16. Assessment of the Other Rockfish stock complex in the Bering Sea/Aleutian Islands

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Executive Summary

The Bering Sea/Aleutian Islands (BSAI) Other Rockfish complex is currently managed in Tier 5 and is assessed on a biennial basis to coincide with the Aleutian Islands groundfish trawl survey, which occurs in even years, and the Bering Sea slope survey, which typically occurs in even years but did not take place in 2018. This assessment also includes data from the Bering Sea shelf survey which takes place annually.

The Bering Sea/Aleutian Islands (BSAI) Other Rockfish complex is defined by what it excludes rather than by what it includes. The Other Rockfish complex includes all species of *Sebastes* and *Sebastolobus*, other than Pacific ocean perch (POP, *Sebastes alutus*), northern rockfish (*Sebastes polyspinis),* rougheye rockfish (*S. aleutianus*), and shortraker rockfish (*S. borealis*). Current definitions of the complex do not specifically exclude blackspotted rockfish (S. *melanostictus)*, a recently recognized species (Orr and Hawkins 2008) that had historically been identified as rougheye rockfish in research surveys. However, blackspotted is currently not distinguished from rougheye rockfish in the fishery catches, and is thus currently managed under the BSAI blackspotted/rougheye complex. The two most abundant species for Other Rockfish complex are shortspine thornyhead (SST, *Sebastolobus alascanus*), and dusky rockfish (*Sebastes variabilis*). Other species include redstripe rockfish (*Sebastes babcocki*), redbanded rockfish (*Sebastes proriger*), yelloweye rockfish (*Sebastes ruberrimus*), harlequin rockfish (*Sebastes variegatus*) and sharpchin rockfish (*Sebastes zacentrus*).

A random effects model was used to estimate exploitable biomass. Separate biomass estimates were made for shortspine thornyhead (SST) and non-SST Other Rockfish in the Eastern Bering Sea and the Aleutian Islands, and separate ABCs and OFLs are presented for these two species/species groups and regions. Survey estimates for non-SST Other Rockfish species were available from Aleutian Islands survey years 1980-2018, from the Southern Bering Sea from survey years 980-2018, from Bering Sea slope survey years 2002-2016, and from Bering Sea shelf survey years 1984-2018. Shortspine thornyhead biomass was estimated from the Aleutian Islands and Southern Bering Sea from Aleutian Islands survey years 1980-2018 and from the Bering Sea slope using slope survey data from 2002-2016.

Summary of Changes in Assessment Inputs

Changes in the input data

1) Catch and fishery lengths updated through October 10, 2018.
2) Biomass estimates, catch per unit effort (CPUE), and length frequency compositions were included from the 2018 Aleutian Islands trawl survey, and the 2017 and 2018 Bering Sea shelf surveys. There has been no Bering Sea slope survey since 2016.

Changes in the assessment methodology

1) There were no changes in the assessment methodology.

Summary of Results

Summary for **SST portion** of the Other Rockfish complex.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2018	2019	2019	2020
M (natural mortality rate)	0.03	0.03	0.03	0.03
Tier	5	5	5	5
Biomass (t)	52,761	52,761	50,057	50,057
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)	1,583	1,583	1,502	1,502
maxABC (t)	1,187	1,187	1,126	1,126
ABC (t)	1,187	1,187	1,126	1,126
AI ABC (t)	398	398	417	417
EBS ABC (t)	789	789	813	813
	As determined *last* year for:		As determined *this* year for:	
Status	2016	2017	2017	2018
Overfishing	No	n/a	No	n/a

Summary for non-SST portion of the Other Rockfish complex.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2018	2019	2019	2020
M (natural mortality rate)*	0.09	0.09	0.09	0.09
Tier	5	5	5	5
Biomass (t)	2,592	2,592	3,233	3,233
F_{OFL}	0.09	0.09	0.09	0.09
$maxF_{ABC}$	0.0675	0.0675	0.0675	0.0675
F_{ABC}	0.0675	0.0675	0.0675	0.0675
OFL (t)	233	233	291	291
maxABC (t)	175	175	218	218
ABC (t)	175	175	218	218
AI ABC (t)	173	173	64	64
EBS ABC (t)	1	1	130	130
	As determined *last* year for:		As determined *this* year for:	
Status	2016	2017	2017	2018
Overfishing	No	n/a	No	n/a

*This natural mortality rate is estimated for dusky rockfish and assumed as a proxy for the non-SST portion of the Other Rockfish complex.

Summary for the entire Other Rockfish complex (SST and non-SST combined).

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2018	2019	2019	2020
M (natural mortality rate)*	-	-	-	-
Tier	5	5	5	5
Biomass (t)	55,312	55,312	53,290	53,290
F_{OFL}*	-	-	-	-
$maxF_{ABC}$	-	-	-	-
F_{ABC}	-	-	-	-
OFL (t)	1,816	1,816	1,793	1,793
maxABC (t)	1,362	1,362	1,345	1,345
ABC (t)	1,362	1,362	1,345	1,345
AI ABC (t)	572	572	377	377
EBS ABC (t)	790	790	942	942
	As determined *last* year for:		As determined *this* year for:	
Status	2016	2017	2017	2018
Overfishing	No	n/a	No	n/a

*Natural mortality and fishing mortality rates are specified separately for the SST and non-SST portions of the Other Rockfish complex.

The following table gives the recent biomass estimates, catch, and harvest specifications, and projected biomass, OFL and ABC for 2017-2020.

Species	Year	Biomass	OFL	ABC	TAC	Catch
Other rockfish	2017	55,312	1,816	1,362	875	831
	2018	55,312	1,816	1,362	845	832*
	2019	53,290	1,793	1,345		
	2020	53,290	1,793	1,345		

* Catch as of Oct 10, 2018

Responses to SSC and Plan Team Comments on Assessments in General

Comments from the SSC October 2017 – June 2017

1. Provide thorough documentation of model evaluation and the logical basis for changes in model complexity in all cases.

Authors' response

The random effects model was used to estimate biomass in this assessment.

2. Over the course of the summer, determine whether any factor or set of factors described in last year's ESR implies that the biomass of your stock will decline by at least 20% this year. Determine whether the current and future condition of your stock and the current and future condition of its ecosystem are "OK" or "not OK." •

Authors' response

Noted, and will be considered in 2019.

Responses to SSC and Plan Team Comments Specific to this Assessment

BSAI Plan Team 2016

Team discussions brought up some general questions regarding the random effects model, which are not specific to this assessment only. In the case of assessments where the biomass data may not support the random effects model (i.e., a flat line, process error not estimable), should it still be used? A further question was how to deal with zero biomass values in the model. These questions may be more appropriate for the survey averaging working group.

Authors' response

The BSAI Other Rockfish assessment presents some problematic datasets for the random effects model, such as the Bering Sea slop non-SST biomass and the EBS shelf biomass. The EBS shelf Other Rockfish dataset contains 12 years between 1982 and 2018 with no observations of Other Rockfish species, and this presents a problem for running the RE model. The author presents several alternatives to this approach. The EBS slope survey non-SST biomass also results in a flat line; process error is not estimable.

Introduction

The two most abundant species for Other Rockfish complex are dusky rockfish (*Sebastes variabilis*) and shortspine thornyhead (SST, *Sebastolobus alascanus*); therefore, more information is available on these species than the other species in the complex. The complex also includes all species of *Sebastes* and *Sebastolobus*, other than Pacific ocean perch (POP, *Sebastes alutus*), northern rockfish (*Sebastes polyspinis),* rougheye rockfish (*S. aleutianus*), and shortraker rockfish (*S. borealis*). An analysis was conducted in the 2001 Other Rockfish SAFE report to distinguish species expected to occur in the BSAI Other Rockfish complex from rarely observed and potentially misidentified species (Reuter and Spencer 2001, http://www.afsc.noaa.gov/REFM/docs/2010/BSAIshortraker.pdf). The criteria used for the analysis was occurrence in at least one haul of the BSAI surveys and/or occurrence in at least 1% of observed fishery hauls. Using data from 1999-2001, seven species (shortspine thornyhead, dusky rockfish; *Sebastes variabilis*, redbanded rockfish; *Sebastes babcocki*, redstripe rockfish; *Sebastes proriger*, yelloweye rockfish; *Sebastes ruberrimus*, harlequin rockfish; *Sebastes variegatus*, and sharpchin rockfish; *Sebastes zacentrus*) were identified as meeting these criteria. Dark rockfish (*Sebastes ciliatus*) also met the criteria, but have since been removed from the Other Rockfish complex and is now managed by the State of Alaska. Species composition of these species in survey and catch is summarized in Table 16.1.

Dusky rockfish and shortspine thornyheads are distributed in different depths and regions of the Bering Sea and Aleutian Islands. Shortspine thornyheads occur throughout the Aleutian Islands (AI) and eastern Bering Sea (EBS) slope but are most abundant in the western Aleutian Islands, where they are found between 200 m and 500 m depth (Reuter and Spencer 2001). In contrast, dusky rockfish are typically captured between 125-200 m in the Aleutian Islands, and are rarely encountered on the EBS slope in either survey or fishery catches.

There is no data on the genetic stock structure of dusky, harlequin, or redbanded rockfish. Isolation by distance population structure has been identified in rockfish species such as copper, brown, and grass rockfishes along the United States west coast (*Sebastes caurinus*, *S. rastrelliger*, and *S. auriculatus*; Buonaccorsi et al. 2002, 2004, 2005), Pacific ocean perch off Alaska (*Sebastes aleutus*; Palof et al. 2011), and northern rockfish in the Bering Sea and Aleutian Islands region of Alaska (*Sebastes polyspinis*; Gharrett et al. 2012). Given the similarity in life history among rockfish species, it may be hypothesized that such genetic population structure could exist in the species that comprise the Other Rockfish complex. Genetic data suggests that the genus *Sebastolobus*, which includes all thornyhead rockfish, are subject to genetic population structure (Stepien et al. 2000).

Rockfish of the genus Sebastes are long-lived and do not attain reproductive maturity until 5-20 years of age. They are viviparious; they mate and fertilize the eggs internally. Embryos develop within the female, and thousands or millions of tiny larvae are released after several months. Juveniles settle in kelp, eelgrass, or rocky habitat and move to deeper water as they mature. The maximum age of dusky rockfish (*Sebastes variabilis*) formerly known as light dusky (Orr and Blackburn 2004) in the GOA is 59 years from the survey and 76 years from the fishery (Lundsford et al. 2009). The generation time for dusky rockfish has been estimated at 23 years following the methods described in Restrepo et al. 1998 and using the estimates available from the dusky age-structured model (Lundsford et al. 2009). Two studies have estimated the age at 50% maturity of dusky rockfish in the GOA and range from 9.2 years to 11.3 years. These values indicate dusky rockfish have a shorter generation time than other rockfish, likely due to the higher natural mortality and earlier maturity.

Species of the genus sebatolobus, including shortspine thornyhead and longspine thornyhead (*Sebastolobus altivelis*) spawn pelagic egg masses that are pelagic between April and July in

Alaska (Pearson and Gunderson 2003). Generation time may be as long as 100 years in shortspine thornyhead (Stepien et al. 2000).

Some progress in our knowledge of the biology of shortspine thornyhead and harlequin rockfish in the Aleutian Islands has occurred from a recently completed project that revealed harlequin rockfish are much older than previously thought. Two specimens collected in the Aleutian Islands reached ages over 70 years, easily eclipsing the previously known maximum age of 47 years (from a specimen collected in the Gulf of Alaska). Age determination for shortspine thornyhead has been recently investigated, with the main focus on establishing some working age criteria. Precision between age readers showed promise for young to moderately old specimens, up to 25+ years. Older specimens resulted in generally poorer precision. A robust study is being planned to look at more specimens, which may help in interpreting patterns. Accuracy of shortspine thornyhead ages, however, remain inconclusive from C_{14} bomb radiocarbon results. Aspects of reproduction between these two species have also been examined. Estimates of maturity for Aleutian Islands harlequin rockfish was not possible due to larger specimens collected in the dataset. The same project, however, did reveal that Gulf of Alaska harlequin rockfish mature at an early age (50% length and age = 4.5 years at 18.7 cm). Maturity for shortspine thornyhead in the Aleutian Islands showed a 50% length and age estimate at 23.1 cm and 12.6 years. Given that ageing shortspine thornyheads are still a work in progress, the maturity-at-age estimate should be viewed as preliminary.

Juvenile rockfish are preyed upon by lingcod (Beaudreau and Essington 2007), salmon, and other fish speices (Palsson et al. 2009). Adults are consumed by harbor seals and other marine mammals (Lance and Jeffries 2007). SST are preyed upon by groundfish such as Pacific cod (*Gadus macrocephalus*), sablefish (*Anoplopoma fimbria*), arrowtooth (*Astheresthes stomias*) and Kamchatka flounder (*Astheresthes evermanni*), walleye pollock (*Gadus chalcogrammus*), and the longnose skate (*Raja rhina*). SST consume smaller fish and crustaceans, such as herring, capelin, and crab, as well as skates, eelpouts, krill, and shrimp.

Historically, the value of *M* of 0.07 has been used to assess the Other Rockfish stock, which represents an approximation based on knowledge of rockfish life histories from other areas. This value is based on the estimate for SST from Ianelli and Ito (1994), as this species comprises well over 90% of the Other Rockfish biomass (as calculated by survey data). In the 2003 GOA SST assessment a value of M of 0.038 was used, which was obtained as an alternate value given in Pearson and Gunderson (2003). We use a value of 0.03 for the SST portion of the BSAI Other Rockfish biomass because this value has been accepted by the Plan Team and SSC, in order to maintain consistency with GOA SST. The parameter estimate for natural mortality for dusky rockfish in the GOA is 0.09, and thus is currently the best estimate of *M* (Clausen and Heifetz 2001). For the 2018 assessment, we used an *M* of 0.09 for the non-SST Other Rockfish.

Fishery

The Other Rockfish category has existed in the BSAI Fishery Management Plan since 1986, and is managed through annual catch limits (Table 16.2). Prior to 2005, separate OFLs were established for EBS and AI management areas for SST and non-SST Other Rockfish. In 2005, the overfishing level was set as a combined limit for the entire BSAI. In that year the BSAI Other Rockfish complex was moved to a biennial assessment schedule to coincide with the frequency of trawl surveys in the AI and the EBS slope surveys. These surveys occur in even years, and for these years a full assessment of the Other Rockfish complex in the BSAI area is conducted. For this assessment, ABCs and OFLs for SST are calculated separately from the non-SST Other Rockfish because SST is the most abundant species in the BSAI Other Species complex, and because it is managed under a lower natural mortality estimate (M=0.03) than the non-SST Other

Rockfish (M=0.09). However, the OFL and ABC reference points are for the entire Other Rockfish complex, and are provided for the Bering Sea and the Aleutians separately.

Historically, foreign catch records did not identify the various Other Rockfish by species, but reported catches in categories such as "other species" (1977-1979), and "Other Rockfish" (1980-1990), with the definitions of these groups changing between years. In the domestic fishery, the NOAA Fisheries Alaska Regional Office “Blend” catch database often reported the catches of Other Rockfish species in a single “Other Rockfish” category, although species-specific catch records have been available with the Catch Accounting System (CAS) database beginning in 2003. From 1991-2002, species catches were 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. An identical procedure was used to reconstruct the estimates of catch by species from the 1977-1989 foreign and joint venture fisheries. Estimated domestic catches in 1990 were obtained from Guttormsen et al. 1992. Catches from the domestic fishery prior to the domestic observer program were obtained from PACFIN records. Catches of Other Rockfish since 1977 by area are shown in Tables 16.2 and 16.3. Table 16.2 reports the catches of the seven most common species identified above (dusky, yelloweye, sharpchin, redbanded, redstripe, and harlequin rockfish, and shortspine thornyhead), as well as less common species that are recorded to species (black, darkblotched, rosethorn, silvergray, and thornyhead rockfish), as well as a final category of rockfish not identified to species called “other rockfish”. Some relatively high catches occurred in the late 1970s – early 1980s; total catch has only exceeded 1,000 t in 1978, 1979, 1980, 1982, and 1990. Reported ABCs, TACs, and catches of Other Rockfish from 2004-2018 are shown in Table 16.2. The catch of other rockfish in the Bering Sea has remained stable, but catch in the AI increased substantially in 2011-2018 relative to the period from 1995-2010.

The catches of Other Rockfish are composed primarily of dusky rockfish and shortspine thornyhead; from 2004 -2018, these two species composed 86% of the catch identified to species in the AI and 92% in the EBS (Tables 16.4 and 16.5). Three species of Sebastolobus are routinely captured in BSAI trawl surveys; broadbanded thornyhead, longspine thornyhead, and shortspine thornyhead. The SST is by far the most abundant, comprising more than 90% of the thornyheads identified in observer records since 2008 (Table 16.4). Shortspine thornyhead are only identified to genus in the fishery; therefore annual observer records of the proportion of SST out of the total thornyhead catch was applied to fishery catch for an extrapolated estimate of the catch of SST (Tables 16.4 and 16.5). Fishery observers record shortspine thornyhead, broadbanded, and longspine thornyhead, as well as thornyhead unid., which could include any of the thornyhead species. In the AI, the catches of dusky rockfish and SST averaged 280.2 t and 150.1 t, respectively, from 2004-2018. The proportion of SST in the EBS Other Rockfish catch was higher, as the catches of dusky rockfish and SST averaged 34.2 t and 176.9 t, respectively from 2004-2018. In the Bering Sea, SST are only encountered on the Bering Sea slope. Discrepancy between total catch and individual catch (e.g. Tables 16.2 and 16.4) is due to the catch weight of less common species and to catch assigned to the “Other Rockfish“ group without being identified to species.

There is no directed fishing for any of the Other Rockfish species; however, incidental catch occurs in multiple fisheries and gear types (Table 16.6). Between 2004 and 2018, approximately 16% of the “Other Rockfish” was caught in the directed rockfish fishery. The highest proportion (38%) has been caught in the Atka mackerel fishery, followed by the rockfish fishery, the flatfish fishery (9%), the sablefish fishery (11%), and Pacific cod fisheries (8%). Other less significant fisheries include Pacific halibut (3%) and walleye pollock (3%). Since 2004 Other Rockfish have been primarily caught by bottom trawl (68%) and hook and line (29%).

Catch estimates of dusky rockfish and SST in various target fisheries and gear types from 2004-2018 is shown in Tables 16.7-16.10. In the EBS, dusky rockfish are primarily caught in the Pacific cod longline fishery (39%), followed by trawl fisheries for pollock (26%), rockfish (13%), Pacific cod (10%), Atka mackerel (3%), and various flatfish (4%) (Table 16.7). Most of the shortspine thornyhead catches in the EBS occur in the bottom trawl fisheries for flatfish (arrowtooth flounder, Kamchatka flounder, Greenland turbot, flathead sole, rock sole, and yellowfin sole) (36%), followed by flatfish longline fisheries (19%), and the rockfish trawl fishery (13%) (Table 16.8). Dusky rockfish in the AI are caught in the Atka mackerel trawl fishery (83%) followed by the rockfish trawl fishery (12%) and Pacific cod longline gear (3%) (Table 16.9). Shortspine thornyhead in the AI are caught primarily in the sablefish longline fishery (46%) followed by the rockfish trawl fishery (29%), and the flatfish longline fishery (7%) (Table 16.10). In the EBS, thornyhead rockfish are caught primarily along the continental slope in NMFS reporting areas 517, 519, and 521 and dusky rockfish are primarily caught in areas 516, 518, and 518 (Tables 16.6 and 16.7). In the AI, the catch of dusky rockfish is almost entirely in the eastern Aleutians (area 541), but thornyhead catch is similar throughout the three Aleutians management areas, 541, 542, and 543 (Tables 16.9 and 16.10).

A summary of the Other Rockfish catch retained and discarded from 2004-2018 indicates that the percent of Other Rockfish retained has ranged from 51% to over 90%, and has generally increased over time (Table 16.11). Low discard rates are primarily from fixed-gear, which yields a higher quality product than trawl gear (Hiatt et al. 2002).

Data

Fishery

Fishery length samples have been collected by observers for both SST and dusky rockfish since 2002. Generally, between 500 and 1,500 length samples are taken each year. The fishery length frequencies for each species since 2002 show little change, with the bulk of the dusky rockfish lengths between approximately 36 and 50 cm (Figure 16.1), and the bulk of the SST lengths between 30 and 60 cm (Figure 16.2).

Catches of the Other Rockfish complex from non-commercial sources (i.e. those not included in the Alaska Regional Office's Catch Accounting System) are shown in Table A1.1. Non-commercial removals ranged from 1.5-23 metric tons (t) between 2004 and 2017.

Survey

Several bottom trawl surveys provide biomass estimates for the EBS and AI regions. The 1979-85 cooperative U.S.-Japan trawl surveys in the EBS were conducted both on the continental shelf and slope, and cooperative surveys were also conducted in the AI from 1980-1986. U.S domestic trawl surveys were conducted in 1979, 1981, 1982, 1985, 1988, 1991, 2002, 2004, 2008, 2010, 2012, and 2016 on the EBS slope, and in 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, and 2018 in the AI (Tables 16.12, 16.13, and 16.14). The 2002 EBS slope survey represented the initiation of a new survey time series distinct from the previous surveys. The EBS slope survey samples depths from 200 to ~1200 m, whereas the AI survey samples depths to 500 m. Thus, survey biomass estimates of deep-water species such as shortspine thornyhead are likely underestimated in the AI survey. The cooperative U.S. – Japan AI trawl survey were conducted with different vessels, survey gear, and sampling design relative to the U.S. domestic trawls surveys that began in 1991. The NMFS EBS shelf survey has been conducted every year since 1982, but few rockfish are found there, primarily dusky and harlequin rockfish.

From 1980-2018, the biomass estimates for Other Rockfish in the AI trawl survey have gradually increased; values since 2002 have been higher than those reported for 1980-1997 (Table 16.12). Biomass estimates for the Aleutian Islands portion of the AI survey have been >14,000 t since 2002. Bering Sea shelf estimates have averaged 135 t since 1982. The highest estimates of Aleutian Islands Other Rockfish biomass from the AI trawl survey include 857 t in 1991, 538 t in 1998, and the highest estimate on record of 1,593 t in 2018 (Table 16.12).

Between 1997 and 2018, the dusky rockfish biomass estimate in the AI area has fluctuated between 236 t (2012) and 6,260 t (2014), although the larger estimates are driven by a small number of very large tows, leading to large coefficients of variation (CV) (Table 16.13). Such large fluctuations would not be expected in such a long-lived species, and are likely due to high uncertainty in the biomass estimates. The biomass estimate of SST in the AI area increased from 6,153 t in 1991 to 13,000-18,000 t from 2002-2018 (Table 16.14).

Biomass estimates of Other Rockfish from the Bering Sea slope have increased from historical levels from 1970-the 1990's (Table 16.12). The 2016 slope survey estimate was the highest ever observed at 35,972 t, nearly all of which was SST. The majority of EBS slope survey Other Rockfish biomass from 2002-2016 has been SST, but has also included broadfin thornyhead, longspine thornyhead, dusky, silvergray, yellowmouth, and redbanded rockfish, although the estimated biomass for redbanded rockfish did not exceed 7 t for any year. Dusky rockfish are fairly rare in the EBS slope survey, and were not seen at all in the 2016 survey (Table 16.13).

The lengths of dusky rockfish obtained in the 2000-2018 AI were generally between 35 and 45 cm, corresponding closely to the length distribution in the BSAI fishery (Figures 16.1 and 16.2). Shortspine thornyhead lengths from the survey are smaller than those for the fishery, falling primarily between 20 and 44 cm (Figures 16.3 and 16.4). Assuming that larger SST in the AI inhabit deeper water, the larger length in the fishery difference is likely related to the 500 m depth limit of the AI survey. Length frequencies were generally consistent between years.

Analytic Approach

Model Structure

Other Rockfish are currently assessed with the Tier 5 methodology, which requires estimates of natural mortality (M) and a reliable biomass estimate. For Tier 5 stocks, F_{OFL} and F_{ABC} are defined as M and 0.75M, respectively. The acceptable biological catch (ABC) is obtained by multiplying F_{ABC} by the estimated biomass, and the overfishing level (OFL) is obtained by multiplying F_{OFL} by the estimated biomass. The estimated natural mortality differs between shortspine thornyhead (0.03) and the remaining stocks in the Other Rockfish complex (0.09); therefore, ABC and OFL (and F_{OFL} and F_{ABC}) are calculated separately for SST and non-SST Other Rockfish. Apportionments between the AI and the EBS are based on survey estimates in those regions.

Biomass estimates for Other Rockfish in 2010-2014 were obtained by taking a weighted (4-6-9) biomass estimate of the most recent three surveys by area, with higher weights applied to more recent surveys (Bering Sea slope, Bering Sea shelf, and Aleutian Islands surveys). The EBS estimated biomass was obtained from summing the weighted average from the EBS slope survey with the weighted average from the SBS portion of the AI survey, and the AI biomass estimate was obtained using the AI portions of the AI surveys.

In 2015, 2016, and 2018 biomass is estimated using the Random Effects model (Figure 16.5), and the most recent biomass estimate from this model is used to estimate biomass for the current year and calculate OFL and ABC. 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).

This method has been selected by the SSC as the preferred approach for Tier 5 assessments.

A random effects model was used to estimate exploitable biomass. Separate biomass estimates were made for shortspine thornyhead (SST) and non-SST Other Rockfish in the Eastern Bering Sea and the Aleutian Islands, and separate ABCs and OFLs are presented for these two species/species groups and regions. Survey estimates for non-SST Other Rockfish species were performed by summing over non-SST survey biomass estimates and CVs, and estimated from Aleutian Islands survey years 1980-2018, from the Southern Bering Sea from survey years 1980-2018, from Bering Sea slope survey years 2002-2016, and from Bering Sea shelf survey years 1984-2018. Shortspine thornyhead biomass was estimated from the Aleutian Islands and Southern Bering Sea from Aleutian Islands survey years 1980-2018 and from the Bering Sea slope using slope survey data from 2002-2016.

Fishery exploitation rates (Figure 16.6) are estimated as the observed catch divided by the RE model biomass. The exploitation rate for SST since 2004 has remained less than 2%. SST exploitation rates in the EBS and AI have remained below area specific OFLs from 2004-2018 (Figure 16.7). Catches of dusky and harlequin rockfish in the AI have increased in recent years (Table 16.4), and the estimate of catch/biomass is high (Figure 16.6). Total Other Rockfish catches in the AI region exceeded ABC in all but two of the last eight years (Table 16.2) and BSAI catch exceeded TAC in 2014. Overall AI catch/biomass ratio exceeded 1 in 2011 and 2012. This indicates that there are more dusky/harlequin rockfish than indicated by the research survey, perhaps in untrawlable areas. The catch of non-SST rockfish in the BSAI has exceeded the area-wide OFL in since 2007 (Figure 16.8). Approximately 82% of dusky rockfish in the Aleutian Islands was caught in the Atka mackerel trawl fishery, which takes place in similar locations as shown in Figure 16.9. Harlequin rockfish is primarily caught in the Aleutian Islands in regions also shown in Figure 16.9 (lower panel). The overall BSAI OFL, however, remains well above the recent catch rates.

Parameter Estimates

Estimates of natural mortality of SST have been variable due to the difficulty of ageing this species. In the GOA shortspine thornyhead assessment, Gaichas and Ianelli (2003) presented natural mortality estimates from several studies. Studies have calculated natural mortality differently due to the age of their oldest sample. Miller (1985) estimated natural mortality to be 0.07 from a sample of SST in Southeast Alaska whose oldest age was 62 years old. A study using west coast SST estimated a natural mortality between 0.05-0.07 with the oldest age in the sample being 80 (Kline 1996). Pearson and Gunderson (2003) suggest that SST from Alaska have an M = 0.013-0.017, based on a study using the gonadosomatic index to estimate natural mortality. A natural mortality rate that low suggests that these fish reach maximum ages from 250-350 years, which would be very old even among rockfish species. One source of variability in these estimates is the variation in otolith age reading techniques. Miller (1985) used surface ageing and the break and burn technique, and found that precision and comparability was low. Kline (1996) used a thin section technique that had better inter-reader ageing agreement, and radiometric verification supported this technique. Subsequent radiometric work by Kastelle et al. (2000) corroborated Kline's results. Thus, Kline's methodology and results are presumed to be the most accurate given the uncertainty of ageing SST. Work is currently being done at the Alaska

Fisheries Science Center to determine the best ageing technique to use for SST (personal communication Todd Tenbrink, AFSC).

Results

Model Evaluation

Twelve of the 37 EBS shelf data years between 1982 and 2018 contained observations of zero non-SST other rockfish. The years with no observations of non-SST Other Rockfish were: 1982, 1983, 1986, 1988, 1989, 1990, 2000, 2001, 2002, 2004, 2007, and 2008. The model was run several ways to compensate for lack of data. Running the model with all years of zero data removed resulted in the fit to the data shown in Figure 16.8, and this method data was used for the non-SST Other Rockfish biomass estimate on the EBS shelf in the 2016 and 2018 assessment. The random effects model was not developed for data in years in which variance is zero; therefore, the data was also run with 0.1 t added to years with a zero biomass estimate and 0.0001 added to the variance. This method changed the estimate of biomass in 2018 from 1,503 t to 720 t (Table 16.15 and Figure 16.10). Several other attempts to increase the variance were made for the zero years, including adding 0.01 and 0.1 to the biomass and adding 10^{-4}, 10^{-3}, and 10^{2} to the variance (Table 16.15 and Figure 16.10). These all resulted in 2018 biomass estimates of ~1,500 t, which was entirely influence by the final year of data. Additionally, a model was run with only years 2009-2018 which all contained non-zero estimates, which resulted in a 2018 biomass estimate of 837 t. Removing the zero value years averaged the data much better than including them. Prior to 2016 the Other Rockfish assessment used a 4, 6, 9 weighting of the most recent 3 years of data. Using this method gives an estimate of 812 t of Other Rockfish on the EBS slope. These various biomass estimates of Other Rockfish on the EBS shelf are presented in Table 16.15 and Figure 16.10. For the current assessment, removing years with zero data was chosen as the preferred method because it allowed the model to average the data, and was justified because it is very close to the estimate with only the past 10 years.

Harvest Recommendations

The 2018 biomass estimate of all species in the Other Rockfish complex from random effect model results is 53,290 t; 50,057 t for the SST component, and 3,233 t for the non-SST component. The 95% confidence intervals are wider for the non-SST component of the stock complex, reflecting uncertainty in those estimates. Survey biomass estimates were used as inputs to the random effect models for each survey and subgroup.

In recent years, BSAI Other Rockfish have been managed with a BSAI-wide OFL level and separate acceptable biological catches (ABCs) for the Aleutian Islands and Eastern Bering Sea subareas. For the 2019 and 2020 fishery, we recommend the maximum allowable ABC of 942 t for the Other Rockfish complex in the Eastern Bering Sea and 377 t in the Aleutian Islands. We also recommend an overfishing limit (OFL) OFL of 1,793 t for the entire complex. Further breakdowns of reference values for SST and the remaining stocks in the Other Rockfish complex are summarized in the following table.

2018	SST	NonSST	Total Other Rockfish
M	0.03	0.09	-
Biomass	50,057	3,233	53,290
LCI	(59,475)	(6,665)	(63,024)
UCI	(42,130)	(1,568)	(45,059)
F_{OFL}	0.03	0.09	-
$maxF_{ABC}$	0.0225	0.0675	-
F_{ABC}	0.0225	0.0675	-
OFL	1,502	291	1,793
maxABC	1,126	218	1,345
ABC	1,126	218	1,345
Aleutian Islands ABC	312	64	377
Eastern Bering Sea ABC	813	130	942

Ecosystem Considerations

Ecosystem Effects on Stock

Little to no information is available to determine the diet of Other Rockfish species, important predators, or their trends over time.

Fishery Effects on the Ecosystem

The Other Rockfish complex is not a targeted fishery, therefore reference on the effects of the fishery on the ecosystem will be described in the SAFE chapters of the fisheries in which Other Rockfish is taken as bycatch.

Data gaps and research priorities

Recent age validation for shortspine thornyhead has been deemed inconclusive and inter-agency collaboration is being sought to aid in this endeavor. Therefore, the ageing patterns observed in shortspine thornyhead need to be clarified so that consistent ageing criteria can be established throughout the entire age range of the species. There has been some progress in this criteria for the first 25 years of age of shortspine thornyheads. Future work has been planned to age more otoliths to identify annual patterns in growth, which would include testing different methods. Until some of this is resolved, any maturity-at-age estimate should be viewed with caution.

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Tables

Table 16.1. The percentage catch of "Other Rockfish" in AFSC research bottom trawl surveys and in observed fisheries hauls from a) 1991-2001 and b) 2004-2018.

a) Period: 1991-2001

		EBS		AI	
Common name	Scientific name	**Survey**	**Fishery**	**Survey**	**Fishery**
Redbanded rockfish	*Sebastes babcocki*	~	~	1%	<1%
Dusky rockfish	*Sebastes variabilis*	18%	39%	22%	45%
Redstripe rockfish	*Sebastes proriger*	~	1%	~	1%
Yelloweye rockfish	*Sebastes ruberrimus*	~	1%	<1%	1%
Harlequin rockfish	*Sebastes variegatus*	~	1%	9%	5%
Sharpchin rockfish	*Sebastes zacentrus*	~	<1%	<1%	<1%
Shortspine thornyhead	*Sebastolobus alascanus*	62%	43%	61%	34%

b) Period: 2004-2018

		EBS		AI	
Common name	Scientific name	**Survey**	**Fishery**	**Survey**	**Fishery**
Redbanded rockfish	*Sebastes babcocki*	<1%	<1%	~	<1%
Dusky rockfish	*Sebastes variabilis*	2%	16%	10%	60%
Redstripe rockfish	*Sebastes proriger*	~	<1%	~	<1%
Yelloweye rockfish	*Sebastes ruberrimus*	~	<1%	~	<1%
Harlequin rockfish	*Sebastes variegatus*	~	<1%	<1%	9%
Sharpchin rockfish	*Sebastes zacentrus*	~	<1%	~	<1%
Shortspine thornyhead	*Sebastolobus alascanus*	98%	73%	90%	22%

Table 16.2. Regulatory catch limits (OFL, ABC, and TAC) and total catch of Other Rockfish in the BSAI, 1995-2018. Data for 2004-2018 is from the NMFS AKRO Catch Accounting System, AKFIN database, accessed October 10, 2018. Catch data previous to 2004 was obtained using several different sources that are described in the text. Light shading indicates catch that exceeded TAC, but not ABC. Shading indicates catch that exceeded both TAC and ABC, but not OFL.

	BSAI				AI				BS			
Year	OFL	ABC	TAC	Catch	OFL	ABC	TAC	Catch	OFL	ABC	TAC	Catch
1995		1135	1022	480	770	770	693	223	365	365	329	257
1996		1449	1354	436	952	952	857	272	497	497	447	164
1997		1087	1087	388	952	714	714	274	497	373	373	114
1998		1054	1054	482	913	685	685	327	492	369	369	155
1999		1054	1054	517	913	685	685	372	492	369	369	145
2000		1054	1054	797	916	685	685	558	492	369	369	239
2001		1037	1037	819	901	676	676	524	482	361	361	295
2002		1037	1037	872	901	676	676	502	482	361	361	370
2003		1594	1594	724	846	634	634	408	1280	960	960	316
2004		1594	1094	633	846	634	634	331	1280	960	460	302
2005	1,870	1,400	1,050	447		590	590	282		810	460	165
2006	1,870	1,400	1,050	570		590	590	421		810	460	149
2007	1,330	999	999	646		585	585	429		414	414	217
2008	1,330	999	999	596		585	585	382		414	414	214
2009	1,380	1,040	1,040	566		555	555	372		485	485	193
2010	1,380	1,040	1,040	766		555	555	498		485	485	269
2011	1,700	1,280	1,000	945		570	500	617		710	500	328
2012	1,700	1,280	1,070	921		570	570	712		710	500	209
2013	1,540	1,159	873	820		473	473	628		686	400	192
2014	1,550	1,163	773	953		473	473	629		690	300	324
2015	1,667	1,250	880	688		555	555	503		695	325	185
2016	1,667	1,250	875	789		555	550	507		695	325	282
2017	1,816	1,362	875	831		571	550	570		791	325	261
2018	1,816	1,362	845	828		571	570	663		791	275	164

Table 16.3. Historical catch (t) of Other Rockfish species from 1977 to 2003 in foreign, joint venture (JV), and domestic fisheries. Data were obtained using several different sources that are described in the text. Data prior to 1990 are on file at the Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Seattle, WA 98115.

	Eastern Bering Sea				Aleutian Islands				BSAI
Year	Foreign	JV	Domestic	Total	Foreign	JV	Domestic	Total	Total
1977	52	0		52	537	0		537	589
1978	304	0		304	795	0		795	1,099
1979	281	0		281	2,053	0		2,053	2,334
1980	566	1		567	484	0		484	1,051
1981	337	0		337	236	0		236	574
1982	365	0		365	2,057	0		2,057	2,422
1983	208	1		210	717	4		721	931
1984	112	7		119	57	25		81	200
1985	35	1		36	1	14		15	51
1986	4	14	81	99	0	10	147	157	256
1987	3	4	535	542	0	5	138	143	684
1988	0	3	252	254	0	68	168	237	491
1989	0	9	171	180	0	0	352	352	533
1990			395	395			822	822	1,217
1991			239	239			313	313	552
1992			201	201			470	470	671
1993			142	142			443	443	584
1994			123	123			272	272	395
1995			257	257			223	223	479
1996			164	164			272	272	437
1997			114	114			274	274	388
1998			155	155			327	327	482
1999			145	145			372	372	517
2000			239	239			558	558	797
2001			295	295			524	524	819
2002			370	370			502	502	872
2003			316	316			408	408	724

Table 16.4. Catch (t) of Other Rockfish species in the Aleutian Islands 2004-2018. Species with catches < 1 ton of catch not shown. Source: NMFS AKRO Catch Accounting System, AKFIN database, NMFS AFSC FMA Observer Debriefed Haul and Length tables, accessed Oct.10, 2018.

Year	dusky rockfish	SST	other thornyheads	% SST in thornyhead catch	harlequin rockfish	sharpchin rockfish	yelloweye rockfish
2004	129.5	60.3	37.1	61.96%	36.9	14.1	0.9
2005	134.2	78.1	35.1	68.98%	14.3	0	5.6
2006	161.4	118.7	39.7	74.92%	25.2	2.0	0.4
2007	231.7	115.9	15.4	88.27%	39.9	0	0.6
2008	179.8	107.4	7.8	93.25%	34.3	0	4.5
2009	142.0	131.9	10.8	92.40%	22.8	0	0.2
2010	226.3	154.8	14.9	91.22%	42.6	0.1	0.5
2011	380.5	153.0	10.7	93.45%	59.3	0	0.3
2012	435.2	171.4	2.7	98.43%	51.9	0	0.1
2013	334.3	254.7	5.0	98.08%	25.9	0	0.7
2014	349.3	241.7	9.1	96.38%	20.0	0	0.1
2015	294.4	150.3	2.9	98.12%	32.7	0	0.1
2016	337.6	130.2	0.0	99.96%	36.1	0.1	1.3
2017	403.6	100.6	0.8	99.24%	47.9	0	0.2
2018	463.1	90.5	0.5	99.43%	92.4	0	0.7
Average	280.2	137.3	12.8	90.27%	38.8	1.1	1.1

Year	redbanded rockfish	redstripe rockfish	black rockfish	silvergray rockfish	darkblotched rockfish	Other rockfish	Total (t)
2004	0.2	3.1	1.4	0	0.2	47.0	330.7
2005	0.2	0	0	0	0	14.0	281.6
2006	0.1	1.7	0.1	0	0.7	71.4	421.4
2007	1.4	0.5	0.1	3	0	20.8	429.3
2008	1.0	0.6	3.2	0	0.1	43.0	381.7
2009	0.4	0	1.2	0	0	63.0	372.3
2010	3.6	0.9	0.4	0	0	53.5	497.6
2011	0.7	0	0.1	0	0	12.4	617.0
2012	3.7	0	0.3	0	0	46.3	711.6
2013	1.0	0	0.5	0	0	6.2	628.3
2014	1.5	0.3	0.4	0	0	6.2	628.6
2015	4.3	0	0.1	0.1	0.4	17.3	502.6
2016	0.5	0.1	0.3	0	0	0.7	506.9
2017	1.7	4.5	0.6	0.1	0	9.9	569.9
2018	0.7	0	0.3	0	0	15.1	663.3
Average	1.4	0.8	0.6	0.2	0.1	28.5	502.9

Table 16.5. Catch (t) of Other Rockfish species in the eastern Bering Sea from 2004-2018. Species with catches less than 1 ton of catch are not shown. Source: NMFS AKRO Catch Accounting System, AKFIN database, Groundfish Total Catch by Fishery, NMFS AFSC FMA Observer Debriefed Haul and Length tables, accessed October 10, 2018.

Year	dusky rockfish	SST	other thornyheads	% SST in thornyhead catch	harlequin rockfish	yelloweye rockfish
2004	31.9	224.2	17.7	92.70%	0.4	1.4
2005	36.2	102.9	15.9	86.65%	0.2	0.7
2006	46.6	88.9	4.3	95.42%	0	1.4
2007	44.9	163.1	5.1	96.99%	0	1.7
2008	15.4	179.1	7.3	96.09%	0	1.0
2009	10.2	177.6	1.1	99.41%	0.1	1.1
2010	33.3	200.1	7.8	96.22%	0.3	1.4
2011	46	257.9	1.2	99.53%	4.6	1.4
2012	35.9	136.1	9.2	93.65%	0.1	0.5
2013	33.3	142.3	3.3	97.72%	0.6	0.7
2014	42.3	246.4	3.3	98.68%	1.5	1.5
2015	47.7	100.3	2.4	97.69%	2.3	1.4
2016	36.7	213.4	10.0	95.51%	3.1	2.5
2017	30.5	212.0	1.1	99.49%	1.7	1.3
2018	22.6	118.3	0.8	99.35%	0.3	0.9
Average	34.2	170.8	6.0	96.3%	1.0	1.3

Year	redbanded rockfish	redstripe rockfish	black rockfish	other rockfish	Total (t)
2004	10.4	0	0.9	14.9	301.9
2005	0.3	0	7.2	1.5	165.2
2006	0.4	0.1	0.2	6.9	148.8
2007	0	0	0.3	1.8	216.9
2008	0	0.1	2.2	8.9	214.2
2009	0.2	0	0.2	2.6	193.2
2010	0.5	0	1.5	23.4	268.8
2011	0.5	0	3.5	12.5	327.7
2012	2.6	0.1	7.2	17.1	209.0
2013	0.2	0	4.6	6.5	191.5
2014	0.1	4.6	1.8	22.9	324.4
2015	0.2	0	1.7	28.8	184.9
2016	0.1	0	5.8	10.1	281.7
2017	1.6	0.3	0.9	10.5	260.8
2018	0.2	0.1	5.5	15.5	164.3
Average	1.2	0.4	2.9	12.3	230.2

Table 16.6. Percentage of the total catch (10,986 t) of Other Rockfish species from 2004-2018 by target fishery and gear type, over the entire Bering Sea and Aleutian Islands management area. Source: NMFS AKRO Catch Accounting System, accessed October 10, 2018. Species include black rockfish, harlequin rockfish, redstripe rockfish, silvergray rockfish, darkblotched rockfish, rosethorn rockfish, other rockish, thornyhead rockfish, dusky rockfish, redbanded rockfish, sharpchin rockfish, and yelloweye rockfish.

	Gear Type				
Fishery	Pelagic Trawl	Longline	Bottom Trawl	Pot	Total
Atka mackerel	0	0	38.3	0	38.31
Flatfish	0	6.33	9.49	0	15.82
Halibut	0	3.38	0	0	3.38
Kamchatka Fl.	0	0	2.05	0	2.05
Other	0	0.03	0.01	0	0.04
Pacific cod	0	7.72	1.84	0.29	9.85
pollock	2.92	0	0.19	0	3.11
rockfish	0	0.24	15.99	0	16.24
sablefish	0	10.8	0.26	0.14	11.20
Total	2.92	28.50	68.14	0.44	100.00

Table 16.7. Sum of total catch (t) of EBS dusky rockfish from 2004-2018 by target fishery and gear type. Areas 508-524 refer to NMFS areas within the EBS. Source: NMFS AKRO Catch Accounting System, accessed October 10, 2018.

Gear	Target	508	509	513	514	516	517	518	519	521	523	524	Total (t)	% of Total
Bottom Trawl	Atka Mackerel	0.00	0.00	0.00	0.00	0.00	0.00	13.93	0.00	0.00	0.00	0.00	13.93	2.72
Bottom Trawl	Flatfish	0.00	2.24	1.47	0.00	3.97	0.03	4.16	9.39	0.00	0.28	0.00	21.54	4.20
Bottom Trawl	Kamchatka Fl.	0.00	0.00	0.00	0.00	0.00	0.19	0.04	0.00	0.00	0.00	0.00	0.23	0.05
Bottom Trawl	Other	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01
Bottom Trawl	Pacific Cod	0.00	5.48	0.00	0.00	18.10	0.00	18.28	8.67	0.12	0.07	0.00	50.72	9.89
Bottom Trawl	Pollock	0.00	0.15	0.00	0.00	0.62	0.00	0.10	0.03	0.00	0.00	0.00	0.91	0.18
Bottom Trawl	Rockfish	0.16	0.00	0.00	0.00	52.61	2.54	7.78	2.49	0.92	0.00	0.00	66.50	12.97
Bottom Trawl	Sablefish	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.08	0.02
Longline	Flatfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.17	0.05	0.00	0.00	2.22	0.43
Longline	Halibut	0.00	0.00	0.13	0.29	0.02	4.20	0.07	3.00	0.03	0.83	0.00	8.58	1.67
Longline	Pacific Cod	0.00	0.20	3.57	0.00	20.53	0.02	6.12	171.10	0.40	0.04	0.00	201.99	39.40
Longline	Rockfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longline	Sablefish	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.05	0.01
Pelagic Trawl	Atka Mackerel	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.05	0.01
Pelagic Trawl	Pacific Cod	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.04
Pelagic Trawl	Pollock	0.00	7.62	0.76	0.06	71.47	0.00	21.87	29.03	1.22	0.29	0.00	132.33	25.81
Pot	Pacific Cod	0.00	2.83	0.04	0.00	2.60	0.07	7.70	0.04	0.00	0.00	0.00	13.28	2.59
Total (t)		0.16	18.52	5.97	0.35	170.18	7.10	80.17	225.93	2.75	1.52	0.00	512.65	100.00

Table 16.8. Sum of total catch (t) of EBS shortspine thornyhead rockfish from 2004-2018 by target fishery and gear type. Areas 508-524 refer to NMFS areas within the EBS. Source: NMFS AKRO Catch Accounting System, AKFIN database, accessed on Oct 13, 2018. NOTE: Thornyheads are identified to genus but not to species in commercial catches; therefore, the weight of shortspine thornyhead is extrapolated by multiplying the proportion of shortspine thornyhead by year in the total catch of thornyhead rockfish based on observer catch data from the NORPAC database.

Gear	Target	508	509	513	514	517	518	519	521	523	524	530	Total (t)	% of Total
Bottom Trawl	Atka Mackerel	0.00	0.00	0.00	0.00	3.69	0.00	29.77	0.00	0.00	0.00	0.00	33.46	1.26
Bottom Trawl	Flatfish	0.00	0.11	3.49	0.08	668.79	6.94	165.81	88.54	5.68	6.16	0.00	945.60	35.64
Bottom Trawl	Kamchatka Fl.	0.00	0.00	0.00	0.00	105.93	7.58	86.54	0.00	0.32	0.39	0.00	200.76	7.57
Bottom Trawl	Other	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.02
Bottom Trawl	Pacific Cod	0.00	0.06	0.00	0.00	43.81	0.00	20.36	0.01	0.00	0.00	0.00	64.24	2.42
Bottom Trawl	Pollock	0.00	0.05	0.00	0.00	12.21	0.20	6.19	1.03	0.00	0.00	0.00	19.68	0.74
Bottom Trawl	Rockfish	0.00	0.00	0.00	0.00	136.40	0.87	163.67	39.76	5.41	0.00	0.00	346.11	13.05
Bottom Trawl	Sablefish	0.00	0.00	0.00	0.00	10.90	0.03	17.62	0.00	0.00	0.00	0.00	28.55	1.08
Longline	Flatfish	0.00	0.00	0.00	0.00	25.92	4.88	1.13	337.67	116.75	4.84	0.00	491.20	18.51
Longline	Halibut	0.00	0.00	1.88	1.54	13.20	60.80	10.09	22.13	9.43	6.64	0.00	125.73	4.74
Longline	Kamchatka Fl.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.00
Longline	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.12	0.00	0.00	0.67	0.03
Longline	Pacific Cod	0.00	0.00	0.00	0.00	8.18	0.44	1.63	47.10	5.83	0.30	0.00	63.47	2.39
Longline	Rockfish	0.00	0.00	0.00	0.00	0.68	1.50	1.61	0.64	1.76	0.51	0.00	6.71	0.25
Longline	Sablefish	0.08	0.05	0.00	0.20	36.63	72.98	25.74	4.34	4.52	0.06	0.15	144.75	5.46
Pelagic Trawl	Pollock	0.00	0.53	0.32	0.00	108.25	0.00	61.47	0.38	0.05	0.01	0.00	171.01	6.45
Pot	Flatfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pot	Pacific Cod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pot	Sablefish	0.00	0.00	0.01	0.00	0.71	5.77	3.57	0.01	0.00	0.00	0.00	10.07	0.38
Total (t)		0.08	0.81	5.69	1.82	1176.08	162.00	595.39	542.16	149.91	18.91	0.15	2653.00	100.00

Table 16.9. Sum of total catch (t) of AI dusky rockfish from 2004-2018 by target fishery and gear type. Areas 541, 542, and 543 refer to NMFS areas within the AI. Source: NMFS AKRO Catch Accounting System, AKFIN database, accessed October 13, 2018.

Gear	Target	541	542	543	Total (t)	% of Total
Bottom Trawl	Atka Mackerel	2790.12	563.06	124.87	3478.06	82.76
Bottom Trawl	Flatfish	30.76	0.00	0.00	30.76	0.73
Bottom Trawl	Kamchatka Flounder	10.56	0.00	0.00	10.56	0.25
Bottom Trawl	Pacific Cod	43.76	5.75	3.24	52.75	1.25
Bottom Trawl	Rockfish	269.47	134.35	102.58	506.41	12.05
Longline	Flatfish	0.00	0.48	0.00	0.48	0.01
Longline	Halibut	1.89	0.89	0.12	2.91	0.07
Longline	Other	0.00	0.02	0.15	0.18	0.00
Longline	Pacific Cod	48.39	49.49	21.88	119.76	2.85
Longline	Sablefish	0.13	0.15	0.00	0.28	0.01
Pelagic Trawl	Pollock	0.06	0.00	0.00	0.06	0.00
Pot	Pacific Cod	0.06	0.49	0.01	0.56	0.01
Pot	Sablefish	0.06	0.00	0.00	0.06	0.00
Total (t)		3195.26	754.69	252.86	4202.81	100.00

Table 16.10. Sum of total catches (t) of Aleutian Island (AI) shortspine thornyhead rockfish from 2004-2018 by target fishery and gear type. Areas 541, 542, and 543 refer to NMFS areas within the AI. Source: NMFS AKRO Catch Accounting System, AKFIN database, as of October 13, 2018. NOTE: Thornyheads are identified to genus but not to species in commercial catches; therefore, the weight of shortspine thornyhead is extrapolated by multiplying the proportion of shortspine thornyhead by year in the total catch of thornyhead rockfish based on observer catch data from the NORPAC database.

Gear	Target	541	542	543	Total (t)	% of Total
Bottom Trawl	Atka Mackerel	7.76	61.49	70.31	139.56	6.20
Bottom Trawl	Flatfish	6.67	0.00	0.00	6.67	0.30
Bottom Trawl	Kamchatka Flounder	7.44	0.00	0.00	7.44	0.33
Bottom Trawl	Pacific Cod	0.52	0.00	0.52	1.05	0.05
Bottom Trawl	Pollock	0.07	0.11	0.00	0.17	0.01
Bottom Trawl	Rockfish	27.29	181.54	448.37	657.20	29.19
Longline	Flatfish	11.69	130.38	0.00	142.08	6.31
Longline	Halibut	75.41	84.69	24.51	184.60	8.20
Longline	Other	0.37	1.96	0.00	2.33	0.10
Longline	Pacific Cod	30.52	13.16	17.84	61.53	2.73
Longline	Rockfish	0.75	6.62	11.97	19.34	0.86
Longline	Sablefish	484.25	346.21	194.04	1024.50	45.50
Pot	Pacific Cod	0.00	0.01	0.00	0.01	0.00
Pot	Rockfish	0.02	0.00	0.00	0.02	0.00
Pot	Sablefish	3.85	0.10	1.04	4.99	0.22
Total (t)		656.78	826.29	768.61	2251.67	100.00

Table 16.11. Retained and discarded catch of Other Rockfish species from 2004 to 2018 in the Aleutian Islands and Bering Sea. Accessed October 10, 2018 from the NMFS AKRO Catch Accounting System, AKFIN database.

Area	Year	Retained (t)	Discarded (t)	Total catch (t)	Percent Discarded
Aleutian Islands	2004	167	170	337	50.45%
	2005	186	100	286	34.97%
	2006	245	181	426	42.49%
	2007	212	224	436	51.38%
	2008	268	122	390	31.28%
	2009	256	147	403	36.48%
	2010	373	124	498	24.90%
	2011	474	143	617	23.18%
	2012	613	99	712	13.90%
	2013	465	164	628	26.11%
	2014	466	163	629	25.91%
	2015	418	84	503	16.70%
	2016	464	43	507	8.48%
	2017	466	104	570	18.25%
	2018	572	93	665	13.98%
Bering Sea	2004	229	89	318	27.99%
	2005	144	34	178	19.10%
	2006	123	34	157	21.66%
	2007	144	76	220	34.55%
	2008	144	78	222	35.14%
	2009	170	38	208	18.27%
	2010	203	66	269	24.54%
	2011	276	52	328	15.85%
	2012	161	48	209	22.97%
	2013	144	48	192	25.00%
	2014	250	74	325	22.77%
	2015	112	73	185	39.46%
	2016	190	92	282	32.62%
	2017	199	62	261	23.75%
	2018	117	49	167	29.34%

Table 16.12. Survey biomass estimates (t) and CVs (in parentheses) for Other Rockfish (including shortstpine thornyhead and dusky rockfish) from 1979 - 2018. Southern Bering Sea refers to NMFS reporting area 799.

	AI survey			EBS Shelf survey	EBS Slope survey
Year	AI	S. Bering Sea	Total		
1979					3,251
1980	930 (0.18)	36 (0.73)	966 (0.18)		
1981					4,975
1982				0	4,381
1983	4,012 (0.17)	802 (0.23)	4,774 (0.15)	0	
1984				18 (1.0)	
1985				36 (1.0)	5,127
1986	6,550 (0.19)	3,253 (0.86)	9,803 (0.31)	0	
1987				50 (1.0)	
1988				0	8,759
1989				0	
1990				0	
1991	6,647 (0.22)	248 (0.48)	6,891 (0.22)	857 (0.94)	4,529
1992				14 (1.0)	
1993				86 (1.0)	
1994	6,456 (0.16)	1,172 (0.48)	7,624 (0.15)	47 (1.0)	
1995				76 (0.70)	
1996				36 (1.0)	
1997	9,539 (0.17)	1,683 (0.63)	11,223 (0.18)	126 (1.0)	
1998				538 (0.68)	
1999				398 (0.75)	
2000	11,924 (0.17)	1,107 (0.45)	13,031 (0.16)	0	
2001				0	
2002	14,798 (0.20)	1,111 (37)	15,892 (0.18)	0	16,978 (0.12)
2003				55 (0.70)	
2004	18,566 (0.18)	6,473 (67)	25,039 (0.22)	0	18,824 (0.09)
2005				36 (1.0)	
2006	23,881 (0.24)	1,706 (0.52)	25,585 (0.23)	357 (0.85)	
2007				0	
2008				0	26,082 (0.12)
2009				122 (0.58)	
2010	18,663 (0.15)	1,172 (0.66)	19,835 (0.15)	57 (0.92)	29,482 (0.12)
2011				56 (1.0)	
2012	14,694 (0.15)	586 (0.61)	15,280 (0.15)	37 (1.0)	29,617 (0.11)
2013				40 (1.0)	
2014	23,254 (0.27)	2799 (0.62)	26,053 (0.31)	28 (1.0)	
2015				143 (1.0)	
2016	18,306 (0.15)	1,825 (0.48)	20,131 (0.14)	20 (1.0)	35,972 (0.11)
2017				169 (0.73)	
2018	14,130 (0.19)	3,243 (0.52)	17,373 (0.18)	1,593 (0.70)	

Table 16.13. Survey biomass estimates (t) and CVs (in parentheses) for Dusky rockfish from 1997 - 2018. Southern Bering Sea refers to NMFS reporting area 799.

	AI survey			EBS Slope survey
Year	AI	S. Bering Sea	Total	
1997	574 (0.76)	138 (0.46)	712 (0.62)	
1998				
1999				
2000	1,250 (0.34)	55 (0.36)	1,306 (0.33)	
2001				
2002	531 (0.32)	97 (0.36)	612 (0.27)	25 (0.57)
2003				
2004	730 (0.44)	1,359 (0.91)	2,089 (0.61)	13(0.57)
2005				
2006	5,957 (0.89)	731 (0.96)	6,687 (0.80)	
2007				
2008				10 (1.00)
2009				
2010	560 (0.34)	120 (0.44)	680 (0.29)	117 (0.87)
2011				
2012	236 (0.32)	135 (0.57)	371 (0.29)	41 (0.61)
2013				
2014	5,542 (0.83)	231 (0.50)	5773 (0.82)	
2015				
2016	1,665 (0.35)	217 (0.54)	1,881 (0.32)	0 (-)
2017				
2018	896 (0.33)	1,639 (0.77)	2,534 (0.51)	

Table 16.14. Survey biomass estimates (t) and CVs (in parentheses) for shortspine thornyhead from 1991- 2018. Southern Bering Sea refers to NMFS reporting area 799.

	AI survey			EBS Slope survey
Year	AI	S. Bering Sea	Total	
1991	6,153 (0.24)	187 (0.58)	6,341 (0.23)	
1992				
1993				
1994	6,240 (0.16)	1,071 (0.52)	7,311 (0.16)	
1995				
1996				
1997	8,896 (0.18)	1,545 (0.69)	10,441 (0.18)	
1998				
1999				
2000	10,649 (0.19)	1,051 (0.48)	11,700 (0.17)	
2001				
2002	14,243 (0.20)	1,012 (0.41)	15,255 (0.19)	16,940 (0.12)
2003				
2004	17,335 (0.19)	945 (0.56)	18,280 (0.18)	18,793 (0.09)
2005				
2006	17,876 (0.12)	968 (0.55)	18,844 (0.12)	
2007				
2008				26,055 (0.12)
2009				
2010	18,075 (0.16)	1,052 (0.73)	19,127 (0.16)	29,334 (0.12)
2011				
2012	14,443 (0.15)	452 (0.77)	14,895 (0.15)	29,565 (0.11)
2013				
2014	17,611 (0.24)	2,567 (0.67)	20,178 (0.23)	
2015				
2016	16,541 (0.16)	1,607 (0.53)	18,148 (0.16)	35,948 (0.11)
2017				
2018	13,216 (0.20)	1,605 (0.68)	14,821 (0.19)	

Table 16.15. Biomass estimate comparison using various methods of calculation for Other Rockfish on the EBS shelf.

Method	2018 Biomass Estimate
Remove 0-value estimate years	720 t
4, 6, 9 weighting	812 t
Add 0.1 t to biomass, 10^{-3} to variance	1,503 t
Add 0.01 t to biomass, 100 to variance	1,593 t
Add 0.1 t to biomass, 10^{-4} to variance	1,593 t
Years 2009-2018 only	837 t
Survey biomass estimate	1,593 t

Figures

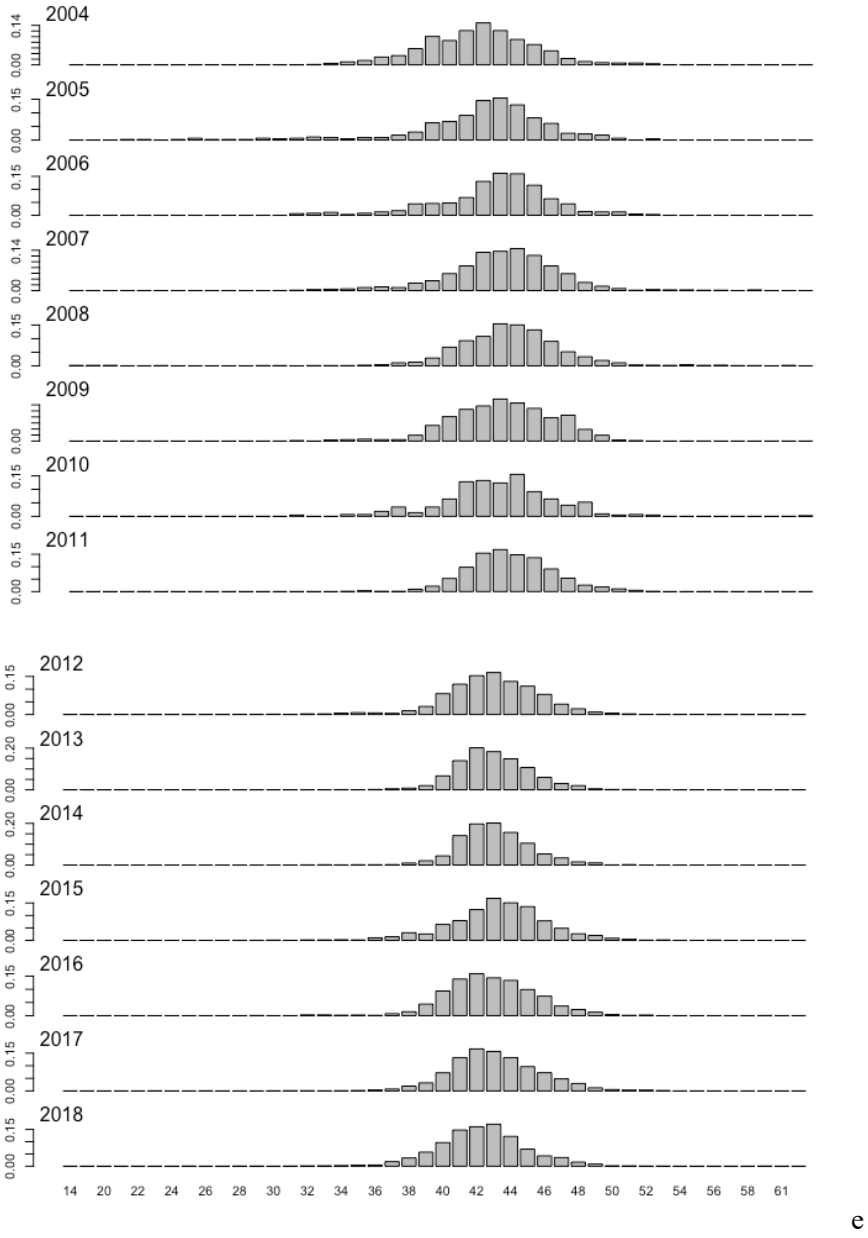


Figure 16.1. Dusky rockfish length frequency data from fishery observers in the BSAI, 2004-2018. Source: NMFS AFSC FMA Observer Debriefed Haul and Length tables.

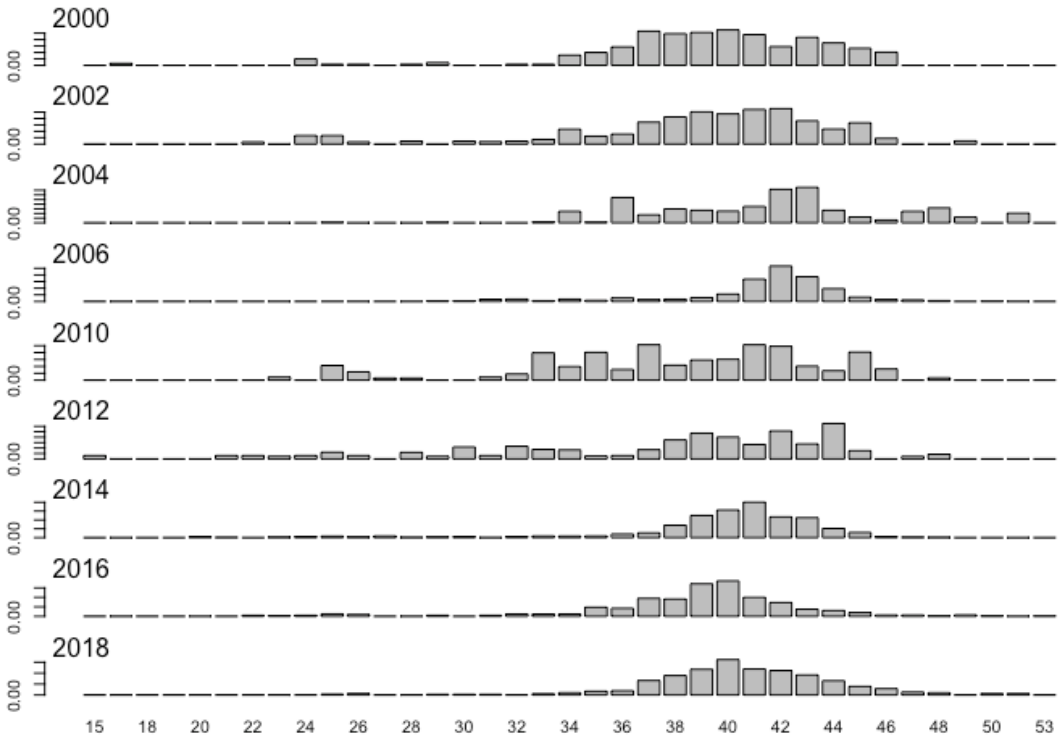


Figure 16.2. Dusky rockfish lengths (cm) from Aleutian Islands survey data 2000-2018.

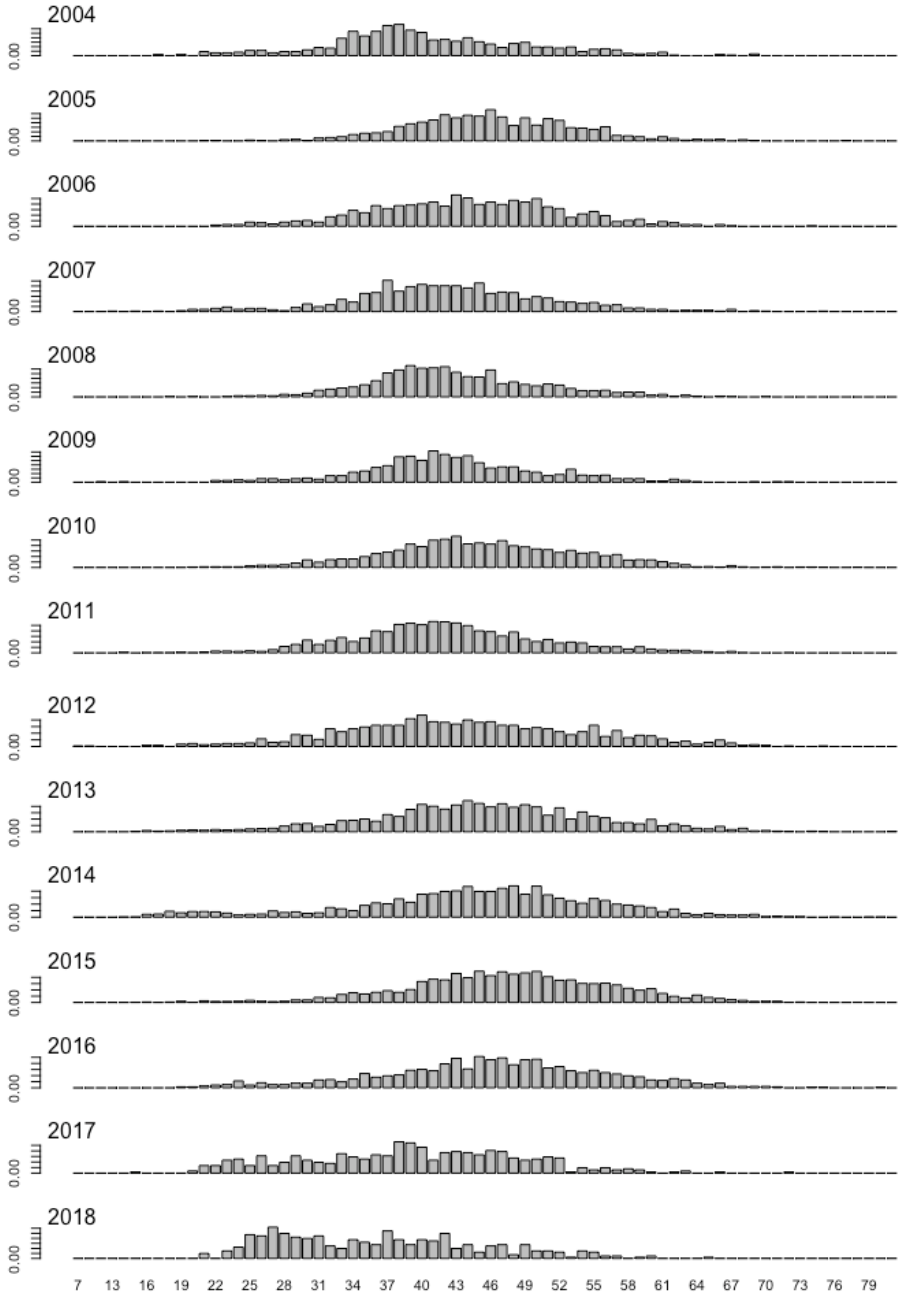


Figure 16.3. Shortspine thornyhead length frequency (cm) data from fisheries observers in the BSAI, 2004-2018. Source: NMFS AFSC FMA Observer Debriefed Haul and Length tables.

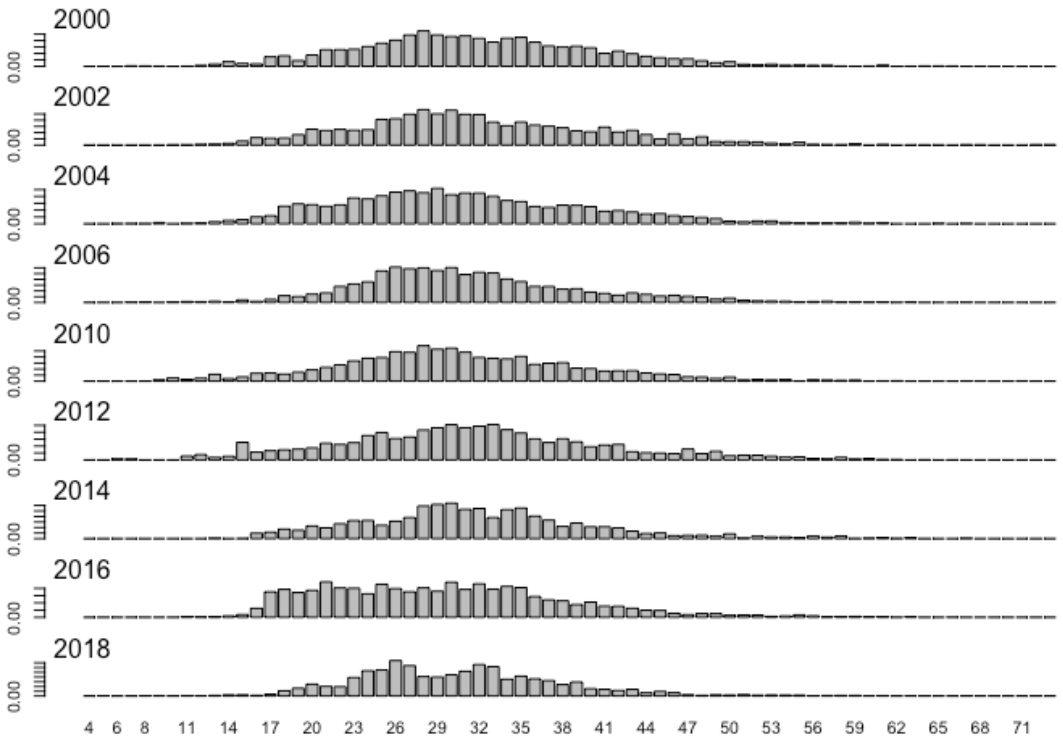
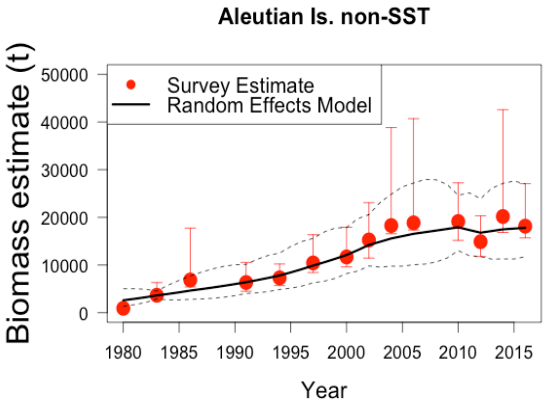
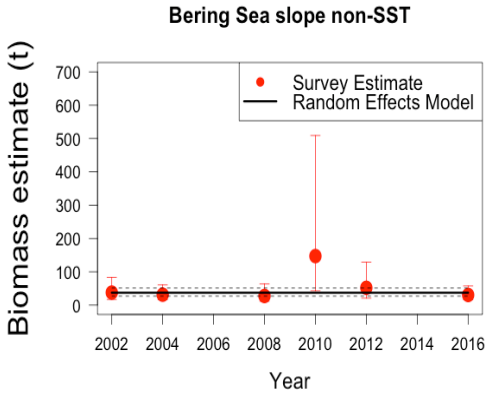


Figure 16.4. Shortspine thornyhead rockfish length frequencies (cm) from Aleutian Islands survey data, 2000-2018.

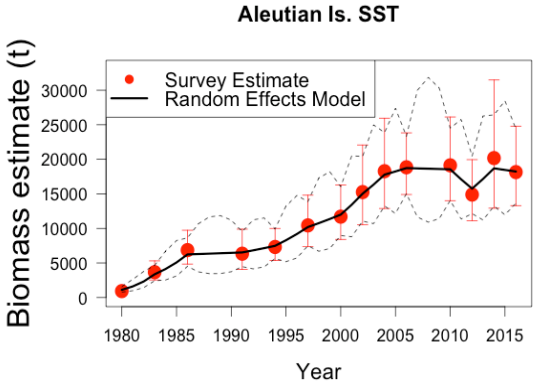
Aleutian Islands non-SST Other Rockfish



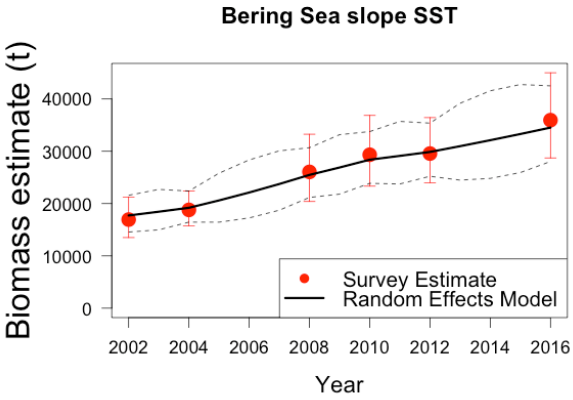
Bering Sea slope non-SST Other Rockfish



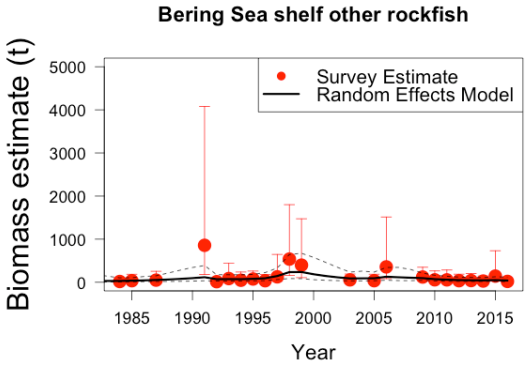
Aleutian Islands SST



Bering Sea slope SST



Bering Sea shelf all Other Rockfish



Combined Random effect estimates of all Other Rockfish biomass (BSAI)

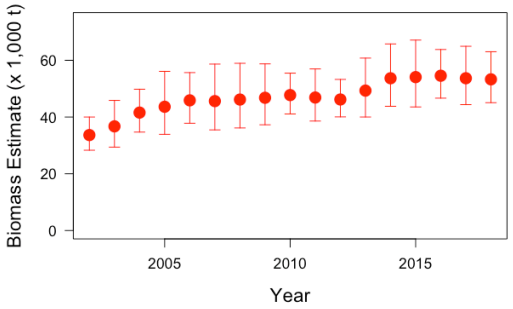


Figure 16.5. Random effect model biomass estimates for shortspine thornyhead (SST) and non-SST Other Rockfish in the Aleutian Islands, Southern Bering Sea, Bering Sea shelf and slope. Observed survey biomass are shown (red data points with 95% confidence

interval), and predicted survey biomass estimates using the random effects model (black lines with 95% confidence intervals are shown as dotted lines).

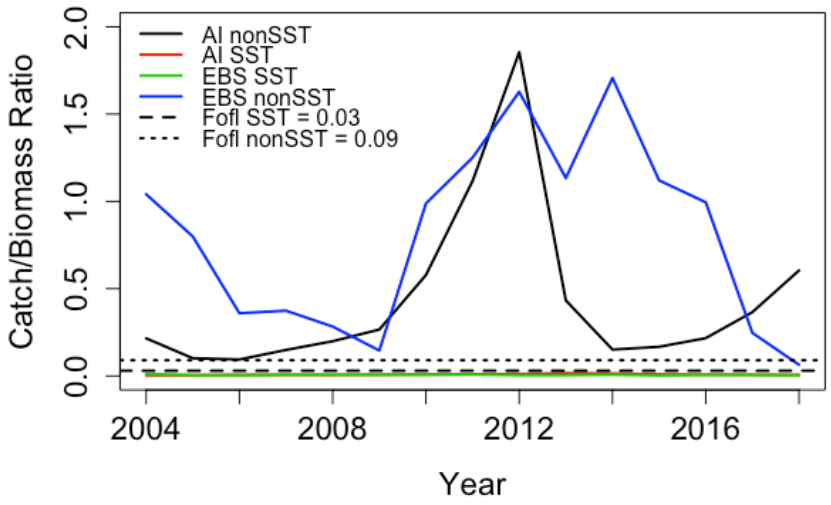


Figure 16.6. Exploitation rates (catch/biomass ratio) for the SST and non-SST components of the Other Rockfish stock in the Aleutian Islands (AI) and the Eastern Bering Sea (EBS).

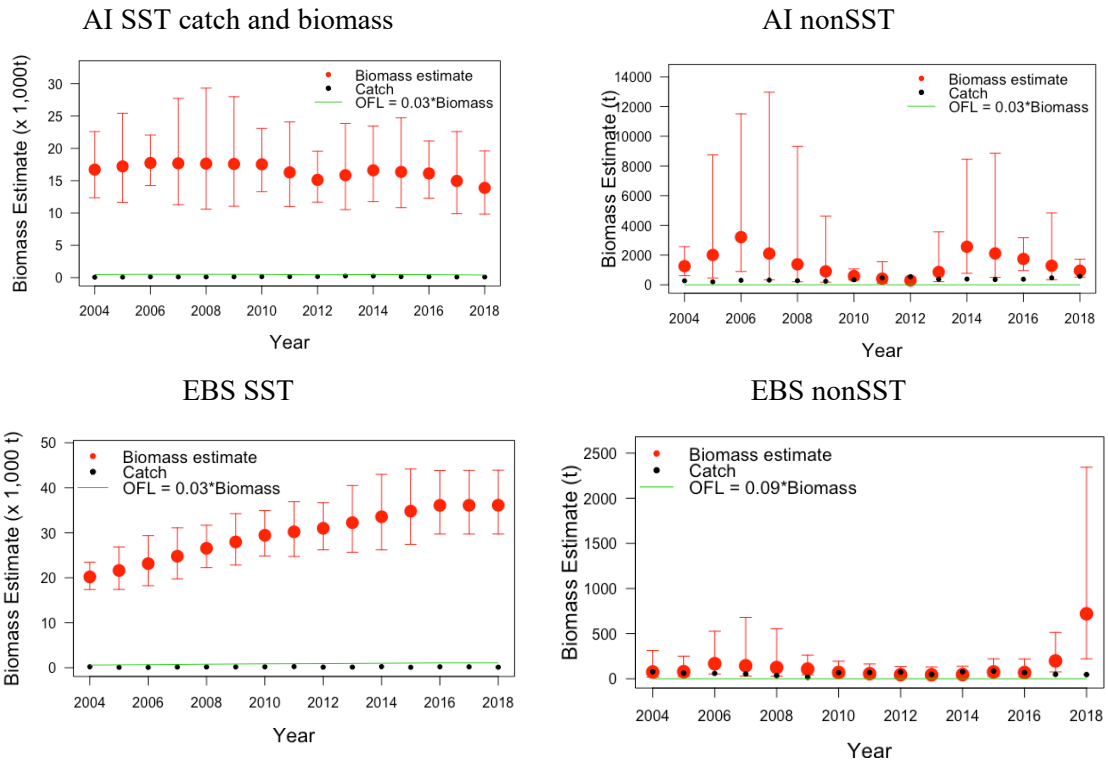


Figure 16.7. Catch and biomass during 2004-2018 for shortspine thornyhead (SST) and non-SST Other Rockfish in the Bering Sea Aleutian Islands region, based on fishery catch and annual biomass predicted by the Random Effects model. Shortspine thornyhead (SST) is plotted separately from nonSST rockfish species (primarily dusky and harlequin rockfish).

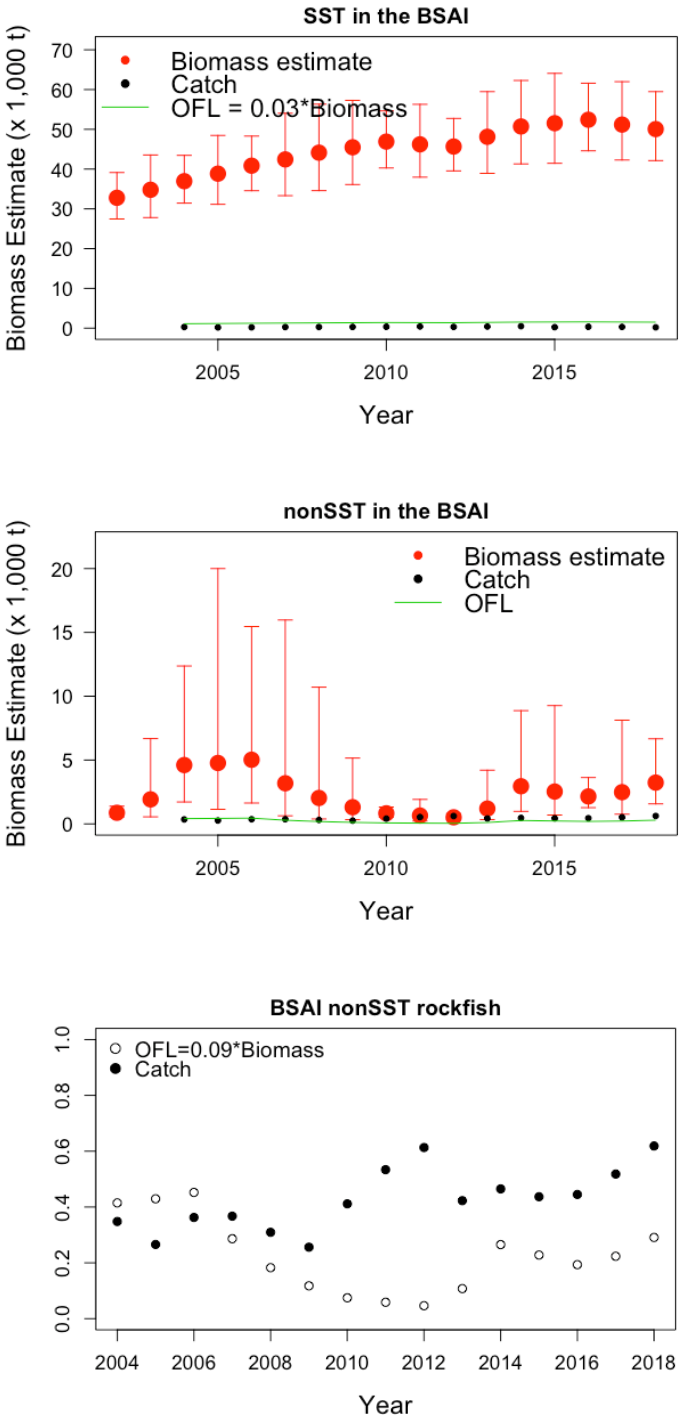


Figure 16.8. The estimate of biomass of shortspine thornyhead (SST, top panel) and non-SST Other Rockfish in the BSAI (middle panel), with confidence intervals. The bottom panel is the comparison of OFL (0.09* estimate of biomass based on the random effects model) and catch of non SST rockfish in the BSAI. All years except 2004, 2005, 2006 indicate catch>OFL for non SST in the BSAI.

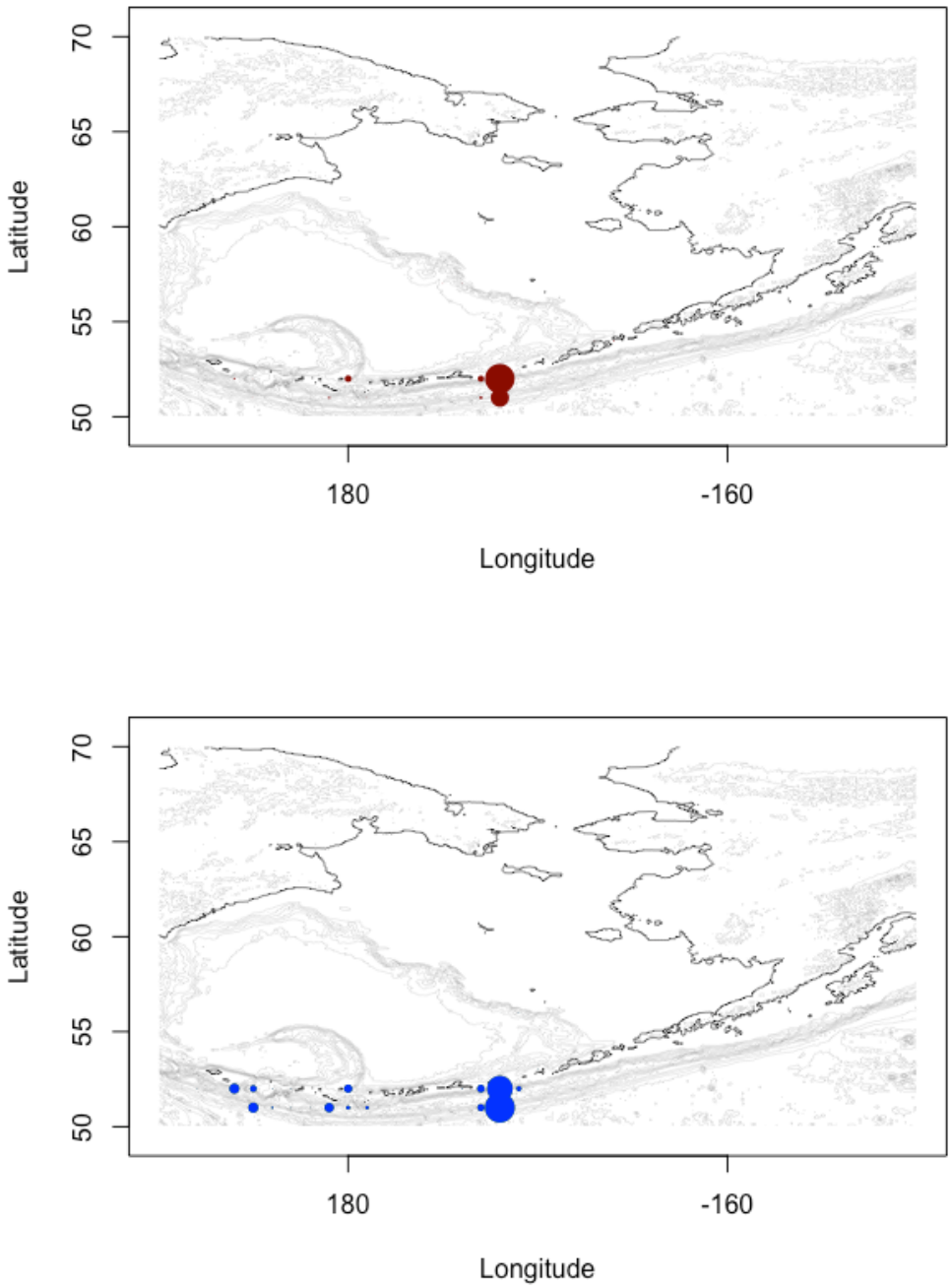


Figure 16.9. Location of dusky catches 2004-2018 in the BSAI (upper plot, in red), and location of harlequin rockfish catches 2004-2018 (lower plot, in blue).

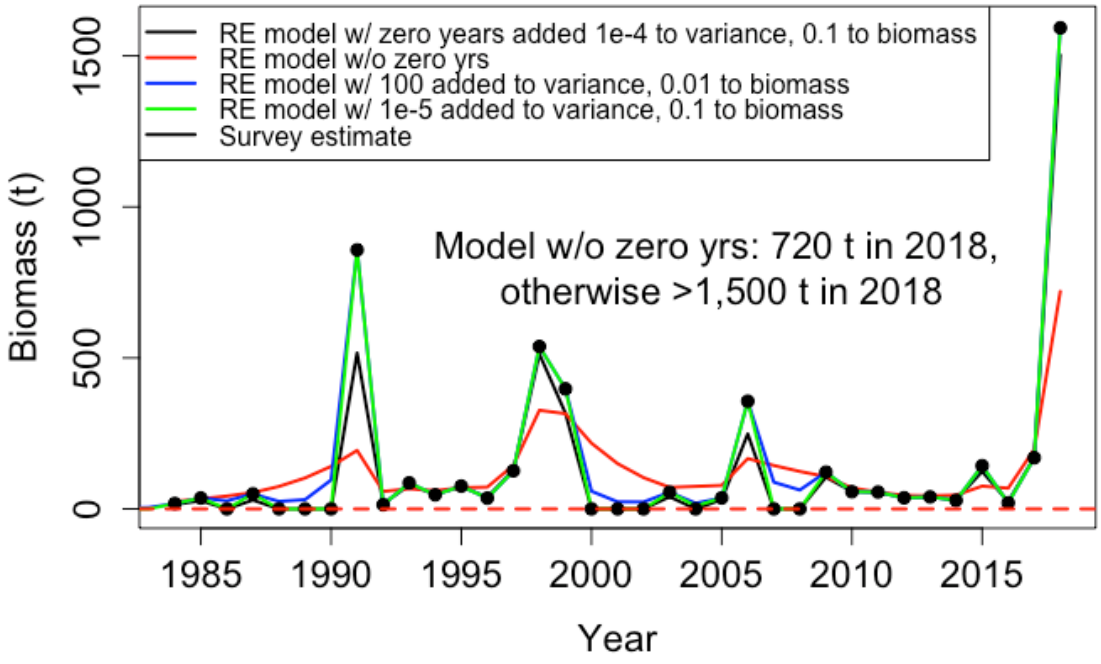


Figure 16.10. Random effects model estimates of Bering Sea non-shortspine thornyhead (SST) Other Rockfish biomass based on different approaches described in the text.

Table A1.1. Removals from sources other than those included in the Alaska Region's official estimate of catch (e.g., removals due to scientific surveys, subsistence fishing, recreational fishing, fisheries managed under other FMPs) from the Alaska Department of Fish and Game (ADFG), International Pacific Halibut Commission (IPHC), and National Marine Fisheries Service (NMFS). Source: NMFS AKRO Catch Accounting System, AKFIN database, accessed October 15, 2018. Data for the current year are not yet available.

	Agency			
Year	ADFG	IPHC	NMFS	Total (t)
2004			1.5	1.5
2005			1.4	1.4
2006			1.7	1.7
2007			1.8	1.8
2008			1.5	1.5
2009			2	2.0
2010	0	0.7	12.8	13.5
2011	0	0.3	23.1	23.4
2012	0	0.3	9.9	10.2
2013	0.1	0.8	3	3.9
2014	0	0.8	4.8	5.6
2015	0.2	0.9	2.9	4.0
2016	0.1	0.3	12	12.4
2017	0	2.5	3	5.5
Average	0.1	0.8	5.8	6.7