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

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Executive Summary

Summary of Changes in Assessment Inputs

Changes in the input data:

1. Total catch weight for GOA thornyheads is updated with 2009, 2010, and partial 2011 data.
2. Length compositions from the 2009, 2010, and 2011 longline and trawl fisheries were added.
3. Biomass and length composition information for GOA thornyheads are updated with 2011 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 2010 and 2011 data.

Changes in assessment methodology:

We continue to assess GOA thornyheads under Tier 5 criteria, using the assessment methodology introduced in 2003. The SSC supported moving thornyhead species to Tier 5 given the lack of age information to support age structured modeling. We will continue to assess thornyheads using the Tier 5 approach until sufficient age composition data become available or with developments using length-based models (previously growth and natural mortality rates were highly confounded). Area apportionment of ABC continues to be based on the most recent GOA bottom trawl survey.

Summary of Results

The 2011 NMFS GOA bottom trawl survey covered depths shallower than 701m (11% of the estimated biomass in 2009 trawl survey occurred in the 701-1000m stratum). With this in mind a 20% decrease occurred relative to the 2009 survey estimate. The largest decline occurred in the Western GOA. When considering only depths <700m, the decline between survey estimates is 9%.

Two alternatives are proposed for the calculation of the ABC and OFL based on treatment of the 2011 survey data.

Alternative 1 uses the estimated biomass from 2011 survey, 63,180 t, without any adjustment due to lack of sampling in 700 -1000 m. This estimate is multiplied by 0.75M (=0.0225) for an ABC of 1,422 t and by M (=0.03) for an OFL of 1,896 t. These ABC and OFL values represent a 20% decrease in the Council's 2010 and 2011 ABC and OFL values of 1,770 t and 2,360 t.

Alternative 2 (recommended) inflates the 2011 survey estimate to account for the lack of sampling in the 701-1000m depth stratum. Area-specific mean percentages of biomass in the 701-1000 m stratum relative to the other depth strata for the Western, Central, and Eastern GOA from the 2005, 2007, and 2009 trawl surveys were calculated and the 2011 area-specific biomass estimates were increased by these percentages. This modification results in a total estimated biomass of 73,990 t, a 17% increase in the observed biomass estimate of 2011 and a 6% decrease from the 2009 total biomass estimate. This modified estimate is multiplied by 0.75M (=0.0225) for an **ABC recommendation of 1,665 t**, and by M (=0.03) for an **OFL recommendation of 2,220 t**. These ABC and OFL recommendations represent a 6% decrease in the Council's 2010 and 2011 ABC and OFL values of 1,770 t and 2,360 t.

This summary table is based on the authors' preferred ABC and OFL values and the adjusted survey biomass values calculated under alternative 2.

Quantity	As estimated or *specified last* year for: 2011	2012	As estimated or *recommended this* year for: 2012	2013
M (natural mortality rate)	0.03	0.03	0.03	0.03
Tier	5	5	5	5
Biomass (t)	78,795	78,795	73,990	73,990
F_{OFL}	0.03	0.03	0.03	0.03
$maxF_{ABC}$	0.0225	0.0225	0.0225	0.0225
F_{ABC}	0.0225	0.0225	0.0225	0.0225
OFL (t)	2,360	2,360	2,220	2,220
maxABC (t)	1,770	1,770	1,665	1,665
ABC (t)	1,770	1,770	1,665	1,665
Status	As determined *last* year for: 2009	2010	As determined *this* year for: 2011	2012
Overfishing	no	no	no	no

The following table shows the recommended area apportionment for 2012 based on the 2011 estimated biomass by area calculated under alternative 2.

GOA Area (NPFMC Area)	**2011 Biomass (t)**	**Percent of Total Biomass**	**Area ABC Apportionment (t)**
Western (610)	6,633	9%	150
Central (620 and 630)	33,949	46%	766
Eastern (640 and 650)	33,408	45%	749
Gulfwide Total	73,990	100%	1,665

The recommended Western Gulf ABC of 150 t is a 65% decrease from the 2011 ABC of 425 t. The recommended ABC values for the Central and Eastern Gulf of 766 t and 749 t are a 20% and 6% increase from 2011 values of 637 t and 708 t. The increases in ABC for the Central and Eastern Gulf are due to those areas having a higher percentage of total estimated biomass than for 2011.

Catches of thornyheads have been relatively low relative to TACs for several years. It is unlikely that thornyheads are overfished or approaching overfished condition. The 2012 Western Gulf ABC of 150 t, however, is similar to the 2011 Western Gulf catch (146 t as of October 10, 2011), indicating the potential for the Western Gulf ABC to be reached or exceeded.

Responses to SSC Comments

SSC comments specific to the GOA thornyheads assessment:

From the December 2009 SSC minutes: *"Despite the difficulties in aging these animals, the SSC continues to encourage development of an age structured assessment for shortspine thornyhead."*

Development of a robust age-structured assesement for thornyhead continues to be problematic due to lack of sufficient age data. Additional resources for conducting assessments may provide opportunities to revisit past age-structured assessment approaches and possibly include mark-recapture data that have accumulated.

The December 2009 SSC minutes to GOA authors in general included the following comments:

"The methods for area apportionment of the ABC that are used in the specific chapters are different from those given in the general introductory material to the SAFE on page 4. The SSC suggests that the table be updated. Also, a different number of years are used for various species (e.g., 5 years for sablefish, 4 years for pollock, 3 surveys, most recent survey). SSC members recall extensive discussions about these issues but the rationale for the decision is not given in the SAFE chapters. The SSC suggests that description of the apportionment rationale in each SAFE chapter of area-apportioned species would be helpful to the reader."

The area apportionment rationale has been described in previous assessments and is again described in the *Apportionment of ABC* section.

Introduction

Description

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 (viviparous) 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* (Eshmeyer *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 (*Sebastolobus alascanus*) extends from 17 to 1,524 m 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 1000 m in the warmer waters of this range (Love *et al.* 2002).

The longspine thornyhead (*S. altivelis*) 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 500-1000 m depth range, which is also a zone of minimal oxygen (Love *et al.* 2002).

The broadfin thornyhead (*S. macrochir*) 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

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 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. 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.

Management Units

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 (*Sebastolobus alascanus*), longspine thornyhead (*S. altivelis*) and broadfin thornyhead (*S. macrochir).* 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. 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.

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.

All shortspine thornyheads in the Gulf of Alaska have been managed as a single stock since 1980 (Ianelli and Ito 1994, 1995, 1998, Ianelli *et al.*1997), and separate management has been applied to shortspine thornyheads on the U.S. west coast (e.g., Hamel 2005). Bering Sea and Aleutian Islands shortspine thornyheads are effectively managed as a separate stock from Gulf of Alaska thornyheads. In the BSAI FMP, all thornyhead species are managed within the "Other rockfish" species complex (Reuter and Spencer 2006).

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 Gulf of Alaska, 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 Gulf of Alaska to date.

Population genetics, phylogeography, and systematics of thornyheads were discussed by Stepian *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 (Stepian *et al.* 2000; Pearcy *et al.* 1977). Differences in geographic genetic patterns between the species are attributed to movement patterns as juveniles and adults.

Fishery

As an element of the deepwater community of demersal fishes, thornyheads have probably been caught in the northeastern Pacific Ocean since the late l9th century, when commercial trawling by U.S. and Canadian fishermen began. In the mid-l960s Soviet fleets arrived in the eastern Gulf of Alaska (Chitwood 1969), where they were soon joined by vessels from Japan and the Republic of Korea. These fleets represented the first directed exploitation of Gulf of Alaska rockfish resources, primarily Pacific ocean perch (*Sebastes alutus*), and likely resulted in the first substantial catches of thornyheads as well. Rockfish catch peaked in 1965 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. Furthermore, we are unable to distinguish shortspine and longspine thornyheads in the historical catch records discussed below, although we believe the overwhelming majority of the catch was shortspine thornyheads because of their dominance in the areas and depths where fisheries have occurred to date.

Shortspine thornyheads are abundant throughout the Gulf of Alaska and are commonly taken by bottom trawls and longline gear. In the past, this species was seldom the target of a directed fishery. 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 using a "bycatch only" fishery status in the Gulf of Alaska 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 Gulf of Alaska rockfish fishery. This is a five-year rationalization program that establishes 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. Potential 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 potential effects on the primary rockfish groups will also affect the secondary species groups. Future analyses regarding the Pilot Project effects on thornyhead rockfish will be possible as more data becomes available.

Data

Fishery data

For this assessment, thornyhead retained and discarded catch by gear type (Table 15.1) has been derived from a variety of sources. The earliest available records of thornyhead catch begin in 1967, as published in French *et al.* (1977). Active data collection began as part of the U.S. Foreign Fisheries Observer Program in l977, when the thornyhead catch in the Gulf of Alaska was estimated at 1,397 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 l984, 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 2003-2011 were provided by NMFS Regional Office Catch Accounting System (CAS), and accessed through the Alaska Fishery Information Network (AKFIN) database. Estimates of discards for the years 1990-2011 are provided by the NMFS AKRO as well. 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 this assessment resulting in a 2%-7% decrease in total catch for this period.

Thornyhead discards before 1990 are unknown. We assumed that the reported catches before 1990 included both retained and discarded catch. 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 and from the unobserved portions of the halibut fishery are given in Appendix 15A.

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 Gulf of Alaska 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 have since averaged about 1,340 t for the period 1990 though 2003. Thornyhead catch over time indicates most is retained (88% since 2005) and since the late 1980s the distribution of catch being mostly from trawlers has shifted to mostly longline gear (55% for 2005-2011; Table 15.1). Recent catches (2004 to the present) have averaged around 715 tons. This drop in recent catches appears to be due to a decrease in thornyhead catches in the deep water flatfish fisheries as thornyhead catches in the sablefish and rockfish fisheries have remained fairly stable over this period.

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 15.2). 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 North Pacific Fishery Management Council 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 2005-2011 are given in Table 15.3. 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. Area-specific ABC values are given in Table 15.4. While total GOA catches have been much lower than the ABC in recent years, catches in the Western Gulf in 2005 slightly exceeded the ABC for this area (Table 15.4).

Given the relatively low catches of thornyheads relative to recent TACs, it seems clear that thornyhead catch is limited more by constraints in the target fisheries in which it occurs: sablefish, rockfish, and to a lesser extent flatfish fisheries. By weight, the directed fishery for sablefish harvested the most thornyheads form 2005-2011, followed by rockfish and combined flatfish fisheries (Table 15.5). The sablefish fishery accounts for 60-75% of thornyhead discards with the rockfish and flatfish accounting for about an equal amount of the remaining discards (Table 15.6). The distribution of thornyhead catches ranges broadly throughout the Gulf of Alaska and is consistent within recent years for the different gear types (Figure 15.7, Lowe and Ianelli 2009). Length frequency data from the 2008-2011 trawl and longline fisheries are shown in Figure 15.1; in general, longline fisheries capture larger thornyheads than trawl fisheries, perhaps because they operate in deeper waters and hook selectivity tends to select for larger fish.

Survey Data

Longline surveys

Longline surveys were conducted jointly by the United States and Japan in the Gulf of Alaska each year from 1979 to 1994 to ascertain the abundance level and length composition of important groundfish species in the depths from 101 to 1,000 m (Sasaki 1985, Sigler and Fujioka 1988). Since 1987, the Alaska Fisheries Science Center has conducted annual longline surveys of the upper continental slope, referred to as domestic longline surveys, designed to continue the time series of the Japan-U.S. cooperative survey (Sigler and Zenger 1989). The U.S. longline survey covered a complete standard area in the Gulf of Alaska beginning in 1990. For selected target species in the longline survey, the catch rate, the area, and the size composition of samples from each depth stratum were used to determine the relative population number (RPN) and weight (RPW) for each depth stratum. The RPNs and RPWs for the various depth strata (201-1,000 m for thornyheads) were summed to obtain GOA totals (Table 15.7). Note that these represent only relative abundance and are not directly comparable with the trawl survey biomass estimates. Length frequency data from the 2009-2011 longline surveys are shown in Figure 15.2. The longline survey length data are very consistent with distinct modes at 33-36 cm.

The use of the longline survey to estimate relative abundance of thornyheads may be questionable because of competition and possible interaction with sablefish abundance. 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*).

Trawl surveys

The most recent NMFS trawl survey for the Gulf of Alaska was conducted during the summer of 2011 (Tables 15.8 and 15.9). This survey employed standard NMFS Poly-Nor'eastern bottom trawl gear and provided biomass estimates using an "area-swept" methodology described in Wakabayashi *et al.* (1985). The 2011 survey did not sample the 701-1000 m depth stratum, which were sampled in the previous three surveys. The 2001 survey and surveys conducted during the early 1990s did not extend to the deeper depths (500-700 m and 701-1000 m depth strata) where concentrations of larger shortspine and all longspine thornyheads are known to exist. This gives survey biomass estimates a disjointed appearance (Figure 15.3, upper panel, Table 15.8). A comparison of survey biomass estimates by management area shows that shortspine thornyheads are most abundant in the Eastern and Central Gulf (Figure 15.3, lower panel). It is important to note that the 2001 survey did not extend into the eastern Gulf, where a significant portion of shortspine thornyhead biomass has been found in past surveys. 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 15.9), and that all of the biomass of longspine thornyheads exists at depths greater than 500 m and mostly in the eastern Gulf (Figure 15.4). Therefore, in assessing the relative abundance of GOA thornyheads, it is important to consider the extent to which an individual surveys covers the full depth and geographic range of the species. In 1999, 2005, 2007, and 2009 the surveys had the most extensive survey coverage of the primary thornyhead habitat (all depths sampled to 1000 m).

The 2011 estimated survey biomass of 63,180 t is a 20% decrease from the 2009 survey estimate. The Western GOA 2011 estimate declined 69% from the 2009 Western GOA estimate while the Central and Eastern GOA estimates declined 2% and 7%. The decline of the 2011 biomass estimate compared to 2009 is reduced to 9% when considering only depths <700m for 2009, equivalent to the 2011 survey sampling design. The decline in biomass continues a downward trend 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 700-1000 m (similar to the 2011 survey). The 2005, 2007, 2009, and 2011 biomass estimates are a decrease of 7%, 16%, 22%, and 38% from the 2003 estimate. The spatial distributions of shortspine thornyhead catch per unit effort in recent surveys appear similar (Figure 15.5). Length frequency data from 2007, 2009, and 2011 trawl surveys are shown in Figure 15.6. The trawl survey length data are consistent with modes at 23-26 cm.

Analytic Approach

Due to difficulties in ageing thornyheads and issues raised with previous age-based methods using length composition data, assessment modeling for this stock was suspended. As a Tier 5 species, ABC and OFL values for thornyheads are a function of natural mortality (*M*). The ABC is the estimated survey biomass multiplied by 0.75*M* and the OFL is the estimated survey biomass multiplied by *M*. *M* is assumed equal to 0.03 and is discussed further in the following section.

Parameters estimated independently

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 are 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 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*.

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.

Results

Projections and Harvest Alternatives

It seems clear that broadfin thornyheads, *Sebastolobus macrochir*, do not range into the Gulf of Alaska and should therefore 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 Gulf of Alaska. 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 Gulf of Alaska 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 Gulf of Alaska.

Acceptable Biological Catch

As in recent assessments, results from the most recent trawl survey (2011) are used to determine biomass for ABC calculations and area apportionments. Use of the most recent trawl is based on the low *CV*s associated with the trawl survey estimates (5% in 2007 and 2009, 6% in 2011; Table 15.8). The F_{ABC} estimate of shortspine thornyhead under Tier 5 is calculated as 0.75 x M, or 0.75 x 0.03 = 0.0225. The ABC estimate under Tier 5 is the survey biomass estimate multiplied by F_{ABC} .

Given the lack of sampling in 701-1000 m depth, two alternatives are proposed for the calculation of the ABC and OFL based on treatment of the 2011 survey data.

Alternative 1 does not account for the lack of sampling coverage and uses the estimated biomass from the 2011 survey, 63,180 t. This estimate is multiplied by 0.75M (=0.0225) for an ABC 1,422 t and by M (=0.03) for an OFL of 1,896 t. These ABC and OFL values are a 20% decrease in the Council's 2010 and 2011 ABC and OFL values of 1,770 t and 2,360 t.

Alternative 2 is recommended since this approach accounts for fish in the 701-1000 m depth stratum. An area-specific mean percentage of biomass in the 701-1000 m stratum relative to the other stratum (biomass ≥ 701 m / biomass <701 m) for the Western, Central, and Eastern GOA for the 2005-2009 trawl surveys was calculated, and the 2011 area-specific biomass estimates were increased by this percentage (Table 15.10). The mean percentage of area-specific biomass in 700-1000 m relative to the other depth strata for Western, Central, and Eastern GOA are 14%, 21%, and 14%. This modification results in an estimated biomass of 73,990 t, a 17% increase in the actual observed biomass estimate. This modified estimate is multiplied by 0.75*M* (=.0225) for an ABC **recommendation of 1,665 t**, and by *M* (=0.03) for an **OFL recommendation of 2,220 t**. These ABC and OFL recommendations represent an 6% decrease in the Council's 2010 and 2011 ABC and OFL values of 1,770 t and 2,360 t.

Apportionment of ABC

We recommend the most recent survey biomass for area apportionment for three reasons: first, the GOA Plan Team and NPFMC SSC have approved using the most recent survey biomass estimate for ABC apportionment since the 2007 assessment; second, we want to appropriately account for the decrease in trawl survey biomass in the Western Gulf; and third, this seems the most reasonable survey distribution to use considering the apportionment will be applied in both 2012 and 2013. Based on the 2011 survey biomass distribution, we computed the following apportionment of the shortspine thornyhead ABC broken out by management areas.

Apportionment

GOA Area (NPFMC Area)	2011 Biomass (t)	Percent of Total Biomass	Area ABC Apportionment (t)
Western (610)	6,633	9%	150
Central (620 and 630)	33,949	46%	766
Eastern (640 and 650)	33,408	45%	749
Gulfwide Total	73,990	100%	1,665

The recommended Western Gulf ABC of 150 t is a 65% decrease from the 2011 ABC of 425 t. The recommended ABC values for the Central and Eastern Gulf of 766 t and 749 t are a 20% and 6% increase from 2011 values of 637 t and 708 t. The increases in ABC for the Central and Eastern Gulf are due to those areas having a higher percentage of total estimated biomass than for 2011.

Catches of thornyheads have been relatively low relative to TACs for several years. It is unlikely that thornyheads are overfished or approaching overfished condition. The 2012 Western Gulf ABC of 150 t, however, is similar to the 2011 Western Gulf catch (146 t as of October 10, 2011), indicating the potential for the Western Gulf ABC to be reached or exceeded. .

Overfishing Level

The Tier 5 estimate of shortspine thornyhead F_{OFL} is equal to M = 0.03. The 2012 OFL for thornyheads is thus 73,990 t x 0.03 = 2,220 t, which is also the 2013 OFL.

Ecosystem Considerations

This section focuses on shortspine thornyheads exclusively, because they overwhelmingly dominate the thornyhead biomass in the Gulf of Alaska. 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 15.7, upper panel) whereas juveniles prey more on invertebrates and are therefore at a lower trophic level (15.7, 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 current 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 15.8). 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 15.8 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 15.9, 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 15.10). Thornyheads are an uncommon prey in the Gulf of Alaska, 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 15.11, upper panel). This preference for shrimp in the adult thornyhead diet combined with consumption rates estimated from stock assessment parameters and biomass estimated from trawl survey, results in an annual consumption estimate ranging from 2,000 to 10,000 tons of shrimp (Figure 15.11, 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 15.11). 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 15.12).

Changes in habitat quality

The physical habitat requirements for thornyheads are relatively unknown, and changes in deepwater habitats have not been measured in the Gulf of Alaska. 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 Gulf of Alaska, 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 Gulf of Alaska. 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 take thornyheads and other rockfish, as well as skates and sharks, but they are presently 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 Gulf of Alaska, 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 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 Gulf of Alaska, 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 Gulf of Alaska, any potential indirect effects on thornyheads should be considered.

Ecosystem considerations for GOA thornyheads are summarized in Table 15.11. 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.

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Tables

Table 15.1. Estimated retained catch and discard of GOA thornyheads (tons) by gear type[1], 1977-2011.

	Trawl gear			Longline gear			All gears combined		
Year	Retained	Discarded	Total	Retained	Discarded	Total	Retained	Discarded	Total
1977	1,163	-	1,163	234	-	234	1,397	-	1,397
1978	442	-	442	344	-	344	786	-	786
1979	645	-	645	454	-	454	1,098	-	1,098
1980	1,158	-	1,158	327	-	327	1,485	-	1,485
1981	1,139	-	1,139	201	-	201	1,340	-	1,340
1982	669	-	669	118	-	118	787	-	787
1983	620	-	620	109	-	109	729	-	729
1984	177	-	177	31	-	31	208	-	208
1985	70	-	70	12	-	12	82	-	82
1986	607	-	607	107	-	107	714	-	714
1987	1,863	-	1,863	14	-	14	1,877	-	1,877
1988	2,132	-	2,132	49	-	49	2,181	-	2,181
1989	2,547	-	2,547	69	-	69	2,616	-	2,616
1990	1,233	38	1,271	284	20	304	1,518	58	1,576
1991	1,188	60	1,248	236	53	289	1,424	113	1,537
1992	1,041	129	1,169	532	375	907	1,573	504	2,077
1993	489	173	662	401	306	707	890	479	1,370
1994	488	222	710	305	295	600	793	516	1,310
1995	471	165	636	392	86	478	863	251	1,114
1996	435	170	605	424	101	525	860	272	1,131
1997	567	224	791	398	61	459	964	285	1,249
1998	470	113	583	508	57	565	978	171	1,148
1999	597	195	792	445	43	488	1,042	240	1,280
2000	557	92	649	580	78	658	1,137	170	1,308
2001	479	52	532	770	38	808	1,249	90	1,339
2002	500	90	590	501	47	548	1,001	137	1,138
2003	705	92	797	323	36	359	1028	128	1,156
2004	414	66	480	314	30	344	728	96	824
2005	333	27	360	319	41	360	652	68	720
2006	297	60	357	384	37	421	681	97	778
2007	368	11	379	355	48	403	723	59	782
2008	318	29	347	330	65	395	648	94	742
2009	252	25	277	318	64	382	570	89	659
2010	179	15	194	313	59	372	492	74	566
2011*	210	30	240	305	41	346	515	71	586

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 2011 catch is incomplete, representing catch reported through October 10, 2011.

Table 15.2. Comparison of Allowable Biological Catch (ABC), Total Allowable Catch (TAC), and actual catch for GOA thornyheads (tons). 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.

Year	ABC	TAC	Total Catch	ABC/TAC
1977	a	a	a	a
1978	a	a	a	a
1979	b	b	b	b
1980[c]	3,750	3,750	1,485	Gulfwide
1981	3,750	3,750	1,340	Gulfwide
1982	3,750	3,750	787	Gulfwide
1983	3,750	3,750	729	Gulfwide
1984	3,750	3,750	208	Gulfwide
1985	3,750	3,750	82	Gulfwide
1986	3,750	3,750	714	Gulfwide
1987	3,750	3,750	1,877	Gulfwide
1988	3,750	3,750	2,181	Gulfwide
1989	3,800	3,800	2,616	Gulfwide
1990	3,800	3,800	1,576	Gulfwide
1991	1,798	1,398	1,537	Gulfwide
1992	1,798	1,798	2,077	Gulfwide
1993	1,180	1,062	1,370	Gulfwide
1994	1,180	1,180	1,310	Split W/C/E
1995	1,900	1,900	1,114	Split W/C/E
1996	1,560	1,248	1,131	Split W/C/E
1997	1,700	1,700	1,249	Split W/C/E
1998	2,000	2,000	1,148	Split W/C/E
1999	1,990	1,990	1,280	Split W/C/E
2000	2,360	2,360	1,308	Split W/C/E
2001	2,310	2,310	1,339	Split W/C/E
2002	1,990	1,990	1,138	Split W/C/E
2003	2,000	2,000	1,156	Split W/C/E
2004	1,940	1,940	824	Split W/C/E
2005	1,940	1,940	720	Split W/C/E
2006	2,209	2,209	778	Split W/C/E
2007	2,209	2,209	782	Split W/C/E
2008	1,910	1,910	742	Split W/C/E
2009	1,910	1,910	659	Split W/C/E
2010	1,770	1,770	566	Split W/C/E
2011[d]	1,770	1,770	586	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/ 2011 catch estimate is reported catch as of October 10, 2011

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.
AKRO website for final harvest specifications (http://www.fakr.noaa.gov/sustainablefisheries/catchstats.htm).

Table 15.3. Gulf of Alaska thornyhead catches (t) by management area, 2005-20011. Percent of total Gulf catch is in parentheses. Discrepancies in total values with Tables 15.1 and 15.2 due to rounding error. 2011 data are reported catch as of October10, 2011.

	Area			
Year	Western	Central	Eastern	Total
2005	190 (26%)	391 (54%)	140 (19%)	721
2006	197 (25%)	399 (51%)	182 (23%)	778
2007	341 (44%)	253 (32%)	188 (24%)	782
2008	271 (36%)	304 (41%)	167 (23%)	742
2009	231 (35%)	275 (42%)	153 (23%)	659
2010	139 (25%)	276 (49%)	150 (26%)	565
2011	146 (25%)	291 (50%)	149 (25%)	586

Table 15.4. Gulf of Alaska allowable biological catch (ABC) (t) apportionment by management area and percent of that area-specific ABC caught (all gear and fisheries). Percent values calculated by dividing ABC values by catch values in Table 15.3. 2011 data are reported catch as of October10, 2011.

	Area		
Year	Western	Central	Eastern
2005	410 (46%)	1,010 (39%)	520 (27%)
2006	513 (38%)	989 (40%)	707 (26%)
2007	513 (67%)	989 (26%)	707 (27%)
2008	267 (102%)	860 (35%)	783 (21%)
2009	267 (86%)	860 (32%)	783 (20%)
2010	425 (33%)	637 (43%)	708 (21%)
2011	425 (34%)	637 (46%)	708 (21%)

Table 15.5. Gulf of Alaska thornyhead catches (t) by target fishery, 2005-2011; approximate percentage of total catch in parentheses. 2011 data are reported catch as of October10, 2011.

	Fishery			
Year	Flatfish	Rockfish	Sablefish	Other
2005	56 (8%)	322 (45%)	337 (47%)	6 (1%)
2006	82 (11%)	312 (40%)	383 (49%)	1 (<1%)
2007	90 (12%)	300 (38%)	384 (49%)	8 (1%)
2008	111 (15%)	248 (33%)	375 (51%)	8 (1%)
2009	117 (18%)	185 (28%)	350 (53%)	8 (1%)
2010	94 (17%)	106 (19%)	359 (64%)	6 (1%)
2011	77 (13%)	160 (27%)	342 (58%)	7 (1%)

Table 15.6. Gulf of Alaska thornyhead discards (t) by target fishery, 2005-2011; approximate percentage of total discards in parentheses. 2011 data are reported catch as of October10, 2011.

	Fishery			
Year	Flatfish	Rockfish	Sablefish	Other
2005	7 (10%)	23 (34%)	38 (56%)	<1 (<1%)
2006	4 (4%)	56 (59%)	36 (37%)	<1 (<1%)
2007	16 (26%)	4 (6%)	40 (68%)	<1 (<1%)
2008	20 (21%)	16 (17%)	57 (61%)	1 (1%)
2009	13 (15%)	19 (22%)	56 (63%)	<1 (<1%)
2010	11 (15%)	7 (9%)	55 (74%)	1 (1%)
2011	8 (11%)	20 (28%)	43 (60%)	<1 (<1%)

Table 15.7. Relative population number (RPN) and weight (RPW) for GOA thornyheads from the domestic longline survey 1990-2011.

Year	RPN	RPW
1990	37,531	20,667
1991	48,841	23,324
1992	63,722	32,068
1993	56,788	28,448
1994	43,168	25,294
1995	52,933	26,323
1996	60,135	32,217
1997	56,357	29,420
1998	56,098	31,045
1999	61,950	33,810
2000	54,632	28,657
2001	82,143	43,719
2002	72,016	38,004
2003	65,048	34,239
2004	48,923	24,557
2005	63,530	32,013
2006	63,711	32,496
2007	67,199	32,258
2008	88,033	43,344
2009	76,205	34,472
2010	93,285	44,535
2011	84,028	38,029

Table 15.8. Biomass estimates (with *CV*) for GOA thornyheads from the NMFS trawl surveys 1984-20011, with comments on survey coverage.

Species/ Year	Biomass (t)	*CV* Biomass	Survey coverage
Shortspine Thornyhead, *Sebastolobus alascanus*			
1984	57,545	0.06	full GOA, all depths
1987	53,358	0.10	full GOA, all depths
1990	19,616	0.11	full GOA, <500 m
1993	33,014	0.08	full GOA, <500 m
1996	51,984	0.07	full GOA, <500 m
1999	77,336	0.05	full GOA, all depths
2001	28,661	0.08	W/C GOA, <500 m
2003	101,576	0.08	full GOA, <700 m
2005	94,740	0.04	full GOA, all depths
2007	84,775	0.05	full GOA, all depths
2009	78,795	0.05	full GOA, all depths
2011	63,180	0.06	full GOA, <700 m
Longspine Thornyhead, *Sebastolobus altivelis*			
1984	0		full GOA, all depths
1987	48	1.00	full GOA, all depths
1990	0		full GOA, <500 m
1993	0		full GOA, <500 m
1996	0		full GOA, <500 m
1999	4,602	0.11	full GOA, all depths
2001	0		W/C GOA, <500 m
2003	1,394	0.11	full GOA, <700
2005	3,526	0.14	full GOA, all depths
2007	4,434	0.12	full GOA, all depths
2009	4,116	0.21	full GOA, all depths
2011	1,142	0.27	full GOA, <700

Table 15.9. Shortspine thornyhead biomass (t), and the percentage distribution by management area from the bottom trawl surveys in the Gulf of Alaska, 1996-2009. The 1996 and 2001 surveys did not survey the deeper depths >500 m, and the 2003 and 2011 surveys did not survey the deeper depths >700 m. In addition, the 2001 survey did not survey the Eastern Gulf of Alaska.

Area	Depth (m)	Biomass (t)							
		1996	1999	2001	2003	2005	2007	2009	2011
Gulf of	1-100	0	116	46	54	180	212	85	17
Alaska (all areas)	101-200	6,625	4,446	1,776	3,988	5,682	4,742	3,002	5,400
	201-300	21,968	23,418	13,619	39,156	28,324	21,330	26,494	20,473
	301-500	23,390	27,872	13,220	37,017	28,394	28,063	22,415	23,800
	501-700	--	14,952	--	21,360	18,213	16,507	17,790	13,491
	701-1000	--	6,531	--	--	13,947	13,920	9,009	--
	Total	51,984	77,336	28,661	101,576	94,740	84,775	78,795	63,180
	% of total biomass	100%	100%	100%	100%	100%	100%	100%	100%
Western Gulf	1-100	0	4	0	0	63	0	0	17
(Area 610)	101-200	313	37	0	500	1,108	7	84	202
	201-300	3,115	2,248	3,981	6,017	5,550	2,910	7,094	1,082
	301-500	4,615	4,739	4,771	8,519	5,630	4,702	5,286	2,245
	501-700	--	5,389	--	5,887	6,377	2,590	5,605	2,272
	701-1000	--	1,679	--	--	3,277	1,943	719	--
	Total	8,043	14,097	8,753	20,922	22,005	12,152	18,789	5,818
	% of total biomass	15%	18%	31%	21%	23%	14%	24%	9%
Central Gulf	1-100	0	2	46	54	103	131	13	0
(Areas 620/630)	101-200	309	690	1,776	1,317	3,000	1,465	559	3,136
	201-300	10,456	10,604	9,637	25,386	13,544	8,190	11,880	9,239
	301-500	8,265	11,638	8,449	16,030	10,780	11,124	7,270	8,797
	501-700	--	6,725	--	10,462	6,728	8,962	5,365	6,885
	701-1000	--	2,930	--	--	8,262	7736	3,469	--
	Total	19,030	32,590	19,908	53,250	42,419	37,607	28,556	28,057
	% of total biomass	37%	42%	69%	52%	45%	45%	36%	44%
Eastern Gulf	1-100	0	111	--	0	14	81	73	0
(Areas 640/650)	101-200	6,003	3,719	--	2,172	1,574	3,271	2,358	2,061
	201-300	8,398	10,565	--	7,753	9,229	10,230	7,520	10,152
	301-500	10,509	11,495	--	12,468	11,983	12,237	9,859	12,758
	501-700	--	2,838	--	5,011	5,107	4,956	6,820	4,334
	701-1000	--	1,922	--	--	2,408	4,241	4,821	--
	Total	24,911	30,649	--	27,404	30,316	35,016	31,451	29,305
	% of total biomass	48%	40%	0%	27%	32%	41%	40%	46%

Table 15.10. Estimate of 2011 biomass (t) for 700-1000m depth stratum.

	Area			
	Western	Central	Eastern	Total
Mean percentage of biomass in 700m-1000 m depth stratum (relative to other depth strata) for 2005, 2007, 2009 surveys (with standard deviation)	14% (8%)	21% (7%)	14% (5%)	--
Survey biomass for 2011	5,818	28,057	29,305	63,180
Estimated biomass in 700m-100m depth stratum for 2011	815	5,892	4,103	10,810
Adjusted total GOA 2011 biomass with estimated 700m-1000m biomass included	6,633	33,949	33,408	73,990

Table 15.11. 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

"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

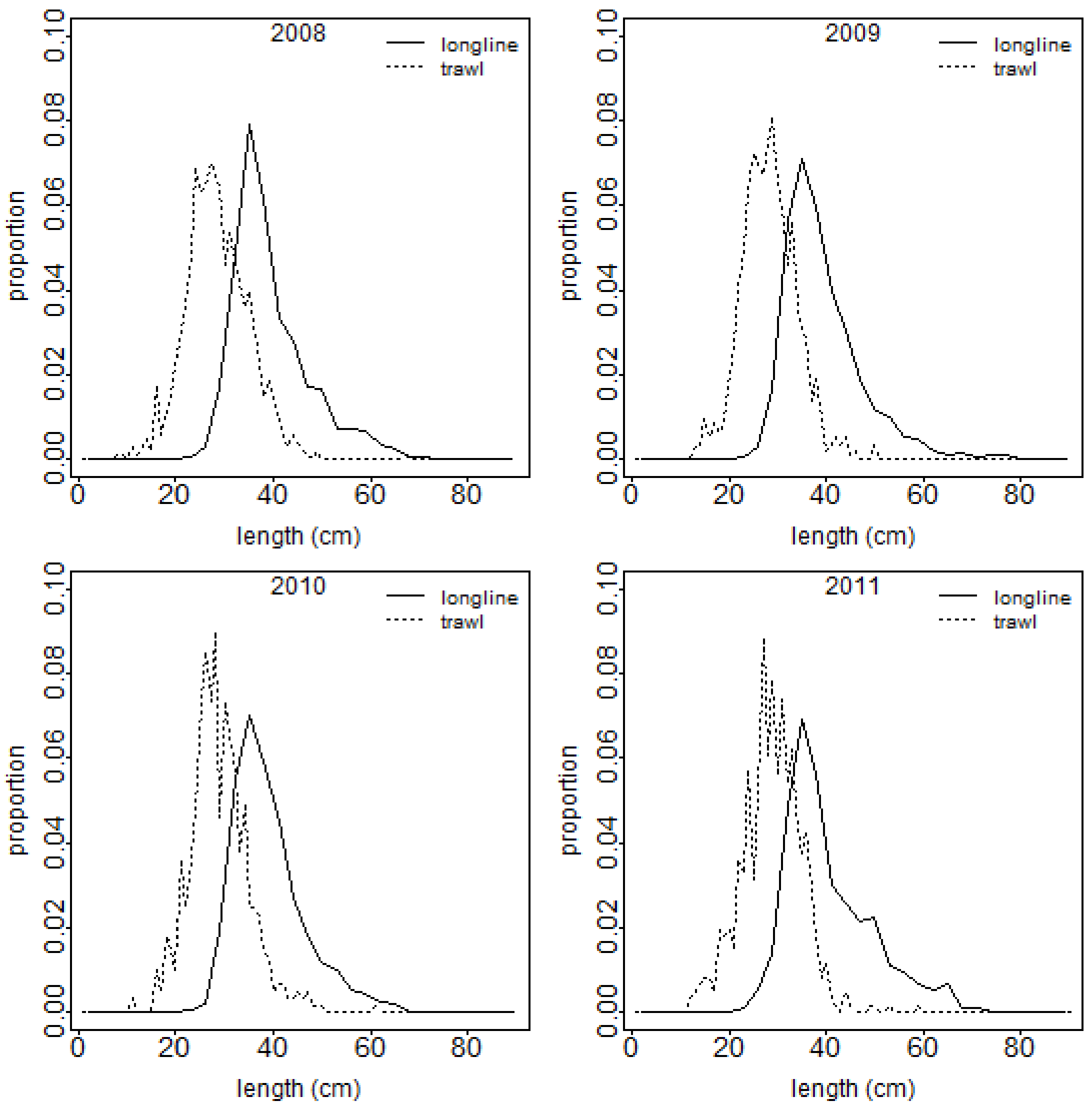

Figure 15.1 Shortspine thornyhead lengths measured in trawl and longline fisheries, 2008-2011.

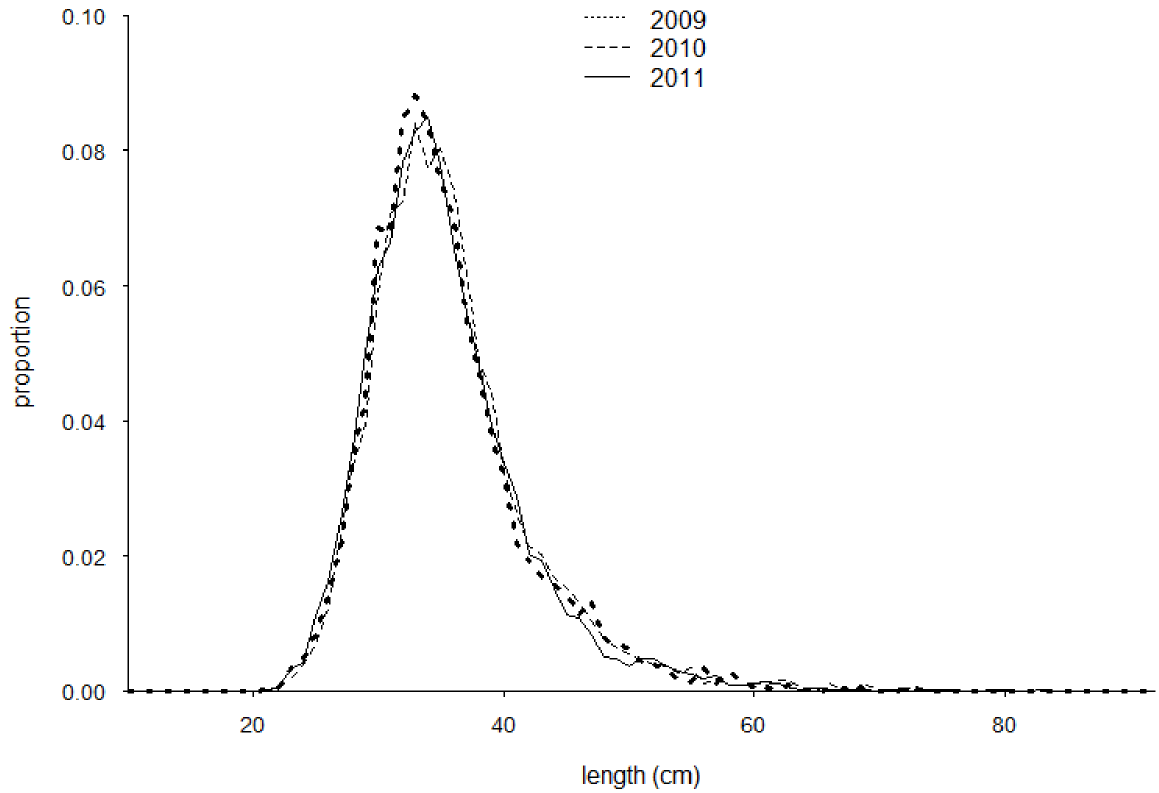

Figure 15.2 Shortspine thornyhead length frequencies from longline surveys, 2009-2011.

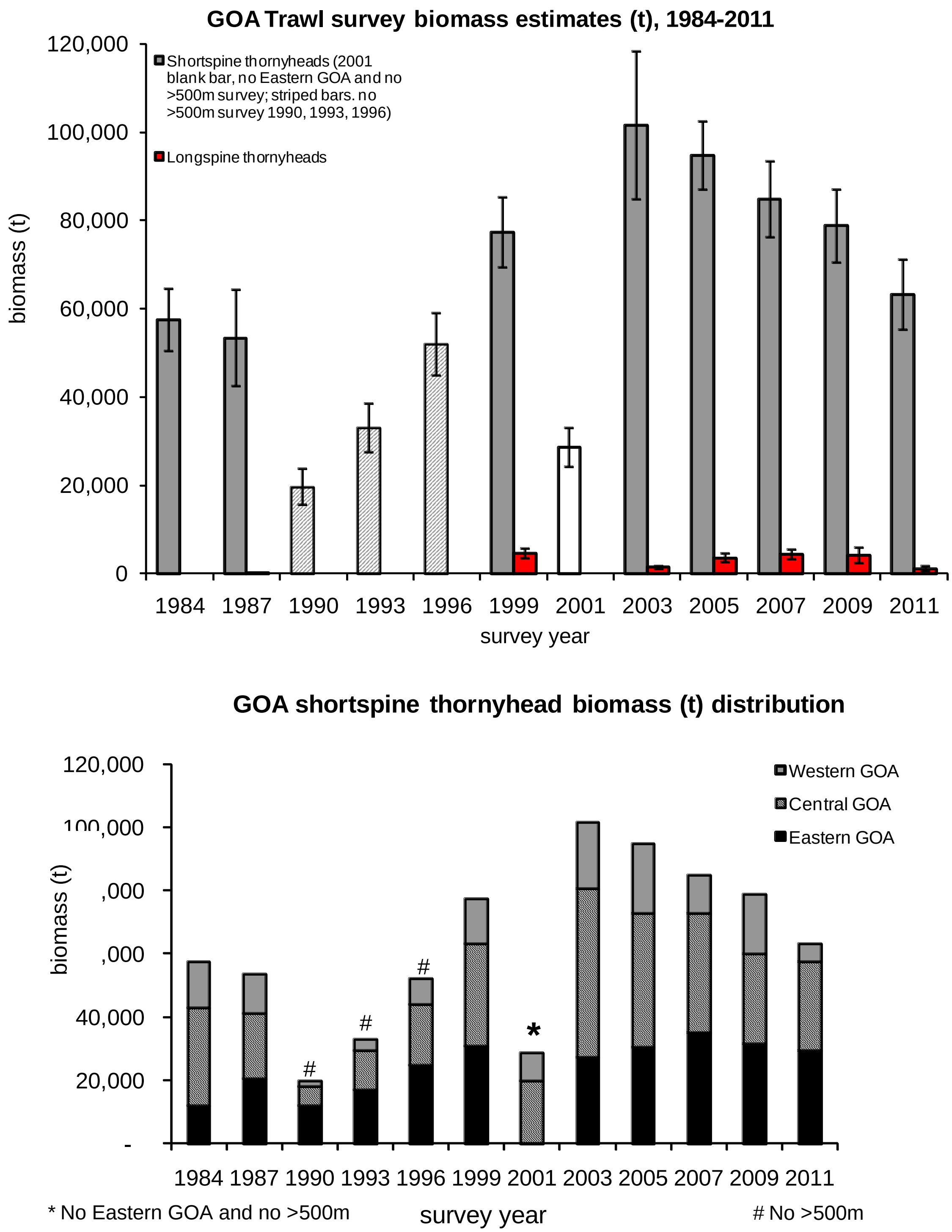

Figure 15.3 Trawl survey biomass estimates for Gulf of Alaska (GOA) shortspine thornyheads (top panel) and by management areas (bottom panel). Error bars represent two standard deviations. The 1990, 1993, 1996, and 2001 surveys did not survey depths >500m. The 2003 and 2011 surveys did not survey depths >700m. The 2001 survey also did not survey the Eastern GOA.

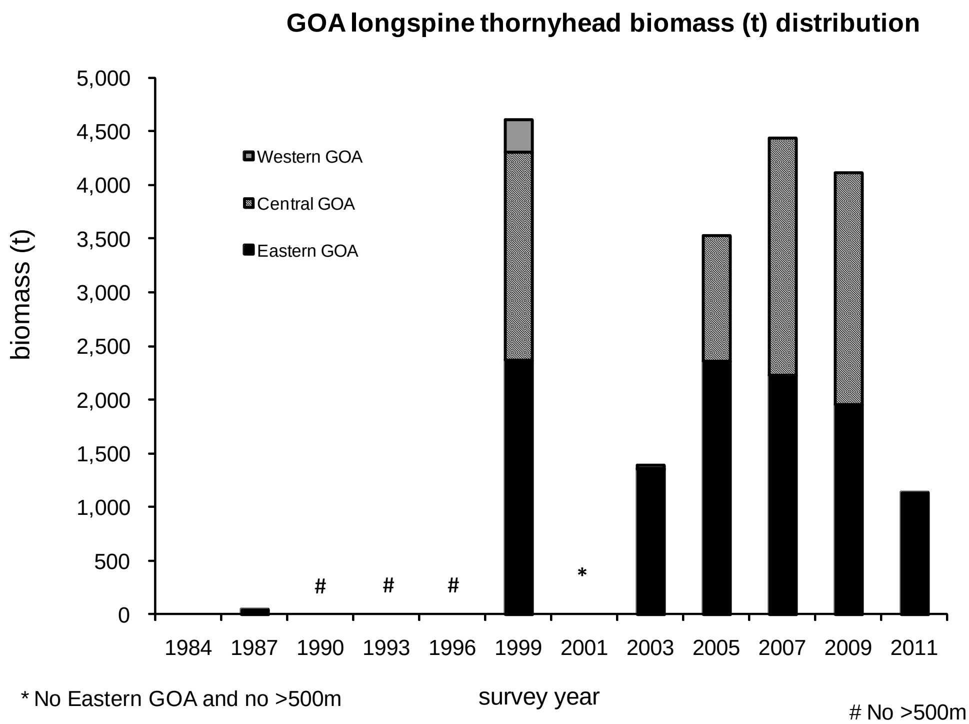

Figure 15.4 Trawl survey biomass estimates for Gulf of Alaska (GOA) longspine thornyheads, which are typically only encountered in depths greater than 500m in the GOA, and are more common in the Eastern GOA (areas 640 and 650) than in the Western and Central GOA.

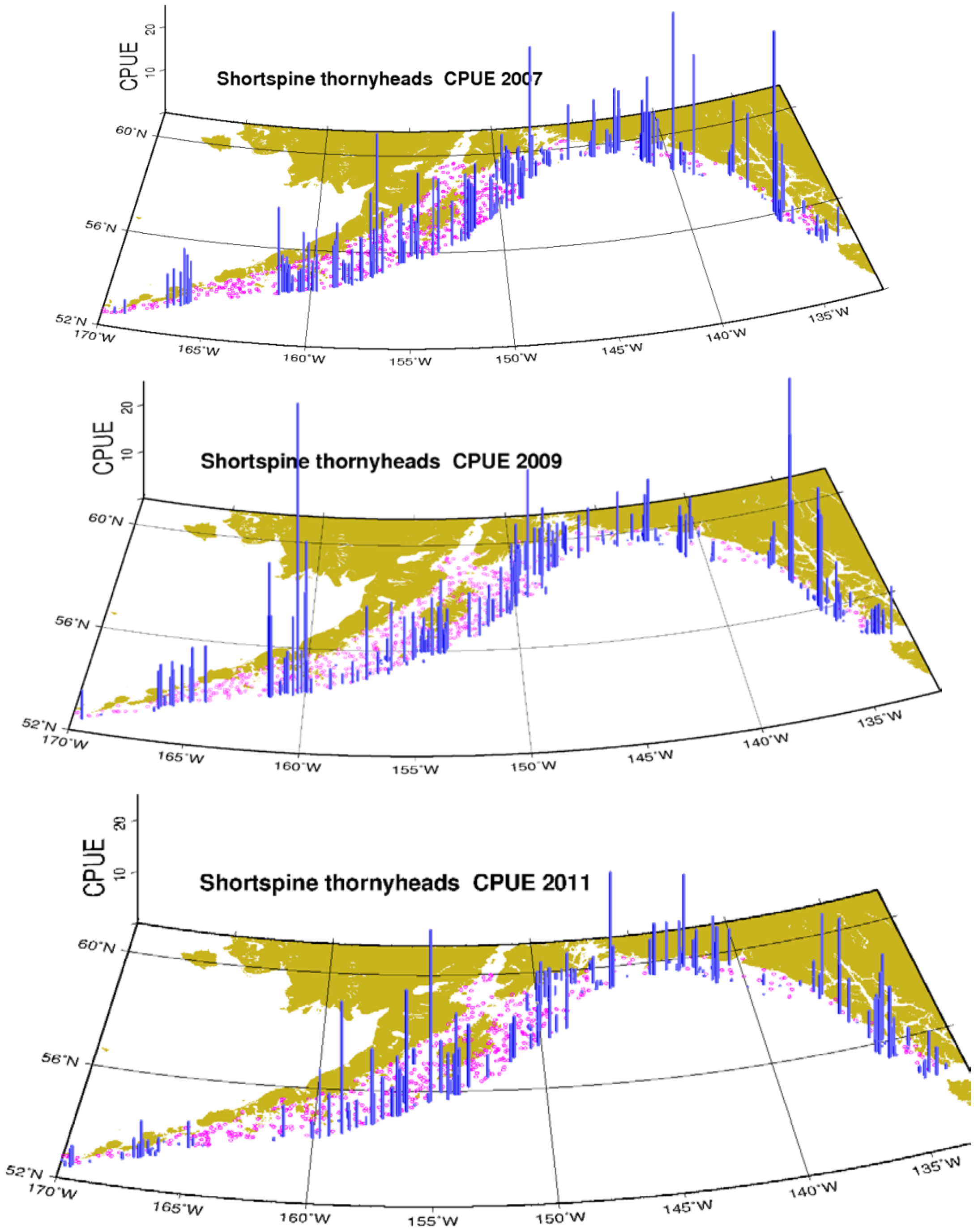

Figure 15.5 Shortspine thornyhead CPUE distributions for GOA trawl surveys in 2007, 2009, and 2011.

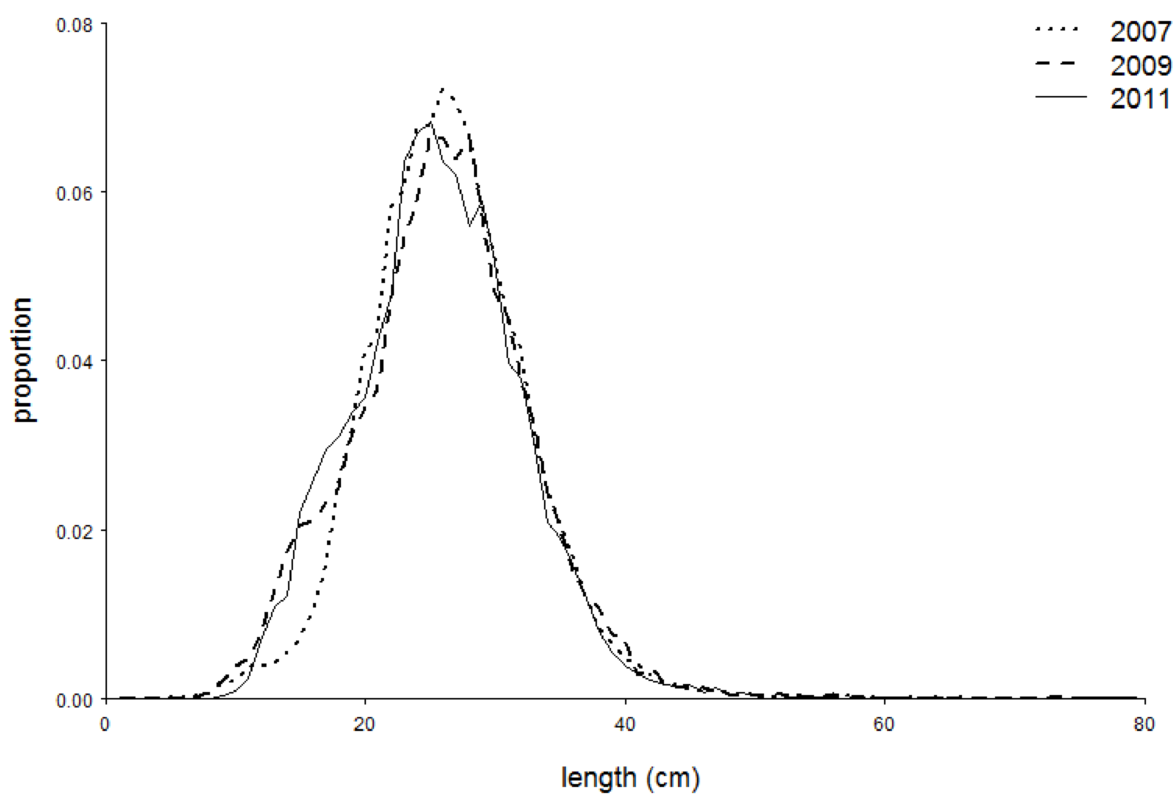

Figure 15.6 Shortspine thornyhead length frequencies from the 2007, 2009, and 2011 trawl surveys.

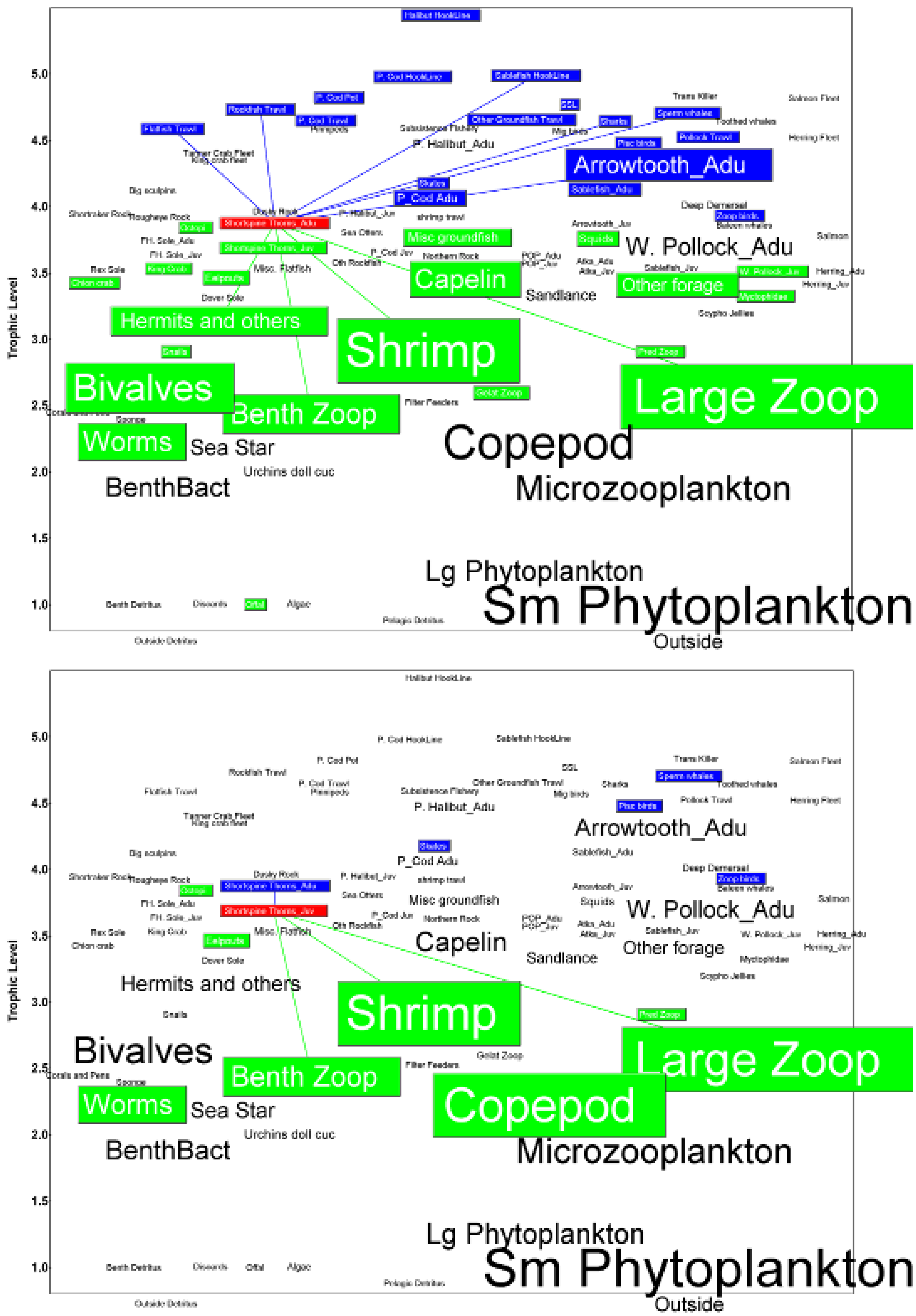

Figure 15.7 Position of shortspine thornyheads within GOA food webs: adults (marked red in upper panel) and juveniles (marked red in lower panel). Groups shaded blue are predators of shortspine thornyheads, and groups shaded green are prey. Similar information for longspine thornyheads is not available.

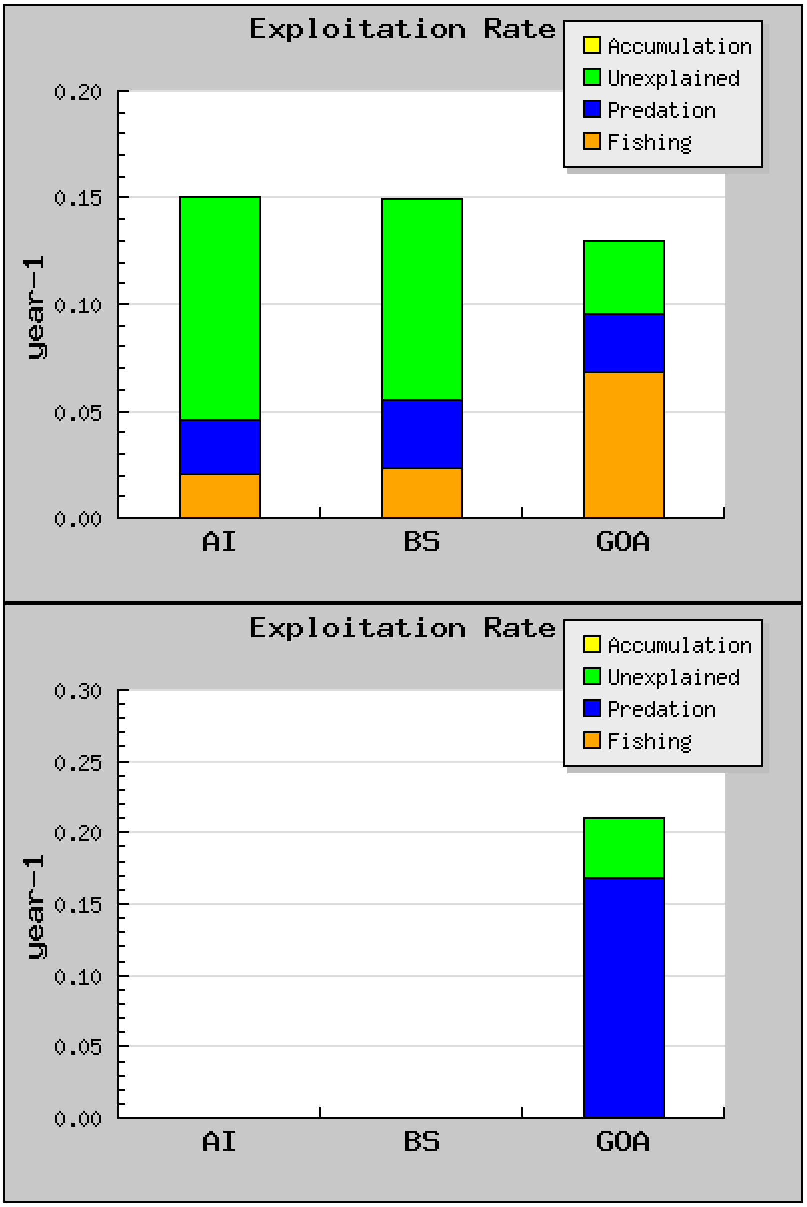

Figure 15.8 Comparison of exploitation rates for shortspine thornyheads across Alaskan ecosystems. Adult shortspine thornyheads (upper panel) have higher predation than fishing mortality in the AI and EBS, but higher fishing mortality in the GOA. Juvenile shortspine thornyheads (lower panel) were only 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.

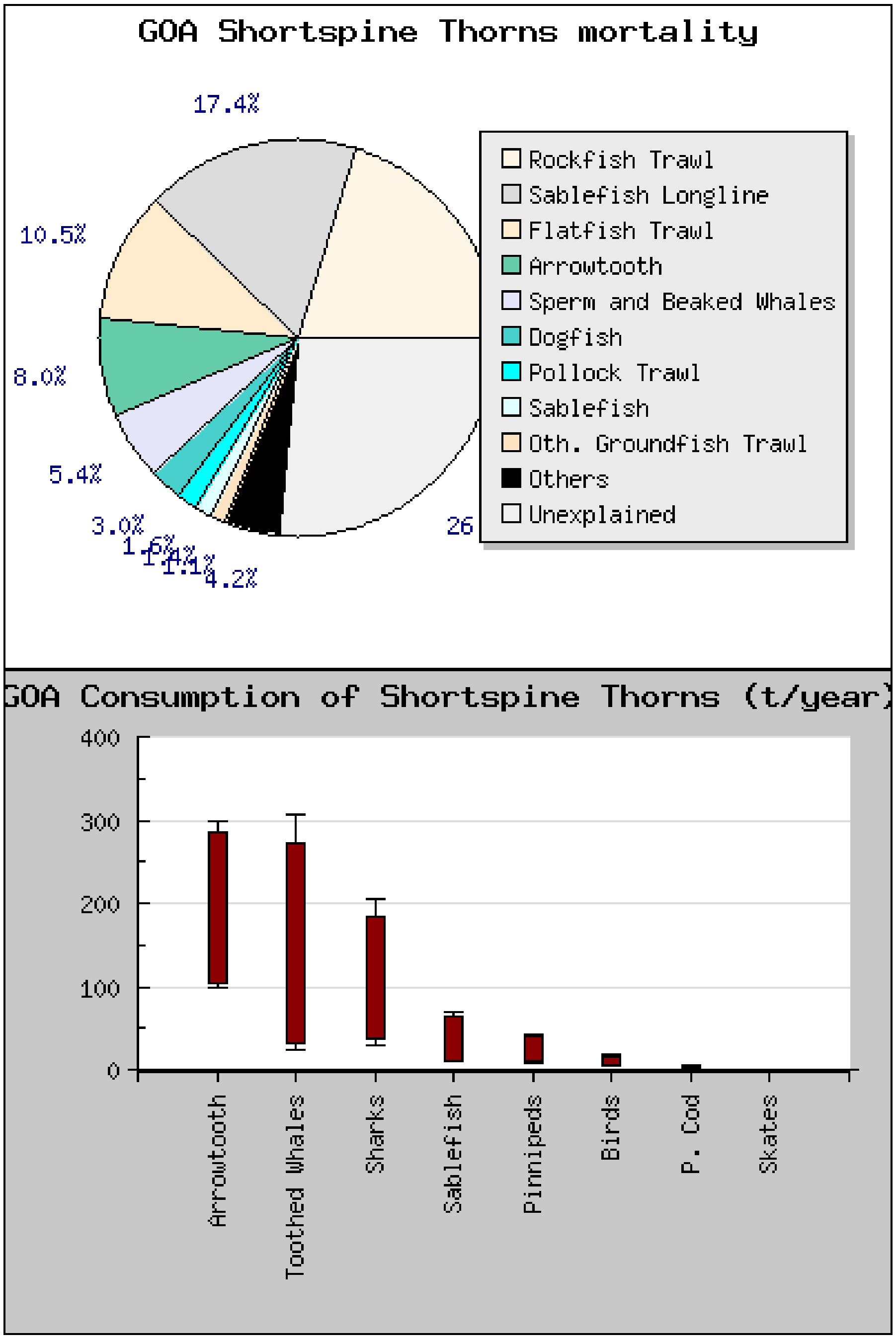

Figure 15.9 Mortality sources (upper panel) and annual consumption in tons (lower panel) by predators of adult shortspine thornyheads in the GOA. Fisheries for rockfish, sablefish, and flatfish account for nearly 50% of total adult shortspine thornyhead mortality, while all predators combined account for about 25% of total mortality.

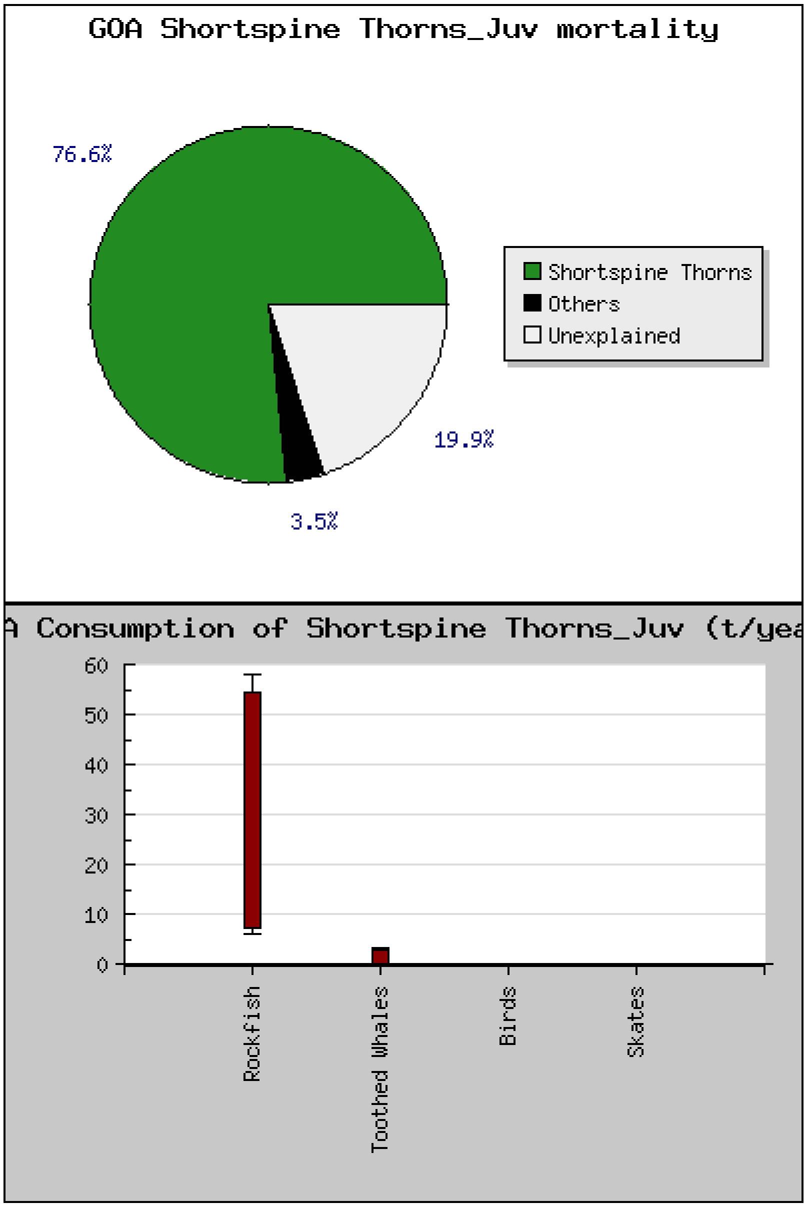

Figure 15.10 Mortality sources (upper panel) and annual consumption in tons (lower panel) by predators of juvenile shortspine thornyheads in the GOA. "Rockfish" in the lower panel refers to adult thornyheads, which account for more than 75% of juvenile thornyhead mortality via cannibalism.

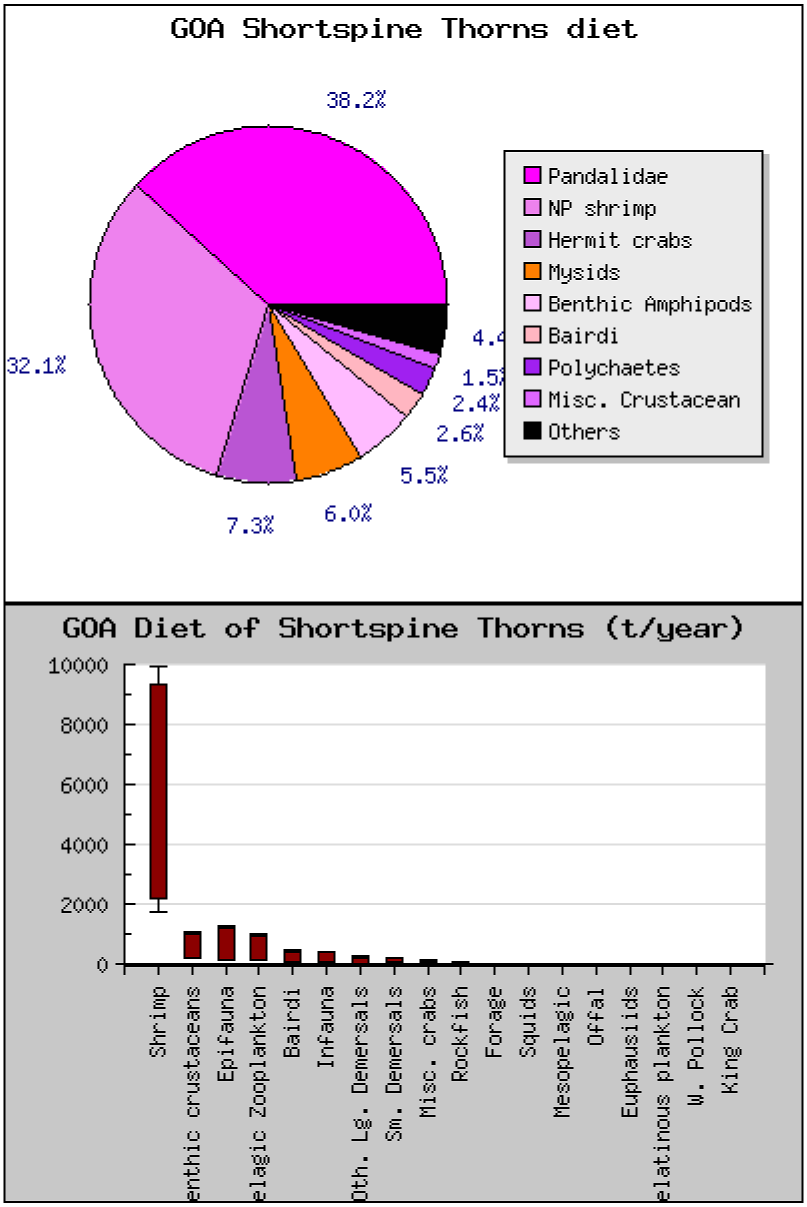

Figure 15.11 Diet composition (upper panel) and annual consumption of prey in tons (lower panel) by adult shortspine thornyheads in the GOA.

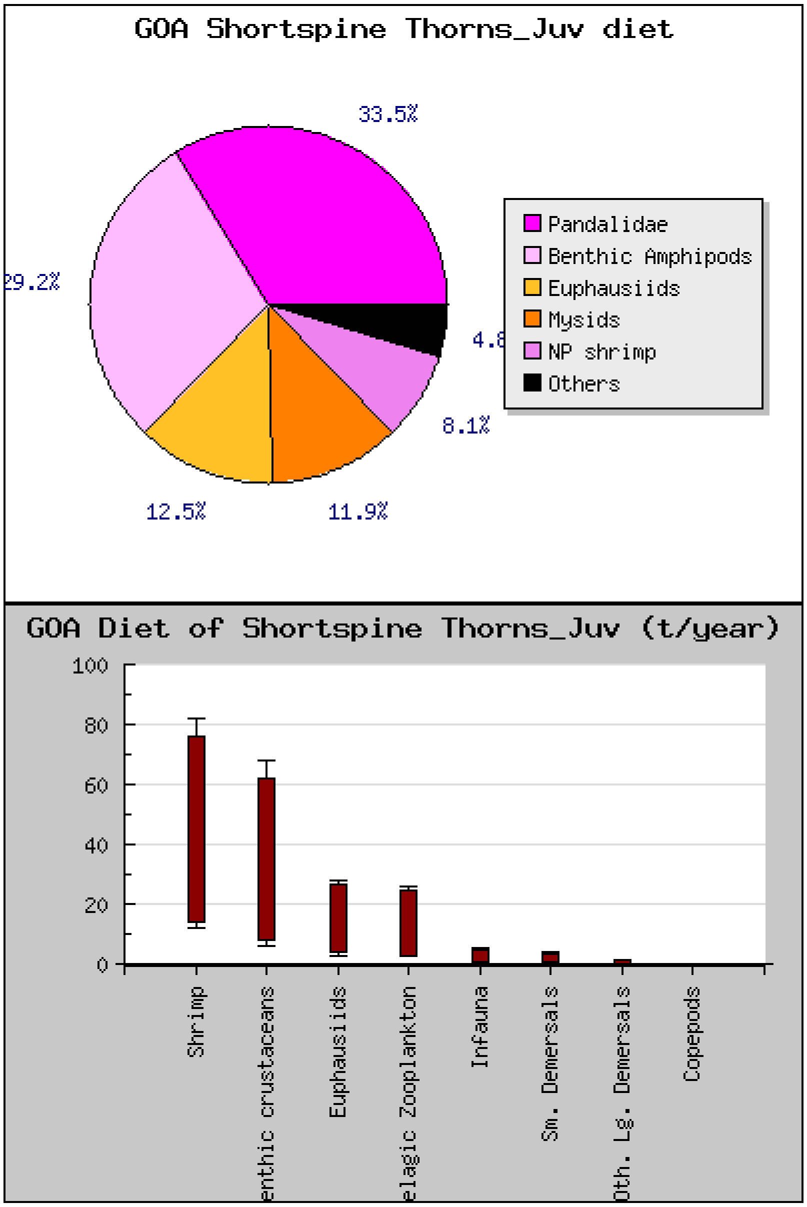

Figure 15.12 Diet composition (upper panel) and annual consumption of prey in tons (lower panel) by juvenile shortspine thornyheads in the GOA.

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) and incidental catch from the halibut IFQ fishery in GOA are presented Non-commercial removals have been presented previously (Lowe and Ianelli 2009) but now include additional data for 2010.

Non-commercial removals

Non-commercial removals are removals that do not occur during directed groundfish fishing activities. This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For thornyheads, these estimates can be compared to the research removals reported in previous assessments (Lowe and Ianelli 2009). The main research removals for thornyheads are from the annual NOAA GOA longline survey and the biennial NOAA GOA bottom trawl survey (Table A.1). Additionally, other miscellaneous research trawl surveys catch small amounts of thornyeads (<1 t). Since 2003, the longline survey catch is between 4-9 t and trawl survey catches are between 7-9 t. The GOA bottom trawl survey only occurs on a biennial schedule in recent years. The International Pacific Halibut Commissions (IPHC) longline survey captures small amounts of sablefish; only 2010 data is available for the IPCH survey and the catch was <1 t. Estimates of non-commercial removals other than research removals (e.g., sport and subsistence catches) are available for 2010 but are neglibible (<1 t). The thornyhead non-commercial removals since 2005 are equivalent to 0.5-2.0% of the fishery catch and <1% of the ABC. These removals do not constitute a significant source of mortality for thornyheads in the GOA.

Halibut fishery incidental catch

Estimates of the incidental catch of groundfish in the halibut IFQ fishery in Alaska for 2001-2010 have been produced by the Halibut Fishery Incidental Catch Estimation (HFICE) working group (Table A.2). To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011). Incidental catches from the halibut fishery range from 3-8 t for 2001-2010, representing less than 1% of the ABC. Due to catch accounting methodology, there is the additional possibility that portions of this incidental catch may have already been accounted for as official thornyhead catch. Incidental catch from the halibut fishery does not represent a significant mortality source for GOA thornyheads.

Literature Cited

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Table A.1. Research catches of GOA thornyheads (tons), 1977-2010. Estimates from IPCH survey and "other" sources only available for 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

Table A.2 Estimates of Gulf of Alaska shortspine thornyhead catch (t) by area from the unobserved portions of the halibut fishery, 2001-2010. Estimates produced by the Halibut Fishery Incidental Catch Estimation (HFICE) working group, 2001-2010.

Year	Western	Central	Eastern	Total
2001	<1	3	1	4
2002	<1	5	2	7
2003	<1	1	2	4
2004	<1	1	2	3
2005	<1	1	4	6
2006	<1	5	3	8
2007	<1	4	3	7
2008	1	0	4	5
2009	<1	3	5	8
2010	<1	2	5	7