Status Review Report:
Scalloped Hammerhead Shark (*Sphyrna lewini*)

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EXECUTIVE SUMMARY

This status review report was conducted in response to a petition to list the scalloped hammerhead shark under the Endangered Species Act (ESA) (WildEarth Guardians and Friend of Animals to U.S. Secretary of Commerce, Acting through the National Oceanic and Atmospheric Administration and the National Marine Fisheries Service (NMFS), August 14, 2011, “Petition to list the scalloped hammerhead shark (*Sphyrna lewini*) under the U.S. Endangered Species Act either worldwide or as one or more distinct population segments”). NMFS evaluated the petition to determine whether the petitioner provided substantial information as required by the ESA to list a species. Additionally, NMFS evaluated whether information contained in the petition might support the identification of a distinct population segment (DPS) that may warrant listing as a species under the ESA. NMFS determined that the August 14, 2011 petition did present substantial scientific and commercial information, or cited such information in other sources, that the petitioned action may be warranted and, subsequently, NMFS initiated a status review of the scalloped hammerhead shark. This status review report is comprised of two components: (1) the “Status Review” of the species, a document that compiles the best available information on the status of the scalloped hammerhead shark as required by the ESA, and (2) the “Assessment of Extinction Risk” for the species, a document that provides the methods and conclusions of the NMFS Extinction Risk Analysis (ERA) team on the current and future extinction risks of the scalloped hammerhead shark.

The scalloped hammerhead shark (*Sphyrna lewini*) is a circumglobal species occurring in coastal warm temperate and tropical seas (Compagno 1984). Scalloped hammerhead sharks are highly mobile and partly migratory and are likely the most abundant of the hammerhead species (Maguire et al. 2006); however the risk of local depletions is of concern. Scalloped hammerhead sharks have a life history that is susceptible to overharvesting, and according to the most recent stock assessment (Hayes et al. 2009) the Northwestern Atlantic and Gulf of Mexico stock has declined to a relatively low level of abundance in recent years. Populations in other parts of the world are assumed to have suffered similar declines, however data to conduct stock assessments are currently lacking.

Based on a review of the best available information, the ERA determined that there exists six DPSs of the scalloped hammerhead shark, as defined by the joint U.S. Fish and Wildlife Service-NMFS interagency policy of 1996 on vertebrate distinct population segments under the ESA. Based on information related to genetic variation among populations, behavior and physical factors, and differences in international regulatory mechanisms, the ERA team identified a Northwest Atlantic & Gulf of Mexico DPS, Central & Southwest Atlantic DPS, Eastern Atlantic DPS, Indo-West Pacific DPS, Central Pacific DPS, and Eastern Pacific DPS of scalloped hammerhead sharks.

The ERA team ranked demographic risks and threats to each of the DPSs. In the case of the Northwest Atlantic & Gulf of Mexico DPS, the ERA team ranked the high at-vessel fishing mortality of scalloped hammerhead sharks as the most serious threat, with overutilization by industrial/commercial and recreational fisheries as moderate risks to the persistence of the DPS. For the Central & Southwest Atlantic DPS as well as the Eastern Atlantic DPS, overutilization by

industrial/commercial fisheries and the high at-vessel fishing mortality of *S. lewini* were ranked as high risks, and overutilization by artisanal fisheries, lack of adequate regulatory mechanisms, IUU fishing, and the schooling behavior of the species were ranked as moderate risks to the persistence of these DPSs. In the Indo-West Pacific DPS, overutilization by industrial/commercial and artisanal fisheries, as well as IUU fishing and the high at-vessel mortality of the sharks were ranked as high risks, with habitat degradation, inadequacy of current regulatory mechanisms, and schooling behavior ranked as moderate risks. The main threat to the Central Pacific DPS was the high at-vessel fishing mortality of scalloped hammerhead sharks, with overutilization by industrial/commercial fisheries ranked as a moderate risk. Finally, for the Eastern Pacific DPS, the threats of overutilization by industrial/commercial and artisanal fisheries, as well as the impact of IUU fishing, high at-vessel fishing mortality and schooling behavior of the species were ranked as high risks, with the lack of current adequate regulatory mechanisms ranked as a moderate risk.

Based on an evaluation of abundance trends, growth and productivity, spatial structure, and diversity, as well as the threats listed above, the ERA team determined that the Central Pacific DPS was at a very low risk of extinction now and in the foreseeable future. The Northwest Atlantic & Gulf of Mexico DPS was at a low risk of extinction now and in the foreseeable future. The Central & Southwest Atlantic DPS and the Indo-West Pacific DPS were at a moderate risk of extinction now and in the foreseeable future, whereas the Eastern Atlantic DPS and Eastern Pacific DPS were at a high risk of extinction now and in the foreseeable future. The ERA team did not find any significant portion of range within a DPS that would warrant a different risk of extinction and therefore concluded that the extinction risk for each DPS applied to the entire range of that DPS.

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STATUS REVIEW OF THE SCALLOPED HAMMERHEAD SHARK (*SPHYRNA LEWINI*)

Photo Credit: Dr. Jill Zamzow

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INTRODUCTION

Scope and Intent of the Present Document

This document is the status review in response to a petition[1] to list the scalloped 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) decided that the petition had sufficient merit for consideration and that a status review was warranted (76 FR 72891, November 28, 2001). The ESA stipulates that listing determinations should be made on the basis of the best scientific and commercial information available. NMFS appointed a contractor in the Office of Protected Resources Endangered Species Division to undertake a scientific review of the biology, population status and future outlook for the scalloped hammerhead shark. Using this scientific review, NMFS convened a team of biologists and shark experts to conduct an extinction risk analysis for the scalloped hammerhead shark. This document reports the findings of the scientific review as well as the team's conclusions regarding the biological status of the scalloped hammerhead shark as a potential candidate for listing under the ESA. These conclusions are subject to revision should important new information arise in the future.

Key Questions in ESA Evaluations

In determining whether a listing under the ESA is warranted, two key questions must be addressed:

1) Is the entity in question a "species" as defined by the ESA?
2) If so, is the "species" threatened or endangered?

The ESA (section 3) defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." NMFS considers a variety of information in evaluating the level of risk faced by a species in deciding whether the species is threatened or endangered. Important considerations include 1) absolute numbers of fish and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and

[1] WildEarth Guardians and Friend of Animals to U.S. Secretary of Commerce, Acting through the National Oceanic and Atmospheric Administration and the National Marine Fisheries Service, August 14, 2011, "Petition to list the scalloped hammerhead shark (*Sphyrna lewini*) under the U.S. Endangered Species Act either worldwide or as one or more distinct population segments"

carrying capacity of the habitat; 3) any trends in abundance; 4) natural and human influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity; and 6) recent events (e.g., a drought or a change in management) that have predictable short-term consequences for abundance of the species. Additional risk factors, such as disease prevalence or changes in life history traits, may also be considered in evaluating risk to populations.

NMFS is required by law (ESA Sec. 4(a)(1)) to determine whether one or more of the following factors is/are responsible for the species' threatened or endangered status:

> The present or threatened
> (A) destruction, modification or curtailment of its habitat or range;
> (B) overutilization for commercial, recreational, scientific, or educational purposes;
> (C) disease or predation;
> (D) inadequacy of existing regulatory mechanisms; or
> (E) other natural or human factors affecting its continued existence.

According to the ESA, the determination of whether a species is threatened or endangered should be made on the basis of the best scientific and commercial information available regarding its current status, after taking into consideration conservation measures that are being made.

Summary of the Scalloped Hammerhead Listing Petition

A document titled "Petition to list the scalloped hammerhead shark (*Sphyrna lewini*) under the U.S. Endangered Species Act either worldwide or as one or more Distinct Population Segments" dated 08/14/11 was sent to NMFS jointly by two parties (WildEarth Guardians and Friends of Animals). In response, NMFS issued a 90-day finding on a petition to list the scalloped hammerhead shark as threatened or endangered under the Endangered Species Act (76 FR 72891, November 28, 2011), and included a formal request for information.

The petition asserts that populations of the species are in decline worldwide, referencing the International Union for Conservation of Nature (IUCN) classification for imperiled subpopulations of the scalloped hammerhead. The petition identified overutilization as the primary cause of this decline. Secondary issues raised by the petition were the inadequacy of existing regulatory mechanisms and other natural or manmade factors (specifically biological vulnerability and human population growth). The petition asserts that listing of scalloped hammerhead shark would provide the species with much needed regulatory protection, including prohibiting the import or export of the species from or to the U.S., and would encourage international efforts to protect the scalloped hammerhead through financial and technical assistance or law enforcement.

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 Genus *Eusphyra*. The hammerhead sharks are recognized by their laterally expanded head that resembles a hammer, hence the common name "hammerhead." The scalloped hammerhead shark (*Sphyrna lewini*) is distinguished from other hammerheads by a marked central indentation on the anterior margin of the head, along with two more indentations on each side of this central indentation, giving the head a "scalloped" appearance. It has a broadly arched mouth and the rear margin of the head is slightly swept backward. The dentition of the hammerhead consists of small, narrow, and triangular teeth with smooth edges (often slightly serrated in larger individuals), and is similar in both jaws. The front teeth are erect while subsequent teeth have oblique cusps, and the lower teeth are more erect than the upper teeth (Bester 2011). The body of the scalloped hammerhead is fusiform, with a large first dorsal fin and low second dorsal and pelvic fins. The first dorsal fin is moderately hooked with its origin over or slightly behind the pectoral fin insertions and the rear tip in front of the pelvic fin origins. The height of the second dorsal fin is less than the anal fin height and has a posterior margin that is approximately twice the height of the fin, with the free rear tip almost reaching the precaudal pit. The pelvic fins have relatively straight rear margins while the anal fin is deeply notched on the posterior margin (Compagno 1984). The scalloped hammerhead generally has a uniform gray, grayish brown, bronze, or olive coloration on top of the body that shades to white on the underside with dusky or black pectoral fin tips.

Range and Habitat Use

The scalloped hammerhead shark is a circumglobal species that lives in coastal warm temperate and tropical seas. It occurs over continental and insular shelves, as well as adjacent deep waters, but is seldom found in waters cooler than 22° C (Compagno 1984, Schulze-Haugen and Kohler 2003). It ranges from the intertidal and surface to depths of up to 450-512 m (Sanches 1991, Klimley 1993), with occasional dives to even deeper waters (Jorgensen et al. 2009). It has also been documented entering enclosed bays and estuaries (Compagno 1984).

Scalloped hammerhead sharks are highly mobile and partly migratory and are likely the most abundant of the hammerhead species (Maguire et al. 2006). These sharks have been observed making migrations along continental margins as well as between oceanic islands in tropical waters (Kohler and Turner 2001, Duncan and Holland 2006, Bessudo et al. 2011, Diemer et al. 2011). The median distance between mark and recapture of 3,278 tagged adult sharks along the eastern United States was less than 100 km (Kohler and Turner 2001). Along the east coast of South Africa, average distance moved by *S. lewini* was 147.8 km (data from 641 tagged scalloped hammerheads; Diemer et al. 2011). In Kāne'ohe Bay, Hawaii, sharks travelled as far as 5.1 km in the same day but the mean distance between capture points was 1.6 km (data from 151 recaptured juveniles; Duncan and Holland 2006). These tagging studies reveal the tendency for scalloped hammerhead sharks to aggregate around and travel to and from core areas or "hot spots" within locations (Holland et al. 1993, Duncan and Holland 2006, Hearn et al. 2010, Bessudo et al. 2011), however they are also capable of traveling long distances (1941 km, Bessudo et al. 2011; 1671 km, Kohler and Turner 2001, Hearn et al. 2010; 629 km, Diemer et al. 2011). In addition, in many of these tagging studies scalloped hammerheads were tracked leaving the study area for long periods of time, ranging from 2 weeks to several months (Hearn et al. 2010, Bessudo et al. 2011) to almost a year (324 days) (Duncan and Holland 2006), but eventually returning, displaying a level of site fidelity to these areas.

Both juveniles and adult scalloped hammerhead sharks occur as solitary individuals, pairs, or in schools. The schooling behavior has been documented during summer migrations off the coast of South Africa as well as in permanent resident populations, like those in the East China Sea (Compagno 1984). In the Gulf of California, Klimley (1985) reported highly polarized and aggressive schools, with females predominating and competing for positions at the center of schools. These adult aggregations are most common offshore over seamounts and near islands, especially near the Galapagos, Malpelo, Cocos and Revillagigedo Islands, and within the Gulf of California (Compagno 1984, CITES 2010, Hearn et al. 2010, Bessudo et al. 2011). Neonate and juvenile aggregations are more common in nearshore nursery habitats, such as Kāne'ohe Bay in Oahu, Hawaii, coastal waters off Oaxaca, Mexico, Guam's inner Apra Harbor, and coastal areas in the Republic of Transkei (Duncan and Holland 2006, Bejarano-Álvarez et al. 2011, Diemer et al. 2011). It has been suggested that juveniles inhabit these nursery areas for up to or more than a year as they provide valuable refuges from predation (Duncan and Holland 2006). Tagging and catch per unit effort (CPUE) data from Kāne'ohe Bay indicate that juvenile scalloped hammerheads prefer to aggregate in deeper water during the day, where the habitat is composed mainly of mud and silt (Duncan and Holland 2006). Areas of higher hammerhead shark abundance also corresponded to locations of greater turbidity and higher sedimentation and nutrient flow (Duncan and Holland 2006). This was also true of sharks around Maleplo Island, in the Eastern Tropical Pacific (ETP), where large schools of scalloped hammerhead sharks gathered on the side of the island where the current was strongest (Bessudo et al. 2011). However, in the ETP and Gulf of California, scalloped hammerheads displayed the reverse diel pattern, spending daytime hours near islands and seamounts and moving offshore at night (Klimley et al. 1988, Hearn et al. 2010, Bessudo et al. 2011), exhibiting highly directional swimming and homing behavior (Klimley 1993). Around Malpelo Island, sharks were detected more often at night and in shallower water (around 18 m) during the cold season, whereas in the warm water season, sharks remained further offshore at deeper depths (around 25m) (Bessudo et al. 2011), presumably to forage. Bessudo et al. (2011) also found that the depth at which scalloped hammerhead sharks commonly swam around Malpelo Island coincided with the thermocline and suggested that scalloped hammerhead seasonal movements to and from the island of Malpelo are linked to oceanographic conditions, with seasonal environmental signals triggering the migratory movements. Likewise, Zeeberg et al. (2006) noted an increase in abundance of hammerhead bycatch in pelagic trawlers operating in the Mauritania EEZ during the summer months, with bycatch probability decreasing significantly during the winter and spring, as trade wind-induced upwellings caused sea surface temperatures to drop from summer maximums of 30°C to 18°C. There is also evidence of size segregation in areas off the coast of Australia (Noriega et al. 2011) as well as in schools around Wolf Island in the Galapagos (Hearn et al. 2010).

The scalloped hammerhead shark is a high trophic level predator (trophic level = 4.1; Cortés 1999) and opportunistic feeder with a diet that includes a wide variety of teleosts, cephalopods, crustaceans, and rays (Compagno 1984, Bush 2003, Júnior et al. 2009, Noriega et al. 2011). In a study on feeding behavior in Kāne'ohe Bay, Bush (2003) found a nocturnal increase in the rate of foraging by juvenile scalloped hammerheads, with sharks consuming a mixture of crustaceans and teleosts. The alpheid and goby species were the most important prey items in their diet. Off the coast of Brazil, immature *S. lewini* frequently fed on reef and pelagic fish, as well as cephalopod species (*Chiroteuthis* sp. and *Vampyroteuthis infernalis*) that inhabit deep waters (Júnior et al. 2009). Stomachs of 466 *S. lewini* off the coast of Australia revealed the importance of bony fish as a prey item, followed by elasmobranchs, octopus and squid, and baitfish, with a positive correlation between shark length and the proportion of elasmobranchs in stomach contents (Noriega et al. 2011).

Reproduction and Growth

The scalloped hammerhead shark is viviparous (i.e., give birth to live young), with a gestation period of 9-12 months (Branstetter 1987, Stevens and Lyle 1989), which may be followed by a one-year resting period (Liu and Chen 1999). Females attain maturity around 200-250 cm (TL) while males reach maturity at smaller sizes (range 128 – 200 cm (TL); Table 1); however, the age at maturity differs by region. For example, in the Gulf of Mexico, Branstettter (1987) estimated that females mature at about 15 years of age and males at around 9-10 years of age. In northeastern Taiwan, Chen et al. (1990) calculated age at maturity to be 4 years for females and 3.8 years for males. On the east coast of South Africa, age at sexual maturity for females was estimated at 11 years (Dudley and Simpfendorfer 2006). Parturition, however, does not appear to vary by region and may be partially seasonal (Harry et al. 2011a), with neonates present year round but with abundance peaking during the spring and summer months (Duncan and Holland 2006, Adams and Paperno 2007, Bejarano-Álvarez et al. 2011, Harry et al. 2011a, Noriega et al. 2011). Females move inshore to birth, with litter sizes anywhere between 1 and 41 live pups (Table 1). Off the coast of northeastern Australia, Noriega et al. (2011) found a positive correlation between litter size and female shark length for scalloped hammerheads, as did White et al. (2008) in Indonesian waters. However, off the northeastern coast of Brazil, Hazin et al. (2001) found no such relationship. Size at birth is estimated between 313-589 mm TL (Table 1).

In the western Atlantic, *S. lewini* appears to grow more slowly and have smaller asymptotic sizes compared to conspecifics in the eastern and western Pacific (Table 1). Data from the northwest Atlantic and Gulf of Mexico indicate the von Bertalanffy growth parameters are: L_∞ = 279 cm (TL), k = 0.13 year^{-1}, t_0 = -1.62 years for males and L_∞ =303 cm TL, k=0.09 year^{-1}, t_0=−2.22

years for females (Piercy et al. 2007). Maximum size observed was 313 cm TL for a female and 304 cm TL for a male, corresponding to an age of 30.5 years. Further south, in Brazil, the asymptotic sizes are similar, but the growth constant (k) is estimated at 0.05 $year^{-1}$ (Kotas et al. 2011). In the northeastern Atlantic Ocean, maximum observed sizes of 320 cm TL and 280 cm TL were recorded for females and males, respectively (Buencuerpo et al. 1998). Off the coast of South Africa, von Bertalanffy growth parameters are estimated at L_∞ = 367 cm (PCL), k=0.057 $year^{-1}$, t_0=−1.6 years with a maximum age of 30 (Dudley and Simpfendorfer 2006). In the eastern Pacific, off the coast of Mexico, von Bertalanffy growth parameters are estimated at L_∞ = 364 cm (TL), k=0.123 $year^{-1}$, t_0= -1.18 years for males and L_∞ =376 cm TL, k=0.1 $year^{-1}$, t_0= -1.86 years for females (Anislado-Tolentino et al. 2008). In the western Pacific, Chen et al. (1990) reported the growth constant as 0.22 and found similar sizes as those found in the northwest Atlantic, with observed maximum sizes of 331 cm TL for a female and 301 cm TL for a male, corresponding to an age of 14 and 10.6 years respectively. Interestingly, Harry et al. (2011a) found significant differences in von Bertalanffy growth parameters between sharks caught in tropical Australian waters (L_∞ = 212 cm (STL – stretched TL), k=0.163 $year^{-1}$ for males) and those caught in temperate Australian waters (L_∞ = 320 cm STL, k=0.093 $year^{-1}$ for males), suggesting possible intraspecific dimorphism among male *S. lewini*. The combined von Bertalanffy growth parameters for both sexes was L_∞ = 331 cm (STL), k=0.077 $year^{-1}$, t_0=−2.502 years with at least a 20-30 year maximum age (Harry et al. 2011a).

While it appears that maturity, age, and growth estimates vary by region, it is unclear whether these differences are truly biological or a result of differences in band interpretations in aging methodology approaches (Piercy et al. 2007). Scalloped hammerhead sharks develop opaque bands on their vertebrae which are used to estimate age. For those studies conducted in the eastern and western Pacific, band formation was assumed to occur bi-annually, whereas in the Atlantic, bands were assumed to form annually (Table 1). Although indirect age validation studies for *S. lewini* are still inconclusive, bomb radiocarbon and calcein methods (direct age validation methods) have been used to validate annual growth bands for two other species of *Sphyrna*, including the great hammerhead shark (*S. mokarran*) and the bonnethead shark (*S. tiburo*) (Parson 1993, Passerotti et al. 2010). Therefore, it seems more likely that the scalloped hammerhead shark undergoes annual band formation, as has been found in other chondrichthyan growth studies (Campana et al. 2002, Okamura and Semba 2009). Using the assumption of annual band formation and accordingly doubling the Pacific age maturity estimates places the average age at maturity for female scalloped hammerheads around 12.8 years and 8.1 years for males (Table 2). Thus, based on analysis of the available data, the scalloped hammerhead shark can be characterized as a long lived (at least 20 – 30 years), late maturing, and relatively slow growing species (based on Branstetter (1990), where k < 0.1/year indicates slow growth for sharks).

Table 1. Compilation of *S. lewini* life history characteristics from the published literature.

Sampled Location	Maximum TL (cm, observed)		Maximum Age (observed)		TL at maturity (cm)		Age at maturity		von Bertalanffy Growth Parameters						Age Method (Ring Formation)		Gestation	Parturition	Litter Size	TL at birth (mm)	Reference
									Female			Male									
	Female	Male	Female	Male	Female	Male	Female	Male	L_∞ (cm)	t_0	k	L_∞ (cm)	t_0	k	Biannual	Annual					
Overall					212	140-165													15-31	420-550	Compagno (1984)
Australia (N)*	346	301			~200	140-160	9.5	4.7-6.7									9 to 10	Spring/Summer	13-23 (mean 16.5)	450-500	Stevens and Lyle (1989)
Australia (NE)																		Spring/Summer	1-25 (mean 8.2)	~500	Noriega et al. (2011)
Australia (NSW - SE)	260	299			195-260	~200															Macbeth et al. (2009)
Australia (E)						>128			331	-2.5	0.08	331	-2.5	0.08				Year round (peak in late Spring/Summer)		465-563	Harry et al. (2011a)
Tropics†		197		12				5.7				212	-1.9	0.16							
Temperate†	260	290	15	21				8.9				320		0.09		X					
Indonesia*	317	240			229	176	12.8	9.0									~8	Year round (peak in Oct - Nov)	14-41 (mean 25.3)	390-570	White et al. (2008)
Taiwan (NE)†††	331	301	14	10.6	210	198	4.1 (8.2)	3.8 (7.6)	320	-0.4	0.25	321	-0.7	0.22	X		10	Summer	~12-38	313-489	Chen et al. (1988), (1990)
Hawaii	309	272																Year round (peak Summer)	15-31	400-500	Clarke (1971), Duncan and Holland (2006)
Gulf of California**					217	163	7.4	3.6													Klimley (1987)
Mexico (Pacific)†††	280	281	12.5	11	223	170	6.5 (13.0)	4.0 (8.0)	376	-1.2	0.10	364	-1.2	0.12	X						Anislado-Tolentino and Robinson-Mendoza (2001), Anislado-Tolentino et al. (2008)
Mexico (SW Pacific)**					220	180	7.6	4.4										Summer	14-40	>510	Bejarano-Álvarez et al. (2011)
Atlantic (NW)	313	304	30.5	30.5					303	-2.2	0.09	279	-1.6	0.13		X			20	380-450	Castro (1993), Piercy et al. (2007)
US (FL)																		Spring/Summer		380-562	Adams and Paperno (2007)
Gulf of Mexico (NW)					250	180	15.0	10.0	329	-2.2	0.07	329	-2.2	0.07		X	~12		>30	490	Branstetter (1987)
Brazil (NE)***	273	321			>240	180-200	15.2	6.3-8.1									~10	Mid-late Summer	2-21 (mean 14.3)	>380	Hazin et al. (2001)
Brazil (S)	217	234	31.5	29.5					300	-3.7	0.05	266	-3.9	0.05		X					Kotas et al. (2011)
Senegal																		Summer	18-22	370-520	Capapé et al. (1998)
South Africa	307	295			212	140-165												Summer	30	500	Bass et al. (1975)
South Africa (E)††			30		184	161	11.0	11.0	519	-1.6	0.06	519	-1.6	0.06					10		Dudley and Simpfendorfer (2006)
Spain	320	280																			Buencuerpo et al. (1998)

*Age at maturity estimates calculated using growth parameters from Harry et al. (2011a)
** Age at maturity estimates calculated using growth parameters from Anislado-Tolentino et al. (2008).
*** Age at maturity estimates calculated using growth parameters from Kotas et al. (2011).
† Length measurements recorded as stretched total length (TL).
†† L_∞ estimates converted from pre-caudal length to total length (TL) using Piercy et al. (2007) equations.

Table 2. Age at maturity estimates based on the assumption of annual band formation in *S. lewini*.

Sampled Location	Age at maturity		Reference
	Female	**Male**	
Australia (N)	9.5	4.7 - 6.7	Stevens and Lyle (1989)
Australia (E) Tropics		5.7	Harry et al. (2011a)
Australia (E) Temperate		8.9	
Indonesia	12.8	9.0	White et al. (2008)
Taiwan (NE)	8.2	7.6	Chen et al. (1988), (1990)
Gulf of California	14.8	7.2	Klimley (1987)
Mexico (Pacific)	13.0	8.0	Anislado-Tolentino and Robinson-Mendoza (2001), Anislado-Tolentino et al. (2008)
Mexico (SW Pacific)	15.2	8.8	Bejarano-Álvarez et al. (2011)
Gulf of Mexico (NW)	15.0	10.0	Branstetter et al. (1987)
Brazil (NE)	15.2	6.3 - 8.1	Hazin et al. (2001)
South Africa (E)	11.0	11.0	Dudley and Simpfendorfer (2006)
AVERAGE	**12.8**	**8.1**	

DISTRIBUTION AND ABUNDANCE

The scalloped hammerhead shark can be found in coastal warm temperate and tropical seas worldwide. In the western Atlantic Ocean, the scalloped hammerhead range extends from the northeast coast of the United States (from New Jersey to Florida) to Brazil, including the Gulf of Mexico and Caribbean Sea. In the eastern Atlantic, it can be found from the Mediterranean to Namibia. Populations in the Indian Ocean are found in the following locations: South Africa and the Red Sea to Pakistan, India, and Myanmar, and in the western Pacific the scalloped hammerhead can be found from Japan and China to New Caledonia, including throughout the Philippines, Indonesia, and off Australia. Distribution in the eastern Pacific Ocean extends from the coast of southern California (U.S.), including the Gulf of California, to Ecuador and possibly Peru (Compagno 1984), and off waters of Hawaii (U.S.) and Tahiti (Figure 1).

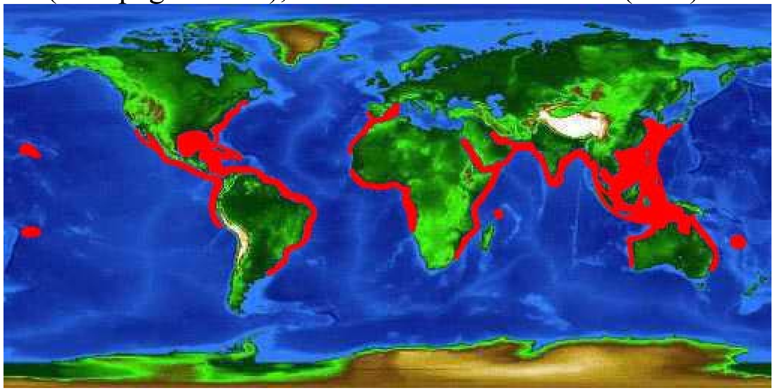

Figure 1. Distribution map of the scalloped hammerhead shark (*Sphyrna lewini*). (Source: Bester 2011)

Historical Population

The oldest living *S. lewini* populations are found in the central Indo-West Pacific, indicating this region as the origin of the species (Duncan et al. 2006, Daly-Engel et al. 2012). During the late Pleistocene period, *S. lewini* underwent several dispersal events (Duncan et al. 2006). Following the closing of the Isthmus of Panama, it was suggested that gene flow occurred from west to east, with *S. lewini* traveling from the Atlantic Ocean into the Indo-Pacific, via southern Africa (Duncan et al. 2006). Although there is no evidence of shared haplotypes between the Atlantic Ocean and the Indian or Pacific Oceans, some haplotypes from the Indo-Pacific are very closely related to the Atlantic (sequence divergence = 0.18%) (Duncan et al. 2006).

In the northwest Atlantic and Gulf of Mexico, the virgin population size was estimated to be between 142,000 and 169,000 individuals (Hayes et al. 2009). Historical estimates of effective population size (or the number of breeding individuals in the population) in the eastern Pacific range from 34,995 to 43,551 individuals (Table 3) (Nance et al. 2011). Using 15 microsatellite loci and mitochondrial DNA (mtDNA) from eastern Pacific *S. lewini* tissue samples, Nance et al. (2011) discovered that the current effective population size is significantly smaller (1-3 orders of magnitude) than the historical effective population size (Table 3), indicating that scalloped hammerheads in the eastern Pacific experienced a bottleneck and suffered significant declines. However, mtDNA data revealed that most populations in this region also experienced expansion, with time estimates ranging from 90,606 to 130,061 years ago (Nance et al. 2011).

Table 3. Estimates of current (Ne_0) and historical (Ne_1) effective population sizes and years (t) since the onset of population decline from microsatellite analysis of *S. lewini* tissues samples from six eastern Pacific sites (LAP = La Paz; MAZ = Mazatlan; TAR = Tarcoles; SCA= Santa Catalina; CEB = Cebaco Island; MAN = Manta; 95% HPD = 95% highest posterior density intervals). (Source: Nance et al. 2011)

Population	N_{e0}	N_{e1}	t (in years)
LAP	435.51	39,627.80	8452.79
95% HPD	(36.16–4717.37)	(4718.46–324,041.03)	(493.06–117,733.49)
MAZ	384.68	43,551.19	6181.59
95% HPD	(28.89–4627.01)	(4927.20–365,426.47)	(386.99–81,320.49)
TAR	481.95	34,994.52	5766.34
95% HPD	(49.57–4607.87)	(4102.99–289,867.82)	(347.46–86,616.37)
SCA	284.32	39,728.30	5870.84
95% HPD	(28.66–2777.15)	(4822.80–326,061.90)	(562.99–59,278.88)
CEB	226.67	38,256.04	3639.15
95% HPD	(8.00–4952.22)	(4463.75–333,042.76)	(116.33–79,031.46)
MAN	604.09	35,958.37	11,917.91
95% HPD	(50.14–6428.36)	(4303.28–296,619.70)	(830.42–145,378.40)

Genetic Data

Highly migratory species typically exhibit little population structure across large regions; however, scalloped hammerhead sharks may be an exception to this pattern. Using mtDNA markers collected from 271 sharks from multiple locations in each of the ocean basins, Duncan et al. (2006) analyzed the global genetic structure of *S. lewini* and found genetic discontinuity within oceans, associated with oceanic barriers, but little population structure along continental margins. The authors theorized that female *S. lewini* move readily among nursery areas connected by a continuous coastline. In contrast, Chapman et al. (2009) found evidence of a finer-scale stock delineation within the western Atlantic and suggested females may display natal homing or remain close to their natal region of origin. However, both studies concluded that oceanic dispersal by females is rare.

To examine the effect of male-mediated gene flow, Daly-Engel et al. (2012) analyzed biparentally-inherited DNA and discovered evidence that suggests males of the species may participate in oceanic migrations. However, the frequency of these migrations is unknown and in some regions may be very low considering the discovery of genetically isolated populations in the ETP (Nance et al. 2011, Daly-Engel et al. 2012) and Gulf of Mexico (Daly-Engel et al. 2012).

Discovery of a possible cryptic species of *Sphyrna* sp. was reported in the northwestern Atlantic (mainly from coastal North Carolina, South Carolina, and Florida) and most recently in the western South Atlantic (Southern Brazil) (Abercrombie et al. 2005, Quattro et al. 2006, Pinhal et al. 2012). Analysis of mitochondrial control region (mtCR) sequences and nuclear ribosomal ITS2 sequences indicate that the cryptic Atlantic hammerhead lineage is significantly different from the group of Atlantic haplotypes that are widely distributed within the ocean basin (Quattro et al. 2006). The sequence divergence between these two lineages is estimated at 5.3 – 7.5% (Duncan et al. 2006, Quattro et al. 2006, Pinhal et al. 2012) with around a ~4.5 Ma (95% CI ~ 2-10 Ma) divergence time (Pinhal et al. 2012).

Description of the Fisheries and Current Catch Estimates

Scalloped hammerhead sharks are both targeted and taken as bycatch in many global fisheries. They are targeted by semi-industrial, artisanal and recreational fisheries and caught as bycatch in pelagic longline tuna and swordfish fisheries and purse seine fisheries. There is a lack of information on the fisheries prior to the early 1970s, with only occasional mentions in historical records. Significant catches of scalloped hammerheads have and continue to go unrecorded in many countries outside the U.S. In addition, scalloped hammerheads are likely under-reported in catch records as many records do not account for discards (example: where the fins are kept but the carcass is discarded) or reflect dressed weights instead of live weights. Also, many catch records do not differentiate between the hammerhead species, or shark species in general, and thus species-specific population trends for scalloped hammerheads are not readily available.

International Catch

Worldwide catches of sphyrnids are reported in the FAO Global Capture Production dataset mainly at the family level, but a select number of countries have reported down to the species level (Table 4). Total catches of the hammerhead family (Figure 2) have increased since the early 1990s (prior years were not reported), from 377 tonnes in 1991 to a current peak of 5,786 tonnes in 2010. This is in contrast to the catches of *S. lewini*, which have decreased, for the most part, since reaching a maximum of 798 tonnes in 2002 (Figure 2). However, in 2010, Mauritania became the seventh country to report catches of *S. lewini* to FAO, increasing the total to 335 tonnes, the highest reported catch since 2005. Then again, only seven countries have reported *S. lewini* data, which is by no means an accurate representation of worldwide *S. lewini* landings data. Additionally, this FAO data does not include discard mortalities.

Table 4. FAO global capture production of *S. lewini* for 1993-2010. (Source: FAO Global Capture Production dataset)

	Nominal Catches (tonnes) by Country							
Year	**Guinea-Bissau**	**Brazil**	**Ecuador**	**Venezuela**	**Spain**	**United Kingdom**	**Mauritania**	**TOTAL**
1993	0	100	0	0	0	0	0	**100**
1994	2	0	0	0	0	0	0	**2**
1995	12	0	0	0	0	0	0	**12**
1996	12	25	0	0	0	0	0	**37**
1997	10	170	0	0	0	0	0	**180**
1998	10	0	0	0	0	0	0	**10**
1999	10	30	0	0	0	0	0	**40**
2000	0	262	0	0	0	0	0	**262**
2001	8	507	0	0	0	0	0	**515**
2002	0	508	0	0	290	0	0	**798**
2003	0	286	0	0	139	0	0	**425**
2004	5	170	0	0	317	0	0	**492**
2005	5	175	0	0	148	0	0	**328**
2006	5	177	11	0	31	0	0	**224**
2007	5	120	52	0	25	0	0	**202**
2008	5	122	26	1	0	4	0	**158**
2009	5	87	0	5	0	12	0	**109**
2010	5	74	0	0	0	0	257	**336**

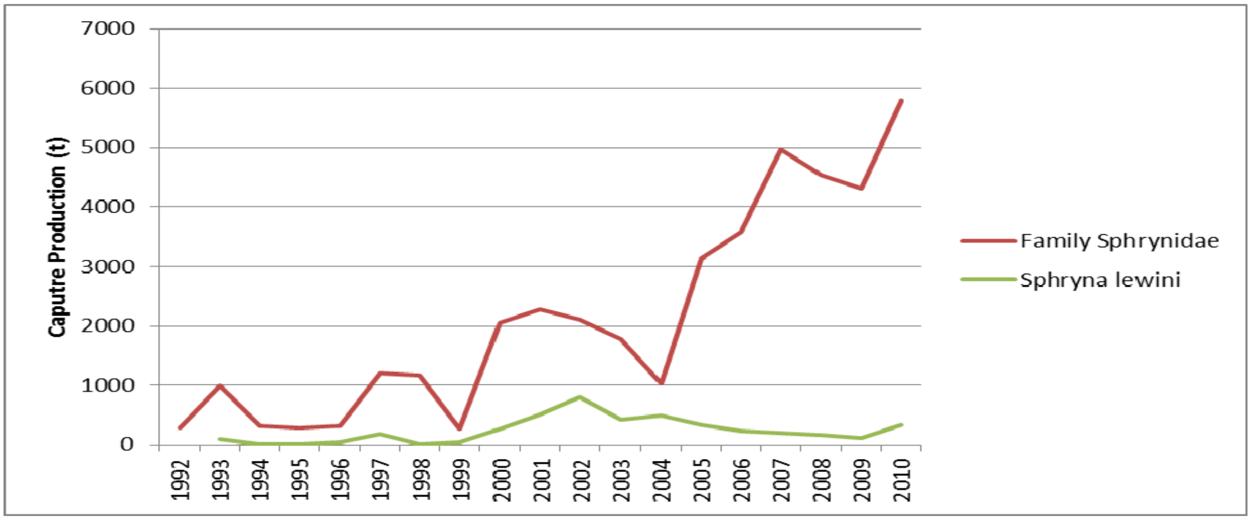

Figure 2. Global capture production (tonnes) of all hammerhead sharks (Sphyrnidae) from 1991-2009, and the scalloped hammerhead shark (*S. lewini*) from 1993-2010. (Source: FAO Global Capture Production dataset)

In order to gain a better estimate of the global shark catch, Clarke et al. (2006a, 2006b) analyzed data from the Asian shark fin trade. According to shark fin traders, hammerheads (*Sphyrna* spp.) are one of the sources for the best quality fin needles for consumption, and fetch a high commercial value in the Asian shark fin trade (Abercrombie et al. 2005). In Hong Kong, the world's largest fin trade market, *S. lewini* and *S. zygaena* (smooth hammerhead) are found under the "Chun chi" market category, the second most traded fin category in the market (Clarke et al. 2006a). Applying a Bayesian statistical method to the Hong Kong shark fin trade data, Clarke et al. (2006b) estimated that between 1 and 3 million hammerhead sharks (*Sphyrna* spp.), with an equivalent biomass of 60 – 70 thousand tonnes, are traded per year.

Although scalloped hammerhead meat is considered essentially unpalatable (due to its high urea concentration), some countries still consume the meat domestically or trade it internationally, including: Colombia, Mexico, Mozambique, Philippines, Seychelles, Spain, Sri Lanka, China (Taiwan), Tanzania, Uruguay, and Kenya, where the meat is actually identified as high quality (Vannuccini, 1999; CITES, 2010). However, it is thought that the current volume of *S. lewini* traded meat and products is insignificant when compared to the volume of *S. lewini* fins in international trade (CITES, 2010).

In the Atlantic, scalloped hammerhead shark catches have been reported by International Commission for the Conservation of Atlantic Tunas (ICCAT) vessels since 1992. ICCAT is a Regional Fisheries Management Organization (RFMO) responsible for the conservation of tunas and tuna-like species in the Atlantic Ocean and adjacent seas. In 2004, following the FAO International Plan of Action for Sharks, ICCAT published recommendation 04-10 requiring Contracting Parties, Cooperating non-Contracting Parties, Entities or Fishing Entities (CPCs) to annually report data for catches of sharks, including available historical data. Combined reported catches of scalloped hammerheads from ICCAT vessels in the Atlantic are shown in Figure 3. Around 93% of the total catch (n=1555t) from 1992-2011 was caught by longline gear.

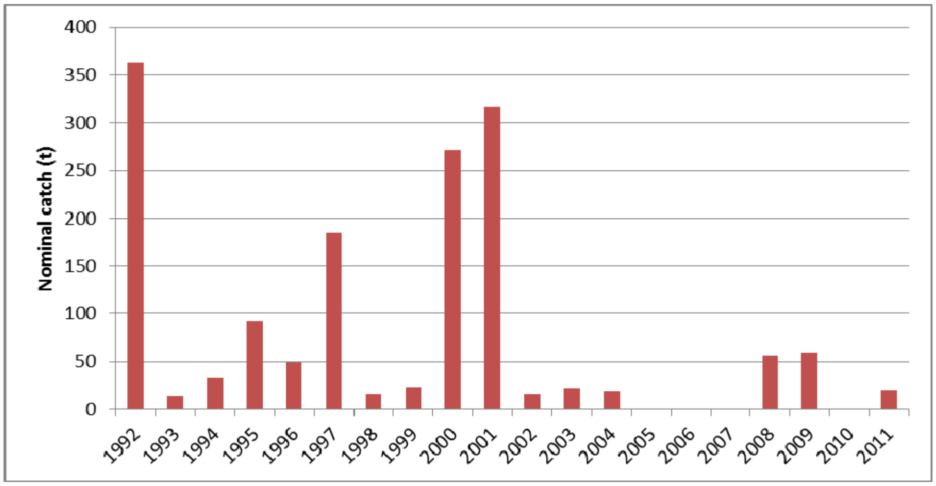

Figure 3. Nominal catches (t) of *S. lewini* reported to ICCAT from 1992-2011. (Source: ICCAT nominal catch information: Task I web-based application, accessed January 2013)

In the early 1990s, the fleets operating under the U.S. flag reported the highest catches of scalloped hammerhead sharks, but after 1995 did not report another catch until 2004 (Figure 4). While the U.S. was responsible for approximately 40% of the catch from 1992 – 2011, fleets under the Brazilian flag were responsible for approximately 49% of the scalloped hammerhead shark catch in the Atlantic Ocean, with a peak catch of 296 mt in 2001. After 2001, reported scalloped hammerhead catches to ICCAT dropped significantly and remained below 60 mt.

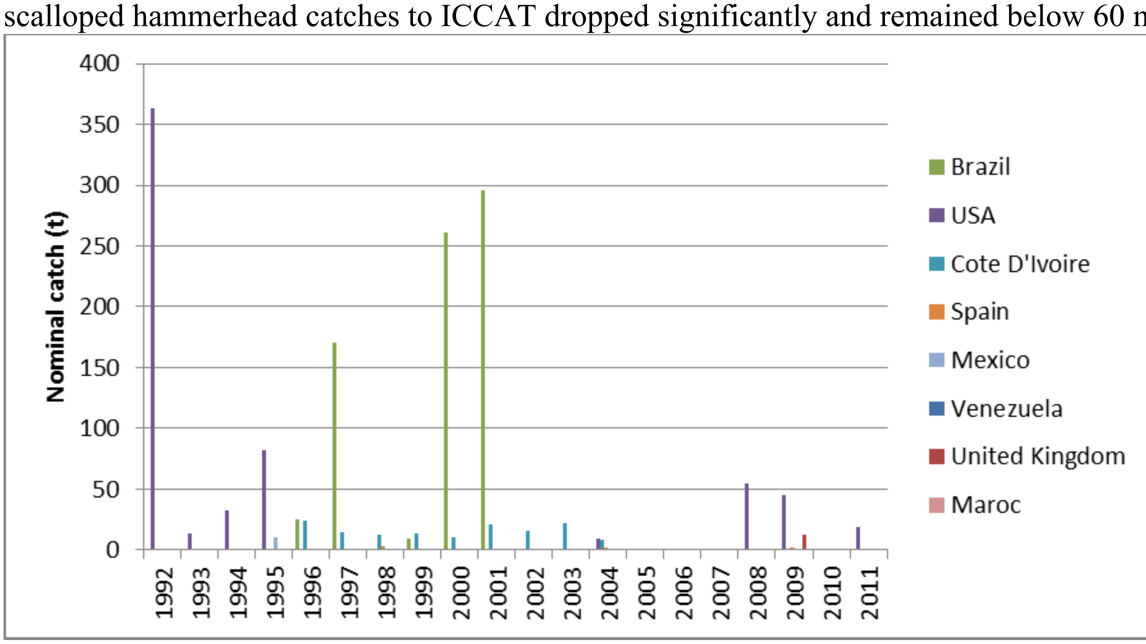

Figure 4. Nominal catches (t) of *S. lewini* by ICCAT CPC vessel flag from 1992-2011. (Source: ICCAT nominal catch information: Task I web-based application, accessed January 2013)

In Mexico, the shark fishery is an important source of food and jobs on both coasts, where up to 90% of the Mexican shark production is consumed domestically. Average annual shark catches in the Gulf of Mexico from 1976-1995 represented one-third of the total national shark production (Castillo-Géniz et al. 1998). A one-year study that monitored catch and effort of a Mexican artisanal coastal shark fishery found that landings peaked in October (CPUE = 27.2 sharks per trip) and were lowest in the month of April (CPUE = 4.46 sharks per trip), with an overall average CPUE of 9.45 (± 1.92) sharks per trip. Of the 84,717 sharks caught from 1993-1994, 5% were scalloped hammerheads (Castillo-Géniz et al. 1998).

Further south, in the ports of Rio Grande and Itajai, Brazil, annual landings of hammerhead sharks have fluctuated over the years. In 1992, reported landings were ~ 30 t but increased rapidly to 700 t in 1994. From 1995 to 2002, catches decreased and fluctuated between 100-300 t (Baum et al. 2007). FAO global capture production statistics from Brazil show a significant increase in catch of *S. lewini* from 30 t in 1999 to 262 t in 2000. In 2001 and 2002, catches almost doubled to 507 t and 508 t, respectively, before decreasing to 87 t in 2009 (see Table 4).

On the other side of the Atlantic Ocean, hammerheads are a large component of the bycatch in the European pelagic freezer-trawler fishery, which operates off Mauritania, Northwest Africa. Between October 2001 and May 2005, 42% of the retained pelagic megafauna bycatch from over 1400 freezer-trawl sets consisted of hammerhead species (*S. lewini, S. zygaena, and S. mokarran*). Around 75% of the hammerhead catch were juveniles of 0.50 – 1.40 m in length (Zeeberg et al. 2006). Off the coasts of Spain and Africa and in the Strait of Gibraltar, Buencuerpo et al. (1998) sampled longline and gillnet landings from July 1991 to July 1992. Catch rate for the scalloped hammerhead was low throughout the year (maximum recorded = 1.36 fish/1000 hooks in November 1991 for longline, and 0.14 fish/unit of effort in July 1992 for gillnet). Females caught in the longline fishery, which operated in oceanic waters off the coasts of Spain and Africa, were slightly larger than males (mean = 170 cm TL females, 150 cm TL males) but the overall mean size was smaller when compared to those sharks caught in the gillnet fishery (220 cm). Additionally, males outnumbered females in the longline fishery, but the reverse was true for the gillnet fishery, which operated further inland in the Strait of Gibraltar. However, given the lack of mature females in the catch, Buenceurpo et al. (1998) concluded that this area was not a breeding ground for scalloped hammerhead sharks. Of note is that the authors of the study refer to the scalloped hammerhead shark as *S. zygaena* so it is unclear whether this data truly represents scalloped hammerhead landings or their close relative, the smooth hammerhead shark.

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) states 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. From 2005 to 2008, shark landings dropped by more than 50 percent, to 12,000 mt (Diop and Dossa, 2011). In 2010, the number of artisanal fishing vessels that landed elasmobranches 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 the Pacific, there is a historical lack of shark reporting on logsheets for most fleets. In addition, if shark catch is reported, it is usually aggregated shark data. For example, in the Taiwanese large-scale and small-scale tuna longline fisheries, bycatch data were not reported until 1981 due to the low economic value of the bycatch in relation to the tunas (Liu et al. 2009). All shark data collected before 2003 was recorded in the logbooks under the category "sharks". After 2003, species-specific information was recorded for the blue shark, mako shark, and silky shark, but all other sharks remained lumped in the category "other sharks" (Liu et al. 2009). Due to these data gaps, the Western and Central Pacific Fisheries Commission (WCPFC), the RFMO that seeks the conservation and sustainable use of highly migratory fish stocks in the western and central Pacific Ocean, recently revised their scientific data reporting requirements. Beginning in 2011, WCPFC vessels are required to report species-specific catch information for the following shark species: blue, silky, oceanic whitetip, mako, thresher, porbeagle, and hammerheads (WCPFC 2011). Despite this requirement, recent catches of hammerheads have not been provided to the WCPFC for a number of longline fleets, including fleets from among the top twenty countries reporting Pacific shark catches to the FAO. The WCPFC also manages the active tuna purse seine fleet in this region, which has expanded significantly since the 1980s and experienced a sharp increase over the past 6 years. In the mid-1980s, the purse seine fishery accounted for only 40% of the total tuna catch, but in 2010, this percentage had increased to 75% (Williams and Terawasi 2011). The majority of the purse seine catch has historically been attributed to Japan, Korea, Chinese-Taipei and the USA fleets, however recently an increased number of Pacific Islands fleets as well as new fleets (from China, Ecuador, El Salvador, New Zealand, and Spain) have entered the WCPFC tropical fishery (Williams and Terawasi 2011). These new additions have brought the number of purse seine vessels up to 280, the highest it has been since 1972 (Williams and Terawasi 2011). However, WCPFC observer data, collected from 1994-2009, indicate that longline sets may pose more of a threat to non-target shark species than purse-seine sets in this convention area, but in terms of hammerhead sharks, observers reported only negligible catch but with high rates of finning in both types of sets (SPC, 2010).

In 2012, Bromhead et al. (2012) published a study that analyzed operational-level logsheet and observer data reported by fleets operating in the Republic of the Marshall Islands EEZ from 2005-2009. Although estimates of total annual longline catches of sharks ranged from 1583 to

2274 t year^{-1}, only five *S. lewini* individuals were observed caught and subsequently discarded and finned during the study period (Bromhead et al. 2012).

In the eastern Pacific, the Inter-American Tropical Tuna Commission (IATTC) RFMO requires the collection of data on principal shark species caught as bycatch in this tuna fishery (IATTC 2005). Since 1993, observers have recorded shark bycatch data onboard large purse seiners in the eastern Pacific. Unfortunately, much of this data is aggregated under the category of "sharks", especially data collected prior to 2005. In an effort to improve species identifications of these data, a one-year Shark Characteristics Sampling Program was conducted to quantify at-sea observer misidentification rates. Román-Verdesoto and Orozco-Zöller (2005) used the program results and IATTC observer field notes to provide summaries of the spatial distributions, size composition, and species identification of the IATTC-observed bycatch of sharks in the eastern Pacific Ocean tuna purse-seine fishery. Bycatch for this report was defined as sharks that were discarded dead after being removed from the net and placed on the vessel, and was recorded from three types of purse-seine sets: 1) sets on tunas associated with dolphins ("dolphin sets"), 2) sets on tunas associated with floating objects ("floating-object sets"), and 3) sets on unassociated schools of tunas ("unassociated sets").

From 1993 – 2004, hammerhead sharks were caught in high numbers as bycatch in the purse seine fisheries (Figure 5) and were most susceptible to the floating-objects type of purse seine set (Román-Verdesoto and Orozco-Zöller 2005). From 2001 to 2003, their observed numbers in the tuna purse seine sets increased by ~ 166% to reach a maximum of 1,898 individuals. Although specific data on scalloped hammerhead numbers are unavailable, results from the one-year Shark Characteristics Sampling Program suggest that scalloped hammerhead sharks may comprise around 54% of the total hammerhead bycatch (Román-Verdesoto and Orozco-Zöller 2005). The IATTC observer data also revealed that the majority of the bycatch consists of large hammerhead individuals (>150 cm TL; Figure 6). This bycatch may or may not include mature scalloped hammerheads since documented *S. lewini* lengths at maturity in the eastern Pacific are ~170-180 cm TL for males and ~220 cm TL for females (see Table 1). Finer resolution of size and sex data is needed to determine the actual effect on the scalloped hammerhead population.

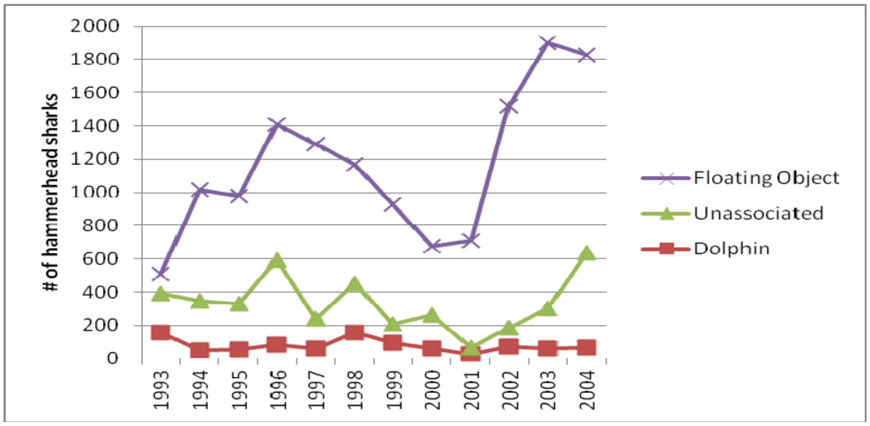

Figure 5. IATTC observed number of hammerhead sharks caught as bycatch from 1993-2004 in three types of purse-seine fishery sets in the Eastern Pacific: 1) sets on tunas associated with floating objects, 2) sets on unassociated schools of tunas, and 3) sets on tunas associated with dolphins. (Source: Román-Verdesoto and Orozco-Zöller 2005)

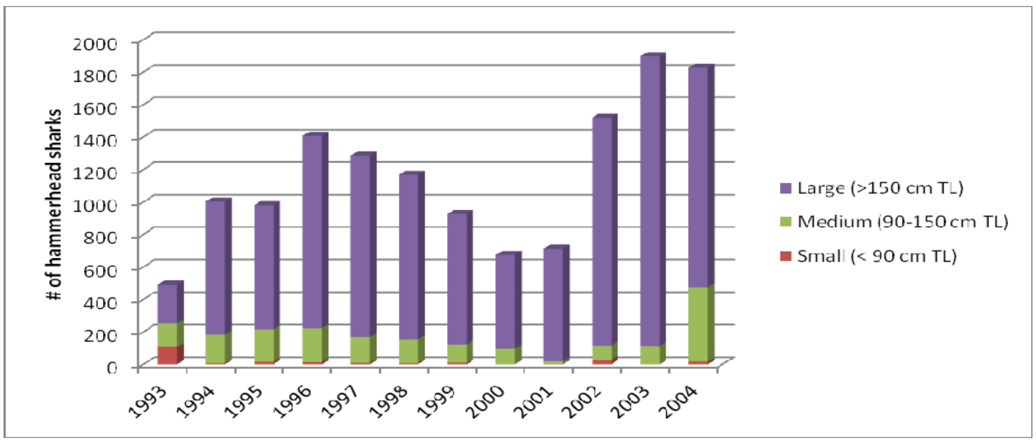

Figure 6. IATTC observed number and size of hammerhead sharks caught as bycatch from 1993-2004 in the eastern Pacific Ocean purse-seine fishery. (Source: Román-Verdesoto and Orozco-Zöller 2005)

In Ecuador, sharks are mainly caught as "incidental catch" in a variety of fishing gear, including pelagic and bottom longlines, and drift and set gill nets, with hammerhead sharks used primarily for the fin trade. A recent study by Jacquet et al. (2008) found that Ecuadorian landings of sharks have been grossly underestimated. Reconstructing catches by small-scale and industrial fishers using government reports and grey literature, Jacquet et al. (2008) estimated Ecuador mainland landings to be 6,868 t (average) per year from 1979-2004, with small-scale fisheries representing 93% of the total landings. For the period of 1991-2004, the reconstructed estimates were 3.6 times greater than what was reported to the FAO.

In the Indian Ocean, scalloped hammerheads are commonly caught as bycatch in pelagic longline tuna and swordfish fisheries and gillnet fisheries, and are also targeted by semi-industrial, artisanal and recreational fisheries. Off the coast of Madagascar, sphyrnids are the most commonly caught shark in longline and gillnet sets in the directed shark fishery (McVean et al. 2006). However, very little information exists on the abundance of these sharks off the coast of Africa or elsewhere in the Indian Ocean. There are currently no quantitative stock assessments or basic fishery indicators available for scalloped hammerhead sharks in the Indian Ocean, and thus the stock status is highly uncertain. The Indian Ocean Tuna Commission (IOTC), the RFMO that manages tuna and tuna-like species in the Indian Ocean and adjacent seas, requires CPCs to annually report scalloped hammerhead shark catch data (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. 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 but simply those retained on board, with weights that likely refer to processed specimens (IOTC 2011). With these cautions in mind, data reported to the IOTC on catches of scalloped hammerheads are available from 2005 to 2010 (Figure 7).

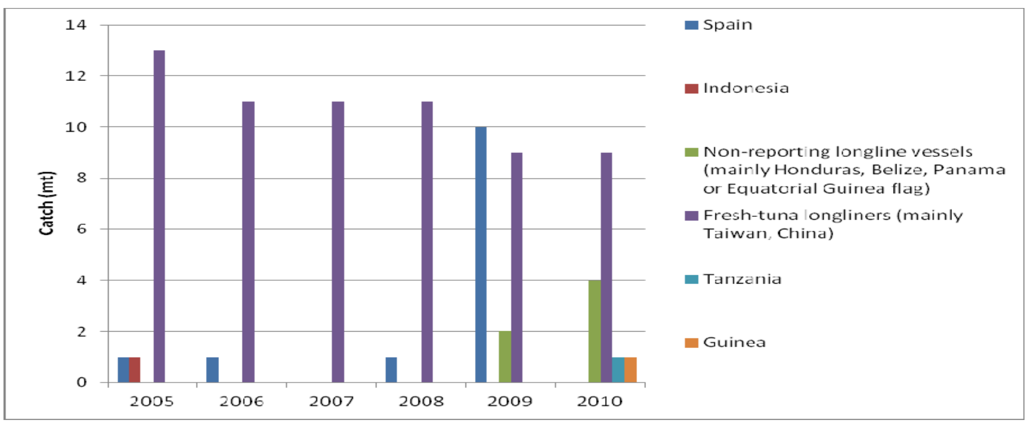

Figure 7. Scalloped hammerhead shark catches (mt) reported to the IOTC from 2005-2010. (Source: IOTC Nominal Catch Database, accessed July 2012)

From 2005 to 2010, the majority of the catch was recorded by small, fresh-tuna longliners operating under various flags, but mainly from Taiwan, China. The fresh-tuna longliners caught an average of 11 mt of scalloped hammerhead sharks per year. Spain also showed an increase in reported catches of scalloped hammerhead sharks, from 1 mt in 2005, 2006 and 2008, to 10 mt in 2009. In 2012, Sri Lanka reported detailed data on its shark catch to the IOTC, with an estimate of 111 mt of scalloped hammerhead sharks caught in 2011, increasing the mean catch reported to the IOTC over the last 5 years (2007 – 2011) to 36 mt of scalloped hammerhead sharks.

Catches of the entire hammerhead shark complex (*Sphryna* spp.) are also available from the IOTC region from 2003 to 2009 (Figure 8). During this 7-year time span, Spain accounted for 72% of the total catch, with an average of 31 mt per year and a maximum of 47 mt in 2005.

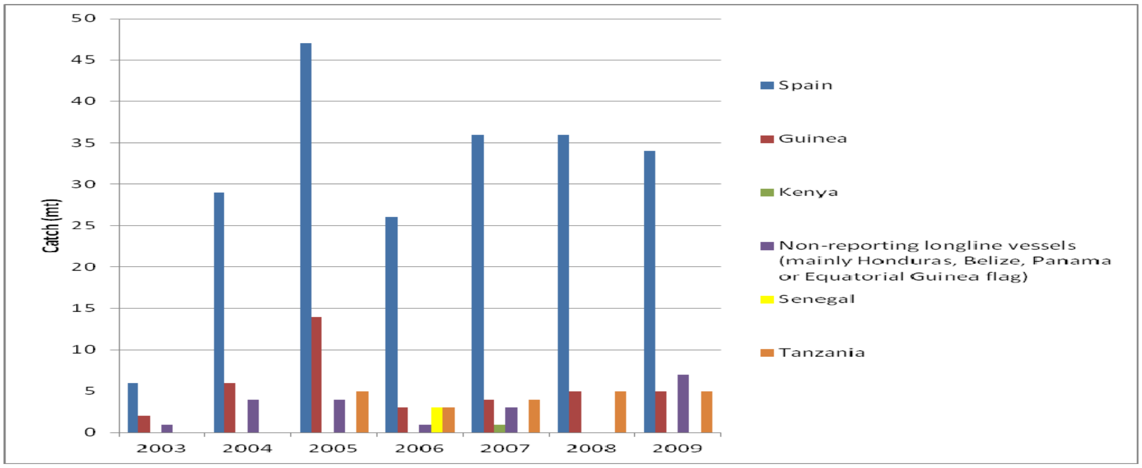

Figure 8. All hammerhead shark catches (mt) reported to the IOTC from 2003-2009. (Source: IOTC Nominal Catch Database, accessed February 2012)

Catches of the hammerhead complex peaked in 2005 at 70 mt while catches of scalloped hammerhead sharks have fluctuated between 11 mt and 21 mt (Figure 9); however, not all CPCs have complied with the IOTC reporting requirements. In 2010, only seven of the 30 CPC countries reported catches of scalloped hammerhead sharks in the IOTC region. In 2011, four CPCs reported detailed data on sharks while nine CPCs reported partial data or data aggregated for all species. Although the IOTC Scientific Committee considers these data highly uncertain it also deems it likely that maintaining or increasing fishing effort on scalloped hammerhead sharks will result in further declines in biomass and productivity (IOTC 2012).

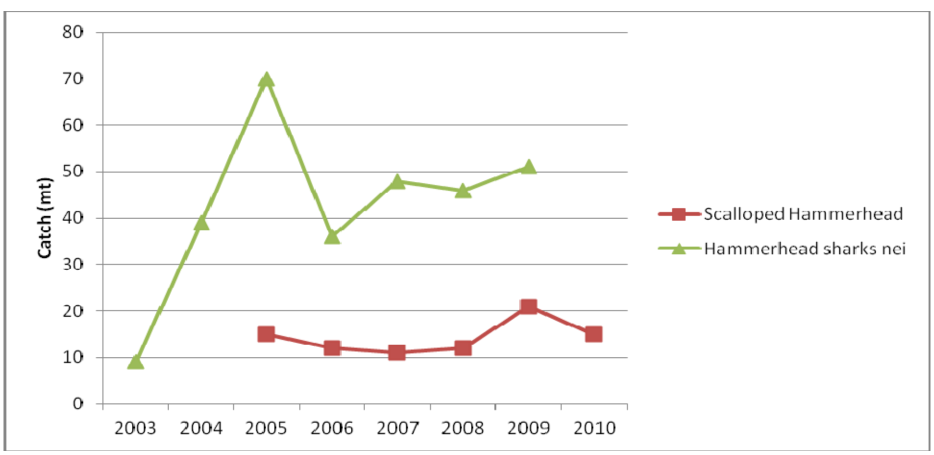

Figure 9. Total catches (mt) of scalloped hammerhead sharks and the hammerhead shark complex as reported to the IOTC from 2003-2010. (Source: IOTC Nominal Catch Database, accessed February 2012)

In Australian waters, sharks are caught by commercial, recreational and traditional fishermen as targeted catch, retained catch, and bycatch. Almost all sharks landed in Australia are used for domestic consumption. According to Bensley et al. (2010), the annual commercial Australian shark catch from 1996 to 2006 ranged from about 8600 t to 11,500 t; however, the reporting of catch weights varied due to the state of processing (e.g. whole weight, processed weight, landed weight, etc.). Scalloped hammerhead sharks are especially abundant off the coast of Queensland (Taylor et al. 2011). In a three-year study of commercial gillnet catch, *S. lewini* was the 4th most abundant elasmobranch (making up 8.8% of the total catch) (Harry et al. 2011b). Similarly, data from a Queensland banana prawn trawl fishery revealed that *S. lewini* was the most frequently caught shark species (based on 184 net trawls) but only represented 0.055% of the total bycatch (Shark Advisory Group 2004). Further south in New South Whales (NSW), the catch of sharks has increased dramatically since 2004. In the NSW Ocean Trap and Line (OTL) fishery, annual catch of sharks increased by ~200% between 2004-2005 and 2006-2007, mainly due to the high value of shark fins in the market. Faced with the threat of overexploitation, the Industry & Investment NSW (I&I NSW) implemented new restrictions on shark fishing in the OTL fishery in 2009, including a total allowable combined catch (TACC) limit of 160 tonnes that included all species of whaler (Family: Carcharhinidae), hammerhead, and mackerel sharks, bycatch limits per fishing trip, and permit restrictions. Also, observers were allowed onboard OTL vessels, and from September 2008 to May 2009 they collected data from 81 fishing trips. Results from the observer data show that only a very small percentage (3.2%) of the total number of TACC shark species caught (n = 1,383) were scalloped hammerheads. In fact, the mean catch rate of *S. lewini* never exceeded 0.8 sharks per 100 hooks per setline deployment in any fishing zone or month combination. The overall mean catch rate for scalloped hammerheads was low, at around 0.18 ± 0.04 sharks per 100 hooks per setline deployment (Macbeth et al. 2009). In addition to the NSW OTL fishery, hammerhead sharks are also caught in Australia's East Coast Tuna and Billfish Fishery as well as the West Coast Tuna and Billfish Fishery.

U.S. Fisheries

In the U.S. Atlantic, scalloped hammerhead sharks are mainly caught by directed shark permit holders using bottom longline (BLL) gear. To a lesser degree they are caught as bycatch in longline and coastal gillnet fisheries. In the recreational fisheries sector, scalloped hammerheads became a popular target species of fisherman in the last several decades following the release of the movie "Jaws" (Hayes et al. 2009). Below provides relevant information about the U.S. shark fisheries and scalloped hammerhead catch, extracted primarily from the 2011 Stock Assessment and Fishery Evaluation (SAFE) Report for Atlantic Highly Migratory Species (HMS) (NMFS 2011a) and the Amendment 2 to the U.S. 2006 Consolidated Atlantic HMS Fishery Management Plan (FMP) (henceforth referred to as the "Consolidated HMS FMP") (NMFS 2007):

U.S. Commercial Fisheries

The commercial shark fishery has been sporadic in nature. In the early 1900s, a Pacific shark fishery supplied limited demands for fresh shark fillets and fish meal as well as a more substantial market for dried fins of soupfin sharks. In 1937, the price of soupfin shark liver skyrocketed when it was discovered to be the richest source of vitamin A available in commercial quantities. A shark fishery in the Caribbean Sea, off the coast of Florida, and in the Gulf of Mexico developed in response to this demand (Wagner 1966). By 1950, the availability of synthetic vitamin A caused most shark fisheries to be abandoned (Wagner 1966).

In the late 1970s, however, the U.S. Atlantic shark fishery developed rapidly due to increased demand for their meat, fins, and cartilage. At the time, sharks were perceived to be underutilized as a fishery resource. The high commercial value of shark fins led to the controversial practice of finning, or removing the valuable fins from sharks and discarding the carcass. Growing demand for shark products encouraged expansion of the commercial fishery throughout the late 1970s and the 1980s. Tuna and swordfish vessels began to retain a greater proportion of their shark incidental catch, and some directed fishery effort expanded as well. As catches accelerated through the 1980s, shark stocks started to show signs of decline. Below describes the various gears that are used in the commercial shark fishery.

Pelagic Longline (PLL)

The pelagic longline (PLL) fishery for Atlantic HMS primarily targets swordfish, yellowfin tuna, and bigeye tuna in various areas and seasons. Secondary target species include dolphin fish, albacore tuna, and, to a lesser degree, sharks. The primary fishing line, or mainline, of the PLL gear can vary from 5 to 40 miles in length, with approximately 20 to 30 hooks per mile. The U.S. PLL fishery has historically been comprised of five relatively distinct segments with different fishing practices and strategies. These segments are: 1) the Gulf of Mexico yellowfin tuna fishery; 2) the South Atlantic-Florida east coast to Cape Hatteras swordfish fishery; 3) the Mid-Atlantic and New England swordfish and bigeye tuna fishery; 4) the U.S. distant water swordfish fishery; and, 5) the Caribbean Islands tuna and swordfish fishery. The PLL is a heavily managed gear type and is strictly monitored.

Landings and dead discards of sharks by U.S. PLL fishermen in the Atlantic are monitored every year and reported to ICCAT. From 1992-2000, elasmobranchs represented 15% of the total catch by the PLL fishery, with *S. lewini* comprising 4.3% of the shark bycatch (only 200 individuals over the 9-year period) (Beerkircher et al. 2002). Analysis of HMS 2005-2009 logbook data indicated that an average of 25 vessels landed 181 hammerhead sharks per year on PLL gear. An additional 1,130 sharks (annual average) were caught and subsequently discarded, with 780 individuals discarded alive and 350 discarded dead. In 2010, the shortfin mako led the shark species in largest amount of landings (in weight), with a total of ca. 217 mt whole weight (ww), followed by blue shark, thresher sharks (*Alopias spp.*), and hammerhead sharks (*Sphyrna* spp.) with ca. 8.4, 7.9, and 4.8 mt ww, respectively. Estimates of dead discards for blue shark amounted to almost 164 mt ww, the largest amount of any shark species discarded by the PLL fleet. The second largest amount of dead discards corresponded to scalloped hammerhead shark, with ca. 50 mt ww (NMFS 2011b).

In the Pacific, 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). This fishery currently targets tunas and billfish and is managed under the auspices of the Western Pacific Regional Fishery Management Council. An observer program has been in place since 1995 with targeted coverage of 25% in the deep-set sector and 100% in the shallow-set sector. Observer data from 1995-2006 indicated a very low catch of scalloped hammerhead sharks (56 individuals on 26,507 sets total, both fishery sectors combined). More recent observer data (2009-2011) from this fishery indicate that scalloped hammerhead sharks continue to be a very rare catch, commensurate with the earlier time period (Walsh et al. 2009; Walsh personal communication, 2012).

In California, the number of longline vessels making high seas trips from a California port steadily increased in the early 1990s. These vessels primarily targeted swordfish and bigeye tuna beyond the EEZ, and fished alongside Hawaiian vessels in the area 135° W longitude in the months from September through May. Many of these vessels found productive swordfish fishing grounds in the fall and winter that were farther east than the Hawaiian fleet usually operated and thus operated out of California ports until about January. As the seasonal pattern of fishing moved to the west, the vessels switched and operated from Hawaii as it became the more convenient port. Consequently, beginning in the latter part of 1995, a number of vessels from the Hawaiian fleet began a similar pattern of fishing operations, moving to California in the fall and winter and then back to Hawaii in the spring and summer. This pattern continued until 2001, when the swordfish targeting prohibition and other restrictions implemented for Hawaii vessels prompted many vessels to remove themselves from their western Pacific longline limited entry permit and shift to California. Then, in 2004, NMFS issued a final rule that prohibited shallow longline sets of the type normally targeting swordfish on the high seas in the Pacific Ocean east and west of the 150° W longitude by vessels managed under the FMP for U.S. West Coast Fisheries for Highly Migratory Species. Vessels under this FMP, however, are permitted to target tunas with deep-set longline gear outside the EEZ, but the number participating is small. During the 2009/2010 fishing season, less than three vessels, with 100% observer coverage, participated in the West Coast-based deep-set pelagic longline fishery operating in the high seas zone outside of the U.S. EEZ (PFMC 2011).

Bottom Longline (BLL)

The shark bottom longline fishery is active in the Atlantic Ocean from about the Mid-Atlantic Bight to south Florida and throughout the Gulf of Mexico. Bottom longline gear is the primary commercial gear employed for targeting large coastal sharks (LCS) in all regions. Gear characteristics vary by region and target species, but in general, BLL consists of a longline between 3 and 8 km (1.8 – 5 miles) long with 200-400 hooks attached and is set for 2 and 20 hours. Depending on the species being targeted, both circle and J hooks are used. Fishermen targeting sharks with BLL gear are opportunistic and often maintain permits for council-managed fisheries such as reef fish, snapper/grouper, tilefish, and other teleosts. Minor modifications to how and where the gear is deployed allow fishermen to harvest sharks and teleosts on the same trip. Currently 214 U.S. fishermen are permitted to target sharks (excluding dogfish) in the Atlantic Ocean and Gulf of Mexico, and an additional 285 fishermen are permitted to land sharks incidentally.

Since 2002, shark BLL vessels are required to take an observer if selected; however, observations of the shark-directed BLL fishery in the Atlantic Ocean and Gulf of Mexico have been conducted since 1994. Data from observed hauls between 2005 and 2010 is presented in

Figure 10. Observed catches of scalloped hammerhead sharks appear to increase significantly from 2008 to 2009. In 2010, catches of scalloped hammerheads dropped, with S. *lewini* comprising ≤ 2.8% of the total number of sharks caught in the BLL hauls (Table 4). However, comparisons of catches over the years should be made with caution as the number of participating vessels, hauls, and trips vary greatly by year.

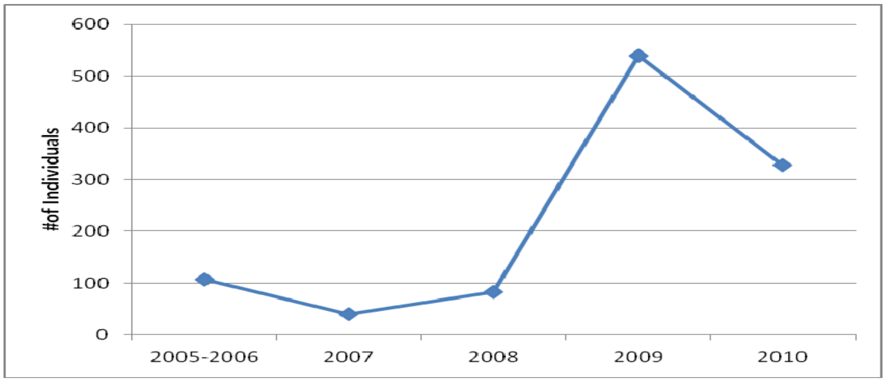

Figure 10. Observed number of scalloped hammerhead sharks caught in bottom longline (BLL) trips in the Gulf of Mexico and South Atlantic from 2005-2010. (Source: Hale et al. 2007, Hale and Carlson 2007, Hale et al. 2009, Hale et al. 2010, Hale et al. 2011)

Table 5. Observed number of scalloped hammerhead individuals caught from 718 BLL hauls over 138 trips on 23 vessels in 2010. (Source: Hale et al. 2011)

BLL Trip Target	**# of Scalloped Hammerhead Shark Caught**	**% of Total Sharks Caught**	**% Kept**	**% Discarded Dead**	**% Discarded Alive**	**% Unknown**
Sandbar sharks in the GOM and South Atlantic	212	2.6%	81.1%	10.8%	6.1%	1.9%
LCS in the GOM and South Atlantic	50	2.1%	88.0%	12.0%	0.0%	0.0%
Shallow water reef fish in GOM	55	2.8%	9.1%	9.1%	80.0%	1.8%
Deep water reef fish in the GOM	11	2.8%	0.0%	0.0%	90.9%	9.1%
TOTAL	328	2.5%	67.4%	10.3%	20.5%	1.8%

Gillnet Fishery

Since the implementation of Amendment 2 to the Consolidated Atlantic HMS FMP (NMFS 2007), the directed LCS gillnet fishery has been greatly reduced. The 33-head LCS trip limit has essentially ended the strike net fishery and limited the number of fishermen targeting LCS with drift gillnet gear. As a result, many gillnet fishers that historically targeted sharks are now targeting teleost species such as Spanish mackerel, king mackerel, and bluefish. Vessels participating in the Atlantic shark gillnet fishery typically possess permits for other Council and/or state managed fisheries and will deploy nets in several configurations based on target species including drift, strike, and sink gillnets. In 2010, a total of 295 sets by various gillnet fisheries in the Atlantic, including the Gulf of Mexico and Caribbean, were observed. In the drift gillnet fishery, 4 drift gillnet vessels were observed. These vessels made 14 sets on 8 trips. Out of the total 2,728 sharks caught during these trips, scalloped hammerhead sharks comprised 1.2% (n=33) with around 79% kept and 21% discarded dead. In the sink gillnet fishery, a total of 53 trips making 281 sets on 17 vessels were observed in 2010. A total of 3,131 sharks were caught, with scalloped hammerhead sharks comprising only 0.6% of this total (n=19); 68% were discarded alive while 5% of the scalloped hammerheads were kept (Passerotti et al. 2011).

In the Pacific, the California/Oregon drift gillnet fishery targets swordfish and common thresher sharks but is closed within 200 miles of the coast of California and Oregon from February 1 to April 30. From May 1 to August 14 the closure changes to 75 miles offshore. The majority of fishing effort takes place from October through December; however, observer data indicates that hammerheads are rarely caught in this fishery. From 1990-2012, a total of 8,310 sets were observed with only 50 hammerhead sharks documented as caught over this time period, but none of the hammerheads were identified as *S. lewini* (SWRO 2012, SWRO personal communication, 2012).

Commercial Handgear

Commercial handgears, including handline, harpoon, rod and reel, buoy gear and bandit gear, are used to fish for Atlantic HMS by fishermen on private vessels, charter vessels, and headboat vessels. Rod and reel gear may be deployed from a vessel that is at anchor, drifting, or underway (*i.e.*, trolling). However, the shark commercial handgear fishery plays a very minor role in contributing to the overall shark landing statistics.

Commercial Fishery Data: Landings by Species

The following table shows domestic commercial landings of Atlantic LCS which were compiled from the most recent stock assessment documents and updates provided by the NMFS Southeast Fishery Science Center (SEFSC).

Table 6. Domestic commercial landings of Atlantic LCS in pounds of dressed weight from 2003-2010. (Source: NMFS 2011a)

Large Coastal Sharks	2003	2004	2005	2006	2007	2008	2009	2010
Basking**	0	0	0	0	0	0	0	0
Bignose*	318	0	98	46	0	104	0	0
Bigeye sand tiger**	0	0	0	0	0	0	0	0
Blacktip	1,474,362	1,092,600	894,768	1,255,255	1,091,502	573,723	601,116	858,311
Bull	93,816	49,556	118,364	173,375	154,945	186,882	207,502	222,795
Caribbean reef*	0	0	0	0	0	0	0	0
Dusky*	23,288	1,025	874	4,209	2,064	0	486	0
Galapagos*	0	0	0	0	0	0	0	0
Hammerhead, great	0	0	0	0	0	0	0	0
Hammerhead, scalloped	0	0	0	0	0	0	0	0
Hammerhead, smooth	0	92	54	150	0	358	4,025	7,802
Hammerhead, unclassified	150,368	116,546	182,387	141,068	65,232	55,907	159,937	95,654
Large coastal, unclassified	51,433	0	0	0	0	0	0	0
Lemon	80,688	67,810	74,436	65,097	72,583	53,427	82,311	46,397
Narrowtooth*	0	0	0	0	0	0	0	0
Night*	20	0	0	0	0	0	0	0
Nurse	70	317	152	2,258	15	58	147	71
Sandbar	1,425,628	1,223,241	1,246,966	1,501,277	691,928	86,640	167,958	129,332

From 2003 – 2010, the commercial landings of the hammerhead shark complex has been variable. Landings decreased by about 69% from 2005 to 2008 but almost tripled the following year and subsequently decreased again in 2010.

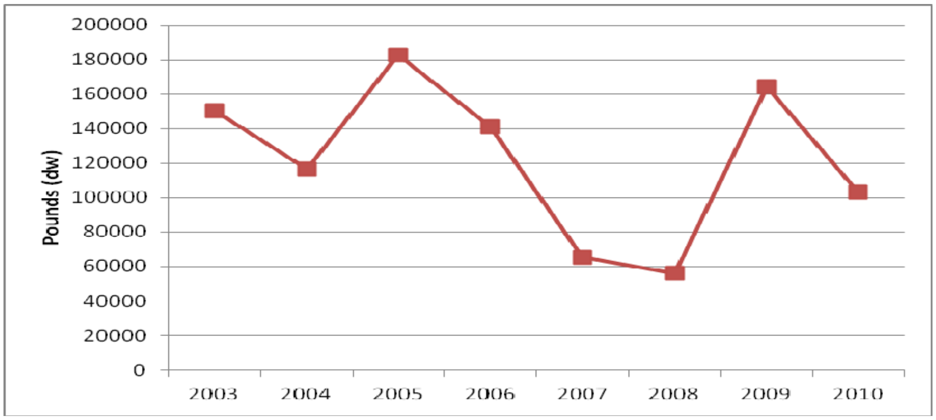

Figure 11. Atlantic commercial landings (lb dw) of the hammerhead shark complex from 2003-2010. (Source: NMFS 2011a)

Total Bycatch Estimates 2005-2006 (Source: NMFS 2011c)
Scalloped hammerhead shark bycatch estimates (by weight or numbers) were provided for nine Southeast Region commercial fisheries and 31 Pacific Islands Region domestic commercial fisheries. In some cases, bycatch estimates were reported for the entire hammerhead complex. In 2005, a total of 139 scalloped hammerhead sharks were caught as bycatch in commercial gillnet gear (drift, strike, bottom) in the South Atlantic large and small coastal shark fisheries. In the Atlantic and Gulf of Mexico Shark Bottom Longline fishery, scalloped hammerhead bycatch from 2005-2006 was 116,989 lbs, with a coefficient of variation (CV) = 0.35. From 2005-2006, bycatch estimates for all hammerhead sharks ranged from 15 individuals in the Gulf of Mexico Coastal Migratory Pelagic Troll, to 730 individuals from the Gulf of Mexico Reef Fish Bottom Longline fishery (with a CV = 129.37). In the South Atlantic Coastal Migratory Pelagic Troll, the annual bycatch of hammerhead sharks was 6.15 individuals (CV = 36.74), whereas in the South Atlantic Snapper-Grouper Handline, this number was much larger, at 135.63 individuals (CV= 64.13). In the Pacific Islands Region, bycatch estimates for scalloped hammerheads caught in the Hawaii-based deep-set pelagic longline fishery for tuna in 2005 averaged 773.82 lbs. For the hammerhead complex (*Sphyrna* spp.), this bycatch estimate tripled to 2,414.06 lbs. Catches in the other fisheries and in other regions were found to be negligible.

U.S. Recreational Shark Fishery
Recreational landings of sharks are an important component of HMS fisheries. Recreational shark fishing with rod and reel is a popular sport at every social and economic level. Depending upon the species, sharks can be caught virtually anywhere in salt water. Recreational shark fisheries often occur in nearshore waters accessible to private vessels and charter/headboats; however, shore-based and offshore fishing also occur. 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. Similar state regulations along the Atlantic seaboard are being implemented through an Atlantic States Marine Fisheries Commission (ASMFC) interstate FMP (ASMFC 2008). Currently, recreational fishermen are allowed one scalloped hammerhead shark > 54" fork length (FL) per vessel per trip. Table 7 provides a summary of recreational landings of scalloped hammerhead sharks as well as unidentified hammerhead sharks collected through three surveys: the NMFS Marine Recreational Fishery Statistics Survey (MRFSS), the NMFS Southeast Region Headboat Survey (SRHS), and the Texas Parks and Wildlife Department (TPWD) Marine Recreational Fishing Survey.

Table 7. Atlantic recreational harvest (# of individuals) of scalloped hammerhead sharks and unclassified hammerhead sharks from 2002 – 2009. (Source: NMFS 2011a)

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010
Scalloped Hammerhead Shark	996	2921	879	5021	458	1726	119	1667	199
Hammerhead, unclassified	5247	0	0	2676	1099	807	0	0	0

Additionally, the Large Pelagic Survey (LPS) provided data from Maine through Virginia on the observed and reported numbers of scalloped hammerheads in the rod and reel fishery from 2002 - 2010. In 2006, only one scalloped hammerhead was observed or reported as "kept." In 2008, four sharks were observed or reported as "released", and in 2009 this number decreased to two. There were no observed or reported catches for the other years.

Scalloped Hammerhead Shark Stock Assessment (Hayes et al. 2009)

In the U.S. Atlantic, the NMFS HMS Management Division manages seventy-two species of sharks (excluding dogfish) under the Consolidated HMS FMP (NMFS 2006a). The management of these sharks is divided into four species groups: large coastal sharks (LCS), small coastal sharks (SCS), pelagic sharks, and prohibited sharks. The LCS complex is comprised of 11 species including sandbar, silky, tiger, blacktip, spinner, bull, lemon, nurse, scalloped hammerhead, great hammerhead, and smooth hammerhead sharks. In 2006, NMFS completed the eleventh Southeastern Data, Assessment and Review (SEDAR 11), in which the LCS complex was determined not to be overfished (NMFS 2006b). However, the Review Panel noted that the available data may not be appropriate for assessing the status of the complex since it was combined for all of the species in the complex. As such, trends in one species may mask trends in another species, or even cancel each other out, making it difficult to determine the status of the group as a whole. Thus, the panel decided that the continued assessment approach for the LCS complex was unlikely to produce effective management advice and was not recommended. Instead, the panel suggested that NMFS conduct species-specific assessment of all large coastal sharks as data permits (NMFS 2006b). In October 2009, Hayes et al. (2009) produced such an assessment for the northwest Atlantic and Gulf of Mexico population of scalloped hammerhead sharks in U.S. waters. This assessment was reviewed by NMFS and deemed appropriate to serve as the basis of U.S. management decisions (NMFS 2010).

Available Data

Below is a brief description of the sources of scalloped hammerhead data used in the Hayes et al. (2009) assessment and recommended by NMFS:

NMFS Marine Recreational Fishery Statistics Survey (MRFSS): The MRFSS is a survey designed to provide regional and state-wide estimates of recreational catch for marine fish species in the Atlantic. It has been in operation since 1979. It was not designed to account for the unique characteristics of HMS fisheries, although information on these species is frequently obtained by the survey. The MRFSS is a random-dial telephone survey, restricted to coastal counties from Virginia through Louisiana. The MRFSS does not cover the state of Texas nor does it cover the charter/headboat fisheries. Information collected by the MRFSS on recreational shark landings is used to estimate the number of fishing trips, the number and species of sharks caught and/or landed, the weight of these sharks, and the number of persons fishing. Shark species are identified to the extent possible.

NMFS Southeast Region Headboat Survey (SRHS): The SRHS is administered by the NMFS component of the Beaufort, NC NOAA Laboratory. The survey has operated along the east coast of the U.S. since 1972 and began operations in the Gulf of Mexico in 1986. The survey is the longest continuous time series of recreational fisheries data on the east coast from federal waters. There are two components to the survey. The first is the dockside intercept sampling program used to obtain biological samples from the landings in order to estimate average sizes of species landed in the headboat fishery. The second component of the SRHS is the self-reported logbook, or daily catch record which asks vessel personnel to fill out reports of catch and effort for each trip they run. The survey is designed to be a comprehensive consensus, with trip tickets prepared for each trip. Annual landings estimates, by area and month, are provided for all species encountered in the survey.

TPWD Marine Recreational Fishing Survey: This survey, which has been in operation since 1974, collects information from private, rental, and charter boats regarding the targeted species, catch composition, catch number, and catch size through stratified proportional random sampling. Data on trip length, angler CPUE, location of fishing, gear and bait used, residence of anglers, and trip satisfaction are also collected. Onsite surveys are conducted to collect trip specific information, and roving surveys are used to collect trailer and empty wet-slip counts.

Pelagic Dealer Compliance (PDC) database: Contains data collected by the NMFS Southeast Fishery Science Center (SEFSC) from selected dealers that have a federal permit in order to purchase shark, swordfish, and/or tuna products from a federally permitted vessel and is located in the Southeast Region. When selected, the dealers are required to submit a report with the landings (purchases) of any species in the highly migratory species management unit that were purchased from U.S. vessels fishing in the Gulf of Mexico and Atlantic Ocean. Dealers are required to provide dressed weight, price per pound and vessel information on each HMS species.

Accumulated Landings Systems: Data consist of information on the quantity and value of seafood products caught by fishermen and sold to licensed seafood dealers or brokers. The general canvas statistics are monthly summaries of the quantities of all species landed at (i.e., purchased by) each licensed seafood dealer.

Commercial Shark Fishery Observer Program (CSFOP): Places fishery observers on commercial shark fishing vessels to observe the composition and disposition of the catch and by-catch and record weights of shark carcasses and fins. Monitoring of the southeastern United States shark fishery began in January 1994.

Pelagic Longline Observer Program (PLLOP): The SEFSC Miami Laboratory is responsible for the administration of the Pelagic Longline Observer Program, which has been in operation since 1992 and conducts scientific sampling of the U.S. large pelagic fisheries longline fleet. The PLLOP collects data on gear characteristics, environmental conditions, species and disposition of the catch, morphometrics, biological characteristics, and interaction with marine mammals, turtles, and birds as they relate to federal fisheries regulations. Area of operation ranges from the Grand Banks to off Brazil and in the Gulf of Mexico.

Gill net observer program (GNOP): Since 1993, an observer program has been underway to estimate species-specific catch and bycatch in the directed shark gillnet fisheries along the southeastern U.S. Atlantic coast. Observers collect data on catch, bycatch, and discard numbers as well as the disposition of the catch in the shark fishery.

NMFS Pascagoula Longline Survey (NMFS LL SE): This coastal shark assessment survey is conducted out of the southeast region by personnel from the NMFS SEFSC Pascagoula (Mississippi) Laboratory. This survey uses a standardized, random sampling design stratified by depth. Monofilament longlines are soaked for 1 hour. The nominal measure of CPUE is 100 hooks per hour. The area of coverage extends from the western Gulf of Mexico to North Carolina along the U.S. southeastern Atlantic seaboard.

NMFS Panama City Gillnet Survey (PCGN): This survey is conducted by personnel from the NMFS SEFSC Panama City (Florida) Laboratory in shallow, coastal areas of the northeastern Gulf of Mexico close to the Florida Panhandle. This survey uses a standardized sampling design. Monofilament gillnets with stretched mesh sizes ranging from 8.9 cm (3.5 inches) to 14.0 cm (5.5 inches) in steps of 1.3 cm (0.5 inches), are set at fixed stations monthly from April to October. Gillnets are soaked for 1 hour.

North Carolina Longline survey (NCLL): A long-term research survey of sharks has been conducted each year since 1972 by Dr. F.J. Schwartz of the University of North Carolina at Chapel Hill Institute of Marine Sciences in Onslow Bay off the central coast of North Carolina near Cape Lookout. Unanchored longlines are set biweekly and survey methods (Schwartz 1984) have remained identical over a 35-year period. Species, sex, and fork length of each hooked shark is recorded and all live sharks are tagged and returned to the sea.

Annual catch data were collected by NMFS from the western North Atlantic Ocean and Gulf of Mexico since 1981. Recreational catch data were collected from three surveys: the MRFSS, SRHS, and the TPWD Marine Recreational Fishing Survey. Commercial landing data on weight were collected from the Pelagic Dealer Compliance program and the Accumulated Landings Systems. Hayes et al. (2009) converted these data into annual catch numbers by dividing the landings weight by an average weight of individual animals as reported in the CSFOP. Dead discard data were collected from the SEFSC using the PLLOP and dealer weigh-out data to produce annual estimates. Discard estimates specifically for scalloped hammerheads were not available before 1987 or after 2001 (due to *S. lewini* being lumped into a larger dealer report category) so estimates for these years were based on average discards in 1987-1992 and 1993-2001 respectively. Table 8 and Figure 11 display the compilation of the recreational and commercial data from 1981 through 2005.

Table 8. Number of scalloped hammerheads caught by year and fishery sector. Estimated discards are given in parentheses and relatively high estimated catch values are marked with an asterisk. (Source: Hayes et al. 2009)

Year	Recreational	Commercial	Discards	Total
1981	5,880	0	(1,487)	7,367
1982	48,138	1	(1,487)	49,626*
1983	20,962	365	(1,487)	22,814
1984	7,003	0	(1,487)	8,490
1985	44,042	0	(1,487)	45,529*
1986	5,321	0	(1,487)	6,808
1987	6,372	0	1,228	7,600
1988	4,518	2	1,674	6,194
1989	6,191	0	1,389	7,580
1990	18,373	12	1,151	19,536
1991	8,935	4	1,221	10,160
1992	7,325	67	2,257	9,649
1993	21,723	91	516	22,330
1994	3,886	301	368	4,554
1995	3,695	1,479	567	5,741
1996	882	1,479	290	2,652
1997	3,905	1,041	938	5,884
1998	1,083	642	234	1,959
1999	545	386	344	1,275
2000	6,350	68	277	6,695
2001	1,112	1,152	339	2,602
2002	6,113	1,180	(431)	7,724
2003	2,859	2,606	(431)	5,896
2004	803	1,351	(431)	2,585
2005	803	2,901	(431)	4,135

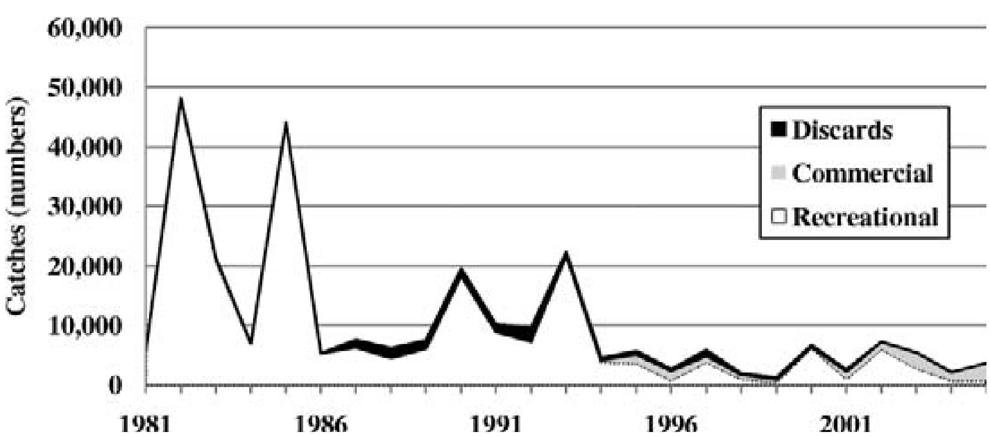

Figure 11. Catches (# of individuals) of scalloped hammerhead sharks from 1981-2001. (Source: Hayes et al. 2009)

Fishery dependent relative abundance incidences, including the CSFOP, GNOP, and PLLOP, were standardized according to the Lo method (Lo et al. 1992) before inclusion in the models. Fishery-independent surveys are less biased indices of abundance and were included in the models after standardization. Table 9 gives a summary of the surveys used for relative abundance indices and Table 10 shows the incidence of the relative abundance of scalloped hammerheads, standardized by the Lo method and normalized to their own means.

Table 9. Fishery-dependent (FD) and fishery independent (FI) surveys used to provide relative abundance indices for the scalloped hammerhead shark assessment. (Source: Hayes et al. 2009)

Index		Geographic coverage	Fishery dependence	Years	Positive hauls (%)	Reference
Code	Name					
CSFOP	Commercial shark fishery observer program	SA and GOM	FD	1994–2005	21	Cortés et al. (2005)
GNOP	Shark drift gill net observer program	SA (Georgia, Florida) and GOM (Florida)	FD	1994–2005	39	Carlson et al. (2005)
PLLOP	Pelagic longline observer program	Western NA	FD	1992–2005	9	Beerkircher et al. (2002)
NMFS LL SE	NMFS Mississippi bottom longline survey	SA and GOM	FI	1995–2005	9	Ingram et al. (2005)
PCGN	NMFS Panama City gill-net survey	Northeastern GOM	FI	1996–2005	23	Carlson and Bethea (2005)
NCLL	University of North Carolina longline survey	Onslow Bay, North Carolina	FI	1972–2005	6	Schwartz et al. (2007)

Table 10. Standardized indices of the relative abundance of scalloped hammerhead sharks from each of the incorporated fishery surveys. (Source: Hayes et al. 2009)

Year	CSFOP	GNOP	PLLOP	NMFS LL SE	PCGN	NCLL
1981						1.329
1982						0.816
1983						1.174
1984						1.438
1985						0.344
1986						0.719
1987						0.886
1988						1.223
1989						0.154
1990						0.049
1991						0.076
1992			2.736			
1993			1.378			0.216
1994	0.183	0.979	0.745			0.102
1995	0.344	4.218	1.162	1.055		
1996	0.362		0.285	0.404	0.127	0.206
1997	0.429		1.091	0.567	0.541	
1998	0.601	1.129	1.201		0.265	0.112
1999	0.161	0.158	0.449	0.947	0.742	0.987
2000	0.012	1.151	0.613	1.322	1.000	0.277
2001	0.421	0.365	0.886	1.244	0.912	0.141
2002	0.825	0.274	0.454	1.347	0.819	0.147
2003	1.000	0.240	0.708	1.530	0.596	0.187
2004	0.773	0.755	0.458	0.584	0.436	0.216
2005	0.452	0.730	0.507		0.459	0.392

Modeling Approach

Two forms of a surplus-production model were used to analyze the data. Surplus-production models are frequently used to conduct shark stock assessments 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. Hayes et al. (2009) used a logistic (Schaefer 1954) and a Fox (1970) surplus-production model to analyze the scalloped hammerhead shark data. The following is the modeling approach quoted directly from the Hayes et al. (2009) stock assessment:

> This study analyzed two forms of the surplus production model: logistic (Schaefer 1954) and Fox (1970). Both variants assume that the maximum sustainable yield (MSY) or maximum surplus production occurs at some population size below carrying capacity. Surplus production increases as individuals are removed from the population to a point (population size associated with maximum sustainable yield, N_{MSY}) below which surplus production begins decreasing. The logistic model assumes N_{MSY} is half of the unfished population size (K), whereas the Fox model assumes N_{MSY} occurs at K/e, or approximately 37% of K. Model goodness of fit was compared through AIC [Akaike information criterion] corrected for small sample size (AIC_c), which provides an unbiased order of model choice and is recommended for use regardless of sample size (Bedrick and Tsai 1994; Burnham and Anderson 2004). (Hayes et al. 2009)

For the stock assessment, the authors compared the model performance of the Fox and Logistic production curves (below) using AIC_c:

Logistic: $G_t = rN_t\,[1 - (N_t/K)]$

Fox: $G_t = rN_t\,\{1 - [\log_e(N_t) / \log_e(K)]\}$

where N_t is the population size at time t; G_t is the population growth or surplus production, r is the intrinsic population growth rate, and K is the unfished (virgin) population size.

<u>Results</u>

The AIC_c results of the logistic and Fox surplus-production models (Table 11) show that the Fox model only marginally outperformed the Logistic model (AIC_c = 172.6 and 173.5 respectively). The Fox model calculated an intrinsic rate of population increase (r) of 0.11, while the logistic model estimated r = 0.29, suggesting that the population was less productive and more susceptible to fishing pressure under the Fox model.

Table 11: Results of the logistic and Fox surplus-production models: r = intrinsic annual population growth, K = size of unfished population before 1981 (in thousands); MSY = maximum sustainable yield (thousands); F = annual fishing mortality rate; N = size of population in 2005 (thousands).

Variable	Logistic	Fox
r	0.29 (0.05–0.45)	0.11 (0.06–0.23)
K	142 (116–260)	169 (126–218)
MSY	10.4 (4–13)	7.1 (5–10)
F_{MSY}	0.15 (0.03–0.23)	0.11 (0.06–0.23)
N_{MSY}	71 (58–130)	62 (47–80)
Depletion (%)	83 (53–90)	83 (67–93)
F_{2005}/F_{MSY} (%)	114 (43–397)	129 (54–341)
N_{2005}/N_{MSY} (%)	35 (19–87)	45 (18–89)

The Fox model estimated a virgin population size (in 1981) of 169,000 (range = 126,000 – 218,000) and a population of 27,900 in 2005. The logistic model estimated a virgin population size of 142,000 (range = 116,000-260,000) and a population of 24,850 in 2005 (Figure 12).

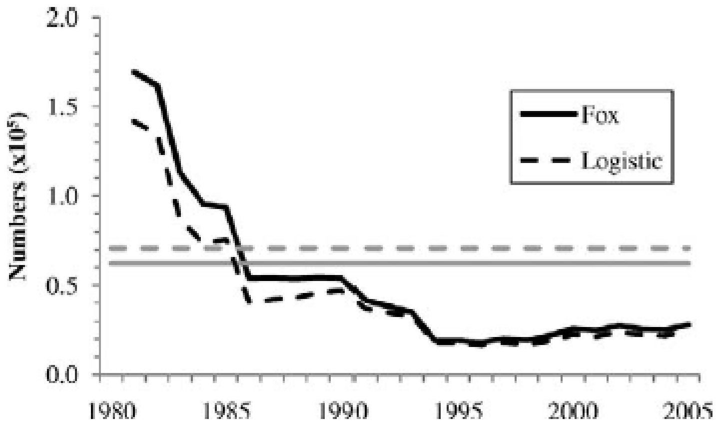

Figure 12. Estimated abundance (# of individuals) of scalloped hammerhead sharks calculated by the Fox and Logistic models for the period of 1981-2005. The light gray horizontal lines represent the populations associated with MSY from the respective models. (Source: Hayes et al. 2009)

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 current status of the scalloped hammerhead shark.

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

The ESA requires an evaluation of any present or threatened destruction, modification, or curtailment of habitat or range. Currently, scalloped hammerhead sharks are found worldwide, residing in coastal warm temperate and tropical seas. They occur over continental and insular shelves, as well as adjacent deep waters, but are seldom found in waters cooler than 22° C (Compagno 1984, Schulze-Haugen and Kohler 2003). *S. lewini* are also found in intertidal and surface waters and depths of up to 450 to 512 m (Sanches 1991, Klimley 1993). The vertical habitat of scalloped hammerheads in the Gulf of California may extend even further to include areas of cold hypoxic waters (Jorgensen et al. 2009). In the southern Gulf of California, the stable oxygen minimum layer occurs between 250 and 800 m, where dissolved oxygen levels are consistently below 0.5 ml l^{-1} and fall to anoxic conditions between 600-700 m. Data from a female *S. lewini* tagged at El Bajo Espiritu Santo Seamount in the ETP revealed vertical movements from surface waters to depths of at least 980 m (Jorgensen et al. 2009). During the tagging period, the shark experienced temperature ranging from 4.8°C to 27.8°C and swam below the 250 m hypoxic threshold on more than half the days for which data were collected. The shark spent an average of 35 min (range 1-180 min) per 12 hour period within this hypoxic region (Jorgensen et al. 2009). Although these data are only from one individual, it suggests that *S. lewini* may be able to utilize a deeper vertical habitat than previously thought, with an ability to tolerate large fluctuations in temperature and dissolved oxygen concentrations.

In the U.S. economic exclusive zone (EEZ), the Magnuson-Stevens Act requires NMFS to identify and describe Essential Fish Habitat (EFH), minimize the adverse effects of fishing on EFH, and identify actions to encourage the conservation and enhancement of EFH. The Magnuson-Stevens Act defines EFH as habitat necessary for spawning, breeding, feeding, and growth to maturity and requires the identification of EFH in FMPs. Towards that end, NMFS has funded two cooperative survey programs intended to help delineate shark nursery habitats in the Atlantic and Gulf of Mexico. The Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Survey and the Cooperative Gulf of Mexico States Shark Pupping and Nursery (GULFSPAN) Survey are designed to assess the geographical and seasonal extent of shark nursery habitat, determine which shark species use these areas, and gauge the relative importance of these coastal habitats for use in EFH determinations. Results from the surveys indicate the importance of estuarine, nearshore, and coastal waters of South Carolina, Georgia, Atlantic Florida, Florida Panhandle, and Alabama as potential nursery habitats for scalloped hammerhead sharks. Below are the designated EFH areas along the U.S. coast that support various life stages of the scalloped hammerhead shark (Source: NMFS 2009):

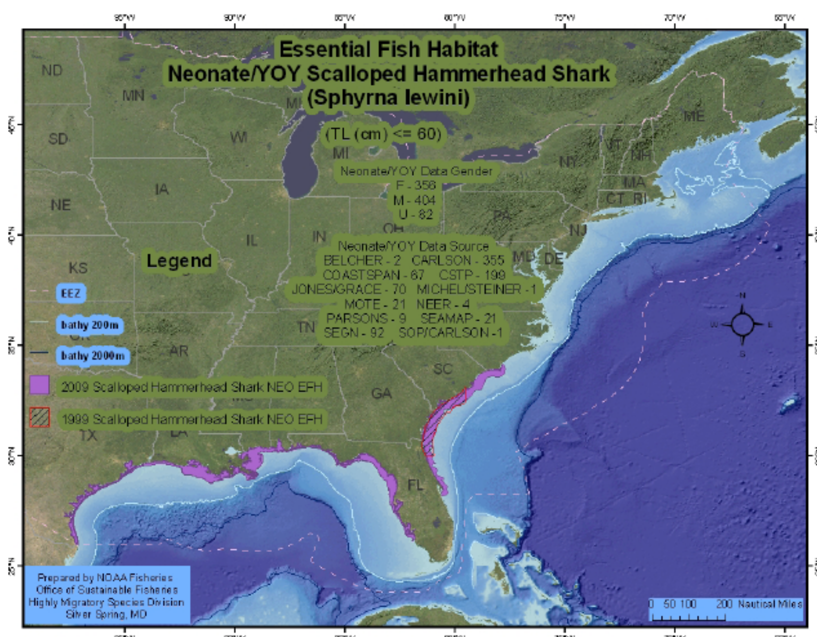

Figure 13. Neonate/YOY (≤ 60 cm TL) EFH (identified by the light purple area): Coastal areas in the Gulf of Mexico from Texas to the southern west coast of Florida, and Atlantic east coast from the mid-east coast of Florida to southern North Carolina.

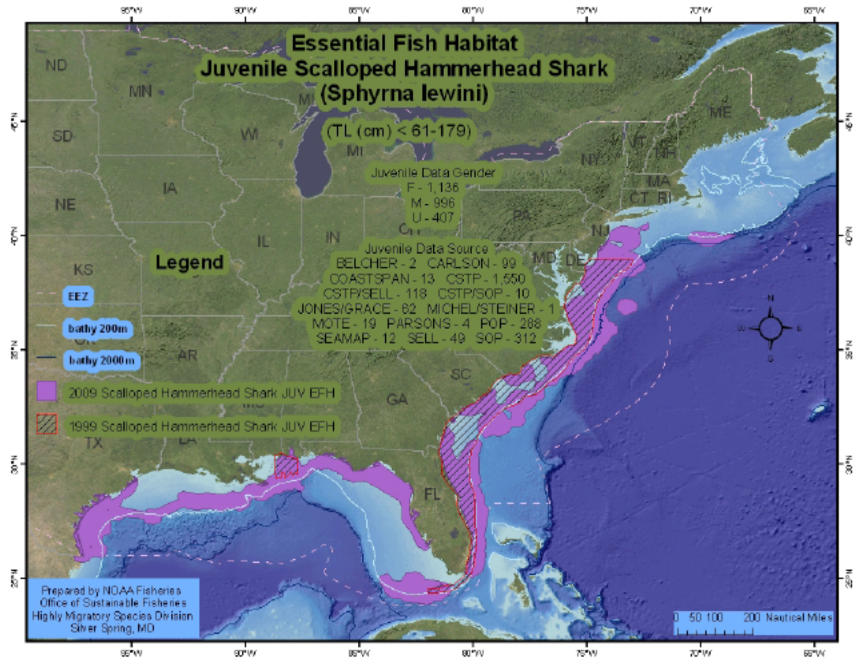

Figure 14. Juvenile (61- 179 cm TL) EFH (identified by the light purple area): Coastal areas in the Gulf of Mexico from the southern to mid-coast of Texas, eastern Louisiana to the southern west coast of Florida, and the Florida Keys. Offshore from the mid-coast of Texas to eastern Louisiana. Atlantic east coast of Florida through New Jersey.

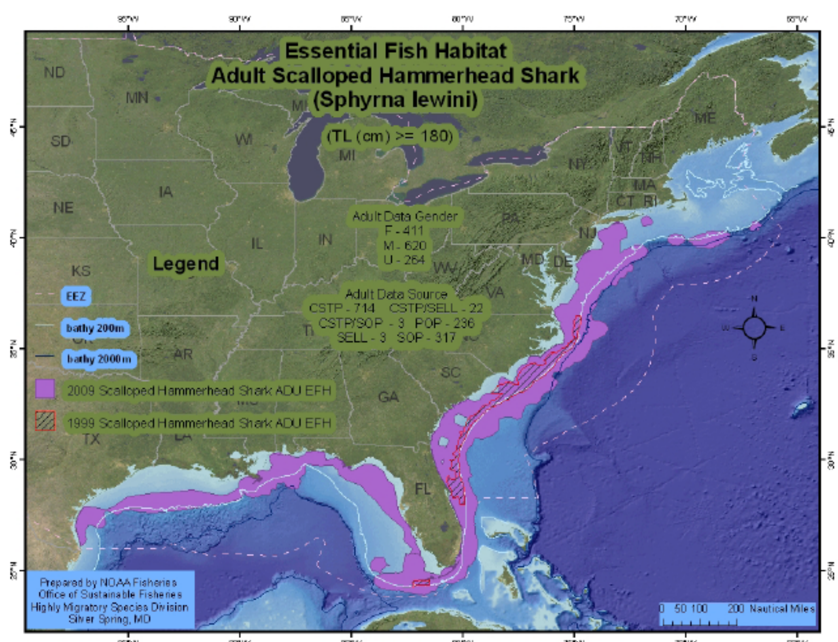

Figure 15. Adult (≥180 cm TL) EFH (identified by the light purple area): Coastal areas in the Gulf of Mexico along the southern Texas coast, and eastern Louisiana through the Florida Keys. Offshore from southern Texas to eastern Louisiana. Atlantic east coast of Florida to Long

Island, NY.

Based on an examination of published literature and anecdotal evidence, NMFS assessed the impact of fishing gears on HMS EFH and determined that there are few anticipated impacts from Federally regulated and non-federally regulated gears to the *S. lewini* EFH (NMFS 2006a). Since the scalloped hammerhead EFH is defined as the water column or attributes of the water column, there are anticipated to be minimal or no cumulative impacts from HMS and non-HMS fishing gears (NMFS 2006a). However, a better understanding of the specific habitat types and characteristics that influence the abundance of scalloped hammerheads within those habitats is needed in order to determine the effects of fishing activities on habitat suitability for *S. lewini*.

In addition, the EFH regulations require that FMPs identify non-fishing related activities that may adversely affect EFH of managed species, either quantitatively or qualitatively, or both. Estuaries and coastal embayments have been identified as particularly important nursery areas for sharks, while offshore waters contain important spawning and feeding areas. All of these waters are or may be used by humans for a variety of purposes that often result in degradation of these and adjacent habitats, posing threats, either directly or indirectly, to the biota they support (NMFS 2006a). These effects, either alone or in combination with effects from other activities within the ecosystem, may contribute to the decline of some species or degradation of the habitat. For example, in Costa Rica, the shallow, turbid waters at the mouth of the Tarcoles River in the Gulf of Nicoya have been identified as an important and productive ecosystem for juvenile hammerheads (Garro et al. 2009, Zanella et al. 2009). However, the basin of this river is highly polluted by industrial, transport and trade, coffee production, and cattle waste which has led to the accumulation of heavy metals near the mouth of the river (Zanella et al. 2009). High concentrations of heavy metals damage the epithelial gill cells of sharks and cause respiratory system failure (de Boeck et al. 2002); however, such effects to *S. lewini* have not been reported in this area. Although pollution and the degradation of water quality may be serious threats to the scalloped hammerhead nursery and juvenile habitats, the cumulative anthropogenic effects on the species' continued existence are difficult to quantify.

The habitat of adult scalloped hammerheads consists of continental areas further offshore, with adult aggregations common over seamounts and near islands like the Galapagos, Malpelo, Cocos and Revillagigedo Islands, and within the Gulf of California (Compagno 1984, CITES 2010, Hearn et al. 2010, Bessudo et al. 2011). Many of these islands are considered "hot spots" for both juvenile and adult scalloped hammerhead sharks and are also designated as marine reserves with primary management goals of habitat and resource conservation. The Eastern Tropical Pacific Seascape, a two million square kilometer region that encompasses national waters, coasts, and islands of Colombia, Costa Rica, Ecuador, and Panama, was created to support marine conservation and sustainable use of resources, and includes the Galapagos, Cocos, and Malpelo Islands. Kāne'ohe Bay in Oahu, Hawaii, is a known breeding and nursery ground for hammerhead sharks and the Hawaii Marine Laboratory Refuge is located within this bay. This refuge consists of the reefs and bay waters surrounding Coconut (Moku-o-loe) Island and prohibits the taking of aquatic life within the boundaries of the refuge. All of these protections are helping to prevent the destruction or modification of important *S. lewini* nursery, breeding, and schooling grounds.

In addition, based on a comparison of *S. lewini* distribution maps from 1984 and 2012 (Figure 16), and current reports of scalloped hammerhead catches (Figure 17), there is no evidence to suggest a range contraction based on habitat degradation for the scalloped hammerhead shark.

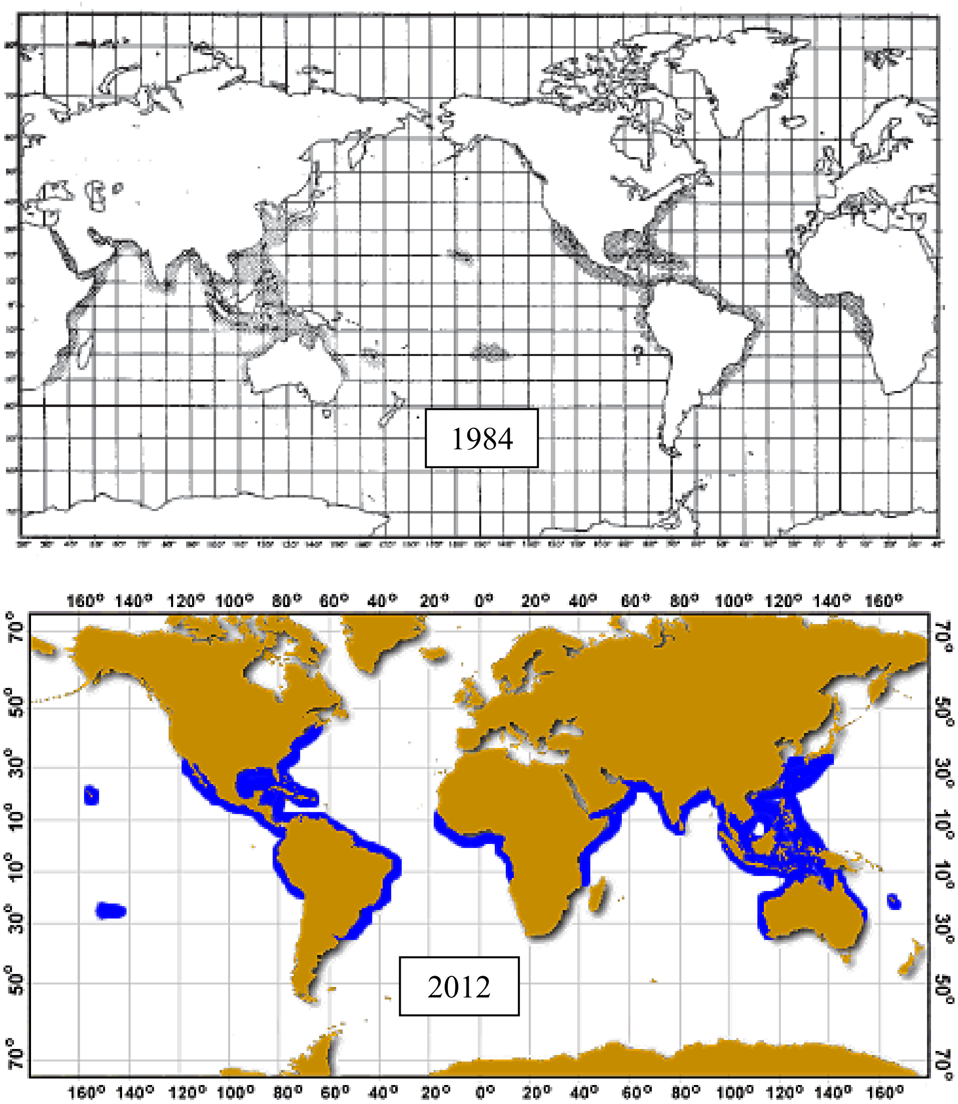

Figure 16. Distribution of the scalloped hammerhead shark in 1984 and 2012. (Source: Compagno 1984; FAO Species Fact Sheet, accessed April 6, 2012)

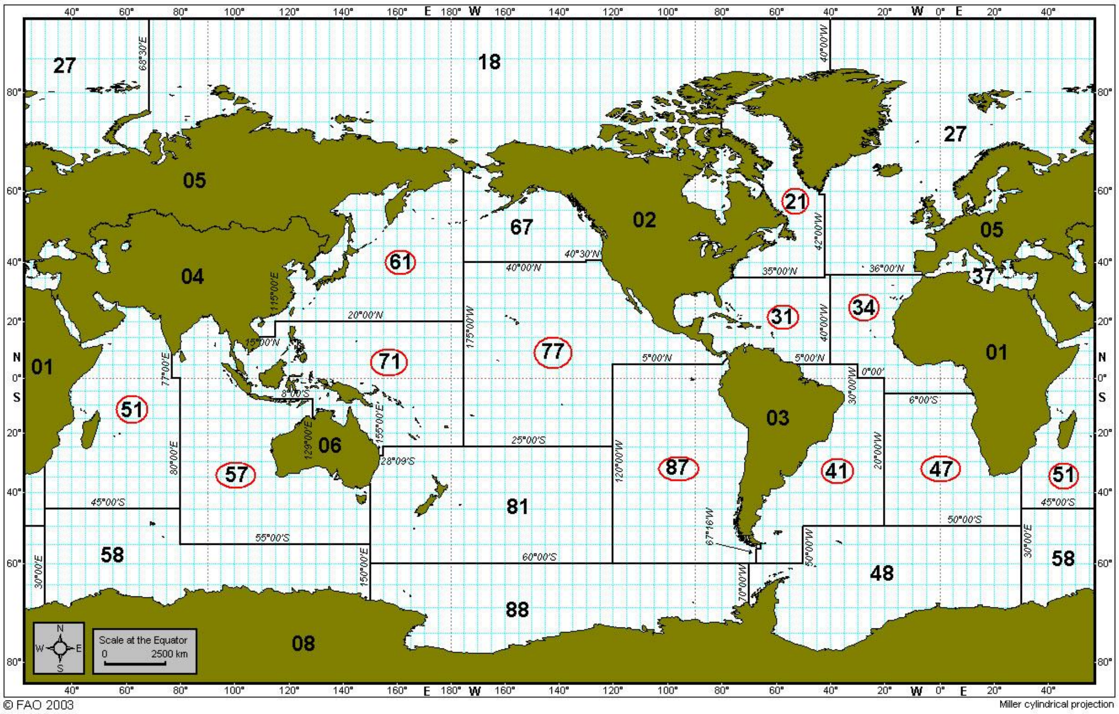

Figure 17. Map of FAO major fishing areas for scalloped hammerhead sharks (identified by a red oval).

Because the scalloped 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, are most likely to pose the greatest threat to this species. However there is currently no evidence to suggest there exists a present or threatened destruction, modification, or curtailment of the scalloped hammerhead shark's habitat or range.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The ESA contains no guidance on how to assess overutilization, nor does it outline levels of population decline relative to an endangered or threatened status. For the purposes of this status review, the following population dynamic characteristics were considered for evaluating the status of the species: historical population size, current population size, population trends, recruitment and depensation, spatial focusing, effects of the shark fin trade, and former modeling approaches. Much of the data come from localized study sites and over small periods of time and thus is difficult to extrapolate to the global population. In addition, data are often aggregated for the entire hammerhead complex.

<u>Historical Population Size</u>

Estimates of historical (~3,600 to 12,000 years ago) effective population sizes in the eastern Pacific region range from 34,995 to 43,551 (see Table 3; Nance et al. 2011). For the northwestern Atlantic and Gulf of Mexico scalloped hammerhead shark stock, Hayes et al. (2009) estimated the virgin, or unfished, population size (in 1981) to be in the range of 142,000 - 169,000. Global estimates of the historical population size are currently unavailable.

Current and Effective Population Size

Current effective population sizes are available for the scalloped hammerhead shark, but are considered qualitative indicators rather than precise estimates given their reliance on mutation rates and generation times (Duncan et al. 2006). Using two generation times (5.7 and 16.7 years), Duncan et al. (2006) calculated the effective female population (N_f) size of *S. lewini* for the major ocean basins. Based on a 1:1 sex-ratio (Clarke 1971, Chen et al. 1988, Stevens and Lyle 1989, Ulrich et al. 2007, White et al. 2008, Noriega et al. 2011), these calculations have been converted into total (both females and males) effective population size (N_e) by using the formula $N_e = 2(N_f)$. Results of N_e greatly varied within and between ocean basins, with the global N_e estimated at 240,000 using a generation time of 5.7 years, and 94,000 using a generation time of 16.7 years.

Table 12. Estimates of current effective population size (N_e) of *S. lewini*. (Adapted from estimates of N_f in Duncan et al. 2006)

Ocean Basin	**Population**	**Sample Size (n)**	**N_e (5.7 year generation time)**	**N_e (16.7 year generation time)**
Pacific	Baja	44	22,000,000	7,600,000
	Pac. Panama	8	62,000,000	2,000,000
	Hawaii	44	3,200	1,100
	Philippines	15	64,000	22,000
	Taiwan	20	15,600,000	5,200,000
	E. Australia	32	70,000	24,000
Indian	W. Australia	26	6,800	22,000
	Seychelles	12	16,200	54,004
	S. Africa	25	18,000	60,010
Atlantic	W. Africa	6	300,000	100,000
	East Coast USA	16	36,000,000	12,000,000
All	Total	271	280,000	94,000

On a smaller scale, Nance et al. (2011) estimated current effective population size at six separate Eastern Pacific sites. Compared to the estimates from the Eastern Pacific presented in Table 12, Nance et al. (2011) results are drastically smaller, with an effective population size estimate ranging from 227 to 604. Moving further west, estimates of mean population sizes in Hawaii during peak densities (i.e. summer season) range from 2,300 to 7,700 sharks born per year (with N_{max} of 4,400 to 9,800) (Duncan and Holland 2006), and for the northwestern Atlantic and Gulf of Mexico scalloped hammerhead stock, Hayes et al. (2009) estimated a population size in 2005 at ~25,000 – 28,000.

Population Trends

Data from multiple sources indicate that the Atlantic population of *S. lewini* has experienced severe declines over the past few decades. It is likely that scalloped hammerheads in the Northwest Atlantic and Gulf of Mexico were overfished beginning in the early 1980s and experienced periodic overfishing from 1983 – 2005 (Figure 18; Jiao et al. 2011).

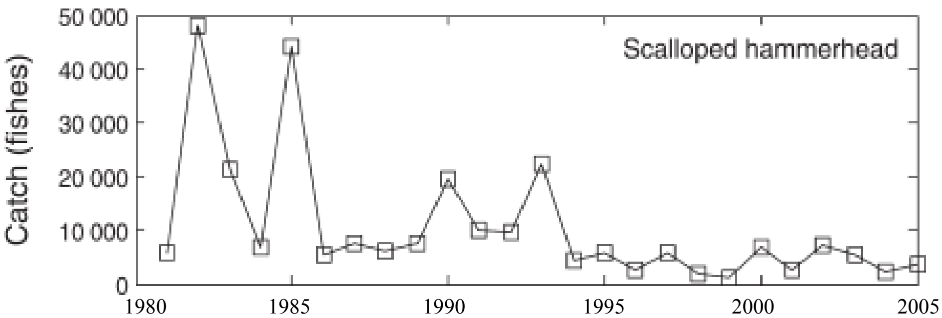

Figure 18. Catches (# of individuals, including recreational, commercial landings, and pelagic longline discards) of *S. lewini* from 1980-2005. (Source: Jiao et al. 2011)

Other studies have also observed similar decreases in *S. lewini* populations along the Atlantic coast. For example, Baum et al. (2003) calculated that the northwest Atlantic population of *S. lewini* has declined 89% since 1986; however this study is controversial due to the reliance on only pelagic longline logbook data. Off the southeastern U.S. coast, Beerkircher et al. (2002) found significant declines in nominal CPUE for *S. lewini* between 1981-1983 (CPUE = 13.37; Berkeley and Campos 1988) and 1992 – 2000 (CPUE = 0.48). On a smaller scale, Myers et al. (2007) documented a 98% decline of *S. lewini* off the coast of North Carolina between 1972 and 2003, using standardized CPUE data from shark targeted, fishery-independent surveys. However, the authors also discovered a significant increase in juvenile scalloped hammerheads (instantaneous rate of change = 0.094) from 1989-2005. Comparing estimates of population size off the coast of South Carolina, Ulrich (1996) reported a 66% decrease between 1983-1984 and 1991-1995.

In a recent stock assessment for the scalloped hammerhead shark, Hayes et al. (2009) concluded that the northwestern Atlantic and Gulf of Mexico *S. lewini* stock has been depleted by approximately 83% since 1981. Using the Fox surplus production model (see previous section on Stock Assessment methods), Hayes et al. (2009) estimated that the 2005 population of scalloped hammerheads was only 45% of the biomass that would produce MSY. Fishing mortality was estimated to be 129% of fishing mortality associated with MSY. In addition, Hayes et al. (2009) estimated that a total allowable catch (TAC) of 2,853 scalloped hammerhead sharks per year (or 69% of 2005 catch) would allow a 70% probability of rebuilding within 10 years, whereas a TAC of 4,135 (or the 2005 catch) would only allow a 58% probability of recovery. If a longer time period were applied, there was an increased probability of attaining a final population size that would be greater than N_{MSY} (Table 13).

Table 13. Probability (in %) of the *S. lewini* stock rebuilding under different time frames and catch scenarios. (Source: Hayes et al. 2009)

		Percent of 2005 catch (number)			
Time frame	No catch	50 (2,068)	69 (2,853)	100 (4,135)	150 (6,203)
10 years	95	85	70	58	20
20 years	99	96	92	86	50
30 years	99	98	96	91	63

Assuming the calculations by Hayes et al. (2009) accurately reflect the stock status of the scalloped hammerhead shark, the *S. lewini* stock in the North Atlantic and Gulf of Mexico will likely rebuild within 10 years. Since 2005, the average total scalloped hammerhead mortality from commercial and recreational landings has remained below the 2,853 TAC recommended by Hayes et al. (2009) (Table 14). In every year but one (2009), the total estimated harvest was less than the recommended TAC to attain a 70% rebuilding probability within 10 years. If 92% of the unclassified hammerhead landings are assumed to consist of scalloped hammerhead sharks (as estimated by Hayes et al. 2009), then only two of the five years had total harvest estimates below the recommended TAC (2008 and 2010). However, the overall average mortality from 2006-2010 was still below the TAC by 244 sharks. Thus, based on this data, the probability of the Northwest Atlantic and Gulf of Mexico scalloped hammerhead shark stock rebuilding within 10 years remains high.

Table 14. Total scalloped hammerhead shark mortality from recreational and commercial landings and discards from 2006-2010. (Source: NMFS 2011a, Hayes et al. 2009)

	2006	**2007**	**2008**	**2009**	**2010**	**Average**
Recreational Landings	458	1726	119	1667	199	834
Commercial Landings*	1353	626	536	1534	918	993
Discard Estimate	431	431	431	431	431	431
TOTAL	**2242**	**2783**	**1086**	**3632**	**1548**	**2258**
Recreational Landings (including unclassified hammerheads percentage)	1469	2468	119	1667	199	1184
Commercial Landings*	1353	626	536	1534	918	993
Discard Estimate	431	431	431	431	431	431
TOTAL	**3253**	**3525**	**1086**	**3632**	**1548**	**2609**

*Commercial landings calculated from lb dw by using average mean weight for the hammerhead complex from 2000 – 2005 (61.5 lb)

Although scalloped hammerhead sharks in the northwest Atlantic may currently be in a rebuilding phase, populations found further south in the Atlantic could still be in danger of decline. Based on yields of sharks from 1974-1997, high numbers of hammerhead sharks have been removed by longliners from off the coast of Brazil (Amroim et al 1998). Amroim et al (1998) analyzed data from a tuna fishery based in Santos City, São Paulo State, Brazil and discovered that although longliners mainly target tuna, sharks have become popular as incidental take. In fact, from 1983 - 1994 Santos longliners began targeting sharks at least part of the time during their trips, and by 1993, sharks comprised ~ 60% of the total longline catch. The total hammerhead yield (includes *S. lewini* and *S. zyganea*) increased slightly from 1972 (7 t) to 1988 (79 t) and then more significantly to a maximum of 290 t in 1990 (as did the number of longliners catching sharks). During this study period (from 1974-1997), *S. lewini* catch was reported throughout the year and represented ~ 60% of the total hammerhead yield. After 1990, hammerhead yield exhibited a decreasing trend (to 59 t in 1996), but this may be a result of a change in gear (Amroim et al 1998). In 1994, Brazilian longliners began replacing the traditional Japanese longline with monofilament longline and decreased the depths at which they fished from the surface. This altered the species composition of the catch and decreased shark yields, and by 1996 all boats of the longline fleet were using the new equipment and fishing in shallower areas (Amorim et al. 1998). Despite the change in gear, a follow-up study conducted from 2007-2008 found that São Paulo State longliners were still targeting sharks and that the catch was dominated by shark species (catch composition: sharks = 49.2%, swordfish = 35.5%, billfish, tuna, other =15.3%) (Amorim et al. 2011). By weight, hammerheads represented only 6.3% of the total shark catch, or 37.7 t, a decrease from the previously reported yield in 1996. Of the 376 hammerhead sharks caught, 131 (or 35%) were *S. lewini* (Amorim et al. 2011).

Some scientists contend that the population of *S. lewini* in the northwest Atlantic is overestimated due to the recent discovery of a cryptic species that appears identical to the scalloped hammerhead shark. This new cryptic species can be found from South Carolina to Brazil (Pinhal et al. 2012), and thus overlaps with the current *S. lewini* range. It is also thought that the coastal waters of South Carolina may be a nursery ground for this cryptic species (Quattro et al. 2006). Currently, there are no available data regarding the ratio of this new cryptic species to the Atlantic *S. lewini* population. One study collected tissue samples from 203 *S. lewini* sharks landed in Brazilian fisheries, and found three sharks that exhibited the cryptic ITS2 and mtCR sequences (Pinhal et al. 2012). However, more data are needed before conclusions can be made on the prevalence of the cryptic species in the Atlantic. Further complicating the matter is that the only way to differentiate these two species is through genetic analysis and vertebral count. Thus, it is possible that catches of this cryptic species may have been included in the recent scalloped hammerhead stock assessment; however, without more data on the abundance and life history of the cryptic species, separate stock assessments for *S. lewini* and the sister species are not possible at this time.

Across the Atlantic Ocean, Ferretti et al. (2008) evaluated trends in population abundance of *Sphryna* spp. in six regions of the Mediterranean Sea during the 19th and 20th centuries. Using historical records and applying generalized linear models, Ferretti et al (2008) estimated an average instantaneous rate of decline of -0.17 in abundance and -0.36 in biomass for the hammerhead species complex. After 1963, hammerheads were no longer caught or seen in coastal areas, and in the early 1980s abundance consistently declined in pelagic waters. After 1995, hammerheads were completely absent in historical records. Based on these data, Ferretti et al. (2008) estimated a decline of >99.99% in both *Sphryna* spp. abundance and biomass over a time period of 178 and 107 years, respectively. Recent reports, however, confirm the presence of both *S. lewini* and *S. zygaena* around southern Italy, suggesting a possible rebuilding of the Mediterranean hammerhead populations (Sperone et al. 2012).

Further south, off the coast of Mauritania, data provided to the FAO show that *S. lewini* abundance was variable from 1982 to 2008 but has endured a statistically significant decrease of 95% since 1999 (FAO 2013). In addition, the information showed evidence of a decrease in average size of the shark since 2006 (FAO 2013). Since 2005, there has been a significant and ongoing decrease in shark landings in the SRFC zone, with an observed extirpation of some species, and a scarcity of others, such as large hammerhead sharks (Diop and Dossa 2011), indicating overutilization of the resource.

In the Pacific, the central Mexican shark fishery began in the early 1940s and grew from catches of less than 5000 tons in the early 1960s to catches of 25,000 tons in the late 1970s, and reached maximum exploitation in the 1980s and 1990s (Pérez-Jiménez et al. 2005). During this time, scalloped hammerheads were an important small shark species that was routinely caught on the southern coast of Sinaloa (Pérez-Jiménez et al. 2005, Bizzarro et al. 2009). From 1998-1999, surveys of 28 Sinaloa artisanal fishing sites revealed the importance of *S. lewini* in the fishery, with the scalloped hammerhead shark comprising 54.4% of the elasmobranch catch and 43.1% of the total recorded catch (n =1584 *S. lewini* individuals) (Bizzarro et al. 2009). In 2006, elasmobranch landings from this area comprised 16.5% of the national elasmobranch production, the most of any Mexican state. However, analysis of *S. lewini* catch data from an artisanal shark fishery located just south of this region showed no evidence of overexploitation but did reveal a catch dominated by juvenile scalloped hammerheads (Pérez-Jiménez et al. 2005). Out of the 1178 females and 1331 males caught from 1995-1996 and 2000-2001, only 0.4% and 1% were mature, respectively (Pérez-Jiménez et al. 2005).

In the Gulf of Tehuantepec, *Sphyrna lewini* is the second most important species in the shark fishery, comprising around 29% of the total shark catch from this area (INP 2006). From 1996-2001, CPUE of all sharks in the Gulf of Tehuantepac declined by around 46%, and for *S. lewini* CPUE declined to nearly zero in 2001 (INP 2006). Using fishing mortality estimates calculated from 1997 and 1998 catches, INP (2006) estimated that the scalloped hammerhead shark population in the Gulf of Tehuantepac is currently decreasing by 6% per year.

From 2004 to 2005, *S. lewini* comprised 64 percent of the artisanal shark catch south of Oaxaca, Mexico (CITES 2012).In Michoacán, hammerheads represent 70 percent of the catch, with fishing effort concentrated in breeding areas and directed towards juveniles and pregnant females

(CITES 2012), with reports of the artisanal fisheries filleting the embryos of *S. lewini* for domestic consumption (Smith et al. 2009).

In Costa Rica, shark catches reported by the artisanal and longline fisheries have shown a dramatic decline (~50%) after reaching a maximum of 5000 tonnes in 2000 (SINAC 2012). According to the Costa Rican Institute of Fishing and Aquaculture, the estimated total catch of *S. lewini* by the coastal artisanal and longline fleet from 2004-2007 was 823.1 t, which represented 3% of the national Costa Rican total catch of sharks for these years (SINAC 2012). Although no shark assessments of the scalloped hammerhead are available from this region, observations of the relative abundance of all pelagic sharks in the Costa Rica EEZ indicate dramatic declines of ~ 58% between 1991 and 2002 (Arauz et al. 2004). In Costa Rica's Pacific mahi-mahi targeted longline fishery, the mean CPUE (per 1000 hooks) of *S. lewini* between 1999 and 2008 was low (0.041 ± 0.279), however the majority of the fishing effort was concentrated in pelagic waters (from 19.5 to 596.2 km offshore) (Whoriskey et al. 2011).

In Ecuador, catch records for the combined hammerhead complex from 2004 to 2010 show no clear trend. Landings in 2004 were approximately 149 t. In 2005, landings decreased by about 67% to 49 t but subsequently increased in the following years to reach a peak of 327 t in 2008. In 2009, landings decreased again by around 71% but tripled the following year to reach approximately 304 t in 2010 (INP 2010).

In the Indian Ocean, the actual status of shark populations off the coasts of Egypt, India, Iran, Oman, Saudi Arabia, Sudan, United Arab Emirates, and Yemen are currently unknown. Off the coasts of Maldives, Kenya, Mauritius, Seychelles, South Africa, and United Republic of Tanzania, the status of the shark population is presumed to be fully to over-exploited (De Young 2006). Few studies on the abundance of *S. lewini* have been conducted in the Indian Ocean making it difficult to determine the rate of exploitation of this species within the ocean basin. One study, off the coast of Oman, found *S. lewini* to be among the most commonly encountered species in commercial landings from 2002-2003 (Henderson et al. 2007). However, in 2003, *S. lewini* experienced a notable decline in relative abundance and, along with other large pelagic sharks, was displaced by smaller elasmobranch species (a trend also reported by informal interviews with fisherman) (Henderson et al. 2007). Off East Lombok, in Indonesia, data provided to the FAO also suggest potential declines in the population as the proportion of scalloped hammerheads in the Tanjung Luar artisanal shark longline fishery catch decreased from 15% to 2% over the period of 2001 to 2011 (FAO 2013). Scalloped hammerhead sharks off the coast of South Africa are also thought to be experiencing similar decreases in population size. Analyses of fishery-independent data from beach protection programs have revealed drastic declines in the catch rates of *S. lewini* since the early 1950s. From 1952-1972 Ferretti et al. (2010) estimated a decline of 99.3% in catch rates of *S. lewini* off Main Beach in South Africa, and a decline of 86% from 1961-1972 off Brighton Beach, South Africa. Dudley and Simpfendorfer (2006) extended the analysis to cover more recent years, using trends in catch rate and size from a KwaZulu-Natal (KZN) beach protection program. From 1978 – 2003, CPUE of *S. lewini* declined significantly (slope of linear regression = -0.0145); however, the authors suggested that the KZN program contributed to this decline as the beach nets were assessed to have a medium potential negative effect on scalloped hammerhead sharks. Interestingly, male scalloped hammerheads showed significant increases in mean annual length over the study period and the average annual catch was relatively high (142 sharks/yr) (Dudley and Simpfendorfer 2006).

Estimates of the decline in Australian hammerhead abundance range from 58-85% (Heupel and McAuley 2007, CITES 2010). Off the northwest coast of Australia, CPUE data are available from fisheries operating from 1996-2005. Significant reductions in hammerhead catches in the northwest marine region occurred between 1998 and 1999, when CPUE declined from a high of 0.18 kg/hook to 0.07 kg/hook (Heupel and McAuley 2007). After 1999, CPUE remained low in this northern shark fishery, varying between 0.05 and 0.11 kg/hook until 2005 (Heupel and McAuley 2007). However, fishing practices also underwent major changes during this period. In the late 1990s, the major source of fishing effort transitioned from mainly pelagic gillnetting to demersal longlining. Around 2002-2003, larger ex-pelagic longliners entered the fishery, expanding the spatial distribution of fishing effort. After mid-2003, reporting efforts changed as research funding ended, calling into question the accuracy of catches. In June 2005, new management practices were introduced and the northern shark fishing effort has since been low and infrequent. Even with these fishery management changes, Heupel and McAuley (2007) suggests that the available northern shark fishery CPUE data from 1996-2005 provides a good indication of the hammerhead abundance. The authors reason that because hammerheads are widely distributed and were never targeted by the fishery, they were less likely affected by the fishing practice changes noted above (Heupel and McAuley 2007). Provided these assumptions are true, then the analysis of the CPUE data from 1996-2005 suggests declines of 58-76% in hammerhead abundance in Australia's northwest marine region (Heupel and McAuley 2007). Data from protective shark meshing programs off beaches in New South Wales and Queensland also suggest significant declines in hammerhead populations off the east coast of Australia. These shark bather protection programs use beach netting and drum lines to catch sharks off the coast of the most popular metropolitan beaches in this region (Harry personal communication, 2012). Over a 35 year period, the number of hammerheads caught per year in NSW beach nets has decreased by more than 90%, from over 300 individuals in 1973 to less than 30 in 2008 (Reid and Krogh 1992, Williamson 2011). Similarly, data from the Queensland shark control program indicates declines of around 79% in hammerhead shark abundance between 1986 and 2010, with *S. lewini* abundance fluctuating over the years but showing a recent decline of 63% between 2005 and 2010 (QLD DEEDI 2011).

Papua New Guinea currently has an active shark longline fishery that is managed separately from its tuna longline fishery. This shark fishery operates entirely within Papua New Guinea's national waters, and is limited to 9 vessels, setting 1,200 hooks per day with a total allowable catch of 2,000 mt dressed weight per year (Usu et al. 2012). This fishery has seen substantial expansion since 2000, when there was only one active vessel with a reported catch of 143 sharks. However, in the last 4 years, an average of 7 vessels has actively fished for sharks, with an average catch of 56,528 sharks (Usu et al. 2012). In 2011, there were 9 active shark longline vessels, reporting the highest overall effort yet (27,934 hundred hooks), and subsequently reporting the highest catches of sharks to date (1,479.66 mt) (Usu et al. 2012). Hammerhead shark species comprised only 1.5 percent of the catch (22.34 mt), which was a decrease of 43% from the previous year and suggests that the intensive and targeted shark fishing effort may be contributing to the hammerhead population decline in these waters.

Recruitment and Depensation

Although scalloped hammerhead sharks are likely the most abundant of the hammerhead species, they may be vulnerable to local depletions (Maguire et al. 2006). Since juvenile sharks of this species tend to aggregate inshore and in coastal waters, they are highly susceptible to fisheries operating in these areas. For example, neonates in Brazil are caught in large numbers by coastal gillnets and recreational fisheries in inshore waters and subsequently their abundance has significantly decreased over time (CITES 2010). The driftnet fishery, operating off southern Brazil, has also documented large catches of juvenile *S. lewini*. From 2005-2006, the average total length of landed *S. lewini* was 171.8 cm (n = 717; median = 170 cm) (Kotas et al. 2008). In Indonesia, artisanal, small-scale shark fisheries use gillnets and longlines to catch substantial numbers of immature *S. lewini* (White et al. 2008). In the Gulf of Mexico and Gulf of Tehuantepec, many of the shark nursery areas are also important fishing grounds for the local communities (Castillo-Géniz et al. 1998, INP 2006). Although scalloped hammerhead sharks are not considered overexploited in the Central Mexican Pacific, artisanal shark fisheries in this region have targeted juvenile scalloped hammerheads for the past three decades (Pérez-Jiménez et al. 2005). From 1996-2003, the sizes of 10,919 scalloped hammerheads from port Madero revealed a catch dominated by immature individuals. Neonates, especially, comprised a large portion of the landings, with over 40% of the total catch sized at ≤ 60cm TL (INP 2006). In southwest Madagascar, McVean et al. (2006) documented substantial takes of immature male and female *S. lewini* (with average size of 161 cm SL and minimum of 80 cm SL). In northern Madagascar, Robinson and Sauer (2011) documented an artisanal fishery that targets sharks primarily for their fins, with Carcharhinidae species accounting for 69 percent of the landings and Sphyrnidae accounting for 24 percent. *S. lewini* was the most common species in the Sphyrnidae landings. In addition, many of these fishers operated in water shallower than 100 m and, subsequently, over 96% of their scalloped hammerhead catch was comprised of immature individuals (Robinson and Sauer 2011). Similarly, the shark fisheries operating in Antongil Bay in northeastern Madagascar commonly land only fins, rather than whole sharks, with the scalloped hammerhead shark as the most represented species in the shark fishery (Doukakis et al. 2011). Both adults, including pregnant females, and juveniles are harvested in the small and large-mesh artisanal gillnet and traditional beach seine fisheries, suggesting largely unregulated and targeted fishing of scalloped hammerhead sharks in a potential breeding ground (Doukakis et al. 2011). In Mauritania, large numbers of neonates and juvenile *S. lewini* are taken by fisheries operating in nursery areas (FAO species fact sheet, accessed April 6, 2012, CITES 2010). Off the east coast of Queensland, fishery observers found that the vast majority (79%) of *S. lewini* caught by commercial gill-net vessels were from inshore coastal areas (Harry et al. 2011b). Because of the location of the targeted fishing area, juveniles dominated the catch, with ~83% juveniles and 8.9% neonates (Harry et al. 2011b).

Increased fishing pressure on juvenile scalloped hammerhead sharks is also evident in parts of the Gulf of California, Gulf of Coronado, and off the west coast of Costa Rica (CITES 2010, SINAC 2012). Seasonal surveys conducted in Sinaloa, Mexico from 1998-1999 depict an active artisanal fishery that primarily targets early life stages of *S. lewini*, with only four specimens (out of 1515) measuring > 200 cm stretched TL (Bizzarro et al. 2009). In addition, comparisons of *S. lewini* landings from Sinaloa in 1998-1999 and 2007-2008 reveal a significant decrease in *S. lewini* size, indicating a possible truncation of the local population (Bizzarro et al. 2009). In the Tarcoles area, Golfo Dulce, and the Southern Nicoya Peninsula of Costa Rica, young scalloped hammerhead sharks aggregate in nutrient-rich, shallow, muddy, and turbid waters (SINAC 2012). However, these identified nursery areas are also popular elasmobranch fishing grounds and are frequented by fishermen using gillnets (Zanella et al. 2009). From 2006-2007, artisanal fishermen operating in the Gulf of Nicoya (central Pacific coast of Costa Rica) landed a total of 253 scalloped hammerhead sharks. The average total length of these sharks ranged from 75.45 – 87.92 cm, significantly below the maturity sizes that have been documented for this species (Zanella et al. 2009). Overall, the data suggest evidence of substantial fishing pressure on juveniles and neonates in certain artisanal fisheries; however the effect of this fishing pressure on stock recruitment is currently unknown.

Depensation is the effect where a decrease in spawning stock leads to reduced survival or production of eggs through increased predation per egg or the reduced likelihood of finding a mate. Although there is evidence that adult scalloped hammerhead sharks prey upon pups in nursery grounds (Clarke 1971), there are no data to suggest that depensatory effects are beginning due to increased predation. However, some studies have reported sexual segregation at certain times during the scalloped hammerhead life cycle (Clarke 1971, Klimley 1987, Stevens and Lyle 1989, Noriega et al. 2011). The consequences of this sexual segregation can have serious implications for fishery management. If certain fisheries focus efforts on schools of *S. lewini*, they may be unknowingly contributing to the "Allee" effect by overfishing one sex. For example, in Australia, observers monitoring commercial gill-net vessels operating in inshore coastal areas and intertidal zones documented a catch comprised mostly of male scalloped hammerhead sharks (Harry et al. 2011b). In the New South Whales OTL fishery, catch was further segregated by size, with female *S. lewini* dominating the smaller shark catch (< 210cm TL) and male *S. lewini* dominating the larger, mature shark catch (>230cm TL) (Macbeth et al. 2009). Off the coast of Queensland, Australia, Noriega et al. (2011) saw a decrease in the average size of females caught by the Queensland Shark Control Program mesh nets and drumlines from 1996-2006, but no trend in males. From 1993 to 2001, Vooren et al. (2005) estimated that the adult female *S. lewini* abundance in Brazil decreased by 60-90% due to inshore fishing pressure. Thus, it is possible that exploitation of these segregated schools may reduce populations of either or both sexes in certain areas; however the effect of this fishing on the likelihood of *S. lewini* finding a mate is currently unknown.

Spatial focusing

In addition to those artisanal fisheries targeting small juvenile hammerhead sharks in nursery habitats (see above section), fishing pressure has also increased on known aggregations of adult scalloped hammerhead sharks. Many of these well known scalloped hammerhead shark "hot spots" (such as off the Cocos Island, Galapagos Islands, and Malpelo Islands) are currently protected conservation areas. However, due to the poor enforcement of these areas coupled with the abundance of scalloped hammerhead sharks, these locations have become "hot spots" for illegal fishing activities as well (Lack and Sant 2008). Although there is no evidence of major changes in the distribution of the scalloped hammerhead shark, their schooling behavior and tendency to form large aggregations inshore and off seamounts and reefs increases their vulnerability to spatial focusing.

Effect of the Shark Fin Trade

Shark fins are a top commodity in Asia and fetch a high price, up to 1,000 € per fin or 80 € per bowl of shark fin soup. Shark meat, on the other hand, sells for considerably less, approximately 10 €/kilo for meat compared to 500 €/kilo for fins (Oceana 2010). Because of this stark difference in price, the practice of "finning" continues to occur as fisherman targeting sharks prefer to keep only the valuable fins onboard their boats for trade (Oceana 2010). In Ecuador, for example, fin exports exceeded mainland catches by 44% from 1998-2004 (Jacquet et al. 2008). Many of these fins are subsequently exported to Hong Kong and sold in the world's largest fin trade market. In 2008, around 10 million kg (10,000 t) of shark fins were imported into Hong Kong from 87 countries and regions worldwide (Oceana 2010). Spain (2,646 t), Singapore (1,201 t), Taiwan (991 t), Indonesia (681 t), and the United Arab Emirates (511 t) were the world's top exporters of shark fins (both frozen and dried) (Oceana 2010). Costa Rica ranked as 6th, with 327 exported tonnes of shark fins to Hong Kong. However, compared to numbers in the early 2000s, Costa Rica has seen a dramatic reduction in shark fin production and catch by the national fleet and artisanal longline fisheries (SINAC 2012). Likewise, global data from FAO's Fishery Commodities and Trade Database also reflects a recent decrease in shark fin exports since 2007; however, the export of all shark products has substantially increased since the early 1990s and appears to be continuing on that trend (Figure 19).

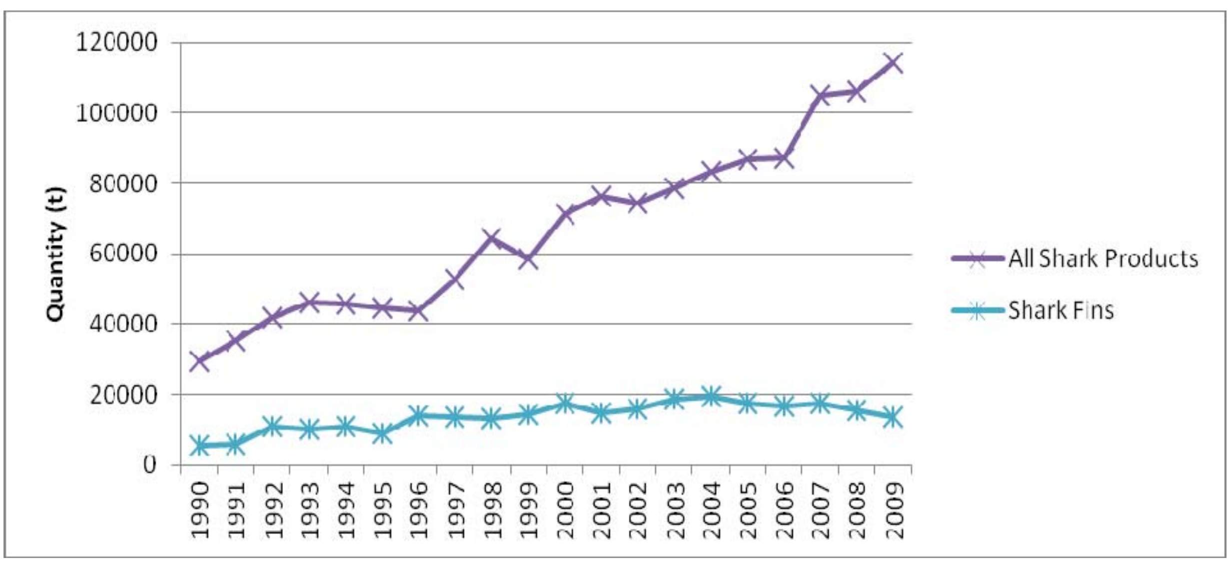

Figure 19. Global exports of shark products from 1990-2009, as reported in the FAO Fishery Commodities and Trade Database. Shark Fins include: shark fins dried, unsalted, salted, in brine but not dried or smoked, frozen, prepared or preserved. All Shark Products include: all shark fins (above); shark fillets, frozen; shark fillets, fresh or chilled; shark oil; shark liver oil; sharks nei, fresh or chilled; sharks nei frozen; sharks, rays, chimaeras nei, frozen; sharks, rays, etc., dried, salted or in brine; sharks, rays, chimaeras, skates, nei fillets frozen; sharks, rays, skates, fresh or chilled, nei ("nei" = not elsewhere included).

Because some countries, such as Spain, do not report shark fins as a separate commodity but lump them into general "shark" categories, the shark fin export data may not be a good indicator of the global trade in shark fins. Instead, Clarke et al. (2006b) analyzed 1999-2001 Hong Kong trade auction data in conjunction with species-specific fin weights and genetic information to estimate the annual number of globally traded shark fins. Using this approach, the authors discovered that the scalloped hammerhead shark is one of the most popularly traded species in the Asian fin market. Because of their large fins with a high fin needle content (a gelatinous product used to make shark fin soup), *S. lewini* fetch a high commercial price in the market (Abercrombie et al. 2005). Together, smooth and scalloped hammerheads comprise 4-5% of the total fins traded in Hong Kong, which translates to an annual estimate of 1.3 to 2.7 million *S. lewini* and *S. zygaena* individuals (Clarke et al. 2006a, 2006b, Camhi et al. 2009). When all shark species are included, the estimate increases to between 26 and 73 million individuals traded annually in the market (median = 38 million/year), with a median biomass estimate of 1.70 million tonnes/year (range: 1.21 - 2.29 million tonnes/year) (Clarke et al. 2006b). This biomass estimate is almost three times higher than the maximum calculated using FAO global capture production statistics (0.60 million tonnes/year), indicating that the FAO database, the only source for current international catch statistics, may be drastically under-representing global shark catches.

<u>Formal Modeling Approaches</u>
No formal Population Viability Analysis (PVA) models for scalloped hammerhead sharks are available. Population projections from the Hayes et al. (2009) stock assessment have provided rebuilding probabilities for the northwestern Atlantic and Gulf of Mexico *S. lewini* stock under a variety of catch scenarios (see Table 13).

Overall, it appears that populations of hammerheads are in decline; however, the extent that overutilization is contributing to the threat of their extinction is unclear. The data from the northwest Atlantic and Gulf of Mexico suggest that fishing pressure has decreased this population by 83%; however, the absence of *S. lewini* global catch and trend data, the common aggregation of all hammerhead landings, and the lack of historical abundance records, especially from the Pacific and Indian Ocean, prevent an analysis of the overutilization threat to the global population of the scalloped hammerhead shark.

Competition, Disease or Predation

The ESA requires an evaluation of competition, disease, and predation factors as they affect scalloped hammerhead sharks. Because scalloped hammerhead sharks are apex predators and opportunistic feeders, covering wide and sometimes deep expanses of ocean waters when foraging (Júnior et al. 2009), it is unlikely that they would lose in the competition for food. In addition, their diet is composed of a wide variety of items, including teleosts, cephalopods, crustaceans, and rays (Compagno 1984, Bush 2003, Júnior et al. 2009, Noriega et al. 2011). Common prey items in the scalloped hammerhead diet include sardines, herring, anchovies, conger eels, silversides, halfbeaks, mullet, barracuda, Spanish mackerel, jacks, grunts, parrotfishes, goatfish, squid, octopus, shrimp, crabs, lobsters, as well as smaller elasmobranchs such as blacktip reef sharks, angelsharks and stingrays (Bester 2011). Although there may be some prey species that have experienced population declines, no information exists to indicate that depressed populations of these prey species are negatively affecting the scalloped hammerhead shark abundance.

As was mentioned previously, new genetic information provides evidence of a cryptic hammerhead shark lineage that occurs in the western Atlantic Ocean. This cryptic species has been reported in the western North Atlantic Ocean by Abercrombie et al. (2005) and Quattro et al. (2006) and most recently in the western South Atlantic Ocean (Southern Brazil) by Pinhal et al. (2012). The cryptic species, referred to as *Sphyrna* sp., is closely related to and morphologically very similar to the scalloped hammerhead shark (*S. lewini*). Little is known about the life history or abundance of this cryptic species, and thus, it is possible that it could compete for similar resources as the scalloped hammerhead shark. However, additional research on the distribution, abundance, and life history of this cryptic species is needed before any conclusions can be made.

Furthermore, no information has been found to indicate that disease is a factor in scalloped hammerhead shark abundance. These sharks likely carry a range of parasites, such as external leeches (*Stilarobdella macrotheca*) and copepods (*Alebion carchariae*, *A. elegans*, *Nesippus crypturus*, *Kroyerina scotterum*); however, they have often been observed visiting parasite cleaning stations (Bester 2011) and no data exist to suggest these parasites are affecting *S. lewini* abundance.

Predation is also not thought to be a factor influencing scalloped hammerhead abundance numbers. The most significant predator on scalloped hammerhead sharks is likely humans; however larger sharks, including adult *S. lewini*, are known to prey upon injured or smaller scalloped hammerheads. In Kāne'ohe Bay, Oahu, a nursery ground for *S. lewini*, Clarke (1971) observed high predation on pups by adult scalloped hammerheads. Clarke (1971) also noted that the pup population remained high and suggested that birth rates may match mortality rates. Subsequently, Duncan and Holland (2006) examined mortality rates in this bay and estimated juvenile attrition to be 0.85 to 0.93 for the first year of life (includes both natural and fishing mortality, as well as emigration), a relatively high rate for a nursery habitat. However, the authors concluded that weight loss, and not predation, significantly contributed to the high natural mortality of the shark pups, and suggested the popularity of the nursery ground was due to its value as a refuge from predation. In the northwestern Pacific, Liu and Chen (1999) estimated a significantly lower attrition rate for age 0 *S. lewini* sharks (0.558/year), with natural mortality rates decreasing even further to 0.279/year for sharks aged 1-15. Furthermore, there are no major predators of adult scalloped hammerhead sharks.

Evaluation of Adequacy of Existing Regulatory Mechanisms

The ESA requires an evaluation of existing regulatory mechanisms to determine whether they may be inadequate to address threats to the global scalloped hammerhead population. Existing regulatory mechanisms may include Federal, state, and international regulations. Below is a description and evaluation of current domestic and international management measures that affect the scalloped hammerhead shark.

Domestic Authorities

The U.S. fisheries are managed under the authority of the Magnuson-Stevens Act, 16 U.S.C. 1801 *et seq.* The U.S. Atlantic tuna and tuna-like species fisheries are managed under the dual authority of the Magnuson-Stevens Act, and the Atlantic Tuna Conventions Act (ATCA), 16 U.S.C. 971 *et seq*. The U.S. vessels that fish for tuna and associated species in the eastern tropical Pacific Ocean may be subject to management measures under the Tuna Conventions Act (16 U.S.C. 951 *et seq*.) and potentially the U.S.-Canada Albacore Treaty.

Atlantic Tunas Convention Act

The Atlantic Tunas Convention Act of 1975 (ATCA) authorizes the Secretary of Commerce to administer and enforce all provisions of the International Convention for the Conservation of Atlantic Tunas (ICCAT). Pursuant to this goal, the Secretary cooperates with the duly authorized officials of the government of any party to the Convention as well as any other Federal department or agency or any State. The Secretary of Commerce is authorized to issue regulations deemed necessary to implement the Convention. ATCA also charges the Secretary with issuing regulations for the advancement of any recommendation from ICCAT. However, regulations promulgated under ATCA are, to the extent practicable, to be consistent with FMPs prepared and implemented under the Magnuson-Stevens Act.

The authority to issue regulations to implement the recommendations from the ICCAT has been delegated from the Secretary to the Assistant Administrator for Fisheries, NOAA. On August 29, 2011, NMFS finalized the implementation of ICCAT recommendation (10-08). This regulation prohibits the taking of scalloped hammerhead sharks and affects the U.S. commercial HMS PLL fishery and recreational fisheries for tunas, swordfish, and billfish in the Atlantic Ocean, including the Caribbean Sea and Gulf of Mexico (76 FR 53652; August 29, 2011).

Tuna Convention Act

The Tuna Convention Act of 1950 provides limited Federal authority to regulate activities of U.S. fishing vessels in the Eastern Pacific Ocean. Under this authority, NMFS promulgates regulations to implement recommendations of the IATTC that have been approved by the U.S.

Department of State. The FMP for U.S. West Coast fisheries for HMS provides a mechanism that can be used to implement or supplement recommendations of the IATTC or other international fishery management bodies, particularly for U.S. fisheries based on the West Coast.

Magnuson-Stevens Fishery Conservation and Management Act
The Magnuson-Stevens Act establishes the authority and responsibility of the Secretary of Commerce to develop fishery management plans and subsequent amendments for managed stocks. The Magnuson-Stevens Act requires NMFS to allocate both overfishing restrictions and recovery benefits fairly and equitably among sectors of the fishery. In the case of an overfished stock, NMFS must establish a rebuilding plan. The FMP or amendment to such a plan must specify a time period for ending overfishing and rebuilding the fishery that shall be as short as possible, taking into account the status and biology of the stock of fish, the needs of fishing communities, recommendations by international organizations in which the U.S. participates, and the interaction of the overfished stock within the marine ecosystem. The rebuilding plan cannot exceed ten years, except in cases where the biology of the stock of fish, other environmental conditions, or management measures under an international agreement in which the U.S. participates dictate otherwise.

Management of U.S. West Coast Fisheries for HMS:
Within the U.S., HMS fishery management in the Pacific area is the responsibility of adjacent states as well as three regional fishery management councils which were established by the Magnuson Fishery Conservation and Management Act of 1976: the Western Pacific Regional Fishery Management Council (WPRFMC), North Pacific Fishery Management Council (NPFMC) and Pacific Fishery Management Council (PFMC). The WPRFMC manages HMS fisheries pursuant to the Fishery Ecosystem Plan (FEP) for Pacific Pelagic Fisheries of the Western Pacific Region (serves as an FMP). The NPFMC does not manage HMS, except that sharks, including some migratory species, are included in the Gulf of Alaska Groundfish FMP and Bering Sea and Aleutian Islands Groundfish FMP. The PFMC has jurisdiction over the EEZ off Washington, Oregon and California, and manages HMS in this region. Prior to the development of a west coast-based FMP for HMS, the fisheries were managed by the States of Washington, Oregon and California, although some federal laws also applied. Then, in 2004, the FMP for U.S. West Coast Fisheries for HMS was developed by the PFMC in response to the need to coordinate state, Federal, and international management. NMFS, on behalf of the U.S. Secretary of Commerce, partially approved the FMP on February 4, 2004. The majority of the FMP implementing regulations became effective on April 7, 2004. Reporting and recordkeeping provisions became effective on February 10, 2005. Since its implementation, this FMP has been amended twice, once in 2007, and again 2011. Species that are managed under FMPs or FEPs are called management unit species and typically include those species that are caught in quantities sufficient to warrant management or specific monitoring by NMFS and the Council. In the FMPs and FEPs for U.S. fisheries in the Pacific, scalloped hammerhead sharks are not considered to be a management unit species and thus are not directly managed.

Management of U.S. Atlantic HMS Fisheries:

On November 28, 1990, the President of the United States signed into law the Fishery Conservation Amendments of 1990. This law amended the Magnuson-Stevens Act and gave the Secretary of Commerce the authority to manage HMS in the U.S. EEZ of the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea (16 U.S.C. 1811 and 16 U.S.C. 1854(f)(3)). The Atlantic HMS Management Division within NMFS develops regulations for Atlantic HMS fisheries and primarily coordinates the management of HMS fisheries in Federal waters (domestic) and the high seas (international), while individual states establish regulations for HMS in state waters. However, in the case of federally permitted shark fisherman, as a condition of their permit, the fisherman are required to follow Federal regulations in all waters, including state waters, unless the state has more restrictive regulations. For example, the Atlantic State Marine Fisheries Commission (ASMFC) recently developed an interstate coastal shark FMP which coordinates management measures among all states along the Atlantic coast (FL to ME). This interstate shark FMP became effective in 2010.

The implementing regulations for the conservation and management of the domestic fisheries for Atlantic swordfish, tunas, sharks, and billfish are published in the 2006 Consolidated HMS FMP (71 FR 58058, NMFS 2006a). Since 2006, this FMP has been amended three times, with five more amendments currently in development. Amendment 5, which is currently in the predraft phase, is especially relevant as it will address the recent NMFS “overfished” and “overfishing” status determination of the scalloped hammerhead stock (76 FR 23794; April 28, 2011). NMFS is mandated to implement conservation and management measures in this Amendment by April 28, 2013 that will allow for the rebuilding of the scalloped hammerhead shark stock.

In the 2006 Consolidated HMS FMP, the scalloped hammerhead shark is a directly managed species, included as part of the LCS complex management unit. Below are the current applicable federal commercial and recreational fishing regulations for U.S. Atlantic HMS fishermen.

Commercial Shark Fishing Regulations:
Any fisherman who fishes for, retains, possesses, sells, or intends to sell, scalloped hammerhead sharks needs a Federal Atlantic Directed or Incidental shark limited access permit. These permits are administered under a limited access program and NMFS is no longer issuing new shark permits. A directed shark permit allows fishermen to retain 33 scalloped hammerhead sharks per vessel per trip. An incidental permit allows fisherman to retain up to 3 scalloped hammerheads per vessel per trip. Authorized fishing gear types for scalloped hammerhead sharks include gillnet, rod and reel, handline, bottom longline, or bandit gear. There are no restrictions on the types of hooks that may be used to catch Atlantic sharks, and there is no commercial minimum size limit.

Every year, NMFS monitors the different shark quota complexes and will close the fishing season for each fishery after 80% of the respective quota has been caught. The non-sandbar LCS commercial quota is split between the Gulf of Mexico and the Atlantic regions. Atlantic sharks and shark fins from federally permitted vessels may be sold only to federally permitted dealers; however, all sharks must have their fins naturally attached through offloading. Logbook reporting is required for selected fishermen with a commercial shark permit. In addition, fishermen may be selected to carry an observer onboard, and some fishermen are subject to vessel monitoring systems depending on the gear used and where they fish.

Recreational Shark Fishing Regulations:
Scalloped hammerhead sharks may also be retained recreationally. Authorized fishing gear includes rod and reel and handline. There are no restrictions on the types of hooks that may be used to catch Atlantic sharks. Scalloped hammerheads that are kept must have a minimum size of 54 inches (4.5 feet) fork length. Sharks that are under the minimum size must be released. One scalloped hammerhead shark may be kept per vessel per trip. There are no reporting requirements unless contacted by the Large Pelagic Survey or Marine Recreational Information Program. Sharks must be landed with their head, fins, and tail naturally attached. Recreational retention of hammerhead sharks is prohibited on recreational trips that also possess a tuna, swordfish or billfish (76 FR 53652; August 29, 2011).

U.S. Shark Conservation Act
On January 4, 2011, the 2010 U.S. Shark Conservation Act was signed. This legislation requires that all sharks caught in U.S. waters, with an exemption for smooth dogfish, be landed with fins naturally attached, effectively ending the practice of removing fins at sea in the United States.

State Fishery Management Regulations
State fishery management agencies have authority for managing fishing activity only in state waters (0-3 miles in most cases; 0-9 miles off Texas and the Gulf coast of Florida). As mentioned above, in the case of federally permitted shark fisherman, fisherman are required to follow Federal regulations in all waters, including state waters, unless the state has more restrictive regulations. Thus, many of the states have regulations that mirror the Federal regulations for scalloped hammerhead sharks (Table 15). The state of Florida recently went even further to protect the scalloped hammerhead shark by prohibiting the harvest, possession, landing, purchasing, selling, or exchanging any or any part of the scalloped hammerhead shark caught in state waters (Florida Fish and Wildlife Conservation Commission, effective January 1, 2012). Additionally, other states have implemented or are working towards the implementation of finning bans (Table 15).

Table 15. Current and relevant shark regulations by U.S. state. (Source: NMFS 2011a)

<table>
<tr><th>U.S. State</th><th>Shark Regulations</th></tr>
<tr><td>New Jersey</td><td rowspan="2">Fishermen must abide by the Interstate FMP for Atlantic Coastal Sharks adopted by the Atlantic States Marine Fisheries Commission (ASMFC 2008). This FMP requires that that all sharks harvested by commercial or recreational fishermen within state waters have the tail and fins attached naturally to the carcass. Commercial fishermen may only land a maximum of 33 LCS. Recreational fishermen may only catch sharks with a fork length of at least 4.5 feet (54 inches) and they must be</td></tr>
<tr><td>Delaware</td></tr>
</table>

<table>
<tr><td>Maryland</td><td rowspan="2">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 scalloped hammerheads) per calendar day. Recreational fishing vessels are allowed a maximum harvest of one shark from the federal recreationally permitted species (including scalloped hammerheads), per trip, regardless of the number of people on board the vessel.

Fishermen are prohibited from possessing scalloped 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 VA, MD, DE, and NJ during the seasonal closure.</td></tr>
<tr><td>Virginia</td></tr>
<tr><td>North Carolina</td><td>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.</td></tr>
<tr><td>South Carolina</td><td>Adopted the ASMFC Coastal Shark Interstate FMP. Additionally, defers to federal regulations. Gillnets may not be used in the shark fishery in state waters.</td></tr>
<tr><td>Georgia</td><td>Adopted the ASMFC Coastal Shark Interstate FMP. Additionally, commercial/recreational regulations: 2 sharks/person or boat, whichever is less, with a minimum size of 48” FL. It is unlawful to have in possession more than one shark greater than eighty-four inches (84") total length. All sharks must be landed with the head and fins intact. Sharks may not be landed in Georgia if harvested using gillnets.</td></tr>
<tr><td>Florida</td><td>Adopted the ASMFC Coastal Shark Interstate FMP. Additionally, no person shall harvest, possess, land, purchase, sell, or exchange any or any part of the scalloped 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.</td></tr>
</table>

Alabama	Recreational & commercial: bag limit – 1 shark/person/day with a minimum size of 54” FL or 30” dressed. 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. Commercial: 33 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. 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 for scalloped hammerheads.
California	The sale, purchase, or possession of shark fins is prohibited. Fins that are already in the state can be sold and used until July 2013, when a total ban takes effect. Sharks may not be taken with drift gillnets of mesh size eight inches or greater except under a revocable permit issued by the Department.
Washington	The sale, trade or distribution of shark fins or derivative products in the state is prohibited.
Oregon	Prohibits the distribution and possession of shark fins within its state. An individual may not possess, sell or offer for sale, trade or distribute a shark fin within the state.
Hawaii	Unlawful to possess, sell, offer for sale, trade, or distribute shark fins. Shark fin is defined as the raw or dried fin or tail of a shark.
Illinois	Bans the possession, sale, or distribution of shark fins.
U.S. Territories:	

American Samoa	Prohibits shark fishing and possession of sharks within three nautical miles of the shoreline and bans the possession, sale, or distribution of rare marine species and products, including all shark species.
Guam	No drift gillnets. Gillnets must be moved every 6 hours. Bans the possession, sale, or distribution of shark products in the U.S. territory.
CNMI	Bans the possession, sale, or distribution of shark fins. The law also forbids the landing of sharks at all ports within the archipelago.

International Authorities

Finning bans have been implemented by a number of countries and the European Union (EU), as well as by nine RFMOs (Tables 16 and 17). These finning bans range from requiring fins remain attached to the body to allowing fishermen to remove shark fins provided that the weight of the fins does not exceed 5% of the total weight of shark carcasses landed or found onboard. A number of countries have also enacted complete shark fishing bans (Table 18), with the Bahamas, Marshall Islands, Honduras, Sabah (Malaysia), and Tokelau (an island territory of New Zealand) adding to the list in 2011, and the Cook Islands in 2012. Shark sanctuaries can also be found in the Eastern Tropical Pacific Seascape (which encompasses around two million km^2 and includes the Galapagos, Cocos, and Malpelo Islands), in waters off the Maldives, Mauritania, Palau, and French Polynesia. In addition, all hammerhead sharks (Sphyrnidae) are listed on Annex I, Highly Migratory Species, of United Nations Convention on the Law of the Sea, in recognition of the importance of collaborative management for these sharks.

Also of relevance is the FAO International Plan of Action for the Conservation and Management of Sharks which recommends that RFMOs carry out regular shark population assessments and that member States cooperate on joint and regional shark management plans. In November 2010, ICCAT adopted recommendation 10-08 prohibiting the retention, transshipment, landing, storing, or offering for sale any part or carcass of hammerhead sharks of the family Sphyrnidae (except for bonnethead shark). However, the hammerhead recommendation includes an exemption for developing coastal states. This exemption allows take for local consumption but requires such states to take necessary measures to ensure these sharks will not enter international trade and to notify the Commission of such measures.

Many of the other RFMOS have passed resolutions for the purpose of collecting better data on catches of shark species, including the scalloped hammerhead shark. In 2005, the IATTC passed Resolution C-05-03 which calls for a more comprehensive data collection system, with each CPC annually reporting data for catches, effort by gear type, landing and trade of sharks by species, and available historical data. The IOTC requires CPCs to annually report shark catch data and provide statistics by species for a select number of sharks, including the scalloped hammerhead shark (Resolutions 05/05, 11/04, 08/04, 10/03, 10/02). In December 2010, WCPFC adopted a Conservation and Management Measure for sharks (CMM 2010-07) which requires each cooperating commission member to include key shark species (including scalloped hammerhead shark) in their annual report of catch and fishing effort statistics and retained and discarded catches, including available historical data. In February 2011, the WCPFC revised their requirement of scientific data to include annual catch estimates and operational level catch and effort data for hammerhead sharks from longline, troll, purse seine and pole and line (in weight) fisheries. The IATTC, IOTC, and WCPFC also encourage the live release of sharks, especially juveniles or pregnant females, caught incidentally (and not used for food or other purposes) in fisheries for tunas and tuna-like species.

Table 16. International regulations that prohibit shark finning by implementing country. (Source: HSI 2012)

Country	Date	Prohibited Shark Finning
Argentina	2009	Ban on shark finning.
Australia	Various	States and Territories govern their own waters. Central government regulates 'Commonwealth' or Federal waters, from 3 to 200 nautical miles offshore. Finning is banned in all State and Territory longline fisheries with the exception of the Northern Territory. In May 2012, the state of New South Wales (NSW) listed *S. lewini* as an endangered species, thus protecting the shark from recreational and commercial fisher in NSW state 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. Minimum size of capture is 60 cm TL (Amorim et al. 2011).
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	Ban on shark finning.
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 Whales	2009	Ban on shark finning.

European Union	2012	Shark finning is prohibited by all vessels fishing in EU waters and on all EU vessels fishing in oceans worldwide.
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.
Guinea-Bissau	2009	Ban on shark fishing in Marine Protected Areas (two parks covering 2,077 km2).
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 bycatch. Prohibits shark finning.
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		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
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.
Taiwan	2012	Enacted a shark finning ban.

Table 17. Regional Fisheries Management Organization (RFMO) shark regulations. (Source: HSI 2012)

<table>
<tr><th>RFMO</th><th>Date</th><th>Shark Regulations</th></tr>
<tr><td>International Commission for the Conservation of Atlantic Tunas (ICCAT)</td><td>2011</td><td rowspan="2">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 along as hammerheads do not enter into international trade.</td></tr>
<tr><td>General Fisheries Commission of the Mediterranean (GFCM)</td><td>2011</td></tr>
<tr><td>Commission for the Conservation of Antarctic Marine living Resources (CCAMLR)</td><td>2006</td><td>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.</td></tr>
<tr><td>Inter-American Tropical Tuna Commission (IATTC)</td><td>2005</td><td rowspan="7">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.</td></tr>
<tr><td>Indian Ocean Tuna Commission (IOTC)</td><td>2005</td></tr>
<tr><td>North Atlantic Fisheries Organization (NAFO)</td><td>2005</td></tr>
<tr><td>Southeast Atlantic Fisheries Commission (SEAFO)</td><td>2006</td></tr>
<tr><td>Western and Central Pacific Fisheries Commission (WCPFC)</td><td>2008</td></tr>
<tr><td>North East Atlantic Fisheries Commission (NEAFC)</td><td>2007</td></tr>
</table>

Table 18. International regulations that prohibit shark fishing by implementing country. (Source: HSI 2012)

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.
Cook Islands	2012	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.
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). (Pending – 2011 measure that will prohibit the landing/storing/selling of hammerhead sharks.)
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	Created shark sanctuary in its waters contiguous with the sanctuary in Cook Islands, and banned trade in all sharks.
Honduras	2011	Moratorium on commercial shark fishing in Honduran waters, effectively creating a shark sanctuary which encompasses all 240,000 square kilometers (92,665 square miles) of the country’s EEZ on its Pacific and Caribbean coasts.
Israel	1980	Banned shark fishing.
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.
Mauritania	2003	Created a 6000 km^2 coastal sanctuary for sharks and rays (Banc d'Arguin National Park - PNBA). Targeted shark fishing is prohibited (however *S. lewini* may be taken as bycatch in nets).
Micronesia	2012	In the process of developing a regional sanctuary where shark fishing is prohibited and authorizing the development of a regional ban on the possession, sale, and trade of shark fins. 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.
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.
Raja Ampat, Indonesia	2010	Banned shark fishing.

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, including the scalloped hammerhead shark, 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.

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

- Bahamas
- Canada (Pending - 2012 Bill C-380 would prohibit importing or attempting to import shark fins that are not attached to the rest of the shark carcass.) Currently, 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
- American Samoa
- Cook Islands
- Egypt
- French Polynesia
- Guam (with an exception for subsistence fishing)
- Republic of the Marshall Islands
- Sabah, Malaysia

<u>Analysis of Adequacy of Domestic Regulatory Mechanisms</u>

Existing domestic management measures implemented under the Magnuson-Stevens Act, ATCA, and state authorities may be adequate to protect scalloped hammerhead sharks in the northwest Atlantic and Gulf of Mexico. According to the Hayes et al. (2009) stock assessment, a TAC of 2,853 scalloped hammerhead sharks would allow for a greater than 70% probability of rebuilding of the stock within 10 years. Hayes et al. (2009) based this assessment on recreational and commercial catch and landings data from the early 1980s through 2005. Under existing federal shark regulations, the average total scalloped hammerhead shark mortality from 2006-

2010 was less than the Hayes et al. (2009) TAC recommendation (Table 14); however, the annual landings of scalloped hammerhead sharks occasionally exceeded the 2,853 TAC rebuilding target. In addition, the recreational landings of scalloped hammerhead sharks exceeded commercial landings each year from 2006 to 2010 (if unclassified hammerhead sharks estimates are included). Currently, the state of Florida has the largest marine recreational fisheries in the United States. It also has the greatest number of HMS angling permits, with 4,035 permitted individuals in 2011, and the second highest number of HMS Charter/Headboat permits (639) (NMFS 2011a). From 2008-2009, NMFS conducted a telephone survey of HMS Angling permit and Atlantic Tunas General permit holders to estimate fishing effort and total catches for private angler recreational HMS trips in Florida. Results indicated that most recreationally caught sharks were not caught on directed trips but rather occurred as bycatch during non-HMS targeted trips and trips targeting other HMS groups (MRIP 2010). In addition, analysis of catch dispositions revealed that more than 99% of shark catches were released (MRIP 2010), indicating that recreational fisheries may not be a significant threat to hammerheads. However, the data in Table 14 suggest that NMFS may still need to modify current recreational retention limits or commercial regulations for the scalloped hammerhead to ensure that landings and discards of this species do not exceed an annual TAC of 2,853 sharks.

Many recent regulations may help attain this goal and provide further protection for scalloped hammerhead sharks. As mentioned previously, on August 29, 2011, NMFS finalized the implementation of ICCAT recommendation 10-08, which prohibits the retention, transshipping, landing, sorting, or selling of hammerhead sharks by the U.S. commercial HMS PLL fishery and recreational fisheries for tunas, swordfish, and billfish in the Atlantic Ocean, including the Caribbean Sea and Gulf of Mexico. (76 FR 53652; August 29, 2011). In addition the state of Florida recently passed legislation prohibiting the landing of scalloped hammerhead sharks in state waters.

In 2008, the U.S. was ranked 7th in the world's top exporters of shark fins to Hong Kong, with a total product weight estimated at 251,310 kg. However, with the passage of the 2011 U.S. Shark Conservation Act, the practice of finning has effectively been prohibited, and coupled with the other federal management regulations mentioned above, should further protect the scalloped hammerhead shark population. Many U.S. states, especially on the west coast, have also passed finning and trade regulations, subsequently decreasing the United States contribution to the fin trade. For example, after the state of Hawaii made it unlawful to harvest or land shark fins in the state or territorial waters of the state in 2000, the shark fin imports from the U.S. into Hong Kong declined significantly (54% decrease, from 374 to 171 tonnes) (Figure 20). In July 2010, Hawaii further strengthened the shark finning ban by making it illegal to possess, sell, offer for sale, trade, or distribute shark fins. Other states are following suit and proposing similar trade bans (see PECE section), which would further decrease the U.S. share of shark fin imports to Hong Kong.

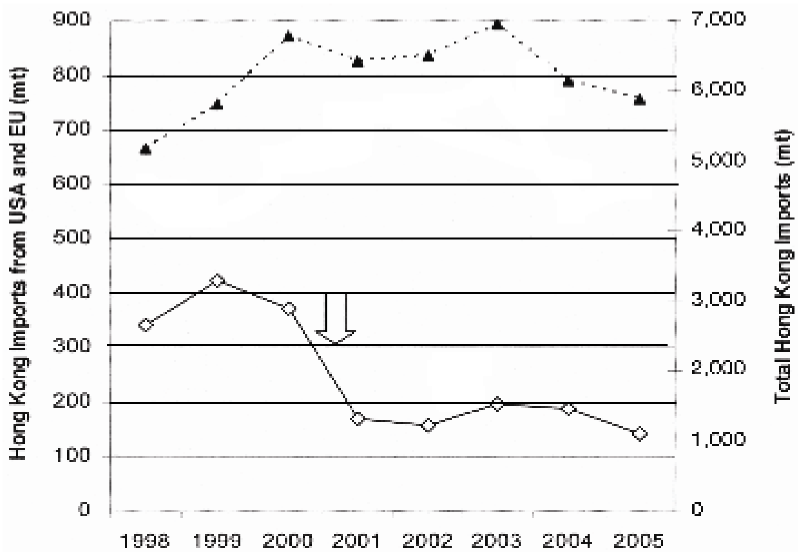

Figure 20. Annual imports of shark fin to Hong Kong from the U.S. (◊) and total Hong Kong imports (▲). The clear arrow indicates the implementation of finning regulations in the state of Hawaii. (Source: Clarke et al. 2007)

Overall, these domestic measures are adequate to protect scalloped hammerhead sharks in U.S. waters, especially populations found in the Atlantic Ocean, but may not be adequate to protect scalloped hammerheads found elsewhere in the world.

Analysis of Adequacy of Existing International Regulatory Mechanisms

Given the lack of data reporting on hammerhead catches, it is difficult to measure the adequacy of current regulatory mechanisms as they relate to the global population scalloped hammerhead sharks. *S. lewini* is a highly migratory species found worldwide and thus requires protections in every ocean basin. Currently, the ICCAT has afforded the species protection in Atlantic waters from fishing by ICCAT vessels but has allowed developing CPCs an exemption for local consumption. This exception may lead to increased fishing effort by these nations, and since many have not developed shark management plans, may result in unsustainable fishing of *S. lewini* in the Atlantic. However, according to ICCAT data (Figure 4), the two countries that accounted for almost 90% of the total scalloped hammerhead catch in the Atlantic from 1992-2011 were the U.S. and Brazil. The U.S. has already implemented regulations prohibiting the taking of scalloped hammerhead sharks in association with its commercial HMS pelagic longline fishery and recreational fisheries for tunas, swordfish, and billfish in the Atlantic Ocean, and Brazil is currently in the process of developing its domestic regulations to achieve the ICCAT recommendation (Hazin personal communication, 2012).

Although not reflected in the ICCAT data, Spain is Europe's top shark fishing nation and is one of the world's top exporters of shark fins to Hong Kong (Oceana 2010). In 2005, 85% of the overall reported Spanish shark catches were caught in the Atlantic Ocean, 8% in the Indian, 6% in the Pacific, and ~1% in the Southern Ocean (Shark Alliance 2007). Although Spain concentrates fishing efforts in the Atlantic, the country represented 72% of the total hammerhead catch from 2003-2009 from the IOTC region (Figure 8). However, these catch numbers should be decreasing in the next few years because Spain recently banned fishing for scalloped hammerhead sharks in all fishing grounds in an effort to protect the species. Given that Spain accounts for 7.3% of the global shark catch (Lack and Sant 2011) and was the world's largest exporter of fins in 2008, this new prohibition will likely drastically decrease total fishing mortality on the global stock of scalloped hammerhead sharks.

In the SRFC region (off west Africa), fishing occurs year-round, including during shark breeding season, and, as such, both pregnant and juvenile shark species may be fished, with shark fins from fetuses included on balance sheets at landing areas (Diop and Dossa 2011). Many of the state-level management measures in this region also lack standardization at the regional level (Diop and Dossa 2011) which weakens some of their effectiveness. For example, Sierra Leone and Guinea both require shark fishing licenses, however these licenses are much cheaper in Sierra Leone, and, as a result, fishers from Guinea fish for sharks in Sierra Leone (Diop and Dossa 2011). Also, although many of these countries have recently adopted FAO recommended National Plans of Action – Sharks, their shark fishery management plans are still in the early implementation phase, and with few resources for monitoring and managing shark fisheries, the benefits to sharks from these regulatory mechanisms have yet to be realized (Diop and Dossa 2011).

In the Indian and Pacific Oceans, existing regulatory mechanisms may not be adequate to protect *S. lewini* from exploitation; however, species-specific data in these regions are currently lacking. The RFMOs which regulate these waters require that fishermen fully utilize sharks and prohibit fins onboard that weigh more than 5% of the weight of sharks. In addition, recent reporting requirements were implemented that require cooperating member countries to report on historical and current catches of scalloped hammerhead sharks in order to obtain a better picture of the exploitation rate of the *S. lewini* population. Major shark fishing countries in the Indian and Pacific Oceans include Indonesia, India, Taiwan, and Costa Rica. Indonesia, which is the top shark fishing nation in the world, currently has no restrictions pertaining to shark fishing. In fact, Indonesian small-scale fisheries, which account for around 90% of the total fisheries production, are not required to have fishing permits (Varkey et al., 2010), nor are their vessels likely to have insulated fish holds or refrigeration units (Tull 2009), increasing the incentive for shark finning by this sector (Lack and Sant 2012). Ultimately, their fishing activities remain largely unreported (Varkey et al. 2010) which suggests that the estimates of Indonesian shark catches are greatly underestimated. In fact, in Raja Ampat, an archipelago in Eastern Indonesia, Varkey et al. (2010) estimated that 44 percent of the total shark catch in 2006 was unreported (includes small-scale and commercial fisheries unreported catch and IUU fishing). Without proper fishery management regulations in place, many of the larger species in Indonesian waters have been severely overfished and have forced Indonesian fishermen to fish elsewhere. Following the noticeable decline in shark species, Indonesian fishermen targeting shark fins began moving south in the late 1990s, from the South China Sea and Gulf of Thailand to waters of northern Australia (Field et al. 2009). After 2001, Australian Customs patrol reported a large increase in the number of illegal, unregulated, and unreported (IUU) vessel sightings (Figure 21), mainly from Indonesia, with a peak occurring in late 2005 and early 2006.

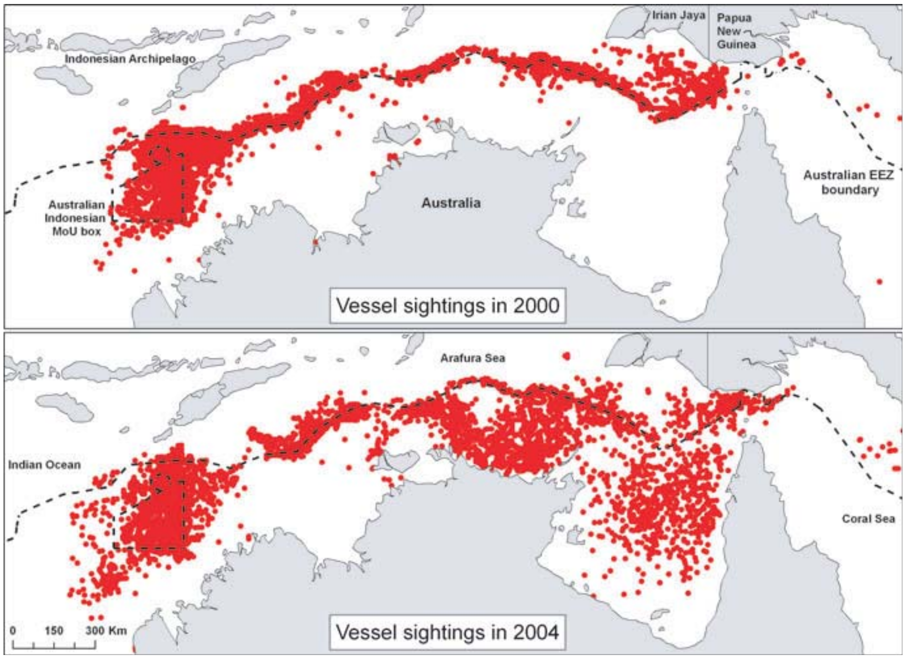

Figure 21. Coastwatch sightings of IUU foreign fishing vessels bordering and within the Australian EEZ in 2000 and 2004. (Source: Field et al. 2009)

Since 2006, there has been a decline in IUU fishing in Australian waters, thought to be due to exhaustion of stocks in easily accessible regions near the Australian EEZ, as well as international government agreements and domestic policies (Field et al. 2009). Between July 2008 and June 2012, only 60 Indonesian vessels targeting sharks were apprehended (Lack and Sant 2012). Because illegal shark fishing is often unreported, there is a lack of information available on the species composition of the IUU shark catch. However, using a small collection of shark fins that were confiscated from IUU fishers in northern Australian waters, the Commonwealth Scientific and Industrial Research Organisation identified that 8.8% of the fins belonged to *S. lewini*. Only one other shark species, the Whitecheek shark (*Carcharhinus dussumieri*), was a source of more fins (27.9%) (Lack and Sant 2008).

Reports of IUU fishing are also prevalent in the waters off West Africa and account for around 37% of the region's catch, the highest regional estimate of illegal fishing worldwide (Agnew et al. 2009, EJF 2012). From January 2010 to July 2012, the UK-based non-governmental organization Environmental Justice Foundation (EJF) conducted a surveillance project in southern Sierra Leone to determine the extent of IUU fishing in waters off West Africa (EJF, 2012). The EJF staff received 252 reports of illegal fishing by industrial vessels in inshore areas, 90 percent of which were bottom trawlers, with many vessels exporting their catches to Europe and East Asia (EJF 2012). The EJF (2012) surveillance also found these pirate industrial fishing vessels operating inside exclusion zones, using prohibited fishing gear, refusing to stop for patrols, attacking local fishers and destroying their gear, and fleeing to neighboring countries to avoid sanctions. Due to a lack of resources, many West African countries are unable to provide effective or, for that matter, any enforcement, with some countries even lacking basic monitoring systems. These deficiencies further increase the countries' susceptibility to IUU fishing, resulting in heavy unregulated fishing pressure and likely overexploitation of their fisheries.

The following are additional documented cases of IUU fishing as compiled by Paul (2009). In 2008, off the coast of Africa, a Namibian-flagged fishing vessel was found fishing illegally in Mozambican waters, with 43 mt of sharks and 4 mt of shark fins onboard. In 2009, a Taiwanese-flagged fishing trawler was found operating illegally in the South Africa EEZ with 1.6 mt of shark fins onboard without the corresponding carcasses. Also in 2009, 250 trawlers were found to be poaching sharks in coastal areas in the Bay of Bengal with the purpose of smuggling the sharks to Myanmar and Bangkok by sea. There are also reports of traders exploiting shark populations in the Arabian Gulf due to the lack of United Arab Emirates enforcement of finning regulations. In the Western Pacific, in 2007, a Taiwanese-flagged tuna boat was seized in Palau for IUU fishing and had 94 shark bodies and 650 fins onboard. In 2008, a Chinese-flagged fishing vessel was arrested by the Federated States of Micronesia (FSM) National Police for fishing within the FSM's EEZ. Based on the number of fins found onboard, there should have been a corresponding 9,000 bodies, however only 1,776 finned shark bodies were counted.

In Somalia, it is estimated that around 700 foreign-owned vessels are operating in Somali waters without proper licenses, and participating in unregulated fishing for highly-valued species like sharks, tunas, and lobsters (HSTF 2006). 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 to 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 IUU catches of sharks worldwide has been estimated at $192 million (HSTF 2006).

In the U.S., reports of IUU fishing by Mexico, a top shark fishing nation accounting for nearly 4.1% of the global shark catch, has been ongoing for the past decade. Since the mid-1990s, the United States Coast Guard (USCG) has documented Matamoros Mexican vessels illegally fishing in the area surrounding South Padre Island, Texas (Brewster-Geisz and Eytcheson 2005). The Mexican IUU fishermen use gillnet and longline gear for shark and red snapper, which are believed to be more prevalent in the U.S. EEZ off Texas than in the Mexican EEZ near Matamoros. The sharks, the majority of which are blacktips and hammerheads, are finned and the fins sold. Based on data from 2000-2005, Brewster-Geisz and Eytcheson (2005) estimated that Mexican fishermen are illegally catching anywhere from 3 to 56% of the total U.S. commercial shark quota, and between 6 and 108% of the Gulf of Mexico regional commercial quota. Updated data since 2005 show a decrease in the number of detected incursions (Brewster-Geisz et al. 2010); however, the extent of IUU fishing on the Gulf of Mexico *S. lewini* population is unknown. Based on the estimates above, this IUU fishing may severely hinder the efforts currently being undertaken by the U.S. to rebuild the *S. lewini* population in this region.

High levels of IUU fishing have also been reported off Central/South America and in the Western and Central Pacific Ocean (WildAid 2003, Lack and Sant 2008). In these areas, longlining and gillnetting are the most frequently cited methods used in illegal shark fishing, with hammerhead sharks a main target (Lack and Sant 2008). In Belém, Brazil, in May 2012, the Brazilian Institute of Environmental and Renewable Natural Resources (IBAMA) seized around 7.7 mt of illegally obtained dried shark fins intended for export to China (Nickel 2012). A few months later, IBAMA confiscated more than 5 mt of illegal shark fins in Rio Grande do Norte (Rocha de Medeiros 2012), suggesting current regulations and enforcement are not adequate to deter or prevent illegal shark finning. In fact, it is estimated that illegal fishing constitutes 32 percent of the Southwest Atlantic region's catch (based on estimates of illegal and unreported catch averaged over the years of 2000 – 2003; Agnew et al. 2009). In the ETP, there is evidence of illegal fishing by both local fisherman and industrial longliners within many of the marine protected areas (WildAid 2003, Hearn et al. 2010, Bessudo et al. 2011). For example, in Cocos Island National Park, off Costa Rica, a "no take" zone was established in 1992, yet populations of *S. lewini* continued to decline by an estimated 71% from 1992-2004 (Myers et al. nd). In Ecuador, concern over illegal fishing around the Galapagos Islands prompted a 2004 ban on the exportation of fins but only resulted in the establishment of new illegal trade routes and continued exploitation of scalloped hammerhead sharks (CITES 2010). In 2007, a sting operation by the Ecuadorian Environmental Police and the Sea Shepherd Conservation Society resulted in a seizure of 19,018 shark fins that were being smuggled over the border on buses from Ecuador to Peru. The fins were believed to come from protected sharks in the Galapagos Islands (Paul 2009). More recently, in November 2011, Colombian environmental authorities reported a large shark massacre in the Malpelo wildlife sanctuary, an area where divers reported sightings of schools of more than 200 hammerhead sharks. The divers counted a total of 10 illegal Costa Rican trawler boats in the wildlife sanctuary and estimated that as many as 2,000 sharks may have been killed for their fins (Brodzinsky 2011). A few months later, thousands of pounds of shark products were confiscated in the Marshall Islands, with the Marshall Islands Marine Resource Authority fining a Japanese tuna transshipment vessel $125,000 for having sharks on board in a designated shark sanctuary (AFP 2012). In Palau, a Taiwanese vessel was spotted by Palau law enforcement officials fishing and finning sharks in its protected waters, and was fined $65,000 and banned from Palauan waters for a year (Turagabeci 2012). Unfortunately, like most of these Pacific Island countries, Palau is small, and patrolling its large oceanic territory is difficult without adequate resources (Bromhead et al. 2012). Currently, Palau has only one patrol boat to enforce fishing regulations in 604,000 km^2 of ocean waters (Turagabeci 2012). Therefore, although the creation of shark sanctuaries is on the rise, especially in areas of known *S. lewini* nursery grounds and "hot spots" (see Table 18), the protections that they afford *S. lewini* populations may be minimal if IUU fishing is not controlled.

Other Natural or Manmade Factors Affecting the Scalloped Hammerhead Shark's Continued Existence

Many sharks are thought to be biologically vulnerable to overexploitation based on their life history parameters. The use of demographic analyses is a common and popular tool for assessing this vulnerability (Musick and Bonfil 2005). The main parameter estimated in the demographic analysis is the intrinsic rate of increase (r), or the measure of potential for growth rate in a population. With regards to the scalloped hammerhead shark, estimates of this intrinsic rate of increase have been calculated mainly using life history parameters from Atlantic *S. lewini* populations (Table 19). Smith et al. (1998) determined that *S. lewini* had one of the lowest recovery capabilities, with an intrinsic rate of population increase at MSY equal to 0.028-0.039 (with a 1.00 and 1.25 fecundity ratio, respectively). Productivity values were strongly affected by age at maturity, which was estimated at 15 years for scalloped hammerhead sharks (Smith et al. 1998). Cortés (2002) used a density independent demographic approach and calculated r = 0.082 yr^{-1} for the northwest Atlantic Ocean population. For the western Pacific population of scalloped hammerheads, Cortés (2002) calculated a much higher intrinsic rate of increase, with r = 0.47 yr^{-1}. However, as mentioned previously, the higher rate of population increase in the Pacific may be a result of variations in aging band interpretations and growth rates rather than actual biological differences (Piercy et al. 2007). A recent ecological risk assessment (ERA) of sharks caught in Atlantic pelagic longline fisheries calculated a median value of r = 0.105/yr for *S. lewini* (Cortés et al. 2010). In 2012, ICCAT updated the ERA by adding five previously un-assessed sharks and new data from five countries. Out of the 20 shark stocks in the Atlantic assessed, the southern *S. lewini* stock ranked 7th in highest productivity value (r = 0.121) followed by the northern *S. lewini* stock which ranked 9th (r = 0.096) (ICCAT 2012). Generation time was estimated at 21.6 years (ICCAT 2012). In a draft report that ranked the relative intrinsic vulnerability of 61 species of sharks to harvesting, *S. lewini* was found to have a high vulnerability based on minimum age at maturity and maximum size, and was ranked 16th in terms of maximum size alone (a variable that has been linked to vulnerability by other studies) (Oldfield et al. 2012). Off the coast of South Africa, Dudley and Simpfendorfer (2006) estimated r = 0.103, with a generation time of 18.3 years for *S. lewini*. Hayes et al. (2009) also calculated a similarly, and relatively low, intrinsic rate of increase value for the scalloped hammerhead (r = 0.11) using a Fox surplus production model.

Table 19. Estimates of the intrinsic rate of increase (r) for the scalloped hammerhead shark using life history parameters from the Atlantic *S. lewini* populations.

Intrinsic rate of population increase (r)	**Reference**
0.028	Smith et al. (1998)
0.082	Cortés (2002)
0.105	Cortés et al. (2010)
0.103	Dudley and Simpfendorfer (2006)
0.110	Hayes et al. (2009)
0.121	ICCAT (2012)
0.096	
Average = 0.092	

Although estimates of (r) for *S. lewini* are rather low (Table 19), when compared to other sharks, scalloped hammerheads appear to have a moderate recovery potential. Using life history traits and environmental data for 105 chondrichthyan species found worldwide, García et al. (2008) determined that oceanic and continental shelf species, such as the scalloped hammerhead, have a significantly lower risk of extinction compared to deep-water species. For *S. lewini*, the $F_{extinct}$ value (fishery mortality to drive a species to extinction) was estimated at 0.540 but may be overly optimistic given that García et al (2008) relied on life history parameters from the Pacific ocean (with max size = 331cm TL, size at maturity = 223cm TL, k = 0.156, max age = 18.6, maturity age = 5.8, litter size = 20.1). Off the coast of South Africa, Dudley and Simpfendorfer (2006) estimated that *S. lewini* could sustain moderate levels of fishing pressure, with a fishing mortality rate at which population growth is zero = 0.14 (using the following: L_{∞} = 367cm PCL, k = 0.057, max age = 30, maturity age = 11, litter size = 10). Likewise, Liu and Chen (1999) suggested that *S. lewini* in the northwestern Pacific had a strong resilience to exploitation as long as fishing pressure targeted mature sharks (>5 years for females). In addition, in a study comparing the scalloped hammerhead to 10 other species of pelagic elasmobranchs, Cortés et al. (2010) found that the scalloped hammerhead had a low risk of vulnerability to overexploitation by pelagic longline fisheries. Thus, compared to other chondrichthyans, *S. lewini* appears able to sustain a higher level of fishing mortality. However, based on FAO's productivity indices for exploited fish species (where r < 0.14 is considered low productivity), overall estimates of (r) values for the scalloped hammerhead shark (Table 19) indicate that *S. lewini* populations are generally vulnerable to depletion and may be slow to recover from overexploitation.

Contributing to the scalloped hammerhead's biological vulnerability is the fact that these sharks are obligate ram ventilators and suffer very high at-vessel fishing mortality in bottom longline fisheries (Morgan and Burgess 2007, Macbeth et al. 2009). From 1994-2005, NMFS observers calculated that out of 455 scalloped hammerheads caught on commercial bottom longline vessels in the northwest Atlantic and Gulf of Mexico, 91.4% were dead when brought aboard. Size did not seem to be a factor influencing susceptibility as 70% of the young *S. lewini* (0-65 cm), 95.2% of the juveniles (66-137cm), and 90.9% of the adults (>137cm) suffered at-vessel fishing mortality. Soak time of the longline had a positive effect on the likelihood of death (Morgan and Burgess 2007), with soak times longer than 4 hours resulting in > 65% mortality (Morgan et al. 2009). When soak time was shortened to 1 hour, *S. lewini* at-vessel fishing mortality decreased to 12% (Lotti 2011). Lotti (2011) also found that at-vessel fishing mortality was negatively correlated with *S. lewini* length (p=0.0032) and dissolved oxygen (p=0.003), with male scalloped hammerheads showing a higher probability of suffering from at-vessel mortality compared to females (p=0.0265). *Sphyrna* spp also suffer high mortality in beach net programs as well (Reid and Krogh 1992, Dudley and Simpfendorfer 2006). In a study examining the protective shark mesh program in New South Wales, Australia, *Sphyrna* spp was the taxonomic group with the lowest net survival rates. The nets used in the protective mesh program were 150 m long and 6 m deep, with a mesh size of 50-60cm and soak time generally between 12 and 48 hours. Out of the 2,031 hammerheads caught by this program (from 1972-1990), only 1.7% were alive when cleared from the nets (Reid and Krogh 1992).

Another potential threat to the continued existence of *S. lewini* is their schooling behavior, which may increase their likelihood of being caught in large numbers. For example, fishermen in Costa Rica were documented using gillnets in shallow, muddy waters to target the schools of juveniles and neonates in these nursery areas (Zanella et al. 2009). Focused fishing pressure (both legal and illegal) on known areas of adult aggregations has also been frequently documented (Brodzinsky 2011, Brewster-Geisz and Eytcheson 2005).

In conclusion, the scalloped hammerhead shark has biological characteristics that may increase its vulnerability to overexploitation.

SUMMARY AND CONCLUSIONS FROM THE EXTINCTION RISK ANALYSIS

In order to assess the extinction risk of the scalloped hammerhead shark, a team of fishery biologists and shark experts, henceforth referred to as the "ERA team", was convened. This ERA team reviewed the best available information in this Status Review document and drew upon their professional knowledge and judgment to evaluate the overall risk of extinction facing the scalloped hammerhead shark now and in the foreseeable future. The ERA team defined the foreseeable future as 50 years (~ 3 generation times), or, in other words, the timeframe over which threats could be predicted reliably to impact the biological status of the species.

Prior to evaluating extinction risk, the ERA team examined the populations of scalloped hammerhead sharks to see whether any qualified as "distinct population segments" (DPSs) under the joint NMFS/USFWS DPS policy (61 FR 4722; February 7, 1996). Based on the criteria for discreteness and significance under the DPS policy, the ERA team identified six DPSs: Northwest Atlantic & Gulf of Mexico DPS, Central & Southwest Atlantic DPS, Eastern Atlantic DPS, Indo-West Pacific DPS, Central Pacific DPS, and Eastern Pacific DPS. Each DPS was subsequently evaluated in terms of its risk of extinction now and in the foreseeable future. The outcomes from those risk assessments are provided below. Specific details on the methods, definitions of risks, results, and conclusions can be found in Appendix I.

Northwest Atlantic & Gulf of Mexico DPS: Although this DPS has suffered a significant decline since the early 1980s (~83% according to Hayes et al. 2009), the ERA team concluded that the main threat of overutilization would decrease in the foreseeable future given the current and future fishery management regulations, allowing for the rebuilding of the stock. Thus, the Northwest Atlantic & Gulf of Mexico DPS was unlikely to be at risk of extinction throughout all or a significant portion of its range due to trends in abundance, productivity, spatial structure, or diversity, however current or projected threats may be altering those trends but not yet by enough to cause the species to be influenced by stochastic or depensatory processes. The ERA team concluded that this DPS is at a low risk of extinction now and in the foreseeable future.

Central & Southwest Atlantic DPS: Although abundance numbers and good catch data were unavailable from this DPS, the evidence of heavy fishing of this species by industrial/commercial fisheries off the coast of Brazil, and by artisanal fisheries in Central America, Caribbean, and Brazil, with documented large takes of juveniles and neonates, suggests this DPS is likely exhibiting a trajectory indicating that it is approaching a level of abundance and productivity that places its current and future persistence in question throughout its entire range. The ERA team concluded that this DPS is at a moderate risk of extinction now and in the foreseeable future.

Eastern Atlantic DPS: Although Spain, along with other EU countries, have implemented regulations aimed at controlling the exploitation of this species, inadequate regulatory mechanisms and overutilization by artisanal fisheries, and extensive IUU fishing along the western coast of Africa are major threats to this DPS. Given these clear and present threats, this DPS is at or near a level of abundance and productivity that places its current and future persistence in question throughout its entire range. The ERA team concluded that this DPS is at a high risk of extinction now and in the foreseeable future.

Indo-West Pacific DPS: Trends in abundance in certain areas, such as off the coast of South Africa and Australia, suggest significant depletions of local populations, however the Indo-West Pacific DPS range covers a large area and abundance estimates for this entire DPS were unavailable. Evidence of heavy fishing pressure by industrial/commercial and artisanal fisheries, and reports of significant IUU fishing, especially off the coast of Australia, have likely led to overutilization of this DPS. Coupled with inadequate regulatory measures, especially in the Western Indian Ocean and Indonesian waters, the present and future threats facing this DPS have set it on a trajectory where it is approaching a level of abundance and productivity that places its current and future persistence in question throughout its entire range. The ERA team concluded that this DPS is at a moderate risk of extinction now and in the foreseeable future.

Central Pacific DPS: Although there were concerns regarding the spatial isolation of this DPS, the evidence of productive pupping grounds in Hawaii, as well as the number of suitable nursery habitats and current regulatory mechanisms in this DPS makes it unlikely that this DPS is at risk of extinction throughout all or a significant portion of its range due to current or projected threats or trends in abundance, productivity, spatial structure, or diversity. The ERA team concluded that this DPS was at a very low risk of extinction now and in the foreseeable future.

Eastern Pacific DPS: Few abundance data from this DPS are available; however, evidence of heavy fishing pressure by artisanal fisherman on schools of immature *S. lewini,* as well as reports of large-scale IUU shark fishing, increases this DPS's demographic risks. In addition, the limited regulatory mechanisms and poor enforcement in the Eastern Pacific contributes to the overutilization of this DPS. As a result of these clear and present threats, this DPS is at or near a level of abundance and productivity that places its current and future persistence in question throughout its entire range. The ERA team concluded that this DPS was at a high risk of extinction now and in the foreseeable future.

ASSESSMENT OF EXTINCTION RISK FOR THE SCALLOPED HAMMERHEAD SHARK (*SPHYRNA LEWINI*)

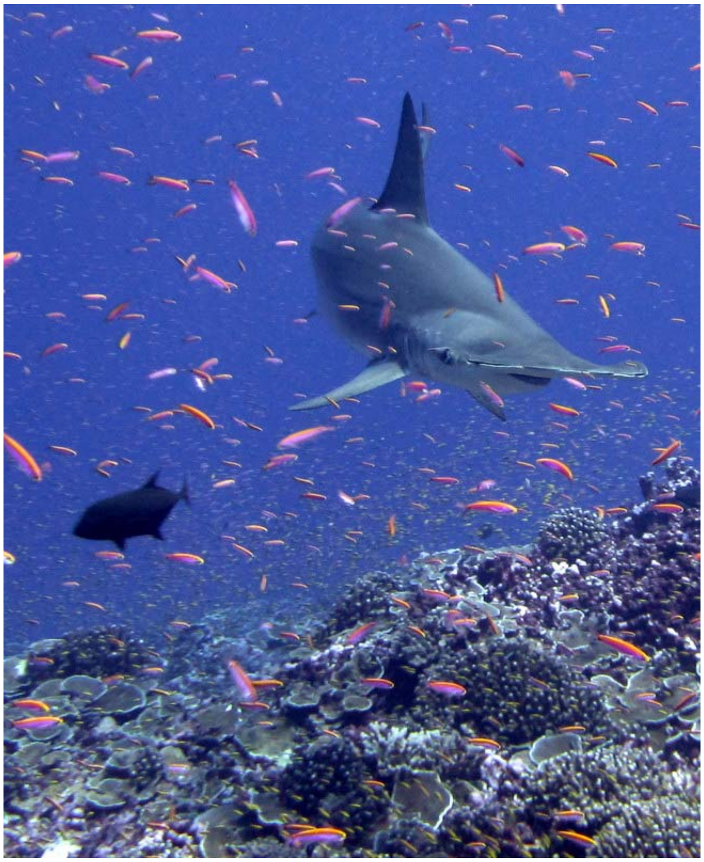

Photo Credit: Dr. Jill Zamzow

Conducted by the Extinction Risk Analysis (ERA) Team

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INTRODUCTION

The Endangered Species Act (ESA) (Section 3) defines endangered species as “any species which is in danger of extinction throughout all or a significant portion of its range.” Threatened species is defined as “any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” Neither the National Marine Fisheries Service (NMFS) nor the U.S. Fish and Wildlife Service (USFWS) have developed any formal policy guidance about how to interpret the definitions of threatened or endangered species in the ESA. In many previous NMFS status reviews, a team has been convened, often referred to as a “Biological Review Team”, in order to compile the best available information on the species and conduct a risk assessment through evaluation of the demographic risks, threats, and extinction risk facing the species or distinct population segment (DPS). This information is ultimately used by the NMFS Protected Resources office, after consideration of the legal and policy dimensions of the ESA standards and benefits of ongoing conservation efforts, to make a listing determination. For purposes of this risk assessment, an Extinction Risk Analysis (ERA) team, comprised of fishery biologists and shark experts, was convened to review the best available information in the Status Review document, conduct a DPS analysis, and evaluate the overall risk of extinction facing the scalloped hammerhead shark now and in the foreseeable future.

DISTINCT POPULATION SEGMENT ANALYSIS

Consideration of the Species Question

In determining whether to list a species, the first issue is whether the petitioned subject is a valid species. The petitioned subject, the scalloped hammerhead shark, or *Sphyrna lewini* (Griffith and Smith 1834), is a valid species for listing. The taxonomic breakdown of *S. lewini* is as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Chondrichthyes
Subclass: Elasmobranchii
Order: Carcharhiniformes
Family: Sphyrnidae
Genus: Sphyrna
Species: S. lewini

Criteria for Identification of Distinct Population Segments

After determining whether the petition identifies a species, the next issue is whether any petitioned populations qualify as DPSs within the species. The joint policy of the USFWS and

NMFS provides guidelines for defining DPSs below the taxonomic level of species (61 FR 4722; February 7, 1996). The policy identifies two elements to consider in a decision regarding whether a population qualifies as a DPS: discreteness and significance of the population segment to the species.

Discreteness

A DPS may be considered discrete if it is markedly separate from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors, or if it is delimited by international governmental boundaries. Genetic differences between the population segments being considered may be used to evaluate discreteness. In addition, international boundaries within the geographical range of the species may be used to delimit a distinct population segment. This criterion is applicable if differences in the control of exploitation of the species, management of the species' habitat, the conservation status of the species, or regulatory mechanisms differ between countries that would influence the conservation status of the population segment.

Significance

If a population segment is considered discrete, its biological and ecological significance must then be evaluated. Significance is evaluated in terms of the importance of the population segment to the overall welfare of the species. Some of the considerations that can be used to determine a discrete population segment's significance to the taxon as a whole include:

1) Persistence of the population segment in an unusual or unique ecological setting;
2) Evidence that loss of the population segment would result in a significant gap in the range of the taxon; and
3) Evidence that the population segment differs markedly from other populations of the species in its genetic characteristics.

Distinct Population Segments of Scalloped Hammerhead Sharks

Proposed DPSs by Petitioners

The petitioners requested that the scalloped hammerhead be divided into 5 DPSs for the purposes of listing under the ESA. These 5 DPSs were: Northwest and Western Central Atlantic Subpopulation (from New Jersey to the Caribbean), Southwest Atlantic Subpopulation (Caribbean and the Gulf of Mexico to Uruguay), Eastern Central Atlantic Subpopulation, Western Indian Ocean Subpopulation, and Eastern Central and Southeast Pacific Subpopulation. Below is an evaluation of these subpopulations as well as other potential population segments of scalloped hammerheads to see if any meet the criteria of a DPS.

Atlantic Ocean & Gulf of Mexico

The petitioners proposed three subpopulations in the Atlantic Ocean: Northwest and Western Central Atlantic Subpopulation, Southwest Atlantic Subpopulation, and Eastern Central Atlantic Subpopulation. Genetic differences, which may be used to qualify under the discreteness criterion and significance criterion, have been identified between *S. lewini* populations in the

Atlantic and populations found in the other ocean basins. Based on mitochondrial control region (mtCR) sequences, Duncan et al. (2006) found no sharing of *S. lewini* haplotypes between the Atlantic and the Pacific or Indian Ocean. Chapman et al. (2009) further substantiated this finding in a subsequent examination of mtDNA from scalloped hammerhead shark fins, confirming the absence of shared haplotypes between *S. lewini* in the western Atlantic (n = 177) and those found in the Indo-Pacific (n = 275). Both of these studies focused on maternally inherited genetic markers and provide evidence that female scalloped hammerhead sharks do not conduct trans-oceanic migrations; however this does not preclude male-mediated gene flow in *S. lewini* populations. In order to test the hypothesis of sex-biased dispersal, Daly-Engel et al. (2012) analyzed 13 microsatellite loci from 403 *S. lewini* specimens collected from each of the three ocean basins. Although results showed some evidence of male-mediated gene flow across and between ocean basins, this pattern was more pronounced in the Indian and Pacific Ocean populations. Samples taken from scalloped hammerheads in the western and eastern Atlantic Ocean were significantly differentiated from all of the other population samples, suggesting that the male scalloped hammerheads in the Atlantic Ocean rarely mix with scalloped hammerheads found elsewhere in the world (Daly-Engel et al. 2012).

Further separation of *S. lewini* populations within the Atlantic Ocean, as proposed by the petitioners, is also supported by genetic data as well as tagging studies. For example, through genetic analysis of maternally inherited DNA, Chapman et al. (2009) structured the western Atlantic scalloped hammerhead population into three distinct mitochondrial stocks: the northern (U.S. Atlantic and Gulf of Mexico), central (Central American Caribbean), and southern (Brazil) stocks. Using microsatellite fragments, Daly-Engel et al. (2012) found significant levels of genetic structure between the Gulf of Mexico and the nearby South Carolina site in the West Atlantic ($F_{ST} = 0.201$, $P<0.001$). This finding contrasts with Chapman et al. (2009) who did not find significant population differentiation between *S. lewini* in the U.S. Atlantic and the Gulf of Mexico, as well as Naylor et al. (2012) who found the Western Atlantic and Gulf of Mexico haplotypes clustered together after analysis of mitochondrial DNA (mtDNA) samples, and Duncan et al. (2006) who found a lack of structure along continental margins using mtDNA samples. Although the genetic data support separating the western Atlantic population into subpopulations, there is disagreement on where the lines should be drawn. Tagging studies of scalloped hammerhead sharks conducted off the northwest Atlantic and Gulf of Mexico provide support for classifying the sharks found in this area as one population. The median distance between mark and recapture of 3,278 adult tagged sharks along the eastern U.S. and Gulf of Mexico was less than 100 km (Kohler and Turner 2001). There is currently no tagging data to suggest a mixing of the Northwest Atlantic and Gulf of Mexico scalloped hammerhead population with the scalloped hammerheads found in Central America or Brazil (Kohler personal communication, 2012). Thus, the genetic and tagging studies support separating the western Atlantic population into two separate sub-populations: the Northwest Atlantic & Gulf of Mexico population and the Central & Southwest Atlantic population.

Furthermore, there are significant differences in the control of exploitation and regulatory mechanisms between countries in the Atlantic that could influence the conservation status of the *S. lewini* populations and provide support for the separation of the Northwest & Gulf of Mexico stock and the Central & Southwest Atlantic stock. For example, the United States has implemented its own strict regulations aimed at controlling the exploitation of the sharks in the northwest Atlantic and Gulf of Mexico, with the development of fishery management plans, requirement for stock assessments, and quota monitoring. Currently, the U.S. is drafting a fishery management plan amendment specifically aimed at rebuilding the northwest Atlantic and Gulf of Mexico scalloped hammerhead population. These comprehensive regulatory mechanisms are expected to help protect *S. lewini* in the Northwest Atlantic and Gulf of Mexico. Although the U.S. regulations extend to the U.S. EEZ in the Caribbean (i.e. surrounding U.S. territories), the vast majority of the Caribbean sea, as well as waters farther south, lack regulatory measures controlling the exploitation of scalloped hammerheads. For example, Brazil, a country that has seen declines of 80% or more in CPUE of scalloped hammerheads in the surface and bottom gillnet fisheries (FAO 2010), does not have regulations specific to scalloped hammerhead sharks or quota monitoring in its artisanal fisheries. Thus, based on genetic characteristics as well as the differences in the control of exploitation and management of *S. lewini* in the western Atlantic Ocean, the Northwest Atlantic & Gulf of Mexico population and the Central & Southwest Atlantic population satisfy the discreteness criterion under the DPS policy. In addition, the genetic and tagging data provide evidence that these two population segments differ markedly from each other, and from other populations found elsewhere, and rarely mix, suggesting that loss of either population segment would result in a significant gap in the range of the taxon, thus satisfying the significance criterion under the DPS policy.

In addition to the western Atlantic subpopulations, the petitioners also proposed an Eastern Central Atlantic Subpopulation. A review of the current evidence lends support to this complete separation between the western and eastern Atlantic scalloped hammerhead populations (Chapman personal communication, 2012). Based on analysis of mtCR sequences, Duncan et al. (2006) found that *S. lewini* haplotypes in West Africa are separated from the haplotypes along the East Coast of the U.S. by one to two mutations (indicating missing hypothetical ancestors). However, migration and population divergence between these two locations were not estimated due to the small sample sizes (Duncan et al. 2006). Daly-Engel et al. (2012) provided evidence of genetic structure across the Atlantic Ocean basin using biparentally-inherited DNA. The subsequent microsatellite data analysis results revealed that scalloped hammerhead samples from West Africa were weakly differentiated from the South Carolina samples ($F_{ST} = 0.052$, $0.05 \geq P \geq 0.01$) and significantly differentiated from the Gulf of Mexico samples ($F_{ST} = 0.312$, $P \leq 0.001$), providing genetic support for the separation of the eastern and western Atlantic populations of scalloped hammerheads. In addition, Daly-Engel et al. (2012) found significant differentiation between South Africa samples and West Africa samples ($F_{ST} = 0.07$, $P \leq 0.01$), with the number of migrants from West Africa into South Africa estimated at only 0.06 per generation, indicating that this Eastern population rarely conducts long distance southern migrations into the Indo-West Pacific to mix with other *S. lewini* individuals. Thus, the genetic partitioning of the scalloped hammerhead shark population found in the Atlantic, as well as the observed tagging movements of this species, suggest that the western Atlantic and eastern Atlantic *S. lewini* populations do not migrate across or between ocean basins for reproduction purposes but instead make limited distance migrations along coastlines and continental margins. This behavior appears to contrast with that exhibited by male *S. lewini* in the Indian and Pacific Oceans, where a lack of genetic structure indicate frequent mixing of these populations (Daly-Engel et al. 2012) and potentially long distance migrations along continental margins between these ocean basins. Therefore, in addition to the aforementioned western populations, the eastern Atlantic population of *S. lewini* also satisfies the discreteness criterion of the DPS policy based on genetic differences and behavior. Loss of this Atlantic population segment may result in a significant gap in the range of the taxon as well as potentially unique genetic characteristics, satisfying the significance criterion of the DPS policy.

In conclusion, the Northwest Atlantic & Gulf of Mexico population segment, the Central & Southwest Atlantic population segment (from Caribbean to Uruguay), and the Eastern Atlantic population segment of *S. lewini* have satisfied the discreteness and significance tests of the DPS policy and will be considered DPSs for purposes under the ESA.

Indian and Pacific Ocean

The petitioners proposed two subpopulations that can be found in the Indian and Pacific Oceans: the Western Indian Ocean Subpopulation and the Eastern Central and Southeast Pacific Subpopulation. Genetic differences are much less evident in and between the West Pacific and Indian Ocean. In fact, the Indo-Pacific region is hypothesized as the center of origin for *S. lewini*, with the oldest extant scalloped hammerhead species found in this region (Duncan et al. 2006, Daly-Engel et al. 2012). Studies using maternally inherited genetic data show strong genetic differentiation in populations separated by large expanses of ocean, but less so between populations connected by a continuous coastline (Duncan et al. 2006, Daly-Engel et al. 2012). Given the low spatial structure and high connectivity of the habitats found along the Indian and western Pacific coasts, it is likely that this region contains a heavily mixed population. A study that examined male-mediated gene flow also supports this assumption. A comparison of microsatellite loci samples from the Indian Ocean, specifically samples from the Seychelles and Western Australia, as well as South Africa and Western Australia, showed either no or weak population differentiation (Daly-Engel et al. 2012). Along the east coast of Australia, Ovenden et al. (2011) found no evidence of more than one genetic stock of *S. lewini*. The samples, spanning almost 2000 km of coastline on Australia's east coast, showed genetic homogeneity based on eight microsatellite loci and mtDNA markers, suggesting long-shore dispersal and panmixia of scalloped hammerhead sharks (Ovenden et al. 2011). No genetic subdivision existed between Indonesia and the eastern or northern coasts of Australia, suggesting this species may move widely between Australia and Indonesia (Ovenden et al. 2009, Ovenden et al. 2011). Additionally, there was no evidence of genetic structure between the Pacific and Indian Oceans, as samples from Taiwan, Philippines, and Eastern Australia in the West Pacific showed no population differentiation from samples in the Indian Ocean ($F_{ST} = -0.018$, $P=.470$) (Daly-Engel et al. 2012), suggesting long-distance male-biased dispersal, most likely along continental margins.

Following the same lines, the Central Pacific population is markedly separate from other populations of the same taxon as a consequence of physical factors. The Central Pacific population is located in the middle of the Pacific Ocean, primarily comprised of the Hawaiian Archipelago, which includes the inhabited main islands in the southeast as well as the largely uninhabited Papahānaumokuākea Marine National Monument which extends from Nihoa to Kure Atoll in the northwest. Johnston Atoll is also included in this population due to its proximity to the Hawaiian Archipelago. In order to reach the other neighboring populations in the Western and Eastern Pacific, the Central Pacific scalloped hammerhead sharks would have to travel over hundreds to thousands of kilometers, overcoming various bathymetric barriers. However, as mentioned previously, tagging studies and mtDNA analyses suggest this species rarely makes long-distance oceanic migrations. Instead, the data supports the assumption that this species more commonly disperses along continuous coastlines, continental margins, and submarine features, such as chains of seamounts, commonly associated with scalloped hammerhead shark "hotspots". This is true even for island populations, with tagging studies revealing *S. lewini* migrations to nearby islands and mainlands, but no evidence or data to support oceanic migrations. For example, Bessudo et al. (2011) observed scalloped hammerhead sharks in the Eastern Tropical Pacific (ETP) and noted that although they are capable of covering long distances (i.e. 1941 km), the sharks remain within the area, moving widely around and occasionally between neighboring islands with similar oceanographic conditions. A study conducted in a nursery ground in Hawaii revealed that sharks travelled as far as 5.1 km in the same day, but the mean distance between capture points was only 1.6 km (Duncan and Holland 2006). Another tagging study in Hawaii indicated that adult males remained "coastal" within the archipelago (Holland personal communication, 2012). Analysis of mtDNA from scalloped hammerhead populations also supports this theory of limited oceanic dispersal, with significant genetic discontinuity associated with oceanic barriers but less so along continental margins (Duncan et al. 2006, Chapman et al. 2009, Daly-Engel et al. 2012).

In addition to the physical oceanic barriers, the population in the Central Pacific is delimited from other populations of *S. lewini* by international governmental boundaries across which regulatory mechanisms differ substantially. Compared to the neighboring West Pacific and Eastern Tropic Pacific, the Central Pacific has many management controls in place that protect important scalloped hammerhead habitats and nursery grounds, as well as fishing regulations that control the exploitation of the species. For example, the fisheries of the Hawaiian Islands are managed by both federal regulations, such as the Magnuson-Stevens Fishery Conservation and Management Act, and also by state regulations aimed at protecting and conserving marine resources. Currently, there are no directed shark fisheries in Hawaii; however, scalloped hammerheads are sometimes caught as bycatch on Hawaii longline gear. The Hawaii pelagic longline (PLL) fishery, which operates mainly in the Northern Central Pacific Ocean, is managed through a Fishery Management Plan (FMP) developed by the Western Pacific Regional Fishery Management Council and approved by NMFS under the authority of the Magnuson-Stevens Fishery Conservation and Management Act. In an effort to reduce bycatch in this fishery, Hawaii has implemented a number of gear regulations and fishery management measures. For example, a 50-75 nm longline fishing buffer zone exists around the Hawaiian Islands, helping to protect scalloped hammerheads from being caught near popular nursery grounds and their coastal adult habitat. Periodic closures and effort limits in the shallow-set sector of this fishery (which has higher shark catch rate) also helps protect scalloped hammerheads in this fishery. In addition, mandatory fishery observers have been monitoring both sectors (shallow and deep) of the limited-entry Hawaii-based PLL fishery since 1994, with observer coverage increasing in recent years to provide a more comprehensive bycatch dataset. Shark finning was also banned in 2000 for the Hawaii-based longline fishery, and a State of

Hawaii ban on the possession of shark fins was imposed in 2010 (State of Hawaii SB2169). In the neighboring ETP, as well as other islands and countries in the West Pacific, management regulations are either missing or inadequate, and enforcement is weak. The island country of Palau, for example, is a shark sanctuary with around 621,600 km^2 of protected waters; however, the country has only one patrol boat to enforce fishing regulations and thus cases of illegal fishing are frequently reported (Turagabeci 2012). Therefore, it is reasonable to assume that the differences in the control of exploitation and regulatory mechanisms between the Central Pacific and the surrounding countries could influence the conservation status of the scalloped hammerhead population around the Central Pacific region.

With regards to the significance, the Central Pacific region can be deemed as biologically and ecologically significant from the other regions due to its central location in the Pacific and evolutionary importance. The Central Pacific region encompasses a vast portion of the scalloped hammerhead sharks' range in the Pacific Ocean. Loss of this region would result in a decline in the number of suitable and productive nursery habitats and create a significant gap in the range of this taxon. Also, from an evolutionary standpoint, the Central Pacific island population is thought to be the "stepping stone" for colonization to the isolated ETP as Duncan et al. (2006) observed two shared haplotypes between Hawaii and the otherwise isolated ETP population. In other words, in the case of an ETP extinction and loss of the Central Pacific population, it would require two separate and rare colonization events to repopulate the ETP population: one for the re-colonization of the Central Pacific and another for the re-colonization of the ETP. Thus, on an evolutionary timescale, loss of the Central Pacific population would result in a significant truncation in the range of the taxon.

In the ETP, samples of *S. lewini* tissue showed significant levels of both mtDNA and microsatellite structure when compared to samples from the Indo-Pacific, Central Pacific, and Atlantic Ocean. Using biparentally-inherited DNA, Daly-Engel et al. (2012) found that scalloped hammerhead samples from the ETP were statistically differentiated from the nearby Hawaii samples ($P \leq 0.01$), but also from every other site sampled in the Pacific, Indian, and Atlantic Oceans ($P \leq 0.001$), providing support for the genetic isolation of the eastern Pacific populations of scalloped hammerheads. Nance et al. (2011) also found genetically isolated populations within the ETP and suggested that the ETP *S. lewini* population may actually exist as a series of small and genetically separate populations. The low genetic diversity that has been observed in the eastern Pacific may indicate peripatric speciation from the Indo-West Pacific hammerhead population (Duncan et al. 2006). From an evolutionary standpoint, the *S. lewini* in the ETP is a relatively young population (<100,000 years old, Duncan et al. 2006, Nance et al. 2011), but has already undergone significant declines (1-3 orders of magnitude) from the ancestral effective population size (onset of decline ~3600 – 12,000 years ago) (Nance et al. 2011). When compared to samples from the Gulf of Mexico, Daly-Engel et al. (2012) found high levels of allelic differentiation ($F_{ST} = 0.519$, $P \leq 0.001$), suggesting that these two populations have never mixed and thus make up the opposing ends of the *S. lewini* dispersal range from the Indo-Pacific. As mentioned above, although Hawaii may be the "stepping stone" for colonization into the ETP region, Duncan et al. (2006) indicate that recovery of a depleted eastern Pacific population would occur slowly through reproduction and not quickly through immigration. Thus, loss of the ETP segment would result in a significant gap in the range of this taxon and potentially unique genetic characteristics that allow it to survive in the variable climate of the eastern Pacific.

Overall, the available data suggest that there are discrete and significant *S. lewini* populations in the Indo-West Pacific, the Central Pacific, and in the Eastern Pacific. The significant mtDNA structure across ocean basins indicates that female scalloped hammerheads remain close to coastlines and areas of nursery habitats, possibly displaying weak philopatry (Duncan et al. 2006, Chapman et al. 2009). Lack of significant microsatellite genetic structure across the Indian and West Pacific Oceans (Daly-Engel et al. 2012) suggests males of the species may make long-distance migrations along continental margins, coastlines, and bathymetric features between ocean basins in this region. Although Daly-Engel et al. (2012) found no significant microsatellite genetic structure between *S. lewini* samples in the Indo-West Pacific and the Central Pacific, tagging studies suggest this species rarely conducts open ocean migrations (Kohler and Turner 2001, Bessudo et al. 2011, Diemer et al. 2011, Holland personal communication, 2012). Thus, the Indo-West Pacific population and Central Pacific populations are discrete and significant from the Atlantic and Eastern Pacific populations as a consequence of genetic differences, and from each other as a consequence of physical factors and differences in regulatory mechanisms across international governmental boundaries. In conclusion, there are three population segments that will be considered DPSs for purposes under the ESA: the Indo-West Pacific population (which includes the tropical and subtropical waters of the Indian Ocean and West Pacific and encompasses the island chains in the West and South Pacific), the Central Pacific population, and the Eastern Pacific population.

<u>Conclusion</u>

Based on the criteria for discreteness and significance under the DPS policy, the DPSs that will be considered in this extinction risk assessment for the scalloped hammerhead shark are as follows: Northwest Atlantic & Gulf of Mexico DPS, Central & Southwest Atlantic DPS, Eastern Atlantic DPS, Indo-West Pacific DPS, Central Pacific DPS, and the Eastern Pacific DPS. Figure 1 displays the locations of these DPSs and Table 1 summarizes the DPS rationale:

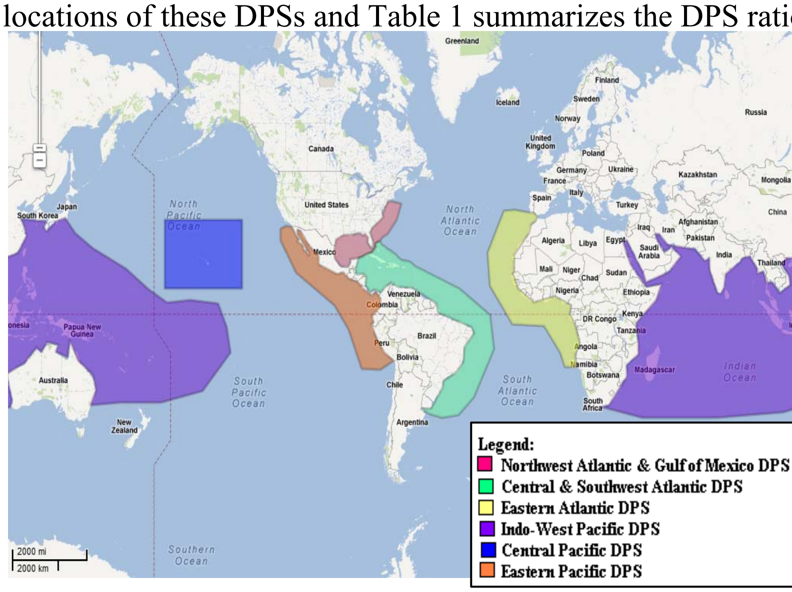

Figure 1. Map of the six scalloped hammerhead DPS locations.

Table 1. Summary of qualifying population segments under the DPS Policy.

DPS	Discreteness	Significance
Northwest Atlantic & GOM	*Genetic Differences*: Isolation from Pacific, Indian, and other Atlantic subpopulations. *Physical/Behavior Factors*: Tagging studies of this DPS show limited movements (median distance = 100 km); no tagged sharks observed in Central America or Brazil (i.e. no mixing with Central & SW Atlantic DPS). Markedly separate from other DPSs by bathymetric barriers. *International Boundaries*: Significant U.S. fishery management measures for this DPS separate it from Central & SW Atlantic DPS (with the exception of U.S. EEZ Caribbean); differences in *S. lewini* exploitation coincide with these international boundaries.	*Loss of segment would result in significant gap in the range of the taxon* (from New Jersey to Florida and throughout the GOM): unlikely to be rapidly repopulated through immigration.
Central & Southwest Atlantic	*Genetic Differences*: Isolation from Pacific, Indian, and other Atlantic subpopulations. *Physical/Behavior Factors*: General tagging studies and genetics suggest *S. lewini* does not travel over open ocean but makes limited migrations along coastlines, continental margins, and submarine features (such as seamounts). No observed mixing with NW Atlantic & GOM population. Markedly separate from other DPSs by bathymetric barriers. *International Boundaries*: Fishery management measures lacking in this DPS compared to NW Atlantic & GOM DPS (with the exception of U.S. EEZ Caribbean); differences in *S. lewini* exploitation coincide with these international boundaries.	*Loss of segment would result in significant gap in the range of the taxon* (from Caribbean to Uruguay): unlikely to be rapidly repopulated through immigration.
Eastern Atlantic	*Genetic Differences*: Isolation from Pacific, Indian, and other Atlantic subpopulations. *Physical/Behavior Factors:* General tagging studies and genetics suggest *S. lewini* does not travel over open ocean but makes limited migrations along coastlines, continental margins, and submarine features (such as seamounts). Genetic studies show migration around the southern tip of Africa is rare	*Loss of segment would result in significant gap in the range of the taxon* (from Mediterranean Sea to Namibia): unlikely to be rapidly repopulated through immigration.

	(i.e. no mixing with Indo-Pacific DPS). Markedly separate from other DPSs by bathymetric barriers.	
Indo-West Pacific	*Genetic Differences*: Isolation from Eastern Pacific and Atlantic subpopulations. *Physical/Behavior Factors*: Tagging studies of this DPS show limited distance migrations (avg distance = 147.8 km, max = 629 km); but lack of genetic differentiation and high connectivity of habitat suggest males mix readily and travel long distances along coastlines and continental margins. Genetic studies show migration around the southern tip of Africa is rare (i.e. no mixing with Eastern Atlantic DPS). Markedly separate from other DPSs by bathymetric barriers. *International Boundaries*: Fishery management measures lacking in this DPS compared to Central Pacific DPS; differences in *S. lewini* exploitation coincide with these international boundaries.	*Loss of segment would result in significant gap in the range of the taxon* (from South Africa to Japan and south to Australia and New Caledonia and neighboring Island countries): unlikely to be rapidly repopulated through immigration.
Central Pacific	*Genetic Differences:* Isolation from Eastern Pacific and Atlantic subpopulations. *Physical/Behavior Factors*: Tagging studies of this DPS show limited distance migrations (avg distance = 1.6 km; max = 5.1km), with adults remaining "coastal" within the archipelago. Markedly separate from other DPSs by bathymetric barriers. *International Boundaries*: Significant U.S. fishery management measures for this DPS separate it from Indo-Pacific DPS; differences in *S. lewini* exploitation coincide with these international boundaries.	*Loss of segment would result in significant gap in the range of the taxon* and valuable and productive nursery grounds (from Kure Atoll to Johnston Atoll, including the Hawaiian Archipelago). This DPS is seen as the stepping stone for evolutionary colonization to the ETP; unlikely to be rapidly repopulated through immigration.
Eastern Pacific	*Genetic Differences:* Isolation from Indo-Pacific, Central Pacific, and Atlantic subpopulations. *Physical/Behavior Factors*: Tagging studies of this DPS suggest wide movements around islands and occasional long-distance dispersals (max = 1941km) traveling back and forth between neighboring islands with similar oceanographic conditions. Markedly separate from other DPSs by bathymetric barriers.	*Loss of segment would result in significant gap in the range of the taxon* (from southern CA, USA to Peru): unlikely to be rapidly repopulated through immigration.

EXTINCTION RISK ANALYSIS

Often the ability to measure or document risk factors is limited, and information is not quantitative and very often lacking altogether. Therefore, in assessing risk, it is important to include both qualitative and quantitative information. In previous NMFS status reviews, Biological Review Teams have used a risk matrix method to organize and summarize the professional judgment of a panel of knowledgeable scientists. This approach is described in detail by Wainright and Kope (1999) and has been used in Pacific salmonid status reviews as well as in reviews of Pacific hake, walleye pollock, Pacific cod, Puget Sound rockfishes, Pacific herring, and black abalone (see http://www.nmfs.noaa.gov/pr/species/ for links to these reviews). In the risk matrix approach, the collective condition of individual populations is summarized at the DPS level according to four demographic risk criteria: abundance, growth rate/productivity, spatial structure/connectivity, and diversity. These viability criteria, outlined in McElhany et al. (2000), reflect concepts that are well-founded in conservation biology and that individually and collectively provide strong indicators of extinction risk. Using these concepts, the ERA team estimated the extinction risk of the scalloped hammerhead shark DPSs based on demographic risks currently and in the foreseeable future. Likewise, the ERA team performed a threats assessment for each DPS by scoring the severity of current threats to the DPS as well as predicting whether the threat will increase, decrease, or stay the same in the foreseeable future. The summary of the demographic risks and threats obtained by this approach was then considered by the ERA team in determining the DPS' overall level of extinction risk. Specifics on each analysis are provided below.

Foreseeable future

For the purpose of this extinction risk analysis, the term "Foreseeable future" was defined as the timeframe over which threats can be predicted reliably to impact the biological status of the species. After considering the life history of the scalloped hammerhead shark, availability of data, and type of threats, the team decided that the foreseeable future should be defined as approximately three generation times for the scalloped hammerhead shark, or 50 years.

Methods

Demographic Risks Analysis

After reviewing all relevant biological and commercial information for the species, including: absolute abundance of each DPS and its spatial and temporal distribution; current abundance in relation to historical abundance and trends in abundance based on indices such as catch statistics; natural and human-influenced factors that cause variability in survival and abundance; and possible threats to genetic integrity; each ERA team member assigned a risk score to each of the four demographic criteria (abundance, growth rate/productivity, spatial structure/connectivity, diversity). Risks for each demographic criterion were ranked on a scale of 1 (no or very low risk) to 5 (very high risk). Below are the definitions that the team used for each ranking:

1 = No or very low risk: It is unlikely that this factor contributes significantly to risk of extinction, either by itself or in combination with other factors

2 = Low risk: It is unlikely that this factor contributes significantly to risk of extinction by itself, but some concern that it may, in combination with other factors.

3 = Moderate risk: It is likely that this factor in combination with others contributes significantly to risk of extinction.

4 = High risk: It is likely that this factor, by itself, contributes significantly to risk of extinction

5 = Very high risk: It is highly likely that this factor, by itself, contributes significantly to risk of extinction

The team members were given a template to fill out and asked to rank the demographic risk currently and in the foreseeable future for each DPS (Table 2). After scores were provided, the team discussed the range of perspectives for each of the demographic risks and the supporting data on which it was based, and was given the opportunity to revise scores if desired after the discussion. The scores were then tallied (mode, median, range) and reviewed by the ERA team and considered in making the overall risk determination. Although this process helps to integrate and summarize a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into a determination of overall extinction risk. Other descriptive statistics, such as mean, variance, and standard deviation, were not calculated as the ERA team felt these metrics would add artificial precision or accuracy to the results.

Table 2. Template for the risk matrix used in ERA team deliberations. The matrix is divided into four sections that correspond to the parameters for assessing population viability (McElhany et al. 2000).

DPS:

RISK CATEGORY	SCORE (1-5)
Abundance Comments:	Now: Foreseeable Future:
Growth rate/productivity Comments:	Now: Foreseeable Future:
Spatial structure and connectivity Comments:	Now: Foreseeable Future:
Diversity Comments:	Now: Foreseeable Future:

Threats Assessment

Section 4(a)(1) of the ESA requires the agency to determine whether the species is endangered or threatened because of any of the following factors:

1) destruction or modification of habitat;
2) overutilization for commercial, recreational, scientific, or educational purposes;
3) disease or predation;
4) inadequacy of existing regulatory mechanisms; or
5) other natural or human factors

After reviewing the best available scientific and commercial data on the scalloped hammerhead shark (see the Status Review document for details), the ERA team identified and evaluated the following potential threats to the species: nursery habitat loss or degradation, overutilization by industrial/commercial fisheries, artisanal fisheries, and recreational fisheries, competition, disease, predation, inadequacy of current regulatory mechanisms, illegal, unreported, and unregulated (IUU) fishing, at-vessel fishing mortality, and the schooling behavior of scalloped hammerhead sharks.

Similar to the demographics risk analysis, the ERA team members were given a template to fill out and asked to rank the current severity of the threats to the extinction risk of the DPS as well as forecast whether the threats would increase (+), decrease (-), or stay the same (0) in the foreseeable future (Table 3). The rankings were defined the same as those in the demographics analysis. After scores were provided, the team discussed the range of perspectives for each of the threats, and the supporting data on which it was based, and was given the opportunity to revise scores if desired after the discussion. The scores were then tallied (mode, median, range) and reviewed by the ERA team and considered in making the overall risk determination.

Table 3. Template for the threats assessment used in ERA team deliberations.

	Nursery habitat loss/degradation	Industrial /Commercial fisheries (including bycatch)	Artisanal fisheries	Recreational fisheries	Competition	Disease	Predation	Current regulatory mechanisms	IUU fishing	At-vessel fishing mortality (biological)	Schooling Behavior
Risk to Scalloped Hammerhead Shark (1-5) (Now)											
Forecast of threats (+,0,-) (50 years)											
ESA Section 4(a)(1) Factor	Habitat destruction, modification or curtailment	Overutilization			Competition, disease, or predation			Inadequacy of existing regulatory mechanisms		Other	

Comments:

Overall Level of Extinction Risk Analysis

Guided by the results from the demographics risk analysis as well as threats assessment, the ERA team members used their informed professional judgment to make an overall extinction risk determination for the DPS now and in the foreseeable future. For these analyses, the ERA team defined five levels of extinction risk:

> 1 = No or very low risk: It is unlikely that this DPS is at risk of extinction due to projected threats or trends in abundance, productivity, spatial structure, or diversity.
>
> 2 = Low risk: It is unlikely that this DPS is at risk of extinction due to trends in abundance, productivity, spatial structure or diversity; however, current threats (or projected threats) may be (or will be) altering those trends but not yet by enough to cause the species to be influenced by stochastic or depensatory processes.
>
> 3 = Moderate risk: The DPS exhibits a trajectory indicating that it is approaching a level of abundance, productivity, spatial structure, and or/diversity that places its current or future persistence in question. A DPS may be at moderate risk of extinction due to declining trends in abundance, productivity, spatial structure, or diversity and current or projected threats that inhibit the reversal of these trends.
>
> 4 = High risk: The DPS is at or near a level of abundance, productivity, spatial structure, and or/diversity that places its current or future persistence in question. Similarly, it faces clear and present threats that are likely to create such demographic risks.
>
> 5 = Very high risk: The DPS is strongly influenced by stochastic or depensatory processes, facing current threats exacerbating the demographic risks, and indicating imminent extinction.

To allow individuals to express uncertainty in determining the overall level of extinction risk facing the species, the ERA team adopted the “likelihood point” (FEMAT) method (see Table 4 for template). This approach has been used in previous status reviews (e.g. Pacific salmon, Southern Resident Killer Whale, Puget Sound Rockfish, Pacific herring, and black abalone) to structure the team’s thinking and express levels of uncertainty in assigning risk categories. For this approach, each team member distributed 10 ‘likelihood points’ among the five levels of risks. The scores were then tallied (mode, median, range) and summarized for each DPS.

Finally, the ERA team did not make recommendations as to whether the species should be listed as threatened or endangered. Rather, the ERA team drew scientific conclusions about the overall risk of extinction faced by the species under present conditions and in the foreseeable future based on an evaluation of the species’ demographic risks and assessment of threats.

Table 4. Template for the overall level of extinction risk analysis used in ERA team deliberations.

Overall level of extinction risk NOW					
	1 = No or Very low risk	2 = Low risk	3= Moderate Risk	4 = High risk	5 = Very high risk
Number of likelihood points					

Overall level of extinction risk through the foreseeable future (50 years)					
	1 = No or Very low risk	2 = Low risk	3= Moderate Risk	4 = High risk	5 = Very high risk
Number of likelihood points					

Extinction Risk Results and Conclusions for Each Scalloped Hammerhead Shark DPS

<u>Northwest Atlantic & Gulf of Mexico DPS</u>

Evaluation of Demographic Risks

<u>Abundance</u>

ERA team scores for current abundance of the Northwest Atlantic & Gulf of Mexico DPS ranged from 2 to 4 with a modal and median score of 3. A score of 3 represents moderate risk, meaning that current trends and levels of abundance in combination with other factors (demographic or threats), contributes significantly to risk of extinction. ERA team scores for abundance in the foreseeable future ranged from 1 to 3 with a modal and median score of 2. A score of 2 represents low risk, meaning that future levels of abundance are unlikely to contribute significantly to risk of extinction, but there is some concern that they may, in combination with other factors.

The ERA team members agreed that this DPS had enough good data to adequately judge scalloped hammerhead shark abundance and trends. The team relied mainly upon the findings of the Hayes et al. (2009) stock assessment, which NMFS reviewed and determined to be complete and appropriate for management decisions. Compared with former abundance numbers, there have been significant declines in the scalloped hammerhead stock in the Northwest Atlantic and Gulf of Mexico. In 2005, it was estimated that the population had declined by over 80% since ~1981. However, from 1995 to 2005, the estimated population numbers have remained fairly stable (Hayes et al. 2009), and using the Hayes et al. (2009) assumptions, there is a 91% probability of rebuilding under 2005 catch levels within 30 years. From 2006 to 2010, the U.S. scalloped hammerhead harvest has been below the 2005 catch levels, and stronger management measures have been in place. Also, a scalloped hammerhead shark rebuilding plan is expected in

2013. As such, the ERA team felt that the future levels of abundance of the Northwest Atlantic and Gulf of Mexico stock are unlikely to contribute significantly to risk of extinction by themselves.

Growth rate/productivity

ERA team scores for current growth rate and productivity of the Northwest Atlantic & Gulf of Mexico DPS ranged from 2 to 3 with a modal and median score of 3. A score of 3 represents moderate risk, meaning that growth rate/productivity in combination with other factors (such as low abundance), contributes significantly to risk of extinction. ERA team scores for growth rate/productivity in the foreseeable future ranged from 2 to 3 with a modal and median score of 3, representing moderate risk.

The ERA team members noted that sharks, in general, have lower reproductive rates and growth rates compared to bony fishes. Estimates for the intrinsic rate of increase (r) for scalloped hammerhead sharks are relatively low, ranging from 0.028 to 0.121, suggesting general vulnerability to depletion. However, compared to other chondrichthyan species, scalloped hammerhead sharks may not be as vulnerable to overexploitation by pelagic longline fisheries as some other species (i.e., silky shark) (Cortés et al. 2010, ICCAT 2012). Given that these sharks have rather low growth rates but moderate rebound potential to pelagic longline fisheries common in this region, the group felt that this factor currently contributed a moderate risk to the DPS and was not likely to change in the foreseeable future.

Spatial structure/connectivity

ERA team scores for the current spatial structure/connectivity of the Northwest Atlantic & Gulf of Mexico DPS ranged from 2 to 3 with a modal and median score of 2. A score of 2 represents low risk, meaning that population spatial structure and connectivity are unlikely to contribute significantly to risk of extinction by themselves, but may, in combination with other factors. ERA team scores for spatial structure/connectivity in the foreseeable future ranged from 1 to 3 with a modal and median score of 2, again representing low risk.

ERA team members felt that the Northwest Atlantic & Gulf of Mexico DPS had a moderate degree of isolation compared to, for example, the eastern Atlantic DPS. Habitat loss does not seem to be an issue in this area, with extensive essential fish habitat identified and ranging from the coastal areas in the Gulf of Mexico from Texas to the southern west coast of Florida and along the Atlantic US southeast coast from Florida up to Long Island, NY. It is not thought that this factor will change over time.

Diversity

Each ERA team member scored a 1 for the diversity demographic factor for the Northwest Atlantic & Gulf of Mexico DPS currently and in the foreseeable future. A score of 1 represents no or very low risk, meaning it is unlikely that diversity contributes significantly to this DPS's risk of extinction.

Currently there are no known ecological or human-caused factors that have been found to substantially alter the rate of gene flow among this population. The species seems quite adaptable and ERA team members did not feel there was a reason to believe that there is a situation of a genetic bottleneck or other imminent threat of extinction in genetic terms currently or in the foreseeable future.

Threats Assessment

The following table gives the results of the ERA team's analysis of the severity of threats to the Northwest Atlantic & Gulf of Mexico DPS.

	Current			Foreseeable Future		
Threat	**Mode**	**Median**	**Range**	**Mode**	**Median**	**Range**
Nursery habitat loss/degradation	2	2	(1-3)	0	0	0
Industrial/Commercial fisheries	3	3	(2-3)	-	-	(- to +)
Artisanal fisheries	1	1	(1-2)	0	0	(0 to +)
Recreational fisheries	3	3	(2-3)	-	-	(- to +)
Competition	1	1	1	0	0	0
Disease	1	1	1	0	0	0
Predation	1	1	1	0	0	0
Current regulatory mechanisms	2	2	(1-2)	-	-	-
IUU fishing	3	3	(2-4)	+	+	(0 to +)
At-vessel fishing mortality	4	4	(4-5)	-	-	(- to 0)
Schooling Behavior	2	2	(2-4)	0	0	(- to +)

The ERA team ranked the at-vessel fishing mortality rate of the scalloped hammerhead shark as the most serious threat to the persistence of this DPS. Because the scalloped hammerhead shark is an obligate ram ventilator, and therefore must swim to breath, this species suffers very high at-vessel fishing mortality in bottom longline fisheries (Morgan and Burgess 2007, Macbeth et al. 2009). BLL gear soak times longer than 4 hours have resulted in > 65% mortality in scalloped hammerhead sharks (Morgan et al. 2009). Because soak times of longline gears are difficult to regulate or enforce, this biological factor of the scalloped hammerhead shark is a significant threat to the species, and thus was ranked as a high risk to extinction. Threats that, in combination with others, were thought to contribute significantly to the risk of extinction included commercial fisheries, recreational fisheries, and IUU fishing. The decline in the scalloped hammerhead shark can mainly be attributed to commercial and recreational fishing. As previously stated, this DPS has suffered over an 80% decline since 1981. However, with the passage of the U.S. Shark Conservation Act, stronger fishery management regulations, and the implementation of the ICCAT recommendations, the threat of overutilization by commercial and recreational fisherman is expected to decline in the foreseeable future. Per the Hayes et al. (2009) stock assessment, there is a 91% probability of rebuilding under 2005 catch levels within 30 years and an 86% probability of rebuilding within 20 years. The threat of IUU fishing, however, is expected to increase. Currently, there is illegal harvesting of this DPS in the Gulf of Mexico, primarily at the hands of Mexican fisherman. Estimates based on 2000-2005 data place IUU catch anywhere from 3-56% of the total U.S. commercial shark quota and between 6 and

108% of the Gulf of Mexico regional commercial quota (Brewster-Geisz and Eytcheson 2005), indicating a high degree of uncertainty surrounding the impact of IUU fishing on U.S. fishing quotas. Currently, this IUU threat is thought to pose a moderate risk of extinction to this DPS and without a way to control it, the threat is expected to increase in the foreseeable future.

Overall Risk Summary

None of the team members placed a likelihood point in the "Very high risk" category for the overall level of extinction risk now or in the foreseeable future. Likelihood points attributed to the other categories for the current level of extinction risk are as follows: No or Very Low Risk (6/50), Low Risk (20/50), Moderate Risk (17/50), High Risk (7/50). Likelihood points attributed to the other categories for the level of extinction risk in the foreseeable future are as follows: No or Very Low Risk (11/50), Low Risk (26/50), Moderate Risk (12/50), High Risk (1/50). Based on the likelihood point distributions, the team was fairly certain that the DPS currently has a low to moderate risk of extinction. However, the difference of only three likelihood points separating these two risk categories indicates a level of uncertainty as to the severity of the current threats and demographic risks. This level of uncertainty diminishes in the foreseeable future, with the increased number and majority of likelihood points for the low risk category.

The ERA team was mainly concerned about the significant decline in the Northwest Atlantic and Gulf of Mexico DPS abundance, which was attributed to commercial and recreational overfishing that began in the 1980s. Hayes et al. (2009) estimated a population size in 2005 at ~25,000 - 28,000. Although there were some concerns about the significant decline in absolute abundance, the high at-vessel mortality rate, and the low intrinsic rate of population growth, because of stronger fishery management measures put in place since the stock assessment results, the ERA team felt that the main threat to the DPS of overutilization would decrease in the foreseeable future. Thus, the population should be allowed to rebuild and the contribution of the demographic abundance factor to the DPS's extinction risk should be decreasing.

Overall, the ERA team ranked the overall risk of extinction for the Northwest Atlantic and Gulf of Mexico DPS as a 2 now and in the foreseeable future, which means the team thought that it is unlikely that this DPS is at risk of extinction throughout all or a significant portion of its range due to trends in abundance, productivity, spatial structure or diversity. However, current or projected threats may be altering those trends but not yet by enough to cause the species to be influenced by stochastic or depensatory processes.

Central and Southwest Atlantic DPS

Evaluation of Demographic Risks

Abundance

ERA team scores for current abundance of the Central and Southwest Atlantic DPS ranged from 3 to 4 with a modal and median score of 4. A score of 4 represents high risk, meaning that current trends and levels of abundance are likely to contribute significantly to risk of extinction. ERA team scores for abundance in the foreseeable future ranged from 4 to 5 with a modal and median score of 4. Thus, future levels of abundance remain likely as a factor that contributes significantly to this DPS's risk of extinction.

The ERA team members commented that abundance numbers for this DPS are unavailable but likely similar to, and probably worse than, those found in the Northwest Atlantic & Gulf of Mexico DPS. Amorim et al. (1998) noted declines in the late 1990's, with heavy fishing by longliners leading to a decrease in the population off the coast of Brazil. According to the FAO global capture production database, Brazil reported a significant increase in catch of *S. lewini* from 30 tonnes in 1999 to 262 tonnes in 2000. In 2001 and 2002, reported catches almost doubled to 507 and 508 tonnes respectively before decreasing to a low of 87 tonnes in 2009. Given the reports of heavy inshore and coastal fishing of all age classes of scalloped hammerheads in this DPS, the ERA team felt that the current and future levels of abundance of the Central and Southwest Atlantic DPS are likely to contribute significantly to risk of extinction.

<u>Growth rate/productivity</u>
ERA team scores for current growth rate and productivity of the Central and Southwest Atlantic DPS ranged from 2 to 3 with a modal and median score of 3. A score of 3 represents moderate risk, meaning that growth rate/productivity in combination with other factors (such as low abundance), contributes significantly to risk of extinction. ERA team scores for growth rate/productivity in the foreseeable future ranged from 2 to 3 with a modal and median score of 3, again representing moderate risk.

The ERA team members noted that the risk of this demographic factor contributing to extinction is similar to what has already been described for the Northwest Atlantic and Gulf of Mexico DPS. These sharks have rather low growth rates but moderate rebound potential to pelagic longline fisheries common in this region (Cortés et al. 2010, ICCAT 2012). However, this DPS also experiences heavy inshore fishing by gillnets and trawl nets. Given the relatively low intrinsic rate of increase estimated for this species, the group felt that this factor currently contributed a moderate risk to the DPS and was not likely to change in the foreseeable future.

<u>Spatial structure/connectivity</u>
The ERA team scored the current spatial structure/connectivity of the Central and Southwest Atlantic DPS as a 2. A score of 2 represents low risk, meaning that population spatial structure and connectivity are unlikely to contribute significantly to risk of extinction by themselves, but may, in combination with other factors. ERA team scores for spatial structure/connectivity in the foreseeable future ranged from 1 to 2 with a modal and median score of 2, again representing low risk.

ERA team members felt that the Central and Southwest DPS seemed to have higher connectivity and less spatial structure than the Northwest Atlantic & Gulf of Mexico DPS. Habitat loss does not seem to be an issue in this area. It is not thought that this factor will change over time.

<u>Diversity</u>
Each ERA team member scored a 1 for the diversity demographic factor for the Central and Southwest Atlantic DPS currently and in the foreseeable future. A score of 1 represents no or very low risk, meaning it is unlikely that diversity contributes significantly to this DPS's risk of

extinction.

Currently there are no known ecological or human-caused factors that have been found to substantially alter the rate of gene flow among this population. The species seems quite adaptable and ERA team members did not feel there was a reason to believe that there is a situation of a genetic bottleneck or other imminent threat of extinction in genetic terms currently or in the foreseeable future.

Threats Assessment

The following table gives the results of the ERA team's analysis of the severity of threats to the Central and Southwest Atlantic DPS.

	Current			**Foreseeable Future**		
Threat	**Mode**	**Median**	**Range**	**Mode**	**Median**	**Range**
Nursery habitat loss/degradation	1	2	(1-3)	0	0	0
Industrial/Commercial fisheries	4	4	(3-4)	+	+	(- to +)
Artisanal fisheries	3	3	(2-4)	+	+	(0 to +)
Recreational fisheries	1	1	(1-3)	0	0	0
Competition	1	1	1	0	0	0
Disease	1	1	1	0	0	0
Predation	1	1	1	0	0	0
Current regulatory mechanisms	3	3	(2-3)	0	0	0
IUU fishing	3	3	(3-4)	+	+	(0 to +)
At-vessel fishing mortality	4	4	(4-5)	0	0	(- to 0)
Schooling Behavior	3	3	(3-4)	0	0	(0 to +)

The ERA team ranked industrial/commercial fisheries and the at-vessel fishing mortality of the scalloped hammerhead shark as the most serious threats to the persistence of this DPS, posing high risks for extinction. Brazil, the country that reports one of the highest scalloped hammerhead landings in South America, maintains heavy industrial fishing of this species off its coastal waters. Although ICCAT recommendations are slated for implementation in this country, Brazil offers no other species-specific protections for scalloped hammerheads in its waters. Similarly, artisanal and IUU fishing were ranked as moderate risks, contributing significantly to the risk of extinction when combined with other factors, such as the overutilization by commercial fishermen, high-at vessel mortality rate, and the lack of adequate regulatory mechanisms. In the Caribbean, *S. lewini* is commonly landed and often a target of artisanal fisheries off Trinidad and Tobago and Guyana as well as pelagic fisheries of the Eastern Caribbean, yet no shark conservation measures have been adopted (Shing 1999). Artisanal gillnet fisheries in Central America are also still active, and in Brazil, artisanal fisheries make up about 50% of the fishing sector. The schooling behavior of the scalloped hammerhead shark was also ranked as a moderate risk because this behavior makes the species especially susceptible to being caught in various fishing gears and, in combination with intense fishing pressure, significantly contributes to this DPS's risk of extinction. In Brazil, for example, schools of neonates and juveniles are caught in large numbers by coastal gillnets and recreational fishermen in inshore waters, and subsequently their abundance has significantly decreased over time (CITES 2010). Additionally, the driftnet fishery operating off the coast of southern Brazil has also been observed catching large numbers of juvenile *S. lewini*, and subsequently, experienced a decline in average catch between 2000 and 2005 (Kotas et al. 2008). Although Brazil added the scalloped hammerhead shark to its list of over-exploited species (Normative Instruction MMA nº 05) and established laws that limit pelagic gillnets and prohibit trawls in waters less than 3 nautical miles from the coast (equivalent to depths less than ~10m), enforcement of these laws has been weak and fishing in nursery areas continues to be a threat to the species (Baum et al. 2007). The threats of overutilization by commercial and artisanal fishermen and IUU fishing are projected to increase for this DPS in the foreseeable future.

Overall Risk Summary

None of the team members placed a likelihood point in the "No or very low risk" category for the overall level of extinction risk now or in the foreseeable future. Likelihood points attributed to the other categories for the current level of extinction risk are as follows: Low Risk (8/50), Moderate Risk (25/50), High Risk (14/50), and Very High Risk (3/50). Likelihood points attributed to the other categories for the level of extinction risk in the foreseeable future are as follows: Low Risk (8/50), Moderate Risk (20/50), High Risk (15/50), and Very High Risk (7/50). Based on the likelihood point distributions, the team was fairly certain that the DPS has a moderate risk of extinction now, receiving half of the votes, but expressed some uncertainty regarding the future level of extinction risk, increasing the number of likelihood points in the high and very high risk categories.

The ERA team was mainly concerned about the level of overutilization in the Central and Southwest Atlantic DPS and ranked the overall risk of extinction for this DPS as a 3, concluding that it had a moderate risk of extinction now and in the foreseeable future. The ERA team felt that the DPS is exhibiting a trajectory indicating that it is approaching a level of abundance and productivity that places its current and future persistence in question throughout its entire range; however, the team acknowledged that there is a lack of good abundance data or catch statistics. Yet, given the inadequacy of current regulatory mechanisms, the reports of heavy fishing, the high at-vessel mortality rate, and the projected increase of commercial, artisanal, and IUU fishing, the team does not envision a reversal of demographic trends in the foreseeable future that would lessen its risk of extinction.

<u>Eastern Atlantic DPS</u>

Evaluation of Demographic Risks

<u>Abundance</u>
ERA team scores for current abundance of the Eastern Atlantic DPS ranged from 3 to 4 with a modal and median score of 3. A score of 3 represents moderate risk, meaning that current trends and levels of abundance are likely to contribute significantly to risk of extinction in combination

with other factors. ERA team scores for abundance in the foreseeable future ranged from 3 to 5 with a modal and median score of 4. A score of 4 represents high risk, meaning that future abundance levels are likely to contribute significantly to the DPS risk of extinction.

The ERA team members commented that abundance numbers for this DPS are unavailable or unreliable but that trends likely reflect those found in the Northwest Atlantic & Gulf of Mexico DPS based on the similar fishing effort of longline fleets in this area (CITES 2010). Ferretti et al. (2008) estimated decreases of >99.99% in both biomass and abundance over the past 100 years in the Mediterranean Sea. However, an ERA team member pointed out that many of the hammerheads found in the Mediterranean are actually smooth not scalloped hammerheads.

Growth rate/productivity

ERA team scores for current growth rate and productivity of the Eastern Atlantic DPS ranged from 2 to 3 with a modal and median score of 3. A score of 3 represents moderate risk, meaning that growth rate/productivity in combination with other factors (such as low abundance), contributes significantly to risk of extinction. ERA team scores for growth rate/productivity in the foreseeable future ranged from 2 to 3 with a modal and median score of 3, again representing moderate risk.

The ERA team members noted that the risk of this demographic factor contributing to extinction is similar to what has already been described for the Northwest Atlantic and Gulf of Mexico DPS. These sharks have rather low growth rates but a moderate rebound potential to pelagic longline fisheries common in this region (Cortés et al. 2010). Given the relatively low intrinsic rate of increase estimated for this species, the group felt that this factor currently contributed a moderate risk to the DPS and was not likely to change in the foreseeable future.

Spatial structure/connectivity

ERA team scores for the current spatial structure/connectivity of the Eastern Atlantic DPS ranged from 1 to 3 with a mode of 1 and median score of 2. The team felt that population spatial structure and connectivity are unlikely to contribute significantly to risk of extinction by themselves, but may, in combination with other factors. ERA team scores for spatial structure/connectivity in the foreseeable future ranged from 1 to 2 with a modal and median score of 2, again representing a relatively low risk of extinction.

ERA team members mentioned that the Eastern Atlantic DPS seemed to have a higher connectivity and less spatial structure than the Central and Southwest DPS. Habitat loss does not seem to be an issue in this area. Although the Ferretti et al. (2008) data suggested a possible range contraction, with hammerheads no longer found in the Mediterranean Sea, it was questionable whether the range contraction was for smooth or scalloped hammerheads. Regardless, recent reports confirm the presence of both *S. lewini* and *S. zygaena* around southern Italy (Sperone et al. 2012). It is not thought that this factor will change over time.

Diversity

Each ERA team member scored a 1 for the diversity demographic factor for the Eastern Atlantic DPS currently and in the foreseeable future. A score of 1 represents no or very low risk, meaning it is unlikely that diversity contributes significantly to this DPS's risk of extinction.

Currently there are no known ecological or human-caused factors that have been found to substantially alter the rate of gene flow among this population. Based on mixed mitochondrial and nuclear markers, the number of migrants into this population from South Africa is estimated at ~1 per generation and 1.5 per generation from the Gulf of Mexico (Daly-Engel et al. 2012). The species seems quite adaptable and ERA team members did not feel there was a reason to believe that there is a situation of a genetic bottleneck or other imminent threat of extinction in genetic terms currently or in the foreseeable future.

Threats Assessment

The following table gives the results of the ERA team's analysis of the severity of threats to the Eastern Atlantic DPS.

	Current			**Foreseeable Future**		
Threat	**Mode**	**Median**	**Range**	**Mode**	**Median**	**Range**
Nursery habitat loss/degradation	1	1	(1-3)	+	+	(0 to +)
Industrial/Commercial fisheries	4	4	(3-4)	+	+	(- to +)
Artisanal fisheries	3	3	(3-4)	+	+	+
Recreational fisheries	1	1	(1-2)	0	0	0
Competition	1	1	1	0	0	0
Disease	1	1	1	0	0	0
Predation	1	1	1	0	0	0
Current regulatory mechanisms	3	3	(2-3)	0	0	0
IUU fishing	3	3	(3-5)	+	+	(0 to +)
At-vessel fishing mortality	4	4	(4-5)	0	0	0
Schooling Behavior	3	3	(3-4)	0	0	0

The ERA team ranked industrial/commercial fisheries and the at-vessel fishing mortality of the scalloped hammerhead shark as the most serious threats to the persistence of this DPS, posing high risks for extinction. Although species-specific data is unavailable from this region, hammerheads are a large component of the bycatch in the European pelagic freezer-trawler fishery that operates off Mauritania. Between 2001 – 2005, 42% of the retained pelagic megafauna bycatch consisted of hammerhead sharks (Zeeberg et al. 2006). Of concern, especially as it relates to abundance and recruitment to the population, is the fact that around 75% of the hammerhead catch were juveniles of 0.50 – 1.40 meters in length (Zeeberg et al. 2006). In addition, Spain, which leads the European nations in shark fishing, obtains 85% of its catch in Atlantic waters and was the number one exporter of shark fins to the Hong Kong market in 2008 (with a total of 2,646 t of shark fins). As scalloped hammerhead sharks are highly valued for their fins, and are the second most traded fin category in the Hong Kong market (Clarke et al. 2006a), it is likely that a great portion of the exported fins from Spain come from scalloped hammerhead sharks. The threat of overutilization by artisanal fisheries is also projected to increase to match the increasing demand for food/protein off the coast of West Africa. Large artisanal fisheries in Mauritania have been documented fishing great quantities of juvenile scalloped hammerhead sharks (CITES 2010). *S. lewini* is also caught in large numbers in the sciaenid fishery operating in this region. Additionally, some artisanal fisheries in West Africa even specialize in catching sphyrnid species (CITES 2010). As current regulatory measures in West Africa are either weak or absent, and with IUU fishing a serious problem in this area, heavy fishing on these sharks continues to occur and will likely contribute significantly to its risk of extinction in the foreseeable future.

Overall Risk Summary

None of the team members placed a likelihood point in the "No or very low risk" category for the overall level of extinction risk in the foreseeable future. Likelihood points attributed to the other categories for the current level of extinction risk are as follows: No or Very Low Risk (1/50), Low Risk (6/50), Moderate Risk (14/50), High Risk (18/50), and Very High Risk (11/50). Likelihood points attributed to the other categories for the level of extinction risk in the foreseeable future are as follows: Low Risk (7/50), Moderate Risk (14/50), High Risk (20/50), and Very High Risk (9/50). Based on the likelihood point distributions, the team was less certain about the current risk of extinction for this DPS, with the moderate risk category separated from the high risk category by only four likelihood points. However, in the foreseeable future, the team expressed increased certainty that the DPS would be at a high risk of extinction with more likelihood points added to this category while the moderate risk category remained the same.

The ERA team had serious concerns regarding the level of overutilization and lack of regulatory mechanisms in the Eastern Atlantic DPS, and thus ranked the overall risk of extinction for this DPS as a 4, concluding it had a high risk of extinction now and in the foreseeable future. Although Spain and other EU countries have implemented new regulations aimed at protecting this species in the Atlantic, these management measures are lacking in the West African region. Even the ICCAT recommendation, which prohibit catches of *S. lewini* by ICCAT fishing vessels, provide exemptions for developing countries. Many of the artisanal fisheries off the west coast of Africa use fishing gear, such as driftnets and fixed gillnets, that have been previously banned by other countries due to their detrimental effects on shark populations. Given the fact that scalloped hammerhead sharks tend to form large schools, they are more susceptible to these types of fishing gears, and as such, have been caught in large quantities off the West African coast from Mauritania to Sierra Leone. In 2010, the first year that Mauritania provided capture production statistics to FAO, Mauritania reported a total catch of 257 tonnes of *S. lewini*, the highest amount reported by any one country since 2003. With little regulation along the western African coast, and no evidence of this changing in the foreseeable future, the ERA team concluded that overutilization by artisanal, industrial, and IUU fishing is creating a DPS that is at or near a level of abundance and productivity that places its current and future persistence in question throughout its entire range.

<u>Indo-West Pacific DPS</u>

Evaluation of Demographic Risks

Abundance

ERA team scores for current abundance of the Indo-West Pacific DPS ranged from 3 to 4 with a modal and median score of 3. A score of 3 represents moderate risk, meaning that current trends and levels of abundance are likely to contribute significantly to risk of extinction in combination with other factors. ERA team scores for abundance in the foreseeable future ranged from 3 to 4 with a modal and median score of 4. A score of 4 represents high risk, meaning that future abundance levels are likely to contribute significantly to the DPS risk of extinction.

The ERA team members commented that much is unknown about abundance in this region, and the catch data from the IOTC is questionable. Some CPUE information from Australia and South Africa beach mesh programs suggest a declining population, but there is a high degree of uncertainty regarding the overall population size given the range of this DPS. There is also a significant gap in data for the northern portion of the Indian Ocean. However, given the large Indian Ocean artisanal fleet, past records of exploitation, and localized depletions of populations, the ERA members hypothesized that the abundance levels in the foreseeable future may decline to a level that would not provide the DPS adequate resilience to environmental or anthropogenic perturbations and thus contribute significantly to the DPS risk of extinction.

Growth rate/productivity

ERA team scores for current growth rate and productivity of the Indo-West Pacific DPS ranged from 2 to 3 with a modal and median score of 3. A score of 3 represents moderate risk, meaning that growth rate/productivity in combination with other factors (such as low abundance), contributes significantly to risk of extinction. ERA team scores for growth rate/productivity in the foreseeable future ranged from 2 to 3 with a modal and median score of 3, again representing moderate risk.

Given the relatively low intrinsic rate of increase estimated for this species, the group felt that this factor currently contributed a moderate risk to the DPS and was not likely to change in the foreseeable future.

Spatial structure/connectivity

ERA team scores for the current spatial structure/connectivity of the Indo-West Pacific DPS ranged from 2 to 3 with a modal and median score of 2. A score of 2 represents low risk, meaning that population spatial structure and connectivity are unlikely to contribute significantly to risk of extinction by themselves, but may, in combination with other factors. ERA team scores for spatial structure/connectivity in the foreseeable future ranged from 2 to 3 with a modal and median score of 2, again representing low risk.

ERA team members commented that the coastal habitats of this DPS are less connected than the other DPSs that have a contiguous coastline, but that the island regions are relatively close together, which should minimize ecological risk from lack of connectivity to habitat areas. There may be some concern of a contraction of the DPS range, as heavy fishing in Indonesian waters have caused a change in catch composition (large, valuable species replaced by smaller, short-lived species) and displaced fishing effort for larger sharks further west into Australian waters (Field et al. 2009).

Diversity
Each ERA team member scored a 1 for the diversity demographic factor for the Indo-West Pacific DPS currently and in the foreseeable future. A score of 1 represents no or very low risk, meaning it is unlikely that diversity contributes significantly to this DPS's risk of extinction.

Currently there are no known ecological or human-caused factors that have been found to substantially alter the rate of gene flow among this population. The Indo-West Pacific is thought to be the evolutionary origin of the scalloped hammerhead population. Based on mixed mitochondrial and nuclear markers, the number of migrants (per generation) into this DPS from Hawaii ranges from 2.32 to 4.14 (Daly-Engel et al. 2012). According to Daly-Engel et al. (2012) the nuclear allelic richness and heterozygosity are high in this DPS. The species seems quite adaptable and ERA team members did not feel there was a reason to believe that there is a situation of a genetic bottleneck or other imminent threat of extinction in genetic terms currently or in the foreseeable future.

Threats Assessment

The following table gives the results of the ERA team's analysis of the severity of threats to the Indo-West Pacific DPS.

	Current			**Foreseeable Future**		
Threat	**Mode**	**Median**	**Range**	**Mode**	**Median**	**Range**
Nursery habitat loss/degradation	3	3	(2-3)	+	+	+
Industrial/Commercial fisheries	4	4	(4-5)	+	+	(0 to +)
Artisanal fisheries	4	4	(3-5)	+	+	(0 to +)
Recreational fisheries	2	2	(1-3)	0	0	0
Competition	1	1	1	0	0	0
Disease	1	1	1	0	0	0
Predation	1	1	1	0	0	0
Current regulatory mechanisms	3	3	(3-4)	-	-	(- to 0)
IUU fishing	4	4	4	0	0	(0 to +)
At-vessel fishing mortality	4	4	(3-5)	0	0	(- to 0)
Schooling Behavior	3	3	(3-4)	0	0	(- to 0)

The ERA team ranked overutilization by industrial/commercial fisheries, artisanal fisheries, and IUU fishing, and the at-vessel fishing mortality of the scalloped hammerhead shark as the most serious threats to the persistence of this DPS, posing high risks for extinction. Increased industrialization of this region, leading to a decrease or degradation of nursery habitat was viewed as a moderate risk, as were the current regulatory mechanisms controlling fisheries in this DPS. Although range-wide abundance trends are missing in this DPS, CPUE data from South Africa and Australia suggest significant depletions of local populations. Declines of 58-76% in the hammerhead population have been estimated for Australia's northwest marine region, and a recent decline of 63% in *S. lewini* abundance was estimated for 2005-2010 based on data from a Queensland shark control program. Similarly, in South Africa, catch rates of *S. lewini* in beach mesh programs revealed significant declines in CPUE from 1978-2003. However, these programs were also assessed to have at least a medium causative impact on these localized depletions. High levels of commercial fishing that target sharks and catch sharks as bycatch occurs in this DPS. For example, in the Republic of the Marshall Islands EEZ, the tuna fishery alone accounted for annual longline catches ranging from 1583 to 2274 tonnes of sharks (over the period of 2005-2009) (Bromhead et al. 2012). The tuna purse seine fleet is also very active in this region and contributes to the incidental catch of scalloped hammerhead sharks. The recent addition of fleets entering the Western and Central Pacific Fishery Commission (WCPFC) tropical fishery have brought the number of purse seine vessels up to 280, the highest it has been since 1972 (Williams and Terawasi 2011), which is especially troubling given hammerheads susceptibility to being caught in large numbers in purse seine nets (Román-Verdesoto and Orozco-Zöller 2005). Furthermore, four of the top five exporters of shark fins to Hong Kong (Singapore, Taiwan, Indonesia, and the United Arab Emirates) are located in this DPS's range. The limited regulatory mechanisms to protect this DPS contribute to the high risk of extinction due to overutilization by these various fisheries. For example, Indonesia, which at the beginning of the 21st century was the world's leading elasmobranch producer accounting for 13% of the world total, currently has very few fishery regulations and in effect has created an open access fishery (Tull 2009). The heavy and unregulated artisanal and industrial fishing by both Indonesian and foreign vessels has depleted many of the large fish stocks, including sharks, in Indonesian waters (Fields et al. 2009, Tull 2009). As a result, many Indonesian fishermen have moved south to illegally fish in Australian waters (Fields et al. 2009). The level of management controls in Indonesia is not expected to increase because of the impact it would have on the livelihood of the many artisanal fisherman that operate in this area (Tull 2009). Likewise, many of the island countries in the western Pacific do not currently have the resources to implement or enforce protective fishery management measures, as any available funds are needed for important national needs, like health and education programs (Bromhead et al. 2012). Inshore fishing pressure is also of concern, as the schooling behavior of this species makes it susceptible to being taken in mass quantities on nursery grounds. Heavy exploitation of immature sharks has been observed in this DPS off the coasts of Madagascar, Queensland, and Southeast Asia (McVean et al. 2006, Harry et al. 2011, CITES 2010). The ERA team concluded that the limited management measures, large takes of immature *S. lewini*, and heavy fishing (both legal and illegal) on shark populations contributes significantly to the risk of this DPS's extinction, and these threats are likely to continue into the foreseeable future.

Overall Risk Summary

None of the team members placed a likelihood point in the "No or very low risk" category for the overall level of extinction risk now or in the foreseeable future. Likelihood points attributed to the other categories for the current level of extinction risk are as follows: Low Risk (4/50), Moderate Risk (20/50), High Risk (17/50), and Very High Risk (9/50). Likelihood points attributed to the other categories for the level of extinction risk in the foreseeable future are as follows: Low Risk (3/50), Moderate Risk (19/50), High Risk (16/50), and Very High Risk (12/50). Based on the likelihood point distributions, the team was fairly certain that the DPS has a moderate to high risk of extinction. However, the difference of only three likelihood points separating these two risk categories indicates a level of uncertainty as to the severity of the current and future threats and demographic risks. In addition, three likelihood points were moved to the very high risk category in the foreseeable future. The team thought the DPS was at a moderate risk of extinction, but were concerned that the situation could actually be worse in the future.

The ERA team was mainly concerned about the level of overutilization and limited regulatory mechanisms in the Indo-West Pacific DPS, and thus ranked the overall risk of extinction for the DPS as a 3, concluding that it had a moderate risk of extinction now and in the foreseeable future. The ERA team concluded that the DPS is exhibiting a trajectory indicating that it is approaching a level of abundance and productivity that places its current and future persistence in question throughout its entire range. Given the inadequacy of current regulatory mechanisms, the reports of heavy fishing, increased industrialization, high at-vessel mortality rate, and the projected increase of commercial, artisanal, and IUU fishing, the team does not envision a reversal of demographic trends in the foreseeable future that would lessen its risk of extinction throughout all or a significant portion of its range.

Central Pacific DPS

Evaluation of Demographic Risks

Abundance

ERA team scores for current abundance of the Central Pacific DPS ranged from 2 to 3 with a modal and median score of 2. A score of 2 represents low risk, meaning that current trends and levels of abundance are unlikely to contribute significantly to risk of extinction, but some concern that they may, in combination with other factors. ERA team scores for abundance in the foreseeable future ranged from 2 to 3 with a modal and median score of 2, again representing low risk of extinction due to this factor.

The ERA team members commented that abundance in this DPS is perceived to be high based on pup data from a large nursery ground in Hawaii as well as professional judgments from NMFS scientists in the Pacific Islands Science Center. In Kaneohe Bay, a large nursery ground in Hawaii, estimates of 7700 ± 2240 SD sharks are born per year and indicate that 180 - 660 adult female sharks annually use this area as a birthing ground (Duncan and Holland 2006). The team did not find evidence to show that abundance would contribute significantly to the risk of extinction now or in the foreseeable future.

Growth rate/productivity

ERA team scores for current growth rate and productivity of the Central Pacific DPS ranged from 2 to 3 with a modal and median score of 2. A score of 2 represents low risk, meaning that growth rate/productivity is unlikely to contribute significantly to the risk of extinction, but some concern that it may, in combination with other factors. ERA team scores for growth rate/productivity in the foreseeable future ranged from 2 to 3 with a modal and median score of 2, again representing low risk.

Data from the highly studied nursery population in Kaneohe Bay, Oahu, indicate *S. lewini* growth rate to be 9.6 cm per year (Duncan and Holland 2006). Juvenile attrition, however, was estimated at 0.85 – 0.93, a relatively high rate for a nursery habitat (Duncan and Holland 2006). However, this demographic factor, alone, was not considered to significantly contribute to this DPS's extinction risk now, or in the foreseeable future, as abundance levels are thought to be high in this region, thus protecting the population from depensatory processes.

Spatial structure/connectivity
ERA team scores for the current spatial structure/connectivity of the Central Pacific DPS ranged from 2 to 3 with a modal and median score of 3. A score of 3 represents moderate risk, meaning that population spatial structure and connectivity, in combination with other factors, are likely to contribute significantly to risk of extinction. ERA team scores for spatial structure/connectivity in the foreseeable future ranged from 2 to 3 with a modal and median score of 3, again representing moderate risk.

ERA team members commented that this DPS has a high degree of isolation, and that the population is limited in its connection to other coastal nursery habitat areas. Although microsatellite data suggests male scalloped hammerheads have migrated across large ocean basins on an evolutionary timescale (Daly-Engel et al. 2012), current tagging studies suggest this species moves more frequently between continuous habitats and to nearby islands, but is not likely to migrate between the Western or Eastern Pacific and the Central Pacific (Duncan et al. 2006, Bessudo et al. 2011). Also, although the habitats within this DPS are fragmented, they are traversable; however, there is limited data on the number of nursery habitats throughout the DPS region (besides Hawaii). Thus, depending on the availability and accessibility of nursery habitats around other islands in this area, given this DPS's isolation, the spatial structure/connectivity may pose a moderate risk of extinction now and in the foreseeable future.

Diversity
Each ERA team member scored a 1 for the diversity demographic factor for the Central Pacific DPS currently and in the foreseeable future. A score of 1 represents no or very low risk, meaning it is unlikely that diversity contributes significantly to this DPS's risk of extinction.

Currently there are no known ecological or human-caused factors that have been found to substantially alter the rate of gene flow among this population. Based on mixed mitochondrial and nuclear markers, the number of migrants into this DPS from Taiwan is estimated to be around 0.31 per generation, and from East Australia the number increases to 1.1 per generation (Daly-Engel et al. 2012). The species seems quite adaptable and ERA team members did not feel there was a reason to believe that there is a situation of a genetic bottleneck or other imminent threat of extinction in genetic terms currently or in the foreseeable future.

Threats Assessment

The following table gives the results of the ERA team's analysis of the severity of threats to the Central Pacific DPS.

	Current			**Foreseeable Future**		
Threat	**Mode**	**Median**	**Range**	**Mode**	**Median**	**Range**
Nursery habitat	1	1	(1-2)	0	0	0

loss/degradation						
Industrial/Commercial fisheries	3	3	(2-3)	0	0	0
Artisanal fisheries	1	2	(1-3)	0	0	(- to +)
Recreational fisheries	2	2	(2-3)	0	0	(- to +)
Competition	1	1	1	0	0	0
Disease	1	1	1	0	0	0
Predation	1	1	1	0	0	0
Current regulatory mechanisms	2	2	(2-3)	-	-	-
IUU fishing	2	2	(2-3)	0	0	(- to 0)
At-vessel fishing mortality	4	4	(2-5)	0	0	(- to 0)
Schooling Behavior	3	3	(2-4)	0	0	(0 to +)

The ERA team ranked the at-vessel fishing mortality rate of the scalloped hammerhead shark as the most serious threat to the persistence of this DPS. Threats that, in combination with others, were thought to contribute significantly to the risk of extinction included overutilization by commercial fisheries and the scalloped hammerhead's schooling behavior. Currently, scalloped hammerheads in this region are mainly caught as bycatch by pelagic longline and purse seine fleets, with the schooling behavior of *S. lewini* making this species especially susceptible to being caught in large numbers in purse seine nets. Observer data from the Hawaii-based PLL fishery from 1995 – 2006 indicated an extremely low catch of scalloped hammerhead sharks (56 observed individuals on 26,507 sets total, both fishery sectors combined), with a nominal CPUE, defined as the number of fish per 1,000 hooks, of 0.001 (Walsh et al. 2009). More recent observer data (2009-2011) from this fishery indicate that scalloped hammerhead sharks continue to be a very rare catch, commensurate with the earlier time period (Walsh et al. 2009; Walsh personal communication, 2012). In non-longline catch, hammerhead shark species are also rare, with a total of 11 sharks caught from 1990-1994 and 11 from 1995-1999, 6 caught from 2000-2004, 17 caught from 2005-2009, and 6 caught from 2010-2011 (Seki and Kokubun personal communication, 2012). Furthermore, in July 2010, the state of Hawaii made it illegal to possess, sell, offer for sale, trade or distribute shark fins, thus providing increased protection for the scalloped hammerhead from fishers looking to take part in the lucrative shark fin trade. Although strong management measures are in place for Hawaiian fisheries, the WCPFC, the regional fisheries management organization that manages these waters, does not currently have any species-specific regulations protecting hammerheads, nor do they have accurate data that reflect the harvest rates of this DPS by other countries. Therefore, given *S. lewini*'s high at-vessel fishing mortality rate, prevalence of purse seine fisheries, and lack of adequate harvest data, there is some concern that the threat of overutilization by commercial fisheries may pose a moderate risk of extinction for this DPS.

Overall Risk Summary

None of the team members placed a likelihood point in the "High risk" or "Very High Risk" categories for the overall level of extinction risk now or in the foreseeable future. Likelihood points attributed to the other categories for the current level of extinction risk are as follows: No or Very Low Risk (24/50), Low Risk (19/50), and Moderate Risk (7/50). Likelihood points attributed to the other categories for the level of extinction risk in the foreseeable future are as follows: No or Very Low Risk (27/50), Low Risk (17/50), and Moderate Risk (6/50). Based on the likelihood point distributions, the team was fairly certain that this DPS is at a no or very low risk of extinction now and in the foreseeable future.

Although there was concern regarding the threat of overutilization by commercial fisheries in combination with the scalloped hammerhead's tendency to school, the ERA team felt that the current abundance and productivity of this DPS, along with the number of suitable nursery grounds and management measures, provided ample protection from extinction for this DPS. Thus, the ERA team ranked the overall risk of extinction for the Central Pacific DPS as a 1, which means the team believes it is unlikely that this DPS is at risk of extinction now or in the foreseeable future throughout all or a significant portion of its range due to projected threats or trends in abundance, productivity, spatial structure, or diversity.

Eastern Pacific DPS

Evaluation of Demographic Risks

Abundance

ERA team scores for current abundance of the Eastern Pacific DPS ranged from 3 to 4 with a modal and median score of 4. A score of 4 represents high risk, meaning that current trends and levels of abundance are likely to contribute significantly to risk of extinction. ERA team scores for abundance in the foreseeable future ranged from 3 to 5 with a modal and median score of 4, again representing high risk of extinction.

The ERA team members commented that there are few good abundance data from this region. Diver sightings reports from 1992 – 2004 reveal declines of 71% in populations of *S. lewini* in Cocos Island National Park (Myers et al. no date). Using fishing mortality estimates calculated from 1997 and 1998 catches, INP (2006) estimated that the scalloped hammerhead population in the Gulf of Tehuantepac is currently decreasing by 6% per year. Substantial fishing by artisanal fisherman on *S. lewini* juveniles and neonates, as well as reports of large harvests of sharks by IUU vessels, suggests significant decreases in abundance and probability for surviving environmental variation and catastrophes, especially in the foreseeable future. From an evolutionary standpoint, Nance et al. (2011) calculated that this DPS has undergone significant declines (1-3 orders of magnitude) from its ancestral population, with the onset of decline occurring ~3600 to 12,000 years ago. Given the high artisanal fishing pressure as well as the frequent reports of IUU, the ERA members thought that the abundance levels may be at a level that contributes significantly to the DPS's risk of extinction in the face of environmental and anthropogenic disturbances now and in the foreseeable future.

Growth rate/productivity

ERA team scores for current growth rate and productivity of the Eastern Pacific DPS ranged from 2 to 3 with a modal and median score of 3. A score of 3 represents moderate risk, meaning that growth rate/productivity in combination with other factors (such as low abundance), contributes significantly to risk of extinction. ERA team scores for growth rate/productivity in the foreseeable future ranged from 2 to 3 with a modal and median score of 3, again representing moderate risk.

Given the relatively low intrinsic rate of increase estimated for this species, the group felt that this factor currently contributed a moderate risk to the DPS and was not likely to change in the foreseeable future.

<u>Spatial structure/connectivity</u>
Each ERA team member scored a 2 for the current spatial structure/connectivity of the Eastern Pacific DPS. A score of 2 represents low risk, meaning that population spatial structure and connectivity are unlikely to contribute significantly to risk of extinction by themselves, but may, in combination with other factors. Each ERA team member scored a 2 for the spatial structure/connectivity of the Eastern Pacific DPS in the foreseeable future, again representing low risk.

ERA team members felt that the Eastern Pacific DPS had a moderate degree of isolation and differentiation. Habitat loss does not seem to be an issue in this area and it is not thought that this factor will change over time.

<u>Diversity</u>
Each ERA team member scored a 1 for the diversity demographic factor for the Eastern Pacific DPS currently and in the foreseeable future. A score of 1 represents no or very low risk, meaning it is unlikely that diversity contributes significantly to this DPS's risk of extinction.

Currently there are no known ecological or human-caused factors that have been found to substantially alter the rate of gene flow among this population. Nance et al. (2011) indicated that the *S. lewini* in the ETP may exhibit demographic asynchrony, a condition for metapopulation persistence. The isolation-with-migration (IM) model showed modest but significant genetic connectivity between most sampled sites in the ETP (with point estimates of Nm = 0.1 – 16.17) (Nance et al. 2011). The species seems quite adaptable and ERA team members did not feel there was a reason a risk of extinction in genetic terms currently or in the foreseeable future.

Threats Assessment

The following table gives the results of the ERA team's analysis of the severity of threats to the Eastern Pacific DPS.

	Current			**Foreseeable Future**		
Threat	**Mode**	**Median**	**Range**	**Mode**	**Median**	**Range**
Nursery habitat loss/degradation	2	2	(1-3)	0	0	(0 to +)
Industrial/Commercial fisheries	4	4	(3-4)	+	+	+
Artisanal fisheries	4	4	(3-4)	+	+	(0 to +)
Recreational fisheries	2	2	(1-2)	0	0	0
Competition	1	1	1	0	0	0

Disease	1	1	1	0	0	0
Predation	1	1	1	0	0	0
Current regulatory mechanisms	3	3	(2-3)	0	0	0
IUU fishing	4	4	(4-5)	+	+	+
At-vessel fishing mortality	4	4	(3-5)	0	0	(- to 0)
Schooling Behavior	4	4	(3-4)	0	0	(0 to +)

The ERA team ranked overutilization by industrial/commercial fisheries, artisanal fisheries, and IUU fishing, exacerbated by the high at-vessel fishing mortality and schooling behavior of *S. lewini*, as the most serious threats to the persistence of this DPS, all posing high risks for extinction. Although abundance data are lacking in this area, studies from artisanal fisheries suggest heavy exploitation of this DPS. For example, analysis of survey data from 1998-1999 collected from 28 Sinaloa artisanal fishing sites revealed that scalloped hammerhead sharks comprised 54.4% of the total elasmobranch catch and 43.1% of the total recorded catch (n=1584 *S. lewini* individuals) (Bizarro et al. 2009). In the Gulf of Tehuantepec, *Sphyrna lewini* is the second most important species in the shark fishery, comprising around 29% of the total shark catch from this area (INP 2006). Of major concern is that many of these artisanal fishermen are targeting schools of immature *S. lewini*, due to the profitability of the younger shark meat (Kotas 2008, Arriatti 2011), and likely negatively affecting recruitment to this DPS. In Costa Rica, many of the identified nursery grounds for scalloped hammerheads are also popular elasmobranch fishing grounds and are heavily fished by gillnets. In "Tres Marias" Islands and Isabel Island in the Central Mexican Pacific, Perez-Jimenez et al. (2005) documented artisanal fishery catches dominated by immature individuals. Out of 1178 females and 1331 males caught from 1995-1996 and 2000-2001, less than 1% were mature. On the coast of Chiapas in Mexico, neonates (≤ 60cm TL) comprised over 40% of the port Madero catch from 1996-2003 (INP 2006). Directed artisanal fishing for hammerheads has been documented in coastal nursery areas in Panama, with artisanal gillnet fishery catches dominated by neonate and juvenile *S. lewini* (Arriatti 2011). Likewise, artisanal fisheries in Sinaloa, Mexico, primarily target immature *S. lewini*, and a comparison of landing sizes from this region between 1998-1999 and 2007-2008 revealed a significant decrease in *S. lewini* size, indicating a possible truncation of the size of the local population (Bizzarro et al. 2009). Large numbers of scalloped hammerheads are also caught as bycatch in industrial purse seine fisheries operating in the eastern Pacific (Román-Verdesoto and Orozco-Zöller 2005), and with limited regulatory mechanisms in this region, the threat of commercial and artisanal fisheries and IUU fishing is only expected to increase.

Overall Risk Summary

None of the team members placed a likelihood point in the "No or very low risk" category for the overall level of extinction risk now or in the foreseeable future. Likelihood points attributed to the other categories for the current level of extinction risk are as follows: Low Risk (6/50), Moderate Risk (17/50), High Risk (21/50), and Very High Risk (5/50). Likelihood points attributed to the other categories for the level of extinction risk in the foreseeable future are as follows: Low Risk (4/50), Moderate Risk (15/50), High Risk (21/50), and Very High Risk (10/50). Based on the likelihood point distributions, the team was fairly certain that the DPS has a moderate to high risk of extinction, with the high risk category receiving more of the votes. In addition, five likelihood points were moved to the very high risk category in the foreseeable future, indicating increased concern for this DPS.

The ERA team had strong concerns regarding the level of overutilization and limited regulatory mechanisms or enforcement of fishery regulations in the Eastern Pacific DPS, and thus ranked the overall risk of extinction for this DPS as a 4, concluding that it had a high risk of extinction because it is at or near a level of abundance and productivity that places its current and future persistence in question throughout its entire range. Likewise, the present threats, which include heavy fishing and overutilization by industrial/commercial and artisanal fisheries, coupled with the behavioral and biological aspects that increase *S. lewini*'s susceptibility and mortality to certain fishing gear, and heavy IUU fishing, will only serve to exacerbate the demographic risks currently faced by the DPS, placing this DPS at a high risk of extinction now and in the foreseeable future.

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