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

Katy B. Echave, Peter-John F. Hulson, and S. Kalei Shotwell
November 2015 Plan Team Draft

Executive Summary

Gulf of Alaska rockfish are assessed on a biennial stock assessment schedule designed to coincide with new data from the Gulf of Alaska bottom trawl survey in odd years. For this on-cycle year, we incorporate new survey biomass from the 2015 bottom trawl survey and update auxiliary data sources.

Following the recommendation of the North Pacific Fisheries Management Council, the methodology to estimate exploitable biomass to calculate the ABC and OFL values has changed to the use of a random effects model.

This is the first full assessment for the Gulf of Alaska thornyhead stock complex since 2011 (Murphy and Ianelli 2011, http://www.afsc.noaa.gov/refm/docs/2011/GOAthornyhead.pdf).

Summary of Changes in Assessment Inputs

Changes in the input data:

1. Total catch weight for GOA thornyheads is updated with partial 2015 data through 13 October 2015.
2. Length compositions from the 2012, 2013, 2014, and 2015 longline and trawl fisheries were added.
3. Biomass and length composition information for GOA thornyheads are updated with 2015 GOA bottom trawl survey data.
4. Relative population numbers and weights and size compositions for GOA thornyheads from the AFSC annual longline surveys are updated with 2012, 2013, and 2014 and 2015 data.

Changes in assessment methodology:

The methodology used to estimate exploitable biomass to calculate the ABC and OFL values for the 2016 and 2017 fisheries has changed this year to the use of a random effects model utilizing trawl survey data from 1984-2015. This new methodology has been recommended for all Tier 5 stocks managed by the North Pacific Fisheries Management Council.

Summary of Results

For the 2016 fishery, we recommend the maximum allowable ABC of 1,961 t for thornyhead rockfish. This ABC is 6.5% higher than the 2015 ABC of 1,841 t. The OFL is 2,615 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[a]: 2015	2016	As estimated or *recommended this* year for: 2016	2017
M (natural mortality rate)	0.03	0.03	0.03	0.03
Tier	5	5	5	5
Biomass (t)[a]	81,816	81,816	87,155	87,155
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)	2,454	2,454	**2,615**	2,615
maxABC (t)	1,841	1,841	1,961	1,961
ABC (t)	1,841	1,841	**1,961**	1,961
Status	As determined *last* year for: 2013	2014	As determined *this* year for: 2014	2015
Overfishing	No	n/a	No	n/a

[a] The values for biomass, OFL, and ABC in these two columns are from Shotwell *et al*. 2014. They are based on the exploitable biomass from the 2013 trawl survey combined with an extrapolation method for the deep water strata (Murphy and Ianelli 2011). The current values (as estimated or recommended for 2016 and 2017) are calculated using the random effects (RE) model fit to all survey biomass by region and depth.

Summaries for Plan Team

All values are in metric tons.

Stock Assemblage	Year	Biomass	OFL	ABC	TAC	*Catch*[1]
Thornyhead rockfish	2014	81,816	2,454	1,841	1,841	1,131
	2015	81,816	2,454	1,841	1,841	931
	2016	87,155	2,615	1,961		
	2017		2,615	1,961		

Stock Assemblage	Area	2015 OFL	ABC	TAC	Catch[1]	2016 OFL	ABC	2017 OFL	*ABC*
Thornyhead rockfish	W		235	235	211		291		291
	C		875	875	526		988		988
	E		731	731	194		682		682
	Total	2,454	1,841	1,841	931	2,615	1,961	2,615	1,961

[1] Catches updated through October 13, 2015: 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 Teams recommend that stock assessment authors calculate biomass for Tier 5 stocks based on the random effects model and compare these values to status quo." (Joint Plan Teams, October 2014)

"*The SSC also requests that stock assessment authors utilize the random effects model for area apportionment of ABCs.*" (SSC, December 2014)

"*The Teams recommend that the random effects survey smoothing model be used as a default for determining current survey biomass and apportionment among areas.*" (Joint Plan Teams, October 2015)

Authors present and recommend using estimated biomass based on the random effects model to calculate ABC and OFL values. Biomass results using the new methodology are compared with status quo.

"The Teams recommended that SAFE chapter authors continue to include "other" removals as an appendix. Optionally, authors could also calculate the impact of these removals on reference points and specifications, but are not required to include such calculations in final recommendations for OFL and ABC." (Plan Team, September 2013)

The AKFIN report on Non-Commercial Catch is used in this year's stock assessment for generating the other removals and is presented in Appendix 15A.

Responses to SSC and Plan Team Comments Specific to this Assessment

"The SSC notes that continuation of the deep stations in the trawl survey and the timely continuation of the slope survey is necessary for continued assessment of this species group." (SSC, December 2014)

Several current research efforts are in progress investigating issues regarding bottom trawl survey catchability and survey biomass estimation. The continued reduction in survey effort over the past several surveys should be considered in these initiatives, as there was a 30% drop in stations sampled on the 2013 survey compared to the long-term average. Precision and accuracy of biomass estimates are particularly vulnerable for deep-water species like thornyhead rockfish due to the already low number of stations sampled in the deep strata. The 2015 trawl survey sampled to 1,000 m, but in only 2% of hauls. Authors agree that to obtain the best biomass estimates of thornyhead rockfish, the trawl survey needs to sample all of the depth strata, and we encourage future surveys sample to a depth of 1,000 m. Use of the random effects model to estimate biomass has been implemented in this year's assessment, as it provides an alternative solution to appropriately account for missing depth strata and regions. In future assessments we also plan to explore the use of the longline survey as an alternative or additional index.

Introduction

Thornyheads (*Sebastolobus* species) are groundfish belonging to the family Scorpanenidae, which contains the rockfishes. The family Scorpanenidae 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, 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 depth 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 Gulf of Alaska south to Baja California. Longspine thornyheads are generally found in deeper habitats ranging from 201-1,756 m (Love *et al.* 2005). They are most commonly found below 500 m throughout their range. Off the California coast, longspine thornyheads are 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 Sea 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 Gulf of Alaska 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 *et al*. 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). Studies comparing shortspine thornyhead abundance estimated via submersible data with trawl survey data showed that mean abundance of shortspine thornyheads estimated in submersible surveys were several times higher than those estimated from the trawl survey (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 the 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 thronyheads 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 food habits collections taken in conjunction with Gulf of Alaska (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. Juvenile shortspine thornyheads are thought to be consumed almost exclusively by adult thornyheads. Thornyheads are an uncommon prey in the Gulf of Alaska, as they generally make up less than 2% of even their primary predators’ diets.

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 are 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 tDNA 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 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.

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, Pacific ocean perch, and dusky rockfish. 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 groups include: 1) extended fishing season lasting from May 1 – 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 groups will also affect the secondary species groups. 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 Gulf of Alaska, the “thornyheads” management unit is currently a species complex which includes shortspine thornyhead, longspine thornyhead and broadfin thornyhead. The broadfin thornyhead is currently believed to be extremely unlikely to stray into the Gulf of Alaska, and is very uncommon even in the Aleutian Islands and eastern Bering Sea. Therefore, it would be reasonable for management to exclude the broadfin thornyhead from consideration within the Gulf of Alaska thornyhead species complex. Longspine thornyheads do occur in the Gulf of Alaska, but are much less common than the shortspine thornyheads and are found much deeper. Because longspine thornyheads are infrequently encountered in the GOA trawl surveys and fisheries, and the GOA thornyheads assemblage is overwhelmingly dominated in biomass and catch by the shortspine thornyhead, the historical single species focus of this assessment and harvest recommendations have been for shortspine thornyheads. However, since 1995, the assessment has provided information on longspine thornyheads from GOA trawl surveys and fishery sampling to help determine whether they should be explicitly considered along with shortspine thornyheads for harvest recommendations in future assessments. The rest of this document will refer to either shortspine or longspine thornyheads explicitly, and will ignore broadfin thornyheads because they do not occur in the Gulf of Alaska.

All shortspine thornyheads in the Gulf of Alaska 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 Gulf of Alaska. This apportionment is to disperse the catch across the Gulf and prevent possible depletion in one area. Separate management has been applied to shortspine thornyheads on the U.S. west coast (e.g., Hamel 2005), and 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 (Reuter and Spencer 2006).

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 2003-2015 were provided by NMFS Regional Office Catch Accounting System (CAS), and accessed through the Alaska Fishery Information Network (AKFIN) database. Previous catch and discard estimates for 2003-2009 included catches and discards from fisheries prosecuted in state of Alaska waters (Lowe and Ianelli 2009). These data were removed from the thornyhead rockfish assessment in 2011, and are no longer included in the reported catch estimates.

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 1,220 t for the period 1990 through 2003. Thornyhead catch over time indicates most is retained (83% since 2005) and since the late 1980s the distribution of catch being mostly from trawlers has shifted to mostly longline gear (62% for 2005-2015; Table 15-2). Recent catches (2004 to the present) have averaged around 805 tons (Table 15-1). This drop in recent catches appears to be due to a decrease in thornyhead catches in the deep water flatfish and rockfish fisheries, as thornyhead catches in the sablefish fishery has increased in recent years (Table 15-3).

Historically, except for the years 1992 to 1994, thornyhead total catch has been less than the Allowable Biological Catch (ABC) and Total Allowable Catch (TAC, Table 15-1). The high (relative to the TAC) thornyhead catches in 1992 to1994 are 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. Since 2000, the NPFMC has set relatively low TACs for GOA thornyheads due to uncertainty in assessment model results which suggested that higher quotas would be sustainable. The assessment model uncertainty resulted from inadequate age and growth information and low levels of biological sampling from the fisheries. Therefore in 2003, the use of the assessment model was suspended. The Tier 5 biomass based approach to calculating ABC and OFL, which was initiated in 2003, results in more conservative ABCs and OFLs. Even with this relative conservatism in recent thornyhead management, fisheries do not appear to be constrained by small TACs for thornyheads.

Catches by management area for 2005-2015 are given in Table 15-1. Over this time period, about 50% of the total Gulf thornyhead catch comes from the Central Gulf, 25% from the Western Gulf, and 25% from the Eastern Gulf. The distribution of thornyhead catches ranges broadly throughout the GOA and is consistent over recent years for the different gear types (Figure 15-1, Lowe and Ianelli 2009).

Survey research 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. In recent years, the sablefish fishery has accounted for nearly 90% of thornyhead discards (Table 15-4). Gulfwide discard rates[1] (% of the total catch discarded within a management category) of thornyhead rockfish are listed below for the years 1991-2015:

Year	Thornyhead rockfish
1991	7.4%
1992	24.0%
1993	35.2%
1994	40.3%
1995	23.5%
1996	26.1%
1997	24.6%
1998	14.0%
1999	21.5%
2000	14.8%
2001	8.9%
2002	13.0%
2003	9.3%
2004	11.6%
2005	9.5%
2006	12.4%
2007	7.5%
2008	12.0%
2009	14.1%
2010	13.1%
2011	14.6%
2012	23.5%
2013	40.7%
2014	17.8%
2015	23.9%

[1]1991-2015: National Marine Fisheries Service, Alaska Region, Catch Accounting System, accessed via the Alaska Fishery Information Network (AKFIN). Updated through October 13, 2015.

Data

Fishery data

Catch

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

Size and Age Composition

Length frequency data from the 2012-2015 trawl and longline fisheries are shown in Figure 15-2; in general, longline fisheries capture larger thornyheads than trawl fisheries (average length of 39 cm versus 29 cm), perhaps because they operate in deeper waters and hook selectivity tends to select for larger fish. 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

Two longline surveys of the continental slope in the Gulf of Alaska provide data on the relative abundance of thornyhead rockfish in this region: the earlier Japan-U.S. cooperative longline survey, and the ongoing Alaska Fisheries Science Center (AFSC) domestic longline survey. These surveys compute relative population numbers (RPNs) and relative population weights (RPWs) for fish on the continental slope as indices of stock abundance. The surveys are primarily directed at sablefish, but also catch considerable numbers of thornyhead rockfish. Results for both surveys concerning rockfish, however, should be viewed with some caution, as the RPNs and RPWs do not take into account possible effects of competition for hooks with other species caught on the longline, especially sablefish. 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. Further research is needed on the effect of hook competition between slow, low metabolism species such as shortspine thornyheads and faster, more actively feeding sablefish. Rodgveller *et al*. (2008) found evidence of competition for hooks in the longline surveys between sablefish and giant grenadiers (*Albatrosia pectoralis*), and between sablefish and shortraker (*Sebastes borealis*) and rougheye rockfish (*Sebastes aleutianus*).

The cooperative longline survey was conducted annually during 1979-94, but RPNs for rockfish are only available for the years 1979-87 (Sasaki and Teshima 1988).

The AFSC domestic longline survey has been conducted annually since 1988, and RPNs and RPWs have been computed for each year (only data since 1992 is presented, Table 15-5). For thornyhead rockfish, Gulfwide RPNs have ranged from a low of approximately 45,000 in 2004 to a high of approximately 98,000 in 2013. Although there has been an overall increasing trend in RPNs, there is still a considerable amount of fluctuation between adjacent years. Some of the fluctuations may be related to changes in the abundance of sablefish, as discussed above, regarding competition for hooks among species. The domestic survey results show that abundance of thornyhead rockfish is highest in the central Gulf of Alaska: the Kodiak and Chirikof areas have consistently had the greatest RPN and RPW values for thornyhead rockfish (Table 15-5).

Longline Survey Size Compositions

Length frequency data from the 2013-2015 longline surveys are shown in Figure 15-3. The longline survey length data are very consistent with distinct modes at 34-36 cm.

AFSC Trawl Survey Biomass Estimates

Bottom trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 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 Gulf of Alaska; furthermore, much of the survey effort in the western and central Gulf of Alaska 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. To deal with this latter problem, fishing power comparisons of rockfish catches have been conducted for the various vessels used in the surveys (for a discussion see Heifetz *et al*. 1994). The reader should be aware that an element of uncertainty exists as to the standardization of the 1984 and 1987 surveys.

The bottom trawl surveys provide much information on thornyhead rockfish, including estimates of absolute abundance (biomass, Table 15-6) and population length compositions, 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 2001 survey and surveys conducted during the early 1990s did not extend to the deeper depths (500-700 m and 701-1,000 m depth strata). 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 Gulf. 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 Gulf. 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 (Figure 15-4); for example, the 2015 estimated survey shortspine biomass of 89,241 t is a 24% increase from the 2013 survey estimate. This follows biomass decreases of 7%, 16%, 22%, and 38% in 2005, 2007, 2009, and 2011 from the 2003 estimate. The Western GOA 2015 estimate increased 38% from the 2013 Western GOA estimate while the Central and Eastern GOA estimates increased 33% and 7%. This increase in biomass reverses the downward trend seen in biomass estimates since 2003. The 2003 survey estimate of 101,576 t is the largest biomass of the survey time series, though the 2003 survey did not sample 700-1,000 m. Spatial distribution of catches of thornyhead rockfish in the last three GOA trawl surveys indicate the fish are rather evenly spread along an offshore band along the continental slope (Figure 15-5).

Compared with many other rockfish species, the biomass estimates for thornyhead rockfish have historically shown relatively moderate confidence intervals and 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 an indication of the generally even distribution of thornyhead rockfish.

Despite the relative precision of the biomass estimates, historically, assessment authors have been uncertain whether the trawl surveys are accurately assessing abundance of thornyhead rockfish. Nearly all the catch of these fish is found on the upper continental slope at depths of 300-700 m. A considerable portion of this area in the GOA is not trawlable by the survey’s gear because of the area’s steep and rocky bottom, except for gully entrances where the bottom is more gradual. In addition, these depths have not always been sampled by the trawl survey.

Trawl Survey Size Compositions

Size compositions for thornyhead rockfish from the 2011, 2013, and 2015 trawl surveys were all consistently unimodal with modes at 24-27 cm (Figure 15-6). These are substantially lower than the mode for the longline survey (Figure 15-3), suggesting that the two surveys may capture different parts of thornyhead population.

Analytic Approach

Modeling Approach

Due to difficulties in ageing thornyheads and issues raised with previous age-based methods using length composition data, recent assessments have all used a biomass-based approach based on trawl survey data to calculate ABCs. We continue to use this approach in the present assessment, however, following the recommendations by the Plan Team Survey Averaging Work Group and the SSC, methodology for calculating exploitable biomass has changed to the use of a random effects model (RE). The process errors (step changes) from one year to the next are the random effects to be integrated over and the process error variance is the free parameter. The observations can be irregularly spaced; therefore this model can be applied to datasets with missing data. Large observation errors increase errors predicted by the model, which can provide a way to weight predicted estimates of biomass (http://www.afsc.noaa.gov/REFM/stocks/Plan _Team/2012/Sept/survey_average_wg.pdf). Estimates were made using the 1984-2015 GOA trawl survey time series for biomass and estimates of uncertainty. The RE model was fit separately by region and depth strata to account for missing survey data, and then summed to obtain Gulfwide biomass. The exploitable biomass from the most recent GOA trawl survey (expanded to missing depth strata) was previously used to determine the recommended ABC (Shotwell *et al.* 2013).

Thornyhead in the GOA are managed under Tier 5, where OFL = M * estimated exploitable biomass, where M represents natural mortality, and F_{ABC} is estimated by 0.75 * M. The acceptable biological catch (ABC) is obtained by multiplying F_{ABC} by the estimated exploitable biomass, ABC $\leq$ 0.75 * M * biomass. M is assumed equal to 0.03 and is discussed in the following section.

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 50-100 years (Kastelle *et al.* 2000, Cailliet *et al.* 2001), but these have high-variance estimates due to sample pooling and other methodological issues. A recent 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.

A contracted age study was completed in August, 2009 (Black 2009). Results were limited as shortspine thornyheads are extremely difficult to age. 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 Gulf of Alaska.

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[a]	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

Harvest Recommendations

Since broadfin thornyheads do not range into the GOA they should not be considered within the GOA thornyheads assemblage.

At present, we do not attempt to estimate natural mortality or apply Tier 5 assessment methods to longspine thornyheads (*S. altivelis*) in the GOA. Our fishery sampling indicates that this species is rarely encountered in fisheries (likely because most fisheries operate at depths shallower than 500 m in the GOA), and surveys suggest that it is uncommon relative to shortspine thornyheads in Alaska, even in its preferred depths from 500 to 1,000 m. The center of longspine thornyhead abundance appears to be off the U.S. West Coast, not in Alaska. Furthermore, the TAC established based on the biomass and natural mortality of shortspine thornyheads has not been fully exploited since 1994, suggesting that fishing pressure on thornyheads in general is relatively light. Therefore, additional management measures specific to longspine thornyheads in the GOA are not recommended at this time. 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. Therefore, the historical single species focus of this assessment on shortspines seems appropriate, and we continue to make harvest recommendations specific to shortspine thornyheads in the GOA.

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).

Methodology for determining current exploitable biomass used to calculate the ABC and OFL values for the 2016 fishery has changed to the use of a random effects model. The RE model was fit to the 1984-2015 GOA trawl survey timeseries of biomass values and estimates of uncertainty by region and depth strata (to account for missing survey data), and then summed to obtain Gulfwide biomass. This new methodology has been recommended for all Tier 5 stocks managed by the NPFMC. Applying the F_{ABC} to the estimate of current exploitable biomass (using the new random effects methodology) of 87,155 t (+/- 95% CI of 78,038 and 114,402) for thornyhead rockfish results in a Gulfwide ABC of 1,961 t and OFL of 2,615 t for the 2016 fishery. Previously the exploitable biomass from the most recent GOA trawl survey, expanded to the missing depth strata, was used to determine recommended ABCs (Murphy and Ianelli 2011, Shotwell *et al*. 2013). For comparison purposes, we applied the F_{ABC} to the status quo estimate of exploitable biomass (89,241 t). This results in a Gulfwide ABC of 2,008 t. Biomass estimates using the random effects method are lower (Figure 15-7). There is a 2.4 % difference in the estimated amount of thornyhead rockfish biomass in the GOA between the newly preferred random effects methodology and status quo.

Area Allocation of Harvests

Since 2007, the Gulfwide ABC for thornyhead rockfish was apportioned using the most recent survey biomass estimate. As recommended by the Plan Team Survey Averaging Work Group and the SSC, methodology for calculating the distribution has changed this year to the use of the random effects model to estimate the exploitable biomass by region (Figure 15-8). Each estimated regional biomass is then multiplied by the respective region's percent distribution. For the 2016 fishery, the percent distribution of exploitable biomass for shortspine thornyhead biomass in the GOA based on the random effects model is: Western Area, 15%; Central Area, 50%, and Eastern Area, 35%. Applying these percentages to the recommended Gulfwide ABC of 1,961 t yields the following apportionments for the GOA in 2016: Western area, 291 t; Central area, 988 t; and Eastern area, 682 t.

GOA Area	2015 Biomass (t)	Percent of Total Biomass	Area ABC Apportionment (t)
Western	12,921	15%	291
Central	43,915	50%	988
Eastern	30,319	35%	682
Gulfwide Total	87,155	100%	1,961

ABC recommendations increased in both the Western and Central Gulf by 19% and 11%, respectively. The recommended Eastern Gulf ABC of 682 t is a 7% decrease from the 2013 ABC of 731 t.

For comparison purposes, we calculated the apportionment of ABC/OFL with the previously used approach (status quo for area allocation; Murphy and Ianelli 2011, Shotwell *et al.* 2013). This results in the following percent distribution of exploitable biomass: Western area, 15.16%. Central area, 50.32%, and Eastern area, 34.52%. Applying these percentages to the status quo calculated ABC of 2,008 yields the following apportionments: Western area, 304 t; Central area, 1,010 t; and Eastern area, 693 t. The percent distribution (for the 2016 fishery) is very similar between the two methods, however, because the RE estimated biomass (87,155 t) is lower than status quo (89,241 t), it is to be expected that the allocated amount of harvest per area be lower as well.

Overfishing Level

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 (87,155 t) yields an overfishing catch limit of 2,615 t for 2016. This stock is not being subjected to overfishing.

Summary

A summary of tier, current exploitable biomass, values of F, and recommended ABC (Gulfwide yield and allocated by area) and OFL using the random effects for thornyhead rockfish is listed below for 2016 (biomass and yield are in t):

Tier	Exploit. biomass	ABC		Overfishing	
		F	Yield	*F*	Yield
5	87,155	$F = 0.75M = 0.0225$	1,961	$F = M = 0.030$	2,615
		Harvest Allocation			
		WGOA	291		
		CGOA	988		
		EGOA	682		

The ABC and OFL values are calculated using the random effects (RE) model. The RE model was fit separately by area, and then summed to obtain Gulfwide biomass. WGOA = Western Gulf of Alaska, CGOA = Central Gulf of Alaska, and EGOA = Eastern Gulf of Alaska.

Ecosystem Considerations

This section focuses on shortspine thornyheads exclusively, because they overwhelmingly dominate 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 (Figure 15-9, upper panel) whereas juveniles prey more on invertebrates and are therefore at a lower trophic level (15-9, lower panel). 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 (Figure 15-10). During these years, approximately 52% of adult GOA shortspine thornyhead exploitation rate was due to the fishery, 22% due to predation, and 26% "unexplained". Adult and juvenile groups were not modeled separately in the EBS and AI, so the upper panel of Figure 15-10 includes all thornyheads in those two ecosystems. Combining adults and juveniles with different sources of mortality could account for the apparent differences between the GOA and BSAI in the overall dominance of fishing versus predation mortality. However, 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 1990's (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

1990's in that ecosystem, followed by "toothed whales" (sperm whales), which consume a similar range of thornyheads annually (Figure 15-11, lower panel). 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 (Figure 15-12). 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 food habits 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 (Figure 15-13, upper panel). 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 (Figure 15-13, lower panel). Other important prey of shortspine thornyheads include crabs, zooplankton, amphipods, and other benthic invertebrates, and thornyheads are estimated to consume up to an additional 1,000 metric tons of each of these prey annually in the GOA (Figure 15-13). 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 (Figure 15-14).

Changes in habitat quality

The physical habitat requirements for thornyheads are relatively unknown, and changes in deepwater habitats have not been measured in the GOA. 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 (*Sebastes alutus*), sablefish (*Anoplopoma fimbria*), 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. The GOA sablefish fishery removes, as bycatch, the highest weight of nontarget species of any GOA fishery. Most of this bycatch is grenadiers. Fisheries for Pacific halibut also catch thornyheads and other rockfish, as well as skates and sharks, but they are largely unmonitored, so it is difficult to assess the impacts of these fisheries on the ecosystem.

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 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. The bycatch of halibut fisheries are largely unmonitored, but estimated to have high bycatch (and potentially discards) of sharks.

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 are 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 15-7. 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 thornyhead 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.

Acknowledgements

We thank Sarah Gaichas and Sandra Lowe for having developed the background information presented in this assessment.

Literature Cited

Alverson, D. L., A. T. Pruter, and L. L. Ronholt. 1964. A study of demersal fishes and fisheries of the northeastern Pacific Ocean. H. R. MacMillan Lectures in Fisheries, Inst. Fish. Univ. Brit. Columbia, Vancouver, B.C., 190 p.

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA Tech Memo. NMFS-AFSC-178. 298 p.

Berger, J.D, J.E. Smoker, and K.A. King. 1986. Foreign and joint venture catches and allocations in the Pacific Northwest and Alaska fishing area under the Magnuson Fishery Conservation and Management Act, 1977-84. NOAA Tech. Memo. NMFS F/NWC-99. 53p.

Black, B. 2009. Shortspine thornyhead ageing and chronology develeplment. Report to the Alaska Fisheries Science Center, Age and Growth Lab, 7600 Sand Point Way NE, Seattle WA 98115.

Cailliet, G.M., A.H. Andrews, E.J. Burton, D.L. Watters, D.E. Kline, and L.A. Ferry-Grahan. 2001. Age determination and validation studies of marine fishes; do deep-dwellers live longer? Experimental Gerontology 36: 739-764.

Chitwood, P. E. 1969. Japanese, Soviet, and South Korean fisheries off Alaska, development and history through l966. U.S. Fish Wildl. Serv., Circ. 310, 34 p.

Cooper, D.W., K.E. Pearson, and D.R. Gunderson. 2005. Fecundity of shortspine thornyhead (*Sebastolobus alascanus*) and longspine thornyhead (*S. altivelis*) (Scorpaenidae) from the northeastern Pacific Ocean, determined by stereological and gravimetric techniques. Fish Bull 103: 15-22.

Du Preez, C. and V. Tunnicliffe. 2011. Shortspine thornyhead and rockfish (Scorpaenidae) distribution in response to substratum, biogenic structures and trawling. Mar Ecol Prog Ser 425: 217-231.

Else, P., L. Haldorson, and K. Krieger. 2002. Shortspine thornyhead (*Sebastolobus alascanus*) abundance and habitat associations in the Gulf of Alaska. Fish. Bull. 100:193-199.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A Field Guide to Pacific Coast Fishes. Houghton Mifflin Co, Boston MA, 336 p.

Fay, G. 2005. Stock assessment and status of longspine thornyhead (Sebastolobus altivelis) off California, Oregon, and Washington in 2005. Pacific Fishery Management Council, Portland OR. Available at http://www.pcouncil.org/groundfish/gfstocks/LST_08_30_05.pdf

French, R., J. Wall, and V. Wespestad. 1977. The catch of rockfish other than Pacific ocean perch by Japan and the USSR in the Gulf of Alaska. Document submitted to the annual meeting of the INPFC 1977. Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

Gunderson, D.R. 1997. Trade-off between reproductive effort and adult survival in oviparous and viviparous fishes. Canadian Journal of Fisheries and Aquatic Science 54: 990-998.

Hamel, O. 2005. Status and future prospects for the shortspine thornyhead resource in waters off Washington, Oregon, and California as assessed in 2005. Pacific Fishery Management Council, Portland OR. Available at: http://www.pcouncil.org/groundfish/gfsafe0406/2005_SST_assessment.pdf

Heifetz, J., D. M. Clausen, and J. N. Ianelli. 1994. Slope rockfish. In Stock assessment and fishery evaluation report for the 1995 Gulf of Alaska groundfish fishery, p. 5-1 - 5-24. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82: 898.903.

Ianelli, J.N., and D.H. Ito. 1995. Thornyheads. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1996. Nov. 1995. N. Pac. Fish. Mgt. Council, P.O Box 103136, Anchorage, AK 99510.

Ianelli, J.N., D.H. Ito, and M. Martin. 1997. Thornyheads. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1998. Nov. 1997. N. Pac. Fish. Mgt. Council, P.O Box 103136, Anchorage, AK 99510.

Ito, D.H. 1982. A cohort analysis of Pacific Ocean perch stocks from the Gulf of Alaska and Bering Sea regions. Seattle: University of Washington Masters' Thesis, 157 pp.

Jacobson, L. D. 1990. Thornyheads--stock assessment for 1990. Appendix D. *In*: Status of the pacific coast groundfish fishery through 1990 and recommended acceptable biological catches for 1991. Pacific Fishery Management Council. Portland, Oregon.

Jones, D.T., C.D. Wilson, A. DeRobertis, C.N. Rooper, T.C. Weber, and J.L. Butler. 2012. Evaluation of rockfish abundance in untrawlable habitat: combining acoustic and complementary sampling tools. Fish Bull. 110:332-343.

Kastelle, C.R., D.K. Kimura, and S.R. Jay. 2000. Using 210Pb/226Ra disequilibrium to validate conventional ages in Scorpaenids (genera Sebastes and Sebastolobus). Fisheries Research 46: 299-312.

Kline, D.E. 1996. Radiochemical age verification for two deep-sea rockfishes Sebastolobus altivelis and S. alascanus. M.S. Thesis, San Jose State University, San Jose CA, 124 pp.

Laman, E. A., S. Kotwicki, and C.N. Rooper. 2015. Correlating environmental and biogenic factors with abundance and distribution of Pacific ocean perch (*Sebastes alutus*) in the Aleutian Islands, Alaska. Fish Bull. 113:3.

Love, M.S., M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley CA, 405 p.

Love, M.S., C.W. Mecklenberg, T.A. Mecklenberg, and L.K. Thorsteinson. 2005. Resource inventory of marine and estuarine fishes of the West Coast and Alaska: a checklist of north Pacific and Arctic Ocean species from Baja California to the Alaska-Yukon Border. U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division, Seattle, Washington, 98104, OCS Study MMS 2005-030 and USGS/NBII 2005-001.

Lowe, S. and J. Ianelli. 2009. Gulf of Alaska thornyheads. *In* Stock Assessment and Evaluation Report for the Groundfish Resources of the Gulf of Alaska. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, Alaska, 99510. http://www.afsc.noaa.gov/refm/docs/2009/GOAthorny.pdf

Miller, P. P. 1985. Life history study of the shortspine thornyhead, *Sebastolobus alascanus*, at Cape Ommaney, south-eastern Alaska. M.S. Thesis, Univ. Alaska, Fairbanks, AK, 61 p.

Murphy, J., and J.Ianelli. 2011. Thornyhead stock complex. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 1199 – 1238. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. http://www.afsc.noaa.gov/REFM/docs/2011/GOAthorny.pdf

Pearcy, W.G., M.J. Hosie, and S.L. Richardson. 1977. Distribution and duration of pelagic life of larvae of Dover sole, *Microstomus pacificus*, rex sole, *Gyptocephalus zachirus*; and petrale sole, *Eopsetts jordani*, in waters off Oregon. Fish. Bull. U.S. 75:173-183.

Pearson, K.E., and D.R. Gunderson, 2003. Reproductive biology and ecology of shortspine thornyhead rockfish (*Sebastolobus alascanus*) and longspine thornyhead rockfish (*S. altivelis*) from the northeastern Pacific Ocean. Environ. Biol. Fishes 67:11-136.

Reuter, R. and P. Spencer. 2006. BSAI Other Rockfish. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O Box 103136, Anchorage, AK 99510. Available at http://www.afsc.noaa.gov/refm/docs/2006/BSAIorock.pdf

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. No. 191, 382 p.

Rodgveller, C.J., C.R. Lunsford, and J.T. Fujioka. 2008. Evidence of hook competition in longline surveys. Fish. Bull. 106:364-374.

Rooper, C.N. and M.H. Martin. 2012. Comparison of habitat-based indices of abundance with fishery-independent biomass estimates from bottom trawl surveys. Fish Bull. 110:21-35.

Rooper, C.N., M.H. Martin, J.L Butler, D.T. Jones, and M. Zimmermann. 2012. Estimating species and size composition of rockfishes to verify targets in acoustic surveys of untrawlable areas. Fish Bull. 110:317-331.

Sakaguchi, S.O., K. Takishita, T. Goto, H. Shibata, S. Kojima, and S. Tsuchida. 2014. Analyses of age and population genetic structure of the broadbanded thornyhead *Sebastolobus macrochir* in North Japan suggest its broad dispersion and migration before settlement. J. Ocean. 70:457-462.

Sasaki, T., and K. Teshima. 1988. Data report of abundance indices of flatfishes, rockfishes, and shortspine thornyhead and grenadiers based on results from Japan-U.S. joint longline surveys, 1979-1987. Unpubl. manuscr., 5 p. (Document submitted to the annual meeting of the International North Pacific Fisheries Commission, Tokyo, Japan, October 1988.) Fisheries Agency of Japan, Far Seas Fisheries Research Laboratory, 5-7-1 Orido, Shimizu, Japan 424.

Shotwell, S.K., J. Ianelli, and J. Heifetz. 2014. Thornyhead stock complex. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 839 – 842. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. http://www.afsc.noaa.gov/REFM/Docs/2014/GOAthorny.pdf

Siebenaller, J.F. 1978. Genetic variability in deep-sea fishes of the genus Sebastolobus (Scorpaenidae). In Marine Organisms, Edited by B. Battaglia and J. Beardmore. Plenum Press, New York, pp. 95-122.

Sigler, M.F. and H. Zenger. 1994. Relative abundance of Gulf of Alaska sablefish and other groundfish based on the domestic longline survey, 1989. NOAA Tech. Memo NMFS-AFSC-40. 79 p.

Stepien, C.A, A.K. Dillion, and A.K. Patterson. 2000. Population genetics, phylogeography, and systematics of the thornyhead rockfishes (Sebastolobus) along the deep continental slopes of the North Pacific Ocean. Can. J. Fish. Aquat. Sci. 57:1701-1717.

Wakabayashi, K., R.G. Bakkala, and M.S. Alton. 1985. Methods of the U.S.-Japan demersal trawl surveys. P. 7-29. *In* R.G. Bakkala and K. Wakabayashi (eds.), Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during May-August 1979. Int. North Pac. Fish. Comm., Bull. 44.

Wakefield, W.W. 1990. Patterns in the distribution of demersal fishes on the upper continental slope off central California with studies on the role of ontogenetic vertical migration in particle flux. PhD dissertation, University of California: San Diego, CA. 281 p.

Wall, J., R. French, and R. Nelson Jr. 1979. Observations of foreign fishing fleets in the Gulf of Alaska, 1978. Document submitted to the annual meeting of the INPFC 1979. Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

Wall, J., R. French, and R. Nelson Jr. 1980. Observations of foreign fishing fleets in the Gulf of Alaska, 1979. (Document submitted to the annual meeting of the INPFC, Anchorage, AK. Sept. 1979.) 78 p. Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

Wall, J., R. French, and R. Nelson Jr. 1981. Observations of foreign fishing fleets in the Gulf of Alaska, 1980. (Document submitted to the annual meeting of the INPFC, Vancouver, B.C., Canada. Sept. 1981.) Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

Wall, J., R. French, R. Nelson Jr., and D. Hennick. 1978. Observations of foreign fishing fleets in the Gulf of Alaska, 1977. Document submitted to the annual meeting of the INPFC 1978. Northwest and Alaska Fish. Sci. Center, NMFS NOAA, 2725 Montlake Blvd. E. Seattle WA 98112.

Tables

Table 15-1.--Comparison of Gulf of Alaska thornyhead catches (t) by management area and total Gulfwide, Allowable Biological Catch (ABC), and Total Allowable Catch (TAC). Changes in ABC and TAC allocation over time are indicated, where Gulfwide means TAC was not allocated by area within the GOA, and Split W/C/E means that TAC was allocated proportional to survey biomass in the Western, Central, and Eastern GOA management areas.

		Area of		Gulfwide	Gulfwide	Gulfwide	
Year	Western	Central	Eastern	total	ABC	TAC	ABC/TAC
1977				a	a	a	a
1978				a	a	a	a
1979				b	b	b	b
1980[c]				1,485	3,750	3,750	Gulfwide
1981				1,340	3,750	3,750	Gulfwide
1982				787	3,750	3,750	Gulfwide
1983				729	3,750	3,750	Gulfwide
1984				208	3,750	3,750	Gulfwide
1985				82	3,750	3,750	Gulfwide
1986				714	3,750	3,750	Gulfwide
1987				1,877	3,750	3,750	Gulfwide
1988				2,181	3,750	3,750	Gulfwide
1989				2,616	3,800	3,800	Gulfwide
1990				1,576	3,800	3,800	Gulfwide
1991	689	596	250	1,535	1,798	1,398	Gulfwide
1992	249	1015	761	2,025	1,798	1,798	Gulfwide
1993	110	849	378	1,337	1,180	1,062	Gulfwide
1994	162	733	341	1,236	1,180	1,180	Split W/C/E
1995	158	603	267	1,027	1,900	1,900	Split W/C/E
1996	177	595	241	1,013	1,560	1,248	Split W/C/E
1997	148	716	244	1,109	1,700	1,700	Split W/C/E
1998	238	716	195	1,149	2,000	2,000	Split W/C/E
1999	283	583	247	1,113	1,990	1,990	Split W/C/E
2000	340	551	244	1,134	2,360	2,360	Split W/C/E
2001	276	523	196	995	2,310	2,310	Split W/C/E
2002	372	505	169	1,045	1,990	1,990	Split W/C/E
2003	317	715	101	1,133	2,000	2,000	Split W/C/E
2004	276	409	138	823	1,940	1,940	Split W/C/E
2005	190	391	140	720	1,940	1,940	Split W/C/E
2006	197	399	182	781	2,209	2,209	Split W/C/E
2007	341	253	188	798	2,209	2,209	Split W/C/E
2008	271	304	167	736	1,910	1,910	Split W/C/E
2009	231	275	153	665	1,910	1,910	Split W/C/E
2010	139	276	150	569	1,770	1,770	Split W/C/E
2011	146	291	149	629	1,770	1,770	Split W/C/E
2012	172	344	223	739	1,665	1,665	Split W/C/E
2013	304	540	310	1,154	1,665	1,665	Split W/C/E
2014	244	667	220	1,131	1,841	1,841	Split W/C/E
2015[d]	211	526	194	931	1,841	1,841	Split W/C/E

a/ Thornyheads were in the rockfish management group.
b/ Thornyheads were removed from the rockfish category and placed in the other fish category.
c/ Thornyheads became a reported species group in 1980.
d/ 2015 catch estimate is reported catch as of October 13, 2015

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 GOA thornyheads (tons) by gear type[1], 1977-2015.

	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	1,188	60	1,248	228	53	281
1992	1,041	129	1,169	499	356	855
1993	489	173	662	297	377	674
1994	488	222	710	250	277	257
1995	471	165	636	307	77	384
1996	435	170	605	306	94	400
1997	567	224	791	398	61	459
1998	625	112	737	363	49	411
1999	597	197	794	277	42	320
2000	557	92	649	397	75	472
2001	479	52	532	424	37	461
2002	500	89	589	404	46	450
2003	705	70	775	321	36	357
2004	414	66	480	314	30	344
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	194	315	60	375
2011	210	30	240	305	41	346
2012	141	56	197	425	117	542
2013	199	17	216	485	453	938
2014	461	16	477	469	185	654
2015*	284	21	305	425	201	626

[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.

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 2015 catch is incomplete, representing catch reported through October 13, 2015.

Table 15-3.--Estimated catch (%) of thornyhead rockfish in the Gulf of Alaska by target fishery, 2005-2015.

	Target Fishery				
Year	Rockfish	Sablefish	Flatfish	Other	Total
2005	45	47	5	4	100
2006	40	49	7	4	100
2007	38	50	6	6	100
2008	34	53	8	5	100
2009	27	56	10	7	100
2010	19	65	10	7	100
2011	26	61	8	6	100
2012	18	73	6	3	100
2013	9	82	5	4	100
2014	21	57	13	8	100
2015	23	67	5	5	100

Source: National Marine Fisheries Service, Alaska Region, Catch Accounting System, accessed via the Alaska Fishery Information Network (AKFIN). Updated through October 13, 2015.

Table 15-4.-- Gulf of Alaska thornyhead discards (t) by target fishery, 2005-2015; approximate percentage of total discards in parentheses. 2005-2015: National Marine Fisheries Service, Alaska Region, Catch Accounting System, accessed via the Alaska Fishery Information Network (AKFIN). Updated through October 13, 2015.

	Fishery			
Year	Flatfish	Rockfish	Sablefish	Other
2005	7 (10%)	23 (34%)	38 (56%)	<1 (<1%)
2006	4 (4%)	56 (58%)	36 (37%)	<1 (<1%)
2007	16 (27%)	4 (7%)	40 (67%)	<1 (<1%)
2008	8 (9%)	16 (18%)	63 (72%)	1 (1%)
2009	11 (12%)	18 (19%)	64 (68%)	<1 (<1%)
2010	9 (12%)	7 (9%)	58 (78%)	1 (1%)
2011	8 (9%)	20 (22%)	63 (68%)	<1 (<1%)
2012	31 (18%)	21 (12%)	121 (70%)	<1 (<1%)
2013	12 (3%)	5 (1%)	448 (95%)	5 (1%)
2014	10 (5%)	10 (5%)	179 (89%)	3 (1%)
2015	15 (7%)	9 (4%)	206 (89%)	1 (<1%)

Table 15-5.--Relative population number (RPN) and relative population weight (RPW) for Gulf of Alaska thornyhead rockfish in the Alaska Fishery Science Center longline survey, 1992-2015. Data are for the upper continental slope only, 201-1,000 m depth (gullies are not included).

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Thornyhead RPN:												
Shumagin	25,908	18,602	22,004	12,044	15,475	7,842	9,796	8,345	8,546	10,654	17,017	13,691
Chirikof	25,767	19,204	18,830	7,887	11,706	7,964	12,357	14,104	13,569	22,287	20,628	17,409
Kodiak	17,208	20,932	16,358	9,951	9,174	14,330	13,187	13,176	10,004	18,664	14,081	13,417
Yakutat	9,062	11,085	11,620	9,042	6,545	9,035	7,204	10,102	7,807	13,258	7,709	10,603
Southeastern	8,081	9,949	9,205	6,677	6,572	6,937	6,850	8,739	10,535	7,467	6,308	5,079
Total	**86,026**	**79,773**	**78,017**	**45,601**	**49,472**	**46,109**	**49,394**	**54,465**	**50,461**	**72,330**	**65,744**	**60,199**
Thornyhead RPW:												
Shumagin	12,305	8,144	9,138	8,676	10,867	5,852	7,849	6,737	6,147	7,327	12,489	8,978
Chirikof	14,893	8,421	10,022	7,000	11,312	6,594	10,715	14,992	10,724	19,398	15,184	14,346
Kodiak	6,346	8,650	5,842	6,817	6,778	10,047	8,419	8,339	6,621	12,411	9,724	9,446
Yakutat	3,891	4,609	4,799	5,353	4,215	6,450	4,320	5,983	5,055	8,192	4,781	6,385
Southeastern	3,880	4,864	3,176	3,980	4,616	4,300	5,607	5,727	6,445	5,914	4,886	3,943
Total	**41,314**	**34,688**	**32,979**	**31,827**	**37,788**	**33,243**	**36,909**	**41,779**	**34,991**	**53,242**	**47,064**	**43,098**

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Thornyhead RPN:												
Shumagin	11,259	10,910	12,330	13,116	17,281	20,581	23,570	15,333	12,792	21,107	17,557	20,689
Chirikof	10,059	13,726	12,575	15,267	21,555	16,319	18,481	17,537	18,237	24,161	21,422	15,511
Kodiak	11,305	14,545	13,418	11,691	18,492	14,697	18,982	19,364	22,023	24,495	19,256	25,610
Yakutat	8,005	11,733	11,133	9,817	14,943	9,431	15,663	14,593	15,965	17,525	10,895	10,292
Southeastern	4,369	8,147	8,325	10,392	11,059	9,692	11,345	12,028	8,304	10,880	12,183	8,634
Total	**44,996**	**59,061**	**57,780**	**60,284**	**83,330**	**70,720**	**88,042**	**78,856**	**77,320**	**98,168**	**81,314**	**80,736**
Thornyhead RPW:												
Shumagin	7,625	8,972	7,770	7,436	10,501	11,391	14,319	8,942	7,262	12,910	13,088	13,027
Chirikof	7,905	11,036	9,690	10,949	17,153	11,320	13,223	11,986	13,782	18,012	16,668	12,344
Kodiak	7,623	8,934	9,953	7,718	11,398	8,700	11,699	12,300	13,646	14,667	11,861	15,981
Yakutat	4,623	6,901	7,337	6,011	9,119	5,470	9,245	7,988	10,183	10,028	7,308	6,720
Southeastern	3,130	5,041	5,851	7,215	7,059	6,484	6,746	7,572	5,521	7,117	6,200	5,968
Total	**30,906**	**40,883**	**40,600**	**39,330**	**55,229**	**43,366**	**55,232**	**48,787**	**50,394**	**62,734**	**55,124**	**54,040**

Source: 1992-2015: AFSC longline survey database accessed via the Alaska Fishery Information Network (AKFIN)

Table 15-6.--Shortspine (top two panels) and longspine (bottom two panels) thornyhead biomass (t), and the percentage distribution by management area from the bottom trawl surveys in the Gulf of Alaska, 1996-2015. The 1996 and 2001 surveys did not survey the deeper depths >500 m, and the 2003, 2011, and 2013 surveys did not survey the deeper depths >700 m. In addition, the 2001 survey did not survey the Eastern Gulf of Alaska.

		Shortspine Thornyhead Biomass (t)									
Area	Depth (m)	1996	1999	2001	2003	2005	2007	2009	2011	2013	2015
Gulf of	1-100	0	116	46	54	180	212	85	17	0	37.3
Alaska (all areas)	101-200	6,625	4,446	1,776	3,988	5,682	4,742	3,002	5,400	9,077	7,664
	201-300	21,968	23,418	13,619	39,156	28,324	21,330	26,494	20,473	26,659	31,171
	301-500	23,390	27,872	13,220	37,017	28,394	28,063	22,415	23,800	19,639	26,549
	501-700	--	14,952	--	21,360	18,213	16,507	17,790	13,491	14,503	11,774
	701-1000	--	6,531	--	--	13,947	13,920	9,009	--	--	12,047
	Total	**51,984**	**77,336**	**28,661**	**101,576**	**94,740**	**84,775**	**78,795**	**63,180**	**69,878**	**89,241**
	CV	7%	5%	8%	8%	4%	5%	5%	6%	7%	6%
	Lower 95% CI	44,611	69,406	24,249	84,549	86,893	76,132	70,445	55,313	60,049	77,916
	Upper 95% CI	59,356	85,265	33,074	118,602	102,444	93,220	87,146	71,046	79,707	100,567

Table 15-6. cont.

		Shortspine Thornyhead Biomass (t)									
Area	Depth (m)	1996	1999	2001	2003	2005	2007	2009	2011	2013	2015
Western Gulf	1-100	0	4	0	0	63	0	0	17	0	0
	101-200	313	37	0	500	1,108	7	84	202	62	329
	201-300	3,115	2,248	3,981	6,017	5,550	2,910	7,094	1,082	4,012	4,578
	301-500	4,615	4,739	4,771	8,519	5,630	4,702	5,286	2,245	2,402	4,746
	501-700	--	5,389	--	5,887	6,377	2,590	5,605	2,272	2,739	2,733
	701-1000	--	1,679	--	--	3,277	1,943	719	--	--	1,147
	Total	8,043	14,097	8,753	20,922	22,005	12,152	18,789	5,818	9,215	13,533
	% of total biomass	15%	18%	31%	21%	23%	14%	24%	9%	13%	15%
Central Gulf	1-100	0	2	46	54	103	131	13	0	0	37
	101-200	309	690	1,776	1,317	3,000	1,465	559	3,136	5,863	3,380
	201-300	10,456	10,604	9,637	25,386	13,544	8,190	11,880	9,239	10,000	18,635
	301-500	8,265	11,638	8,449	16,030	10,780	11,124	7,270	8,797	8,006	10,973
	501-700	--	6,725	--	10,462	6,728	8,962	5,365	6,885	8,196	4,666
	701-1000	--	2,930	--	--	8,262	7736	3,469	--	--	7,214
	Total	19,030	32,590	19,908	53,250	42,419	37,607	28,556	28,057	32,064	44,906
	% of total biomass	37%	42%	69%	52%	45%	45%	36%	44%	46%	50%
Eastern Gulf	1-100	0	111	--	0	14	81	73	0	0	0
	101-200	6,003	3,719	--	2,172	1,574	3,271	2,358	2,061	3,153	3,955
	201-300	8,398	10,565	--	7,753	9,229	10,230	7,520	10,152	12,646	7,958
	301-500	10,509	11,495	--	12,468	11,983	12,237	9,859	12,758	9,231	10,830
	501-700	--	2,838	--	5,011	5,107	4,956	6,820	4,334	3,569	4,374
	701-1000	--	1,922	--	--	2,408	4,241	4,821	--	--	3,686
	Total	24,911	30,649	--	27,404	30,316	35,016	31,451	29,305	28,600	30,803
	% of total biomass	48%	40%	0%	27%	32%	41%	40%	46%	41%	35%

Table 15-6. cont.

		Longspine Thornyhead Biomass (t)									
Area	Depth (m)	1996	1999	2001	2003	2005	2007	2009	2011	2013	2015
Gulf of Alaska (all areas)	1-100	0	0	0	0	0	0	0	0	0	0
	101-200	0	0	0	0	0	0	0	0	0	0
	201-300	0	0	0	0	0	0	0	0	0	0
	301-500	0	0	0	0	0	0	2.3	0	0	0
	501-700	0	1,652	--	1,394	1,537	1,390	969	1,142	394	802
	701-1000	0	2,950	--	--	1,989	2,993	3,144	--	--	4,744
	Total	**0**	**4,602**	**0**	**1,394**	**3,526**	**4,383**	**4,116**	**1,142**	**394**	**5,546**
	CV	--	11%	--	11%	14%	12%	21%	27%	67%	19%
	Lower 95% CI	--	3,515	--	950	2,390	2,903	1,726	177	0	2,610
	Upper 95% CI	--	5,689	--	1,838	4,661	5,863	6,505	2,107	1,526	8,483

Table 15-6. cont.

		Longspine Thornyhead Biomass (t)									
Area	Depth (m)	1996	1999	2001	2003	2005	2007	2009	2011	2013	2015
Western Gulf	1-100	0	0	0	0	0	0	0	0	0	0
	101-200	0	0	0	0	0	0	0	0	0	0
	201-300	0	0	0	0	0	0	0	0	0	0
	301-500	0	0	0	0	0	0	0	0	0	0
	501-700	0	9.7	--	31.2	0	0	0	0	0	0
	701-1000	0	285	--	--	0	0	0	0	0	0
	Total	0	295	0	31.2	0	0	0	0	0	0
	% of total biomass	--	6%	--	2%	--	--	--	--	--	--
Central Gulf	1-100	0	0	0	0	0	0	0	0	0	0
	101-200	0	0	0	0	0	0	0	0	0	0
	201-300	0	0	0	0	0	0	0	0	0	0
	301-500	0	0	0	0	0	0	0	0	0	0
	501-700	0	289	0	10	385	0	41.4	0	0	0
	701-1000	0	1,646	0	--	779	2,205	2,119	0	0	3,379
	Total	0	1,936	0	10	1,164	2,205	2,160	0	0	3,379
	% of total biomass	--	42%	--	1%	33%	50%	52%	--	--	61%
Eastern Gulf	1-100	0	0	--	0	0	0	0	0	0	0
	101-200	0	0	--	0	0	0	0	0	0	0
	201-300	0	0	--	0	0	0	0	0	0	0
	301-500	0	0	--	0	0	0	2.3	0	0	0
	501-700	0	1,353	--	1,353	1,152	1,390	928	1,142	394	802
	701-1000	0	1,019	--	--	1,210	787	1,025	--	--	1,366
	Total	0	2,372	--	1,353	2,362	2,177	1,955	1,142	394	2,169
	% of total biomass	--	52%	--	97%	67%	50%	47%	100%	100%	39%

Table 15-7.--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 Gulf of Alaska.	Unknown	Unknown

Table 15-7 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

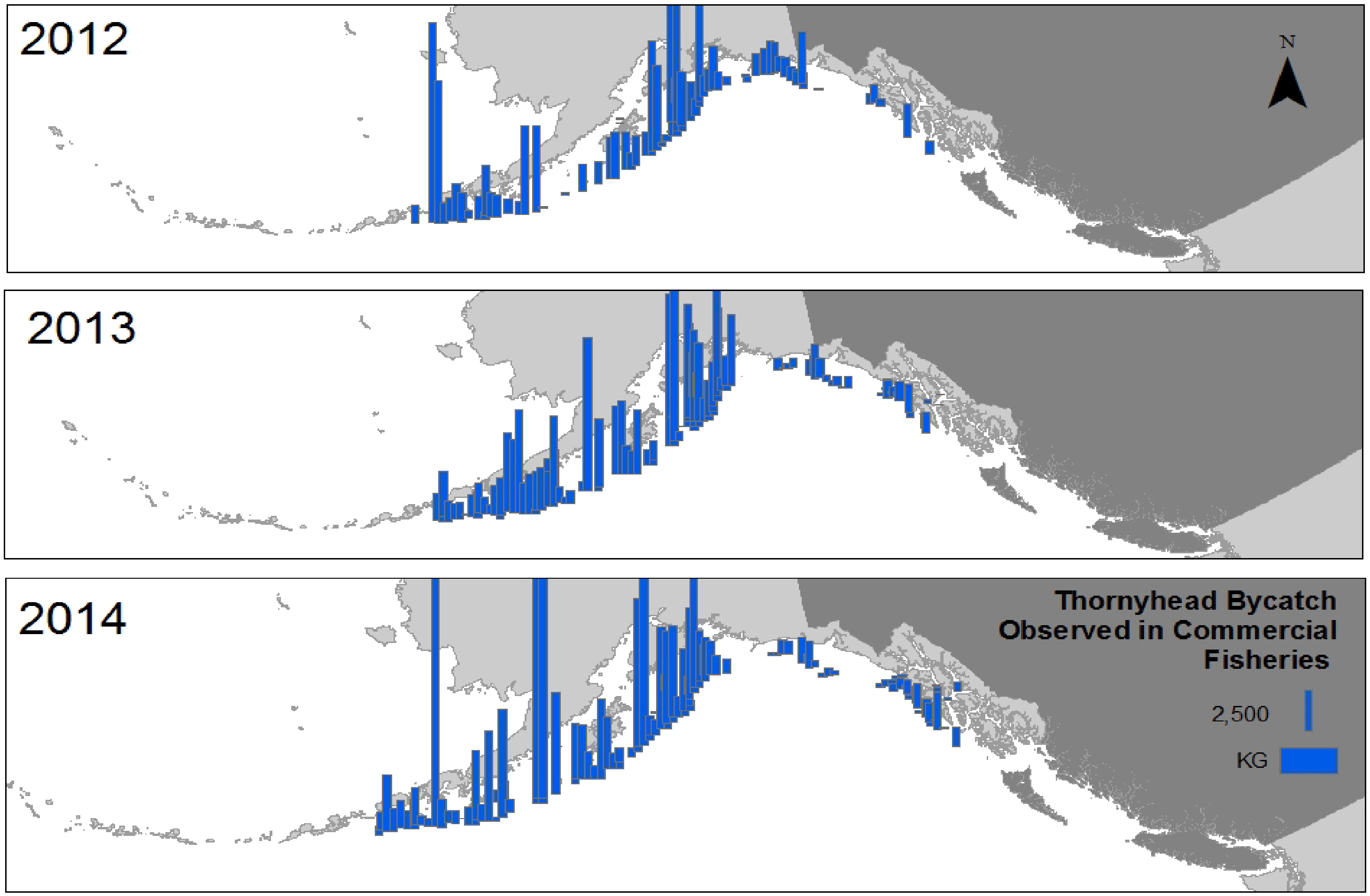


Figure 15-1.-- Spatial distribution of observed thornyhead rockfish catch in the GOA from 2012 - 2014. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 400km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 20, 2015 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

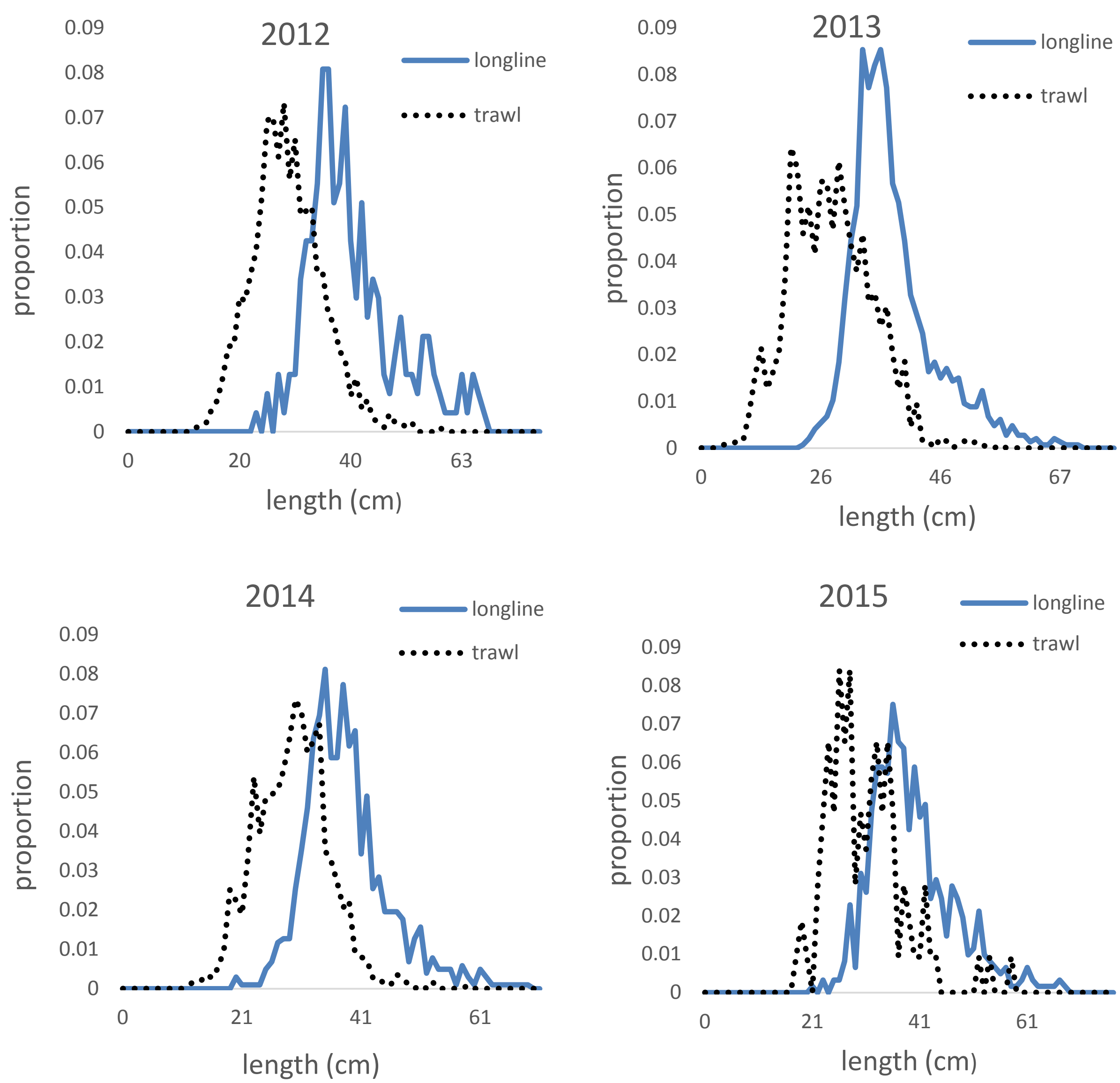


Figure 15-2.--Shortspine thornyhead lengths measured in trawl and longline fisheries, 2012-2015.

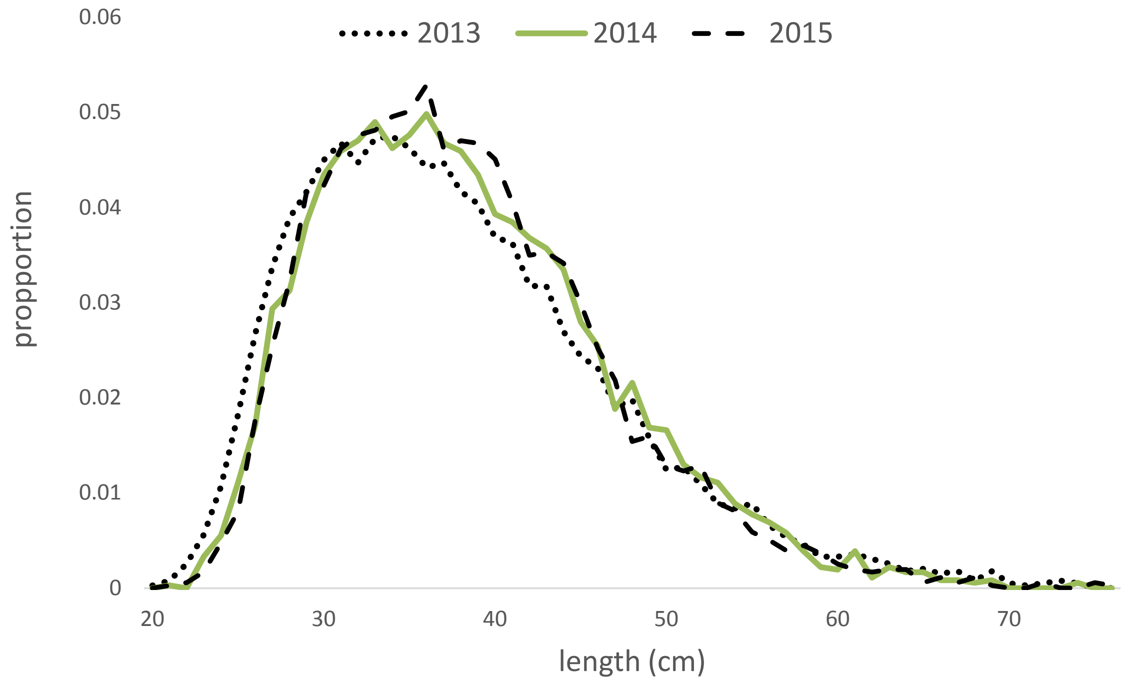


Figure 15-3.--Shortspine thornyhead length frequencies from the NMFS longline surveys, 2013-2015.

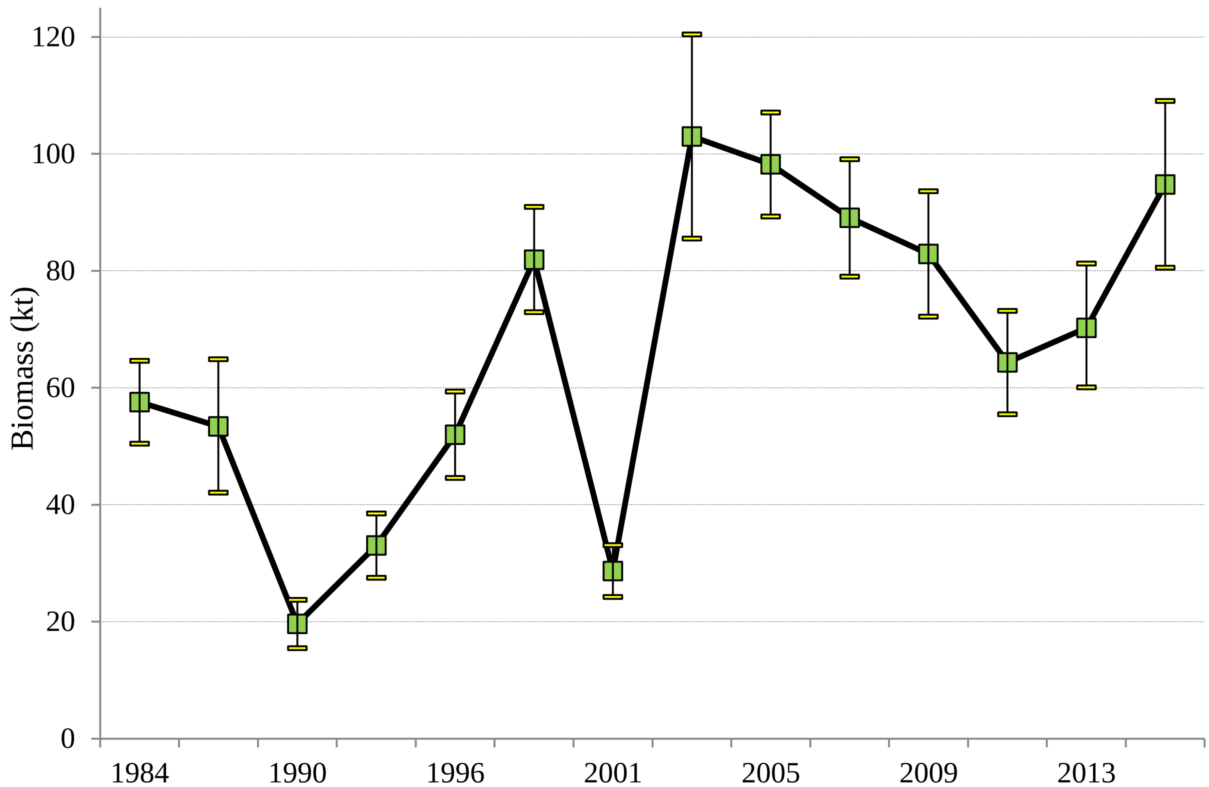


Figure 15-4.--Trawl survey biomass estimates for Gulf of Alaska (GOA) thornyhead rockfish. The 1990, 1993, 1996, and 2001 surveys did not survey depths >500m. The 2003, 2011, and 2013 surveys did not survey depths >700m. The 2001 survey also did not survey the Eastern GOA.

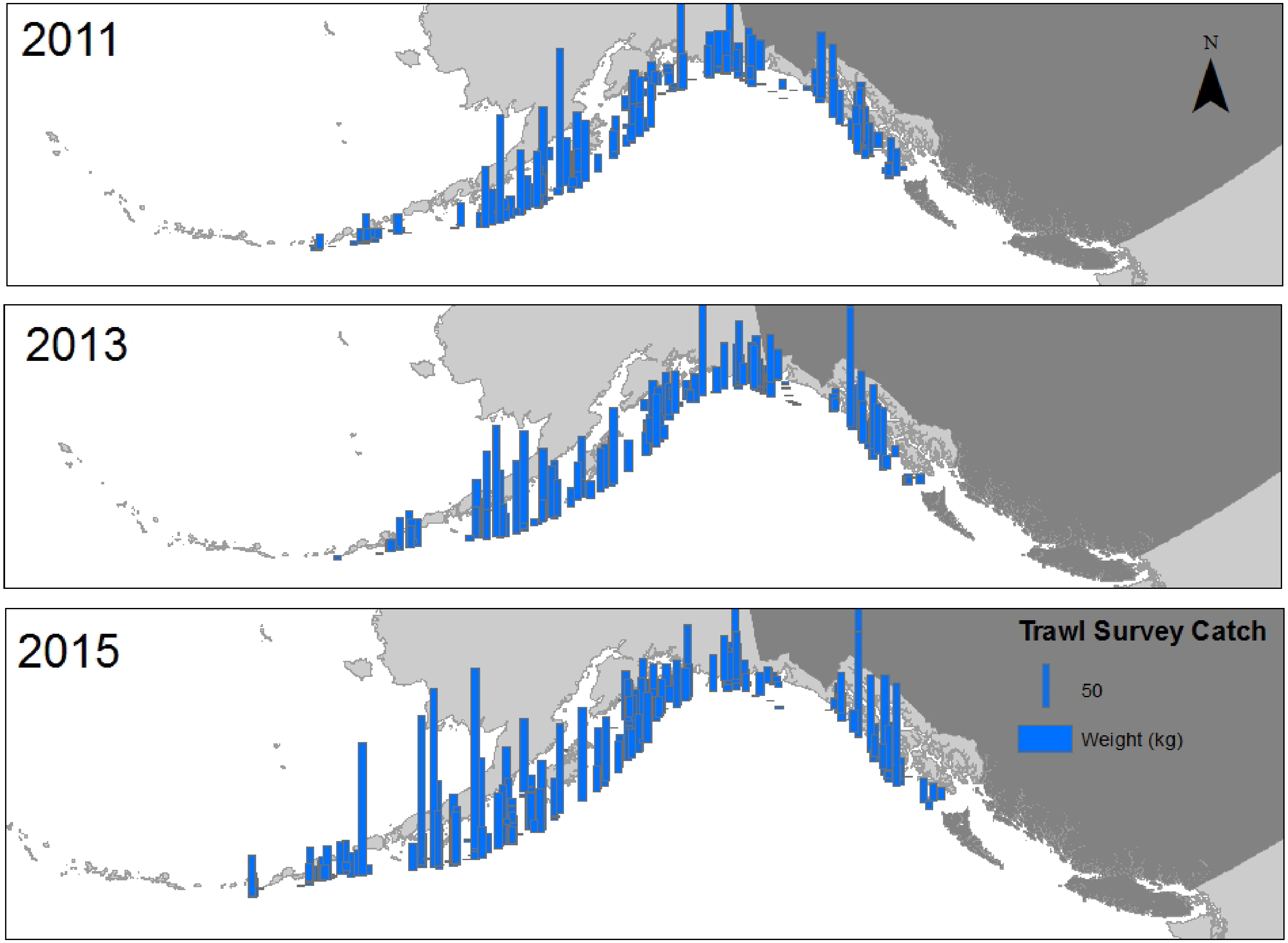


Figure 15-5.--Spatial distribution of thornyhead rockfish catches in the Gulf of Alaska 2011, 2013, and 2015 NMFS bottom trawl surveys.

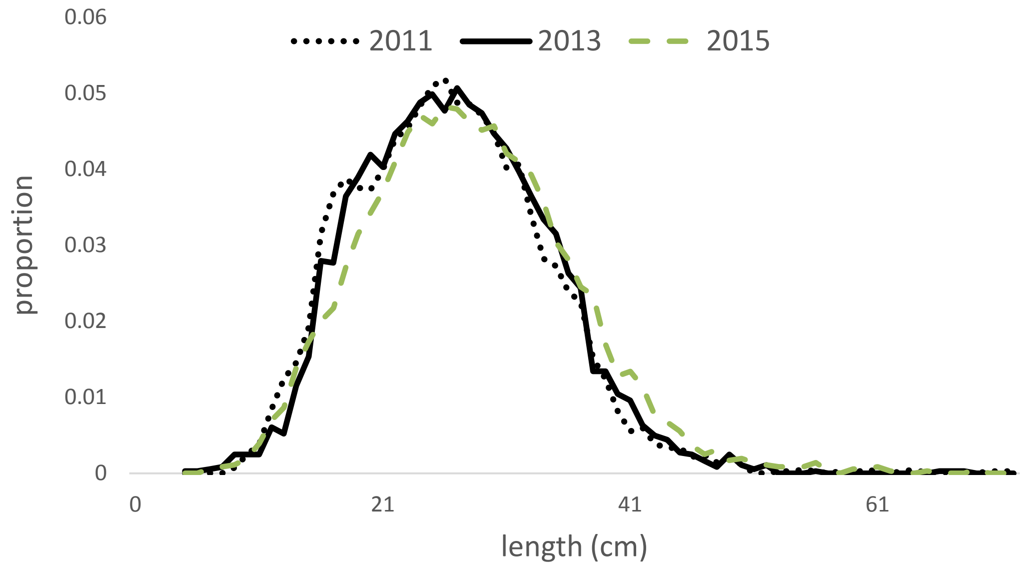


Figure 15-6.--Shortspine thornyhead length frequencies from the 2011, 2013, and 2015 trawl surveys.

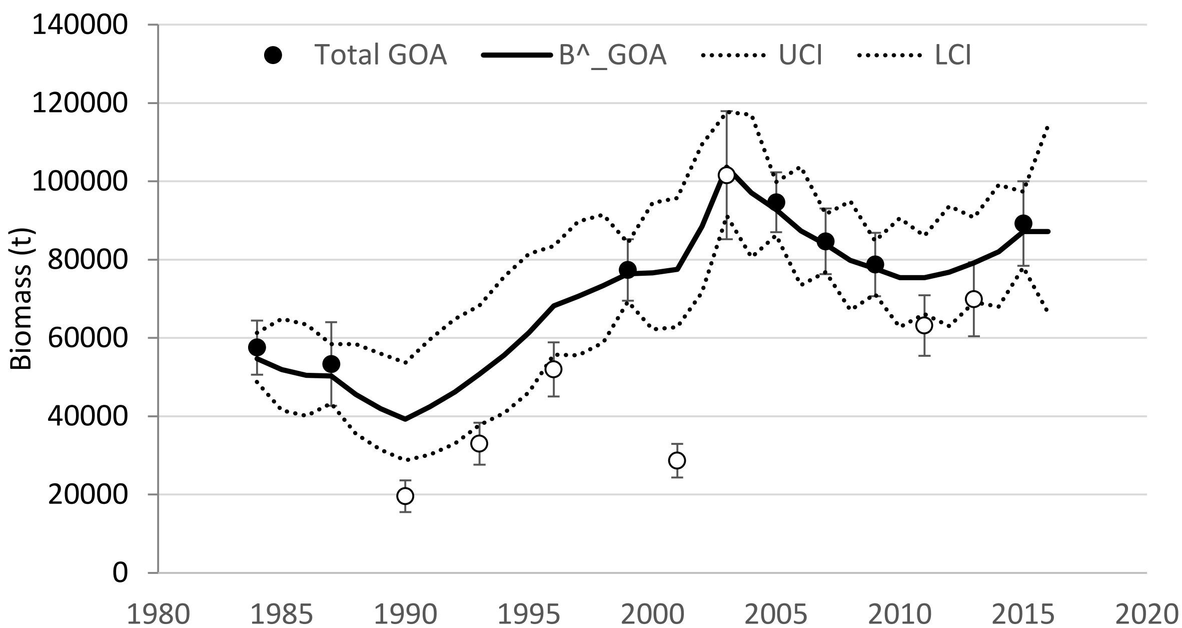


Figure 15-7.--Biomass estimates (t) of thornyhead rockfish from NMFS bottom trawl surveys (filled circle) and from a random effects model (solid black line) that utilizes trawl survey biomass estimates from all years (with 95% confidence intervals, UCI/LCI). Open circle points in the figure denote years with missing regional/depth strata data.

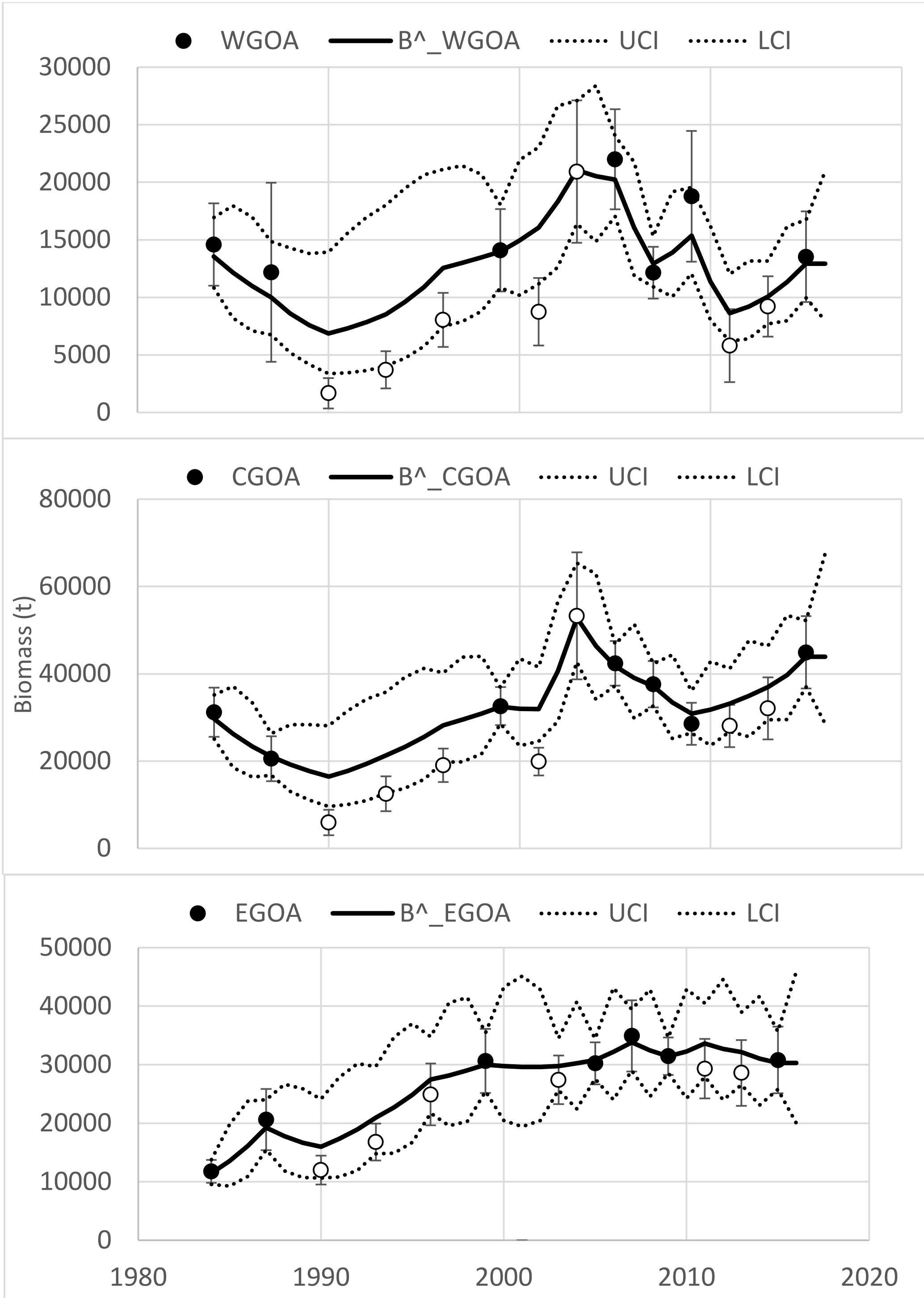
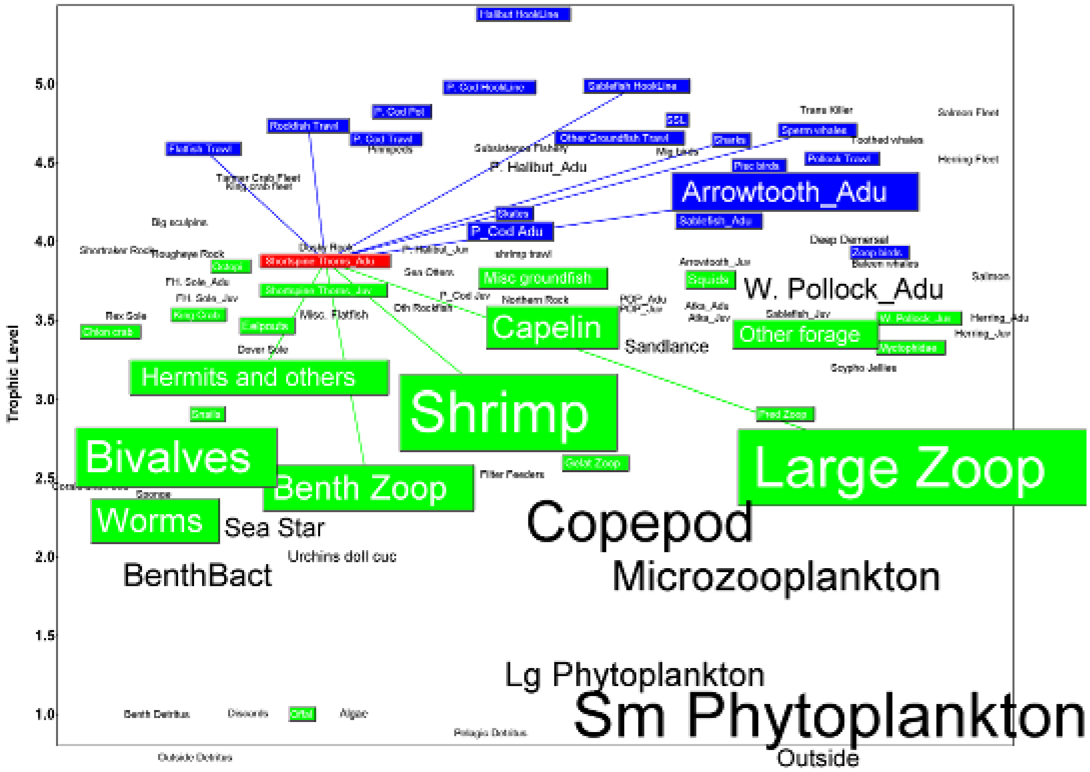


Figure 15-8.-- Biomass estimates (t) of thornyhead by area from NMFS bottom trawl surveys (filled circle) and from a random effects model (solid black line) that utilizes trawl survey biomass estimates from all years (with 95% confidence intervals, UCI/LCI). Open circle points in the figure denote years with missing depth strata data. Top panel is the Western Gulf of Alaska (WGOA) area, middle panel is the Central Gulf of Alaska (CGOA) area, and bottom panel is the Eastern Gulf of Alaska (EGOA) area. Please note the different scales between panels on the y-axis.



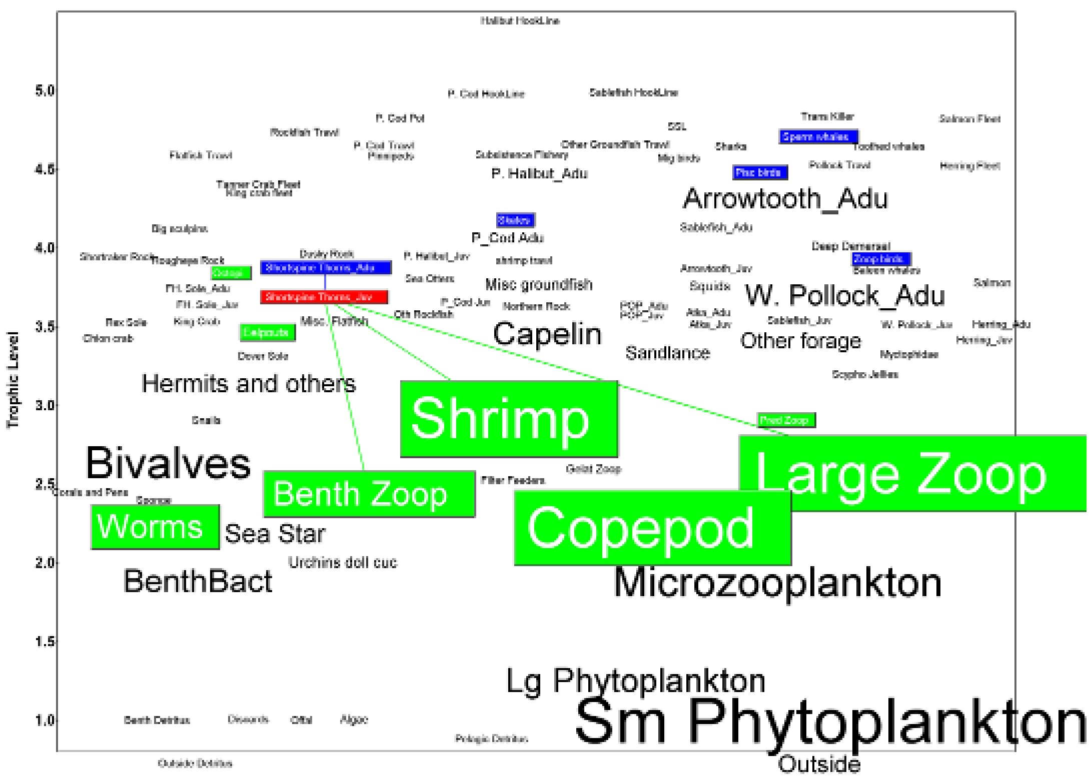


Figure 15-9.--Position of shortspine thornyheads within GOA food webs: adults (marked red in upper panel) and juveniles (marked red in lower panel). Groups shaded blue are predators of shortspine thornyheads, and groups shaded green are prey. Similar information for longspine thornyheads is not available.

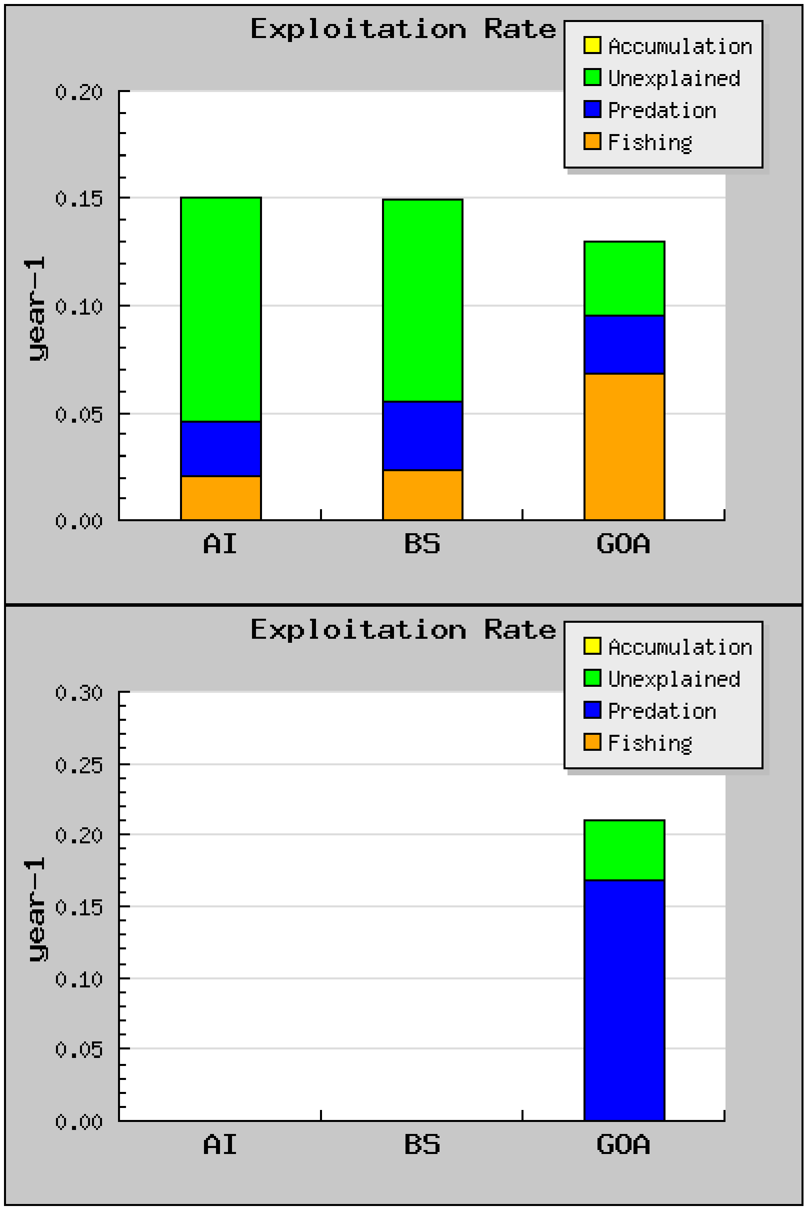


Figure 15-10.--Comparison of exploitation rates for shortspine thornyheads across Alaskan ecosystems. Adult shortspine thornyheads (upper panel) have higher predation than fishing mortality in the AI and EBS, but higher fishing mortality in the GOA. Juvenile shortspine thornyheads (lower panel) were only modeled in the GOA, where they do not experience fishing mortality but do experience substantial predation mortality. Because juvenile thornyheads were not explicitly modeled in AI and EBS ecosystem models, juvenile mortality is included along with adult mortality in the top panel for AI and EBS, which exaggerates the differences between predation and fishing mortality between the two systems.

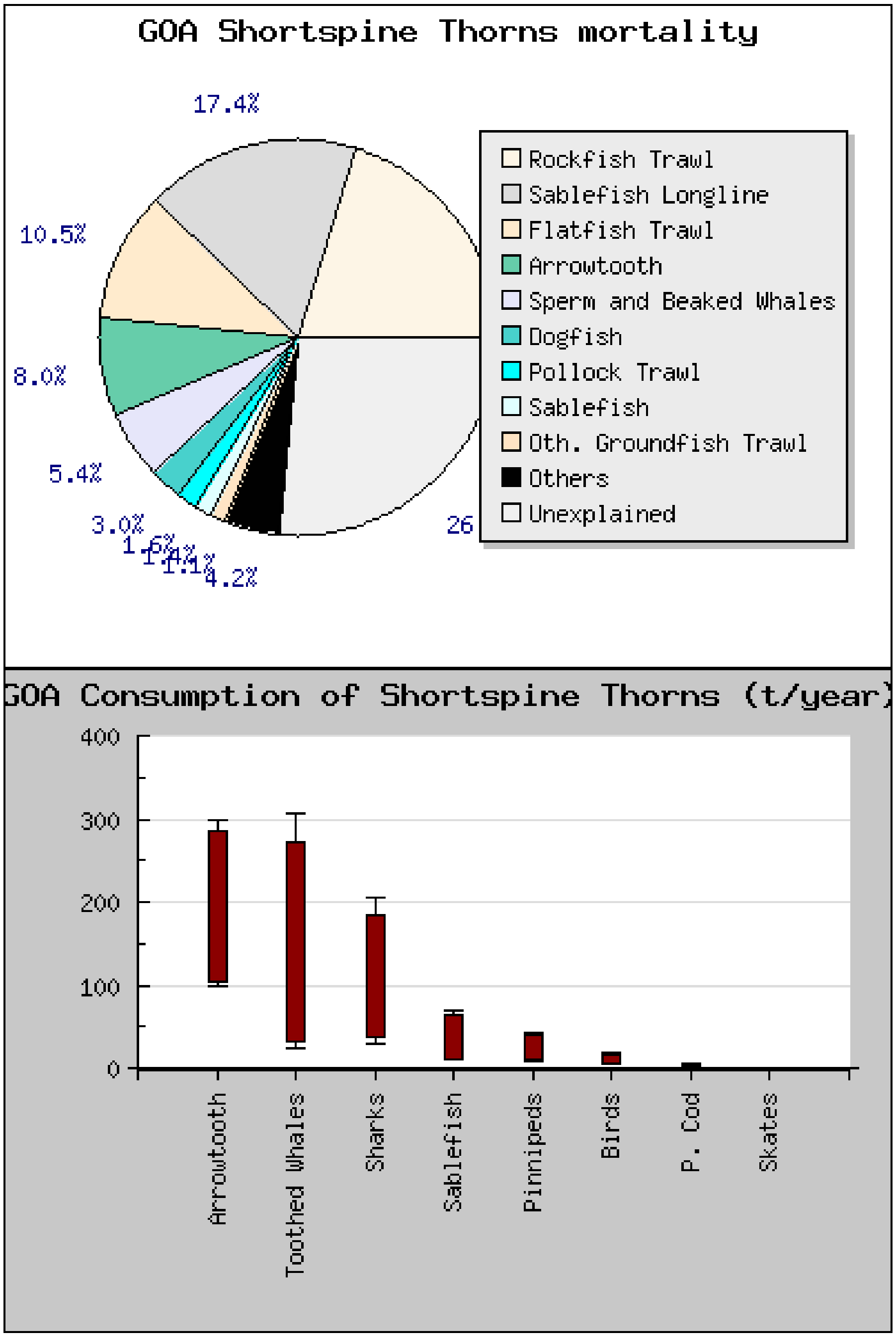


Figure 15-11.--Mortality sources (upper panel) and annual consumption in tons (lower panel) by predators of adult shortspine thornyheads in the GOA. Fisheries for rockfish, sablefish, and flatfish account for nearly 50% of total adult shortspine thornyhead mortality, while all predators combined account for about 25% of total mortality.

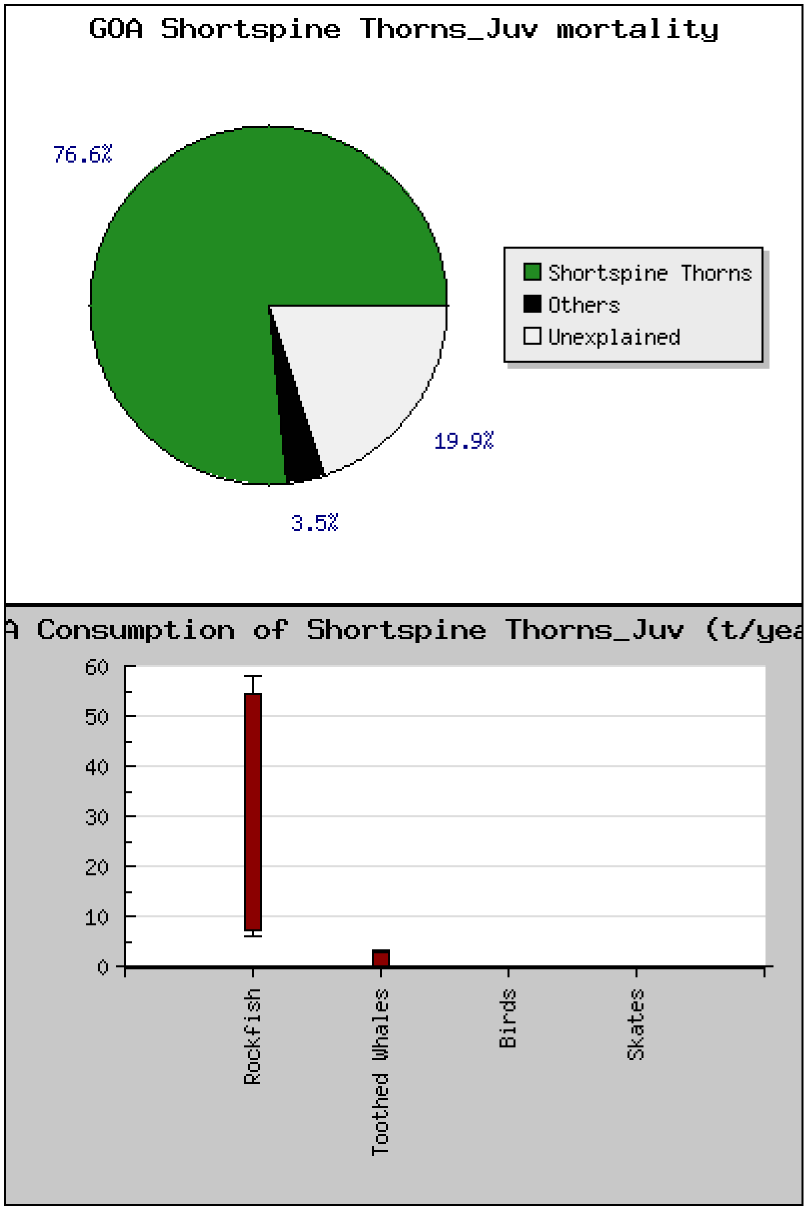


Figure 15-12.--Mortality sources (upper panel) and annual consumption in tons (lower panel) by predators of juvenile shortspine thornyheads in the GOA. "Rockfish" in the lower panel refers to adult thornyheads, which account for more than 75% of juvenile thornyhead mortality via cannibalism.

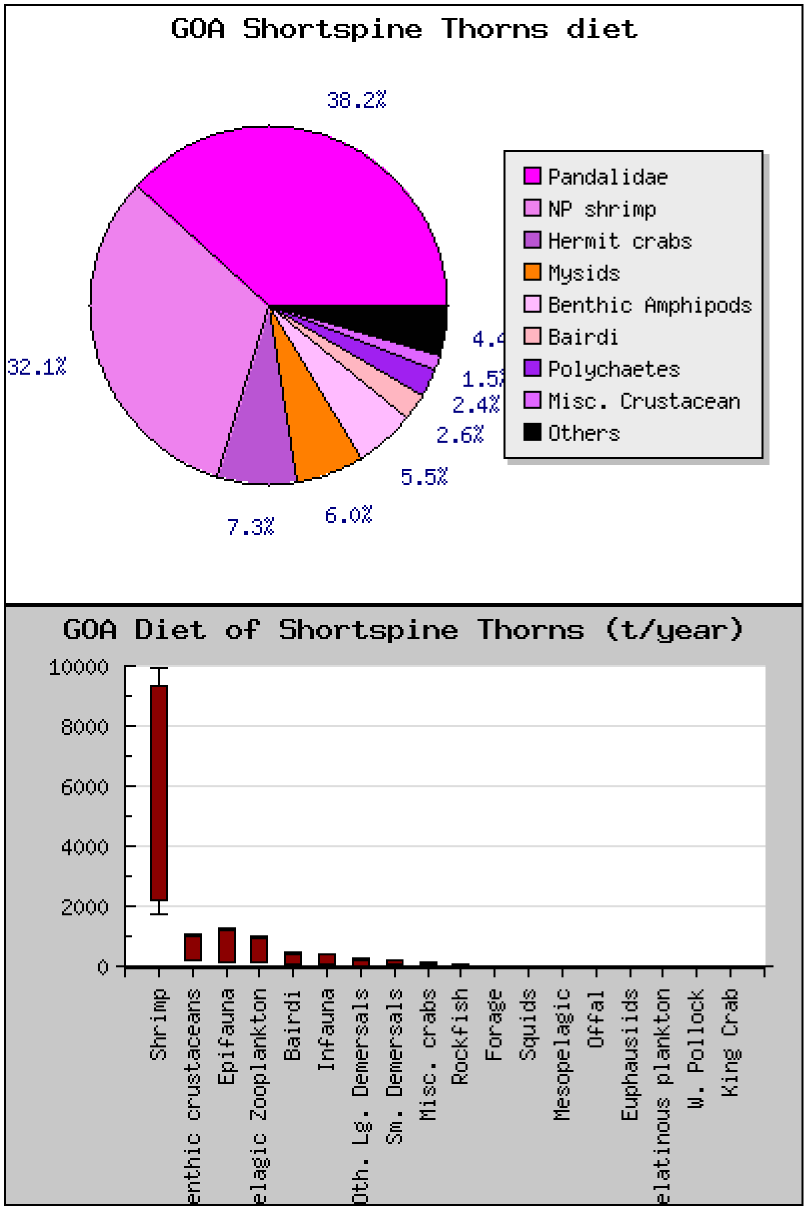


Figure 15-13.--Diet composition (upper panel) and annual consumption of prey in tons (lower panel) by adult shortspine thornyheads in the GOA.

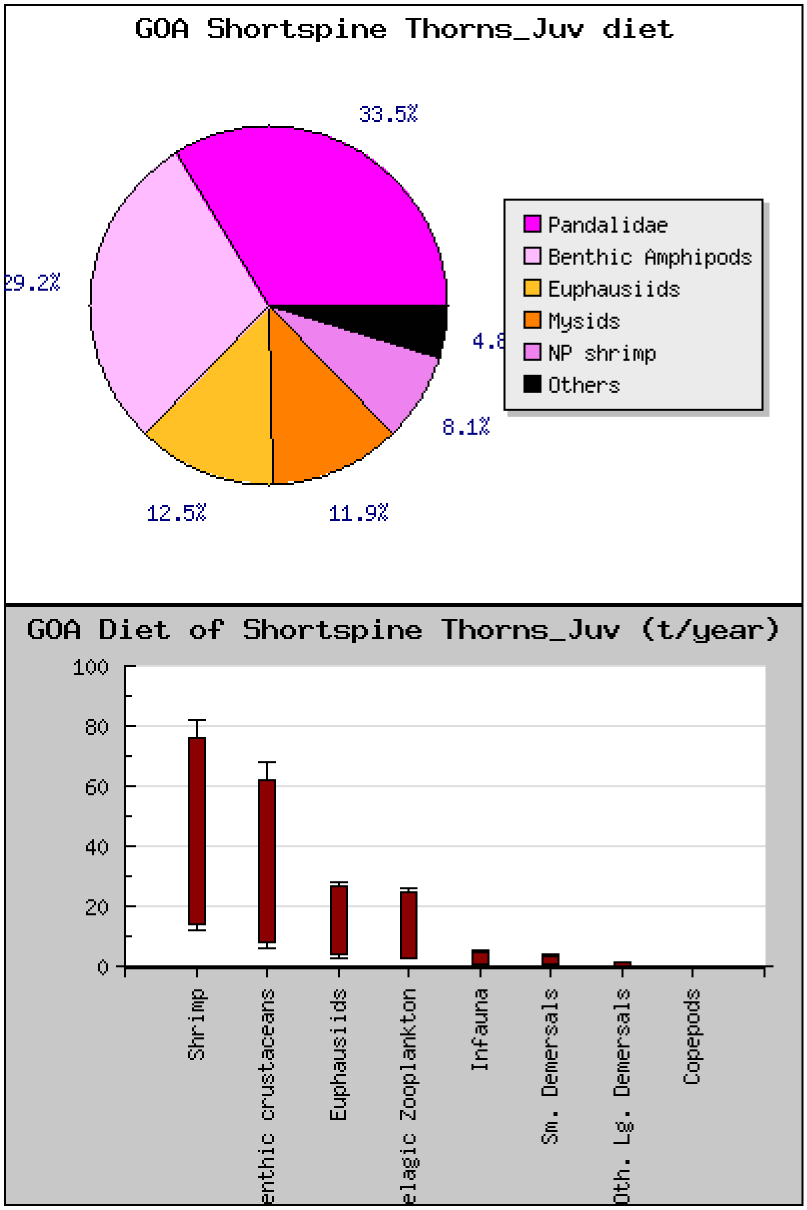


Figure 15-14.--Diet composition (upper panel) and annual consumption of prey in tons (lower panel) by juvenile shortspine thornyheads in the GOA.

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 1977-2014 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 almost 10.3 t of thornyhead rockfish was taken in 2014 during research cruises (Table 15A-1). This total is < 1% of the reported commercial catch of 1,131 t for thornyhead rockfish in 2014 (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), 1977-2014. Estimates from IPCH survey and "other" sources only available since 2010.

Year	Domestic Longline Survey	Trawl Survey	Japan US Longline Survey	IPHC Survey	Other	Total research catch
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