ENDANGERED SPECIES ACT STATUS REVIEW REPORT

Smooth Hammerhead Shark (*Sphyrna zygaena*)

June 2016

National Marine Fisheries Service
National Oceanic and Atmospheric Administration
Silver Spring, MD

ACKNOWLEDGEMENTS

Numerous individual fishery scientists and managers provided information that aided in preparation of this report and deserve special thanks. I particularly wish to thank Dr. Rafael Tavares, Ms. Elizabeth Scott-Denton, Ms. Rachael Wadsworth and Ms. Celia Barroso for information, data, and professional opinions, and Ms. Marta Nammack, Ms. Chelsey Young, Ms. Karyl Brewster-Geisz, and Ms. Krista Graham for their review of this document. I would also like to thank those who submitted information through the public comment process.

Additionally, I would especially like to thank the peer reviewers Dr. Alberto Amorim, Dr. Juan Carlos Pérez-Jiménez, and Dr. Emilio Sperone for their time and professional review of this report.

This document should be cited as:

Miller, M.H. 2016. Endangered Species Act Status Review Report: Smooth Hammerhead Shark (*Sphyrna zygaena*). Report to National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD. June 2016. 167 pp.

EXECUTIVE SUMMARY

This report was produced in response to a petition received from Defenders of Wildlife on April 27, 2015, to list the smooth hammerhead shark (*Sphyrna zygaena*) as endangered or threatened under the Endangered Species Act (ESA). On August 11, 2015, the National Marine Fisheries Service (NMFS) announced in the *Federal Register* that the petition had sufficient merit for consideration and that a status review was warranted (80 FR 48053). This report is the status review for the smooth hammerhead shark. This report summarizes the best available data and information on the species and presents an evaluation of its status and extinction risk.

The smooth hammerhead shark is a circumglobal species, found worldwide in temperate to tropical waters and thought to be the hammerhead species most tolerant of temperate waters. It is a coastal-pelagic and semi-oceanic species and generally occurs close inshore and in shallow waters, most commonly in depths of up to 20 m; however, the species may also be found over continental and insular shelves to offshore areas in depths as great as 200 m. Smooth hammerhead sharks are highly mobile and can travel significant distances, with excursion estimates over 2,000 km.

The general life history characteristics of the smooth hammerhead shark are that of a long-lived, slow-growing, and late maturing species. Although there are very few age or growth studies, based on the best available data, smooth hammerhead sharks exhibit life-history traits and population parameters that make them one of the more productive species among sharks.

While smooth hammerhead sharks are a wide-ranging species, their distribution and abundance throughout its range is not well known. With respect to general trends in population abundance, multiple studies indicate that smooth hammerhead sharks may have experienced historical population declines of varying magnitudes over the past few decades; however, many of these studies suffer from very low sample sizes and a lack of reliable data due to the scarcity of the smooth hammerhead sharks in the fisheries data.

In terms of threats to the species, the primary concern is potential overutilization of the species stemming from commercial and artisanal fisheries, including illegal fishing of smooth hammerhead sharks, with the shark fin trade driving exploitation. Smooth hammerhead sharks are currently being exploited throughout their range, particularly juveniles of the species in the southwest and eastern Atlantic Ocean, western Indian Ocean, and eastern Pacific Ocean. However, species-specific fisheries information is severely lacking. Additionally, much of the available data on the exploitation of the species is from localized study sites and over small periods of time, and thus is difficult to extrapolate to the global population. The best available data, as it relates to the impact of the threat of overutilization on the extinction risk of the species, was therefore evaluated for each region (Atlantic, Indian, and Pacific) to better inform a global analysis.

The results from the above threats assessment were considered in conjunction with a demographic risks analysis (which examined the species' abundance, productivity, spatial structure, and diversity) to evaluate the overall risk of extinction of the smooth hammerhead. Because species-specific information (such as current abundance) was sparse, qualitative 'reference levels' of extinction risk were used to describe the overall assessment of extinction risk.

Results from the extinction risk analysis indicate that while the species' life history characteristics increases its inherent vulnerability to depletion, and likely contributed to past population declines of varying magnitudes, the best available information suggests that present demographic risks are low. However, it is important to note that there was very little to no available information regarding species' abundance, estimates of growth rate and population growth rate-related parameters, spatial processes, and requisite levels of diversity, which increased the uncertainty associated with the evaluation of the demographic risks.

Smooth hammerhead sharks continue to be exploited throughout their range, particularly juveniles of the species, but information is severely lacking for the species,

including basic catch and effort data from throughout the species' range, global, regional, and local population size estimates, abundance trends, life history parameters (particularly from the Pacific and Indian Oceans), and distribution information. Presently, the best available data does not indicate that current fishing levels and associated mortality are causing declines in the species to such a point that the species is at risk of extinction from overutilization or likely to become so in the foreseeable future. Furthermore, no significant portions of the species' range could be identified. Thus, based on the evaluation of demographic risks and threats to the species, the smooth hammerhead shark is likely to be at a low overall risk of extinction throughout its range.

TABLE OF CONTENTS

INTRODUCTION 7
Scope and Intent of the Present Document 7
LIFE HISTORY AND ECOLOGY 7
Taxonomy and Distinctive Characteristics 7
Range and Habitat Use 8
Reproduction and Growth 11
Demography 14
Diet and Feeding 14
Population Structure 15
DISTRIBUTION AND ABUNDANCE 16
ANALYSIS OF THE ESA SECTION 4(A)(1) FACTORS 25
Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range 26
Overutilization for Commercial, Recreational, Scientific, or Educational Purposes 27
Disease or Predation 120
Inadequacy of Existing Regulatory Mechanisms 120
Other Natural or Manmade Factors Affecting the Smooth Hammerhead Sharks' Continued Existence 124
EXTINCTION RISK ANALYSIS 127
Demographic Risk Analysis 129
Threats Assessment 136
Overall Risk of Extinction 138
Significant Portion of its Range Analysis 139
REFERENCES 142
APPENDIX 157

INTRODUCTION

Scope and Intent of the Present Document

This document is the status review in response to a petition[1] to list the smooth hammerhead shark under the Endangered Species Act (ESA). Under the ESA, if a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. 1533(b)(3)(A)). The National Marine Fisheries Service (NMFS) determined that the petition had sufficient merit for consideration and that a status review was warranted (80 FR 48053, August 11, 2015).

This document is the scientific review of the biology, population status and future outlook for the smooth hammerhead shark. It provides a summary of the available data and information on the species and presents an evaluation of the species' status and extinction risk. The conclusions in this status review are subject to revision should important new information arise in the future. Where available, there are literature citations to review articles that provide even more extensive citations for each topic. Public comments, data and information were reviewed through June 2016.

LIFE HISTORY AND ECOLOGY

Taxonomy and Distinctive Characteristics

All hammerhead sharks belong to the family *Sphyrnidae* and are classified as ground sharks (Order Carcharhiniformes). Most hammerheads belong to the Genus *Sphyrna* with one exception, the winghead shark (*E. blochii*), which is the sole species in the

[1] (1) Defenders of Wildlife to U.S. Secretary of Commerce, acting through the National Oceanic and Atmospheric Administration and the National Marine Fisheries Service, April 21, 2015, "A petition to list the smooth hammerhead shark (*Sphyrna zygaena*) as an endangered, or alternatively as a threatened species pursuant to the Endangered Species Act, either in its own right or due to is similarity of appearance to the listed scalloped hammerhead sharks (*Sphyrna lewini*) populations, and for the concurrent designation of critical habitat" .

Genus *Eusphyra*. The smooth hammerhead was first described in 1758 by Karl Linnaeus and named *Squalus zygaena*; however, this name was later changed to current scientific species name of *Sphyrna zygaena* (Linneaus 1758) (Bester n.d.).

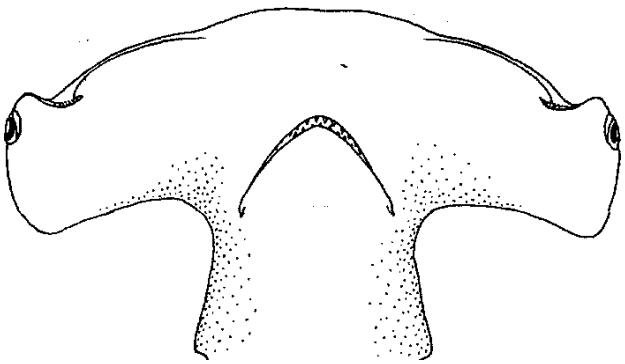


Figure 1. Shape of the cephalophoil (head) of the smooth hammerhead shark (image from Compango (1984))

Hammerhead sharks are recognized by their laterally expanded head that resembles a hammer (hence the common name "hammerhead"). In comparison to the other hammerhead sharks, the head of the smooth hammerhead shark has a scalloped appearance but a rounded un-notched anterior margin (which helps to distinguish it from scalloped hammerhead sharks) and depressions opposite each nostril (Figure 1; Bester n.d.). While scientists previously debated on the evolutionary purpose for this unique head shape, McComb et al. (2009) conclusively showed that the laterally expanded head and eye placement gives hammerhead sharks superior forward stereovision and depth perception, and excellent stereo rear vision as well, providing the sharks with a 360-degree view of their surroundings.

The smooth hammerhead also has a ventrally located and strongly arched mouth with smooth or slightly serrated teeth (Compagno 1984). The body of the shark is fusiform and lacks a mid-dorsal ridge (Compagno 1984; Bester n.d.). The species has a moderately tall and hooked first dorsal fin and a lower second dorsal fin that is shorter than the notched anal fin (Bester n.d.). The smooth hammerhead shark has a color that ranges from a dark olive to greyish-brown and fades into a white underside, which is different than most other hammerhead species whose colors are commonly brown (Bester n.d.).

Range and Habitat Use

The smooth hammerhead shark is a circumglobal species, found worldwide in temperate to tropical waters between 59°N and 55°S (CITES 2013). It is thought to be

the hammerhead species most tolerant of temperate waters (Compagno 1984). Figure 2 provides the range of the species in the Atlantic and Mediterranean. In the northwestern Atlantic Ocean, the range of the smooth hammerhead shark extends from Nova Scotia, Canada to Florida and partly into the Caribbean; however, the species is said to be rare in Canadian waters and only found offshore in the Gulf Stream (Fisheries and Oceans Canada 2010). Additionally, its presence off the Caribbean Islands cannot be confirmed, although these waters are noted to be part of its range in Compagno (1984). A review of available historical checklists from countries in the Caribbean (Puerto Rico – Erdman (1974); revised 1983); U.S. Virgin Islands – Smith-Vaniz and Jelks (2014)) do not list the species as occurring in these waters; however, catches of the species have been noted off Venezuela (Tavares 2005), indicating that the species may occasionally venture from Atlantic waters into nearby areas in the southern Caribbean Sea.

In the southwestern Atlantic, the smooth hammerhead shark range extends from Brazil to southern Argentina (Compagno 1984; Bester n.d). In the eastern Atlantic Ocean, smooth hammerhead sharks can be found from the British Isles to Guinea, including the Cape Verde Islands, and have also been observed in the Côte d'Ivoire and equatorial West Africa (Compagno 1984; Bester n.d). Its range also extends throughout the Mediterranean Sea (Compagno 1984; Bester n.d).

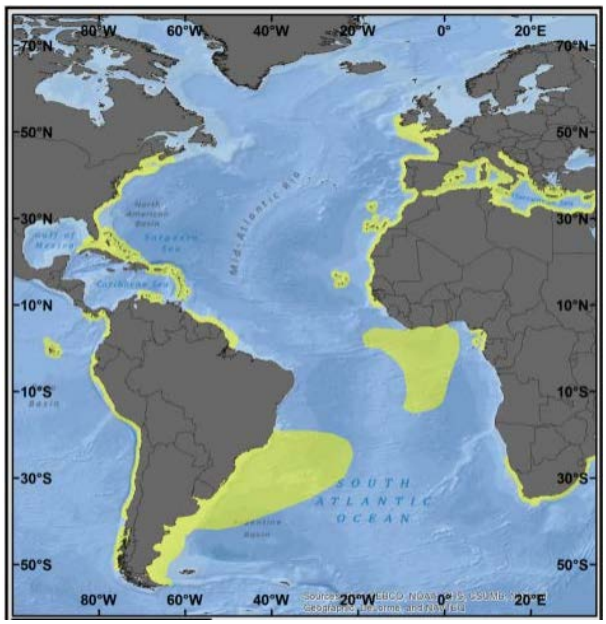


Figure 2. Range of *Sphyrna zygaena* in the Atlantic Ocean and Mediterranean Sea (Source: Cortés et al. (2012))

Figure 3 provides a depiction of the species' range throughout the Indian and Pacific Oceans. In the Indian Ocean, the shark is found off the coasts South Africa, within the Persian Gulf, along the southern coast of India, Sri Lanka and off Indonesia, and along the western and southern coasts of Australia. Its range in the western and central Pacific extends from Japan to Vietnam, includes the southeast coasts of Australia and waters off New Zealand, American Samoa (PIFSC unpublished data), and in the Hawaiian Islands. In the northeastern Pacific, the smooth hammerhead shark range extends from northern California to the Nayarit state of Mexico, and in the southeastern Pacific, the species' range extends from Panama to Chile. While some maps have the range of the species extending all the way to southern Chile (Compagno 1984; IUCN 2005; Bester n.d.), according to Brito (2004), records only place the species as far south as San Antonio Bay and note that it is generally rare in Chilean waters.

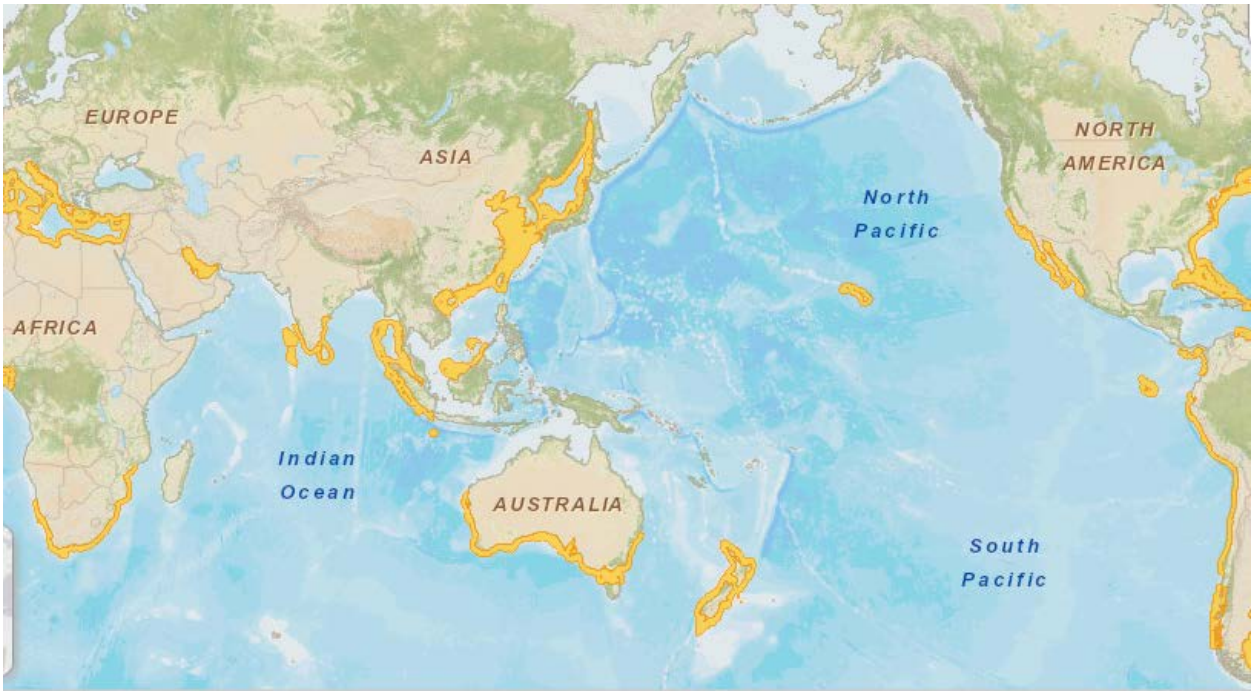


Figure 3. Range of *Sphyrna zygaena* in the Indian and Pacific Oceans (Source: IUCN 2005)

The smooth hammerhead shark is a coastal-pelagic and semi-oceanic species and generally occurs close inshore and in shallow waters, most commonly in depths of up to 20 m (CITES 2013). However, the species may also be found over continental and insular shelves to offshore areas in depths as great as 200 m (Compagno 1984; Ebert et

al. 2013; Bester n.d.). In fact, Clarke et al. (2015) note that *S. zygaena* is likely the most oceanic of the hammerhead species, leaving the coastal environment at around 2-3 years of age.

Smooth hammerhead sharks are highly mobile and may undergo seasonal migrations (toward cooler waters in the summer and the reverse in the winter), with juveniles (of up to 1.5 m in length) occasionally forming large aggregations during these migrations (Compagno 1984; Diemer et al. 2011; Ebert et al. 2013; Bester n.d.). Bass et al. (1975) also noted observations of large aggregations of young smooth hammerheads near surface waters along the southern coast of South Africa, with no evidence of concerted movements. Adult smooth hammerheads, on the other hand, are generally solitary (Compagno 1984). Based on available tagging data from recaptured adult smooth hammerhead sharks (n=6), observed maximum distance travelled for *S. zygaena* is 919 km, with a maximum speed of 4.8 km/day and time at liberty of 2.1 years (Kohler and Turner 2001). In June 2015, NOAA scientists tagged a female smooth hammerhead shark (~213 cm fork length (FL)) off San Clemente Island, CA. Data from the tag showed that the animal traveled more than 400 miles south to the central Baja Peninsula and then returned north to waters off Ventura, CA, making the total distance traveled equal to more than 1,000 miles (>1609 km) (SWFSC 2015). Clarke et al. (2015) also noted the ability of the species to travel significant distances, citing to a study off New Zealand that found tagged individuals traveled to Tonga, a distance of around 1,200 nm (2,222 km).

Reproduction and Growth

The general life history characteristics of the smooth hammerhead shark are that of a long-lived, slow-growing, and late maturing species. The average size of a smooth hammerhead shark ranges between 2.5-3.5 m in length, but individuals can reach maximum lengths of 5 m and weights of 880 pounds (400 kg) (CITES 2013; Bester n.d.). Based on observed and estimated sizes of smooth hammerhead sharks from both the Atlantic and Pacific oceans (see Table 1), females appear to reach sexual maturity between 250 cm and 290 cm total length (TL). Males are considered sexually mature at smaller sizes than females, with estimates of 210-250 cm TL from the Atlantic and 250-

260 cm TL in the western Pacific. More recent data from the eastern Pacific (specifically the Gulf of California) estimate much smaller maturity sizes for smooth hammerheads, with 50% of females and males of the population maturing at 200 cm and 194 cm TL, respectively (Nava Nava and Fernando Marquez-Farias 2014). Longevity of the species is unknown but thought to be at least 20 years (Bester n.d.), with female and male smooth hammerhead sharks aged up to 18 years and 21 years, respectively, from the eastern equatorial Atlantic Ocean (Coelho et al. 2011).

The smooth hammerhead shark is viviparous (*i.e.*, give birth to live young), with a gestation period of 10-11 months (White et al. 2006) and an assumed annual reproductive periodicity; however this has yet to be verified (Clarke et al. 2015) (Table 1). Possible pupping grounds and nursery areas for this species (based on the presence of pregnant females, neonates, and juveniles) include the Gulf of California, Gulf of Guinea, Strait of Sicily, coastal and inshore waters off Baja California, Venezuela, southern Brazil, Uruguay, Morocco, the southern and eastern cape of South Africa, Kenya (including Ungwana Bay), and New Zealand (Sadowsky 1965; Castro and Mejuto 1995; Buencuerpo et al. 1998; Arocha et al. 2002; Celona and Maddalena 2005; Costa and Chaves 2006; Bizzarro et al. 2009; Cartamil et al. 2011; Coelho et al. 2011; Diemer et al. 2011; CITES 2013; Kyalo and Stephen 2013; Bornatowski et al. 2014; Nava Nava and Fernando Marquez-Farias 2014). Litter sizes range from around 20 to 50 live pups, with an average litter size of around 33 pups; however, Stevens (1984) noted that the species tends to abort pups upon capture. Parturition occurs in the summer, with an average length at birth estimated between 49-64 cm (Table 1). Smooth hammerhead sharks are estimated to grow an average of 25 cm per year over the first 4 years of its life before slowing down later in its life (Coelho et al. 2011). Differences in growth curves have been identified for smooth hammerhead sharks in the Atlantic compared to the Pacific Ocean (with sharks in the Pacific growing to significantly smaller sizes); however, there is significant uncertainty regarding study parameters and analyses and further information and research is needed to confirm the findings (Clarke et al. 2015).

Table 1: Life History Parameters for *Sphyrna zygaena* (obs. = observed; m = male; f = female; *for estimates in FL, used conversion formula of TL = (FL – 12.72)/0.84 from Coelho et al. (2011))

Parameter	Estimate	References
Growth rate (von Bertalanffy k)	0.07 year -1 (f; E. Atlantic) 0.06 year -1 (m; E. Atlantic) 0.06 year -1 (f; Atlantic) 0.09 year -1 (m; Atlantic)	Coelho et al. 2011 Rosa et al. 2015 (cited in Clarke et al. 2015)
Size at maturity (cm TL)*	210-240 210-250 (m); 270 (f) 250-260 (m); 265 (f) (Australia; Pacific) 247-288 (f) (obs. Atlantic) 194 (m); 200 (f) (Gulf of California; Pacific)	Bigelow and Schroeder 1948 Muus and Nielsen 1999 (cited in Hayes 2007) Stephens 1984 Castro and Mejuto 1995; Nava Nava and Marquez-Farias 2014
Age at maturity	9 years (median)	Cortes et al. 2012
Longevity	>20 years 18 years (f; obs. E. Atlantic) 21 years (m, obs. E. Atlantic)	Bester n.d. Coelho et al. 2011
Gestation Period	10- 11 months	White et al. 2006
Reproductive Periodicity	1 year	Cortes et al. 2012
Litter size	*Average*: 33 pups/litter *Ranges* 30-40 29-37 34-53	Stephens 1984; Castro and Mejuto 1995 Muus and Nielsen 1999; Bigelow and Schroeder 1948; Bass et al. 1975

	20-49	Stephens 1984
Size at Birth (cm TL)	49-64	Bigelow and Schroeder 1948; Compagno 1984; Stephens 1984; Bass et al. 1975; Vooren and Klippel 2005; Chow 2004 cited in Clarke 2015
Generation Time	13.4 years (N. Atlantic)	Cortes et al. 2012
Productivity (r, intrinsic rate of population increase, yr^{-1})	0.225 (N. Atlantic)	Cortes et al. 2012

Demography

Although there are very few age/growth studies, based on the best available data, smooth hammerhead sharks exhibit life-history traits and population parameters that place the species towards the faster growing end along the "fast-slow" continuum of population parameters that have been calculated for 38 species of sharks by Cortés (2002, Appendix 2). In an Ecological Risk Assessment study of 20 species caught in Atlantic pelagic fisheries, Cortés et al. (2012) found that the smooth hammerhead shark ranked among the most productive species (with the 4th highest productivity rate; r = 0.225) and had one of the lowest vulnerabilities to pelagic longline fisheries. Based on these estimates, smooth hammerhead sharks can be characterized as having "medium" productivity (based on categorizations in Musick (1999)), with demographic parameters that provide the species with moderate resilience to exploitation.

Diet and Feeding

The smooth hammerhead shark is a high trophic level predator (trophic level = 4.2; Cortés (1999)) and opportunistic feeder that consumes a variety of teleosts, small sharks (including its own species), dolphins, skates and stingrays, sea snakes, crustaceans, and cephalopods (Nair and James 1971; Compagno 1984; Bornatowski et al. 2007; Masunaga et al. 2009; Rogers et al. 2012; Galvan-Magana et al. 2013; Bornatowski et al. 2014; Sucunza et al. 2015). Skates and stingrays , in particular, tend to comprise the

majority of the species diet in inshore locations (Nair and James 1971; Bester n.d.). In coastal waters off Brazil, analysis of juvenile smooth hammerhead shark stomachs showed a predominance of cephalopods (including *Doryteuthis* spp., *Lolliguncula brevis*, and *Loligo* spp.) and teleosts (Bornatowski et al. 2007; Bornatowski et al. 2014). Similarly, cephalopods are the most important prey item in the diet of smooth hammerhead sharks found in Pacific waters, specifically squid of the Ommastrephidae and Ancistrocheiridae families (Galvan-Magana et al. 2013). In gulf and shelf waters off southern Australia, juvenile smooth hammerhead sharks feed on a broad variety of benthic and pelagic species, with prey items documented from 22 taxonomic groups and 9 trophic groups (not including unidentifiable items) (Rogers et al. 2012). Again, Ommastrephid squids and also cuttlefish species (*Sepia* spp.) were the most important prey items in the sharks' diet (Rogers et al. 2012).

Population Structure

Due to sampling constraints, very few studies have examined the population structure of the smooth hammerhead shark. Using mitochondrial DNA (which is maternally inherited) Naylor et al. (2012) found only a single cluster of smooth hammerhead sharks (in other words, no evidence to suggest matrilineal genetic partitioning of the species). This analysis, however, was based on only 16 specimens (4 from Gulf of California, 6 from Northwest Atlantic, 3 from Taiwan, and 1 each from Senegal, Vietnam, and Japan). In contrast, Testerman (2014) found statistically significant matrilineal genetic structuring within oceanic basins and significant genetic partitioning between oceanic basins. Specifically, Testerman (2014) analyzed both mitochondrial control region sequences (mtCR; n=303, 1,090 bp) and 15 nuclear microsatellite loci (n=332) from smooth hammerhead sharks collected from eight regional areas: western North Atlantic (n=21); western South Atlantic (n=55); western Indian Ocean (n=63); western South Pacific (n=44); western North Pacific (n=11); eastern North Pacific (n=55); eastern Tropical Pacific (n=15); and eastern South Pacific (n=26). Results from the analysis of mitochondrial DNA indicated significant genetic partitioning, with no sharing of haplotypes, between the Atlantic and Indo-Pacific basins (mtCR ϕ_{ST} = 0.8159) (Testerman 2014). A geographic pattern of shallow genetic variation was also evident between individuals from the Atlantic, eastern Tropical/South Pacific, western North

Pacific, and western Indian Ocean. Analysis of the nuclear DNA also showed significant genetic structure between ocean basins (nuclear F_{ST} = 0.0495), with the Atlantic and Indo-Pacific considered to comprise two genetically distinct populations (Testerman 2014). However, unlike the mitochondrial DNA results, no significant structure was detected within oceanic basins using the nuclear markers, suggesting evidence of potential female philopatry and male mediated gene flow (Testerman 2014). Additional studies are needed to further refine the population structure of the smooth hammerhead shark and confirm the above results, including, as Testerman (2014) suggests, using samples from individual smooth hammerhead sharks of known size class and gender.

DISTRIBUTION AND ABUNDANCE

The smooth hammerhead shark can be found in coastal warm temperate and tropical seas worldwide. Its distribution and abundance within these waters is not well known. Based on records (data points) from the Ocean Biogeographic Information System (OBIS) and the Global Biodiversity Information Facility (GBIF) databases (Figure 4), a distribution map of *Sphyrna zygaena*, including relative probabilities of the species' occurrence throughout its range, is shown in Figure 5. The following provides what little information there is available on the distribution and relative abundance of the species in the different ocean basins.

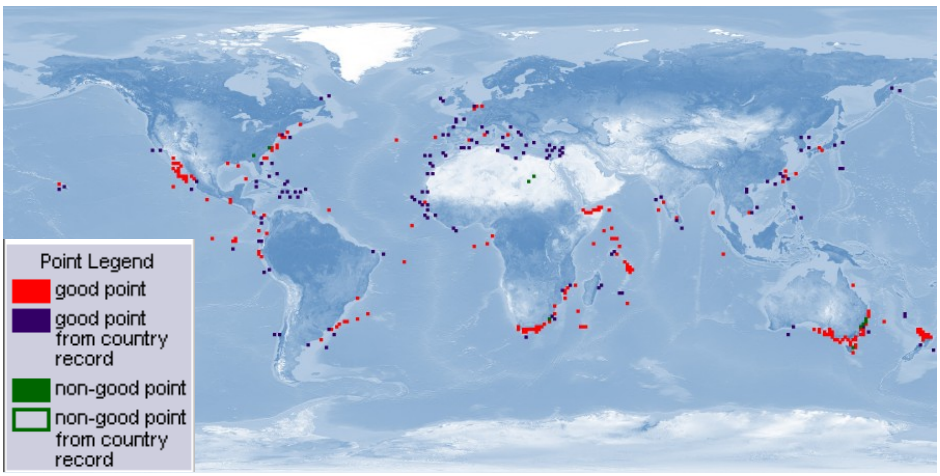


Figure 4. Point map displaying positive records of *S. zygaena* contained in the OBIS and GBIF database (Source: AquaMaps- http://www.aquamaps.org/receive.php?type_of_map=regular)

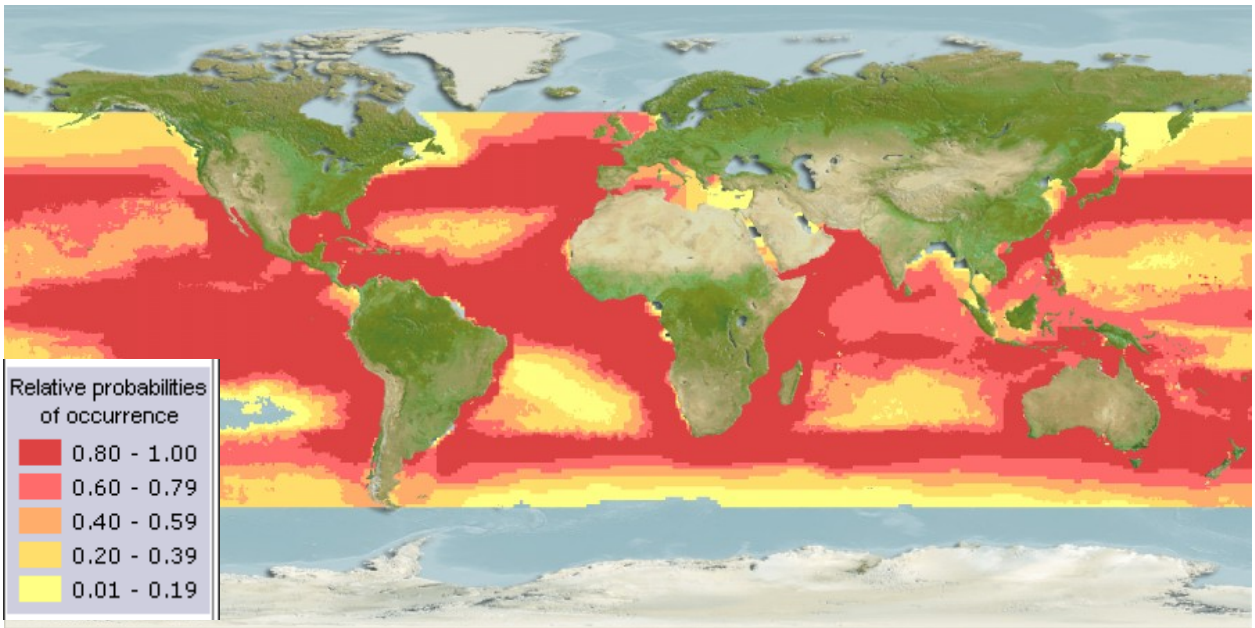


Figure 5. Distribution map for *Sphyrna zygaena* with modeled relative probabilities of occurrence denoted by a color gradient (Source: AquaMaps-http://www.aquamaps.org/receive.php?type_of_map=regular).

In the Atlantic, off the western coast of Africa, Cadenat and Blache (1981) noted the occurrence of only immature smooth hammerhead sharks, and only after water temperatures had cooled from summer highs. In Senegal, this period lasted from late December to early May (Cadenat and Blache 1981). In the Mediterranean, the species is noted as occurring off southern Italy, despite previously being characterized as functionally extinct due to the disappearance of the species in historical records (Sperone et al. 2012). In the Indian Ocean, in waters off India, the species is found in greater abundance on the southwest coast as opposed to the east coast (CITES 2013). Within the Pacific, Stevens (1984) found that smooth hammerhead sharks were most abundant off New South Wales, Australia, between December and May, but had difficulty explaining the absence of the species in the cooler months. Off New Zealand, juveniles and sub-adults of the species are most abundant around the northern North Island, with the majority of captures in the Firth of Thames, Hauraki Gulf, 90-Mile Beach and eastern Bay of Plenty (Francis and Lyon 2012). Within the Eastern Pacific, distribution of the species appears to be concentrated off Mexico, Ecuador, and Peru (based on fisheries data; see **Overutilization** section), with the species considered rare in Chilean waters (Brito 2004).

In terms of actual estimates of abundance, there is very little information available, with only occasional mention of the species in historical records. Although more countries and regional fishery management organizations (RFMOs) are working towards better reporting of fish catches down to species level in order to provide data for establishing population trends, catches of smooth hammerhead sharks have and continue to go unrecorded in many countries outside of the United States. Also, many catch records that do include hammerhead sharks do not differentiate between the *Sphyrna* species or shark species in general. These numbers may also be likely under-reported as many catch records reflect dressed weights instead of live weights, or do not account for discards (example: where the fins are kept but the carcass is discarded). Thus, given this type of available data, estimates of global and even regional abundance for smooth hammerheads is not feasible at this time.

With respect to general trends in population abundance, multiple studies indicate that smooth hammerhead sharks have likely experienced population declines over the past few decades. However, many of these studies suffer from very low sample sizes and a lack of reliable data due to the scarcity of the smooth hammerhead sharks in the fisheries data. For example, in coastal northwest Atlantic waters, Myers et al. (2007) estimated a 99% decline in smooth hammerhead sharks between 1970 and 2005; however, this estimate was based on data from a shark-targeted survey off North Carolina that recorded a total of only 5 smooth hammerhead sharks caught between 1973 and 1989.

Unlike the scalloped hammerhead shark, and to a lesser extent, the great hammerhead shark, NMFS fishery scientists note that there are hardly any data for smooth hammerhead sharks, particularly in U.S. Atlantic waters (personal communication J. Carlson). Hayes (2007) remarks that the species rarely occurs throughout the majority of U.S. Atlantic waters, and is thought to be less abundant than the scalloped and great hammerhead sharks. Due to these data deficiencies, no official stock assessment has been conducted (or accepted) by NMFS for the species in this region. However, two preliminary species-specific stock assessments (Hayes 2007; Jiao et al. 2011) are

available for review and inclusion in this report. Both stock assessments used surplus-production models, which are common for dealing with data-poor species, and are useful when only catch and relative abundance data are available (Hayes et al. 2009). Surplus-production models can also handle mixed-metric data. Unfortunately, given the limited amount and low quality of available data on smooth hammerhead sharks, the only catch-per-unit-effort (CPUE) dataset with sufficient sample size that could be used as an index of relative abundance was the U.S. Pelagic Longline (PLL) Logbook dataset. [Ideally, more than one index of relative abundance would be used as an input into the stock assessment, covering both fishery-independent and fishery-dependent datasets; however, this was not feasible for the smooth hammerhead shark stock assessment model.]

Using the available data, the results from the Hayes (2007) stock assessment indicated that the smooth hammerhead shark stock was depleted by 91% between 1982 and 2005 (Figure 6). Specifically, the Schaefer model (see Hayes 2007 for an explanation of different models) estimated a virgin population size (in 1982) of 56,000 sharks (range = 51,000 – 67,000) and a population of 5,130 in 2005. The Fox model estimated a virgin population size of 60,000 (range = 57,000 – 71,000) and a population of 5,280 individuals in 2005 (Figure 6). However, as Hayes (2007) notes, sharks are not targeted by the pelagic longline fisheries and, as such, data from the U.S. Atlantic pelagic longline logbook program (which was the only available index of abundance)

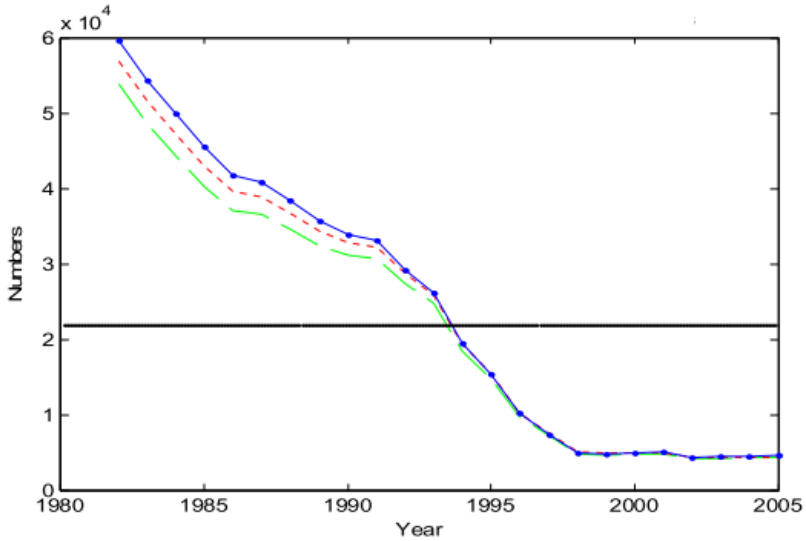


Figure 6. Hayes (2007) abundance trajectory for smooth hammerhead sharks (blue line = Fox model; green line = Schaefer model; red line = Pella-Tomlinson model; black line = population size that produces MSY)

does not adequately sample coastal sharks. Additionally, Burgess et al. (2005) cautions against inferring percentage declines using indices of relative abundance from a single data series, especially logbook data, given the major caveats associated with these datasets for a bycatch species (e.g., under- and over-reporting, misidentification of species, inadequate sampling). Taking into account these limitations, the results from the stock assessment suggest that the smooth hammerhead northwest Atlantic population likely experienced a significant historical decline of uncertain magnitude, but based on the modeled trajectory in the stock assessment (Figure 6), abundance appears to have stabilized in recent years.

Due to the lack of quality species-specific data mentioned above, with catch records generally failing to differentiate between the *Sphyrna* species, many of the available studies examining abundance trends have, instead, looked at the entire hammerhead shark complex (scalloped, smooth, and great hammerhead sharks combined). Jiao et al. (2009), for example, estimated a decline of approximately 72% in hammerhead abundance in the northwest Atlantic and Gulf of Mexico from 1981 to 2005 using a Bayesian hierarchical surplus production model and various NMFS fisheries data. Likewise, Baum and Blanchard (2010) found a similar decline of 76% in relative hammerhead abundance from 1992 to 2005 using generalized linear mixed models and U.S. PLL logbook and observer data. However, scalloped hammerheads comprise the majority of the hammerhead complex catch in this region. In fact, Jiao et al. (2011) estimates that scalloped hammerhead sharks comprise up to 70-80% of the hammerhead complex, and in the data that Baum and Blanchard (2010) analyzed, 742 of the hammerhead sharks were identified as scalloped compared to only 12 smooth hammerhead sharks. As such, trends in the hammerhead complex, particularly the estimated magnitudes of decline, more likely reflect the trends in the scalloped hammerhead shark abundance within this region rather than the rarely observed smooth hammerhead shark.

The same is true for the southwest and eastern Atlantic region, where many of the reported trends for the hammerhead complex are largely based on scalloped hammerhead shark data. For example, in its 2009 assessment of proposals to the

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) the Food and Agriculture Organization (FAO) (2010) reported that the CPUE of surface longline and bottom gillnet fisheries targeting hammerhead sharks off southern Brazil declined by more than 80% from 2000 to 2008, noting that the targeted hammerhead fishery was abandoned after 2008 due to the rarity of the sharks. However, upon further review, this assertion appears to be based specifically off of unstandardized CPUE of scalloped hammerhead sharks (FAO 2010) and does not necessarily reflect the trend (or magnitude of decline) in the smooth hammerhead shark population in this region. In fact, the CPUE data from the surface gillnet fishery (which is the gear responsible for the majority of smooth hammerhead shark catch in this region; see **Overutilization** section; Vooren and Klippel 2005) did not show any trend for the same time period. Similarly, Vooren and Klippel (2005) also presented CPUE trends data for the oceanic gillnet, longline, and recreational fisheries from an earlier time period for this region (1992-2004) for a lumped hammerhead complex (identified as *S. lewini* and *S. zygaena*), but acknowledged the predominance of scalloped hammerhead sharks in the region, estimating the abundance of *S. zygaena* adults to be less than 5% that of *S. lewini*. For the oceanic gillnet and recreational fisheries, there was no discernible trend in the CPUE data, and in the longline fisheries, CPUE showed an increasing trend from 1993 to 2000 followed by a decline to 2002. Again, based on the proportion of smooth to scalloped hammerhead sharks in the dataset, these trends (or lack thereof) can likely be primarily attributed to the scalloped hammerhead shark status in the region.

In the eastern Atlantic, a historical lack of reporting of catch data, including species-specific information, prevents reliable estimates of abundance trends in this region. Similar to the studies in the western Atlantic, Dia et al. (2012) used survey data for both *S. lewini* and *S. zygaena* to illustrate the decline in the abundance of hammerhead species off Mauritania over the past decade. Based on both the survey data as well as artisanal catch data from the region, it is clear that *S. lewini* is the more commonly observed and caught hammerhead species. In 2009, for example, scalloped hammerhead sharks comprised 8.1% of the total artisanal shark catch by weight in Mauritania (163 mt), whereas smooth hammerhead sharks comprised only 1.76% of the

catch (35 mt). Similarly, in the research survey data, the CPUE of scalloped hammerhead sharks was around twice that of smooth hammerhead sharks (Dia et al. 2012). Thus, given the evidence of the dominance of the scalloped hammerhead shark in the fisheries data, attributing the estimated abundance trend to both species may not provide an accurate portrayal of the status of the smooth hammerhead shark.

The Mediterranean Sea, on the other hand, is one region where trends in the hammerhead complex data would reflect the status of *S. zygaena*, as the other, tropical species of hammerhead sharks (e.g., *S. lewini* and *S. mokarran*), are only rarely observed in these more temperate waters of the Mediterranean. In this region, rough estimates of the declines in abundance and biomass of hammerhead sharks range from 96-99% (Celona and Maddalena 2005; Ferretti et al. 2008). Yet, similar to the previous studies, these findings are hindered by a lack of reliable data and sufficient sample sizes. For example, in the Ferretti et al. (2008) study, which reported a 99% in the *Sphyrna* complex, the findings were based primarily on: public sightings records (for the Adriatic Sea; authors acknowledge data assumptions easily violated), tuna trap logbook data (for Tyrrhenian and Ligurian Seas; however, *S. zygaena* are very rarely caught in tuna traps, see Cattaneo-Vietti et al. (2015) citing Boero and Carli (1979)), and pelagic longline records (for Strait of Sicily, Spanish Mediterranean waters, and Ionian Sea). A review of the datasets used in the study indicated that *S. zygaena* is generally a rare occurrence, with small sample sizes further increasing the uncertainty of the estimated percentage decline (Cattaneo-Vietti et al. (2015) citing Boero and Carli (1979); Axiak et al. (2002); Megalofonou et al. (2005); Ferretti et al. (2008)). While the authors note that after 1963, hammerhead sharks were no longer caught or seen in coastal areas of the Mediterranean, and after 1995, were completely absent in fishery records (from Ionian longline catches; Ferretti et al. 2008), based on recent observational and catch data from 2000 to 2009, Sperone et al. (2012) confirmed the presence of *S. zygaena* around southern Italy. Referencing the previous findings by Ferretti et al. (2008), Sperone et al. (2012) indicate that these new observations suggest the potential recovery of smooth hammerhead shark populations in Ionian waters off Calabria, Italy.

In the Indian Ocean, data on trends in smooth hammerhead abundance are available from only two studies conducted in waters off South Africa. As such, the results are not likely indicative of the status of the species throughout this region. Furthermore, based on the findings from the two studies, the trend in the species' abundance within South African waters is unclear. For example, one study, which consisted of a 25-year tagging survey (conducted from 1984-2009) off the eastern coast of South Africa, concluded that the abundance of smooth hammerhead sharks (based on their availability for tagging) peaked in 1987 (n=468 tagged) and declined thereafter (Diemer et al. 2011).

In contrast, a 25-year time series of annual CPUE of smooth hammerhead sharks in beach protective nets set off the KwaZulu-Natal beaches in South Africa showed no significant trend (Figure 7; Dudley and Simpfendorfer 2006). Additionally, the authors of the study found no evidence of a change in the mean or median size of *S. zygaena* in the nets over the time period (1978-2003), which could also have served as an indication of a potential decline in the population due to growth overfishing (Dudley and Simpfendorfer 2006). Given the limited spatial coverage of these two surveys, with no other trend data for smooth hammerhead sharks within the Indian Ocean, the abundance or growth of *S. zygaena* populations within this region cannot be determined at this time.

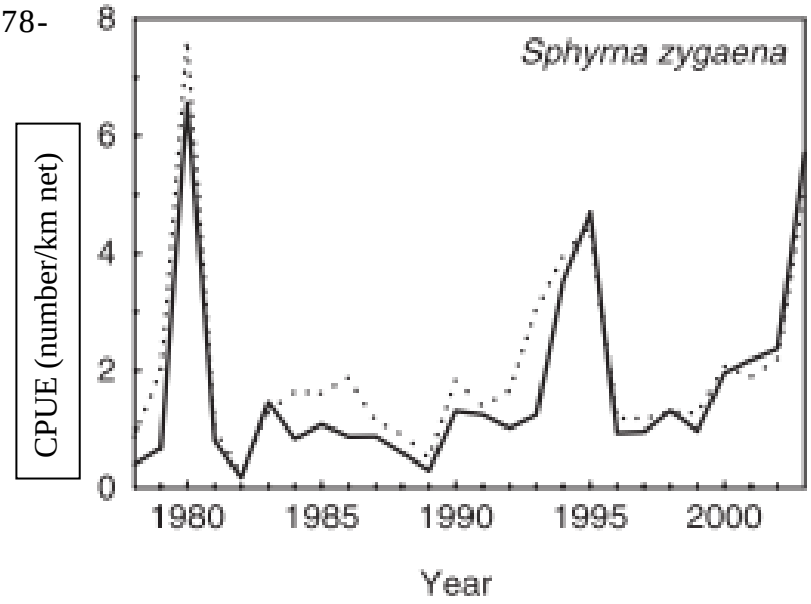


Figure 7. Annual CPUE (shark per km of net) of *S. zygaena* in the KwaZulu-Natal beach protection program from 1978-2003. Dotted line represents effects of the "sardine run" in winter months (Source: Dudley and Simpfendorfer 2006)

In the Pacific, very little data is available regarding abundance levels of the smooth hammerhead shark. Similar to the Atlantic, the few studies that examined trends in

hammerhead sharks used CPUE data that was lumped for multiple hammerhead species. For example, Rice et al. (2015) analyzed western and central Pacific longline catches of hammerheads from 1997-2013; however, over half of the hammerhead observations were not identified down to species (categorized simply as “hammerhead” sharks). The authors found an increase in the CPUE from 1997 to 2001, followed by a relatively stable trend from 2002 -2013 (Rice et al. 2015); however, given that the data was lumped and the locations of the catches covered the range of smooth, great, and scalloped hammerheads, the results provide little insight into the abundance of *S. zygaena* in the region.

Off New South Wales (NSW), Australia, CPUE data from a shark meshing (bather protection) program was also lumped for a hammerhead complex (scalloped, smooth, and great hammerhead sharks) and indicated that hammerhead sharks have declined by ~85% over the past 35 years (Reid et al. 2011). Although the data was not broken out by species, the majority of the hammerhead catch was assumed to comprise *S. zygaena* given the species’ tolerance of temperate waters (Reid and Krogh 1992; Reid et al. 2011; Williamson 2011). However, changes in the methods and level of effort of the program since its inception have complicated long-term analyses. Since 2009, the program has operated in accordance with a Joint Management Agreement (JMA) between the NSW Department of Primary Industries and the Minister for Primary Industries and an associated management plan that is designed to minimize the impact of the shark meshing program on threatened species and ensure the program does not cause species to become threatened. With the implementation of the JMA, hammerhead species identification improved. Based on data collected since 2009, annual catches of smooth hammerhead sharks in the nets have remained fairly stable (see Figure 8).

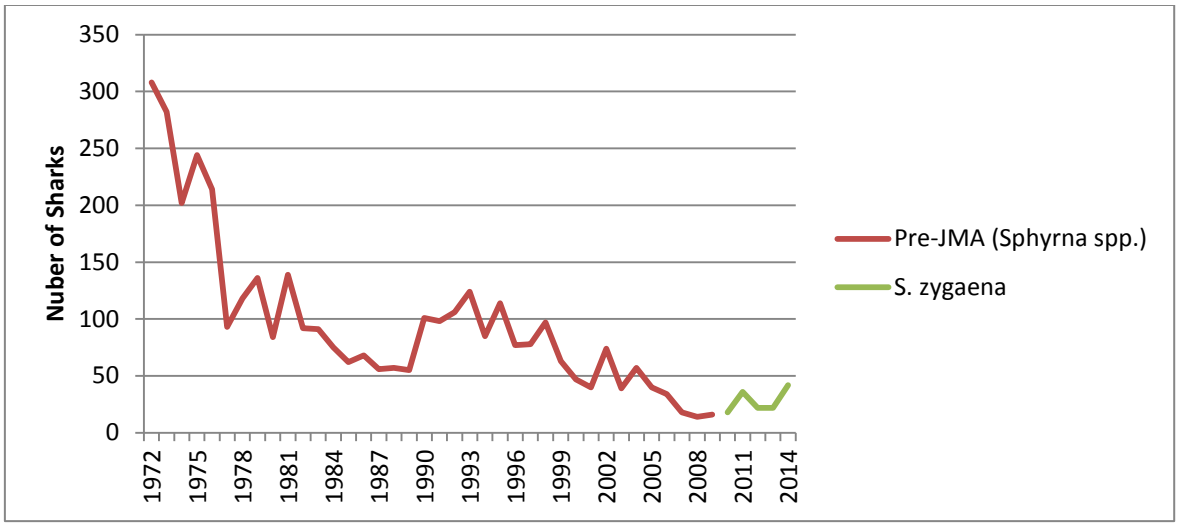


Figure 8. Number of hammerhead sharks entangled in nets deployed for the NSW Shark Meshing (Bather Protection) Program from 1972 to 2014. Red line depicts count of all *Sphyrna* spp. prior to the implementation of the Joint Management Agreement (JMA) and management plan. Green line depicts entanglements of *S. zygaena* after JMA and management plan implementation.

In conclusion, the available regional data suggests that the global population of smooth hammerhead sharks has likely experienced a decline from historical numbers, the magnitude of this decline is highly uncertain. In addition, recent data from some portions of the species' range suggest a potentially stable or no trend in abundance; however, as mentioned previously, reliable species-specific data on the smooth hammerhead shark are extremely limited.

ANALYSIS OF THE ESA SECTION 4(A)(1) FACTORS

The ESA requires NMFS to determine whether a species is endangered or threatened because of any of the factors specified in section 4(a)(1) of the ESA. The following provides information on each of these five factors as they relate to the status of the smooth hammerhead shark. The likely contribution of each threat to the extinction risk of the species is evaluated, with "significant" defined as increasing the risk to such a degree that affects the species' demographics (i.e., abundance, productivity, spatial structure, diversity) either to the point where the species is strongly influenced by stochastic or depensatory processes or is on a trajectory toward this point.

Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Currently, smooth hammerhead sharks are found worldwide, residing in temperate to tropical seas. Although the species was thought to be "functionally extinct" in the Mediterranean Sea, based on the absence of the species in records after 1995 (as noted in Ferretti et al. (2008)), as mentioned previously, this study was hindered by a lack of reliable species-specific data. Recent studies provide evidence of the species continued existence in the Mediterranean Sea, specifically within the Ionian and Tyrrhenian Seas and Strait of Sicily (Celona and de Maddalena 2005; Sperone et al. 2012); although the viability of this population is unknown. And while the exact extent of the species' global range is not well known, based on the best available data, there does not appear to be any indication of a curtailment of range due to habitat destruction or modification.

Additionally, there is very little information on habitat utilization of smooth hammerhead sharks. For example, habitat deemed necessary for important life history functions, such as spawning, breeding, feeding, and growth to maturity, is currently unknown for this species. Although potential nursery areas for the species have been identified in portions of its range (see **Growth and Reproduction** section), information on threats to these habitat areas that are directly impacting smooth hammerhead populations is not available.

Because the smooth hammerhead range is comprised of open ocean environments occurring over broad geographic ranges, large-scale impacts such as global climate change that affect ocean temperatures, currents, and potentially food chain dynamics, may pose a threat to this species. Although studies on the impacts of climate change specific to smooth hammerhead sharks have not been conducted, results from a recent vulnerability assessment of Australia's Great Barrier Reef shark and ray species to climate change indicate that the closely related great and scalloped hammerhead sharks have a low overall vulnerability to climate change (Chin et al. 2010). These findings were, in part, based on the species' low vulnerabilities to each of the assessed climate change factors (i.e., water and air temperature, ocean acidification, freshwater input,

ocean circulation, sea level rise, severe weather, light, and ultraviolet (UV) radiation) (Chin et al. 2010). While this is a very broad analysis of potential climate change impacts on hammerhead species, no further information specific to the direct effects of climate change on *S. zygaena* populations could be found. Furthermore, given the highly migratory and opportunistic behavior of the smooth hammerhead shark, these sharks likely have the ability to shift their range or distribution to remain in an environment conducive to their physiological and ecological needs, providing the species with some resilience to the effects of climate change. Therefore, while climate change has the potential to pose a threat to sharks in general, including through changes in currents and ocean circulation and potential impacts to prey species, there is presently no information to suggest climate change is a significant threat negatively affecting the status of the smooth hammerhead shark or its habitat.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Threats to the smooth hammerhead shark related to overutilization stem primarily from commercial and artisanal fisheries, including illegal fishing of the species, with the shark fin trade driving exploitation. Smooth hammerhead sharks are both targeted and taken as bycatch in many global fisheries by a variety of gear types, including: pelagic and bottom longlines, handlines, gillnets, purse seines, and pelagic and bottom trawls. These sharks are mostly targeted for their large, high-quality fins for use in shark fin soup. Hammerhead meat, on the other hand, is considered essentially unpalatable due to its high urea concentration. However, some countries still consume the meat domestically or trade it internationally. In Brazil, for example, there is a market for shark meat where smooth hammerhead sharks are preferred over scalloped hammerhead sharks and sold for consumption (Amorim et al. 2011). Hammerhead meat has also been documented in fish markets in Trinidad and Tobago and eastern Venezuela (F. Arocha, personal communication). In Kenya, it is dried and salted and actually identified as high quality meat, and in Japan, hammerhead meat is consumed in steak form (Vannuccini 1999). However, it is likely that the current volume of traded hammerhead meat and products is insignificant when compared to the volume of hammerhead fins in international trade, with the fin trade as the driving force behind the exploitation of *S. zygaena*

(CITES 2013).

Due to the growing concern of the level of trade and utilization of hammerhead sharks, there has been an increased emergence of regulatory and management measures, including retention bans, specifically for hammerhead sharks, and finning regulations (see **Appendix**). These regulations are aimed at decreasing the number of hammerhead sharks being landed or finned just for the shark fin trade; however, the effectiveness of these regulations are complicated by the fact that these sharks have rather high mortality rates after being caught in fishing gear such as longlines and nets. For example, in a study conducted off southern Australia and in Bass Strait, demersal gillnets were deployed with net soak times ranging from 2.4-20.6 hours (Braccini et al. 2012). A total of 122 smooth hammerhead sharks were caught but only 13 were still alive prior to discarding. Of those 13, the authors estimated a delayed survival probability (probability of surviving after discard) of 57% (Braccini et al. 2012). Based on the immediate and delayed survival probability figures, the authors estimated an overall post-capture survival probability of only 6.1% for the smooth hammerhead shark, indicating a very high likelihood of mortality after incidental capture in nets (Braccini et al. 2012). Based on the previous study, it is perhaps not surprising that smooth hammerhead sharks also have a very low survival rate after capture in beach/bather protection shark nets. Cliff and Dudley (1992) found that out of the 65 smooth hammerhead sharks caught by shark nets deployed along the southern Natal coast of South Africa, only 2% were found alive when the nets were serviced (which occurred, on average, around 20 times per month).

On demersal longline gear, Butcher et al. (2015) estimated that after initial hooking, smooth hammerhead sharks survive for a mere 7 to 16 hours, although this study was based on only 2 individuals. In a larger study that analyzed hooking mortality of elasmobranchs captured by Portuguese longliners targeting swordfish, a total of 372 smooth hammerhead sharks (average size = 197.5 cm FL (220 cm TL)) were observed caught over the course of 834 longline fishing sets (Coelho et al. 2012). The large majority (71%) of the captured smooth hammerhead sharks were dead when brought to the boat (Coelho et al. 2012). Off Brazil, smooth hammerhead sharks were found to have

a 47% at-vessel mortality rate based on observations from monitored tuna longline sets (Kotas et al. 2000). Similarly, in a study that examined potential mitigation measures to reduce the incidental bycatch in the tuna and swordfish longline fisheries, smooth hammerhead sharks were found to have high at-vessel mortality rates, ranging from 61 – 64% (Fernandez-Carvalho et al. 2015).

Thus, while fishermen may be less likely to take a smooth hammerhead onboard (due to current regulations), this behavior may not necessarily translate to significant decreases in fishery-related mortality levels for the species. With such high mortality rates from simply being caught in fishing gear (from 47-71% in longlines and 94-98% in nets), strong consideration will be given to examining levels of bycatch and whether these levels may be contributing to overutilization of the species. For the purposes of this status review, population dynamic characteristics, such as historical and current population sizes, trends by regions, levels of catch and bycatch in various fisheries, and the trade in shark fins were considered when evaluating whether this species is currently experiencing overutilization throughout its range. The sections below describe this information on a global and regional scale.

Global Trends in Utilization

Worldwide catches of sphyrnids, including smooth hammerhead sharks, are reported in the FAO Global Capture Production dataset mainly at the family level. Total catches of the hammerhead family (*Sphyrnidae*) (Figure 9) have increased since the early 1990s, from 75 tonnes (mt) in 1990 to a peak of 6,313 mt in 2010. Although the FAO dataset ostensibly represents the most comprehensive data available on world fisheries production, there are several caveats to interpreting these data and the data are not likely representative of the catch of these species through time. Because FAO data are derived from reports provided by the fisheries agencies of individual countries, the data are affected by the same limitations in reporting capabilities, including issues related to species identification and a lack of species-specific reporting altogether. Further, some species may only be reported from a few nations despite the species having a very wide distribution. Additionally, many nations that report catch volumes to the FAO do not include catches that are discarded at sea (e.g., incidental catch or bycatch) (Rose 1996).

Although more countries and RFMOs are working towards improving reporting of species-specific fish catches, catches of hammerhead sharks have gone and continue to go unrecorded in many countries. Thus, given these types of data, global population and utilization trends for hammerhead sharks, and specifically smooth hammerhead sharks, are largely unavailable and highly uncertain.

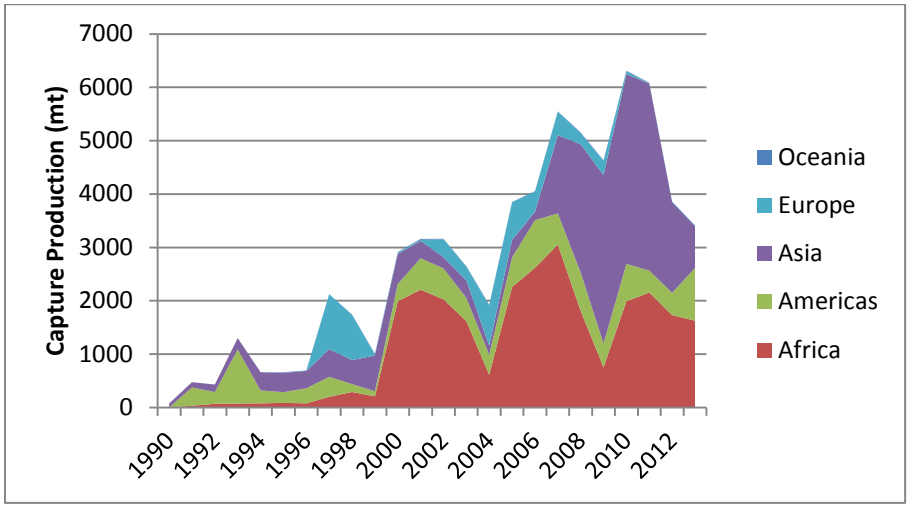


Figure 9. Global capture production (mt) of all hammerhead sharks (*Sphyrnidae*) from 1990-2013. (Source: FAO Global Capture Production; Accessed October 20, 2015)

Rather, much of the available data on the exploitation of the species comes from localized study sites and over small periods of time; thus, it is difficult to extrapolate this information to the global population. Further complicating the analysis is the fact that data are often aggregated for the entire hammerhead complex. However, to use a hammerhead complex or other hammerhead species as a proxy for estimates of smooth hammerhead utilization and abundance could be erroneous, especially given the distribution and proportion of *S. zygaena* compared to other hammerhead species. As smooth hammerheads tend to occur more frequently in temperate waters compared to other *Sphyrna* species, they are likely to be impacted by different fisheries, which may explain the large differences in the proportions that *S. zygaena* comprise in the available commercial and artisanal "hammerhead" catch. In fact, based on the available information (discussed below), the proportion of smooth hammerhead sharks compared to the other hammerhead species in the fisheries data ranges from <1% to 100%,

depending on the region, location, and timing of the fishing operations. As such, using other *Sphyrna* spp. abundance indices estimated from fisheries data to describe the status of *S. zygaena* is likely highly inaccurate. Therefore, more weight is given to the analysis of the available species-specific fisheries information compared to the hammerhead complex data in determining whether overutilization is a significant threat to the species. Due to the lack of global estimates and the above data limitations, the available information on the threat of overutilization, including species-specific fishery data, is presented below by region (Atlantic, Indian, and Pacific) to better inform a global analysis.

Atlantic Ocean

Northwest Atlantic

In the northwestern Atlantic, smooth hammerhead sharks are mainly caught, albeit rarely, as bycatch in the U.S. Highly Migratory Species (HMS) commercial longline and net fisheries and by U.S. recreational fishermen using rod and reel. Their rare occurrence in the fisheries data is likely a reflection of the low abundance of the species in this region (Hayes 2007; NMFS 2015a). For example, in the pelagic longline fishery, which primarily targets swordfish, yellowfin tuna, and bigeye tuna, catches of smooth hammerhead sharks have been minimal. In fact, observer data recorded only 15 smooth hammerhead sharks caught on U.S. pelagic longline gear between 1992 and 2005, representing 1.8% of the identified hammerhead species, 1.2% of all hammerhead catch, and <0.001% of all shark species caught (Baum and Blanchard 2010). Analysis of HMS logbook data indicated that an average of 25 vessels landed 181 hammerhead sharks per year on pelagic longline gear from 2005-2009, the majority of which were likely scalloped hammerheads (NMFS 2011c). In 2011, the shortfin mako (*Isurus oxyrinchus*) led the shark species in largest amount of landings (in weight) by U.S. Atlantic pelagic longline fishermen, with a total of ca. 372 mt, followed by thresher sharks (*Alopias* spp.), blue shark (*Prionace glauca*), and hammerhead sharks (*Sphyrna* spp.) with ca. 89, 65, and 3.8 mt, respectively (NMFS 2012a). The estimates for hammerhead shark landings declined by 1 mt from 2010 (NMFS 2011a). Since 2011, the United States has prohibited retaining, transshipping, landing, storing, or selling hammerhead sharks in the family *Sphyrnidae* (except for *Sphyrna tiburo*) caught in association with

International Commission for the Conservation of Atlantic Tunas (ICCAT) fisheries (consistent with ICCAT Recommendations 09-07, 10-07, 10-08, and 11-08). During 2012 and 2014, no smooth hammerhead sharks were reported caught by pelagic longline vessels, and in 2013, only one was reported caught and subsequently released alive (NMFS 2013a; NMFS 2014b).

In the U.S. bottom longline fishery, which is the primary commercial gear employed for targeting large coastal sharks, including hammerheads, *S. zygaena* is a rare occurrence in both the shark catch and bycatch. Based on data from the NMFS shark bottom longline observer program, between 2005 and 2014, only 6 smooth hammerhead sharks were observed caught by bottom longline vessels fishing in the Gulf of Mexico and South Atlantic (data from 214 observed vessels, 833 trips, and 3,032 hauls; see NMFS Reports available at http://www.sefsc.noaa.gov/labs/panama/ob/bottomlineobserver.htm). Currently, about 198 U.S. fishermen are permitted to target sharks (excluding spiny dogfish) managed by the NMFS Highly Migratory Species (HMS) Management Division in the Atlantic Ocean and Gulf of Mexico, and an additional 252 fishermen are permitted to land sharks incidentally.

Total U.S. domestic commercial landings of hammerhead species in the Atlantic region (this does not include the Gulf of Mexico; however, no *S. zygaena* were landed in the Gulf of Mexico region) is provided in Table 2. Data were compiled from the most recent stock assessment documents (for scalloped hammerhead sharks) and updates provided by the NMFS Southeast Fisheries Science Center (SEFSC). From 2009 – 2014, the commercial landings of hammerhead sharks have been variable (Figure 10), decreasing from 2009 to 2012 and then increasing in the last two years of the dataset. Prior to 2012, landings were primarily lumped into an unclassified hammerhead category; however, it has been estimated that the majority (~59%) of the unclassified hammerhead landings are likely *S. lewini* (based on data from the Commercial Shark Fishery Observer Program; NMFS 2010). Starting in 2013, NMFS no longer accepts unclassified shark data. Since 2012, landings specifically for smooth hammerhead sharks exhibit a declining trend, which is likely partly due to the aforementioned 2011 hammerhead retention prohibition in the pelagic longline fisheries (Figure 11).

Table 2. Domestic commercial landings of hammerhead sharks in the Atlantic Region in pounds (lb) of dressed weight (dw) from 2009- 2014 (Source: NMFS 2015)

Large Coastal Shark	2009	2010	2011	2012	2013	2014
Hammerhead, great	0	0	0	371	7,406	13,538
Hammerhead, scalloped	0	0	0	15,800	27,229	24,652
Hammerhead, smooth	4,025	7,802	110	3,967	1,521	601
Hammerhead, unclassified	62,825	43,345	35,618	9,617	0	0
Total	66,850	51,147	35,728	29,755	36,156	38,791

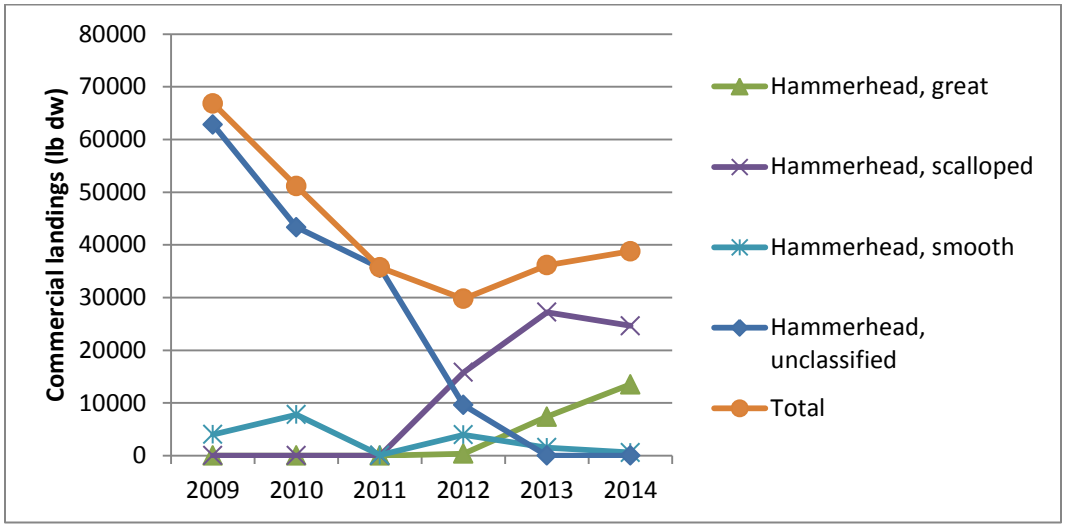


Figure 10. U.S. domestic commercial landings of hammerhead sharks in the Atlantic Region in pounds (lbs) of dressed weight (dw) from 2009- 2014

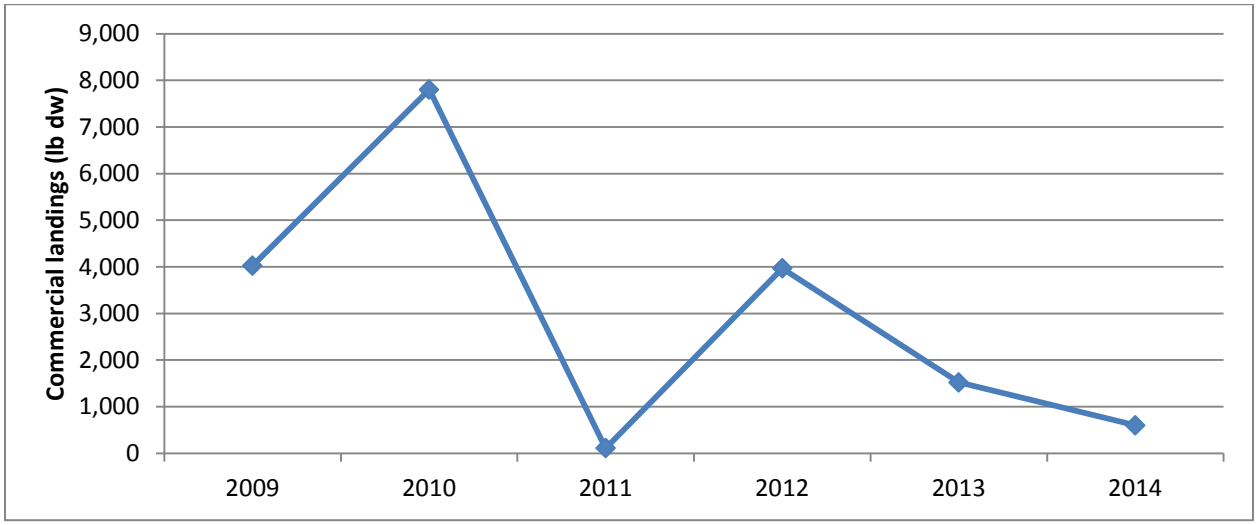


Figure 11. U.S. domestic commercial landings of smooth hammerhead sharks in the Atlantic Region in pounds (lbs) of dressed weight (dw) from 2009- 2014

Recreational landings of sharks are also an important component of the U.S. HMS fisheries operating in the northwest Atlantic. Recreational shark fishing with rod and reel is a popular sport at every social and economic level. The recreational shark fishery operating in the Atlantic Ocean, including the Gulf of Mexico and Caribbean, is managed using bag limits, minimum size requirements, and landing requirements (sharks must be landed with head and fins naturally attached). Since 2003, this recreational fishery has been limited to rod and reel and handline gear only. Currently, recreational fishermen are allowed one hammerhead shark >78" FL (198 cm) per vessel per trip. NMFS recently increased the minimum size limit for hammerheads from 54 inches FL (137 cm) to the current 78 inches FL (198 cm) to ensure that primarily mature individuals are retained. Since 2005, no smooth hammerhead sharks have been recorded in the recreational harvest data, with the exception of 2013, when 352 *S. zygaena* were reported as landed (NMFS 2012b; NMFS 2014b). No explanation was provided for the unusual 2013 landings data. Additionally, the Large Pelagic Survey (LPS) provided data from Maine through Virginia on the observed and reported numbers of hammerheads caught in the rod and reel fishery from 2002 - 2014. Only 1 smooth hammerhead shark was reported as "kept" in 2008. An additional 17 smooth hammerheads were observed or reported in the rod and reel fishery from 2002-2014, but all were released (NMFS 2012b; NMFS 2014b; NMFS 2015a).

As mentioned previously, two preliminary species-specific stock assessments, using surplus-production models, have been conducted on smooth hammerhead sharks to examine the effect of U.S. commercial and recreational fishing on the species' abundance (Hayes 2007; Jiao et al. 2011). These stock assessments draw conclusions about the status of the stock (e.g., "overfished" or "experiencing overfishing") in relation to the fishery management terms defined under the Magnuson-Stevens Fishery Conservation and Management Act (MSA), such as "maximum sustainable yield" (MSY). These statuses, which provide information for determining the sustainability of a fishery, are based on different criteria than those under the ESA, which relate directly to the likelihood of extinction of the species. In other words, the status under MSA does not necessarily have any relationship to a species' extinction risk. For example, a species could be harvested at levels above MSY but which do not pose a risk of extinction. As

such, the analysis of the results from these stock assessments will be considered in conjunction with available catch and bycatch trends, abundance, biological information, and other available fisheries data in evaluating whether overutilization is a threat to the species.

For the stock assessment models, the limited amount and low quality of available data on smooth hammerhead sharks allowed for the input of only one index of relative abundance (the PLL logbook dataset) into the models. Catch time series data for the models included recreational catches, commercial landings, and pelagic longline discards (Figure 12). Based on this data, both assessments found significant catches of smooth hammerhead sharks in the early 1980s, over two orders of magnitude larger than the smallest catches, but Hayes (2007) suggested that these large catches, which correspond mostly to the NMFS Marine Recreational Fishery Statistics Survey (MRFSS), are likely overestimated. Hayes (2007) also identified other data deficiencies that add to the uncertainty surrounding these catch estimates including: misreporting of the species, particularly in recreational fisheries, leading to overestimates of catches; underreporting of commercial catches in early years; and unavailable discard estimates for the pelagic longline fishery for the period of 1982-1986.

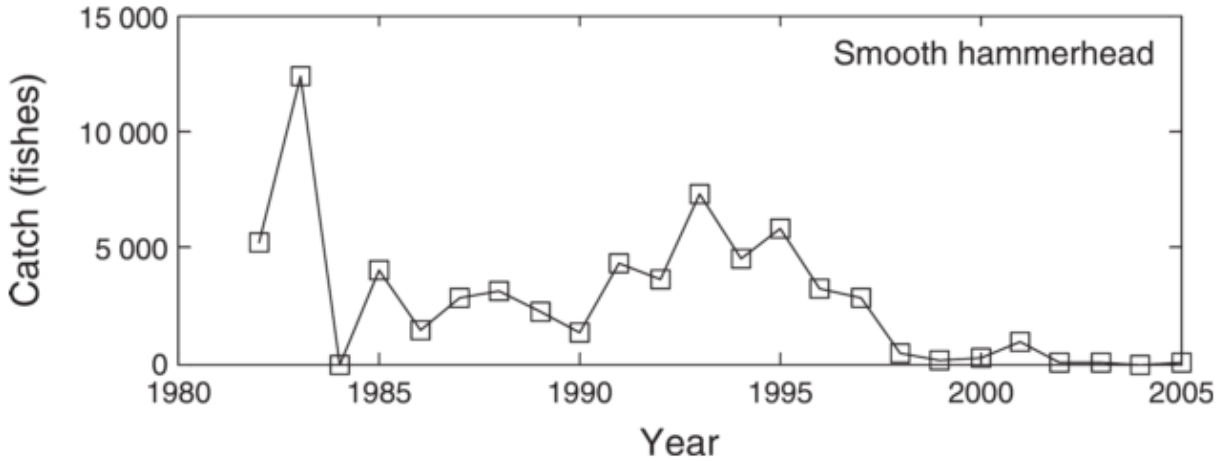


Figure 12. Catches of *S. zygaena* (number of individuals; includes recreational, commercial landings, and pelagic longline discards) in the Northwest Atlantic and Gulf of Mexico from 1980-2005 (Source: Jiao et al. 2011)

Results from the stock assessments indicated that the northwest Atlantic smooth hammerhead shark population has significantly declined from virgin levels (by up to 91%; Hayes 2007), likely a consequence of fishery-related mortality and exacerbated by the species' low growth rate. Although modeled fishing mortality rates were variable over the years, both assessments found a high degree of overfishing during the mid-1990s for smooth hammerhead sharks that likely led to the decline in the population of the species. Towards the end of the modeled time series, however, Hayes (2007) noted that the stock assessment was highly sensitive to the inclusion of pelagic discards for the determination of whether the stock was experiencing overfishing in 2005. Specifically, including estimates of pelagic discards in the models led to a status of an overfished stock with overfishing occurring in 2005. Fishing mortality was estimated to be 150% of fishing mortality associated with maximum sustainable yield (MSY) and population size was only 19% (Schaefer model) or 24% (Fox model) of the biomass that would produce MSY. However, if reported catch (i.e., 26 individuals and no discards) is assumed to be accurate, then overfishing did not occur in 2005, with fishing mortality estimated to be 22% of fishing mortality associated with MSY. The stock was still overfished, with a population size of only 14% (Schaefer model) or 20% (Fox model) of the biomass that would produce MSY. The latter finding, using reported catch, is similar to the results from the Jiao et al. (2011) stock assessment model, which indicated that after 2001, the risk of overfishing was very low and that the smooth hammerhead population was still overfished but no longer experiencing overfishing. Additionally, as noted in the **Distribution and Abundance** section, the modeled trajectory of abundance appears to depict a depleted but stable population since the early 2000s. It is important to note, however, that both studies point out the high degree of uncertainty associated with these stock assessment models, with Jiao et al. (2011) warning that the stock assessment model should be "viewed as illustrative rather than as conclusive evidence of their [*S. zygaena*] present status," and Hayes (2007) noting that the "Questionable data give us little confidence in the magnitude of the results." Furthermore, as mentioned previously, inferring percentage declines using a single index of relative abundance from logbook data is cautioned against, given the major caveats particularly associated with logbook datasets.

Based on the above population abundance and catch trends, overutilization of the smooth hammerhead shark in the northwestern Atlantic does not appear to be a significant threat contributing to the extinction risk of the species. While the population may be depleted from historical numbers, the magnitude of decline is highly uncertain. In addition, harvest and bycatch of the species is very low, with regulatory measures that appear adequate to protect the species from overutilization. For example, presently, harvest of the species is managed under the 2006 Consolidated HMS Fishery Management Plan (FMP). With the passage of Amendment 5a to this FMP, which was finalized on July 3, 2013 (78 FR 40318), management measures have been implemented in the U.S. Federal Atlantic HMS fisheries which will help decrease fishery-related mortality of the species. These measures include separating the commercial hammerhead quotas (which includes great, scalloped, and smooth hammerheads) from the large coastal shark (LCS) complex quotas, and linking the Atlantic hammerhead shark quota to the Atlantic aggregated LCS quotas, and the Gulf of Mexico hammerhead shark quota to the Gulf of Mexico aggregated LCS quotas. In other words, if either the aggregated LCS or hammerhead quota is reached, then both the aggregated LCS and hammerhead management groups will close. These quota linkages were implemented as an additional conservation benefit for the hammerhead shark complex due to the concern of hammerhead bycatch and additional mortality from fishermen targeting other sharks within the LCS complex. Furthermore, the separation of the hammerhead species from other sharks within the LCS management unit for quota monitoring purposes will allow NMFS to better manage the specific utilization of the hammerhead complex.

Since these management measures have been in place, landings of hammerheads have significantly decreased. In fact, in 2013 only 49% of the Atlantic hammerhead shark quota was reached due to the closure of the Atlantic aggregated LCS group. In 2014, the Atlantic LCS quota was reached when only 46% of the Atlantic hammerhead quota had been caught. Most recently, in 2015, 66% of the Atlantic hammerhead quota was caught. In other words, due to existing regulatory measures, the mortality of hammerheads from both targeted fishing and bycatch mortality on fishing gear for other LCS species

appears to have been significantly reduced, with current levels unlikely to lead to overutilization of the species.

Central and Southwest Atlantic

In the Caribbean Sea, virtually no information is available on the level of utilization (or even occurrence) of the species, as these waters are generally not considered to be part of the species' range (see **Range and Habitat Use**). The only available information on the catch of the species in Caribbean waters comes from the Venezuelan Pelagic Longline Observer Program database. From 1994 to 2000, observers recorded 88 smooth hammerheads caught by the Venezuelan industrial longline fleet targeting tuna and swordfish in the Caribbean Sea and central Atlantic (Arocha et al. 2002). Although smooth hammerhead sharks were the 6th most commonly caught shark species on the longline gear, they comprised only 4.6% of the total shark catch (Arocha et al. 2002). The observed *S. zygaena* sharks ranged in size from 92 cm to 292 cm FL (94 to 332 cm TL), with an average of 148.6 cm FL (161.8 TL), which is below the estimated size at maturity (Arocha et al. 2002). Tavares (2005) examined this dataset extended out to year 2003, and found that when broken out by Caribbean and Atlantic catch, smooth hammerhead sharks (n=27 individuals) comprised only 1.26% of the catch from the Caribbean. In the Atlantic, they comprised 4% of the shark catch but with a total of only 18 individuals captured. Over the course of the study, the average index of abundance for smooth hammerhead sharks (in number of sharks per 1000 hooks) was 2.54 (±1.87), with the majority of the sharks concentrated around the oceanic islands and near the edge of the continental shelf (Figure 13.). No information on trends in relative abundance for the species was provided in the study; however, overall, Tavares (2005) considered *S. zygaena* to be one of the least frequently caught species of sharks by the Venezuelan industrial longline fleet.

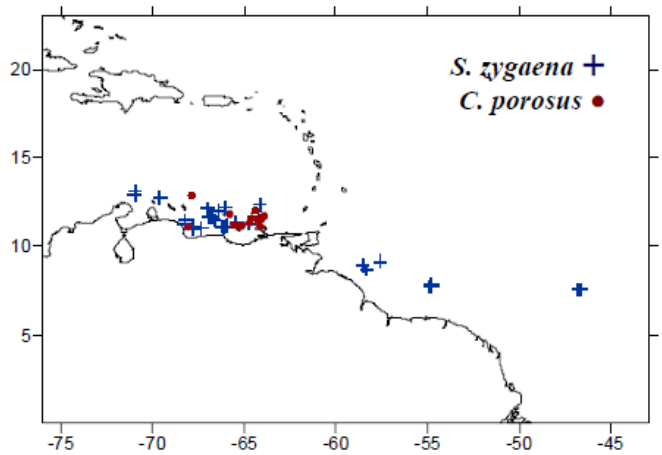


Figure 13. Observed smooth hammerhead shark (*S. zygaena*) and smalltail shark (*C. porosus*) catches by the Venezuelan longline fleet from 1994-2003 (Source: Tavares 2005)

In the southwest Atlantic, hammerhead sharks are susceptible to being caught by the artisanal, industrial, and recreational fisheries operating off the coast of Brazil and Uruguay. The artisanal net, recreational, and industrial trawl fishing in this region occurs within inshore areas and on the continental shelf, placing neonate and juvenile hammerheads at risk of fishery-related mortality (Vooren and Klippel 2005; CITES 2013). The industrial gillnet and longline fisheries operate throughout the continental shelf and adjacent oceanic waters, posing potential risks to the larger juveniles and adults of the species (Vooren and Klippel 2005; CITES 2013). However, the magnitude of this risk, particularly to the *S. zygaena* population, remains unclear as the available landings data from this region, which tend to be lumped for all hammerhead species (*Sphyrna* spp.), have fluctuated over the years (Vooren and Klippel 2005)

The majority of the hammerhead catch in this region is caught by the oceanic drift gillnet fleet, which operates on the outer shelf and slope between 27°S and 35°S latitudes (Vooren and Klippel 2005). From 1992-2002, the annual CPUE of this fishery varied between 100 kg and 300 kg (of S. *lewini* and *S. zygaena*) per fishing trip, with no downward trend. Using estimates of average size, Vooren and Klippel (2005) calculated that this CPUE translated to a catch of only 1-3 hammerhead sharks per fishing trip; however, the authors note that the practice of shark finning was common and, therefore, these fishery statistics likely underestimate the number of hammerheads killed during this time period. In 2002, hammerhead sharks comprised 56% of the total fish catch from the oceanic drift gillnet fishery, indicating likely targeted fishing of these sharks. In addition, total hammerhead landings from all fisheries in 2002 totaled 356 t, with 92%

of the landings attributed to the gillnet fleet. However, similar to the findings from the northwest Atlantic, the available species-specific fisheries data indicate that smooth hammerhead sharks comprise a very small proportion of the hammerhead catch from these fisheries, with estimates of around <1 – 5% (Sadowsky 1965; Vooren and Klippel 2005).

Although not as frequent as in the oceanic gillnet fisheries, catches of smooth hammerhead sharks are also observed in the longline fisheries operating in the shelf and oceanic waters off southern Brazil and Uruguay. In a study on the removal of shark species by São Paulo tuna longliners, which operate off the coast of Brazil (Figure 14), Amorim et al. (1998) documented catches of smooth and scalloped hammerhead sharks from 1974 – 1997, mainly on the southern continental slope. In general, sharks became an increasingly larger component of the fleet's longline catch over the study period, reaching a peak of around 59% in 1993 before decreasing thereafter. However, the authors attribute this trend mainly to blue shark catches, which comprised around 30% of the total yield. Still, hammerhead sharks (particularly *S. lewini* and *S. zygaena*) were characterized in the study as having relatively high abundance (defined as >5% in numbers) in the total shark catches of Santos City, São Paulo longliners off southern Brazil. Scalloped hammerhead sharks comprised the majority of the hammerhead shark catch, at around 60%, but smooth hammerhead sharks were reportedly caught year-round by the fishermen. Total hammerhead catches by Santos longliners increased from around 7 t in 1972 to a peak of 290 t in 1990, before strongly decreasing in the following years to 59 t in 1996 (Amorim et al. 1998). However, the decreasing catch trend observed after 1990 may be partially

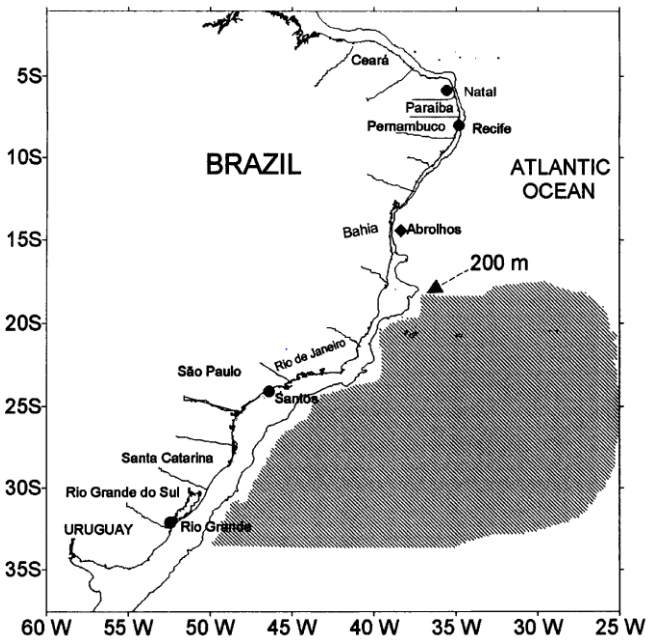


Figure 14. Santos longliners area of fisheries operation (Source: Amorim et al. 1998)

explained by a change in fishing gear, as the authors mention that Brazilian longliners began to replace their traditional Japanese longline with monofilament longline (which is better at catching swordfish) in 1994, leading to a decrease in total shark yields in the following years.

In a follow up study, conducted from 2007-2008, Amorim et al. (2011) examined shark catches of five surface longline fisheries from Sao Paulo State over the course of 27 fishing trips. The authors found that sharks represented 49.2% of the yield, indicating that the decrease in shark yields following the gear change in longline material was only temporary. Hammerheads comprised 6.3% of the shark total by weight, at 37.7 t, which is similar to the range of yields reported by Silveira (2007) in Amorim et al. (2011), with estimates from 9 t (in 2002) to 55 t (in 2005). In total, 376 smooth and scalloped hammerheads were recorded as caught from 2007-2008, but this time smooth hammerhead sharks comprised the majority of the hammerhead catch (n=245 *S. zygaena*; 65% of hammerhead catch). These sharks were caught between 20°3o'S and 32°50'S and mainly along the continental slope (Figure 15). Life stages of 30 male smooth hammerhead sharks were ascertained, with the large majority (n=20) constituting juveniles; however, 10 adults were also caught by the longliners, primarily during fishing operations in depths of 200 m - 3,000 m (Amorim et al. 2011).

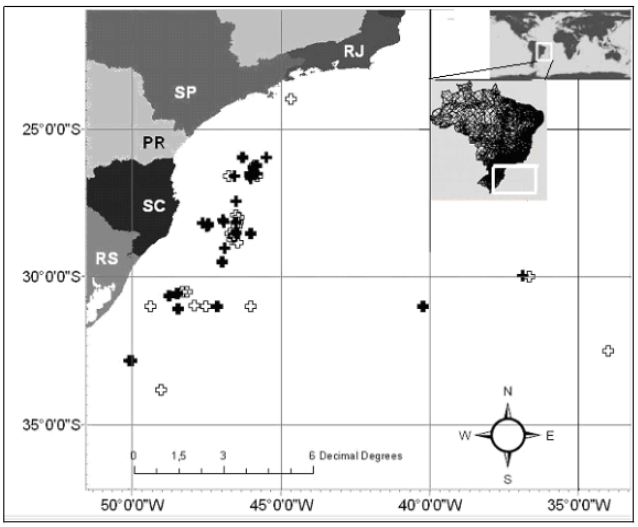


Figure 15. Catch locations of scalloped and smooth hammerheads as reported by Santos longliners (white crosses = scalloped, black crosses = smooth) (Source: Amorim et al. 2011)

In the Brazilian artisanal net fisheries, which also catch smooth hammerhead sharks, gillnets are deployed off beaches in depths of up to 30 m. Given their area of operation (e.g., closer to shore, in shallower waters), hammerhead catches from these artisanal fishing operations consist mainly of juveniles of both *S. lewini* and *S. zygaena*, but with

a higher proportion of *S. lewini*. However, surveys of artisanal fishing communities indicate potential local areas of higher abundance of smooth hammerheads. For example, in a study of two artisanal fishing communities on the coast between the border of Parana and Santa Catarina, Brazil, Costa and Chaves (2006) noted that between 2001 and 2003 smooth hammerhead sharks were the most commonly caught shark in the spring months, and 2nd most frequently caught shark over the course of the study period (behind the Brazilian sharpnose shark, *Rhizoprionodon lalandii*). It is worth noting, however, that the total number of juvenile smooth hammerhead sharks amounted to only 25 individuals over the two years. Similarly, in a study examining the diet of the six most commonly landed shark species off Parana by artisanal fishermen, Bornatowski et al. (2014) observed a higher percentage of smooth hammerhead sharks in the hammerhead catch than has previously been reported. From April 2010 to March 2012, the authors documented 77 juveniles of *S. zygaena* (with sizes ranging from 67.1 – 185 cm TL) and 123 scalloped hammerhead sharks. Smooth hammerheads comprised around 38.5% of the observed catch of hammerheads by the artisanal gillnet fishermen. As noted in the Costa and Chaves (2006) study, the explanation for the higher occurrence of smooth hammerhead sharks (in comparison to scalloped hammerhead sharks) is likely related to the more temperate water temperatures in the study areas. However, the Vooren and Klippel (2005) review, which examined survey data and sampled artisanal fishing operations in waters south of Parana (i.e., in more temperate waters, specifically, off Rio Grande do Sul, Brazil), the proportion of *S. zygaena* in the hammerhead catch was notably less. In fact, artisanal fishermen operating near Solitude Lighthouse (30°42'S) reported a fish haul of 120 kg of newborn hammerhead sharks, with around 180 scalloped hammerheads and only 2 smooth hammerhead sharks, or 1% of the hammerhead catch. Similarly, from November 2002 to March 2003, Vooren and Klippel (2005) report data from 24 sampling trips to a stretch of beach between Chui and Tramandai, where artisanal fish catches from beach seines, cable nets, and gillnets were recorded. Over the course of the monitoring period, a total of 218 hammerhead sharks were caught, with only 4 (or 1.8%) identified as smooth hammerhead sharks. In other words, even in more temperate waters, the distribution of the smooth hammerhead shark appears to be patchy, with the likelihood of catching the species highly uncertain.

Based on the data, the observed low abundance of smooth hammerhead sharks does not appear to be an artifact of overutilization of the species as surveys from over three decades ago also indicate a low occurrence of the species, particularly in comparison to scalloped hammerhead sharks. For example, bottom trawl survey data from the early 1980s show that *S. zygaena* average CPUE ranged from 1.3 to 2.1 kg/hour whereas *S. lewini* CPUE estimates (from 1980-2005) were over 50 kg/hour depending on the season (Vooren and Klippel 2005). In a sampling of fish from shallow waters off Cassino beach in 1983, the catch was comprised of 100 *S. lewini* and only 5 *S. zygaena* (Vooren and Klippel 2005), a scalloped to smooth hammerhead proportion similar to that reflected in the data 20 years later. Therefore, although the available data indicate that primarily juvenile and neonate smooth hammerhead sharks are taken by the Brazilian artisanal and industrial net and line fisheries (Sadowsky 1965; Vooren and Klippel 2005), based on the proportion of the species in the catch, as well as the lack of any trends in the CPUE or landings data, there is no evidence to suggest that this level of utilization has or is significantly impacting recruitment to the population in this region.

Overall, it is clear that all life stages of the smooth hammerhead shark are susceptible to the fisheries operating in the southwest Atlantic. Because of the type of fishing gear and area of operation, neonate and juveniles appear more vulnerable to the industrial and artisanal net fisheries, which operate closer to shore and in shallower water, with juveniles also occasionally caught by longliners on the continental shelf. Adult smooth hammerheads, on the other hand, tend to occur farther offshore, near the slope and adjacent oceanic waters, and, as such, are more vulnerable to the industrial trawl and line fisheries that operate in these deeper waters. However, the degree to which these fisheries are contributing to the species' extinction risk is highly uncertain. Although there has been a general decline in hammerhead shark catches since the peaks observed in the 1990s, the species-specific data do not indicate that overutilization of smooth hammerhead sharks is a significant threat to the species. Analysis of the available CPUE data as a reflection of abundance does not indicate any trends that would suggest the smooth hammerhead shark is at an increased risk of extinction. The available hammerhead CPUE data (for *S. lewini* and *S. zygaena* combined) from the fishery that catches the majority of smooth hammerhead sharks, the oceanic gillnet fishery, shows a

variable trend over the period of 1992 to 2004. From 1992 to 1997, CPUE decreased from 0.28 (t/trip) to 0.05 (t/trip), and then increased to 0.25 (t/trip) by 2002. Similarly, there was no discernible trend in the recreational fisheries CPUE data for hammerhead sharks for the period covering 1999 to 2004 (Vooren and Klippel 2005). The CPUE of the longline fisheries was also variable, increasing from 0.02 (t/trip) in 1993 to 0.87 (t/trip) in 2000 and then decreasing to 0.02 (t/trip) in 2002 (Vooren and Klippel 2005). However, according to personal communication from the authors, cited in FAO (2010), the effort data used to estimate CPUE did not account for changes in the size of gillnets or number of hooks in the longline fisheries. Given these results, and noting that smooth hammerhead sharks tend to generally be harvested at low levels (comprising less than 5% of the fisheries catch), the available species-specific information does not indicate that overutilization is a significant threat presently contributing to the species' risk of extinction in this region.

Northeastern and Central Atlantic

In the northeastern and central Atlantic, smooth hammerhead sharks are caught primarily by the artisanal and industrial fisheries operating throughout the region. Compared to the western Atlantic, smooth hammerheads appear to comprise a higher proportion of the hammerhead catch and bycatch in the fisheries operating throughout the eastern Atlantic, which may be due to a greater overlap of these fisheries with the distribution of the species (i.e., higher fishing effort in more temperate waters). However, the available data still suggest that overall catches of the species, at least compared to other shark species, tend to be far less. For example, in a sample of the Spanish longline fleet landings (106 longline and 69 gillnet landings) at the Algeciras fish market (the largest fish market in southwestern Spain), Buencuerpo et al. (1998) observed 757 smooth hammerhead sharks, which translated to around 1.4% of the total fish catch. Smooth hammerhead sharks were the 3rd most abundant shark in the landings; however, their numbers were still significantly lower than the other two more commonly caught sharks: blue sharks (32,661 individuals; 63.7% of the total catch) and shortfin mako sharks (5,947 individuals; 11.6% of total catch). The vast majority of the smooth hammerhead sharks were caught by Spanish longliners fishing in waters off of northwestern Africa (20°W longitude to the strait of Gibraltar); however, catch rates of

S. zygaena over the year of the study were low and never exceeded 1 fish/1000 hooks (Buencuerpo et al. 1998).

While the impact of this level of catch on the smooth hammerhead population is unknown, due to the lack of information on population size, CPUE trend data, or other time-series information that could provide insight into *S. zygaena* population dynamics, Spain has since taken significant steps to protect hammerhead sharks from potential overutilization. In 2011, Spain published Royal Decree N°139/2011, adding hammerhead sharks to their List of Wild Species under Special Protection (Listado de Especies Silvestres en Régimen de Protección Especial). This listing prohibits the capture, injury, trade, import and export of hammerhead sharks, with a periodic evaluation of their conservation status. Given that Spain is Europe's top shark fishing nation, and from 2000-2011 accounted for 8% of the global shark and ray catch and 17% of the world's export volume of fins (Dent and Clarke 2015), this new regulation should provide some protection for smooth hammerhead sharks from Spanish fishing vessels. However, the effectiveness of this prohibition in reducing the fishery-related mortality rate of smooth hammerhead sharks will largely depend on whether fishermen can successfully avoid incidental catch of smooth hammerhead sharks (presumably through fishing in areas where occurrence of *S. zygaena* is low). Presently, the best available information does not allow for this type of analysis.

Farther south in the eastern Atlantic, off the west coast of Africa, fisheries data is severely lacking, particularly species-specific data; however, the available information suggests there has been a significant decline in the abundance of shark species, including hammerhead sharks. According to a review of shark fishing in the Sub Regional Fisheries Commission (SRFC) member countries (Cape-Verde, Gambia, Guinea, Guinea-Bissau, Mauritania, Senegal, and Sierra Leone), Diop and Dossa (2011) state that shark fishing has been occurring in this region for around 30 years. Shark fisheries and trade in this region first originated in Gambia, but soon spread throughout the region in the 1980s and 1990s, as the development and demand from the worldwide fin market increased. From 1994 to 2005, shark catch reached maximum levels, with a continued increase in the number of boats, with better fishing gear and people entering

the fishery, especially in the artisanal fishing sector. Before 1989, artisanal catch was less than 4,000 mt. However, from 1990 to 2005, catch increased dramatically from 5,000 mt to over 26,000 mt, as did the level of fishing effort (Diop and Dossa 2011). Including estimates of bycatch from the industrial fishing fleet brings this number over 30,000 mt in 2005 (however, discards of shark carcasses at sea were not included in bycatch estimates, suggesting bycatch may be underestimated) (Diop and Dossa 2011). In the SRFC region, an industry focused on the fishing activities, processing, and sale of shark products became well established. Hammerhead sharks, in particular, faced targeted exploitation by the Senegalese and Gambian fisheries. However, from 2005 to 2008, shark landings subsequently dropped by more than 50%, to 12,000 mt (Diop and Dossa 2011). In 2010, the number of artisanal fishing vessels that landed elasmobranchs in the SRFC zone was estimated to be around 2,500 vessels, with 1,300 of those specializing in catching sharks (Diop and Dossa 2011).

In terms of available hammerhead-specific information in the SRFC region, the data show a variable trend in the catch and abundance of hammerhead sharks over the past decade. Data from Senegal's annual fisheries reports depict fairly stable landings in recent years, but with peak highs of around 1,800 mt in 2006 and most recently in 2014 (Figure 16).

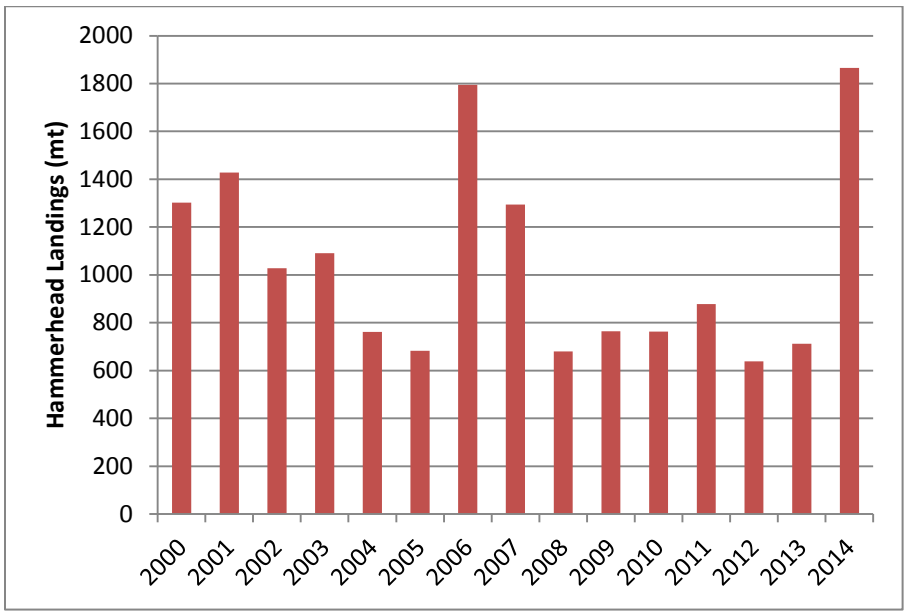


Figure 16. Annual hammerhead landings (mt) as documented in Senegal's Marine Fisheries Reports from 2000-2014.

Seemingly in contrast, in Mauritanian waters, scientific research survey data collected from 1982-2010 indicate that the abundance of *Sphyrna* spp. (identified as *S. lewini* and *S. zygaena*) has sharply declined, particularly since 2005, with virtually no *Sphyrna* spp. caught in 2010 (Figure 17; Dia et al. 2012).

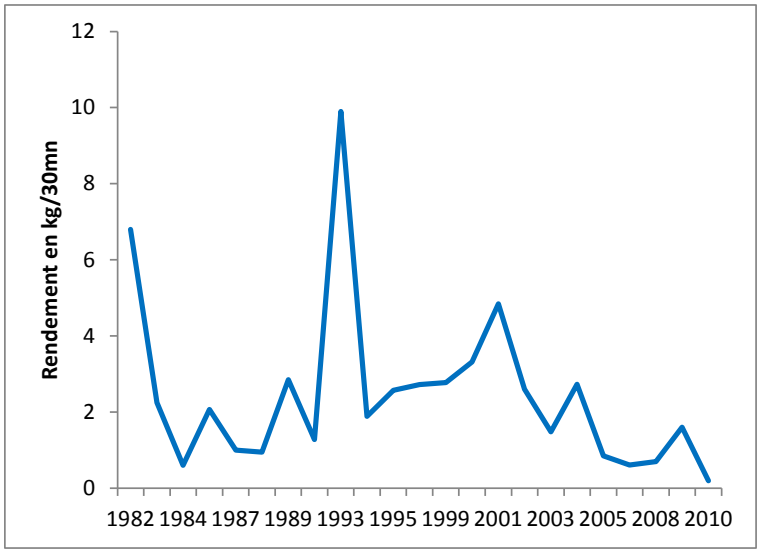


Figure 17. Change in average abundance indices (Kg/30min) of genus *Sphyrna* spp. (S. *lewini* and *S. zygaena*) from 1982 to 2010 (Source: Dia et al. 2012)

However, similar to the findings from the other areas in the Atlantic, scalloped hammerhead sharks appear to be the more common hammerhead shark in this region, comprising the majority of the hammerhead catches and likely influencing the trends observed in the hammerhead data. For example, from 1962 to 2002, 246 fishery surveys were conducted along the west coast of Africa (from Mauritania to Guinea, including Cape Verde), with species data reported in two databases: Trawlbase and Statbase, as part of the Système d'Information et d'Analyse des Pêches (SIAP) project (Mika Diop, Program Officer at Sub-Regional Fisheries Commission, personal communication 2015). Based on the information from the databases, *S. zygaena* was recorded rather sporadically in the surveys since the 1960s (prior to the expansion of the shark fisheries), and in low numbers (Figure 18). The greatest number of smooth hammerhead sharks observed during any single survey year was 12 individuals, recorded in 1991 (Figure 18). In contrast, scalloped hammerhead sharks occurred more frequently in the survey data, with a peak of 80 individuals recorded in 1993.

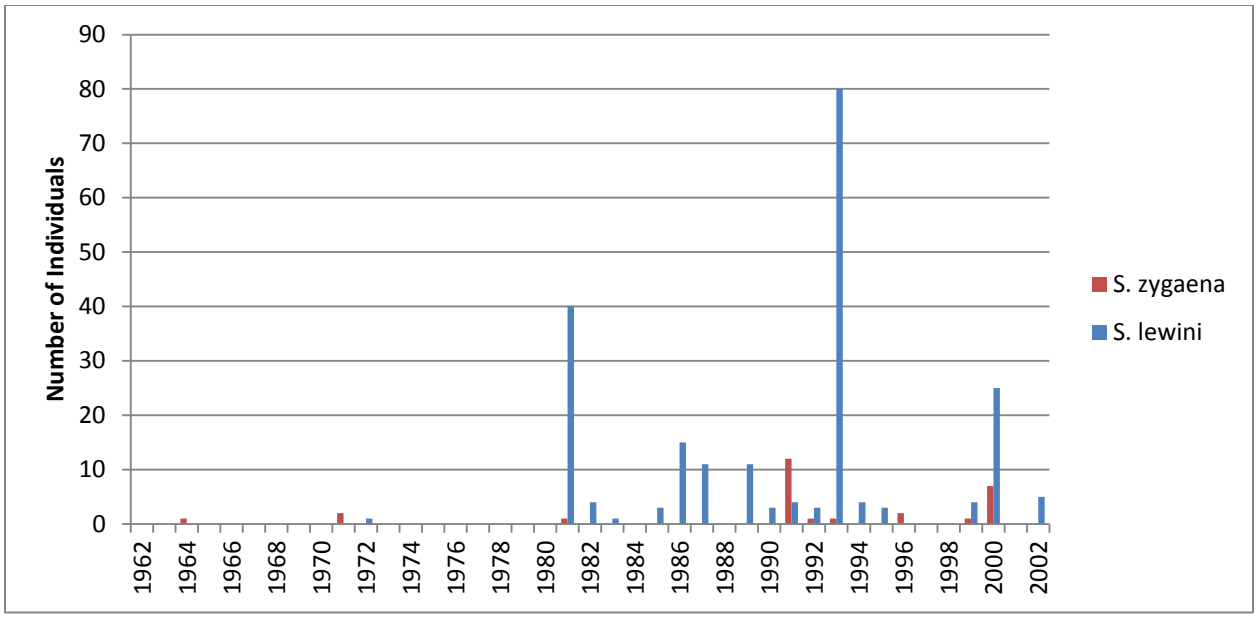


Figure 18. Number of *S. lewini* and *S. zygaena* individuals observed in trawl surveys conducted off the coast of West Africa from 1962 to 2002 (Source: SIAP project database)

In 2009, Dia et al. (2012) reported that the total catches of sharks in Mauritanian waters amounted to 2,010 mt, with total hammerhead landings of 221 mt. Smooth hammerheads constituted only 1.76% of the total shark catch (or 35 mt) and 16% of the hammerhead total (Dia et al. 2012). Farther south, in Orango National Park in Guinea-Bissau, 77 fishermen were surveyed for 4 weeks in 2011 in order to obtain an idea of annual shark catches in this area. Over those four weeks, a total of 6.31 mt of sharks were caught, of which around only 0.53 mt were smooth hammerhead sharks (comprising a third of the total hammerhead catch) (Betunde 2011).

Although the impact of the present level of utilization of smooth hammerhead sharks on the population is unknown, the fact that many of the hammerheads currently captured in these Eastern Atlantic fisheries are juveniles could have serious implications on the future recruitment of hammerhead sharks to the population (Zeeberg et al. 2006; Dia et al. 2012). For example, in the Buencuerpo et al. (1998) study mentioned previously, the average sizes of the smooth hammerhead sharks in the longline landings off northwestern Africa were 170 cm TL for females and 150 cm TL for males, indicating a tendency for these fisheries to catch immature individuals. Similarly, Portuguese

longliners targeting swordfish in the eastern equatorial Atlantic were also observed catching smooth hammerheads that were smaller than the estimated sizes at maturity. Between June and September 2009, 139 smooth hammerhead sharks were caught with 73% of the individuals between 160 cm and 190 cm FL (estimated 175 cm and 211 cm TL) (Coelho et al. 2011). Expanding the dataset to include smooth hammerheads caught between August 2008 and December 2011, Coelho et al. (2012) reported that the average length for captured smooth hammerheads (n=372) was 197.5 cm FL (220 cm TL) (Coelho et al. 2012), which falls within the range of maturity size estimates for the species. However, given that this is an average, it indicates that both adults and immature smooth hammerhead sharks are being caught by longliners operating in the Atlantic. Bycatch data from the European pelagic freezer-trawler fishery, which operates off Mauritania, also provides evidence of immature hammerhead dominance in the fishery catch. Between October 2001 and May 2005, 42% of the retained pelagic megafauna bycatch from over 1,400 freezer-trawl sets consisted of hammerhead species (*S. lewini, S. zygaena,* and *S. mokarran*), with around 75% of the hammerhead catch juveniles of 50 – 140 cm in length (Zeeberg et al. 2006). Zeeberg et al. (2006) go on to state that this level of hammerhead bycatch is likely unsustainable for this region; however, they report that hammerhead abundance was seasonal. The probability of catching hammerheads was low during the winter and spring months, as temperature decreased from 30°C to 18°C (Zeeberg et al. 2006). However, according to Cadenat and Blanchard (1981), it is precisely during this time, after water temperatures have cooled from summer highs, when young smooth hammerhead sharks are actually observed off the coast of West Africa. In other words, based on the timing and location of the Zeeberg et al. (2006) study, as well as the comments and observations from the authors, the catches and subsequent conclusions regarding the sustainability of the bycatch more likely reflect the status of *S. lewini* in this region as opposed to *S. zygaena*.

Although there are no stock assessments for any hammerhead shark species from the Eastern Atlantic region, the FAO has evaluated a number of pelagic and demersal fish and invertebrate stocks in the region and consider most to be fully fished to overfished due to historical and current fishing practices (FAO 2014). Driving this exploitation is the increasing need for protein resources in this region, both as a trade commodity and

as a dietary staple. In fact, many people in Sub-Saharan Africa depend on fish for protein in their diet, with fish accounting for around 22% of their protein intake (WorldFish Center 2005). Additionally, fishing activities in West Africa constitute a major contributor to Gross Domestic Product (GDP), particularly in Ghana, Mauritania, and Sierra Leone (de Graaf and Garibaldi 2014). With population growth in the SRFC predicted to increase from 35 million (in 2007) to around 76 million by 2050 (Diop and Dossa 2011), and with 78.4% of the population living within 100 km of the coast, there will likely be higher demand and fishing pressure on marine resources in future years (Diop and Dossa 2011). Presently, the FAO reports that ''the Eastern Central Atlantic has 48% of its assessed stocks at biologically unsustainable levels, and 52 percent within sustainable levels'' (FAO 2014). Although there have been some improvements in the status of fishery stocks in recent years (FAO 2014), the high demand for dietary protein in this region as well as the economic importance of fishing suggests that potential fishing pressure on hammerhead species, and particularly juveniles, will continue into the future. However, without additional information on present abundance levels, distribution information, or catch and overall utilization rates of the smooth hammerhead shark in this region, conclusions regarding the impact of this projected fishing pressure specifically on the extinction risk of the species would be highly uncertain and speculative.

Mediterranean

In the temperate waters of the Mediterranean Sea, smooth hammerhead sharks have been fished for over a century and have consequently suffered significant declines in abundance in this region. In the early 20th century, coastal fisheries would target large sharks and also land them as incidental bycatch in gill nets, fish traps, and tuna traps (Feretti et al. 2008). Feretti et al. (2008) hypothesized that certain species, including *S. zygaena,* found refuge in offshore pelagic waters from this intense coastal fishing. However, with the expansion of the tuna and swordfish longline and drift net fisheries into pelagic waters in the 1970s, these offshore areas no longer served as protection from fisheries, and sharks again became regular bycatch. Consequently, the hammerhead shark abundance in the Mediterranean Sea (primarily *S. zygaena*) is estimated to have declined by more than 99% over the past 107 years, with the authors

considering hammerheads to be functionally extinct in the region. Although these specific estimates are highly uncertain, hindered by a lack of reliable species-specific data and small sample sizes, they indicate a likely serious decline in the population of hammerheads within the Mediterranean that is further confirmed by findings from Celona and de Maddalena (2005).

Specifically, Celona and de Maddalena (2005) reviewed historical and more recent data (through 2004) on hammerhead occurrence (which the authors say are likely primarily *S. zygaena*) from select areas off Sicily (Figure 19) and found that smooth hammerheads have been fished to the point where they are now extremely rare.

Figure 19. Map of Sicily with noted locations of hammerhead shark captures and sightings (Source: Celona and de Maddalena 2005)

In the Messina Strait, which separates Sicily from southern Italy, hammerheads were historically caught throughout the year and observed in schools, especially when bullet tuna schools (*Auxis rochei rochei*) were present in these waters. An average of 10-12 hammerheads were caught per year as bycatch by tuna fishermen, with hammerheads

considered to be of high value. However, since 1998, no hammerheads have been observed in the Messina Strait.

The authors note that Palermo was another area where hammerhead sharks were also historically common. Based on data from the most important landing site for the area, Portciello di Santa Flavia, around 300-400 sharks were caught per year as bycatch in driftnets targeting swordfish, and around 50 hammerheads were caught annually in pelagic longlines. However, by the late 1970s, these sharks became noticeably less abundant, with only 1-2 sharks caught per year and the last observed hammerhead shark in this area caught in 2004. According to the authors, fishermen acknowledge that the main cause for collapse of the hammerhead population off Palermo was due to the extensive use of the drift net gear and its ability to catch large schools of smooth hammerhead sharks.

On the west coast of Sicily, Marsala was the main landing site for the area. Up until the 1990s, hammerheads were regularly caught by Marsalan pelagic fishermen targeting swordfish north of Ustica Island. Around 100 sharks would be caught per year by each fishing boat, with especially large individuals (between 150-200 kg) caught in the 1980s. However, hammerheads are now considered rare around Trapani and Marsala. Similarly, after once considered a common capture for longline fishermen off Selinunte in western-southern Sicily, hammerheads are now rarely encountered and have been for at least 15 years, with the last record of the species caught in 1998.

On the Ionian side, Celona and de Maddalena (2005) note that around 6-7 hammerhead sharks were caught per year in drift nets and occasionally tuna-traps from the areas of Portopalo di Capo Passero and Marzamemi, but for at least 10 years have been absent in sightings and catch data. Similarly, off Catania, hammerheads were regularly caught by swordfish and tuna fishermen (in both nets and longlines), but since 1999, only 1-2 sharks have been caught per year. The waters around Lampedusa Island in the Sicilian Channel were also noted as an area where hammerheads were frequently caught by fishermen. Up until the 1990s, fishermen would commonly observe schools of smaller hammerheads swimming near the surface (a behavior attributed to S. *zygaena*; Bass et

al. 1975). Around 6 to 8 hammerhead sharks were regularly caught by a single longline, with each fishing boat landing around 700-800 kg of hammerheads a year. The authors note that these hammerheads were likely used locally with no evidence of links to continental Italy. Currently, landing a hammerhead shark is rare, with fishermen acknowledging the negative effect that the historical heavy fishing pressure has had on the abundance of hammerhead sharks (Celona and de Maddalena 2005).

Celona and de Maddalena (2005) state that, historically, there were no regulations or management of the hammerhead shark fishery in Italy. When captured, these sharks were usually retained and sold, fresh and frozen, for human consumption. In Sicily, hammerhead meat is actually considered to be of high quality and value (selling for up to 7-10 Euros/kg) and primarily marketed for domestic consumption. In the 1970s, when a specific hammerhead fishery existed and these sharks were caught in large numbers, their price even climbed to around 30% of swordfish prices. The high value and demand for the species, in combination with the lack of any regulations to control the fishery, led to significant overutilization of the species in Sicilian waters. Although a quantitative assessment of the status of the species could not be conducted, due to a lack of data from the hammerhead fishery, the authors “roughly” estimate that captures of hammerhead shark have declined by at least 96-98% in the last 30 years as a result of overexploitation. Presently, hammerhead sharks are rarely observed or caught, and only as bycatch, as the hammerhead shark fishery in Italy no longer exists.

The disappearance of hammerhead sharks is not just relegated to waters off Italy. In a sampling of fleets targeting swordfish and tuna throughout the Mediterranean from 1998 to 2000, smooth hammerhead sharks were rarely observed. Data were obtained from 5,124 landing sites and 702 fishing days (onboard commercial fishing vessels) covering the vast majority of the Mediterranean Sea (see Figure 20) (Megalofonou et al. 2005). Over the two-year sampling period, only 4 smooth hammerhead sharks were observed at-set or recorded at landing sites (Megalofonou et al. 2005).

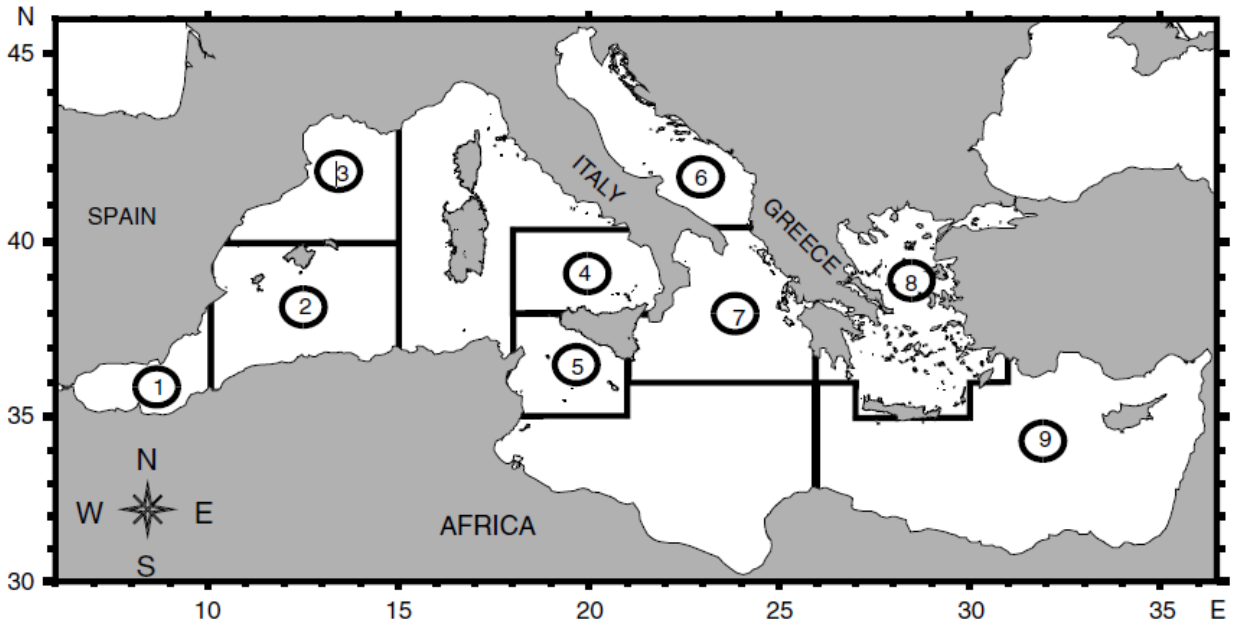


Figure 20. Map of the Mediterranean depicting the nine areas that were sampled for sharks onboard commercial fishing vessels during 1998-2000 (Source: Megalofonou et al. 2005)

Similarly, the Mediterranean Large Elasmobranchs Monitoring (MEDLAM) program, which was designed to monitor the captures and sightings of large cartilaginous fishes occurring in the Mediterranean Sea, also has very few records of the *S. zygaena* in its database. Since its inception in 1985, the program has collected around 1,866 records (including historical records) of more than 2,000 specimens from 20 participating countries. Figure 21 shows the locations of the reported 2,048 individuals, providing a depiction of the extent of coverage of this program. Out of the 2,048 elasmobranchs documented in the database through 2012, there are records identifying only 17 individuals of *S. zygaena* [note: without access to the database, the dates of

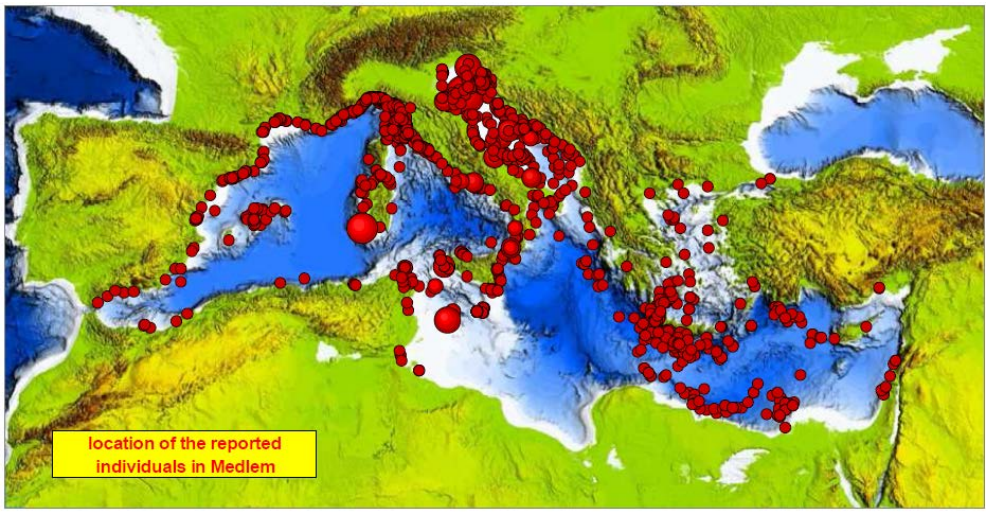


Figure 21. MEDLAM program reported locations of individual elasmobranchs. (Source: Baino et al. 2012)

these observations are unknown] (Baino et al. 2012).

Recently, Sperone et al. (2012) provided evidence of the contemporary occurrence of the smooth hammerhead shark in Mediterranean waters, recording 7 individuals over the course of 9 years (from 2000-2009) near the Calabria region of Italy. Previous findings by Ferretti et al. (2008) indicated the species was likely extirpated from this area based on Ionian longline data from 1995 to 1999. Although Sperone et al. (2012) suggest these new findings may indicate the potential recovery of smooth hammerhead shark populations in Ionian waters off Calabria, Italy, the populations in the Mediterranean are still significantly depleted. Any additional fishing mortality on these existing populations is likely to significantly contribute to its risk of extirpation in the Mediterranean, and given the large fishing fleet in the Mediterranean, this likelihood remains high. In fact, in 2012, the European Commission (2014) reported a Mediterranean fleet size of 76,023 vessels, with a total fishing capacity of 1,578,015 gross tonnage and 5,807,827 kilowatt power. As of January 2016, the General Fisheries Commission for the Mediterranean (GFCM) identified 9,343 large fishing vessels (i.e., larger than 15 meters) as authorized to fish in the GFCM convention area (which includes Mediterranean waters and the Black Sea). Of these vessels, 12% (or 1,086 vessels) reported using longlines or nets (drift nets, gillnets, trammel nets) as their main fishing gear (see http://www.gfcmonline.org/data/avl/). While the GFCM passed Recommendation GFCM/35/2011/7 (C), based on the ICCAT recommendation 10-08, prohibiting the onboard retention, transshipment, landing, storing, selling, or offering for sale any part or whole carcass of hammerhead sharks of the family Sphyrnidae (except for the *Sphyrna tiburo*) taken in the Convention area, as noted previously, the smooth hammerhead exhibits high rates of at-vessel mortality. Given the extremely depleted status of the species, it is therefore unlikely that this regulation will significantly decrease the fishery-related mortality of the smooth hammerhead shark to the point where it is no longer at significant risk of further declines and potential extirpation from overutilization.

Southeastern Atlantic

In the southeastern Atlantic, hammerhead sharks (likely primarily *S. zygaena* given the

more temperate waters of this region) have also been reported caught by commercial and artisanal fisheries operating off Angola, Namibia and the west coast of South Africa. In a study on the impact of longline fisheries in the Benguela Current Large Marine Ecosystem (defined as west of 20º E, north of 35º S and south of 5º S.) Petersen et al. (2007) reported observer data from the Namibian and South African longline fisheries and found that hammerheads were only a minor component of the shark bycatch. In Namibia, the longline fishery targets tuna species, swordfish, and large pelagic sharks and has 100% observer coverage. From 2002 to 2004, observers recorded a total of 8,829,000 hooks set by approximately 20 vessels (Petersen et al. 2007). Over 750,000 sharks were caught during this time period; however, hammerheads (*Sphyrna* spp.) comprised only 0.2% of the total shark bycatch (n=1,857 sharks), with a very low catch rate of 0.2 sharks/1000 hooks (Petersen et al. 2007). Similarly, hammerheads were also rarely caught by the South African pelagic longline fishery. This fishery is made up of two fleets: one which targets swordfish and is comprised mainly of South African vessels, and the other which targets tuna species and is comprised mainly of Asian vessels (Japanese, Korean, and Philippine vessels). From 2000 to 2005, observers reported catches from 447,000 hooks set by the South African fleet and 278,900 hooks set by the Asian fleet. A total of 10,436 sharks were observed caught by the South African fleet, with only one identified as a hammerhead shark (Petersen et al. 2007). The shark bycatch by Asian vessels amounted to 888 sharks, with no reported hammerhead sharks (Petersen et al. 2007).

In the shark directed longline fishery off South Africa, hammerhead sharks also appear to comprise a small component of the catch (by number). As a group, hammerheads, copper sharks, cowsharks, threshers, and skates made up only 3% of the total number of sharks caught by the shark directed longline fishery based on logsheet landings data from 1992-2005 (Petersen et al. 2007). Additionally, local demand for smooth hammerhead sharks (particularly meat) does not appear to be a threat in these waters, with smooth hammerheads generally relegated to the colloquial “bad” trade category due to the lower value of its flesh in South African markets (Da Silva and Burgener 2007).

Petersen et al. (2007) also looked at the pelagic longline fishery in Angolan waters but no specific shark catch information was available. However, the authors did sample the Angolan artisanal subsistence handline fishery at beaches during 2002 and 2003 and identified smooth hammerhead sharks as one of the species landed in this fishery. Insufficient data prevented any further analysis.

Regional Fishery Management Organization (RFMO) Information

Similarly, fisheries information and catch data for the entire Atlantic region from ICCAT also depict a species that is not regularly caught by industrial fishing vessels operating throughout this entire region. ICCAT is the RFMO responsible for the conservation of tunas and tuna-like species in the Atlantic Ocean and adjacent seas. Since 2004, Contracting Parties, Cooperating non-Contracting Parties, Entities or Fishing Entities (CPCs) fishing in the ICCAT convention area (which covers all waters of the Atlantic as well as adjacent Seas, including the Mediterranean) are required to annually report data for catches of sharks, including available historical data. The reported catches of smooth hammerheads from ICCAT vessels since 1987 are shown in Figure 22.

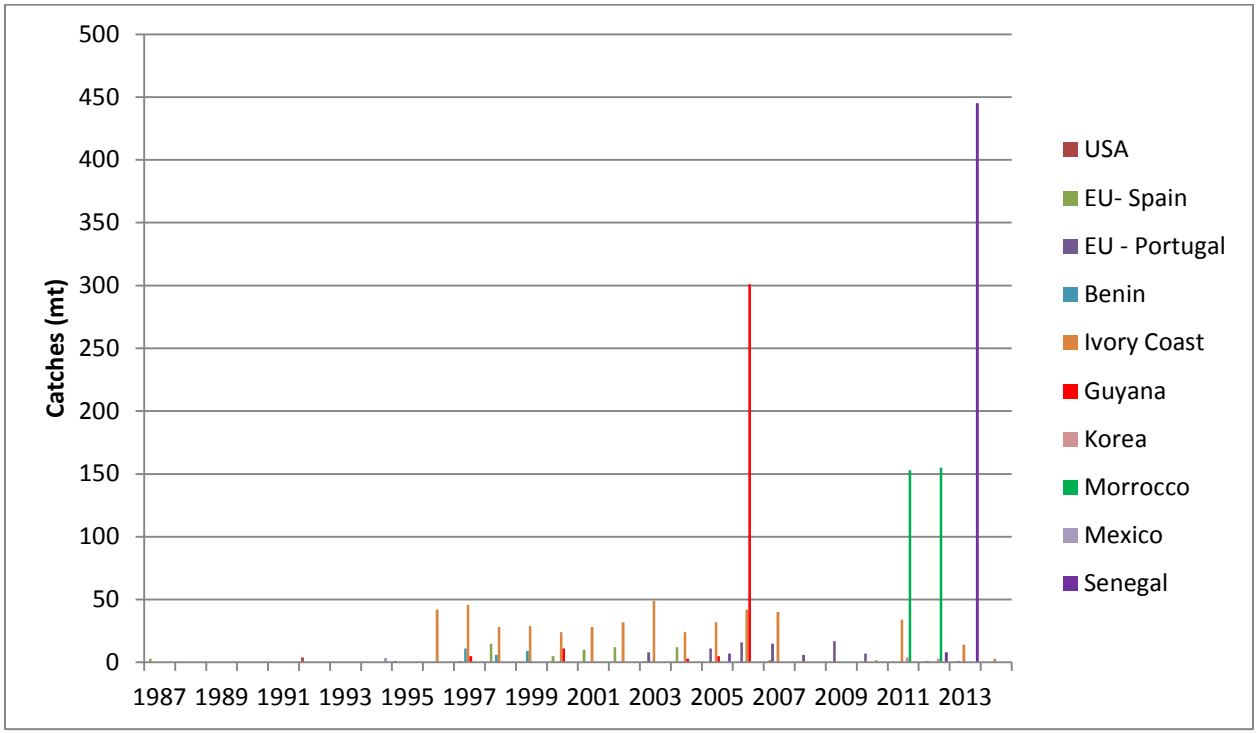


Figure 22. Nominal catches (mt) of *S. zygaena* reported to ICCAT by CPC vessel flag from 1987-2013. (Source: ICCAT nominal catch information: Task I web-based application, accessed March 2016)

Smooth hammerhead sharks are taken in the ICCAT convention area by longlines, purse seine nets, gillnets, and handlines, with around 44% of the total catch from 1987-2014 caught by drift gillnet gear, followed by 23% caught by longlines. In total, approximately 1,746 mt of smooth hammerhead catches were reported to ICCAT from 1987-2014 (Figure 22). The peaks in catches in 2006 and in the last three years of the dataset are attributed to specific country's reporting of catches. In 2006, fleets flying under the Guyana flag reported 301 mt of smooth hammerhead sharks captured in drift gillnet gear. Prior to 2006, the total from Guyana vessels ranged only from 3 to 11 mt, and after 2006, no other catches were reported. Similarly, vessels flying under Moroccan flags reported around 150 mt of smooth hammerheads in 2011 and 2012 but no catches prior to these years. In 2013, vessels under the Senegal flag reported a peak high of 445 mt of smooth hammerhead sharks, with only two years prior to this of captures (7 mt in 2005 and 8 mt in 2012). Given the uncertainties with catch reporting, including the common practice of lumping hammerhead sharks together, misidentification of hammerhead species, and irregular reporting practices, it is difficult to draw any conclusions regarding trends in catches of smooth hammerhead sharks from the available ICCAT data.

In 2010, ICCAT adopted recommendation 10-08 prohibiting the retention onboard, transshipment, landing, storing, selling, or offering for sale any part or whole carcass of hammerhead sharks of the family Sphyrnidae (except for *Sphyrna tiburo*) taken in the Convention area in association with ICCAT fisheries. However, there is an exception for developing coastal nations for local consumption as long as hammerheads do not enter into international trade. This exception may explain the larger reported catches from vessels flying under the flags of Morocco and Senegal after 2010, and why the majority of reported captures are from the eastern Atlantic Ocean (Figure 23).

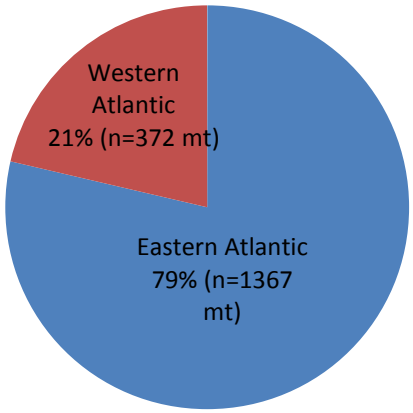


Figure 23. Nominal catches (mt) of *S. zygaena* from 1987-2013 reported to ICCAT and broken out by regional proportion (Source: ICCAT nominal catch information: Task I web-based application, accessed March 2016)

Analysis of more reliable observer data from ICCAT fishing vessels show that, in general, smooth hammerhead catches appear to be fairly minimal in the industrial fisheries operating throughout the Atlantic. For example, data from French and Spanish observer programs, collected over the period of 2003-2007, show that smooth hammerhead sharks represented 3.5% of the shark bycatch (in numbers) in the European purse seine fishery (Amandè et al. 2010). This fishery primarily operates in latitudes between 20°N and 20°S and longitudes from 35°W to the African coast. In total, only 12 smooth hammerhead sharks were caught on the 27 observed trips which corresponded to 598 sets. The observer coverage rate averaged 2.9% of the total number of trips over the sampling period, increasing from 1.5% in 2003 to 6.5% in 2007 (Amandè et al. 2010).

In the tropical Atlantic Ocean, Chinese fishery observers onboard two Chinese tuna longline vessels collected shark bycatch data from December 2007 to April 2008. The longliners were targeting bigeye tuna in the high seas of the tropical Atlantic Ocean (Figure 24). In total, 90 fishing days (sets) were observed and

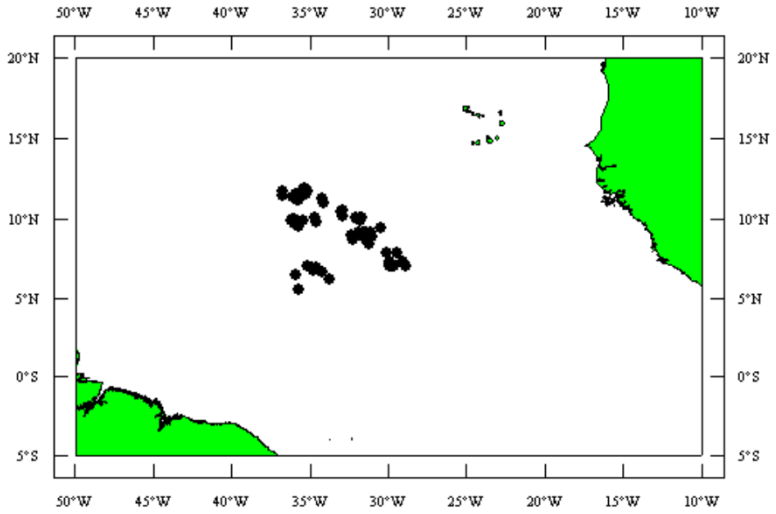


Figure 24. Locations of observed Chinese longline shark bycatch (Source: Dai et al. 2009)

226,848 hooks deployed, with an average of 2,520 hooks per set (Dai et al. 2009). Eight shark species were caught, with the blue shark being the most common in the landings (n=308 individuals) and the bigeye sand tiger being the least common (n=1 individual). Only 7 smooth hammerhead sharks were observed during the study period (making it the second least commonly encountered shark), comprising 3% of the shark bycatch by weight and 1.1% by number. The average CPUE of *S. zygaena* was 0.031 (number of sharks/1000 hooks) and ranged from 0 (sharks/1000 hooks) to 0.147 (sharks/1000 hooks), with the highest CPUE reported in December.

The Japanese Observer program also collected data from tuna longliners operating throughout the Atlantic Ocean. Two recent studies provide information on the species composition of the catch and bycatch from these tuna longline fleets. Based on observer data collected from 1995-2000, Matsushita and Matsunaga (2002) found that shark species comprise 20-80% of the bycatch depending on the fishing area within the Atlantic. The observers specifically collected data from 20 trips, covering 886 fishing operations and 2,026,049 deployed hooks throughout five areas in the Atlantic (Figure 25).

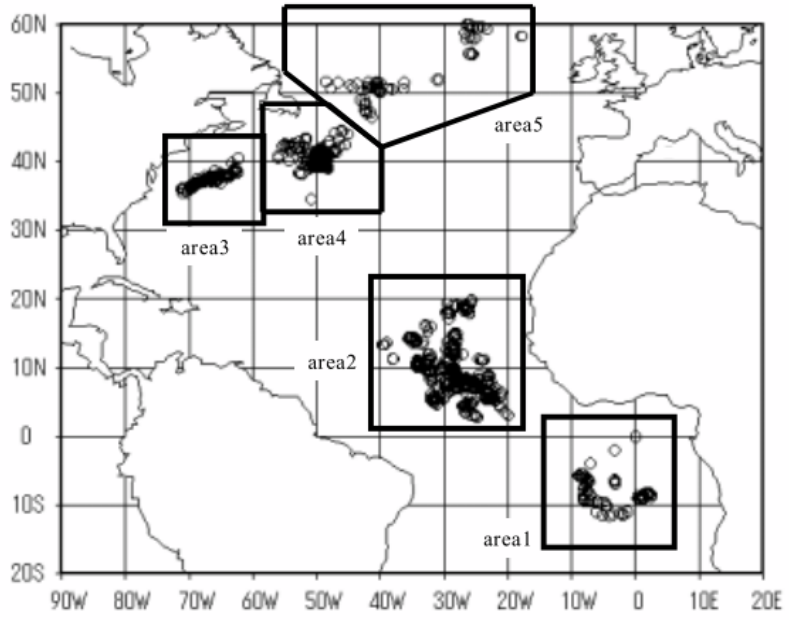


Figure 25. Locations of observed Japanese tuna longline operations in the Atlantic Ocean from 1995 to 2000 (Source: Matsushita and Matsunaga 2002)

In total, 9,921 sharks were observed, with most caught in the north Atlantic (Area 4 on Figure 25); however, the authors note that these results were mainly driven by the significant amount of blue shark catches during the study period (n=6,519 blue sharks). The tropical Atlantic (Area 2 on Figure 25) had the second highest capture of sharks, and with the exception of one individual, all of the smooth hammerhead sharks were caught in this area. However, in terms of actual numbers and composition in the bycatch, smooth hammerhead sharks were a very minor component, with a total of only 22 sharks caught over the 5-year study, comprising 1.4% (by number) of the shark bycatch in the tropical Atlantic and 0.2% of the total shark bycatch overall (covering all areas).

Using observer data collected a year later, from September 2001 to March 2002, Matsumoto et al. (2003) reported similar findings with regards to smooth hammerhead sharks. Over the course of 6 months, 7 cruises (310 fishing days) were monitored covering fishing activities from 5 vessels operating in the temperate North Atlantic (off Iceland, Newfoundland Island, Grand Bank, and east of Bermuda), and 2 vessels operating in the equatorial and tropical eastern Atlantic (off Dakar, Abidjan, and Angola) (Matsumoto et al. 2003; Figure 26). The observers recorded a total of 8,629 fish covering 51 species. Similar to the Matsushita and Matsunaga (2002) observations, smooth

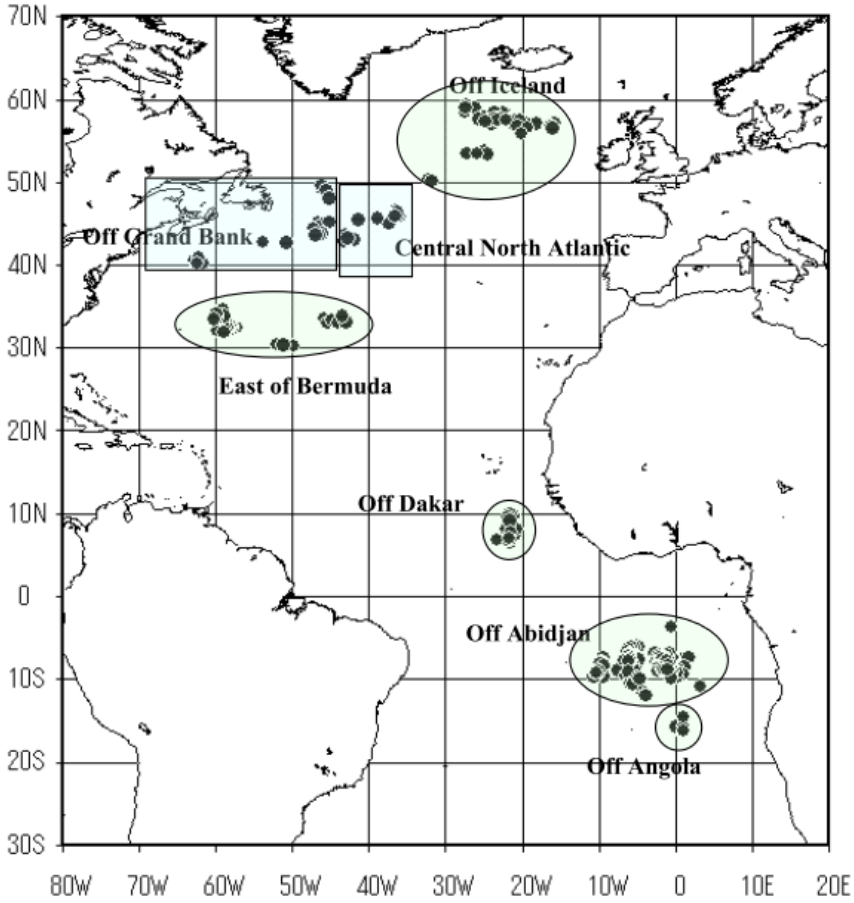


Figure 26. Locations of observed Japanese tuna longline operations in the Atlantic Ocean from 2001 to 2002 (Source: Matsumoto et al. 2003)

hammerheads were only present in the tropical eastern Atlantic, in the catches off Dakar and Abidjan, and in low amounts, comprising only a very small percentage of the catch. Off Dakar, observers recorded 1,924 fish of which only 2 (or 0.1%) were smooth hammerhead sharks, and off Abidjan, 3,115 fish were caught, with only 4 (0.1%) being smooth hammerhead sharks. Of the 6 observed smooth hammerhead sharks, 5 were already dead when pulled on to the boat (Matsumoto et al. 2003).

Observers aboard Portuguese longline fishing vessels collected more recent data from 834 longline sets (1,078,200 deployed hooks) targeting swordfish and conducted between August 2008 and December 2011 (Coelho et al. 2012). Similar to the previously discussed longline fishing vessels, the Portuguese longliners also operate across the entire Atlantic (Figure 27). A total of 36,067 elasmobranchs were recorded over the course of the 3-year study, of which 372 (or roughly 1%) were smooth hammerhead sharks.

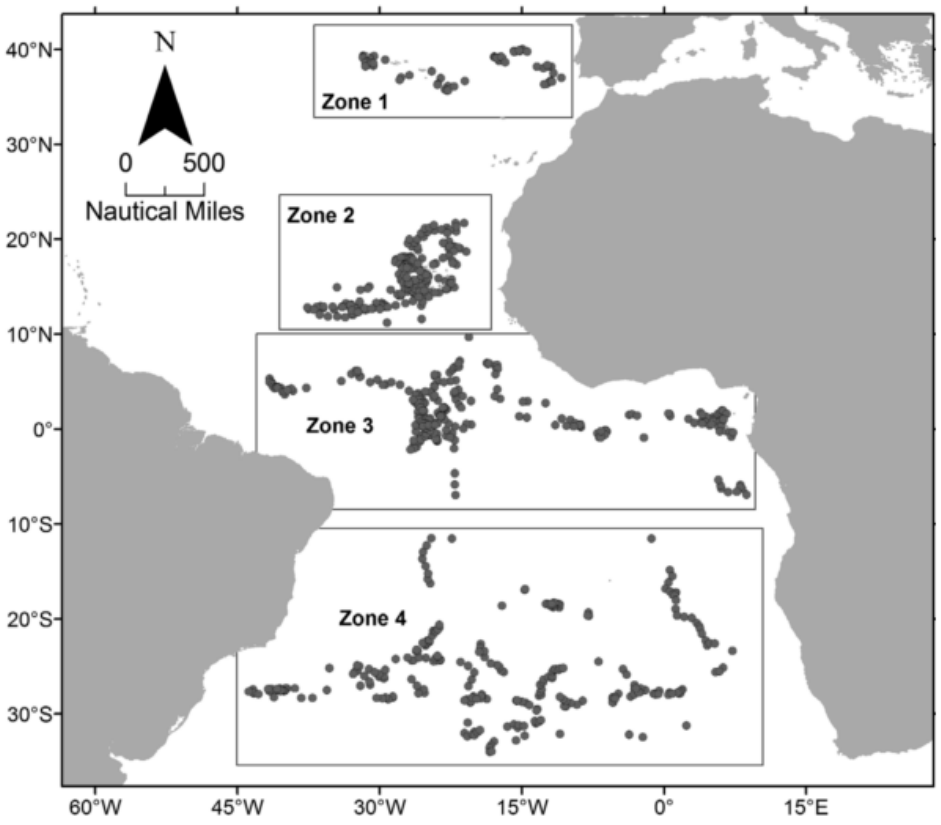


Figure 27. Locations of observed Portuguese longline operations in the Atlantic Ocean from 2008 to 2011 (Source: Coelho et al. 2012)

Perhaps not surprising, given the above data on ICCAT longline catches, Cortés et al. (2012) conducted an Ecological Risk Assessment and concluded that smooth hammerheads were one of the least vulnerable stocks to overfishing by the ICCAT pelagic longline fisheries. Ecological Risk Assessments are popular modeling tools that take into account a stock's biological productivity (evaluated based on life history characteristics) and susceptibility to a fishery (evaluated based on availability of the species within the fishery's area of operation, encounterability, post capture mortality and selectivity of the gear) in order to determine its overall vulnerability to overexploitation (Cortés et al. 2012; Kiszka 2012). Productivity and susceptibility scores are normally plotted on an x-y scatter plot, and an overall vulnerability or risk score is calculated as the Euclidean distance from the origin of x-y scatter plot. For example, a species with low productivity and high susceptibility would be at a high risk to overexploitation by the fishery. In this way, vulnerability scores can be ranked and compared between species. Ecological Risk Assessment models are useful because they can be conducted on a qualitative, semi-quantitative, or quantitative level, depending on the type of data available for input.

Results from the Cortés et al. (2012) Ecological Risk Assessment, which used observer information collected from a number of ICCAT fleets, indicate that smooth hammerheads face a relatively low risk in ICCAT fisheries (signified by numerically high "vulnerability" scores). Out of the 20 assessed shark stocks, smooth hammerheads ranked 11th in terms of their susceptibility (S) to pelagic longline fisheries in the Atlantic Ocean (lower ranks indicate higher risk). The population's estimated productivity (P) value ($r = 0.225$) ranked 17th, making it one of the most productive species assessed. The authors then calculated overall vulnerability (v) scores using three methods: the Euclidean distance, a multiplicative index (defined as $v=P(1-S)$), and the arithmetic mean of the productivity and susceptibility ranks. Using the Euclidean distance method, smooth hammerheads ranked 13th in terms of their overall vulnerability to the PLL fisheries in the Atlantic Ocean. For the other two methods, the vulnerability rankings were even higher ($v = 17$ using multiplicative index; $v = 18$ using arithmetic mean), indicating lower risk to PLL fisheries.

Atlantic & Mediterranean Region – Summary

While the species' schooling behavior and surface swimming suggest an increased susceptibility to fisheries operating throughout this portion of their range, with the exception of the Mediterranean, this does not appear to be the case. Where species-specific data is available, the regional and local information above indicates that smooth hammerhead sharks tend to be a rare occurrence, observed (for the most part) only sporadically in the fisheries data and in low numbers.

In the northwestern Atlantic, data from preliminary stock assessments suggest a depleted but potentially stable population, with a high degree of uncertainty regarding the decline in abundance. Additionally, existing regulatory measures appear adequate in protecting *S. zygaena* from overutilization in this portion of its range. In the central and southwest Atlantic, species-specific data is severely lacking. Based on the estimated proportions of smooth hammerheads in the combined hammerhead catch, many of the trends identified in this part of the region can likely be attributed to the more abundant scalloped hammerhead shark. Generally, smooth hammerhead sharks tend to be harvested at low levels (and comprising less than 5% of the fisheries catch), with no species-specific information to suggest that overutilization is a significant threat presently contributing to the species' risk of extinction in this region.

The data from the Mediterranean provide evidence of the sensitivity of the smooth hammerhead shark to exploitation, with the Mediterranean population declining almost to the point of extirpation due to historical overutilization of the species. Fishing pressure remains high in this portion of the species' range, and, despite the implementation of regulations prohibiting the catch of the species in association with ICCAT/GFCM fisheries, smooth hammerhead sharks may still be incidentally caught during normal fishing operations, which will likely result in additional fishing mortality and continued declines in the population. However, the Mediterranean comprises only a small portion of the species' range and it is currently unknown whether the species conducts trans-Atlantic migrations from the Mediterranean to other portions of the species' range. As such, the impact of the present status of the species within the Mediterranean on the species' overall extinction risk is highly uncertain. Furthermore,

given the lack of trends or evidence of significant declines elsewhere in the Atlantic, with data suggesting some stability of local populations, the available data does not indicate that the depletion of the Mediterranean population has significantly affected other *S. zygaena* populations.

In the eastern Atlantic, smooth hammerhead sharks are caught in low numbers (particularly in comparison to other hammerhead species as well as sharks in general) and are only observed sporadically in both the historical and more recent fisheries-dependent and independent data and surveys. Potentially, the species' less frequent occurrence in the survey and catch data may be a result of their seasonal presence, particularly off western Africa, showing up only after summer water temperatures have cooled (Cadenat and Blanchard 1981). Regardless, at present, there is no substantial evidence to indicate that smooth hammerhead shark populations off the eastern or southeastern Atlantic are declining to such an extent that would suggest depensatory processes may be at work and indicating overutilization as a threat. While the available information does suggest that primarily juveniles of the species are caught in this region, the limited data does not allow for conclusions to be drawn regarding the level of utilization of the species or if this level is a threat significantly contributing to its extinction risk.

Overall, the best available data from the Atlantic region suggest that while smooth hammerhead sharks are caught as both targeted catch and bycatch, and then marketed for both their fins and meat, the present level of utilization, based on available catch and trend data, does not appear to be a threat significantly contributing to the species' risk of extinction.

Indian Ocean

In the Indian Ocean, smooth hammerhead sharks have historically been and continue to be caught as bycatch in pelagic longline tuna and swordfish fisheries and gillnet fisheries, and may also be targeted by semi-industrial, artisanal and recreational fisheries; however, fisheries data, particularly species-specific information, are severely lacking. No quantitative stock assessments exist for the smooth hammerhead shark

throughout the entire Indian Ocean, and thus the status is highly uncertain. For shark populations, in general, de Young (2006) characterizes their status within the Indian Ocean, off the coasts of Egypt, India, Iran, Oman, Saudi Arabia, Sudan, United Arab Emirates, and Yemen as currently unknown, and general shark populations off the coasts of the Maldives, Kenya, Mauritius, Seychelles, South Africa, and United Republic of Tanzania are presumed to be fully to over-exploited. Presently, there are very few studies that have examined the status of or collected data specifically on smooth hammerhead sharks in the Indian Ocean, making it difficult to determine the level of exploitation of this species within the ocean basin.

In the western Indian Ocean, where artisanal fisheries are highly active, studies conducted in waters off Madagascar and Kenya provide some data on the catch and use of smooth hammerheads from this region. However, for the most part, many of the fisheries operating throughout this region are poorly monitored, with catches largely undocumented and underestimated. For example, in southwest Madagascar, McVean et al. (2006) investigated the directed shark fisheries of two villages over the course of 10 and 13 months, respectively, and found that the scale of these fisheries was "largely unexpected." These fisheries, described as "traditional fisheries" (i.e., fishing conducted on foot or in non-motorized vessels), used both surface-set longlines and also gillnets to catch sharks. Sharks are processed immediately after landing, with valuable fins exported to the Far East at high prices and shark meat sold locally. Out of the examined 1,164 catch records, hammerhead sharks (*Sphyrna* spp.; fishermen did not differentiate between species) were the most commonly caught shark (n=340), comprising 29% of the total sharks caught and 24% of the total wet weight. Overall, the fisheries landed 123 mt of sharks, which was significantly higher than the previous annual estimate of 500 kg per km of Madagascar coastline. The data also provided evidence of declines in both the numbers of sharks landed and size (McVean et al. 2006). Due to the high economic returns associated with shark fishing in Madagascar, the authors predicted that these fisheries will likely continue despite the potential risks of resource depletion. However, without more accurate species-specific data, the effect of this level of exploitation, particularly on smooth hammerhead sharks, remains uncertain. In fact, in other areas of Madagascar, studies examining the artisanal and shark fisheries, including the genetic

testing of fins from these fisheries, report hammerhead catches that consist mainly of scalloped hammerhead sharks and, to a lesser degree, great hammerhead sharks, but no smooth hammerhead sharks (Doukakis et al. 2011; Robinson and Sauer 2011). In other words, smooth hammerhead sharks may not even occur in these waters and, therefore, would not face fishing pressure by these fisheries. Conversely, as these studies were conducted off the northern and eastern coasts of Madagascar, it could be that smooth hammerheads occur only on its western coast; however, again, without more reliable data, the effect of these fisheries on the population dynamics of the smooth hammerhead shark in the Indian Ocean is highly uncertain.

Similar to the McVean et al. (2006) study, Kyalo and Stephen (2013) analyzed data from various landing sites along the coast of Kenya, as well as observer data from commercial and scientific trawl surveys, to examine the extent of shark catch in Kenya's artisanal tuna fisheries and semi-industrial prawn trawls. In Kenya, sharks are primarily caught as bycatch, with the meat consumed locally and fins exported to Far East countries (including Hong Kong and China). Based on data collected over a 1-year period (July 2012-July 2013), hammerhead sharks (*S. lewini* and *S. zygaena*) comprised 58.3% of the shark catch in the semi-industrial prawn trawl fisheries. Smooth hammerheads, alone, made up 27% of the sharks (n=69), with a catch rate estimated at 2 kg/hour. Additionally, all of the smooth hammerheads caught were neonates, with the vast majority within the estimated size at birth range, indicating that the fishing grounds likely also serve as parturition and nursery grounds for the species. While it is particularly concerning that the Kenyan semi-industrial trawl fisheries are harvesting juvenile smooth hammerhead sharks, the degree to which this harvest is impacting recruitment of *S. zygaena* to the population is unknown. However, the authors do note that the general catch trend of elasmobranchs in Kenya has exhibited a declining trend since 1984, and suggest additional research is needed to determine current harvest rates and sustainable catch and effort levels.

While range maps place smooth hammerhead sharks within the Persian Gulf (see IUCN 2005; Figure 3), there is no available information on the abundance or magnitude of catches of *S. zygaena* within this body of water. In the waters of the United Arab

Emirates (UAE), hammerhead sharks are noted as generally "common" and are currently protected from being retained or landed. However, while the UAE prohibits the export of hammerheads caught in UAE waters, it still allows for the re-export of these sharks caught elsewhere (such as in Oman, Yemen, and Somalia) (Todorova 2014). In fact, in the past decade, the UAE has emerged as an important regional export hub for these countries in terms of the international shark fin trade, exporting up to 500 mt of dried raw fins annually to Hong Kong. Yet, information on the species traded and quantities involved is limited. Based on data collected from 2010-2012 at the Deira fish market (the only auction site in UAE for sharks destined for international trade), hammerheads were the second most represented family in the trade (at 9.3%) behind *Carcharinidae* sharks (which represented 74.9% of the species) (Jabado et al. 2015). A total of 12,069 individuals were recorded at the fish market, with the majority of sharks originating from Oman (Jabado et al. 2015). Around half (6,751) were identified to species, with 186 identified as *S. zygaena* caught in Oman waters (Jabado et al. 2015). Thus, while the UAE affords protections to hammerhead within its own waters, its re-export business continues to drive the demand for the species throughout the region. However, while UAE traders confirmed that fins from hammerheads are highly valued, they also noted that the general trend in recent years has been a decline in prices and profits due to a reduction in demand of fins in Hong Kong (see **Shark Fin Trade** section for more details) (Jabado et al. 2015). As such, this decrease in demand may translate to a decrease in fishing pressure on the species, but without any data on catch trends, fishing effort or the size of the *S. zygaena* population in this region, the impact of current or even future fishing mortality rates on the smooth hammerhead population remains unknown.

In the central Indian Ocean, data on smooth hammerhead utilization is available from the countries of Sri Lanka, India, and Indonesia. In Sri Lanka, shark meat, both fresh and dried, is used for human consumption as well as for a cheap animal feed source, while shark fins are exported to other countries (SL-NPOA-Sharks 2013). Historically, sharks were a significant component of the fish catch in Sri Lanka, accounting for more than 45% of the total large pelagic fish production until 1974 (SL-NPOA-Sharks 2013). With the rapid development of the marine fisheries sector in Sri Lanka and expansion of

the pelagic shark fishery into offshore areas beyond the exclusive economic zone (EEZ), shark catches steadily increased from the 1950s. Shark catches reached high levels in the 1980s, coinciding with demand for shark products in the international market, and peaked in 1999 at 34,842 mt (SL-NPOA-Sharks 2013). However, since 1999, annual shark catches have exhibited a significant decline, down to a low of 1,611 t in 2014 (Jayathilaka and Maldeniya 2015). According to Jayathilaka and Maldeniya (2015), the decline in annual shark production, particularly over the past few years, can be mainly attributed to the implementation and enforcement of new regulations on sharks and, specifically, conservation provisions for thresher sharks (which were one of the more dominant species in the shark catches). The authors further go on to state that the declining price of shark fins has also influenced fishermen to shift to export-oriented tuna fisheries. In 2014, the annual pelagic shark bycatch was less than 2% of weight of the total large pelagic catch for the country.

When the data is broken out by shark species, hammerheads have and continue to comprise a small proportion of the catch. Based on landings data over the past decade (and similarly reported in historical catches), silky sharks tend to dominate the shark catch, followed by blue sharks, thresher sharks (until their prohibition in 2012), and oceanic whitetip sharks. In fact, in 2014, around 88% of the shark catch comprised silky sharks, blue sharks, and oceanic white tip sharks (*Carcharhinus longimanus*) (Jayathilaka and Maldeniya 2015). As such, the historical catch trends in the shark data likely reflect trends in the catches of these particular species. Additionally, available landings data for all hammerhead species from 2005-2014 showed no clear trend (Figures 28 and 29; SL-NPOA-Sharks 2013; Jayathilaka and Maldeniya 2015). In 2014, *S. zygaena* comprised around only 1% of the retained shark bycatch in Sri Lanka, with a total of 18 mt caught (7 mt by gillnet within EEZ and 11 mt by longline outside of EEZ; (Hewapathirana et al. 2015; Jayathilaka and Maldeniya 2015). While sharks have generally declined in Sri Lankan waters due to historical overutilization, there is no information to indicate that present catch levels of *S. zygaena* are a significant threat to the species in this portion of its range.

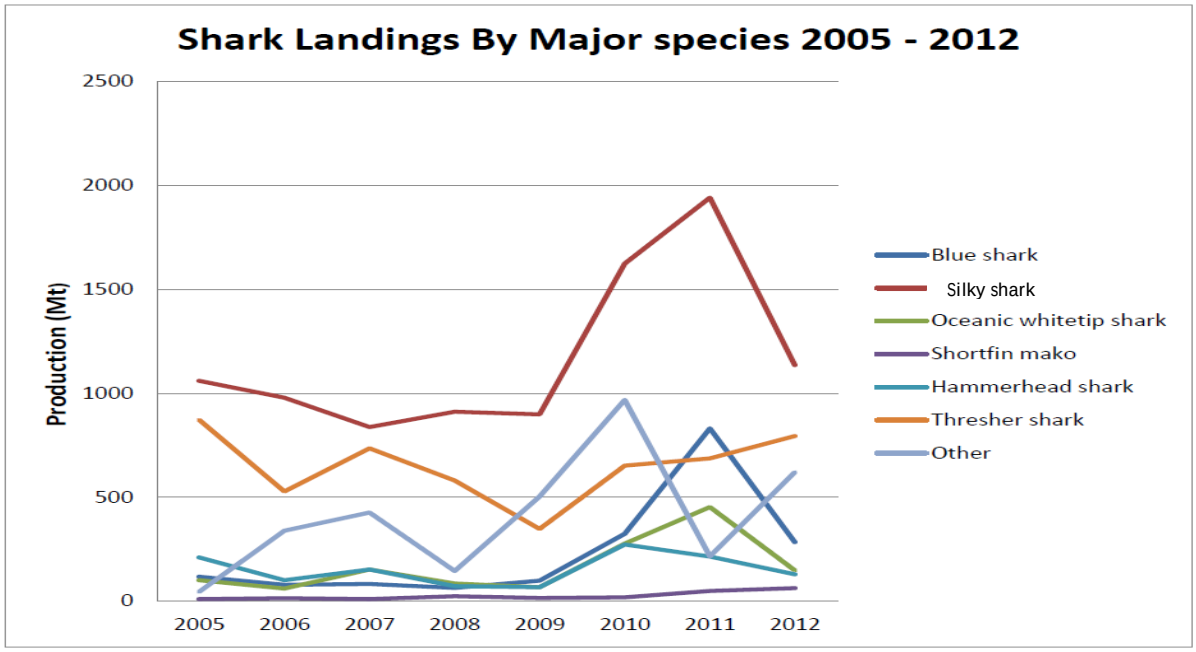


Figure 28. Sri Lanka shark landings (in mt) by major species from 2005-2012 (Source: SL-NPOA-Sharks 2013)

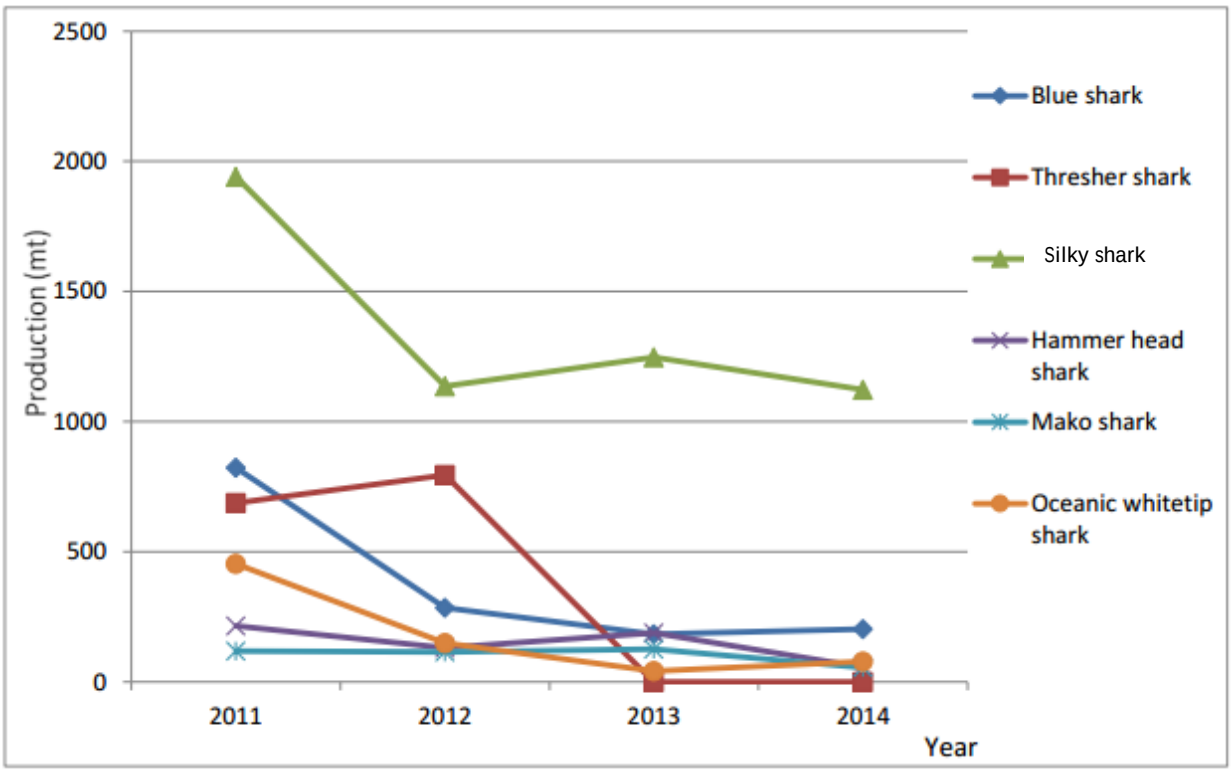


Figure 29. Sri Lanka shark landings (in mt) by major species from 2011-2014 (Source: Jayathilaka and Maldeniya 2015)

Similarly, in Indian waters, available longline survey data collected from within the EEZ show that smooth hammerheads tend to comprise a small portion of the shark bycatch (0.5-5%) (Varghese et al. 2007; John and Varghese 2009). These estimates are based off of data obtained from six tuna longline survey vessels operating within three areas of the Indian EEZ: west coast waters, east coast waters, and Adaman and Nicobar waters. A total of 3.092 million hooks were deployed during the survey period (1984-2006), with sharks comprising 45-50% of the fish catch. Over the course of the study, CPUE of all sharks (combined) showed a clear decline in all three regions. The declines were especially alarming in the west coast and east coast waters where the average hooking rate decreased to less than 0.1% during the last five years of the survey. In the Andaman and Nicobar region, where catch of *S. zygaena* is more prevalent, total shark CPUE declined sharply (approximately 81%) from peak CPUE in years 1992-1993 to years 1996-1997. Although the catch proportions reported for smooth hammerhead sharks in the study were minimal (1% west coast waters; 0.6% in east coast waters; 5% in Andaman & Nicobar), these estimates were based on data from after the reported decline in CPUE. However, since the declines, CPUE of sharks has remained low but relatively stable, particularly in Andaman and Nicobar waters, although the time series ends in 2005. Recent CPUE data specifically for smooth hammerhead sharks is unavailable. Although India is considered to be one of the top shark-fishing nations, smooth hammerhead sharks, in particular, are not considered to be a species of interest (based on 2008-2013 IOTC data holdings) (Clarke and IOTC Secretariat 2014).

Indonesia is considered to be the largest shark-catching country in the world. In 2007, total elasmobranch catch in Indonesia was estimated at more than 110,000 tonnes (Camhi et al. 2009), with this harvest representing the largest ever recorded in the world (Tull 2009). This level of catch has likely caused declines in abundance for many shark species; however, the impact on specifically smooth hammerhead shark populations is unclear. In fact, the available landings and observer data suggest that *S. zygaena* distribution is not likely concentrated within Indonesian fishing areas. For example, in an analysis of data collected from Indonesian tuna longline fishing vessels from 2005-2013 (Figure 30), scientific observers recorded only 6 smooth hammerheads over the 9 years of data (covering 94 trips, 2,268 operations, and 3,264,588 hooks). A

total of 3,421 sharks were caught, with smooth hammerheads representing only 0.18% of the total catch, and unidentified Sphyrnids representing not a great deal more, at only 0.38% (Novianto et al. 2014).

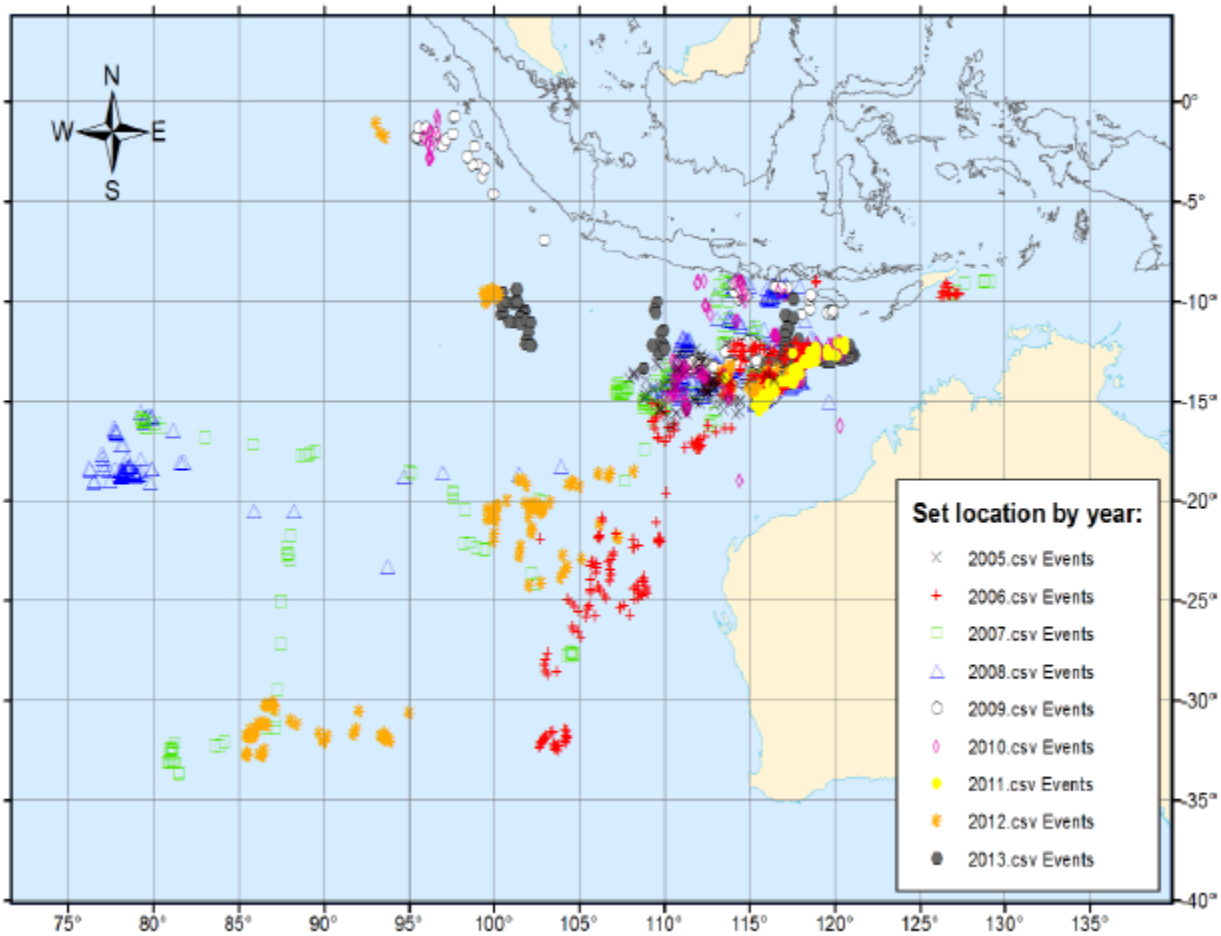


Figure 30. Locations of observed Indonesian tuna longline operations in the Indian Ocean during 2005-2013 (Source: Novianto et al. 2014)

In another study, data were collected and analyzed from numerous fish markets and landing sites throughout Indonesia from 2001-2005, including Central Java, Bali, Jakarta, West Java, and Lombok. This study revealed that *Sphryna* spp. are among the most commonly taken shark species as bycatch; however, when identified to species, only *S. lewini* was detected within the landings data (Blaber et al. 2009). White et al. (2008) also visited a number of fish landing sites in Indonesia between 2001 and 2006, and found that out of the 21,651 recorded sharks, only 0.1% were smooth hammerheads whereas scalloped hammerhead sharks comprised 3.3%. Similarly, a study that used

DNA barcoding to identify shark fins from numerous traditional fish markets and shark-fin exporters across Indonesia (from mid-2012 to mid-2014) found a relatively high frequency of scalloped hammerhead sharks in the data (10.48% of fins; 2nd most common shark), whereas *S. zygaena*, while present in the fish markets, comprised only 1.03% of the fins (n=6 fins) (Sembiring et al. 2015). These results are not that surprising given the more temperate distribution of the smooth hammerhead shark compared to the tropical scalloped hammerhead. However, it also speaks to the threat of overutilization in that the largest shark-catching country in the world appears to primarily target sharks in tropical waters, so the smooth hammerhead sharks may be provided some protection from these intensive fisheries due to its more temperate distribution.

This likely distribution of smooth hammerhead sharks is further supported by its absence in fisheries data from Australia's northern fisheries within Australia's EEZ waters that border Indonesia's EEZ. In a study that examined the fishing impact of Australia's northern prawn fishery on elasmobranch bycatch species, smooth hammerhead sharks were not present in the survey data. The sampling was extensive, conducted from 1979 to 2003 and throughout northern Australian's EEZ, including inshore areas where immature smooth hammerheads would likely be expected (Figure 31) (Zhou and Griffiths 2008).

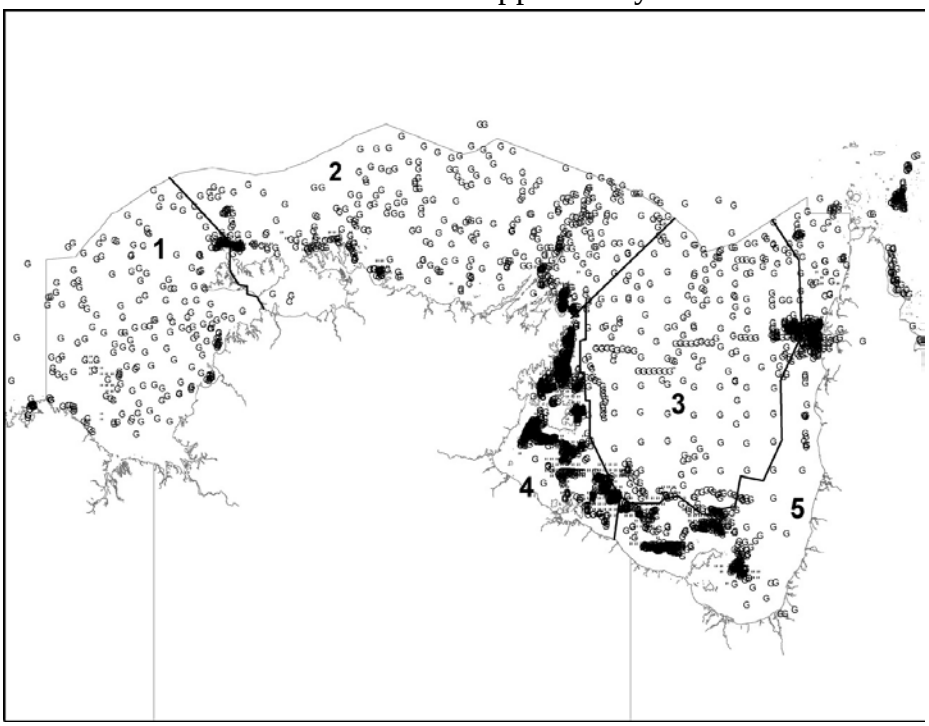


Figure 31. Locations of samples taken in scientific surveys in Australia's northern prawn fishery from 1979-2003 (Source: Zhou and Griffiths 2008)

Similarly, based on 2002-2007 observer data from Australia's Northern Territory Offshore Net and Line (NTONL) fishery, which targets black-tip sharks and grey mackerels and operates off the coastline of Australia's Northern Territory, smooth hammerhead sharks were absent in the catch. Additionally, although there have been reports of a number of illegal, unregulated, and unreported (IUU) vessels targeting sharks in the northern Australian EEZ over the past decade, mainly from Indonesia, based on the identification of shark fins confiscated from these IUU vessels, none can be attributed to *S. zygaena* (Lack and Sant 2008; Field et al. 2009).

Smooth hammerhead sharks do, however, occur in waters off northwest and western Australia, but very little information on the level of utilization of the species or impact on the population is available. In northwest Australia, hammerhead sharks were historically caught in the "northern shark fisheries," which comprised the state-managed Western Australia North Coast Shark Fishery (WANCSF) in the Pilbara and western Kimberley areas, and the Joint Authority Northern Shark Fishery (JANSF) in eastern Kimberly. The CPUE data from these fisheries indicated potential declines of 58-76% in hammerhead abundance between 1996 and 2005; however, species-specific information was unavailable (Heupel and McAuley 2007; McAuley and Rowland 2012). Additionally, since 2009, these fisheries have not been in operation, and as such, no longer pose a threat of overutilization to those hammerhead species.

Because of the more temperate distribution of the smooth hammerhead shark, the majority of *S. zygaena* catches in Australian waters are actually attributed to the Western Australian temperate gillnet and longline fisheries, which operate in continental shelf waters along the southern and lower west coasts (Figure 32). The main commercial shark species targeted in these fisheries are gummy sharks (*Mustelus antarcticus*), dusky sharks (*Carcharhinus obscurus*), whiskery sharks (*Furgaleus macki*) and sandbar sharks (*Carcharhinus plumbeus*). Smooth hammerhead sharks are considered to be a bycatch species and tend to comprise over 98% of the hammerhead catch from this fishery (Australian Government 2014; Commonwealth of Australia 2015). A recent multi-fisheries bycatch assessment, which examined the sustainability of bycatch species in multiple fisheries, found smooth hammerhead sharks to be at a low to

moderate risk in this region, with the risk largely influenced by the species' biological profiles (vulnerable life history traits) as opposed to fishery impacts (Evans and Molony 2010). Between 1994 and 1999, McAuley and Simpfendorfer (2003) estimated that the average annual take of smooth hammerheads in the Western Australian temperate gillnet and longline fisheries was around 53 t. Based on recent catches of hammerheads (Table 3) harvest levels have increased slightly since the 1990s, but have remained fairly stable over the past 4 years.

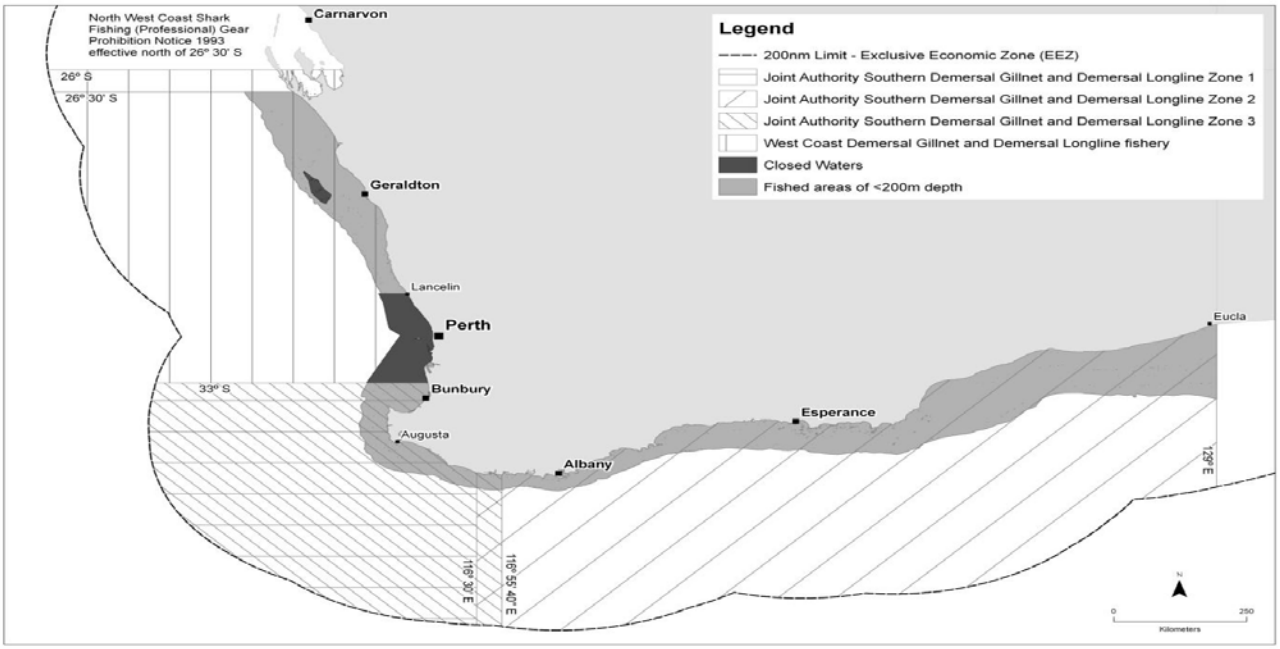


Figure 32. Management boundaries of the Western Australian Temperate Demersal Gillnet and Demersal Longline Fisheries (Source: Government of Western Australia (2015))

Table 3. Hammerhead shark catch in the Western Australian Temperate Demersal Gillnet and Demersal Longline Fisheries from 2009-2013 (Source: Commonwealth of Australia 2015)

Year	South coast bioregion (t)	West coast bioregion (t)	Total (t)
2009/10	54.7	16.3	**71.0**
2010/11	42.6	25.0	**67.6**
2011/12	39.2	20.8	**60.0**
2012/13	42.9	17.0	**59.9**

These harvest levels are considered to be within the recommended sustainable take for the species, which has been estimated at around 70 t per year (Australian Government 2014). The increasing CPUE trend specifically for hammerhead sharks in this fishery also suggests that abundance has not declined over time (Figure 33). As such, the ongoing harvest of the species by the Western Australian temperate gillnet fisheries is not considered to be a significant threat to the species.

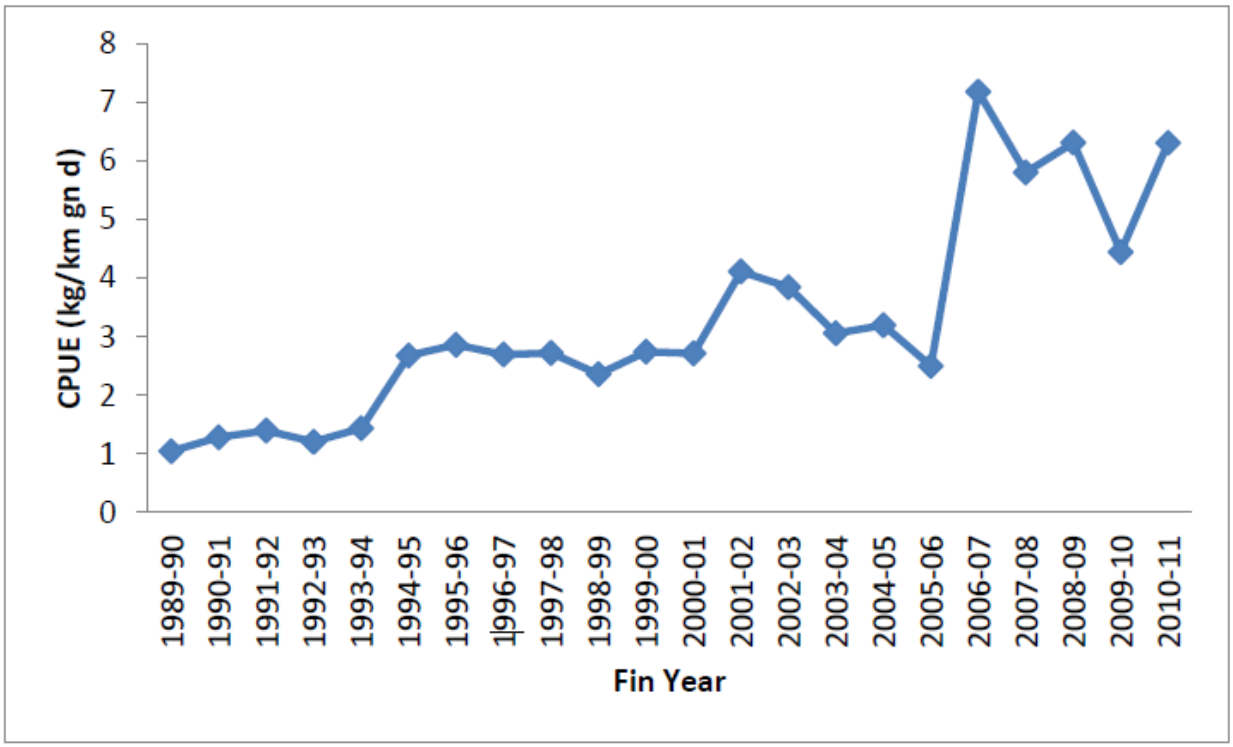


Figure 33. Catch per unit effort (in kg per kilometer gillnet days) of hammerheads (>99% likely *S. zygaena*) in the Western Australian Temperate Demersal Gillnet and Demersal Longline Fisheries from 1989 – 2011 (Source: Simpfendorfer 2014)

Furthermore, total gillnet effort within the fisheries has been on a declining trend since the late 1980s. In fact, the estimated level of fishing effort in 2013-2014, which was around 165,000 gillnet h^{-1}, is only about one third of the peak level from 1988-1989 (495,000 km gillnet h^{-1}). Additionally, the data also show that effort on the west coast (i.e., WCGL) is now at low historical levels (Figure 34), which should also decrease the amount of smooth hammerhead bycatch in this fishery.

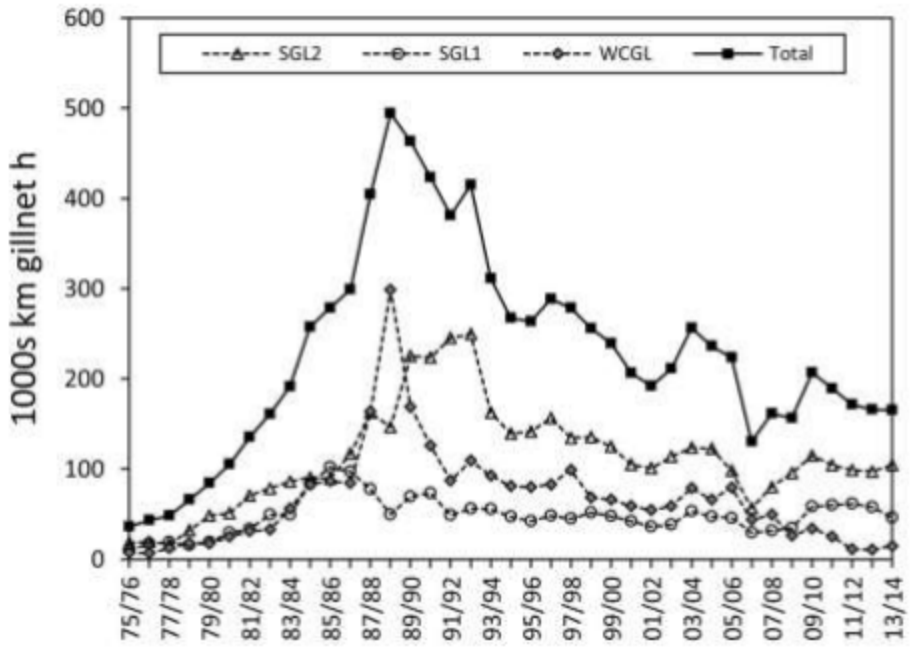


Figure 34. Fishing effort (1000s km gillnet h^{-1}) by the Western Australian Temperate Demersal Gillnet and Demersal Longline Fisheries between 1975-1976 and 2013-2014 (SGL1 and SGL2 = Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery in Zone 1 and 2, respectively. WCGL = West Coast Demersal Gillnet and Demersal Longline Interim Managed Fishery) (Source: Government of Western Australia 2015)

Although not as common, the smooth hammerhead shark is also occasionally caught in Australia's Western Tuna and Billfish Fishery, which operates throughout the Northern Territory, Western Australia, South Australia, and around Christmas Island and the Cocos (Keeling) Islands, using primarily longline gear (Figure 35). In a sustainability assessment of the fishery, Zhou et al. (2009) determined that the current fishing effort poses a low risk to many non-target species caught within this fishery, including smooth hammerhead sharks. In fact, the authors estimated that the instantaneous fishing mortality rate for *S. zygaena* during 2004-2007 (F = 0.01) was significantly lower than the rate that corresponds to maximum sustainable fishing mortality (F=0.12), indicating that the species was being fished at sustainable levels. The low mortality rate was due to a combination of low fishing efforts and minimal spatial overlap between these efforts and the species' distribution (Zhou et al. 2009).

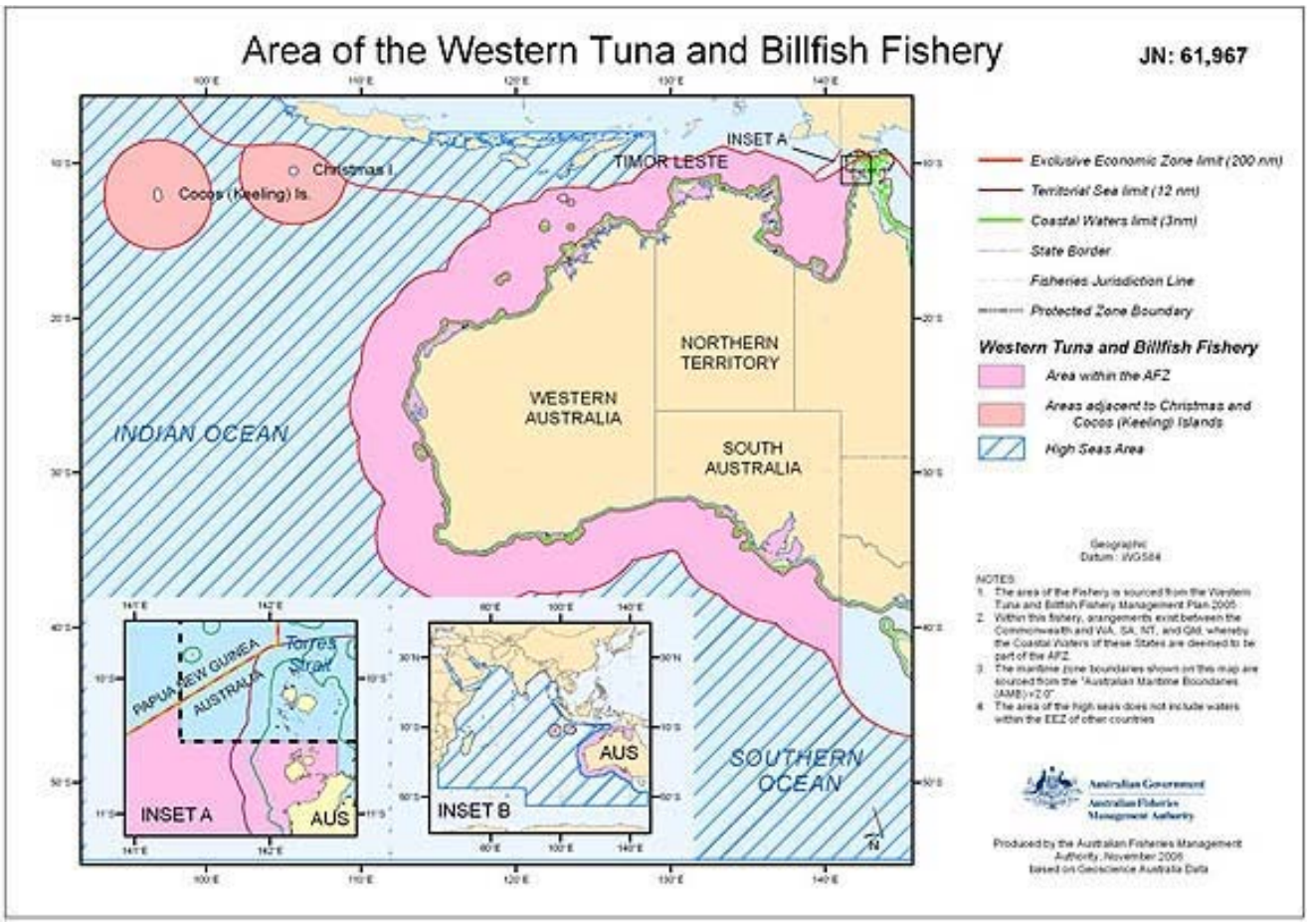


Figure 35. Area of operation (shaded in pink) of Australia's Western Tuna and Billfish Fishery (Source: Zhou et al. 2009)

RFMO Information

Fisheries information and catch data from the RFMO that operates throughout the Indian Ocean (the Indian Ocean Tuna Commission (IOTC)) also depict a species that is not regularly caught by industrial fishing vessels, nor does this RFMO consider the species to be a key "priority species" (i.e., those shark species whose status the IOTC is concerned about and have scheduled future stock assessments).

In terms of available catch data, the IOTC requires its CPCs to annually report hammerhead shark catch data in its convention area (see IOTC Resolutions 05/05, 11/04, 08/04, 10/03, 10/02); however, the current reported catches are thought to be incomplete and largely underestimated. In fact, Murua et al. (2013) estimated that, on average, the total amount (in mt) of sharks caught are around 7 times higher than the

average amount actually declared by species in the Indian Ocean. The IOTC acknowledges that catches of sharks are usually not reported. When catch statistics are provided, they may not represent the total catches of the species (including discards) but simply those sharks retained on board, with weights that likely refer to processed specimens (IOTC 2015b).

Based on the reported nominal catches from 1986–2014 in the IOTC public domain database, smooth hammerhead sharks appear to be caught mainly in the Eastern Indian Ocean (Figure 36b); however, these findings are strongly influenced by reported Sri Lanka catches, which comprise more than 80% of the smooth hammerhead catch data (Figure 36a). Artisanal fisheries are responsible for over 95% of the smooth hammerhead catches (Figure 36c), with the majority of sharks caught by gillnet (Figure 36d).

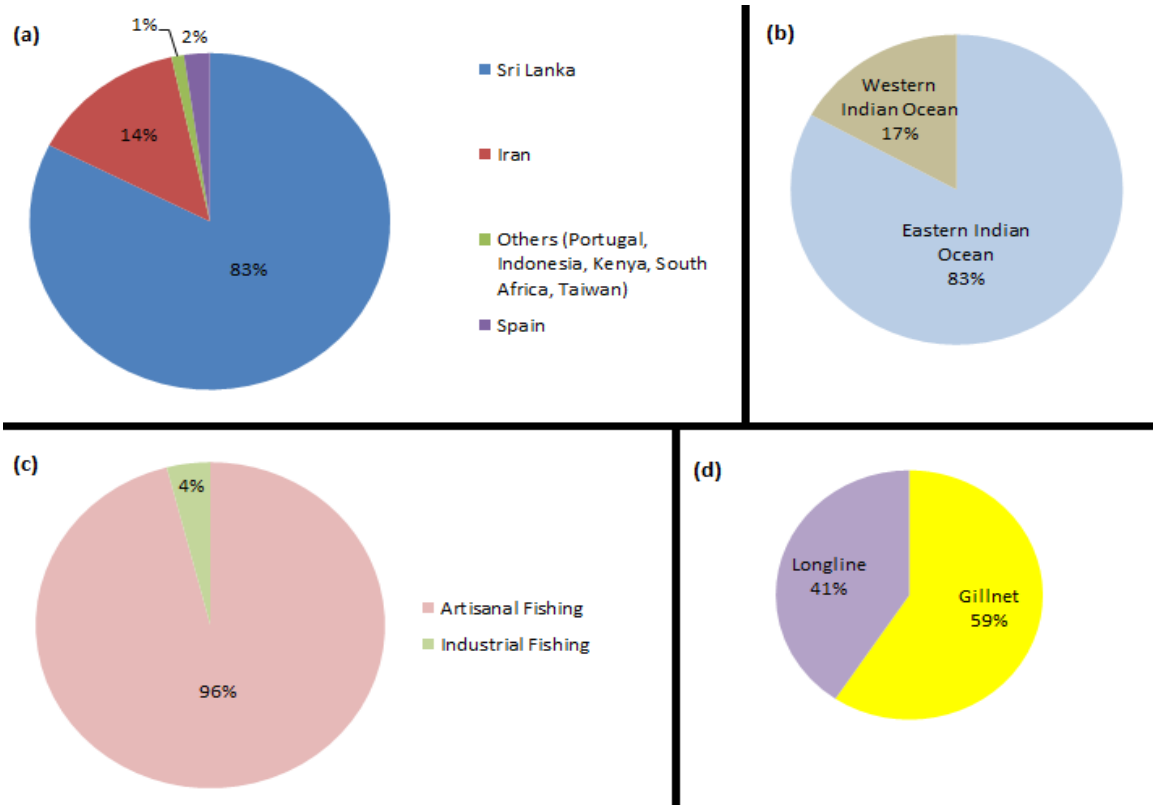


Figure 36. Percentage of total nominal catches of *S. zygaena* reported to the IOTC from 1986-2014: a) by CPC flag vessel; b) by location of catches within Indian Ocean; c) attributed to fishing type; d) attributed to fishing gear (Source: IOTC public domain database, accessed November 17, 2015)

In terms of actual numbers, the nominal catches for scalloped and smooth hammerheads are presented in Figure 37. Similar to the other regions, the scalloped hammerhead shark is the hammerhead species that is more commonly caught, and in larger numbers, compared to the smooth hammerhead shark. The trend in catch shows an increase and peak in the late 1990s/early 2000s, concurrent with the growth of the international shark fin trade (Clarke et al. 2007), and then a subsequent and substantial decrease in catch. The recent smaller peak in the *S. zygaena* data, to the point where catches actually outnumbered catches of *S. lewini*, reflects data reported by the Islamic Republic of Iran. Prior to 2012, there were no reported Iranian catches of the species in the dataset. Yet, based on an estimation of the "possible" shark catches caught by major fleet in the IOTC from 2000-2011, Murua et al. (2013) indicated that 60% can be attributed to gillnetters from Iran, Sri Lanka, and Indonesia, followed by Taiwanese longliners, which suggests that catches prior to 2012 were likely greatly underestimated. However, Murua et al. (2013) also notes that the significant underestimations are mainly related to the species that are most frequently caught in this region, which includes blue sharks, silky sharks, oceanic whitetips, threshers, and shortfin makos, but not hammerhead sharks. Again, given the data limitations mentioned above, with evidence of highly uncertain catch reporting, it is difficult to draw any conclusions regarding trends in the catch or potential abundance of smooth hammerhead sharks and impacts of present levels of utilization of the species in the IOTC convention area.

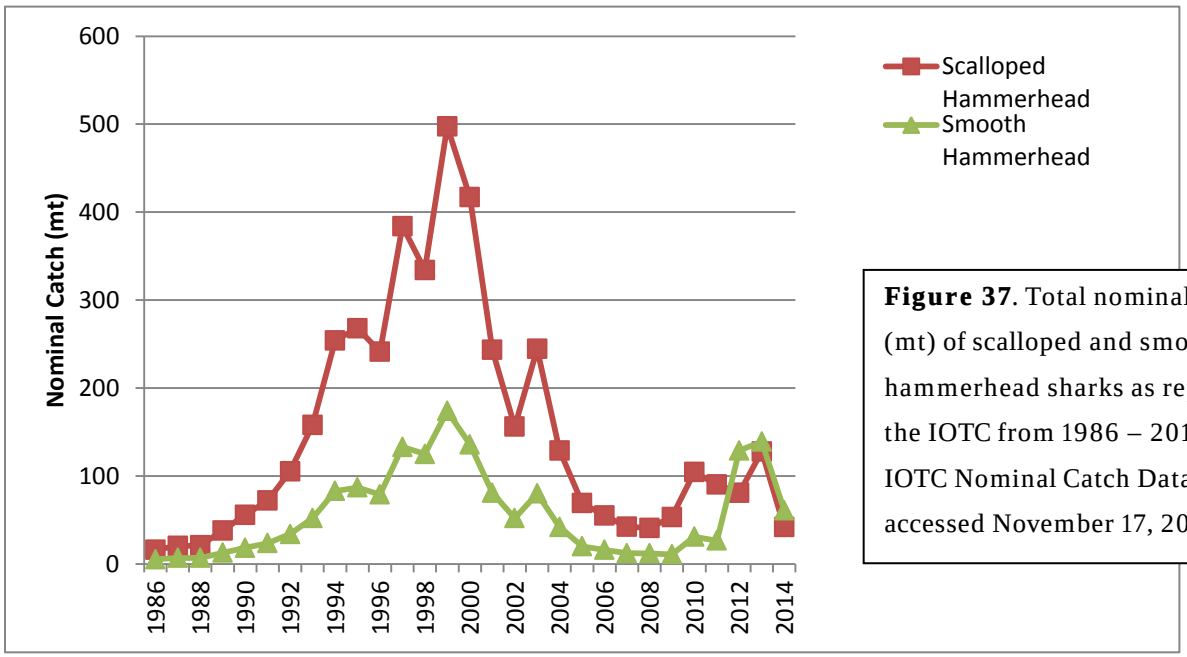


Figure 37. Total nominal catches (mt) of scalloped and smooth hammerhead sharks as reported to the IOTC from 1986 – 2014. (Source: IOTC Nominal Catch Database, accessed November 17, 2015)

The available observer data from the IOTC convention area also tend to confirm the rarity of smooth hammerhead sharks in the various industrial and artisanal fisheries catch. For example, between June 2004 and March 2008, observers collected fisheries information from Taiwanese large-scale longline fishing vessels operating throughout the Indian Ocean, but primarily in tropical waters (between 10°N and 10°S – see Figure 38) (Huang and Liu 2010). The data covered 77 trips and 4,409 sets. A total of 7,803 sharks were caught as bycatch but only 5 of these were smooth hammerheads. However, it is worth nothing that the majority of the observed sets were conducted in the tropical Indian Ocean, where smooth hammerhead sharks are less commonly found.

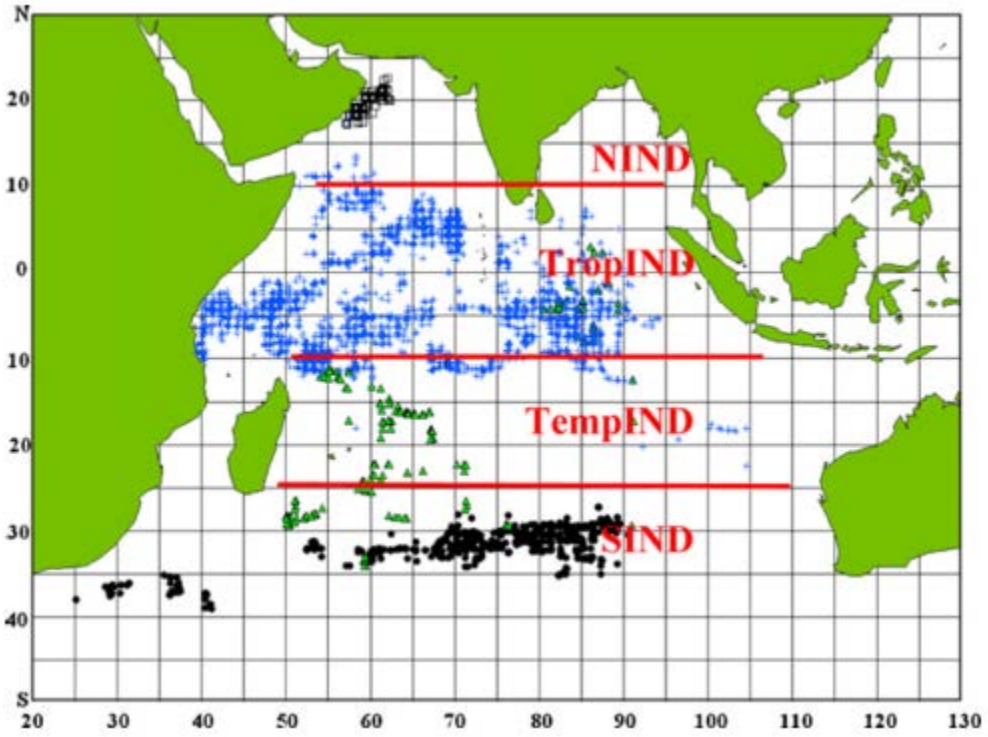


Figure 38. Locations of observed Taiwanese large-scale longline fishing vessel operations in the Indian Ocean from 2004-2008 (Source: Huang and Liu 2010)

In 2012, Murua et al. (2012) conducted an Ecological Risk Assessment for 17 shark species using available data from six IOTC longline fleets (Soviet Union research longline, Portuguese, Japanese, Korean, La Reunion Island, and Chinese longline fleets) and the combined IOTC purse seiner fleet. The results revealed that the smooth hammerhead shark ranked 6 out of 17 in terms of its overall vulnerability to the IOTC longline fisheries (with low numbers being more vulnerable) compared to the other

identified species (Table 4). The smooth hammerhead shark was characterized by higher productivity but also higher susceptibility compared to the other vulnerable species. Post capture mortality was estimated to be 99.7% for smooth hammerheads. In terms of vulnerability to purse seines, it was ranked as #7 out of the 17 assessed species; however, its susceptibility estimate was significantly lower than that calculated for longlines. In other words, when comparing across fisheries, the species is much less likely to be impacted by purse seines than longlines (Table 4) (Murua et al. 2012).

Table 4. Productivity and susceptibility analysis for *S. zygaena* caught by fisheries operating in the IOTC convention area (Source: Murua et al. 2012)

	Productivity	**Susceptibility**					**Vulnerability**	
IOTC Fishery	Lambda	Availability	Encounterability	Selectivity	Post-capture mortality	Susceptibility	Vulnerability	RANK (out of 17)
Pelagic LL	1.281 (1.257-1.303)	0.909	1	0.997	0.997	0.904	0.298	6
Purse Seine	1.281 (1.257-1.303)	0.480	1	0.327	0.500	0.078	0.964	7

However, both of these Ecological Risk Assessment models used the International Union for Conservation of Nature (IUCN) distribution maps of the species (see Figure 3) to evaluate the overlap between the species spatial distribution and fleet effort distribution. The IUCN distribution maps are continually being updated and improved, which can ultimately affect the values of availability and encounterability (and overall susceptibility estimate). For example, based on the data collected for this review, the availability of the species off Indonesia, particularly within more tropical waters (which is indicated as part of the distribution on the IUCN map), would likely be low; yet the distribution maps do not speak to the likelihood of encountering the species in these areas. Additionally, when longline effort within the IOTC is considered, it is apparent that most of the effort is focused in the tropical and oceanic waters of the Indian Ocean, as opposed to the more temperate regions where smooth hammerheads are more common (Figure 39) (IOTC 2015a). As such, results from these Ecological Risk Assessments should always be considered along with the available species-specific fisheries information from the region. In this case, while the general distribution of the species may overlap with the fisheries areas of operation, based on the available

observer and fisheries data, the species does not appear to be caught very frequently or in large numbers within the Indian Ocean. Hence, it is likely that the "availability" value in the assessment is overestimated, which would contribute to a lower overall vulnerability ranking.

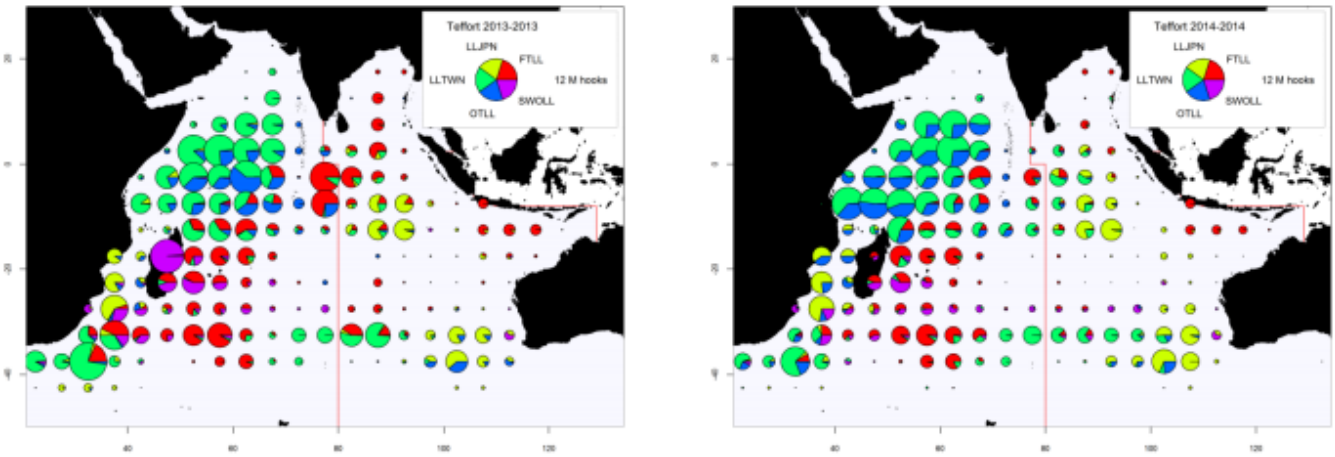


Figure 39. Number of hooks set (millions) from longline vessels by five degree square grid and main fleets, for the years 2013 (left) and 2014 (right) as of September 2015. LLJPN (yellow): deep-freezing longliners from Japan; LLTWN (green): deep-freezing longliners from Taiwan, China; SWOLL (purple): swordfish longliners (Australia, EU, Mauritius, Seychelles, and other fleets); FTLL (red) fresh tuna longliners (China, Taiwan, China and other fleets); OTLL (blue): Longliners from other fleets (Belize, China, Phillipines, Seychelles, South Afrcia, Rep. of Korea, others) (Source: IOTC 2015a)

Indian Ocean Region - Summary

As was the case in the Atlantic Ocean, the regional and local information above indicates that smooth hammerhead sharks tend to be a rare occurrence, observed (for the most part) only sporadically in the fisheries data, primarily in more temperate waters, and at low catch and abundance levels. The best available data, albeit severely lacking, confirms that smooth hammerhead sharks are caught as catch and bycatch in this region and marketed for their fins and meat. However, the lack of trends or evidence of significant declines of *S. zygaena* within the Indian Ocean does not indicate that the species' is at risk of extinction due to present levels of utilization. Fishing effort appears to be concentrated in the more tropical waters of the Indian Ocean, which decreases the impact of fisheries on the more temperate-occurring smooth hammerhead shark. This is particularly evident in the available fisheries datasets, with the tropical *S. lewini* more frequently encountered and at higher numbers compared to *S. zygaena*. Again, while

data is severely lacking in this region, with significant uncertainty surrounding current catch and reporting estimates, and no information on present abundance levels, at this time, the best available information does not show that overutilization is presently a threat that is significantly contributing to the species' risk of extinction.

Pacific Ocean

Western and Central Pacific

In the western Pacific, smooth hammerheads appear regularly in fisheries catch data, particularly from the temperate waters off southeastern Australia and New Zealand. They have also been reported in historical landings data from Japan, as far north as Hokkaido (Taniuchi 1974). In fact, in a study that examined logbook records of commercial longline vessels operating off southwestern Japan in 1953, a number of smooth hammerhead sharks were reported as catch. In total, 1,107 *S. zygaena* were landed over the course of the year, comprising around 12% of the hammerhead catch. *Sphyrna lewini* still made up the large majority of the hammerhead catch, with 6,999 landed sharks. In terms of utilization, according to Taniuchi (1974), smooth hammerheads were widely distributed throughout Japan, with their flesh sold at fish markets from Shikoku to the Kanto District and Hokkaido. However, historical species-specific data is lacking. Over the past decade, reported catches of hammerhead sharks (not identified to species) at main fishing ports in Japan have been low and variable, with no clear trend (Figure 40) (Fisheries Agency of Japan 2015).

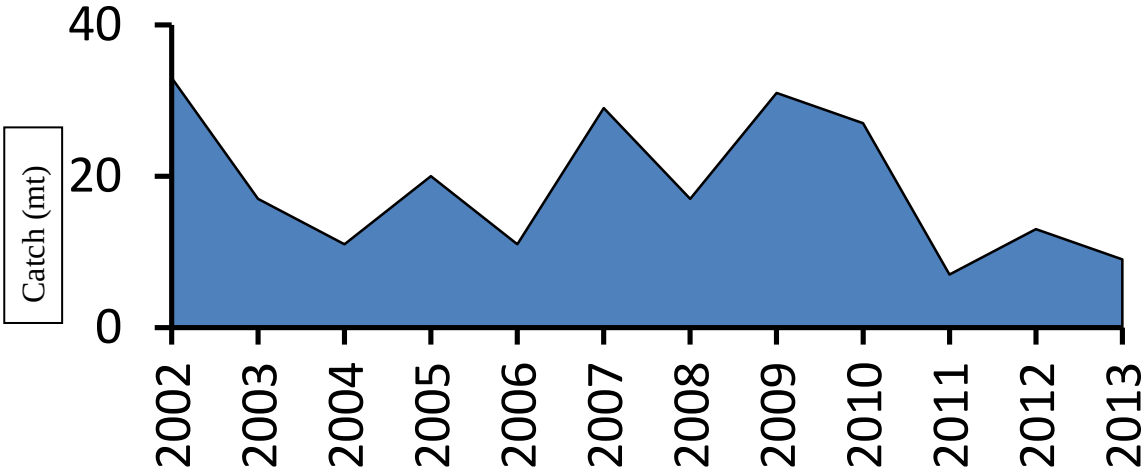


Figure 40. Catch (mt) of hammerhead sharks at main fishing ports in Japan from 2002-2013 (Fisheries Agency of Japan 2015)

Fisheries targeting or catching substantial numbers of sharks as bycatch are strictly regulated through licenses issued by Japan's Minister of Agriculture, Forestry and Fisheries or prefectural governments. As a result, the expansion of the scale of these fisheries unlikely (Fisheries Agency of Japan 2011). Furthermore, overall fishing effort by Japanese longliners (which are responsible for the majority of shark catches) has been on a declining trend since the late 1980s, with significant declines noted particularly in the Pacific Ocean (Figure 41) (Fisheries Agency of Japan 2011; Uosaki et al. 2015).

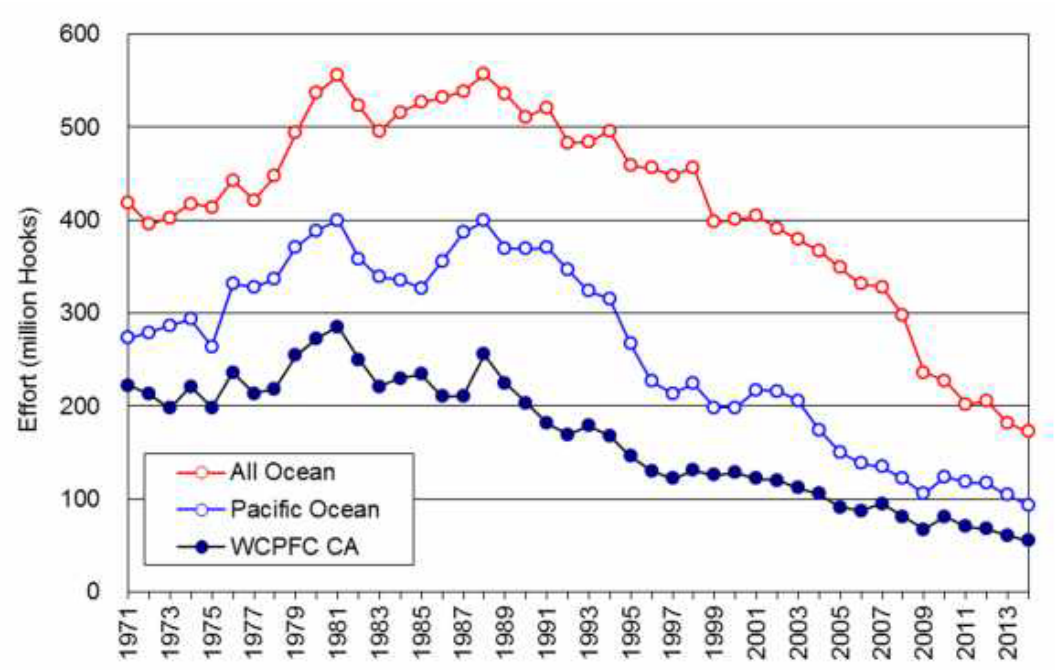


Figure 41. Historical changes in fishing effort (million hooks per year) of the Japanese distant water and offshore longline fishery in the Western and Central Pacific Fishery Commission (WCPFC) Convention Area (does not include small offshore fishery). Values in 2013 and 2014 are provisional (Source: Uosaki et al. 2015)

Although Japan is a significant producer and exporter of sharks fins, ranking 10th worldwide in terms of chondrichthyan catches and 11th in (dried) shark fin exports from 2000-2011, both capture production and fin exports have steadily declined over the past decade (Dent and Clarke 2015). Compared to statistics from 2000, Japan's catches of chondrichthyans decreased by 68% in 2011 and fin exports dropped by 52% in 2012. While Japan's export of shark meat has steadily increased (Fisheries Agency of Japan

2011), hammerhead sharks are not particularly desired for their meat as the meat contains high levels of urea, giving it a particular smell and bitter acidic taste, and requires more processing and preparation (Vannuccini 1999). As such, it is unlikely that this increasing trend in meat exports will result in increased targeting of smooth hammerhead sharks.

Additionally, Japan has also stated that due to the uncertainty of the stock structure of hammerhead sharks, as well as the lumping of all hammerhead sharks in the available Japanese data, it is unable to make a CITES non-detriment finding for the export of scalloped hammerhead sharks (and, by default, the other CITES-listed hammerhead species) (Fisheries Agency of Japan 2015). Effective September 14, 2014, scalloped, smooth, and great hammerhead sharks are listed on CITES Appendix II, which means that international trade in specimens of these species may be authorized by the granting of a CITES export permit or re-export certificate. However, permits or certificates should only be granted if that trade will not be detrimental to the survival of the species. This is done through the development of a "non-detriment" finding, or NDF. Because Japan is unable to make an NDF for the export of scalloped, smooth, or great hammerhead sharks, it will not issue any permits for the export of products from these species. This decision has likely significantly decreased the incentive for Japanese fishermen to target the smooth hammerhead shark primarily for the export of its fins to the international trade market, and, as such, has decreased the threat of overutilization of the species within Japanese waters.

In the western Pacific, smooth hammerhead sharks are also documented in the fisheries catch data from Taiwan and the Philippines. In Taiwan, there are two types of tuna fleets that operate in the North Pacific Ocean: large-scale tuna longliners and small-scale tuna longline vessels. Sharks comprise the majority of the bycatch of these fleets; however, the bycatch was historically never reported because of the low economic value of it compared to tunas. Additionally, although reporting of shark catches began in 1981, data through 2003 are not species-specific, and since 2003, only four sub-categories of "sharks" have been reported on logbooks: blue shark, mako shark, silky shark, and "other" sharks. Of concern, as it relates to the threat of overutilization, is the fact that

Taiwan's fleet ranks 4th in terms of global shark catches. They declare catches of around 6 million sharks annually, accounting for almost 6% of the global figures (Liu et al. 2013), making species-specific reporting essential for determining the impact of this fleet on shark populations.

Between 1996 and 2006, annual Taiwanese shark landings (coastal, offshore, and pelagic combined) averaged between 39,000 and 55,000 mt. While the proportion of this total attributed to smooth hammerhead sharks is unknown, from 2002-2010, Liu and Tsai (2011) examined offloaded landings at two major fish markets in Tawian (Nanfangao and Chengkung) to get a better sense of the catch composition and whole weight of the sharks commonly caught by Taiwanese offshore tuna longliners. What they found was that there are 11 species of pelagic sharks that are commonly caught by the longliners, with blue sharks dominating the shark landings (by weight), comprising an average of 44.54% of the landings, followed by scalloped hammerheads (at 9.87%) and shortfin makos (at 9.42%). Smooth hammerhead sharks, on the other hand, were one of the least represented species, comprising an average of only 1.38% of the landings over the study period, which translated to around 78 mt per year. Since 2010, reported catches of smooth hammerhead sharks by Taiwan's tuna longline fleets have ranged from 81 mt and 149 mt (Table 4).

Table 4. Catches (in mt, round weight) of smooth hammerhead sharks in the Chinese Taipei tuna longline fisheries in the WCPFC Convention Area from 2011-2014 (*2014 is a preliminary estimate) (Source: Fisheries Agency of Chinese Taipei 2015)

2011	**2012**	**2013**	**2014***
149	108	81	82

According to the annual reports of Chinese Taipei, provided to the Western and Central Pacific Fishery Commission (WCPFC), over 93% of the smooth hammerhead bycatch can be attributed to the small scale tuna longline vessels, which operate mostly in the EEZ of Taiwan but also beyond the EEZ (particularly those vessels with freezing equipment which allows for expansion to more distant waters). While reported catches

by both the large and small-scale longline fleets have decreased since 2011 (Table 4), so has the number of active vessels engaged in the fisheries: from 1,376 vessels in 2011 to 1,275 in 2014 for the small scale tuna longline fleet, and from 95 vessels in 2011 down to 73 in 2014 for the large scale tuna longline fleet (Fisheries Agency of Chinese Taipei 2015). Additionally, fishing effort has also clearly decreased, particularly in the small scale tuna longline fishery (Figures 42a and 42b).

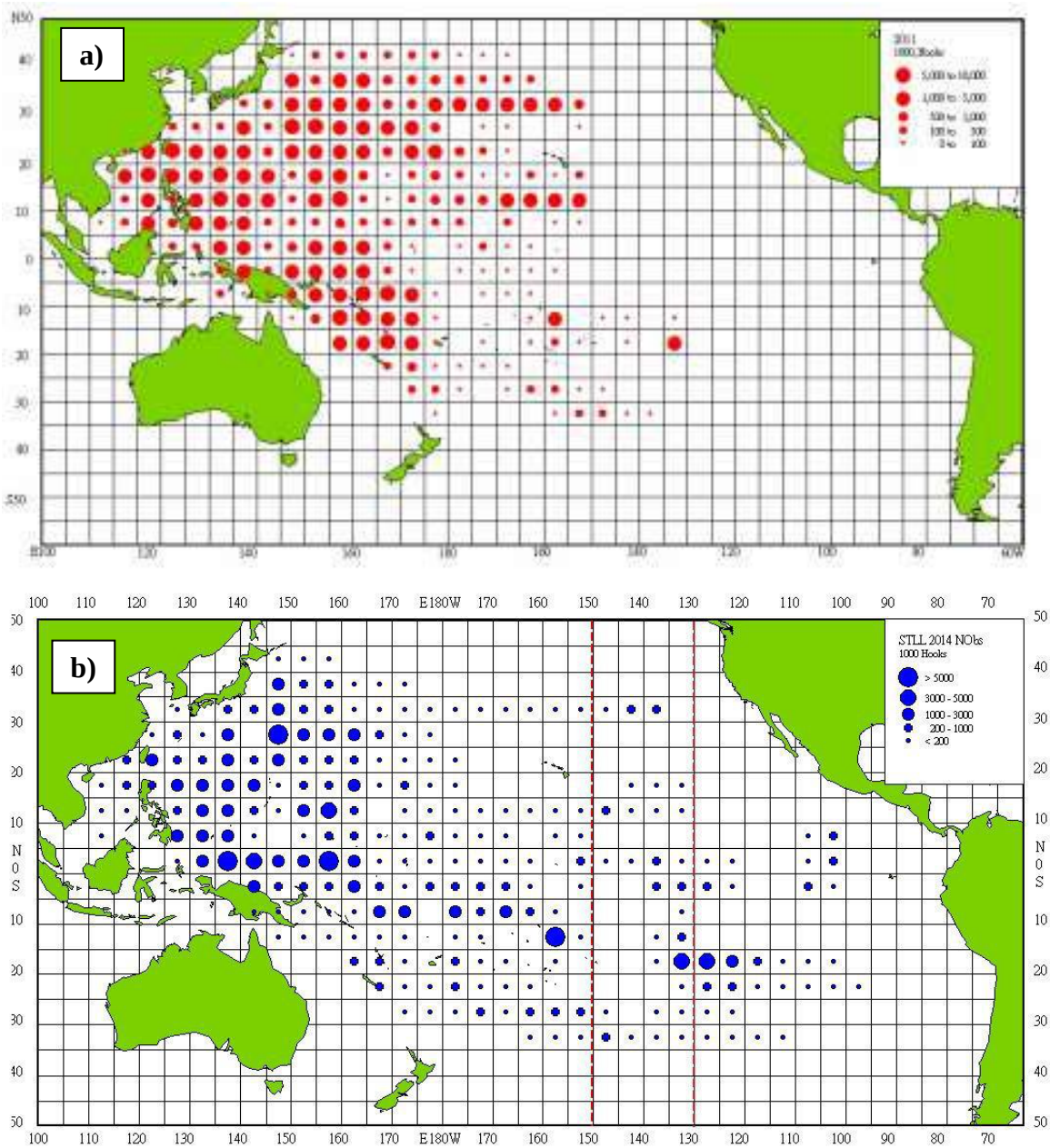


Figure 42. Effort distribution of the Taiwanese small scale tuna longline fishery in **a)** 2011 and **b)** 2014. The 2014 effort distribution is still preliminary. (Source: Fisheries Agency of Chinese Taipei 2015)

While the available data suggest that smooth hammerhead sharks are susceptible to the Taiwanese tuna longline fleet, they represent a small fraction of the total shark catch within these fisheries. Whether this minimal amount of take is contributing to population declines of the species in this region is unknown. There is no information to indicate abundance of *S. zygaena* has decreased, and while catches of smooth hammerhead sharks have declined in the past few years, so has fishing effort. Without additional information, including historical information on the abundance and distribution of the species within the fishing grounds of Taiwan's fleet, conclusions regarding the status of the population in this area would be highly uncertain and speculative.

Similar to the situation in Taiwan, little is known regarding the species composition of elasmobranch catches in the Philippines as reporting is usually down to a generic "shark" category in fisheries statistics (Philippine NPOA-Sharks 2009). As such, little data is available that is specific to smooth hammerhead sharks. In the Philippines FAO National Plan of Action for Sharks, catches of smooth hammerhead are provided but only from one year (2000) and one location (Iligan Bay). This data showed that a total of 450 kg (0.45 mt) of *S. zygaena* were reportedly caught by drift gillnet in Iligan Bay and sold at markets in Cagayan de Oro and Cebu. No other information on catches or trends of smooth hammerhead sharks could be found.

Off the east coast of Australia, smooth hammerhead sharks are normally found in continental shelf waters. Given their more temperate distribution, there is reportedly minimal overlap with the other hammerhead species that occur in Australia, and, as such, the species tends to be caught in different fisheries than those that are known to catch *S. lewini* and *S. mokarran*. While the majority of smooth hammerhead catches are taken in the previously discussed Western Australian fisheries, minimal numbers are also caught in the Commonwealth-managed southern shark fishery (see Figure 43 for area of operation: "Commonwealth Gillnet and Shark Hook Sector") and the New South Wales Offshore Trap and Line (NSW OTL) Fishery, which operates off the eastern and southern coasts of Australia.

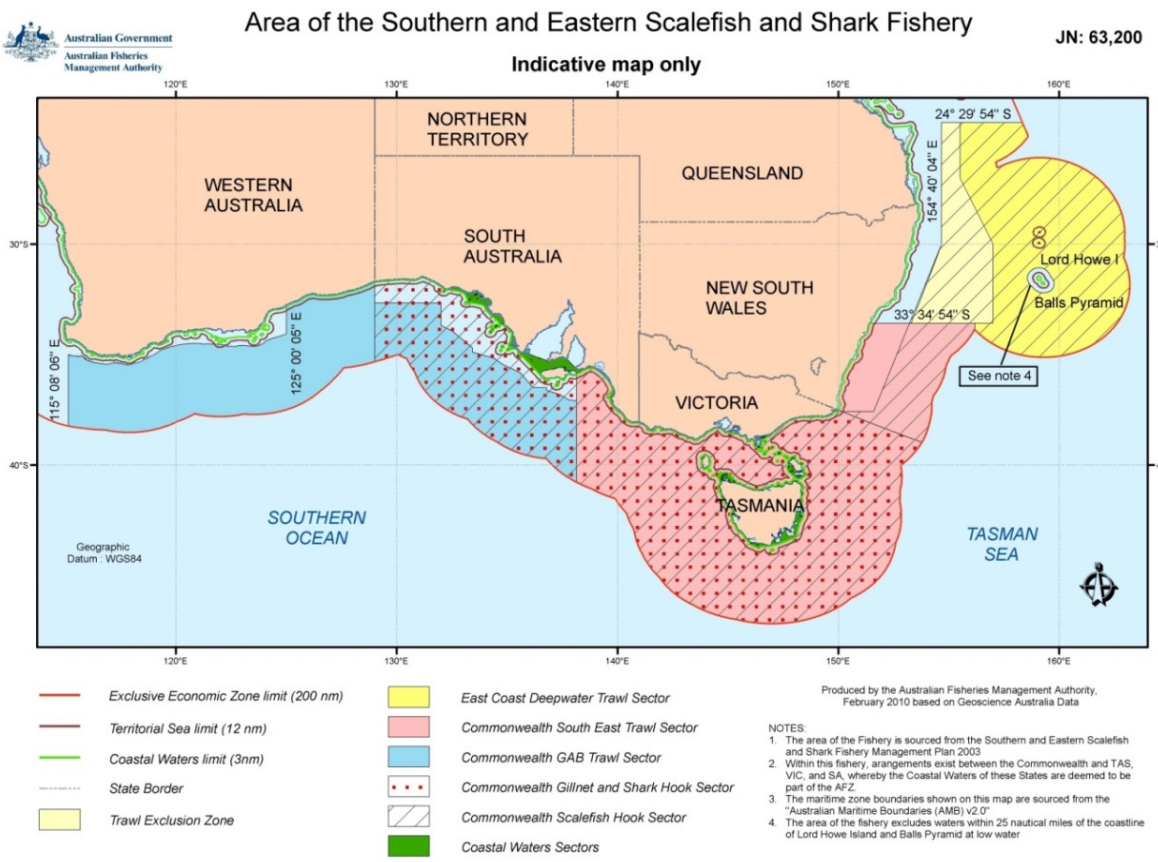


Figure 43. Area of operation of Australia's Southern and Eastern Scalefish and Shark Fishery. The Commonwealth Gillnet and Shark Hook Sector area of operation is designated by red polka dots. (Source: http://www.afma.gov.au/fisheries/southern-eastern-scalefish-shark-fishery/)

According to the Australian Government, Department of the Environment, take in the Commonwealth southern shark fishery is low, with annual catches ranging between 2 and 10 t (Table 5) (Simpfendorfer 2014). Similarly, catches in the state-managed fisheries of NSW and South Australia are even lower, on the order of 1-2 t annually (Simpfendorfer 2014). Based on observer data from the NSW OTL fishery, smooth hammerheads represented a fairly small percentage (4.3%) of the total targeted shark catch, with estimates of mean catch rate (in number per 100 hooks) ranging from 0.16 (± 0.06) to 0.21 (± 0.09) (Macbeth et al. 2009).

Table 5: Annual reported catches of *S. zygaena* in the Southern and Eastern Scalefish and Shark Fishery (Simpfendorfer 2014)

Year	Reported catch (t)
2003	9.4
2004	4
2005	7.3
2006	7.6
2007	7.2
2008	3.6
2009	10.3
2010	10.2
2011	3.7
2012	1.6

Recreational fishermen in Australia also catch smooth hammerhead sharks; however no detailed data exist that would allow for estimates of exact catch levels (Simpfendorfer 2014). General information from the NSW Gamefish Tournament and Monitoring Program show that over the period of 1994–2013, a total of 541 hammerhead sharks (majority likely smooth hammerhead sharks) were reported caught, with over 89% released back into the water (Ghosn et al. 2015). An average of 27 individuals were recorded per fishing year, with catch rates highly variable but relatively low compared to the other primary shark species (e.g., mako, blue, and tiger sharks). Hammerheads comprised <1.5% (in numbers) of the catch by game fish tournament anglers over the study period (Ghosn et al. 2015).

In addition to the Australian commercial and recreational fisheries, hammerhead sharks are also occasionally caught in Australia's NSW Shark Meshing Program (SMP). The beach meshing program is a form of shark control to provide beachgoers some level of protection from sharks. The NSW SMP annually deploys a series of bottom-set mesh nets between September 1st and April 30th along 51 ocean beaches from Wollongong to Newcastle. Since the 1950s, at least 16,064 animals have been caught in these nets, consisting mostly of hammerhead sharks (29%), rays (18.9%), whalers (which could include up to 10 species of the genus *Carcharhinus*; 18.4%), and angel sharks (14.4%) (Green et al. 2009). Prior to 1972, whalers and angel sharks were the dominant species in the SMP, but their numbers have declined and hammerheads have become a larger proportion of the catch (Figure 44). In fact, from 1972 to 2008, hammerheads averaged approximately 50% of the annual catch (range 34% - 67%) (Green et al. 2009). However, Green et al. (2009) notes that in the past few years (from 2002–2008), their average has declined to 35% (range 20-42%).

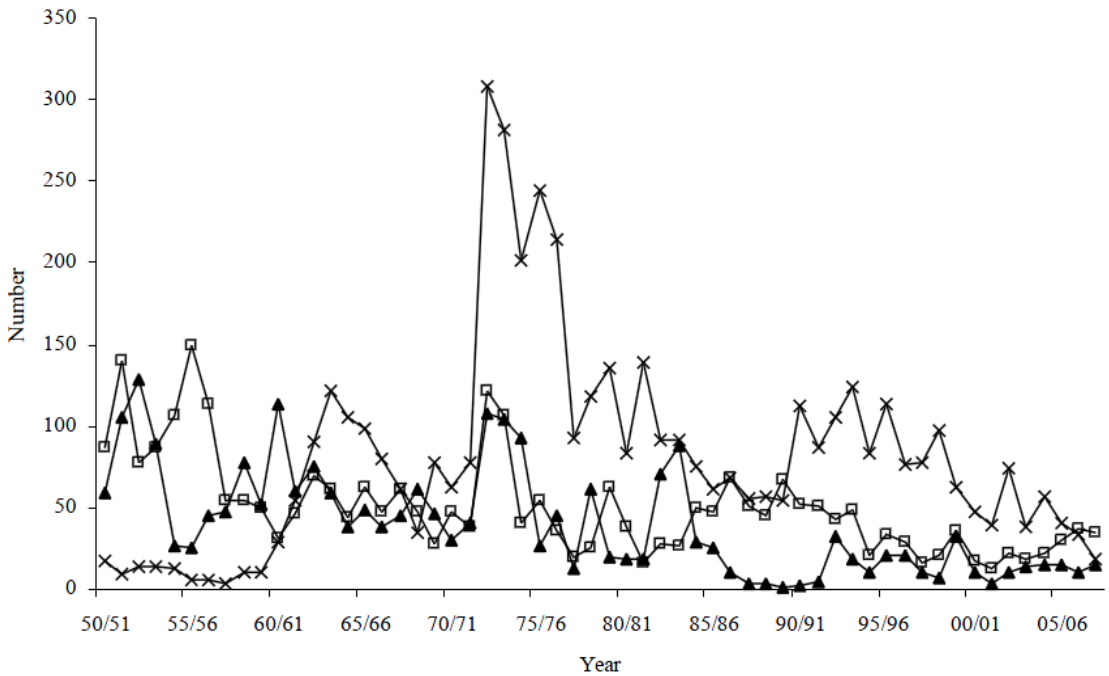


Figure 44. Annual catches of hammerhead sharks (X), whalers (□), and angel sharks (▲) in the NSW SMP from 1950 – 2008 (Source: Green et al. 2009)

Similarly, the CPUE of hammerhead sharks over the past decade has also exhibited a declining trend, although no significant trend was found when data from the start of the program was included (from 1950 – 2010, Figure 45; Reid et al. 2011). Yet, since the 1970s, the number of hammerheads caught per year in the NSW beach nets has decreased by more than 90%, from over 300 individuals in 1973 to less than 30 in 2008 (Williamson 2011). Between 1990 and 2010, a total of 1,331 hammerhead sharks were captured in the beach nets. While the SMP did not break out the hammerhead complex by species, the majority of

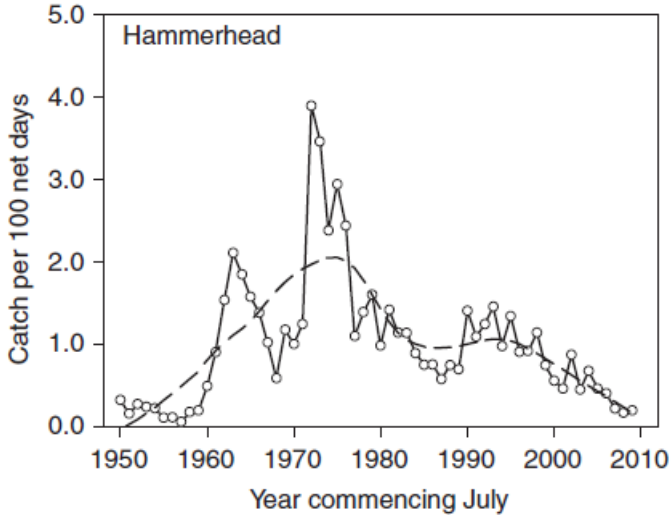


Figure 45. CPUE of hammerhead sharks in the NSW SMP from 1950 – 2010. (Source: Reid et al. 2011)

the hammerhead catch are likely smooth hammerhead sharks (*S. zygaena*) (Reid et al. 2011; Williamson 2011) given the placement of the nets in more temperate waters.

As mentioned previously (see **Abundance and Distribution**), changes in the methods and level of effort of the SMP program since its inception have complicated long-term analyses; however, in 2005, the SMP was listed as a "key threatening process" by the NSW Fisheries Scientific Committee (convened under the Fisheries Management Act 1994) and the NSW Scientific Committee (convened under the Threatened Species Conservation Act 1995). It was listed as such due to its adverse effect on threatened species, populations, or ecological communities, and its ability to cause species, populations, or ecological communities that are not threatened to become threatened. As such, since 2009, the program has operated in accordance with Joint Management Agreements (JMAs) and an associated management plan, with an objective of minimizing the impact of its nets on non-target species (such as smooth hammerhead sharks) and threatened species to ensure that the SMP does not jeopardize the survival or conservation status of the species. To meet this objective, the SMP developed a "trigger point" that, when tripped, indicates additional measures are needed to comply with the objective. The trigger point is defined as: "*entanglements of non-target species and threatened species over two consecutive meshing seasons exceed twice the annual average catch of the preceding 10 years for those species*." For smooth hammerhead sharks, the trigger point was estimated at 55 individuals. Based on recent species-specific data from the SMP program, the annual catch of smooth hammerhead sharks has remained below the trigger point for the past 5 years, ranging from 18 sharks captured in 2010 to 42 sharks in 2014, indicating that under the current evaluation parameters, the SMP is not considered to be impacting *S. zygaena* to the extent that it would jeopardize its survival or conservation status (NSW Department of Primary Industries 2015).

To the east, in New Zealand, smooth hammerhead sharks are occasionally caught as bycatch in commercial fisheries, but are prohibited from being targeted. The available data from New Zealand waters, covering the time period from 1986-1997, show no clear trend in smooth hammerhead landings (Figure 46) (Francis and Shallard 1998), and

corresponding effort information is unavailable. When compared to all shark landings for the same time period, smooth hammerhead sharks comprised <1% of the total, indicating that the commercial fisheries in this region do not likely pose a significant threat to the species. However, in an analysis of 195 shark fillets from marketed cartons labelled as lemon fish (*Mustelus lenticulatus)*, 14% were identified as *S. zygaena* (n=28). Similarly, analysis of 392 shark fins obtained from commercial shark fisheries operating in the Bay of Plenty indicated that 12% (n=47) came from smooth hammerhead sharks. These data suggest that while smooth hammerhead sharks may be prohibited from being targeted in New Zealand waters, they are still occasionally landed. The impact of this take on the population, whether legal or not (given the misidentification of the fillets), remains to be determined (Smith and Benson 2001).

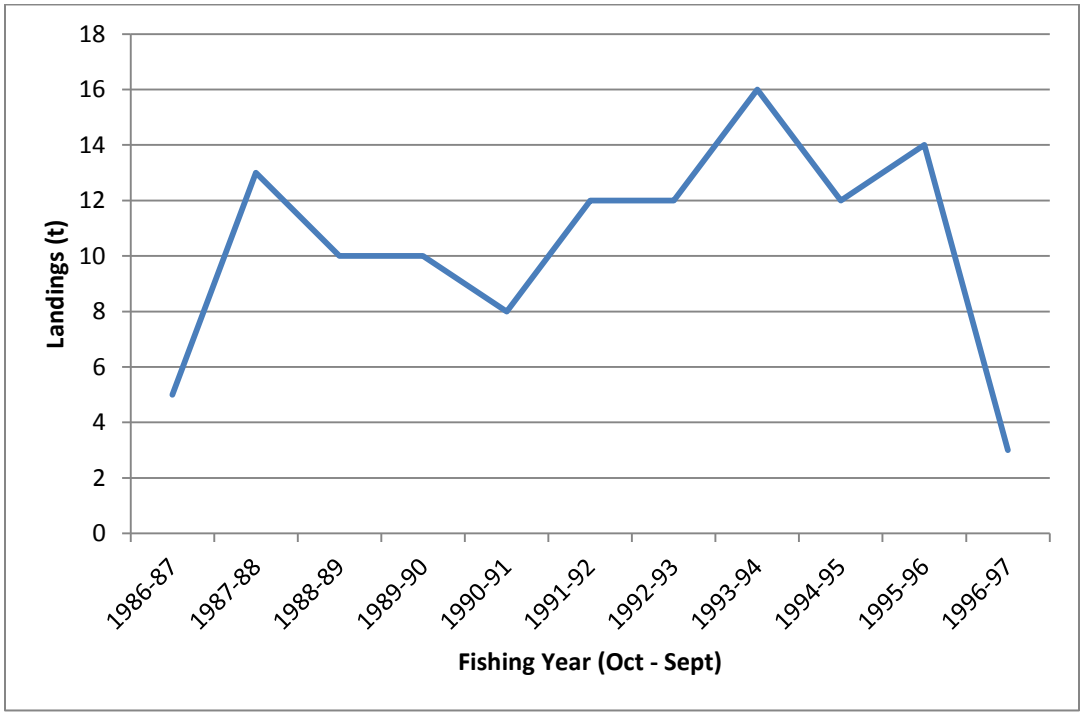


Figure 46. New Zealand commercial landings of *S. zygaena* for the period of 1986-1997 (Source: Francis and Shallard 1998)

Smooth hammerhead sharks are also taken in the recreational fisheries in New Zealand, and particularly during shark fishing competitions (Francis and Shallard 1998), but no information on the impacts of present levels of recreational catch on the population is available. Additionally, in the southern regions of New Zealand (i.e., Fiordland,

Kaikoura, South-East, and Southland areas), the bag limit for recreational fishermen is limited to 1 hammerhead shark.

In the central Pacific, smooth hammerhead sharks are caught as bycatch in the Hawaii pelagic longline fisheries. The Hawaii-based pelagic longline fishery has been in operation since approximately 1917, and underwent considerable expansion in the late 1980's to become the largest fishery in the state (Boggs and Ito 1993). Since 2004, there are two separately regulated Hawaii pelagic longline fisheries: deep-set pelagic longline used to target primarily tuna, and shallow-set pelagic longline used to target swordfish. NMFS authorizes the pelagic longline fisheries under the Fishery Ecosystem Plan for Pelagic Fisheries of the Western Pacific (Pelagics FEP) developed by the Western Pacific Fishery Management Council (WPFMC) and approved by NMFS under the authority of the Magnuson-Stevens Act. Due to the mostly unregulated historical take that occurred in these fisheries, and the demand to continue fishery operations, the WPFMC implemented strict management controls for these fisheries. Although smooth hammerheads are not target species in the Hawaii pelagic longline fisheries, the measures that regulate the longline fishery operations have helped to monitor the bycatch of smooth hammerhead sharks and may minimize impacts to the species. Some of these regulations include mandatory observers, designated longline buffer zones, areas of prohibited fishing, and periodic closures and effort limits (see Miller et al. (2014a) for more details). A mandatory observer program for the Hawaii-based pelagic longline fishery was also initiated in 1994, with coverage rate that has ranged between 3% and 10% from 1994 to 2000 and increased to a minimum of 20% in 2001. The deep-set pelagic longline fishery is currently observed at a minimum of 20% and the shallow-set pelagic fishery has 100% observer coverage. Based on the available observer data, smooth hammerhead sharks appear to be caught in low numbers and comprise a very small proportion of the bycatch. For example, from 1995-2006, only 49 *S. zygaena* individuals on 26,507 sets total were observed caught (for both Hawaii-based pelagic longline fishery sectors combined), translating to an estimated nominal CPUE of 0.001 fish per 1,000 hooks (Walsh et al. 2009). Additionally, according to the U.S. National Bycatch Report (NMFS 2011d; NMFS 2013b), the Hawaii-based deep-set pelagic longline fishery reported only 2,453.74 pounds (1.1 mt) of smooth hammerheads as

bycatch in 2005 and 3,173.91 pounds (1.44 mt) in 2010. The Hawaii based shallow-set pelagic longline fishery reported even lower levels of bycatch, with 930.35 pounds (0.422 mt) in 2005 and no bycatch of smooth hammerhead sharks in 2010. Given the strict management of the Hawaii-based pelagic longline fisheries and the low levels of bycatch, with no evidence of population declines of smooth hammerhead sharks in this area, there is no information to suggest that overutilization is presently a threat in this portion of the species' range.

Similarly, in American Samoa, smooth hammerheads are primarily caught as bycatch by the pelagic longline fishery, which is limited entry and operates mainly in the U.S. EEZ around American Samoa. This longline fishery targets albacore tuna (*Thunnus alalunga*) and is managed under the Pelagics FEP by the WPFMC. Like the Hawaii-based pelagic longline fishery, the American Samoa fishery operates under extensive regulatory measures including gear, permit, and logbook requirements, vessel monitoring systems, and protected species workshop requirements. The American Samoa longline fishery has also had an observer program since 2006, with coverage ranging between 6% and 8% from 2006-2009, and between 20% and 33% since 2010. From 2010 t0 2013, only three smooth hammerheads were observed caught in the American Samoa longline fishery, all in 2011, with total take extrapolated to 12 individuals (PIFSC, unpublished data). The number of unidentified hammerhead sharks observed caught for the same period was 2, extrapolated to 11 total (PIFSC, unpublished data). There is no information to suggest that this level of bycatch is significantly impacting the smooth hammerhead population in the central Pacific.

RFMO Information

The Western and Central Pacific Fisheries Commission (WCPFC), the RFMO that seeks the conservation and sustainable use of highly migratory fish stocks throughout the western and central Pacific Ocean, has also collected data on the longline and purse seine fisheries operating within the region; however, data specific to smooth hammerhead sharks (and hammerhead sharks in general) is severely limited. Only since 2011 have WCPFC vessels been required to report specific catch information for hammerhead sharks (in their annual reports to the WCPFC), and it tends to be for the

entire hammerhead group (including *S. mokarran*, *S. lewini*, *S. zygaena*, and *Eusphyra blochii*). Table 6 provides the available aggregated hammerhead catch information since 2011, as reported by Australia, Papua New Guinea, South Korea, Tonga, and Cook Islands fleets to the WCPFC (annual reports are available on the WCPFC website at: http://www.wcpfc.int/meetings/). Table 7 provides the annual longline discards (in numbers) from 2011-2014 as reported by Australian fleets to the WCPFC. In terms of species-specific information, in 2014, French Polynesia reported around 22 smooth hammerhead sharks (or 0.3 mt) as discards (sharks are prohibited from being fished in the EEZ), but none were released alive. As previously mentioned, Chinese Taipei has also reported hammerhead catch down to species level since 2011 (Table 4).

Table 6. Annual catches (mt) of all hammerhead shark species by longliners in WCPFC Convention Area (Source: compiled from Annual Reports to the Commission available at http://www.wcpfc.int/meetings/). [* In 2012, Cook Islands saw a peak in total catch and effort, attributed to 17 additional chartered longline vessels that were introduced for a bigeye and swordfish Exploratory Program – however, in December 2012, the entire Cook Islands EEZ was declared a shark sanctuary, prohibiting the targeting or capturing of any shark species.]

Country	2011	2012	2013	2014
Australia	4.9	3.9	3.2	1.0
Papua New Guinea	22.3	18.6	31.1	15.1
South Korea	<0.1	4	21	13
Tonga				0.03
Cook Islands*		58.1		
TOTAL	27.3	66		

Table 7. Annual longline discard estimates (in numbers) of all hammerhead shark species in WCPFC Convention Area by Australian fleets (Source: compiled from Australia's Annual Reports to the WCPFC).

2011	2012	2013	2014
140	180	76	88

In terms of purse seine data, even less information is available. In their 2015 annual report to the WCPFC, New Zealand noted the catch of 100 kg of smooth hammerhead shark based on data from 5 observed purse seine sets within New Zealand waters in 2013 and 2014. Two smooth hammerhead sharks were reported caught by Papua New Guinea by purse seine gear in 2014. Table 8 provides annual purse seine bycatch (mt) from 2011-2014 as reported by European Union (EU) fleets, with Figure 47 depicting where fishing effort was concentrated in 2014. Given the lumping of all hammerhead species together and the limited information on catches and discards, the available data provides little insight into the impact of present utilization levels on the status of smooth hammerhead shark in this region.

Table 8. Purse seine bycatch in metric tonnes in the WCPFC as reported by EU fleets from 2011-2014 (Source: compiled from EU's Annual Reports to the WCPFC)

2011	2012	2013	2014
0.06	0.16	0.24	0.40

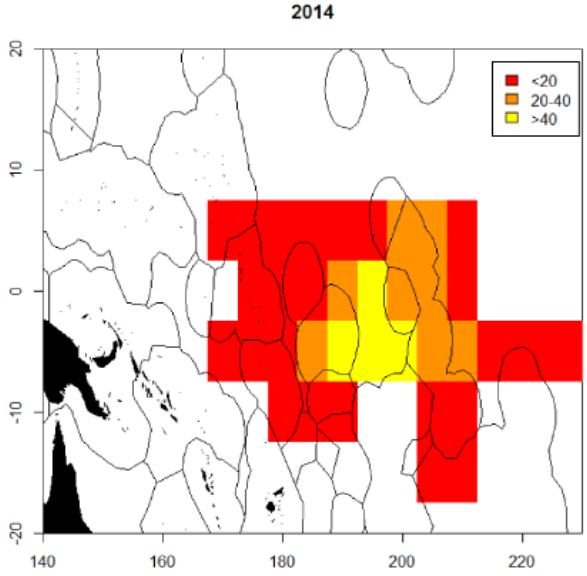


Figure 47. Distribution of the purse seine effort by EU fleets in fishing days, by (5°x 5°) area in 2014 (Source: 2014 EU Annual Report to WCPFC)

Similarly, available WCPFC observer data is also lacking, hindered by low observer rates and spatio-temporal coverage of fishing effort throughout the region. This is particularly true in the longline fisheries where coverage rates have been below 2% since 2009, despite the requirement under CMM 2007-01 requiring 5% observer coverage by June 2012 in each longline fishery (Clarke 2013). With these limitations in mind, the available

observer data, from 1994 – 2009 indicate that, in general, catches of hammerhead sharks (*S. mokarran*, *S. lewini*, *S. zygaena*, and *Eusphyra blochii)* are negligible in all WCPFC fisheries (Figure 48). Additionally, longline sets appear to pose more of a threat to non-target shark species than purse-seine sets in this convention area (Ocean Fisheries Programme 2010).

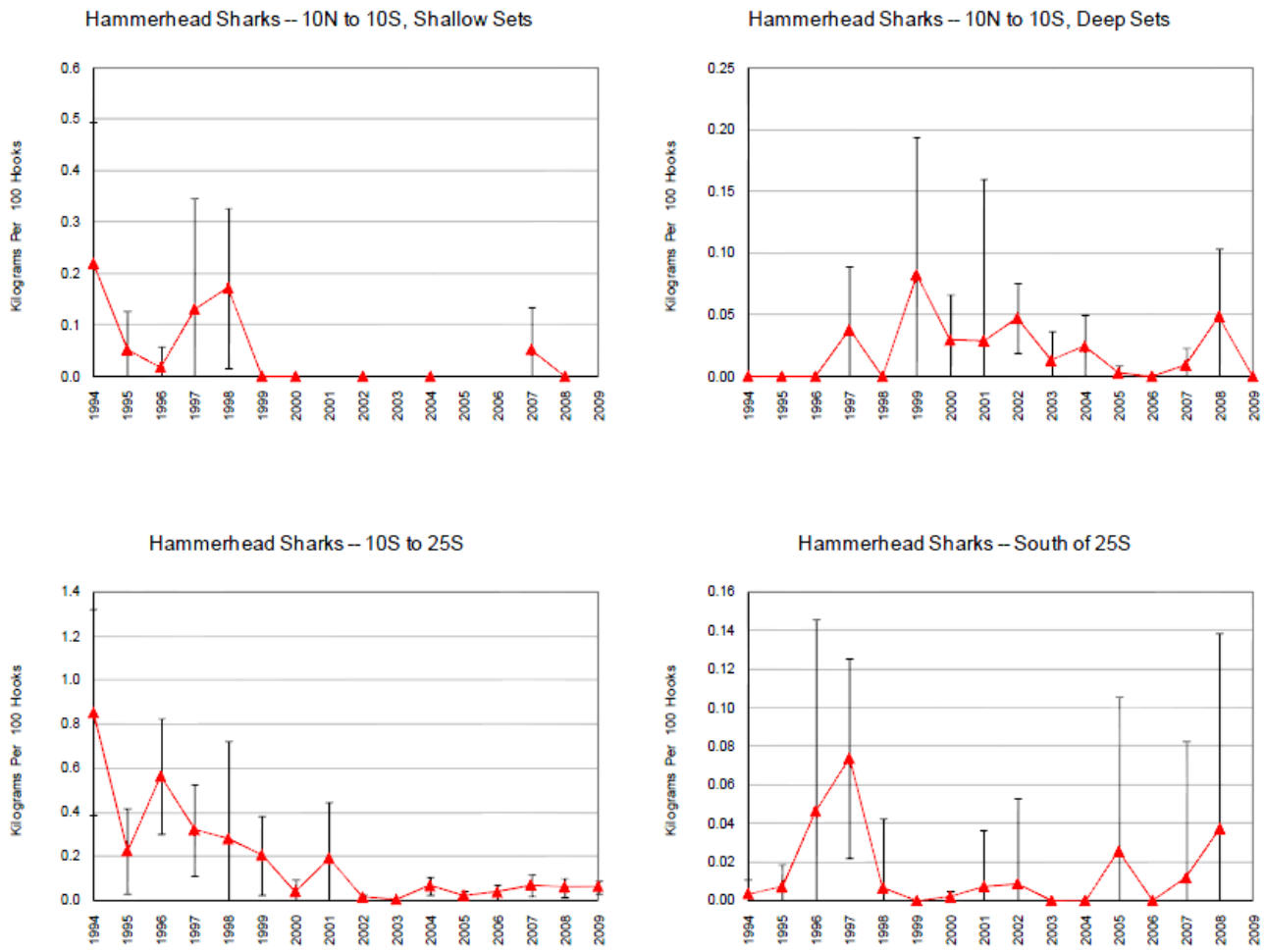


Figure 48. Nominal catch rates of hammerhead sharks determined from observer data collected onboard longliners in the Western and Central Pacific Ocean (Source: Ocean Fisheries Programme 2010)

Rice et al. (2015) analyzed the WCPFC observer data through 2014 and found that hammerhead sharks generally have low encounter rates (i.e., low frequency of occurrence in the western and central Pacific Ocean). In the purse-seine fisheries data, Rice et al. (2015) noted that observations of hammerhead sharks are "virtually non-existent." In the longline observer data, hammerheads had a patchy distribution (Figure

49), with two regions, the northeast (Hawaiian Islands) and southwest (Papua New Guinea, Australian east coast), reporting the largest presence of hammerhead sharks; however, due to the overall low frequency of occurrence of the species in the data, no conclusions could be made regarding hammerhead shark temporal trends (Rice et al. 2015).

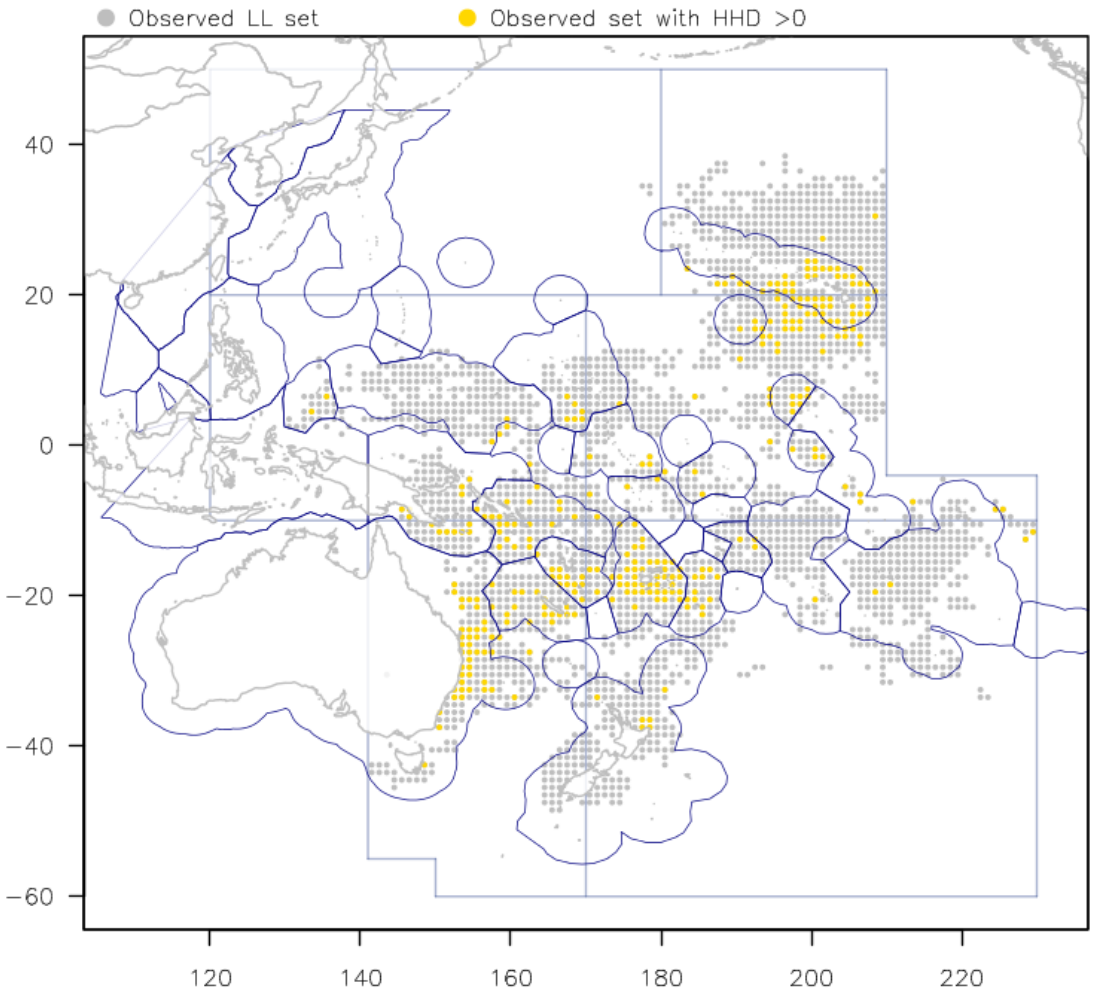


Figure 49. Distribution of observed longline sets (grey) and observed longline sets with catches of hammerhead sharks (yellow) from 1995-2014 within the WCPFC convention area (Source: Rice et al. 2015)

Using the longline data, Rice et al. (2015) analyzed the nominal and standardized CPUE for the hammerhead complex (primarily from the southwest region -- Papua New Guinea, Australian east coast) and found a large increase in CPUE for the years 1997 to 2001, but a relatively stable CPUE thereafter (2002-2013; Figure 50). However, as the

observed sets with positive hammerhead catches (Figure 49) cover areas where scalloped hammerhead sharks are more commonly observed (see Miller et al. (2014a)), and over half of the hammerhead observations from 1995-2014 were recorded into a general "hammerhead" category, conclusions regarding the trend in abundance of *S. zygaena* in this region would be highly uncertain (Rice et al. 2015).

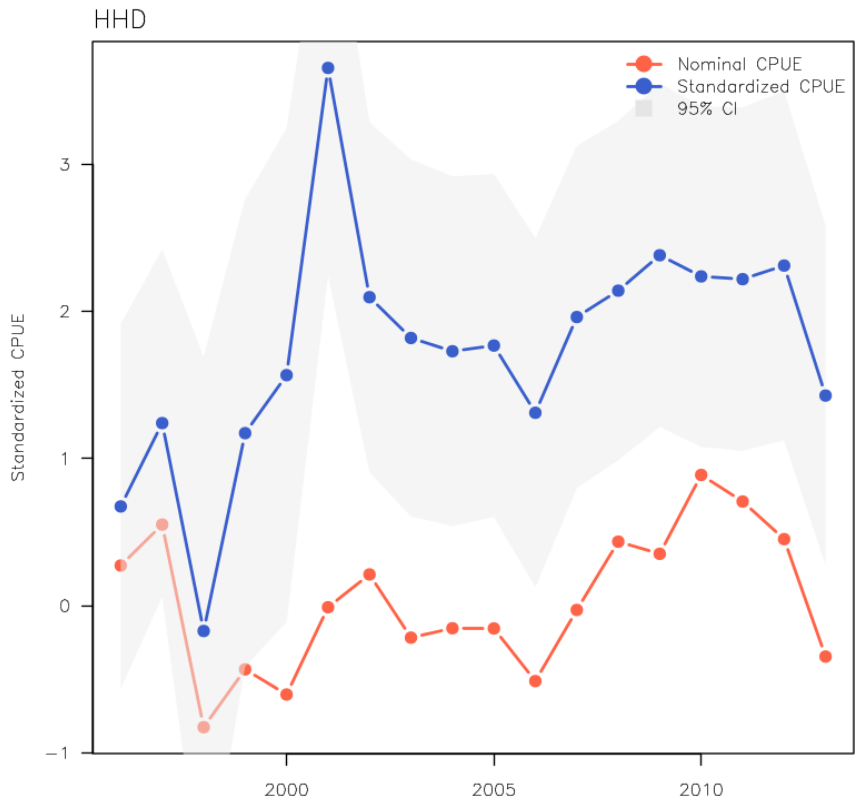


Figure 50. Nominal and standardized CPUE for hammerhead sharks from 1997-2013 based on longline data from the WCPFC convention area. Grey shaded area indicates the limits of the 5% and 95% confidence intervals (Source: Rice et al. 2015)

Furthermore, while the available length data for hammerhead sharks indicated that the majority of observed sharks in the longline fishery were immature (based on maturity sizes for *S. lewini*, which are smaller than those found for *S. zygaena*), the data was largely limited to observations in the adjoining seas of Papua New Guinea and the Solomon Islands' territorial waters from 1998-2008 (Rice et al. 2015). Although the proportion of scalloped to smooth hammerhead sharks in the territorial waters of

Solomon Islands could not be discerned, in Papua New Guinea, catches of scalloped hammerhead sharks by longline vessels were much greater in comparison to catches of smooth hammerhead sharks. In 2014, for example, 230 scalloped hammerheads were estimated as caught by Papua New Guinea longliners compared to only 18 smooth hammerhead sharks. As such, and was similarly found in other tropical waters, the trends and general findings from this area more likely reflect the status of *S. lewini* rather than *S. zygaena*.

However, overall, given the meager amount and quality of available data in this region, with issues ranging from low longline observer coverage to lack of historical reporting of sharks and the common practice of lumping all hammerhead species into one complex, Rice et al. (2015) concluded that a stock assessment to determine the status of the hammerhead shark species would not be feasible at this time.

Western and Central Pacific Region - Summary

While the fisheries operating within the temperate portions of this region report regular catches of smooth hammerhead sharks in the fisheries data, the available information, including catch time series and CPUE data, does not indicate that the impact of this utilization is contributing significantly to the species' risk of extinction. Reported catches of hammerhead sharks (not identified to species) at main fishing ports in Japan show no clear trend over time, with evidence of a decline in Japanese longline fishing effort, suggesting that fishing pressure on the species (and potential for fishery-related mortality) has likely been reduced. Off Australia, catch of smooth hammerheads in the shark fisheries is reportedly low, and based on 1950-2008 CPUE data from the NSW SMP program, no significant trend could be found in the abundance of hammerheads. While the actual numbers caught in the SMP program have declined in recent years, the SMP program is being regularly monitored and managed, with current mortality rates of *S. zygaena* not considered to be at a level that will jeopardize the survival or conservation status of the species. Smooth hammerhead sharks are also vulnerable to the longlines fisheries operating within the more tropical portion of its range in the Central Pacific; however, these fisheries are strictly regulated, and catch of the species is low with no evidence of declines in these populations.

Although there is significant uncertainty surrounding current catch and reporting estimates, the best available information does not indicate that overutilization is presently a threat that is significantly contributing to the species' risk of extinction. Further research and data collection on smooth hammerhead sharks is needed to determine the impact of current fishing pressure on the status of the smooth hammerhead sharks.

Eastern Pacific

In the eastern Pacific Ocean, smooth hammerhead sharks are both targeted and taken as bycatch in industrial and artisanal fisheries. While the range of the smooth hammerhead is noted as extending as far north as northern California waters, based on the available data, the distribution of the species appears to be concentrated in waters off Mexico and areas south. Observer data of the west-coast based U.S. fisheries further confirms this finding, with smooth hammerheads rarely observed in the catches. For example, in the California/Oregon drift gillnet fishery, which targets swordfish and common thresher sharks and operates off the U.S. Pacific coast, observers recorded only 70 bycaught smooth hammerheads and 2 unidentified hammerheads in 8,698 sets conducted over the past 25 years (from 1990-2015; data available from http://www.westcoast.fisheries.noaa.gov/fisheries/wc_observer_programs/sw_observer_program_info/data_summ_report_sw_observer_fish.html).

In Mexico, however, sharks, including hammerheads, are considered an important component of the artisanal fishery (Instituto Nacional de la Pesca 2006), and artisanal fisheries account for around 80% of the elasmobranch fishing activity (Cartamil et al. 2011). Sharks are targeted for both their fins, which are harvested by fishermen for export, and for their meat, which is becoming increasingly important for domestic consumption; yet, details regarding fishing effort and species composition of artisanal landings are generally unavailable (Cartamil et al. 2011).

In this review, information on Mexican artisanal catches, specifically of smooth hammerhead sharks, was found in studies examining artisanal fishing camps operating

off Sinaloa (purple star on Figure 51), the "Tres Marias" Islands of Mexico (yellow star on Figure 51), and Laguna Manuel (red star on Figure 51). These studies are discussed in further detail below.

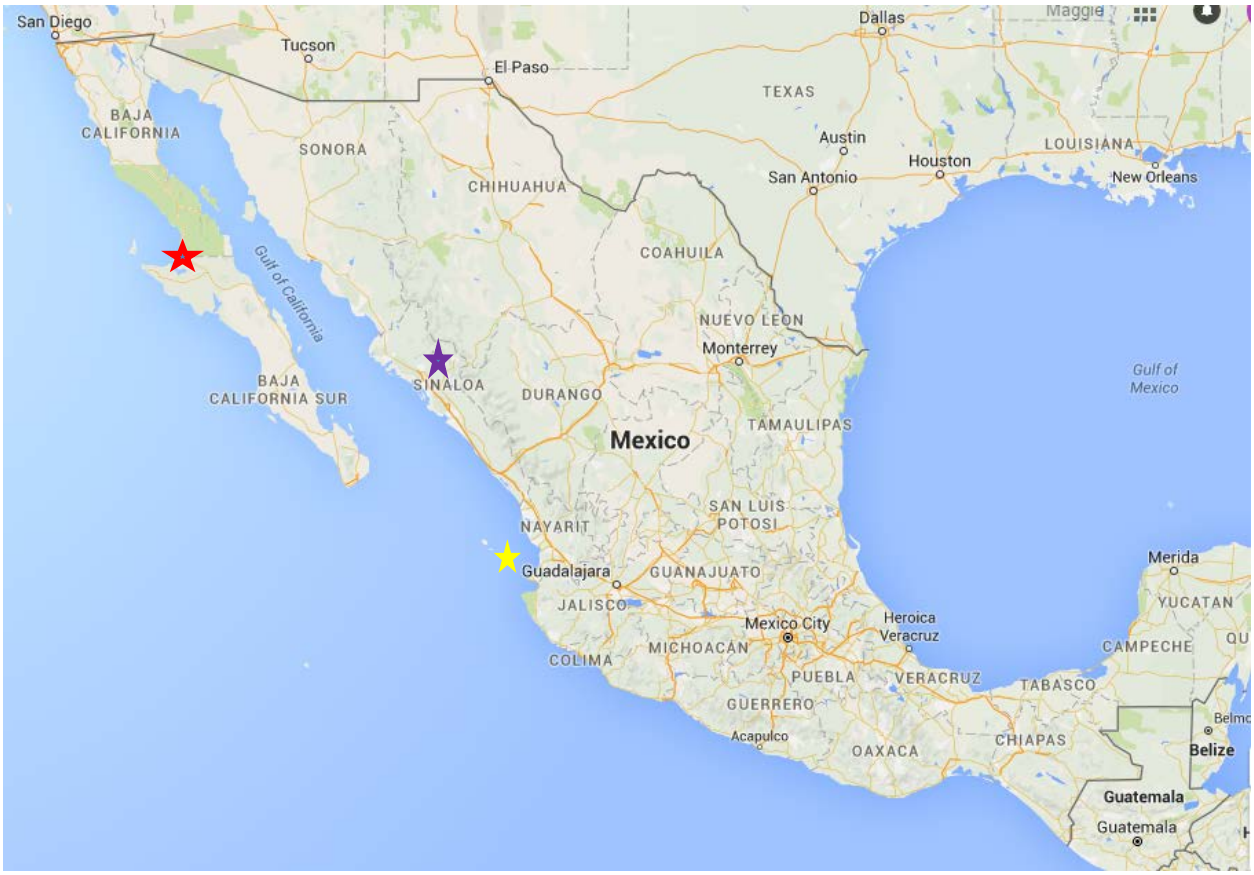


Figure 51. Location of available Mexican artisanal fishery studies. Red star = Laguna Manuel; Purple star = Sinaloa; Yellow star = "Tres Marias" Islands

The Mexican state of Sinaloa has an active artisanal elasmobranch fishery that operates within the southeastern Gulf of California. In 2006, elasmobranch landings from Sinaloa comprised 16.5% of Mexico's total elasmobranch production, the greatest of any Mexican state (Bizzarro et al. 2009). From 1996-2006, elasmobranch landings ranged from 1,924 t – 5,883 t, averaging 1.6% of total fishery production for the state (Bizzarro et al. 2009). In 1999, a survey of the Sinaloa targeted artisanal elasmobranch fishery revealed that sharks numerically dominated the landings, with *S. lewini* a primary target for the fisheries. Over the course of the year, 1,584 scalloped hammerheads were landed, making it the most caught species of shark (accounting for 66% of total shark

landings and 44% of total elasmobranch landings) (Bizzarro et al. 2009). While smooth hammerhead sharks were the third most frequently caught shark (n=112), the species comprised only 5% of the total shark landings and 3% of the total elasmobranch landings (Bizzarro et al. 2009). The CPUE (# individuals/vessel/trip) of smooth hammerhead sharks varied from 0.7 in the winter season (December – February) to 0.6 in spring (March-May), 0.1 in the summer (June-August), and 0 in the autumn (September-November), with the majority caught by bottom set longlines (Bizzarro et al. 2009). Of concern is the fact that of the 85 sampled individuals landed during this survey, all were juveniles of sizes 85-155 cm stretched TL (Bizzarro et al. 2009).

Similarly, findings from 1995-1996 and 2000-2001 surveys of the artisanal fishery off the "Tres Marias" Islands of Mexico also indicated a predominance of immature smooth hammerhead sharks in the artisanal landings. In total, 883 smooth hammerhead sharks were landed, primarily from waters south of "Tres Marias" Islands (where the shark fishing season lasts from October – March), with only 20% of the females and 1% of the males considered mature (Pérez-Jiménez et al. 2005). Unlike the findings from the Sinaloa artisanal fisheries, where the majority of smooth hammerhead sharks were caught by longline, the CPUE of smooth hammerheads was higher when fishermen used drift gillnets. The authors note that due to the lack of effort information in the Mexican catch statistics, catch trends cannot be assessed (Pérez-Jiménez et al. 2005). Instead, only the species that appear to be most important in the catches can be identified and compared with results from past studies. Based on past reports of catches and the findings from the present study, the authors came to the conclusion that the Pacific sharpnose shark (*Rhizoprionodon longurio*) and scalloped hammerhead shark have likely been exploited off the coast from Sinaloa to Nayarit for the past three or four decades (Pérez-Jiménez et al. 2005). Smooth hammerhead sharks, on the other hand, were not identified as an important shark species in the historical reports from the 1960s through the 1980s (Pérez-Jiménez et al. 2005), suggesting likely minimal historical exploitation of S. *zygaena*.

From 2006-2008, the Laguna Manuela artisanal fishing camp, on the Pacific coast of Baja California, was surveyed after it was identified as one of the most important

elasmobranch fishing camps in Baja California. Over the 2-year study, beach surveys covered 387 panta trips (small-scale operations, using 5-8 m long boats), which captured 10,595 elasmobranchs using gillnet, longline, and trap gear (Cartamil et al. 2011). A total of 306 smooth hammerhead sharks were caught by gillnet, with a CPUE of 1.32 (mean catch per trip), and 10 were caught on longline, with a corresponding CPUE of 0.08 (Cartamil et al. 2011). Smooth hammerhead sharks comprised around 3% of the total elasmobranch catch, with the majority of the individuals <160 cm TL, indicating that fishing may be taking place in juvenile habitat for the species. Carcass discards sites were also surveyed outside of the Laguna Manuela fishing camp, with species composition within the sites very similar to the beach survey catch. Within the 17 carcass discard sites, 31,860 elasmobranch carcasses were identified, with 374 attributed to smooth hammerhead sharks (1.17%) (Cartamil et al. 2011).

Given the species' slow growth rate and late maturity, the removal of primarily immature individuals from the *S. zygaena* population is concerning and may contribute to declines in abundance. In fact, this has already been observed for other hammerhead species in Mexican Pacific waters. In a review of data from both fishery dependent and fishery-independent surveys and ichthyological records, Pérez-Jiménez (2014) concluded that three species of hammerhead sharks (*S. media*, *S. mokarran*, and *S. tiburo*), which were previously abundant in the Gulf of California in the 1960s, are now potentially extirpated due to historical and continued fishing pressure. On the other hand, scalloped hammerheads were identified as the most frequently landed hammerhead species in the data, and the smooth hammerhead shark as the second most frequent. While these two species were still evidently abundant in the datasets, the authors noted that regional efforts to coordinate management strategies and constant monitoring of catches are still required for these species. For smooth hammerhead sharks, in particular, Pérez-Jiménez (2014) reiterates the need for further investigation into threats, trends, and life history parameters in order to more accurately determine the status of the species.

In July 2015, the CITES Scientific Authority of Mexico (CONABIO) held a workshop in an effort to collect information and assess the vulnerability of CITES-listed shark

species to harvesting pressures in fishing grounds throughout all Mexican waters. Participants from government agencies, academic institutions, civil associations and independent consultants with experience on the management and knowledge of shark fisheries in all fishing areas and coasts of Mexico gathered to discuss the available data and conduct Productivity and Susceptibility Assessments for each shark species (following methods proposed by Patrick et al. 2010; Benítez et al. (2015)). For *S. zygaena*, the semi-quantitative assessment looked at the species' vulnerability in specific fishing zones along the Pacific coast and also by fishing vessel type (small or coastal vessels versus large fishing vessels). Results from the assessment showed that *S. zygaena* had a medium (brown) to low (green) vulnerability to fishing pressure by large Mexican fishing vessels for all evaluated fishing zones (Figure 52; Benítez et al. 2015).

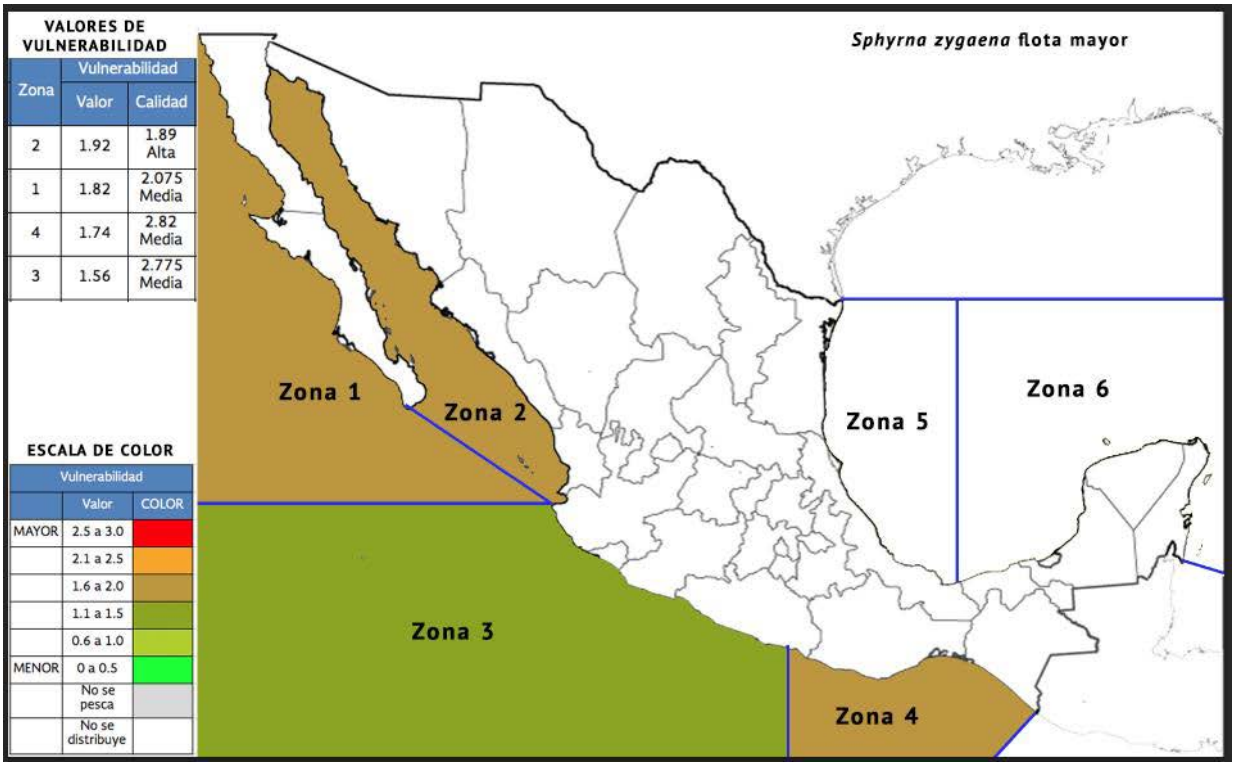


Figure 52. Map showing the vulnerability gradient of *S. zygaena* to fishing pressure by Mexico's large fishing vessels in different zones. Vulnerability gradient ranges from green (low vulnerability) to red (high vulnerability) (Source: Benítez et al. 2015)

Perhaps not as surprising, given the above information regarding artisanal fisheries, *S. zygaena* showed a higher vulnerability (orange) to fishing by smaller/coastal vessels,

particularly off the Pacific coast of Baja California south to Jalisco (Zone 1 on Figure 53; Benítez et al. 2015).

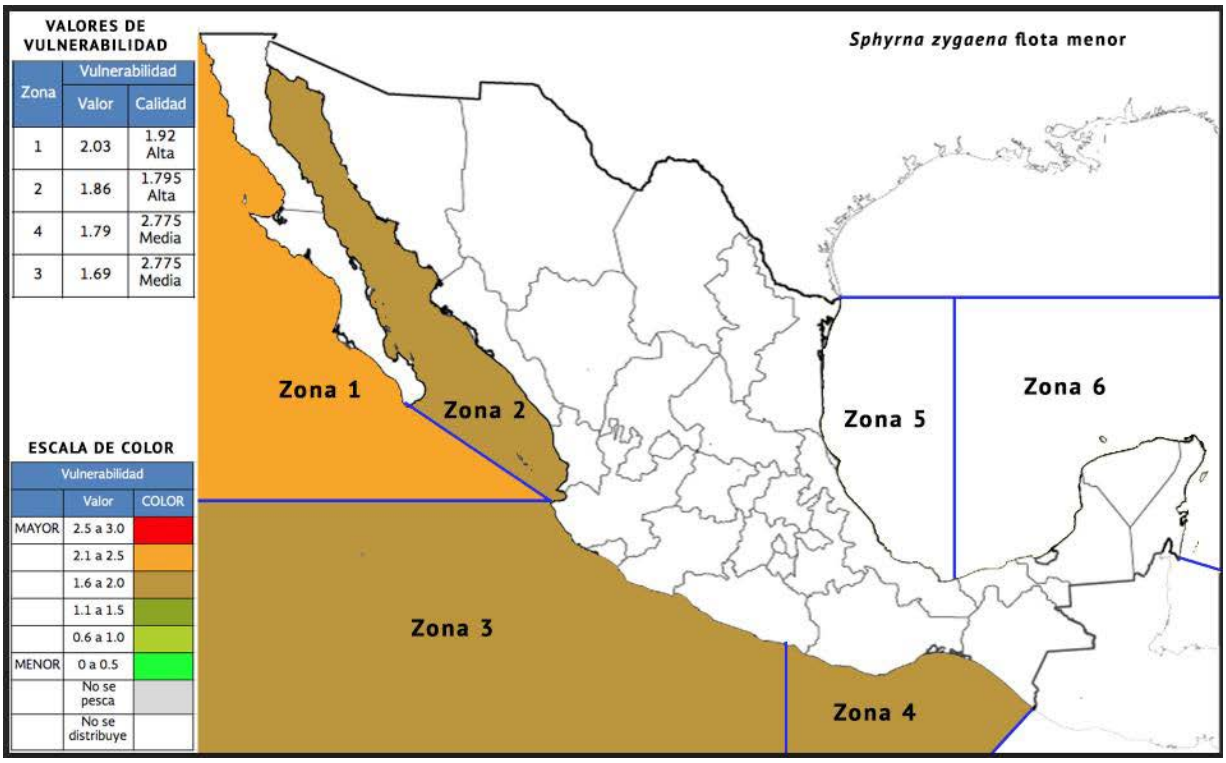


Figure 53. Map showing the vulnerability gradient of *S. zygaena* to fishing pressure by Mexico's small and coastal fishing vessels in different zones. Vulnerability gradient ranges from green (low vulnerability) to red (high vulnerability) (Source: Benítez et al. 2015)

While these assessments provide managers and scientists with an index of the vulnerability of target and non-target species to overfishing within a fishery (e.g. *S. zygaena* is more likely to experience overfishing by smaller/coastal vessels as opposed to the larger fishing vessels), it does not provide information on the current status of the species or whether the species, is, in fact, being overfished. However, based on the above information from the assessment and the fisheries surveys, it is clear that smooth hammerhead sharks are being utilized and potentially facing high fishing pressure, particularly in the artisanal fisheries. Given the life history traits of the species, and the evidence that the majority of the captured *S. zygaena* have not yet reached maturity, the fishing pressures and related mortality may lead to declines in this population from which recovery would be difficult. Yet, without any information on current population

size or CPUE trends in this region, it is difficult to conclude, with any certainty, the impact of this level of utilization on the extinction risk of the species. Due to the limited data available, the status of the Mexican *S. zygaena* population remains highly uncertain.

In waters farther south in the Eastern Pacific, three countries (Costa Rica, Ecuador and Peru) contribute significantly to shark landings and are important suppliers of shark fins for the Asian market. In Costa Rica, the available fisheries data suggest that smooth hammerhead sharks are only rarely caught as catch and bycatch. For example, in a study that analyzed observer data from Costa Rica's Pacific mahi-mahi (*Coryphaena hippurus*) targeted longline fishery, only 3 smooth hammerhead sharks were reported as caught from 217 sets observed between 1999 and 2008 (Figure 54) (Whoriskey et al. 2011). In another study that examined observer data recorded on Costa Rican longline vessel (482 sets and over 320,000 hooks), a total of only 17 smooth hammerhead sharks were caught from 1999-2010, with a mean catch rate of 0.052 sharks per 1000 hooks (Dapp et al. 2013).

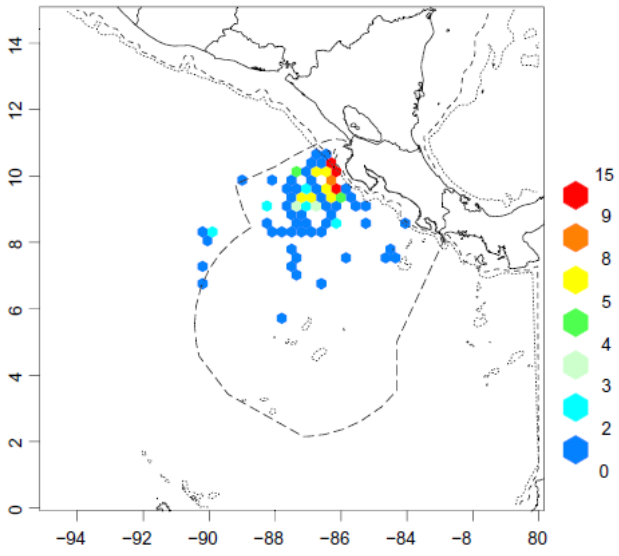


Figure 54. Observed mahi-mahi targeted pelagic longline fishing effort in number of sets between 1999 and 2008 (Source Whoriskey et al. 2011).

While shark fishing is still allowed in Costa Rican waters, no other information on current catch or bycatch levels of smooth hammerhead sharks in the Costa Rican fisheries could be found. However, in December 2014, around 259.2 kg of *S. zygaena* fins and 152 kg of *S. lewini* fins were exported out of Costa Rica to Hong Kong. In

February 2015, Costa Rican officials allowed the export of another batch of scalloped and smooth hammerhead fins, with estimates of total weight between 249-490 kg (depending on the source of information) (Boddiger 2015). Based on the weight of the fins from these two shipments, and after factoring in the loss of weight due to drying of the fins, the conservation group Sea Turtle Recovery Programme (PRETOMA) estimates that the fins came from between 1,500 and 2,000 hammerhead sharks (a much higher estimate than what officials had previously reported; Boddiger 2015). Of concern is the fact that the CITES Administrative Authority of Costa Rica granted export permits for the above shipment without first identifying the amount of fins allowed for a CITES NDF. Consequently, this action spurred a number of protests by environmental groups who condemned the issuing of export permits before the NDF process had been completed. As a result, the National System of Conservation Areas (SINAC), in its role as the CITES Administrative Authority of Costa Rica, stated in March 2015 that no more export permits for hammerhead fins will be issued until the NDF process is completed (Murias 2015).

Although the moratorium on exports may curb illegal fishing of the species (which was suspected to be the origin for some of the fin exports; see Boddiger 2015), smooth hammerheads can still be caught as bycatch during normal fishing operations, so fishery mortality rates may not substantially decrease for the species. In addition, depending on the findings from the NDF process, some level of export of hammerhead products may still be allowed in the future. Nevertheless, without information on the size of the smooth hammerhead population in this region, the impact of present levels of fishery-related mortality on the extinction risk of *S. zygaena* remains unknown.

In Ecuador, directed fishing for sharks is prohibited, but sharks can be landed if bycaught. Hammerhead sharks, in particular, tend to be landed as incidental catch and used primarily for the fin trade. Unlike many of the other areas discussed in this report, smooth hammerhead sharks appear to be the dominant hammerhead species caught in Ecuadorian waters. Based on artisanal records from 2007-2011, catches of *S. zygaena* are on the order of three to four times greater than catches of *S. lewini* (Figure 55). Additionally, over the time series, catches of *S. zygaena* depict a generally increasing

trend; however, effort data is unavailable, and, as indicated by Jacquet et al. (2008), catches are likely significantly under-reported.

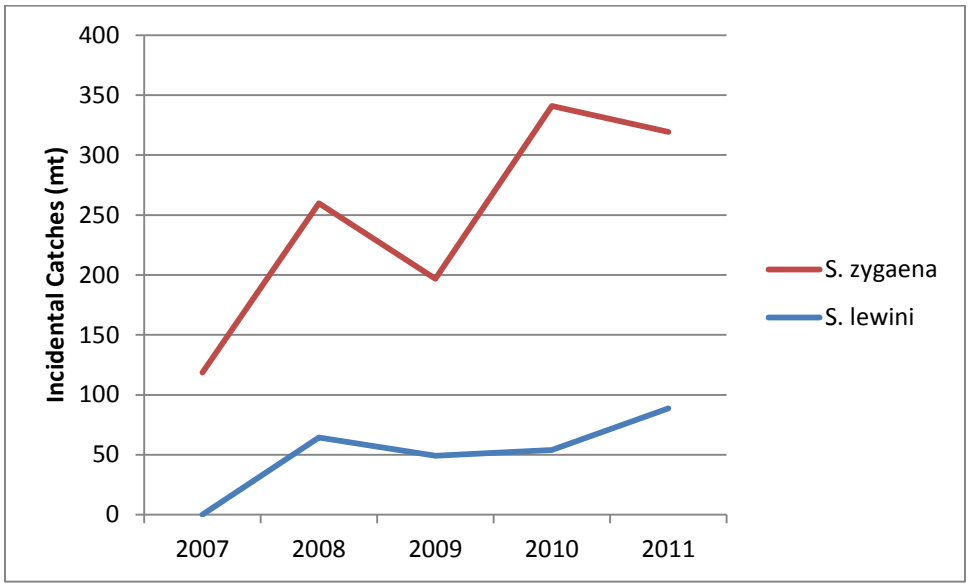


Figure 55. Total incidental catches (mt) of smooth hammerhead sharks (red line) and scalloped hammerhead sharks (blue line) from September 2007 to December 2011, landed by Ecuador's artisanal fishing fleet. Catches were landed the following major ports of Ecuador: Esmeralds, Muisne, Pedernales, Bahia, Manta, Puerto Lopez, Santa Rosa, Anconcito, Puerto Boliva (Source: http://tiburon.viceministerioap.gob.ec/tiburon-en-ecuador/estadisticas)

Aguilar et al. (2007) notes that the schooling behavior of scalloped and smooth hammerhead sharks increases their vulnerability to being caught in large numbers, particularly by the surface gillnets used in certain ports such as Manta, Puerto Lopez, and Santa Rosa. These ports also happen to be the ones reporting the largest amounts of incidental catch of smooth hammerhead sharks (see Monthly Ecuadorian Port Statistics, available at: http://tiburon.viceministerioap.gob.ec/tiburon-en-ecuador/estadisticas). However, contrary to this assumption, results from a study examining 2008-2012 data from the artisanal fishery landing monitoring program of the Republic of Ecuador (SCM), found that 76% of the *S. zygaena* landings (by weight) were attributed to longline fisheries (Martinez-Ortiz et al. 2015).

Regardless of the type of fishery, the majority of the smooth hammerheads taken in Ecuadorian fisheries appear to be immature (Aguilar et al. 2007; Cabanilla and Fierro

2010), which, as mentioned previously, could potentially contribute to declines in the abundance of the smooth hammerhead population, particularly given the species' life history parameters. However, without information on corresponding fishing effort or population sizes, inferences regarding the status of the species or the impacts of current levels of take on the extinction risk of the species cannot be made with any certainty at this time.

In a recent 61-year analysis of Peruvian shark fisheries, Gonzalez-Pestana et al. (2014) noted that from 1950-2010, Peru had the second highest number of chondrichthyan landings in the Eastern Pacific after Mexico, and the sixth highest accumulated landings in the entire Pacific. From 2006-2010, *S. zygaena* was the third most commonly landed shark species (comprising 15% of the shark landings) by the Peruvian small-scale fishery (Gonzalez-Pestana et al. 2014). The majority (83%) of the smooth hammerhead sharks were caught by gillnets (likely immature; Castañeda (2001)) and landed at ports in central and northern Peru. Between 2000 and 2010, the authors noted a significant increase in the amount of reported landings for smooth hammerhead sharks, with peaks in 1998 and 2003 (Figure 56). They estimated that landings increased by 7.14% per year (CI: 1.2% - 13.4%); however, this estimate may be strongly influenced by the peak in 2003. In fact, if the 2003 estimates are removed from the graph, smooth hammerhead landings appear to have been fairly stable since 1999 (below 500 t). Based on the latest available landings data, this trend does not appear to have changed, with estimates of 364 t of *S. zygaena* landed in Peru in 2014 (Instituto del Mar del Peru 2014), although, as Gonzalez-Pestana et al. (2014) note, without accompanying information on fishing effort, it is difficult to fully understand the dynamics of the shark fishery, and particularly, in this case, its impact on the smooth hammerhead population.

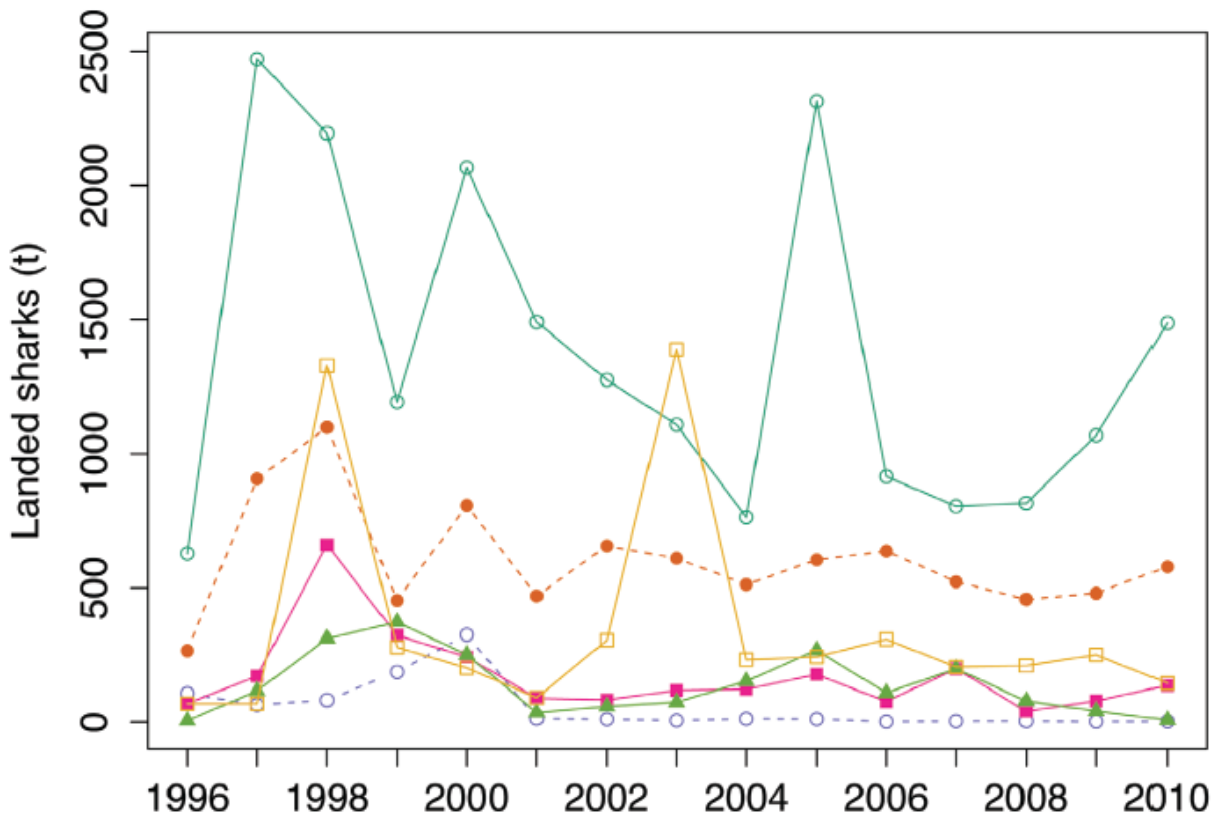


Figure 56. Annual landings (1996-2010) of the six most important commercial shark species in Peru: *Sphyrna zygaena* (yellow solid line, open square), *Prionace glauca* (blue solid line-open circle), *Isurus oxyrinchus* (orange dashed line-closed circle), *Squatina californica* (light purple dashed line-open circle), *Mustelus whitneyi* (pink solid line-closed square), and *Alopias vulpinus* (light green solid line-closed triangle) (Source: Gonzalez-Pestana et al. 2014)

In Chile, reports of *S. zygaena* are less common, which is likely due to this region representing the southern extent of the species' range in the Eastern Pacific. While *S. zygaena* does not appear to be recorded in the annual landing fishery statistics for Chile, the species has been reported as bycatch in the swordfish longline fisheries operating within Chile's EEZ (Sebastian et al. 2008). And although artisanal fishermen consider smooth hammerhead meat to be undesirable to buyers, due to a thick layer of fat (Universidad Austral de Chile 2005a), the species does occasionally appear in the Chilean fish markets (Universidad Austral de Chile 2005b). Sebastian et al. (2008) also provides evidence of the species occurrence in the Chilean shark fin trade. Using genetic sampling, Sebastian et al. (2008) analyzed 654 fins from two fin drying facilities and 251 fins from two fin-storage warehouses in central Chile and found that while none of the

samples from the drying facilities matched to smooth hammerhead sharks, 13% of the fins in the storage facilities were identified as *S. zygaena* (n=33). These findings provide evidence of the utilization and interest in the species for the fin trade in this southern portion of the its range; however, given the scarcity of *S. zygaena* within the fisheries data from Chile, with the smooth hammerhead shark generally characterized as rare in Chilean waters (Brito 2004), it is unlikely that this level of utilization will cause significant impacts on the population of the species to the point where it is at risk of extinction in this region.

RFMO Information

In the Eastern Pacific, the Inter-American Tropical Tuna Commission (IATTC) is the RFMO responsible for the conservation and management of tuna and other marine resources in this region. Since 1993, observers have recorded shark bycatch data onboard large purse seiners in the eastern Pacific. Records show that between 1993 and 2013, the number of hammerheads caught as bycatch has been variable. Catches peaked in 2003-2004, at around 3,000 sharks, before significantly decreasing (Figure 57). This decline is thought to be, in part, a result of purse seiners moving fishing effort farther offshore in recent years to waters with fewer hammerhead sharks (Figure 58), but it could also reflect a decline in the actual abundance of hammerhead sharks (Hall and Roman 2013). Since 2006, catches have fluctuated between 750 and 1,400 animals (Román-Verdesoto and Hall 2014).

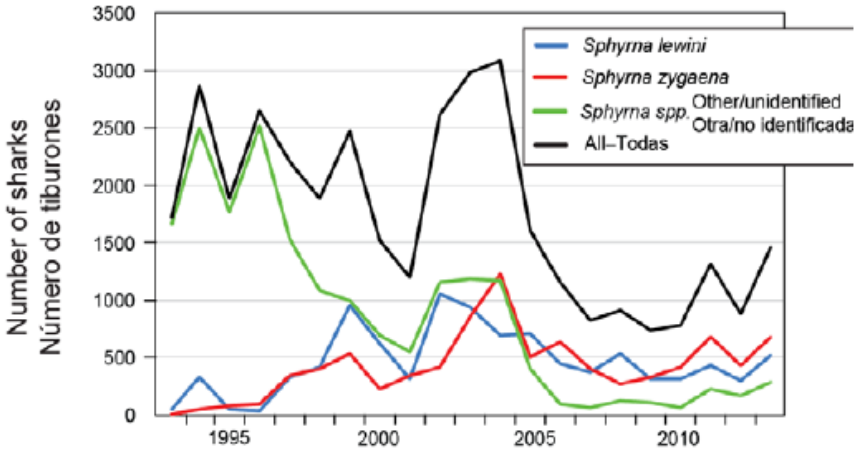


Figure 57. Observer-recorded annual bycatch of hammerhead sharks (in numbers) by purse-seine vessels operating in the Eastern Pacific Ocean from 1993-2013 (Source: Román-Verdesoto and Hall 2014)

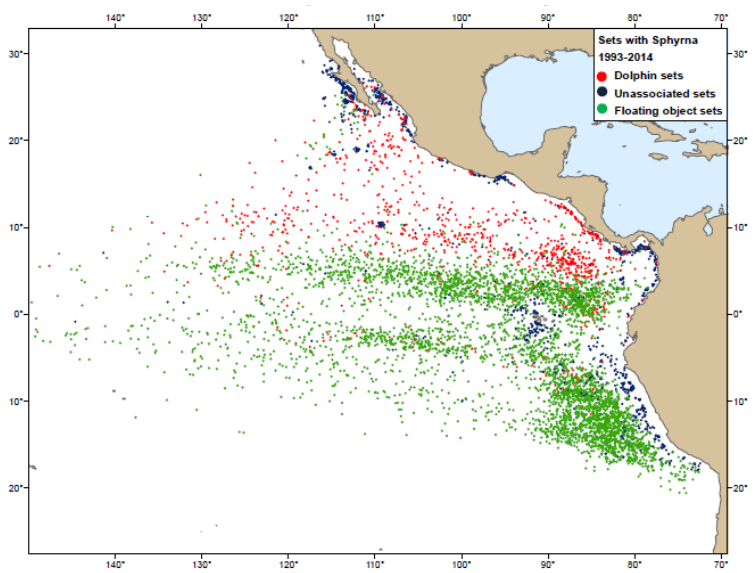


Figure 58. Spatial distribution of tuna purse-seine sets with positive captures of *Sphyrna* individuals in the Eastern Pacific Ocean (Source: Román-Verdesoto 2015)

The Scientific Advisory Committee to the IATTC noted that this purse-seine catch may represent only a relatively small portion of the overall harvest of hammerhead sharks in this region, with insufficient data (due to the rarity of *Sphyrna* spp. in the catch) to provide for a meaningful analysis. Rather, the Committee indicated that the majority of harvest in this region is likely taken by the artisanal fisheries, which operate more in coastal and inshore waters and exert considerable fishing effort on hammerhead populations, targeting both juveniles and adults (Hall and Roman 2013; IATTC 2015). However, as already discussed, and further acknowledged by others in reviewing the IATTC information (Hall and Roman 2013; Román-Verdesoto 2015), the data from these artisanal fishing operations are, for the most part, largely unavailable or not of the detail needed (e.g., species-specific with corresponding fishing effort over time) to examine impacts on the populations (Hall and Roman 2013; Román-Verdesoto 2015).

Eastern Pacific Region - Summary

As noted in many of the previously discussed studies from this region, the trends and status of the species is highly uncertain. Without additional information on fishing effort, population sizes, or trends in abundance, it is difficult to determine whether the historical levels of take and current fishing pressure and associated mortality present a significant threat to the species. As it stands, the best available information do not indicate that the species has suffered declines to the point where it is at risk of

depensatory processes. While the species does appear to be a target for many of the artisanal fisheries operating within the region, with evidence of *S. zygaena* fins being exported to the Far East, the available data does not suggest that present utilization levels are impacting populations of *S. zygaena* to such a degree that would significantly increase the species' risk of extinction.

Shark Fin Trade

As noted in the above regional reviews examining overutilization of the species, hammerhead sharks are targeted and valued particularly for their fins. While a demand for other shark products (including liver oil, hides, meat, teeth and jaws) has existed since the early 1900s, beginning in the 1980s, the focus shifted to fins primarily due to the increasing demand for shark fin soup (Biery and Pauly 2012). As hammerhead fins tend to be large in size, with high fin needle content (a gelatinous product used to make shark fin soup), they are one of the most valuable fins in the international market. Based on 2003 figures, smooth hammerhead shark fins fetch prices as high as $88/kg (Abercrombie et al. 2005).

In the Hong Kong fin market, which is the largest fin market in the world, *S. lewini* and *S. zygaena* are mainly traded under a combined market category called *Chun chi,* and found in a 2:1 ratio, respectively (Abercrombie et al. 2005; NMFS 2014a). *Chun chi* is the second most traded category, comprising around 4-5 % of the annual total fins (Clarke et al. 2006a). Based on data from 2000-2002, Clarke et al. (2006b) applied a Bayesian statistical method to the Hong Kong fin trade data and estimated that around 1.3-2.7 million individuals of scalloped and smooth hammerhead sharks (equivalent to a biomass of 49,000-90,000 tons) were traded in this market each year.

Given their relatively high price and popularity in the Hong Kong market, there is concern that many smooth hammerhead sharks may be either targeted or caught as incidental catch but kept for the fin trade as opposed to released alive. In fact, the lucrative incentive of the shark fin trade has also led to many instances of illegal fishing of sharks, and hammerhead species in particular (see **Inadequacy of Existing Regulatory Mechanisms** section below for more information on illegal fishing). Due

to the concern over the extent of use of the hammerhead species in the international shark fin trade, the scalloped, smooth, and great hammerhead sharks were listed on CITES Appendix II (effective September 14, 2014) at the Sixteenth Meeting of the Conference of the Parties to CITES. This listing helps to conserve these species and ensure that international trade of these species is legal and sustainable. Additionally, there has been a global push to decrease the overall demand of shark fins, especially for shark fin soup, and a recent decline in the trade of shark fins through Hong Kong.

With the growing awareness of overfishing, particularly of chondrichthyan species due to the demand for their fins, many countries and states began passing "finning" laws in the early and mid-2000s. Finning is the term used to describe the controversial practice of severing the valuable fins from sharks and returning the remaining shark carcass to the sea in order to maximize cargo space for more valuable fishery products. By 2011, the Pew Environment Group conducted a review of 211 countries, territories, and political entities and found that approximately one third had shark finning regulations in place (PEW Environment Group 2012). Usually, these bans are in the form of either a "fins-attached" policy, meaning that fins need to be naturally attached to the shark when landed, or a fins-to-carcass ratio, meaning that the weight of fins compared to the weight of carcasses onboard cannot exceed a certain percent. For many of the fins-to-carcass type of regulation, this percent is set at 5%. However, this universal ratio may not be appropriate for certain shark species whose fins have less mass, which would therefore allow fishing vessels to land more fins than bodies and still pass inspection. For smooth hammerhead sharks, this does not appear to be the case. Based on data from 127 smooth hammerhead sharks, the average wet fin-to-round mass ratio is estimated to be 5.74 (±0.04) (Biery and Pauly 2012), indicating that the 5% ratio would likely be effective at preventing the finning of smooth hammerhead sharks.

While these regulations are aimed at curbing the practice of shark finning, they do not prohibit the fishing of sharks. However, beginning in 2001, countries and states started implementing complete bans on the possession, sale, and trade of shark fins or products to dis-incentivize fishermen from targeting sharks, and many others have completely prohibited shark fishing altogether (see **Appendix**) (PEW Environment Group 2012;

Whitcraft et al. 2014). By 2003-2004, both global catches of chondrichthyans and trade in shark fins had peaked, and, despite the continued expansion of the Chinese economy, in the following years (2008-2011), quantities leveled out at around 82-83% of the peak figure (Dent and Clarke 2015; Eriksson and Clarke 2015; Figure 59). In 2012, the trade in shark fins through China, Hong Kong Special Administrative Region (SAR), which has served as an indicator of the global trade for many years, saw a decrease of 22% from 2011 figures, indicating that recent government-led backlash against conspicuous consumption in China, combined with global conservation momentum, appears to have had some impact on traded volumes (Dent and Clarke 2015; Eriksson and Clarke 2015). Dent and Clarke (2015) also note that a number of other factors may have contributed to this downturn in the trade of fins through China, Hong Kong SAR, including:

- increased domestic chondrichthyan production by the Chinese fleet;
- new regulations in China government officials' expenditures;
- consumer backlash against artificial shark fin products;
- increased monitoring and regulation of finning;
- a change in trade dynamics related to China's entry into the World Trade Organization in 2001 and subsequent trade agreements with China, Hong Kong SAR;
- other trade bans and curbs; and
- a growing conservation awareness.

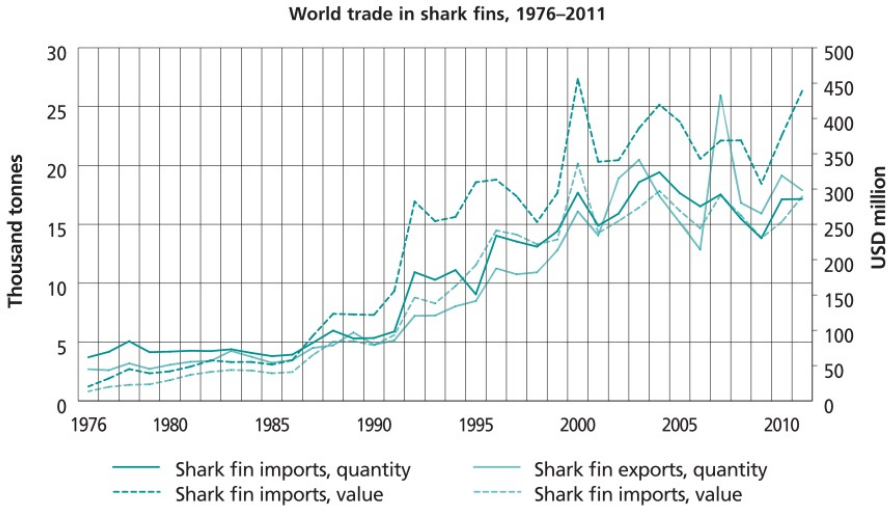


Figure 59. Trends in the global trade in shark fins (including exports and imports) from 1976 to 2011 (Source: Dent and Clarke 2015).

As trade in shark fins appears to have stabilized and may even be on the decline, the opposite is true for the trade in shark meat. From 2000-2011, the shark meat trade has grown at a steady rate of 4.5% per year. The latest official FAO figure of chondrichthyan meat imported in 2011 (121,641 t worth $379.8 million) represents a 42% increase by volume compared with 2000 (Dent and Clarke 2015). Additionally, the trend observed in shark meat trade unit values in many key trading countries has increased in the past decade, even as the quantity of shark meat being traded has risen substantially, suggesting a growing underlying demand for these products (Dent and Clarke 2015). Dent and Clarke (2015) caution that is it not clear at this time whether part of the increasing trend in the meat trade data has been due to more species-specific commodity coding in trade database; however, they expect the meat trade to continue to grow as fishermen continue to move towards full utilization of shark carcasses (i.e., historically underutilized chondrichthyan species will be increasingly utilized for their meat). While smooth hammerhead shark meat is preferred over the other hammerhead species, in general, hammerhead meat is considered essentially unpalatable due to its high urea concentration which requires more intensive processing and preparation for consumption (Vannuccini 1999). Therefore, it is unlikely that this increasing demand for shark meat will create new demand for the species. Even if smooth hammerhead sharks do become increasingly utilized for their meat, they are one of the top valued species for their fins, so this trend is unlikely to contribute to additional fishing pressure on the species (as the species is rarely discarded as it is). Furthermore, as smooth hammerhead sharks tend to have relatively low survival rates after being caught by various fishing gears (including longlines and gillnets), a change in market demand (from fins to meat) would not necessarily change the species' mortality rates in commercial fisheries.

Overall, while it is clear that the shark fin trade is likely the driving force behind the industrial and artisanal fisheries exploitation of the species, the best available information on the present levels of utilization do not indicate that the species is at a significant risk of extinction. With the CITES Appendix II listing, mechanisms are also now in place to monitor and control international trade in the species and ensure that this trade is not detrimental to the survival of the species in the wild. Furthermore, the

overall demand for shark fins may be on a declining trend; however, whether this decline will also translate to lower fishing mortality rates is highly uncertain. Potentially, if the demand for fins continues to decrease in the future, so will the direct targeting of hammerhead sharks (and illegal fishing of the species). However, in many cases (as evidenced by the best available information), smooth hammerheads are caught as bycatch during fishing operations for other species, like tuna and swordfish. While a decrease in the demand for shark fins may decrease the likelihood of retention of the species, given the high at-vessel mortality of the species, it may not have a significant impact on decreasing current fishing mortality rates. Regardless, at this time, the best available information does not provide substantial evidence that the demand for smooth hammerhead sharks in the shark fin trade is contributing to declines in the species that place it at a significant risk of extinction.

Disease or Predation

No information has been found to indicate that disease or predation is a factor that negatively affects smooth hammerhead shark abundance. These sharks have been documented as hosts for the nematodes *Parascarophis sphyrnae* and *Contracaecum* sp. (Knoff et al. 2001); however, no data exist to suggest these parasites are affecting *S. zygaena* abundance. Additionally, predation is also not thought to be a factor negatively influencing smooth hammerhead abundance numbers. The most significant predator on smooth hammerhead sharks is likely humans; however, a study from New Zealand observed two killer whales (*Orcinus orca*) feeding on a small, juvenile (~100 cm TL) smooth hammerhead shark (Visser 2005). In a 12-year period that documented 108 encounters with New Zealand killer whales, only 1 smooth hammerhead shark was preyed upon (Visser 2005); thus, predation on *S. zygaena* by killer whales is likely opportunistic and not a contributing factor to abundance levels of smooth hammerhead sharks. Juvenile smooth hammerhead sharks also likely experience predation by adult sharks (including their own species); however, the rate of juvenile predation and the subsequent impact to the status of smooth hammerhead sharks is unknown.

Inadequacy of Existing Regulatory Mechanisms

Although none of the previously discussed ESA section 4(a)(1) factors were identified as

significant threats to *S. zygaena*, existing regulatory mechanisms in some portions of the species' range could be strengthened (or better enforced) to promote the long-term viability of the species. For example, in a recent study that examined current regulatory and management measures for smooth hammerhead sharks, including data collection requirements and level of compliance, Lack et al. (2014) concluded that additional management intervention may be warranted for the species. Lack et al. (2014) came to this conclusion by following a rapid assessment framework for determining exposure and management risk (M-Risk). This framework is based on three elements: (1) stock status; (2) adaptive, species-specific management; and (3) generic management. All three elements are weighted to determine the overall M-risk score, but not equally. The element of adaptive, species-specific management was given the greatest emphasis in calculating the M-Risk scores.

According to Lack et al. (2014), the M-Risk assessment framework is intended to be used as a guide to identify and prioritize the species or stocks of sharks where closer scrutiny of management measures may be warranted. For the smooth hammerhead shark, six management unit/stocks (based on RFMO units) were included in the assessment: CCBST (Commission for the Conservation of Southern Bluefin Tuna), GFCM, WCPFC, IOTC, IAATC, and ICCAT. In terms of adaptive management, the smooth hammerhead shark received fairly low scores (indicating high risk/poor management), primarily due to the lack of species-specific management of the shark. However, in terms of the generic management element, which addressed issues of whether general management measures (like shark finning measures or catch quotas on target species) are likely to reduce the impacts on the species being assessed, the scores were higher (indicating lower risk). Additionally, it is important to note that this framework adopts a precautionary approach to uncertainty arising from lack of information, which will bias the overall M-risk scores toward higher risk (i.e., poorer management). For example, in the case of the smooth hammerhead shark assessment, all reviewers noted that the stock status element was "unknown" or "uncertain." In the assessment, "unknown" or "uncertain" received the lowest score of 1, equivalent to a stock that is overfished with overfishing occurring and/or where the exploitation rate is excessive. As such, when scores were averaged and weighted (again, with the adaptive

management scores receiving the most weight, followed by the stock status, and then generic management), the smooth hammerhead shark received high overall M-Risk ratings for each management unit (Lack et al. 2014). While this assessment is by no means a definitive assessment of the risk faced by the smooth hammerhead shark, it does suggest that additional management measures (particularly species-specific management measures) could benefit the species. For a comprehensive list of current management measures pertaining to hammerheads, as well as sharks in general, see **Appendix**.

Illegal fishing

Despite the number of existing regulatory measures in place to protect sharks and promote sustainable fishing, enforcement tends to be difficult and illegal fishing has emerged as a problem in many fisheries worldwide. Specifically, illegal fishing occurs when vessels or harvesters operate in violation of the laws of a fishery. In order to justify the risks of detection and prosecution involved with illegal fishing, efforts tend to focus on high value products (e.g., shark fins) to maximize returns to the illegal fishing effort. Thus, as the lucrative market for shark products, particularly shark fins, developed, so did increased targeting, both legal and illegal, of sharks around the world. Given that illegal fishing tends to go unreported, it is difficult to determine, with any certainty, the proportion of current fishery-related mortality rates that can be attributed to this activity. This is particularly true for smooth hammerhead sharks, where even legal catches go unreported. A study that provided regional estimates of illegal fishing (using FAO fishing areas as regions) found the Western Central Pacific (Area 71) and Eastern Indian Ocean (Area 57) regions have relatively high levels of illegal fishing (compared to the rest of the regions), with illegal and unreported catch constituting 34% and 32% of the region's catch, respectively (Agnew et al. 2009). The annual value of high seas illegal, unreported and unregulated (IUU) catches of sharks worldwide has been estimated at $192 million (High Seas Task Force 2006) and annual worldwide economic losses from all IUU fishing is estimated to be between $10 billion and $23 billion (NMFS 2015c).

However, as mentioned in the **Overutilization** section of this review, given the recent

downward trend in the trade of shark fins (Dent and Clarke 2015; Eriksson and Clarke 2015), illegal fishing for the sole purpose of shark fins may not be as prevalent in the future. It is also a positive sign that most (70%) of the top 26 shark-fishing countries, areas and territories have taken steps to combat IUU fishing, either by signing the Port State Measures Agreement (PSMA) (46%) or by adopting a National Plan of Action to prevent, deter, and eliminate IUU (NPOA-IUU) or similar plan (23%) (Fischer et al. 2012). However, whether these agreements or plans translate to less IUU fishing activity is unclear. For example, in quite a few countries, the effective implementation of monitoring, control, and surveillance schemes is problematic, often due to a lack of personnel and financial resources (Fischer et al. 2012), and a number of instances of IUU fishing, specifically involving sharks, have been documented over the past decade. For instance, as recently as May 2015, it was reported that Ecuadorian police confiscated around 200,000 shark fins from at least 50,000 sharks after raids on 9 locations in the port of Manta (BBC 2015). In September 2015, Greenpeace activists boarded a Taiwan-flagged boat fishing near Papua New Guinea and found 110 shark fins but only 5 shark carcasses (which was in violation of both the Taiwanese and the WCPFC rules requiring onboard fins to be at most 5% of the weight of the shark carcasses) (News24 2015). Recreational fishermen have also been caught with illegal shark fins. A report from June 2015 identified three unlicensed recreational fishers operating in waters off Queensland, Australia and in possession of 3,200 illegal shark fins most likely destined for the black market (Buchanan and Sparkes 2015). While these reports provide just a few examples of recent illegal fishing activities, more evidence and additional reports of specific IUU fishing activities throughout the world can be found in Miller et al. (2014a) and Miller et al. (2014b).

In terms of tracking IUU fishing, most of the RFMOs maintain lists of vessels they believe to be involved in illegal fishing activities, with the latest reports on this initiative seeming to indicate improvement in combatting IUU. In the most recent 2015 Biennial Report to Congress, which highlights U.S. findings and analyses of foreign IUU fishing activities, NMFS reports that all 10 nations that were previously identified in the 2013 Biennial Report for IUU activities took appropriate actions to address the violations (e.g., through adoption of new laws and regulations or by amending existing ones,

sanctioning vessels, and improving monitoring and enforcement) (NMFS 2015b). In the current report, 6 countries were identified for having vessels engaged in IUU fishing activities; however, no countries were identified for engaging in protected living marine resources (PLMR) bycatch or for catching sharks on the high seas (although NMFS caveats this by noting the inability to identify nations due primarily to the restrictive time frames and other limitations in the statute) (NMFS 2015b).

While it is likely that *S. zygaena* is subject to IUU fishing, particularly for its valuable fins, based on the best available information on the species' population trends throughout its range, as well as present utilization levels, the mortality rates associated with illegal fishing and impacts on smooth hammerhead shark populations do not appear to be contributing significantly to the species' extinction risk. Furthermore, this additional mortality that the species presently endures from illegal fishing activities will likely decrease in the future as nations step up to combat IUU fishing and, particularly, if the demand for shark fins continues on a downward trend.

Other Natural or Manmade Factors Affecting the Smooth Hammerhead Sharks' Continued Existence

In terms of other natural or manmade factors, environmental pollutants were identified as a potential threat to the species. Many pollutants in the environment, such as brevotoxins, heavy metals, and polychlorinated biphenyls, have the ability to bioaccumulate in fish species. Because of the higher trophic level position and longevity of hammerhead sharks, these pollutants tend to biomagnify in liver, gill, and muscle tissues (Storelli et al. 2003; García-Hernández et al. 2007; Marsico et al. 2007; Escobar-Sanchez et al. 2010; Maz-Courrau et al. 2012; Lee et al. 2015). A number of studies have attempted to study and quantify the concentration levels of these pollutants in fish species, but with a focus on human consumption and safety (Storelli et al. 2003; García-Hernández et al. 2007; Marsico et al. 2007; Escobar-Sanchez et al. 2010; Maz-Courrau et al. 2012; Lee et al. 2015). As such, many of the results from these studies may indicate either "high" or "low" concentrations in fish species, but this is primarily in comparison to recommended safe concentrations for human consumption and does not necessarily have any impact on the biological status of the species.

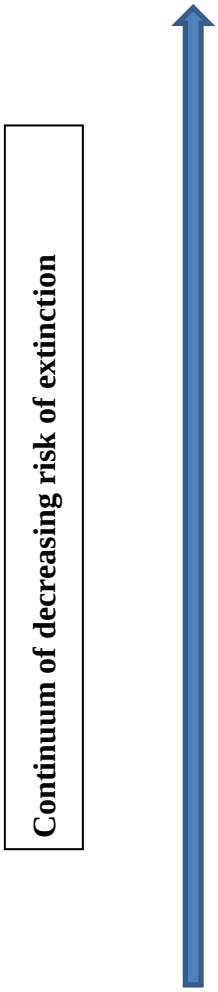
In terms of smooth hammerhead sharks, mercury appears to be the most studied environmental pollutant in the species. International agencies, such as the Food and Drug Administration and the World Health Organization, have set a recommended maximum mercury concentration of 1 µg/g wet weight in seafood tissues for human consumption. However, observed mercury concentrations in the tissues of smooth hammerhead sharks are highly variable. For example, Storelli et al. (2003) tested tissue samples from four smooth hammerhead sharks from the Mediterranean Sea (size range: 277-303 cm TL) and found that, on average, tissue samples from the liver and muscle had concentrations of mercury that greatly exceeded the 1 µg/g recommended limit. Mean mercury concentration in muscle samples were 12.15 ± 4.60 µg/g and mercury concentration in liver samples averaged 35.89 ± 3.58 µg/g. Similarly, García-Hernández et al. (2007) found high concentrations of mercury in tissues of four smooth hammerhead sharks (size range: 163-280 cm TL) from the Gulf of California, Mexico, with mean mercury concentration in muscle tissue of 8.25 ± 9.05 µg/g. In contrast, Escobar-Sanchez et al. (2010) tested muscle tissue of 37 smooth hammerhead sharks from the Mexican Pacific (Baja California Sur, Mexico; size range: >55–184 cm TL) and found mercury concentrations were below the maximum safety limit of 1 µg/g (average = 0.73 µg/g; median = 0.10 µg/g). Out of the 37 studied sharks, only one shark had a mercury concentration that exceeded the recommended limit (1.93 µg/g). Likewise, Maz-Courrau et al. (2012) also found "safe" concentrations of mercury in smooth hammerhead sharks from the Baja California peninsula. Analysis of muscle tissue samples from 31 smooth hammerhead sharks (mean size = 114 cm TL ± 19.2) showed an average mercury concentration of 0.98 ± 0.92 µg/g dry weight (range: 0.24-2.8 µg/g). The authors also tested mercury concentrations in four prey species of Pacific sharks (mackerel *S. japonicas*, lantern fish *S. evermanni*, pelagic red crab *P. planipes*, and giant squid *D. gigas*) and found that *D. gigas*, a common prey item for smooth hammerhead sharks (see **Diet and Feeding**), had the lowest mercury concentration (0.12 ± 0.05 µg/g). The authors suggest that the transfer of mercury to smooth hammerhead sharks is unlikely to come from feeding on cephalopods; however, these results may very well explain the observed low levels of mercury in smooth hammerhead shark tissues (i.e., if these sharks prefer to feed on cephalopods, then the bioaccumulation of mercury in tissues would likely be low).

In Atlantic waters, Marsico et al. (2007) also found that smooth hammerhead sharks had rather low levels of mercury concentrations (in comparison to the recommended 1 µg/g human consumption limit). Based on muscle tissue samples from 5 smooth hammerhead sharks caught off the coast of Santa Catarina, Brazil, average mercury concentration was 0.443 ± 0.299 µg/g with a range of 0.015–0.704 µg/g. In Indo-Pacific waters, the only information on *S. zygaena* mercury bioaccumulation is an analysis of muscle tissue from a single smooth hammerhead that was caught off Port Stephens, New South Wales, Australia (Paul et al. 2003). The smooth hammerhead shark was 232 cm in length and had a muscle tissue mercury concentration of 1.9 µg/g.

Based on the above information, it appears that mercury concentrations may correlate with size of the smooth hammerhead shark, with larger sharks, such as those examined in the Paul et al. (2003), Storelli et al. (2003), and García-Hernández et al. (2007) studies, containing higher mercury concentrations. However, analyses examining this very relationship show conflicting results (Escobar-Sanchez et al. (2010) – no correlation; Maz-Courrau et al. (2012) – significant correlation). Furthermore, the effect of these and other mercury concentrations in smooth hammerhead shark populations, and potential risk to the viability of the species, remains unknown. It is hypothesized that these apex predators can actually handle higher body burdens of anthropogenic toxins due to the large size of their livers which "provides a greater ability to eliminate organic toxicants than in other fishes" (Storelli et al. 2003) or may even be able to limit their exposure by sensing and avoiding areas of high toxins (like during *K. brevis* red tide blooms) (Flewelling et al. 2010). Currently, the impact of toxin and metal bioaccumulation in smooth hammerhead shark populations is unknown. In fact, there is no information on the lethal concentration limits of toxins or metals in smooth hammerhead sharks or evidence to suggest that current concentrations of environmental pollutants are causing detrimental physiological effects to the point where the species may be at an increased risk of extinction. As such, at this time, the best available information does not indicate that the present bioaccumulation rates and concentrations of environmental pollutants in the tissues of smooth hammerhead sharks are significant threats to the species.

EXTINCTION RISK ANALYSIS

In determining the extinction risk of a species, it is important to consider both the demographic risks facing the species as well as current and potential threats that may affect the species' status. To this end, a demographic analysis was conducted for the smooth hammerhead shark and considered alongside the information presented on threats to the species in the first section of this status review report. A demographic risk analysis is an assessment of the manifestation of past threats that have contributed to the species' current status and informs the consideration of the biological response of the species to present and future threats. This analysis evaluated the population viability characteristics and trends available for the smooth hammerhead shark, such as abundance, growth rate/productivity, spatial structure and connectivity, and diversity, to determine the potential risks these demographic factors pose to the species. The information from this demographic risk analysis in conjunction with the available information on threats (summarized in a separate threats assessment section below) was interpreted to determine an overall risk of extinction for *S. zygaena*. Because species-specific information (such as current abundance) is sparse, qualitative 'reference levels' of extinction risk were used to describe the assessment of extinction risk. The definitions of the qualitative 'reference levels' of extinction risk are provided below:

Qualitative 'Reference Levels' of Extinction Risk	
	<u>Low Risk</u>: A species is at low risk of extinction if it is not at moderate or high level of extinction risk (see "Moderate risk" and "High risk" above). A species may be at low risk of extinction if it is not facing threats that result in declining trends in abundance, productivity, spatial structure, or diversity. A species at low risk of extinction is likely to show stable or increasing trends in abundance and productivity with connected, diverse populations. <u>Moderate Risk</u>: A species is at moderate risk of extinction if it is on a trajectory that puts it at a high level of extinction risk in the foreseeable future (see description of "High risk" above). A species may be at moderate risk of extinction due to projected threats or declining trends in abundance, productivity, spatial structure, or diversity. * <u>High Risk</u>: A species with a high risk of extinction is at or near a level of abundance, productivity, spatial structure, and/or diversity that places its continued persistence in question. The demographics of a species at such a high level of risk may be highly uncertain and strongly influenced by stochastic or depensatory processes. Similarly, a species may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create imminent and substantial demographic risks.

* The appropriate time horizon for evaluating whether a species is more likely than not to be at high risk in the "foreseeable future" depends on various case- and species-specific factors. For example, the time horizon may reflect certain life history characteristics (e.g., long generation time or late age-at-maturity) and may also reflect

the time frame or rate over which identified threats are likely to impact the biological status of the species (e.g., the rate of disease spread). The appropriate time horizon is not limited to the period that status can be quantitatively modeled or predicted within predetermined limits of statistical confidence.

With these caveats in mind, the "foreseeable future" for this extinction risk analysis was considered to extend out several decades. Given the species' life history traits, with longevity estimated to be greater than 20 years, maturity at around 8 years, and generation time estimated to be around 13 years, it would likely take more than a decade (i.e., multiple generations) for any recent management actions to be realized and reflected in population abundance indices (e.g., impact of declining shark fin trade). Furthermore, as the main potential operative threat to the species is overutilization by commercial and artisanal fisheries, this timeframe would allow for reliable predictions regarding the impact of current levels of fishery-related mortality on the biological status of the species. As depicted in the very limited available CPUE time-series data, trends in the species' abundance can manifest within this time horizon.

Demographic Risk Analysis

Threats to a species' long-term persistence, such as those evaluated in the **Analysis of the ESA Section 4(A)(1) Factors** section of this review, are manifested demographically as risks to its abundance; productivity; spatial structure and connectivity; and genetic and ecological diversity. These demographic risks thus provide the most direct indices or proxies of extinction risk. In this section, the current status of each of these risks is assessed in turn by responding to a set of questions adapted from McElhany et al. (2000) and incorporated into the NMFS Guidance on Responding to Petitions and Conducting Status Reviews under the Endangered Species Act (internal NMFS document). These questions are based on general conservation biology principles applicable to a wide variety of species. These questions were used as a guide to the types of considerations that are important to each of the broader demographic risk categories of abundance, productivity, spatial structure, and diversity.

The level of risk attributed to demographic problems with abundance, productivity, spatial structure, or diversity was taken into consideration and then assigned a qualitative score as follows:

- very low or low risk
  - (e.g., stable or increasing trends in abundance and productivity, well-connected populations and resource patches, diverse populations).
- medium risk
  - (e.g., declining trends in abundance, productivity, spatial structure, or diversity)
- high risk
  - (e.g., severely low or high variability in abundance, unstable or very low population growth rates below replacement, significant loss of habitat or resource patches and critical source populations, significant loss of diversity)

Below provides the discussion of the demographic risks followed by the score assessment.

<u>Abundance</u>

- *Is the species' abundance so low that it is at risk of extinction due to environmental variation or anthropogenic perturbations (of the patterns and magnitudes observed in the past and expected in the foreseeable future)?*

Current and accurate abundance estimates are unavailable for the smooth hammerhead shark. In the Northwest Atlantic region, a preliminary stock assessment estimated a virgin population size of anywhere between 51,000 and 71,000 and a population size in 2005 of around 5,200. However, as mentioned in the review of this stock assessment, these are very crude estimates, based on only one abundance index, hampered by significant uncertainty, and should only be used for illustrative purposes.

Although no population estimates are available, based primarily on anecdotal accounts and catch records, the species' abundance within the Mediterranean region may be so

low that it is at a high risk of extirpation due primarily to anthropogenic perturbations. However, elsewhere, there is no information to indicate that the species' abundance is so low that it is at risk of extinction from environmental variation or anthropogenic perturbations, as addressed previously in the threats section of this status review.

- *Is the species' abundance so low, or variability in abundance so high, that it is at risk of extinction due to depensatory processes?*

The variability in abundance is not well understood, but the life history characteristics of long life and slow reproduction, coupled with the best available information regarding hammerhead population sizes, indicate that these sharks are not subject to extreme fluctuations that would lead to an imminent risk of depensation.

- *Is the species' abundance so low that its genetic diversity is at risk due to inbreeding depression, loss of genetic variants, or fixation of deleterious mutations?*

An analysis of mitochondrial DNA collected from smooth hammerhead sharks in multiple locations throughout their range indicated high genetic diversity, with significant genetic partitioning and no sharing of haplotypes between individuals in the Atlantic and Indo-Pacific basins (Testerman 2014). A geographic pattern of shallow genetic variation was also evident between individuals from the Atlantic, eastern Tropical/South Pacific, western North Pacific, and western Indian Ocean. Results from the nuclear DNA analysis indicate likely male mediated gene flow. These sharks are highly migratory and can likely travel large distances to reproduce. Currently, there is no evidence to suggest that present abundance levels are so low that they are leading to inbreeding depression, loss of genetic variations, of the fixation of deleterious mutations.

- *Is the species' abundance so low that it is at risk of extinction due to its inability to provide important ecological functions throughout its lifecycle?*

This situation would normally be a concern for a species that depends on critical numbers or density for modification of its or another organism's physical or biological environment. No aspect of the smooth hammerhead shark's life cycle is known to depend on this type of relationship.

- *Is the species' abundance so low that it is at risk due to demographic stochasticity?*

If a population is critically small in size chance variations in the annual number of births and deaths can put the population at added risk of extinction. Demographic stochasticity refers to the variability of annual population change arising from random birth and death events at the individual level. When populations are very small (e.g., <100 individuals), chance demographic events can have a large impact on the population. However, large sharks, including hammerheads, tend to be long-lived and generally have relatively high annual survival rates, which should reduce the risk of demographic stochasticity. While population sizes are unknown, available catch data suggest that total abundance is unlikely to be at or near the level that would place them at risk due to demographic stochasticity.

<u>Productivity</u>

- *Is the species' average productivity below replacement and such that it is at risk of satisfying the abundance conditions described above?*

The current net productivity (population trends) of *S. zygaena* is unknown due to the imprecision or lack of available abundance estimates or indices. Generally, based on the best available data, smooth hammerhead sharks exhibit life-history traits and population parameters that place the species towards the faster growing end along a spectrum of shark species (Cortés 2002, Appendix 2). Cortés et al. (2012) found that the smooth hammerhead shark ranked among the most productive species among 20 species of sharks. Based on the estimate of its intrinsic rate of population increase (r = 0.225), smooth hammerhead sharks can be characterized as having "medium" productivity (Musick 1999) with moderate resilience to exploitation. Given the available

information, with no evidence of declining population trends, it is unlikely that the species' average productivity is below replacement to the point where the species is at risk of extinction from low abundance.

- *Is the species' average productivity below replacement and such that it is unable to exploit requisite habitats/niches/etc. or at risk due to depensatory processes during any life history stage?*

As stated above, the average productivity is not known to be below replacement. Smooth hammerhead sharks are thought to occupy all of their historically observed ranges and habitats, with no barrier to habitat exploitation.

- *Does the species exhibit trends or shifts in demographic or reproductive traits that portend declines in per capita growth rate which pose a risk of satisfying any of the preceding conditions?*

The limited amount of information on the demography or reproductive traits of the smooth hammerhead shark throughout its range precludes identification of any shifts or trends in per capita growth rate.

<u>Spatial Structure</u>

- *Are habitat patches being destroyed faster than they are naturally created such that the species is at risk of extinction due to environmental and anthropogenic perturbations or catastrophic events?*

The smooth hammerhead shark range is comprised of open ocean environments occurring over broad geographic ranges. There is very little information on specific habitat (or patches) used by smooth hammerhead sharks. For example, habitat deemed necessary for important life history functions, such as spawning, breeding, feeding, and growth to maturity, is currently unknown for this species. Although potential nursery areas for the species have been identified in portions of its range, there is no information that these areas are at risk of destruction or directly impacting the extinction risk of

smooth hammerhead populations.

- *Are natural rates of dispersal among populations, meta-populations, or habitat patches so low that the species is at risk of extinction due to insufficient genetic exchange among populations, or an inability to find or exploit available resource patches?*

Although dispersal rates are currently unknown, there is no reason to believe that they are low within the range of *S. zygaena*. While the available data suggest a potentially patchy distribution for the species, given the relative absence of physical barriers within their marine environments (compared with terrestrial or river systems) and the shark's highly migratory nature, with tracking studies that indicate its ability to move long distances, it is unlikely that insufficient genetic exchange or an inability to find and exploit available resource patches are risks to the species.

- *Is the species at risk of extinction due to the loss of critical source populations, subpopulations, or habitat patches?*

This question is more relevant to species characterized by meta-population dynamics. At this time, there is no information to indicate that *S. zygaena* is composed of conspicuous source-sink populations and habitat patches.

<u>Diversity</u>

- *Is the species at risk due to a substantial change or loss of variation in life history traits, population demography, morphology, behavior, or genetic characteristics?*

There are no documented specific risks for *S. zygaena* related to such changes or losses.

- *Is the species at risk because natural processes of dispersal and gene flow among populations have been significantly altered?*

Rates of dispersal and gene flow are not known to have been altered.

- *Is the species at risk because natural processes that cause ecological variation have been significantly altered?*

Smooth hammerhead sharks are wide-ranging inhabitants of open ocean, coastal, and inshore ecosystems and thus are continually exposed to ecological variation at a broad range of spatial and temporal scales. As such, large-scale impacts that affect ocean temperatures, currents, and potentially food chain dynamics, may pose a threat to this species. However, given the highly migratory and opportunistic behavior of the smooth hammerhead shark, these sharks likely have the ability to shift their range or distribution to remain in an environment conducive to their physiological and ecological needs, providing the species with resilience to these effects. At this time, there is no information to suggest that natural processes that cause ecological variation have been significantly altered to the point where the species is at risk.

<u>Uncertainty</u>

Species status evaluations should take into account uncertainty regarding abundance, estimates of growth rate and population growth rate-related parameters, spatial processes, and requisite levels of diversity. Although noted in the above answers to the demographic risk questions, uncertainty in relation to the assigned risk score of the demographic factor was also reflected with a confidence rating, on a scale of 0 to 3. Below are the definitions of the confidence rating scores (adapted from the confidence ratings in Lack et al. (2014)):

- 0 (no confidence) = No information
- 1 (low confidence) = Very limited information
- 2 (medium confidence) = Some reliable information available, but inference and extrapolation required
- 3 (high confidence) = Reliable information with little to no extrapolation or inference required;

Assessment of Demographic Risks

Demographic factor	Risk	Confidence Rating
Abundance	Low	0-1
Productivity	Low	1
Spatial Structure	Very Low	0-1
Diversity	Very Low	0

Threats Assessment

According to section 4 of the ESA and NMFS' implementing regulations, the Secretary (of Commerce or the Interior) determines whether a species is threatened or endangered as a result of any of the following five section 4(a)(1) factors: (A) destruction or modification of habitat, (B) overutilization, (C) disease or predation, (D) inadequacy of existing regulatory mechanisms, or (E) other natural or man-made factors. Collectively, the Services simply refer to these factors as "threats." The first part of this status review provides a detailed description and evaluation of the likely impact of the above threats on the status of the species. This information is summarized below:

The main threat identified for the smooth hammerhead shark is overutilization for commercial and artisanal purposes. Smooth hammerhead sharks are both targeted and caught as bycatch in a number of global fisheries throughout their range. Historically, there was little interest in the species; however, as the demand for shark fin soup increased in the 1980s, the international trade in shark products shifted to a focus on fins. This, in turn, increased the rate of exploitation (and retention) of smooth hammerhead sharks as their fins, which are large in size with high fin needle content (a gelatinous product used to make shark fin soup), are one of the most valuable fins in the international market. Yet, based on the best available data throughout the species' range, present utilization levels of the shark do not appear to be a threat significantly contributing to its risk of extinction.

In the Atlantic, where species-specific data is available, the regional and local information indicates that smooth hammerhead sharks tend to be a rare occurrence, observed only sporadically in the fisheries data and in low numbers. In the northwest Atlantic, strong management measures are in place to prevent overfishing of the species. In the southwest Atlantic, while the majority of the catch appears to be juveniles, smooth hammerhead sharks are generally harvested at low levels and comprise less than 5% of the fisheries catch. In the temperate waters of the Mediterranean Sea, smooth hammerhead sharks were historically a common occurrence. However, with the intense coastal fishing and the expansion of the tuna and swordfish longline and drift net fisheries in the 1970s, smooth hammerhead sharks have been fished almost to extinction in the Mediterranean Sea. Fishing pressure remains high in this portion of the species' range, which will likely result in additional fishing mortality and continued declines in the population. However, the Mediterranean comprises only a small portion of the species' range, and given the lack of trends or evidence of significant declines elsewhere in the Atlantic, the available data does not indicate that the overutilization and depletion of the Mediterranean population has significantly affected other *S. zygaena* populations in the Atlantic.

Similarly, in the Indian and Pacific Oceans, the available data, albeit severely lacking, depict a species that is not regularly caught, or caught in large numbers, by fisheries operating in these regions. The majority of fishing effort, particularly in the Indian Ocean, tends to be concentrated in more tropical waters, thereby decreasing the threat of overutilization by these fisheries on the more temperately-distributed smooth hammerhead shark. However, in the Western Pacific, there are a number of fisheries operating within the temperate portions of this region (e.g., off Japan, Australia, New Zealand) that report regular catches of smooth hammerhead sharks. Based on the available data from these fisheries, including catch time series and CPUE data, no clear trends were found that would suggest overutilization is a significant threat to the species. In the Eastern Pacific, artisanal fisheries are responsible for the majority of the smooth hammerhead catch, and land primarily juveniles of the species. However, based on preliminary information on catch trends (primarily from Peru and Ecuador), there is no evidence to suggest that this level of utilization has or is significantly impacting

recruitment to the population.

Furthermore, the number of regulatory and management measures, including hammerhead retention bans and finning regulations, as well as the creation of shark sanctuaries, have been on the rise in recent years. These regulations are aimed at decreasing the amount of sharks being landed or finned just for the shark fin trade and work to dis-incentivize fishermen from targeting vulnerable shark species. Already it appears that the demand for shark fins is on the decline. While it is unclear how effective these regulations will be in ultimately reducing fishing mortality rates for the smooth hammerhead shark (given their high at-vessel mortality rates), it is likely to decrease fishing pressure on the species, particularly in those fisheries that target the species and by those fishermen that illegally fish for the species solely for use in the shark fin trade.

Overall Risk of Extinction

While the species' life history characteristics increases its inherent vulnerability to depletion, and likely contributed to past population declines of varying magnitudes, the best available information suggests that present demographic risks are low. Smooth hammerhead sharks continue to be exploited throughout their range, particularly juveniles of the species. While it is universally acknowledged that information is severely lacking for the species, including basic catch and effort data from throughout the species' range, global, regional, and local population size estimates, abundance trends, life history parameters (particularly from the Pacific and Indian Oceans), and distribution information, the best available data does not indicate that present fishing levels and associated mortality are causing declines in the species to such a point that the species is at risk of extinction from overutilization, or likely to become so in the foreseeable future. Thus, based on the above evaluation of demographic risks and threats to the species, the smooth hammerhead shark is likely to be at a **low overall risk of extinction**.

Significant Portion of its Range Analysis

Because the range-wide analysis indicates that the species is at a low overall risk of extinction, a Significant Portion of its Range (SPOIR) analysis must be conducted to determine if the species is at high or moderate risk of extinction in a SPOIR. The SPOIR policy (79 FR 37577, July 1, 2014) specifies that, in order to identify only those portions of the species' range that warrant further consideration, the agency must determine whether there is substantial information indicating that (1) the portions may be significant *and* (2) the species may be in danger of extinction in those portions or likely to become so within the foreseeable future. An affirmative answer to these questions is not a determination that the species is endangered or threatened throughout a significant portion of its range—rather, it is a preliminary step in determining whether a more detailed analysis is required to determine whether a species is threatened or endangered in a significant portion of its range.

The SPOIR policy further explains that, depending on the particular facts of each situation, it may be more efficient to address the significance issue first, but in other cases it will make more sense to examine the status of the species in the potentially significant portions first. Whichever question is asked first, an affirmative answer is required to proceed to the second question. If it is determined that a portion of the range is not "significant,'' then there is no need for a determination on whether the species is endangered or threatened in that portion; if it is determined that the species is not endangered or threatened in a portion of its range, then a determination on if that portion is ''significant" is not needed. Thus, if the answer to either question is negative, then the analysis concludes.

After a review of the best available information, the data do not indicate any portion of the smooth hammerhead shark's range as being more significant than another. Smooth hammerhead sharks are highly mobile, with a global distribution, and very few restrictions governing their movements. While the Mediterranean region was recognized as a portion of the species' range in which it is likely at risk of extinction due to threats of overutilization, the Mediterranean represents only a small portion of the

global range of the smooth hammerhead sharks. Furthermore, there is no indication that loss of that part of the species' range would constitute an extinction risk to the global species. As was mentioned previously, the available population and trend data do not indicate that the depletion of the Mediterranean population has significantly affected other *S. zygaena* populations. Thus, the Mediterranean would not qualify as "significant" under the SPR Policy.

Likewise, there is no substantial evidence to indicate that the loss of genetic diversity from one portion of the species' range (such as loss of an ocean basin population) would result in the remaining populations lacking enough genetic diversity to allow for adaptations to changing environmental conditions. Similarly, there is no information to suggest that loss of any portion would severely fragment and isolate the species to the point where individuals would be precluded from moving to suitable habitats or have an increased vulnerability to threats. In other words, loss of any portion of its range would not likely isolate the species to the point where the remaining populations would be at risk of extinction from demographic processes.

Areas exhibiting source-sink dynamics, which could affect the survival of the species, were not evident in any part of the smooth hammerhead sharks' range. There is also no evidence of a portion that encompasses aspects that are important to specific life history events but another portion that does not, where loss of the former portion would severely impact the growth, reproduction, or survival of the entire species. In fact, potential pupping grounds and nursery areas for the species were identified in all three major ocean basins. In other words, the viability of the species does not appear to depend on the productivity of the population or the environmental characteristics in any one portion.

It is important to note that the overall distribution of the smooth hammerhead shark is still uncertain, considered to be generally patchy but also unknown in large areas, such as the Indian Ocean. As better data becomes available, the species distribution (and potentially significant portions of its range) will become better resolved; however, at this time, there is no evidence to suggest that any specific portion of the species' range has

increased importance over another with respect to either species' survival.

Thus, under the policy, the preliminary determination that a portion of the species' range may be both significant and the species may be in danger of extinction in those portions or likely to become so within the foreseeable future has not been met.

REFERENCES

Abercrombie DL, Clarke SC, Shivji MS (2005) Global-scale genetic identification of hammerhead sharks: Application to assessment of the international fin trade and law enforcement. Conservation Genetics 6: 775-788 doi 10.1007/s10592-005-9036-2

Agnew DJ, Pearce J, Pramod G, Peatman T, Watson R, Beddington JR, Pitcher TJ (2009) Estimating the worldwide extent of illegal fishing. PLoS One 4: e4570 doi 10.1371/journal.pone.0004570

Aguilar F, Revelo W, Coelho D, Cajas J, Ruiz W, Diaz M, Moreno J (2007) Desembarques artesanales de tiburones y rayas en los principales puertos pesqueros del Ecuador durante 2006 INP, Guayaquil

Amandè MJ, Ariz J, Chassot E, de Molina AD, Gaertner D, Murua H, Pianet R, Ruiz J, Chavance P (2010) Bycatch of the European purse seine tuna fishery in the Atlantic Ocean for the 2003–2007 period. Aquatic Living Resources 23: 353-362 doi 10.1051/alr/2011003

Amorim AF, Arfelli CA, Fagundes L (1998) Pelagic elasmobranchs caught by longliners off southern Brazil during 1974-97: an overview. Marine and Freshwater Research 49: 621-632 doi Doi 10.1071/Mf97111

Amorim AF, Della-Fina N, Piva-Silva N (2011) Hammerheads sharks, *Sphyrna lewini* and *S. zygaena* caught by longliners off southern Brazil, 2007-2008. Collect Vol Sci Pap ICCAT 66

Arocha F, Arocha O, Marcano LA (2002) Observed shark bycatch from the Venezuelan tuna and swordfish fishery from 1994 through 2000. ColVolSciPap ICCAT 54: 1123-1131

ASFMC (2008) Fishery Management Report No. 46 of the Atlantic States Marine Fisheries Commission. Atlantic States Marine Fisheries Commission

Australian Government (2014) Non-Detriment Finding for the export of shark species listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and harvested from Australian waters: Sphyrna lewini, Sphyrna mokarran, Sphyrna zygaena, Lamna nasus, Carcharhinus longimanus. In: Environment Dot (ed)

Axiak V, Gauci V, Mallia A, Mallia E, Schembri PJ, Vella AJ, Vella L (2002) State of the Environment Report for Malta: 2002. Ministry for Home Affairs and the Environment

Baino R, C. Mancusi MB, G. Morey, M. Vacchi, L. Gil de Sola, M. N. Bradai, E., Sperone AK, F. Hemida, A. A. Saad, M. Dimech, P. Peristeraki, M. Bariche,, G. Cavlan SC, E. De Sabata, L. Castellano, F. Garibaldi, F. Tinti, A. Pais, C. Follesa,, P. Micarelli FP, R. Carlucci, A. Soldo, M. Bottaro, D. Cebrian, C. Fortuna, B., Seret FF, Alaa El-Far, I. Saygu, E. A. Shakman, A. Bartolí, J. Guallart, D., Damalas PM, G. Notarbartolo di Sciara, R. Cannas, F. Serena (2012) The data collection on large

cartilaginous fishes in the Mediterranean basin: an update of the MEDLEM database 16th annual conference of European Elasmobranchs Association, Milan, Italy

Bass AJ, D'Aubrey JD, Kistnasamy N (1975) Sharks of the east coast of southern Africa. III. The families Carcharhinidae (excluding Mustelus and Carcharhinus) and Sphyrnidae. Investigational Report Oceanographic Research Institue 38: 1-100

Baum JK, Blanchard W (2010) Inferring shark population trends from generalized linear mixed models of pelagic longline catch and effort data. Fisheries Research 102: 229-239 doi 10.1016/j.fishres.2009.11.006

BBC (2015) Ecuador seizes huge illegal shark fin haul BBC News

Benítez H, López G, Rivera-Téllez E, (Comps.) (2015) Taller de Evaluación de Productividad, Susceptibilidad y Manejo de tiburones mexicanos listados en el Apéndice II de la CITES. Comisión Nacional Para el Conocimiento y Uso de la Biodiversidad (CONABIO), México, D.F.

Bester C (n.d.) Smooth hammerhead shark

Betunde DG (2011) Conservation et Gestion Durable de Requins au PNO 2011 Colloque International Sur Les Requins: Conservation et gestion durable des Requins en Afrique de l'Ouest, Senegal

Biery L, Pauly D (2012) A global review of species-specific shark-fin-to-body-mass ratios and relevant legislation. Journal of fish biology 80: 1643-1677 doi 10.1111/j.1095-8649.2011.03215.x

Bizzarro JJ, Smith WD, Castillo-Geniz JL, Ocampo-Torres A, Marquez-Farias JF, Hueter RF (2009) The seasonal importance of small coastal sharks and rays in the artisanal elasmobranch fishery of Sinaloa, Mexico. Pan-American Journal of Aquatic Sciences 4: 513-531

Blaber SJM, Dichmont CM, White W, Buckworth R, Sadiyah L, Iskandar B, Nurhakim S, Pillans R, Andamari R, Dharmadi, Fahmi (2009) Elasmobranchs in southern Indonesian fisheries: the fisheries, the status of the stocks and management options. Reviews in Fish Biology and Fisheries 19: 367-391 doi 10.1007/s11160-009-9110-9

Boddiger D (2015) Shark fin scandal in Costa Rica has Solís administration on the defensive The Tico Times

Boggs CH, Ito RY (1993) Hawaii's Pelagic Fisheries. Marine Fisheries Review 55: 69-82

Bornatowski H, Braga RR, Abilhoa V, Correa MFM (2014) Feeding ecology and trophic comparisons of six shark species in a coastal ecosystem off southern Brazil. Journal of fish biology 85: 246-263 doi 10.1111/jfb.12417

Bornatowski H, Costa L, Robert MdC, Pina JVd (2007) Hábitos alimentares de tubarões-martelo jovens, Sphyrna zygaena (Carcharhiniformes: Sphyrnidae), no litoral sul do Brasil. Biota Neotropica 7: 0-0 doi 10.1590/s1676-06032007000100025

Braccini M, Van Rijn J, Frick L (2012) High post-capture survival for sharks, rays and

chimaeras discarded in the main shark fishery of Australia? PLoS One 7: e32547 doi 10.1371/journal.pone.0032547

Brito JL (2004) Presencia del tiburón martillo Sphyrna zygaena (Carchariniformes: Sphyrnidae) y nuevo registro del tiburón espinudo Echinorhinus cookei (Squaliformes: Squalidae) en San Antonio, Chile central. Investigaciones Marinas 32: 141-144

Buchanan K, Sparkes D (2015) Fishers fined for illegal haul of 3,200 shark fins ABC Rural

Buencuerpo V, Rios S, Moron J (1998) Pelagic sharks associated with the swordfish, Xiphias gladius, fishery in the eastern North Atlantic Ocean and the Strait of Gibraltar. Fishery Bulletin 96: 667-685

Butcher PA, Peddemors VM, Mandelman JW, McGrath SP, Cullis BR (2015) At-vessel mortality and blood biochemical status of elasmobranchs caught in an Australian commercial longline fishery. Global Ecology and Conservation 3: 878-889 doi 10.1016/j.gecco.2015.04.012

Cabanilla C, Fierro C (2010) Informe pesquero Abril 2010: Desembarque de tiburones. Instituto Nacional de Pesca

Cadenat J, Blache J (1981) Requins de Mediterranee et d'Atlantique (plus particulierement de la Cote Occidental d'Afrique), Paris, France

Camhi MD, Valenti SV, Fordham SV, Fowler SL, Gibson C (2009) The Conservation Status of Pelagic Sharks and Rays: Report of the IUCN Shark Specialist Group Pelagic Shark Red List Workshop. IUCN Species Survival Commission Shark Specialist Group, Newbury, UK.

Cartamil D, Santana-Morales O, Escobedo-Olvera M, Kacev D, Castillo-Geniz L, Graham JB, Rubin RD, Sosa-Nishizaki O (2011) The artisanal elasmobranch fishery of the Pacific coast of Baja California, Mexico. Fisheries Research 108: 393-403 doi 10.1016/j.fishres.2011.01.020

Castañeda J (2001) Biología y pesquería del tiburón martillo (Sphyrna zygaena) en Lambayeque, 1991-2000. Inf Prog Inst Mar Perú 139: 3-16

Castro JA, Mejuto J (1995) Reproductive parameters of blue shark, Prionace glauca, and other sharks in the Gulf of Guinea. Marine and Freshwater Research 46: 967-973 doi 10.1071/mf9950967

Cattaneo-Vietti R, Cappanera V, Castellano M, Povero P (2015) Yield and catch changes in a Mediterranean small tuna trap: a warming change effect? Marine Ecology 36: 155-166 doi 10.1111/maec.12127

Celona A, Maddalena AD (2005) Occurrence of hammerhead sharks (chondrichthyes: sphyrnidae) in waters off silicy (central mediterranean): historical and recent data. Annales Ser hist nat 15: 57-64

Chin A, Kyne PM, Walker TI, McAuley RB (2010) An integrated risk assessment for climate change: analysing the vulnerability of sharks and rays on Australia's Great Barrier Reef. Global Change Biology 16: 1936-1953 doi 10.1111/j.1365-

2486.2009.02128.x

CITES (2013) Consideration of proposals for amendment of Appendices I and II (CoP16 Prop. 43)

Clarke S (2013) Towards an Integrated Shark Conservation and Management Measure for the Western and Central Pacific Ocean Western and Central Pacific Fisheries Commission Scientific Committee Ninth Regular Session, Pohnpei, Federated States of Micronesia

Clarke S, IOTC Secretariat (2014) Issues for T-RFMOS in relation to the listing of shark and ray species by the CITES with particular reference to the Indian Ocean Tuna Commission. IOTC

Clarke S, Milner-Gulland EJ, Bjorndal T (2007) Perspectives: Social, Economic, and Regulatory Drivers of the Shark Fin Trade. Marine Resource Economics 22: 305-327

Clarke SC, Coelho R, Francis M, Kai M, Kohin S, Liu K-M, Simpfendorfer C, Tovar-Avila J, Rigby C, Smart J (2015) Pacific Shark Life History Expert Panel Workshop: Final Report. WCPFC-SC11-2015/EB-IP-13

Clarke SC, Magnussen JE, Abercrombie DL, McAllister MK, Shivji MS (2006a) Identification of shark species composition and proportion in the Hong Kong shark fin market based on molecular genetics and trade records. Conservation biology : the journal of the Society for Conservation Biology 20: 201-211 doi 10.1111/j.1523-1739.2006.00247.x

Clarke SC, McAllister MK, Milner-Gulland EJ, Kirkwood GP, Michielsens CG, Agnew DJ, Pikitch EK, Nakano H, Shivji MS (2006b) Global estimates of shark catches using trade records from commercial markets. Ecology letters 9: 1115-1126 doi 10.1111/j.1461-0248.2006.00968.x

Cliff G, Dudley SFJ (1992) Protection against Shark Attack in South-Africa, 1952-90. Aust J Mar Fresh Res 43: 263-272

Coelho R, Fernandez-Carvalho J, Amorim S, Santos MN (2011) Age and growth of the smooth hammerhead shark, Sphyrna zygaena, in the Eastern Equatorial Atlantic Ocean, using vertebral sections. Aquatic Living Resources 24: 351-357 doi 10.1051/alr/2011145

Coelho R, Fernandez-Carvalho J, Lino PG, Santos MN (2012) An overview of the hooking mortality of elasmobranchs caught in a swordfish pelagic longline fishery in the Atlantic Ocean. Aquatic Living Resources 25: 311-319 doi 10.1051/alr/2012030

Commonwealth of Australia (2015) Assessment of the Western Australian Temperate Demersal Gillnet and Demersal Longline Fisheries. In: Department of the Environment CoA (ed)

Compagno LJV (1984) Vol. 4, Part 2 Sharks of the World an annotated and illustrated catalogue of shark species known to date. FAO

Cortés E (1999) Standardized diet compositions and trophic levels of sharks. Ices

Journal of Marine Science 56: 707-717 doi DOI 10.1006/jmsc.1999.0489

Cortés E, Domingo A, Miller P, Forselledo R, Mas F, Arocha F, Campana S, Coelho R, Da Silva C, Hazin F, Holtzhausen H, Keene K, Lucena F, Ramirez K, Santos MN, Semba-Murakami Y, Yokawa K (2012) Expaneded ecological risk assessment of pelagic sharks caught in Atlantic pelagic longline fisheries. Collect Vol Sci Pap ICCAT 71: 2637-2688

Costa L, Chaves PdTdC (2006) Elasmobrânquios capturados pela pesca artesanal na costa sul do Paraná e norte de Santa Catarina, Brasil. Biota Neotropica 6: 0-0 doi 10.1590/s1676-06032006000300007

Da Silva C, Burgener M (2007) South Africa's demersal shark meat harvest. TRAFFIC Bulletin 12

Dai XJ, Zheng Y, Jiang RL, Xu LX (2009) Shark by-catch observation in ICCAT waters by Chinese longline observations in 2007. Collect Vol Sci Pap ICCAT 64

Dapp D, Arauz R, Spotila JR, O'Connor MP (2013) Impact of Costa Rican longline fishery on its bycatch of sharks, stingrays, bony fish and olive ridley turtles (Lepidochelys olivacea). Journal of Experimental Marine Biology and Ecology 448: 228-239 doi 10.1016/j.jembe.2013.07.014

de Graaf G, Garibaldi L (2014) The value of African fisheries, Rome

de Young C (2006) Review of the state of world marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper

Dent F, Clarke S (2015) State of the global market for shark products, Rome

Dia AD, Wagne OH, Kidé SO, Abdel Hamid ML, Meissa B, Diop M (2012) Plan d'action National pour la conservation et la gestion des populations de requins en Mauritanie: Volet recherche. IMROP

CSRP/SRFC

Diemer KM, Mann BQ, Hussey NE (2011) Distribution and movement of scalloped hammerheadSphryna lewiniand smooth hammerheadSphyrna zygaenasharks along the east coast of southern Africa. African Journal of Marine Science 33: 229-238 doi 10.2989/1814232x.2011.600291

Diop M, Dossa J (2011) 30 Years of shark fishing in west africa

Doukakis P, Hanner R, Shivji M, Bartholomew C, Chapman D, Wong E, Amato G (2011) Applying genetic techniques to study remote shark fisheries in northeastern Madagascar. Mitochondrial DNA 22 Suppl 1: 15-20 doi 10.3109/19401736.2010.526112

Dudley SFJ, Simpfendorfer CA (2006) Population status of 14 shark species caught in the protective gillnets off KwaZulu-Natal beaches, South Africa, 1978-2003. Marine and Freshwater Research 57: 225-240 doi 10.1071/MF05156

Ebert DA, Fowler S, Compagno LJV (2013) Sharks of the world. Wild Nature Press, pp 528

Erdman DS (1974) Nombres vulgares de peces en Puerto Rico/Common names of fishes

in Puerto Rico. Estado Libre Asociado de Puerto Rico, Departamento de Agricultura, Area de Servicios Especiales, Laboratorio de Pesquería Comercial, Cabo Rojo

Eriksson H, Clarke S (2015) Chinese market responses to overexploitation of sharks and sea cucumbers. Biological Conservation 184: 163-173 doi 10.1016/j.biocon.2015.01.018

Escobar-Sanchez O, Galvan-Magana F, Rosiles-Martinez R (2010) Mercury and Selenium Bioaccumulation in the Smooth Hammerhead Shark, Sphyrna zygaena Linnaeus, from the Mexican Pacific Ocean. Bulletin of Environmental Contamination and Toxicology 84: 488-491 doi 10.1007/s00128-010-9966-3

European Commission (2014) Report from the Commission to the European Parliamentt and the Council on Member States' efforts during 2012 to achieve a sustainable balance between fishing capacity and fishing opportunities, Brussels

Evans R, Molony BW (2010) Ranked Risk Assessment for Bycatch in Multiple Fisheries: a Bioregional Risk Assessment Method. Department of Fisheries, Western Australia

FAO (2010) Third FAO Expert Advisory Panel for the assessment of proposals to amend Appendicies I and II of CITES concerning commercially-exploited aquatic species

FAO (2014) The State of World Fisheries and Aquaculture: Opportunities and challenges. FAO, Rome

Fernandez-Carvalho J, Coelho R, Santos MN, Amorim S (2015) Effects of hook and bait in a tropical northeast Atlantic pelagic longline fishery: Part II—Target, bycatch and discard fishes. Fisheries Research 164: 312-321 doi 10.1016/j.fishres.2014.11.009

Ferretti F, Myers RA, Serena F, Lotze HK (2008) Loss of large predatory sharks from the Mediterranean Sea. Conservation biology : the journal of the Society for Conservation Biology 22: 952-964 doi 10.1111/j.1523-1739.2008.00938.x

Field IC, Meekan MG, Buckworth RC, Bradshaw CJA (2009) Chapter 4 Susceptibility of Sharks, Rays and Chimaeras to Global Extinction56: 275-363 doi 10.1016/s0065-2881(09)56004-x

Fischer J, Erikstein K, D'Offay B, Guggisberg S, Barone M (2012) Review of the Implementation of the International Plan of Action for the Conservation and Management of Sharks. FAO, Rome

Fisheries Agency of Chinese Taipei (2015) National Report: Tuna Fisheries Status Report of Chinese Taipei in the Western and Central Pacific Region WCPFC Scientific Committee Eleventh Regular Session, Pohnpei, Federated States of Micronesia

Fisheries Agency of Japan (2011) Japan's Report on Trade in Shark Species and Implementation of the National Action Plan for Conservation and Management of Sharks CITES: Twenty-fifth meeting of the Animals Committee

Fisheries Agency of Japan (2015) NDF Guidelines for Aquatic Species CITES: Twenty-

eighth meeting of the Animals Committee, Tel Aviv, Israel

Fisheries and Oceans Canada (2010) Aquatic Species Details for Hammerhead Shark

Flewelling LJ, Adams DH, Naar JP, Atwood KE, Granholm AA, O'Dea SN, Landsberg JH (2010) Brevetoxins in sharks and rays (Chondrichthyes, Elasmobranchii) from Florida coastal waters. Marine biology 157: 1937-1953 doi 10.1007/s00227-010-1463-z

Francis MP, Lyon WS (2012) Review of research and monitoring studies on New Zealand sharks, skates, rays and chimaeras, 2008–2012. Ministry for Primary Industries, New Zealand Government, 102

Francis MP, Shallard B (1998) 18: New Zealand shark fishery management Case studies of the management of elasmobranch fisheries Part 2. Fishery and Aquaculture Economics and Policy Division; FAO

Galvan-Magana F, Polo-Silva C, Berenice Hernandez-Aguilar S, Sandoval-Londono A, Ruth Ochoa-Diaz M, Aguilar-Castro N, Castaneda-Suarez D, Cabrera Chavez-Costa A, Baigorri-Santacruz A, Eden Torres-Rojas Y, Andres Abitia-Cardenas L (2013) Shark predation on cephalopods in the Mexican and Ecuadorian Pacific Ocean. Deep-Sea Research Part Ii-Topical Studies in Oceanography 95: 52-62 doi 10.1016/j.dsr2.2013.04.002

García-Hernández J, Cadena-Cárdenas L, Betancourt-Lozano M, García-De-La-Parra LM, García-Rico L, Márquez-Farías F (2007) Total mercury content found in edible tissues of top predator fish from the Gulf of California, Mexico. Toxicological & Environmental Chemistry 89: 507-522 doi 10.1080/02772240601165594

Ghosn DL, Collins DP, Gould AP (2015) The NSW Game Fish Tournament Monitoring Program 1994–2013: Data summary and assessment of program role and design, Nelson Bay, NSW

Gonzalez-Pestana A, Kouri J C, Velez-Zuazo X (2014) Shark fisheries in the Southeast Pacific: A 61-year analysis from Peru. F1000Research doi 10.12688/f1000research.4412.1

Government of Western Australia (2015) Application to the Department of the Environment Western Australia's Temperate Demersal Gillnet and Demersal Longlilne Fisheries. In: Fisheries Do (ed), Perth, Western Australia, pp 40

Green M, Ganassin C, Reid DD (2009) Report into the NSW Shark Meshing (Bather Protection) Program

Hall M, Roman M (2013) Bycatch and non-tuna catch in the tropical tuna purse seine fisheries of the world, Rome

Hayes C (2007) Investigating single and multiple species fisheries management: stock status evaluation of hammerhead (Sphyrna spp.) sharks in the western North Atlantic Ocean and Gulf of Mexico.

Hayes CG, Jiao Y, Cortés E (2009) Stock Assessment of Scalloped Hammerheads in the Western North Atlantic Ocean and Gulf of Mexico. North American Journal of

Fisheries Management 29: 1406-1417 doi 10.1577/m08-026.1

Heupel MR, McAuley RB (2007) Sharks and Rays (Chondrichthyans) in the North-west Marine Region. Department of the Environment and Water Resources, National Oceans Office Branch., Hobart, Tasmania

Hewapathirana HPK, Maldeniya R, Perera ULK (2015) [Sri Lanaka] National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2015

High Seas Task Force (2006) Closing the net: Stopping illegal fishing on the high seas. Governments of Australia, Canada, Chile, Namibia, New Zealand, and the United Kingdom, WWF, IUCN and the Earth Institute at Columbia University

Huang H-W, Liu K-M (2010) Bycatch and discards by Taiwanese large-scale tuna longline fleets in the Indian Ocean. Fisheries Research 106: 261-270 doi 10.1016/j.fishres.2010.08.005

Humane Society International (2015) National laws, multi-lateral agreements, regional and global regulations on shark protection and shark finning. HSI

IATTC (2015) Meeting Report Inter-American Tropical Tuna Commission Scientific Advisory Committee Sixth Meeting, La Jolla, California, pp 52

Instituto del Mar del Peru (2014) Reporte Trimestral de las estadisticas pesqueras artesanales

Instituto Nacional de la Pesca (2006) Sustentabilidad y Pesca Responsable en México, Evaluación y Manejo. INP, Mexico

IOTC (2015a) Status of the Indian Ocean Indo-Pacific sailfish (SFA: Istiophorus platypterus) resource IOTC-SC18

IOTC (2015b) Status of the Indian Ocean Scalloped Hammerhead Shark (SPL: Sphyrna lewini) IOTC SC18

IUCN (2005) Sphyrna zygaena Range Map. The IUCN Red List of Threatened Species

Jabado RW, Al Ghais SM, Hamza W, Henderson AC, Spaet JLY, Shivji MS, Hanner RH (2015) The trade in sharks and their products in the United Arab Emirates. Biological Conservation 181: 190-198 doi 10.1016/j.biocon.2014.10.032

Jacquet J, Alava JJ, Ganapathiraju P, Henderson S, Zeller D (2008) In hot soup: sharks captured in Ecuador's waters. Environmental Sciences 5: 269-283

Jayathilaka RAM, Maldeniya R (2015) Impact of policies on the conservation of sharks in the large pelagic fishery WPEB-IOTC

Jiao Y, Cortes E, Andrews K, Guo F (2011) Poor-data and data-poor species stock assessment using a Bayesian hierarchical approach. Ecol Appl 21: 2691-2708

Jiao Y, Hayes C, Cortes E (2009) Hierarchical Bayesian approach for population dynamics modelling of fish complexes without species-specific data. Ices Journal of Marine Science 66: 367-377 doi 10.1093/icesjms/fsn162

John ME, Varghese BC (2009) Decline in CPUE of Oceanic Sharks in the Indian EEZ: Urgent Need for Precautionary Approach. IOTC-2009-WPEB-17

Kiszka JJ (2012) An Ecological Risk Assessment (ERA) for marine mammals, sea turtles and elasmobranchs captured in artisanal fisheries of the SW Indian Ocean based on interview survey data WPEB-IOTC

Knoff M, de Sao Clemente SC, Pinto RM, Gomes DC (2001) Nematodes of elasmobranch fishes from the Southern Coast of Brazil. Memorias Do Instituto Oswaldo Cruz 96: 81-87 doi 10.1590/s0074-02762001000100009

Kohler NE, Turner PA (2001) Shark tagging: a review of conventional methods and studies. Environmental Biology of Fishes 60: 191-223

Kyalo KB, Stephen N (2013) Shark bycatch - small scale tuna fishery interactions along the Kenyan coast. IOTC–2013–WPEB09–13

Lack M, Sant G (2008) Illegal, unreported and unregulated shark catch: A review of current knowledge and action. WWF

IUCN, Canberra, Australia

Lack M, Sant G, Burgener M, Okes N (2014) Development of a rapid management-risk assessment method for fish species through its application to sharks: framework and results. TRAFFIC

Lee HK, Kim SJ, Jeong Y, Lee S, Jeong W, Lee WC, Choy EJ, Kang CK, Moon HB (2015) Polybrominated diphenyl ethers in thirteen shark species from offshore and coastal waters of Korea. Marine pollution bulletin 95: 374-379 doi 10.1016/j.marpolbul.2015.04.018

Liu K-M, Tsai W-P (2011) Catch and life history parameters of pelagic sharks in the Northwestern Pacific ISC Shark Working Group Workshop, Keelung, Chinese Taipei

Liu SY, Chan CL, Lin O, Hu CS, Chen CA (2013) DNA barcoding of shark meats identify species composition and CITES-listed species from the markets in Taiwan. PLoS One 8: e79373 doi 10.1371/journal.pone.0079373

Macbeth WG, Geraghty PT, Peddemors VM, Gray CA (2009) Observer-based study of targeted commercial fishing for large shark species in waters off northern New South Wales, Cronulla, NSW

Marsico ET, Machado MES, Knoff M, Clemente SCS (2007) Total mercury in sharks along the southern Brazilian Coast. Arquivo Brasileiro De Medicina Veterinaria E Zootecnia 59: 1593-1596 doi 10.1590/s0102-09352007000600039

Martinez-Ortiz J, Aires-da-Silva AM, Lennert-Cody CE, Maunder MN (2015) The Ecuadorian Artisanal Fishery for Large Pelagics: Species Composition and Spatio-Temporal Dynamics. PLoS One 10: e0135136 doi 10.1371/journal.pone.0135136

Masunaga G, Kosuge T, Asai N, Ota H (2009) Shark predation of sea snakes (Reptilia: Elapidae) in the shallow waters around the Yaeyama Islands of the southern Ryukyus, Japan. Marine Biodiversity Records 1 doi 10.1017/s1755267207009700

Matsumoto T, Saito H, Miyabe N (2003) Report of observer program for Japanese tuna longline fishery in the Atlantic Ocean from September 2001 TO March 2002. Col

Vol Sci Pap ICCAT 55: 1679-1718

Matsushita Y, Matsunaga H (2002) Species composition and CPUE of pelagic sharks observed by Japanese observers for tuna longline fisheries in the Atlantic Ocean. Col Vol Sci Pap ICCAT 54: 1371-1380

Maz-Courrau A, Lopez-Vera C, Galvan-Magana F, Escobar-Sanchez O, Rosiles-Martinez R, Sanjuan-Munoz A (2012) Bioaccumulation and Biomagnification of Total Mercury in Four Exploited Shark Species in the Baja California Peninsula, Mexico. Bulletin of Environmental Contamination and Toxicology 88: 129-134 doi 10.1007/s00128-011-0499-1

McAuley R, Rowland F (2012) Northern Shark Fisheries Status Report. In: Fletcher WJ, Santoro K (eds) Status Reports of the Fisheries and Aquatic Resources of Western Australia 2011/12: The State of the Fisheries. Department of Fisheries, Western Australia, pp 222-228

McAuley R, Simpfendorfer C (2003) Catch composition of the Western Australian temperate demersal gillnet and demersal longline fisheries, 1994 to 1999. Department of Fisheries, Western Australia

McComb DM, Tricas TC, Kajiura SM (2009) Enhanced visual fields in hammerhead sharks. The Journal of experimental biology 212: 4010-4018 doi 10.1242/jeb.032615

McVean AR, Walker RCJ, Fanning E (2006) The traditional shark fisheries of southwest Madagascar: A study in the Toliara region. Fisheries Research 82: 280-289 doi 10.1016/j.fishres.2006.06.016

Megalofonou P, Yannopoulos C, Damalas D, De Metrio G, Deflorio M, de la Serna JM (2005) Incidental catch and estimated discards of pelagic sharks from the swordfish and tuna fisheries in the Mediterranean Sea. Fishery Bulletin 103: 620-634

Miller MH, Carlson J, Cooper P, Kobayashi D, Nammack M, Wilson J (2014a) Status review report: scalloped hammerhead shark (Sphyrna lewini). Final Report to the National Marine Fisheries Service. OPR/NMFS/NOAA, Silver Spring, MD

Miller MH, Carlson J, Hogan L, Kobayashi D (2014b) Status review report: great hammerhead shark (Sphyrna mokarran). Final Report to the National Marine Fisheries Service. OPR/NMFS/NOAA, Silver Spring, MD

Murias A (2015) Authorisation to Export Shark Fins Cancelled. Project Aware

Murua H, Abascal FJ, Amande J, Ariz J, Bach P, Chavance P, Coelho R, Korta M, Poisson F, Santos MN, Seret B (2013) Provision of scientific advice for the purpose of the implementation of the EUPOA sharks. Final Report. European Commission, Studies for Carrying out the Common Fisheries Policy

Murua H, Coelho R, Santos MN, Arrizabalaga H, Yokawa K, Romanov E, Zhu JF, Kim ZG, Bach P, Chavance P, Delgado de Molina A, Ruiz J (2012) Preliminary Ecological Risk Assessment (ERA) for shark species caught in fisheries managed by the Indian Ocean Tuna Commission (IOTC) IOTC SC15

Musick JA (1999) Criteria to define extinction risk in marine fishes - The American Fisheries Society initiative. Fisheries 24: 6-14 doi Doi 10.1577/1548-8446(1999)024<0006:Ctderi>2.0.Co;2

Myers RA, Baum JK, Shepherd TD, Powers SP, Peterson CH (2007) Cascading effects of the loss of apex predatory sharks from a coastal ocean. Science 315: 1846-1850 doi 10.1126/science.1138657

Nair RV, James DB (1971) On the occurrence of sting-ray spines in the jaws and gills of the hammerhead sharks *Sphyrna zygaena* (Linnaeus) JOURNAL BOMBAY NATURAL Hist Society 69: 432-434

Nava Nava P, Fernando Marquez-Farias J (2014) Size at maturity of the smooth hammerhead shark, Sphyma zygaena, captured in the Gulf of California. Hidrobiologica 24: 129-135

Naylor GJP, Caira JN, Jensen K, Rosana KAM, White WT, Last PR (2012) A DNA Sequence-Based Approach to the Identification of Shark and Ray Species and Its Implications for Global Elasmobranch Diversity and Parasitology. Bulletin of the American Museum of Natural History 367: 1-262

News24 (2015) Taiwan boat caught with huge illegal shark fin haul News24

NMFS (2011a) 2011 Annual report of the United States to ICCAT. U.S. Department of Commerce, NOAA Fisheries

NMFS (2011b) 2011 Stock assessment and fishery evaluation (SAFE) report for Atlantic highly migratory species. U.S. Department of Commerce, NOAA

NMFS (2011c) Final Environmental Assessment, Regulatory Impact Review, and Final Regulatory Flexibility Analysis for a Final Rule to Implement the 2010 International Commission for the Conservation of Atlantic Tunas Recommendations on Sharks. In: Commerce USDo (ed). Highly Migratory Species Management Division

NMFS (2011d) U.S. National Bycatch Report. U.S. Department of Commerce, NOAA, NMFS

NMFS (2012a) 2012 Annual report of the United States to ICCAT. U.S. Department of Commerce, NOAA, National Marine Fisheries Service (NMFS)

NMFS (2012b) 2012 Stock Assessment and Fishery Evaluation Report for Atlantic Highly Migratory Species. U.S. Department of Commerce, NOAA

NMFS (2013a) Atlantic Highly Migratory Species Stock Assessment and Fishery Evaluation (SAFE) Report 2013. U.S. Department of Commerce

NMFS (2013b) U.S. National Bycatch Report First Edition Update 1. U.S. Department of Commerce

NMFS (2014a) 2014 Shark Finning Report to Congress. U.S. Department of Commerce, NOAA, NMFS

NMFS (2014b) 2014 Stock Assessment and Fishery Evaluation (SAFE) Report for Atlantic Highly Migratory Species. U.S. Department of Commerce

NMFS (2015a) 2015 Stock Assessment and Fishery Evaluation (SAFE) Report for Atlantic Highly Migratory Species. NOAA Fisheries, U.S. Department of Commerce, Silver Spring, MD

NMFS (2015b) Improving International Fisheries Management. U.S. Department of Commerce, NOAA, Washington, D.C.

NMFS (2015c) NOAA to work with 6 nations to address illegal, unreported, and unregulated fishing

Novianto D, Rochman F, Nugraha B (2014) Species composition, CPUE and length frequency of oceanic sharks based on observer data from the Indonesian longline fishery in the Indian Ocean WPEB-IOTC

NSW Department of Primary Industries (2015) Shark Meshing (Bather Protection) Program 2014-15 Annual Performance Report

Ocean Fisheries Programme (2010) Non-Target Species Interactions with the Tuna Fisheries of the Western and Central Pacific Ocean WCPFC SCIENTIFIC COMMITTEE SIXTH REGULAR SESSION, Nuku'alofa, Tonga

Paul MC, Toia RF, von Nagy-Felsobuki EI (2003) A novel method for the determination of mercury and selenium in shark tissue using high-resolution inductively coupled plasma-mass spectrometry. Spectrochimica Acta Part B: Atomic Spectroscopy 58: 1687-1697 doi 10.1016/s0584-8547(03)00143-5

Pérez-Jiménez JC (2014) Historical records reveal potential extirpation of four hammerhead sharks (Sphyrna spp.) in Mexican Pacific waters. Reviews in Fish Biology and Fisheries 24: 671-683 doi 10.1007/s11160-014-9353-y

Pérez-Jiménez JC, Sosa-Nishizaki O, Furlong-Estrada E, Corro-Espinosa D, Venegas-Herrera A, Barragán-Cuencas OV (2005) Artisanal Shark Fishery at "Tres Marias" Islands and Isabel Island in the Central Mexican Pacific. Journal of Northwest Atlantic Fishery Science 35: 333-343 doi 10.2960/J.v35.m489

Petersen S, Nel D, Omardien A (2007) Towards an ecosystem approach to longline fisheries in the benguela. WWF South Africa Report Series

PEW Environment Group (2012) Navigating Global Shark Conservation: Current Measures and Gaps. PEW Environment Group, Washington, D.C.

Philippine NPOA-Sharks (2009) National Plan of Action for the conservation and management of sharks in the Philippines. In: Department of Agriculture BoFaAR (ed)

Reid DD, Krogh M (1992) Assessment of Catches from Protective Shark Meshing Off New-South-Wales Beaches between 1950 and 1990. Aust J Mar Fresh Res 43: 283-296

Reid DD, Robbins WD, Peddemors VM (2011) Decadal trends in shark catches and effort from the New South Wales, Australia, Shark Meshing Program 1950-2010. Marine and Freshwater Research 62: 676-693 doi 10.1071/MF10162

Rice J, Tremblay-Boyer L, Scott R, Hare S, Tidd A (2015) Analysis of stock status and related indicators for key shark species of the Western Central Pacic Fisheries

Commission. WCPFC-SC11-2015/EB-WP-04-Rev 1

Robinson L, Sauer W (2011) A Preliminary Assessment of the Artisanal Shark Fishery in Northern Madagascar. In: Obura D, Samoilys M (eds) CORDIO Status Report 2011. CORDIO East Africa, pp 1-10

Rogers PJ, Huveneers C, Page B, Hamer DJ, Goldsworthy SD, Mitchell JG, Seuront L (2012) A quantitative comparison of the diets of sympatric pelagic sharks in gulf and shelf ecosystems off southern Australia. Ices Journal of Marine Science 69: 1382-1393 doi 10.1093/icesjms/fss100

Román-Verdesoto M (2015) Updated summary regarding hammerhead sharks caught in the tuna fisheries in the Eastern Pacific Ocean 6th Meeting of the Scientific Advisory Committee IATTC, La Jolla, CA (USA)

Román-Verdesoto M, Hall M (2014) Updated summary regarding hammerhead sharks caught in the tuna fisheries in the Eastern Pacific Ocean Inter-American Tropical Tuna Commission Scientific Advisory Committee Fifth Meeting, La Jolla, California

Rose DA (1996) An overview of world trade in sharks and other cartilaginous fishes. A TRAFFIC Network Report

Sadowsky V (1965) The hammerhead sharks of the littoral zone of Sao Paulo, Brazil, with the description of a new species. Bulletin of Marine Science 15

Sebastian H, Haye PA, Shivji MS (2008) Characterization of the pelagic shark-fin trade in north-central Chile by genetic identification and trader surveys. Journal of fish biology 73: 2293-2304 doi 10.1111/j.1095-8649.2008.02016.x

Sembiring A, Pertiwi NPD, Mahardini A, Wulandari R, Kurniasih EM, Kuncoro AW, Cahyani NKD, Anggoro AW, Ulfa M, Madduppa H, Carpenter KE, Barber PH, Mahardika GN (2015) DNA barcoding reveals targeted fisheries for endangered sharks in Indonesia. Fisheries Research 164: 130-134 doi 10.1016/j.fishres.2014.11.003

SL-NPOA-Sharks (2013) Sri Lanka National Plan of Action for the conservation and management of sharks. In: Resources FaA (ed), Sir Lanka

Smith-Vaniz WF, Jelks HL (2014) Marine and inland fishes of St. Croix, U. S. Virgin Islands: an annotated checklist. Zootaxa: 1-120 doi 10.11646/zootaxa.3803.1.1

Smith PJ, Benson PG (2001) Biochemical identifi cation of shark fins and fillets from the coastal fi sheries in New Zealand. Fish Bull 99: 351-355

Sperone E, Parise G, Leone A, Milazzo C, Circosta V, Santoro G, Paolillo G, Micarelli P, Tripepi S (2012) Spatiotemporal patterns of distribution of large predatory sharks in Calabria (central Mediterranean, southern Italy). Acta Adriatica 53: 13-24

Stevens JD (1984) Biological Observations on Sharks Caught by Sport Fishermen Off New-South-Wales. Aust J Mar Fresh Res 35: 573-590

Storelli MM, Ceci E, Storelli A, Marcotrigiano GO (2003) Polychlorinated biphenyl, heavy metal and methylmercury residues in hammerhead sharks: contaminant

status and assessment. Marine pollution bulletin 46: 1035-1039 doi 10.1016/s0025-326x(03)00119-x

Sucunza F, Doria E, Alves LCPdS, do Prado JHF, Ferreira E, Andriolo A, Danilewicz D (2015) Observations of antipredator tactics among pantropical spotted dolphins (Stenella attenuata) attacked by smooth hammerhead sharks (Sphyrna zygaena). Marine Mammal Science 31: 748-755 doi 10.1111/mms.12169

SWFSC (2015) Tagged Hammerhead Shark Travels Widely In Warm Pacific Waters

Taniuchi T (1974) Three species of hammerhead sharks in the southwestern waters of japan. Japanese Journal of Icthyology 21: 145-152

Tavares R (2005) Abundancia Relativa, Distribucion y Estructura Poblacional de Tiburones en el Caribe y Atlantico Centro-Occidental. Instituto Oceanográfico de Venezuela; Marine Sciences, Cumana, Venezuela

Testerman CB (2014) Molecular Ecology of Globally Distributed Sharks. Nova Southeastern University Oceanographic Center

Todorova V (2014) UAE ruling on fishing and sale of sharks welcomed by conservationists The National, United Arab Emirates

Tull M (2009) The History of Shark Fishing in Indonesia: A HMAP Asia Project Paper. In: Asia Research Centre MU (ed), Perth, Western Australia

Universidad Austral de Chile (2005a) Informe Final Volumen 1: Antecedentes para la elaboracion del Plan de Accion Nacional. Insttituto de Zoologia, Universidad Austral de Chile, Valdivia

Universidad Austral de Chile (2005b) Informe Final Volumen 2: Estado Actual de la Biologia y Pesqueria de los Condrictios en Chile. Instituto de Zoologia, Universidad Austral de Chile, Valdivia

Uosaki K, Minami H, Matsunaga H, Satoh K, Senba Y, Matsumoto T, Akatsuka Y (2015) Annual Report to the Commission Part 1: Information on fisheries, research and statistics; National Tuna Fisheries Report of Japan SCIENTIFIC COMMITTEE ELEVENTH REGULAR SESSION, Pohnpei, Federated States of Micronesia

Vannuccini S (1999) Shark utilization, marketing and trade, Rome

Varghese S, Somvanshi VS, Varghese SP (2007) By-catch of sharks and incidental catches of sea turtle in the long line fishery of Indian waters as observed during tuna resources survey. IOTC-2007-WPEB-13

Visser IN (2005) First Observations of Feeding on Thresher <I>(Alopias vulpinus)</I> and Hammerhead <I>(Sphyrna zygaena)</I> Sharks by Killer Whales <I>(Orcinus orca)</I> Specialising on Elasmobranch Prey. Aquatic Mammals 31: 83-88 doi 10.1578/am.31.1.2005.83

Vooren CM, Klippel S (2005) Ações para a conservação de tubarões e raias no sul do Brasil. Instituto Igaré, Porto Alegre, Brazil, pp 262

Walsh WA, Bigelow KA, Sender KL (2009) Decreases in Shark Catches and Mortality in the Hawaii-Based Longline Fishery as Documented by Fishery Observers. Marine

and Coastal Fisheries 1: 270-282 doi 10.1577/c09-003.1

Whitcraft S, Hofford A, Hilton P, O'Malley M, Jaiteh V, Knights P (2014) Evidence of Declines in Shark Fin Demand, China. WildAid, San Francisco, CA

White WT, Bartron C, Potter IC (2008) Catch composition and reproductive biology of Sphyrna lewini (Griffith & Smith) (Carcharhiniformes, Sphyrnidae) in Indonesian waters. Journal of fish biology 72: 1675-1689 doi 10.1111/j.1095-8649.2008.01843.x

White WT, Last PR, Stevens JD, Yearsley GK, Fahmi, Dharmadi (2006) Economically Important Sharks & Rays of Indonesia. Australian Centre for International Agricultural Research, Canberra, Australia

Whoriskey S, Arauz R, Baum JK (2011) Potential impacts of emerging mahi-mahi fisheries on sea turtle and elasmobranch bycatch species. Biological Conservation 144: 1841-1849 doi 10.1016/j.biocon.2011.03.021

Williamson J (2011) Proposed Determination: The Scalloped Hammerhead – Sphyrna lewini as an Endangered Species

WorldFish Center (2005) Fish and Food Security in Africa. WorldFish Center, Penang, Malaysia

Zeeberg J, Corten A, de Graaf E (2006) Bycatch and release of pelagic megafauna in industrial trawler fisheries off Northwest Africa. Fisheries Research 78: 186-195 doi 10.1016/j.fishres.2006.01.012

Zhou S, Fuller M, Smith T (2009) Rapid quantitative risk assessment for fish species in additional seven Commonwealth fisheries. Commonwealth Scientific and Industrial Research Organisation, Australia

Zhou S, Griffiths SP (2008) Sustainability Assessment for Fishing Effects (SAFE): A new quantitative ecological risk assessment method and its application to elasmobranch bycatch in an Australian trawl fishery. Fisheries Research 91: 56-68 doi 10.1016/j.fishres.2007.11.007

APPENDIX

I. Current and relevant shark regulations by U.S. state and territory

Source: (NMFS 2011b; NMFS 2015a):

U.S. State	Shark Regulations
Maine	Although part of the Atlantic States Marine Fisheries Commission (ASMFC), both Maine and New Hampshire were granted de minimis status for the Interstate FMP for Atlantic Coastal Sharks (see further details below) that was adopted by the ASFMC in 2008 (ASFMC 2008). Maine - Commercial harvest of sharks (except spiny dogfish) in state waters prohibited; finning prohibited; sharks harvested elsewhere but landed in Maine, or sharks landed recreationally, must be landed with head, fins, and tail naturally attached to the carcass; porbeagle cannot be landed commercially after federal quota closes. Dealers who purchase sharks must obtain a federal dealer permit. Recreational anglers must possess a federal HMS angling permits.
New Hampshire	
Massachusetts	Also a part of the ASMFC, and was granted de minimis status for the Interstate FMP for Atlantic Coastal Sharks. Granted an exemption from the possession limit for non-sandbar large coastal sharks and closures of the non-sandbar large coastal shark fisheries.
Rhode Island	Fishermen must abide by the Interstate FMP for Atlantic Coastal Sharks adopted by the ASMFC (ASMFC 2008). This FMP requires that all sharks harvested by commercial or recreational fishermen within state waters have the tail and fins attached naturally to the carcass. ASFMC opens and closes the hammerhead fishery when NOAA Fisheries opens and closes the corresponding federal fisheries. Recreational fishermen may only catch sharks with a fork length of at least 78 inches (6.5 feet; 198 cm) and they must be caught using a handline or rod & reel. Each recreational shore-angler is allowed a maximum harvest of one shark from the federal recreationally permitted species (including smooth hammerheads) per calendar day. Recreational fishing vessels are allowed a maximum harvest of one shark from the federal recreationally permitted species (including smooth hammerheads), per trip, regardless of the number of people on board the vessel. Fishermen are prohibited from possessing smooth
Connecticut	
New York	
New Jersey	
Delaware	
Maryland	
Virginia	

	hammerheads in the state waters of Virginia, Maryland, Delaware and New Jersey from May 15 through July 15—regardless of where the shark was caught. Fishermen who catch any of these species in federal waters may not transport them through the state waters of Virginia, Maryland, Delaware, and New Jersey during the seasonal closure. However, recreational fishers may still catch and transport hammerhead sharks during the seasonal closure. New York amended its Environmental Conservation Law to prohibit sharks (excluding spiny dogfish) from being taken for commercial or recreational purposes by baited hooking except with the use of non-stainless steel non-offset circle hooks. New York, Maryland, and Delaware have shark fin laws that ban the possession, sale, or distribution of shark fins. All three laws in these states exempt Spiny dogfish and Smooth dogfish fins from the ban. Each state law also includes other exceptions including for education, research, and other situations. Maryland requires reporting of all recreationally landed common thresher (and other) sharks through state administered HMS catch card program.
North Carolina	Adopted the ASMFC Coastal Shark Interstate FMP. Additionally, the Director may impose restrictions for size, seasons, areas, quantity, etc. via proclamation. The longline in the shark fishery shall not exceed 500 yds or have more than 50 hooks.
South Carolina	Adopted the ASMFC Coastal Shark Interstate FMP. Additionally, defers to federal regulations. Gillnets may not be used in the shark fishery in state waters.
Georgia	Adopted the ASMFC Coastal Shark Interstate FMP. Additionally, commercial/recreational regulations: Hammerheads (great, scalloped and smooth) -1/person or boat, whichever is less, minimum size – 78” FL. All sharks must be landed with the head and fins intact. Sharks may not be landed in Georgia if harvested using gillnets.
Florida	Adopted the ASMFC Coastal Shark Interstate FMP. Additionally, no person shall harvest, possess, land, purchase, sell, or exchange any or any part of the smooth hammerhead shark. However, the prohibitions on harvest shall not apply to lawful harvest in federal waters when such harvest is transported directly through state

	waters with gear appropriately stowed.
Alabama	Recreational: bag limit – 1 hammerhead shark/person/day with a minimum size of 78” FL. Commercial - no size limit and no possession limit on any non-prohibited species. State waters close when federal season closes and no shark fishing on weekends, Memorial Day, Independence Day, or Labor Day. Restrictions on chumming and shore-based angling if creating unsafe bathing conditions. Regardless of open or closed season, gillnet fishermen targeting other fish may retain sharks with a dressed weight not exceeding 10% of total catch.
Louisiana	Recreational: bag limit 1 shark/person/day with a minimum size of 54” FL (137 cm). Commercial: 36 sharks/vessel/day limit and no minimum size. Commercial and recreational harvest of sharks prohibited from April 1st through June 30th. Fins must remain naturally attached to carcass through off-loading. Owners/operators of vessels other than those taking sharks in compliance with state or federal commercial permits are restricted to no more than one shark from either the large coastal, small coastal, or pelagic group per vessel per trip within or without Louisiana waters.
Mississippi	Recreational: bag limit - LCS/Pelagics 1 shark/person (possession limit) up to 3 sharks/vessel (possession limit) with a minimum size of 37” TL (94 cm). Finning is prohibited.
Texas	Commercial/recreational: bag limit – 1 shark/person/day; Commercial/recreational possession limit is twice the daily bag limit (i.e., 2 sharks/person/day) with a minimum size of 64” TL (163 cm) for hammerheads.
California	California’s Shark Fin Prohibition law prohibits the sale, purchase, or possession of detached shark fins. The law exempts licensed shark fishers that land sharks in California from the possession ban. Includes an education and research exemption. Sharks may not be taken with drift gillnets of mesh size eight inches (20 cm) or greater except under a revocable permit issued by the California Department of Fish and Game.
Washington	Washington’s shark fin law prohibits the sale, trade or distribution of detached shark fins or derivative products

	in the state. The law does not restrict possession of detached shark fins. Includes exemptions for education and research.
Oregon	An individual may not possess, sell or offer for sale, trade or distribute a shark fin within the state. The law includes a variety of exemptions including for fins from spiny dogfish.
Hawaii	Unlawful to possess, sell, offer for sale, trade, or distribute shark fins. Includes exemptions for education and research.
Illinois	Bans the possession, sale, or distribution of detached shark fins.
U.S. Territories:	
U.S. Virgin Islands	Federal regulations and federal permit requirements apply in territorial waters.
Puerto Rico	Federal regulations and federal permit requirements apply in territorial waters.
American Samoa	Prohibits the possession, delivery, or transportation of any shark species or shark body party. Includes an exemption for research.
Guam	No drift gillnets. Gillnets must be moved every 6 hours. Bans the possession, sale, offer for sale, take, purchase, barter, transport, export, import, trade or distribution of shark fins. Includes exemptions for research and subsistence fishing.
CNMI	Bans the possession, sale, offer for sale, trade, or distribution of shark fins. Includes exemptions for research and subsistence fishing.

*Regulations pertaining to fishing for sharks in Federal waters in the Atlantic can be found on the NMFS Atlantic Highly Migratory Species website (http://www.fisheries.noaa.gov/sfa/hms/compliance/regulations/index.html), and in the Pacific can be found on the NMFS West Coast Region Highly Migratory Species webpage (http://www.westcoast.fisheries.noaa.gov/fisheries/migratory_species/highly_migratory_species.html).

II. International regulations that prohibit shark fishing by implementing country Source: (Humane Society International 2015):

Country	Date	Prohibited Shark Fishing
Bahamas	2011	Commercial shark fishing in the approximately 630,000 square kilometers (243,244 square miles) of the country's waters is prohibited.

British Virgin Islands	2014	No commercial fishing of sharks or rays
Brunei	2013	Ban on harvest of any shark species.
Colombia	1995	Shark fishing is prohibited in the Malpelo Wildlife Sanctuary
Cook Islands	2012	Commercial shark fishing banned. Created a sanctuary in its waters, contiguous with the sanctuary in French Polynesia and bans the possession or sale of shark products.
Congo-Brazzaville	2001	Shark fishing is prohibited.
Costa Rica	1978	Shark fishing is prohibited in Cocos Island National Park.
Dutch Caribbean Islands of Bonaire and Saba	2015	Creation of marine sanctuary.
Ecuador	2004	Directed fishing for sharks is banned in all Ecuadorian waters, but sharks caught in “continental” (i.e., not Galapagos) fisheries may be landed if bycaught (finning is banned).
Egypt	2005	Shark fishing is prohibited throughout the Egyptian Red Sea territorial waters to 12 miles from the shore, as is the commercial sale of sharks.
French Polynesia	2012	All shark fishing banned. Created shark sanctuary in its waters contiguous with the sanctuary in Cook Islands, and banned trade in all sharks.
Guinea-Bissau	2009	Ban on shark fishing in Marine Protected Areas (two parks covering 2,077 km^2).
Indonesia	2010	No shark fishing in Raja Ampat
Kiribati	2015	No commercial shark fishing in the Phoenix Islands Protected Area and Southern Line Islands
Maldives	2010	Bans fishing, trade and export of sharks and shark products in the country, effectively converting its 35,000-square-mile (90,000-square-kilometer) EEZ into a sanctuary for sharks, a swath of the Indian Ocean about the size of the U.S. State of Maine.
Marshall Islands	2011	No commercial shark fishing or sale of shark products
Mauritania	2003	Created a 6000 km^2 coastal sanctuary for sharks and rays (Banc d'Arguin National Park - PNBA). Targeted shark fishing is prohibited.

Micronesia	2015	Passed legislation (Public Law No. 18-108) in early 2015 to establish the Micronesia Regional Shark Sanctuary, which covers the country's full EEZ and encompasses nearly 3 million square kilometers (1.1 million square miles) in the western Pacific Ocean. The measure prohibits the commercial fishing and trade of sharks and rays and their parts. The sanctuary includes the waters of the Republic of Marshall Islands, Republic of Palau, Guam, CNMI, Federated States of Micronesia and its four member states, Yap, Chuuk, Pohnpei, and Kosrae.
New Caledonia	2013	Passed regulations to prohibit all shark fishing in its EEZ. Regulations also ban the taking, possession, sale or export of all species of sharks. The Pacific waters of this French overseas territory are roughly the size of South Africa and can protect upwards of 50 species of sharks.
Palau	2009	Created a shark sanctuary that encompasses 240,000 square miles (621,600 square kilometers, roughly size of France) of protected waters. Prohibits the commercial fishing of sharks.
Republic of the Marshall Islands	2011	Created world's largest shark sanctuary. Bans commercial fishing of sharks in all 1,990,530 square kilometers (768,547 square miles) in the country's waters, an ocean area four times the landmass of California. A complete prohibition on the commercial fishing of sharks as well as the sale of any sharks or shark products. Any shark caught accidentally by fishing vessels must be set free. A ban on the use of wire leaders, a longline fishing gear which is among the most lethal to sharks.
Sabah, Malaysia	2011	Prohibits shark fishing.
Spain	2011	Prohibits the capture, injury, trade, import and export of specific shark species, and requires periodic evaluations of their conservation status.
Tokelau (an island territory of New Zealand in the South Pacific)	2011	Created a shark sanctuary which encompasses all 319,031 square kilometers (123,178 square miles) of Tokelau's exclusive economic zone.
Venezuela	2012	Commercial shark fishing is prohibited throughout the 3,730 square kilometers (1,440 square miles) of the Caribbean Sea that make up the Los Roques and Las Aves archipelagos.

III. International regulations that prohibit shark finning by implementing country (Source: HSI 2015):

Country	Date	Prohibited Shark Finning

Argentina	2009	Retaining the fins and discarding the carcass is banned.
Australia	Various	States and Territories govern their own waters. Central government regulates 'Commonwealth' or Federal waters, from 3 to 200 nautical miles offshore. Sharks must be landed with fins naturally attached in Commonwealth, NSW and Victorian waters, and must be landed with corresponding fins in a set fin to carcass ratio in Tasmanian, Western Australian, Northern Territory and Queensland waters.
Brazil	1998	Sharks must be landed with corresponding fins. Fins must not weigh more than 5% of the total weight of the carcass. All carcasses and fins must be unloaded and weighed and the weights reported to authorities. Pelagic gillnets and trawls are prohibited in waters less than 3 nautical miles (5.6 km) from the coast.
Canada	1994	Finning in Canadian waters and by any Canadian licensed vessel fishing outside of the EEZ is prohibited. When landed, fins must not weigh more than 5% of the dressed weight of the shark.
Cape Verde	2005	Finning prohibited throughout the EEZ.
Chile	2011	Bans shark finning in Chilean waters. Sharks must be landed with fins naturally attached.
Colombia	2007	Sharks must be landed with fins naturally attached to their bodies.
Costa Rica	2006	Requires fins to be landed attached to shark carcasses.
El Salvador	2006	Shark finning is prohibited. Sharks must be landed with at least 25% of each fin still attached naturally. The sale or export of fins is prohibited without the corresponding carcass.
England and Wales	2009	Sharks must be landed with fins naturally attached.
European Union	2013	Shark finning is prohibited by all vessels fishing in EU waters and on all EU vessels fishing in oceans worldwide. Sharks must be landed with fins naturally attached.
Gambia	2004	Ban on finning in all territorial waters. Mandatory to land sharks caught in Gambian waters on Gambian soil.
Guinea	2009	Ban on finning in all territorial waters.
India	2013	Bans removal of shark fins on board a vessel in the sea.
Japan	2008	Ban on shark finning by Japanese vessels; however, Japanese vessels operating and landing outside Japanese waters are exempt.

Mexico	2007	Shark finning is prohibited. Shark fins must not be landed unless the bodies are on board the vessel. In 2011, Mexico banned shark fishing from May 1 to July 31 in Pacific Ocean and from May 1 to June 30 in Gulf of Mexico & Caribbean Seas.
Namibia	2003	Generally prohibits the discards of harvested or bycaught marine resources. Prohibits shark finning.
New Zealand	2009/2016	Finning of live sharks (and disposing of carcasses at sea) is prohibited. By October 2016, all species of sharks must be released alive or brought to shore with fins naturally attached. Hammerhead sharks are prohibited from being targeted but may be landed as bycatch.
Nicaragua	2004	Fins must not weigh more than 5% of the total weight of the carcass. Export of fins allowed only after proof that carcass has been sold as the capture of sharks for the single use of their fins is prohibited.
Oman	1999	Prohibits the throwing of any shark part or shark waste in the sea or on shore. It is also prohibited to separate shark fins and tails unless this is done according to the conditions set by the competent authority.
Pakistan		Require that all parts of the shark are used and fins be landed naturally attached.
Panama	2006	Shark finning is prohibited. Industrial fishers must land sharks with fins naturally attached. Artisanal fishers may separate fins from the carcass but fins must not weigh more than 5% of the total weight of the carcass.
Seychelles	2006	Fins may not be removed onboard a vessel unless authorized. Must produce evidence that they have the capacity to utilize all parts or the shark. Fins may not be transshipped. Fins must not weigh more than 5% of the total weight of the carcass (after evisceration) or 7% (after evisceration and beheading).
Sierra Leone	2008	Ban on shark finning.
South Africa	1998	Sharks must be landed, transported, sold, or disposed of whole (they can be headed and gutted). Sharks from international waters may be landed in South Africa with fins detached.
Sri Lanka	2001	Ban on shark finning.
Taiwan	2012	Enacted a shark finning ban.
United Arab Emirates	2014	Smooth, scalloped, and great hammerheads are protected in UAE waters. Prohibits the export of any shark products caught in UAE waters. Shark finning and the export or re-exports of shark fins are banned

		from the UAE. Annual fishing ban in effect from February 1 to June 30.
Venezuela	2012	Sharks caught in Venezuelan waters must be brought to port with fins naturally attached.

IV. Countries that prohibit the sale or trade of shark fins or products:

- American Samoa
- Bahamas
- Brunei
- Canada - The cities of Brantford, Oakville, Newmarket, Mississauga, London, Pickering and Toronto, as well as six municipalities in British Colombia: Abbotsford, Coquitlam, Nanaimo, Port Moody, North Vancouver, and Maple Ridge, have all passed bans on the sale of shark fins.
- CNMI
- Cook Islands
- Egypt
- French Polynesia
- Guam (with an exception for subsistence fishing)
- India
- Republic of the Marshall Islands
- Sabah, Malaysia
- Turks and Caicos
- United Arab Emirates

V. Summary of RFMO Regulations pertinent to Hammerhead Sharks:

RFMO	Date	Shark Regulations
International Commission for the Conservation of Atlantic Tunas (ICCAT)	2011	Developed recommendation 10-08 which specifically prohibits the retention, transshipping, landing, sorting, or selling of hammerhead sharks, other than bonnethead sharks, caught in association with ICCAT fisheries. However, there is an exception for developing coastal nations for local consumption as long as hammerheads do not enter into international trade.
General Fisheries Commission of the Mediterranean (GFCM)	2012	Adopted ICCAT recommendation 10-08 on hammerhead sharks; hammerheads cannot be retained on board, transhipped, landed, transferred, stored, sold or displayed or offered for sale.

Commission for the Conservation of Antarctic Marine living Resources (CCAMLR)	2006	Directed fishing on shark species in the Convention Area, for purposes other than scientific research, is prohibited. Any bycatch of shark, especially juveniles and gravid females, taken accidentally in other fisheries, shall, as far as possible, be released alive.
Indian Ocean Tuna Commission (IOTC)	2005	Requires that fishers fully utilize any retained catches of sharks. Full utilization is defined as retention by the fishing vessel of all parts of the shark excepting head, guts, and skins, to the point of first landing. Onboard fins cannot weigh more than 5% of the weight of sharks onboard, up to the first point of landing. WCPFC also adopted a CMM 2014-05 (effective July 2015) that requires each national fleet to ban the use of wire trace as branch lines or leaders
Inter-American Tropical Tuna Commission (IATTC)	2005	
North Atlantic Fisheries Organization (NAFO)	2005	
Southeast Atlantic Fisheries Commission (SEAFO)	2006	
Western and Central Pacific Fisheries Commission (WCPFC)	2008	
North East Atlantic Fisheries Commission (NEAFC)	2007	

VI. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

Scalloped, smooth, and great hammerhead sharks are also listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). CITES is an international agreement between governments that regulates international trade in wild animals and plants. It encourages a proactive approach and the species covered by CITES are listed in appendices according to the degree of endangerment and the level of protection provided.

- Appendix I - includes species threatened with extinction; trade in specimens of these species is permitted only in exceptional circumstances.
- Appendix II - includes species not necessarily threatened with extinction, but for which trade must be controlled to avoid exploitation rates incompatible with species survival.
- Appendix III - contains species that are protected in at least one country, which has asked other CITES Parties for assistance in controlling the trade.

In March 2013, at the CITES Conference of the Parties meeting in Bangkok, member nations, referred to as “Parties,” voted in support of listing these three species of

hammerhead sharks in CITES Appendix II – an action that means increased protection, but still allows legal and sustainable trade. This CITES listing went into effect on September 14, 2014. Any person or entity that plans to engage in international trade in specimens of Appendix II species must apply for and obtain appropriate CITES documents. Permits are issued based on two analyses:

(1) A non-detriment finding – data or expert scientific opinion on the biological status of the species indicating that international trade is not detrimental to species survival.

(2) A legal acquisition finding – evidence that specimens to be traded were not obtained in violation of any state, federal, or other jurisdictional law.

If both of these analyses are positive (i.e., the proposed activity is legal and sustainable), a permit would be issued to conduct international trade in products of the species.