CHAPTER 13A

SHORTRAKER ROCKFISH

by

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Executive Summary

In previous years, the shortraker and rougheye rockfish were assessed with a two-species surplus production model that accounted for potential covariance in catch estimates. The reading of archived rougheye rockfish otoliths has allowed an age-structured model to be developed for this species, and this assessment is now presented in a separate chapter. This chapter describes the application of a single-species surplus production model to BSAI shortraker rockfish.

The last full assessment for shortraker rockfish was presented to the Plan Team in 2006, and an updated assessment was presented in 2007. The following changes were made to the shortraker rockfish assessment relative to the November 2006 SAFE:

Summary of Changes in Assessment Inputs

Changes in the Input Data

(1) The landings data have been revised and updated through October 18, 2008.
(2) The historical Aleutian Islands survey data were updated based on the estimates provided by the AFSC/RACE Division.

Changes in the Assessment Methodology

The two-species surplus production model has been converted to a single-species surplus production model applied only to shortraker rockfish.

Summary of Results

A summary of the 2009 recommended ABCs and OFLs relative to the 2008 recommendations for shortraker rockfish is as follows:

Assessment Year	2007		2008	
Projection Year	2008	2009	2009	2010
M	0.03	0.03	0.03	0.03
Tier	5	5	5	5
Total Biomass (mt)	18,857	18,857	17,187	17,187
Max F_{abc} (=0.75*M*)	0.0225	0.0225	0.0225	0.0225
Rec. F_{abc}	0.0225	0.0225	0.0225	0.0225
F_{ofl} (=*M*)	0.03	0.03	0.03	0.03
OFL (mt)	564	564	516	516
Max ABC (mt)	424	424	387	387
Recommended ABC	424	424	387	387

INTRODUCTION

Shortraker rockfish (*S. borealis*) and four other species of rockfish (Pacific ocean perch, *S. alutus*; northern rockfish, *S. polyspinis*; rougheye rockfish, *S. aleutianus*; 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.

In previous years, the shortraker and rougheye rockfish were assessed with a two-species surplus production model that accounted for potential covariance in catch estimates. The reading of archived rougheye rockfish otoliths has allowed an age-structured model to be developed for this species, and this assessment is now presented in a separate chapter. This chapter describes the application of a single species surplus production model to BSAI shortraker rockfish.

Information on Stock Structure

A variety of types of research can be used to infer stock structure of shortraker rockfish, including larval distribution patterns, genetic studies, and other life-history information. 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.

Population structure for shortraker rockfish has 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 shortraker 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.

The trawl survey information also provides information on length composition in the EBS and AI areas. This information may be helpful in assessing whether shortraker rockfish might be considered separate stocks in these two areas, as differences in length composition may reflect differences in recruitment patterns. 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 analysis was applied to the combined length composition from the 2002 and 2004 survey, as the difference between years was non-significant. The test indicates that the mean size of shortraker in the southern Bering Sea area was different from other areas (Table 1), although this is likely due to an unusual number of very large fish found in this area (Figure 1).

FISHERY

Catches of shortraker rockfish have been reported in a variety of species groups in the foreign and domestic Alaskan fisheries. Foreign catch records did not report shortraker rockfish by species, but in categories such as "other species" (1977, 1978), "POP complex" (1979-1985, 1989), and "rockfish without POP" (1986-1988). As mentioned above, shortraker rockfish have been managed in the domestic fishery as part of the “other red rockfish” or “shortraker/rougheye” complexes. The ABCs, TACS, and catches by management complex from 1988-2008 are shown in Table 2. Since 2003, the catch accounting system (CAS) has reported catch of shortraker rockfish by species and area. From 1991-2002, shortraker rockfish catch was 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 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 shortraker rockfish since 1977 are shown in Table 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 4. Estimates of discarding of the other red rockfish complex in the EBS were generally above 56% from 1993 to 2002, with 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 RE/SR 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. Discard rates of BSAI shortraker rockfish from 2004-2007 have ranged from 23% to 49%.

Shortraker rockfish in the AI have been primarily taken in the longline fisheries for turbot, arrowtooth flounder, sablefish, halibut, and Pacific cod rockfish trawl, and the rockfish trawl fishery (Table 5). From 2004-2007, these fisheries accounted for 90% of the Aleutian Islands catch of shortraker. The central Aleutians contributed 58% of the 2004-2007 AI shortraker catch, followed by the western Aleutians (24%) and eastern Aleutians (18%). Catches of shortraker rockfish from 2004-2007 in the EBS management area were caught largely in midwater pollock and arrowtooth flounder trawl fisheries and longline fisheries for Pacific cod, turbot, and halibut; these fisheries contributed 92% of the total EBS catch (Table 6). Catches of shortraker rockfish in the EBS management area were concentrated in areas 517 and 521, the areas occupying much of the EBS slope.

DATA

Fishery Data

The catch data used in the assessment model are the estimates of single species catch described above and shown in Table 3. However, given the history of previously managing EBS rockfish as separate stock complexes, it is prudent to examine how current catches compare to potential area-specific harvest levels.

A comparison of 2002-2007 catch by species and area with what might have been used as an area-specific ABC level is shown in Table 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 shortraker have been far below their potential AI ABC levels. In contrast, the catch of EBS shortraker has exceeded the potential EBS ABC level from 2002 to 2005 and in 2007. However, because information on the degree of linkage between the EBS and AI areas is not clear, it is uncertain whether disproportionate harvest in the EBS is a management concern.

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, 2004, and 2008 on the eastern Bering Sea slope, and in 1991, 1994, 1997, 2000, 2002, 2004, and 2006 in the Aleutian Islands (Table 13.8). The 2008 Aleutian Islands survey was canceled due to lack of funding. 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 shortraker rockfish, as the bulk of the population are believed to be centered in the Aleutian Islands. Shortraker 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 surveys 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 biennial EBS slope survey was initiated in 2002. The most recent slope survey prior to 2002, excluding some preliminary tows in 2000 intended for evaluating survey gear, was in 1991. The 2008 EBS slope survey was completed, but the 2006 survey was canceled due to lack of funding. The survey biomass estimates of shortraker rockfish from the 2002, 2004, and 2008 surveys were 4,851 t, 2,570 t, and 7,552 t, respectively, with CVs of 0.44, 0.22, and 0.31. The slope survey results are not used in this assessment, and the feasibility of incorporating this time series will be evaluated in future years.

ANALYTICAL APPROACH

Model Structure

A simple surplus production model, the Gompertz-Fox model, was used to model the shortraker rockfish population, and the Kalman filter provided a method of statistically estimating the parameter values. The model was implemented in the software program AD Model Builder. 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 (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 0_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. For the shortraker rockfish application there is a single state variable at each time step (the log biomass) and the problem simplifies considerably and all terms become scalars. Finally, the state variable is described by a distribution with an estimated mean $\forall_t$ 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 $,_t$ 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 $\forall_{t-1}$ 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 $\forall_{t-1}$. Because this prior estimate of X_t uses all the data up to time $t-1$, it is denoted as $\forall_{t|t-1}$. 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 $\forall_{t|t-1}$. The Kalman filter updates the prior and produces a posterior estimate, $\forall_{t|t}$, 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

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

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 $<_t$ (the one step ahead prediction error) is $y_t - Z_t \forall_{t|t-1} - d_t$.

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

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

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

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

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

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

where)t is a discrete time period. For a single species case, defining $T_t = e^{-a)t}$ and $c_t = (1\text{-}T_t)B_t$ produces the deterministic portion of the state equation (Eq. 3).
For shortraker rockfish, 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,

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

where s_sr_t is the survey biomass estimates of shortraker rockfish in year t, c_sr_t is the aggregated catch of shortraker rockfish during year t, q_sr is the survey catchability coefficient, and f_sr_t is the rate of removal 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:

$$Y_t = [\ln(c\_sr_t)], \qquad Z_t = [1], \text{ and } d_t = [\ln(f\_sr_t)]$$

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 ($\forall_0$ 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 rockfish 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 shortraker rockfish catch would be obtained by

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

where p_{SR} is the proportion of 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. 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 of the log of estimated catch can be obtained from the Delta method (Seber 1982) and is

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

where N is the assumed sample size for the multinomial distribution, Φ 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. In addition, two species-specific estimates of catch are likely to be correlated because they are functions with some variables in common, but this covariance is not utilized in the single species model.

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

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

where i indexes the total number terms in the summation, and the means and variances of each of the terms within this summation are additive.

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 Φ = 0.15. Because of the longevity and perceived low population growth rate of shortraker rockfish, the process error CV was set to the relatively low value of 0.05.

Parameters Estimated Conditionally

The parameters estimated conditionally in the model include a, k, and f_t. The estimation of a 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 of 0.03, and a large CV of 1.0 was used for the variance. This estimate of natural mortality is consistent with estimates for north Pacific shortrakers using the gonad somatic index, which ranged from 0.027 to 0.042 (McDermott 1994). 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 and fishing mortality rates

Estimated shortraker rockfish biomass decreased slightly from 29,138 t in 1980 to 26,331 t in 1997, and have since declined to 17,187 t in 2009 (Figure 2, Table 9). The time series of estimated fishing mortality show the largest values of approximately 0.025 to 0.03 in the early 1980s and early 1990s, which are comparable to assumed natural mortality estimate of 0.03 (Figure 3).

Annual Surplus Production

Considerable uncertainty in the parameter estimates of *a* in the Gompertz-Fox model exists for the shortraker rockfish. 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 4, and indicate little information on the *a* parameter for shortraker rockfish. 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 shortraker rockfish, 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 shortraker rockfish life-history characteristics.

Projections and Harvest Alternatives

Shortraker rockfish 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 shortraker rockfish 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:

	2009 biomass	M	ABC	OFL
Shortraker rockfish	17,187	0.03	387 t	516 t

Summary

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

Quantity	Value
M	0.03
Tier	5
Year 2009 Total Biomass	17,187 t
F_{OFL} (Shortraker)	0.03
Maximum F_{ABC} (Shortraker)	0.0225
Recommended F_{ABC} (Shortraker)	0.0225
OFL (Shortraker)	516 t
Maximum allowable ABC (Shortraker)	387 t
Recommended ABC (Shortraker)	387 t

REFERENCES

Dorn, M.W. 1992. Detecting environmental covariates of Pacific whiting *Merluccius productus* growth using a growth-increment model. Fish. Bull. 90:260:275.

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

Kimura, D.K., and S. Chikuni. 1987. Mixtures of empirical distributions: an iterative application of the age-length key. Biometrics 43:23-34.

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.

Gharrett, A.J., A.P. Matala, E.L. Peterson, A.K. Gray, Z. Li, and J. Heifetz. 2004. Distribution and population genetic structure of sibling species of rougheye rockfish based on microsatellite and mitochondrial variation. Semiannual progress report to the North Pacific Research Board, Anchorage, AK.

Gharrett, A.J., A.P. Matala, E.L. Peterson, A.K. Gray, Z. Li, and J. Heifetz. 2005. Two genetically distinct forms of rougheye rockfish are different species. Trans. Am. Fish. Soc. 132:242-260.

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.

McDermott, S.F. 1994. Reproductive biology of rougheye and shortraker rockfish, *Sebastes aleutianus* and *Sebastes borealis*. M.S. thesis, University of Washington, Seattle. 76 pp.

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

Orlov,A.M. 2001. Ocean current patterns and aspects of life-history of some northwestern Pacific scorpaenids. Pp. 161-184. In: G.H. Kruse, N. Bez, A. Booth, M.W. Dorn, S. Hills, R.N. Lipcius, D. Pelletier, C. Roy, S.J. Smith, and D. Witherell (ed.). Spatial process and management of marine populations. Pub. No. AK-SG-01-02. Univeristy of Alaska Sea Grant College Program, Fairbanks, AK.

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

Area	EBS	SBS	Central AI	Eastern AI	Western AI
EBS		0.043	0.887	0.160	0.212
SBS			0.048	0.008	0.010
Central AI				0.116	0.160
Eastern AI					0.912

Table 2. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the species groups used to manage shortraker rockfish from 1988 to 2008. The "other red rockfish" group includes, shortraker rockfish, rougheye rockfish, northern rockfish, and sharpchin rockfish. The "POP complex includes the other red rockfish species plus POP.

Year	Area	Management Group	ABC (t)	TAC (t)	Catch (t)
1988	BS	POP Complex	6,000		1,509
	AI	POP Complex	16,600		2,629
1989	BS	POP Complex	6,000		2,873
	AI	POP Complex	16,600		3,780
1990	BS	POP Complex	6,300		7,231
	AI	POP Complex	16,600		15,224
1991	BS	Other Red Rockfish	1,670	1,670	942
	AI	Rougheye/Shortraker	1,245	1,245	388
1992	BS	Other Red Rockfish	1,400	1,400	467
	AI	Rougheye/Shortraker	1,220	1,220	1,470
1993	BS	Other Red Rockfish	1,400	1,200	1,226
	AI	Rougheye/Shortraker	1,220	1,100	1,139
1994	BS	Other Red Rockfish	1,400	1,400	129
	AI	Rougheye/Shortraker	1,220	1,220	925
1995	BS	Other Red Rockfish	1,400	1,260	344
	AI	Rougheye/Shortraker	1,220	1,098	559
1996	BS	Other Red Rockfish	1,400	1,260	207
	AI	Rougheye/Shortraker	1,250	1,125	959
1997	BS	Other Red Rockfish	1,050	1,050	218
	AI	Rougheye/Shortraker	938	938	1,043
1998	BS	Other Red Rockfish	267	267	112
	AI	Rougheye/Shortraker	965	965	685
1999	BS	Other Red Rockfish	356	267	238
	AI	Rougheye/Shortraker	1,290	965	514
2000	BS	Other Red Rockfish	259	194	253
	AI	Rougheye/Shortraker	1,180	885	480
2001	BSAI	Rougheye/Shortraker	1,028		
	BS	Rougheye/Shortraker		116	72
	AI	Rougheye/Shortraker		912	722
2002	BSAI	Rougheye/Shortraker	1,028		
	BS	Rougheye/Shortraker		116	105
	AI	Rougheye/Shortraker		912	478
2003	BSAI	Rougheye/Shortraker	967		
	BS	Rougheye/Shortraker		137	124
	AI	Rougheye/Shortraker		830	306
2004	BSAI	Shortraker	526	526	240
2005	BSAI	Shortraker	596	596	169
2006	BSAI	Shortraker	580	580	209
2007	BSAI	Shortraker	424	424	322
2008*	BSAI	Shortraker	424	424	132

* Estimated removals through October 18, 2008.

Table 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	0		27	0		27
1978	1069	0		874	0		1943
1979	279	0		3008	0		3286
1980	649	0		185	0		833
1981	441	0		381	0		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	0	36	64
1988	0	0	31	0	0	37	69
1989	0	0	58	0	0	130	188
1990			116			546	662
1991			205			251	456
1992			79			289	368
1993			221			216	437
1994			46			178	224
1995			49			166	215
1996			87			138	225
1997			36			85	122
1998			52			158	209
1999			66			131	197
2000			130			213	343
2001			57			137	194
2002			93			230	323
2003			107			131	238
2004			119			121	240
2005			108			61	169
2006			47			162	209
2007			113			209	322
2008*							132

* Estimated removals through October 18, 2008.

Table 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 was managed as a single complex.

Area	Species 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	RE/SR	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	SR	2004	143	97	240	40.6%
		2005	129	39	168	23.3%
		2006	130	78	209	37.6%
		2007	163	159	322	49.4%

Table 5. Aleutian Islands catch (t) of shortraker rockfish by management area and target fishery from 2004-2007, from the NMFS Alaska Regional Office catch accounting system database.

		Management area			
Target Fishery	Gear	541	542	543	Total
Rockfish	Bottom trawl	41.90	104.00	126.17	272.07
Turbot	Longline	0.24	111.07		111.31
Arrowtooth	Longline	1.57	59.71		61.27
Sablefish	Longline	26.18	30.34	0.39	56.91
Halibut	Longline	7.48	12.96	11.56	32.00
Pacific Cod	Longline	27.30	2.72	1.62	31.63
Other species	Bottom trawl		21.13		21.13
Atka	Bottom trawl	0.59	4.19	11.94	16.71
Pacific Cod	Bottom trawl	0.48	6.49	0.02	6.99
Other species	Longline		6.24		6.24
Sablefish	Pot	3.86	1.73		5.59
Arrowtooth	Bottom trawl	2.24			2.24
Pacific Cod	Pot		0.64		0.64
Pollock	Pelagic trawl	0.47			0.47
Rockfish	Longline		0.10	0.23	0.33
Pollock	Pelagic trawl	0.03			0.03
Rockfish	Pot	0.01			0.01
Total		112.76	361.29	151.93	625.99

Table 6. Eastern Bering Sea catch (t) of shortraker rockfish by management area and target fishery from 2004-2007, from the NMFS Alaska Regional Office catch accounting system database. Gear types abbreviations are pelagic trawl (PT), bottom trawl (BT), and longline (LL).

		Management area									
Target Fishery	Gear	508	509	513	517	518	519	521	523	524	Total
Pollock	PT		0.20	2.25	193.11		3.80	22.46	0.05		221.87
Pacific Cod	LL				6.79	0.04	0.90	60.69	15.24	0.01	83.67
Turbot	LL				1.26	0.01	0.15	32.62	17.27	0.77	52.08
Halibut	LL			0.01	1.06	5.17	0.15	7.68	0.48	0.43	14.98
Arrowtooth	BT				3.55	1.74	4.51		0.30	0.08	10.18
Sablefish	LL	0.00			6.83	0.29	0.12		0.43		7.67
Turbot	BT				5.00						5.00
Other Species	LL							0.36	4.19	0.01	4.55
Other Flatfish	BT				2.09		1.74				3.82
Arrowtooth	LL				0.70	0.59	0.01		1.47		2.77
Rockfish	LL					0.04		1.65	0.01		1.70
Rockfish	BT				1.28		0.22				1.50
Flathead sole	BT				0.03		0.65	0.78			1.45
Pacific Cod	BT				0.19		0.30	0.87			1.37
Sablefish	Pot				0.04	0.81	0.50				1.36
Other Species	BT				1.30						1.30
Atka mackerel	BT						0.43				0.43
Rock Sole	BT				0.08						0.08
Sablefish	BT						0.04				0.04
Total		0.00	0.20	2.26	223.28	8.69	13.54	127.09	39.44	1.30	415.82

Table 7. Comparison of catch (t) of shortraker from 2002 to 2007 with potential area-specific ABC levels.

	Aleutian Islands		Eastern Bering Sea	
Year	Total Catch	ABC	Total Catch	ABC
2001	137	682	57	84
2002	230	682	93	84
2003	131	615	107	104
2004	121	442	119	84
2005	61	501	108	95
2006	162	487	47	93
2007	209	373	113	50

Table 8. Estimated biomass (t) of shortraker rockfish from the NMFS bottom trawl surveys, with the coefficient of variation (CV) is shown in parentheses.

Year	AI survey	EBS Slope survey
1979		1,391
1980	6,874 (0.55)	
1981		3,571
1982		5,176
1983	35,831 (0.19)	
1984		
1985		4,010
1986	18,153 (0.28)	
1987		
1988		1,260 (0.43)
1989		
1990		
1991	23,760 (0.64)	2,758 (0.38)
1992		
1993		
1994	28,244 (0.21)	
1995		
1996		
1997	38,487 (0.26)	
1998		
1999		
2000	37,797 (0.44)	
2001		
2002	16,846 (0.19)	4,851 (0.44)
2003		
2004	33,215 (0.37)	2,570 (0.22)
2005		
2006	12,961 (0.23)	
2007		
2008		7,552 (0.31)

Table 9. Estimated fishing mortality rates and beginning year biomass for shortraker rockfish from the 2006 and 2008 assessments.

	Biomass (t)		Fishing Mortality Rate	
Year	2008 Assessment	2006 Assessment	2008 Assessment	2006 Assessment
1980	30,045	21,707	0.028	0.039
1981	28,573	20,817	0.028	0.038
1982	27,747	20,357	0.022	0.029
1983	27,254	20,342	0.008	0.011
1984	28,677	21,029	0.003	0.004
1985	28,183	21,373	0.001	0.001
1986	27,709	21,870	0.001	0.001
1987	25,705	22,748	0.002	0.003
1988	25,563	22,989	0.003	0.003
1989	25,470	23,268	0.007	0.008
1990	25,264	23,432	0.025	0.026
1991	25,530	23,795	0.017	0.019
1992	25,461	24,010	0.014	0.030
1993	25,305	23,786	0.017	0.020
1994	25,291	23,972	0.009	0.009
1995	25,546	24,869	0.008	0.009
1996	25,338	24,849	0.009	0.008
1997	25,128	24,865	0.005	0.004
1998	26,147	26,503	0.009	0.009
1999	25,049	25,549	0.008	0.008
2000	24,007	24,617	0.015	0.015
2001	23,095	23,960	0.009	0.008
2002	22,087	23,163	0.016	0.015
2003	20,365	21,005	0.012	0.011
2004	19,859	20,801	0.012	0.012
2005	19,890	21,057	0.009	0.009
2006	19,252	20,479	0.012	0.007
2007	17,703		0.018	
2008	17,348		0.008	

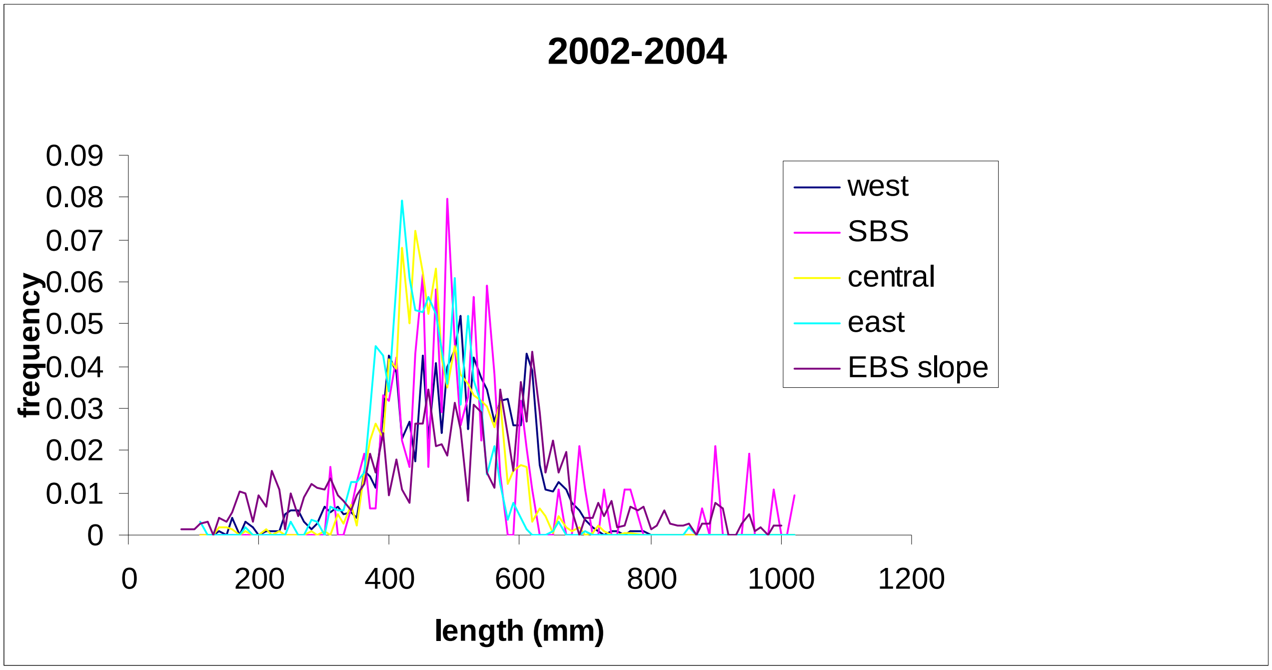

Figure 1. Combined length composition of shortraker rockfish from the EBS slope survey and four areas of the AI survey from 2002 and 2004.

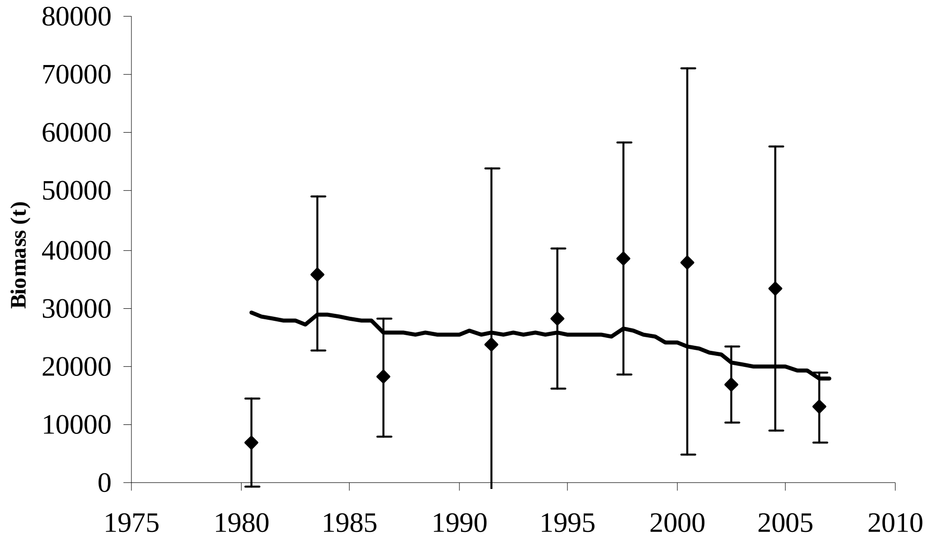

Figure 2. Observed AI survey biomass (data points +/- 2 standard deviations) and predicted survey biomass estimates from the Kalman filter model.

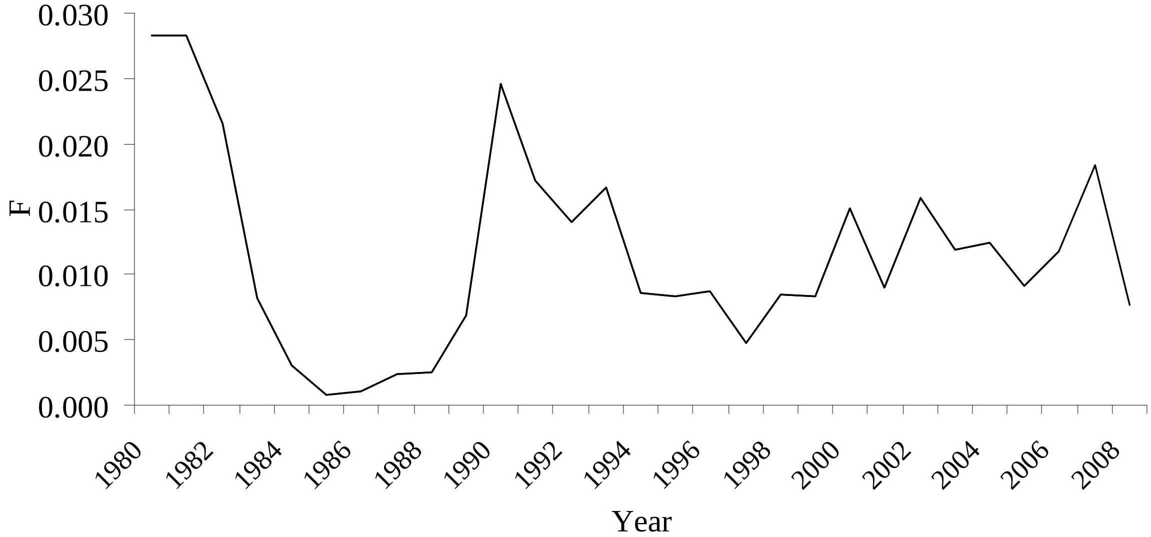

Figure 3. Estimated fishing mortality rate of BSAI shortraker rockfish.

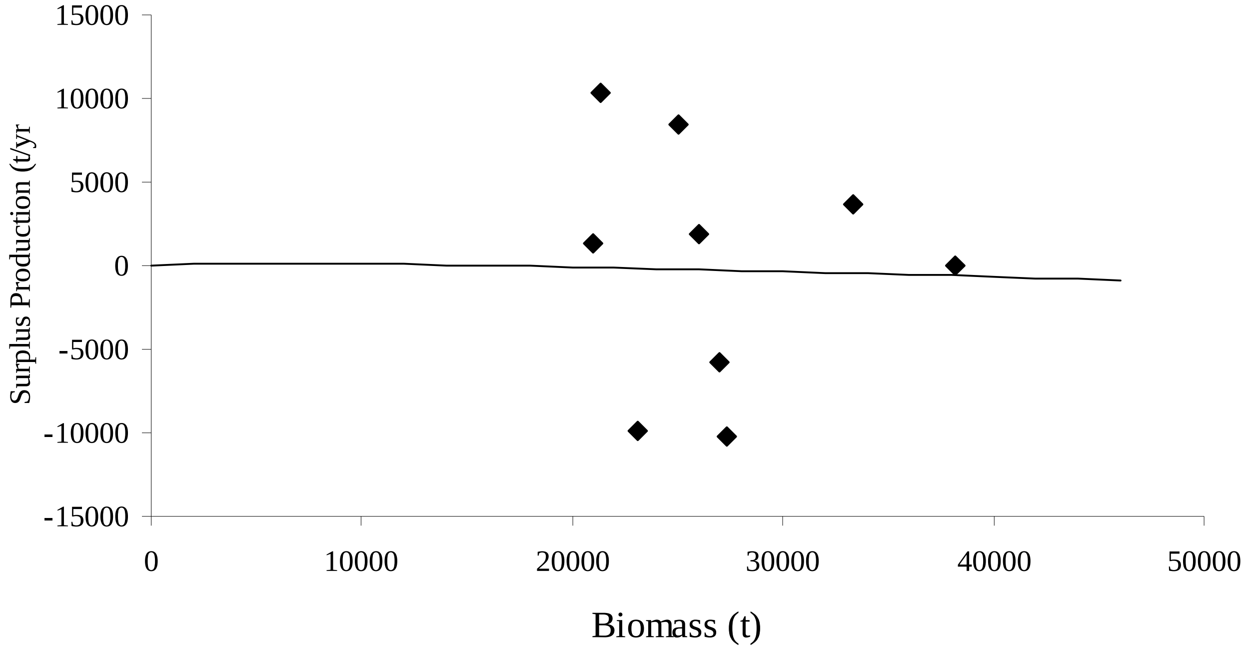

Figure 4. Annual surplus production and production model fits of BSAI shortraker rockfish.