15. Assessment of the shortraker rockfish stock in the Bering Sea and Aleutian Islands

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Executive Summary

Summary of Changes in Assessment Inputs

Changes in the input data:

1) The catch data have been revised and updated through October 31, 2014.
2) The biomass estimate from the 2014 Aleutian Islands (AI) trawl survey was added to the model input data.

Changes in the assessment methodology:

The assessment methodology has changed since the last full assessment in 2012. The previous method used the Gompertz-Fox surplus production model to estimate the shortraker rockfish population, and the Kalman filter to statistically estimate the parameter values. In 2014 biomass is estimated using the random effects model. This is the authors' preferred model used in setting ABC and OFL.

Summary of Results

The recommended 2015 ABC and OFL for BSAI shortraker rockfish are 518 t and 690 t, respectively. This is an increase of 40% from the 2014. A summary of the recommend ABCs and OFLs for 2015 relative the ABC and OFL specified last year is shown below.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2014	2015	2015	2016
M (natural mortality rate)	0.03	0.03	0.03	0.03
Tier	5	5	5	5
Biomass (t)	16,447	16,447	23,009	23,009
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)	493	493	690	690
maxABC (t)	370	370	518	518
ABC (t)	370	370	518	518
	As determined *last* year for:		As determined *this* year for:	
Status	2012	2013	2013	2014
Overfishing		n/a		n/a

Summaries for the Plan Team

The following table gives the recent biomass estimates, catch, harvest specifications, and projected biomass, OFL and ABC for 2015-2016.

Year	Biomass	OFL	ABC	TAC	Catch
2013	16,447	493	370	370	372
2014	16,447	493	370	370	187[1]
2015	23,009	690	518		
2016	23,009	690	518		

[1] Catch as of November 3, 2014.

Responses to SSC and Plan Team Comments on Assessments in General

None pertaining to this assessment.

Responses to SSC and Plan Team Comments Specific to this Assessment

October 2014 SSC meeting: The Plan Team recommended and the SSC agrees that the random effects model be included in the November assessment anticipating that this will be the Team's preferred model for use in setting ABC and OFL.

Authors' response: The 2014 assessment is based on the random effects model. Results using the surplus production model, last year's approved model, are presented in an appendix.

Introduction

Shortraker rockfish (*Sebastes 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(AI) and northern Gulf of Alaska (GOA). Studies of habitat preferences in the GOA 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 myctophids, shrimp and squid (Yang et al. 2006).

Several 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 GOA). 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 indicated 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 rockfish 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* (Pacific ocean perch), *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 AI.

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 AI (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 EBS or western AI 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. Recent, ^{14}C age validation studies appeared 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). Shortraker rockfish were managed in the domestic fishery as part of the “other red rockfish” from 1991-2000 and the “shortraker/rougheye” complex from 2001-2003. The ABCs, TACS, and catches by management complex from 1988-2014 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 Aleutian Island areas, the central (CAI), Western (WAI), and Eastern Aleutian Islands (EAI)) and gear type from 1994-2002. For 1991-1993, the Regional Office blend catch data for the AI 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 1994-2014 have been variable, with the largest catches often occurring in the EBS (Table 3). From 2003 to 2014, 35% of the shortraker catch occurred in the EBS, with 24%, 23%, and 13% in the central, western, and eastern AI areas respectively. Catches in the western AI increased in 2011-2013 to an average of 164 t, as compared to an average of 34 t from 2003-2010, which resulted in the proportion of catch in the western AI in 2011-2013 increasing to an average of 47% of the total eastern Bering Sea/Aleutian Islands (BSAI) catch for those years. Catch as of November 3, 2014 was only 26 t in the Western AI.

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 shortraker/rougheye (SR/RE) complex from 2001 to 2003 were below 52%, and discard rates of AI SR/RE complex from 1993-2003 were below 41%. In general, the discard rates of EBS SR/RE 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 2004-2014 have ranged from 23% to 50%, and were 30% in 2013 and 45% for 2014 (through November 3).

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 2004-2014, these fisheries accounted for 98% of the AI catch of shortraker. Catches of shortraker rockfish from 2004-2014 in the AI management area were caught primarily in the rockfish bottom trawl fishery (58%), followed by sablefish longline (10%) and Atka mackerel bottom trawl fisheries (9%). Catches of shortraker rockfish from 2004-2014 in the EBS were caught largely in the midwater pollock trawl fishery (22%), Pacific cod (20%), Greenland turbot (9%), and halibut (10%) longline fisheries, and arrowtooth flounder (15%), other flatfish (1%), and rockfish trawl fisheries (19%); 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 (Table 6).

Shortraker rockfish and four other species of rockfish (Pacific ocean perch, northern rockfish, rougheye rockfish, *S. aleutianus*; and sharpchin rockfish, *S. zacentrus*) were managed as a complex in the EBS and 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 AI 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 EBS was split into two groups, shortraker/rougheye and sharpchin/northern, matching the complexes used in the AI. 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. Additionally, separate TACs were established for the EBS and AI management areas, but the overfishing level (OFL) pertained to the entire BSAI area. 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. Shortraker rockfish has been assessed separately since 2008.

Data

Fishery

The length composition from observer sampling of the domestic fishery (Figure 1), indicate relatively consistent length distributions with the bulk of the sampled fish generally between 30 and 70 cm. There are no apparent trends in the size distribution. The number of length observations taken by fishery observers in the BSAI is shown in the following table.

Year	Number of fishery length observations	Year	Number of fishery length observations
1991	1,230	2003	5,608
1992	1,144	2004	4,315
1993	1,153	2005	3,904
1994	125	2006	3,409
1995	88	2007	3,727
1996	55	2008	2,362
1997	50	2009	3,100
1998	107	2010	3,685
1999	627	2011	2,174
2000	330	2012	2,121
2001	302	2013	2,017
2002	440	2014	1,847

The catch data 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 applying the proportional biomass in each region, based on a 3 year (4,6,9) weighted average, to the total biomass, estimated by the random effects model.

Exploitation rates in the CAI and EAI have been below *M* and generally low from 2004-2014 (Figure 2a). Increases in the catch in the western AI in 2011-2013 resulted in the exploitation rates in this area exceeding F_{ABC} in these years, but not F_{OFL} (Table 3, Figure 2a). The 2014 catch in the WAI is lower than previous years, as of November 3, 2014. Catch of shortraker rockfish in the SBS is variable, ranging from 2-40 t from 2003-2014 (Table 3). Biomass in that region appears to be decreasing, and the current year estimate of 28 t is the second lowest on record (Table 7, Figures 3 and 4). Exploitation rates in the SBS was higher than F_{OFL} (0.03), in 2012 (Figure 2a). The exploitation rate for the entire BSAI has remained below F_{ABC} and F_{OFL} since 2002 (Figure 2b).

Removals from sources other than those that are included in the Alaska Region's official estimate of catch are presented in Appendix 1.

Survey

Biomass estimates for other red rockfish were produced from cooperative U.S.-Japan trawl surveys from 1979-1985 on the EBS Bering Sea slope, and from 1980-1986 in the AI. U.S domestic trawl surveys were conducted in 1988, 1991, 2002, 2004, 2008, 2010, and 2012 on the EBS slope, and in 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, and 2014 in the AI (Table 7). The 2008 AI survey and 2006 and 2010 EBS slope survey were canceled. The 2002 EBS slope survey represents the initiation of a new

survey time series distinct from the previous surveys in 1988 and 1991. EBS slope and the AI surveys were used to compute biomass estimates in this assessment. The EBS slope survey was initiated in 2002; therefore, biomass estimates are available from 2002-2014.

In contrast to the fishery length compositions, the survey length compositions reveal fewer large fish (Figure 5). In surveys from 1994 to 2014, fish lengths from survey samples generally occurred between 30 cm and 65 cm.

The AI surveys from 1980 to 2014 indicated higher abundances in the Western (543) and Central (542) than in the eastern AI (541), with the SBS area having the lowest abundance (Figure 4). Biomass in the SBS has shown a consistent decline in biomass estimated by the survey since 1983.

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.

Analytic Approach

The random effects model was used to estimate biomass of shortraker rockfish in the BSAI. The random effects (RE) model is an approximation to the Kalman Filter approach. The process errors (step changes) from one year to the next are the random effects to be integrated over and the process error variance is a free parameter. The observations can be irregularly spaced; therefore this model can be applied to datasets with missing data. Large observation errors increase errors predicted by the model, which can provide a way to weight predicted estimates of biomass (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2012/Sept/survey_average_wg.pdf).

Estimates were made using the 1980-2014 AI and 2002-2012 EBS slope survey time series for biomass and estimates of uncertainty. The most recent slope survey was conducted in 2012; therefore the best estimate of the past 2 years of slope biomass is the 2012 estimate. This method produces estimates of BSAI shortraker biomass from 2002-2014.

Shortraker rockish in the BSAI are managed under Tier 5, where OFL = M * average survey biomass, where M represents natural mortality, and F_{ABC} is estimated by 0.75 * M. The acceptable biological catch (ABC) is obtained by multiplying F_{ABC} by the estimated biomass, ABC $\leq$ 0.75 * M * biomass.

Parameter Estimates

Shortraker rockfish are assumed to have a natural mortality rate (M) of 0.03. 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).

Results

Estimated shortraker rockfish biomass in the BSAI has been relatively stable since 2002. Biomass has decreased slightly from 23,938 t in 2002 to 20,896 t in 2006, and has increased to 23,009 t in 2014 (Figure 6, Table 8). Biomass estimates using last year's approved method, the surplus production model, are shown in Appendix 2 Table 1. The random effect model results are higher than the 2012 model results due to the inclusion of Bering Sea slope biomass estimates from the Bering Sea slope survey. The random effects model estimates of Aleutian Island and Eastern Bering Sea slope shortraker rockfish biomass from 2002- 2014, as well as the total biomass estimate, are shown in Table 9.

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:

Shortraker rockfish	2014 biomass	*M*	ABC	OFL
	23,009 t	0.03	518 t	690 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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Tables

Table 1. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the species groups used to manage shortraker rockfish from 1988 to 2014. 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. *Estimated removals through November 3, 2014.

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	Shortraker/rougheye	1,245	1,245	388
1992	BS	Other Red Rockfish	1,400	1,400	467
	AI	Shortraker/rougheye	1,220	1,220	1,470
1993	BS	Other Red Rockfish	1,400	1,200	1,226
	AI	Shortraker/rougheye	1,220	1,100	1,139
1994	BS	Other Red Rockfish	1,400	1,400	129
	AI	Shortraker/rougheye	1,220	1,220	925
1995	BS	Other Red Rockfish	1,400	1,260	344
	AI	Shortraker/rougheye	1,220	1,098	559
1996	BS	Other Red Rockfish	1,400	1,260	207
	AI	Shortraker/rougheye	1,250	1,125	959
1997	BS	Other Red Rockfish	1,050	1,050	218
	AI	Shortraker/rougheye	938	938	1,043
1998	BS	Other Red Rockfish	267	267	112
	AI	Shortraker/rougheye	965	965	685
1999	BS	Other Red Rockfish	356	267	238
	AI	Shortraker/rougheye	1,290	965	514
2000	BS	Other Red Rockfish	259	194	253
	AI	Shortraker/rougheye	1,180	885	480
2001	BSAI	Shortraker/rougheye	1,028		
	BS	Shortraker/rougheye		116	72
	AI	Shortraker/rougheye		912	722
2002	BSAI	Shortraker/rougheye	1,028		
	BS	Shortraker/rougheye		116	105
	AI	Shortraker/rougheye		912	478
2003	BSAI	Shortraker/rougheye	967		
	BS	Shortraker/rougheye		137	124
	AI	Shortraker/rougheye		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	133
2009	BSAI	Shortraker	387	387	184
2010	BSAI	Shortraker	387	387	300
2011	BSAI	Shortraker	393	393	333
2012	BSAI	Shortraker	393	393	344
2013	BSAI	Shortraker	370	370	372
2014*	BSAI	Shortraker	370	370	187

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			47			165	212
2007			114			210	323
2008			41			91	133
2009			69			116	184
2010			161			139	300
2011			106			227	333
2012			117			227	344
2013			105			268	372
2014*			88			99	187

* Estimated removals through November 3, 2014.

Table 3. Area-specific catches of shortraker rockfish (t) in the BSAI area from 1994-2014, obtained from the North Pacific Groundfish Observer Program, NMFS Alaska Regional Office. Abbreviations are: Western Aleutian Islands (WAI), Central Aleutian Islands (CAI), Eastern Aleutian Islands (EAI), Southern Bering Sea (SBS), Eastern Bering Sea (EBS), and Bering Sea (BS).

Year	WAI	CAI	EAI	SBS	BS	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
Year	WAI	CAI	EAI	SBS	EBS	Total
2003	30	65	37	0	107	239
2004	32	76	15	5	114	242
2005	27	17	18	5	103	170
2006	39	103	23	2	45	212
2007	23	145	43	6	108	323
2008	40	35	17	12	29	133
2009	34	41	41	15	54	184
2010	48	40	51	7	154	300
2011	162	37	28	21	85	333
2012	168	32	27	40	77	344
2013	163	68	37	12	93	372
2014*	26	32	41	8	80	187

* Estimated removals through November 4, 2014.

Table 4. Estimated retained (t), discarded (t), 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	SR/RE	1993	737	403	1,139	35.3%
		1994	701	224	925	24.2%
		1995	456	103	559	18.4%
		1996	751	208	959	21.7%
		1997	733	310	1,043	29.7%
		1998	447	238	685	34.8%
		1999	319	195	514	38.0%
		2000	285	196	480	40.8%
		2001	476	246	722	34.1%
		2002	333	146	478	30.4%
		2003	214	92	306	29.9%
BSAI	SR	2004	143	99	242	41.1%
		2005	129	40	170	23.9%
		2006	130	82	212	38.7%
		2007	163	161	323	49.7%
		2008	102	31	133	23.3%
		2009	136	48	184	26.2%
		2010	230	70	300	23.4%
		2011	299	34	333	10.2%
		2012	290	54	344	15.8%
		2013	262	111	372	29.8%
		2014*	103	84	187	44.8%

* Estimated removals through November 3, 2014.

Table 5. Aleutian Islands catch (t) of shortraker rockfish by management area and target fishery from 2004-2014, from the NMFS Alaska Regional Office catch accounting system database.

		Management area			
Target Fishery	Gear	541	542	543	Percentage
Pacific cod	Longline	43.06	34.39	10.76	5.16%
Halibut	Longline	32.26	16.67	7.79	3.32%
Rockfish	Longline	0.02	4.01	0.51	0.27%
Other species	Longline		6.18		0.36%
Sablefish	Longline	67.44	77.92	19.19	9.62%
Turbot	Longline	0.91	117.93		6.95%
Arrowtooth flounder	Longline	1.60	59.76		3.59%
Atka mackerel	Bottom Trawl	28.60	90.73	29.16	8.68%
Pacific cod	Bottom Trawl	0.90	6.49	0.02	0.43%
Rockfish	Bottom Trawl	77.57	217.23	694.43	57.83%
Turbot	Bottom Trawl	2.35			0.14%
Arrowtooth flounder	Bottom Trawl	55.46			3.24%
Pacific cod	Pot		0.67		0.04%
Sablefish	Pot	4.94	1.73		0.39%
Sum (all targets and gears)		315.11	633.70	761.85	1,710.66

Table 6. Eastern Bering Sea catch (t) of shortraker rockfish by management area and target fishery from 2004-2014, from the NMFS Alaska Regional Office catch accounting system database.

		Management area										
Target Fishery	Gear	508	509	513	514	517	518	519	521	523	524	Percentage
Atka mackerel	Bottom trawl							6.59				0.6%
Bottom pollock	Bottom trawl					0.32	1.00	0.30	0.65			0.2%
Pacific cod	Pot					0.05		0.05				0.0%
Pacific cod	Longline		0.01	0.04		15.21	0.12	12.95	142.94	38.30	0.04	19.5%
Pacific cod	Bottom trawl					0.18		0.94	0.87			0.2%
Other flatfish	Bottom trawl					9.20		3.48				1.2%
Halibut	Longline			0.37	0.49	2.68	10.89	3.37	69.09	8.59	7.05	9.5%
Rockfish	Longline					0.59	0.01		5.22	2.96		0.8%
Rockfish	Bottom trawl					84.49	6.28	39.84	55.04	15.95		18.7%
Flathead sole	Bottom trawl					3.35		0.65	1.27	3.27		0.8%
Other species	Longline								0.36	4.20		0.4%
Other species	Bottom trawl					1.30						0.1%
Sablefish	Pot					0.19	1.27	0.99				0.2%
Sablefish	Longline					6.82	1.43	0.87	0.98	0.48		1.0%
Turbot	Longline					1.33	1.29	0.17	69.67	21.64	1.22	8.8%
Turbot	Bottom trawl					5.00	0.16		0.57			0.5%
Arrowtooth flounder	Longline					0.70	0.63	0.01	1.15	2.65		0.5%
Arrowtooth flounder	Bottom trawl			0.25		70.62	17.39	15.40	55.43	0.23	1.26	14.9%
Midwaterpollock	Pelagic trawl		0.25	2.27		206.47		4.02	23.91	0.29		22.0%
Sum (all targets and gears)			0.26	2.92	0.49	408.50	40.47	89.62	427.15	98.53	9.57	1,077.51

Table 7. Estimated biomass (t) of shortraker rockfish from the NMFS bottom trawl surveys, with the coefficient of variation (CV) shown in parentheses. The Aleutian Island survey data includes the Southern Bering Sea.

Year	WAI	CAI	EAI	SBS	AI survey (total)	EBS Slope survey
1979						1,391
1980	0	2,665	4,165	45	6,874 (0.55)	
1981						3,571
1982						5,176
1983	7,249	7,239	11,787	9,477	35,753 (0.19)	
1984						
1985						4,010
1986	1,821	4,291	5,554	6,485	18,153 (0.28)	
1987						
1988						1,260 (0.43)
1989						
1990						
1991	17,558	3,225	1,053	1,925	23,761 (0.64)	2,758 (0.38)
1992						
1993						
1994	6,493	8,164	11,627	1,959	28,244 (0.21)	
1995						
1996						
1997	6,658	21,560	7,840	2,428	38,487 (0.26)	
1998						
1999						
2000	17,746	13,543	5,863	645	37,797 (0.44)	
2001						
2002	3,906	8,639	2,797	1,463	16,805 (0.19)	4,851 (0.44)
2003						
2004	16,333	8,779	7,499	630	33,242 (0.37)	2,570 (0.22)
2005						
2006	2,471	5,335	3,975	1,180	12,961 (0.23)	
2007						
2008						7,308 (0.31)
2009						
2010	6,729	7,424	4,071	15	18,239 (0.23)	4,365 (0.28)
2011						
2012	4,455	7,182	4,031	562	16,230 (0.26)	9,299 (0.57)
2013						
2014	1,579	12,678	2,144	28	16,429 (0.38)	

Table 8. Estimated fishing mortality rates and beginning year biomass for shortraker rockfish from the 2010, 2012, and 2014 assessments. The 2010 and 2012 assessments were based on the surplus production model, and the 2014 biomass estimate was based on the random effects model, which includes the Bering Sea slope and Aleutian Islands survey data. The Bering Sea slope survey was initiated in 2002; therefore, the 2014 assessment estimates biomass from 2002 through 2014.

	Biomass (t)				
Year	**2010 Assessment**	**2012 Assessment**	**2014 Assessment (95% confidence intervals)**		
1980	29,722	29,776			
1981	28,313	28,350			
1982	27,537	27,561			
1983	27,091	27,101			
1984	28,580	28,564			
1985	28,125	28,102			
1986	27,684	27,655			
1987	25,722	25,690			
1988	25,614	25,574			
1989	25,550	25,503			
1990	25,373	25,320			
1991	25,599	25,560			
1992	25,528	25,493			
1993	25,388	25,350			
1994	25,378	25,341			
1995	25,645	25,609			
1996	25,458	25,419			
1997	25,269	25,220			
1998	26,305	26,249			
1999	25,226	25,165			
2000	24,201	24,139			
2001	23,301	23,251			
2002	22,316	22,223	23,938	(16,262,	31,613)
2003	20,584	20,519	23,402	(15,385,	31,418)
2004	20,129	20,055	22,906	(14,977,	30,836)
2005	20,192	20,113	21,792	(13,801,	29,783)
2006	19,599	19,512	20,896	(12,276,	29,515)
2007	18,033	17,953	21,709	(12,528,	30,891)
2008	17,758	17,662	22,641	(13,511,	31,770)
2009	17,647	17,530	22,492	(14,077,	30,907)
2010	17,503	17,369	22,356	(15,454,	29,259)
2011		17,216	22,693	(14,215,	31,171)
2012		16,858	23,093	(13,278,	32,909)
2013			23,051	(12,248,	33,855)
2014			23,009	(11,554,	34,464)

Table 9. Random effect estimates of biomass for shortraker rockfish from 2002-2014, for the Aleutian Islands (AI, including the Southern Bering Sea portion of the survey) and theh Eastern Bering Sea slope survey.

Year	Bering Sea slope	Aleutian Islands	Total
2002	3,763	20,175	23,938
2003	3,376	20,025	23,402
2004	3,029	19,877	22,906
2005	3,538	18,254	21,792
2006	4,132	16,763	20,896
2007	4,826	16,883	21,709
2008	5,637	17,004	22,641
2009	5,366	17,125	22,492
2010	5,109	17,248	22,356
2011	5,669	17,024	22,693
2012	6,290	16,804	23,093
2013	6,290	16,761	23,051
2014	6,290	16,719	23,009

Figures

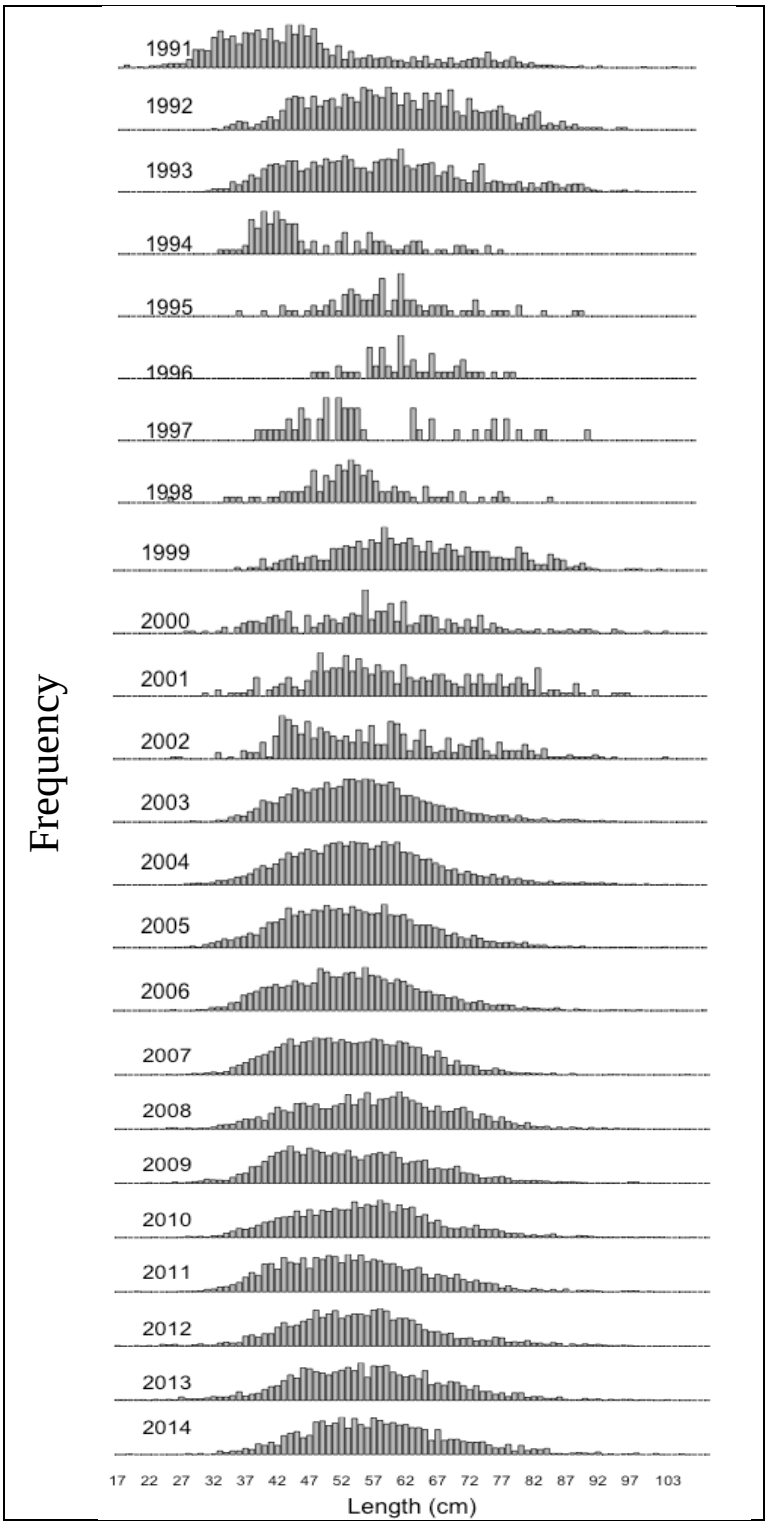

Figure 1. Length compositions from the US domestic fishery, 1991-2014.

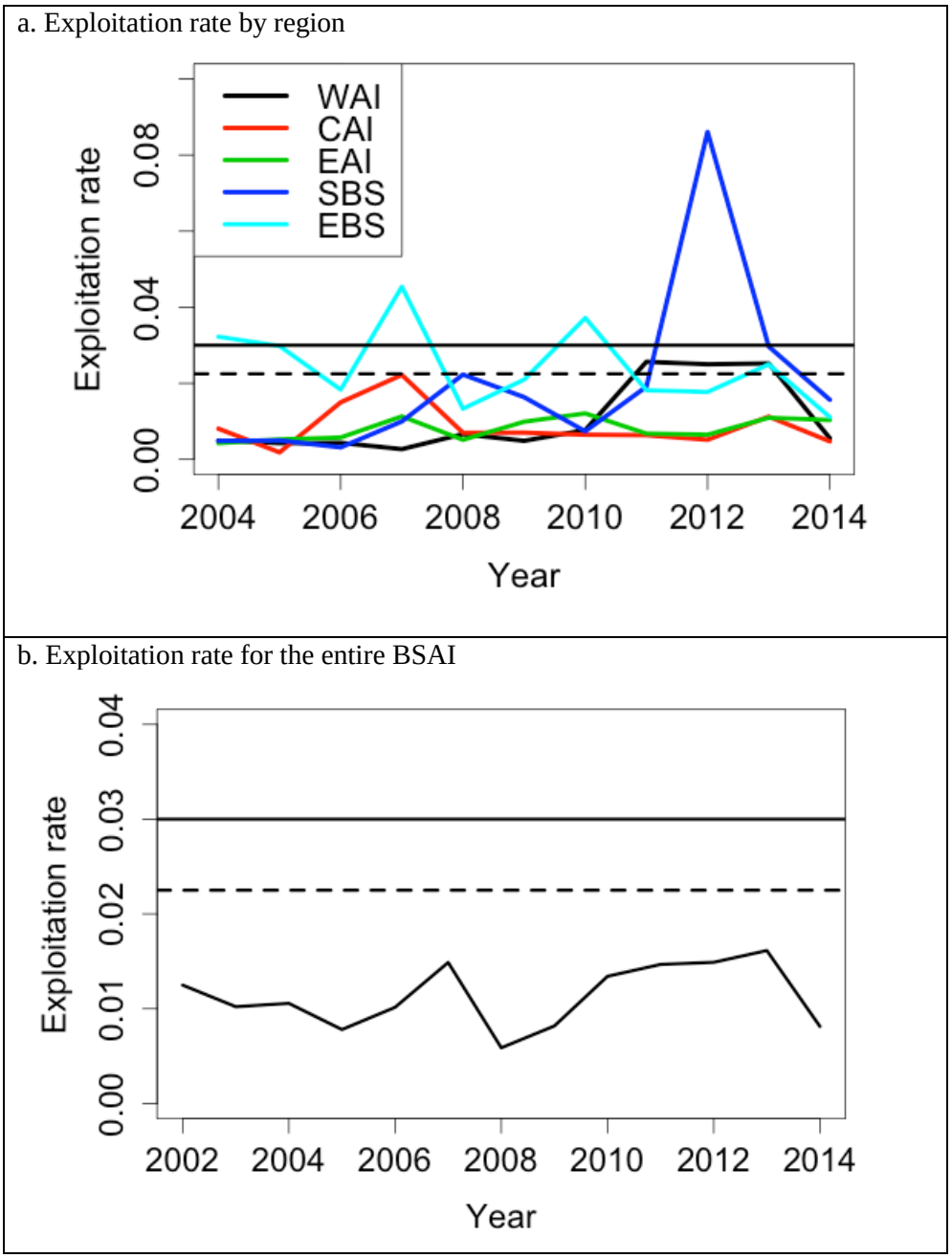

Figure 2. Area-specific exploitation rates for BSAI shortraker rockfish from 2003-2014 (panel a.), and for the entire BSAI (panel b). Abbreviations are: Western Aleutian Islands (WAI), Central Aleutian Islands (CAI), Eastern Aleutian Islands (EAI), Southern Bering Sea (SBS), Eastern Bering Sea (EBS), and Bering Sea (BS).

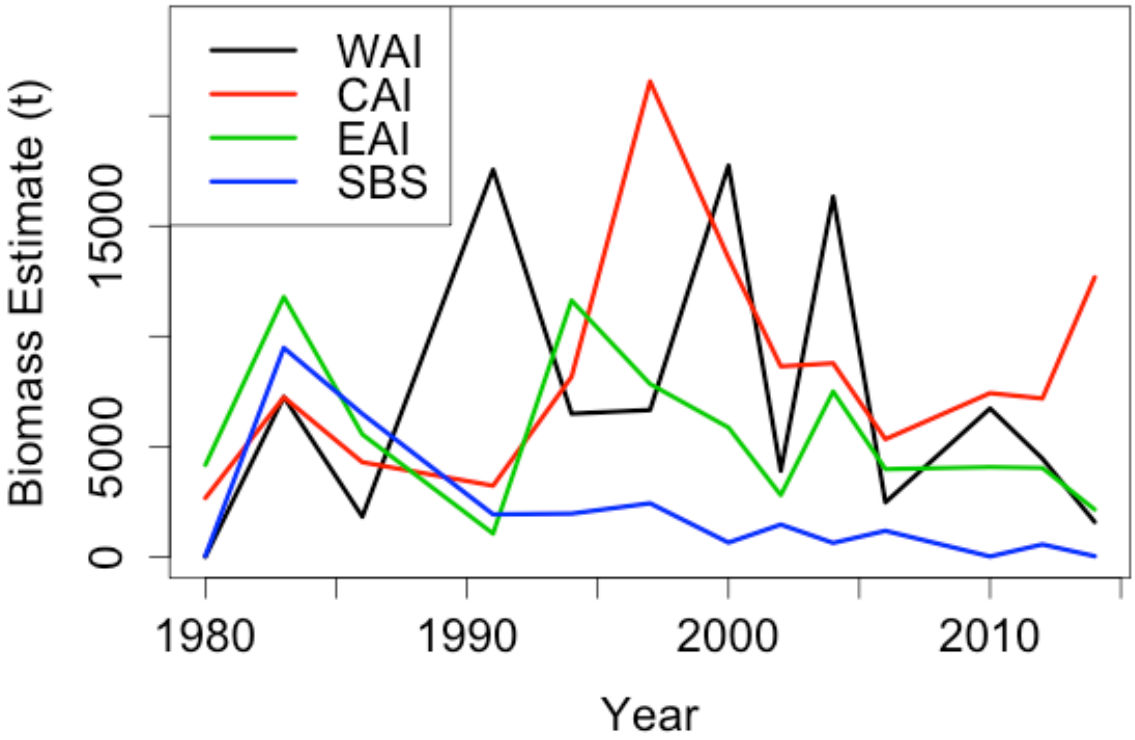

Figure 3. Survey estimates of biomass in the Western Aleutian Islands (WAI), Central Aleutian Islands (CAI), Eastern Aleutian Islands (EAI), Southern Bering Sea (SBS), Eastern Bering Sea (EBS), and Bering Sea (BS).

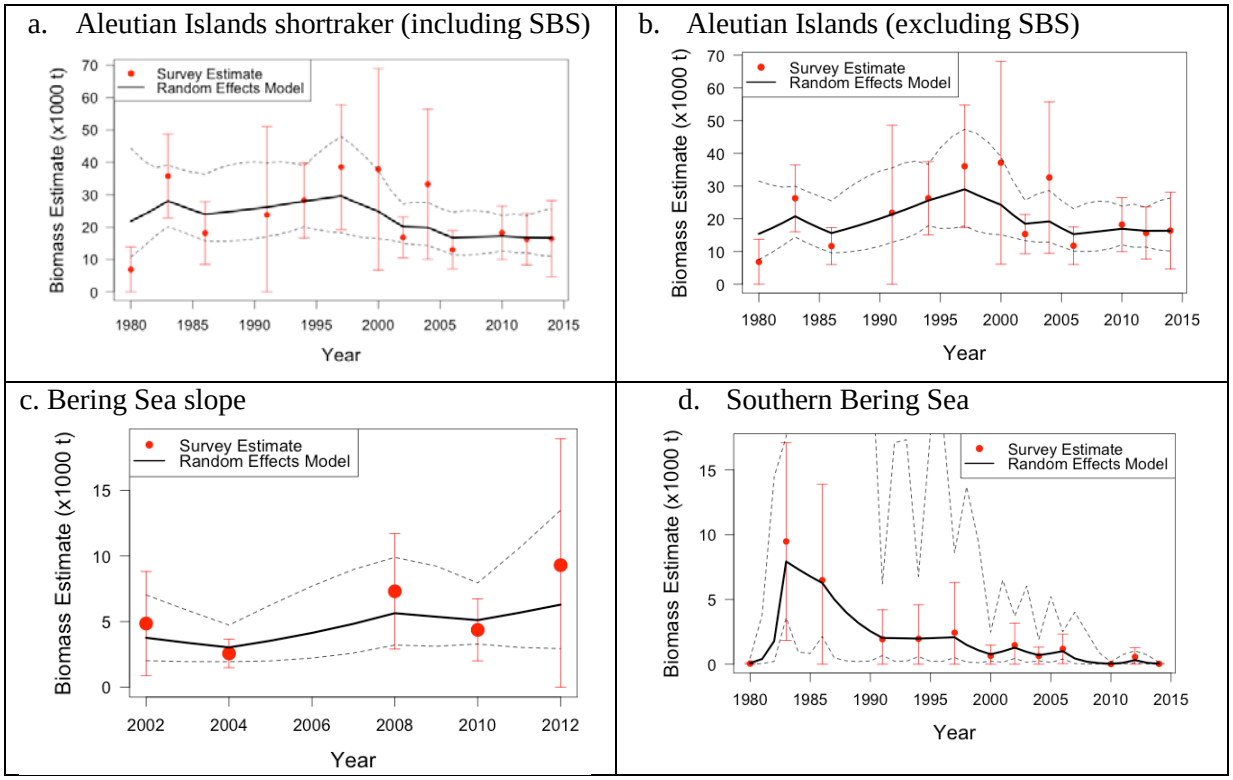

Figure 4. Observed survey biomass (red data points +/- 2 standard deviations), and predicted survey biomass estimates using the random effects model (black lines with 95% confidence intervals shown as dotted lines). Panel (a.) Aleutian Islands (AI), including the Southern Bering Sea (SBS), (b.) AI, excluding the SBS, (c.) Bering Sea slope, and (d.) the SBS.

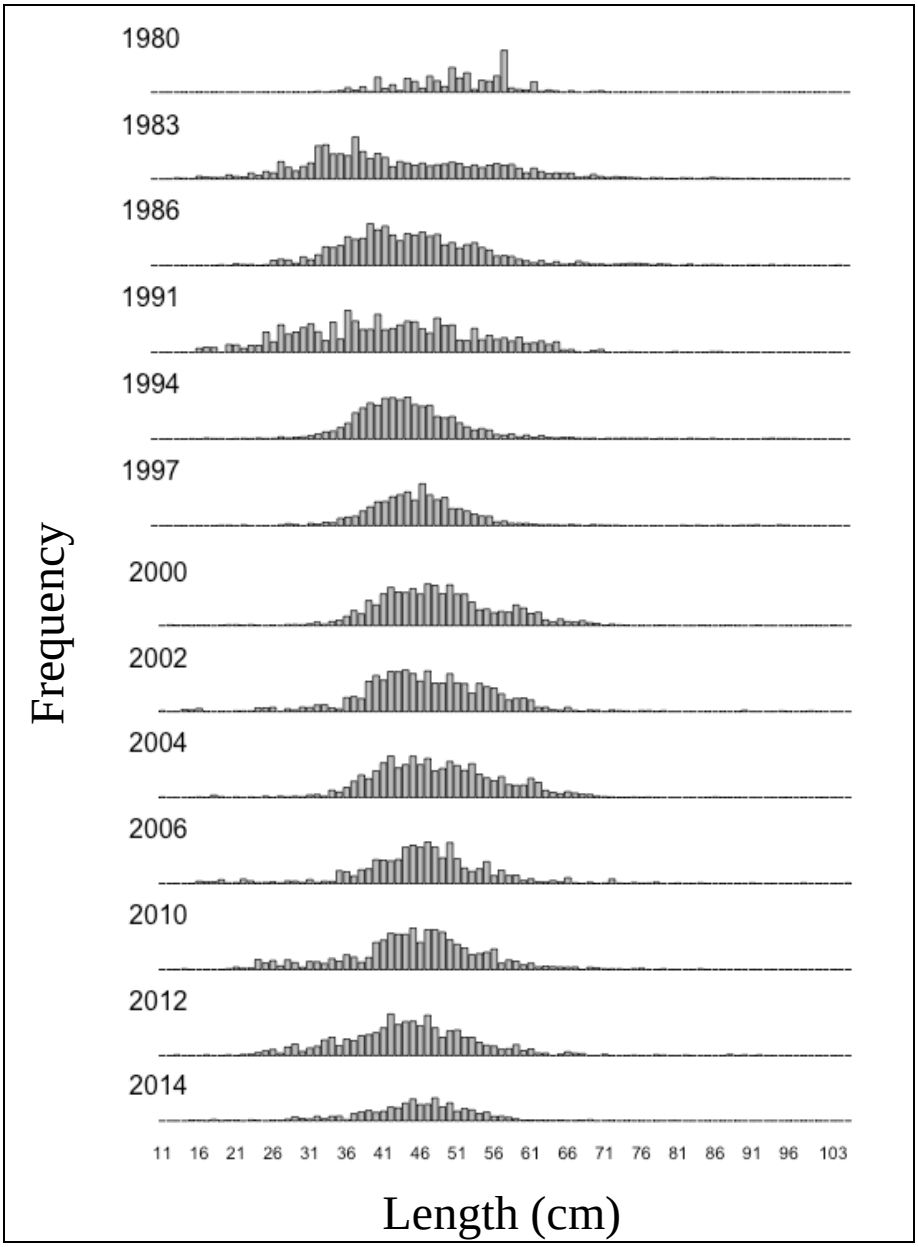

Figure 5. Length compositions from the Aleutian Islands trawl surveys, 1980-2014.

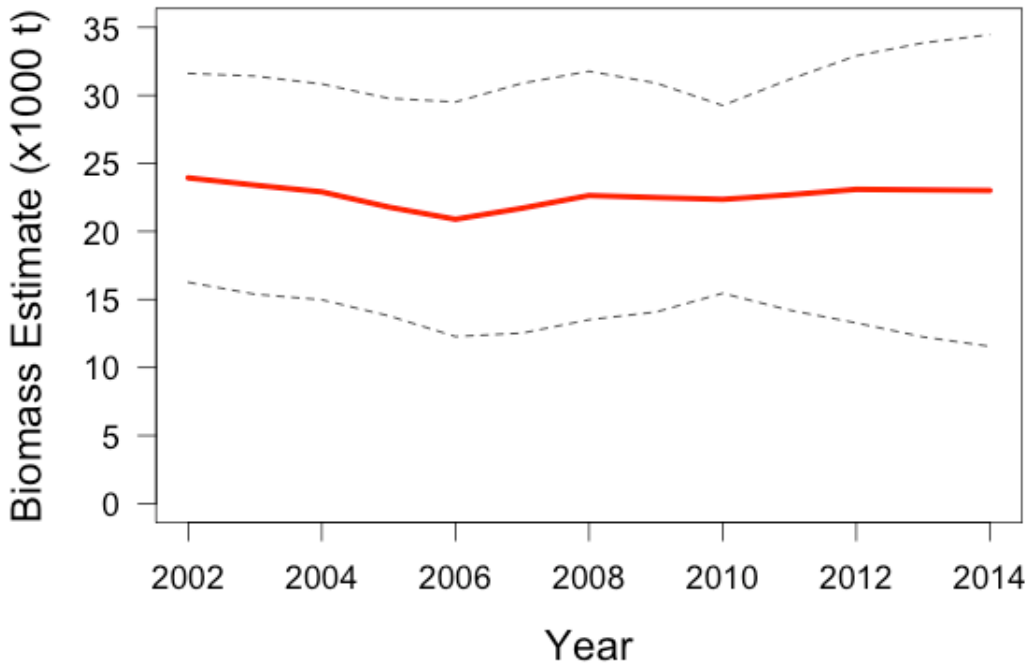

Figure 6. Estimated Bering Sea/Aleutian Islands (BSAI) Shortraker biomass (t) time series, from 2002-2014.

Appendix 1. 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 (Appendix 1 Table 1). 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 Bering Sea/Aleutian Islands (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 Aleutian Islands (AI) trawl survey was canceled) are higher due to the biennial cycle of the AFSC bottom trawl survey in the AI. 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 (GOA) and BSAI 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 -2014. Years with relatively high catches are caused by increased catches in the eastern and central AI.

Appendix 1 Table 1. Removals (t) 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						
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	NMFS-AFSC survey databases					
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		1.424	2.544			0.411
2012		3.874				
2013		1.205				
2014		1.571				

Appendix 1 Table 2. Estimates of the BSAI shortraker rockfish catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group. The 2014 values are incomplete.

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
2011					1.12
2012					0.56
2013					0.51
2014					
Average	4.33	3.38	0.67	0.01	7.99

Literature Cited

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Heifetz, J., D. Hanselman, J. N. Ianelli, S. K. Shotwell, and C. Tribuzio. 2009. Gulf of Alaska northern rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2010. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. pp. 817-874.

Tribuzio, C.A., S. Gaichas, J. Gasper, H. Gilroy, T. Kong, O. Ormseth, J. Cahalan, J. DiCosimo, M. Furuness, H. Shen, K. Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams ofthe North Pacific Fishery Management Council.

Appendix 2.
Assessment of shortraker rockfish in the Bering Sea and Aleutian Islands using last year's approved method, the surplus production model.

Executive Summary

Summary of Changes in Assessment Inputs

1) The catch data have been revised and updated through October 31, 2014.
2) The biomass estimate from the 2014 AI survey was added to the model input data.

The assessment methodology has not changed since the last full assessment in 2012. The Gompertz-Fox surplus production model is used to estimate the shortraker rockfish population, and the Kalman filter to statistically estimate the parameter values.

Summary of Results

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2014	2015	2015	2016
M (natural mortality rate)	0.03	0.03	0.03	0.03
Tier	5	5	5	5
Biomass (t)	16,447	16,447	16,073	16,073
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)	493	493	482	482
maxABC (t)	370	370	362	362
ABC (t)	370	370	362	362
	As determined *last* year for:		As determined *this* year for:	
Status	2012	2013	2013	2014
Overfishing		n/a		n/a

Introduction

This document presents the 2014 shortraker rockfish assessment with biomass estimated using last year's approved methodology, the surplus production model.

Responses to SSC and Plan Team Comments Specific to this Assessment

October 2014 SSC meeting: The Plan Team recommended and the SSC agrees that the random effects model be included in the November assessment anticipating that this will be the Team's preferred model for use in setting ABC and OFL.

Authors' response: The 2014 assessment is based on the random effects model. Results using the surplus production model, last year's approved model, are presented in Appendix 2.

Fishery

Please refer to the main document for this section.

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

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

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

$$b = ke^{-f/a} \tag{2}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

For 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,

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

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

Estimated shortraker rockfish biomass decreased slightly from 28,856 t in 1980 to 26,430 t in 1997, and have since declined to 16,073 t in 2014 (Figure 1, Table 1). The time series of estimated fishing mortality

shows the largest values of approximately 0.025 to 0.029 in the early 1980s and early 1990s, which are comparable to assumed natural mortality estimate of 0.03 (Table 1, Figure 2).

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 3new, 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:

Shortraker rockfish	2014 biomass	M	ABC	OFL
	16,073 t	0.03	361 t	482 t

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Tables

Appendix 2 Table 1. 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	2014 Preferred model	2012 Assessment	2014 Assessment
1980	29,776	28,856		0.028	0.029
1981	28,350	28,048		0.028	0.028
1982	27,561	27,487		0.022	0.022
1983	27,101	28,793		0.008	0.008
1984	28,564	28,251		0.003	0.003
1985	28,102	27,771		0.001	0.001
1986	27,655	25,792		0.001	0.001
1987	25,690	25,695		0.002	0.002
1988	25,574	25,629		0.003	0.003
1989	25,503	25,502		0.007	0.007
1990	25,320	25,971		0.025	0.025
1991	25,560	25,806		0.017	0.017
1992	25,493	25,621		0.014	0.014
1993	25,350	25,648		0.017	0.017
1994	25,341	25,818		0.009	0.009
1995	25,609	25,624		0.008	0.008
1996	25,419	25,434		0.009	0.009
1997	25,220	26,430		0.005	0.005
1998	26,249	25,377		0.009	0.009
1999	25,165	24,332		0.008	0.008
2000	24,139	23,505		0.014	0.014
2001	23,251	22,416		0.011	0.011
2002	22,223	20,727	23,938	0.015	0.015
2003	20,519	20,231	23,402	0.012	0.012
2004	20,055	20,298	22,906	0.012	0.012
2005	20,113	19,658	21,792	0.009	0.009
2006	19,512	18,099	20,896	0.012	0.012
2007	17,953	17,866	21,709	0.018	0.018
2008	17,662	17,664	22,641	0.010	0.010
2009	17,530	17,525	22,492	0.012	0.012
2010	17,369	17,429	22,356	0.019	0.019
2011	17,216	17,085	22,693	0.020	0.020
2012	16,858	16,678	23,093	0.021	0.021
2013		16,348	23,051		0.023
2014		16,073	23,009		0.018

Figures

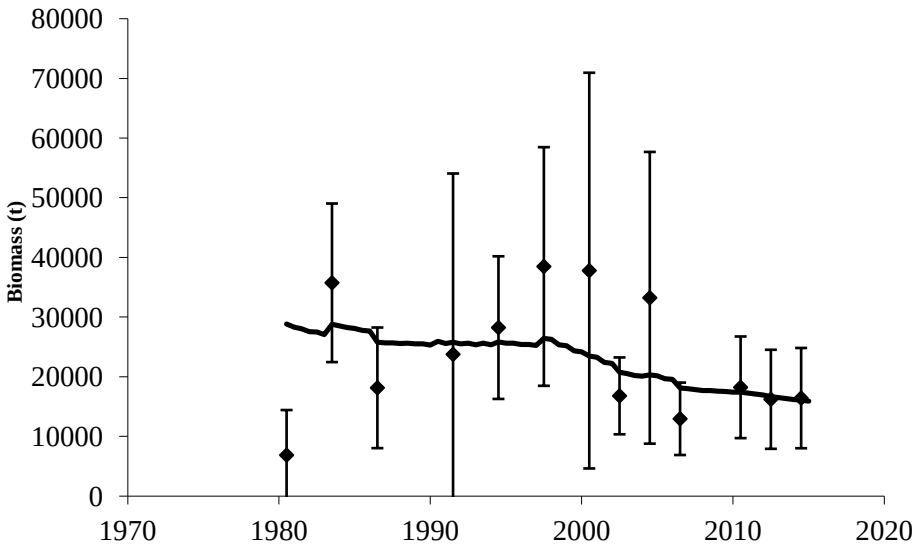

Figure 1. Observed AI survey biomass (data points +/- 2 standard deviations) and predicted survey biomass estimates from the Kalman filter model.

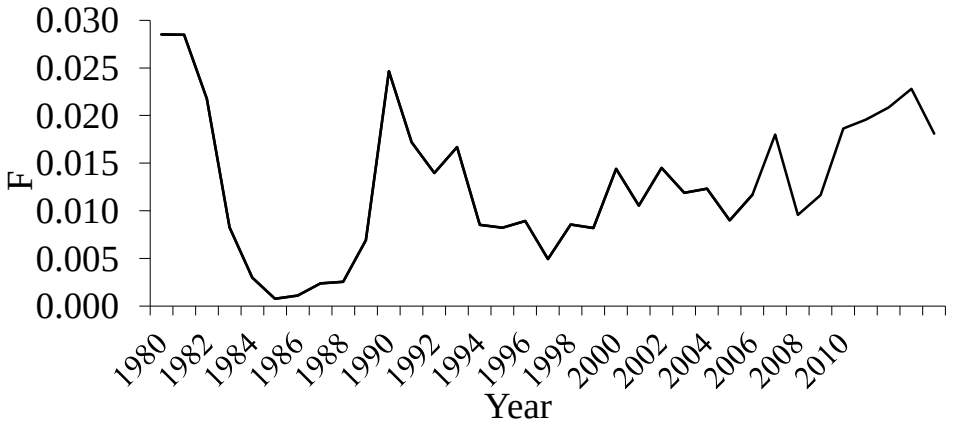

Figure 2. Estimated fishing mortality rate of BSAI shortraker rockfish, 1980-2014.

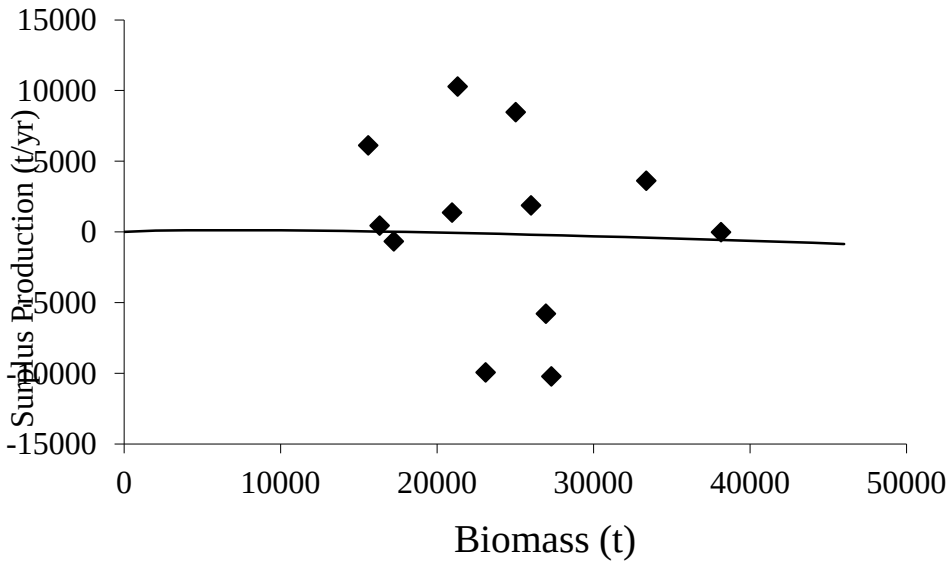

Figure 3. Estimated annual surplus production (data points, estimated as the harvest plus the change in biomass over a time interval), and production model fits of BSAI shortraker rockfish.