15. Assessment of the Shortraker Rockfish stock in the Bering Sea/Aleutian Islands

by

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Executive Summary

Prior to 2008, the shortraker and rougheye rockfish were assessed with a two-species surplus production model that accounted for potential covariance in catch estimates. An age-structured model for rougheye rockfish was developed in 2008, which resulted in a separate assessment for shortraker rockfish. No changes were made in the surplus production model from the 2008 assessment, which was re-run with the most recent catch and survey data.

Summary of Changes in Assessment Inputs

Changes in the input data

1) The landings data have been revised and updated through October 6, 2012.
2) The biomass estimate from the 2012 AI survey was added to the model input data.

Changes in the assessment methodology

1) There were no changes in the assessment methodology

Summary of Results

The recommended 2013 ABC and OFL for BSAI shortraker rockfish are 370 t and 493 t, respectively, and are 6% declines from the 2012 values of 393 and 524 t. A summary of the recommended ABCs and OFLs from this assessment relative the ABC and OFL specified last year is shown below:

Quantity/Status	As estimated or *specified last* year for: 2012	2013	As estimated or *recommended this* year for: 2013	2014
M (natural mortality rate)	0.03	0.03	0.03	0.03
Tier	5	5	5	5
Biomass (t)	17,452	17,452	16,447	16,447
F_{OFL}	0.03	0.03	0.03	0.03
$maxF_{ABC}$	0.0225	0.0225	0.0225	0.0225
F_{ABC}	0.0225	0.0225	0.0225	0.0225
OFL (t)	524	524	493	493
maxABC (t)	393	393	370	370
ABC (t)	393	393	370	370
Status	As determined *last* year for: 2010	2011	As determined *this* year for: 2011	2012
Overfishing	No	n/a	No	n/a
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)				

Summaries for the Plan Team

The following table gives the recent biomass estimates, catch, and harvest specifications, and projected biomass, OFL and ABC for 2013-2014.

Year	Biomass	OFL	ABC	TAC	Catch
2011	17,452	524	393	393	234
2012	17,452	524	393	393	283[1]
2013	16,447	493	370		
2014	16,447	493	370		

[1] Catch as of October 6, 2012.

Responses to SSC and Plan Team Comments on Assessments in General

"The SSC is pleased to see that many assessment authors have examined retrospective bias in the assessment and encourages the authors and Plan Teams to determine guidelines for how to best evaluate and present retrospective patterns associated with estimates of biomass and recruitment. We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments." (SSC, December 2011)

"The SSC concurs with the Plan Teams' recommendation that the authors consider issues for sablefish where there may be overlap between the catch-in-areas and halibut fishery incidental catch estimation (HFICE) estimates. In general, for all species, it would be good to understand the unaccounted for catches and the degree of overlap between the CAS and HFICE estimates, and to discuss these at the Plan Team meetings next September." (SSC, December 2011)

"The Teams recommend that authors continue to include other removals in an appendix for 2013. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment must also be presented. The Teams recommend that the "other" removals data set continue to be compiled, and expanded to include all sources of removal." (Plan Team, September 2012)

"For the November 2012 SAFE report, the Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous years." (Plan Team, September 2012)

Tables of other removals are reported in an Appendix in this assessment. Retrospective model runs do not apply to this Tier 5 assessment

Responses to SSC and Plan Team Comments Specific to this Assessment

There were no comments or requests from the 2010-2012 SSC or Plan Team meetings pertaining to BSAI shortraker rockfish.

Introduction

Shortraker rockfish (*S. borealis*) are distributed along the continental slope in the north Pacific from Point Conception in southern California to Japan, and are commonly found between eastern Kamchatka and British Columbia (Love et al. 2002). Shortraker rockfish are among the longest lived animal species in the world, reaching ages > 150 years. The species is viviparous with spawning believed to occur throughout the spring and summer (Westerheim 1975, McDermott 2004). Little is known of shortraker rockfish early life history and habitat preferences, as immature fish are rarely observed. Love et al. (2002) indicates the species is found at shallower depths during early life history. As adults the species occurs in a narrow range of depths on the continental slope centered at ~350 m (Rooper 2008) often in areas of steep slope (Rooper and Martin 2012). In bottom trawl survey data, the species is most common through the Aleutian Islands and northern Gulf of Alaska. Studies of habitat preferences in the Gulf of Alaska indicate shortraker rockfish may be more abundant in boulder patches with associated *Primnoa* coral (Krieger and Ito 1999, Krieger and Wing 2002). Shortraker rockfish consume large benthic or near-bottom prey, including of myctophids, shrimp and squid (Yang et al. 2006).

Shortraker rockfish 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. Prior to 2008, the shortraker and rougheye rockfish were assessed with a two-species surplus production model that accounted for potential covariance in catch estimates. An age-structured assessment model was developed for rougheye rockfish in 2008, which resulted in a separate assessment for 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 and genetic studies. In 2002, an analysis of archived *Sebastes* larvae was undertaken by Dr. Art Kendall; using data collected in 1990 off southeast Alaska (650 larvae) and the AFSC ichthyoplankton database (16,895 *Sebastes* larvae, collected on 58 cruises from 1972 to 1999, primarily in the Gulf of Alaska). The southeast Alaska larvae all showed the same morph, and were too small to have characteristics that would allow species identification. A preliminary examination of the AFSC ichthyoplankton database indicates that most larvae were collected in the spring, the larvae were widespread in the areas sampled, and most were small (5-7 mm). The larvae were organized into three size classes for analysis: <7.9 mm, 8.0-13.9 mm, and >14.0 mm. A subset of the abundant small larvae was examined, as were all larvae in the medium and large groups. Species identification based on morphological characteristics is difficult because of overlapping characteristics among species, as few rockfishes species in the north Pacific have published descriptions of the complete larval developmental series. However, all of the larvae examined could be assigned to four morphs identified by Kendall (1991), where each morph is associated with one or more species. Most of the small larvae examined belong to a single morph, which contains the species *S. alutus* (POP), *S. polyspinus* (northern rockfish), and *S. ciliatus* (dusky rockfish). Some larvae (18) belonged to a second morph which has been identified as *S. borealis* (shortraker rockfish) in the Bering Sea. The locations of these larvae were near Kodiak Island, the Semidi Islands, Chirkof Island, the Shumagin Islands, and near the eastern end of the Aleutian Islands.

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.

Spatial differences in life-history characteristics, such as growth rates and age at maturity, could also provide information on stock structure. However, little data is available on these processes, in part because of the difficulty of aging shortraker rockfish. Production aging of shortraker rockfish is currently impeded by the lack of consistent age criteria. Recently, ^{14}C age validation studies appear promising, but additional testing regarding the accuracy of ages may be needed before initiating production aging.

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 1988-2010 are shown in Table 1. Since 2003, the catch accounting system (CAS) has reported catch of shortraker rockfish by species and area. From 1991-2002, shortraker rockfish catch was reconstructed 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. This reconstruction was conducted by estimating the shortraker catch for each area (i.e., the EBS and each of the three AI areas) and gear type from 1994-2002. For 1991-1993, the Regional Office blend catch data for the Aleutian Islands was not reported by AI subarea, and the AI catch was obtained using the observer harvest proportions by gear type for the entire AI area. Similar procedures were used to reconstruct 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 2. Catches were relatively high during the late 1970s, declined during the late 1980s as the foreign fishery was reduced, increased in the early 1990s, and declined in the mid-1990s.

The catches by area from 1994-2012 have been variable, with the largest catches often occurring in the EBS (Table 3). From 1996 to 2010, 38% of the shortraker catch occurred in the EBS, with 28%, 16%, and 17% in the central, western, and eastern AI areas respectively. Catches in the western Aleutians increased in 2011-2012 to an average of 164 t, as compared to an average of 37 t from 1996-2009, which resulted in the proportion of catch in the western AI in 2011-2012 increasing to 53%.

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 55% from 1993 to 2000, with the exception of 1993 and 1995 when discarding rates were less than 26%. The variation in discard rates may reflect different species compositions of the other red rockfish catch. Discard rates of EBS RE/SR complex from 2001 to 2003 have been below 52%, and discard rates of AI SR/RE complex from 1993-2003 have been below 41%. In general, the discard rates of EBS RE/SR are less than the discard rates of EBS other red rockfish in most years, likely reflecting the relatively higher value of rougheye and shortraker rockfishes over other members of the complex. Discard rates of BSAI shortraker rockfish from 2004-2010 have ranged from 23% to 50%, but declined to 12% in 2011 and 19% for 2012 (through Oct 6).

Shortraker rockfish in the AI have been primarily taken in the rockfish trawl fishery, the turbot, sablefish, arrowtooth flounder, halibut, and Pacific cod longline fisheries, and the Atka mackerel, Pacific cod, arrowtooth flounder, and Kamchatka flounder trawl fisheries (Table 5). From 2004-2012, these fisheries accounted for 98% of the Aleutian Islands catch of shortraker. Catches of shortraker rockfish from 2004-2010 in the EBS management area were caught largely in the midwater pollock trawl fishery, Pacific cod, turbot, halibut, and sablefish longline fisheries, and arrowtooth flounder, other flatfish, and rockfish trawl fisheries; these fisheries contributed 95% 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 length composition from observer sampling of the domestic fishery is shown in Figure 1, and indicate relatively consistent length distributions with the bulk of the sampled fish generally between 30 and 70 cm. The proportion of “large” (defined here as greater than or equal to 60 cm) fish in the fishery has varied between 15% and 54% between 1991 and 2012.

The catch data used in the assessment model are the estimates of single species catch described above and shown in Table 2. However, given the history of previously managing EBS rockfish as separate stock complexes, and recent information on genetic population structure for other BSAI rockfish species, it is prudent to examine how area-specific exploitation rates compare to F_{abc} and F_{ofl} reference points.

Area-specific exploitation rates for a given year were obtained by dividing the yearly catch by the estimate of biomass for the subarea. The subareas considered here are the 3 AI subareas, the southern Bering Sea (i.e., areas 518 and 519) and the EBS (i.e., the remainder of the EBS managemnent area minus the southern Bering Sea). The subarea biomass for each year was obtained by partitioning the estimated biomass at the beginning of the year (obtained from Kalman filter model) into the subareas. A weighted average of the three most recent surveys was applied to each subarea (weights of 4, 6, and 9, with recent surveys higher weights), and the proportions from these averages were used to partition the projected biomass. The variable but high catches in the EBS have resulted in variable but generally high exploitation rates in the EBS, which have exceeded the estimated natural mortality rate (M) of 0.03 in 4 of the 8 years from 2004-2011 (Figure 2). The recent increase in the catch in the western AI has also resulted in the exploitation rates in this area exceeding M in 2011. Exploitation rates in the central AI and eastern AI have been below M and generally low from 2004-2011.

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, 2008, 2010, and 2012 on the eastern Bering Sea slope, and in 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, and 2012 in the Aleutian Islands (Table 7). The 2008 Aleutian Islands survey and 2006 EBS slope survey were 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.

In contrast to the fishery length compositions, the survey length compositions reveal less fish at the larger sizes (Figure 3). In surveys from 1994 to 2006, fish lengths from survey samples generally occurred between approximately 30 cm and 65 cm. The proportion of fish greater than or equal to 60 cm) has varied between 4% and 12% between 1980 and 2012. In the 2010 and 2012 surveys, a larger proportion of samples were less than 30 cm in the 2010 and 2012 survey relative to the 1994-2006 surveys.

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 did not use 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 Aleutian Island surveys from 1991 to 2012 indicated higher abundances in the Western (543) and Central (542) than in the eastern Aleutian Islands (541), with the southern Bering Sea area having the lowest abundance (Figure 4). However, in the 2010 and 2012 shortraker rockfish were relatively evenly spread across throughout the AI management area. In particular, areas near Atka and Adak Islands, Amchitka and Kiska Islands, and Attu Island and Stalemate Bank showed high CPUE in 2010 and 2012 survey tows.

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 survey biomass estimates of shortraker rockfish from the 2002-2012 EBS slope surveys have ranged between 2570 t (2004) and 9,299 t (2012), with CVs between 0.22 and 0.57. The slope survey results are not used in this assessment, and the feasibility of incorporating this time series will be evaluated in future assessments.

Analytic 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

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

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

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

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

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

where X_t is a vector of state variables at time t, T_t is a matrix containing the parameter that define state dynamics , c_t is a $m \times 1$ vector of constants (in, general, this could be set to zero), 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. 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 α_t and variance P_t.

The observation equation is

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

where Y_t is a vector of observed variables, Z_t is a matrix containing parameters that define how observations are generated, d_t is a $n \times 1$ vector (in general, this could be set to zero) 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

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

where F_t is $Z_tP_{t|t-1}Z_t^{'} + H_t$, $P_{t|t-1}$ (the prior estimate of the variance of the state variable) is $T_tP_{t-1}T_t^{'} + R_tQ_tR_t^{'}$, 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

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

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

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

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

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

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 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,

$$Y_t = \begin{bmatrix} \ln(s_t) \\ \ln(c_t) \end{bmatrix},\ Z_t = \begin{bmatrix} 1 \\ 1 \end{bmatrix},\ \text{and}\ d_t = \begin{bmatrix} \ln(q) \\ \ln(f_t) \end{bmatrix}$$

where s_t is the survey biomass estimates of shortraker rockfish in year t, c_t is the aggregated catch of shortraker rockfish during year t, q is the survey catchability coefficient, and f_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:

$$Y_t = [\ln(c_t)],\quad Z_t = [1],\ \text{and}\ d_t = [\ln(f_t)]$$

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 (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 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, 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. 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.

Parameter estimates

The survey catchability coefficient for each species was fixed at 1.0. Attempts to obtain reasonable estimate of survey catchability were not successful, reflecting a catch history that does not provide information regarding the scale of population biomass. 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 rate of shortraker rockfish, the process error CV was set to the relatively low value of 0.05.

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 shortraker rockfish 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 29,776 t in 1980 to 26,249 t in 1997, and have since declined to 16,858 t in 2012 (Figure 5, Table 8). 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 6).

Annual Surplus Production

Considerable uncertainty in the parameter estimates of a in the Gompertz-Fox model exists for 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 7, 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.

Harvest Recommendations

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. The estimate of *M* for shortraker rockfish was obtained from Heifetz and Clausen (1991), and for Tier 5 stocks, F_{ofl} and F_{abc} are defined as *M* and 0.75*M*, respectively. 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:

	2013 biomass	M	ABC	OFL
Shortraker rockfish	16,447 t	0.03	370 t	493 t

Data Gaps and Research Priorities

Validating aging techniques of shortraker rockfish, and obtaining ages from archived samples, remains research priorities and are required for age-structured population modeling. More information on the genetic population structure within the BSAI area is needed. Little is known regarding most aspects of the biology of shortraker rockfish, including the reproductive biology and distribution, duration, and habitat requirements of various life-history stages. Given the relatively unusual reproductive biology of rockfish and its importance in establishing management reference points, data on reproductive capacity should be collected on a periodic basis.

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Table 1. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the species groups used to manage shortraker rockfish from 1988 to 2012. 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	242
2005	BSAI	Shortraker	596	596	170
2006	BSAI	Shortraker	580	580	213
2007	BSAI	Shortraker	424	424	323
2008	BSAI	Shortraker	424	424	170
2009	BSAI	Shortraker	387	387	205
2010	BSAI	Shortraker	387	387	324
2011	BSAI	Shortraker	393	393	334
2012	BSAI	Shortraker	393	393	283

* Estimated removals through October 6, 2012.

Table 2. 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	1,069	0		874	0		1,943
1979	279	0		3,008	0		3,286
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			176	223
1995			49			164	213
1996			87			143	230
1997			36			90	126
1998			52			159	211
1999			66			129	195
2000			130			200	330
2001			57			172	229
2002			93			206	299
2003			107			131	239
2004			119			123	242
2005			108			62	170
2006			48			165	213
2007			113			210	323
2008			60			110	170
2009			83			122	205
2010			181			143	324
2011			103			231	334
2012*			58			225	283

* Estimated removals through October 6, 2012.

Table 3. Area-specific catches of shortraker rockfish (t) in the BSAI area, obtained from the North Pacific Groundfish Observer Program, NMFS Alaska Regional Office.

Year	WAI	CAI	EAI	EBS	Total
1994	2	84	91	46	223
1995	7	44	113	49	213
1996	33	48	63	87	230
1997	47	14	29	36	126
1998	27	100	32	52	211
1999	23	63	43	66	195
2000	20	85	95	130	330
2001	58	87	27	57	229
2002	78	62	66	93	299
2003	30	65	37	107	239
2004	32	76	15	119	242
2005	27	17	18	108	170
2006	39	103	23	48	213
2007	23	145	43	113	323
2008	42	45	23	60	170
2009	32	46	44	83	205
2010	49	41	52	181	324
2011	162	40	29	103	334
2012*	165	32	28	58	283

* Estimated removals through October 6, 2012.

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	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.	SR/RE	2001	27	16	43	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	214	92	306	29.9%
BSAI	SR	2004	143	99	242	41.1%
		2005	129	40	170	23.9%
		2006	131	82	213	38.5%
		2007	163	161	323	49.7%
		2008	108	62	170	36.4%
		2009	147	58	205	28.4%
		2010	248	76	324	23.3%
		2011	295	39	334	11.6%
		2012*	228	55	283	19.3%

* Estimated removals through October 6, 2012.

Table 5. Aleutian Islands catch (t) of shortraker rockfish by management area and target fishery from 2004-2012, from the NMFS Alaska Regional Office catch accounting system database.

		Management area			
Target Fishery	Gear	541	542	543	Total
Rockfish	Bottom trawl	57.41	187.94	512.87	758.21
Sablefish	Longline	58.39	63.79	5.34	127.51
Turbot	Longline	0.42	119.24		119.66
Atka mackerel	Bottom trawl	17.29	37.42	28.66	83.37
Pacific cod	Longline	46.07	23.48	11.04	80.60
Halibut	Longline	17.01	32.12	13.72	62.85
Arrowtooth flounder	Longline	1.63	59.76		61.39
Arrowtooth flounder	Bottom trawl	47.13			47.13
Kamchatka flounder	Bottom trawl	19.78			19.78
Pacific cod	Bottom trawl	0.70	6.49	0.02	7.21
Other species	Longline		6.24		6.24
Rockfish	Longline	0.34	5.48	0.42	6.24
Sablefish	Pot	4.48	1.73		6.21
Turbot	Bottom trawl	2.38			2.38
Sum (all targets and gears)		274.34	544.36	572.06	1390.76

Table 6. Eastern Bering Sea catch (t) of shortraker rockfish by management area and target fishery from 2004-2012, 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	514	517	518	519	521	523	524	Total
Pelagic pollock	PT		0.21	2.25		199.42		3.90	23.14	0.05		228.96
Pacific cod	LL		0.00	0.03		14.60	0.12	7.29	137.30	43.03	0.04	202.41
Rockfish	BT					46.92	2.06	19.61	55.03	14.13		137.76
Turbot	LL					1.35	1.29	0.15	74.95	23.08	1.79	102.62
Arrowtooth flounder	BT					34.91	17.58	13.65	28.93	0.23	3.20	98.51
Halibut	LL			0.01	0.55	2.47	14.52	4.19	12.94	1.86	2.77	39.30
Sablefish	LL	0.00				7.22	0.84	0.78	1.34	0.43		10.61
Other flatfish	BT					6.25		3.44				9.70
Flathead sole	BT					3.35		0.65	1.27	3.27		8.53
Turbot	BT					5.00	0.16		0.57			5.73
Arrowtooth flounder	LL					0.70	0.59	0.01	0.34	3.34		4.97
Rockfish	LL					0.25	0.07		1.65	2.90		4.87
Other species	LL								0.38	4.19	0.01	4.58
Atka mackerel	BT							3.93				3.93
Sablefish	Pot					0.17	1.30	1.08	0.00			2.55
Pacific cod	BT					0.18		0.94	0.87			1.99
Kamchatka flounder	BT					0.02	0.73	0.42	0.10		0.23	1.50
Sum (all targets and gears)		0.00	0.21	2.37	0.55	326.64	39.25	60.60	338.94	96.58	8.04	873.18

Table 7. 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	35,753 (0.19)	
1984		
1985		4,010
1986	18,153 (0.28)	
1987		
1988		1,260 (0.43)
1989		
1990		
1991	23,761 (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	16,805 (0.19)	4,851 (0.44)
2003		
2004	33,242 (0.37)	2,570 (0.22)
2005		
2006	12,961 (0.23)	
2007		
2008		7,308 (0.31)
2009		
2010	18,239 (0.23)	4,365 (0.28)
2011		
2012	16,230 (0.26)	9,299 (0.57)

Table 8. Estimated fishing mortality rates and beginning year biomass for shortraker rockfish from the 2010 and 2012 assessments.

	Biomass (t)		Fishing Mortality Rate	
Year	2012 Assessment	2010 Assessment	2012 Assessment	2010 Assessment
1980	29,776	29,722	0.028	0.029
1981	28,350	28,313	0.028	0.028
1982	27,561	27,537	0.022	0.022
1983	27,101	27,091	0.008	0.008
1984	28,564	28,580	0.003	0.003
1985	28,102	28,125	0.001	0.001
1986	27,655	27,684	0.001	0.001
1987	25,690	25,722	0.002	0.002
1988	25,574	25,614	0.003	0.003
1989	25,503	25,550	0.007	0.007
1990	25,320	25,373	0.025	0.025
1991	25,560	25,599	0.017	0.017
1992	25,493	25,528	0.014	0.014
1993	25,350	25,388	0.017	0.017
1994	25,341	25,378	0.009	0.009
1995	25,609	25,645	0.008	0.008
1996	25,419	25,458	0.009	0.009
1997	25,220	25,269	0.005	0.005
1998	26,249	26,305	0.009	0.008
1999	25,165	25,226	0.008	0.008
2000	24,139	24,201	0.014	0.015
2001	23,251	23,301	0.011	0.009
2002	22,223	22,316	0.015	0.016
2003	20,519	20,584	0.012	0.012
2004	20,055	20,129	0.012	0.012
2005	20,113	20,192	0.009	0.009
2006	19,512	19,599	0.012	0.012
2007	17,953	18,033	0.018	0.018
2008	17,662	17,758	0.010	0.009
2009	17,530	17,647	0.012	0.012
2010	17,369	17,503	0.019	0.012
2011	17,216		0.020	
2012	16,858		0.021	

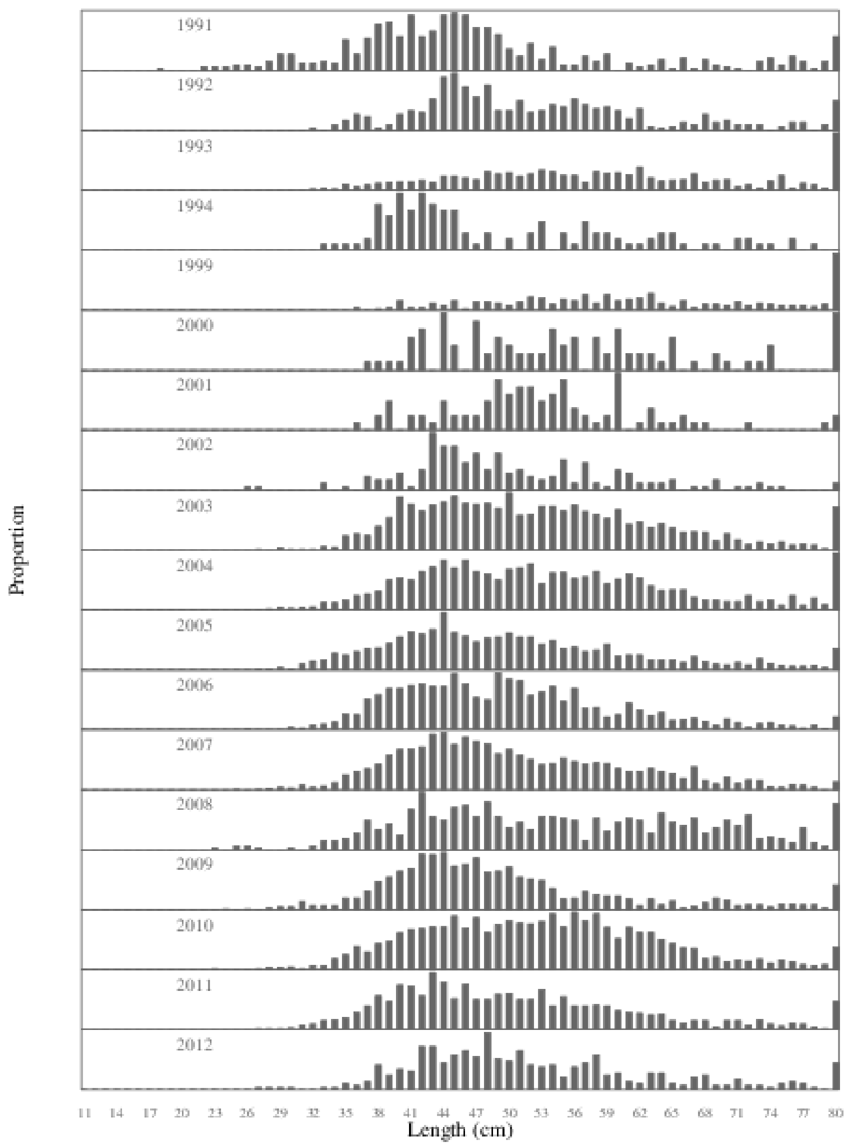

Figure 1. Length composition from the US domestic fishery, 1991-2012.

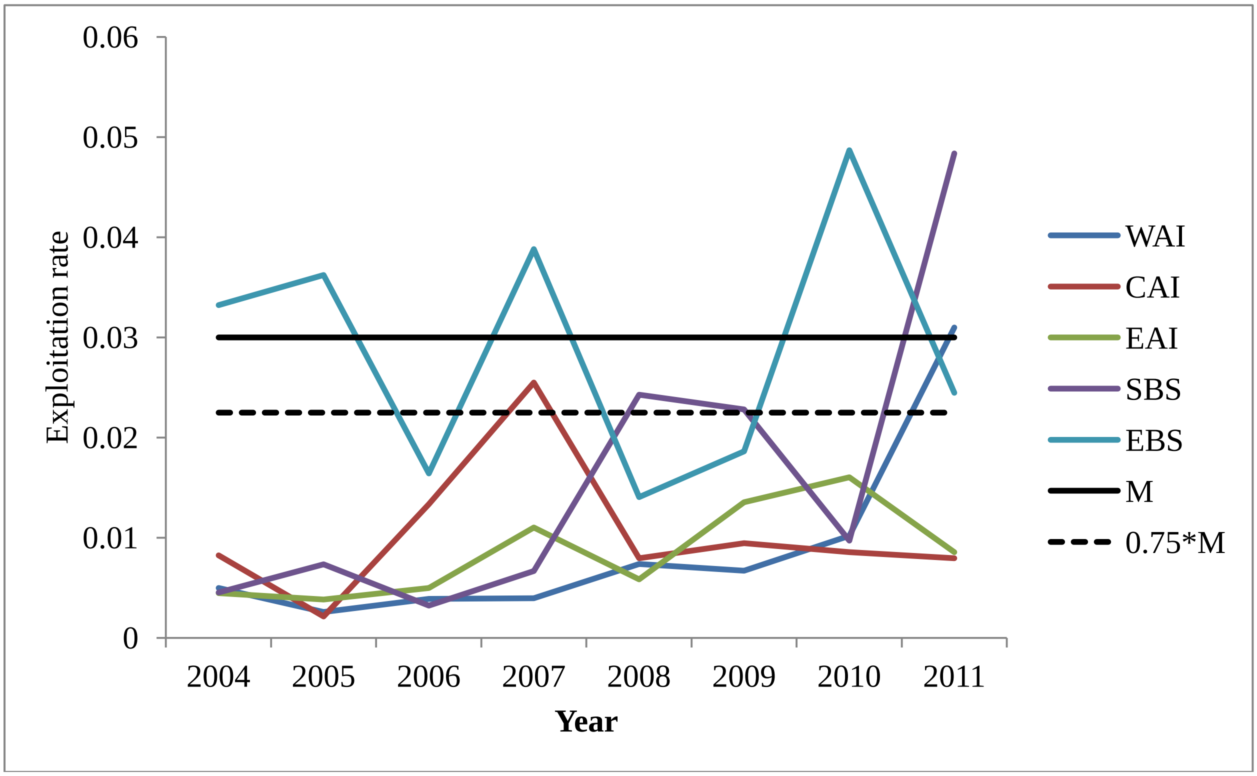

Figure 2. Area-specific exploitation rates for BSAI shortraker rockfish.

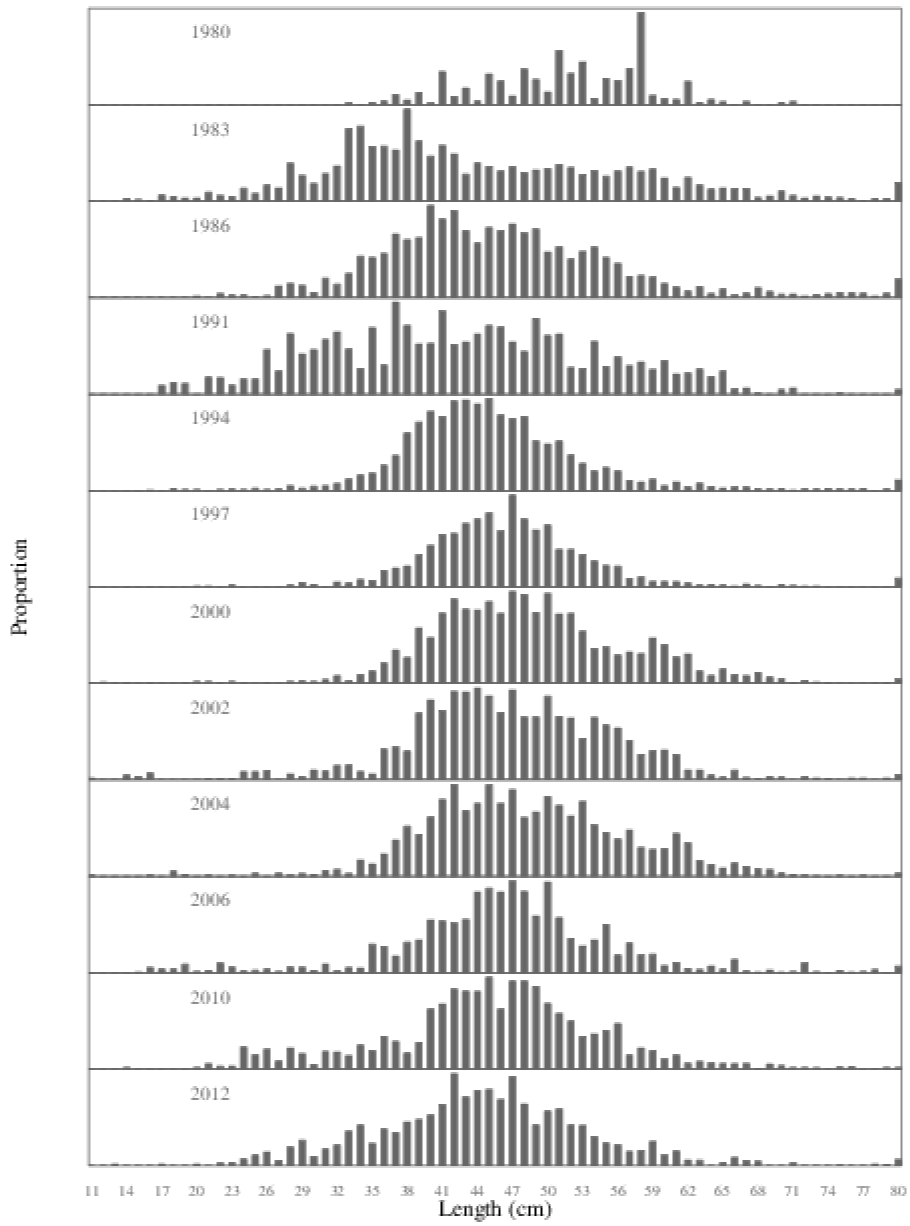

Figure 3. Length composition from the Aleutian Islands trawl surveys, 1980-2012.

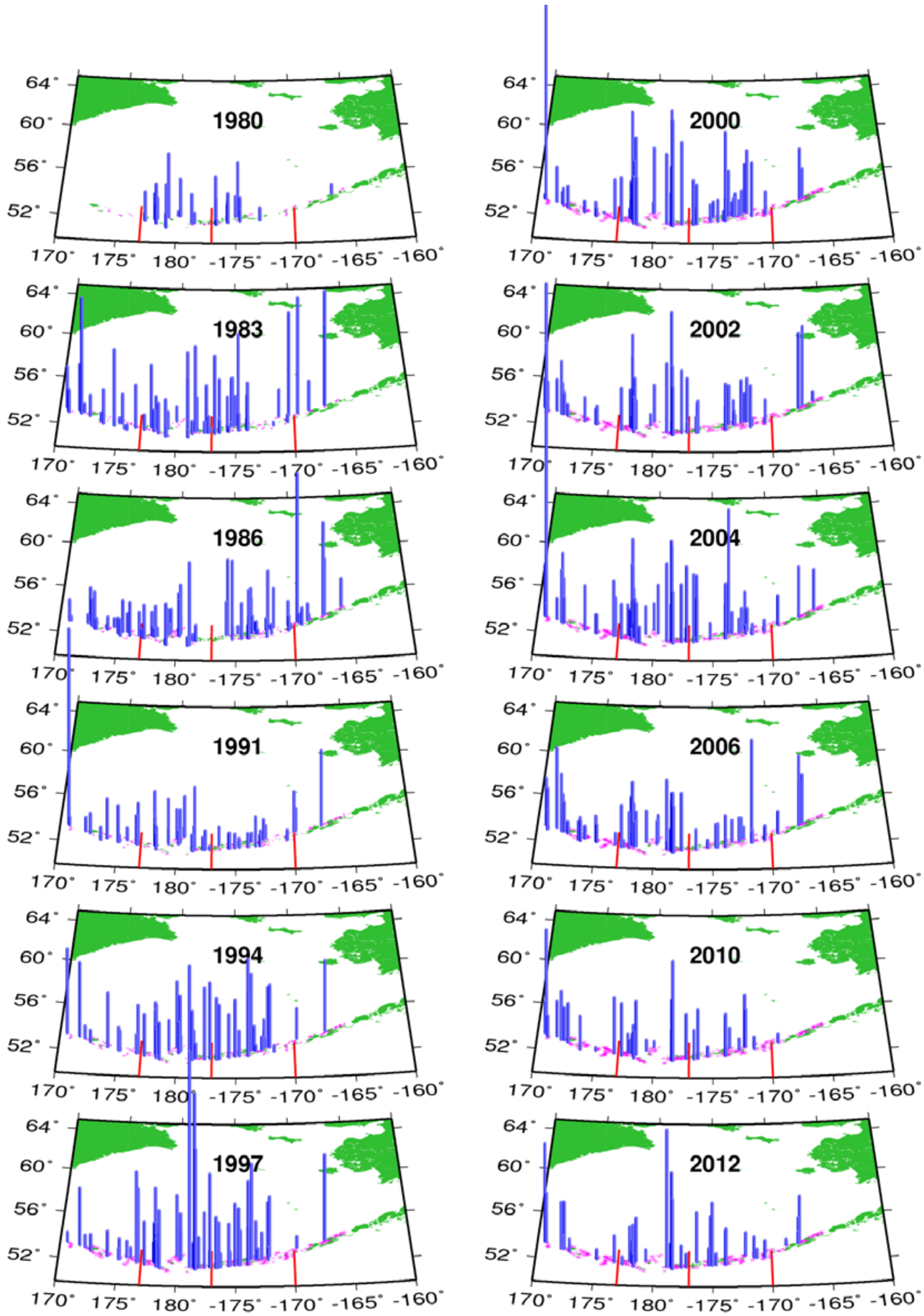

Figure 4. Scaled AI survey shortaker rockfish CPUE (square root of kg/km^2) from 1980-2012; the symbol × denotes tows with no catch. The red lines indicate boundaries between the WAI, CAI, EAI, and EBS areas.

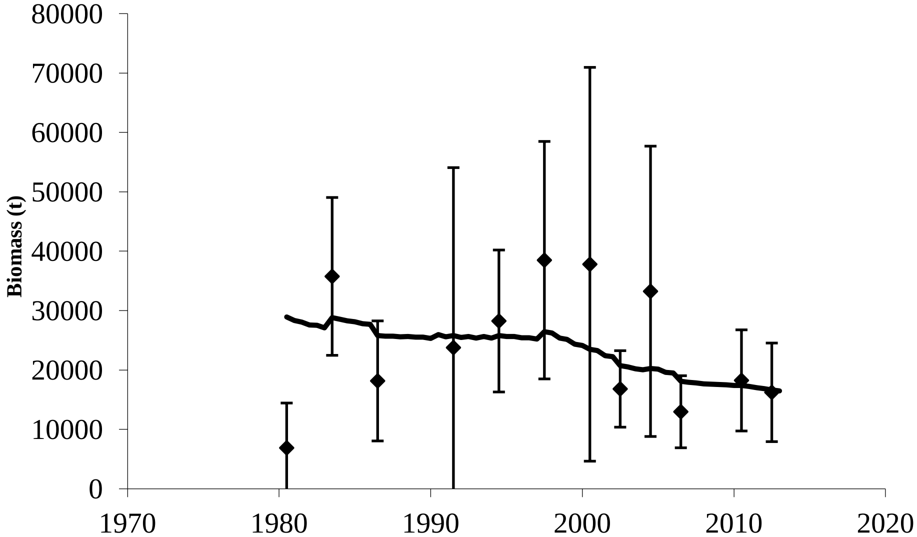

Figure 5. Observed AI survey biomass (data points +/- 2 standard deviations) and predicted survey biomass estimates from the Kalman filter model.

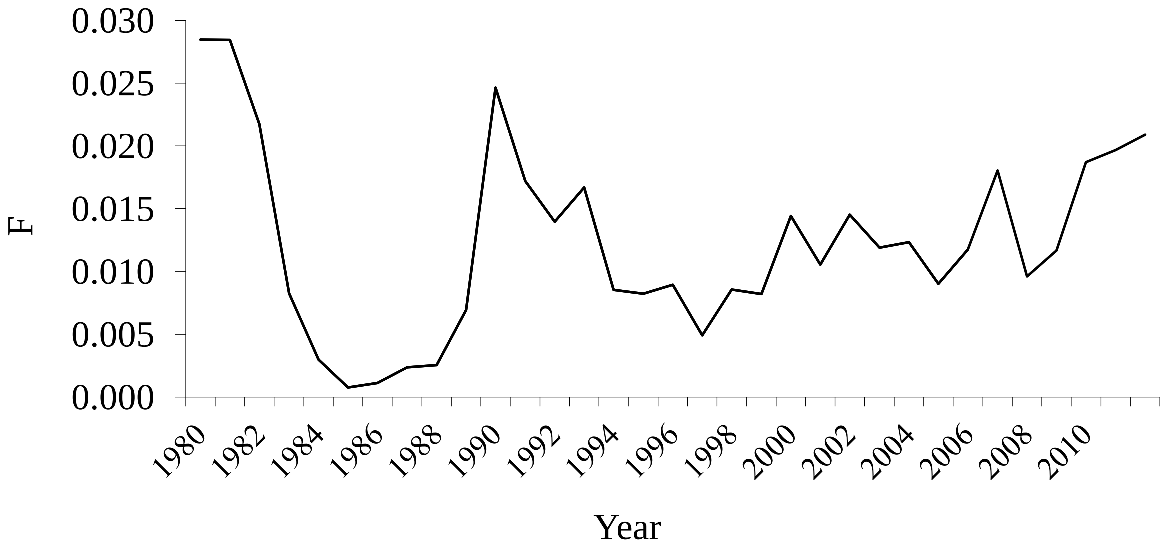

Figure 6. Estimated fishing mortality rate of BSAI shortraker rockfish.

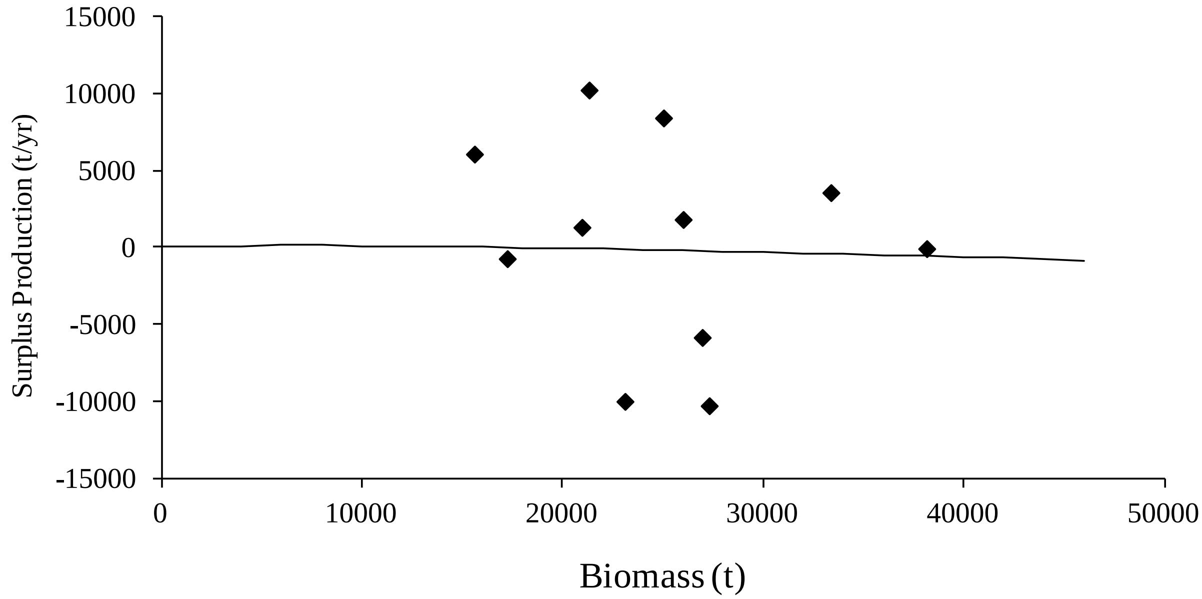

Figure 7. Estimated annual surplus production (data points, estimated as the harvest plus the change in biomass over a time interval), and production model fits of BSAI shortraker rockfish.

Appendix A. Supplemental Catch Data.

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska. The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities (Table A1). This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For BSAI shortraker rockfish, these estimates can be compared to the trawl research removals reported in previous assessments. Shortraker rockfish research removals are small relative to the fishery catch. The majority of removals are taken by the Alaska Fisheries Science Center's (AFSC) biennial bottom trawl survey which is the primary research survey used for assessing the population status of BSAI shortraker rockfish. Other research activities that harvest shortraker rockfish include other trawl research activities and minor catches occur in longline surveys conducted by the International Pacific Halibut Commission and the AFSC. Some catches in the AFSC longline survey are reported as shortraker/rougheye. There was no recorded recreational harvest or harvest that was non-research related in 2010 and 2011. Total removals of shortraker and "shortraker/rougheye" rockfish were less than 7 t and 3 t in 2010 and 2011, respectively, which represent less than 2% of the ABC in these years. Research harvests in even years beginning in 2000 (excluding 2008, when the AI trawl survey was canceled) are higher due to the biennial cycle of the AFSC bottom trawl survey in the Aleutian Islands. These catches have varied between 2 and 6 t.

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

These estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between "retained" or "discarded" catch. These estimates should be considered a separate time series from the current CAS estimates of total catch. Because of potential overlaps HFICE removals should not be added to the CAS produced catch estimates. The overlap will apply when groundfish are retained or discarded during an IFQ halibut trip. IFQ halibut landings that also include landed groundfish are recorded as retained in eLandings and a discard amount for all groundfish is estimated for such landings in CAS. Discard amounts for groundfish are not currently estimated for IFQ halibut landings that do not also include landed groundfish. For example, catch information for a trip that includes both landed IFQ halibut and sablefish would contain the total amount of sablefish landed (reported in eLandings) and an estimate of discard based on at-sea observer information. Further, because a groundfish species was landed during the trip, catch accounting would also estimate discard for all groundfish species based on available observer information and following methods described in Cahalan et al. (2010). The HFICE method estimates all groundfish caught during a halibut IFQ trip and thus is an estimate of groundfish caught whether landed or discarded. This prevents simply adding the CAS total with the HFICE estimate because it would be analogous to counting both retained and discarded groundfish species twice. Further, there are situations where the HFICE estimate includes groundfish caught in State waters and this would need to be considered with respect to ACLs (e.g. Chatham Strait sablefish fisheries). Therefore, the HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery will become available following restructuring of the Observer Program in 2013, when all vessels >25 ft will be monitored for groundfish catch.

The HFICE estimates of BSAI shortraker rockfish catches are variable, ranging between 2 and 18 t from 2001 -2010 with an average 8 t. Years with relatively high catches are caused by increased catches in the eastern and central Aleutian Islands.

Appendix Table A1. Removals of BSAI shortraker rockfish from activities other than groundfish fishing. Trawl and longline include research survey and occasional short-term projects. “Other” is recreational, personal use, and subsistence harvest.

		Shortraker			Shortraker/Rougheye	
Year	Source	Trawl	Longline	Other	Trawl	Longline
1977	NMFS-AFSC survey databases					
1978						
1979		0.933				
1980		5.707				
1981		4.972				
1982		7.646				
1983		15.496				
1984						
1985		9.246				
1986		9.151				
1987						
1988		0.336				
1989						
1990						
1991		3.437				
1992						
1993		0.008				
1994		4.604				
1995						
1996						
1997		5.824				
1998			0.830			2.174
1999		0.017	1.198			0.494
2000		6.348	0.973			2.066
2001		0.010	1.258			0.422
2002		3.875	0.785			1.649
2003			2.138			0.376
2004		5.367	0.691			1.680
2005		0.011	1.299			0.347
2006		2.176	1.186			3.367
2007			1.307			0.429
2008		2.321	0.650			1.544
2009			1.706			0.571
2010	NMFS-Alaska Regional Office	2.764	2.556		0.018	1.546
2011			2.544			0.411

Appendix Table A2. Estimates BSAI shortraker rockfish catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group.

Year	Eastern AI	Central AI	Western AI	Central/Western AI	Total
2001	0.85	2.68	2.88	0.00	6.40
2002	1.65	1.50	0.17	0.00	3.32
2003	0.00	4.52	0.00	0.00	4.52
2004	1.31	0.00	1.09	0.00	2.40
2005	14.05	1.27	0.15	0.00	15.47
2006	10.69	4.95	0.00	0.00	15.65
2007	1.98	4.10	0.44	0.00	6.52
2008	1.95	2.65	0.00	0.00	4.60
2009	3.36			0.11	3.47
2010	7.52	8.74	1.32	0.00	17.58
Average	4.33	3.38	0.67	0.01	7.99

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