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 even years to coincide with the Aleutian Islands (AI) bottom trawl survey. The Other Rockfish complex is assessed in two parts: (1) shortspine thornyhead (SST, *Sebastolobus alascanus*), which comprise approximately 95% of the estimated total Other Rockfish exploitable biomass; and (2) the remaining "non-SST" species, which are dominated by dusky rockfish (*Sebastes variabilis*) but include at least eleven other *Sebastes* and *Sebastolobus* species. The assumed natural mortality differs between SST (0.03) and the remaining non-SST species in the Other Rockfish complex (0.09). Therefore, they have different definitions of F_{OFL} and F_{ABC}.

Summary of Changes in Assessment Inputs

Changes in the input data

1) Catch and fishery lengths updated through October 3, 2022.
2) The 2022 AI bottom trawl survey (BTS) for both SST and non-SST species.
3) The 2021 and 2022 Eastern Bering Sea (EBS) shelf BTS for non-SST species.
4) New in 2022: NMFS longline survey (LLS) relative population weights (RPWs) for SST on the EBS slope, 1997-2021 (Table 1). The EBS slope is sampled by the LLS in odd years.

Changes in the assessment methodology

The random effects model was fit in Template Model Builder (TMB; Kristensen et al. 2016) using the new *rema* R library. The models presented as follows:

1) **Model 20:** The accepted model in the last full assessment now fit in TMB using the multivariate version of the random effects (REM) model. Model 20 was bridged from AD Model Builder (ADMB; Fournier et al. 2012) to TMB in Sullivan et al. (2022a). This bridging analysis was presented to and endorsed by the BSAI Groundfish Plan Team and Scientific and Statistical Committee in September and October 2022. In Model 20, two separate REM models are fit, one for SST and one for non-SST. The SST model has three strata (AI, EBS slope, southern Bering Sea; SBS), and the non-SST model has four strata (AI, EBS shelf, EBS slope, SBS). Both models share process error across strata (Sullivan et al. 2020).
2) **Model 22 (author-recommended):** Same as Model 20 and also fits to the EBS slope LLS RPWs for SST (Sullivan et al. 2022a). The non-SST model is the same as Model 20.

Summary of Results

Using Model 22, the recommended ABCs and OFLs (in bold) for 2023 and 2024 relative to last year for the Bering Sea/Aleutian Islands (BSAI) Other Rockfish complex is as follows:

Quantity	As estimated or *specified last* year for: 2022	2023	As estimated or *recommended this* year for: 2023	2024
M (natural mortality rate) for SST	0.03	0.03	0.03	0.03
M for non-SST	0.09	0.09	0.09	0.09
Tier	5	5	5	5
RE Model Combined Biomass (t)	53,248	53,248	52,733	52,733
F_{OFL} (F=M) for SST	0.03	0.03	0.03	0.03
F_{OFL} (F=M) for non-SST	0.09	0.09	0.09	0.09
$maxF_{ABC}$ for SST	0.0225	0.0225	0.0225	0.0225
$maxF_{ABC}$ for non-SST	0.0675	0.0675	0.0675	0.0675
F_{ABC} for SST	0.0225	0.0225	0.0225	0.0225
F_{ABC} for non-SST	0.0675	0.0675	0.0675	0.0675
OFL (t)	1,751	1,751	**1,680**	**1,680**
maxABC (t)	1,313	1,313	**1,260**	**1,260**
ABC (t)	1,313	1,313	**1,260**	**1,260**
	As determined *last* year for:		As determined *this* year for:	
Status	2020	2021	2021	2022
Overfishing	No	No	No	n/a

Area apportionment

The ABCs for the BSAI Other Rockfish complex are apportioned to the AI and EBS by summing the proportion of biomass in each region estimated by the random effects (RE) model for the SST and non-SST components of the complex. Separate ABCs and OFLs are presented below for each area and species/species group to illustrate how ABCs and OFLs are calculated for the complex. In recent years BSAI Other Rockfish have been managed with a BSAI-wide OFL and ABCs for the AI and EBS (in bold). The apportionment of ABCs and calculation of the OFL is as follows for 2023 and 2024:

		AI	**EBS**	**Total BSAI**
SST	RE model biomass (t)	13,065	38,034	51,098
	Proportion biomass by region	0.26	0.74	
	Area ABC (t)	294	856	1,150
	OFL (t)	392	1,141	1,533
non-SST	RE model biomass (t)	1,283	352	1,635
	Proportion biomass by region	0.78	0.22	
	Area ABC (t)	87	24	110
	OFL (t)	115	32	147
Total Other Rockfish	RE model biomass (t)	14,348	38,386	52,733
	ABC (t)	**380**	**880**	**1,260**
	OFL (t)			**1,680**

Summaries for Plan Team

The following table gives the projected biomass in the year harvest specifications were recommended, OFL, ABC, TAC and estimated catch to date for 2021-2024.

Species	Year	Biomass	OFL	ABC	TAC	Catch
Other rockfish	2021	53,248	1,751	1,313	916	1,002
	2022	53,248	1,751	1,313	1,144	999*
	2023	52,733	1,680	1,260		
	2024	52,733	1,680	1,260		

*Catch as of Oct 3, 2022 (NFMS Alaska Regional office and Alaska Fisheries Information Network)

Responses to SSC and Plan Team Comments to Assessments in General

There were several general comments related to VAST and the spatial management policy in the December 2020 and 2021 SSC meetings, none of which pertain to this assessments.

The SSC recommends that groundfish, crab and scallop assessment authors do not change recommendations in documents between the Plan Team and the SSC meetings, because it makes it more difficult to understand the context of the Plan Team's rationale and seems counter to the public process without seeing a revision history of the document. (December 2021 SSC)

Noted.

Responses to SSC and Plan Team Comments Specific to this Assessment

The Team recommended that the author pursue the planned work in collaboration with other authors to consider issues with the Tier 5 model process for stocks with variable, and at times sparse or missing, survey observations. Specifically, the manner in which biomass estimates of 0 are handled (i.e., currently ignored) should be revisited. (November 2020 BSAI GPT)

The topic of zero biomass observations was further explored by the Tier 4/5 and random effects model working group in Sullivan et al. (2022). In the new *rema* R package, zeros are treated as NA values by default and an automatic warning message will alert the user if zeros are present in the data, but no zero assumption has been explicitly defined. Users can explore zero assumptions using the prepare_rema_input() function. Options include (1) treating the observation as an NA, (2) adding a small constant and fixed coefficient of variation (CV), and (3) the experimental Tweedie distribution.

The non-SST component of BSAI other rockfish has the most zero biomass observations of any Alaska groundfish assessment. In the EBS shelf BTS, 14 out of 39 observations are zeros. This assessment treats zeros as NAs or failed surveys, an assumption that was evaluated using the three options available in the *rema* R package. We found that the Tweedie distribution performed most closely to the NA assumption and both were effective at dampening spasmodic high biomass estimates (see figure below). While the Tweedie distribution performed well for non-SST on the EBS shelf, it was slow to run and failed to converge when applied to other cases (e.g. GOA thornyheads and shortrakers). We recommend that zeros continue to be treated as NAs in this assessment for the following reasons: (1) it is what it used in all other Tier 5 assessments that have zeros (Monnahan et al. 2021), (2) it effectively dampens periodic high biomass estimates, and (3) it most closely mimics the Tweedie, which under certain parameterizations is positive, continuous distribution that includes zeros.

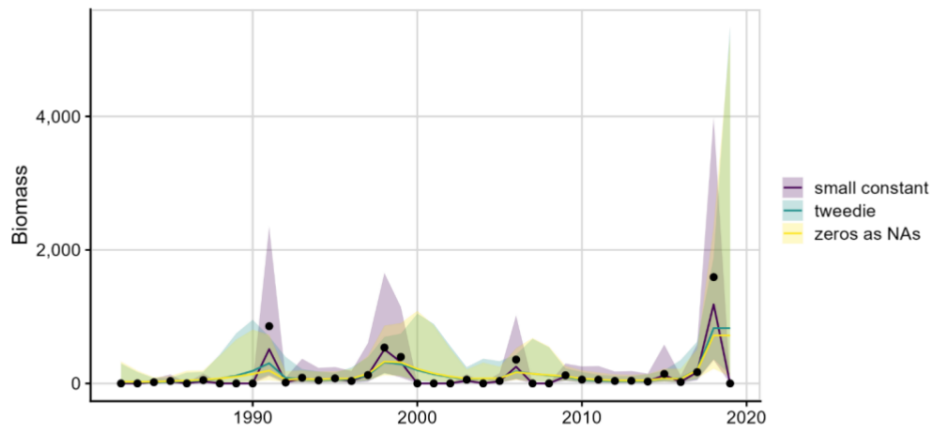

Figure – A comparison of model fits with 95% confidence intervals to the non-shortspine thornyhead other rockfish trawl survey biomass in the eastern Bering Sea using three different assumptions about how to treat zero biomass observations: 1) zeros as NAs, (2) adding a small constant = 0.1 with a CV = 3.0, and (3) modeled using the Tweedie distribution.

The Team recommended that the author consult with other rockfish assessment authors to consider revising M for the non-SST portion of the population in future assessments, noting that recent assessments reported to have based the M=0.09 assumption on GOA dusky rockfish, when in fact M=0.07 has been the GOA dusky rockfish value used since 2006. (November 2020 BSAI GPT)

In response to this and other Plan Team recommendations related to rockfish *M*, a group of stock assessment authors collaborated on a NOAA Tech. Memo. to revisit available life history data and *M* for dusky and ten other rockfish species in Alaska (Sullivan et al. 2022b). This manuscript was only recently published and will be used to reevaluate *M* for BSAI other rockfish in future years. Additionally, Todd TenBrink and others with the AFSC Age and Growth Program have a manuscript in preparation that focuses on updating maximum age, growth, and natural mortality for harlequin and dusky rockfish in the AI.

The Team recommended that the author do more spatial analysis of AI catch of non-SST rockfish. The Team recommended the author explore the locations, depths, seasons, the encounter rates and concentration of catch (i.e., frequent constant bycatch rates or a smaller number of highly concentrated hauls). (November 2020 BSAI GPT)

In collaboration with Matt Callahan (AKFIN) and Andy Kingham (FMA/AFSC), we developed queries to the observer program database (NORPAC) and analyzed bycatch rates of non-SST rockfish in the AI. Analyses were limited to the Atka mackerel and Pacific Ocean perch (POP)/rockfish trawl fisheries, where almost all non-SST bycatch occurs. The time series of observer data analyzed was 1996-2021; the 2022 observer data were not complete in time for this analysis. Here we provide a brief summary of results related to the concentration of bycatch in sampled hauls, differences between the Atka mackerel and rockfish trawl fisheries, and the distribution of bycatch over space, time, and by depth.

<u>Concentration of bycatch</u>: When data from both the Atka mackerel and rockfish trawl fisheries were combined across all years, we found that only 36% of hauls contained non-SST bycatch. This bycatch was not distributed uniformly across hauls; 48% of all bycatch by weight occurred in the top 10% of hauls where non-SST were present. The distribution of bycatch was right skewed, with most hauls containing zero or small catches and only a few hauls catching large catches.

<u>Differences between the Atka mackerel and rockfish trawl fisheries</u>: Of all hauls analyzed (regardless of whether non-SST were present or absent), 74% were identified as Atka mackerel target. Of all of the hauls where non-SST bycatch was present, 81% of these were Atka mackerel target and this represented 80% of the total non-SST bycatch by weight.

<u>Spatial distribution:</u> (Atka mackerel and rockfish trawl combined): Bycatch rates were highest in the eastern AI (NMFS reporting area 541); only 36% of all hauls occurred in this area but it comprised 67% of the bycatch by weight. There was high fishing effort in a small area south of Seguam and Amutka Islands, and bycatch was highly concentrated in this area (see figure below).

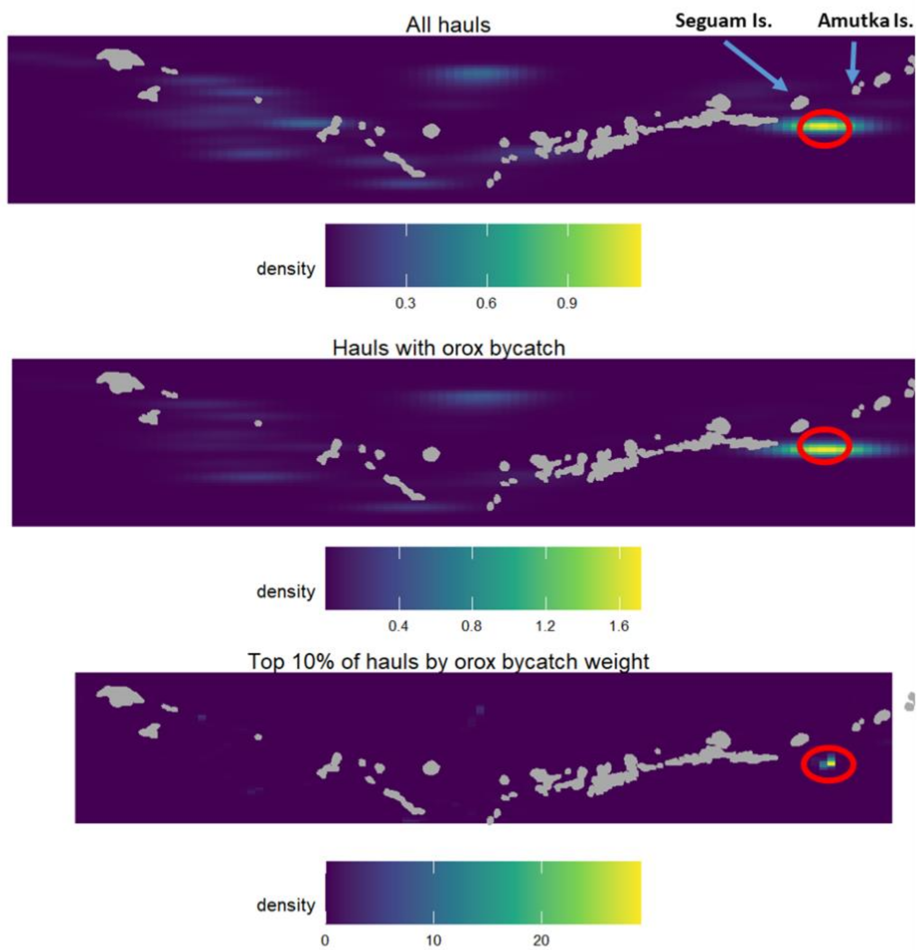

Figure – Two dimensional kernel density maps of all Atka mackerel and rockfish trawl hauls examined (1996-2021) (top), hauls where bycatch was present (middle), and the top 10% of hauls by non-shortspine thornyhead bycatch weight. The hotspot south of Seguam and Amutka Islands in the eastern AI (NMFS area 541) is highlighted in the red circle.

Depth: Bycatch rates were independent of depth in the Atka mackerel fishery (generally 75-175 m; see figure below). However, shallow rockfish hauls (100-200 m) had higher incidences of non-SST bycatch than deeper hauls (>200 m).

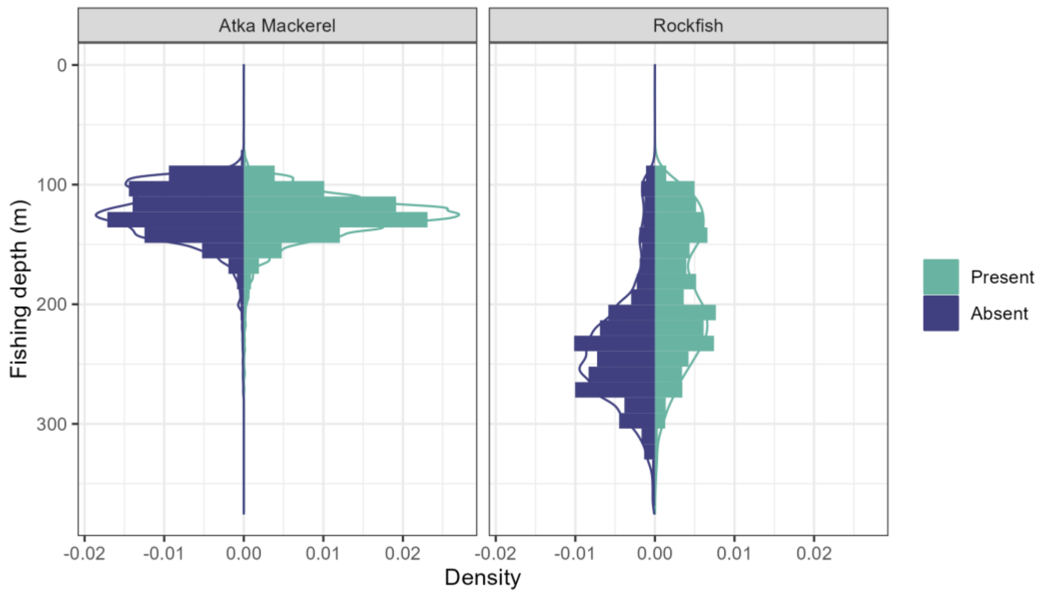

Figure – Distribution of hauls by depth (m) where non-shortspine thornyhead were present (green) or absent (purple) in the Aleutian Islands Atka mackerel and rockfish trawl fisheries, 1996-2021.

Temporal patterns: Effort (number of hauls) and non-SST bycatch has increased over time in both the Atka mackerel and rockfish trawl fisheries, with a peak in 2018 (see figure below). Effort and bycatch are highest in September and October in the Atka mackerel fishery and July in the rockfish fishery.

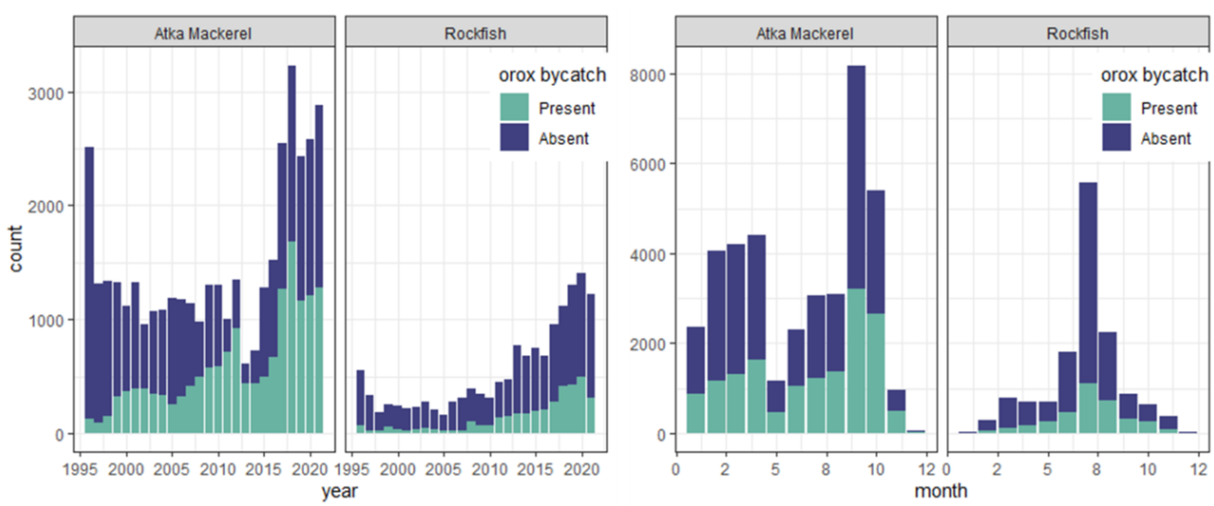

Figure – Count of hauls by year (left panels) and month (right panels) where non-shortspine thornyhead were present (green) or absent (purple) in the Aleutian Islands Atka mackerel and rockfish trawl fisheries, 1996-2021.

Introduction

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. The Other Rockfish complex includes all species of *Sebastes* and *Sebastolobus*, except Pacific ocean perch (POP, *Sebastes alutus*), northern rockfish (*Sebastes polyspinis),* rougheye rockfish (*S. aleutianus*), and shortraker rockfish (*S. borealis*). The two most abundant species for Other Rockfish complex are SST and dusky rockfish. Other species include redstripe rockfish (*Sebastes proriger*), redbanded rockfish (*Sebastes babcocki*), yelloweye rockfish (*Sebastes ruberrimus*), harlequin rockfish (*Sebastes variegatus*), sharpchin rockfish (*Sebastes zacentrus*), longspine thornyhead (*Sebastolobus altivelis*), and broadbanded (also called broadfin) thornyhead (*Sebastolobus macrochir*). 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 are currently not distinguished from rougheye rockfish in the fishery catches, and are therefore managed under the BSAI blackspotted/rougheye complex.

The Other Rockfish complex was defined in the BSAI Fishery Management Plan since 1986 and is managed through annual catch limits (Table 16.1). Prior to 2005, separate OFLs were established for BS 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 EBS slope. For this assessment, ABCs and OFLs for SST are calculated separately from 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 apportioned to the EBS and AI.

Distribution

SST and dusky rockfish, the most abundant non-SST species, are distributed in different depths and regions of the Bering Sea and Aleutian Islands. SST occur throughout the AI and EBS slope, but are most abundant in the western AI, 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. Evidence suggests that numerous Other Rockfish species are found in high relief, untrawlable habitat, which may lead to the underestimation of total exploitable biomass (Jones et al. 2012).

Life History Information

Rockfish of the genus *Sebastes* are long-lived and do not attain reproductive maturity until 5-27 years of age (Conrath 2017). 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 AI is 70 years (TenBrink et al. in prep). 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 (Lunsford et al. 2009). Two studies described in GOA dusky rockfish assessment estimated the age at 50% maturity of dusky rockfish in the GOA and range from 9.2-11.3 years (Chilton 2010, Fenske et al. 2018). These values indicate dusky rockfish have a shorter generation time than other rockfish, likely due to the higher natural mortality and earlier maturity. The maximum age of harlequin rockfish is 79 years (TenBrink et al., in prep). Maturity estimates are not available for the Aleutian Islands; however, GOA harlequin rockfish mature at an early age and small sizes. The estimate of 50% female maturity is 4.7 years and18.7 cm (TenBrink and Helser 2021).

Species of the genus *Sebastolobus*, including SST, broadbanded thornyhead, and longspine thornyhead, spawn pelagic egg masses that are pelagic between April and July in Alaska (Pearson and Gunderson 2003). Longevity may be as long as 100 years in SST (Butler et al. 1995). Age determination for SST 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. Accuracy of SST ages, however, remain inconclusive from C_{14} bomb radiocarbon results (Kastelle et al. 2020). Maturity for SST in the Aleutian Islands showed a 50% length and age estimate at 23.1 cm and 12.6 years (personal communication Todd TenBrink, AFSC). Given that ageing SST are still a work in progress, the maturity-at-age estimate should be viewed as preliminary.

Prey and Predators

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.

Evidence of Stock Structure

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).

Fishery

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 Table 16.2. 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. Tables 16.2 and 16.3 report catches of the seven most common species identified above since 2003 (dusky, yelloweye, sharpchin, redbanded, redstripe, and harlequin rockfish, and SST), 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." Reported ABCs, TACs, and catches of Other Rockfish from 2004-2022 are shown in Table 16.1.

The catches of Other Rockfish are composed primarily of dusky rockfish and SST; from 2003-2022, these two species composed 83% of the catch in the AI and 90% in the EBS (Tables 16.3 and 16.4). Three species of *Sebastolobus* are routinely captured in BSAI trawl surveys; broadbanded thornyhead, longspine thornyhead, and SST. The SST is by far the most abundant, comprising more than 90% of the thornyheads identified in observer records since 2008 (Tables 16.3 and 16.4). Thornyheads 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 in CAS to obtain an estimate of SST catch. Fishery observers record SST, broadbanded, and longspine thornyhead, as well as thornyhead unid., which could include any of the thornyhead species. In the Bering Sea, SST are only encountered on the Bering Sea slope.

There is no directed fishing for any of the Other Rockfish species; however, incidental catch occurs in multiple fisheries and gear types (Figure 16.1). The highest proportion (36%) has been caught in the Atka mackerel fishery, followed by the rockfish fishery (18%), the flatfish fishery (13%), the sablefish fishery (10%), and Pacific cod fisheries (9%). Other less significant fisheries include Pacific halibut (4%) and walleye pollock (3%). Since 2003 Other Rockfish have been primarily caught by bottom trawl (71%) and hook-and-line gear types (25%).

A summary of the Other Rockfish catch retained and discarded from 2003-2022 indicates that the percent of Other Rockfish discarded has ranged from 9-32% in the AI (mean = 53%) and 12-24% in the EBS (mean = 37%; Table 16.5). Discard rates are higher on average for the non-SST species like dusky and harlequin rockfish (38%) compared to SST (17%), which are a higher value speci. Discard rates are lower in fixed gear fisheries, which account for a higher proportion of SST catch and yield 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 tends to encounter larger SSTs than the BTS, although SST were smaller on average in the 2017-2019 fishery data (Figure 16.2). Similarly, the fishery tends to catch slightly larger dusky rockfish than the BTS, and there has been little change in the fishery length compositions over time (Figure 16.3).

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 averaged from 5.6 t between 2004 and 2021.

Survey

Bottom trawl surveys (BTS)

Exploitable biomass of Other Rockfish is estimated using bottom trawl survey biomass from the AI, EBS shelf, and EBS slope BTS (Table 16.6). Standardized U.S. domestic trawl surveys were conducted in 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, and 2022 in the AI and Southern Bering Sea (SBS), which is defined by the International North Pacific Fisheries Commission (INPFC) and sampled in the AI BTS; 2002, 2004, 2008, 2010, 2012, and 2016 on the EBS slope; and annually 1982-2022 on the EBS shelf. Planned 2020 AI and EBS shelf surveys were canceled due to Covid-19 restrictions.

The AI BTS is a multi-species survey and biomass estimates are based on a stratified random design of habitat stratified by management area, sub-region, and depth zones (0-100 m, 101-200 m, 201-300 m and 301-500 m). However, the AI BTS is based on a stratified random design of previously successful stations and is therefore an index survey. Design-based biomass estimates may be more appropriately viewed as weighted mean catch-per-unit-effort expanded by strata over the survey area. The AI BTS time series began in 1980 but gear was not standardized until the 1991 survey when the Poly'Noreastern (PNE) bottom trawl was uniformly implemented. Before then, a mix of large, fortified nets and a similar net to the PNE were used. Also haul duration was generally 30 minutes prior to 1997 when haul duration was reduced to 15 minutes. Based on recommendations from the Groundfish Assessment Program (GAP), we start the AI BTS biomass time series in 1991.

The EBS slope BTS is a multi-species survey with sampling effort distributed in proportion to the survey surface area by sub-region and depth (200-400 m, 400-600 m, 600-800 m, 800-1000 m, and 1000-1200 m; Hoff 2013). The survey used a standardized PNE with a tow duration of 30 minutes and towing speed of 2.5 knots. Although the EBS slope BTS only occurred six times and ended in 2016, it is likely our best depiction of deepwater rockfish species (e.g., SST, shortaker rockfish) in this region.

EBS shelf BTS is conducted annually using fixed stations at the center of a 20 x 20 nautical mile grid (Lauth and Nichol 2013). Design-based estimates of EBS shelf BTS biomass are based on 12 strata that include four sub-regions and 3 depth strata (<50 m, 50-100 m, and 101-200 m). The survey design has been standardized since 1982 and uses a tow duration of 30 minutes and a 3 knot towing speed. The EBS shelf BTS uses a standard 83-112 Eastern otter trawl employing a 25.3 m head rope and 34.1 m footrope. In 1987, 20 additional stations were added in the northern Bering Sea; however, we do not use biomass estimates based on these strata.

The largest survey biomass for SST is found on the EBS slope, and there was an increasing trend over the survey time period from 2002-2016 (Table 16.6, Figure 16.5). The biomass estimates for SST in the AI BTS gradually increased from 1980-2010 and are now decreasing (Table 16.6, Figure 16.5). The SBS, an area defined by the INPFC northeast of Samalga Pass that is sampled in the AI BTS, has the smallest survey biomass of any of the areas (Table 16.6, Figure 16.4). Like the other survey areas, the SBS has seen a modest increase in SST over the available time series, though there was a decrease in 2022. There are no SST on the EBS shelf. SST in the EBS slope BTS are primarily caught in the 401-600 m stratum, followed by the 601-800 m, 200-400 m, and 801-1000 m strata. In contrast, SST are primarily caught in the 301-500 m stratum in the AI BTS, which is the deepest stratum in that survey. Estimates of deep-water species such as SST are likely underestimated in the AI BTS, because it does not sample <500 m.

Although modest in comparison to SST, the largest survey biomass for non-SST species occurs in the AI and SBS (Table 16.6, Figure 16.6). The non-SST component of the complex is dominated by dusky rockfish across all survey regions, though harlequin rockfish are sporadically sampled in the AI and SBS (Figure 16.7). Catch of non-SST catch in the AI BTS is split between the 1-100 m and 101-200 m strata. The EBS shelf BTS frequently has zero biomass observations of non-SST, including the 2019 and 2021 surveys (Table 16.6, Figure 16.6). The treatment of these zeros in the estimation of exploitable biomass remains the subject of active discussion and analysis (Spies et al. 2018; Sullivan et al. 2022a). When observed in the EBS shelf BTS, non-SST rockfish are primarily caught in the 101-200 m, followed by the 50-100 m strata. The EBS slope hosts a very small biomass of non-SST, which includes several *Sebastes* and *Sebastolobus* species. The biomass estimates fluctuate in all areas, and the occasionally large biomass estimates are driven by a small number of large tows, leading to large coefficients of variation (CV; Table 16.6, Figure 16.6). The non-SST species are primarily observed in the 200-400 m stratum, though occasionally there are large catches of some of the slope non-SST species (e.g., redbanded rockfish) in deeper strata. Such large fluctuations would not be expected in a long-lived species, and are attributed to high uncertainty in the biomass estimates or a mismatch between the areas surveyed and the untrawlable habitat preferred by many rockfish species.

NMFS longline survey (LLS)

The LLS has been conducted annually since 1988 in the GOA, biennially in odd years along the EBS slope since 1997, and biennially in even years in the AI (Table 16.6; Figure 16.4; Siwicke et al. 2021; Rodgveller et al. 2011). This survey provides data on the relative abundance of SST and computes relative population numbers (RPNs) and relative population weights (RPWs) for fish on the continental slope as indices of stock abundance. Relative population abundance indices are computed annually using survey catch per unit of effort (CPUE) rates that are multiplied by the area size of the stratum within each geographic area. The RPWs are further weighted by the mean weight of fish caught by station and stratum, which is obtained from length frequency data and previously established length-weight relationship.

Although the survey is primarily directed at sablefish, SST are considered to be well-sampled by the LLS gear, and the LLS RPWs are also used to inform abundance trends in the GOA SST stock assessment (Echave et al. 2018, Hulson et al. 2021). Like any hook-and-line survey, there is the potential that CPUE may be affected by hook competition. Negative correlations between the catch rates of sablefish and some species exist, and there is likely competition between slope species (Rodgveller et al. 2008; Rodgveller et al. 2011). However, baited hook occupancy on the LLS is much higher than other hook-and-line surveys (e.g. the International Pacific Halibut Commission); therefore, hook competition is not concerning at this time but should continue to be monitored.

The inclusion of LLS relative population weights (RPWs) for SST in the EBS slope region in the 2022 assessment was prompted by concerns over the cessation of the EBS slope BTS in 2016 (e.g., Sullivan et al. 2020), coupled with recent declines in the Gulf of Alaska (GOA) SST stock (Echave et al. 2020). Biomass of SST in the EBS slope region is currently estimated to be 65% of the entire BSAI other rockfish stock (Sullivan et al. 2020). We recommend including the EBS slope LLS RPWs to inform abundance trend information in recent years, thus reducing reliance on the 2016 estimate of biomass in that region. The potential use of LLS RPWs in the AI was explored; however, we do not recommend using the AI RPWs at this time due to a mismatch in the spatial extent and resolution of the AI BTS and LLS (Figure 16.4). The LLS only samples the eastern AI, and the LLS area boundaries would need to be manually redefined in order to make them comparable with the BTS strata (Figure 16.4).

Length composition data from the bottom trawl and longline surveys

Survey lengths are available for SST in the AI and SBS from the AI BTS starting in 1997 and in alternating years in the LLS since 1996 (even years = AI, odd years = EBS). SST lengths from the AI BTS are smaller than the LLS and fishery data in both regions, falling primarily between 20 and 44 cm (Figure 16.2). Assuming that larger SST in the AI inhabit deeper water, the larger lengths in the LLS and fishery is likely related to the 500 m depth limit of the AI BTS. In general, the LLS length distributions are similar to the fishery, though SST fishery lengths have been smaller than the LLS since 2018. This likely attributed to a shift in SST catch proportionally from fixed gear to trawl fisheries over that time period in the EBS (Figure 16.1).

Survey lengths are available for dusky rockfish in the AI and SBS from the AI BTS starting in 1997. In general, length data are sparser for dusky rockfish in the EBS than AI, and the SBS AI BTS length data suggest that they are smaller on average than in the AI. The lengths of dusky rockfish obtained in the 1997-2022 AI surveys were generally between 35 and 45 cm, and the mode of the survey length distributions tends to be smaller than the fishery length distributions in the AI and EBS (Figure 16.3).

Analytic Approach

Model structure

Exploitable biomass is estimated using a state-space random walk model, referred to broadly as the random effects (RE) model. The RE model is fit to design-based estimates of survey biomass and observation error. Population biomass is modeled as a series of random effects, and the overall smoothness of the population relative to survey biomass is governed by the process error variance, the only fixed effect parameter estimated in the model. There are two extensions to the RE model, a multivariate version that can be used to fit to multiple strata simultaneously and share process error across one or more strata (REM), and another version that can fit to an additional relative abundance index (REMA; Hulson et al. 2021). For Other Rockfish we use the REM version of the model. Equations for the RE, REM, and REMA models, and a guide to fitting these models in TMB using the *rema* R package is provided in Sullivan et al. (2022).

Model 20

In the current BSAI other rockfish assessment (Model 20), two REM models are fit (one for SST and non-SST), and biomass for each species group is stratified by survey and Fishery Management Plan (FMP) subarea (i.e., EBS and AI). Process error is shared across all strata for both species groups. The SST biomass is estimated with three strata, where the AI BTS is split into two strata, the AI (eastern, central, and western AI combined) and southern Bering Sea (SBS), and the EBS slope BTS is treated as a single stratum. The non-SST biomass is estimated using four strata, where the AI BTS biomass is split into the AI and SBS, and the EBS slope and shelf BTS biomass are estimated as unique strata. There are no SST on the EBS shelf, therefore the EBS shelf survey data is not used for that component of the stock. The EBS shelf survey frequently does not catch non-SST, and 14 out of 39 survey years are zero biomass observations. Consistent with past assessments, we assume these zeros are failed surveys and treat them as NAs in the model.

Model 22

In recent years, concerns have been raised about the lack of abundance information for SST in the EBS slope following the cessation of the EBS slope BTS in 2016 (Sullivan et al. 2020). In response, this year we developed an alternative model that addresses these concerns by including the NMFS longline survey (LLS) relative population weights (RPWs) in the EBS slope region. This model estimates an additional scaling parameter (q), which is a multiplier on the predicted population biomass used to obtain predicted RPW. Other than SST on the EBS slope, the model structure in Model 22 is identical to Model 20.

Reference points
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 SST M of 0.03 is borrowed from the current GOA thornyhead stock assessment and is the average M over a range of published values for SST (Echave and Hulson 2018). The non-SST M of 0.09 is the M previously used for dusky rockfish, the most abundant species in the non-SST component of the complex (Clausen and Heifetz 2001). 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 the estimated biomass of SST and non-SST in those regions. In this case, the SBS, EBS slope, and EBS shelf, when appropriate, are summed to be obtain the EBS biomass.

Results

In both Models 20 and 22, SST comprise approximately 95% of the total estimated exploitable biomass for BSAI Other Rockfish. SST biomass is greatest on the EBS slope, followed by the AI and SBS, and there are no SST on the EBS shelf. Both models perform well for SST in all survey regions (Figure 16.5). The fit to SST survey biomass shows an increase on the EBS slope from 2002-2016, an increase in the AI from 1991-2005 followed by a slight decrease after 2010, as well as a slight increase in the Southern Bering Sea since 1980.

The LLS RPWs and BTS biomass estimates of SST on the EBS slope follow a similar trend, therefore, long-term predicted biomass trajectories are similar between Models 20 and 22 (Figure 16.5). However, the estimate of process error is higher in Model 22, resulting in slightly more inter-annual variability in biomass in Model 22 (Table 16.7). The inclusion of the LLS RPW index uses the most comprehensive data on SST abundance in the EBS slope region, and therefore, Model 22 is the author-preferred model. Although adding this new data source does not change our current understanding of SST abundance on the EBS slope, recent declines in the RPWs and declines in SST predicted biomass in the GOA, suggest there may be continued changes to the dynamics of this stock (Echave et al. 2020, Appendix A of Sullivan et al. 2022a). The addition of LLS RPWs in Model 22 will allow us to track these future trends in the population and make adjustments to harvest recommendations as needed.

The non-SST component of the model is the same between Model 20 and Model 22, because there are no LLS RPWs available for non-SST Other Rockfish species (Figure 16.6). The RE-estimated 2022 non-SST biomass was greatest in the AI and SBS, followed by the EBS shelf and lastly EBS slope. The RE model effectively dampens the spasmodic survey biomass estimates of non-SST, because estimates in most years are highly uncertain (Figure 16.6). Dusky rockfish are the dominant species in the non-SST group in all survey areas (Figure 16.7).

Although SST make up the vast majority of the biomass in the BSAI, catch is dominated by non-SST. Fishery exploitation rates, estimated as the total catch estimates from CAS divided by the RE model biomass, differ substantially between the species groups (Figure 16.8). While the exploitation rate for SST since 2003 has remained less than 2%, the non-SST exploitation rate has averaged around 40% and 15% in the AI and EBS, respectively (Figure 16.8). Notably, the exploitation rate exceeded 1 in 2012 for non-SST in the AI, indicating catch was greater than the estimated biomass. This is a reflection of the highly variable non-SST biomass estimates from bottom trawl surveys in all areas (Figure 16.6). Additionally, catches of dusky and harlequin rockfish in the AI have increased in recent years (Table 16.3), primarily due to bycatch in the Atka mackerel bottom trawl fishery in the eastern Aleutian Islands (NMFS reporting area 541; Figure 16.1).

Harvest recommendations

In recent years, BSAI Other Rockfish (SST and non-SST combined) have been managed with a BSAI-wide OFL level with apportioned ABCs for the AI and EBS. Total Other Rockfish catches in the AI region exceeded ABC in all but two of the last ten years and BSAI catch exceeded TAC in 2014 and 2019 (Table 16.1). The overall BSAI OFL, however, remains well above the recent catch.

The 2022 biomass estimate of the BSAI Other Rockfish complex from the random effects model results is 52,733 t; 51,098 t for the SST component and 1,635 t for the non-SST component. For the 2023 and 2024 fishery, we recommend the maximum allowable ABC of 880 t for the Other Rockfish complex in the EBS and 380 t in the AI. We recommend a BSAI-wide OFL of 1,680 t for the entire complex. Further breakdowns of reference values for SST and non-SST in the Other Rockfish complex are summarized in the following table.

2023	**SST**	**non-SST**	**Total Other Rockfish**
M	0.03	0.09	-
Biomass	51,098	1,635	52,733
F_{OFL}	0.03	0.09	-
$maxF_{ABC}$	0.0225	0.0675	-
F_{ABC}	0.0225	0.0675	-
OFL	1,533	147	1,680
maxABC	1,150	110	1,260
ABC	1,150	110	1,260
Aleutian Islands ABC	294	87	380
Bering Sea ABC	856	24	880

Risk Table and ABC Recommendation

Overview

The following template is used to complete the risk table:

	Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
Level 1: Normal	Typical to moderately increased uncertainty/minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns

Level 2: Substantially increased concerns	Substantially increased assessment uncertainty/ unresolved issues.	Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or recruitment pattern is atypical.	Some indicators showing adverse signals relevant to the stock but the pattern is not consistent across all indicators.	Some indicators showing adverse signals but the pattern is not consistent across all indicators
Level 3: Major Concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock)	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types
Level 4: Extreme concern	Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented; More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock; Potential for cascading effects on other ecosystem components	Extreme anomalies in multiple performance indicators that are highly likely to impact the stock

The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. These considerations are stock assessment considerations, population dynamics considerations, environmental/ecosystem considerations, and fishery performance. Examples of the types of concerns that might be relevant include the following:

1. "Assessment considerations—data-inputs: biased ages, skipped surveys, lack of fishery-independent trend data; model fits: poor fits to fits to fishery or survey data, inability to simultaneously fit multiple data inputs; model performance: poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds; estimation uncertainty: poorly-estimated but influential year classes; retrospective bias in biomass estimates.

2. "Population dynamics considerations—decreasing biomass trend, poor recent recruitment, inability of the stock to rebuild, abrupt increase or decrease in stock abundance.

3. "Environmental/ecosystem considerations—adverse trends in environmental/ecosystem indicators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.

4. "Fishery performance—fishery CPUE is showing a contrasting pattern from the stock biomass trend, unusual spatial pattern of fishing, changes in the percent of TAC taken, changes in the duration of fishery openings."

Assessment considerations

The BSAI Other Rockfish complex is split into SST, which comprises ~95% of the total exploitable biomass for the complex, and the smaller non-SST component, which is dominated by dusky rockfish but includes at least eleven other *Sebastes* and *Sebastolobus* species. Both SST and non-SST components of the complex are assessed under Tier 5, and exploitable biomass is estimated by fitting the standard RE model to AI, EBS shelf, and EBS slope trawl survey biomass estimates (Table 16.6, Figures 16.5 and 16.6).

The RE model performs well for the SST component of the stock; few survey data points fall outside the confidence interval, there are no concerning residual patterns, and the survey biomass trend is clear and consistent in all areas (Figure 16.5). However, the largest estimated biomass of SST is in on the EBS slope, which has not been surveyed since 2016 and may not be surveyed for the foreseeable future given survey reductions (ICES 2020). In response, in 2022 we added the LLS RPW index of abundance for SST on the EBS slope to inform trend information in this region (Model 22; Figure 16.5). There is a high level of agreement between the EBS slope BTS biomass index and LLS RPWs in overlapping years, lending support to the use of the LLS data for SST in this assessment. The addition of the LLS RPWs in the EBS slope in 2022 effectively reduced risk for the SST component of the stock.

The application of the RE model to the non-SST component of the complex is problematic for several reasons. The survey biomass estimates for non-SST are dominated by dusky rockfish, and therefore, are not reliable indices for the numerous other species contained in the non-SST component of the complex (Figure 16.7). The trends in non-SST survey biomass are characterized by several years of zero or low biomass interspersed with high estimates of biomass with wide confidence intervals (Figure 16.6). The zero survey biomass observations are treated as NAs in the model, and despite analysis of this issue in past assessments, no suitable alternatives have been found (Spies et al. 2018, Sullivan et al. 2022a). The NA assumption is consistent with other Tier 5 assessments, including GOA Other Rockfish and BSAI Other Flatfish (Tribuzio and Echave 2019, Monnahan 2020, Monnahan et al. 2021).

The exploitation rate (catch/biomass ratio) has been consistently high for the non-SST component of the Other Rockfish complex (Figure 16.8). Notably, the estimate of catch/biomass exceeded 1.0 in 2011 and 2012 for non-SST in the AI, indicating catch was greater than the estimated biomass. These findings indicate biomass estimates of non-SST may not be reliable, making it difficult to evaluate current harvest rates of non-SST species. Catches of dusky and harlequin rockfish in the AI have been higher since 2010 compared to pre-2010 (Table 16.3), primarily due to bycatch in the Atka mackerel bottom trawl fishery in the eastern AI (area 541; Figure 16.1).

In the 'Responses to SSC and Plan Team comments specific to this assessment' section, we conducted a spatial analysis of non-SST bycatch. Our findings suggests bycatch is highly concentrated to a small number of tows and in a small area south of Seguam and Amukta Islands. This hotspot is known to be a highly productive spawning area for Atka mackerel and seasonal peaks in bycatch (September and October) correspond with spawn timing for Atka mackerel (personal communication Ivonne Ortiz, AFSC, October 2022). Because non-SST bycatch appears to be independent of depth in the Atka mackerel fishery, there is no obvious bycatch avoidance measure that could be taken to reduce non-SST bycatch other than avoiding the hotspot altogether. Bycatch of non-SST did not increase in 2022 relative to previous years and will continue to be monitored in the assessment.

Despite ongoing concerns with the non-SST components of the stock, the addition of LLS RPWs for SST in the EBS slope warranted a reduction in overall risk from level 2 to 1.

Population dynamics considerations

As described in the Assessment considerations, the index of non-SST biomass may not reliably reflect exploitable biomass, resulting in persistently high exploitation rates for this component of the stock. These biomass trends, although problematic for non-SST, are typical for the Other Rockfish stock. We therefore set the concern level to 1 for this consideration.

Environmental/Ecosystem considerations

Provided by Ivonne Ortiz and Elizabeth Siddon

Environment: The average bottom temperature from the AI BTS (165°W – 172°E, 30-500 m) was ~4.4°C, similar to 2018 and cooler than the highest observed in 2016 but still above the long term mean, as have the last four surveys (2014 onwards). Mid-depth (100-300 m) and water column temperature (surface to bottom) from the NMFS LLS (164°W to 180°W) and AI BTS show a similar pattern, with warmer temperatures throughout the water column starting 2014. EBS slope temperatures from the LLS were above average between 2015–2021 (odd-year survey) (Hennon et al., 2021). Surface temperature both from the AI BTS, as well as satellite, show an increasing trend in temperatures during both summer and winter, with 2022 being one of the warmest years in summer throughout the AI and in wintertime for the western and central AI. Most of the year through August has been under some level of heatwave in the central and western AI, less so in the eastern AI. This is in sharp contrast to the GOA where only a few days were under marine heatwave (Bond et al. 2022).

For this risk table, ecosystem information is largely based on relevance to SST and dusky rockfish. Dusky rockfish and SST are generally found between 3.5-5.7°C and 3.5-5°C, respectively. SST and dusky rockfish depth distributions have remained stable over time in the AI BTS, unlike that of most rockfish which are shifting to shallower depths (Laman 2022). The increasing temperatures at mid-depth, bottom, and surface waters observed in the data from both the LLS and BTS, indicate dusky rockfish and SSTs are vulnerable to these increases despite being distributed up to 400 m (dusky rockfish) and 500 m depth (SST, within BTS; maximum depth recorded 1500 m). In general, higher ambient temperatures incur bioenergetic costs for ectothermic fish such that, all else being equal, consumption must increase to maintain fish condition. Thus, the persistent higher temperatures may be considered a negative indicator for rockfish. However, increased bioenergetic demands may be mitigated by their generalist diet and for SST, depths greater than 500 m. Primary productivity as measured by satellite chlorophyll has been declining in the EBS off shelf region since 2014, concomitant with the potential decrease observed in the Aleutian Islands (Bond et al. 2022 and Nielsen et al. 2022).

In terms of their reproduction, dusky rockfish are viviparous while SST spawn pelagic gelatinous egg masses, making them more vulnerable to environmental conditions during this stage compared to dusky rockfish. Dusky rockfish release larvae in late spring, early summer while SST spawn at similar times (Conrath 2019; Pearson and Gunderson 2003). This timing makes the larvae and eggs vulnerable to the more intense and frequent marine heatwaves that occur in summer in the AI.

Prey: Based on stomachs of dusky rockfish and SST sampled during the AI BTS, the Other Rockfish can be split between planktivorous (dusky rockfish) and generalists (SSTs). Dusky rockfish feed largely on pelagic gelatinous filter feeders, jellyfish and shrimp in the western and central AI (NMFS areas 543, 542), but feed more heavily on euphausiids, pelagic amphipods, copepods, and mysids in the eastern AI (areas 541 and SBS). In contrast, SSTs prey on shrimp, benthic amphipods and general fish when small ($\leq$ 20 cm) while larger SST (> 20 cm) feed primarily on sculpin, Atka mackerel, shrimp, cephalopods, snow and King crab, and occasionally on skates among other prey.

Competitors and predators: Dusky rockfish may compete somewhat with POP for prey, while SST share prey items with shortraker rockfish (sculpins, general fish, and shrimp) and rougheye rockfish (Atka mackerel, shrimp, and squid). Among these prey, sculpin, shrimp, and Atka mackerel increased compared to the most recent AI BTS in 2018. There are no recorded fish predators of dusky rockfish or SST in the AI. Steller sea lions have been found to consume SST occasionally (Sinclair et al. 2013). Steller sea lions were found to be stable from 2002 to 2018, with declines in some colony complexes offset by increases at other colony complexes (Sweeney and Gelatt 2022).

The indicator most relevant to reflecting habitat disturbance is the estimated area disturbed by trawl gear from the Essential Fish Habitat fishing effects model (Olson 2021). Trends in potential habitat disturbance are relevant for adult dusky rockfish and SST as they can be found on soft substrates, where shrimp are abundant, and in areas with frequent boulders and steep slopes, which are generally not targeted by bottom trawlers. Some habitat forming species might be more impacted as the relative CPUE of sponges and hydrocorals from the BTS show slight decreases (Laman 2022b), coinciding with a decrease in bycatch of structural epifauna in the fishery (Whitehouse 2022). Rooper et al. (2019) concluded the removal of deep coral and sponges is likely to reduce the overall density of rockfishes. The fishing effects model has not indicated large changes in habitat disturbance trends, and has remained below 3% for the AI since 2009, so we assume that the level of habitat disturbance for the Other Rockfish complex has been stable in the AI.

Taken together, these indicators suggest no clear concerns for the Other Rockfish stock complex aside from the recent stretch of increased temperatures and potential spatial competition with POP. However, the lack of ecological data relevant to the stock complex limits our assessment of more detailed potential recent ecosystem impacts on this stock complex. We therefore set the concern level to 1 for this consideration.

Fishery performance

There are no directed fisheries for Other Rockfish. The majority of catch is of non-SST dusky rockfish in the Atka mackerel bottom trawl fishery in the eastern AI (Tables 16.1 and 16.3, Figure 16.1). Any concerns related to the apparent high exploitation rate of non-SST are reflected in our Assessment concerns, and we therefore assigned a level 1 concern for the fishery performance consideration.

Summary and ABC recommendation

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*
Level 1: no increased concerns	Level 1: no increased concerns	Level 1: no increased concerns	Level 1: no increased concerns

We ranked all risk table considerations as Level 1, and therefore, we recommend the maximum permissible ABC under the relevant harvest control rule.

Status Determination

The stock/complex is not being subjected to overfishing as determined by comparing the catch from the most recent complete year to the specified OFL for that year.

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Tables

Table 16.1. Regulatory catch limits (OFL, ABC, and TAC) and total catch of Other Rockfish in the BSAI, 1995-2022. Data for 2003-2022 is from the NMFS AKRO Catch Accounting System, AKFIN database, accessed October 3, 2022. Catch data previous to 2003 was obtained using several different sources that are described in the text. Shading highlights years catch exceeded TAC or ABC.

	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	685	846	634	634	390	1280	960	960	295
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	422		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	268
2011	1,700	1,280	1,000	945		570	500	617		710	500	328
2012	1,700	1,280	1,070	919		570	570	711		710	500	208
2013	1,540	1,159	873	789		473	473	597		686	400	192
2014	1,550	1,163	773	913		473	473	589		690	300	324
2015	1,667	1,250	880	651		555	555	467		695	325	184
2016	1,667	1,250	875	768		555	550	490		695	325	278
2017	1,816	1,362	875	828		571	550	568		791	325	260
2018	1,816	1,362	845	986		571	570	775		791	275	211
2019	1,793	1,345	663	1,274		388	388	570		956	275	704
2020	1,793	1,345	1,088	1,095		388	388	740		956	700	355
2021	1,751	1,313	916	1,002		394	394	610		919	522	392
2022	1,751	1,313	916	999		394	394	453		919	522	546

Table 16.2. 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.

	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 16.3. Catch (t) of Other Rockfish species in the Aleutian Islands 2003-2022. Source: NMFS AKRO Catch Accounting System, AKFIN database, NMFS AFSC FMA Observer Debriefed Haul and Length tables, accessed Oct. 3, 2022.

Year	dusky rockfish	SST	other thornyheads	% SST in thornyhead catch	harlequin rockfish	yelloweye rockfish	redbanded rockfish	redstripe rockfish	black rockfish	other rockfish	Total (t)
2003	151.5	129.3	47.8	73%	34.5	2.4	0.2	0.9	0.2	3.2	389.6
2004	129.5	60.3	37	62%	36.9	0.9	0.2	3.1	1.4	47.9	331.2
2005	134.2	78.1	35.1	69%	14.3	5.6	0.2	0	0	14.1	281.6
2006	161.4	118.7	39.7	75%	25.2	0.4	0.1	1.7	0.1	72.2	421.6
2007	231.7	115.9	15.4	88%	39.9	0.6	1.4	0.5	0.1	23.9	429.4
2008	179.8	107.4	7.8	93%	34.3	4.5	1	0.6	3.2	43.3	382
2009	142	131.8	10.8	92%	22.8	0.2	0.4	0	1.2	63	372.3
2010	226.2	154.8	14.9	91%	42.6	0.5	3.6	0.9	0.4	53.5	497.6
2011	380.5	152.9	10.7	93%	59.3	0.3	0.7	0	0.1	12.2	616.7
2012	435.2	171.1	2.7	98%	51.9	0.1	3.7	0	0.3	46.3	711.4
2013	334.3	226.2	4.6	98%	25.9	0.7	0.9	0	0.5	3.7	596.8
2014	349.3	202.4	8.7	96%	20	0.1	1.5	0.3	0.4	6.2	588.9
2015	294.4	119.7	2.3	98%	32.7	0.1	0.3	0	0.1	17.6	467.1
2016	337.6	113.5	0	100%	36.1	1.3	0.5	0.1	0.3	0.7	490.2
2017	403.5	99.6	0.8	99%	47.9	0.1	1.7	4.5	0.5	9.6	568.2
2018	570.6	90.2	1.3	99%	95.4	0.8	0.9	0	0.3	15.3	774.8
2019	332.4	135	0	100%	92.2	0.3	2	0	0.8	7.2	569.9
2020	426.6	186	0.1	100%	97.8	1	2.3	0.1	1.1	24.3	739.5
2021	361.4	164.3	6.1	96%	67.6	0.6	0.6	0.8	0.1	8.2	610
2022	248.9	121	0.1	100%	79.2	0.6	0.5	0.5	0	2.2	452.9
Average	291.6	133.9	12.3	91%	47.8	1	1.1	0.7	0.6	23.7	514.6

Table 16.4. Catch (t) of Other Rockfish species in the Bering Sea, 2003-2022. Source: NMFS AKRO Catch Accounting System, AKFIN database, NMFS AFSC FMA Observer Debriefed Haul and Length tables, accessed Oct. 3, 2022.

Year	dusky rockfish	SST	other thornyheads	% SST in thornyhead catch	harlequin rockfish	yelloweye rockfish	redbanded rockfish	redstripe rockfish	black rockfish	other rockfish	Total (t)
2003	22.2	218.9	20.8	91%	0	1.1	17	1	0.3	13.6	295
2004	31.9	224.3	17.7	93%	0.4	1.4	10.4	0	0.9	15	301.9
2005	36.2	103	15.9	87%	0.2	0.7	0.3	0	7.2	1.6	165.2
2006	46.6	89	4.3	95%	0	1.4	0.4	0.1	0.2	6.9	148.8
2007	44.9	163.1	5.1	97%	0	1.7	0	0	0.3	1.8	217.1
2008	15.4	179.1	7.3	96%	0	1	0	0.1	2.2	9.2	214.3
2009	10.2	177.6	1	99%	0.1	1.1	0.2	0	0.2	2.8	193.3
2010	33.3	199.5	7.8	96%	0.3	1.4	0.5	0	1.5	23.8	268.3
2011	46.1	258	1.7	99%	4.6	1.4	0.5	0	3.5	12.7	328.4
2012	35.9	134.8	9.1	94%	0.1	0.5	2.6	0.1	7.2	17.3	207.6
2013	33.3	142.7	3	98%	0.6	0.7	0.2	0	4.6	7	192.2
2014	42.2	245.9	3.4	99%	1.5	1.5	0.1	4.6	1.8	22.8	323.9
2015	47.7	99.8	2.3	98%	2.3	1.4	0.2	0	1.7	28.5	183.9
2016	36.4	210.1	9.4	96%	3.1	2.5	0.1	0	6.2	10.2	278.1
2017	30.2	210.9	1.1	100%	1.7	1.3	1.6	0.3	0.8	11.9	259.8
2018	38.4	148.6	0.7	100%	0.5	1	0.2	0.1	5.2	16.7	211.4
2019	88.3	599.7	1.9	100%	3.4	1.3	0.6	0.1	0.7	7.6	703.6
2020	64.3	247.8	0.4	100%	0.3	0.8	0	0	7.6	33.8	355
2021	65.4	310.5	0.1	100%	3.4	0.8	0	0	0.2	11.6	391.8
2022	66.9	456.1	9.4	98%	2	1.6	0.3	0	1	8.8	546.1
Average	41.8	221	6.1	97%	1.2	1.2	1.8	0.3	2.7	13.2	289.3

Table 16.5. Retained and discarded catch of Other Rockfish species from 2003-2022 in the Aleutian Islands and Bering Sea. Accessed Oct. 3, 2022 from the NMFS AKRO Catch Accounting System, AKFIN database.

Area	Year	Discarded	Retained	Total catch	Percent discarded
AI	2003	187	202	389	48%
	2004	166	165	331	50%
	2005	95	186	281	34%
	2006	177	245	422	42%
	2007	218	212	430	51%
	2008	114	268	382	30%
	2009	116	256	372	31%
	2010	124	373	497	25%
	2011	143	474	617	23%
	2012	98	613	711	14%
	2013	152	445	597	25%
	2014	147	442	589	25%
	2015	65	402	467	14%
	2016	41	449	490	9%
	2017	102	466	568	18%
	2018	197	578	775	25%
	2019	255	315	570	45%
	2020	394	346	740	53%
	2021	277	333	610	45%
	2022	133	320	453	29%
EBS	2003	44	251	295	15%
	2004	73	229	302	24%
	2005	21	144	165	13%
	2006	26	123	149	18%
	2007	73	144	217	34%
	2008	70	144	214	33%
	2009	23	170	193	12%
	2010	66	203	269	24%
	2011	50	278	328	15%
	2012	44	163	207	21%
	2013	47	146	193	24%
	2014	67	256	323	21%
	2015	67	116	183	37%
	2016	85	193	278	31%
	2017	58	202	260	22%
	2018	60	151	211	28%
	2019	161	542	703	23%
	2020	99	256	355	28%
	2021	90	302	392	23%
	2022	176	370	546	32%

Table 16.6. Bottom trawl survey (BTS) biomass estimates (t) and longline survey (LLS) relative population weights (RPW) with coefficient of variations in parentheses from the Aleutian Islands (AI), Eastern Bering Sea (EBS) shelf, and EBS slope. These abundance estimates were used as inputs to the random effects model for shortspine thornyhead (SST) and non-SST components of the Other Rockfish complex. The Southern Bering Sea is defined by the International North Pacific Fisheries Commission (INPFC) and is sampled during the AI trawl survey. SST do not occur on the EBS shelf. Zero biomass observations are treated as NA values in the random effects model.

	SST				non-SST			
	BTS biomass			LLS RPWs	BTS biomass			
Year	AI	SBS	EBS Slope	EBS Slope	EBS Shelf	AI	SBS	EBS Slope
1982					0 (NA)			
1983					0 (NA)			
1984					18 (1)			
1985					36 (1)			
1986					0 (NA)			
1987					49 (1)			
1988					0 (NA)			
1989					0 (NA)			
1990					0 (NA)			
1991	6,153 (0.24)	187 (0.58)			842 (0.94)	494 (0.38)	61 (0.83)	
1992					14 (1)			
1993					86 (1)			
1994	6,244 (0.16)	1,071 (0.52)			47 (1)	213 (0.61)	101 (0.49)	
1995					74 (0.7)			
1996					35 (1)			
1997	8,894 (0.18)	1,545 (0.69)		12,110 (0.23	127 (1)	643 (0.68)	138 (0.46)	
1998					527 (0.68)			
1999				4,192 (0.12)	390 (0.75)			
2000	10,648 (0.19)	1,051 (0.48)			0 (NA)	1,276 (0.33)	55 (0.36)	
2001				9,444 (0.24)	0 (NA)			
2002	14,244 (0.2)	1,012 (0.41)	16,940 (0.12)		0 (NA)	554 (0.31)	99 (0.36)	38 (0.42)
2003				11,050 (0.27)	54 (0.7)			
2004	17,335 (0.19)	945 (0.56)	18,793 (0.09)		0 (NA)	1,231 (0.41)	5,528 (0.78)	31 (0.35)
2005				13,503 (0.15)	36 (1)			

	SST				non-SST			
	BTS biomass			LLS RPWs	BTS biomass			
Year	AI	SBS	EBS Slope	EBS Slope	EBS Shelf	AI	SBS	EBS Slope
2006	17,878 (0.12)	968 (0.55)			351 (0.84)	6,003 (0.88)	738 (0.95)	
2007				13,135 (0.28)	0 (NA)			
2008			26,055 (0.12)		0 (NA)			27 (0.45)
2009				16,118 (0.22)	120 (0.58)			
2010	18,075 (0.16)	1,052 (0.73)	29,334 (0.12)		57 (0.92)	588 (0.32)	120 (0.44)	147 (0.7)
2011				28,630 (0.17)	55 (1)			
2012	14,443 (0.15)	452 (0.77)	29,565 (0.11)		36 (1)	250 (0.3)	135 (0.57)	52 (0.49)
2013				24,760 (0.09)	39 (1)			
2014	17,611 (0.24)	2,567 (0.67)			28 (1)	5,643 (0.81)	232 (0.5)	
2015				31,782 (0.14)	142 (1)			
2016	16,541 (0.16)	1,607 (0.53)	35,948 (0.11)		20 (1)	1,765 (0.33)	218 (0.54)	30 (0.33)
2017				28,295 (0.14)	170 (0.73)			
2018	13,216 (0.2)	1,605 (0.68)			1,562 (0.7)	914 (0.32)	1,638 (0.77)	
2019				26,073 (0.16)	0 (NA)			
2020								
2021				25,497 (0.18)	0 (NA)			
2022	12,867 (0.16)	1,278 (0.75)			43 (1)	1,332 (0.53)	217 (0.39)	

Table 16.7. Parameter estimates with standard errors (SE) and lower/upper 95% confidence intervals (LCI/UCI) for the random effects (RE) models fit to the shortspine thornyhead (SST) and non-SST species biomass estimates. Estimates are shown on the natural (i.e., arithmetic scale) for ease of interpretation but are estimated in log-space. Process error is pooled across all survey regions for both species groups. Results are show for Model 20, the multivariate random effects (REM) model, and Model 22, which also fits to the EBS slope longline survey relative population weights for SST and thus has a scaling parameter (q). Because there is no longline survey abundance data for non-SST species, Models 20 and 22 are identical. Model 22 is the author-preferred model.

Species group	Model	Parameter	Estimate	SE	LCI	UCI
SST	Model 20	Process error	0.12	0.03	0.07	0.18
SST	Model 22	Process error	0.17	0.03	0.11	0.25
SST	Model 22	Scaling parameter (q)	0.70	0.06	0.59	0.84
non-SST	Model 20	Process error	0.67	0.13	0.46	0.97
non-SST	Model 22	Process error	0.67	0.13	0.46	0.97

Figures

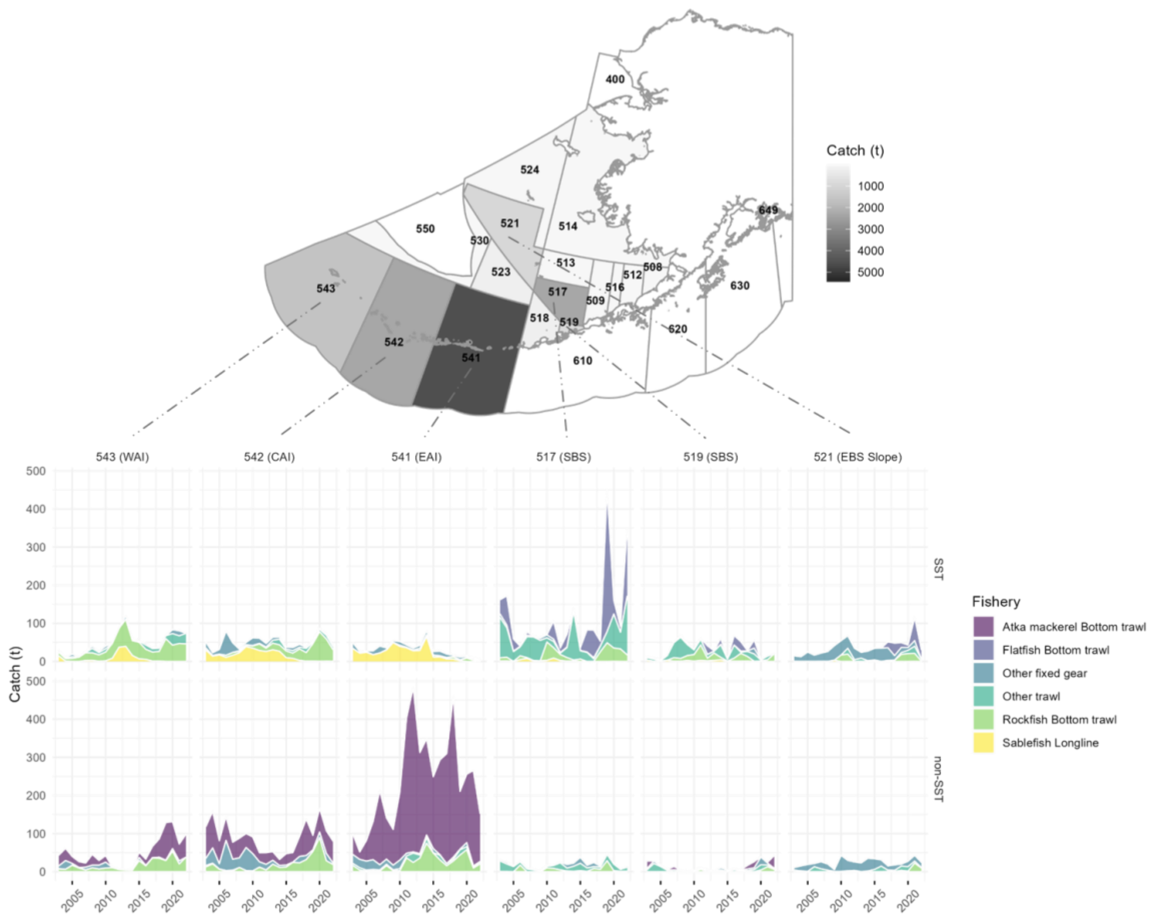

Figure 16.1. Upper panel: Map of aggregated catch of all Other Rockfish in the Bering Sea and Aleutian Islands (BSAI) by NMFS reporting area, 2003-2022. Lower panel: Annual catches of shortspine thornyhead (SST) and non-SST rockfish by dominant fishery and gear type for the NMFS reporting areas with the greatest catch. Source: NMFS AKRO Catch Accounting System, AKFIN database, as of October 3, 2022.

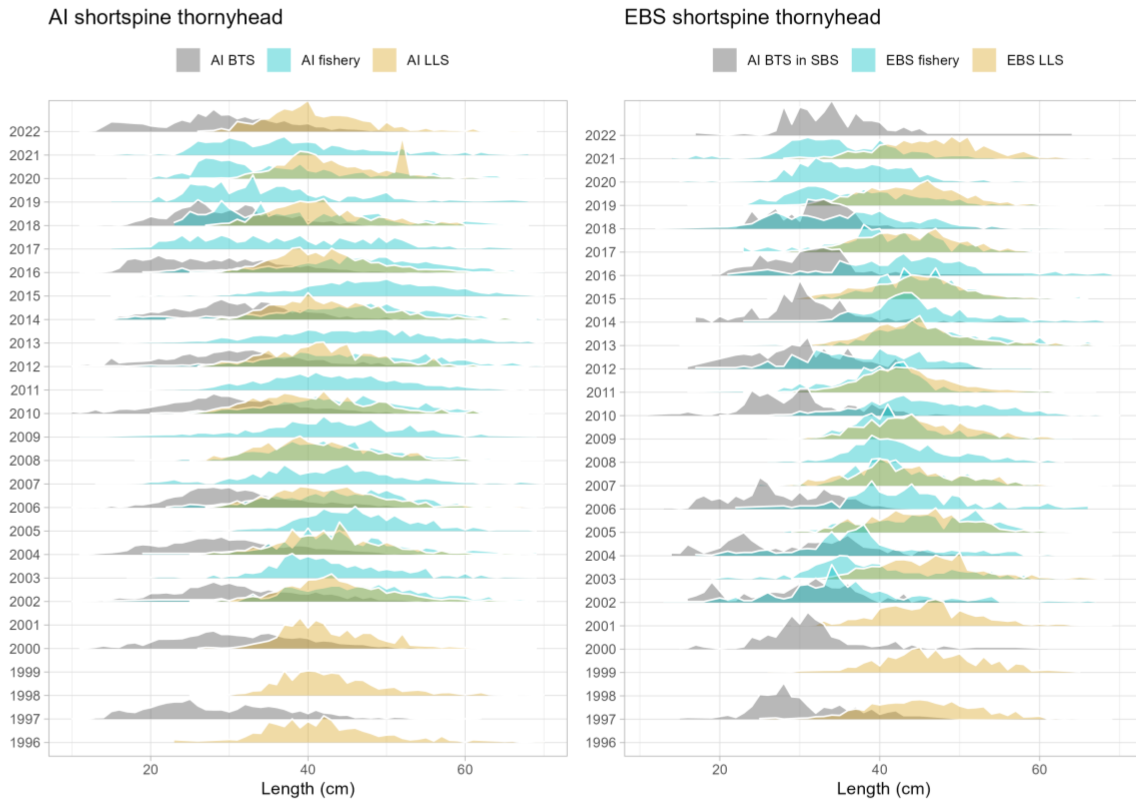

Figure 16.2. Shortspine thornyhead length frequency data from the Aleutian Islands (AI) bottom trawl survey (BTS; grey), fishery (teal), and longline survey (LLS; goldenrod) in the AI and eastern Bering Sea (EBS), 1996-2022. Fishery data source: NMFS AFSC FMA Observer Debriefed Haul and Length tables.

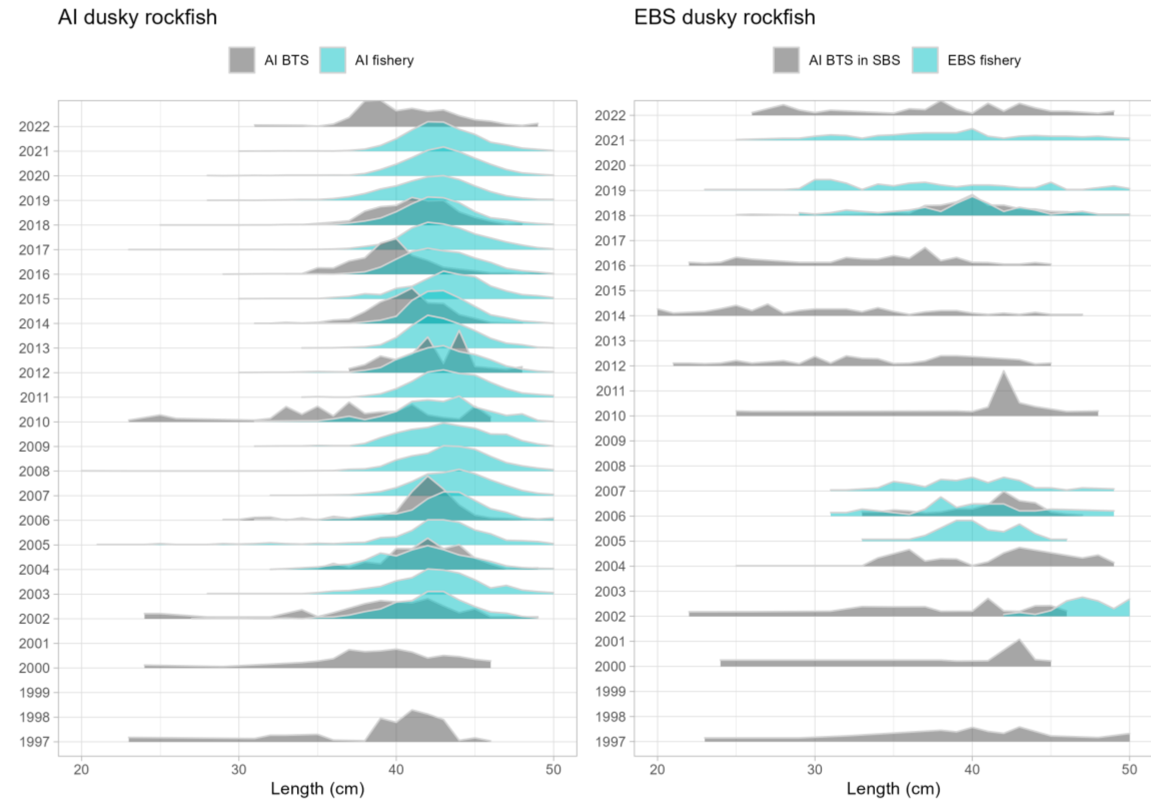

Figure 16.3. Dusky rockfish length frequency data from the Aleutian Islands (AI) bottom trawl survey (BTS; grey) and fishery (teal) in the AI and eastern Bering Sea (EBS), 1997-2022. The AI BTS only samples the southern Bering Sea (SBS), an area defined by the International North Pacific Fisheries Commission (INPFC) northeast of Samalga Pass.

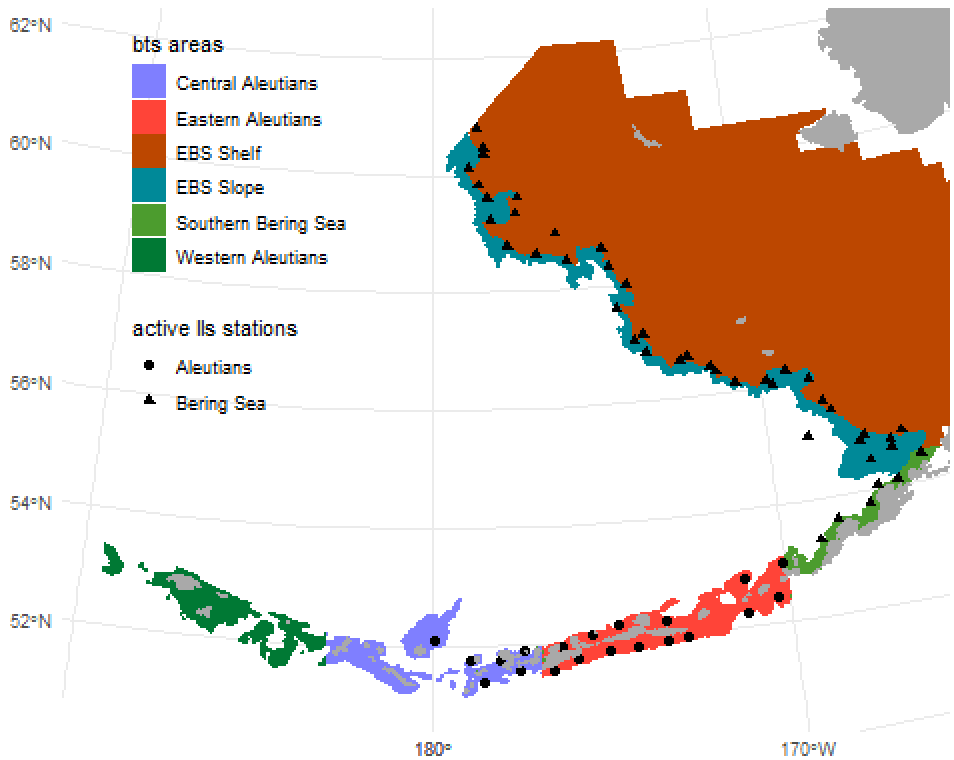

Figure 16.4. Bottom trawl surveys (BTS) strata and active longline survey (LLS) stations in the Aleutian Islands and eastern Bering Sea.

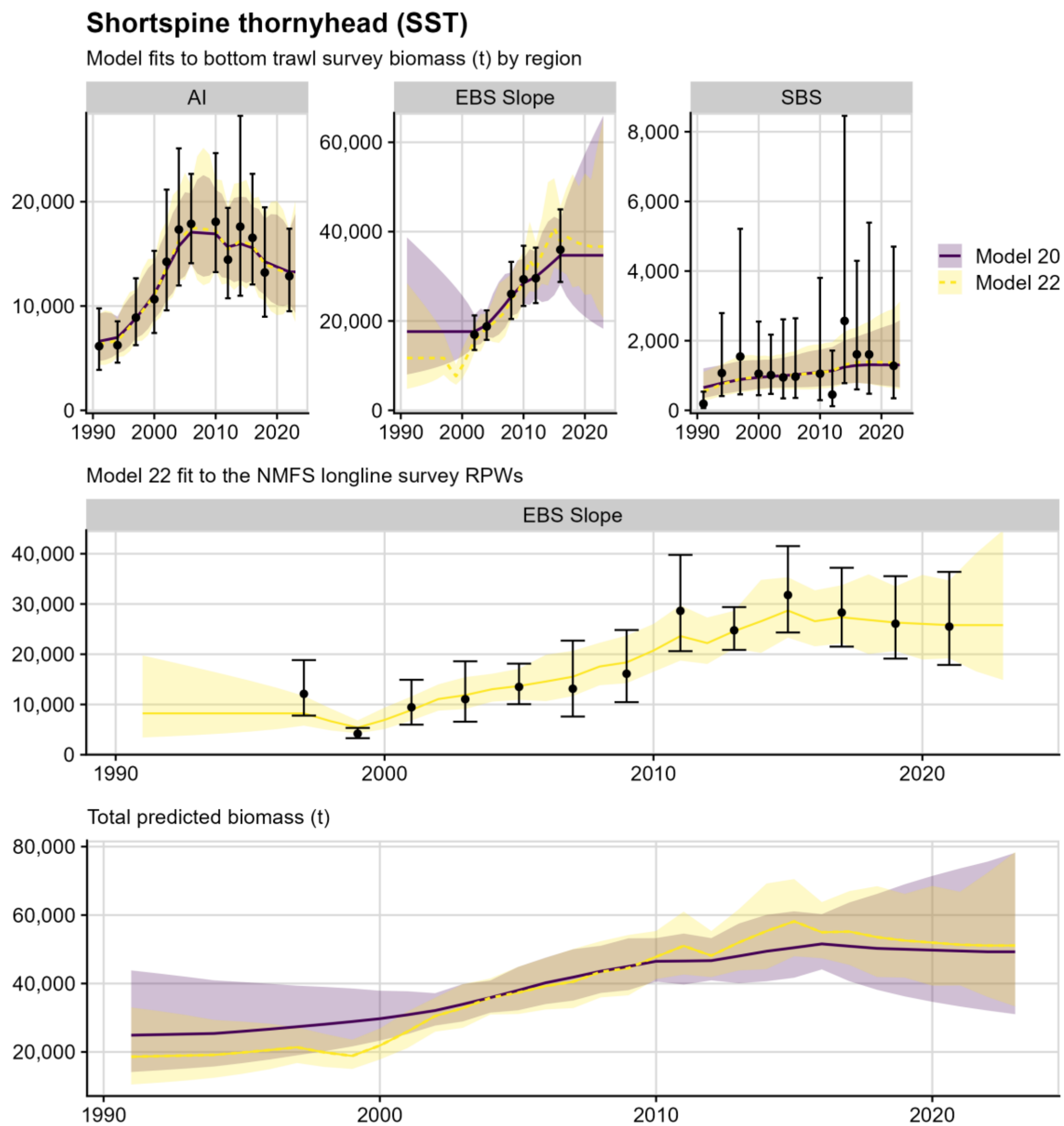

Figure 16.5. Model fits to the Aleutian Islands (AI) and eastern Bering Sea (EBS) bottom trawl surveys (BTS) by region (top), fits to the EBS slope longline survey relative population weights (RPWs; middle), and total predicted biomass for shortspine thornyhead (SST; bottom). The Southern Bering Sea (SBS) is an area defined by the International North Pacific Fisheries Commission (INPFC) northeast of Samalga Pass and is sampled in the AI BTS. Results are shown for Model 20 (purple), the multivariate random effects (REM) model, and the Model 22 (yellow), which also fits to the EBS slope RPWs. Model 22 is the author-recommended model.

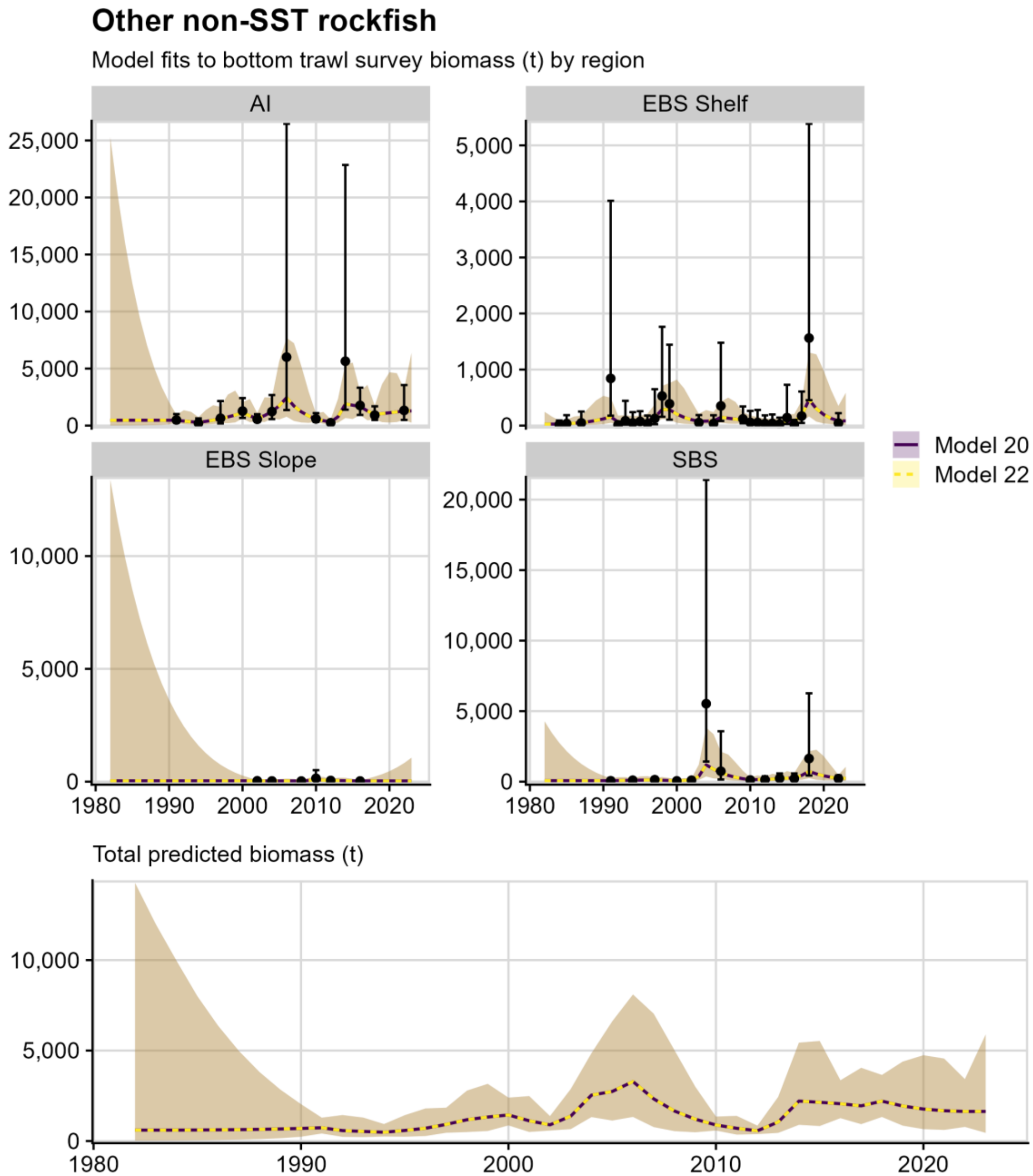

Figure 16.6. Model fits to the Aleutian Islands (AI) and eastern Bering Sea (EBS) bottom trawl surveys (BTS) by region (top), and total predicted biomass for all non-shortspine thornyhead (i.e., non-SST) species (bottom). The Southern Bering Sea (SBS) is an area defined by the International North Pacific Fisheries Commission (INPFC) northeast of Samalga Pass and is sampled in the AI BTS. Results are shown for Model 20 (purple), the multivariate random effects (REM) model, and Model 22 (yellow), which also fits to the EBS slope relative population weights for SST. Because there is no longline survey abundance data for non-SST species, Models 20 and 22 are identical.

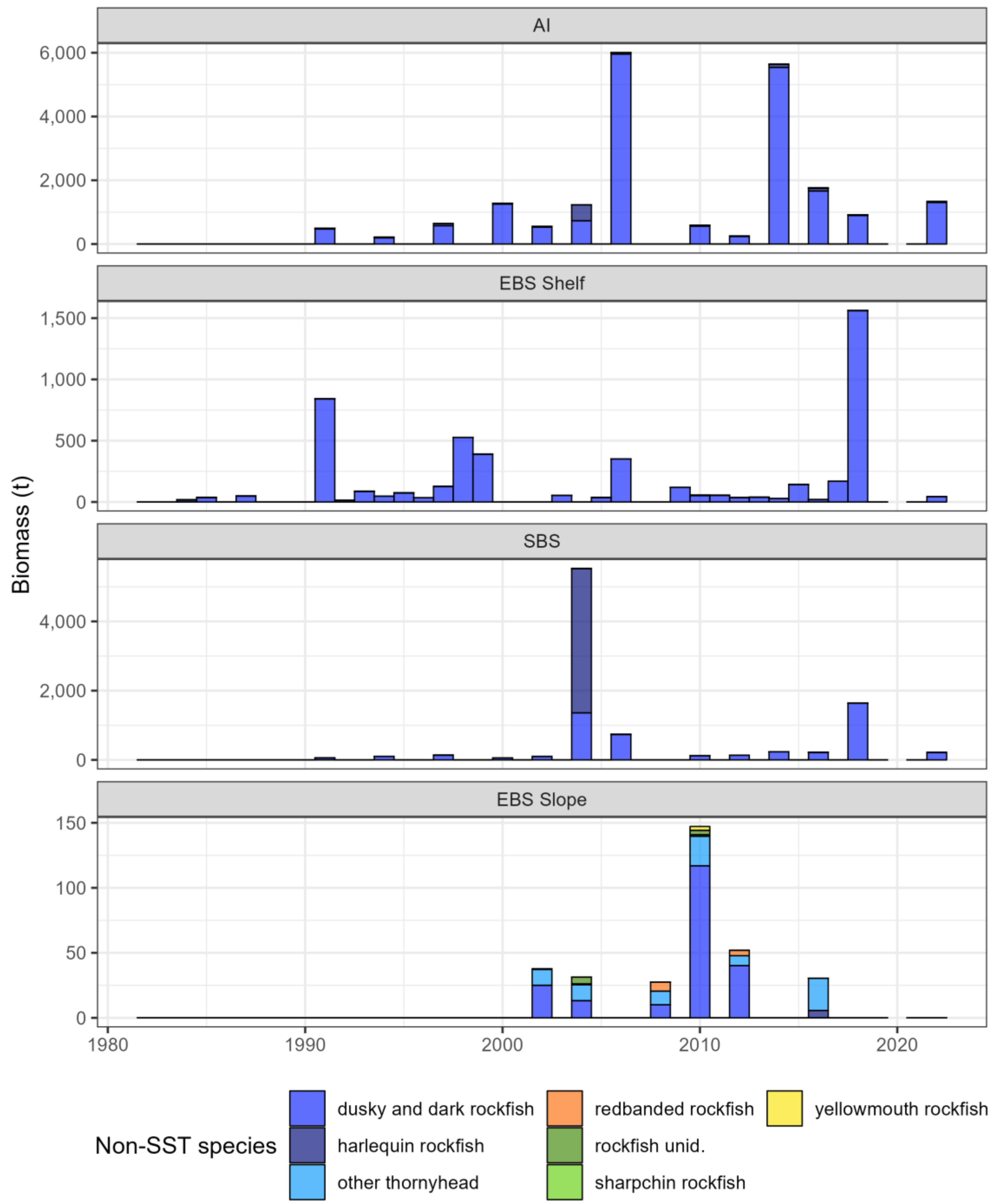

Figure 16.7. Survey biomass of non-SST (all Other Rockfish except shortspine thornyhead, SST) in the Aleutian Islands (AI), Southern Bering Sea (SBS), eastern Bering Sea (EBS) shelf, and EBS slope regions. The SBS is defined by the International North Pacific Fisheries Commission (INPFC) and is sampled during the Aleutian Islands (AI) survey. Note the difference in *y*-axis scales.

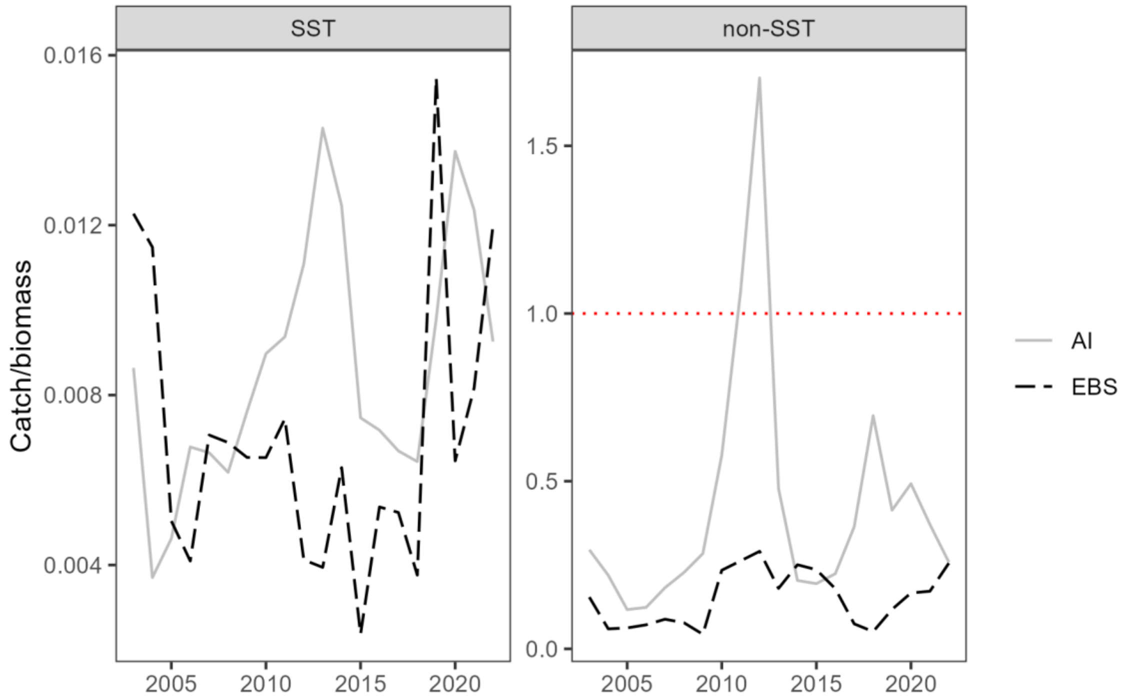

Figure 16.8. Exploitation rates (catch/biomass ratio) for the shortspine thornyhead (SST) and non-SST components of the Other Rockfish complex in the Aleutian Islands (AI) and the eastern Bering Sea (EBS). The red dotted line highlights the point beyond which catch exceeds estimated biomass. Catch data for 2003-2022 is from the NMFS AKRO Catch Accounting System, AKFIN database, accessed October 3, 2022. Note the difference in *y*-axis scales.

Table A1.1. Removals (t) 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 21, 2022. Data for the current year are not yet available.

	Agency			
Year	ADFG	IPHC	NMFS	Total
2004			1.47	1.47
2005			1.36	1.36
2006			1.68	1.68
2007			1.78	1.78
2008			1.49	1.49
2009			1.99	1.99
2010	0.01	0.73	12.81	13.54
2011	0.00	0.31	23.07	23.38
2012	0.01	0.33	9.88	10.22
2013	0.10	0.79	2.98	3.87
2014	0.02	0.84	4.83	5.69
2015	0.18	0.86	2.85	3.89
2016	0.08	0.27	12.05	12.40
2017	0.11	2.46	3.00	5.57
2018	0.39	0.39	4.26	5.04
2019	0.58	1.20	2.19	3.96
2020	0.36	0.38	1.42	2.16
2021	0.01	0.20	1.49	1.70
Average	0.15	0.73	5.03	5.62