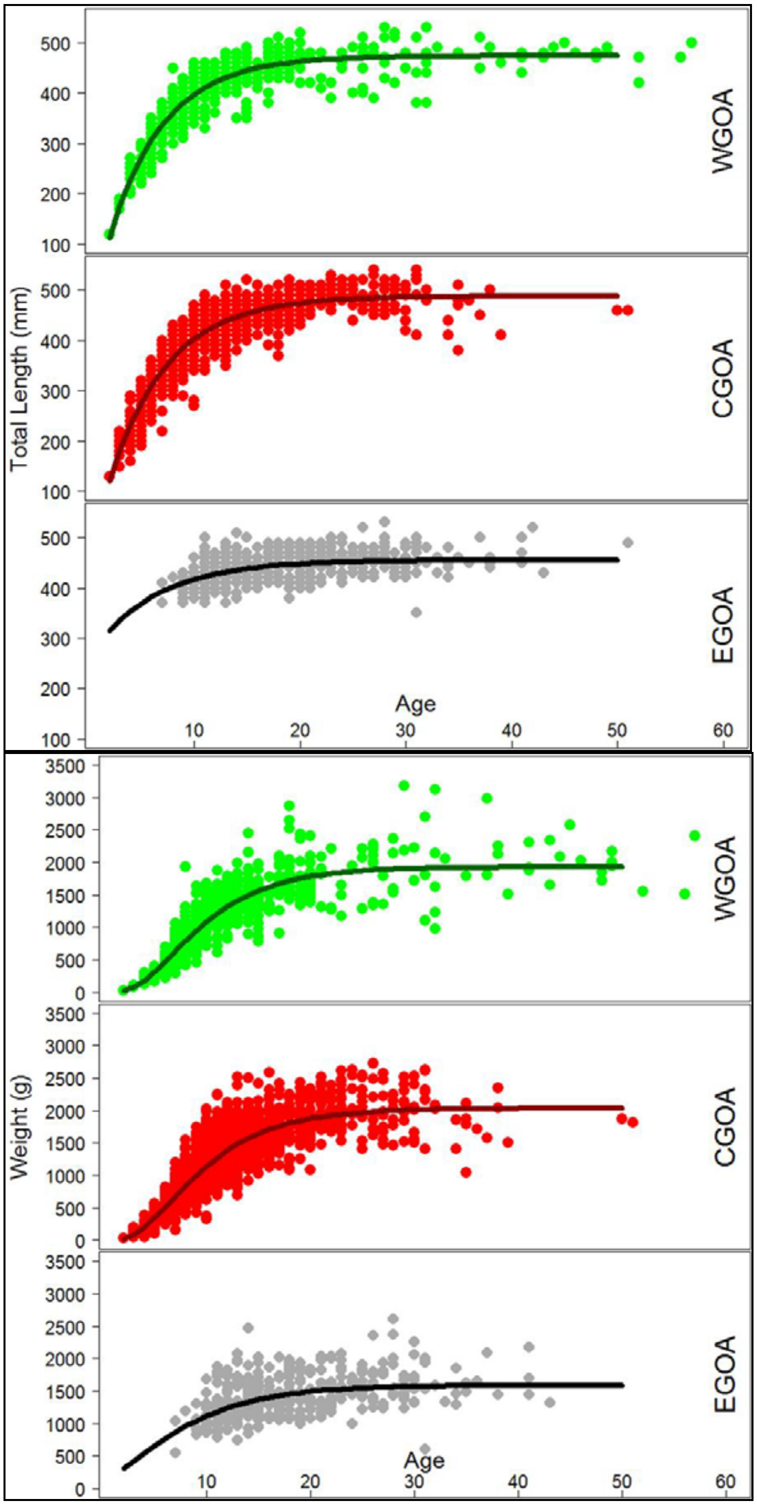


Figure 12A-8. Mean length-at-age and mean weight-at-age and fitted von Bertalanffy growth curves for dusky rockfish rockfish in the GOA using bottom trawl survey data by individual region for the Western GOA, Central GOA, Eastern GOA, and all GOA combined.

Appendix 12B

Management Reorganization of Species in the Gulf of Alaska Pelagic Shelf Rockfish and "Other Slope Rockfish" Assemblages

Discussion Paper for Gulf of Alaska Groundfish Plan Team

By
Dave Clausen, Tom Pearson, and Chris Lunsford
August 2011

Background

Sebastes rockfish species in Federal waters of the Gulf of Alaska (GOA) were first split into three broad management assemblages by the North Pacific Fishery Management Council in 1988: slope rockfish, pelagic shelf rockfish, and demersal shelf rockfish. Species in each group were thought to share a somewhat similar habitat as adults, and separate "Stock Assessment and Fishery Evaluation" (SAFE) reports were prepared for each assemblage. Since 1988, major modifications have occurred in the GOA slope rockfish group, as Pacific ocean perch, northern rockfish, and shortraker and rougheye rockfish have been separated from the assemblage, and the remaining slope species are now called "other slope rockfish". In the pelagic shelf rockfish (PSR) assemblage, black and blue rockfish were removed from the group in 1998 and dark rockfish removed in 2009; management responsibilities for each of these species were transferred to the Alaska Department of Fish & Game. The other three species of PSR, dusky rockfish (*Sebastes variabilis*), yellowtail rockfish (*S. flavidus*), and widow rockfish (*S. entomelas*), have remained in the assemblage since its inception.

Now that the PSR assemblage consists of just three species, the validity of this management group has become questionable. The group is dominated by dusky rockfish, which has a large biomass in the GOA and supports a valuable directed fishery, especially in the central GOA. In contrast, yellowtail and widow rockfish have a relatively low abundance in the GOA and are only taken commercially in very small amounts as bycatch. Moreover, since 2003, dusky rockfish has been assessed by an age-structured model and is considered a "Tier 3" species in the North Pacific Fishery Management Council's (NPFMC) harvest policy definitions, while yellowtail and widow rockfish have remained "Tier 5" species in which the assessment is based on simple estimates of biomass and natural mortality. Thus, in the present assessment for PSR, values of acceptable biological catch (ABC) and the overfishing level (OFL) for dusky rockfish are determined separately than those for yellowtail and widow rockfish, and the numbers are added together to yield an overall ABC and OFL for the PSR group.

Based on these reasons, GOA rockfish assessment authors began informally discussing that it made sense for dusky rockfish to have its own SAFE report and to be separated from the other two PSR species. Changing to a stand-alone assessment for dusky rockfish would make it analogous to the other GOA rockfish that are currently assessed with age-structured models (Pacific ocean perch, northern rockfish, and rougheye/blackspotted rockfish), each of which has its own SAFE chapter. These discussions were formalized by recommendations of the GOA Groundfish Plan Team (PT) in 2009 and 2010, as indicated in the following text from minutes of GOA PT meetings in each year.

November 2009 PT minutes, in section titled "Pelagic shelf rockfish": *"…The Plan Team recommends reorganization of future chapters to pull dusky out as a separate assessment and move yellowtail and* *widow into an 'other rockfish' category.*

The Team discussed the potential problems in future management under ACLs in that complexes must have similar life-history characteristics. The Team recommends the use of the vulnerability analysis to assist in grouping similar species. It was also noted that the minor species are primarily located in the eastern GOA and by default protected under trawl ban. Furthermore, moving yellowtail and widow in with other slope rockfish would effectively prohibit targeting on this species. Assessment would track individual species catch against species-specific ABCs and OFLs.

Plan Team recommendations for the next assessment:

The Team recommends reorganizing PSR assessment and management such that separate specifications would be established for dusky and consideration given to best groupings of complexes for the remaining species."

November 2010 PT minutes, in section titled "Rockfish-general": "*The author will bring forward a proposal to the Team in September regarding revised groupings of rockfish by complex, especially in regards to separating dusky rockfish from the other pelagic shelf species. This may include a recommendation to break out shortraker from other slope species, add yellowtail and widow to the remaining "other slope" species. This would result in an "other rockfish" complex made up of minor species."*

The North Pacific Council's Scientific and Statistical Committee (SSC) endorsed the GOA PT recommendations in their December 2009 and December 2010 meetings, as listed in the following minutes from these meetings.

December 2009 SSC minutes, in section titled "GOA Pelagic Shelf Rockfish": *"The Plan Team recommended reorganizing the complex to managing dusky rockfish as a single species group. They considered the implications of this action on management of widow and yellowtail rockfish and noted that one option would be to manage widow and yellowtail rockfish as part of the Other Slope rockfish complex. The SSC agreed that reorganization of the complex should be considered and noted that the option to manage widow and yellowtail rockfish as part of the other slope complex should be considered. The SSC notes that these changes could be assessed as part of consideration of assemblage membership that will occur in FMP amendments to implement the ACL requirements."*

December 2010 SSC minutes, in section titled "GOA Shortraker and other slope rockfish": *The SSC agrees with the Plan Team that the author should explore an option for breaking shortraker out of the other slope species chapter and adding yellowtail and widow rockfish to the remaining "other slope" species.*

December 2010 SSC minutes, in section titled "GOA - Pelagic Shelf Rockfish": *"The SSC notes that the author plans to address our request for options regarding reorganization of the PSR assessment and management. The GOA Plan Team minutes described a suggestion to break dusky rockfish from the pelagic shelf rockfish complex. The SSC agrees that this alternative should be explored."*

This paper has been prepared to provide information in response to the recommendations of the GOA PT and the SSC regarding management reorganization of the three species currently in the GOA PSR assemblage and the other slope rockfish assemblage.

Discussion

Biological Considerations

When the three rockfish assemblages were originally created in 1988, the decision on which species should be included in each assemblage was made by the GOA PT members serving at that time. The decision was based on the PT members' general perceptions of what the appropriate habitat was for each species and not on a detailed analysis of habitat preference. Furthermore, in 1988 there was less information available than at present to categorize GOA rockfish into assemblages. For example, we now know that the species classified as "dusky rockfish" in 1988 is actually comprised of two different species, dusky rockfish and dark rockfish (*S. ciliatus*). The dark species is the one that has a more pelagic distribution, and GOA PT members may have been thinking of the dark form when they placed dusky rockfish into the PSR assemblage.

Extensive GOA trawl survey data and other information now exist that indicate dusky rockfish does not generally share the same geographic distribution and habitat with the other two PSR species, yellowtail and widow rockfish. The trawl surveys show that dusky rockfish biomass is mostly concentrated in the central GOA (Chirikof and Kodiak areas), whereas abundance is consistently low in the Southeastern area (Table 1). In contrast, nearly all the relatively small biomass of yellowtail and widow rockfish in Alaska is in the Southeastern area. Dusky rockfish appears to have its center of abundance in the GOA (Lunsford et al. 2009), while yellowtail and widow rockfish are at the northern edge of their range in Alaska and are most abundant farther south off British Columbia and the U.S. West Coast (Wallace and Lai 2005; Love et al. 2002). In addition to generally not being distributed in the same geographic area, the habitat of dusky rockfish appears to be different than that of yellowtail and widow rockfish. Dusky rockfish are apparently more of a of a bottom-oriented species and are caught almost exclusively with bottom trawls in the GOA at relatively shallow offshore banks of the outer continental shelf (Lunsford et al. 2009), while yellowtail and widow rockfish are often found considerably off the bottom (Love et al. 2002). Off the U.S. West Coast, yellowtail rockfish are harvested with both midwater and bottom trawls (Wallace and Lai 2005), and the fishery for widow rockfish first developed around 1980 when large pelagic concentrations of the fish were discovered and taken with midwater trawls (Williams et al. 2000). Similarly, catch statistics from British Columbia indicate that yellowtail rockfish are caught with both midwater and bottom trawls, while widow rockfish are taken predominantly with midwater trawls5. Finally, a habitat study of dusky rockfish in the GOA based on both survey and fishery data showed virtually no co-occurrence with the other PSR species (Reuter 1999). In fact, the study found the two rockfish species most frequently associated with dusky rockfish were northern rockfish and Pacific ocean perch, the most abundant species of "slope" rockfish.

Break-up of the PSR Assemblage

Because yellowtail and widow rockfish do not share a common distribution and habitat with dusky rockfish in the GOA, the GOA PT proposal to manage dusky rockfish separately from the other two species is justifiable from a biological perspective. It is also reasonable from an assessment standpoint because, as mentioned in the "Background" section, the assessment of dusky rockfish is now based on population modeling rather than on the "Tier 5" biomass-based approach that is still used for yellowtail and widow rockfish. However, if dusky rockfish is removed from the PSR group and becomes its own management entity, the biomass of yellowtail and widow rockfish in the GOA would be too small to comprise a viable management assemblage. To address this problem, the GOA PT has proposed that the PSR assemblage be dissolved and that yellowtail and widow rockfish be moved to the "other slope rockfish" management group in the GOA. Because yellowtail and widow rockfish mostly inhabit the outer continental shelf rather than the slope, "other slope rockfish" would then be renamed "other

5 R. Stanley, Canada Department of Fisheries and Oceans, Science Branch, Pacific Biological Station, Nanaimo, B.C. Canada V9T 6N7. Personal communication. August 2011.

rockfish" as a management group.

The proposal to include yellowtail and widow rockfish with the species that are now in the GOA "other slope rockfish" group has merit for a number of reasons. The "other slope rockfish" group is a diverse collection of 15 species, the majority of which have a low abundance in the GOA. With the exception of harlequin rockfish, most of the biomass for these species in the GOA is found in Southeastern Alaska, and for all but one or two species, the center of abundance is south of Alaska (Clausen 2009). Acceptable Biological Catch is determined using a "Tier 5" biomass-based approach for all "other slope rockfish" (exception: sharpchin rockfish is Tier 4), and these species will likely remain in Tier 5 for the foreseeable future. There has been no directed fishing for any of the "other slope rockfish" in many years, and present catches are all taken as incidental bycatch in other directed fisheries. Because yellowtail and widow rockfish share all these characteristics with "other slope rockfish", transferring these two species into the "other slope rockfish" group and renaming it "other rockfish" would be a logical and practical decision.

Effects on the Commercial Fishery and Management Considerations

Estimates of the species composition of the PSR commercial catch indicate that dusky rockfish has comprised the overwhelming majority (Table 12B-2). This is not surprising based on the survey biomasses in Table 12B-1 and is a further indication of the low abundance of yellowtail and widow rockfish in the GOA. If the percentages for yellowtail and widow rockfish are applied to the total catches of PSR in the GOA (Table 12B-3), for most years, the combined catch of yellowtail and widow has been less than 10 t. For example, in 2009 only 5.4 t of the two species are estimated to have been harvested.

In the current PSR assessment, ABC for dusky rockfish is determined using a Tier 3 modeling approach, whereas ABC for yellowtail and widow rockfish is determined using a simple Tier 5 computational formula (Lunsford et al. 2009). The ABC calculated for dusky rockfish is then added to the ABCs calculated for yellowtail and widow rockfish to yield an overall recommended Gulfwide ABC for the PSR assemblage. The NPFMC has always set TACs for PSR equal to the ABCs (Table 12B-3). For 2010, the ABC for dusky rockfish was 4,957 t, for yellowtail rockfish was 93 t, and for widow rockfish was 9 t, which adds to 5,059 t, the total ABC for the PSR group.

The Gulfwide ABC for PSR is allocated to geographic management areas in the GOA by using a weighted average of the three most recent trawl survey biomass estimates for these species in each area (see Lunsford et al. 2009 for details). The contribution of each PSR species in 2010 to the geographic allocation of ABC and to the Gulfwide OFL is shown in Table 12B-4. It should be noted that because the allocation procedure is based on the combined biomass of the three PSR species, the contribution of yellowtail and dusky rockfish to the allocation ends up being relatively high in the central GOA, even though most of the survey biomass for the two species is actually in the eastern GOA. This contradictory allocation result is further support for moving yellowtail and dusky rockfish to a new "other rockfish" category in the GOA, where the two species would be grouped with other minor rockfish species whose biomass is concentrated in the eastern GOA.

The PSR catch statistics indicate that the proposed management reorganization of the three species in the PSR group would have no economic impact on commercial fishermen in the GOA. This is because catches in the PSR fishery have always been substantially less than the TACs, with the exception of 1999 (Table 12B-3); thus, the small reduction in the TACs for the dusky rockfish fishery that would occur as a result of moving yellowtail and widow to "other rockfish" would be inconsequential. This would be true both GOA-wide and for the Central GOA Rockfish Program. For example, if the reorganization had been implemented in 2010, the Gulf-wide ABC and TAC for a directed dusky rockfish fishery would be 4,957 t, instead of the 5,059 t that was actually allocated to the PSR fishery (see preceding discussion concerning how ABC is determined for PSR). The lower ABC and TAC would result because the 102 t attributable to yellowtail and widow rockfish in the PSR computations of ABC would now be allocated to “other rockfish”. The total GOA catch for dusky rockfish in 2010, estimated to be 3,102 t, would be still be much less than the TAC of 4,957, and effects on fishermen would be nil. Similarly, little or no impact is expected for the Central GOA Rockfish Program if the management reorganization is implemented. For each year since the Program began in 2007, quota share catches for PSR in the Central GOA have been much less than the quota share allocations (Table 12B-5). This indicates the Program could easily accept the very small reduction in quota share allocation that would be caused by moving yellowtail and widow rockfish to the new “other rockfish” group.

Moving yellowtail and widow rockfish from PSR to a new species group, “other rockfish” could provide a conservation benefit for these two species. Although it has not happened, it is hypothetically possible that under the current rockfish management regime in the GOA, the relatively large ABC for PSR could be used to overharvest the small number of yellowtail and widow rockfish in this group. This would be especially true if catches of yellowtail and widow were taken in the central GOA, where trawl surveys indicate abundance of the two species is very low. Moving yellowtail and widow rockfish to “other rockfish” would transfer them to a group that is on bycatch status year-round rather than open to directed fishing as they presently are in the PSR assemblage.

Finally, dissolving the PSR assemblage would not have a significant impact on either the Observer Program or on the NMFS Alaska Region “Catch Accounting System”. When observers sample catches, they are currently instructed to identify all rockfish species and are not concerned with how these species are categorized for management purposes. The Catch Accounting System could accommodate a change in the management classification of GOA rockfish species with changes in the System’s programming code.

Summary and Conclusions

The PSR group no longer appears justifiable as a rockfish assemblage in the GOA. Dusky rockfish generally do not inhabit the same geographic area in the GOA as yellowtail and widow rockfish and seldom co-occur with the latter two species. Yellowtail and widow rockfish are frequently encountered off-bottom and are often caught with midwater trawls off British Columbia and the U.S. West Coast, whereas dusky rockfish in the GOA are more associated with the substrate and are taken with bottom trawls. Present assessment methods in the GOA for dusky rockfish versus yellowtail and widow rockfish are very different. Dusky rockfish is much more abundant in Alaska than the other two species and, like other important rockfish in the GOA, is now assessed with an age-structured model; however, yellowtail and widow rockfish continue to be assessed by a simple “Tier 5” biomass-based procedure. Yellowtail and widow rockfish actually appear to share more attributes with many of the species in the “other slope rockfish” assemblage than they do with dusky rockfish. Due to all these reasons, the proposal to establish dusky rockfish as its own management category in the GOA and to transfer yellowtail and widow rockfish to “other slope rockfish” (which would be renamed “other rockfish”) would improve rockfish management in this area. Moving yellowtail and widow rockfish to a bycatch-only “other rockfish” group would also provide a conservation benefit for these two species by decreasing the chance that they could be overfished in the GOA, as possibly could occur if they were to remain in the PSR assemblage.

If these proposed actions are implemented, anticipated effects on the commercial fishery would be negligible. Abundance of yellowtail and widow rockfish is so low in the GOA that they contribute very little to the TAC and ABC for the directed PSR fishery. Furthermore, the catch of PSR, which is comprised almost entirely of dusky rockfish, has been substantially less than the TAC for many years. Thus, a small loss of TAC in the directed fishery would not cause any economic harm.

References

Clausen, D. M. 2009. Assessment of shortraker rockfish and "other slope rockfish" in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 875-924. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501.

Love, M. S., M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley. 405 p.

Lunsford, C. R., S. K. Shotwell, and D. H. Hanselman, and D. M. Clausen. 2007. Gulf of Alaska pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 781-842. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501.

Lunsford, C. R., S. K. Shotwell, and D. H. Hanselman. 2009. Assessment of pelagic shelf rockfish in the Gulf of Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 925-992. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501.

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

Wallace, J. and H.-L. Lai. 2005. Status of the yellowtail rockfish in 2005. National Marine Fisheries Service, Northwest Fishery Science Center, 2725 Montlake Blvd. E., Seattle WA 98028. 115 p.

Williams, E. H., A. D. MacCall, S. V. Ralston, and D. E. Pearson. 2000. Status of the widow rockfish resource in Y2K. Appendix to: Status of the Pacific Coast groundfish fishery through 2000 and recommended acceptable biological catches for 2001, stock assessment and fishery evaluation. 122 p. Pacific Fishery Management Council, 2130 SW 5th Ave, Suite 224, Portland OR 87201.

Table 12B-1. Biomass estimates (t) for species in the pelagic shelf rockfish assemblage in the Gulf of Alaska, based on results of bottom trawl surveys from 1984 through 2009 (from Lunsford et al. 2009).

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

(Table continued on next page.)

Table 12B-1 (continued). Biomass estimates (t) for species in the pelagic shelf rockfish assemblage in the Gulf of Alaska, based on results of bottom trawl surveys from 1984 through 2009.

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

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

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

Table 12B-2. Estimated species composition of the Pelagic Shelf Rockfish (PSR) assemblage commercial catch in the Gulf of Alaska, 1991-2009 (from Lunsford et al. 2007 and Lunsford et al. 2009).

	Percent of PSR assemblage catch			
Year	Dusky	Dark[1]	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
2007	99.7	0.3	trace	trace
2008	99.3	0.5	0.1	0.1
2009	99.8	-	trace	0.2

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

Table 12B-3. Commercial catch[a] (t) of fish in the pelagic shelf rockfish assemblage in the Gulf of Alaska, with Gulfwide values of acceptable biological catch (ABC) and total allowable catch (TAC), 1991-2010 (1991-2008 from Lunsford et al. 2009; 2009-2010 from NMFS Alaska Region, Sustainable Fisheries Division, Catch Accounting).

	Regulatory Area[b]							
Year	Western	Central	Eastern	West Yakutat[c]	Southeast Outside[d]	Gulfwide Total	Gulfwide ABC	Gulfwide TAC
1991	215	1,191	936	-	-	2,342	4,800	4,800
1992	105	2,622	887	-	-	3,605	6,886	6,886
1993	238	2,061	894	-	-	3,193	6,740	6,740
1994	290	1,702	997	-	-	2,989	6,890	6,890
1995	108	2,247	536	471	64	2,891	5,190	5,190
1996	182	1,849	265	190	75	2,296	5,190	5,190
1997	96	1,959	574	536	38	2,629	5,140	5,140
1998[1]	60	2,477	576	553	22	3,113	4,880	4,880
1999[2]	130	3,835	694	672	22	4,659	4,880	4,880
2000[3]	190	3,074	467	445	22	3,731	5,980	5,980
2001	121	2,436	451	439	12	3,008	5,980	5,980
2002	185	2,680	457	448	9	3,322	5,490	5,490
2003	164	2,194	617	607	10	2,975	5,490	5,490
2004	281	2,182	211	199	12	2,885	4,470	4,470
2005	118	1,843	218	215	3	2,397	4,553	4,553
2006	557	1713	174	173	1	2,444	5,436	5,436
2007[4]	595	2,485	294	293	4	3,374	5,542	5,542
2008	577	2,870	196	195	1	3,643	5,227	5,227
2009[5]	717	2,162	178	177	1	3,057	4,781	4,781
2010	533	2,492	86	75	11	3,111	5,048	5,048

Management Actions

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

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

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

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

[5]Dark rockfish removed from federal management plan.

Catch Accounting Notes

[a]Catches for 1991-97 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]West Yakutat area is comprised of statistical areas 640 and 649.

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

Table 12B-4. Contribution of yellowtail/widow rockfish and dusky rockfish to the 2010 geographic allocation of Pelagic Shelf Rockfish ABC in the Gulf of Alaska, by management area, and to the 2010 Gulfwide OFL of Pelagic Shelf Rockfish. Note: since actual ABCs and OFLs for Pelagic Shelf Rockfish are based on the entire management group, individual species are shown only for illustrative purposes. (ABC = acceptable biological catch; OFL = overfishing level; WGOA = Western Gulf of Alaska; CGOA = Central Gulf of Alaska; WYak = West Yakutat; EYak/SEO = East Yakutat/Southeast Outside).

	ABC (t)				OFL (t)
	WGOA	CGOA	WYak	EYak/SEO	Gulfwide
Yellowtail/Widow	13	66	9	14	136
Dusky	637	3,183	425	712	6,006
PSR total	650	3,249	434	726	6,142

Table 12B-5. Catch statistics (t) for Pelagic Shelf Rockfish in the Central Gulf of Alaska, including the Central Gulf of Alaska Rockfish Program, 2007- 2010 (from NMFS Alaska Region, Sustainable Fisheries Division, Catch Accounting). (TAC = total allowable catch; CGOA = Central Gulf of Alaska).

	Total CGOA		CGOA Rockfish Program[1]		
	Catch	TAC	Quota share catch	Quota share allocation	Entry level allocation
2007	2,485	3,325	2,282	3,026	199
2008	2,870	3,626	1,963	3,350	176
2009	2,162	3,404	2,080	3,139	165
2010	2,492	3,249	2,373	2,992	157

[1] Catch of PSR by vessels in the entry level fishery is confidential due to the small number of participants. The entry level catch is included in total catch. The entry level fishery has never exceeded its allocation.

Appendix 12C

Total Catch Accounting Data

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

The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities. This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For Gulf of Alaska (GOA) dusky rockfish, these estimates can be compared to the research removals reported in previous assessments (Lunsford et al. 2009) (Table 12C-1). Dusky rockfish research removals are minimal relative to the fishery catch and compared to the research removals for many other species. The majority of removals are taken by the Alaska Fisheries Science Center's (AFSC) biennial bottom trawl survey which is the primary research survey used for assessing the population status of dusky rockfish in the GOA. Other research activities that harvest dusky rockfish include longline surveys by the International Pacific Halibut Commission and the AFSC. Recreational harvest of dusky rockfish does occur and in 2010 was estimated at 8 t. This indicates that annually the level of recreational harvest of dusky rockfish is comparable to the research harvest. Total removals from activities other than a directed fishery were near 10 t in 2010. This is <1% of the 2011 recommended ABC of 5,118 t and represents a very low risk to the dusky rockfish stock. Research harvests in recent years are higher in odd years due to the biennial cycle of the AFSC bottom trawl survey in the GOA and have been less than 10 t except in 2005 when 13 t were removed. Even when accounting for recreational harvest, the estimated removals would generally be less than than 20 t, which do not pose a significant risk to the dusky rockfish stock in the GOA.

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

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

HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery may become available following restructuring of the Observer Program in 2013.

The HFICE estimates of GOA dusky rockfish catch are minimal indicating the halibut fishery does encounter dusky rockfish but catches are likely low (Table 12C-2). There is likely very little chance of overlap with the CAS and the estimates here are minor in comparison to the total catch reported in CAS. There may be some overlap with state of Alaska waters and fisheries as dusky rockfish are commonly caught in near-shore waters but the amount of overlap is unknown. Based on these estimates, the impact of the halibut fishery on dusky rockfish stocks is minimal.

References:

Cahalan J., J. Mondragon., and J. Gasper. 2010. Catch Sampling and Estimation in the Federal Groundfish Fisheries off Alaska. NOAA Technical Memorandum NMFS-AFSC-205. 42 p.

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

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

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

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

*May include catch of dark rockfish.

Table 12C-2. Estimates of Gulf of Alaska dusky rockfish catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group. WGOA = Western Gulf of Alaska, CGOA = Central Gulf of Alaska, EGOA = Eastern Gulf of Alaska, PWS = Prince William Sound.

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
WGOA	0	<1	<1	0	<1	<1	<1	0	<1	<1
CGOA-Shumagin	0	0	0	<1	<1	0	0	0	0	<1
CGOA-Kodiak	0	0	<1	<1	<1	0	0	0	0	<1
EGOA-Yakutat/PWS*	0	0	0	0	0	<1	0	<1	0	<1
EGOA-Southeast	1	0	0	<1	0	<1	<1	1	1	<1
Southeast Inside*	0	0	0	0	3	0	0	0	0	0
Total	1	<1	1	1	4	1	1	1	1	1

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

(This page intentionally left blank)