CHAPTER 13

SHORTRAKER AND ROUGHEYE ROCKFISH

by

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The last full assessment for rougheye and shortraker rockfish was presented to the Plan Team in 2004, and an updated assessment using 2005 catch data was presented in 2005. The following changes were made to rougheye and shortraker rockfish assessment relative to the November 2004 SAFE:

1) The landings data have been revised and updated through August 5, 2006.
2) The biomass estimates of the 2006 Aleutian Islands survey are included in the assessment.
3) Information on differences on length compositions, age compositions, and size at age between eastern Bering Sea and Aleutian Islands is presented, based upon recent survey in the two areas.

A summary of the 2007 recommended ABCs and OFLs relative to the 2006 recommendations is as follows:

	Eastern Bering Sea/Aleutian Islands			
	ABC		OFL	
	2006	2007	2006	2007
Rougheye	224 t	202 t	299 t	269 t
Shortraker	580 t	424 t	774 t	564 t

Responses to the Comments of the Statistical and Scientific Committee (SS5C)

"The SSC concurs with Plan Team's request that authors provide additional information on the distribution of fishery catches during the next stock assessment cycle in 2006."

Information on the distribution of the fishery catches was presented at the September, 2006 Plan Team meeting and is contained within this assessment.

<u>Preliminary Responses to the Comments of the Center of Independent Experts (CIE)</u>

A CIE review of rockfish stock assessments was conducted in June 2006. The CIE panel commented on several aspects of Alaska rockfish assessments, including estimation of numbers at age in the first year of the model, evaluating the utility of using fishery CPUE data, the estimation of survey catchability if rockfish densities differ between trawlable and untrawlable grounds, and estimation of natural mortality from age data. The question of trawl survey catchability may require the most effort to address, and will likely require field research. It is expected that future research will address the proportions of the survey area that consists of trawlable and untrawlable grounds, and the potential differences in densities between these habitat types, in order to gain more precise information on survey *q*. Further discussion on rockfish research, and responses to the CIE review, will occur at the February 2007 SSC meeting.

INTRODUCTION

Pacific ocean perch (POP), and four other associated species of rockfish (northern rockfish, *S. polyspinis*; rougheye rockfish, *S. aleutianus*; shortraker rockfish, *S. borealis*; and sharpchin rockfish, *S. zacentrus*) were managed as a complex in the eastern Bering Sea (EBS) and Aleutian Island (AI) management areas from 1979 to 1990. Known as the POP complex, these five species were managed as a single entity with a single TAC (total allowable catch) within each management area. In 1991, the North Pacific Fishery Management Council enacted new regulations that changed the species composition of the POP complex. For the eastern Bering Sea slope region, the POP complex was divided into two subgroups: 1) Pacific ocean perch, and 2) shortraker, rougheye, sharpchin, and northern rockfishes combined, also known as "other red rockfish" (ORR). For the Aleutian Islands region, the POP complex was divided into three subgroups: 1) Pacific ocean perch, 2) shortraker/rougheye rockfishes, and 3) sharpchin/northern rockfishes. 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. These subgroups were established to protect Pacific ocean perch, shortraker rockfish, and rougheye rockfish (the three most valuable commercial species in the assemblage) from possible overfishing. In 2002, sharpchin rockfish were assigned to the "other rockfish" category, leaving only northern rockfish and the shortraker/rougheye complex as members of other red rockfish. In 2004, rougheye and shortraker rockfishes were managed by species in the BSAI area.

Information on Stock Structure

A variety of types of research can be used to infer stock structure of rougheye and shortraker rockfishes, including larval distribution patterns, other life-history information, and genetic studies. In 2002, an analysis of archived *Sebastes* larvae was undertaken by Dr. Art Kendall; using data collected in 1990 off southeast Alaska (650 larvae) and the AFSC ichthyoplankton database (16,895 *Sebastes* larvae, collected on 58 cruises from 1972 to 1999, primarily in the Gulf of Alaska). The southeast Alaska larvae all showed the same morph, and were too small to have characteristics that would allow species identification. A preliminary examination of the AFSC ichthyoplankton database indicates that most larvae were collected in the spring, the larvae were widespread in the areas sampled, and most were small (5-7 mm). The larvae were organized into three size classes for analysis: <7.9 mm, 8.0-13.9 mm, and >14.0 mm. A subset of the abundant small larvae was examined, as were all larvae in the medium and large groups. Species identification based on morphological characteristics is difficult because of overlapping characteristics among species, as few rockfishes species in the north Pacific have published descriptions of the complete larval developmental series. However, all of the larvae examined could be assigned to four morphs identified by Kendall (1991), where each morph is associated with one or more species. Most of the small larvae examined belong to a single morph, which contains the species *S. alutus* (POP), *S. polyspinus* (northern rockfish), and *S. ciliatus* (dusky rockfish). Some larvae (18) belonged to a second morph which has been identified as *S. borealis* (shortraker rockfish) in the Bering Sea. The locations of these larvae were near Kodiak Island, the Semidi Islands, Chirkof Island, the Shumagin Islands, and near the eastern end of the Aleutian Islands. Another morph, represented by 58 samples in the Gulf of Alaska, could possibly represent rougheye rockfish, whose larvae have not been previously described.

For rougheye rockfish, recent studies determined large genetic differences in stock structure that indicate two distinct species (Gharrett 2003, Gharett et al. 2005). 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.

The existence of two species of rougheye rockfish motivates examination of stock structure within each species. Analysis of microsatellite molecular variation indicates that although low F_{ST} values were found for both type I and type II rockfish, indicating little divergence, both species showed statistically significant population structure based upon log-likelihood ratio analyses (Gharrett et al. 2004). In particular, for type I rougheye, the species found in the Aleutian Islands, four partitioning schemes were examined in which the samples were assigned to non-overlapping populations. Each of these four schemes indicates that significant divergence occurred between specimens from the central Aleutian Islands, the eastern Bering Sea and eastern Aleutian Islands. A similar partitioning for type II fish revealed six non-overlapping groups of populations. Overall, stronger divergence was observed for type II fish, suggesting that population structure for this species occurs at a finer scale than current management areas.

For shortraker rockfish, population structure has also been observed in microsatellite data (Matala et al. 2004), with the geographic scale consistent with current management regions (i.e., GOA, AI, and EBS). The most efficient partitioning of the genetic variation into non-overlapping sets of populations identified three groups: a southeast Alaska group, a group extending from southeast Alaska to Kodiak Island, and a group extending from Kodiak Island to the central Aleutians (the western limit of the samples). The available data are consistent with a neighborhood genetic model, suggesting that the expected dispersal of a particular specimen is much smaller than the species range. A parallel study with mtDNA revealed weaker stock structure than that observed with the microsatellite data. It is not known how shortrakers in the eastern Bering Sea or western Aleutians relate to the large population groups identified by Matala et al. (2004) due to a lack of samples in these areas.

The observed genetic data may be explained by multiple factors. If larval dispersal and adult movements are limited then the geographic genetic structure may correspond to population productivity units. If larval dispersal and adult movement are more extensive, then at least two explanations are consistent with geographic genetic structure. First, adults may return to natal areas to spawn after being dispersed as larvae, as has been proposed for shortraker rougheye by Orlov (2001). Second, if successful reproduction in a given year derives predominately from relatively few spawners of a specific cohort, then the observed structure may reflect genetic differences between members of separate cohorts rather than geographic separation. Our current knowledge is not sufficient to fully evaluate these hypotheses, although ongoing research on rockfish genetics is being conducted by Dr. Anthony Gharrett and colleagues at the University of Alaska.

CATCH HISTORY

Catches of shortraker and rougheye rockfishes have been reported in a variety of species groups in the foreign and domestic Alaskan fisheries. Foreign catch records did not identify rougheye and shortraker rockfishes by species; instead, rougheye and shortraker rockfishes were reported in management categories such as "other species" (1977, 1978), "POP complex" (1979-1985, 1989), and "rockfish without POP" (1986-1988). As mentioned above, the rougheye and shortraker rockfishes have been managed in the domestic fishery as part of the “other red rockfish” or “shortraker/rougheye” complexes. Reported catches by management complex, and estimated catches by species, from 1992-2006 are shown in Table 13.1. Since 2003, the catch accounting system (CAS) bas reported catch of rougheye and shortraker 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 and shortraker since 1977 are shown, by species, in Tables 13.2 and 13.3. 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.

Estimates of discarding by species complex are shown in Table 13.4. Estimates of discarding of the other red rockfish complex in the EBS was generally above 56% from 1993 to 2002, which the exception of 1993 and 1995 when discarding rates were less than 26%. The variation in discard rates may reflect different species composition of the other red rockfish catch. Discarding rates of EBS RE/SR complex from 2001 to 2003 have been below 52%, and discarding rates of AI SR/RE complex from 1993-2003 have been below 41%. In general, the discard rate of EBS RE/SR are reduced from 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 other red rockfish complex.

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 2004-2005, these three fisheries accounted for 95% of the AI rougheye catch. In contrast, shortraker rockfish in the AI have been primarily take in the rockfish trawl, “other species” trawl, sablefish longline, and halibut longline fisheries; from 2004-2005, these three fisheries accounted for 85% of the catch (Table 13.5). Catches of AI rougheyes in 2004-2005 were primarily taken in the western and central Aleutians, with 61% and 30% in areas 543 and 542, respectively (Table 13.5). In contrast, the central Aleutians contributed 50% of the 2004-2005 AI shortraker catch, followed by the western Aleutians (33%).

Catches of rougheye rockfish from 2004-2005 in the EBS management area were caught largely in the “other species” trawl, Pacific cod longline, turbot longline, arrowtooth trawl, and “other flatfish” trawl fisheries, which contributed approximately 76% of the catch. Catches of shortraker rockfish from 2004-2005 in the EBS management area were caught largely in midwater pollock , Pacific cod longline, and turbot longline fisheries, which contributed 95% of the catch. Catches of both rougheye and shortraker in the EBS management area were concentrated in areas 517 and 521, the areas occupying much of the EBS slope (Table 13.6).

DATA

Fishery Catch

The catch data used in the assessment model are the estimates of single species catch described above and shown in Tables 13.2 and 13.3. However, given the recent genetic data 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 2002-2006 (through August 5) catch by species and area with what might have been used as an area-specific ABC level is shown in Table 13.7, 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 the EBS and AI but rougheye/shortraker were managed as a two-species complex in each area with a single BSAI OFL. In contrast, since 2004, rougheye and shortraker have been managed as separate species but 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 analysis 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 2002-2006. 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 AI shortraker have been far below their potential AI ABC levels. Catches of EBS rougheye have been below their potential EBS ABC level, with the exception of 2004 when the catch of 24 t is marginally above the potential EBS ABC level of 21 t. In contrast, the catch of EBS shortraker has exceeded the potential EBS ABC level from 2002 to 2005.

Information on the 2003-2006 weekly catch by species, from the CAS database, reveals that rougheye and shortraker catches do not occur uniformly in time, but occasionally large portions of the catch are taken in short time periods. For example, nearly all of the catch of AI rougheye occurs between weeks 23 and 32 of the year. In contrast, this period contributes a large share of the AI shortraker catch but some catch is also taken during other periods of the year (Figure 13.1). For EBS rougheye, the catch from weeks 23-32 contributed from 45% (2006) to 80% (2004) of the catch. In particular, 9 t of the 24 t catch of EBS rougheye in 2004 occurred in a single week, with most of this catch coming from the “other species” fishery (Figure 13.2). For EBS shortraker, the catch from weeks 5-12 contributed from 44% (2003 and 2004) to 63% of the catch, with most of the catch during this period occurring in the midwater pollock fishery. In 2005, 50 t of the total EBS shortraker catch of 108 t occurred in week 10.

Survey data

Biomass estimates for other red rockfish were produced from cooperative U.S.-Japan trawl surveys from 1979-1985 on the eastern Bering Sea slope, and from 1980-1986 in the Aleutian Islands. U.S domestic trawl surveys were conducted in 1988, 1991, 2002, and 2004 on the eastern Bering Sea slope, and in 1991, 1994, 1997, 2000, 2002, 2004, and 2006 in the Aleutian Islands (Table 13.8). The 2002 eastern Bering Sea slope survey represents the initiation of a new survey time series distinct from the previous surveys in 1988 and 1991.

Consistent with the data used for the age-structured POP assessment, the AI survey biomass estimates are used as a suitable index of the BSAI rougheye and shortraker rockfish, as the bulk of these populations are believed to be centered in the Aleutian Islands. Shortraker and rougheye assessments prior to 2003 have not used the cooperative U.S. – Japan AI trawl survey estimates, as these surveys were conducted with different vessels, survey gear, and sampling design relative to the U.S. domestic trawls surveys that began in 1991 (Skip Zenger, National Marine Fisheries Service, Seattle, WA, personal communication). Additionally, these assessments relied upon an average of survey biomass estimates to obtain the current estimate of stock size, and the more recent surveys were viewed most appropriate for this task. In this assessment, the early survey in the 1980s were used in the assessment model in order to provide some information on stock size during this portion of the time series, although it should be recognized that these data may not be strictly comparable with the most recent surveys.

The 2002 EBS slope survey represents the initiation of a new biennial survey, as the most recent slope survey prior to 2002 (excluding some preliminary tows in 2000 intended for evaluating survey gear) was in 1991. A 2006 EBS slope survey was scheduled but canceled due to lack of funding. The estimates of shortraker and rougheye rockfishes in the 2002 and 2004 EBS slope surveys were small relative to the AI survey estimates, with one exception being the estimate of EBS slope shortraker rockfish in 2002 of 4,851 t which had an unusually high coefficient of variation (44%). For these reasons, the EBS slope survey results are not used in this assessment, and the feasibility of incorporating this time series will be evaluated in future years. Thus, the assessment procedure is conservative because the EBS biomass estimates of shortraker and rougheye rockfishes are not used is determining the recommended total harvest levels.

The 2006 AI survey biomass estimates for rougheye and shortraker rockfish were 9,505 t and 12,961 t, respectively, which represent declines of 36% and 61% from the 2004 estimates of 15,039 and 33,257 t.

Age and length compositions, and size at age

The survey data also provides information on differences between the EBS and AI with regard to age composition, length composition, and size at age, and this information may be helpful in assessing whether shortraker and rougheye rockfish might be considered separate stocks in these two areas.

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 13.3. 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. The p-values for pairwise comparisons for rougheye mean length are shown in Table 13.9. In 2002, rougheye mean length in the EBS slope was significantly different from mean length in the central, eastern, and western AI, but not the southern Bering Sea area. In 2004, rougheye mean length in the EBS was significantly different from mean length in the central and eastern AI, but not the SBS and western AI. Note, however, that the length distribution in the western AI in 2004 is bimodal; thus, the distributions may be significantly different between the EBS and western AI even though the mean lengths are not significantly different.

The length compositions of shortraker rockfish are shown in Figure 13.4. In 2004, it appears there is somewhat higher proportion of smaller fish in the EBS slope, although the pattern is not as striking as it appeared for rougheye. In 2002, there looks to be little difference in the length composition. The statistical analysis reveals that none of the eight comparisons between the SBS and four Aleutian areas in the two years were statistically significant at the 0.05 level, although one comparison was significant at the 0.10 level (Table 13.10).

Age data is not available for shortraker rockfish, but rougheye rockfish the 2004 EBS slope survey and the 2004 AI survey have been aged. The estimated age compositions of the rougheye rockfish from the 2004 EBS slope survey and three areas of the 2004 AI survey are shown in Figure 13.5. 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 35. Analogous to the nested ANOVA for comparing mean length, a nested ANOVA for testing differences in mean age between areas could be applied for this data set. However, this would require an estimate of age composition within each haul, and this remains a task for future research.

The rougheye age samples can also be used to assess differences in size at age between the areas. For the EBS slope survey, otoliths were collected randomly from each rougheye encountered (n=216) and the mean length at age and standard deviation of mean length at age were computed. For the AI survey, length-stratified collection of otoliths occurred in each sampling region, and mean lengths and standard deviation of mean length within each sampling were obtained by multiplying the estimated size composition of the population by the age-length key (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, and the negative log-likelihood was minimized. The resulting von-Bertalanffy growth parameters are as follows:

Area	Sample size	L_{inf}	k	t_{zero}
EBS slope	216	48.19	0.14	0.679
central AI	165	52.45	0.06	-2.22
eastern AI	132	49.70	0.08	-1.238

The rougheye on the EBS slope reaches a similar maximum size as the rougheyes in the central and eastern AI, but the rate at which this size is approached (the *k* parameter) is approximately twice that of either central AI or eastern AI rougheyes (Figure 13.6). To test whether the curves were significantly different, the Akaike Information Criterion (AIC) was used to compare a model with a single curve for all three areas versus a model with separate curves for each area. The area-specific model produced an AIC value of 802 whereas the single curve model produced an AIC value of 1073, indicating that the growth pattern is statistically significant between the EBS and the central and eastern Aleutians.

ANALYTICAL APPROACH

Model structure

A simple surplus production model, the Gompertz-Fox model, was used to model the rougheye/shortraker complex, and the Kalman filter provided a method of statistically estimating the parameter values. The Gompertz-Fox model (Fox 1970) describes the rate of change of stock size as

$$\frac{dx}{dt} = ax(\ln(k) - \ln(x)) - fx \qquad (1)$$

where x is stock size, k is carrying capacity, and f is fishing mortality. The model is mathematically equivalent to a model of individual growth developed by Gompertz, and describes a situation where stocks at low sizes would show a sigmoidal increase in stock size to an asymptote. The Gompertz-Fox model can be derived from the Pella-Tomlinson model (Pella and Tomlinson 1969) by taking the limit as n (the parameter controlling the location of the peak of the production curve) approaches 1. The peak of the production curve occurs at approximately 37% of the carrying capacity, in contrast to the logistic model where the peak occurs at 50% of the carrying capacity. The Gompertz-Fox model was chosen for this analysis because it is a simple model that offers some information on growth rate and carrying capacity, and it is easily transformed into a linear form suitable for the Kalman filter (Thompson 1996).

Under the Gompertz-Fox model, the rate of change of yield is modeled as $y = fx$, and the f level corresponding to the maximum sustainable yield (MSY) is equivalent to the growth parameter a. Equilibrium biomass is (b) is

$$b = ke^{-f/a} \qquad (2)$$

and the equilibrium stock size corresponding to MSY, B_{msy}, is k/e.

The Kalman filter

A brief review of the Kalman filter is provided here, as more thorough presentations are provided in Meinhold and Singpurwalla (1983), Harvey (1990), and Pella (1993). The Kalman filter separates the system into a model of the state variable, which describes the true (but unobserved) state of nature, and a model of the observation variables, which describes how the observed data relate to the state variable. The state variable is modeled as

$$X_t = T_t X_{t-1} + c_t + R_t \eta_t \qquad (3)$$

where X_t is a vector of m state variables at time t, T_t is a $m \times m$ matrix, c_t is a $m \times 1$ vector of constants, R_t is a $m \times g$ matrix and η_t is a $g \times 1$ vector of random process errors with a mean of zero and a covariance matrix of Q_t. The inclusion of the R_t vector is useful when a particular state variable is affected by more than one type of random disturbance. Note that when there is only a single state variable the problem simplifies considerably and all terms become scalars. For the shortraker/rougheye complex, the state variables at each time step are the log biomass of each species. Finally, the state variable is described by a distribution with an estimated mean α_t and variance P_t.

The observation equation is

$$Y_t = Z_t X_t + d_t + \varepsilon_t \qquad (4)$$

where Y_t is a $n \times 1$ vector of observed variables, Z_t is a $n \times m$ matrix, d_t is a $n \times 1$ vector and ϵ_t is a $n \times 1$ vector of random observation errors with mean zero and covariance matrix H_t.

A distinct advantage of the Kalman filter is that both the process errors and observation errors are incorporated into the parameter estimation procedure. The method by which this occurs can be understood by invoking the Bayesian concepts of "prior" and "posterior" estimates of the state variable (Meinhold and Singpurwalla 1983). Denote α_{t-1} as the posterior estimate of X_{t-1} using all the data up to and including time t-1. At time step t, a prior estimate of the state variable is made from the state equation (Eq. 3) and the posterior estimate from the previous step α_{t-1}. Because this prior estimate of X_t uses all the data up to time t-1, it is denoted as $\alpha_{t|t-1}$. The prior estimate can be used with Eq. 4 to predict the observation variables at time t. Upon observation of Y_t there are now two estimates of the observed variables; the observed data Y_t and the prediction from the prior estimate $\alpha_{t|t-1}$. The Kalman filter updates the prior and produces a posterior estimate, $\alpha_{t|t}$, that results in a value of Y_t between these two points, and the extent to which the posterior estimate differs from the prior estimate is a function of the magnitude of prediction error and the observation error variance relative to the process error variance. The posterior estimates are then used as prior estimates in the next time step to continue the recursive procedure.

Parameter estimation can be obtained by minimizing the log likelihood of the data, and the log likelihood (without constant terms) is

$$\ln L = -\frac{1}{2}\sum_{t=1}^{T}\ln|F_t| - \frac{1}{2}\sum_{t=1}^{T}\nu_t' F_t^{-1}\nu_t \qquad (5)$$

where F_t is $Z_t P_{t|t-1} Z_t' + H_t$, $P_{t|t-1}$ (the prior estimate of the variance of the state variable) is $T_t P_{t-1} T_t' + R_t Q_t R_t'$, and ν_t (the one step ahead prediction error) is $y_t - Z_t \alpha_{t|t-1} - d_t$.

Application of the Gompertz-Fox model to the Kalman filter can be obtained by defining the state variable as log biomass, and using catch and survey biomass as observation variables. The log transformation of Eq. 1 is

$$\frac{dX}{dt} = a(B - X) \tag{6}$$

where X = ln(x) and B = ln(b) = ln($ke^{-f/a}$). The solution to this differential equation is

$$X_t = e^{-at} X_0 + (1 - e^{-at}) B_t \tag{7}$$

where annual changes in f_t result in $B_t = \ln(ke^{-f_t/a})$. This solution can be also expressed in a recursive form as

$$X_{t+\Delta t} = e^{-a\Delta t} X_t + (1 - e^{-a\Delta t}) B_t \tag{8}$$

where Δt is a discrete time period. For a single species case, defining $T_t = e^{-a\Delta t}$ and $c_t = (1-T_t)B_t$ produces the deterministic portion of the state equation (Eq. 3). For the two-species shortraker/rougheye example, a version of Eq. 8 would exist for each species. In this case, T_t is a matrix of dimension 2 with the $e^{-a\Delta t}$ terms along the diagonal, and c_t is a vector of length 2 with each term corresponding to each species.

For rougheye and shortraker rockfishes, we typically have annual estimates of catch but triennial or biennial estimates of survey biomass, and this missing data complicates the observation equation. For years in which both data types are available,

$$Y_t = \begin{bmatrix} \ln(s\_re_t) \\ \ln(s\_sr_t) \\ \ln(c\_re_t) \\ \ln(c\_sr_t) \end{bmatrix}, \qquad Z_t = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}, \text{ and } d_t = \begin{bmatrix} \ln(q\_re) \\ \ln(q\_sr) \\ \ln(f\_re_t) \\ \ln(f\_sr_t) \end{bmatrix}$$

where s_re_t and s_sr_t are the survey biomass estimates of rougheye and shortraker in year t, c_re_t and c_sr_t are the aggregated catch of shortraker and rougheye during year t, q_re and q_sr are the survey catchability coefficients, and f_re_t and f_sr_t are the rates of removals from fishing. Note that this model formulation assumes the non-logged survey biomasses are proportional to the true biomass. Additionally, the aggregated catch during the year is used as an estimate of the rate of catch at the time of the survey, a reasonable approximation for BSAI rockfish because the survey occurs at the midpoint of the year. The observation equation simplifies when only catch data are available:

$$Y_t = \begin{bmatrix} \ln(c\_re_t) \\ \ln(c\_sr_t) \end{bmatrix}, \qquad Z_t = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \text{ and } d_t = \begin{bmatrix} \ln(f\_re_t) \\ \ln(f\_sr_t) \end{bmatrix}$$

Although the observed data reflect the system at the midpoint of a year, it is expected that the instantaneous fishing mortality rate would change between calendar years; thus, a time-step of one-half year was chosen for the discretized model. At the beginning of the calendar year neither data type is available, and updating the prior estimates with observed data is not possible. In these cases, the posterior estimate is set equal to the prior estimate for the next time step (Kimura et al. 1996).

An initial estimate of the mean and variance of the state variable (α_0 and P_0, respectively) is required to begin the recursive calculations, and can be obtained in several ways. These terms could also be estimated freely along with the other model parameters, or a diffuse prior may be placed upon them (Pella 1993). However, freely estimating these parameters increases the complexity of the estimation procedure and is not recommended (Pella 1993). For this analysis, a concentrated likelihood function was used to obtain maximum likelihood estimates of the initial state variables, which were then used in a standard Kalman filter (Rosenberg 1973).

Catch estimation error

As mentioned above, species-specific catches of shortraker and rougheye are often made from application of an observed proportion of the catch (from observer sampling) to the estimated aggregated catch for the species complex. For example, in years where shortraker and rougheye catches are reported as a two species complex, the species-specific catches would be obtained by

$$C_{RE} = p_{RE} * C_{RE/SR}$$
$$C_{SR} = p_{SR} * C_{RE/SR}$$

where p_{RE} and p_{SR} are the proportion of rougheye and shortraker observed in observer sampling and $C_{re/sr}$ is the aggregated catch. This estimation procedure produces quantities that can be viewed as the product of two random variables. While overall catch data are often viewed as relatively precisely observed as compared to other fisheries information, the proportions from observer sampling adds additional error. In addition, two species-specific estimates of catch are likely to be correlated because they are functions with some variables in common. For this assessment, it was assumed that the aggregated species complex catch were lognormally distributed, the species proportions from observer sampling followed a multinomial distribution, and these two random variables were independent. The variances and covariances of the log of estimated catches can be obtained from the Delta method (Seber 1982), with the variances equal to

$$V(\ln(C_{RE})) = \sigma^2 + \frac{p_{SR}}{Np_{RE}}$$
$$V(\ln(C_{SR})) = \sigma^2 + \frac{p_{RE}}{Np_{SR}}$$

and the covariance between the catches equal to

$$Cov(\ln(C_{RE}), \ln(C_{SR})) = (e^{\sigma^2} - 1) - \frac{1}{N}$$

where N is the assumed sample size for the multinomial distribution, σ is approximately the coefficient of variation of the aggregated complex catch, and the levels of p_{RE} and p_{SR} are taken at their expected values.

An additional complication arises when the species-specific catch estimation procedure is applied across several areas and/or fisheries, and the total catch for each species is a sum of several random variables. In this case, define S_{RE} and S_{SR} as

$$S_{RE} = \sum_i p_{RE,i} * C_{RE/SR,i}$$

$$S_{SR} = \sum_i p_{SR,i} * C_{RE/SR,i}$$

where i indexes the total number terms in the summation. The means and variances of each of the terms within this summation are additive, and application of the Delta method yields the covariances of the log catches:

$$\sum_i V(C_{SR/RE,i}) * \frac{p_{RE,i}\, p_{SR,i}}{S_{RE,i} S_{SR,i}} + Cov(p_{RE,i}\, p_{SR,i}) * \frac{(C_{SR/RE,i})^2}{S_{RE,i} S_{SR,i}}$$

Parameters Estimated Independently

The survey catchability coefficient for each species was fixed at 1.0. The parameters relating to the estimation error on catches were fixed such that $N = 100$ and $\sigma = 0.15$. Because of the longevity and perceived low population growth rates of shortraker and rougheye rockfishes, the process error CV was set to the relatively low value of 0.05.

Parameters Estimated Conditionally

The parameter estimated conditionally in the model include the a, k, and f_t parameters for each species. The estimation of a for each species proved problematic with this dataset, and lognormal priors were utilized to stabilize parameter values. The mean of the lognormal prior was equal to the assumed natural mortality rate M for rougheye rockfish (0.025), and a large CV of 1.0 was used for the variance. The natural mortality rate for rougheye rockfish was catch curve analysis (Heifetz and Clausen 1991). The rationale for expecting a to approximate M is because the a parameter in the Gompertz-Fox model is equivalent to F_{msy}, and M is often used as an approximation of F_{msy} (Gulland 1970).

RESULTS

Biomass trends

For rougheye rockfish, the differences between the high cooperative survey biomass estimates in the 1980s and the lower U.S. survey biomass estimates since 1991 resulted in a decline of predicted stock biomass (Figure 13.7a). The differences in methodology between these two portions of the time series should be considered in interpreting this predicted decline, although the cooperative survey estimates are the only data available from the 1980s. The biomass estimates for the beginning of the year decline from 26,079 t in 1980 to 10,782 t for 2007. Shortraker rockfish have shown an increasing trend from 21,707 t in 1980 to 26,503 t in 1998, and have since declined to 18,857 t in 2007 (Figure 13.7b). The time series of rougheye biomass is slightly smaller than that obtained in the 2004 assessment, whereas the time series of shortraker biomass is more substantially smaller, reflecting the relative reductions of the 2006 survey biomass estimates (Table 13.11).

Fishing mortality

The time series of estimated fishing mortality are shown in Figure 13.8, and show higher fishing mortality rates for rougheye rockfish than shortraker rockfish. Relatively high fishing mortality rates for rougheye rockfish occurred in the 1990s, but have been reduced since 2000 (except for 2001). The catches of rougheye rockfish in the 1990s must be viewed in the context of the existing management a two-species complex with OFL based upon uncertain observed survey biomass estimates. The time series of fishing mortality rates are shown in Table 13.12.

Annual Surplus Production

Considerable uncertainty in the parameter estimates of a in the Gompertz-Fox model exists for the rougheye and shortraker stocks. The lack of data regarding this parameter can be seen in plots of annual surplus production (ASP), which is the change in biomass over a period plus the catch during that period, expressed on an annual basis. Plots of ASP as a function of mean biomass are shown in Figure 13.9, and indicate little information on the a parameter for either rougheye or shortraker rockfishes. The a parameter is related to the slope of the production curve at low stock sizes, and one could imagine alternate production curves with high levels of a providing suitable fits to ASP data. Given the longevity of rougheye and shortraker rockfishes, one would not expect observed surplus production to deviate far from zero, and this was the motivation for constraining a by information on the natural morality rate. The observation of some levels of surplus production substantially different from zero reflects large fluctuations in estimated survey biomass that are generally inconsistent with perceived rougheye and shortraker life-history characteristics.

Projections and harvest alternatives

Rougheye and shortraker rockfishes are currently managed under Tier 5 of Amendment 56 of the NPFMC BSAI Groundfish FMP, which requires a reliable estimate of stock biomass and natural mortality rate. Estimates of M for rougheye and shortraker rockfishes were obtained from Heifetz and Clausen (1991), and the F_{abc} is defined as 75% of M . The acceptable biological catch (ABC) is obtained by multiplying F_{abc} by the estimated biomass. This procedure results in the following BSAI ABCs and OFLs :

	2007 biomass	M	ABC	OFL
Rougheye rockfish	10,782	0.025	202 t	269 t
Shortraker rockfish	18,857	0.03	424 t	564 t

Area allocation, and future research activities

In recent assessments, we have recommended separate, area-specific ABCs of rougheye and shortraker for the EBS and AI regions. The current information on genetics, size at age, length composition, and age composition suggest that rougheye rockfish on the EBS may be not be the same stock as rougheye rockfish in the AI. For shortraker rockfish, genetic samples are not available along the EBS slope, age data do not currently exist, and the differences in length composition between the areas are generally not significant; thus, information on stock structure is less clear. However, the current harvest patterns indicate that rougheye rockfish are taken in each area in proportion to the estimated biomass level. Disproportionate harvest may occur in the EBS for shortraker, but if the EBS shortraker are not a separate stock from AI shortraker then this may not be a management problem.

We recommend that further consideration of area-specific management for rougheye rockfish be deferred until September, 2007, when an age-specific model for rougheye rockfish will be presented to the Plan Team. Ages now exist for the 1991, 2000, 2002, and 2004 AI surveys, and the 2005 BSAI fishery. An age-structured model using these new data may affect the estimated size of the population and subsequent management recommendations; thus, it seems useful to postpone consideration of area-specific ABCs until this new model is developed.

Summary

In summary, several quantities pertinent to the management of the shortraker and rougheye rockfish are listed below.

Quantity	Value
M (Rougheye)	0.025
M (Shortraker)	0.03
Tier	5
Year 2007 Total Biomass	
Rougheye	10,782 t
Shortraker	18,857 t
F_{OFL} (Rougheye)	0.025
F_{OFL} (Shortraker)	0.03
Maximum F_{ABC} (Rougheye)	0.0188
Maximum F_{ABC} (Shortraker)	0.0225
Recommended F_{ABC} (Rougheye)	0.0188
Recommended F_{ABC} (Shortraker)	0.0225
OFL (Rougheye)	269 t
OFL (Shortraker)	564 t
Maximum allowable ABC (Rougheye)	202 t
Maximum allowable ABC (Shortraker)	424 t
Recommended ABC (Rougheye)	202 t
Recommended ABC (Shortraker)	424 t

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Table 13.1. Estimated removals (t) from 1992-2006 of other red rockfish (the sum of northern rockfish, sharpchin rockfish, shortraker rockfish, and rougheye rockfish) and the shortraker/rougheye (SRRE) complex from the eastern Bering Sea and Aleutian Islands regions, with estimates of species-specific catches. Catches are obtained from NMFS Regional Office blend and catch accounting system data, and are grouped by the management categories used in each year.

		Eastern Bering Sea			Aleutian Islands			BSAI	
Year	ORR	SRRE	Est RE	Est SR	SRRE	Est RE	Est SR	RE	SR
1992	934		139	155	2942	2356	586		
1993	1226		137	230	1139	881	258		
1994	129		22	46	925	751	174		
1995	343		28	49	559	376	182		
1996	207		34	87	959	850	109		
1997	217		15	37	1043	968	75		
1998	112		17	50	685	529	156		
1999	238		8	67	514	402	112		
2000	252		23	133	480	273	208		
2001		72	16	56	722	614	108		
2002		105	12	93	478	266	213		
2003		124	17	107	306	180	126		
2004								208	241
2005								90	169
2006								184	140

*Estimated removals through August 5, 2006

Table 13.2. Catches of rougheye rockfish (t) in the BSAI area, obtained from the North Pacific Groundfish Observer Program, NMFS Alaska Regional Office, and PACFIN.

	Eastern Bering Sea			Aleutian Islands			
Year	Foreign	Joint Venture	Domestic	Foreign	Joint Venture	Domestic	Total
1977	1			2			157
1978	66			99			2522
1979	637			477			3553
1980	94	0		160			820
1981	166	0		283			878
1982	124	0		124	0		312
1983	53	0		53	2		111
1984	79	0		79	4		114
1985	18	0		18	9		27
1986	3	1	48	3	2	19	74
1987	1	2	96	1	3	76	179
1988		1	110	0	5	70	185
1989		2	202	0	0	381	585
1990			369			1619	1988
1991			113			138	250
1992			139			2356	2495
1993			137			881	1018
1994			22			751	773
1995			28			376	404
1996			34			850	884
1997			15			968	983
1998			17			529	546
1999			8			402	411
2000			23			273	295
2001			16			614	630
2002			12			266	277
2003			17			180	197
2004			24			184	208
2005			12			78	90
2006*			6			178	184

* Estimated removals through August 5, 2006.

Table 13.3. Catches of shortraker rockfish (t) in the BSAI area, obtained from the North Pacific Groundfish Observer Program, NMFS Alaska Regional Office, and PACFIN.

	Eastern Bering Sea			Aleutian Islands			
Year	Foreign	Joint Venture	Domestic	Foreign	Joint Venture	Domestic	Total
1977	0			27			27
1978	1069			874			1943
1979	279			3008			3286
1980	649	0		185			833
1981	441	0		381			821
1982	242	0		379	0		621
1983	145	0		89	1		235
1984	54	0		28	0		83
1985	19	0		1	0		21
1986	2	2	14	0	0	12	30
1987	0	0	28		0	36	64
1988		0	31		0	37	69
1989		0	58		0	130	188
1990			116			546	662
1991			211			250	462
1992			155			586	741
1993			230			259	489
1994			46			174	219
1995			49			182	232
1996			87			109	196
1997			37			75	112
1998			50			156	207
1999			67			112	179
2000			133			208	341
2001			56			108	164
2002			93			213	306
2003			107			126	233
2004			120			121	241
2005			108			61	169
2006*			34			105	140

* Estimated removals through August 5, 2006.

Table 13.4. Estimated retained, discarded, and percent discarded of other red rockfish (ORR) and shortraker/rougheye (SR/RE) from the eastern Bering Sea (EBS) and Aleutian Islands (AI) regions. Prior to 2001, ORR in the eastern Bering Sea were managed as a single complex.

Species Area	Group	Year	Catch (t) Retained	Discard	Total	Percent 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	47	25	72	34.7%
		2002	50	54	104	51.9%
		2003	66	58	124	46.8%
AI	SR/RE	1993	737	403	1,139	35.3%
		1994	701	224	925	24.2%
		1995	456	103	559	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	197	84	306	27.5%
BSAI	RE	2004	83	101	184	54.9%
		2005	72	6	78	7.7%
BSAI	SR	2004	71	50	121	41.3%
		2005	37	24	61	39.3%

Table 13.5. Combined Aleutian Islands catch (t) of shortraker and rougheye rockfishes by management area and target fishery in 2004 and 2005, from the NMFS Alaska Regional Office catch accounting system database.

Rougheye

		Management area			
Target Fishery	Gear	541	542	543	Total
Atka mackerel	Bottom trawl	1.67	6.58	23.83	32.08
Pacific cod	Longline	6.38	17.35	4.06	27.78
Halibut	Longline	4.27	3.47	1.34	9.07
Rockfish	Bottom trawl	7.74	46.95	128.24	182.92
Other species	Bottom trawl		0.15		0.15
Sablefish	Longline	0.99	1.62		2.62
Turbot	Longline		2.06		2.06
Total		21.04	78.17	157.46	256.67

Shortraker

		Management area			
Target Fishery	Gear	541	542	543	Total
Atka mackerel	Bottom trawl	0.25	0.37	7.76	8.38
Bottom pollock	Pelagic trawl	0.47			0.47
Pacific cod	Longline	6.95	1.14	0.65	8.73
Halibut	Longline	3.72	2.46	5.44	11.62
rockfish	Bottom trawl	7.67	46.10	43.88	97.66
Other species	Bottom trawl		21.13		21.13
Sablefish	Longline	10.73	7.60	0.39	18.72
Turbot	Longline	0.08	8.40		8.48
Total		29.87	87.19	58.12	175.18

Table 13.6. Combined eastern Bering Sea catch (t) of shortraker and rougheye rockfish by management area and target fishery in 2004 and 2005, from the NMFS Alaska Regional Office catch accounting system database.

Rougheye

		Management area								
Target Fishery	Gear	509	513	517	518	519	521	523	524	Total
Atka mackerel	Bottom trawl					0.19				0.19
Bottom pollock	Pelagic trawl			0.01						0.01
Pacific cod	Longline			0.55			4.78	0.29	0.03	5.66
Pacific cod	Bottom trawl	0.06		0.69		0.42	0.34	0.28		1.78
Other flatfish	Bottom trawl			1.44		1.49				2.92
Halibut	Longline			1.63	0.57	0.01	0.04		0.01	2.26
Rockfish	Bottom trawl			1.08						1.08
Flathead sole	Bottom trawl		0.99	0.47			0.04			1.50
Other species	Bottom trawl			8.19						8.19
Midwater pollock	Pelagic trawl	0.01	0.01	0.32		0.34	0.59	0.01	0.01	1.28
Rock sole	Bottom trawl			0.04						0.04
Sablefish	Pot			0.00	0.35	0.03				0.38
Turbot	Longline			0.00			3.71	1.60	0.03	5.34
Arrowtooth	Bottom trawl			3.26		0.94				4.20
Total		0.06	1.00	17.68	0.92	3.41	9.50	2.17	0.08	34.82

Shortraker

		Management area									
Target Fishery	Gear	508	509	513	517	518	519	521	523	524	Total
Bottom pollock	Bottom trawl				1.23						1.23
Pacific cod	Longline				6.38	0.04	0.66	33.31	4.34	0.01	44.74
Other flatfish	Bottom trawl				1.39		0.75				2.14
Hallibut	Longline			0.01	0.41	0.90	0.05	1.34	0.02		2.74
Rockfish	Longline								0.01		0.01
Flathead sole	Bottom trawl							0.48			0.48
Other species	Longline							0.36	1.76		2.12
Midwater pollock	Pelagic trawl		0.02	2.23	101.15		1.50	16.37	0.02		121.28
Rock sole	Bottom trawl				0.08						0.08
Sablefish	Longline	0.00			0.13		0.12		0.09		0.33
Sablefish	Pot				0.02	0.65	0.24				0.91
Turbot	Longline				1.02	0.01		24.40	13.61	0.74	39.77
Arrowtooth	Longline								1.40		1.40
Total		0.00	0.02	2.23	111.81	1.60	3.32	76.26	21.23	0.75	217.22

Table 13.7. Comparison of catch (t) of rougheye and shortraker rockfish in the Aleutian Islands from 2002 to 2006 with potential area-specific ABC levels.

		Aleutian Islands		Eastern Bering Sea	
Year	Species	Total Catch	ABC	Total Catch	ABC
2001	Rougheye	614	230	16	32
	Shortraker	108	682	56	84
2002	Rougheye	266	230	12	32
	Shortraker	213	682	93	84
2003	Rougheye	180	215	17	32
	Shortraker	126	615	107	104
2004	Rougheye	184	174	24	21
	Shortraker	121	442	120	84
2005	Rougheye	78	198	12	25
	Shortraker	61	501	108	95
2006	Rougheye	178	199	6	25
	Shortraker	105	487	34	93

Table 13.8. Estimated biomass (t) of rougheye and shortraker rockfish from the NMFS bottom trawl surveys, with the coefficient of variation (CV) is shown in parentheses.

	AI survey		EBS Slope survey	
Year	Rougheye	Shortraker	Rougheye	Shortraker
1979			1053	1391
1980	22,807 (0.79)	16,983 (0.20)		
1981			816	3571
1982			605	5176
1983	23,412 (0.37)	40,992 (0.69)		
1984				
1985			1716	4010
1986	52,354 (0.62)	25,823 (0.28)		
1987				
1988			876 (0.32)	1260 (0.43)
1989				
1990				
1991	11,131 (0.45)	23,703 (0.64)	884 (0.30)	2758 (0.38)
1992				
1993				
1994	14,552 (0.26)	28,190 (0.21)		
1995				
1996				
1997	11,596 (0.21)	38,487 (0.26)		
1998				
1999				
2000	15,259 (0.21)	37,781 (0.44)		
2001				
2002	9,613 (0.19)	16,845 (0.19)	553 (0.20)	4851 (0.44)
2003				
2004	15,039 (0.25)	33,257 (0.37)	648 (0.16)	2534 (0.22)
2005				
2006	9,505 (0.22)	12,961 (0.23)		

Table 13.9. P-values for pairwise comparisons in mean length at age between rougheye sampled in 2002 and 2004 in the EBS slope survey and four areas of the AI survey.

2002

Area	EBS	SBS	Central AI	Eastern AI	Western AI
EBS		0.350	0.002	0.000	0.000
SBS			0.109	0.038	0.010
Central AI				0.575	0.144
Eastern AI					0.288

2004

Area	EBS	SBS	Central AI	Eastern AI	Western AI
EBS		0.112	0.023	0.018	0.887
SBS			0.853	0.982	0.122
Central AI				0.755	0.048
Eastern AI					0.036

Table 13.10. P-values for pairwise comparisons in mean length at age between shortraker sampled in 2002 and 2004 in the EBS slope survey and four areas of the AI survey.

2002

Area	EBS	SBS	Central AI	Eastern AI	Western AI
EBS		0.209	0.468	0.301	0.071
SBS			0.106	0.077	0.030
Central AI				0.686	0.210
Eastern AI					0.424

2004

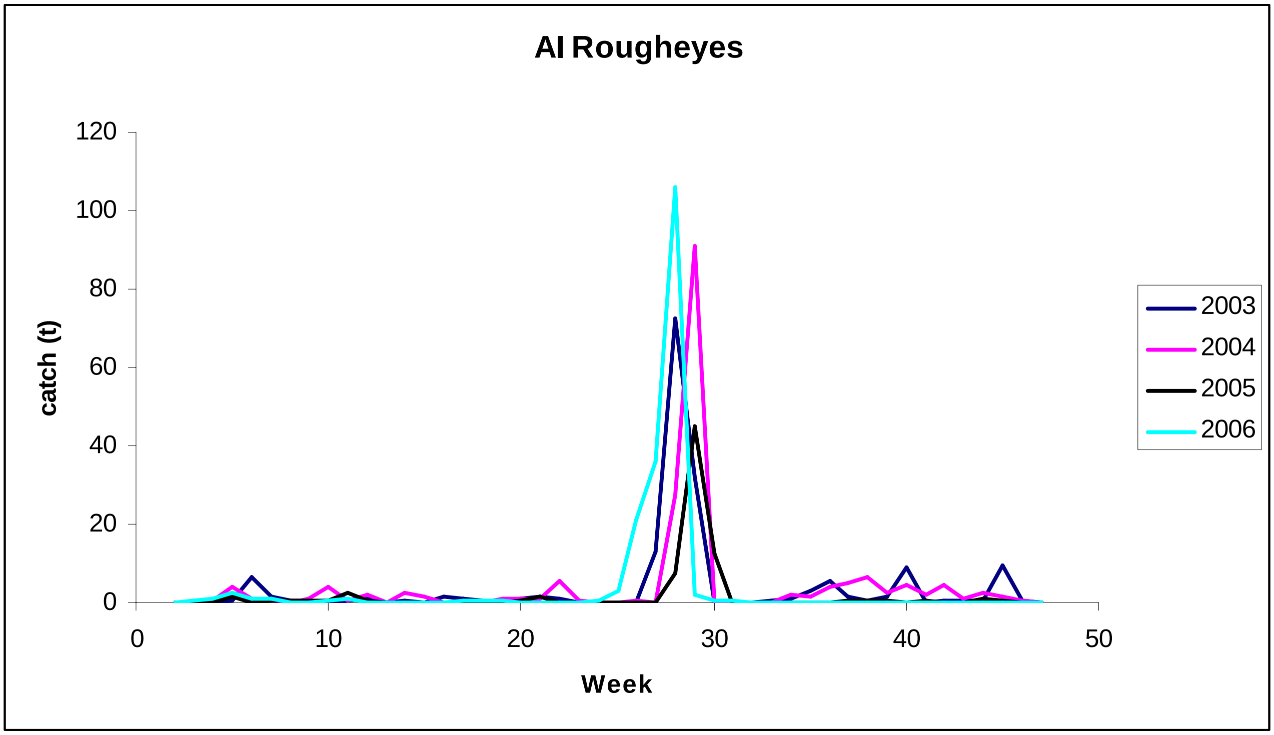
Area	EBS	SBS	Central AI	Eastern AI	Western AI
EBS		0.107	0.488	0.276	0.774
SBS			0.186	0.038	0.091
Central AI				0.095	0.389
Eastern AI					0.489

Table 13.11. Estimated beginning year biomass (t) for rougheye and shortraker rockfishes from the 2006 and 2004 assessments.

	Rougheye		Shortraker	
Year	2006 Assessment	2004 Assessment	2006 Assessment	2004 Assessment
1980	26,079	23,946	21,707	35,043
1981	25,071	23,509	20,817	34,334
1982	24,039	22,789	20,357	33,659
1983	23,568	22,424	20,342	33,041
1984	23,335	22,361	21,029	33,255
1985	23,112	22,182	21,373	33,015
1986	22,980	22,102	21,870	32,830
1987	23,498	22,603	22,748	32,439
1988	23,016	22,145	22,989	32,275
1989	22,542	21,695	23,268	32,116
1990	21,643	20,808	23,432	31,844
1991	19,130	18,301	23,795	31,246
1992	18,193	17,416	24,010	30,285
1993	15,827	16,213	23,786	30,038
1994	14,921	15,266	23,972	29,797
1995	14,305	14,528	24,869	29,453
1996	14,014	14,232	24,849	29,564
1997	13,261	13,488	24,865	29,627
1998	12,324	12,516	26,503	31,189
1999	12,067	12,277	25,549	30,498
2000	11,936	12,176	24,617	29,833
2001	12,340	12,624	23,960	30,010
2002	11,642	11,998	23,163	28,911
2003	11,006	11,299	21,005	25,426
2004	10,977	11,405	20,801	25,588
2005	11,339	11,913	21,057	26,470
2006	11,223		20,479	
2007	10,782		18,857	

Table 13.10. Estimated fishing mortality rates for rougheye and shortraker rockfishes from the 2006 and 2004 assessments.

	Rougheye		Shortraker	
Year	2006 Assessment	2004 Assessment	2006 Assessment	2004 Assessment
1980	0.032	0.015	0.039	0.013
1981	0.036	0.028	0.038	0.017
1982	0.013	0.014	0.029	0.018
1983	0.005	0.005	0.011	0.007
1984	0.005	0.005	0.004	0.003
1985	0.001	0.001	0.001	0.001
1986	0.003	0.003	0.001	0.001
1987	0.008	0.008	0.003	0.002
1988	0.008	0.009	0.003	0.002
1989	0.027	0.029	0.008	0.006
1990	0.101	0.107	0.026	0.021
1991	0.013	0.014	0.019	0.015
1992	0.145	0.074	0.030	0.012
1993	0.065	0.065	0.020	0.016
1994	0.052	0.052	0.009	0.007
1995	0.028	0.028	0.009	0.008
1996	0.064	0.063	0.008	0.006
1997	0.076	0.075	0.004	0.004
1998	0.044	0.043	0.009	0.007
1999	0.034	0.033	0.008	0.006
2000	0.024	0.024	0.015	0.012
2001	0.054	0.052	0.008	0.006
2002	0.025	0.024	0.015	0.012
2003	0.018	0.012	0.011	0.007
2004	0.019	0.015	0.012	0.008
2005	0.008		0.009	
2006	0.017		0.007	



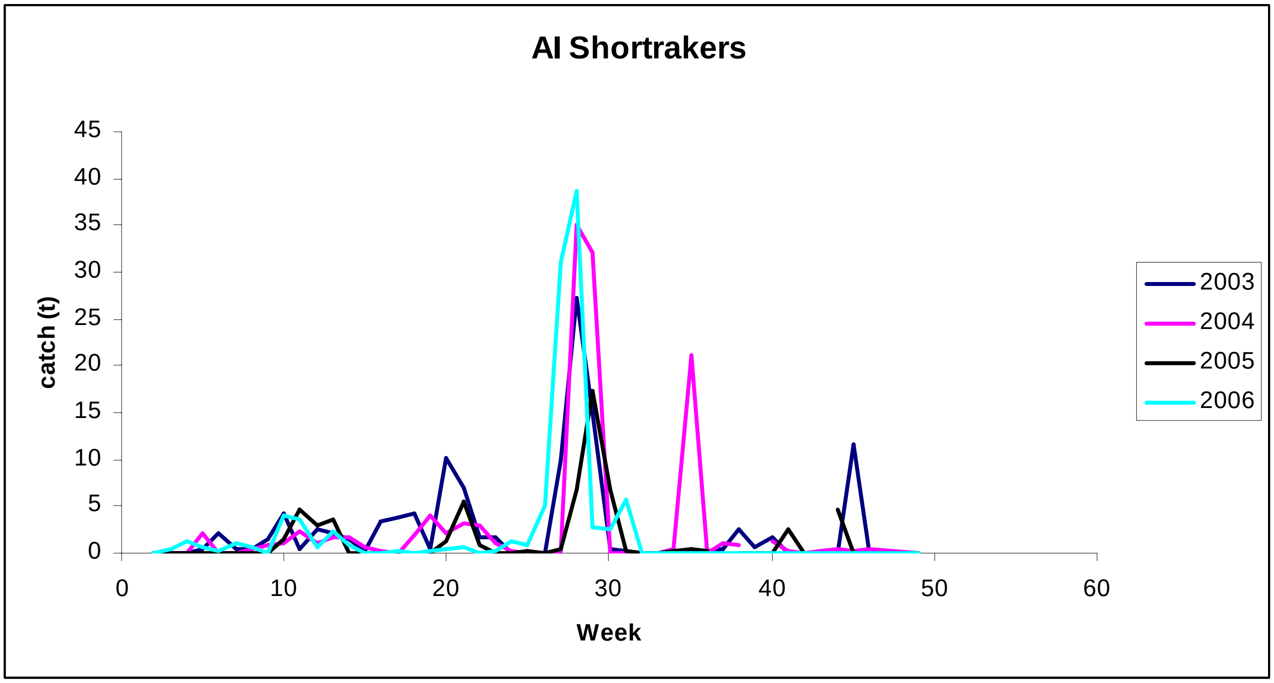
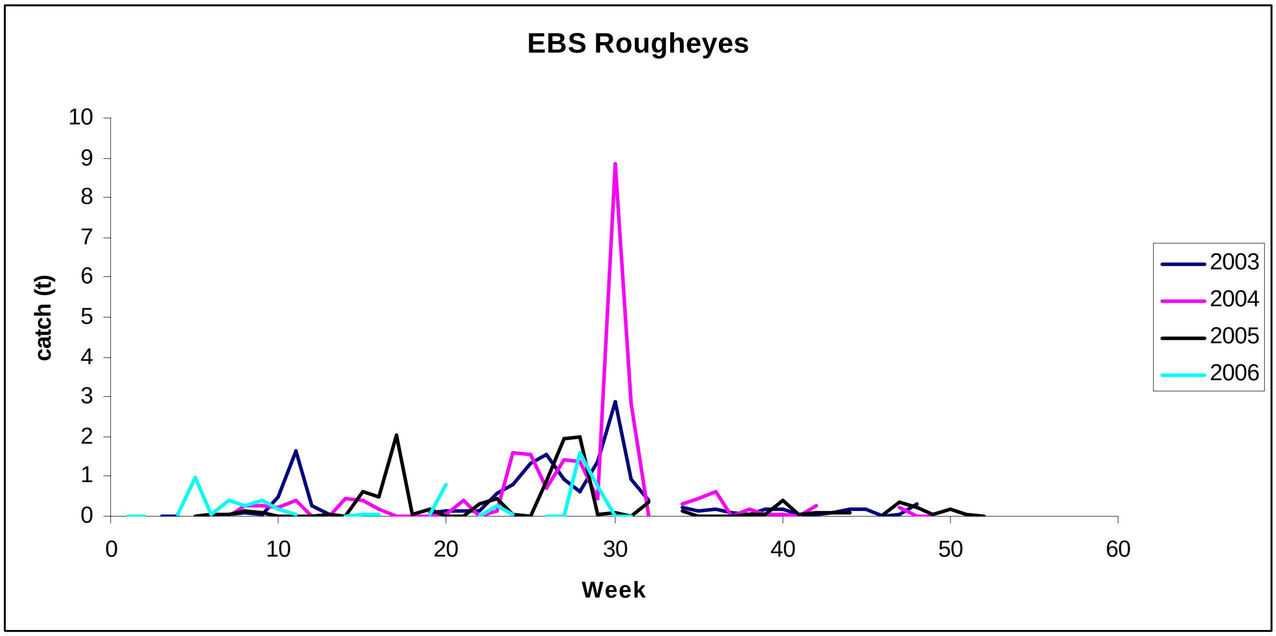


Figure 13.1. Aleutian Islands rougheye and shortraker catch by week from 2003 to 2006 (through August 5).



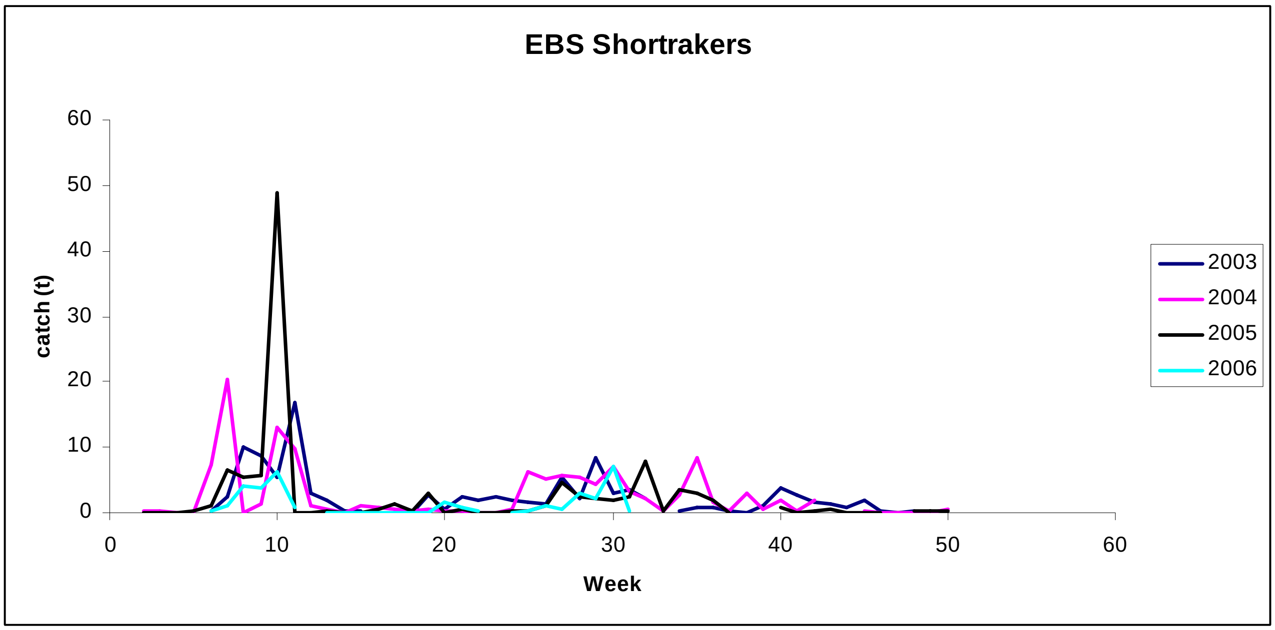


Figure 13.2. Eastern Bering Sea rougheye and shortraker catch by week from 2003 to 2006 (through August 5).

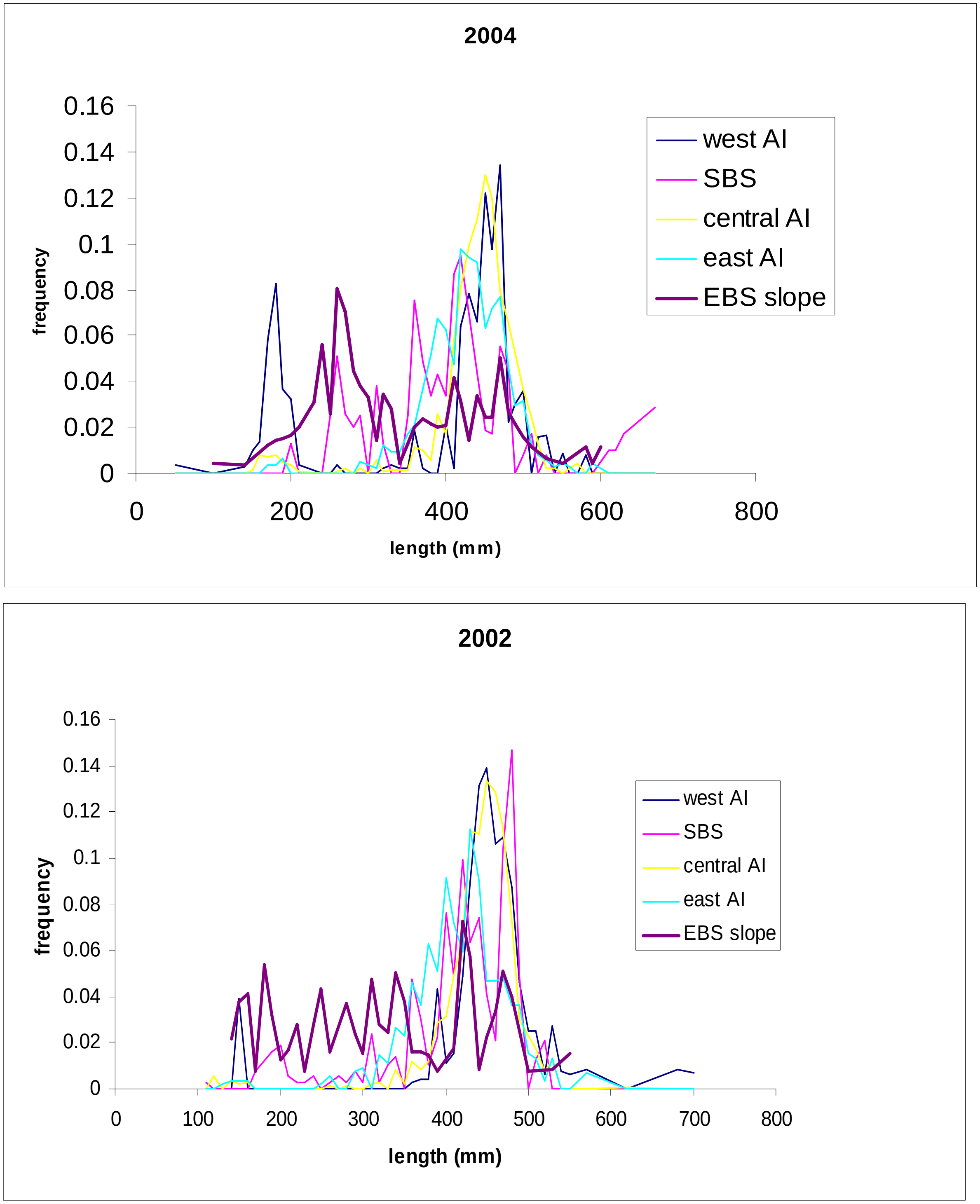
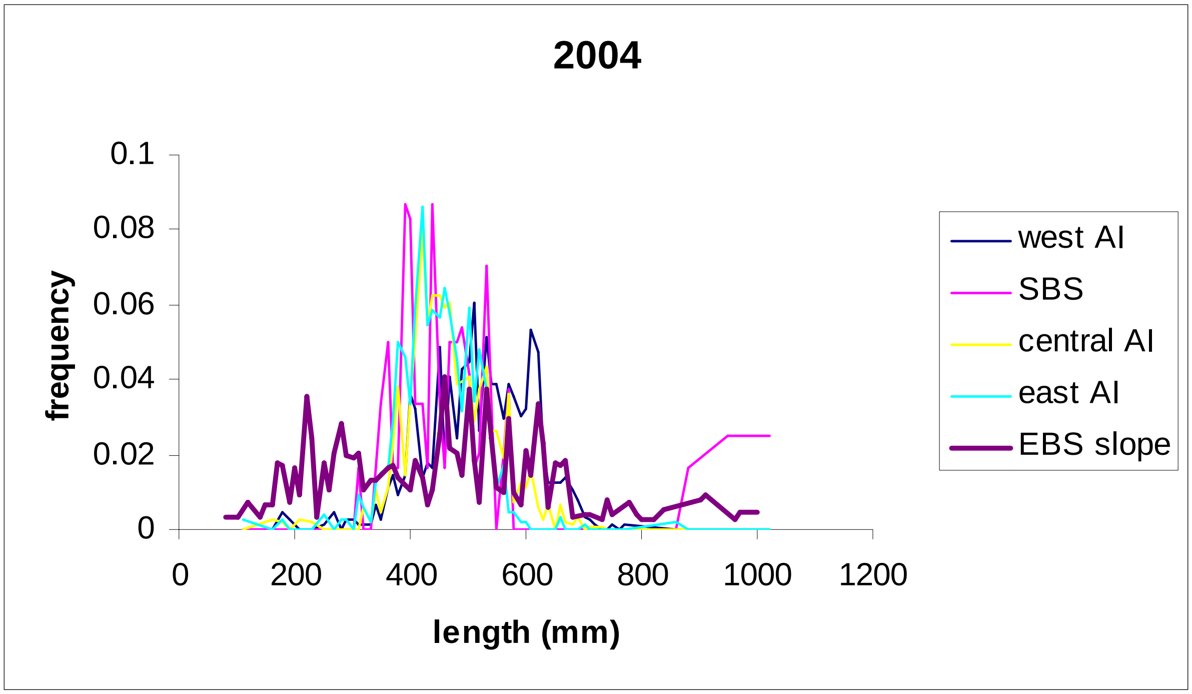


Figure 13.3. Length composition of rougheye rockfish from the EBS slope survey and four areas of the AI survey in 2004 (top) and 2002 (bottom).



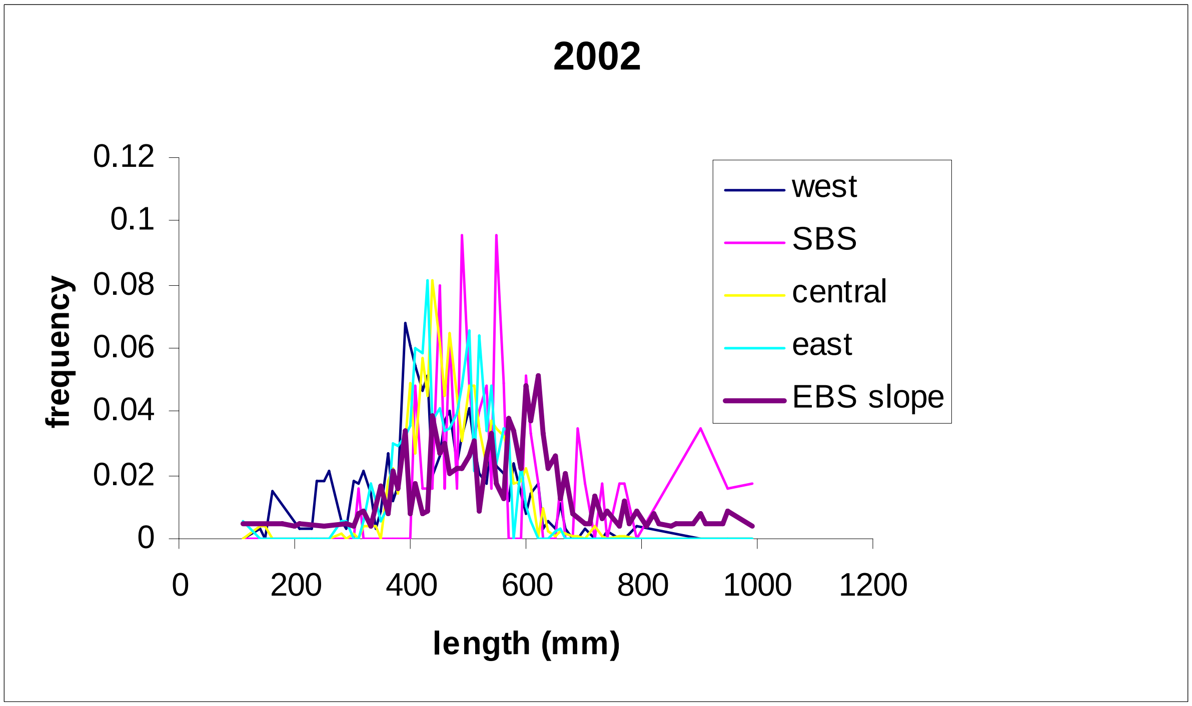


Figure 13.4. Length composition of shortraker rockfish from the EBS slope survey and four areas of the AI survey in 2004 (top) and 2002 (bottom).

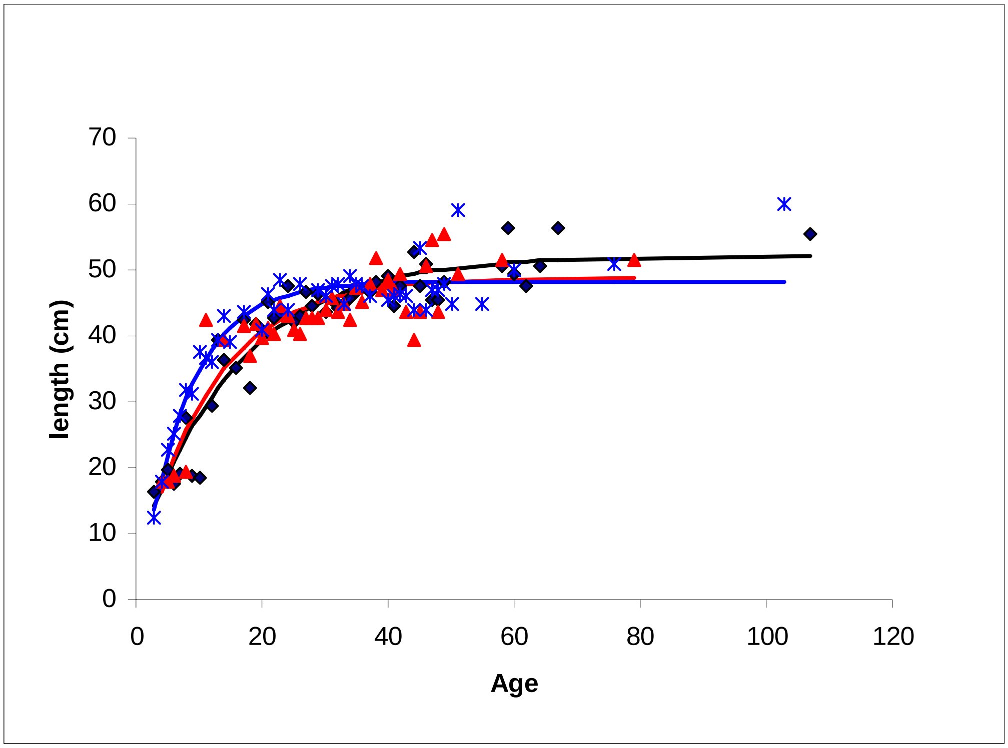


Figure 13.5 Rougheye rockfish growth curves from the central AI (black), eastern AI (red), and eastern Bering Sea slope (blue).

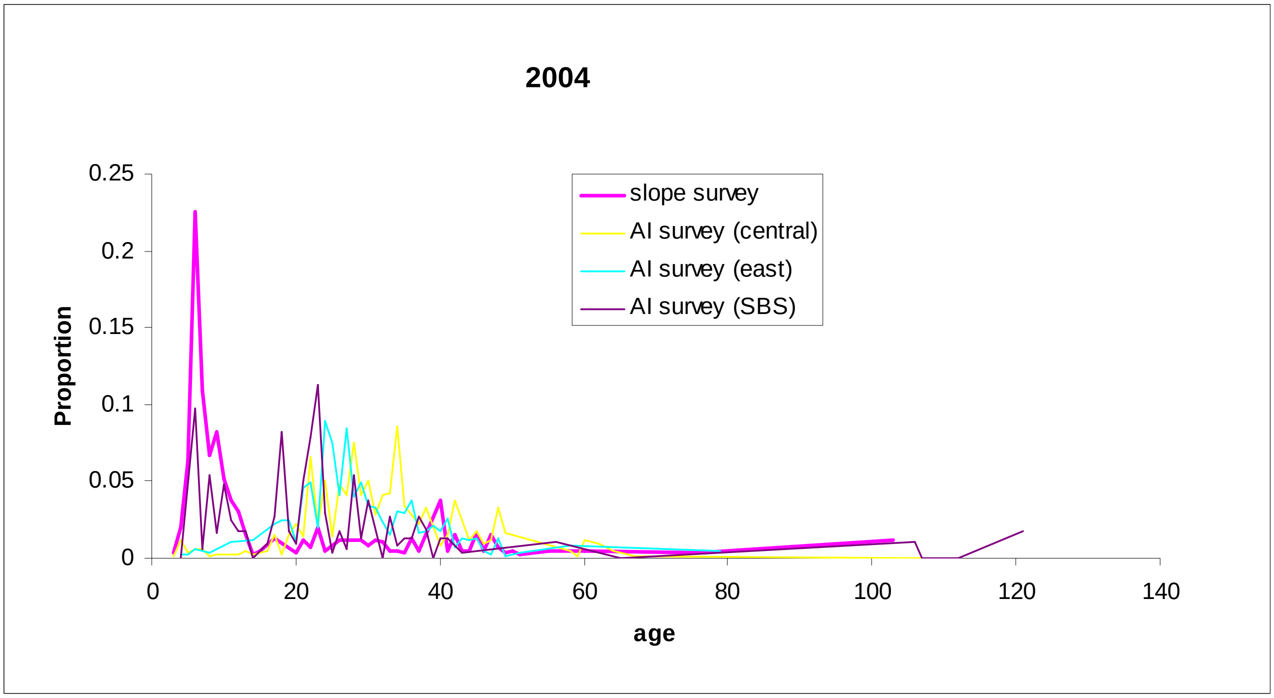


Figure 13.6. Estimated proportion at age for rougheye rockfish in the 2004 EBS slope survey and three areas of the AI survey

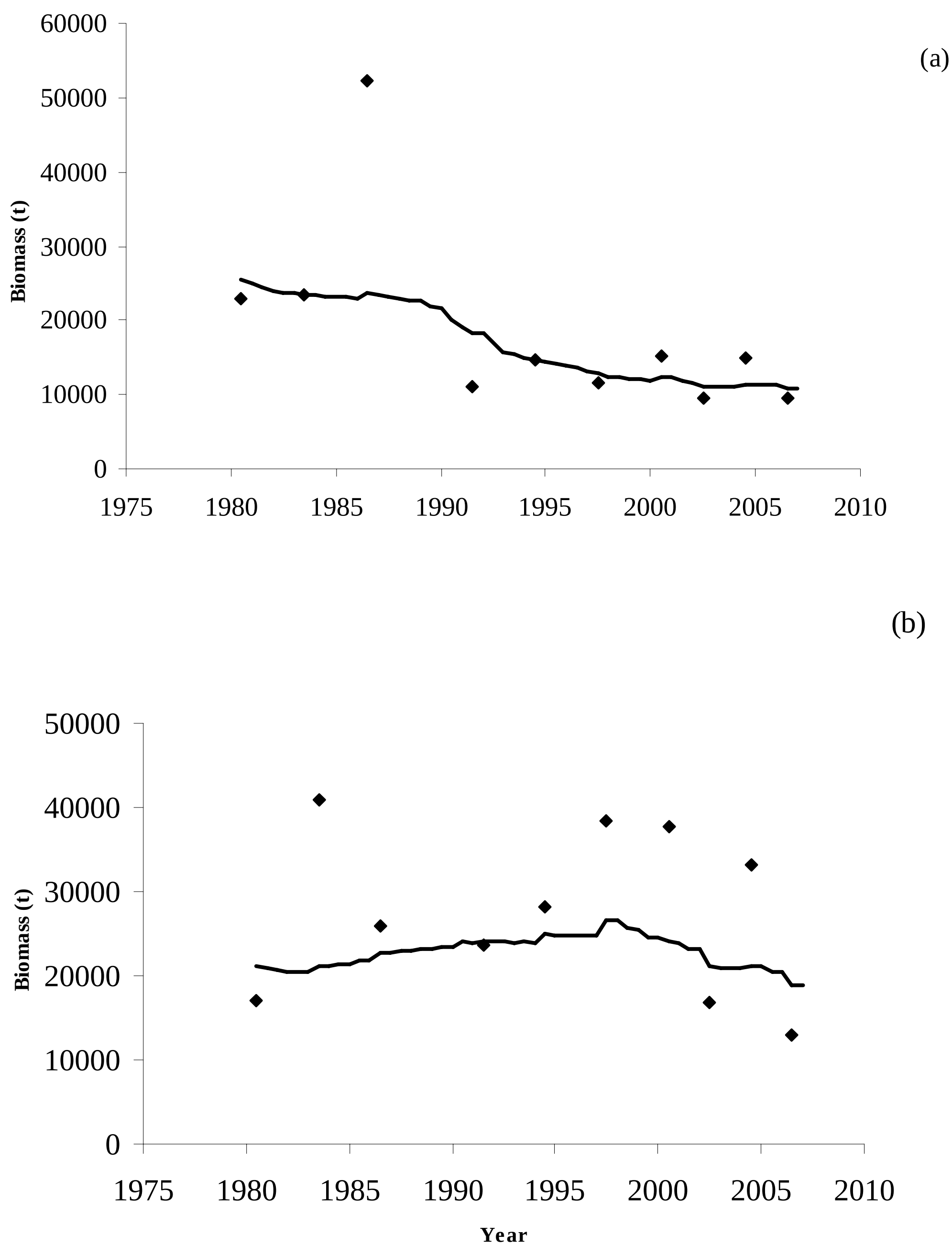


Figure 13.7. Survey biomass and estimated biomass of BSAI rougheye (a) and shortraker (b) rockfish.

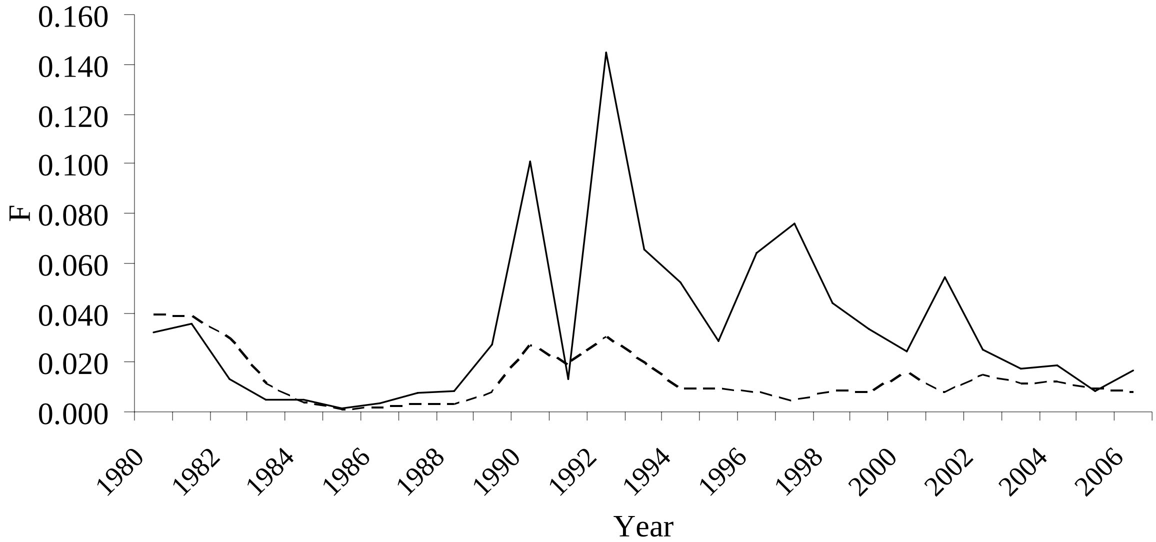
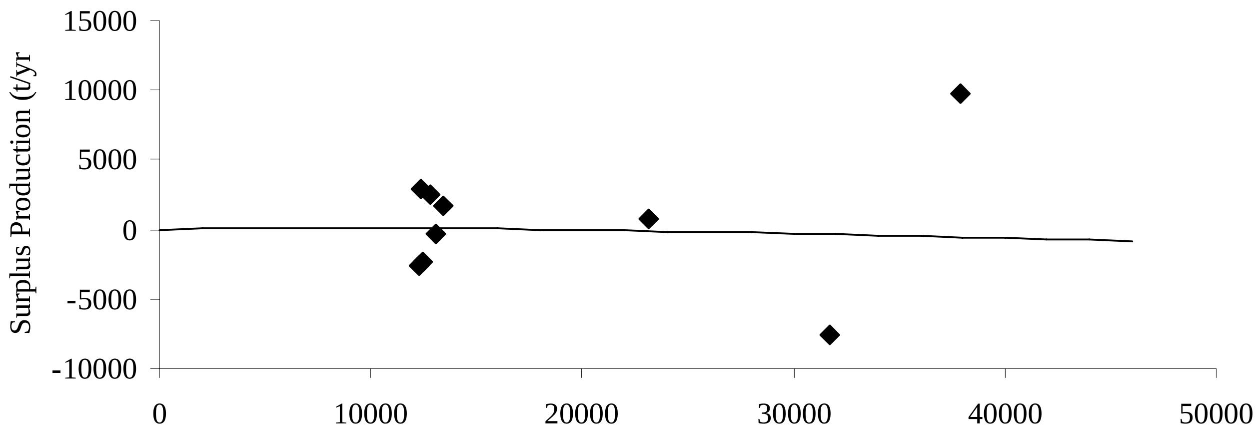


Figure 13.8. Estimated fishing mortality rate of BSAI rougheye (solid line) and shortraker (dashed line) rockfish.

(a)



(b)

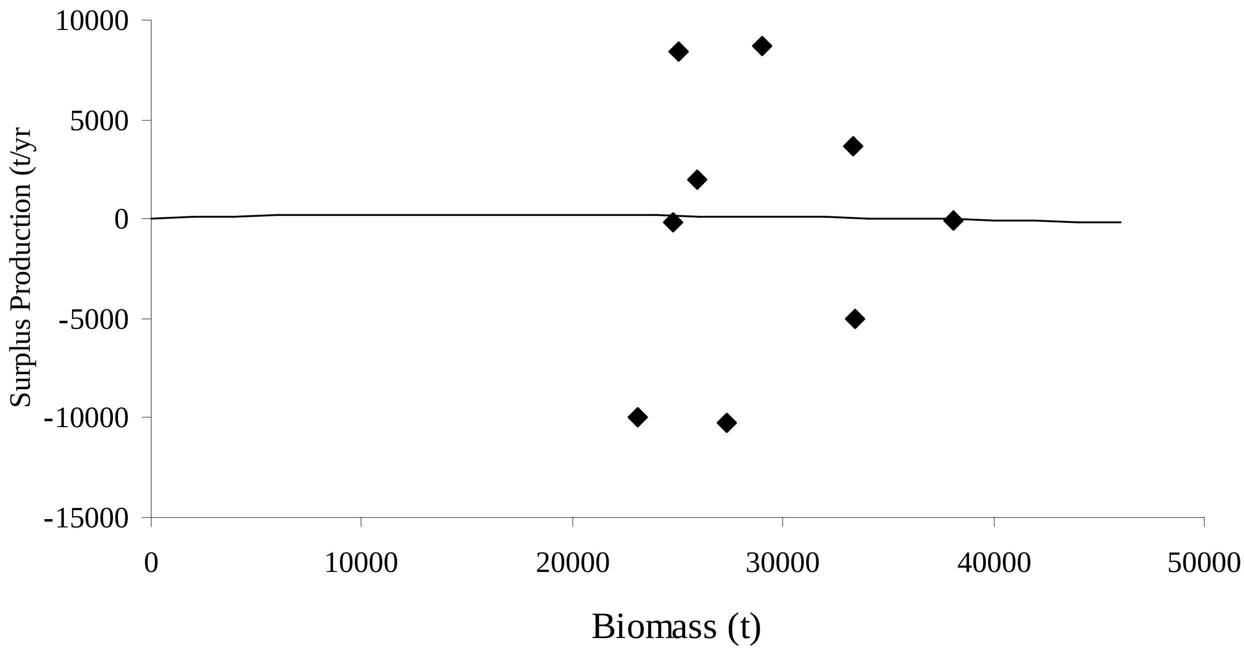


Figure 13.9. Annual surplus production and production model fits of BSAI rougheye (a) and shortraker rockfish (b).

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