15. Assessment of the Thornyhead stock complex in the Gulf of Alaska

Katy B. Echave, Kevin A. Siwicke, Jane Sullivan, Bridget Ferris, and Peter-John F. Hulson

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Executive Summary

The Gulf of Alaska (GOA) thornyhead complex remain on a biennial stock assessment schedule with a full stock assessment produced in even years and no stock assessment produced in odd years. Previously, rockfish assessments occurred on a biennial stock assessment schedule to coincide with the availability of new trawl survey data (odd years). For this on-cycle year, we incorporate new survey biomass from the 2021 bottom trawl survey, new Relative Population Weights (RPWs) from the 2021 and 2022 longline surveys, and update auxiliary data sources.

The thornyhead complex is classified as a Tier 5 stock. We continue to use a Random Effects Multi-area model with an Additional survey (REMA) model fit to survey data to estimate exploitable biomass and determine the recommended Acceptable Biological Catch (ABC; Hulson et al. 2021, Monnahan et al. 2021, and Sullivan et al. 2022a). The REMA model was fit to the time series of the Alaska Fisheries Science Center (AFSC) bottom trawl survey estimated shortspine thornyhead (*Sebastolobus alascanus*) biomass including uncertainty by region and depth strata and the AFSC longline survey estimated shortspine thornyhead RPW including uncertainty by region. These regional biomass estimates from the REMA model were summed to obtain Gulfwide biomass. Two models are presented, where Model 18* is an error-corrected version of the 2018 accepted model (Model 18.1), and Model 22 is a new model which estimates an additional observation error term for each survey (Sullivan et al. 2022a).

Summary of Changes in Assessment Inputs

Changes in the Input Data

1. Total catch was updated with partial 2022 data through 6 October 2022.
2. Length compositions from the 2020 and 2021 longline and trawl fisheries were added.
3. Length compositions from the 2021 GOA bottom trawl survey data were added.
4. Length compositions from the 2021 and 2022 AFSC annual longline surveys were added.
5. RPWs from 1992 to 2022 GOA longline survey were updated for use in the REMA model. Note that slight changes to RPWs in the eastern GOA resulted from updating all area sizes for extrapolating RPWs using Echave et al. (2013).
6. Biomass estimated from the 1984 and 1987 GOA trawl surveys were removed from input to the REMA model, and values from 1990 to 2021 were updated.

Changes in Assessment Methodology

The methodology used to estimate exploitable biomass to calculate ABC and OFL (Over Fishing Limit) values for the 2023 fishery has changed. This year, a coding error in the REMA model was corrected, and a new model with an additional observation error term estimated for both the AFSC longline survey and bottom trawl survey is recommended (Sullivan et al. 2022a).

Summary of Results

For the 2023 fishery, we recommend the maximum allowable ABC of 1,628 t for thornyhead rockfish. This ABC is a decrease of 16.6% from the 2022 ABC of 1,953 t. Approximately two-thirds of this decrease can be attributed to changes in the model structure with the remainder due to updates in abundance indices provided by the trawl and longline surveys. The OFL is 2,170 t. Reference values for thornyhead rockfish are summarized in the following table, with the recommended ABC and OFL values in bold. The stock was not being subjected to overfishing last year.

Quantity	As estimated or specified last year for:		As estimated or recommended this year for:	
	2022	2023	2023	2024
M (natural mortality rate)	0.03	0.03	0.03	0.03
Tier	5	5	5	5
Biomass (t)	86,802	86,802	72,349	72,349
F_{OFL}	$F=M=0.03$	$F=M=0.03$	$F=M=0.03$	$F=M=0.03$
maxF_{ABC}	$0.75M=0.0225$	$0.75M=0.0225$	$0.75M=0.0225$	$0.75M=0.0225$
F_{ABC}	0.0225	0.0225	0.0225	0.0225
OFL (t)	2,604	2,604	**2,170**	2,170
maxABC (t)	1,953	1,953	1,628	1,628
ABC (t)	1,953	1,953	**1,628**	1,628
Status	As determined *last* year for:		As determined *this* year for:	
	2020	2021	2021	2022
Overfishing	No	n/a	No	n/a

Updated catch data (t) for thornyhead rockfish in the GOA as of October 6, 2022 (NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database, http://www.akfin.org) are summarized in the following table.

Year	Western	Central	Eastern	Gulfwide Total	Gulfwide ABC	Gulfwide TAC
2021	42	101	130	273	1,953	1,953
2022	107	167	71	345	1,953	1,953

Area Apportionment

For apportionment of ABC/OFL, the REMA model was fit to area-specific biomass and RPWs, and subsequent proportions of biomass by area were calculated. The following table shows the recommended apportionment, estimated biomass, and ABC value by regulatory area for 2023.

	Regulatory area			
	Western	Central	Eastern	Total
Area Apportionment	19%	43%	38%	100%
Estimated Area Biomass (t)	13,944	30,810	27,595	72,349
Area ABC (t)	314	693	621	1,628
OFL (t)				2,170

Summaries for Plan Team

All values are in metric tons.

Stock/ Assemblage	Year	Biomass	OFL	ABC	TAC	Catch[1]
Assemblage	2021	86,802	2,604	1,953	1,953	273
	2022	86,802	2,604	1,953	1,953	345
	2023	72,349	2,170	1,628		
	2024	72,349	2,170	1,628		

Stock/		2022				2023		2024	
Assemblage	Area	OFL	ABC	TAC	Catch[1]	OFL	ABC	OFL	ABC
Thornyhead rockfish	W		352	352	107		314		314
	C		910	910	167		693		693
	E		691	691	71		621		621
	Total	2,604	1,953	1,953	345	2,170	1,628	2,170	1,628

[1]Catches updated through October 6, 2022: National Marine Fisheries Service, Alaska Region, Catch Accounting System, accessed via the Alaska Fishery Information Network (AKFIN).

Responses to SSC and Plan Team Comments on Assessments in General

"The SSC supports the JGPT's recommendation that stock assessment authors transition from the ADMB RE variants to the rema framework, which implements the same model variants in a single framework with several improvements."(SSC, Oct 2022)
The authors follow the recommendation of transitioning from the ADMB RE variants to the R package rema framework that allows for estimating additional observation error and present it as the author recommended Model 22 in this year's assessment.

Responses to SSC and Plan Team Comments Specific to this Assessment

"The Plan Team recommends the authors investigate hook competition with sablefish on the longline survey and, if appropriate, develop a corrections factor either by using existing data or conducting a hook timer study. This work could also have implications on other assessments that use longline survey indices (e.g, rougheye/blackspotted rockfish, northern rockfish, etc.)." (Plan Team, Nov 2020)
The longline survey staff have not formally analyzed hook competition on the survey, but a decrease in the number of baits was noted in 2022 with an increase in the number of empty hooks returning. Shortspine thornyhead catch on the longline survey was up in 2022 despite large increase in sablefish catch. Hook competition in longline surveys can be difficult to ascertain and no adjustments to account for competition are currently being made to the thornyhead catch on the AFSC longline survey.

"*The SSC supports the GOA GPT recommendations to (1) investigate hook competition with sablefish on the longline survey and, if appropriate, develop a correction factor either by using existing data or conducting a hook timer study; and (2) investigate potential shifts in gear or fishing behavior in thornyhead habitat as a possible cause of the decrease in catch."* (SSC, Dec 2020)
In response to (1), see the previous response. (2) Authors report changes in gear use as a potential cause of the decrease of thornyhead catch. This can most likely be attributed to the increased use of slinky pots by the sablefish fishery, which catch very little bycatch. This is addressed in the Fishery section.

"The Plan Team also recommends the authors investigate potential shifts in the number of commercial operations in thornyhead habitat as a possible cause of the decrease in catch." (Plan Team, Nov 2020)
Authors investigated the spatial extent of commercial operations. The most evident change has been the shift of gear to target sablefish, from hook and line to pot.

"The SSC notes an unprecedented increase in biomass in the EGOA 1–100 m survey depth bin (Table 15-6 in the assessment). The SSC recommends further investigation into the length composition of these fish as well as the spatial extent of the event. The IPHC survey may be useful for comparison with the trawl survey information to determine the spatial extent of the event." (SSC, Dec 2020)
Authors followed the recommendations to further investigate the increased biomass in the EGOA 1–100 m stratum in the trawl survey. After further review, it was found that this reported value in 2019 in the 1-100 m stratum was actually based on one haul that had a gear depth of 188 m. We were informed by RACE staff that in this particular situation, Rule 2 for resolving conflicts between station location and stratum depths was followed: shelf strata shall be towed at their prescribed station locations, even if it means towing shallower or deeper than prescribed. Catch in this stratum has returned to an average level in 2021. Additionally, it is important to note that when estimating the exploitable biomass of thornyhead, all biomass in 0–500 m on the trawl survey are combined, therefore this data discrepancy has little to no impact to the estimated exploitable biomass of thornyhead.

"The authors' indicate that discards in the longline fishery are higher than expected. The SSC notes that some discard is expected in the longline fishery because rockfish will drop off the line as the gear is brought onboard. The SSC appreciates any information the author can provide related to the amount of discard expected under the newly implemented full-retention regulation." (SSC, Dec 2020)
The authors have continued to monitor discarding of thornyheads in the longline fishery, and discard rates have decreased since last reported in the 2020 assessment. AKRO staff comment that the amount still being reported are likely due to drop offs at the rail, among other factors. Authors will continue to monitor in the future.

"Finally, the SSC continues to encourage research focused on aging shortspine thornyheads to potentially allow moving to an age-structured assessment in the future." (SSC, Dec 2020)
The ageing of thornyhead continues to be on hold as there is still no reliable method of ageing these species.

"The Team recommended excluding BTS data from 1984 and 1987 due to different survey methodology and to continue utilizing a two-survey model." (Plan Team, Sept 2022)
Authors have removed the 1984 and 1987 bottom trawl survey data from the estimation of exploitable biomass, and continue utilizing a two-survey model for biomass estimation.

"The Team recommended simplifying the model naming convention where Model 18 represents the status quo model, Model 18 is the corrected model in TMB with new data, and Model 22 is the model with additional observation error on BTS and LLS."* (Plan Team, Sept 2022)
The authors present two models following the recommended naming convention.

"The Team recommended discontinuing the misspecified status quo model (Model 18) and bringing forward both the corrected model (Model 18) and the model with observation error on both the BTS and LLS (Model 22) for the November assessment."* (Plan Team, Sept 2022)
Authors have discontinued the misspecified status quo model, and present two models: 1) Model 18* is the corrected status quo model, and 2) Model 22 is the same as status quo but with additional observation error on the bottom trawl and longline surveys.

Introduction

Thornyheads (*Sebastolobus* species) are groundfish belonging to the family Scorpaenidae, which contains the rockfishes. The family Scorpaenidae is characterized morphologically within the order by venomous dorsal, anal, and pelvic spines, numerous spines in general, and internal fertilization of eggs. While thornyheads are considered rockfish, they are distinguished from the “true” rockfish in the genus *Sebaste*s primarily by reproductive biology; all *Sebastes* rockfish are live-bearing (ovoviviparous) fish, while thornyheads are oviparous, releasing fertilized eggs in floating gelatinous masses. Thornyheads are also differentiated from *Sebastes* in that they lack a swim bladder. There are three species in the genus *Sebastolobus*, including the shortspine thornyhead *Sebastolobus alascanus*, the longspine thornyhead *Sebastolobus altivelis*, and the broadfin thornyhead *Sebastolobus macrochir* (Eschmeyer et al. 1983, Love et al. 2002).

General Distribution

Thornyheads are distributed in deep water habitats throughout the north Pacific, although juveniles can be found in shallower habitats. The range of the shortspine thornyhead extends from 17 to 1,524 m in depth and along the Pacific Rim from the Seas of Okhotsk and Japan in the western north Pacific, throughout the Aleutian Islands, Bering Sea, Gulf of Alaska (GOA), and south to Baja California in the eastern north Pacific (Love et al. 2005). Shortspine thornyheads are considered most abundant from the Northern Kuril Islands to southern California. They are concentrated between 150- and 450-m depths in cooler northern waters, and are generally found in deeper habitats up to 1,000 m in the warmer waters of this range (Love et al. 2002).

The longspine thornyhead is found only in the eastern north Pacific, where it ranges from the Shumagin Islands in the GOA south to Baja California. Longspine thornyheads are generally found in deeper habitats ranging from 201 to 1,756 m (Love et al. 2005). They are most commonly found below 500 m throughout their range. Off the California coast, longspine thornyhead is a dominant species in the 500–1,000-m depth range, which is also a zone of minimal oxygen (Love et al. 2002).

The broadfin thornyhead is found almost entirely in the western north Pacific, ranging from the Seas of Okhotsk and Japan into the Aleutian Islands and eastern Bering Sea. The depth range of the broadfin thornyhead, 100–1,504 m, is similar to that of the shortspine thornyhead. The broadfin thornyhead is relatively uncommon in the eastern north Pacific, and some researchers believe that historical records of this species from the Bering Sea may have been misidentified shortspine thornyheads.

Life History Information

Shortspine thornyhead spawning takes place in the late spring and early summer, between April and July in the GOA and between December and May along the U.S. west coast. It is unknown when longspine thornyheads spawn in the Alaskan portion of their range, although they are reported to spawn between January and April on the U.S. West coast (Pearson and Gunderson 2003). Unlike rockfish in the genus *Sebastes*, which retain fertilized eggs internally and release hatched, fully developed larvae, thornyheads spawn a bi-lobed mass of fertilized eggs which floats in the water column (Love et al. 2002). Once the pelagic egg masses hatch, larval and juvenile thornyheads spend far more time in a pelagic life stage than the young-of-year rockfish in the genus *Sebastes* (Love et al. 2002). Shortspine thornyhead juveniles spend 14–15 months in a pelagic phase, and longspine thornyhead juveniles are pelagic even longer, with up to 20 months passing before they settle into benthic habitat. While shortspine thornyhead juveniles tend to settle into relatively shallow benthic habitats between 100 and 600 m and then migrate deeper as they grow, longspine thornyhead juveniles settle out into adult longspine habitat depths of 600 to 1,200 m.

Once in benthic habitats, both shortspine and longspine thornyheads associate with muddy/hard substrates, sometimes near rocks or gravel, and distribute themselves relatively evenly across this habitat, appearing to prefer minimal interactions with individuals of the same species. Research focusing on non-trawlable habitats found rockfish species often associate with biogenic structure (seafloor relief; Du Preez and Tunnicliffe 2011, Laman et al. 2015), and that thornyhead rockfish are often found in both trawlable and untrawlable habitats (Rooper and Martin 2012, Rooper *et al*. 2012). Several of these studies are notable as results indicate adult thornyhead biomass may be underestimated by traditional bottom trawl surveys because of issues with extrapolating survey catch estimates to untrawlable habitat (Jones *et al*. 2012; Rooper et al. 2012). Mean abundance of shortspine thornyheads estimated in submersible surveys were several times higher than those estimated from trawl surveys (Else et al. 2002).They have very sedentary habits and are most often observed resting on the bottom in small depressions, especially longspine thornyheads, which occupy a zone of minimal oxygen at their preferred depths (Love et al. 2002).

Like all rockfish, thornyheads are generally longer lived than most other commercially exploited groundfish. Both shortspine and longspine thornyheads are long-lived, relatively slow-growing fishes, but shortspines appear to have greater longevity. Shortspine thornyheads may live 80–100 years with the larger-growing females reaching sizes up to 80-cm fork length (Love *et al*. 2002). Longspine thornyheads are generally smaller, reaching maximum sizes less than 40 cm and maximum ages of at least 45 years (Love *et al*. 2002).

Prey and Predators

Diets of shortspine thornyheads are derived from stomach content collections taken in conjunction with GOA trawl surveys. Over 70% of adult shortspine thornyhead diet measured in the early 1990s was shrimp, including both commercial (Pandalid) shrimp and non-commercial (NP or Non-Pandalid shrimp) in equal proportions. Other important prey of shortspine thornyheads include crabs, zooplankton, amphipods, and other benthic invertebrates. Juvenile thornyheads have diets similar to adults, but in general prey more on invertebrates.

Shortspine thornyheads are consumed by a variety of piscivores, including arrowtooth flounder, sablefish, “toothed whales” (sperm whales), and sharks. Although, thornyheads are not a common prey item for these predators and make up less than 2% of their diets in the GOA. Juvenile shortspine thornyheads are thought to be consumed almost exclusively by adult thornyheads.

Stock Structure

Population structure of longspine thornyheads has not been studied in Alaska. Longspine thornyheads are not the target of a directed fishery in the GOA, but this species is the target of directed fisheries off the U.S. west coast where they are managed separately from shortspine thornyheads (e.g., Fay 2005). They have not been explicitly managed in the GOA to date.

Population genetics, phylogeography, and systematics of thornyheads were discussed by Stepien et al. (2000). Genetic variation using mtDNA was analyzed for shortspine thornyheads from seven sites off the west coast, but only included one Alaska site off Seward. Longspine thornyheads were sampled from five sites off the Washington-Oregon-California coast, and a single site off Abashiri, Japan was sampled for broadfin thornyheads. Significant population structure was found in this study that was previously undetected with allozymes (Siebenaller 1978). Gene flow was substantial among some locations and diverged significantly in other locations. Significant genetic differences among some sampling sites for shortspine and longspine thornyheads indicated barriers to gene flow. Genetic divergences among sampling sites for shortspine thornyheads indicated an isolation-by-geographic-distance pattern. In contrast, population genetic divergences of longspine thornyheads were unrelated to geographic distances and suggested larval retention in currents and gyres (Pearcy et al. 1977, Stepien et al. 2000). Differences in geographic genetic patterns between the species are attributed to movement patterns as juveniles and adults. While not a part of this complex, another *Sebastolobus* species, the broadbanded thornyhead, was part of an age and population genetic structure study in North Japan (Sakaguchi et al. 2014). While significant differences in body size (growth) was detected between certain year classes off the Pacific coast of Tohoku and off Abashiri, the Sea of Okhotsk, Japan, it appears that broadbanded thornyheads do not migrate extensively after settlement and subsist on food within the settled environment. At the same time, no genetic isolation was observed between the populations at the two sites. Sakaguchi et al. (2014) concluded that it was highly likely that its pelagic eggs, larvae and juveniles widely disperse and migrate before settlement. Recent research by the AFSC Auke Bay Genetics Laboratory screened millions of genetic markers in shortspine thornyhead sampled from southeast Alaska to the Bering Sea and Aleutian Islands as far west -180°. The whole genome resequencing approach that was used has substantially more power to detect structure than allozymes or mtDNA. No spatial structure was observed in this dataset, providing further evidence that gene flow is high in shortspine thornyhead across relatively large spatial scales. This recent genetic research indicates that shortspine thornyhead represent a single genetic stock in Alaskan waters (Wes Larson, pers. comm.).

The National Marine Fisheries Service (NMFS) Auke Bay Laboratory (ABL) has released 15,512 tagged shortspine thornyhead in Alaska waters since 1992, and 297 of those fish have been recovered by members of the fishing industry (to date). A review of this tagging data show that the majority of tagged shortspines show little to no movement: 19% traveled < 2 nautical miles (nm) between tagging and recovery location, 36% traveled 2–5 nm, 18% traveled 6–10 nm, 12% traveled 11–50 nm, 4% traveled 51–100 nm, and 11% traveled >100 nm (Echave 2017). The amount of movement varied by tagging location, as did the direction of movement. However, there was no significant difference in movement by fish size, and all fish included in the analysis were assumed mature. The majority of fish that moved generally traveled east/southeast, and fish that were tagged and released in the Eastern GOA were more inclined to move than fish from other areas. These regional differences in recapture patterns may highlight an actual propensity for movement from the Eastern GOA, or reflect geographic differences in fishing effort, particularly at depth. Shortspine thornyhead released in the Eastern GOA displayed the most movement. Of the 102 recoveries that were released in the Eastern GOA, 76% remained within the Eastern GOA, 18% were recovered in British Columbia, Canada (BC), 5% were recovered in the Central GOA, and 1% were recovered on the West Coast (WC). Overall, the majority of recovered shortspine thornyhead remained within their management area of release, and very near their actual release location. While a small percentage of tagged shortspine thornyhead traveled large distances, at times crossing management and international boundaries, the low movement rate coupled with an isolation-by-geographic-distance pattern (Siebenaller 1978), indicate that the current scale of management of using at least sub-areas in Alaska is appropriate. When defining the stock structure of shortspine thornyhead in Alaska waters, one may conclude that this species displays little movement, but that large movements are possible (Echave 2017).

Fishery

Fishery History

Shortspine thornyheads are abundant throughout the GOA and are commonly taken by bottom trawls and longline gear. In the past, this species was seldom the target of a directed fishery. Thornyheads have probably been caught in the northeastern Pacific Ocean since the late 19th century, when commercial trawling by U.S. and Canadian fishermen began. In the mid-1960s Soviet fleets arrived in the eastern GOA (Chitwood 1969), where they were soon joined by vessels from Japan and the Republic of Korea. These fleets represented the first directed exploitation of GOA rockfish resources, primarily Pacific ocean perch (*Sebastes alutus*), and likely resulted in the first substantial catches of thornyheads as well. Today, thornyheads are one of the most valuable of the rockfish species, with most of the domestic harvest exported to Japan. Despite their high value, they are still managed as a “bycatch only” fishery in the GOA because they are nearly always taken in fisheries directed at sablefish (*Anoplopma fimbria*) and other rockfish (*Sebastes* spp.). The incidental catch of shortspine thornyheads in these fisheries has been sufficient to capture a substantial portion of the thornyhead quota established in recent years, so directed fishing on shortspine thornyheads exclusively is not permitted. Although the thornyhead fishery is managed operationally as a “bycatch” fishery, the high value and desirability of shortspine thornyheads means they are still considered a “target” species for the purposes of management.

In 2007, the Central Gulf of Alaska Rockfish Pilot Program was implemented to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central GOA rockfish fishery. In 2012 this pilot program was permanently put in to place as the Central Gulf of Alaska Rockfish Program. This is a rationalization program that established cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish species. The primary rockfish management groups are northern (*Sebastes polyspinis*), Pacific ocean perch, and dusky rockfish (*Sebastes ciliates*). Thornyhead rockfish are a secondary species that has an allocation of quota share which can be caught while fishing for the primary management groups. Effects of this program on the primary rockfish stocks include: 1) extended fishing season lasting from May 1 to November 15, 2) changes in spatial distribution of fishing effort within the Central GOA, 3) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, and 4) a greater potential to harvest 100% of the TAC in the Central GOA region. Many of the effects on the primary rockfish stocks will also affect the secondary stocks. Future analyses regarding the Rockfish Program and the effects on thornyhead will be possible as more data become available.

Management Measures and History

After passage of the Fishery Conservation and Management Act (FCMA) in 1977, thornyheads were placed in the rockfish management group which contained all species of rockfish except Pacific ocean perch (Berger et al. 1986). In 1979, thornyhead rockfish were removed from the rockfish group and placed in the “other fish” group. Thornyhead rockfish became a reported species group in 1980. For the GOA, the “thornyheads” management unit is currently a species complex which includes shortspine thornyhead and longspine thornyhead. A third species, broadfin thornyhead, occurs rarely in the Aleutian Islands but does not appear to inhabit the GOA. Longspine thornyheads do occur in the GOA but are much less common than the shortspine thornyheads and are generally deeper. Consequentially, in this assessment we focus on shortspine thornyheads and monitor available information on longspine thornyheads from GOA trawl surveys and fishery sampling.

Thornyheads in the GOA have been managed as a single stock since 1980 (Ianelli and Ito 1995, Ianelli et al.1997). In practice, the NPFMC apportions the ABCs and TACs for thornyhead rockfish in the GOA into three geographic management areas: the Western, Central, and Eastern GOA. This apportionment is to disperse the catch across the Gulf and prevent possible depletion in one area. Bering Sea and Aleutian Islands (BSAI) shortspine thornyheads are managed as a separate stock from GOA thornyheads. In the BSAI FMP, all thornyhead species are managed within the “Other rockfish” species complex. A timeline of management measures that have affected thornyhead rockfish, along with the corresponding gulfwide annual catch and ABC/TAC levels are listed Table 15-1.

Catch History

The earliest available records of thornyhead catch begin in 1967, as published in French et al. (1977). Rockfish catch peaked in 1965 when foreign fleets occupied Alaska waters, with nearly 350,000 metric tons removed (Ito 1982). However, records of catch and bycatch from this fishery were insufficient for precise estimation of historical catch for thornyheads. Active data collection began as part of the U.S. Foreign Fisheries Observer Program in 1977, when the thornyhead catch in the GOA was estimated at 1,317 t. Catch estimates from 1977–1980 are based on the following reports: Wall et al. (1978, 1979, 1980, and 1981). Beginning in 1983, the observer program also estimated the catches of thornyheads in joint venture fisheries where U.S. catcher vessels delivered catch to foreign processor vessels, and beginning in 1984, thornyheads were identified as a separate entity in the U.S. domestic catch statistics. Data from 1981 to 1989 are based on reported domestic landings extracted from the Pacific Fishery Information Network (PacFIN) database and the reported foreign catch from the NMFS Observer Program. Catches for the years 1990–2002 are based on "blended" fishery observer and industry sources using an algorithm developed by the NMFS Alaska Regional Office (AKRO). Catches for 2003–2022 were provided by NMFS Regional Office Catch Accounting System (CAS), and accessed through the Alaska Fishery Information Network (AKFIN) database.

Catch trends for GOA thornyheads appear to result mainly from management actions rather than from thornyhead stock fluctuations. Thornyhead catches averaged 1,090 tons between 1977 and 1983 in the GOA (Table 15-1). The greatest foreign-reported harvest activities for thornyheads in the GOA occurred during the period 1979–83. The catches of thornyheads in the GOA declined markedly in 1984 and 1985, primarily due to restrictions on foreign fisheries imposed by U.S. management policies. In 1985, the U.S. domestic catch surpassed the foreign catch for the first time. U.S. catches of thornyheads continued to increase, reaching a peak in 1989 with a total removal of 2,616 t. Catches averaged about 980 t between 2003 and 2018, when annual catch began to decrease (Table 15-1). Current catch of thornyhead rockfish in the GOA is the second lowest since 1985 (Table 15-1).Thornyhead catch over time indicates most is retained (average retention rate of 83% since 2005) and since the late 1980s the distribution of catch has been a relatively even split between trawl and longline gear (Table 15-2). However, in recent years the majority of thornyhead catch has shifted to trawl gear (Table 15-2), primarily within the rockfish fisheries (Table 15-3). These observed shifts of catch to trawl gear, as well as decreasing catch of thornyhead as a whole, can most likely be attributed to the legalization of pot fishing in the GOA and the increased use of slinky pots in the sablefish fishery (Goethel et al. 2022). In 2022, pot gear became the primary gear used in the GOA sablefish fishery (156 vessels), as opposed to traditional hook and line (133 vessels; M. Furreness pers. comm., AKRO staff). Experimental studies comparing catch between hook and line and slinky pots on the AFSC longline survey in 2021 found that slinky pots caught a lower proportion of non-sablefish species. Across all sets, 95–98% of all fish caught in pots were sablefish, whereas 79–87% of fish caught on hook-and-line sets were sablefish. The biggest species composition discrepancies between the two gear types were for giant grenadier and shortspine thornyhead: shortspine thornyhead made up 3–7% of the hook-and-line catches and 0–0.2% of pot catches (Sullivan et al. 2022b).

Historically, except for the years 1992 to 1994, thornyhead total catch has been less than the ABC and Total Allowable Catch (TAC, Table 15-1). The high (relative to the TAC) thornyhead catches in 1992 to 1994 were attributed to high discards in the sablefish longline fishery during the years preceding the implementation of IFQs for sablefish in 1995. From 1980 to 1990, the ABCs and TACs were set at the estimate of maximum sustainable yield for thornyheads which was determined to be 3.8% of the 1987 estimated GOA biomass. The drop in ABC/TAC in 1991 was in response to a large decrease in estimated biomass from the GOA trawl survey. The age-structured assessment model was suspended in 2003 due to uncertainty in the reliability of age and growth information. Consequently, a (more conservative) Tier 5 biomass-based approach for ABC and OFL specifications was adopted.

Catches by management area for 2005–2022 are given in Table 15-1. Over this period, about 50% of the total thornyhead catch comes from the Central GOA, 25% from the Western GOA, and 25% from the Eastern GOA. Catch in the Eastern GOA had been increasing in recent years (44% and 48% of total GOA catch was from the Eastern GOA in 2020 and 2021, respectively), but has decreased to 20% of total catch in 2022. The spatial distribution of thornyhead catches ranges broadly throughout the GOA and is consistent over recent years (Figure 15-1).

Survey catches of all thornyhead species are a very small component of overall removals, and recreational and other catches are assumed negligible. Estimates of non-commercial catches (research and sport) are given in Appendix 15A.

Discards

For this assessment, thornyhead retained and discarded catch by gear type (Table 15-2) has been derived from a variety sources that are described above in the fishery data section. Thornyhead discards before 1990 are unknown. We assumed that the reported catches before 1990 included both retained and discarded catch. While discard rates had been increasing in recent years (~21% average discard rate since 2010, see discussion in the 2018 Thornyhead SAFE), a reverse of this trend has been seen since 2020 (7% discard rate in 2022, Table 15-4). In addition, while discard rates had become very disproportionate between gear types (in recent years, the sablefish fishery had accounted for nearly 90% of thornyhead discards, Table 15-4), regulatory changes in March 2020 requiring full retention of rockfish by catcher vessels using fixed gear while fishing for groundfish or halibut (Amendment 107 to the Fishery Management Plan for Groundfish of the Gulf of Alaska https://www.fisheries.noaa.gov/action/amendment-119-fmp-groundfish-bering-sea-and-aleutian-islands-and-amendment-107-fmp) has resulted in more spread among the various fisheries (Table 15-4).

Fishery Data

Catch

Detailed catch information for thornyhead rockfish is listed in Table 15-1.

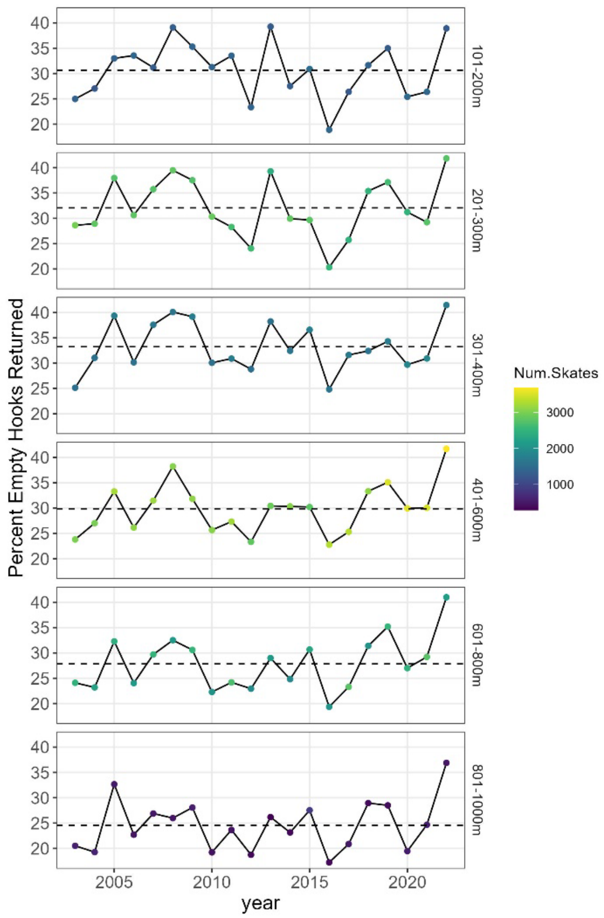
Length and Age Composition

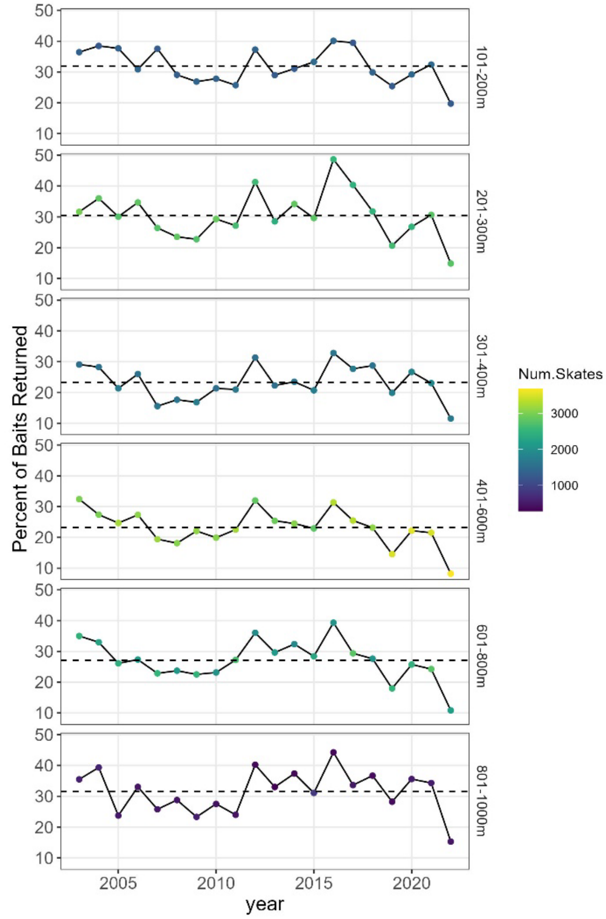
Length composition data from the trawl and longline fisheries (1990–2022) indicate longline fisheries capture larger shortspine thornyheads than trawl fisheries (average length of 40.2 cm versus 29.0 cm), perhaps because they operate in deeper waters and hook selectivity tends to select for larger fish (Figure 15-2). Few age samples for this species have been collected from the fishery, and none have been aged.

Survey Data

Longline Surveys in the Gulf of Alaska

The Alaska Fisheries Science Center (AFSC) longline survey has been conducted annually since 1988. This survey samples the continental slope in the GOA, providing data to calculate relative abundance in this area (Rutecki et al. 2016, Siwicke et al. 2022). The survey is primarily directed at sablefish, but also catches considerable numbers of thornyhead rockfish. For this species, hook competition with other species such as sablefish could affect the relative index. For example, Sigler and Zenger (1994) found that thornyhead catch increased in areas where sablefish abundance decreased. They suggested that the increase in thornyhead catch rates between 1988 and 1989 (their data) might be partly due to the decline in sablefish abundance. They reasoned that availability of baited hooks to thornyheads may have increased. In recent years, sablefish abundance has increased (Goethel et al. 2022), while thornyhead catch has decreased. However, in 2022, thornyhead catch increased above 2020 and 2021 RPWs, while sablefish also increased. In addition, there was a decrease in the proportion of hooks with bait returning on the survey in 2022, though this was accompanied by an increase in the proportion of empty hooks returning. The figures below show the time series of the percentage of empty hooks (left panel) and baited hooks (right panel) by depth stratum on the longline survey. This will continue to be monitored by authors.





Relative population numbers (RPNs) are converted to relative population weights (RPWs) for the AFSC longline survey, and are available for shortspine thornyhead beginning in 1992 (Table 15-5; Sigler 2000). Note that there were slight changes to the RPWs in the eastern GOA from previous assessments from updating all area sizes for extrapolating RPWs using Echave et al. (2013). The gulfwide RPW of thornyhead increased in 2022 (43,469), reversing the downward trend observed since 2020 (Table 15-5). Both the Western (7,885 in 2021 to 6,740 in 2022) and Central GOA (16,328 in 2021 to 16,028 in 2022) saw RPW decreases in 2022, while the Eastern GOA increased by 87% (Table 15-5). Historically, there has been a considerable amount of fluctuation for thornyhead RPWs between adjacent years (Table 15-5). Some of the fluctuations may be related to changes in the abundance of sablefish, as discussed above, regarding competition for hooks among species.

Length composition data from the 1992–2022 longline surveys are shown in Figure 15-3. Years of data are included to match what is available for the RPW calculations. While the longline survey length data have displayed a mean from 36.2 to 40.4 cm and overall length compositions are relatively stable across all years, the mean has been at the larger end of that range since 2020. This could be indicative of fewer small fish entering the population.

AFSC Trawl Surveys

Bottom trawl surveys were conducted on a triennial basis in the GOA from 1984 through 1999, and these surveys became biennial starting in 2001. This survey employs standard NMFS Poly-Nor'eastern bottom trawl gear and provided biomass estimates using an "area-swept" methodology described in Wakabayashi et al. (1985). The trawl surveys have covered all areas of the GOA out to a depth of 500 m (in some surveys to 1,000 m), but the 2001 survey did not sample the Eastern GOA. Also, in 1984 a different, non-standard survey design was used in the Eastern GOA; furthermore, much of the survey effort in the Western and Central GOA in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. For these reasons, we follow the NPFMC Groundfish Plan Team and SSC recommendations (September, October 2022) to exclude the bottom trawl survey data from 1984 and 1987. This data will no longer be reported in the SAFE report and will not be used in the estimation of thornyhead exploitable biomass.

The bottom trawl surveys provide much information on thornyhead rockfish, including estimates of absolute abundance (biomass, Table 15-6) and annual population length composition, however, in assessing the relative abundance of GOA thornyheads, it is important to consider the extent to which an individual survey covers the full depth and geographic range of the species. The 1990, 1993, 1996 and 2001 surveys did not survey the depths >500 m, and the 2003, 2011, 2013, 2017, 2019, and 2021 surveys did not survey depths >700 m. It is evident from trawl survey results that a significant portion of the biomass of shortspine thornyheads exists at depths greater than 500 m (Table 15-6), and that all of the biomass of longspine thornyheads exists at depths greater than 500 m and mostly in the Eastern GOA. In addition, the 2001 survey did not sample the Eastern GOA, and a comparison of survey biomass estimates by management area shows that shortspine thornyheads are most abundant in the Eastern and Central GOA. In 1999, 2005, 2007, 2009, and 2015, the surveys had the most extensive survey coverage of the primary thornyhead habitat (all depths sampled to 1,000 m).

Gulfwide biomass estimates for thornyhead rockfish have sometimes shown rather large fluctuations between surveys (Table 15-6). The 2021 GOA biomass estimate decreased by 13% from the 2019 estimate, putting it slightly below the long-term mean. Trawl survey estimates were down in 2021 in all areas (Table 15-6).

Spatial distributions of catches of shortspine and longspine thornyhead in the last three GOA trawl surveys indicate these species are rather evenly spread along an offshore band along the continental slope (Figure 15-4). While shortspine thornyhead are predominately found at depths of 300 to 500 m, the 2019 survey saw a large increase in biomass in the 1–100 m depth stratum (Table 15-6). Historically, the amount of shortspine thornyhead in the Eastern GOA 1–100 m depth stratum has ranged between 0 and 111 t, while the estimated biomass in 2019 was 2,197 t. After further review, it was found that this reported value in 2019 in the 1-100 m stratum was actually based on one haul that had a gear depth of 188 m. We were informed by RACE staff that in this particular situation, Rule 2 for resolving conflicts between station location and stratum depths was followed: shelf strata shall be towed at their prescribed station locations, even if it means towing shallower or deeper than prescribed. Catch in this stratum has returned to an average level in 2021 (Table 15-6). Additionally, it is important to note that when estimating the exploitable biomass of thornyhead, all biomass in 0–500 m on the trawl survey are combined, therefore this data discrepancy has little to no impact to the estimated exploitable biomass of thornyhead.

Compared with many other rockfish species, the biomass estimates for thornyhead rockfish have historically been relatively precise with low CVs (compare CVs for thornyhead in Table 15-6 versus those for sharpchin, redstripe, harelequin, and silvergray rockfish in the "Other Rockfish" chapter of this SAFE report). The low CVs are consistent with this species being relatively evenly distributed on the sea floor. Despite the relatively precise biomass estimates, other factors could impact their reliability. Their main habitat is the upper continental slope at depths of 300–700 m. A considerable portion of this area is untrawlable by the survey's gear because of the area's steep and rocky bottom.

Length compositions for thornyhead rockfish from the 1990–2021 trawl surveys were generally consistent with means between 23.2 and 27.0 cm (Figure 15-5). For all survey years combined, shortspine thornyhead mean length was larger on the longline survey (mean length of 37.4 cm) than the bottom trawl survey (mean length of 26.0; Figure 15-6), suggesting that the two surveys may capture different parts of thornyhead population. This discrepancy mirrors that of the fishery, where longline gear caught fish with a mean length of 40.2 while trawl gear captured fish with a mean length of 29.0 (Figure 15-2). This became more evident in 2019 with the increased catch of smaller thornyhead. While historically we have been unable to estimate recruitment for any of the thornyhead stocks, the 2019 trawl survey composition data shows a small bump at 14–16 cm, which may possibly be an indication of a larger year class entering the population (Figure 15-5).

Analytic Approach

General Model Structure

Due to difficulties in ageing thornyheads and issues raised with previous age-based methods using length composition data, this stock complex has reverted to using a biomass-based approach. Both trawl and longline survey data affect the trends used to estimate the ABCs. The application of the REMA model smooths trends in survey estimates. The process errors (step changes) from one year to the next are the random effects that are integrated over, and the process error variance terms are freely estimated. The observations can be irregularly spaced, so for years where data are missing estimates can be made. Specified survey observation error terms (provided each year) effectively weights the survey estimates and can affect the predictions.

In 2018, Model 18.1 was selected which is a multivariate version of the random effects model that was fit to an additional relative abundance index, the AFSC longline survey RPWs (Hulson et al. 2021). In 2022, the R package *rema* was developed that is version-controlled online and includes a set of utility functions for visualizing results and conducting model comparisons. The *rema* package provides a flexible and extensible framework for users to fit RE, REM, and REMA models, and the models have been recoded using Template Model Builder (TMB; Kristensen et al. 2016). The *rema* package also introduces a method to estimate additional observation error, which is further explored for the thornyhead complex in this year's author recommended model.

The Tier 5 estimate of the OFL is simply *M* multiplied by the estimated exploitable biomass and under the FMP the maximum permissible ABC is 75% of OFL. Here we assume 0.03 as a value for M (see the Parameters Estimates section for how this estimate was derived). For all models considered, input data starts in 1990.

Modeling Selection

Several models were presented to the GOA Plan Team in September of 2022 (PT presentation), and following their recommendation, only two models are included here. The following table provides the model case name and description of the changes made to the model.

Model case	Description
18*	Model 18.1 accepted in 2018 with coding error corrected, run using the *rema* package
22	Model 18* with additional observation error estimated for each survey (bottom trawl and longline), run using *rema* package

A brief description of each model case is provided below.

18 – Corrected Model 18.1*

A coding error was found in Model 18.1, the status quo model which was accepted in 2018 and used in 2020, and that version has now been discontinued. Model 18* is Model 18.1 (described in Echave and Hulson 2018) with that error corrected and run using the newly developed *rema* package (Sullivan et al. 2022a).

Model 18* is a REMA model that can be represented as a state-space random walk model with added noise. Two surveys are combined in this model, with the AFSC bottom trawl survey providing biomass estimates and uncertainty, and the AFSC longline survey providing RPW estimates and uncertainty. The RPWs contribute trend information to the model, while the trawl biomass contributes both scale and trend information to the model. Each survey contributes an observation error component to the likelihood. The RPWs are scaled to the biomass estimated by a single estimated scaling coefficient (q), and three regional process error components which are shared across surveys ($\sigma_{PE,W}$ for the WGOA, $\sigma_{PE,C}$ for the CGOA, and $\sigma_{PE,E}$ for the EGOA) are estimated. To accommodate trawl surveys that did not always survey all depths in all years, biomass survey estimates are further divided into three depth strata for each region (0–500 m, 501–700 m, and 701–1000 m). This model has three likelihood components: 1) the bottom trawl survey biomass estimate observation error component 2) the longline survey RPW index observation error component, and 3) the shared process error component (which represents the amount of variation across time of the random effect parameters). Process error is shared across depths within each region, but no correlation is assumed across regions.

The first observation model is comprised of an index of log-transformed annual bottom trawl survey biomass data $ln(B_{y,r,d})$ with associated standard deviations $\sigma_{ln\,(B_{y,r,d})}$, where r is region (WGOA, CGOA, or EGOA) and d is depth strata (0–500 m, 501–700 m, and 701–1000 m), and $\sigma_{ln\,(B_{y,r,d})}$ is approximated using the coefficient of variation of the annual survey biomass by region and depth strata ($\sigma_{B_{y,r,d}}/B_{y,r,d}$), such that:

$$\sigma_{ln(B_{y,r,d})} = \sqrt{ln\left(\left(\frac{\sigma_{B_{y,r,d}}}{B_{y,r,d}}\right)^2 + 1\right)}.$$

The biomass survey measurement or observation equation, which describes the relationship between the observed survey biomass $ln(B_{y,r,d})$ and the latent state variable, estimated population biomass $ln(\hat{B}_{y,r,d})$, is expressed as:

$$ln(B_{y,r,d}) = ln(\hat{B}_{y,r,d}) + \epsilon_{y,r,d}, \text{ where } \epsilon_{y,r,d} \sim N(0, \sigma^2_{ln(B_{y,r,d})}).$$

The state equation and associated process error variance $\sigma^2_{PE,r}$ is defined as:

$$ln(\hat{B}_{y,r}) = ln(\hat{B}_{y-1,r}) + \eta_{y-1,r}, \text{ where } \eta_{y,r} \sim N(0, \sigma^2_{PE,r}), \text{ and}$$

$$\hat{B}_{y,r} = \sum_D e^{ln\left(\hat{B}_{y,r,d}\right)}.$$

The second observation model using the annual/regional longline survey RPW index ($I_{y,r}$) is similarly structured with associated standard deviations $\sigma_{ln(I_{y,r})}$ approximated using the coefficient of variation of the annual survey RPW ($\sigma_{I_{y,r}}/I_{y,r}$), such that:

$$\sigma_{ln(I_{y,r})} = \sqrt{ln\left(\left(\frac{\sigma_{I_{y,r}}}{I_{y,r}}\right)^2 + 1\right)}$$

The longline survey measurement or observation equation is similarly expressed as:

$$ln(I_{y,r}) = ln(\hat{I}_{y,r}) + \omega_{y,r}, \text{ where } \omega_{y,r} \sim N(0, \sigma^2_{ln(I_{y,r})}),$$

where the estimated index ($\hat{I}_{y,r}$) is scaled to the estimated population biomass using an estimated scaling coefficient (q) such that:

$$\hat{I}_{y,r} = e^{ln(\hat{I}_{y,r})} = q\hat{B}_{y,r}$$

The state equation for the longline survey shares a regional process error variance $\sigma^2_{PE,r}$ with the trawl survey:

$$ln(\hat{I}_{y,r}) = ln(\hat{I}_{y-1,r}) + \eta_{y-1,r}, \text{ where } \eta_{y,r} \sim N(0, \sigma^2_{PE,r})$$

The parameters estimated are q, $\sigma_{PE,W}$, $\sigma_{PE,C}$, and $\sigma_{PE,E}$, in addition to the unobserved population biomass $ln(\hat{B}_y)$ estimated as a vector of random effects.

22 – Additional observation error terms

Model 22 is setup the same as Model 18*, but with additional observation error estimated. Based on experience gained using alternative observed index estimates (e.g. relative CPUE indices), there appears to be cases where the estimates of observation error variances for the biomass and/or CPUE survey are too low. That is, there is a mismatch between biologically reasonable inter-annual variability and the precision of index estimates. In these instances, the model estimates of the sum of observation errors from the bottom trawl and longline surveys divided by the estimated process error, ($\sigma^2_{B_{y,r}} + \sigma^2_{I_{y,r}}$) / $\sigma^2_{PE,r}$, may be lower than what should be expected based on an individual species' life history traits. For example, if the ratio of observation to process error variation is low, model predictions of population biomass may exhibit high inter-annual variability. This behavior would be unexpected in low productivity species, such as thornyheads, which should exhibit low inter-annual variation in biomass (i.e. low process error variance), especially in situations when fishing exploitation is low.

One approach to address this issue is to estimate additional observation error. This method is commonly implemented in Alaskan crab stock assessments and has been explored in several groundfish assessment models as well. For the biomass survey variance, the extra estimated observation error ($\sigma_{\tau,B}$) is specified as an additional coefficient of variation component:

$$\sigma_{ln(B_{y,r},d)} = \sqrt{ln\left(\left(\frac{\sigma_{B_{y,r,d}}}{B_{y,r,d}}\right)^2 + \sigma_{\tau,B}^2 + 1\right)}.$$

For the longline survey, the extra estimated observation error ($\sigma_{\tau,I}$) is specified as an additional coefficient of variation component:

$$\sigma_{ln(I_{y,r})} = \sqrt{ln\left(\left(\frac{\sigma_{B_{y,r}}}{B_{y,r}}\right)^2 + \sigma_{\tau,I}^2 + 1\right)}.$$

The parameters estimated are q, $\sigma_{PE,W}$, $\sigma_{PE,C}$, $\sigma_{PE,E}$, $\sigma_{\tau,B}$, and $\sigma_{\tau,I}$, in addition to the unobserved population biomass $ln(\hat{B}_y)$ estimated as a vector of random effects.

Parameter Estimates

Age and Growth, Maximum Age, and Natural Mortality (M)

Despite a general knowledge of the life history of thornyheads throughout their range, precise information on age, growth, and natural mortality *(M)* remains elusive for shortspine thornyheads in Alaska and is unknown for longspine thornyheads. Miller (1985) estimated shortspine thornyhead natural mortality by the Ricker (1975) procedure to be 0.07. The oldest shortspine thornyhead found was 62 years old in that study. On the U.S. continental west coast, at least one large individual was estimated to have a maximum age of about 150 years (Jacobson 1990). Another study of west coast shortspine thornyheads found a 115 year-old individual using conventional ageing methods (Kline 1996). Kline (1996) also used radiochemical aging techniques to estimate a maximum age of about 100 years. These maximum ages would suggest natural mortality rates ranging from 0.027 to 0.036 if we apply the relationship developed by Hoenig (1983). Recent radiometric analyses suggest that the maximum age is between 50 and 100 years (Kastelle et al. 2000, Cailliet et al. 2001), but these have high-variance estimates due to sample pooling and other methodological issues. An analysis of reproductive information for Alaska and west coast populations also indicates that shortspine thornyheads are very long-lived (Pearson and Gunderson 2003). The longevity estimate was based on an empirically derived relationship between gonadosomatic index (GSI) and natural mortality (Gunderson 1997) and suggested much lower natural mortality rates (0.013–0.015) and therefore much higher maximum ages (250–313 years) than had ever been previously reported using any direct ageing method.

Results of an age study completed in August 2009 were limited as shortspine thornyheads are extremely difficult to age (Black 2009). Out of the 428 otoliths included in this study, an age was obtained for just over half of the samples. Approximately a quarter of the total number of otoliths (109 out of 428) were of a high enough clarity for ages to be considered reliable. Ageing confidence was found to decrease with fish age, compounding the difficulty in establishing a reasonable range of maximum ages. Maximum ages in this study were approximately 85 years, with the possibility of 100 years. These maximum ages are in agreement with other studies, including those that employed radiometric validation. All the samples for this study were from specimens >20 cm selected to obtain older aged individuals. The AFSC Age and Growth Lab will continue aging work on smaller specimens, which can be surface read, to compliment the older ages so that a more complete length-at-age data set can be compiled. It is hoped that a full range of ages could provide improved age and growth information specific to the GOA.

Although shortspine thornyheads are extremely difficult to age, studies seem to indicate that Miller's (1985) estimate of maximum age of 62 is low, and an estimate of *M* of 0.07 based on this would be high.

Conversely, the maximum ages implied by Pearson and Gunderson (2003, 250–313 years) may be high and infer natural mortality rates that may be inappropriately low. The maximum ages from Kline (1996) and Jacobson (1990) are 115 and 150 years, respectively. The average natural mortality rate from these studies is 0.030. Preliminary results from Black's (2009) work are in line with this estimate of *M*. Assuming *M*=0.03 implies a longevity in the range of 125 years, which is bracketed by estimates derived from Jacobson (1990) and Kline (1996). Until we gather more information on shortspine thornyhead productivity, age, and growth in the GOA, we will continue to assume *M*=0.03 is a reasonable and best available estimate of *M*.

A summary of the estimates of mortality and maximum age for thornyhead rockfish are listed as follows:

Mortality rate	Maximum Age	Ageing Method	Species	Area	References
0.07	62	-	Shortspine	AK	1
~0.03	150	-	Shortspine	WC	2
0.027	115	conv	Shortspine	WC	3
0.036	100	radio	Shortspine	WC	3
-	50–100	radio	Shortspine	-	4,5
0.013-0.015	250–313	GSI	Shortspine	AK, WC	6
	85–100	conv	Shortspine	-	7

Area indicates location of study: West Coast of U.S. (WC), Alaska (AK)
Conv: conventional ageing method; radio: radiochemical aging technique; GSI: gonadosomatic index
References: 1) Miller 1985; 2) Jacobson 1990; 3) Kline 1996; 4) Kastelle *et al*. 2000; 5) Cailliet *et al*. 2001; 6) Pearson and Gunderson 2003; 7) Black 2009.

Fecundity and Maturity at Length

Fecundity at length has been estimated by Miller (1985) and Cooper et al. (2005) for shortspine thornyheads in Alaska. Cooper et al. (2005) found no significant difference in fecundity at length between Alaskan and West Coast shortspine thornyheads. It appeared that fecundity at length in the more recent study was somewhat lower than that found in Miller (1985), but it was unclear whether the difference was attributable to different methodology or to a decrease in stock fecundity over time. Longspine thornyhead fecundity at length was estimated by Wakefield (1990) and Cooper et al. (2005) for the West Coast stocks; it is unknown whether this information is applicable to longspine thornyheads in Alaska.

Size at maturity varies by species as well. The size-at-maturity schedule estimated in Ianelli and Ito (1995) for shortspine thornyheads off the coast of Oregon, suggests that female shortspine thornyheads appear to be 50% mature at about 22 cm. More recent data analyzed in Pearson and Gunderson (2003) confirmed this, estimating length at maturity for Alaska shortspine thornyheads at 21.5 cm (although length at maturity for west coast fish was revised downward to about 18 cm). Male shortspine thornyheads mature at a smaller size than females off Alaska (Love et al. 2002). Longspine thornyheads reach maturity between 13 and 15 cm off the U.S. west coast; it is unknown whether this information applies in the Alaskan portion of the longspine thornyheads range.

Estimates of age- and size-at-50% maturity for thornyhead rockfish are listed below:

Age at Maturity	Size at Maturity	Species	Sex	Area	References
-	22 cm	shortspine	Female	O	1
-	21.5 cm	shortspine	Female	AK	2
-	13–15 cm	longspine	Male	WC	3

12	-	shortspine	Male/Female	AK	4

Area indicates location of study: Oregon (O); West Coast of U.S. (WC), Alaska (AK)
References: 1) Ianelli and Ito 1995; 2) Pearson and Gunderson 2003; 3) Love *et al*. 2002; 4) Miller 1985.

Results

Model Results

Several alternative models were presented to the GOA Groundfish Plan Team in September 2022 (e.g., additional observation error for the trawl survey only, additional observation error for the longline survey only, and only including the bottom trawl survey with an additional observation error). However, the best fitting (based on AIC) and recommended model (Model 22) included an additional observation error on both the trawl and longline surveys (Sullivan et al. 2022a). Model fits for 18* and 22 can be compared at the regional and depth strata level by survey (Figure 15-7), and at the Gulfwide level (Figure 15-8).

The biomass trajectories in Model 18* are highly variable and closely track the noise in the bottom trawl survey and longline survey observations (Figure 15-8). This result is attributed to the relatively high precision of the bottom trawl survey biomass and longline survey RPW estimates, which leads to an over-emphasis on the data and high estimates of process error variance (Sullivan et al. 2022a). These results are biologically unrealistic for *Sebastolobus* species, which are notably long-lived fish that should exhibit low variability in population biomass. In response to these findings, an alternative model that estimates additional observation error for both the bottom trawl survey biomass and longline survey RPW indices (Model 22) was proposed. In this year's assessment we recommend Model 22. The inclusion of additional observation error parameters for the bottom trawl survey biomass and longline survey RPW indices resulted in a substantial decrease in the marginal negative log-likelihood (i.e., the objective function) and smoother biomass trajectories that fit the data well without over-fitting to the noisy survey observations (Sullivan et al. 2022a; Figures 15-7 and 15-8). Model 22 parameter estimates show that the REMA model effectively balances the tradeoff between observation and process error when allowed to estimate additional observation error for the survey abundance indices (Sullivan et al. 2022a). Detailed information regarding development of Model 22 and comparison with Model 18* can be found in Sullivan et al. 2022a.

Parameter estimates, standard errors (SE), and corresponding lower (LCI) and upper (UCI) 95% confidence intervals from Models 18 * and 22 are below.

	Model 18*				Model 22			
Parameter	Parameter Estimate	SE	LCI	UCI	Parameter Estimate	SE	LCI	UCI
WGOA process error($\sigma_{PE,W}$)	0.339	0.054	0.247	0.464	0.224	0.068	0.124	0.406
CGOA process error($\sigma_{PE,C}$)	0.218	0.043	0.148	0.321	0.115	0.036	0.063	0.212
EGOA process error ($\sigma_{PE,E}$)	0.208	0.033	0.152	0.285	0.105	0.032	0.058	0.191
Scaling parameter (q)	0.591	0.014	0.564	0.620	0.602	0.022	0.561	0.647
Extra BTS biomass observation error ($\sigma_{\tau,B}$)					0.180	0.052	0.101	0.308
Extra LLS RPW observation error ($\sigma_{\tau,I}$)					0.145	0.024	0.104	0.199

Harvest Recommendations

Presently the Tier 5 approach is based solely on shortspine thornyheads; the rarely occurring longspine thornyheads are ignored. This is defensible because they are distributed deeper than where most fisheries operate. Also, the center of longspine thornyhead abundance appears to be off the U.S. West Coast and Alaskan waters may be near the limit of their range. In the future, if fisheries shift to deeper depths along the continental slope, and/or the catch of shortspine thornyheads increases dramatically, specific management measures for longspine thornyheads should be considered.

Amendment 56 Reference Points

We recommend keeping thornyhead rockfish as "Tier 5" in the NPFMC definitions for ABC and OFL based on Amendment 56 to the Gulf of Alaska FMP. The population dynamics information available for Tier 5 species consists of reliable estimates of biomass and natural mortality M, and the definition states that for these species, the fishing rate that determines ABC (i.e., F_{ABC}) is $\leq 0.75M$. Thus, the recommended F_{ABC} for thornyhead rockfish is 0.0225 (i.e., 0.75 x M, where $M = 0.03$). The overfishing limit for Tier 5 species is defined to occur at a harvest rate of $F=M$. As described in the previous section, the recommended RE Model 22 was fit to the 1990–2021 GOA trawl survey time-series of biomass values and estimates of uncertainty by region and depth strata (to account for missing survey data) and regional RPW indices from the 1992–2022 AFSC longline survey (with associated estimates of uncertainty; Figure 15-7). These regional biomass estimates from the RE Model 22 were then summed to obtain Gulfwide biomass of 72,349 t (+/- 95% CI of 60,736 and 86,181; Table 15-7) for thornyhead rockfish (Figure 15-8).

Specification of OFL and Maximum Permissible ABC

Applying the F_{ABC} to the estimate of current exploitable biomass (using the new random effects methodology) of 72,349 t (+/- 95% CI of 60,736 and 86,181) for thornyhead rockfish results in a Gulfwide ABC of 1,628 t and OFL of 2,170 t for the 2023 fishery.

Risk Table and ABC Recommendation

The following table is to be 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	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or	Multiple indicators showing consistent adverse signals a)

	uncertainty; strong retrospective bias.	recruitment patterns.	down trophic levels (i.e., predators and prey of the stock)	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—
   a. Data-inputs: biased ages, skipped surveys, lack of fishery-independent trend data
   b. Model fits: poor fits to fishery or survey data, inability to simultaneously fit multiple data inputs
   c. Model performance: poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds
   d. Estimation uncertainty: poorly estimated but influential year classes
   e. 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 GOA thornyhead stock complex is a Tier 5 species, meaning only reliable biomass estimates are available to calculate ABCs. The GOA thornyhead assessment is one of few Tier 5 assessments in Alaska that is fit to multiple abundance indices (trawl survey biomass estimates and longline survey RPWs). In recent years, the trawl survey depth range has been restricted (the 1996 and 2001 surveys did not survey the depths >500 m, and the 2003, 2011, 2013, 2017, 2019, and 2021 surveys did not survey depths >700 m), which is a concern for thornyhead rockfish. By including the longline survey RPWs as an abundance index in the random effects model, we are able to get informative biomass estimates for all depths. These two surveys have often shown opposing trends, which is not unexpected due to the differing habitats sampled, but the inclusion of these two data sources has allowed for increased stability of biomass estimates and more consistent regional apportionments across time. We rated the assessment-related concern as level 1, normal. While biomass estimates have historically shown large changes from year to year (typical of several rockfish assessments), the CVs have generally remained low.

Population Dynamics Considerations

In general, very little is known regarding the life history of thornyhead, and current techniques do not produce reliable age estimates for the species, thus, we are unable to estimate recruitment with a statistical model. Further, any data collected during larval cruises lump all rockfish species together and do not identify thornyheads to species. Even with large annual variability, likely due to sampling error as opposed to actual fluctuations in the population, biomass has been stable in recent years. While the longline survey had shown a downward trend in RPWs beginning in 2017 possibly due to hook competition with several above average sablefish year classes (Goethel et al. 2022), the 2022 longline survey RPW saw a reverse in this trend. Overall, we rated the population-dynamic concern as level 1, normal, due to the fact that little to no information exists on the population dynamics of this species and there are no alarming or sudden changes in population abundance from the biomass data we have available.

Environmental/Ecosystem Considerations

Changes in structural habitat present a possible concern for thornyhead rockfish. Vertical structure, including sponges, corals, and rocky habitat, have been shown to provide habitat for thornyhead rockfish and has experienced multi-year decline (with high uncertainty) across the GOA. Observations in 2021 from AFSC's bottom trawl and observer data of non-target catches (both not designed to sample structural epifauna and associated with high uncertainty) can be used to monitor trends in structural epifauna, although with high uncertainty as these surveys/fisheries are not designed to target these species (AFSC bottom trawl, Palsson 2021; Observer data, Whitehouse and Gaichas 2021). A VAST model was run for gorgonian corals, pennatulaceans (e.g., sea pens), and sponges integrating and modeling trawl station densities across the Gulf of Alaska (Palsson 2021). The coral abundance index is variable over time but the trend suggests low abundances resulting from the two most recent surveys (2019 and 2021) compared to most index values observed before 2017. The gulf-wide abundance of pennatulaceans shows an increasing trend from 1990 to 2005 and then a variable trend thereafter and a peak in 2017 followed by a decline in 2019. However, the 2021 index value increased from the 2019 value. The trend of sponges shows relative stability until 2015 followed by a continual 7 year decline in the GOA wide index through 2021 to a historic low value. Sea anemones (not modeled in VAST) declined in Shumagin in 2019 and 2021, and Kodiak experienced a slight decline in 2021.

Thermal conditions for thornyhead rockfish are considered moderate in 2022, within the optimal range for growth and survival. Thornyhead juveniles spend 14-15 (shortspine) to 20 (longspine) months in a pelagic phase, before they settle into benthic habitat (Krieger and Ito 1999). Younger rockfish in the pelagic stages experienced surface temperatures that were below average in the winter, transitioned from below average to above average in the spring (Satellite, Lemagie and Callahan 2022; Seward Line 5.7°C, Danielson and Hopcroft 2022; AFSC SECM survey in Icy Strait, Fergusson 2022; ADF&G trawl survey, Worton 2022), and above average in the summer across the GOA (Seward Line 12.3°C, Danielson and Hopcroft 2022; Satellite, Lemagie and Callahan 2022; AFSC SECM survey in Icy Strait, Fergusson 2022; ADF&G trawl survey, Worton 2022). Summer benthic thermal conditions in adult benthic habitat (shortspine: 100-600 m initially and move deeper as grow, and longspine: 600 to 1,200 m) along the shelf edge was slightly above average in the western GOA (5.17°C at 250 m longline survey, Siwicke 2022). Temperatures at depth on the shelf were below average in the spring (5.4°C Seward Line Survey, Danielson and Hopcroft 2022), and above average in the summer (5.52°C Seward Line Survey, Danielson and Hopcroft 2022; 6.09°C ADF&G trawl survey off Kodiak, Worton 2022).

The prey base for thornyhead rockfish is potentially average to good, with little data from adult slope habitat. Pandalid and non-pandalid shrimp (a key prey group for shortspine thornyhead rockfish; Yang and Nelson 2000) continues to increase in the WGOA (ADF&G trawl, Worton 2022). Other important prey of shortspine thornyhead rockfish include crabs, zooplankton, amphipods, and other benthic invertebrates (with juveniles more reliant on invertebrates; Yang and Nelson 2000). Tanner crab continued to increase in ADF&G trawl surveys off Kodiak Island (Worton 2022) and the zooplankton densities seem to be above average in central and eastern GOA (Seward Line survey, Danielson and Hopcroft 2022; seabird reproductive success, Drummond and Renner 2022, Hatch et al. 2022).

There is no indication of increased predation or competition on thornyhead rockfish. Little is known about the impacts of predators, such as fish and marine mammals. However, survival of larvae are thought to be more related to the abundance and timing of prey availability than predation, due to the lack of rockfish as a prey item in diets.

Overall, we rated the environmental/ecosystem considerations as level 1. While there has been an increased level of concern due to the latest (2021) observations of continued decline of structural epifauna habitat (with high uncertainty), there is little to no understanding of what the connection would be, or if there is, between these structural declines and the biology as it pertains to stock assessment of thornyhead. Prey availability is considered average to above average for adults and unknown for juveniles, with little data from adult slope habitat. There is no indication of change in predation and competition, but these interactions are not well known. In general there is a lack of a mechanistic understanding for the direct and indirect effects of environmental change on the survival and productivity of thornyhead rockfish.

Fishery Performance

There is no directed fishing of thornyheads, and they can only be retained as “incidentally-caught.” Catch of thornyheads varies greatly by area, gear type, and year, but catch has always remained below the TAC, and has generally remained stable. Current catch of thornyheads in the GOA is at its second lowest value since 1985. The reason for lower catch is unknown, but may be in part due to hook competition with the increase of sablefish abundance as well as an increase in the use of pot gear within the IFQ sablefish fishery which do not catch thornyheads as effectively as longline gear. Overall, we rated the fishery performance concern as level 1, normal, due to the low stable catch of this non directed fishery species that historically has always remained below the TAC.

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

The summarized results of the risk matrix exercise suggests no need to set the ABC below the maximum permissible.

Area Allocation of Harvests

We used area-specific survey biomass estimates and a random-walk smoother (the “random effects” model) to apportion ABCs among regions. The fit of this model is shown in Figures 15-7 and 15-8. The result is responsive to both the bottom trawl and longline survey indices which may reflect different components of the population. For 2023, the estimated distribution of biomass is shown as:

GOA Area	2023 Biomass (t)	Percent of Total Biomass	Area ABC Apportionment (t)
Western	13,944	19%	314
Central	30,810	43%	693
Eastern	27,595	38%	621
Gulfwide Total	72,349	100%	1,628

Status Determination

Based on Amendment 56 of the Gulf of Alaska FMP, overfishing for Tier 5 species such as thornyhead rockfish is defined to occur at a harvest rate of $F=M$. Therefore, applying the estimate of M for thornyhead rockfish (0.03) to the estimate of current exploitable biomass (72,349 t) yields an overfishing catch limit of 2,170 t for 2023. This stock is not being subjected to overfishing.

Ecosystem Considerations

This section focuses on shortspine thornyheads exclusively, because this species overwhelmingly dominates the thornyhead biomass in the GOA. Shortspine thornyheads occupy different positions within the GOA food web depending upon life stage. Adults are generally more piscivorous and are also available to fisheries whereas juveniles prey more on invertebrates and are therefore at a lower trophic level. These food webs were derived from mass balance ecosystem models assembling information on the food habits, biomass, productivity and consumption for all major living components in each system (Aydin et al. 2007). See the 2011 Ecosystem Assessment's ecosystem modeling results section for a description of the methodology for constructing the food web.

Ecosystem Effects on GOA Shortspine Thornyheads

Predators

One simple way to evaluate ecosystem effects relative to fishing effects is to measure the proportions of overall mortality attributable to each source. Apportionment of shortspine thornyhead mortality between fishing, predation, and unexplained mortality from mass balance ecosystem modeling based on information from 1990–1994, indicates that adult shortspine thornyheads experience more fishing mortality than predation mortality, while juvenile thornyheads only experience predation mortality . During these years, approximately 52% of adult GOA shortspine thornyhead exploitation rate was due to the fishery, 22% due to predation, and 26% "unexplained". Since shortspine thornyheads are retained at higher levels in the GOA fisheries relative to the BSAI, it is likely that fishing mortality is a more important component of total mortality for GOA thornyheads than for those populations in the AI and EBS.

In terms of annual tons removed, it is clear that fisheries were annually removing 1,300 tons of thornyheads from the GOA on average during the early 1990s (see Fishery section above). While estimates of predator consumption of thornyheads are more uncertain than catch estimates, the ecosystem models incorporate uncertainty in partitioning estimated consumption of shortspine thornyheads between their major predators in each system. Of the 22% of mortality due to predation, 36% (8% of total) is due to arrowtooth flounder, 24% (5.4% of total) due to "toothed whales" (sperm whales), 14% (3% of total) due to sharks, and 6% (1.4% of total) due to sablefish. If converted to tonnages, this translates to between 100 and 300 metric tons of thornyheads consumed annually by arrowtooth flounder during the early 1990s in that ecosystem, followed by "toothed whales" (sperm whales), which consume a similar range of thornyheads annually. Sharks consumed between 50 and 200 tons of shortspine thornyheads annually, and sablefish were estimated to consume less than 75 tons of adult thornyheads. Juvenile shortspine thornyheads are consumed almost exclusively by adult thornyheads, according to these models. Thornyheads are an uncommon prey in the GOA, as they generally make up less than 2% of even their primary predators' diets.

Prey

Diets of shortspine thornyheads are derived from stomach contents collections taken in conjunction with GOA trawl surveys. Over 70% of adult shortspine thornyhead diet measured in the early 1990s was shrimp, including both commercial (Pandalid) shrimp and non commercial (NP or Non-Pandalid shrimp) in equal measures. This preference for shrimp in the adult thornyhead diet combined with consumption rates estimated from stock assessment parameters and biomass estimated from the trawl survey, results in an annual consumption estimate ranging from 2,000 to 10,000 tons of shrimp. Other important prey of shortspine thornyheads include crabs, zooplankton, amphipods, and other benthic invertebrates. Thornyheads are estimated to consume up to an additional 1,000 metric tons of each of these prey annually in the GOA. Juvenile thornyheads have diets similar to adults, but they are estimated to consume far less prey overall than adults, as might be expected when a relatively small proportion of the population is in the juvenile stage at any given time.

Changes in Habitat Quality

There have been changes in structural habitat that may present a concern for thornyhead rockfish: vertical structure, including sponges, corals, and rocky habitat, has experienced multi-year decline (with high uncertainty) across the GOA (AFSC bottom trawl, Palsson 2021; Observer data, Whitehouse and Gaichas 2021). However, the physical habitat requirements for thornyheads are relatively unknown. Furthermore, the ecosystem models employed in this analysis are not designed to incorporate habitat relationships or any effects that human activities might have on habitat.

Fishery Effects on the Ecosystem

Fishery Contribution to Bycatch

While it is difficult to evaluate the ecosystem effects of a "thornyhead fishery" since there are no directed thornyhead fisheries in the GOA, we can examine the ecosystem effects of the primary target fisheries which catch thornyheads. According to Alverson et al. (1964), groundfish species commonly associated with thornyheads include: arrowtooth flounder (*Atheresthes stomias*), Pacific ocean perch, sablefish, rex sole (*Glyptocephalus zachirus*), Dover sole (*Microstomus pacificus*), shortraker rockfish (*Sebastes borealis*), rougheye rockfish (*Sebastes aleutianus*), and grenadiers (family Macrouridae). As described above, most thornyhead catch comes from fisheries directed at sablefish, rockfish, and flatfish in the GOA. Discussions of the ecosystem effects of these fisheries can be found in their respective stock assessments.

Fishery Concentration in Time and Space

Fisheries which catch thornyheads are widespread throughout the GOA, as is the distribution of thornyheads.

Fishery Effects on Amount of Large Size Thornyheads

Poor length sampling of thornyheads from other target fisheries makes it difficult to evaluate the effects of the fishery on large size thornyheads. It is noted that in general, longline fisheries capture larger thornyheads than trawl fisheries, perhaps because they operate in deeper waters and due to hook selectivity, which tends to select for larger fish.

Fishery Contribution to Discards and Offal Production

Most of the bycatch in the GOA sablefish fishery is grenadiers which are discarded.

Fishery Effects on Age-at Maturity and Fecundity

The effects of fisheries on the age-at-maturity and fecundity of thornyheads are unknown. Cooper et al. (2005) found a slightly lower fecundity at length for GOA shortspine thornyheads than had been estimated in an earlier study by Miller (1985). Further studies would be needed to determine whether this difference was due to different methodology or to a real decrease in fecundity at length over time, and whether changes could be attributed to the fisheries.

Summary of Ecosystem Effects on GOA Thornyheads and Fisheries Effects on the Ecosystem

Examining the trophic relationships of shortspine thornyheads suggests that the direct effects of fishing on the population which are evaluated with standard stock assessment techniques is likely to be the major ecosystem factors to monitor for this species, because fishing is the dominant source of mortality for shortspine thornyheads in the GOA, and there are currently no major fisheries affecting their primary prey. However, if fisheries on the major prey of thornyheads—shrimp and to a lesser extent deepwater crabs—were to be re-established in the GOA, any potential indirect effects on thornyheads should be considered.

Ecosystem considerations for GOA thornyheads are summarized in Table 15-8. The observation column represents the best attempt to summarize the past, present, and foreseeable future trends. The interpretation column provides details on how ecosystem trends might affect the stock (ecosystem effects on the stock) or how some aspects of fisheries for other targets which catch thornyheads may affect the ecosystem. The evaluation column indicates whether the trend is of: *no concern, probably no concern, possible concern, definite concern,* or *unknown.*

Data Gaps and Research Priorities

Because fishing mortality appears to be a larger proportion of adult thornyhead mortality in the GOA than predation mortality, highest priority research should continue to focus on direct fishing effects on shortspine thornyhead populations. The most important component of this research is to fully evaluate the age and growth characteristics of GOA thornyheads to re-institute the age-structured population dynamics model with adequate information. Additionally, mark recapture studies should continue since in the long term this may provide insight on mortality and growth rates, research should continue on the effect of hook competition with faster growing species such as sablefish, and the newly estimated natural mortality estimates (Sullivan et al. 2022c) should be incorporated in the next assessment cycle.

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Tables

Table 15-1.--Comparison of Gulf of Alaska thornyhead catches (t) by management area and total gulfwide, Allowable Biological Catch (ABC), Total Allowable Catch (TAC), and management measures.

	Area			Gulfwide	Gulfwide	Gulfwide	
Year	Western	Central	Eastern	Total	ABC	TAC	Management Measure
1977				1,317			After passage of the Fishery Conservation and Management Act (FCMA), thornyheads were placed in the rockfish management group which contained all species of rockfish except Pacific ocean perch.
1978							
1979							Thornyheads were removed from the rockfish category and placed in the "other fish" category. TAC is set gulfwide.
1980				1,485	3,750	3,750	Thornyheads became a reported species group and are managed as a single stock.
1981				1,340	3,750	3,750	
1982				787	3,750	3,750	
1983				729	3,750	3,750	
1984				208	3,750	3,750	
1985				82	3,750	3,750	
1986				714	3,750	3,750	
1987				1,877	3,750	3,750	
1988				2,181	3,750	3,750	
1989				2,616	3,800	3,800	
1990				1,576	3,800	3,800	
1991	689	596	250	1,535	1,798	1,398	
1992	249	1015	761	2,025	1,798	1,798	
1993	110	849	378	1,337	1,180	1,062	
1994	162	733	341	1,236	1,180	1,180	The NPFMC apportions the ABC and TAC into three geographic management areas: the Western, Central, and Eastern Gulf of Alaska.
1995	158	603	267	1,027	1,900	1,900	
1996	177	595	241	1,013	1,560	1,248	
1997	148	716	244	1,109	1,700	1,700	
1998	238	716	195	1,149	2,000	2,000	
1999	283	583	247	1,113	1,990	1,990	Trawling is prohibited in the Eastern Gulf east of 140 degrees W longitude. Eastern Gulf trawl closure becomes permanent with the implementation of FMP Amendments 41 and 58 in 2000 and 2001, respectively.

Table 15-1. cont.

	Area			Gulfwide	Gulfwide	Gulfwide	
Year	Western	Central	Eastern	Total	ABC	TAC	Management Measure
2000	340	551	244	1,134	2,360	2,360	
2001	276	523	196	995	2,310	2,310	
2002	372	505	169	1,046	1,990	1,990	
2003	317	715	101	1,133	2,000	2,000	
2004	276	409	138	823	1,940	1,940	
2005	190	391	140	720	1,940	1,940	
2006	197	400	184	781	2,209	2,209	
2007	342	258	197	798	2,209	2,209	Amendment 68 creates the Central Gulf Rockfish Pilot Program, which affects trawl catches of rockfish in this area.
2008	270	299	167	736	1,910	1,910	
2009	235	276	154	665	1,910	1,910	
2010	140	278	151	568	1,770	1,770	
2011	159	303	167	629	1,770	1,770	
2012	171	345	222	739	1,665	1,665	The Central Gulf Rockfish Program is permanently put into place.
2013	293	519	305	1,117	1,665	1,665	
2014	239	660	217	1,116	1,841	1,841	
2015	225	573	210	1,008	1,841	1,841	
2016	198	691	221	1,111	1,961	1,961	
2017	141	613	248	1,002	1,961	1,961	
2018	172	684	322	1,179	2,038	2,038	
2019	121	379	264	763	2,016	2,016	
2020	49	206	198	453	2,016	2,016	Amendment 107 requires GOA wide full retention of rockfish by catcher vessels using pot, hook-and-line, and jig gear while fishing for groundfish or halibut.
2021	42	101	130	273	1,953	1,953	
2022	107	167	71	345	1,953	1,953	

[a] 2022 catch estimate is reported catch as of October 6, 2022
Catch Sources: 1977–1980 catches based on estimates extracted from NMFS observer reports (e.g., Wall *et al*. l978) 1981-1989 based on PACFIN and NMFS observer data; 1990–2002 based on blended NMFS observer data and weekly processor reports; 2003–present from the NMFS Alaska Regional Office (AKRO) Catch Accounting System (CAS), accessed with the AKFIN database.

Table 15-2.--Estimated retained catch and discard of Gulf of Alaska thornyheads (tons) by gear type[1], 1977–2022.

	Trawl gear			Longline gear		
Year	**Retained**	**Discarded**	**Total**	**Retained**	**Discarded**	**Total**
1977	1,163	-	1,163	234	-	234
1978	442	-	442	344	-	344
1979	645	-	645	454	-	454
1980	1,158	-	1,158	327	-	327
1981	1,139	-	1,139	201	-	201
1982	669	-	669	118	-	118
1983	620	-	620	109	-	109
1984	177	-	177	31	-	31
1985	70	-	70	12	-	12
1986	607	-	607	107	-	107
1987	1,863	-	1,863	14	-	14
1988	2,132	-	2,132	49	-	49
1989	2,547	-	2,547	69	-	69
1990	1,233	38	1,271	284	20	304
1991	1188	60	1248	233	53	287
1992	1041	129	1169	499	356	855
1993	489	173	663	377	297	674
1994	488	222	710	250	277	527
1995	471	165	635	315	77	391
1996	435	170	606	313	94	407
1997	567	224	791	269	50	319
1998	625	112	737	363	49	412
1999	597	197	794	277	42	320
2000	557	92	649	397	75	472
2001	479	52	532	425	37	462
2002	500	89	589	410	46	457
2003	705	70	775	323	36	358
2004	414	66	480	314	30	343
2005	333	27	360	319	41	360
2006	297	60	357	387	37	424
2007	368	11	379	370	49	419
2008	318	29	347	330	59	390
2009	252	25	277	320	69	388
2010	179	15	193	316	59	375
2011	215	31	245	324	59	384
2012	141	57	197	426	115	542
2013	199	17	216	477	424	901
2014	461	16	477	457	182	639
2015	317	27	344	459	205	664
2016	411	69	480	454	177	631
2017	379	26	406	435	161	596
2018	424	51	474	494	209	703
2019	294	18	312	377	73	451
2020	192	11	203	225	18	243
2021	137	9	147	109	11	120
2022*	254	18	272	62	5	67

[1] Prior to 1990, retained catch was assumed to equal retained and discarded catch combined. Catches by gear type from 1981–1986 were estimated by apportioning 85% of the total catch to trawl and 15% to longline gear. Total catch reported will not equal reported catches in Executive Summary tables because all gear types are not being reported here.

Sources: 1977–1980 based on estimates extracted from NMFS observer reports (e.g., Wall et al. l978) 1981–1989 based on PACFIN and NMFS observer data; 1990–2002 based on blended NMFS observer data and weekly processor reports; 2003–present from the NMFS Alaska Regional Office Catch Accounting System (CAS), accessed through the AKFIN database system. *The 2022 catch is incomplete, representing catch reported through October 6, 2022.

Table 15-3.--Estimated catch (t) of thornyhead rockfish in the Gulf of Alaska by target fishery, 2005–2022; approximate percentage of total catch in parentheses.

	Target Fishery				
Year	Rockfish	Sablefish	Flatfish	Halibut	Other[1]
2005	322 (45%)	337 (47%)	35 (5%)	35 (3%)	6 (1%)
2006	312 (40%)	386 (49%)	52 (7%)	52 (4%)	1 (<1%)
2007	300 (38%)	398 (50%)	50 (6%)	50 (5%)	8 (1%)
2008	248 (34%)	389 (53%)	62 (8%)	62 (4%)	8 (1%)
2009	177 (27%)	371 (56%)	69 (10%)	69 (6%)	8 (1%)
2010	106 (19%)	367 (65%)	57 (10%)	57 (6%)	6 (1%)
2011	161 (26%)	381 (61%)	52 (8%)	52 (4%)	10 (2%)
2012	129 (18%)	539 (73%)	45 (6%)	45 (3%)	4 (<1%)
2013	108 (10%)	898 (80%)	62 (6%)	62 (4%)	9 (1%)
2014	244 (22%)	634 (57%)	143 (13%)	143 (3%)	62 (6%)
2015	220 (22%)	655 (65%)	61 (6%)	61 (4%)	31 (3%)
2016	337 (30%)	620 (56%)	27 (2%)	27 (3%)	89 (8%)
2017	363 (36%)	555 (55%)	20 (2%)	20 (3%)	30 (3%)
2018	362 (31%)	711 (60%)	55 (5%)	55 (4%)	5 (<1%)
2019	177 (23%)	429 (56%)	124 (16%)	124 (4%)	2 (<1%)
2020	138 (30%)	246 (54%)	55 (12%)	55 (3%)	0 (0%)
2021	113 (41%)	121 (44%)	24 (9%)	24 (4%)	3 (1%)
2022*	215 (62%)	78 (23%)	40 (12%)	9 (2%)	4 (1%)

Source: National Marine Fisheries Service, Alaska Region, Catch Accounting System, accessed via the Alaska Fishery Information Network (AKFIN). *Updated through October 6, 2022.
[1]The Other category includes catch from Pollock, Pacific Cod, and Other target fisheries.

Table 15-4.--Estimated Gulf of Alaska (GOA) thornyhead discards (t) by target fishery, 2005–2022; approximate percentage of total discards in parentheses.

	Fishery					
Year	Rockfish	Sablefish	Flatfish	Halibut	Other[1]	Total GOA Discard Rate
2005	23 (34%)	38 (56%)	4 (6%)	2 (3%)	0 (0%)	9%
2006	56 (58%)	36 (37%)	3 (3%)	1 (1%)	<1 (<1%)	12%
2007	4 (6%)	40 (66%)	5 (9%)	11 (18%)	<1 (<1%)	8%
2008	16 (18%)	63 (71%)	8 (9%)	0 (0%)	1 (1%)	12%
2009	18 (19%)	64 (68%)	2 (2%)	9 (10%)	<1 (<1%)	14%
2010	7 (9%)	57 (77%)	5 (7%)	4 (5%)	<1 (<1%)	13%
2011	19 (22%)	62 (68%)	7 (8%)	< 1 (0%)	1 (1%)	14%
2012	21 (12%)	119 (69%)	31 (18%)	0 (0%)	<1 (<1%)	23%
2013	5 (1%)	419 (95%)	2 (1%)	10 (2%)	5 (1%)	39%
2014	10 (5%)	176 (89%)	2 (1%)	8 (4%)	2 (1%)	18%
2015	11 (5%)	199 (86%)	6 (3%)	12 (5%)	5 (2%)	23%
2016	7 (3%)	179 (73%)	2 (1%)	5 (2%)	53 (22%)	22%
2017	23 (12%)	149 (79%)	3 (2%)	6 (3%)	7 (4%)	19%
2018	20 (8%)	231 (89%)	< 1 (0%)	9 (4%)	<1 (<1%)	22%
2019	13 (15%)	70 (76%)	4 (4%)	4 (4%)	<1 (1%)	12%
2020	8 (26%)	19 (62%)	3 (10%)	<1 (1%)	<1 (<1%)	7%
2021	6 (27%)	12 (57%)	1 (4%)	2 (11%)	1 (1%)	8%
2022*	12 (48%)	7 (28%)	4 (15%)	2 (8%)	1 (1%)	7%

Source: National Marine Fisheries Service, Alaska Region, Catch Accounting System, accessed via the Alaska Fishery Information Network (AKFIN). *Updated through October 6, 2022.
[1]The Other category includes catch from Pollock, Pacific Cod, and Other target fisheries.

Table 15-5.--Relative population weight (RPW) for Gulf of Alaska shortspine thornyhead rockfish in the Alaska Fishery Science Center longline survey by management area and depth stratum, 1992–2022. Data are for the upper continental slope and select gullies used to calculate the RPWs.

		Shortspine Thornyhead RPW													
Area	Depth (m)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Gulf of	151–200	117	642	609	622	223	547	110	110	1,353	168	467	861	1,152	537
Alaska	201–300	9,401	8,531	6,188	5,355	8,715	7,808	7,077	6,977	5,867	9,828	7,608	6,690	5,150	8,431
(all	301–400	7,828	6,713	5,787	6,315	8,207	7,992	8,579	7,130	8,000	9,754	8,360	7,377	6,212	6,097
areas)	401–600	9,629	8,313	6,994	9,218	9,866	9,525	9,550	11,270	8,703	12,268	11,650	9,356	6,626	8,337
	601–800	7,933	7,103	7,114	7,671	10,071	8,822	10,439	9,763	8,808	13,577	11,517	11,281	8,070	9,603
	801–1000	8,686	9,623	9,595	7,839	8,556	7,012	7,318	13,404	8,884	15,903	13,538	12,572	7,932	13,917
	Total	**43,595**	**40,925**	**36,287**	**37,019**	**45,638**	**41,707**	**43,074**	**48,655**	**41,616**	**61,498**	**53,139**	**48,136**	**35,142**	**46,921**
	Variance	4,994	5,995	5,461	4,820	5,592	4,995	3,669	5,537	5,562	7,277	7,770	5,363	3,892	7,711
Western	151–200	9	11	395	77	87	415	64	59	8	103	364	672	730	91
Gulf	201–300	3,351	1,645	2,353	1,078	1,897	762	1,761	797	992	1,255	1,358	1,540	1,033	1,008
	301–400	3,376	1,379	1,938	1,119	2,039	1,201	1,568	1,129	1,154	1,305	1,226	1,049	1,396	761
	401–600	3,278	1,560	1,656	2,730	2,644	1,421	1,259	2,642	1,512	1,559	2,465	2,051	1,447	1,157
	601–800	1,375	1,201	1,625	1,835	2,596	1,397	2,371	1,579	1,578	1,574	3,040	2,538	2,158	1,775
	801–1000		2,512	882	1,745	1,387	525	689	103	800	1,555	4,704	956	803	5,130
	Total	**11,390**	**8,308**	**8,849**	**8,585**	**10,650**	**5,721**	**7,712**	**6,309**	**6,043**	**7,352**	**13,157**	**8,807**	**7,566**	**9,922**
	Variance	1,391	1,216	1,754	1,227	1,303	645	780	936	957	1,291	3,707	1,565	1,241	3,040
Central	151–200	108	632	69	51	0	0	47	0	51	65	41	131	0	0
Gulf	201–300	1,893	1,111	1,134	560	906	803	1,567	1,768	1,722	2,040	1,874	1,589	1,573	2,504
	301–400	1,787	1,611	1,161	1,104	1,540	1,067	1,141	971	1,406	1,781	1,975	1,341	983	1,328
	401–600	4,101	3,398	2,693	2,898	3,571	4,202	4,848	4,566	3,327	6,114	5,774	3,476	2,479	3,643
	601–800	5,109	4,225	3,858	3,530	5,336	4,789	5,409	5,149	4,277	8,523	6,105	6,106	4,041	5,146
	801–1000	7,698	5,361	7,101	4,898	5,862	4,587	5,071	11,380	6,172	12,553	7,340	10,218	5,869	6,959
	Total	**20,697**	**16,337**	**16,017**	**13,043**	**17,215**	**15,449**	**18,083**	**23,834**	**16,954**	**31,076**	**23,109**	**22,861**	**14,944**	**19,580**
	Variance	2,543	3,369	2,598	2,139	2,680	2,668	1,888	2,721	2,747	4,247	2,665	2,362	1,300	2,966
Eastern	151–200	0	0	146	493	136	132	0	51	1,294	0	62	58	422	446
Gulf	201–300	4,157	5,775	2,701	3,716	5,912	6,243	3,750	4,411	3,154	6,533	4,375	3,560	2,544	4,918
	301–400	2,665	3,724	2,688	4,091	4,628	5,725	5,870	5,031	5,441	6,667	5,159	4,987	3,833	4,008
	401–600	2,250	3,355	2,644	3,589	3,651	3,902	3,443	4,062	3,864	4,594	3,411	3,829	2,700	3,536
	601–800	1,449	1,676	1,630	2,305	2,139	2,636	2,659	3,036	2,954	3,480	2,372	2,636	1,871	2,682

	801–1000	988	1,750	1,611	1,195	1,308	1,899	1,558	1,921	1,913	1,795	1,494	1,398	1,260	1,828
	Total	**11,508**	**16,280**	**11,420**	**15,391**	**17,773**	**20,537**	**17,280**	**18,512**	**18,619**	**23,071**	**16,872**	**16,468**	**12,631**	**17,418**
	Variance	1,060	1,410	1,110	1,455	1,609	1,682	1,001	1,880	1,858	1,740	1,398	1,437	1,351	1,706

Shortspine Thornyhead RPW

Area	Depth (m)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gulf of	151–200	566	291	2,215	1,013	2,906	1,300	3,728	869	1,222	1,770	1,777	1,994	2,168	2,574
Alaska	201–300	8,472	8,287	14,168	8,952	13,726	10,661	8,995	14,238	13,100	13,391	13,135	14,126	14,202	13,454
(all	301–400	7,802	8,488	8,899	9,726	12,503	8,302	9,267	12,991	12,307	11,788	12,320	10,885	10,096	8,966
areas)	401–600	8,420	7,210	11,238	9,117	9,765	9,922	9,655	12,595	10,013	10,077	9,236	9,986	8,729	7,352
	601–800	8,278	8,720	12,537	8,721	11,937	11,194	12,369	15,543	12,190	9,904	9,198	12,162	8,406	10,873
	801–1000	12,833	13,484	13,335	11,902	14,028	12,693	11,787	14,215	13,324	12,258	9,632	11,747	12,141	12,898
	Total	**46,371**	**46,479**	**62,393**	**49,431**	**64,865**	**54,072**	**55,801**	**70,451**	**62,156**	**59,188**	**55,297**	**60,900**	**55,742**	**56,117**
	Variance	5,230	5,578	8,475	7,079	9,220	6,350	5,831	7,213	9,890	6,362	5,836	6,868	6,868	8,357
Western	151–200	98	163	1,505	924	2,627	958	2,082	581	557	1,631	1,451	1,856	1,509	2,150
Gulf	201–300	2,291	1,894	4,029	2,508	3,401	1,686	2,326	4,252	4,282	5,043	5,473	6,036	3,366	3,483
	301–400	1,752	1,756	1,106	2,324	1,579	1,465	1,169	3,245	3,331	3,654	2,636	2,825	2,466	2,786
	401–600	1,410	784	1,602	2,118	1,667	1,294	739	2,201	1,586	933	2,187	1,324	1,557	1,380
	601–800	960	452	798	1,122	1,629	953	544	1,806	2,664	372	1,727	1,123	793	3,352
	801–1000	1,003	2,628	903	2,293	3,601	2,853	0			756	0	265	3,962	4,954
	Total	**7,514**	**7,676**	**9,943**	**11,290**	**14,504**	**9,208**	**6,860**	**12,085**	**12,420**	**12,389**	**13,473**	**13,429**	**13,652**	**18,104**
	Variance	1,275	1,564	2,318	1,747	3,677	1,935	1,151	1,402	1,920	1,967	2,285	2,377	3,046	5,162
Central	151–200	0	0	208	7	0	190	151	0	110	47	41	20	609	190
Gulf	201–300	2,074	2,537	3,370	3,088	4,588	3,827	2,964	4,450	3,282	3,683	2,969	4,177	3,525	3,797
	301–400	1,234	1,508	1,920	1,797	2,384	1,560	1,845	2,483	2,237	2,443	1,959	2,086	1,891	2,420
	401–600	3,270	2,740	4,674	2,907	3,398	3,816	4,590	4,527	4,290	4,794	3,260	3,708	3,303	2,304
	601–800	4,190	4,685	7,347	4,565	6,423	6,665	7,972	9,036	6,583	6,436	4,645	7,066	4,437	5,600
	801–1000	8,783	7,455	9,720	7,437	7,207	6,983	8,866	11,377	11,395	9,727	6,918	8,809	5,872	5,018
	Total	**19,550**	**18,925**	**27,239**	**19,802**	**24,000**	**23,041**	**26,388**	**31,873**	**27,897**	**27,130**	**19,793**	**25,866**	**19,637**	**19,329**
	Variance	2,215	2,718	3,547	3,868	3,161	2,800	2,608	4,271	5,938	2,907	1,503	1,999	1,914	2,262
Eastern	151–200	468	128	502	82	279	153	1,494	289	556	92	285	118	50	234
Gulf	201–300	4,107	3,855	6,769	3,356	5,738	5,148	3,706	5,535	5,536	4,666	4,693	3,913	7,311	6,174
	301–400	4,816	5,225	5,873	5,605	8,540	5,277	6,252	7,263	6,739	5,691	7,724	5,974	5,740	3,760
	401–600	3,740	3,685	4,962	4,093	4,700	4,813	4,326	5,867	4,137	4,350	3,789	4,954	3,869	3,668

	601–800	3,128	3,583	4,392	3,033	3,885	3,575	3,854	4,702	2,943	3,096	2,826	3,973	3,176	1,920
	801–1000	3,048	3,402	2,712	2,171	3,220	2,857	2,921	2,837	1,929	1,775	2,714	2,673	2,307	2,927
	Total	**19,307**	**19,878**	**25,211**	**18,339**	**26,361**	**21,823**	**22,553**	**26,493**	**21,839**	**19,669**	**22,031**	**21,605**	**22,453**	**18,684**
	Variance	1,740	1,297	2,610	1,463	2,382	1,615	2,071	1,540	2,032	1,488	2,048	2,493	1,908	933

Shortspine Thornyhead RPW

Area	Depth (m)	2020	2021	2022
Gulf of Alaska (all areas)	151–200	1,103	1,759	1,021
	201–300	7,983	7,126	10,038
	301–400	5,901	5,475	9,270
	401–600	5,196	4,917	6,948
	601–800	6,536	6,000	7,577
	801–1000	14,708	10,018	8,615
	Total	**41,426**	**35,294**	**43,469**
	Variance	6,103	3,079	5,171
Western Gulf	151–200	812	1,554	353
	201–300	2,686	1,766	1,094
	301–400	874	1,624	1,529
	401–600	731	1,038	1,072
	601–800	809	623	968
	801–1000	3,557	1,280	1,724
	Total	9,469	7,885	6,740
	Variance	1,492	731	1,549
Central Gulf	151–200	221	180	55
	201–300	1,795	1,819	2,595
	301–400	945	1,010	1,362
	401–600	1,862	1,582	2,519
	601–800	3,987	4,004	4,500
	801–1000	9,846	7,732	4,997
	Total	18,657	16,328	16,028
	Variance	3,782	1,696	1,688
Eastern Gulf	151–200	70	25	613
	201–300	3,501	3,540	6,349
	301–400	4,082	2,841	6,379

401–600	2,603	2,297	3,357
601–800	1,740	1,373	2,108
801–1000	1,305	1,006	1,895
Total	**13,300**	**11,081**	**20,701**
Variance	829	652	1,934

Source: 1992–2022: AFSC longline survey database accessed via the Alaska Fishery Information Network (AKFIN) Yakutat includes both West and East Yakutat areas (area between 137° W and 147° W). *Starting in 2018, RPWs are calculated using the new area sizes from Echave et al. (2013).

Table 15-6.--Shortspine thornyhead biomass (t), and the percentage distribution by management area from the bottom trawl surveys in the Gulf of Alaska, 1990–2021. The 1990, 1993, 1996 and 2001 surveys did not survey depths >500 m, and the 2003, 2011, 2013, 2017, 2019, and 2021 surveys did not survey depths >700 m. In addition, the 2001 survey did not survey the Eastern Gulf of Alaska.

		Shortspine Thornyhead Biomass (t)												
Area	Depth (m)	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011	2013	2015	2017
Gulf of	1–100	0	2	0	116	46	54	180	212	85	17	0	37	153
Alaska	101–200	2,936	2,144	6,625	4,446	1,776	3,988	5,682	4,742	3,002	5,400	9,077	7,664	9,965
(all	201–300	7,553	12,957	21,968	23,418	13,619	39,156	28,252	21,330	26,494	20,473	26,659	31,171	27,459
areas)	301–500	9,127	17,912	23,390	27,872	13,220	37,017	28,394	28,063	22,415	23,800	19,639	26,549	31,030
	501–700			--	14,952	--	21,360	18,213	16,409	17,790	13,491	14,503	11,774	11,885
	701–1000			--	6,531	--	--	13,947	13,920	9,009	--	--	12,047	--
	Total	**19,616**	**33,014**	**51,984**	**77,336**	**28,661**	**101,576**	**94,668**	**84,676**	**78,795**	**63,180**	**69,878**	**89,241**	**80,492**
	CV	11%	8%	7%	5%	8%	8%	4%	5%	5%	6%	7%	6%	7%
	Lower	15,493	27,501	44,611	69,406	24,249	84,549	86,893	76,132	70,445	55,313	60,049	77,916	69,254
	Upper	23,740	38,528	59,356	85,265	33,074	118,602	102,444	93,220	87,146	71,046	79,707	100,567	91,730

		Shortspine Thornyhead Biomass (t)	
Area	Depth (m)	2019	2021
Gulf of	1–100	2,240	123
Alaska	101–200	8,111	5,053
(all	201–300	23,156	21,942
areas)	301–500	27,129	23,794
	501–700	17,834	17,312
	701–1000	--	--
	Total	**78,470**	**68,224**
	CV	8%	8%
	Lower	66,061	56,709
	Upper	90,879	79,739

Table 15-6 cont.

		Shortspine Thornyhead Biomass (t)												
Area	Depth (m)	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011	2013	2015	2017
Western	1–100	0	0	0	4	0	0	63	0	0	17	0	0	17
Gulf	101–200	5	0	313	37	0	500	1,108	7	84	202	62	329	269
	201–300	676	490	3,115	2,248	3,981	6,017	5,550	2,910	7,094	1,082	4,012	4,578	5,680
	301–500	998	3,216	4,615	4,739	4,771	8,519	5,630	4,702	5,286	2,245	2,402	4,746	6,230
	501–700			--	5,389	--	5,887	6,377	2,590	5,605	2,272	2,739	2,733	2,740
	701–1000			--	1,679	--	--	3,277	1,943	719	--	--	1,147	--
	Total	1,679	3,706	**8,043**	**14,097**	**8,753**	**20,922**	**22,005**	**12,152**	**18,789**	**5,818**	**9,215**	**13,533**	**14,936**
	% of total biomass	9%	11%	15%	18%	31%	21%	23%	14%	24%	9%	13%	15%	19%
Central	1–100	0	2	0	2	46	54	103	131	13	0	0	37	86
Gulf	101–200	108	369	309	690	1,776	1,317	3,000	1,465	559	3,136	5,862	3,380	3,384
	201–300	2,743	6,997	10,456	10,605	9,638	25,386	13,545	8,190	11,880	9,239	10,000	18,635	15,524
	301–500	3,091	5,141	8,266	11,638	8,449	16,031	10,780	11,124	7,270	8,797	8,006	10,973	9,597
	501–700			--	6,725	--	10,463	6,728	8,962	5,365	6,885	8,196	4,666	4,845
	701–1000			--	2,930	--	--	8,262	7,736	3,469	--	--	7,214	--
	Total	5,941	12,509	**19,030**	**32,590**	**19,908**	**53,250**	**42,419**	**37,607**	**28,556**	**28,057**	**32,064**	**44,906**	**33,436**
	% of total biomass	30%	38%	37%	42%	69%	52%	45%	44%	36%	44%	46%	50%	42%
Eastern	1–100	0	0	0	111	--	0	14	81	73	0	0	0	51
Gulf	101–200	2,823	1,775	6,003	3,719	--	2,172	1,574	3,271	2,358	2,061	3,153	3,955	6,312
	201–300	4,135	5,469	8,398	10,565	--	7,753	9,157	10,230	7,520	10,152	12,646	7,958	6,255
	301–500	5,039	9,556	10,510	11,495	--	12,468	11,984	12,237	9,859	12,758	9,231	10,830	15,203
	501–700			--	2,838	--	5,011	5,108	4,858	6,820	4,334	3,569	4,374	4,301
	701–1000			--	1,922	--	--	2,408	4,241	4,821	--	--	3,686	--
	Total	11,996	16,800	**24,911**	**30,649**	**--**	**27,404**	**30,244**	**34,918**	**31,451**	**29,305**	**28,600**	**30,803**	**32,121**
	% of total biomass	61%	51%	48%	40%	--	27%	32%	41%	40%	46%	41%	35%	40%

Table 15.6 cont.

		Shortspine Thornyhead Biomass (t)	
Area	Depth (m)	2019	2021
Western Gulf	1–100	44	61
	101–200	1,555	25
	201–300	2,889	2,218
	301–500	6,297	8,120
	501–700	7,992	4,269
	701–1000	--	--
	Total	**18,777**	**14,693**
	% of total biomass	24%	22%
Central Gulf	1–100	0	29
	101–200	2,848	2,148
	201–300	13,129	12,817
	301–500	11,621	6,390
	501–700	6,015	7,601
	701–1000	--	--
	Total	**33,613**	**28,985**
	% of total biomass	43%	42%
Eastern Gulf	1–100	2,197	34
	101–200	3,708	2,880
	201–300	7,138	6,907
	301–500	9,211	9,283
	501–700	3,827	5,443
	701–1000	--	--
	Total	**26,080**	**24,546**
	% of total biomass	33%	36%

Table 15-7.--Time series of estimated exploitable biomass using the random effects Model (22) for the Western Gulf of Alaska (WGOA), Central Gulf of Alaska (CGOA), Eastern Gulf of Alaska (EGOA), and the Gulfwide total (GOA Total), with 95 % lower (LCI) and upper confidence intervals (UCI).

Year	WGOA	CGOA	EGOA	GOA Total	LCI	UCI
1990	15,083	23,897	20,452	59,432	48,201	73,280
1991	15,507	24,953	21,116	61,576	51,485	73,645
1992	15,996	26,111	21,810	63,916	55,358	73,798
1993	14,767	26,277	23,188	64,233	56,725	72,734
1994	14,539	26,728	23,877	65,144	57,603	73,672
1995	14,473	27,256	25,866	67,595	60,094	76,031
1996	14,748	28,651	28,145	71,544	63,944	80,047
1997	12,532	29,569	29,515	71,615	63,852	80,322
1998	12,609	31,106	29,821	73,536	65,817	82,160
1999	12,582	33,026	30,478	76,086	68,603	84,386
2000	12,634	33,937	30,841	77,411	69,240	86,547
2001	14,163	35,831	31,199	81,193	72,700	90,678
2002	16,187	37,024	29,912	83,123	73,870	93,534
2003	17,288	38,004	29,182	84,474	74,952	95,205
2004	16,270	35,522	28,680	80,472	71,728	90,282
2005	17,314	36,126	30,026	83,466	74,928	92,978
2006	14,880	35,599	31,539	82,017	73,930	90,989
2007	13,878	35,706	33,012	82,597	75,063	90,887
2008	15,338	36,304	34,110	85,752	77,071	95,411
2009	16,594	35,582	33,806	85,982	77,771	95,060
2010	15,249	36,874	35,471	87,594	78,361	97,914
2011	12,629	37,718	35,527	85,874	77,192	95,531
2012	13,277	39,636	35,976	88,889	79,326	99,605
2013	15,071	40,773	36,108	91,952	82,166	102,904
2014	17,138	41,012	35,155	93,304	82,940	104,964
2015	17,704	40,743	33,985	92,433	83,066	102,855
2016	19,360	38,563	34,047	91,970	82,110	103,013
2017	19,658	38,093	33,549	91,300	81,650	102,091
2018	19,713	36,015	32,138	87,867	78,107	98,846
2019	18,916	34,863	29,744	83,522	74,689	93,400
2020	16,547	33,112	27,257	76,916	68,216	86,726
2021	14,868	31,717	26,366	72,951	64,585	82,401
2022	13,944	30,810	27,595	72,349	62,824	83,318
2023	13,944	30,810	27,595	72,349	60,736	86,181

Table 15-8.--Shortspine thornyhead ecosystem considerations.

Ecosystem effects on GOA Thornyheads (evaluating level of concern for thornyhead populations)

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Shrimp Benthic invertebrates Pelagic zooplankton	Trends are not currently measured directly Gulfwide. Shrimp biomass in isolated nearshore habitats may have declined since 1977, but it is unclear if all biomass declined, especially in deeper habitats occupied by thornyheads. Only short time series of food habits data exist for potential retrospective measurement	Unknown	Unknown
Predator population trends			
Arrowtooth flounder	Increasing since 1960's, leveling recently	Possibly higher mortality on thornyheads, but still small relative to fishing mortality	Probably no concern
Toothed whales	Unknown population trend	Predation mortality is small relative to fishing mortality	Probably no concern
Sharks	Unknown population trend	Predation mortality is small relative to fishing mortality	Probably no concern
Shortspine thornyheads	Adults prey on juveniles, but population biomass is apparently stable	Stable mortality on juvenile thornyheads	No concern
Changes in habitat quality			
Benthic slope habitats	Physical habitat requirements for thornyheads are unknown, and changes in deepwater habitats have not been measured in the GOA.	Unknown	Unknown

Table 15-8 cont.

"Thornyhead fishery" effects on the ecosystem (evaluating level of concern for ecosystem)

Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Sablefish fishery	GOA sablefish removes the highest weight of nontarget species bycatch of any GOA fishery, mostly grenadiers	Possible effects on grenadier populations, deep slope food webs	Possible concern
Rockfish fishery	Small bycatch of skates, grenadiers and other non-specified demersal fish	Catch of skates small relative to other fisheries	Probably no concern
Non-halibut flatfish fisheries	Small bycatch of skates, sculpins, and grenadiers, moderate bycatch of halibut	Catch of skates moderate relative to other fisheries	Probably no concern
Halibut fisheries	Bycatch unmonitored, high estimated bycatch of skates, moderate estimated bycatch of sharks, flatfish and rockfish	Catch of skates estimated high relative to all groundfish fisheries	Possible concern
Fishery concentration in space and time	Fisheries are widespread throughout the GOA, as are thornyheads	Unlikely impact	No concern
Fishery effects on amount of large size target fish	Poor length sampling of thornyheads from fisheries makes this difficult to evaluate	Unknown	Unknown
Fishery contribution to discards and offal production	High discard of grenadiers in sablefish fishery, lower offal production in all	Dead grenadiers affect energy flow?	Unknown
Fishery effects on age-at-maturity and fecundity	Lower thornyhead fecundity-at-length in 2005 than 1985 study could be methodology or real difference	Requires more investigation	Unknown

Figures

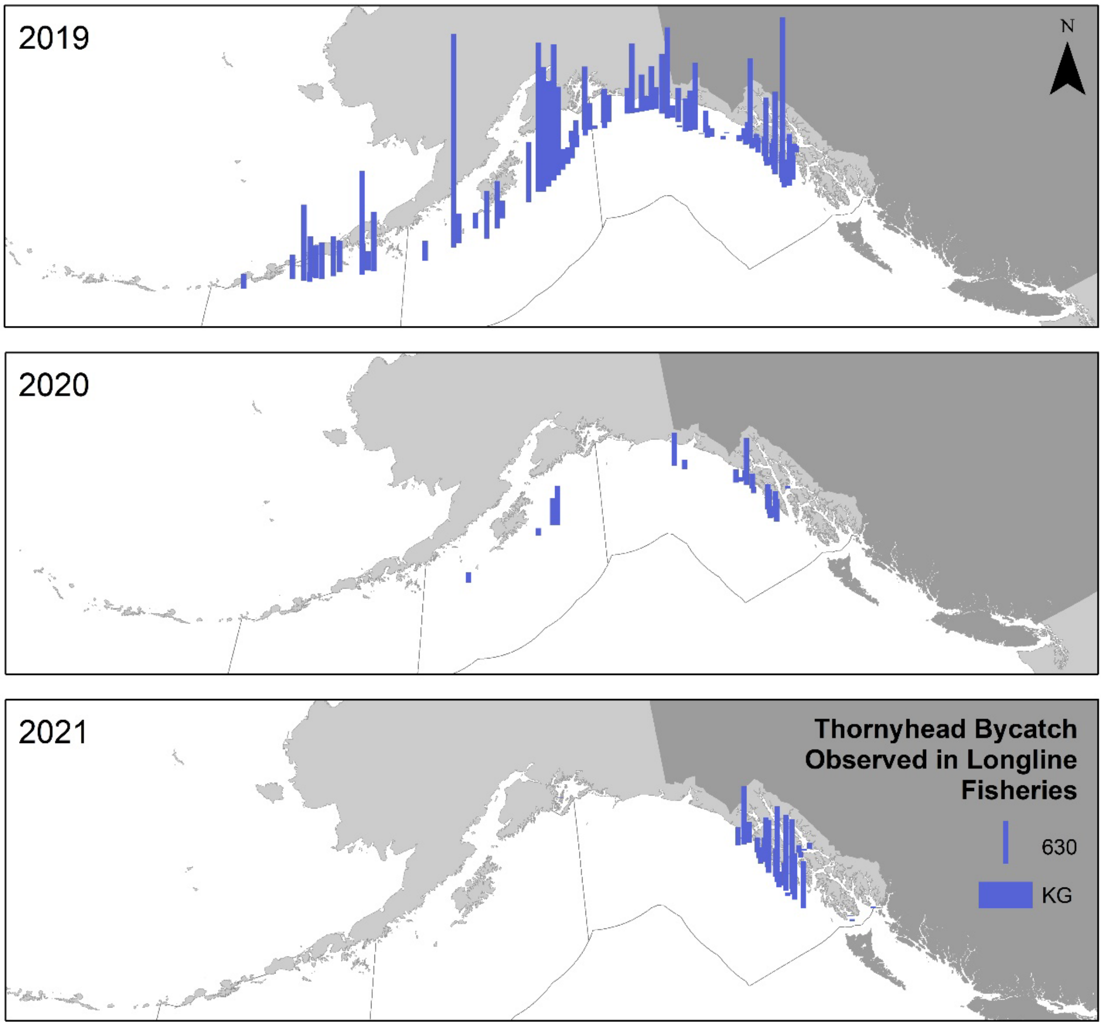

Figure 15-1.-- Spatial distribution of observed thornyhead rockfish catch in the longline fisheries in the GOA from 2019– 2021. Height of the bar represents the catch in kilograms. Note different scale of bars between the panels. Each bar represents non-confidential catch data summarized into 400km^2 grids. Note that catch within the inside waters of Southeast are not within federal waters. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 11, 2022 (https://www.fisheries.noaa.gov/resource/map/alaska-groundfish-fishery-observer-data-map).

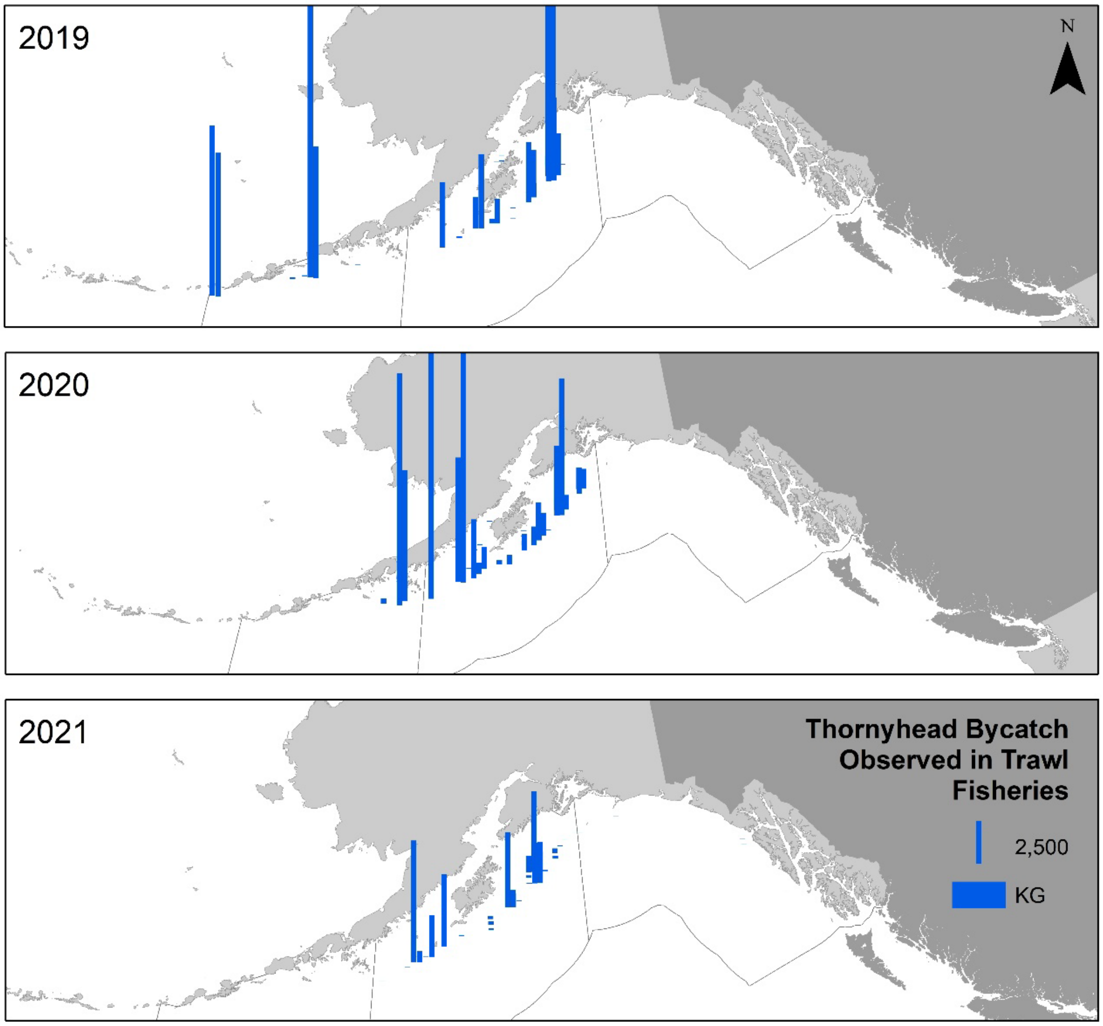

Figure 15-1. cont..-- Spatial distribution of observed thornyhead rockfish catch in the trawl fisheries (bottom three panels) in the GOA from 2019– 2021. Height of the bar represents the catch in kilograms. Note different scale of bars between the panels. Each bar represents non-confidential catch data summarized into 400km^2 grids. Note that catch within the inside waters of Southeast are not within federal waters. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 11, 2022 (https://www.fisheries.noaa.gov/resource/map/alaska-groundfish-fishery-observer-data-map).

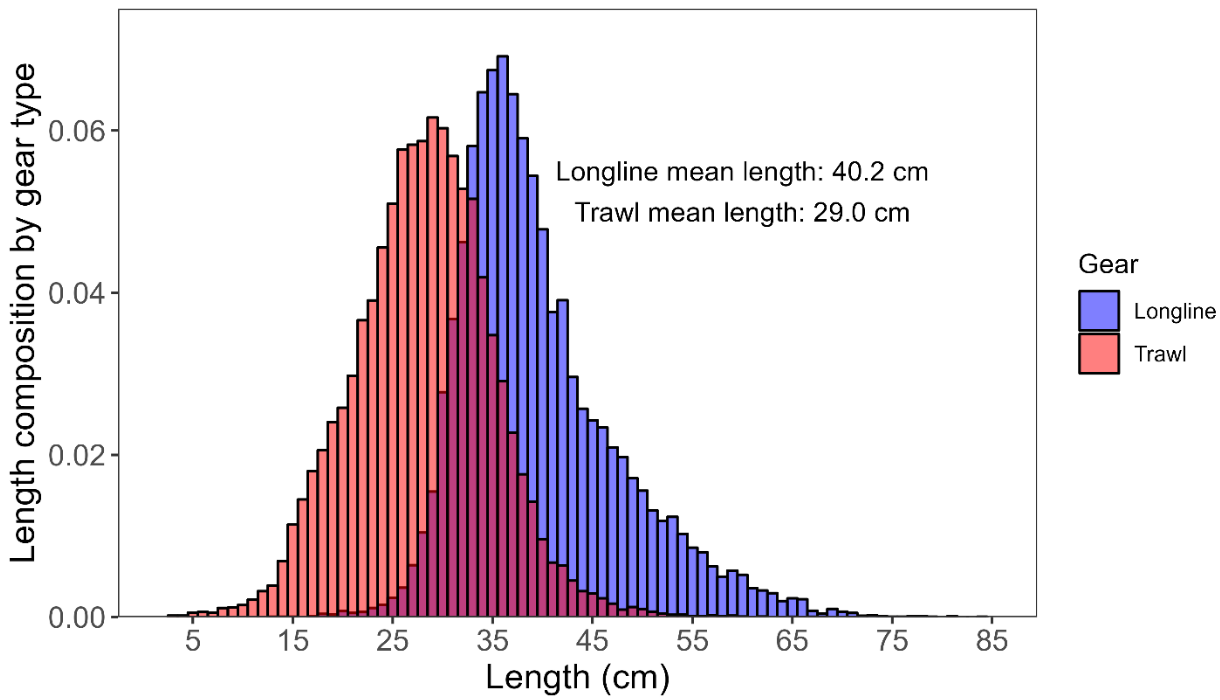

Figure 15-2.--Comparison of shortspine thornyhead length composition from trawl (red) and longline (blue) fisheries using data from 1990–2022.

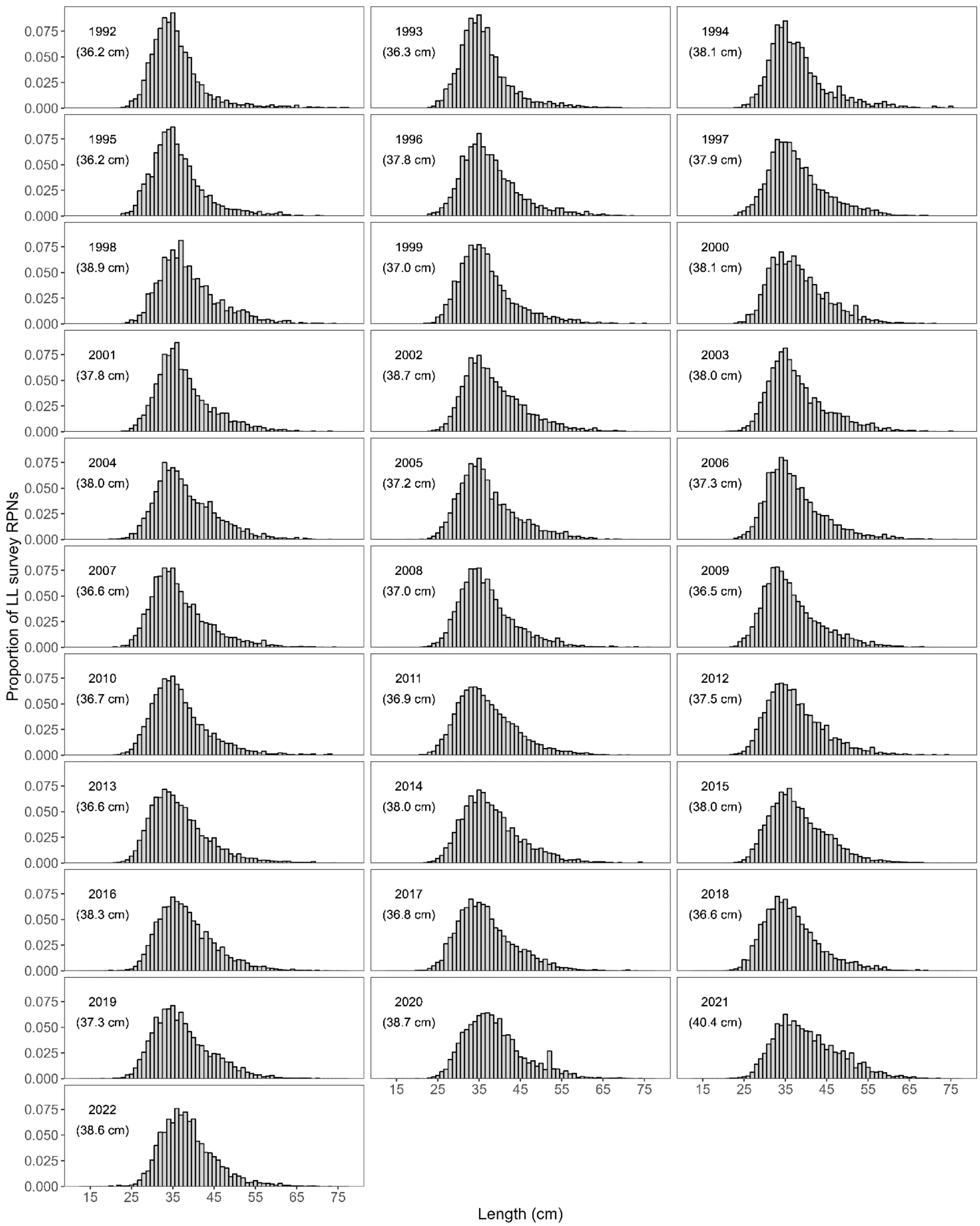

Figure 15-3.-- Size composition of the estimated population of shortspine thornyhead in the Gulf of Alaska based on AFSC longline surveys conducted between 1992 and 2022, and annual mean lengths shown in parentheses.

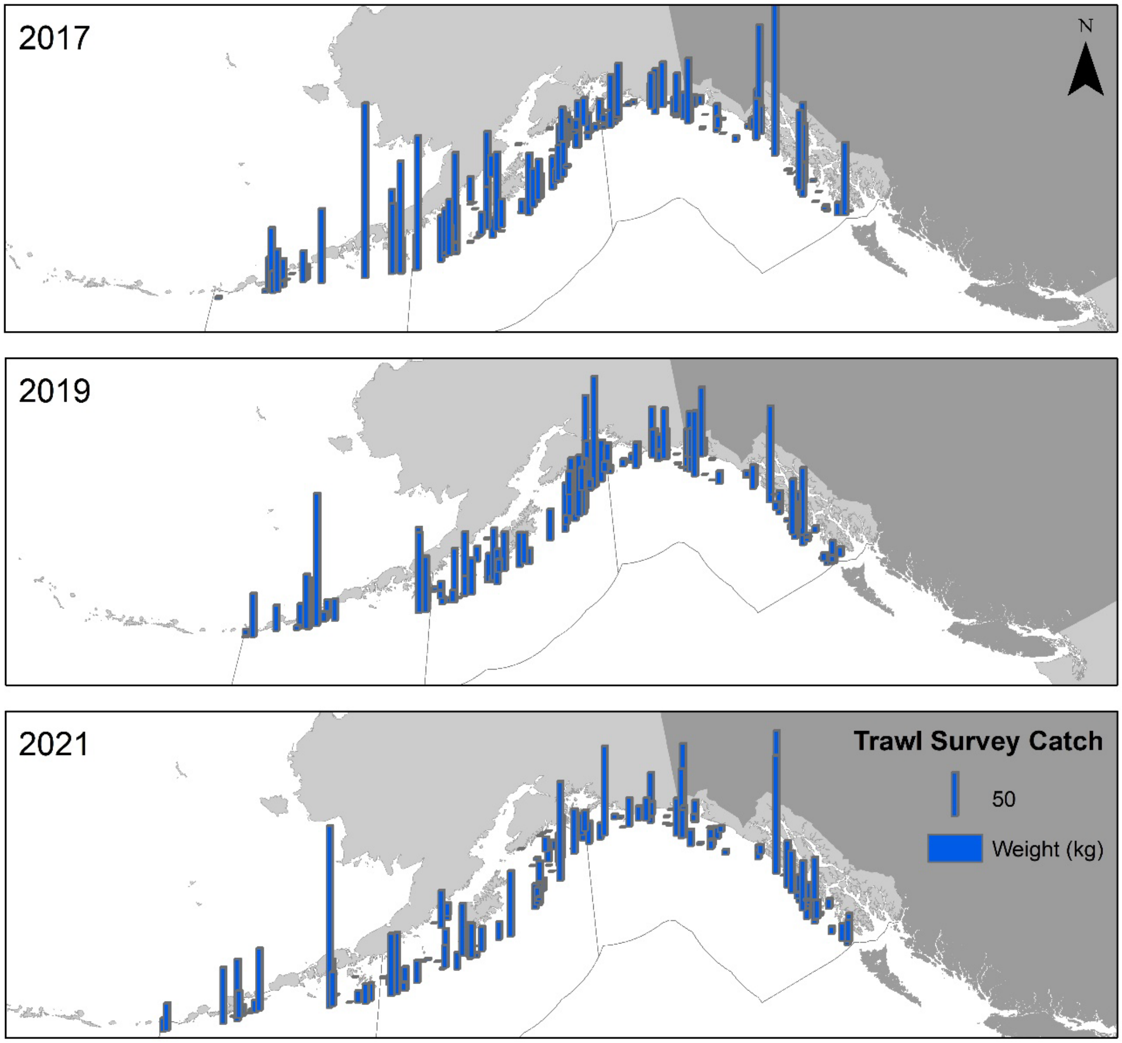

Figure 15-4.--Spatial distribution of thornyhead rockfish catches in the Gulf of Alaska 2017, 2019, and 2021 NMFS bottom trawl surveys.

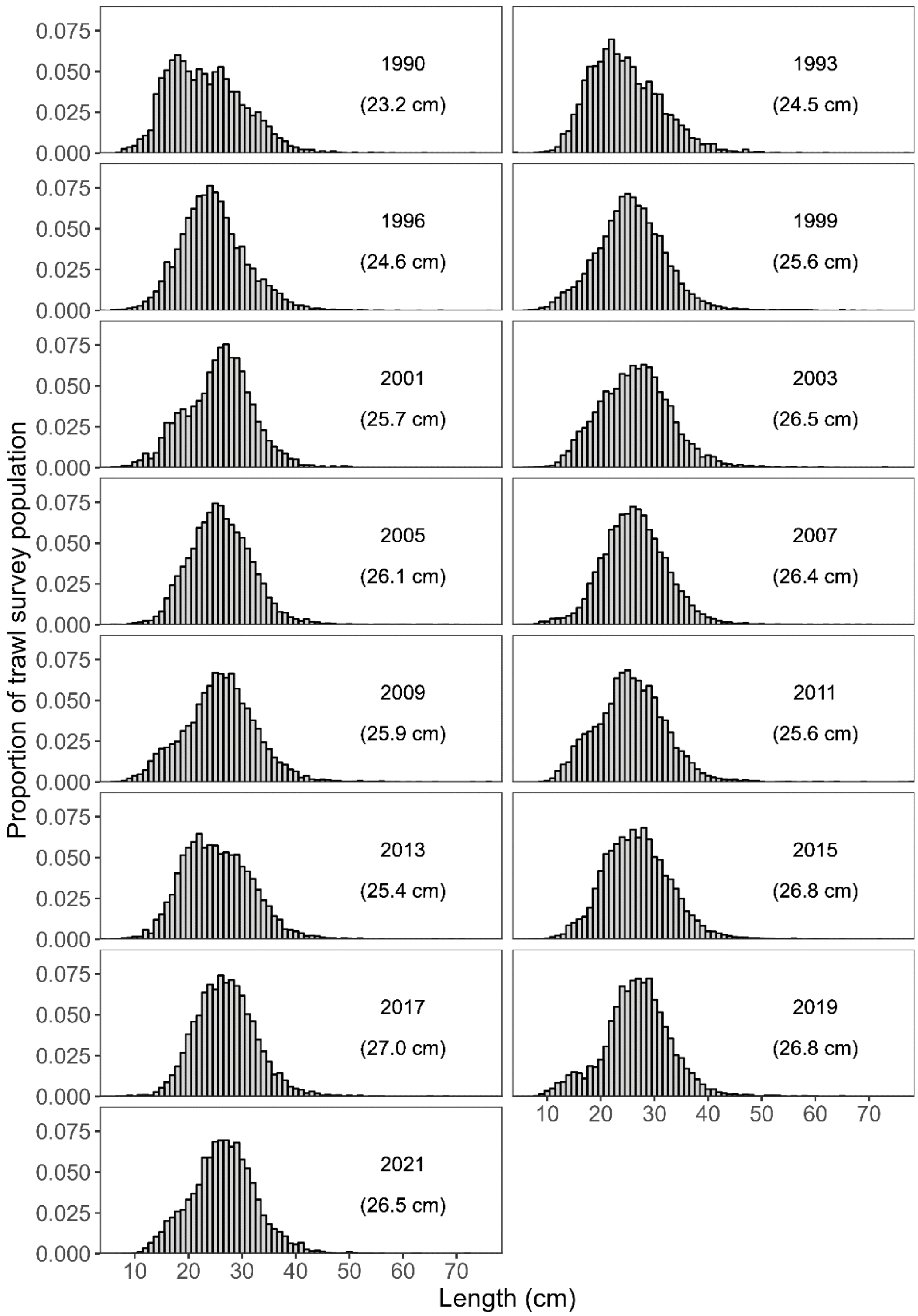

Figure 15-5.-- Size composition of the estimated population of shortspine thornyhead in the Gulf of Alaska based on AFSC bottom trawl surveys conducted between 1990 and 2021, and annual mean lengths shown in parentheses.

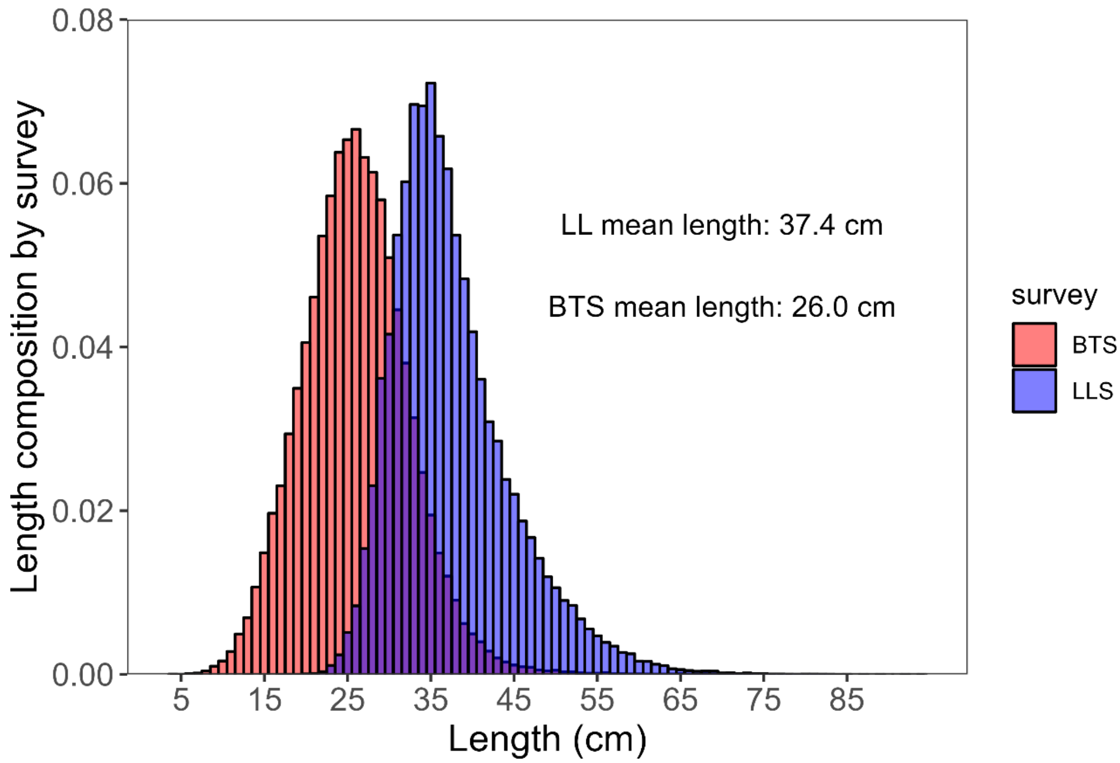

Figure 15-6--Comparison of size composition of the estimated population of shortspine thornyhead in the Gulf of Alaska based on AFSC bottom trawl survey (BTS, shown in red), and the AFSC longline survey (LLS, shown in blue).

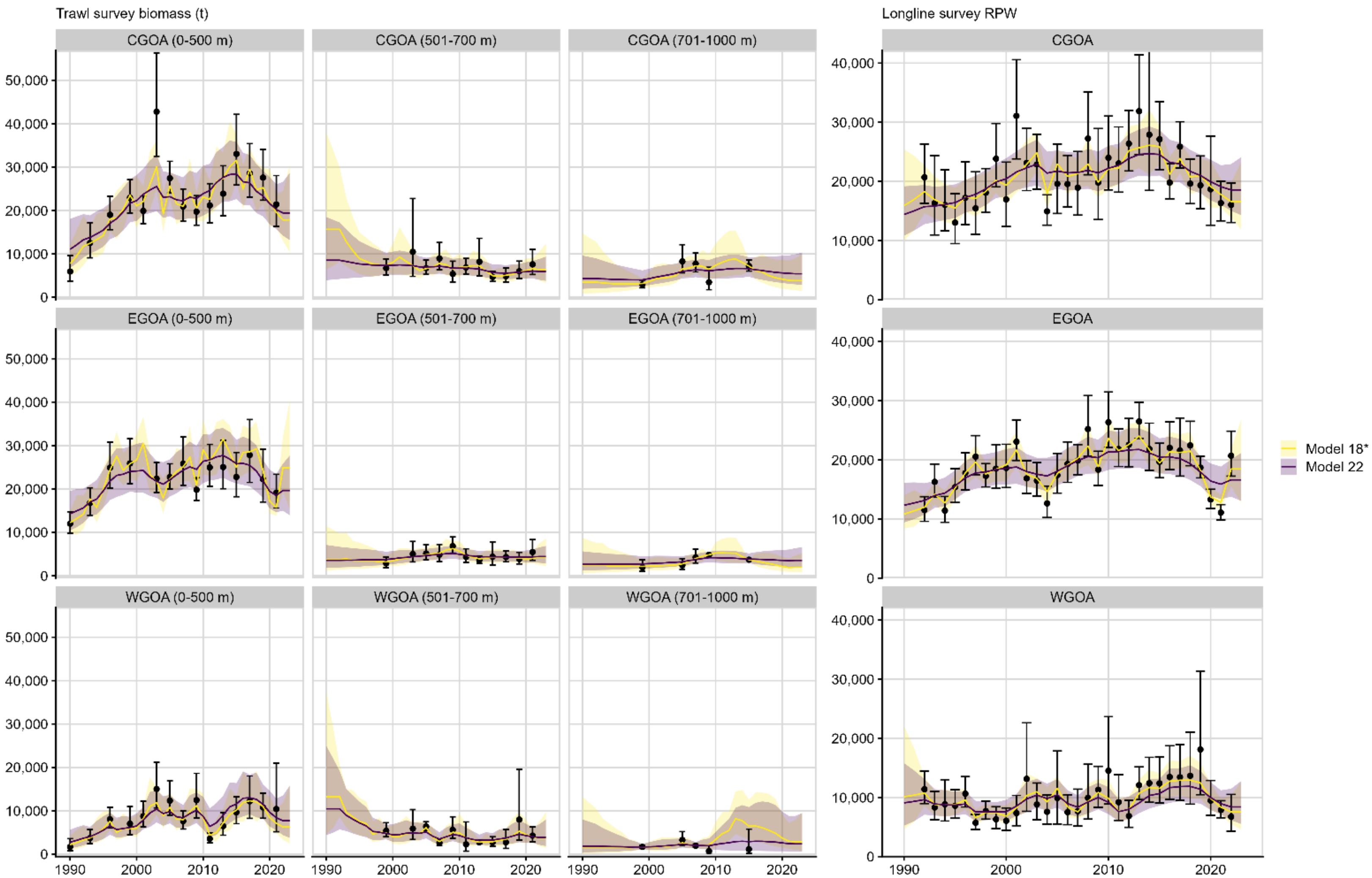

Figure 15-7.-- Biomass estimates (t) of shortspine thornyhead by survey, area, and depth stratum used in the models from the AFSC bottom trawl survey (9 panels on the left) and AFSC longline survey (3 panels on the right). Filled black circles with error bars for the 95% confidence intervals are survey produced estimates (biomass or relative population weight, RPW) fit to the recommended random effects model (solid lines with 95% confidence intervals in shaded regions) for the status quo model Model 18* (yellow), and the recommended Model 22 (purple).

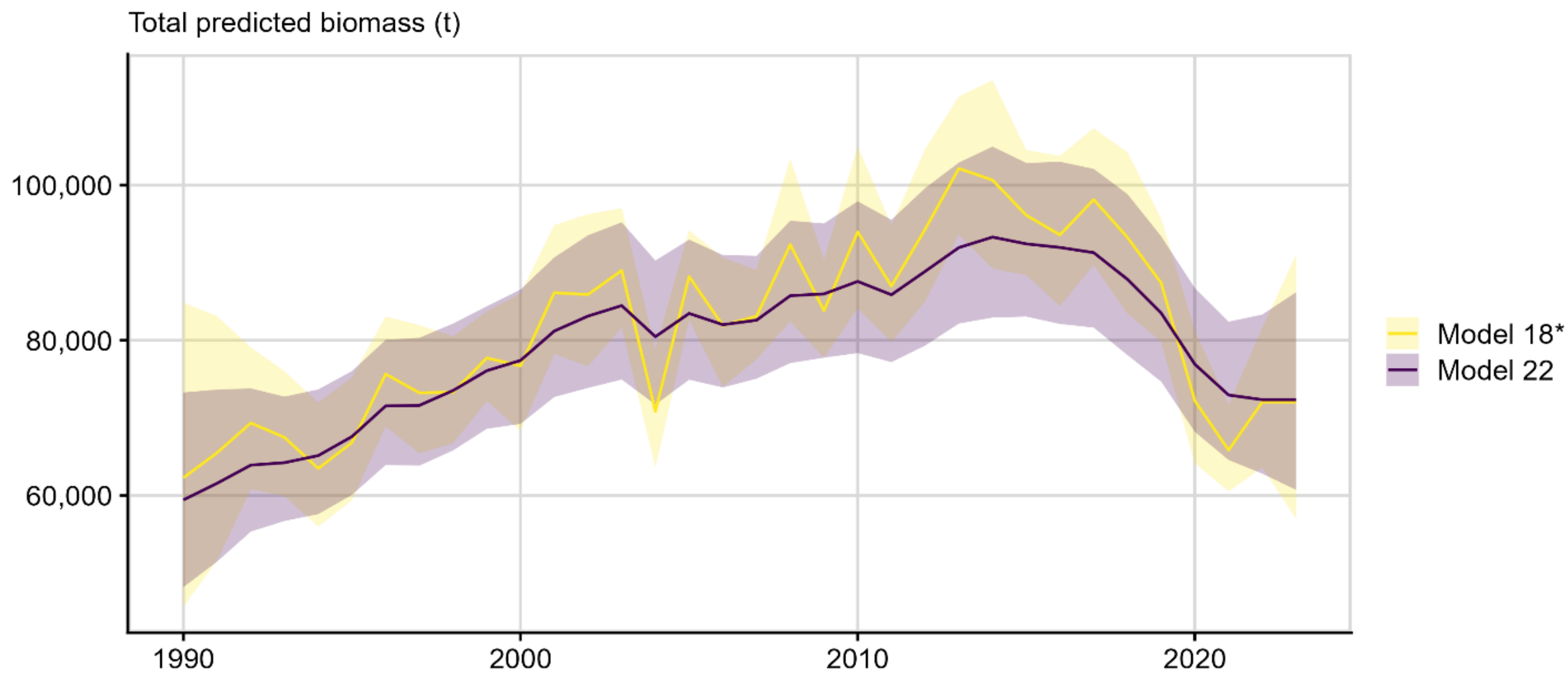

Figure 15-8.--Total Gulfwide biomass estimates (t) of shortspine thornyhead rockfish from the random effects model (solid lines with 95% confidence intervals in shaded regions) for the status quo Model 18* (yellow), and the recommended Model 22 (purple).

Appendix 15A – Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, non-commercial removals in the Gulf of Alaska (GOA) are presented. Non-commercial removals are estimated total removals that do not occur during directed groundfish fishing activities (Table 15A-1). This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates.

Research catches of thornyhead rockfish for the years 1977–2021 are listed in Table 15A-1. Although data are not available for a complete accounting of all research catches, the values in the table indicate that generally these catches have been modest. The majority of research removals of thornyhead rockfish are taken by the Alaska Fisheries Science Center's (AFSC) annual longline survey. Other research activities that harvest minor amounts of thornyhead rockfish include other trawl research activities conducted by the AFSC and the Alaska Department of Fish and Game (ADFG), and the International Pacific Halibut Commission's (IPHC) longline survey. There are no records of recreational harvest or harvest that was non-research related. The non-commercial removals show that a total of approximately 10 t of thornyhead rockfish was taken in 2021 during research cruises (Table 15A-1). This total is approximately 2.9% of the reported commercial catch of 345 t for thornyhead rockfish in 2021 (see Table 15-1 in the main document). Therefore, this presents no risk to the stock especially because commercial catches in recent years have been much less than ABCs.

Table 15A-1.--Research catches of GOA thornyheads (t), 1977–2021. Estimates from IPHC survey and “other” sources only available since 2010.

Year	AFSC LL Survey	AFSC Trawl Survey	Japan US LL Survey	IPHC LL Survey	Other	Total
1977		1				1
1978		1				1
1979		5	3			8
1980		1	5			6
1981		10	5			14
1982		6	4			10
1983		1	4			5
1984		24	3			27
1985		12	4			16
1986		2	4			5
1987		17	4			20
1988	2	0	5			7
1989	3	0	5			8
1990	3	4	4			11
1991	4		3			7
1992	5		4			9
1993	5	5	4			14
1994	4		5			9
1995	5					5
1996	6	6				12
1997	6					6
1998	6	9				15
1999	6	23				29
2000	5					5
2001	7	2				9
2002	5					5
2003	5	7				12
2004	4					4
2005	5	9				14
2006	5					5
2007	5	9				14
2008	7					7
2009	6	7				13
2010	9	<1		<1	<1	9
2011	10	4		<1	<1	14
2012	9			<1	<1	9
2013	13	4		<1	<1	17
2014	10			<1	<1	10
2015	10	8		0.5		18.5
2016	9			<1		9
2017	11	5		<1	<1	16
2018	9			<1	<1	9
2019	9	4		1	<1	14
2020	7			<1	<1	7
2021	6	4		<1	<1	10