CHAPTER 13

SHORTRAKER AND ROUGHEYE ROCKFISH

by

Paul D. Spencer and Rebecca F. Reuter

Relative to the November 2003 BSAI SAFE Report, the following changes have been made in the assessment of the Shortraker and Rougheye Rockfish.

1) The 2003 landings have been updated and the 2004 landings through September 27, 2004 have been included in the assessment.

A summary of the 2005 recommended ABCs relative to the 2004 recommendations is as follows:

	ABC				
	Eastern Bering Sea		Aleutian Islands		
	2005	2004	2005	2004	2005 Total
Rougheye	25 t	21 t	198 t	174 t	223 t
Shortraker	95 t	84 t	501 t	442 t	596 t

A summary of the 2005 recommended ABCs relative to the 2004 recommendations is as follows:

	OFL	
	Eastern Bering Sea/Aleutian Islands	
	2005	2004
Rougheye	298 t	259 t
Shortraker	794 t	701 t

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

From the December, 2003, minutes: "*Because the Kalman filter is unfamiliar to members of the Council family, it may be advantageous to highlight the potential advantages and limitations of this application of the Kalman filter during the October 2004 review of innovations in stock assessment models.* Additionally, the SSC "*recommends that additional genetic analysis be undertaken to more fully investigate the potential segregation of these species between the Aleutians and the eastern Bering Sea*" The methodology for the Kalman filter model for shortraker and rougheye rockfishes was presented to the BSAI Plan Team during the September, 2003, Plan Team meeting. Additionally, the methodology was presented at the 2003 Lowell Wakefield Symposium on Assessment and Management of Stocks in Data-Poor situations and has resulted in the following publication:

Spencer, P.D. and J.N. Ianelli. 2005. Application of a Kalman filter to a multispecies stock complex. *In* G. Kruse, V. Galluci, I. Perry, T. Shirley, P. Spencer, B. Wilson, and D. Woodby. [eds.]. Assessment and management of new and developed fisheries in data-poor situations. University of Alaska Sea Grant, Fairbanks, AK. In press.

The assessment authors agree that additional research on the genetic population structure of rougheye and shortraker rockfishes in the BSAI area would be useful.

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) pertains 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.

Sufficient age composition data exist to apply an age-structured model to northern rockfish, and the assessment of this species is presented in a separate chapter. In addition, a Kalman filter is applied to the remaining shortraker/rougheye complex. An advantage of the Kalman filter is that it utilizes both the catch estimates and the survey biomass estimates. In contrast, the method applied in previous assessments (straight averaging of survey biomass) utilizes only the catch information. The Kalman filter methodology for a single-species case was presented to the Plan Team at the Sept 2003 meeting, and the method is extended to apply to a two-species complex in this assessment. Although rougheye and shortraker rockfishes were managed by species in the BSAI area in 2004, this history of reporting the combined catches warrants continuation of the Kalman filter for these species.

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 and 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 are 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, fixed differences at a microsatellite locus and divergent mtDNA complements indicate two distinct species (Gharrett 2003). The ranges of the two species of rougheye are not coincident, although both species were caught in the same hauls in some areas. There are also two color morphs of rougheye rockfish, but these do not correspond exactly to the two species, and a way to distinguish the species morphometrically has not been identified. For the type A (western) rougheye, the microsatellite data showed weaker population structure than seen for shortraker, with one group in the central Aleutians and two large groups overlapping at Kodiak Island.

For shortraker rockfish, population structure was observed in microsatellite DNA analysis of 12 collections from Baranof Island to the western Aleutians revealed population structure roughly on a spatial scale consistent with our current management areas, although increased sample sizes may reveal finer spatial structuring (Matala et al. in press). 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. The relationships among the mtDNA haplotypes suggest a population decline followed by a relatively recent (in geological time) population expansion (Gharrett 2003).

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 1992-2004 are shown in Table 13.1, with the species catches 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” or “catch accounting system” data). An identical procedure was used to obtain the estimates of catch by species from the 1977-1989 foreign and joint venture fisheries. Estimates of discarding by species complex are shown in Table 13.2. Rougheye and shortraker rockfishes are relatively high valued species compared to northern rockfish, accounting for the lower discard rates for the “rougheye/shortraker” complex as compared to the “other red rockfish” complex.

Shortraker and rougheye rockfishes in the Aleutian Islands are caught primarily in the rockfish, Pacific cod, and Atka mackerel fisheries in recent years. The annual proportion of the catch in the rockfish fisheries ranged from 40% to 71% during 1994-2002, as compared to 6%-31% and 3%-15% for the Pacific cod and Atka mackerel fisheries during this time period. In contrast, catches of shortraker and rougheye rockfishes from 1994-2002 in the EBS management area were caught largely in the Pacific cod, sablefish, Greenland turbot, and arrowtooth flounder fisheries, whose combined contribution to the catch ranged from 58% -84%. Catches of shortraker and rougheye rockfishes in the 2003 AI fishery were relatively evenly distributed across the three management areas, with approximately one-half the catch occurring the Pacific ocean perch fishery; the remaining catch divided among the Pacific halibut, Akta mackerel, sablefish, and Pacific cod fisheries (Table 13.3). In the eastern Bering Sea, the 2003 catch of 90 t was taken primarily in the Greenland turbot , the midwater pollock, and the Pacific cod fisheries. The catch from the Greenland turbot fishery was taken largely in management area 521 (near the Pribilof Islands), whereas the catches from the midwater pollock and Pacific cod fisheries were taken from areas 521 and 517 (the southeastern slope) (Table 13.4).

DATA

Fishery Catch

Catches from the domestic fishery prior to the domestic observer program were obtained from PACFIN records. Estimated domestic catches in 1990 were obtained from Guttormsen et al. 1992. Estimates of catch in 2004 were based on NMFS Alaska Regional Office data through September 27, 2004. The time series of estimated catches from 1977-2004 are shown in Tables 13.5-13.6. Catches of shortraker and rougheye rockfishes appear low in the mid-1980’s, when the foreign fishery was reduced.

Estimates of catch by species can be compared to potential single-species ABC and OFL levels in order to evaluate whether excessive harvests may have occurred in the past (Tables 13.7-13.9). Beginning in 2001, the OFL levels for other red rockfish pertain to the entire BSAI area. Thus, the retrospective analysis of what single-species harvest limits might have been in these years is shown separately in Table 13.7, whereas years 1994 to 2000 for the AI and EBS areas are shown in Tables 13.8 and 13.9, respectively. 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. 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. It should also be noted that the definition of the ABC and OFL levels under past assessment procedures were highly sensitive to variability in survey biomass estimates, which was one motivation for application of a biological model to the existing data rather than sole reliance on observed biomass estimates measured with considerable uncertainty.

The estimated harvest of rougheye rockfish has occasionally exceeded their potential single-species harvest limits, sometimes by large amounts. For example, the 2001 BSAI rougheye rockfish catch of 614 t exceeds what the potential single-species BSAI OFL level might have been from applying an exploitation rate to the average of recent survey biomass estimates (350 t) (Table

13.7), and a similar situation occurred in 1996 when the estimated AI rougheye catch was 850 t and the potential OFL level was 587 t.

Note that observers can report shortraker and rougheye rockfishes by species, or with a combined shortraker/rougheye species code. Although the combined code could not be used for estimating proportions, it has accounted for a large percentage of all shortraker and rougheye observed in some recent years. The use of the combined code was especially prevalent on longline vessels, where species identifications were often made without benefit of close examination of a basket sample of fish. For example, in 2002 approximately 56% of the SR/RE observed on longline vessels was classified with the combined code. In 2003, the North Pacific Observer Program undertook changes to improve estimation of shortraker and rougheye in order to obtain representative species compositions, including making species identifications from basket sample where a detailed examination can occur. This change is revealed in the 2003 data, where only 18 t (of 240 t total) of the observed AI shortraker/rougheye catch was reported in the group code.

Survey data

Biomass estimates for other red 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 domestic trawl surveys were conducted in 1988, 1991, 2002, and 2004 on the eastern Bering Sea slope, and in 1991, 1994, 1997, 2000, 2002, and 2004 in the Aleutian Islands (Table 13.10). 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 populations, as the bulk of these population is 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 survey 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. 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 4851 t with 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.

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 (Figure 13.1). 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 with a distribution with an estimated mean α_t and variance P_t.

The observation equation is

$$Y_t = Z_t X_t + d_t + \varepsilon_t \tag{4}$$

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

$$\ln L = -\frac{1}{2}\sum_{t=1}^{T}\ln\left|F_t\right| - \frac{1}{2}\sum_{t=1}^{T}\nu_t' F_t^{-1}\nu_t \tag{5}$$

where G_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 of 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 13.1a). 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 23,946 t in 1980 to 11,913 t for 2005.

Shortraker rockfish has also shown a decline in predicted beginning year stock biomass, from 35,043 t in 1980 to 26,470 t in for 2005. The time series of biomass are slightly larger than those obtained in the 2003 assessment, reflecting the increased survey biomass estimates in 2004 (Table 13.11).

Fishing mortality

The time series of estimated fishing mortality are shown in Figure 13.2, and show higher fishing mortality rates for rougheye rockfish than shortraker rockfish. The higher fishing mortality rates for rougheye rockfish in the 1990s are consistent with the analysis presented in Table 13.6 showing occasionally disproportionate catches relative to survey biomass estimates. The fishing mortality rates for rougheye rockfish since 2000 are lower (except for 2001) than those estimated for much of the 1990s. 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 exist for the rougheye and shortraker stocks. The lack of data regarding this parameter can be seen in plots that express the observed survey biomass and estimated catch data in unit of annual surplus production (ASP), which is the change in biomass over a period plus the catch during the period, expressed on an annual basis. Plots of ASP as a function of mean biomass are shown in Figure 13.3, 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 is obtained by multiplying F_{abc} by the estimated biomass. This procedure results in the following BSAI ABCs and OFLs :

	2005 biomass	M	ABC	OFL
Rougheye rockfish	11,913	0.025	223 t	298 t
Shortraker rockfish	26,470	0.03	596 t	794 t

As in previous assessments, it is recommended that the ABCs be partitioned between the EBS and AI areas as a precautionary measure given the uncertainty regarding stock structure over the BSAI area. Because the AI trawl survey spans the two management areas, one option is to use the proportional survey biomass from the two areas to partition the ABCs. For rougheye rockfish, the average biomass from 1991-2004 in the AI management area is 11,964 t, whereas the average from the southern Bering Sea is 901 t; thus 93% of the estimated Aleutians Islands survey biomass for rougheye occurs in the Aleutian Islands management area. A similar calculation indicates that 95% of the shortraker rockfish AI survey biomass is found in the AI management area. Because the Aleutian Islands survey does not cover the EBS slope, it may be useful to consider the 2002 and 2004 EBS slope survey biomass estimates, which average of 601 t and 3692 t for rougheye and shortraker, respectively. For rougheye rockfish, the combined biomass in the EBS management area (901 t +601 t=1,501 t) is 11% of the combined BSAI biomass from both surveys of 13,465 t. For shortraker rockfish, the combined biomass in the EBS management area (1,509 t + 3,692 t = 5,201 t) is 16% of the combined BSAI biomass from both surveys of 33,403 t. Thus, it is recommended that 11% of the rougheye ABC, or 25 t, be allocated to the EBS region and 198 t be allocated to the AI region. For shortraker rockfish, it is recommended that 16% of the ABC, or 95 t, be allocated to the EBS region and 501 t be allocated to the AI region. These results are summarized below

	AI ABC	EBS ABC	OFL
Rougheye rockfish	198 t	25 t	298 t
Shortraker rockfish	501 t	95 t	794 t

Summary

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

Quantity	Value
M (Shortraker)	0.03
M (Rougheye)	0.025
Tier	5
Year 2005 Total Biomass	
Shortraker	26,470 t
Rougheye	11,913 t
F_{OFL} (Shortraker)	0.03
F_{OFL} (Rougheye)	0.025
Maximum F_{ABC} (Shortraker)	0.0225
Maximum F_{ABC} (Rougheye)	0.0188
Recommended F_{ABC} (Shortraker)	0.0225
Recommended F_{ABC} (Rougheye)	0.0188
OFL (Shortraker)	794 t
OFL (Rougheye)	298 t
Maximum allowable ABC (Shortraker)	596 t
Maximum allowable ABC (Rougheye)	223 t
Recommended ABC (Shortraker)	596 t
Recommended ABC (Rougheye)	223 t

REFERENCES

Fox, W.W. 1970. An exponential surplus-yield model for optimizing exploited fish populations. Trans. Am Fish. Soc. 99:80-88.

Gelman, A., J.B. Carlin, H.S. Stern, and D.A. Rubin. 1995. Bayesian data analysis. Chapman and Hall, New York. 552 pp.

Gharrett, A..J. 2003. Population structure of rougheye, shortraker, and northern rockfish based on analysis of mitochondrial DNA variation and microsatellites: completion. Juneau Center of Fisheries and Ocean Sciences, University of Alaska-Fairbanks. 136 pp.

Gulland, J.A. 1970. The fish resources of the ocean. FAO Fish. Tech. Pap. 97. 425 pp.

Guttormsen, M., R. Narita, J. Gharrett, G. Tromble, and J. Berger. 1992. Summary of observer sampling of domestic groundfish fisheries in the northeast Pacific ocean and eastern Bering Sea, 1990. NOAA Tech. Memo NMFS-AFSC-5. 281 pp.

Harvey, A.C. 1990. Forcasting, structural time series models, and the Kalman Filter. Cambridge: Cambridge University Press. 554 pp.

Heifetz, J. and D. Clausen. 1991. Slope rockfish. *In* Stock assessment and fishery evaluation report for groundfish report for the 1992 Gulf of Alaska groundfish fishery. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK.

Kendall, A.W. Jr. 1991. Systematics and identification of larvae and juveniles of the genus *Sebastes*. Env. Biol. Fish. 30:173-190.

Matala, A.P., A.K. Gray, J. Heifetz, and A.J. Gharrett. In press. Population structure of Alaskan shortraker rockfish, Sebastes borealis, inferred from microsatellite variation. Env. Biol. Fish.

Meinhold, R.J. and N.D. Singurwalla. 1983. Understanding the Kalman Filter. Am. Stat. 37(2):123-127.

Pella, J.J. 1993. Utility of structural time series models and the Kalman filter on for predicting consequences of fishery actions. *In* Proceedings of the international symposium on management strategies for exploited fish populations, G. Kruse, D.M. Eggers, R.J. Marasco, C. Pautzke, and T.J. Quinn II (eds), 571-593. Alaska Sea Grant College Program, Fairbanks, AK.

Pella, J.J. and P.K. Tomlinson. 1969. A generalized stock production model. Bulletin of the Inter-American Tropical Tuna Commission 13:419-496.

Rosenberg, B. 1973. Random coefficient models: the analysis of a cross-section of time-series by stochastically convergent parameter regression. Annals of Economic and Social Measurement 2:399-428.

Seber, G.A.F. 1982. The estimation of animal abundance, 2nd ed. Macmillian, New York. 654 pp.

Thompson, G.G. 1996. Application of the Kalman Filter to a stochastic differential equation model of population dynamics. *In* Statistics in Ecology and Environmental Monitoring 2: Decision Making and Risk Assessment in Biology, D.J. Fletcher, L. Kavalieris, and B.J. Manly (eds.), 181-203. Otago Conference Series No. 6. University of Otago Press, Dunedin, New Zealand.

Table 13.1. Estimated removals (t) from 1992-2004 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	467		69	78	1471	1178	293		
1993	1226		137	230	1140	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		104	12	93	478	266	213		
2003		90	6	84	229	141	89		
2004*								184	204

*Estimated removals through September 27, 2004

Table 13.2. 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			Catch (t)			
Area	Group	Year	Retained	Discard	Total	Percentage
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	51	38	90	42.2%
AI	SR/RE	1993	737	403	1,140	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	150	80	230	34.8%

Table 13.3. Combined Aleutian Islands catch (t) of shortraker and rougheye rockfishes by management area and target fishery in 2003, from the NMFS Alaska Regional Office catch accounting system database.

	Management area			
Target Fishery	541	542	543	Total
Atka mackerel		6.49	18.31	24.81
Pacific cod	0.48	12.85	2.38	15.72
Halibut	13.14	15.72	4.80	33.66
POP	51.22	35.39	38.86	125.48
Other species			0.23	0.23
Sablefish	6.84	15.63	1.56	24.03
Turbot	0.43	5.59		6.02
Total	72.12	91.68	66.14	229.93

Table 13.4. Combined eastern Bering Sea catch (t) of shortraker and rougheye rockfishes by management area and target fishery in 2003, from the NMFS Alaska Regional Office catch accounting system database.

	Management area										
Target Fishery	508	509	513	514	517	518	519	521	523	524	Total
Turbot					1.65	4.58	0.23	19.22	2.74	0.20	28.61
Midwater pollock		0.00			11.21		1.42	9.21			21.84
Pacific cod		0.00	0.02		7.02	0.13	0.20	8.45	2.66	0.03	18.50
Bottom Trawl Pollock					9.88						9.88
Halibut				0.50		2.01	0.15	1.66	4.02		8.35
Sablefish	0.24				0.46	0.90	0.39				1.99
Other flatfish					0.25						0.25
Arrowtooth					0.16						0.16
Other species									0.02		0.02
POP			0.01								0.01
Total	0.24	0.00	0.03	0.50	30.64	7.62	2.39	38.53	9.44	0.23	89.61

Table 13.5. 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			26			27
1978	713			131			844
1979	372			977			1,349
1980	380	0		74			455
1981	258	0		315			573
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			212			250	462
1992			78			293	371
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			84			89	172
2004*							204

* Estimated removals through September 27, 2004.

Table 13.6. 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			153			155
1978	66			364			430
1979	637			999			1,636
1980	94	0		265			359
1981	166	0		493			658
1982	124	0		189	0		312
1983	53	0		56	2		111
1984	79	0		31	4		114
1985	18	0		1	9		27
1986	3	1	48	0	2	19	74
1987	1	2	96		3	76	179
1988		1	110		5	70	185
1989		2	202		0	381	585
1990			369			1,619	1,988
1991			113			138	250
1992			69			1,178	1,247
1993			137			881	1,018
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			6			141	147
2004*							184

* Estimated removals through September 27, 2004.

Table 13.7. Catch (t) of rougheye and shortraker rockfishes in the Aleutian Islands from 2001 to 2003, with reported species ABC and OFL levels. The SR/RE species code includes both shortraker and rougheye rockfishes. The total catch estimates were produced by multiplying the ratios in the observer data to the total catch estimates for the SR/RE group in the blend data, and adding these estimates to the blend estimates of catch by species.

		Aleutian Islands			Eastern Bering Sea			
	Species	Observed Catch	Total Catch	ABC	Observed Catch	Total Catch	ABC	BSAI OFL
2003	Rougheye	136.26	141.30	215	5.22	5.92	32	330
	Shortraker	85.47	88.63	615	73.89	83.76	104	959
	SR/RE	18.00			21.01			
2002	Rougheye	174.94	265.62	230	2.48	11.75	32	350
	Shortraker	146.33	212.77	682	32.74	92.88	84	1021
	SR/RE	40.44			11.50			
2001	Rougheye	362.59	613.90	230	6.53	15.87	32	350
	Shortraker	52.69	107.97	682	21.95	56.48	84	1021
	SR/RE	68.47			9.38			

Table 13.8. Catch (t) of rougheye and shortraker rockfishes in the Aleutian Islands from 1994 to 2000, with potential single-species ABC and OFL levels. The SR/RE species code includes both shortraker and rougheye rockfishes. The total catch estimates were produced by multiplying the ratios in the observer data to the total catch estimates for the SR/RE group in the blend data, and adding these estimates to the blend estimates of catch by species.

	Species	Observed Catch	Proportion of Sp. Group	Total Catch	Estimated Species Catch	ABC	OFL
2000	Rougheye	141.91	0.58	31.58	272.69	239	319
	Shortraker	104.11	0.42	30.85	207.73	646	861
	SR/RE	83.77		418.00			
1999	Rougheye	285.04	0.79	53.09	402.50	405	540
	Shortraker	76.08	0.21	18.72	111.98	560	747
	SR/RE	39.28		442.67			
1998	Rougheye	347.62	0.79	44.87	528.95	405	540
	Shortraker	90.97	0.21	29.56	156.24	560	747
	SR/RE	73.48		610.76			
1997	Rougheye	723.73	0.92	132.87	968.09	440	587
	Shortraker	64.23	0.08	1.25	75.36	498	664
	SR/RE	6.49		909.34			
1996	Rougheye	519.52	0.89	27.80	850.14	587	587
	Shortraker	66.44	0.11	4.17	109.33	664	664
	SR/RE	8.79		927.50			
1995	Rougheye	195.61	0.68	13.36	376.26	632	632
	Shortraker	91.72	0.32	12.27	182.43	590	590
	SR/RE	1.58		533.07			
1994	Rougheye	465.96	0.81	3.58	751.38	632	632
	Shortraker	108.18	0.19	0.02	173.64	590	590
	SR/RE	0.79		921.42			

Table 13.9. Catch (t) of in the eastern Bering Sea from 1994 to 2000, with potential single-species ABC and OFL levels. The SR/RE species code includes both shortraker and rougheye rockfishes. The total catch estimates were produced by multiplying the ratios in the observer data to the total catch estimates for the SR/RE group in the blend data, and adding these estimates to the blend estimates of catch by species.

	Species	Observed Catch	Proportion of Sp. Group	Total Catch	Estimated Species Catch	ABC	OFL
2000	Rougheye	10.55	0.14	5.41	22.70	35	47
	Shortraker	63.23	0.86	29.57	133.24	125	167
	SR/RE	15.95		120.96			
1999	Rougheye	6.46	0.13	2.21	8.42	51	68
	Shortraker	41.56	0.87	26.86	66.78	185	247
	SR/RE	5.05		46.12			
1998	Rougheye	6.91	0.23	4.25	17.17	51	68
	Shortraker	23.69	0.77	6.13	50.40	185	247
	SR/RE	8.55		57.19			
1997	Rougheye	6.97	0.29	3.41	15.03	56	75
	Shortraker	16.81	0.71	8.45	36.51	207	276
	SR/RE	4.66		39.68			
1996	Rougheye	12.05	0.25	8.15	33.84	75	
	Shortraker	35.97	0.75	10.01	86.70	276	
	SR/RE	0.93		102.39			
1995	Rougheye	7.33	0.23	14.90	28.12	75	75
	Shortraker	24.05	0.77	5.86	49.22	276	276
	SR/RE	0.93		56.58			
1994	Rougheye	11.63	0.33	0.51	21.92	75	75
	Shortraker	23.79	0.67	2.06	45.85	276	276
	SR/RE	0.00		65.20			

Table 13.10. Estimated biomass (t) of rougheye, shortraker, and northern rockfishes from the NMFS bottom trawl surveys. For the Aleutian Islands surveys since 1991 and the eastern Bering Sea surveys since 1988, the coefficient of variation (CV) is shown in parentheses.

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

Table 13.11. Estimated beginning year biomass (t) for rougheye and shortraker rockfishes from the 2004 and 2003 assessments.

	Rougheye		Shortraker	
Year	2004 Assessment	2003 Assessment	2004 Assessment	2003 Assessment
1980	23,946	26,227	35,043	38,299
1981	23,509	25,498	34,334	37,156
1982	22,789	24,513	33,659	36,092
1983	22,424	23,898	33,041	35,120
1984	22,361	23,499	33,255	34,902
1985	22,182	23,137	33,015	34,356
1986	22,102	22,860	32,830	33,895
1987	22,603	23,183	32,439	33,172
1988	22,145	22,565	32,275	32,738
1989	21,695	21,964	32,116	32,329
1990	20,808	20,950	31,844	31,812
1991	18,301	18,390	31,246	31,145
1992	17,416	17,386	30,285	30,084
1993	16,213	16,123	30,038	29,639
1994	15,266	15,157	29,797	29,225
1995	14,528	14,341	29,453	28,813
1996	14,232	13,949	29,564	28,700
1997	13,488	13,128	29,627	28,559
1998	12,516	12,113	31,189	30,165
1999	12,277	11,757	30,498	29,348
2000	12,176	11,541	29,833	28,496
2001	12,624	12,029	30,010	28,929
2002	11,998	11,243	28,911	27,901
2003	11,299	10,510	25,426	23,748
2004	11,405	10,379	25,588	23,379
2005	11,913		26,470	

Table 13.12. Estimated fishing mortality rates for rougheye and shortraker rockfishes from the 2004 and 2003 assessments.

	Rougheye		Shortraker	
Year	2004 Assessment	2003 Assessment	2004 Assessment	2003 Assessment
1980	0.015	0.014	0.013	0.012
1981	0.028	0.026	0.017	0.015
1982	0.014	0.013	0.018	0.017
1983	0.005	0.005	0.007	0.007
1984	0.005	0.005	0.003	0.002
1985	0.001	0.001	0.001	0.001
1986	0.003	0.003	0.001	0.001
1987	0.008	0.008	0.002	0.002
1988	0.009	0.009	0.002	0.002
1989	0.029	0.028	0.006	0.006
1990	0.107	0.105	0.021	0.021
1991	0.014	0.014	0.015	0.015
1992	0.074	0.073	0.012	0.012
1993	0.065	0.061	0.016	0.014
1994	0.052	0.052	0.007	0.008
1995	0.028	0.027	0.008	0.007
1996	0.063	0.064	0.006	0.006
1997	0.075	0.077	0.004	0.005
1998	0.043	0.044	0.007	0.006
1999	0.033	0.033	0.006	0.006
2000	0.024	0.023	0.012	0.011
2001	0.052	0.056	0.006	0.005
2002	0.024	0.024	0.012	0.013
2003	0.012	0.015	0.007	0.008
2004	0.015		0.008	

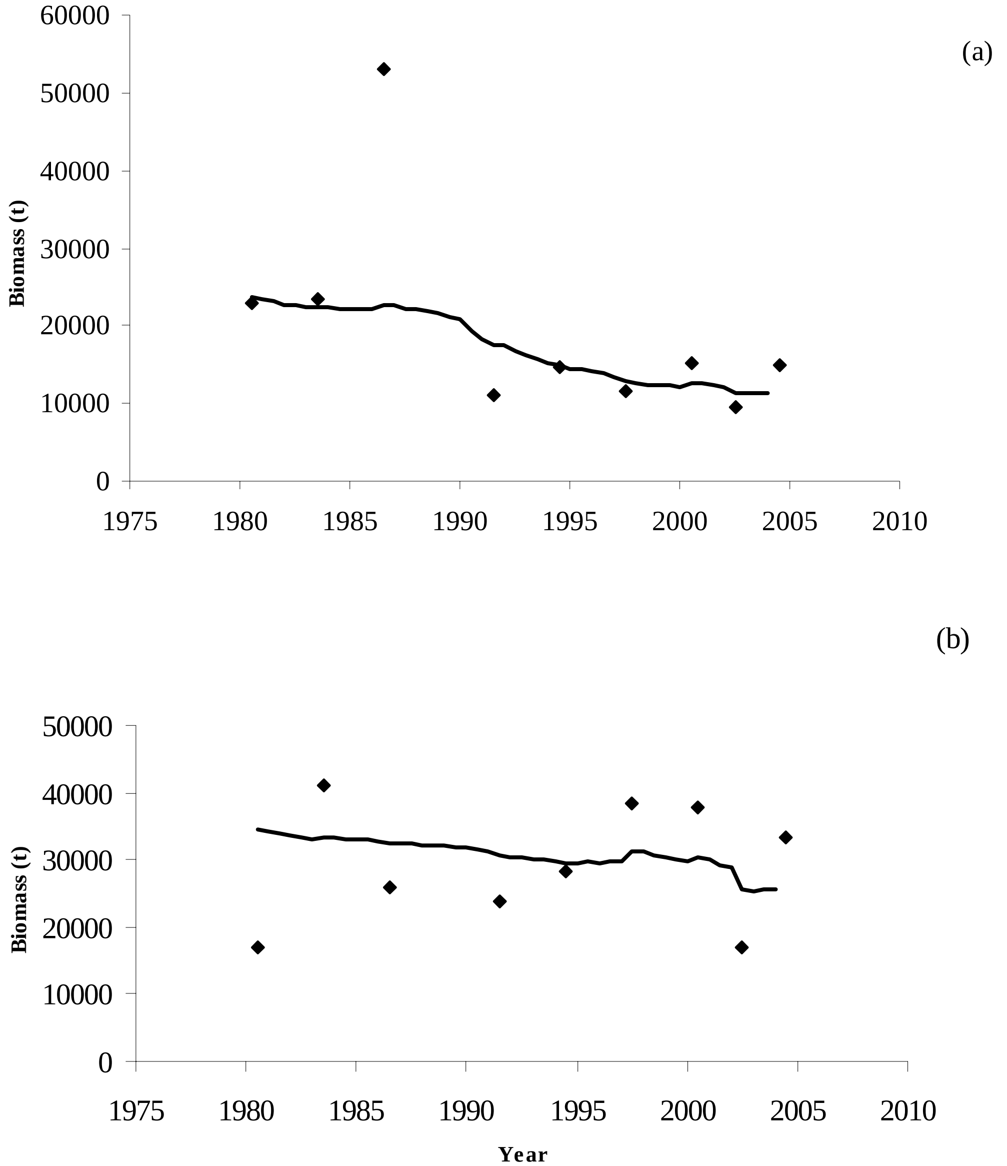

Figure 13.1. Survey biomass and estimated biomass of BSAI rougheye (a) and shortraker (b) rockfish.

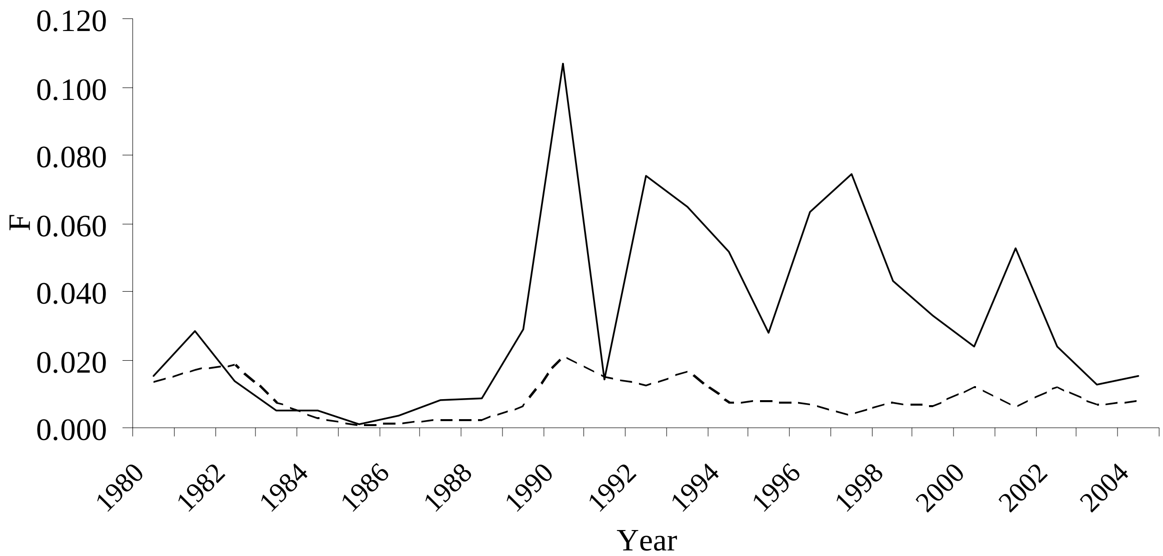

Figure 13.2. Estimated fishing mortality rate of BSAI rougheye (solid line) and shortraker (dashed line) rockfish.

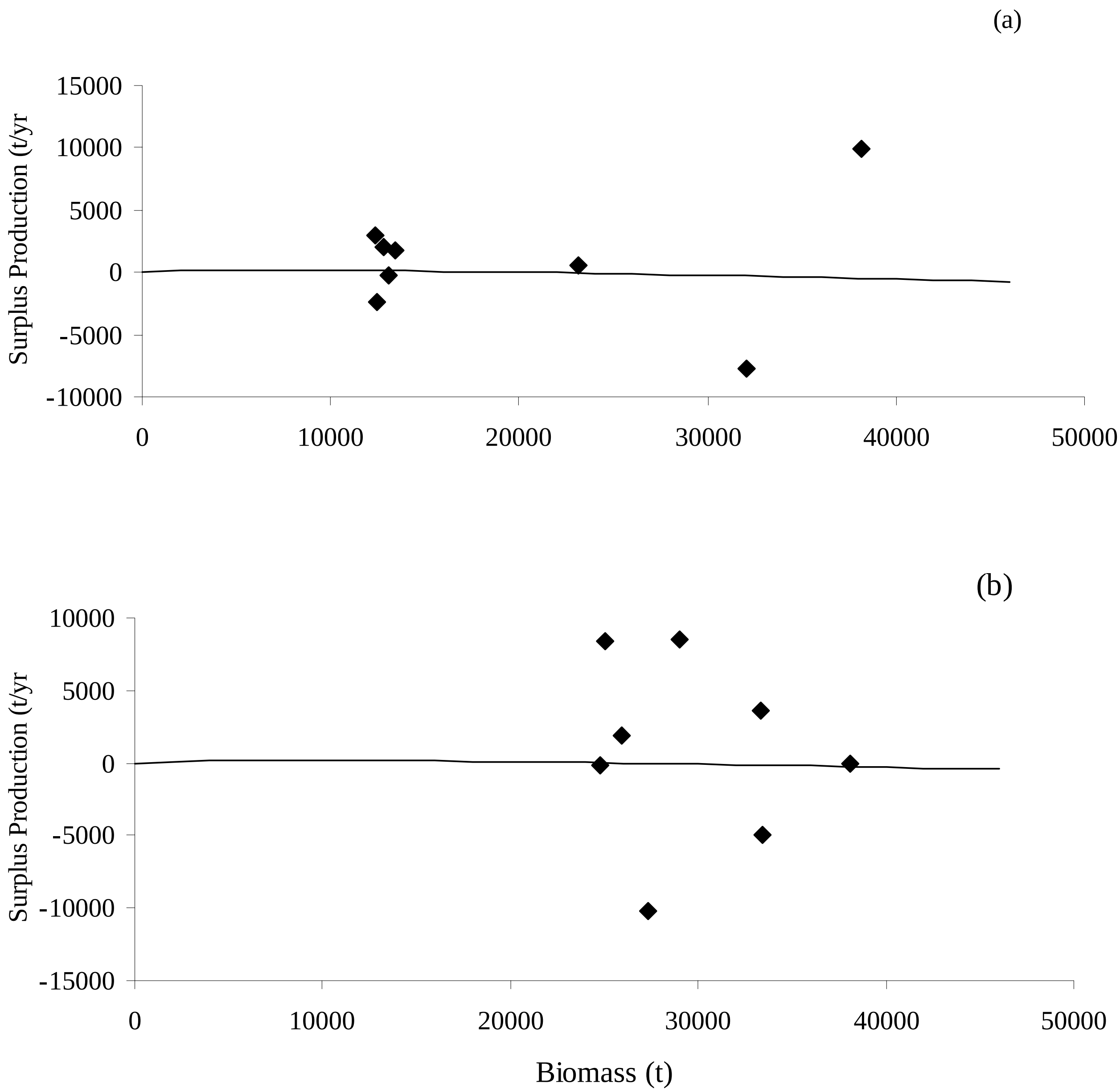

Figure 13.3. Annual surplus production and production model fits of BSAI rougheye (a) and shortraker rockfish (b).