15. Gulf of Alaska Thornyheads

Sandra Lowe, Sarah Gaichas and James Ianelli
NMFS Alaska Fisheries Science Center

Executive Summary

Summary of Major Changes

Changes in the input data:

1. Total catch weight for GOA thornyheads is updated with 2005, 2006, and partial 2007 data.
2. Length composition from the 2006 longline fishery was added.
3. Biomass and length composition information for GOA thornyheads are updated with 2007 GOA bottom trawl survey data.
4. Relative population numbers and weights and size compositions for GOA thornyheads from ABL longline surveys are updated with 2006 and 2007 data.
5. Information on the position of thornyheads within the GOA ecosystem and the potential ecosystem effects on thornyheads are included.

Changes in assessment methodology:
We continue to assess GOA thornyheads using Tier 5 criteria, using the assessment methodology introduced in 2003. In their December 2003 minutes, 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 age composition data become available.

In the past, the average of the 2 most recent complete surveys was used to compute biomass for Tier 5 calculations. This was done to accommodate the lack of survey coverage in certain depth and area strata in past years. However, the 2005 and 2007 surveys covered all depths and areas, so this is not an issue at this time. A point of concern for the 2007 survey is that while there was a 10% decrease Gulfwide, the majority of this decrease was observed in the western GOA. Because thornyheads have very low *CV*s associated with the trawl surveys (4 and 5% in 2005 and 2007, respectively), and to appropriately account for the area specific decrease, we recommend using the most recent survey (2007) to compute biomass and for the ABC apportionment.

Changes in assessment results:
Gulfwide thornyhead biomass declined 10% in the 2007 GOA trawl survey compared with the 2005 trawl survey. However, most of this decrease was observed in the western GOA. The 2007 trawl survey biomass declined 45% and 11% in the Western and Central Gulf areas, while the Eastern Gulf biomass increased 15%. The updated method described above with 2007 survey data is used to calculate ABC and OFL under Tier 5. The most recent (and complete) 2007 GOA trawl survey biomass estimate of 84,774 t, was multiplied by 0.75*M* (=0.0225) for an **ABC recommendation of 1,910 t** and *M*=0.03 for an **OFL recommendation of 2,540 t**. This compares with values estimated in the 2005 assessment (for 2006 and 2007) based on the 2003 and 2005 survey estimates, which gave an average biomass of 98,158 t, an ABC of 2,209 t, and an OFL of 2,945 t. The 2008 ABC recommendation represents a 13% decrease from the Council's 2007 ABC. This is due to a 10% decrease in biomass and the use of only the most recent survey estimate (which has a *CV* of ~5%).

SSC comments specific to the GOA thornyheads assessment:
There were no specific SSC comments on the GOA thornyheads assessment in 2005 and 2006.

SSC comments on assessments in general:
There were no SSC comments on assessments in general that applied to the GOA thornyheads assessment given that they are Tier 5.

Introduction

Description
Thornyheads (*Sebastolobus* species) are groundfish belonging to the order Scorpaeniformes and 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 themselves, they are distinguished from the "true" rockfish in the genus Sebastes primarily by reproductive biology; all Sebastes rockfish are live-bearing (viviparous) fish, but 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 slope and 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 1000m 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 and 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 Seas of Okhotsk and Japan, but also ranges 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 earlier along the U.S. west coast, between December and May). 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 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 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 reach 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 and Stock Structure

After passage of the Magnuson Fishery Conservation and Management Act (MFCMA) 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. 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).

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 by Siebenaller (1978). Gene flow was substantial among some locations and others diverged significantly. 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. This 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. 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 would be 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 conducted 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 pelagic shelf

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, 4) a higher 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.

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 NMFS Observer Program. Catches in more recent years (1990-2002) are based on "blended" fishery observer and industry sources using an algorithm developed by the NMFS Alaska Regional Office (AKRO). Catches from 2003 to the present were provided by NMFS Regional Office Catch Accounting System (CAS), an improved form of the "blend" used previously. Estimates of discards for the years 1990 through the present are provided by the NMFS AKRO as well. Thornyhead discards before 1990 are unknown. We assumed that the reported catches before 1990 included both retained and discarded catch. The only other known catch of thornyheads occurs as a result of scientific surveys in the Gulf of Alaska. Survey research catches of all thornyhead species (Table 15.2) are a very small component of overall removals.

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. Recent catches from 2004 to the present have averaged around 800 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) established by management (Table 15.3). 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. Management decisions since 2000 have tended to favor 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, so in 2003, the use of the assessment model was suspended. The Tier 5 biomass based approach to calculating ABC and OFL for GOA thornyheads which was initiated in

2003, results in similar recommendations as the more conservative assessment model predictions previously preferred by management. Even with this relative conservatism in recent thornyhead management, fisheries do not appear to be constrained by small TACs for thornyheads.

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 in 2004, 2005, and 2006, followed by rockfish and combined flatfish fisheries (Figure 15.1). Discards in 2003 were more characteristic of past years in that thornyhead discards from the flatfish fisheries was higher while relatively fewer discards were incurred from the sablefish and rockfish fisheries (Figure 15.2). In 2004 and 2006, most thornyhead discards came from the rockfish fishery, followed by the sablefish and flatfish fisheries. The distribution of thornyhead catches ranges broadly throughout the Gulf of Alaska and is consistent within recent years for the different gear types (Figures 15.3 and 15.4). Length sampling from trawl and longline fisheries for 1990-2006 is shown in Figures 15.5 and 15.6; in general, longline fisheries capture larger thornyheads than trawl fisheries, perhaps because they operate in deeper waters and hook selectivity which 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 15.4). Note that these represent only relative abundance and are not generally comparable with the trawl survey estimates of abundance. Length sampling from longline surveys for 1990-2007 is shown in Figure 15.7.

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.

Trawl surveys

The most recent NMFS trawl survey for the Gulf of Alaska was conducted during the summer of 2007 (Tables 15.5 and 15.6). This survey employed standard NMFS Poly-Nor'eastern bottom trawl gear and provide biomass estimates using an "area-swept" methodology described in Wakabayashi *et al.* (1985). The 1984, 1987, 1999, 2003, 2005, and 2007 surveys extended into deeper water (>500 m) and covered the range of primary habitat for the shortspine thornyhead stock. The 2001 survey and surveys during the early 1990s did not extend to the deeper zones where concentrations of larger shortspine and all longspine thornyheads are known to exist. This gives survey biomass estimates a disjointed appearance (Figure 15.8, upper panel, Table 15.6). A comparison of survey biomass estimates by depth strata suggests that different portions of the shortspine thornyhead population are sampled depending on survey depth coverage (Figure 15.8, lower panel). In addition, the 2001 survey did not extend into the eastern Gulf, where a significant portion of shortspine thornyhead biomass has been found in past surveys (Fig. 15.8,

lower panel). It is evident from trawl survey results that a significant portion of the biomass of shortspine thornyheads exists beyond depths of 500 m, and that all of the biomass of longspine thornyheads exists beyond depths of 500m (Figure 15.9). Therefore, in assessing the relative abundance of GOA thornyheads, it is important to consider only surveys covering the full depth and geographic range of the species, which in recent years limits us to only the 1999, 2003, 2005, and 2007 surveys.

Thornyhead biomass declined 10% in the 2007 GOA trawl survey compared with the 2005 trawl survey. However, most of this decrease was observed in the western GOA. The 2007 trawl survey biomass declined 45% and 11% in the Western and Central Gulf areas, while the Eastern Gulf biomass increased 15%. Previous to this, survey biomass from the 2005 survey declined about 7% relative to the 2003 survey. The spatial distribution of shortspine thornyhead catch per unit effort in recent complete trawl surveys appears relatively similar (Figure 15.10) Length sampling from trawl surveys for 1990-2007 is shown in Figure 15.11.

Analytic Approach, Model Evaluation, and Results

At present, the available data do not support population modeling for any species of thornyheads in the GOA, so none of these stock assessment sections are relevant for this Tier 5 assessment, except for one:

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 she found was 62 years old. 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 (0.013-0.016) and therefore much higher maximum ages (250-313 years) than had ever been previously reported using any direct ageing method.

In past years, we attempted to estimate shortspine thornyhead growth and examined multiple assumptions about natural mortality from Miller (1985), Kline (1996), Kastelle *et al.* (2000), and Pearson and Gunderson (2003) within a size-based model for shortspine thornyheads. These natural mortality estimates, along with several others, are summarized in Table 15.7. These explorations did not result in a definitive growth relationship for GOA shortspine thornyheads, and it was concluded that the age and length data available for this species in Alaska were inadequate to resolve the uncertainties related to these parameters within a modeling context. Improved otolith ageing techniques are in development at AFSC to address this problem.

Considering the uncertainty inherent even in applying the Tier 5 method to thornyhead species in the GOA, we elected to use one of the more conservative estimates of M derived from these methods (M=0.03, Table 15.7). 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). This natural mortality rate is

lower than the *M*=0.05 applied to shortspine thornyheads on the U.S. West Coast and in the BSAI other rockfish assessment (Hamel 2005, Reuter and Spencer 2006). Applying this comparatively low estimate of *M*=0.03 for use in the GOA was suggested by the GOA Plan Team and the NPFMC SSC, and is considered conservative because it will result in the low estimates of ABC and OFL under Tier 5 which still allow for historical levels of catch to be taken in the fishery. Until we find better information on shortspine thornyhead productivity, age, and growth in the GOA, this is the best interim measure balancing shortspine thornyhead conservation and allowing for historical levels of incidental catch in target groundfish fisheries.

Fecundity and maturity at length

Fecundity at length has been estimated by Miller (1985) and Cooper *et al.* (2005) for shortspine thornyheads in Alaska (and 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 Alaskan.

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.

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

In the past, the average of the 2 most recent complete surveys was used to compute biomass for Tier 5 calculations. This was done to accommodate the lack of survey coverage in certain depth and area strata in past years. However, the 2005 and 2007 surveys covered all depths and areas, so this is not an issue at this time. The 2007 survey indicates a 10% decrease in shortspine thornyhead biomass with the majority

of this decrease was observed in the western GOA. Because thornyheads have very low *CV*s associated with the trawl surveys (4 and 5% in 2005 and 2007, respectively), and to appropriately account for the area specific decrease, the most recent survey (2007) was used for the ABC estimate and for area-apportionments.

A Tier 5 estimate of ABC is calculated based on the 2007 survey biomass estimate of 84,775 t and assuming an *M* of 0.03. 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 recommended 2008 ABC for thornyheads is thus 84,775 t x 0.0225 = 1,910 t, which is also the recommendation for the 2009 ABC.

The 2008 ABC recommendation represents a 13% decrease from the Council's 2007 ABC, which is in line with the 10% decrease in biomass between the 2005 and 2007 bottom trawl surveys.

Apportionment of ABC
Based on the 2007 survey biomass distribution, we computed the following apportionment of shortspine thornyheads ABC broken out by management areas. We recommend the most recent survey biomass for the apportionment for three reasons: first, the GOA Plan Team and NPFMC SSC have approved of using the most recent survey biomass estimate for ABC apportionment since the 2003 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 2008 and 2009.

GOA Area (NPFMC Area)	2007 Biomass	Percent of Total Biomass	Area ABC Apportionment
Western (610)	12,152	14%	267
Central (620 and 630)	37,607	45%	860
Eastern (640 and 650)	35,016	41%	783
Gulfwide Total	84,775	100%	1,910

Overfishing Level

The Tier 5 estimate of shortspine thornyhead F_{OFL} is equal to *M* = 0.03. The 2008 OFL for thornyheads is thus 84,775 t x 0.03 = 2,540 t, which is also the 2009 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 15.12, upper panel) whereas juveniles prey more on invertebrates and are therefore at a lower trophic level (Figure 15.12, 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.*, in press). 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 15.13). 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 15.13 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 vs 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 15.14, 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 15.15). 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 15.16, 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 15.16, 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 15.16). 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 15.17).

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" because no isolated thornyhead fishery exists 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 the highest weight of nontarget species of bycatch 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 are 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 15.8. The observation column represents the best attempt to summarize the past, present, and foreseeable future trends. The interpretation column provides details on how ecosystem trends might affect the stock (ecosystem effects on the stock) or how some aspects of fisheries for other targets which catch thornyheads may affect the ecosystem. The evaluation column indicates whether the trend is of: *no concern, probably no concern, possible concern, definite concern,* or *unknown.*

Data Gaps and Research Priorities

Because fishing mortality appears to be a larger proportion of adult thornyhead mortality in the GOA than predation mortality, highest priority research should continue to focus on direct fishing effects on shortspine thornyhead populations. The most important component of this research is to fully evaluate

the age and growth characteristics of GOA thornyhead to re-institute the age structured population dynamics model with adequate information.

Summary

2008 GOA shortspine thornyheads	
M	0.03
Tier	5
Biomass	84,775
F_{OFL}	0.03
Max F_{ABC}	0.0225
Recommended F_{ABC}	0.0225
Max ABC	1,910
Recommended ABC	1,910
OFL	2,540

Acknowledgements

We thank Nancy Maloney for providing information and support for the shortspine thornyhead tag release-recapture database. Chris Lunsford provided updates for the longline survey data. Mark Wilkins provided the NMFS trawl survey data. Thanks also to the entire participating RACE Division staff for implementing and conducting the 2007 survey under severe time constraints.

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. *In press*. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA Tech Memo.

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.

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.

Dawson, P.K. and H.H. Shippen. 1989. Thornyheads *In* Condition of resources of the Gulf of Alaska in 1988. NOAA Tech. Memo. F/NWC-165. pp.151-169.

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

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. 1994. Thornyheads. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1995. Nov. 1994. N. Pac. Fish. Mgt. Council, P.O Box 103136, Anchorage, AK 99510.

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. and D.H. Ito. 1998. Thornyheads. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 1999. Nov. 1998. 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.

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.

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.

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.

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.

Sasaki, T., 1985. Studies on the sablefish resources in the North Pacific Ocean. Bulletin 22, (1-108), Far Seas Fisheries Research Laboratory, Shimizu, 424, Japan.

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 J.T. Fujioka. 1988. Evaluation of variability in sablefish, Anoplopoma fimbria, abundance indices in the Gulf of Alaska using the bootstrap method. Fish. Bull. 86:445-452.

Sigler, M.F. and H. Zenger. 1989. Assessment of Gulf of Alaska sablefish and other groundfish based on the domestic longline survey, 1987. NOAA Tech. Memo NMFS F/NWC-169. 54 p.

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. Estimated retained catch and discard of GOA thornyheads (tons) by gear type[1], 1977-2007.

	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	707	997	804	369	39	408	1,076	136	1,212
2004	414	61	476	367	30	397	781	91	872
2005	333	27	360	369	41	410	702	68	770
2006									805
2007									761

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; 2003-2005 from the NMFS Alaska Regional Office Catch Accounting System; 2006-2007 pers. comm. Jennifer Mondragon, NMFS Alaska Regional Office, Juneau, Alaska.

*The 2007 catch is incomplete, representing catch reported through October 3, 2007.

Table 15.2. Research catches of GOA thornyheads (tons), 1977-2007. (Sources: NMFS trawl survey database; Mike Sigler, Chris Lunsford, and Michael Martin personal communications.)

Year	Domestic Longline Survey Catch	Trawl Survey Catch	Co-op Longline Survey Catch	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	6	7		13
2004	5			5
2005	6	9		14
2006	6			6
2007	7	9		16

Table 15.3. 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	1,212	Split W/C/E
2004	1,940	1,940	872	Split W/C/E
2005	1,940	1,940	770	Split W/C/E
2006	2,209	2,209	805	Split W/C/E
2007[d]	2,209	2,209	761	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/ 2007 catch estimate is reported catch as of October 3, 2007

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; 2003-2005 from the NMFS Alaska Regional Office Catch Accounting System; 2006-2007 pers. comm. Jennifer Mondragon, NMFS Alaska Regional Office (AKRO), Juneau, Alaska.

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

Table 15.4. Relative population number (RPN) and weight (RPW) for GOA thornyheads from the domestic longline survey 1990-2007 (Chris Lunsford, NMFS Auke Bay Lab, pers. comm.).

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

Table 15.5. Biomass estimates (with *CV*) for GOA thornyheads from the NMFS trawl surveys 1984-2007, with comments on survey coverage.

Species/ Year	Biomass (tons)	*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
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

Table 15.6. Shortspine thornyhead biomass (t), and the percentage distribution and coefficients of variation (*CV*) by management area from the bottom trawl surveys in the Gulf of Alaska, 1993-2007. The 1993, 1996, and 2001 surveys did not survey the deeper depths >500 m, and the 2003 survey 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)						
		1993	1996	1999	2001	2003	2005	2007
Gulf of Alaska	1-100	2		116	46	54	180	212
	101-200	2,143	6,625	4,446	1,776	3,988	5,682	4,742
	201-300	12,957	21,968	23,418	13,619	39,156	28,324	21,330
	301-500	17,912	23,390	27,872	13,220	37,017	28,394	28,063
	501-700	--	--	14,952	--	21,360	18,213	16,507
	701-1000	--	--	6,531	--	--	13,947	13,920
	Total	33,014	51,984	77,336	28,661	101,576	94,740	84,775
	Area % of biomass total	100%	100%	100%	100%	100%	100%	100%
Western 610	1-100			4			63	
	101-200		313	37		500	1,108	7
	201-300	490	3,115	2,248	3,981	6,017	5,550	2,910
	301-500	3,215	4,615	4,739	4,771	8,519	5,630	4,702
	501-700	--	--	5,389	--	5,887	6,377	2,590
	701-1000	--	--	1,679	--	--	3,277	1,943
	Total	3,706	8,043	14,097	8,753	20,922	22,005	12,152
	Area % of biomass total	11%	15%	18%	31%	21%	23%	14%
Central 620/630	1-100	2		2	46	54	103	131
	101-200	369	309	690	1,776	1,317	3,000	1,465
	201-300	6,997	10,456	10,604	9,637	25,386	13,544	8,190
	301-500	5,141	8,265	11,638	8,449	16,030	10,780	11,124
	501-700	--	--	6,725	--	10,462	6,728	8,962
	701-1000	--	--	2,930	--	--	8,262	7736
	Total	12,509	19,030	32,590	19,908	53,250	42,419	37,607
	Area % of biomass total	38%	37%	42%	69%	52%	45%	45%
Eastern 640/650	1-100			111	--		14	81
	101-200	1,775	6,003	3,719	--	2,172	1,574	3,271
	201-300	5,469	8,398	10,565	--	7,753	9,229	10,230
	301-500	9,556	10,509	11,495	--	12,468	11,983	12,237
	501-700	--	--	2,838	--	5,011	5,107	4,956
	701-1000	--	--	1,922	--	--	2,408	4,241
	Total	16,800	24,911	30,649	--	27,404	30,316	35,016
	Area % of biomass total	51%	48%	40%	0%	27%	32%	41%

Table 15.7. Range of empirical estimates of natural mortality (*M*) for GOA shortspine thornyheads. This assessment assumes an *M* = 0.03 from Gaichas and Ianelli (2003), while other assessments assume an *M* = 0.05.

Estimate	Source
0.013	Pearson and Gunderson 2003
0.027	Kline 1996
0.036	Jacobsen 1990
0.038	Pearson and Gunderson 2003
0.07	Miller 1985

Table 15.8. Shortspine thornyhead ecosystem considerations.

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

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

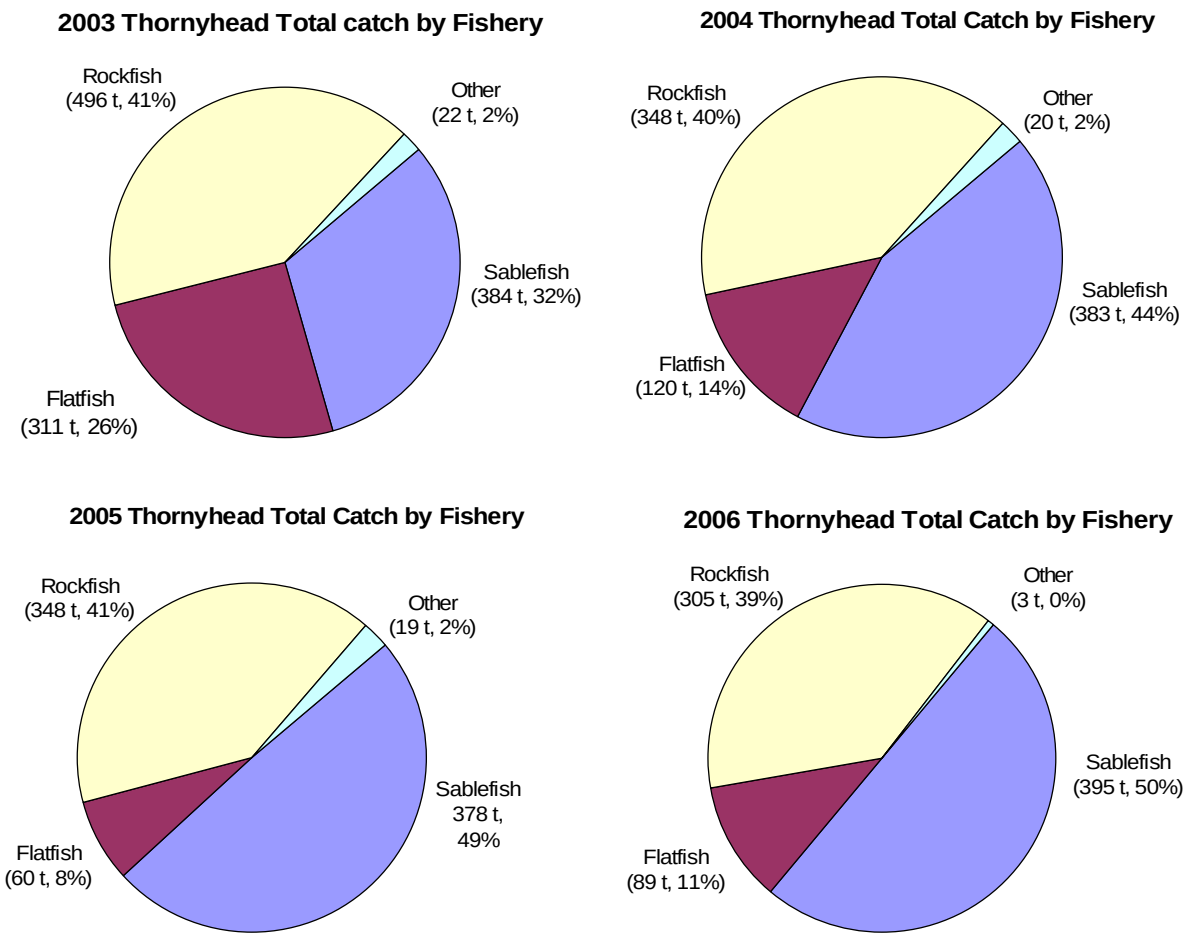

Figure 15.1 Distributions of total catches of GOA thornyheads by target fishery for 2003, 2004, 2005, and 2006. Fisheries are labeled with target, tons of thornyheads caught, and percentage of total thornyhead catch for the year.

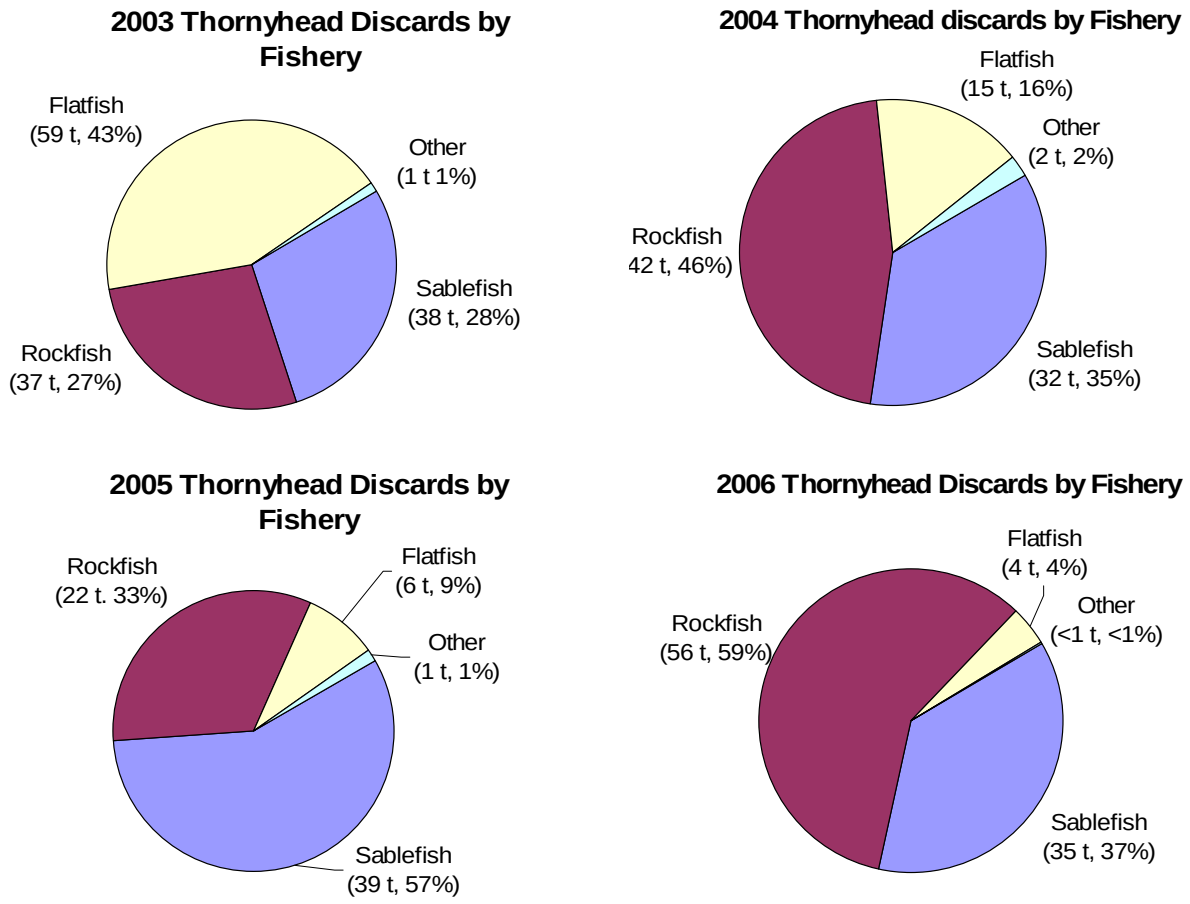

Figure 15.2 Distributions of discarded catches of GOA thornyheads by target fishery for 2003, 2004, 2005 and 2006. Fisheries are labeled with target, tons of thornyheads discarded, and percentage of total thornyhead discard for the year.

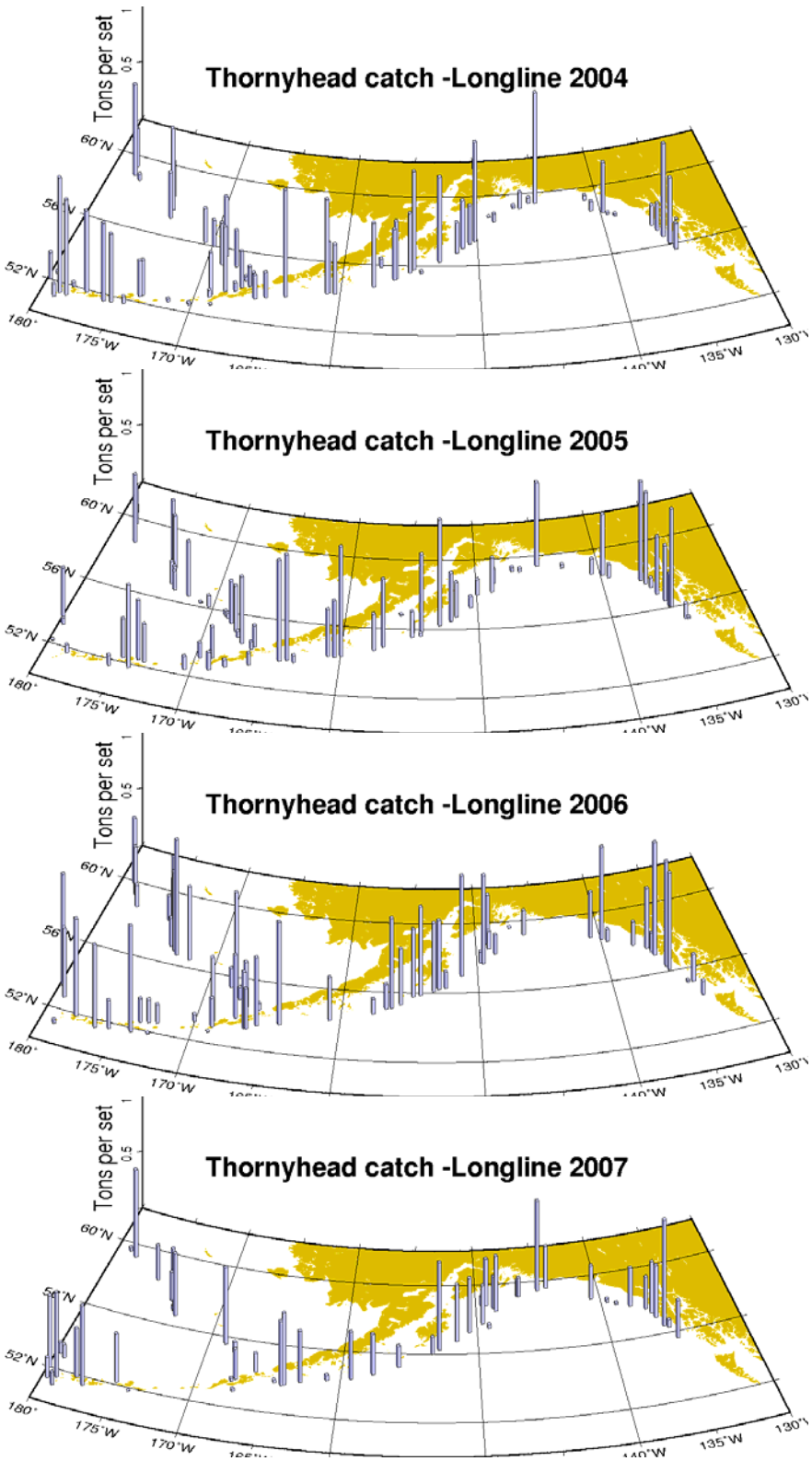

Figure 15.3 Distribution of observed thornyhead catch in longline gear, 2004-2007.

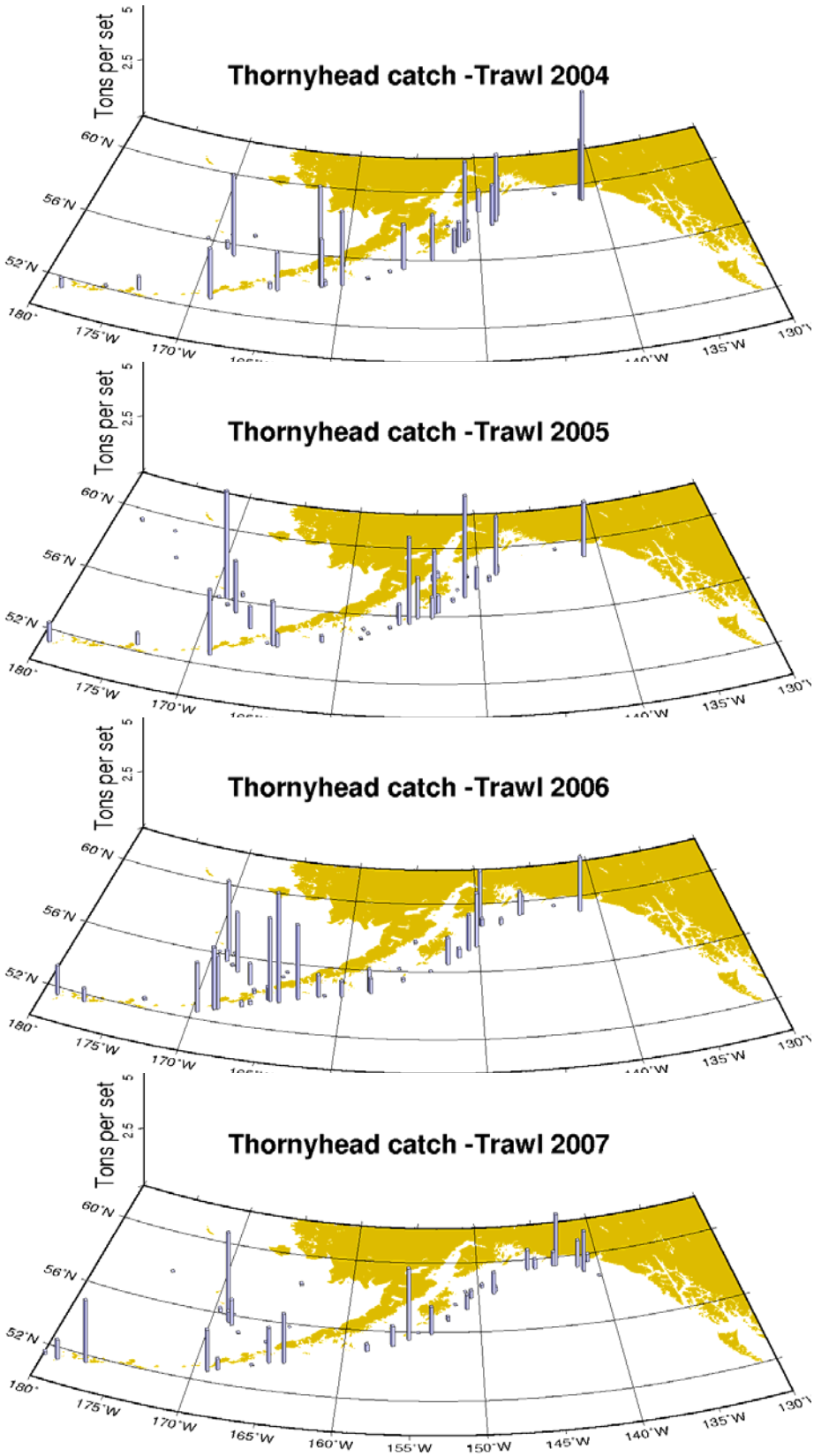

Figure 15.4 Distribution of observed thornyhead catch in trawl gear, 2004-2007.

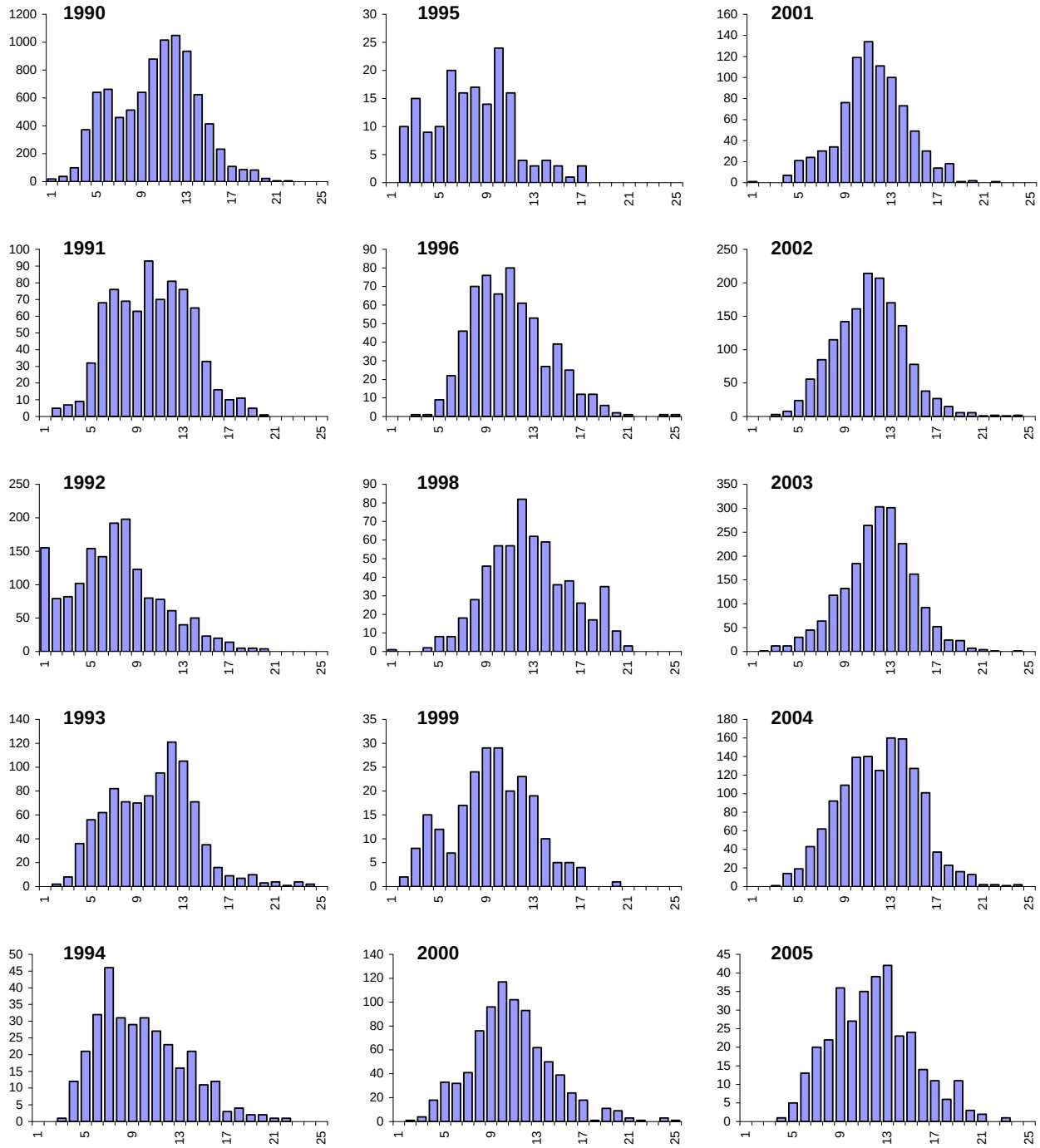

Figure 15.5. Shortspine thornyhead lengths measured in trawl fisheries, 1990-2005. No shortspine thornyheads were measured in 2006 from the trawl fisheries. Length bins on x axes are assigned as follows: bin 1, 1-9 cm fish;, bins 2-18, 10 to 47 cm fish (2 cm per bin); bins 19-24, 48 to 67 cm fish (4 cm per bin), and bin 25 spans 68 to 100 cm.

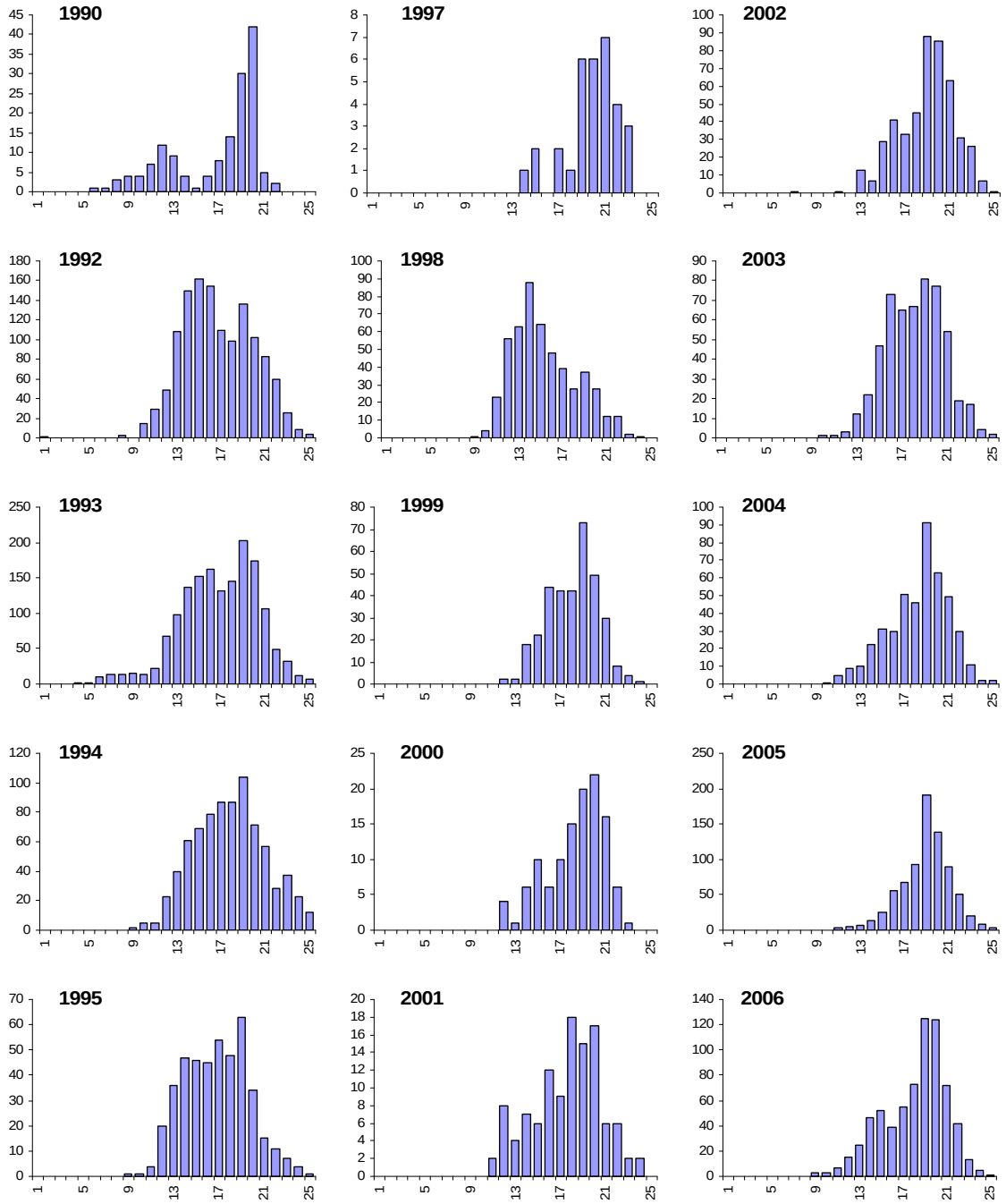

Figure 15.6. Shortspine thornyhead lengths measured in longline fisheries, 1990-2006. Length bins on x axes are assigned as follows: bin 1, 1-9 cm fish;, bins 2-18, 10 to 47 cm fish (2 cm per bin); bins 19-24, 48 to 67 cm fish (4 cm per bin), and bin 25 spans 68 to 100 cm.

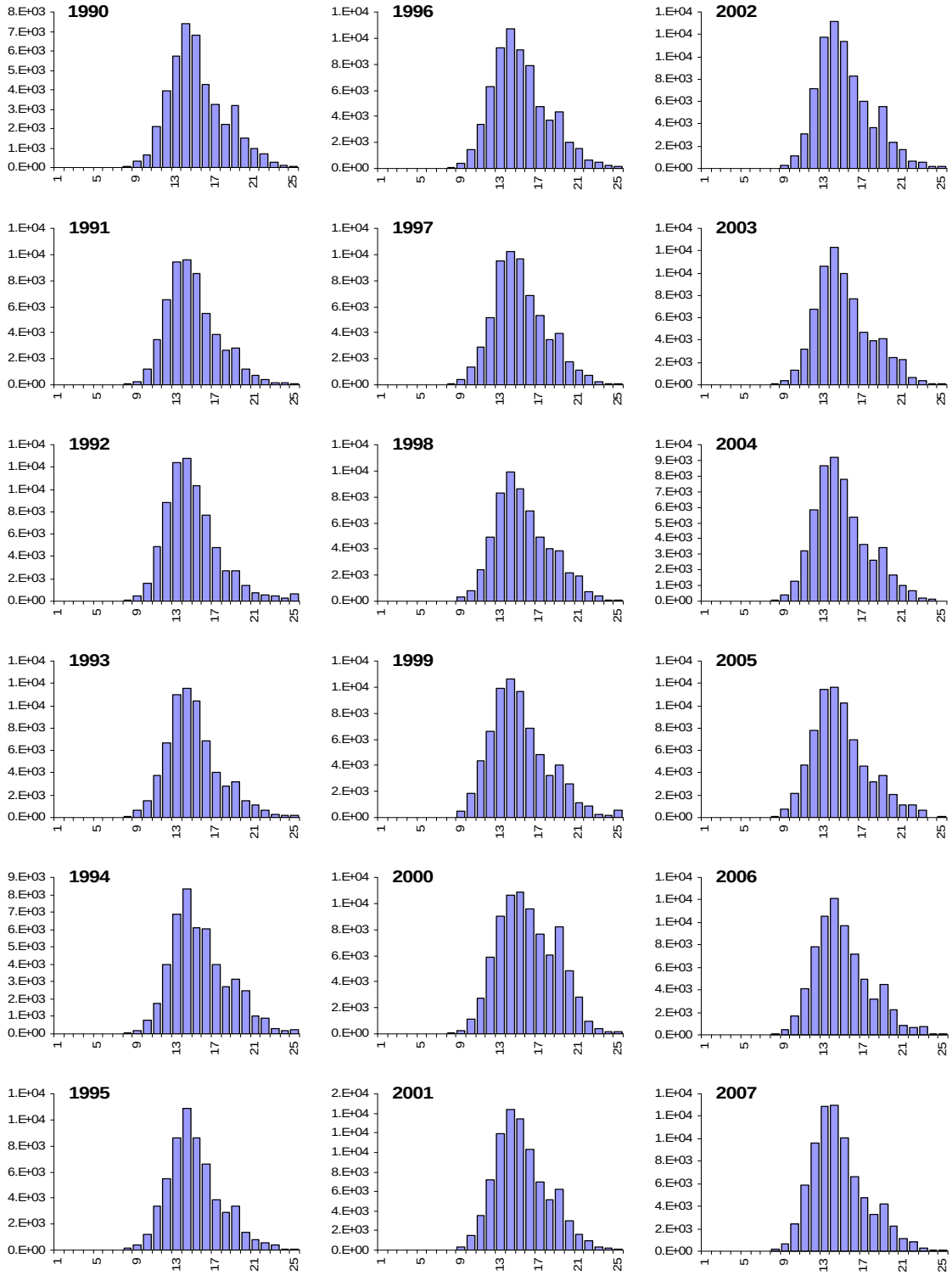

Figure 15.7. Shortspine thornyhead length frequencies from longline surveys, 1990-2007. Length bins on x axes are assigned as follows: bin 1, 1-9 cm fish;, bins 2-18, 10 to 47 cm fish (2 cm per bin); bins 19-24, 48 to 67 cm fish (4 cm per bin), and bin 25 spans 68 to 100 cm.

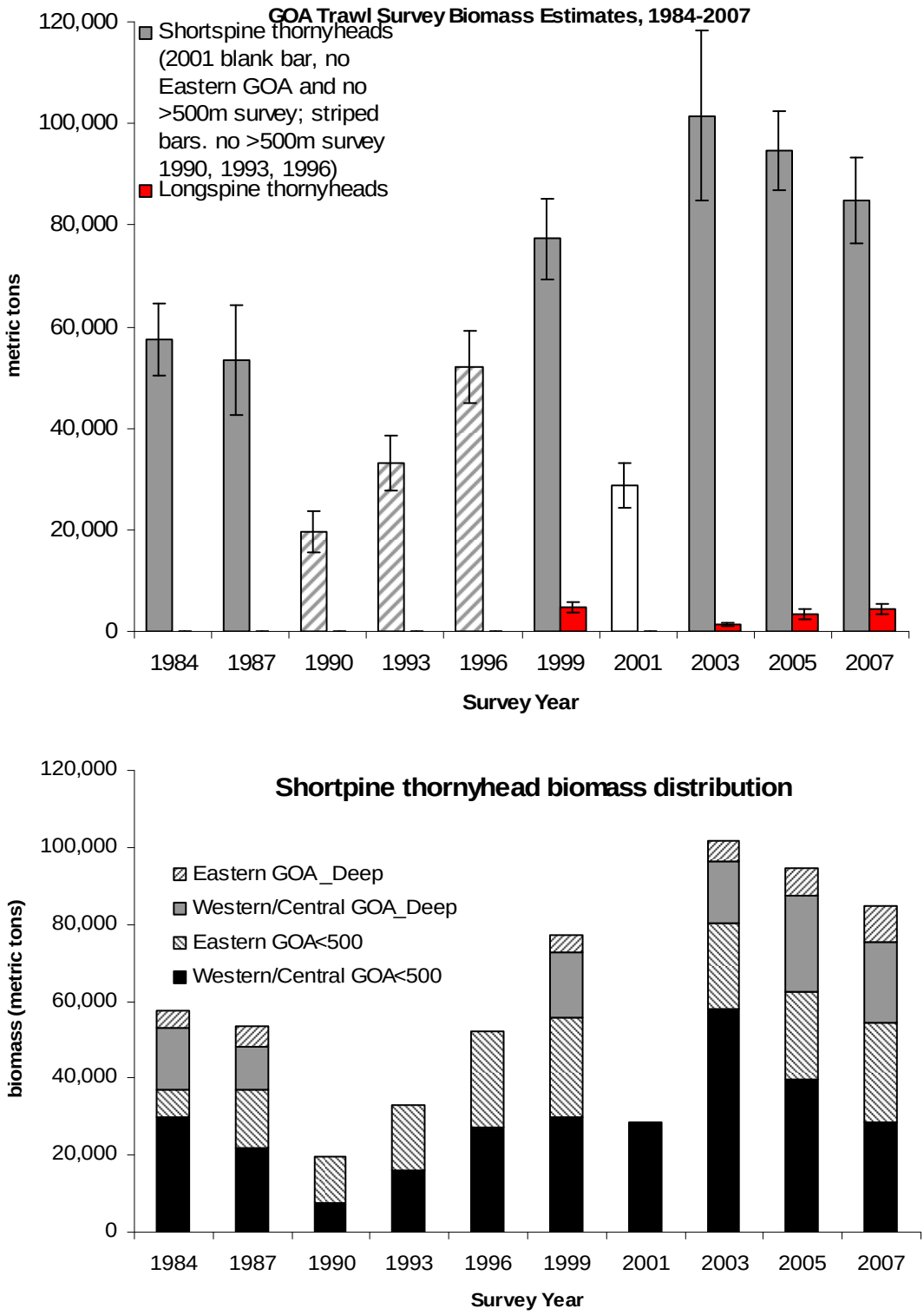

Figure 15.8. Trawl survey biomass estimates for Gulf of Alaska (GOA) thornyheads (top panel) and shortspine thornyheads (bottom panel). Error bars represent two standard deviations.

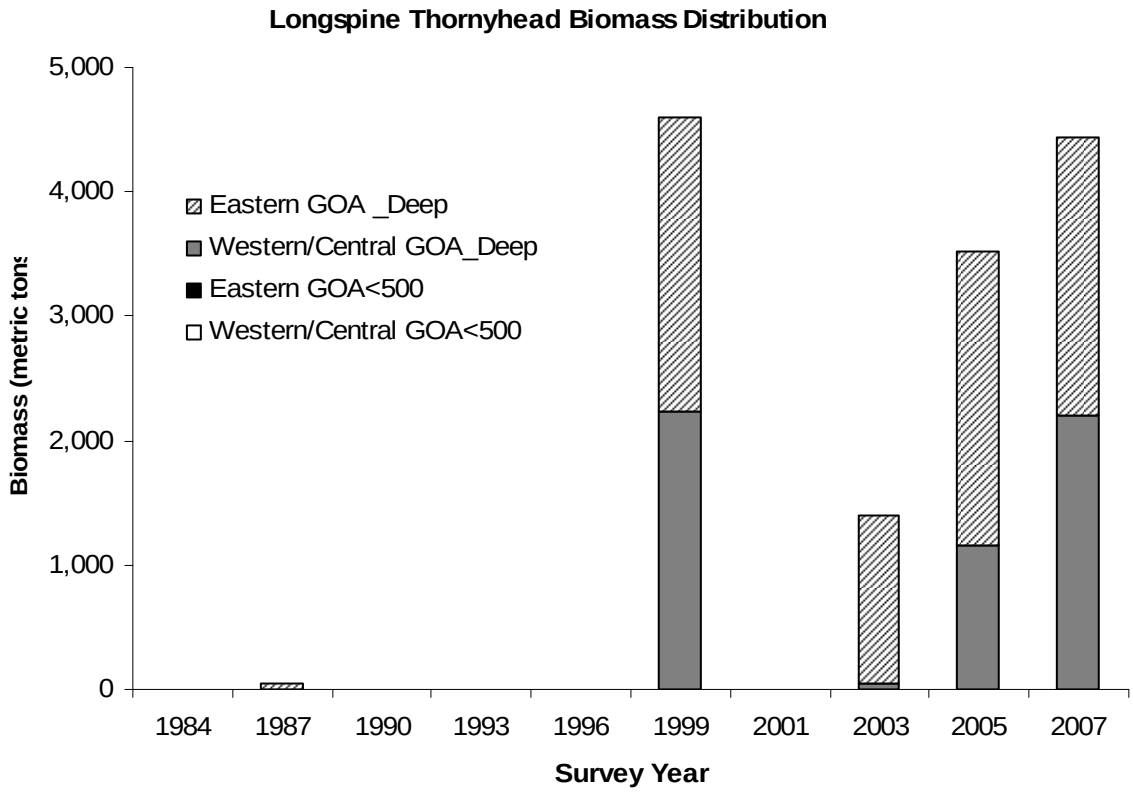

Figure 15.9. Trawl survey biomass estimates for Gulf of Alaska (GOA) longspine thornyheads, which are only encountered in depths greater than 500m in the GOA, and are more common in the Eastern GOA (areas 640 and 650) than in the Western and Central GOA.

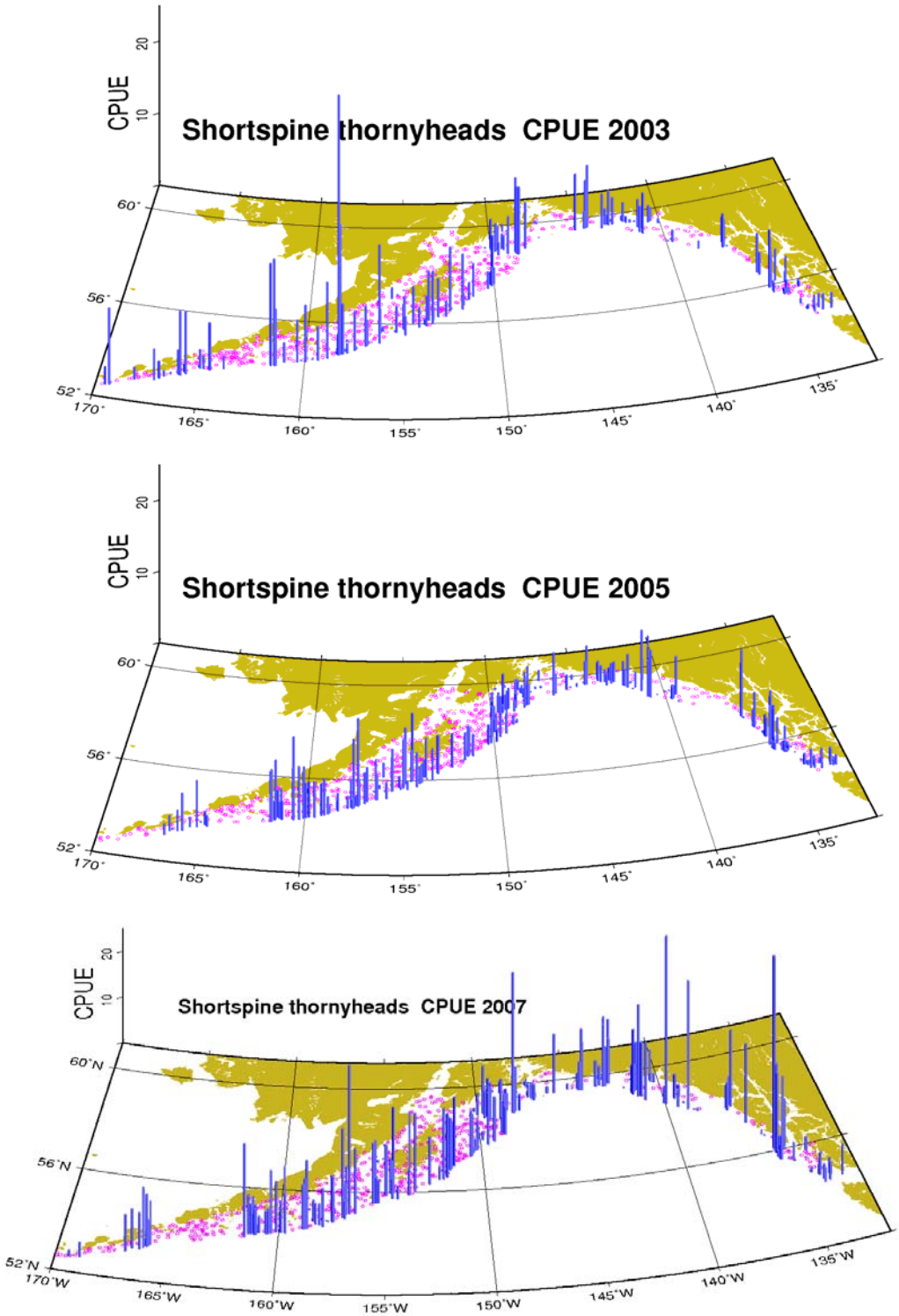

Figure 15.10. Shortspine thornyhead CPUE distributions for the most recent complete GOA trawl surveys in 2003, 2005, and 2007.

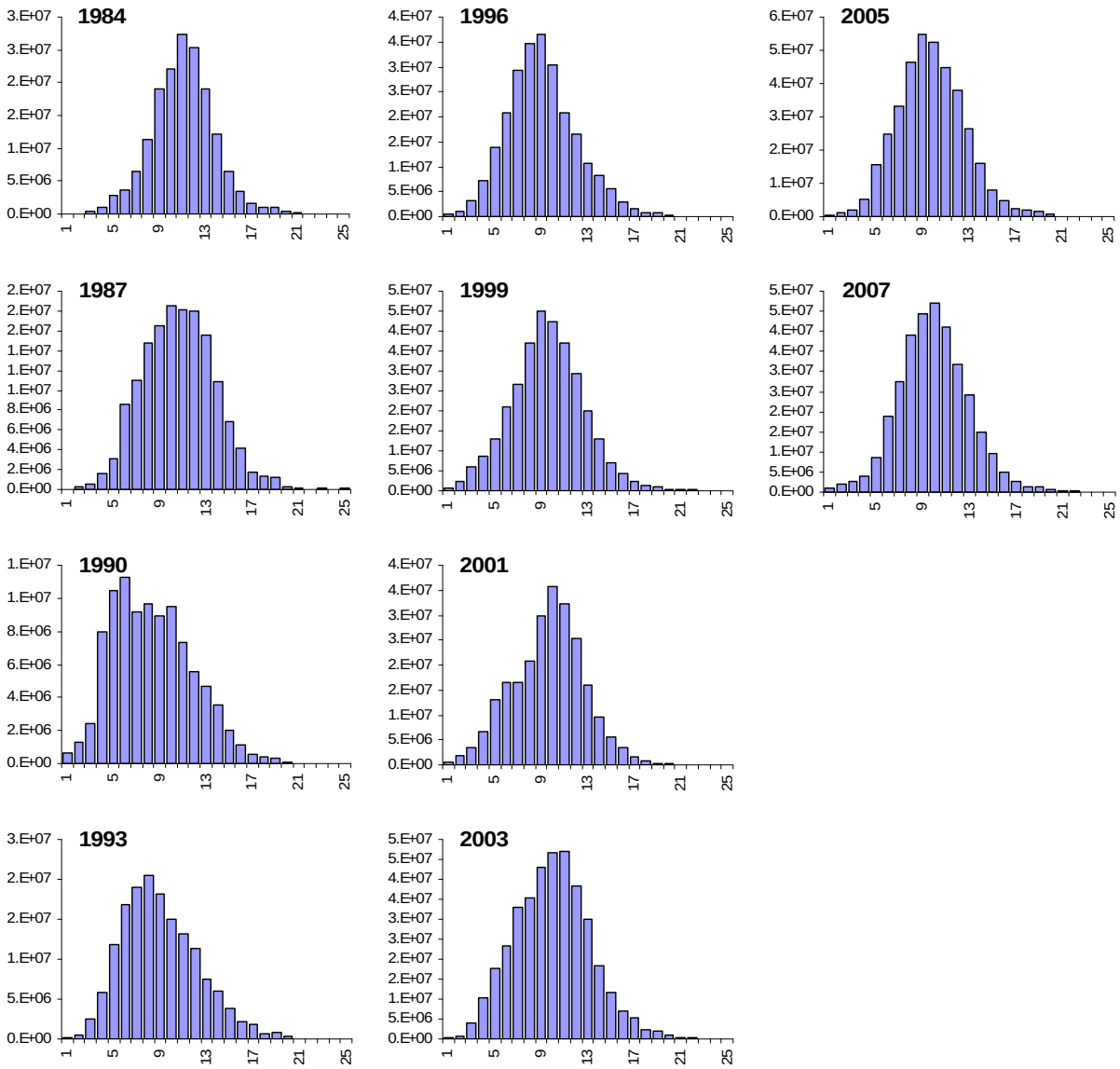

Figure 15.11. Shortspine thornyhead length frequencies from trawl surveys, 1984-2007. Length bins on x axes are assigned as follows: bin 1, 1-9 cm fish;, bins 2-18, 10 to 47 cm fish (2 cm per bin); bins 19-24, 48 to 67 cm fish (4 cm per bin), and bin 25 spans 68 to 100 cm.

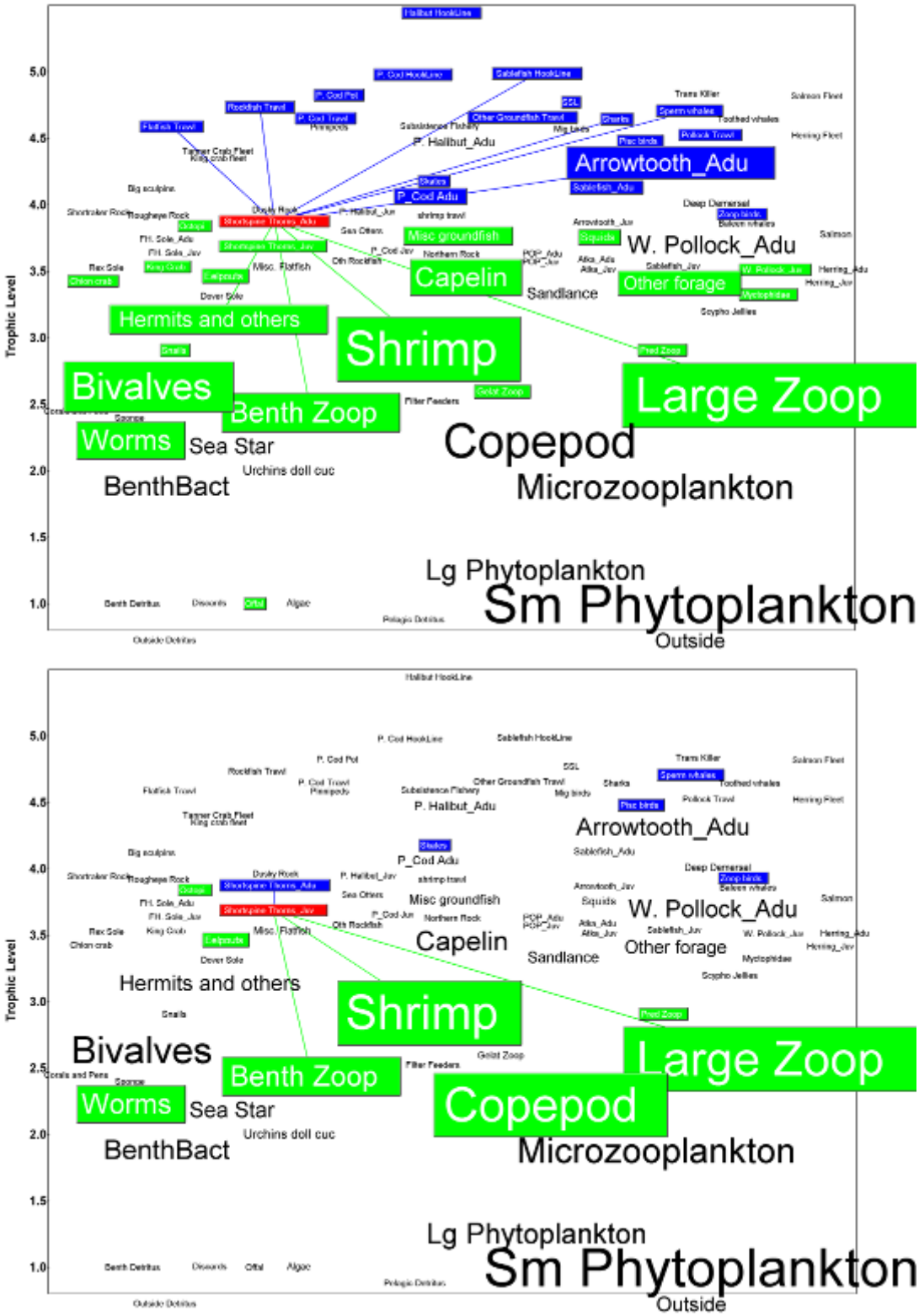

Figure 15.12 Position of shortspine thornyheads within GOA food webs: adults (marked red in upper panel) and juveniles (marked red in lower panel). Groups shaded blue are predators of shortspine thornyheads, and groups shaded green are prey. Similar information for longspine thornyheads is not available.

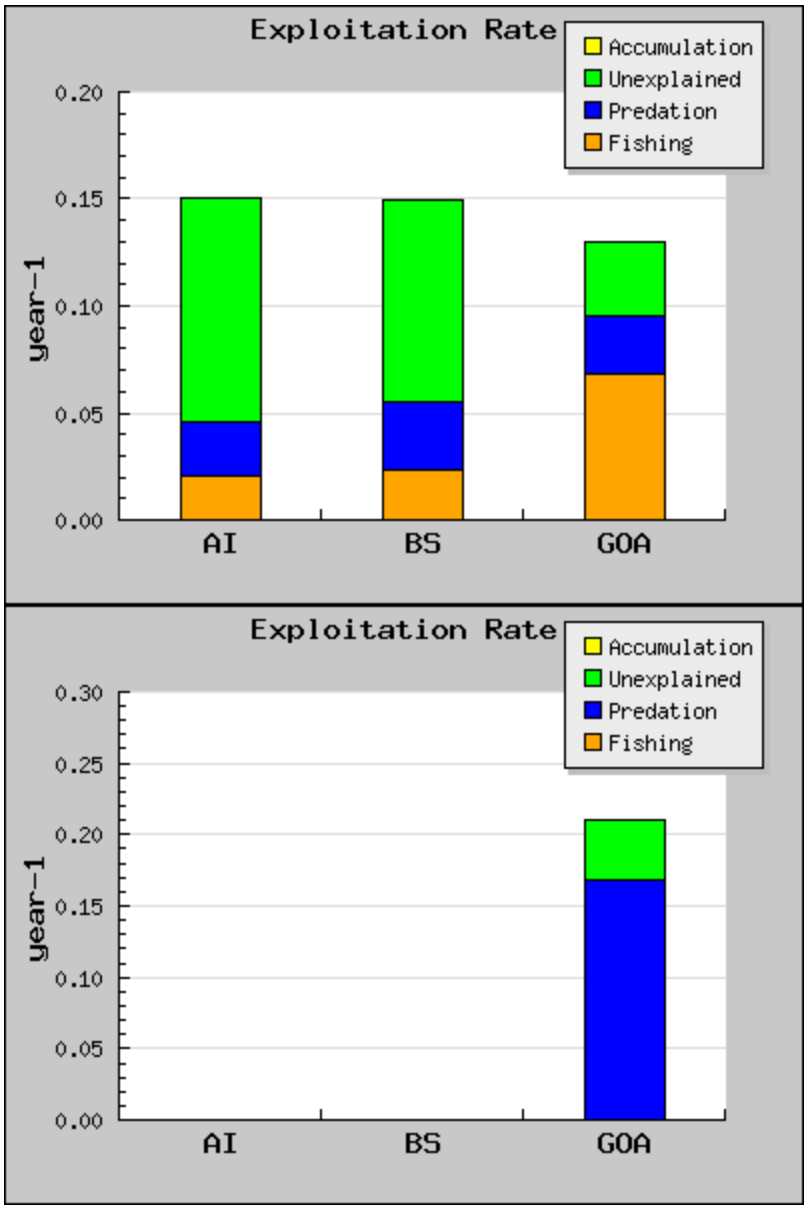

Figure 15.13 Comparison of exploitation rates for shortspine thornyheads across Alaskan ecosystems. Adult shortspine thornyheads (upper panel) have higher predation than fishing mortality in the AI and EBS, but higher fishing mortality in the GOA. Juvenile shortspine thornyheads (lower panel) were only 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.

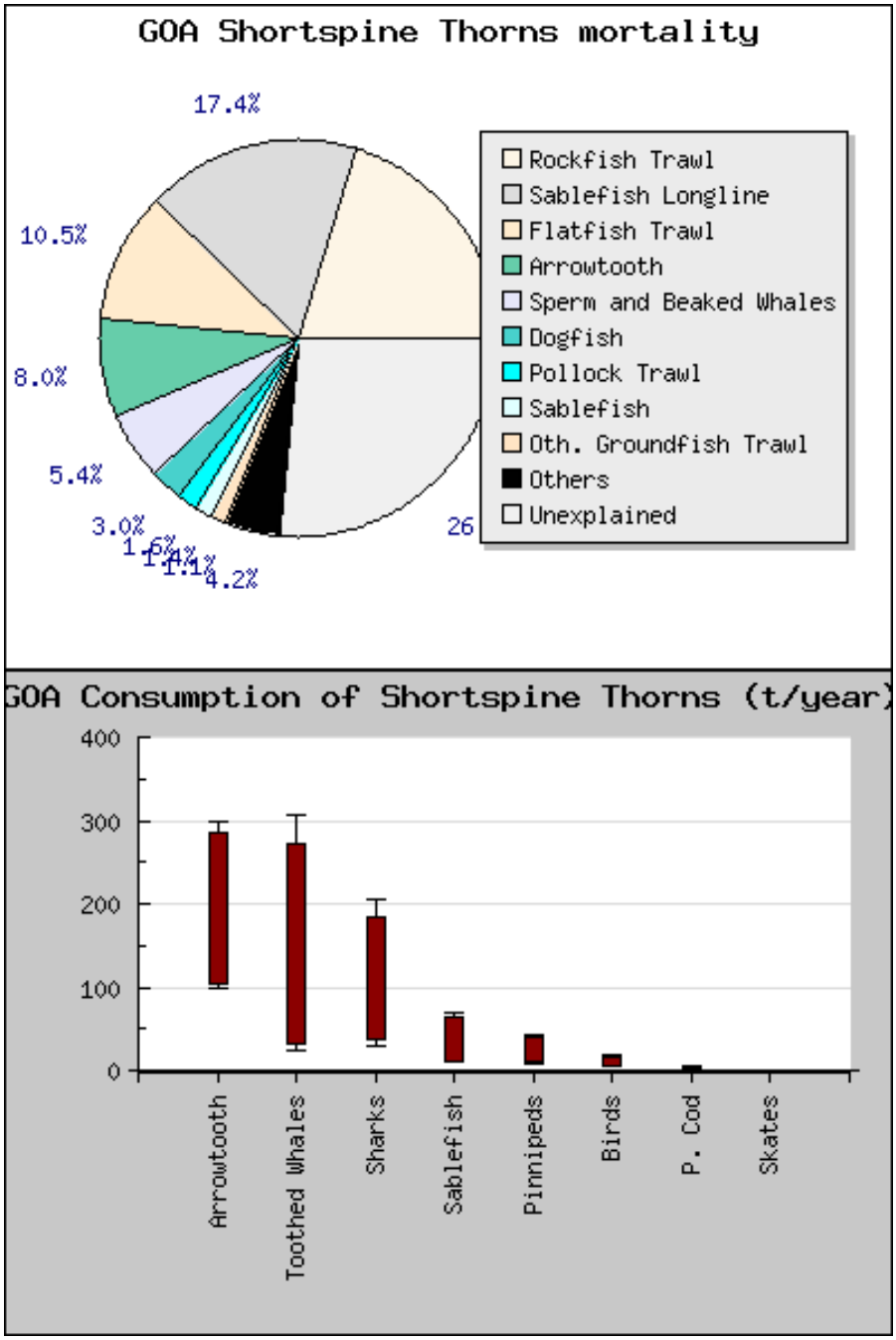

Figure 15.14 Mortality sources (upper panel) and annual consumption in tons (lower panel) by predators of adult shortspine thornyheads in the GOA. Fisheries for rockfish, sablefish, and flatfish account for nearly 50% of total adult shortspine thornyhead mortality, while all predators combined account for about 25% of total mortality.

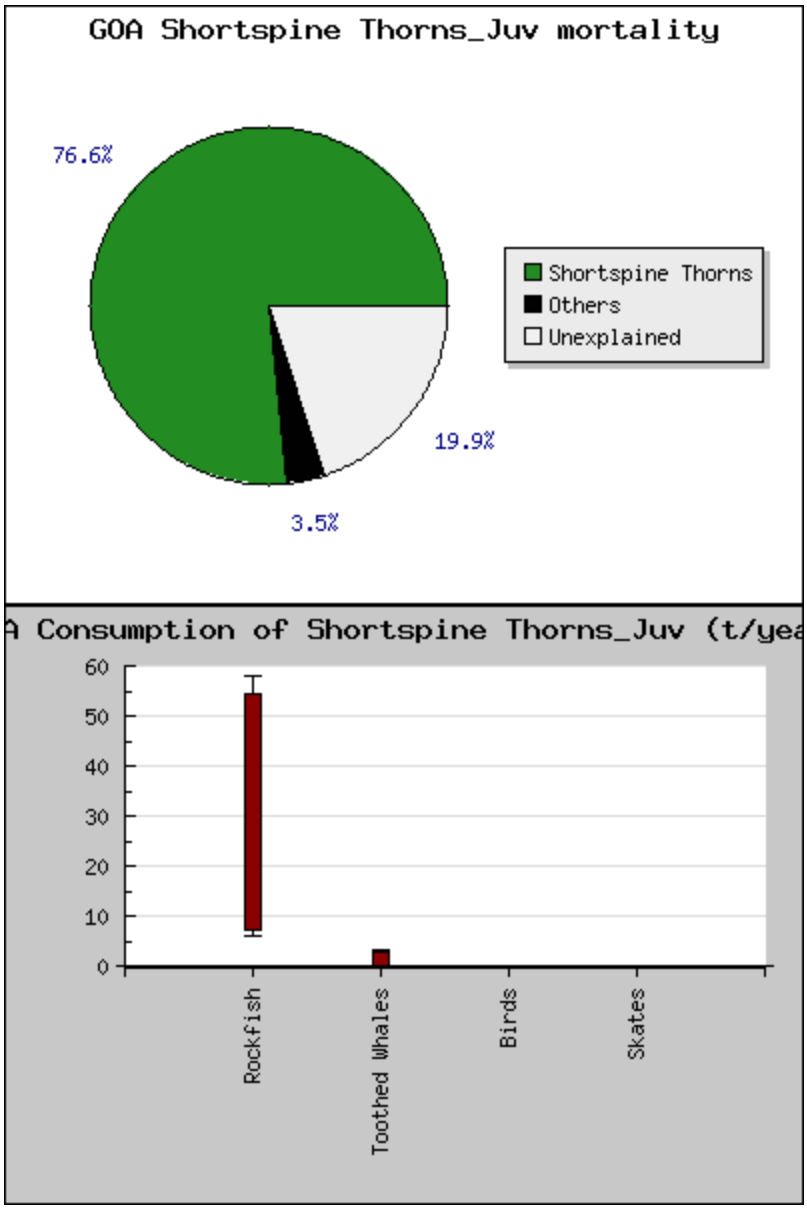

Figure 15.15 Mortality sources (upper panel) and annual consumption in tons (lower panel) by predators of juvenile shortspine thornyheads in the GOA. “Rockfish” in the lower panel refers to adult thornyheads, which account for more than 75% of juvenile thornyhead mortality via cannibalism.

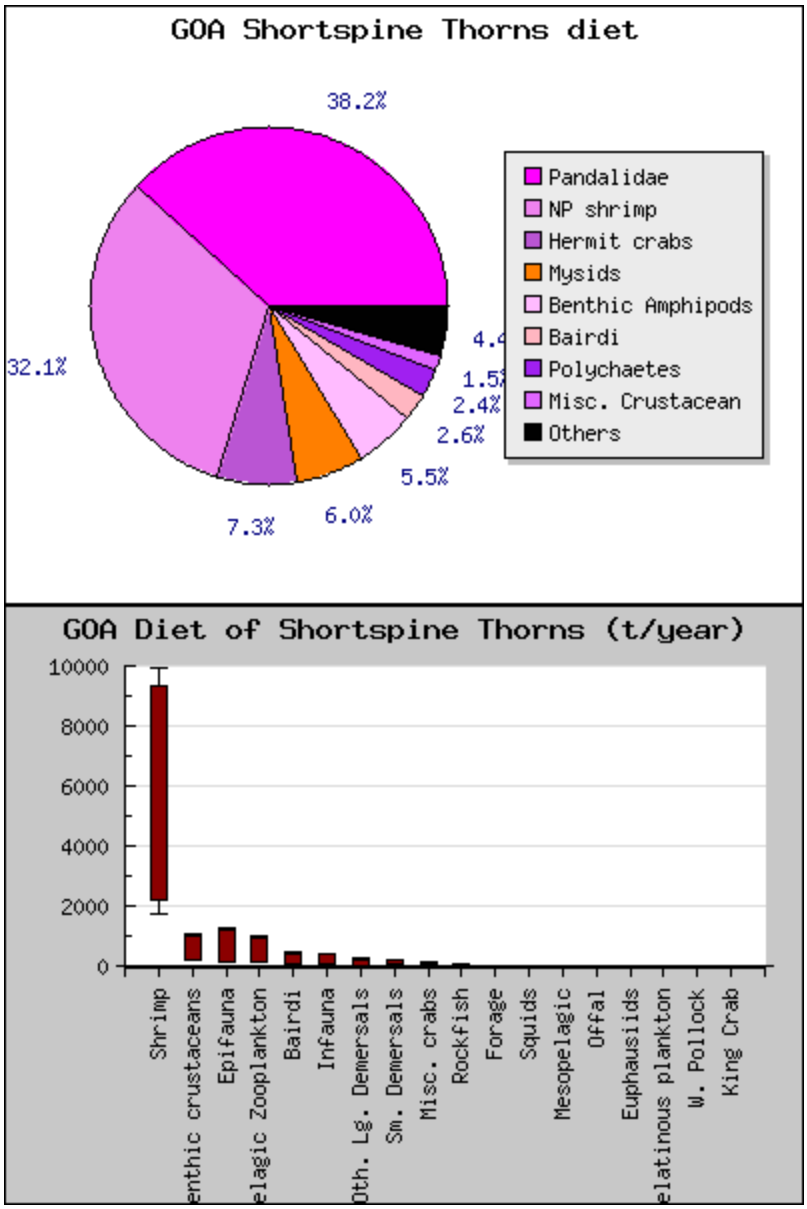

Figure 15.16 Diet composition (upper panel) and annual consumption of prey in tons (lower panel) by adult shortspine thornyheads in the GOA.

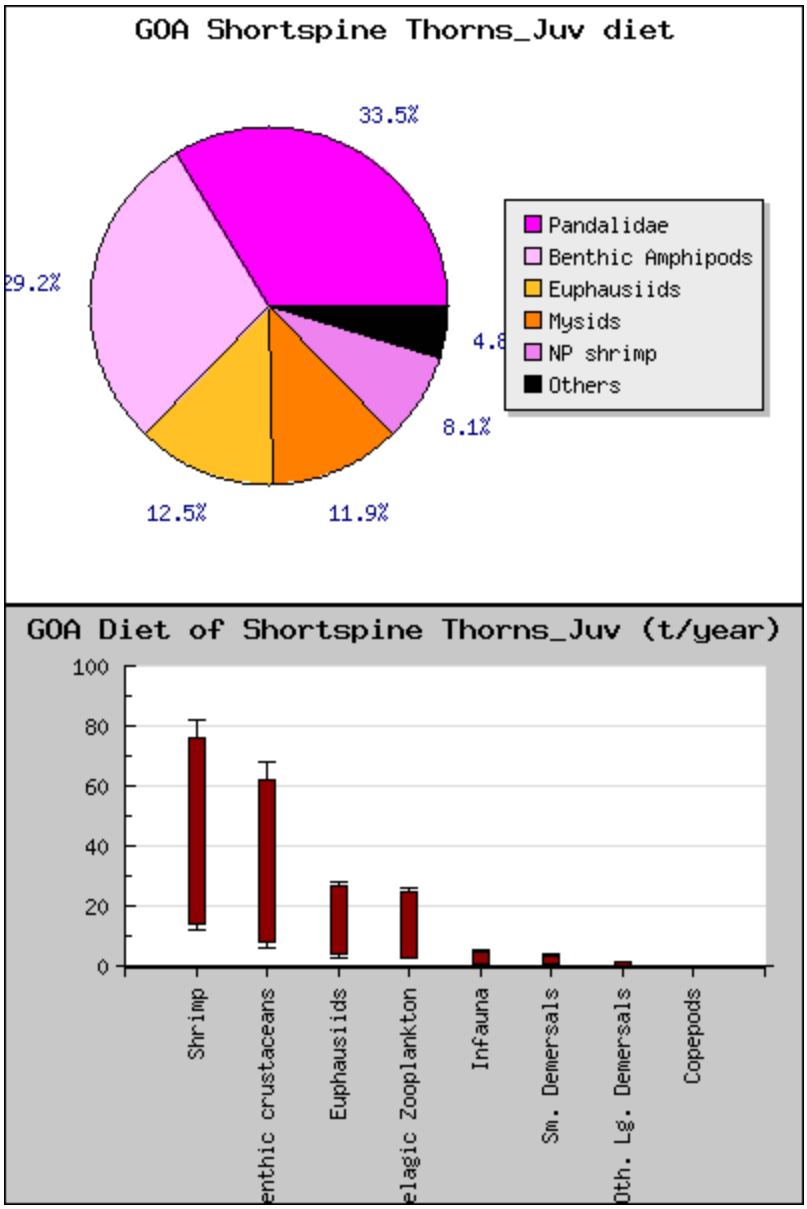

Figure 15.17 Diet composition (upper panel) and annual consumption of prey in tons (lower panel) by juvenile shortspine thornyheads in the GOA.

(This page intentionally left blank)