CHAPTER 13B

BLACKSPOTTED AND ROUGHEYE ROCKFISH

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Executive Summary

Fish previous referred to as rougheye rockfish are now recognized as consisting of two species, the rougheye rockfish (*Sebatses aleutianus*) and blackspotted rockfish (*Sebastes melanostictus*) (Orr and Hawkins 2007). The current information on these two species is not sufficient to support species-specific assessments, so they are combined in this assessment. In previous years, the BSAI rougheye rockfish complex and shortraker rockfish were assessed with a two-species surplus production model that accounted for potential covariance in catch estimates. The reading of archived rougheye rockfish otoliths from research surveys has allowed the development of an age-structured model, which was presented to the BSAI Plan Team in September, 2008. The Plan Team also received genetic, growth, and demographic data pertinent to the question of whether the rougheye complex in the BS should be considered a distinct stock from rougheye complex in the AI. Both the Plan Team and the SSC encouraged presenting the following two models for the November meeting: 1) a BSAI-wide model; and 2) an AI-only model with the BS rougheye complex assessed with Tier 5 methods.

Summary of Changes in Assessment Inputs

Changes in the input data

1) Catch updated through October 18, 2008
2) The historical Aleutian Islands survey data were updated based on the estimates provided by the AFSC/RACE Division.
3) Incorporation of age and length composition data from the BSAI fishery and AI trawl survey.

Changes in the assessment methodology

A new age-structured assessment model was applied to BSAI blackspotted and rougheye rockfish.

Summary of Results

A summary of the 2008 assessment recommended ABC's relative to the 2007 recommendations is shown below. The 2008 assessment recommendations are based upon an Aleutian Islands age-structured model and application of Tier 5 methodology to obtain EBS harvest levels. Blackspotted and rougheye rockfish are not overfished or approaching an overfished condition.

Assessment Year	2007		2008	
Projection Year	2008	2009	2009	2010
M	0.03	0.03	0.032	0.032
Tier	5	5	3b	3b
Total Biomass (ages 3+)	10,782 t	10,782 t	18,978 t	19,093 t
Spawner Biomass	--	--	6,535 t	6,427 t
$B_{100\%}$	--	--	16,808 t	16,808 t
$B_{40\%}$	--	--	6,723 t	6,723 t
$B_{35\%}$	--	--	5,883 t	5,883 t
Max F_{abc}	0.019	0.019	0.038	0.038
F_{OFL}	0.025	0.025	0.047	0.046
ABC (BSAI)	202 t	202 t	--	--
OFL (BSAI)	269 t	269 t	--	--
ABC (AI)			499 t	482 t
ABC (EBS)			40 t	40 t
OFL (AI)			607 t	587 t
OFL (EBS)			53 t	53 t

Responses to the comments of the Statistical and Scientific Committee

The SSC December 2007 minutes included the following comments concerning all stock assessments:

The SSC notes that the approach for calculating ABC and other biological reference points is not fully described in the SAFE's. It would be desirable to have a general description in the introduction of the SAFE. In each SAFE chapter, specific details could be provided, if the calculation is done differently. For example, the range of years that is used to calculate average recruitment for converting SPR to B_{40} should be given.

We assume that the equilibrium level of recruitment is equal to the average of age 3 recruits from 1980-2008 (year classes between 1980 and 2005) for rougheye rockfish as detailed in the Amendment 56 Reference Points section of the Projections and Harvest Alternatives of this stock assessment.

The SSC December 2007 minutes included the following comments concerning all rockfish:

For all of the rockfish assessments, the SSC recognizes the efforts of the stock assessment authors to respond fully to the 2006 CIE review comments. The SSC requests that the draft response to the CIE review be finalized and made available.

The response to the 2006 CIE rockfish review is available online at the following web address: ftp://ftp.afsc.noaa.gov/afsc/public/rockfish/RWG%20response%20to%20CIE%20review.pdf

INTRODUCTION

Rougheye rockfish (*Sebastes aleutianus*) have historically been managed within various stock complexes within the Bering Sea/Aleutian Islands (BSAI) region. For example, from 1991 to 2000 rougheye rockfish in the eastern Bering Sea (EBS) area were managed under the "other red rockfish" species complex, which consisted of shortraker (*Sebastes borealis*), rougheye (*S. aleutianus*), sharpchin (*S. zacentrus*), and northern rockfish (*S. polyspinis*), whereas in the Aleutian Islands (AI) area during this time rougheye rockfish were managed within the rougheye/shortraker complex. In 2001, the other red rockfish complex in the eastern Bering Sea was split into two groups, rougheye/shortraker and sharpchin/northern, matching the complexes used in the Aleutian Islands. Additionally, separate TACs were established for the EBS and AI management areas, but the overfishing level (OFL) pertained to the entire BSAI area. By 2004, rougheye, shortraker, and northern rockfish were managed with species-specific OFLs applied to the BSAI management area.

The most recent full assessment of rougheye rockfish occurred in 2006, when rougheye were assessed within a rougheye/shortraker surplus production model that accounted for covariance in catch estimates. Since 2006, a substantial amount of archived rougheye otoliths from the Aleutian Islands trawl survey have been aged and provide the basis for age-structured modeling approaches.

As a new age-structured model for BSAI rougheye rockfish is developed, it is appropriate to consider information which may reveal the spatial structure of the BSAI stocks. Gulland (1983) offers a variety of types of information that, in addition to genetic data, can be used in the evaluation of stock structure, including differences in population parameters (i.e., growth, mortality, age and size composition), morphological characteristics, and tagging data.

In 2006, a variety of information on area-specific size at age, age compositions, and length compositions of rougheye were presented to the BSAI Plan Team; this followed presentation of genetic data which was presented to the 2005 Plan Team. It was recognized by the 2006 Plan Team that an age-structured rougheye model was in the process of being developed, and could offer new insights on recruitment dynamics and stock productivity. Thus, it was agreed to defer any decisions regarding stock structure until they could be evaluated in the context of the new assessment model. An additional complication is the recognition that fish historically referred to as "rougheye" rockfish are now recognized as consisting of two separate species, with rougheye rockfish retaining the name *S. aleutianus* and a new species blackspotted rockfish (*S. melanostictus*) being recognized (Orr and Hawkins 2008). Information from recent bottom trawl surveys suggests that although the two species overlap to some degree, blackspotted rockfish are the predominant species found in the Aleutian Islands, while rougheye rockfish are more common in the Gulf of Alaska and southeastern Bering Sea.

In the remainder of the introduction we review information pertaining to stock structure of rougheye rockfish within the BSAI area. The genetic data on stock structure pertains to each species within the blackpotted/rougheye complex. However, other information examined such as size at age and age and length compositions apply to the combined blackspotted/rougheye complex because field identification of the two species has occurred only since 2006. Thus, area differences in these characteristics could reflect differences between stocks of the same species, or different proportions of the two species between the areas, or some combination of these effects. Some new age data (i.e., ages from the 2002 EBS slope survey) that has been generated since the 2006 Plan Team meeting and might contribute to our understanding of stock structure, as well as some analyses requested by the 2006 Plan Team, are presented. Additionally, identification by species in the 2008 EBS slope survey that allows comparison of species composition between the EBS slope and AI survey area is presented.

Genetic data

For rougheye rockfish, genetic and morphological data reveal large differences in stock structure that indicate two distinct species (Gharrett et al. 2005, Gharrett et al. 2006, Orr and Hawkins 2008). In a study using over 700 samples from Oregon to the Aleutian Islands and the Bering Sea, Gharrett et al. (2005) found fixed allele differences at one microsatellite locus, with each of two alleles corresponding very strongly to mitochondrial DNA haplotypes. Aleutian Islands rougheye rockfish were predominately composed of type I fish. Both type I and type II rougheye rockfish occurred in the Gulf of Alaska, although type II fish were more common (particularly east of Kodiak) and any particular trawl haul was composed of predominately one type. Although most of the type II fish examined were lightly colored, the type I fish consisted of both lightly and darkly colored individuals. Gharrett et al. (2006) further examined the appearance of the two species with Gulf of Alaska (GOA) samples by characterizing appearance as "light" or "dark", with type II fish being having mostly light coloration by type I fish being either light or dark. Orr and Hawkins (2008) provide the most detailed description of the morphology of the two rougheye species across the range of both species and clarify the nomenclature, retaining the name *S. aleutianus* for the light form and resurrecting the name *S. melanostictus* for the dark form.

The existence of two species of rougheye rockfish motivates examination of stock structure within each species (Gharrett et al. 2007). Each of the two species corresponds to a neighborhood model of genetic structure in which a strong boundary does not exist between populations but rather fish within a certain distance (representing the range of individuals over their lifespan) would not differ genetically. Analysis of allele frequencies was conducted for each species. For type I fish, corresponding to *S. melanostictus* and representing most fish with the BSAI area, the samples from the central Aleutian Islands were distinct from adjacent samples. For type II rougheye, corresponding to *S. aleutianus*, population structure occurs on a smaller spatial scale, suggesting more limited dispersal. However, the data for type II rockfish were obtained primarily from the GOA region and sample sizes within the BSAI area were limited.

A recent re-analysis of the blackspotted rockfish data by Dr. A.J. Gharrett of the University of Alaska focused more closely on the question of whether blackspotted rockfish in the Aleutian Islands are genetically distinct from those in the eastern Bering Sea. First, a direct comparison between samples indicates that the samples in the central Aleutians (location 13 in Figure 1) are distinct from all other samples, and samples in the eastern/central Aleutians (location 12) are distinct from each of the two samples on the EBS slope. In this analysis, each sample consists of fish collected from several locations that were close to each other. Additionally, one can consider if the genetic distance between individual fish is associated with physical distance along a line extending from the Aleutian Islands to the Unimak Pass area and then along the EBS slope; the assumption here is that movement between the AI and EBS slope follows the continental slope rather than through the Aleutian basin. Application of an isolation by distance test for this data show a significant correlation between genetic divergence and physical distance (Fig. 2, *P*=0.00485). Dr. Gharrett's conclusion from this re-analysis is that there does not seem to be substantial movement between the EBS and AI and whatever exchange does exist would be measured over multigenerational time scales (Dr. Anthony Gharrett, UAF, pers. comm.).

Size at age data

Age data from the EBS slope surveys and AI trawl surveys conducted in 2002 and 2004 offer information on area-specific size at age. Differences in size-at-age within a species between areas are suggestive of growth differences and suggest a minimal amount of mixing of fish. For the EBS slope survey, otoliths were collected from each rougheye encountered, and the mean length at age was computed. For the AI survey, length-stratified collection of otoliths occurred in each sampling region, and mean lengths within each area were obtained by multiplying the estimated size composition of the population by the age-length key for that area and year (Kimura and Chikuni 1987; Dorn 1992). Von Bertalanffy growth curve parameters were fit to the mean lengths by assuming the deviations between the model prediction and the observed data follow a normal distribution. The resulting von-Bertalanffy growth parameters are as follows:

Year	Area	Sample size	t_{izero}	k	L_{inf}
2002	EBS slope	104	0.53	0.14	46.68
	S. Bering Sea	114	-3.92	0.07	48.64
	Eastern AI	186	-6.63	0.05	51.81
	Central AI	114	-2.93	0.08	49.09
	Western AI	59	-12.91	0.04	55.63
2004	EBS slope	216	0.45	0.13	48.39
	S. Bering Sea	103	-10.46	0.05	52.44
	Eastern AI	73	-2.51	0.07	49.79
	Central AI	165	-1.25	0.07	50.35
	Western AI	134	-0.22	0.08	50.68

In each year, there is no relationship between maximum length (L_{inf}) and area, and L_{inf} generally varied between 48 and 52 cm across the various areas (with the exception of the western Aleutians in 2002, which had a small sample size). However, the rate at which this size is approached (the *k* parameter) is substantially larger in the EBS slope that any of the areas within the Aleutian Islands. In 2004, *k* was 0.13 for the EBS slope and ranges from 0.05 to 0.08 for other areas. In 2002, *k* was 0.14 for the EBS slope and ranged from 0.04 to 0.08 for the other areas. *F*-tests indicate that within each year a model with separate curves for each area fits the data significantly better than a model with a single curve over all areas.

The primary difference in the growth curves is an increased size at age in the EBS slope relative to the Aleutian Islands for ages between approximately 10 and 30 years old (Figure 3). For 20 year old fish, the 2004 EBS growth curve predicts a size of 44.7 cm whereas the predicted size from the four Aleutian subareas range from 39.5 cm to 40.8 cm, an approximately 10% increased in predicted size. A nearly identical pattern is seen in 2002, where the predicted size of 20 year old fish in the EBS slope was 43.4 cm and the predicted size from the four Aleutian subareas ranged from 39.3 cm to 40.4. Examination of the size at age data directly reveal the source of the differences in the growth curves. For most ages between 10 and 25 observed in 2002 and 2004, the mean size at age from the EBS slope was either larger than or nearly larger than the maximum of the mean size at age from the Aleutian subareas (Figure 4).

Size composition data

Differences in age or length composition may represent differences in recruitment patterns between the EBS and AI, and the length compositions of rougheye rockfish from the EBS and four areas of the AI survey are shown in Figure 5. In both 2002 and 2004, the relative proportion of fish at smaller sizes (< 300 mm) is greater in the EBS slope than in the any of the four areas of the Aleutians Islands. Differences in mean length in each of these areas was tested with a nested ANOVA, in which haul was nested within area; this formulation was necessary because fish from the same haul would not be expected to be independent in size, and thus the true sample size is less than the number of fish measured from all hauls. Year of sampling was included as a factor and found to be not significant; thus, the *P*-values shown below for pairwise comparisons for rougheye mean length by area combine data from 2002 and 2004.

Area	S. Bering Sea	Central AI	Eastern AI	Western AI
EBS	0.0911	0.0005	<0.0001	0.0395
S. Bering Sea		0.4053	0.1970	0.8910
Central AI			0.5071	0.4488
Eastern AI				0.2047

Of the 10 possible comparisons, three are significant at the 0.05 level and all involve the EBS data. The mean length in the observed from the EBS slope survey is significantly different from that in the eastern Aleutians, central Aleutians, and western Aleutians, and is also marginally significant ($P < 0.10$) from the mean length in the Southern Bering Sea. None of the comparisons between the 4 subareas of the Aleutian Islands were significant.

Age composition data

The estimated age compositions of the rougheye rockfish from the 2004 surveys are shown in Figure 6. The bulk of the age composition in the EBS slope consists of fish less than ~ 15 years, whereas in each of the AI areas examined large portion of the age composition occur between ages 15 and 40. Analogous to the ANOVA for comparing mean length, an ANOVA for testing differences in mean age between areas was applied. This requires the mean age for each haul, which was produced by multiplying the length composition for each haul by the age-length key. As with the ANOVA for mean length, the year of sampling was not a significant factor and the table of *P*-values below reflects comparisons of mean age by area for years 2002 and 2004.

Area	S. Bering Sea	Central AI	Eastern AI	Western AI
EBS	0.3326	0.0022	0.0002	0.0722
S. Bering Sea		0.9640	0.7392	0.9977
Central AI			0.9232	0.9968
Eastern AI				0.8541

The mean age observed in the EBS slope survey is significantly different from that in the eastern Aleutians and central Aleutians, and marginally different ($P<0.10$) from the mean age in the western Aleutians. As with the comparisons for mean length, none of the comparisons between the 4 subareas of the Aleutian Islands were significant.

Species composition between the two areas

The comparison of genetic and morphologic traits between various subareas within the BSAI management area are suitable for determining stock structure under the presumption that they pertain to a single species. Orr and Hawkins (2008) found that within the BSAI management area, blackspotted rockfish were much more common than rougheye rockfish, similar to results obtained from the sampling of Gharrett et al. (2007). In both studies, rougheye rockfish were not found in Aleutian Islands management area, and some rougheye rockfish were found along the EBS slope south of the Pribilof Islands but blackspotted rockfish were more common. The two species were distinguished in the 2006 AI trawl survey and the biomass estimates were 8807 t for blackspotted rockfish and 698 t for rougheye rockfish. Biomass estimates from the 2008 EBS slope survey just became available at the time of printing and are 530 t for blackspotted rockfish and 324 t for rougheye rockfish. It is important to note that the identification of rougheye and blackspotted rockfish in AFSC surveys is a recent development and the consistency of identification may uncertain, and studies should be conducted to verify the field identification. However, the best available information to date indicates that the proportion of the rougheye rockfish on the EBS slope may be higher than that observed by Gharrett et al. (2007) and Orr and Hawkins (2008), and the species composition of the two-species complex may differ between the AI and EBS management areas.

Options for assessing and managing BSAI rougheye rockfish

The differences between the EBS and AI management areas in several of the non-genetic traits above may result from either from separate stocks of the same species, or different mixtures of the two-species blackspotted/rougheye complex. Either case would suggest separate management of the two management subareas to ensure that disproportionate harvesting did not occur on the smaller stock (or species) as the linkages between the AI and EBS do not appear strong. Examples of the separation between the EBS and AI include the differences in allele frequencies of Gharrett et al.'s (2007) type I rougheye, the differences in growth pattern and size at age, and the differences in the length and age compositions (and mean length and age). While alternative explanations may exist for any one of these types of data, the simultaneous occurrence of each of these patterns (in some cases, over multiple years of sampling) suggests that the most parsimonious explanation is true differences between the EBS and AI management areas.

As additional information becomes available on the abundance, distribution, and life-history parameters (i.e., growth, maturity, and mortality) of the two species within the rougheye complex, species-specific models will be developed. This data does not currently exist, as field identification within BSAI surveys has only been completed on the 2006 AI trawl survey and the 2008 EBS slope survey; thus, the assessment options below pertain to the two-species rougheye complex.

Two assessment model options are considered here. A combined BSAI model is developed in order to be consistent with other BSAI rockfish assessments and previous assumptions of rougheye rockfish stock structure. As in the BSAI POP and northern rockfish model, the AI trawl survey is used as an index of population size, and is thus conservative because it does not include fish from the EBS slope. Now that three survey biomass estimates exist for the EBS slope survey (2002, 2004, and 2008), the feasibility of including this survey time series can be evaluated in future work.

A second alternative is separate AI and EBS models. In this formulation, data from the fishery and the AI survey are parsed into the two management areas, and an age-structured model is developed for the AI area. Because the distribution of rougheye rockfish and available data come primarily from the AI management area, the AI model would be expected to be very similar to the BSAI model. Sufficient data does not occur to develop an age-structured model for the EBS management area, and under the separate area approach rougheye in this area would be assessed with Tier 5 methods using the EBS slope survey data and the portion of the AI survey within the EBS management area.

FISHERY

Historical Background

Catches of rougheye rockfish have been reported in a variety of species groups in the foreign and domestic Alaskan fisheries. Foreign catch records did not identify rougheye rockfish by species, but reported catches in categories such as "other species" (1977, 1978), "POP complex" (1979-1985, 1989), and "rockfish without POP" (1986-1988). Rougheye rockfish have been managed in the domestic fishery as part of the "other red rockfish" or "shortraker/rougheye" complexes. Reported ABCs, TACs, and catches by management complex from 1988-2008 are shown in Table 1. Since 2004, the catch accounting system (CAS) has reported catch of rougheye by species and area. From 1991-2002, species catches were produced by computing the harvest proportions within management groups from the North Pacific Foreign Observer Program database, and applying these proportions to the estimated total catch obtained from the NOAA Fisheries Alaska Regional Office "blend" database. An identical procedure was used to obtain the estimates of catch by species from the 1977-1989 foreign and joint venture fisheries. Estimated domestic catches in 1990 were obtained from Guttormsen et al. 1992. Catches from the domestic fishery prior to the domestic observer program were obtained from PACFIN records. Catches of rougheye since 1977 are shown, by area, in Table 2. Catches were relatively high during the late 1970s, declined during the late 1980s as the foreign fishery was reduced, increased in the early 1990s, and declined in the mid-1990s.

Discards

Estimates of discarding by species complex are shown in Table 3. Estimates of discarding of the other red rockfish complex in the EBS were generally above 56% from 1993 to 2000, which the exception of 1993 and 1995 when discard rates were less than 26%. The variation in discard rates may reflect different species composition of the other red rockfish catch. Discard rates of EBS RE/SR complex from 2001 to 2003 have been below 52%, and discard rates of AI SR/RE complex from 1993-2003 have been below 41%. In general, the discard rate of EBS RE/SR are less than the discard rates of EBS other red rockfish in most years, likely reflecting the relatively higher value of rougheye and shortraker rockfishes over other members of the complex. From 2004 to 2007, discard rates of rougheye in the Aleutian Islands were below 19% (with the exception of 2004), and discard rates in the EBS were below 39% (with the exception of 2005).

Recent Distribution of Catch across Areas and Target Fisheries

Rougheye rockfish in the Aleutian Islands have been caught primarily in the rockfish trawl, Pacific cod longline, and Atka mackerel trawl fisheries in recent years. From 2004-2007, these three fisheries accounted for 91% of the AI rougheye catch. Catches of AI rougheye rockfish from 2004-2007 were primarily taken in the western and central Aleutians, with 51% and 27% in areas 543 and 542, respectively (Table 4). Approximately 76% of the catches of rougheye rockfish from 2004-2007 in the EBS management area were in the Pacific cod longline , “other species” trawl, walleye pollock trawl, turbot longline, arrowtooth trawl, and “other flatfish” trawl fisheries. Catches of rougheye in the EBS management area were concentrated in areas 517, 519 and 521, the areas occupying much of the EBS slope (Table 4).

Given the information on stock structure presented above, and the history of previously managing the EBS rockfish as separate stock complexes, it is prudent to examine how current catches compare to potential area-specific harvest levels, and temporal nature of the fishery removals. A comparison of 2001-2007 rougheye catch by area with what might have been used as an area-specific ABC level is shown in Table 5, where the area-species ABC is obtained by partitioning the BSAI ABC in accordance with the relative distribution of survey biomass estimates by area. Note that the management groups have varied over these years in these areas. For example, in 2001-2003, separate TACs existed for rougheye/shortraker complexes in the EBS and AI with a single BSAI OFL. In contrast, since 2004, rougheye and shortraker have been managed as separate species with the single-species BSAI ABCs and OFLs. Care should be taken not to interpret the results as evidence of overfishing, as this definition depends upon the definition of the stock or stock complex, and at no point has the catch of a stock or stock complex exceeded its OFL level. The intent of this comparison is to investigate how our historical estimates of catch compare with species biomass estimates, and if disproportionate catch levels (relative to the biomass levels) have occurred in the past. Catches of AI rougheye have been near or below potential AI ABC levels from 2002-2007. In 2001, the catch of rougheye of 614 t was higher than the potential AI ABC levels, but a reduction in the maximum retainable bycatch limit has been enacted since 2001 and appears to have helped regulate the catch. Catches of EBS rougheye have been below their potential EBS ABC level, with the exception of 2004 when the catch of 24 t is above the potential EBS ABC level of 21 t.

DATA

Fishery data

The catch data used in the assessment model are the estimates of single species catch described above and shown in Table 2.

Prior to 1999, the fishery data is characterized by inconsistent sampling of length (Table 6) and age (Table 7), as many fished were measured in some years whereas other years had no data. In 1979, 1990, 1992, and 1993 over 1000 fish were measured and the size compositions were used in the assessment model. In the domestic fishery, changes in observer sampling protocol since 1999 increased the number of fish and hauls from which rougheye rockfish age and length data were collected, increasing the utility for stock assessment modeling. The size compositions in 2003 and 2007, and the age compositions in 2004 and 2005, were used in the assessment model.

Survey data

Biomass estimates for rougheye rockfish were produced from cooperative U.S.-Japan trawl survey from 1979-1985 on the eastern Bering Sea slope, and from 1980-1986 in the Aleutian Islands. U.S trawl surveys, conducted by the National Marine Fisheries Service (NMFS) were conducted in 1988 and 1991 on the eastern Bering Sea slope, and in 1991, 1994, 1997, 2000, 2002, 2004, and 2006 in the Aleutian Islands (Table 8). The Aleutian Islands survey scheduled for 2008 was canceled to due lack of funding. Differences exist between the 1980-1986 cooperative surveys and the 1991-2006 U.S. domestic surveys with regard to the vessels and gear design used. For example, the Japanese nets used in the 1980, 1983, and 1986 cooperative surveys varied between years and included large roller gear, in contrast to the poly-nor'eastern nets used in the current surveys (Ronholt et al 1994, Stauffer 2004), and similar variations in gear between surveys occurred in the cooperative EBS surveys.

In the 1980 -2004 AI surveys, rougheye rockfish were relatively evenly distributed throughout the Aleutian Islands, with higher densities observed from the southern portion of Petral Bank to Tahoma Bank, and near Atka Island. In the 2006 survey, higher densities (both *S. aleutianus* and *S. melanostictus* combined) were also observed in these areas (Figure 5). The 2006 AI combined survey biomass estimate for rougheye and blackspotted rockfish was 9,505 t, which represent a decline of 36% from the 2004 estimate of 14,929 t. The bulk of the biomass in the AI survey comes from the central and eastern Aleutian Islands, contributing 42% and 36% of the average biomass from the 1991-2006 surveys.

The biennial EBS slope survey was initiated in 2002. The most recent slope survey prior to 2002 (excluding some experimental tows in 2000 to evaluate survey gear) was in 1991. The 2008 EBS slope survey was completed, but the 2006 survey was canceled due to lack of funding. The distribution of rougheyes in the 2002 and 2004 EBS slope surveys were concentrated in the southern portion of the EBS slope, approximately from the Alaska Peninsula to just west of the Pribilof Islands. Each rougheye obtained in the 2002 and 2004 EBS slope surveys (104 and 216 fish, respectively) was measured and sampled for otoliths, which provided the data for growth patterns discussed above. The survey biomass estimates of blackspotted and rougheye rockfish from the 2002 and 2004 were surveys were 553 t and 646 t, respectively, with CVs of 0.20 and 0.16. As mentioned above, the 2008 EBS slope survey biomass estimates for blackspotted and rougheye rockfish were 530 t and 324 t, respectively, with a CV for the combined blackspotted/rougheye of 0.25. Given these low levels of biomass, the slope survey results are not used in this assessment, and the feasibility of incorporating this time series in the age-structured model will be evaluated as new data becomes available.

Biological Data

The AI survey provides data on age and length composition of the population, growth rates, and length-weight relationships. The number of lengths measured and otoliths sampled are shown in Tables 9 and 10, along with the number of hauls producing these data. The survey data produce reasonable sample sizes of lengths and otoliths throughout the survey area. The maximum age observed in the survey samples was 121 years.

The survey otoliths were read with the break and burn method, and were thus considered unbiased (Chilton and Beamish 1982); however, the potential for aging error exists. Information on aging error was obtained from multiple independent readings on GOA otoliths collected in 1990, 1999, and 2003 (Shotwell et al. 2007). These data were used to estimate the error in age reading based on the percent agreement between the readers. A fitted relationship describing the standard deviation in age read by age was used to produce the aging error matrix.

The AI survey otolith data was used to estimate size at age and von Bertalannfy growth parameters. Unbiased estimates of mean length at age were generated from multiplying the survey length composition by the age-length key in order to produce a matrix of estimated population numbers by age and length, from which an unbiased average length for each age can be determined. Preliminary analyses did not reveal any patterns by year or subarea within the AI survey areas, so the mean length at age from each survey year from 1980 to 2006 was used to fit the growth curve. The estimated von Bertalannfy parameters are as follows, and were used to create a conversion matrix and a weight-at-age vector:

L_{inf}	K	t_0
50.68	0.07	-1.27

A conversion matrix was created to convert modeled number at ages to modeled number at length bin, and consists of the proportion of each age that is expected in each length bin. This matrix was created by regressing the observed standard deviation in length at each age (obtained from the aged fish from the 1980-2006 surveys) against age, and the predicted relationship was used to produce some variation around the predicted size at age from the von Bertalanffy relationship. The resulting CVs of length at age of the conversion matrix decrease from 0.20 at age 3 to 0.08 at age 45.

A length-weight relationship of the form $W = aL^b$ was fit from the survey data, and produced estimates of $a = 6.52 \times 10^{-6}$ and $b = 3.24$. This relationship was used in combination with the von Bertalanffy growth curve to obtain the estimated weight at age vector of the population (Table 11).

The following table summarizes the data available for the both the AI and combined BSAI rougheye rockfish assessment models:

Component	BSAI
Fishery catch	1977-2008
Fishery age composition	2004-2005, 2007
Fishery size composition	1979, 1990, 1992, 1993, 2003
Survey age composition	1986, 1991, 1994, 1997, 2000, 2002, 2004, 2006
Survey biomass estimates	1980, 1983, 1986, 1991, 1994, 1997, 2000, 2002, 2004 2006

ANALYTIC APPROACH

Model structure

The assessment model for rougheye rockfish is very similar to that currently used for other BSAI rockfish, which was used as a template for the current model. Population size in numbers at age *a* in year *t* was modeled as

$$N_{t,a} = N_{t-1,a-1} e^{-Z_{t-1,a-1}} \qquad 3 \le a < A, \quad 1977 < t \le T$$

where Z is the sum of the instantaneous fishing mortality rate ($F_{t,a}$) and the natural mortality rate (M), A is the maximum number of age groups modeled in the population (defined as 45), and T is the terminal year of the analysis (defined as 2008). The numbers at age A are a "pooled" group consisting of fish of age A and older, and are estimated as

$$N_{t,A} = N_{t-1,A-1} e^{-Z_{t-1,A-1}} + N_{t-1,A} e^{-Z_{t-1,A}}$$

The numbers at age in the first year are estimated as

$$N_a = R_0 e^{-M(a-3)+\gamma_a}$$

where R_0 is the mean number of age 3 recruits prior to the start year if the model, and γ_a is an age-dependant deviation assumed to be normally distributed with mean of zero and a standard deviation equal to Φ_r, the recruitment standard deviation. Estimation of the vector of age-dependant deviations from average recruitment allows estimation of year class strength.

The total numbers of age 3 fish from 1977 to 2008 are estimated as parameters in the model, and are modeled with a lognormal distribution

$$N_{t,3} = e^{(\mu_R + \nu_t)}$$

where ν_t is a time-variant deviation.

The fishing mortality rate for a specific age and time ($F_{t,a}$) is modeled as the product of a fishery age-specific selectivity (*fishsel*) that increases asymptotically with age and a year-specific fully-selected fishing mortality rate *f*. The fully selected mortality rate is modeled as the product of a mean (:$_f$) and a year-specific deviation (,$_t$), thus $F_{t,a}$ is

$$F_{t,a} = fishsel_a * f_t \equiv fishsel_a * e^{(\mu_f + \varepsilon_t)}$$

The logistic curve is used to model fishery selectivity at age:

$$fishsel_a = \frac{1}{1 + \exp(-slope(a - a_{50\%}))}$$

where the $a_{50\%}$ and *slope* parameters control the age at 50% selectivity and the slope of the curve at this point, respectively. Survey selectivity and maturity are also modeled with the logistic function.

The mean number at age for each year was computed as

$$\overline{N}_{t,a} = N_{t,a} * (1 - e^{-Z_{t,a}}) / Z_{t,a}$$

The predicted length composition data were calculated by multiplying the mean numbers at age by a conversion matrix, which gives the proportion of each age (rows) in each length group (columns). The age bins range from 3 to 45 and the length bins range from 12 to 50, with the terminal bin being a plus group that includes all older (or larger) fish. The mean number of fish at age available to the survey or fishery is multiplied by the aging error matrix to produce the observed survey or fishery age compositions.

Catch biomass at age was computed as the product of mean numbers at age, instantaneous fishing mortality, and weight at age. The predicted trawl survey biomass (*pred_biom*) was computed as

$$pred\_biom_t = qsurv \sum_a \left(\overline{N}_{t,a} * survsel_a * W_a \right)$$

where W_a is the population weight at age, $survsel_a$ is the survey selectivity, and *qsurv* is the trawl survey catchability.

To facilitate parameter estimation, prior distributions were used for the survey catchability the natural mortality rate *M*. A lognormal distribution was also used for the natural mortality rate *M*, with the mean set to 0.03 with the coefficient of variation (CV) set to 0.05. The value used for *M* in previous assessments was 0.025, and the increase to 0.03 was based on an estimate from McDermott (1994) using the gonadosomatic index and is consistent with estimates of *M* from several methods (Shotwell et al. 2007). The prior distribution for *qsurv* followed a lognormal distribution with a mean of 1.0 and a CV of 0.05, essentially fixing *qsurv* at 1.0. The standard deviation of log recruits, Φ_r, was fixed at 0.75, after conducting several runs evaluating the effect of this parameter on the results.

Several quantities were computed in order to compare the variance of the residuals to the assumed input variances. The root mean squared error (RMSE) should be comparable to the assumed coefficient of variation of a data series. This quantity was computed for the AI trawl survey and the estimated recruitments, and for lognormal distribution is defined as

$$RMSE = \sqrt{\frac{\sum_n (\ln(y) - \ln(\hat{y}))^2}{n}}$$

where y and $\hat{y}$ are the observed and estimated values, respectively, of a series length n. The standardized deviation of normalized residuals (SDNR) is closely related to the RMSE; values of SDNR greater approximately 1 indicate that the model is fitting a data component as well would be expected for a given specified input variance. The normalized residuals for a given year i of the AI trawl survey data was computed as

$$\delta_i = \frac{\ln(B_i) - \ln(\hat{B}_i)}{\sigma_i}$$

where σ_i is the input sampling standard deviation of the estimated survey biomass. For age or length composition data assumed to follow a multinomial distribution, the normalized residuals for age/length group a in year i were computed as

$$\delta_{i,a} = \frac{(y_{i,a} - \hat{y}_{i,a})}{\sqrt{\hat{y}_{i,a}(1 - \hat{y}_{i,a}) / n_i}}$$

where y and $\hat{y}$ are the observed and estimated proportion, respectively, and n is the input assumed sample size for the multinomial distribution. The effective sample size was also computed for the age and length compositions modeled with a multinomial distribution, and for a given year i was computed as

$$E_i = \frac{\sum_a \hat{y}_a * (1 - \hat{y}_a)}{\sum_a (\hat{y}_a - y_a)^2}.$$

An effective sample size that is nearly equal to the input sample size can be interpreted as having a model fit that is consistent with the input sample size.

Parameters Estimated Independently

The parameters estimated independently include the age error matrix, the age-length conversion matrix, individual weight at age, and proportion mature females at age. The derivation of the age error matrix, the age-length conversion matrix, and the weight at age vector are described above. The proportion of females mature at age (Table 11) was obtained from the Gulf of Alaska rougheye rockfish model (Shotwell et al. 2007).

Parameters Estimated Conditionally

Parameter estimation is facilitated by comparing the model output to several observed quantities, such as the age and length composition of the survey and fishery catch, the survey biomass, and the catch biomass. The general approach is to assume that deviations between model estimates and observed quantities are attributable to observation error and can be described with statistical distributions. Each data component provides a contribution to a total log-likelihood function, and parameter values that maximize the log-likelihood are selected.

The log-likelihood of the initial recruitments were modeled with a lognormal distribution

$$\lambda_1 \sum_t \frac{\left(\nu_t + \frac{\sigma^2}{2}\right)^2}{2\sigma^2} + n\ln(\sigma)$$

The adjustment of adding $\sigma_r^2/2$ to the deviation was made in order to produce deviations from the mean, rather than the median, recruitment. The log-likelihood of the recruitment of cohorts represented in the first year of the model treated in a similar manner:

$$\lambda_1 \sum_{a-1} \frac{\left(\gamma_t + \frac{\sigma^2}{2}\right)^2}{2\sigma^2} + (a-1)\ln(\sigma)$$

where the (a-1) refers to the cohorts in the first year of age data that recruited prior to start year of the model. The log-likelihoods of the fishery and survey age and length compositions were modeled with a multinomial distribution. The log of the multinomial function (excluding constant terms) for the fishery length composition data, with the addition of a term that scales the likelihood, is

$$n_{f,t,l} \sum_{s,t,l} p_{f,t,l} \ln(\hat{p}_{f,t,l}) - p_{f,t,l} \ln(p_{f,t,l})$$

where n is the number of hauls that produced the data, and $p_{f,t,l.}$ and $\hat{p}_{f,t,l}$ are the observed and estimated proportion at length in the fishery by year and length. The likelihood for the age and length proportions in the survey, $p_{surv,t,a}$ and $p_{surv,t,l}$, respectively, follow similar equations.

The log-likelihood of the survey biomass was modeled with a lognormal distribution:

$$\lambda_2 \sum_t (\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2cv_t^2$$

where obs_biom_t is the observed survey biomass at time t, cv_t is the coefficient of variation of the survey biomass in year t, and λ_2 is a weighting factor. The log-likelihood of the catch biomass was modeled with a lognormal distribution:

$$\lambda_3 \sum_t (\ln(obs\_cat_t) - \ln(pred\_cat_t))^2$$

where obs_cat_t and $pred\_cat_t$ are the observed and predicted catch. Because the catch biomass is generally thought to be observed with higher precision that other variables, λ_3 is given a very high weight so as to fit the catch biomass nearly exactly. This can be accomplished by varying the *F* levels, and the deviations in *F* are not included in the overall likelihood function. The overall negative log-likelihood function (excluding the catch component) is

$$\begin{aligned}
&\lambda_1 \left(\sum_t \left(\frac{\nu_t + \sigma^2 / 2}{2\sigma^2} \right)^2 + n \ln(\sigma) \right) + \\
&\lambda_1 \left(\sum_{a-1} \left(\frac{\gamma_t}{2\sigma^2} \right)^2 + (a-1) \ln(\sigma) \right) + \\
&\lambda_2 \sum_t (\ln(obs_biom_t) - \ln(pred_biom_t))^2 / 2 * cv_t^2 + \\
&n_{f,t,l} \sum_{s,t,l} p_{f,t,l} \ln(\hat{p}_{f,t,l}) - p_{f,t,l} \ln(p_{f,t,l}) + \\
&n_{f,t,a} \sum_{s,t,l} p_{f,t,a} \ln(\hat{p}_{f,t,a}) - p_{f,t,a} \ln(p_{f,t,a}) + \\
&n_{surv,t,a} \sum_{s,t,a} p_{surv,t,a} \ln(\hat{p}_{surv,t,a}) - p_{surv,t,a} \ln(p_{surv,t,a}) + \\
&n_{surv,t,l} \sum_{s,t,a} p_{surv,t,l} \ln(\hat{p}_{surv,t,l}) - p_{surv,t,l} \ln(p_{surv,t,l}) + \\
&\lambda_3 \sum_t (\ln(obs_cat_t) - \ln(pred_cat_t))^2
\end{aligned}$$

For the model runs in this assessment, λ_1, λ_2, and λ_3 were assigned weights of 1,1, and 50, reflecting the strong emphasis on fitting the catch data. The sample sizes for the age and length compositions were set to the number of hauls from which these demographic data were obtained. Additionally, the fishery length and age compositions were assigned one-half the weight of the survey age composition as it was generally perceived as a less reliable source of information. In the results below, comparisons of effective sample size to input sample size were made after scaling the input sample sizes by their weights (Table 12).

The negative log-likelihood function was minimized by varying the following parameters:

Parameter type	*Number*
1) fishing mortality mean ($;_f$)	1
2) fishing mortality deviations ($,_t$)	32
3) recruitment mean ($;_r$)	1
4) recruitment deviations ($<_t$)	32
5) historic recruitment (R_0)	1
6) first year recruitment deviations	42
7) biomass survey catchability	1
8) natural mortality rate	1
9) survey selectivity parameters	2
10) fishery selectivity parameters	2
Total parameters	115

RESULTS

Model Evaluation

The negative log-likelihood associated with the various data components of the two models are shown in Table 12. The fits for the likelihood components cannot be compared directly to each other because the underlying data is slightly different, as the BSAI model includes additional survey data from the southern Bering Sea portion of the AI survey and the catch data from the EBS management subarea. However, the overall fit of the model to the data is similar, with most of the likelihood coming from the fit to the fishery length and survey age data. For both models the effective sample sizes for the age and size composition data was greater than the input samples sizes, indicating good data fits to these components; this is also reflected in the small (<0.5) values for the standard deviations of normalized residuals. The standard deviations of normalized residuals and the root mean squared error of the survey and recruitment series were nearly identical between the two models. The modeling stock projection results below refer to the AI model. The results for the two models were very similar due to the similarity of the data, and is indicated in the time series of estimated total biomass for the two models (Figure 8).

Biomass trends

The estimated survey biomass decreases from 11,126 t in 1977 to 8,204 t in 1980 due to large catches in the late 1970s, increased to 12,760 in 1989, declined throughout the 1990s and has gradually increased to 13,356 in 2008 (Figure 9). The total and spawning biomass also show a decline in the late 1970s, increases throughout the 1980s, and a decline in most of the 1990s. Since 1998, the spawning biomass has increased from 5,926 t to 6,534 t in 2008, and the total biomass has increased from 16,463 t to 18,552 t over this period (Figures 10). The time series of estimated total biomass, spawner biomass, and recruitment are shown in Table 13.

Age/size compositions

The model fits to the fishery age and size compositions are shown in Figures 11 and 12, and the model fit to the survey age compositions are shown in Figure 13. The model does not capture some of the peaks in the fishery age and length composition data (i.e. length compositions in 1990 and 1992), reflecting the relatively low number of hauls sampled and the down-weighting of the fisheries data relative to the survey data. The model captures the general trends in the survey age data with the exception of 1986 which had a low number of sampled hauls.

Natural mortality and survey catchability

The CVs of 5% for the priors on survey catchability and natural mortality constrained these parameters to values of 1.057 and 0.0323, respectively, a slight increase from the prior distribution means of 1.0 and 0.03, respectively.

Fishery and survey selectivity

Similar asymptotic selection curves were obtained for the AI survey and fishery, with an age at 50% selection for the fishery and AI survey of 20.0 years 20.8 years, respectively (Figure 14).

Fishing mortality

The estimates of instantaneous fishing mortality rate are shown in Figure 15. Very high rates of fishing mortality are required in 1978 and 1979 to account for the high catches during these years, followed by rapid decreases in the early 1980s. Fishing mortality rates began to increase during the late 1980s, and were relatively high for several years between the late 1980s and mid 1990s. Fishing mortality rates began to decline in late 1990s, and have been below the $F_{35\%}$ reference rate since 2000 (with the exception if 2001). The catches of rougheye rockfish in the 1990s must be viewed in the context of the existing management the rougheye/shortraker species complex. A plot of fishing mortality rates and spawning stock biomass in reference to the ABC and OFL harvest control rules indicates that the current rate of fishing stock is currently below $F_{35\%}$ and the spawning stock biomass is below $B_{40\%}$ (Figure 16).

Recruitment

Recruitment strengths by year class are shown in Figure 17. There is little information to discern strong recruitments in the early years of the model, although relatively strong year classes are estimated for 1976 and 1981 and are observed in several years of survey sampling. Stronger year classes are observed for the 1998-2002 year classes, but these have been observed only in the 2004 and 2006 surveys and consist of young fish not fully selected to the survey gear, thus increasing the uncertainty of these estimates. The scatterplot of recruitment against spawning stock biomass is shown in Figure 18.

Projections and Harvest Alternatives

The reference fishing mortality rate for rougheye rockfish is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Estimates of $F_{0.40}$, $F_{0.35}$, and $SPR_{0.40}$ were obtained from a spawner-per-recruit analysis. Assuming that the average recruitment from the 1977-2005 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{0.40}$ is calculated as the product of $SPR_{0.40}$ * equilibrium recruits, and this quantity is 6,723 t. The year 2009 spawning stock biomass is estimated as 6,535 t. Since reliable estimates of the 2009 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B<B_{0.40}$ (6,535 t < 6,723 t), POP reference fishing mortality is defined in tier 3b. For this tier, F_{ABC} is constrained to be < $F_{0.40}$, and F_{OFL} is constrained to be < $F_{0.35}$. The values of $F_{0.40}$ and $F_{0.35}$ are 0.040 and 0.048, respectively, whereas the values F_{abc} and F_{ofl} are 0.038 and 0.047. The 2009 ABC and OFL resulting from these rates are 499 t and 607 t, respectively. A summary of these values is below.

2009 SSB estimate (B)	= 6,535 t
$B_{0.40}$	= 6,723 t
$F_{0.40}$	= 0.040
F_{ABC}	= 0.038
$F_{0.35}$	= 0.048
F_{OFL}	= 0.047

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

For each scenario, the projections begin with the vector of 2008 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2009 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2008. 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 is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2009, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

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

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2009 recommended in the assessment to the *max* F_{ABC} for 2009. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

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

Scenario 4: In all future years, F is set equal to the 2003-2007 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

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

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, and five-year projections of the mean harvest and spawning stock biomass for the remaining four scenarios are shown in Table 14.

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

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

Scenario 7: In 2009 and 2010, 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 2011 under this scenario, then the stock is not approaching an overfished condition.)

The projections of the mean spawning stock biomass, fishing mortality rate, and harvest for these scenarios are shown in Table 11.12. The results of these two scenarios indicate that the AI rougheye rockfish stock is neither overfished or approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2009 of scenario 6 is 1.11 times its $B_{35\%}$ value of 5,883 t. With regard to whether AI rougheye rockfish is likely to be overfished in the future, the expected stock size in 2011 of scenario 7 is 1.08 times the $B_{35\%}$ value.

The projections and harvest alternatives above refer the AI model, and similar results are obtained for the BSAI model (Table 15). A summary of harvest quantities associated with the two models shown below.

Quantity	AI Model	BSAI Model
M	0.032	0.032
Tier	3b	3b
Year 2009 Total Biomass	18,978 t	19,583 t
Year 2010 Total Biomass	19,093 t	19,695 t
Year 2009 Spawning stock biomass	6,535 t	6,769 t
$B_{100\%}$	16,808 t	17,680 t
$B_{40\%}$	6,723 t	7,072 t
$B_{35\%}$	5,883 t	6,188 t
F_{OFL}	0.047	0.049
Maximum F_{ABC}	0.038	0.040
Recommended F_{ABC}	0.038	0.040
OFL (2009)	607 t	626 t
OFL (2010)	587 t	611 t
Maximum allowable ABC (2009)	499 t	512 t
Recommended ABC (2009)	499 t	512 t
Maximum allowable ABC (2010)	482 t	500 t
Recommended ABC (2010)	482 t	500 t

Area Allocation of Harvests

The spatial allocation of harvest quota for blackspotted and rougheye rockfish depends upon the spatial scale of the assessment model as well as the area allocation of harvest recommendations. These two aspects can be considered somewhat independent, and the 2009 ABC and OFL values associated with various combinations are shown in the table below.

Area allocation of ABC and OFL

Assessment Methodology	Separate ABC and OFL	Separate ABC, Combined OFL	Combined ABC and OFL
Age-structured AI model; BS harvest quotas obtained from Tier 5 methods	(a) 2009 AI ABC: 499 t 2009 BS ABC: 40 t 2009 AI OFL: 607 t 2009 BS OFL: 53 t	(b) 2009 AI ABC: 499 t 2009 BS ABC: 40 t 2009 BSAI OFL: 660 t	(c) 2009 BSAI ABC: 539 t 2009 BSAI OFL: 660 t
Age-structured BSAI Model	(d) Not considered	(e) 2009 AI ABC: 436 t 2009 BS ABC: 76 t 2009 BSAI OFL: 626 t	(f) 2009 BSAI ABC: 512 t 2009 BSAI OFL: 626 t

The approach recommended in this assessment is to apply an age-structured assessment model to the data from the Aleutian Islands, and use EBS survey biomass estimates and Tier 5 methods to produce EBS harvest recommendations. This assessment methodology is recommended because it is consistent with the best available scientific information suggesting limited movement between the EBS and AI areas. In the AI model, the F_{abc} and F_{ofl} for the AI stock are 0.038 and 0.047, respectively, and the ABC and OFL are 499 t and 607 t, respectively. For EBS rougheye, a Tier 5 harvest policy is recommended. The available survey biomass estimates for EBS blackspotted and rougheye rockfish includes the southern Bering Sea portion of the AI survey, and the 2002, 2004, and 2008 EBS slope survey estimates. For each survey, weighted averages are used to give more weight to more recent survey data. A weighted average of the three most recent biomass estimates of the southern Bering Sea is 1050 t, and was added to a weighted average of the two EBS slope survey estimates of 725 t, yielding a survey biomass estimate of 1,775 t. Using an estimate of M of 0.03 results in F_{abc} and F_{ofl} of 0.0225 and 0.03, respectively, and an ABC and OFL of 40 t and 53 t, respectively.

Three methods for partitioning these ABC and OFL are shown in cells (a)-(c) in the table above. The most conservative is separate AI and EBS ABCs and OFLs (cell a), as this would ensure that harvest in each area would not exceed the area-specific OFL. BSAI-wide ABCs and OFLs (cell c) is not recommended because it is inconsistent with the assessment model and with information pertaining to stock structure. An intermediate approach is shown in cell (b), in which has area-specific ABCs but a BSAI-wide OFL. This approach would prohibit retention of blackspotted and rougheye rockfish once the area-specific ABC has been reached, and could thus help prevent the process of “topping off” on these species. Give the recent area-specific catch history, the prevention of targeting on these species, and the lowered maximum retained allowance, it is possible that the area-specific OFLs will not be reached. This, while our recommended approach is to have area-specific ABCs and OFLs, managing under area-specific ABCs and a BSAI OFL is an acceptable alternative.

For comparison, the ABCs and OFLs when using a BSAI model are shown in cells (e) and (f). Managing with area-specific ABCs and OFLs is not consistent with a BSAI-wide assessment model and is not considered. The area-specific ABC shown in cell (e) are obtained by multiplying the relative proportion of the two areas (85% for AI and 15% for EBS) by the BSAI ABC by the total ABC from the BSAI-wide model. These proportions were obtained from a 4-6-9 weighted average of the three most recent survey biomass estimates, which were 2002, 2004, and 2006 for the AI survey and 2002, 2004, and

2008 for the EBS slope estimates. The average survey biomass of the southern Bering Sea portion of the AI survey was combined with the eastern Bering Sea slope estimates.

In previous assessments, rougheye rockfish were assessed with a surplus production model, and Tier 5 harvest recommendations were production by applying the F_{abc} and F_{ofl} of 0.019 and 0.025 to the most recent estimated biomass level. In 2006, the last full assessment of rougheye, the estimated biomass level was 10,782 and the recommended BSAI ABC and OFL were 202 t and 269 t, respectively.

The increase in the harvest recommendation between the Tier 5 approach and the age-structured Tier 3 approach can be attributed to the use of fishing selectivity curves, which increases the harvest rate on selected fish. The Tier 5 approach assumes that all ages are equally vulnerable to both the fishery, whereas the age-structured model recognizes that younger fish are less vulnerable. One useful comparison is to compute the exploitation rate implied by the Tier 3 catch recommendation, as this puts the catch in units equivalent to those under Tier 5. In the separate area model, the AI exploitation rate is associated with the ABC is 499 t divided by an estimated total biomass of 18,978 t, yielding an exploitation rate of 0.026, which is somewhat higher than that of 0.019 used in the Tier 5 approach.

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Table 1. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the species groups used to manage rougheye rockfish from 1988 to 2008. The "other red rockfish" group includes, shortraker rockfish, rougheye rockfish, northern rockfish, and sharpchin rockfish. The "POP complex" includes the other red rockfish species plus POP.

Year	Area	Management Group	ABC (t)	TAC (t)	Catch (t)
1988	BS	POP Complex	6,000		1,509
	AI	POP Complex	16,600		2,629
1989	BS	POP Complex	6,000		2,873
	AI	POP Complex	16,600		3,780
1990	BS	POP Complex	6,300		7,231
	AI	POP Complex	16,600		15,224
1991	BS	Other Red Rockfish	1,670	1,670	942
	AI	Rougheye/Shortraker	1,245	1,245	388
1992	BS	Other Red Rockfish	1,400	1,400	467
	AI	Rougheye/Shortraker	1,220	1,220	1,470
1993	BS	Other Red Rockfish	1,400	1,200	1,226
	AI	Rougheye/Shortraker	1,220	1,100	1,139
1994	BS	Other Red Rockfish	1,400	1,400	129
	AI	Rougheye/Shortraker	1,220	1,220	925
1995	BS	Other Red Rockfish	1,400	1,260	344
	AI	Rougheye/Shortraker	1,220	1,098	559
1996	BS	Other Red Rockfish	1,400	1,260	207
	AI	Rougheye/Shortraker	1,250	1,125	959
1997	BS	Other Red Rockfish	1,050	1,050	218
	AI	Rougheye/Shortraker	938	938	1,043
1998	BS	Other Red Rockfish	267	267	112
	AI	Rougheye/Shortraker	965	965	685
1999	BS	Other Red Rockfish	356	267	238
	AI	Rougheye/Shortraker	1,290	965	514
2000	BS	Other Red Rockfish	259	194	253
	AI	Rougheye/Shortraker	1,180	885	480
2001	BSAI	Rougheye/Shortraker	1,028		
	BS	Rougheye/Shortraker		116	72
	AI	Rougheye/Shortraker		912	722
2002	BSAI	Rougheye/Shortraker	1,028		
	BS	Rougheye/Shortraker		116	105
	AI	Rougheye/Shortraker		912	478
2003	BSAI	Rougheye/Shortraker	967		
	BS	Rougheye/Shortraker		137	124
	AI	Rougheye/Shortraker		830	306
2004	BSAI	Rougheye	195	195	208
2005	BSAI	Rougheye	223	223	90
2006	BSAI	Rougheye	224	224	203
2007	BSAI	Rougheye	202	202	166
2008	BSAI	Rougheye	202	202	171*

*Catch data through Oct 18, 2008, from NMFS Alaska Regional Office.

Table 2. Catch of rougheye rockfish (t) in the BSAI area.

	Eastern Bering Sea				Aleutian Islands				BSAI
Year	Foreign	JV	Domestic	Total	Foreign	JV	Domestic	Total	Total
1977	2	0		2	155	0		155	157
1978	99	0		99	2423	0		2423	2522
1979	477	0		477	3077	0		3077	3553
1980	160	0		160	660	0		660	820
1981	283	0		283	595	0		595	878
1982	124	0		124	189	0		189	312
1983	53	0		53	56	2		57	111
1984	79	0		79	31	4		35	114
1985	18	0		18	1	9		9	27
1986	3	1	48	52	0	2	19	22	74
1987	1	2	96	100	0	3	76	79	179
1988	0	1	110	110	0	5	70	75	185
1989	0	2	202	203	0	0	381	381	585
1990			369	369			1619	1619	1988
1991			106	106			137	137	243
1992			77	77			1181	1181	1258
1993			146	146			924	924	1070
1994			22	22			747	747	769
1995			28	28			393	393	421
1996			34	34			821	821	855
1997			15	15			958	958	973
1998			16	16			528	528	543
1999			9	9			383	383	392
2000			26	26			267	267	294
2001			15	15			585	585	600
2002			11	11			249	249	260
2003			17	17			175	175	192
2004			24	24			184	184	208
2005			12	12			78	78	90
2006			7	7			196	196	203
2007			10	10			156	156	166
2008			24	24			147	147	171*

*Catch data through Oct 18, 2008, from NMFS Alaska Regional Office.

Table 3. Estimated retained, discarded, and percent discarded of other red rockfish (ORR), shortraker/rougheye (SR/RE), and rougheye (RE) from the eastern Bering Sea (EBS) and Aleutian Islands (AI) regions.

Species		Catch (t)			Percent	
Area	Group	Year	Retained	Discard	Total	Discarded
EBS	ORR	1993	916	308	1226	25.2%
		1994	29	100	129	77.6%
		1995	273	70	343	20.4%
		1996	58	149	207	71.9%
		1997	43	174	217	80.0%
		1998	42	70	112	62.4%
		1999	75	162	238	68.4%
		2000	111	141	252	55.9%
EBS	RE/SR	2001	27	16	43	37.8%
		2002	50	54	104	52.0%
		2003	66	58	124	46.8%
AI	RE/SR	1993	737	403	1,139	35.3%
		1994	701	224	925	24.2%
		1995	456	103	558	18.4%
		1996	751	208	959	21.7%
		1997	733	310	1,043	29.7%
		1998	447	238	685	34.8%
		1999	319	195	514	38.0%
		2000	285	196	480	40.8%
		2001	476	246	722	34.1%
		2002	333	146	478	30.4%
		2003	214	92	306	29.9%
AI RE		2004	83	101	184	54.8%
		2005	72	6	78	7.9%
		2006	166	30	196	15.2%
		2007	127	29	156	18.6%
EBS RE		2004	15	9	24	38.2%
		2005	3	9	12	72.7%
		2006	5	2	7	27.3%
		2007	7	3	10	26.9%

Table 4. Aleutian Islands and eastern Bering Sea catch (t) of rougheye rockfish by management area and target fishery in 2004-2007, from the NMFS Alaska Regional Office catch accounting system database.

Aleutian Islands

		Management Area			
Target	Gear	541	542	543	Total
Atka Mackerel	Bottom Trawl	1.72	16.10	37.64	55.46
Pacific Cod	Longline	13.59	31.23	13.58	58.39
Pacific Cod	Bottom Trawl	1.78	3.57	0.21	5.56
Halibut	Longline	4.49	5.90	1.36	11.75
Rockfish	Bottom Trawl	110.08	79.00	258.15	447.23
Sablefish	Longline	3.42	5.39		8.80
Turbot	Longline	0.01	9.32		9.34
Arrowtooth	Longline	0.02	16.23		16.25
Total		135.94	167.12	310.94	614.00

Eastern Bering Sea

		Management Area							
Target	Gear	509	513	517	518	519	521	523	524	Total
Pacifc Cod	Longline		0.00	0.65		0.35	7.87	0.46	0.04	9.37
Pacifc Cod	Bottom Trawl	0.06		0.69		0.42	0.34	0.28		1.78
Other flatfish	Bottom Trawl			2.19		2.54				4.73
Halibut	Longline			1.75	0.97	0.02	0.62	0.02	0.05	3.43
Rockfish	Bottom Trawl			2.00		0.02				2.01
Flathead sole	Bottom Trawl		0.99	0.47			0.04			1.50
Other Species	Bottom Trawl			8.84						8.84
Walleye pollock	Pelagic Trawl	0.03	0.01	4.29		1.10	0.73	0.01	0.03	6.19
Sablefish	Longline			0.94	0.08	0.18		0.06		1.25
Turbot	Longline			0.00		0.05	4.21	1.71	0.03	6.00
Arrowtooth	Bottom Trawl			3.61		1.62				5.22
Total		0.09	1.00	25.93	1.50	7.74	14.04	2.56	0.16	53.02

Table 5. Comparison of catch (t) of rougheye rockfish in the Aleutian Islands from 2001 to 2007 with potential area-specific ABC levels.

	Aleutian Islands		Eastern Bering Sea	
Year	Total Catch	ABC	Total Catch	ABC
2001	585	230	15	32
2002	251	230	11	32
2003	175	215	17	32
2004	184	174	24	21
2005	78	198	12	25
2006	196	199	7	25
2007	156	178	10	24

Table 6. Samples sizes of rougheye lengths from fishery sampling, with the number of hauls from which these data were collected, from 1977-2007.

	EBS		AI		BSAI	
Year	Lengths	Hauls	Lengths	Hauls	Lengths	Hauls
1977						
1978			54	6	54	6
1979	2340	132	4406	93	6746	225
1980						
1981						
1982						
1983			33	1	33	1
1984						
1985						
1986						
1987						
1988						
1989						
1990	800	29	1161	20	1961	49
1991	95	16	49	1	144	17
1992	61	1	1182	67	1243	68
1993	2	2	1046	39	1048	41
1994			27	1	27	1
1995	42	3			42	3
1996	14	3			14	3
1997						
1998						
1999	4	2	53	4	57	6
2000	4	1	160	21	164	22
2001	10	1	277	42	287	43
2002		0	336	49	336	49
2003	76	18	832	100	908	118
2004	215	41	1265	242	1480	283
2005	71	39	314	94	385	133
2006	61	16	266	56	327	72
2007	103	39	716	160	819	199

Table 7. Samples sizes of rougheye otoliths from fishery sampling, with the number of hauls from which these data were collected, from 1977-2007.

	Otoliths Sampled			Otoliths Read			Hauls (Otoliths Read)		
Year	EBS	AI	BSAI	EBS	AI	BSAI	EBS	AI	BSAI
1977									
1978									
1979	440	383	823	14	38	52	6	4	10
1980									
1981									
1982									
1983									
1984									
1985									
1986									
1987									
1988									
1989									
1990	54	0	54						
1991									
1992		50	50						
1993									
1994									
1995									
1996									
1997									
1998									
1999	4	4	8						
2000	2	24	26						
2001	2	76	78						
2002		67	67						
2003	19	120	139						
2004	14	147	161	14	146	160	11	90	101
2005	37	100	137	35	97	132	23	65	88
2006	5	83	88		82	82		47	47
2007	14	138	152						

Table 8. Estimated biomass (t) of rougheye rockfish from the EBS slope survey and AI trawl survey (by management), with the coefficient of variation (CV) is shown in parentheses.

	AI survey			EBS Slope survey
Year	AI	S. Bering Sea	Total	
1979				1053
1980	8,987 (0.07)	6 (1.00)	8,993 (0.07)	
1981				816
1982				605
1983	13,100 (0.19)	2,111 (0.33)	15,211 (0.17)	
1984				
1985				1716
1986	57,363 (0.51)	2,724 (0.49)	60,087 (0.49)	
1987				
1988				876 (0.32)
1989				
1990				
1991	10,638 (0.47)	676 (0.12)	11,314 (0.44)	884 (0.30)
1992				
1993				
1994	13,374 (0.28)	1,208 (0.49)	14,582 (0.26)	
1995				
1996				
1997	11,035 (0.22)	561 (0.66)	11,596 (0.21)	
1998				
1999				
2000	14,218 (0.23)	1,054 (0.26)	15,271 (021)	
2001				
2002	8,361 (0.21)	1,251 (0.48)	9,613 (0.19)	553 (0.20)
2003				
2004	14,275 (0.26)	654 (0.31)	14,929 (0.25)	648 (0.16)
2005				
2006	8,281 (0.25)	1,224 (0.33)	9,505 (0.23)	
2007				
2008				854 (0.25)

Table 9. Samples sizes of rougheye lengths from the Aleutian Island trawl survey, with the number of hauls from which these data were collected, from 1980-2006.

	Fish Lengthed			Hauls		
Year	SBS	AI	Total	SBS	AI	Total
1980	440	5009	5449	6	68	74
1981						
1982						
1983	602	3312	3914	8	84	92
1984						
1985						
1986	622	3768	4390	7	54	61
1987						
1988						
1989						
1990						
1991	79	981	1060	5	30	35
1992						
1993						
1994	412	1963	2375	14	90	104
1995						
1996						
1997	90	1727	1817	13	108	121
1998						
1999						
2000	165	1508	1673	18	101	119
2001						
2002	258	1030	1288	19	79	98
2003						
2004	103	1419	1522	13	104	117
2005						
2006	177	1082	1259	20	102	122

Table 10. Samples sizes of rougheye otoliths from the Aleutian Island trawl survey, with the number of hauls from which these data were collected, from 1980-2006.

	Otoliths sampled			Otoliths Read			Hauls (Otoliths Read)		
Year	SBS	AI	Total	SBS	AI	Total	SBS	AI	Total
1980									
1981									
1982									
1983	0	36	36	0	0	0	0	0	0
1984									
1985									
1986	70	343	413	64	341	405	2	11	13
1987									
1988									
1989									
1990									
1991	79	401	480	79	397	476	6	23	29
1992									
1993									
1994	194	535	729	130	356	486	13	55	68
1995									
1996									
1997	76	790	866	52	526	578	9	83	92
1998									
1999									
2000	116	376	492	115	375	490	16	71	87
2001									
2002	114	359	473	114	337	451	15	66	81
2003									
2004	103	372	475	102	370	472	14	83	97
2005									
2006	120	339	459	120	339	459	13	76	89

Table 11. Predicted weight and proportion mature at age for BSAI rougheye rockfish.

Age	Predicted weight (g)	Proportion mature
3	28	0
4	49	0
5	78	0
6	113	0.001
7	155	0.001
8	202	0.003
9	255	0.008
10	312	0.015
11	372	0.03
12	435	0.053
13	500	0.09
14	566	0.141
15	633	0.209
16	701	0.29
17	768	0.378
18	834	0.467
19	899	0.551
20	963	0.625
21	1026	0.689
22	1086	0.742
23	1145	0.785
24	1201	0.82
25	1256	0.847
26	1308	0.87
27	1358	0.888
28	1405	0.902
29	1451	0.914
30	1494	0.924
31	1535	0.932
32	1574	0.939
33	1611	0.944
34	1646	0.949
35	1679	0.953
36	1711	0.956
37	1740	0.959
38	1768	0.962
39	1794	0.964
40	1819	0.966
41	1842	0.968
42	1864	0.969
43	1884	0.97
44	1903	0.971
45	2047	0.977

Table 12. Negative log likelihood of model components, average effective and input sample sizes, root mean squared errors and standard deviation of normalized residuals for the BSAI model and the AI model.

Component	Negative log likelihood	
	AI Model	BSAI Model
Recruitment	4.12	4.09
AI survey biomass	11.34	11.88
Catch	0.00	0.00
F penalty	5.70	3.95
Fishery ages	787.04	935.39
Fishery lengths	973.28	1530.81
Survey ages	1637.97	1957.55
Prior for *q_srv*	0.63	0.47
Prior for *M*	1.12	0.72
Total likelihood	3800.25	4807.21
Average Effective Sample Size		
Fishery ages	93.29	83.50
Fishery lengths	69.92	150.62
Survey ages	189.98	263.93
Average Sample Sizes		
Fishery ages	59.50	70.50
Fishery lengths	47.85	75.15
Survey ages	87.75	104.25
Root Mean Squared Error		
survey	0.57	0.56
recruitment	0.64	0.61
Standard Deviation of Normalized Residuals		
Fishery ages	0.80	0.84
Fishery lengths	0.53	0.54
Survey ages	0.66	0.63
AI trawl survey	1.45	1.44

Table 13. Estimated time series of AI rougheye total biomass (t), spawner biomass (t), and recruitment (thousands).

	Total Biomass (ages 3+)		Spawner Biomass (ages 3+)		Recruitment (age 3)	
	Assessment Model		Assessment Model		Assessment Model	
Year	BSAI	AI	BSAI	AI	BSAI	AI
1977	20,635	18,738	6,335	5,798	841	933
1978	21,297	19,328	6,526	5,944	1,062	1,138
1979	19,483	17,551	5,775	5,219	1,962	1,778
1980	16,589	15,092	4,891	4,455	1,553	1,377
1981	16,513	15,117	4,927	4,508	955	960
1982	16,364	15,200	4,969	4,603	970	1,016
1983	16,788	15,706	5,210	4,844	1,352	1,454
1984	17,426	16,350	5,515	5,134	1,963	1,588
1985	18,058	17,013	5,822	5,436	1,554	1,272
1986	18,770	17,695	6,154	5,748	1,179	1,079
1987	19,418	18,349	6,456	6,052	775	775
1988	19,938	18,926	6,713	6,334	637	653
1989	20,433	19,486	6,929	6,590	666	642
1990	20,491	19,707	6,872	6,628	593	563
1991	19,048	18,592	6,420	6,310	460	451
1992	19,393	19,000	6,530	6,457	404	396
1993	18,657	18,293	6,278	6,234	394	378
1994	18,085	17,822	6,117	6,116	411	382
1995	17,792	17,504	6,093	6,088	511	440
1996	17,832	17,523	6,167	6,157	789	578
1997	17,410	17,075	6,072	6,054	1,046	662
1998	16,845	16,463	5,961	5,926	913	731
1999	16,704	16,275	6,013	5,958	844	744
2000	16,709	16,223	6,116	6,040	986	917
2001	16,913	16,414	6,217	6,125	4,778	5,703
2002	16,795	16,255	6,211	6,099	1,978	1,818
2003	17,067	16,501	6,314	6,183	2,121	2,433
2004	17,423	16,847	6,422	6,280	1,138	1,199
2005	17,785	17,207	6,510	6,356	1,078	1,116
2006	18,285	17,697	6,617	6,446	1,070	1,049
2007	18,718	18,107	6,689	6,492	967	925
2008	19,164	18,552	6,750	6,534	983	930
2009	19,583	18,978	6,769	6,535		

Table 14. Projections of AI spawning biomass (t), catch (t), and fishing mortality rate for each of the several scenarios resulting from the AI model. The values of $B_{40\%}$ and $B_{35\%}$ are 6,723 t and 5,883 t, respectively.

Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2008	185	185	185	185	185	185	185
2009	499	499	252	166	0	607	499
2010	482	482	252	167	0	577	482
2011	469	469	253	168	0	553	570
2012	459	459	256	169	0	535	550
2013	456	456	261	171	0	525	539
2014	459	459	264	174	0	523	536
2015	468	468	269	177	0	529	541
2016	481	481	274	182	0	540	550
2017	497	497	281	187	0	555	564
2018	507	507	289	193	0	572	581
2019	517	517	297	200	0	591	598
2020	528	528	306	206	0	607	613
2021	538	538	315	213	0	618	622
Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2008	6531	6531	6531	6531	6531	6531	6531
2009	6535	6535	6554	6561	6573	6526	6535
2010	6427	6427	6558	6604	6693	6371	6427
2011	6348	6348	6583	6668	6833	6250	6341
2012	6307	6307	6637	6761	7001	6171	6254
2013	6313	6313	6733	6895	7211	6144	6220
2014	6368	6368	6874	7076	7468	6170	6239
2015	6466	6466	7056	7299	7767	6240	6304
2016	6584	6584	7259	7540	8085	6332	6390
2017	6712	6712	7474	7795	8418	6437	6489
2018	6838	6838	7691	8051	8753	6539	6586
2019	6958	6958	7902	8303	9087	6632	6674
2020	7061	7061	8097	8539	9408	6704	6742
2021	7150	7150	8280	8765	9722	6759	6794
F	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2008	0.01416	0.01416	0.01416	0.01416	0.01416	0.01416	0.01416
2009	0.03844	0.03844	0.01922	0.01260	0	0.04689	0.03844
2010	0.03778	0.03778	0.01923	0.01260	0	0.04571	0.03778
2011	0.03729	0.03729	0.01931	0.01260	0	0.04480	0.04549
2012	0.03703	0.03703	0.01948	0.01260	0	0.04420	0.04483
2013	0.03707	0.03707	0.01977	0.01260	0	0.04400	0.04457
2014	0.03741	0.03741	0.01981	0.01260	0	0.04419	0.04472
2015	0.03802	0.03802	0.01981	0.01260	0	0.04473	0.04521
2016	0.03875	0.03875	0.01981	0.01260	0	0.04543	0.04586
2017	0.03954	0.03954	0.01981	0.01260	0	0.04622	0.04661
2018	0.03961	0.03961	0.01981	0.01260	0	0.04699	0.04735
2019	0.03961	0.03961	0.01981	0.01260	0	0.04769	0.04801
2020	0.03961	0.03961	0.01981	0.01260	0	0.04821	0.04837
2021	0.03961	0.03961	0.01981	0.01260	0	0.04837	0.04839

Table 15. Projections of spawning biomass (t), catch (t), and fishing mortality rate for each of the several scenarios resulting from the BSAI model. The values of $B_{40\%}$ and $B_{35\%}$ are 7,072 t and 6,188 t, respectively.

Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2008	202	202	202	202	202	202	202
2009	512	512	258	186	0	626	512
2010	500	500	261	188	0	601	500
2011	490	490	264	190	0	581	599
2012	483	483	269	192	0	565	581
2013	480	480	275	194	0	555	570
2014	482	482	280	197	0	552	565
2015	489	489	283	200	0	555	567
2016	498	498	288	204	0	560	572
2017	510	510	293	209	0	569	580
2018	522	522	299	214	0	580	590
2019	528	528	305	219	0	592	601
2020	535	535	313	226	0	604	612
2021	544	544	321	232	0	616	623
Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2008	6747	6747	6747	6747	6747	6747	6747
2009	6769	6769	6789	6795	6809	6760	6769
2010	6684	6684	6818	6857	6957	6624	6684
2011	6624	6624	6866	6939	7124	6519	6616
2012	6597	6597	6939	7046	7317	6451	6540
2013	6610	6610	7047	7188	7545	6429	6509
2014	6664	6664	7192	7370	7813	6451	6524
2015	6754	6754	7370	7585	8116	6511	6577
2016	6860	6860	7565	7815	8434	6589	6649
2017	6973	6973	7768	8054	8761	6677	6732
2018	7084	7084	7970	8293	9089	6763	6813
2019	7187	7187	8167	8525	9412	6842	6887
2020	7278	7278	8351	8746	9726	6907	6947
2021	7360	7360	8528	8960	10037	6960	6995
F	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2008	0.01580	0.01580	0.01580	0.01580	0.01580	0.01580	0.01580
2009	0.04002	0.04002	0.02001	0.01434	0	0.04911	0.04002
2010	0.03949	0.03949	0.02010	0.01434	0	0.04807	0.03949
2011	0.03912	0.03912	0.02025	0.01434	0	0.04726	0.04800
2012	0.03895	0.03895	0.02048	0.01434	0	0.04675	0.04742
2013	0.03903	0.03903	0.02081	0.01434	0	0.04657	0.04719
2014	0.03937	0.03937	0.02096	0.01434	0	0.04674	0.04730
2015	0.03993	0.03993	0.02096	0.01434	0	0.04720	0.04771
2016	0.04059	0.04059	0.02096	0.01434	0	0.04780	0.04826
2017	0.04130	0.04130	0.02096	0.01434	0	0.04847	0.04889
2018	0.04191	0.04191	0.02096	0.01434	0	0.04914	0.04952
2019	0.04191	0.04191	0.02096	0.01434	0	0.04974	0.05008
2020	0.04191	0.04191	0.02096	0.01434	0	0.05024	0.05054
2021	0.04191	0.04191	0.02096	0.01434	0	0.05064	0.05090

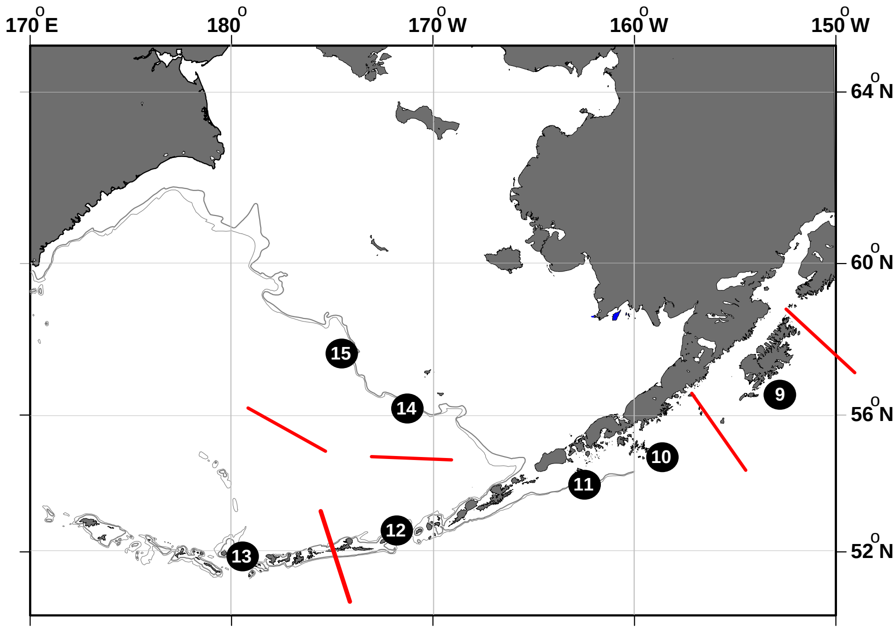


Figure 1. Locations of genetic samples of blackpotted rockfish. Samples separated by lines showed statistically significant genetic divergence based on allele frequencies (Figure from Dr. A.J. Gharrett, UAF, pers. comm.).

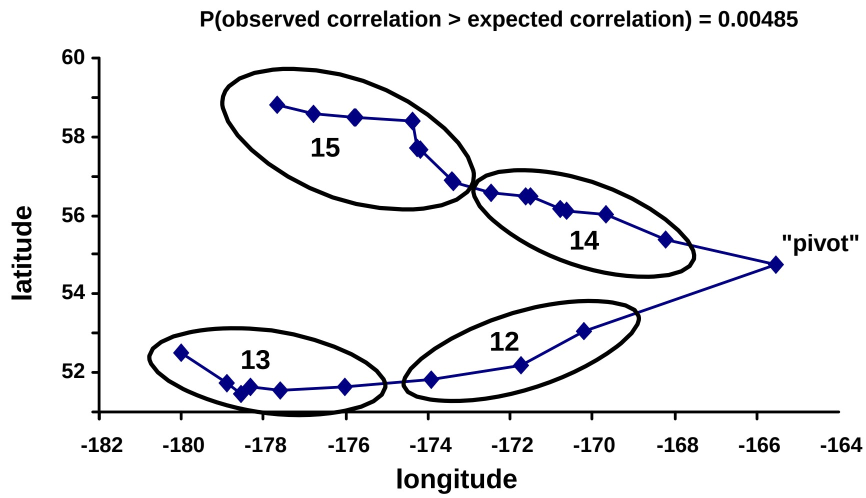
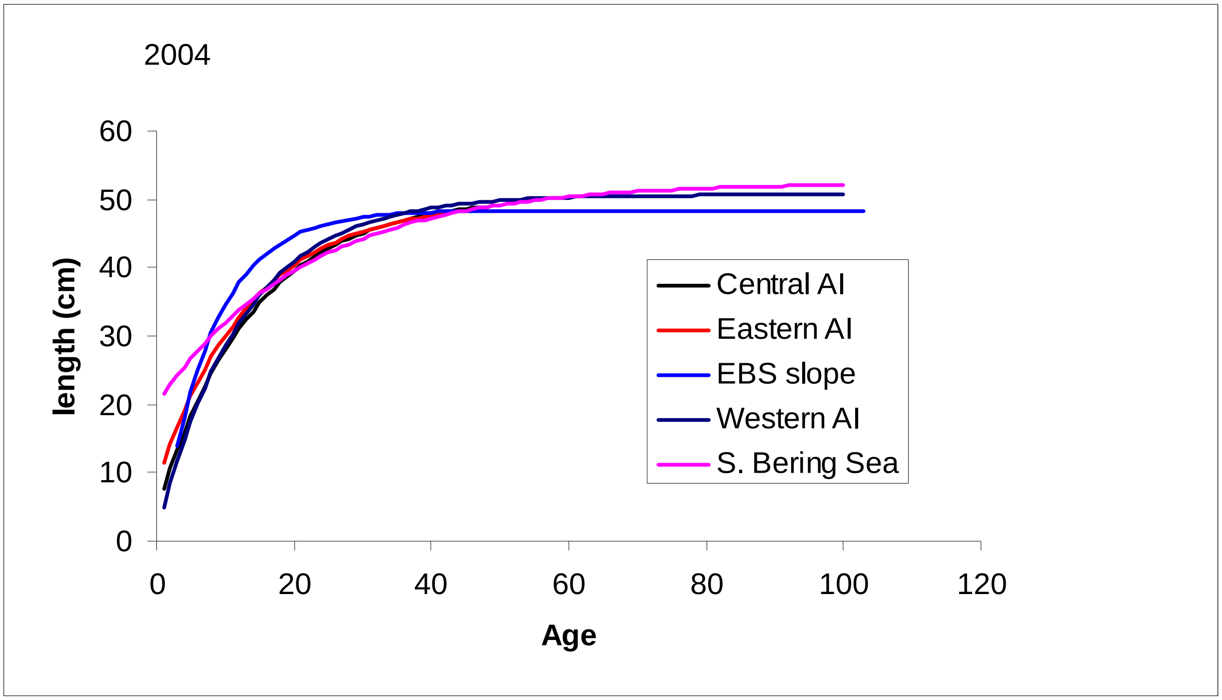


Figure 2. Location of AI (areas 13 and 12) and EBS samples (areas 15 and 14) along a line extending from AI to Unimak Pass and along the EBS shelf, with the *P*-value for an isolation by distance test. (Figure from Dr. A.J. Gharrett, UAF, pers. comm.).



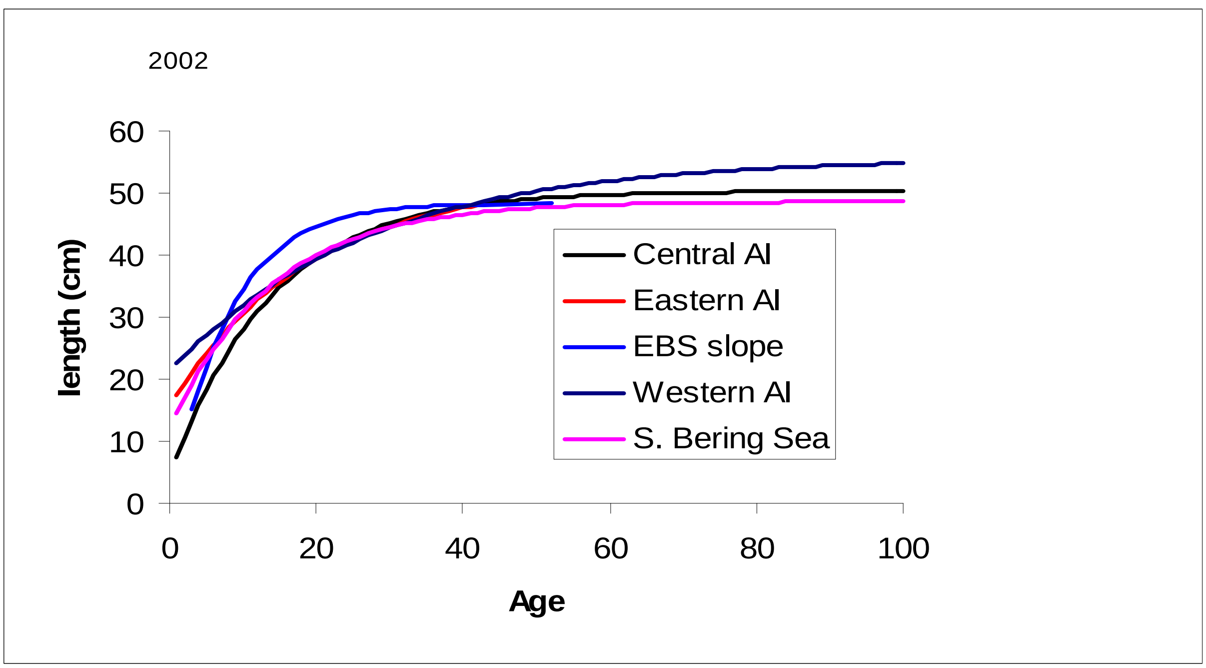


Figure 3. Rougheye rockfish growth curves from the BSAI subareas in 2002 and 2004.

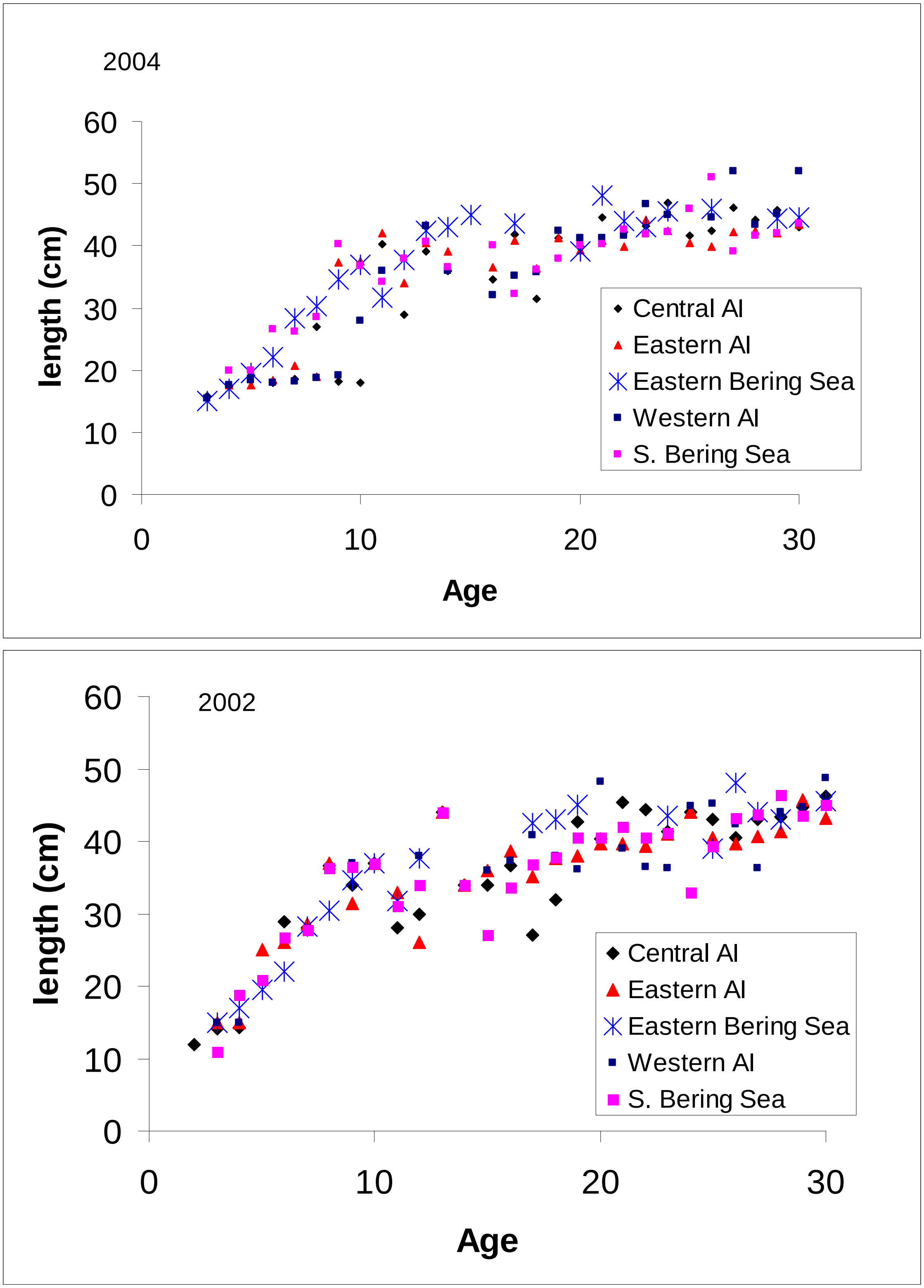
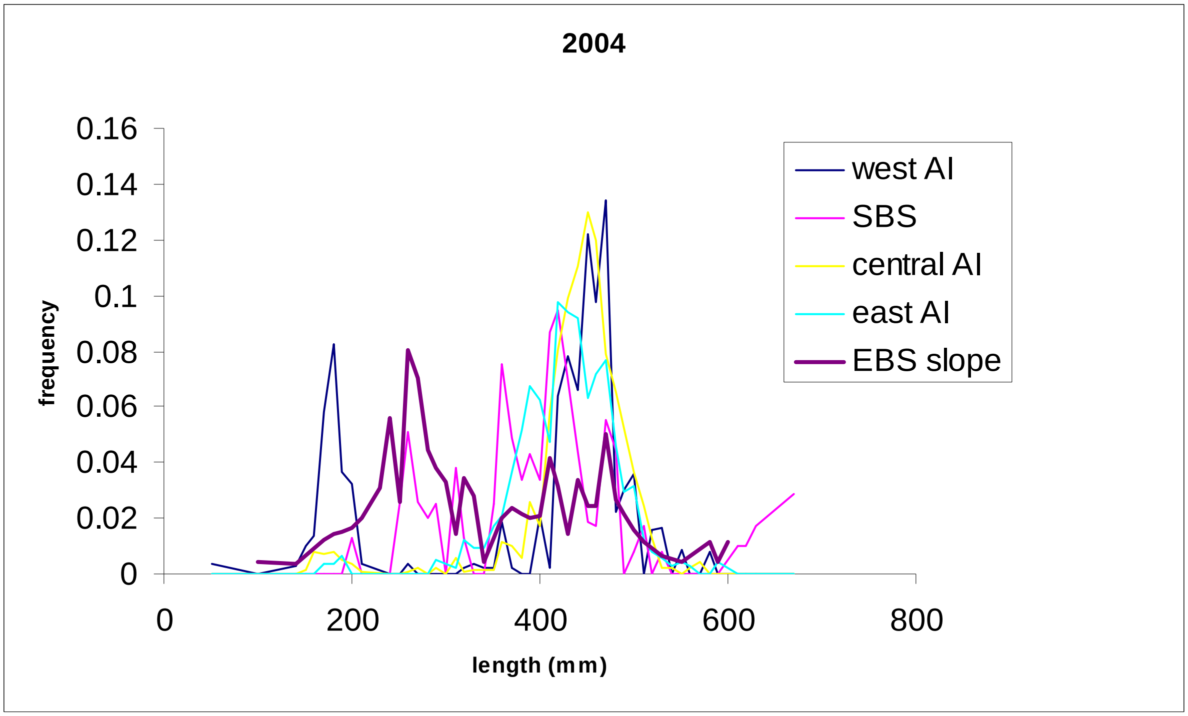


Figure 4. Rougheye rockfish mean length at age from the BSAI subareas in 2002 and 2004.



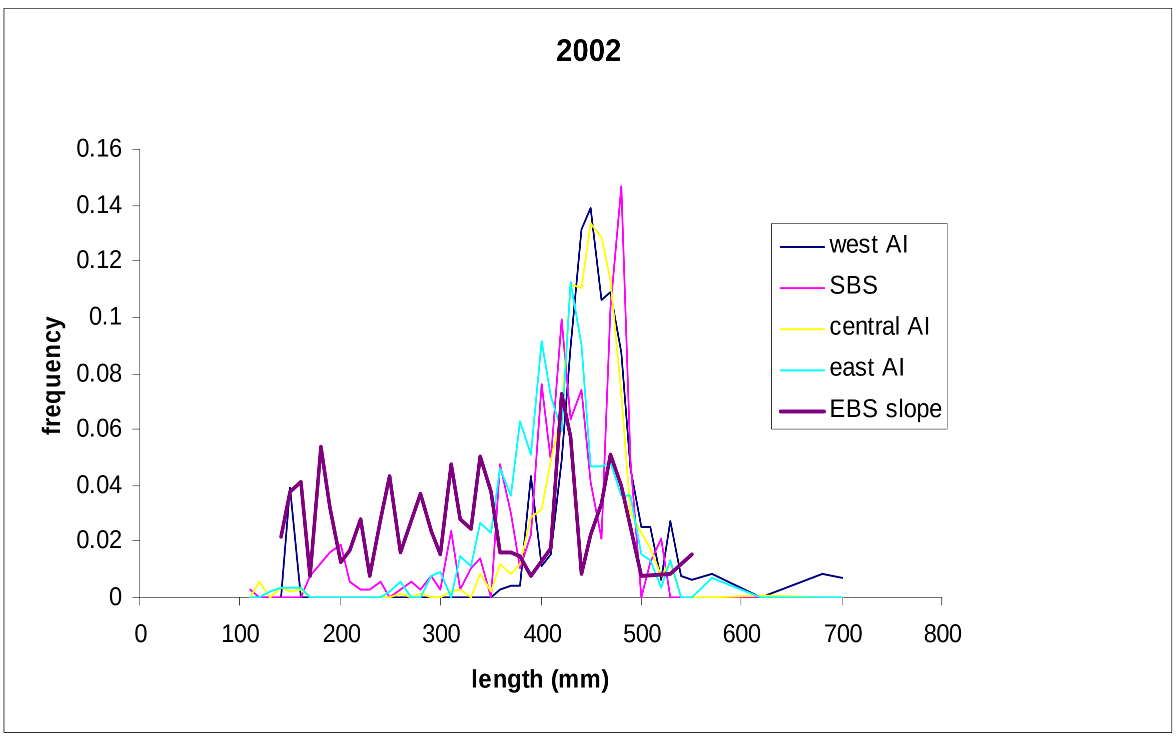
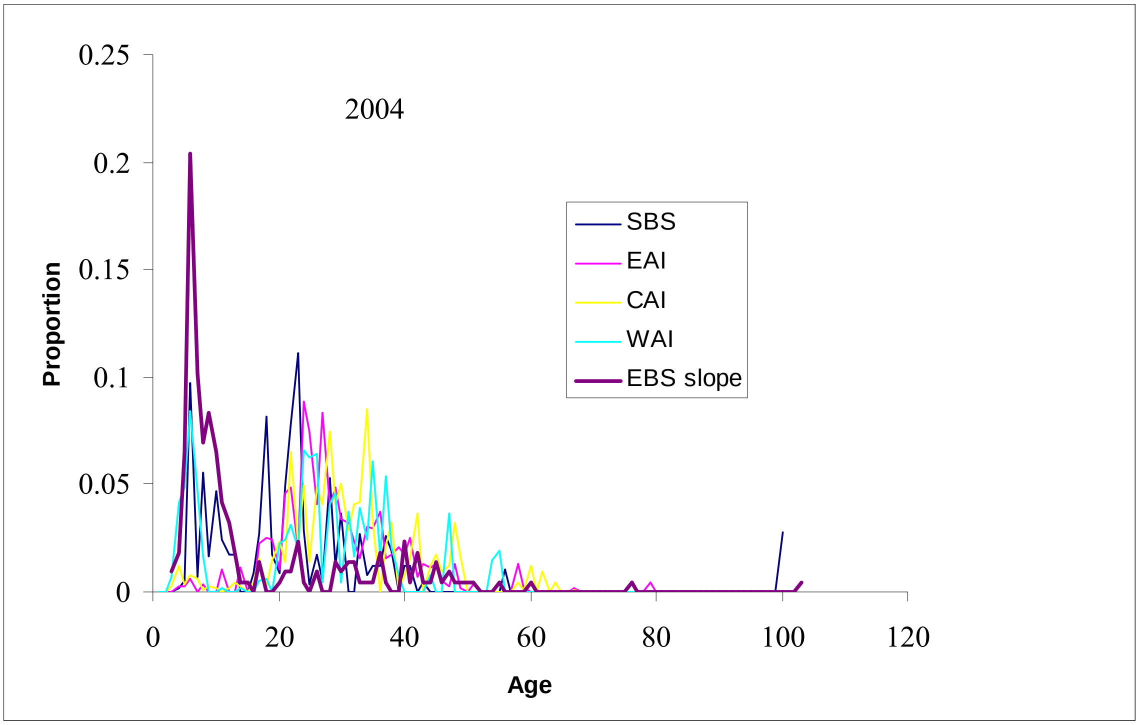


Figure 5. Length composition of rougheye rockfish from the EBS slope survey and four areas of the AI survey in 2004 (top) and 2002 (bottom).



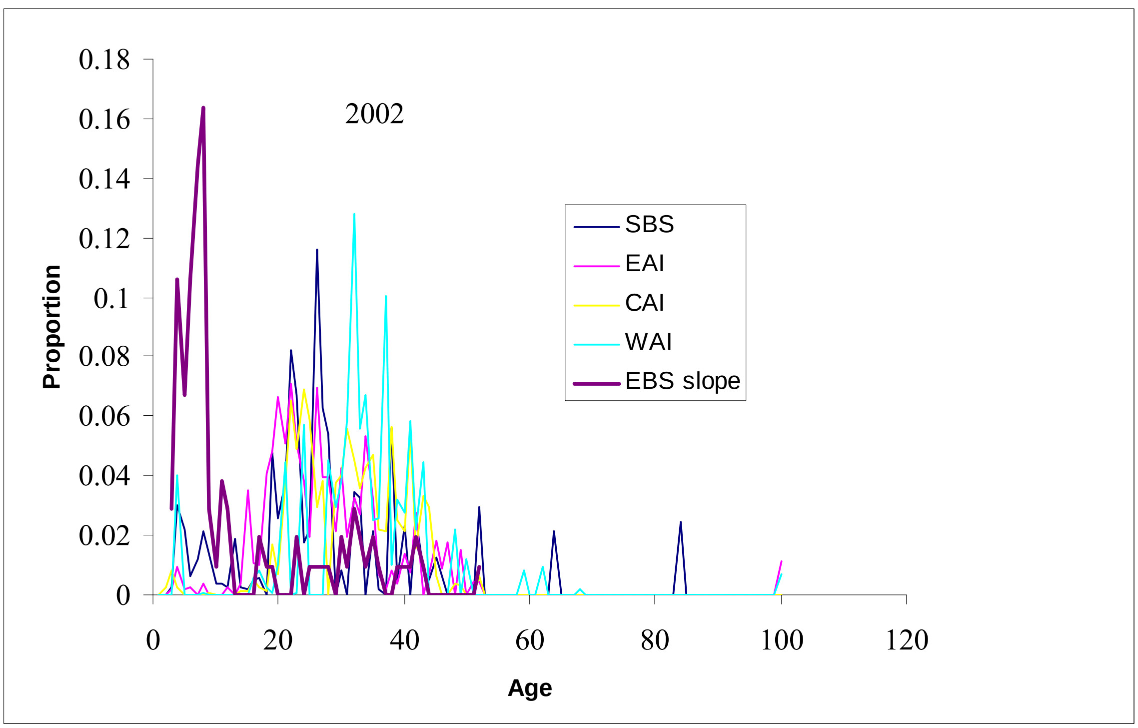


Figure 6. Age composition of rougheye rockfish from the EBS slope survey and four areas of the AI survey in 2004 (top) and 2002 (bottom).

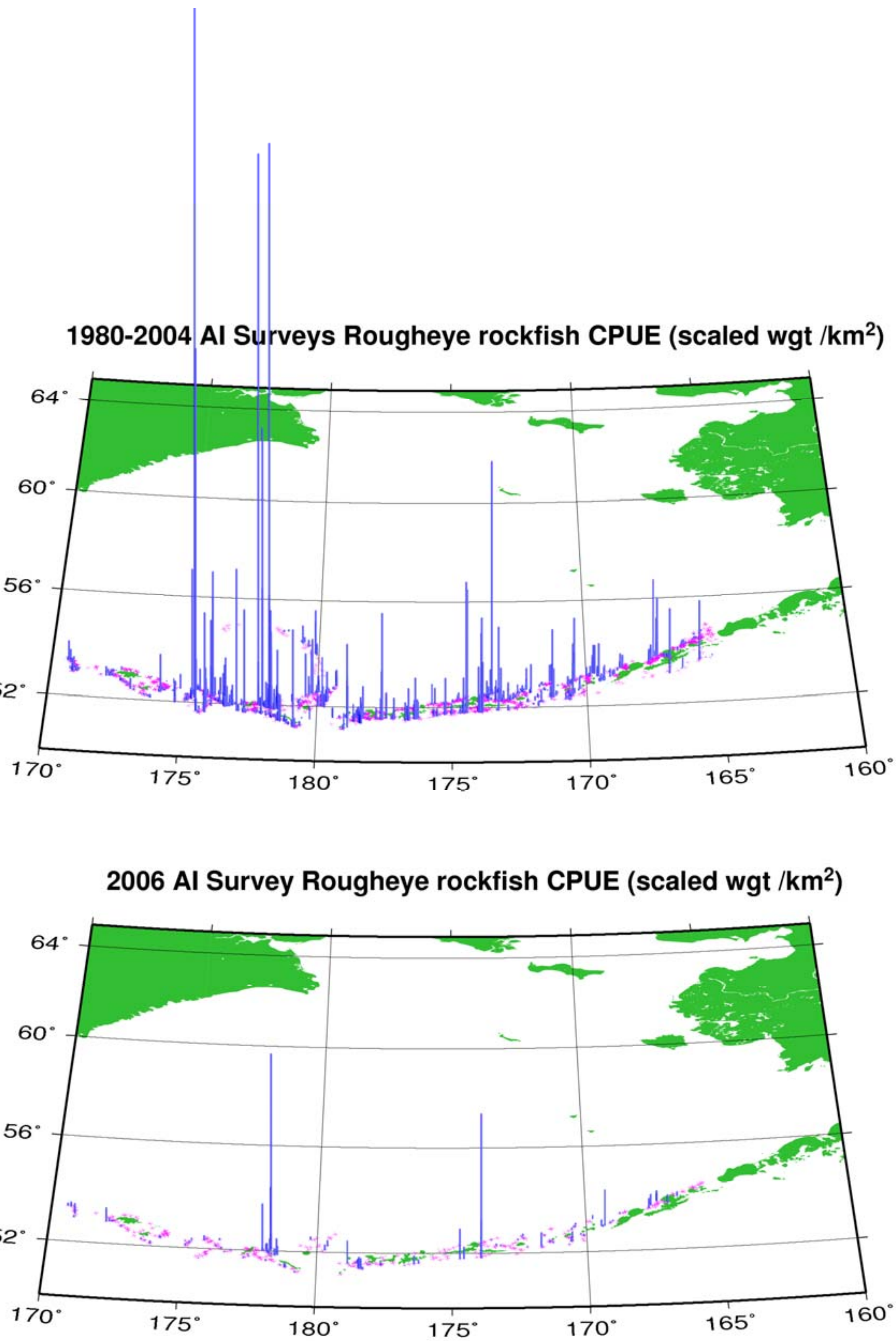


Figure 7. Scaled AI survey blackspotted and rougheye rockfish CPUE from 1980-2004 (top panel) and 2006 (bottom panel).

Figure 8. Estimated total biomass from the AI and BSAI models for blackspotted/rougheye rockfish.

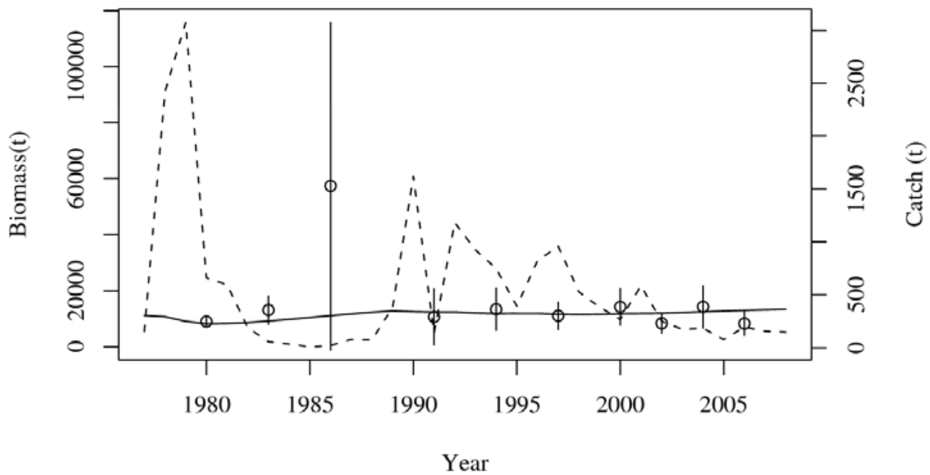


Figure 9. Observed AI survey biomass(data points, +/– 2 standard deviations), predicted survey biomass(solid line), and AI harvest (dashed line).

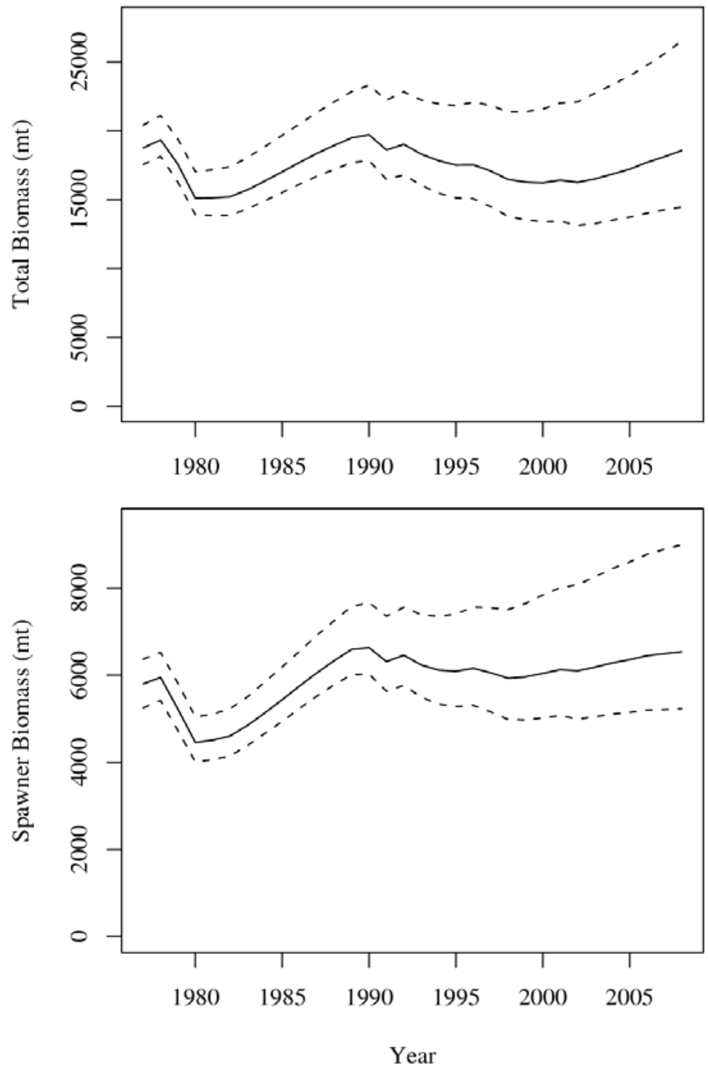


Figure 10. Total and spawner biomass for AI rougheye rockfish

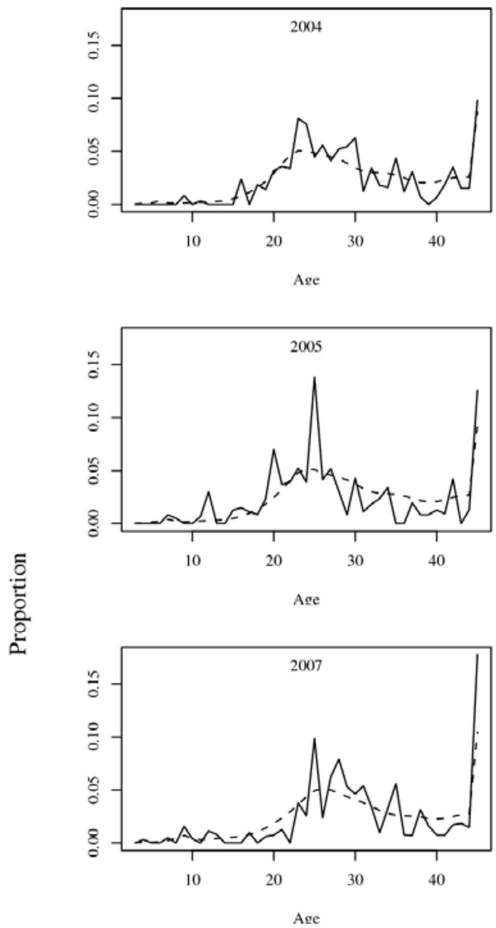


Figure 11. Fishery age composition by year (solid line = observed, dotted line = predicted)

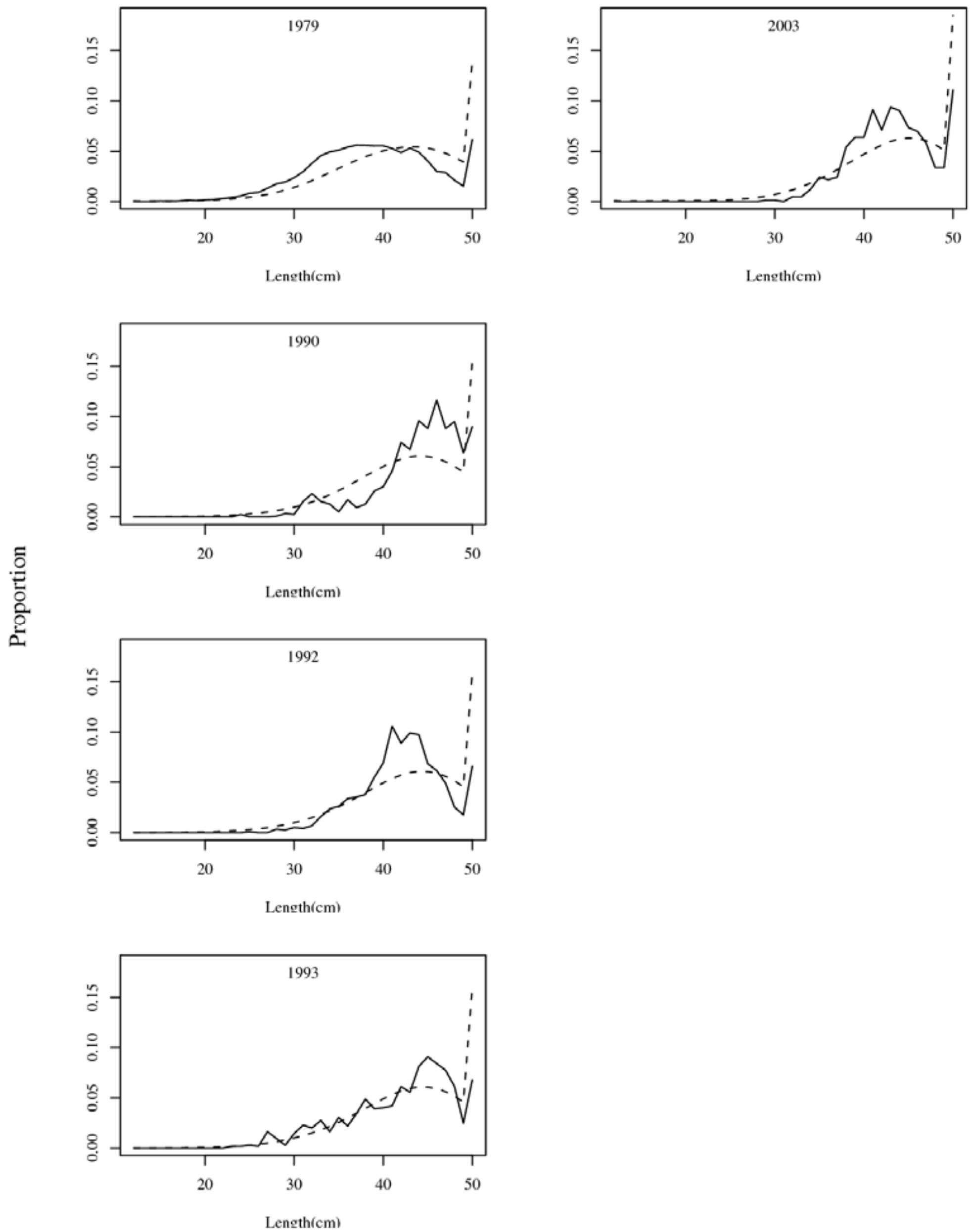


Figure 12. Fishery length composition by year (solid line = observed, dotted line = predicted)

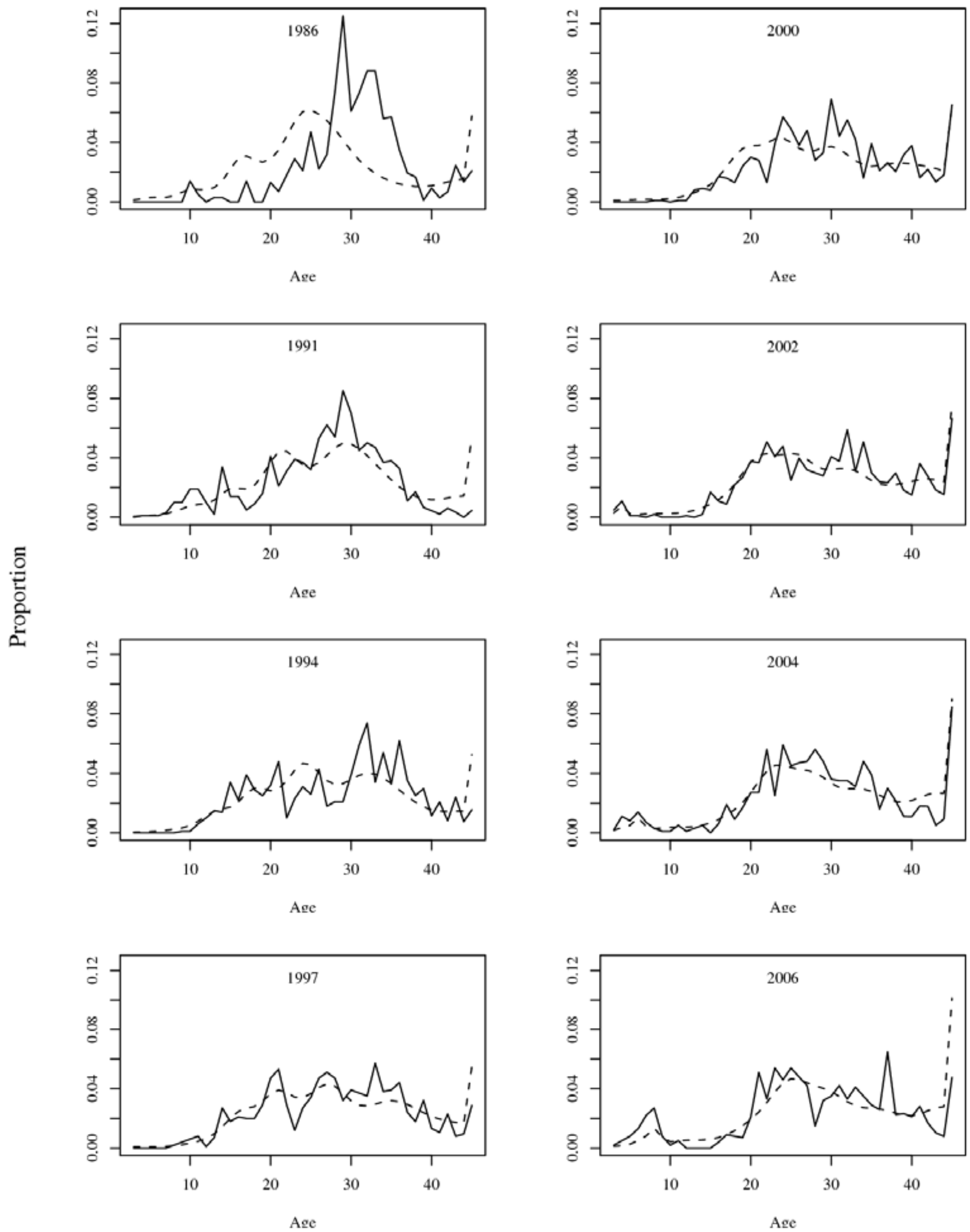


Figure 13. AI Survey age composition by year (solid line = observed, dotted line = predicted)

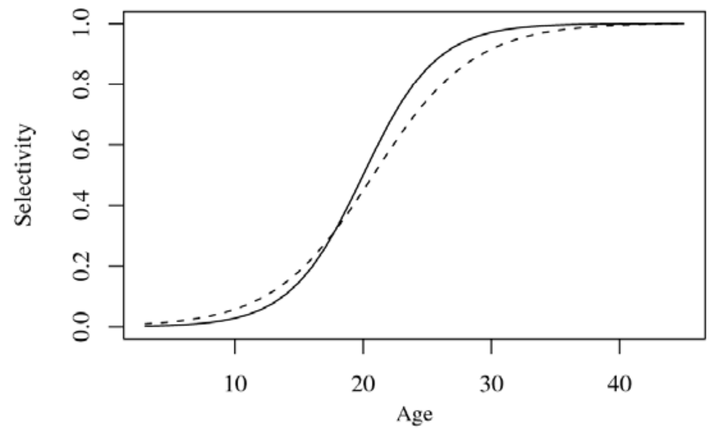


Figure 14. Estimated fishery (solid line) and survey (dashed line) selectivity curve by age.

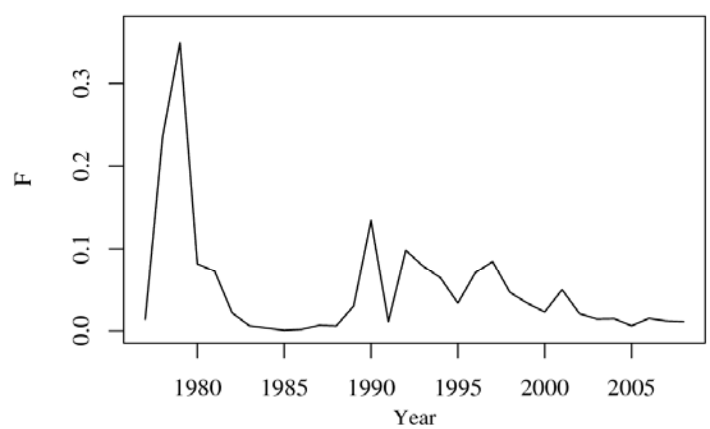


Figure 15. Estimated fully selected fishing mortality for AI rougheye rockfish.

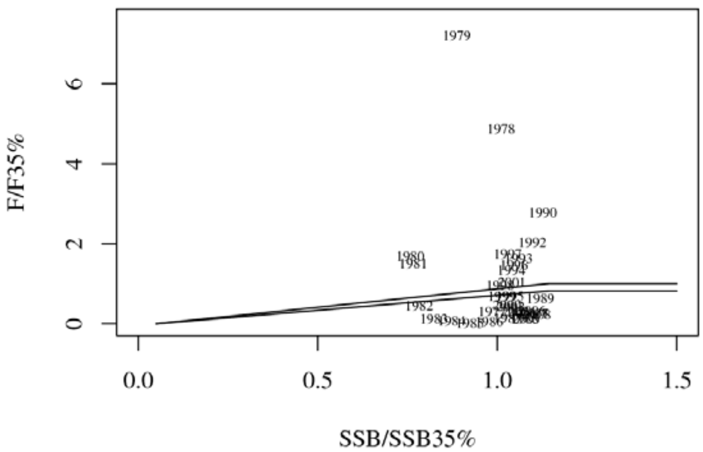


Figure 16. Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvest control rules

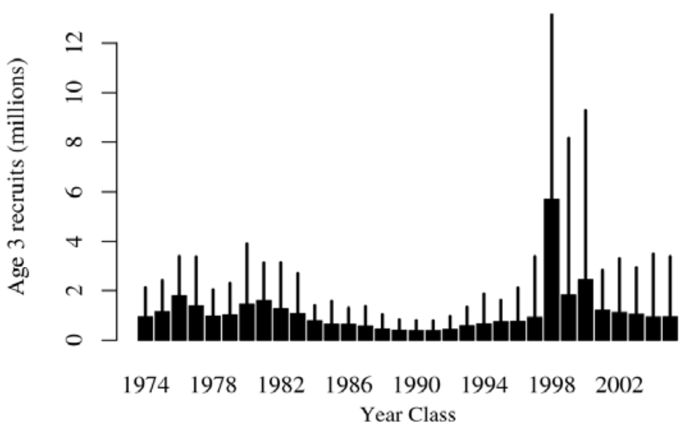


Figure 17. Estimated recruitment (age 3) of AI rougheye rockfish

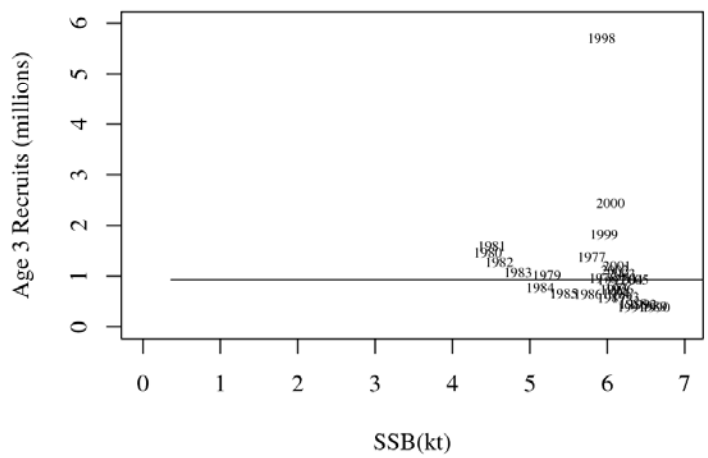


Figure 18. Scatterplot of AI rougheye rockfish spawner−recruit data; label is year class.

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