Scalloped Hammerhead Shark (Sphyrna lewini) 5-Year Review: Summary and Evaluation

National Marine Fisheries Service Office of Protected Resources
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(Sphyrna lewini)

5-Year Review:
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5-YEAR REVIEW
Species reviewed: Scalloped hammerhead shark/*Sphyrna lewini*

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1.0 GENERAL INFORMATION

1.1 Reviewers

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1.2 Methodology used to complete review

A 5-year review is a periodic analysis of a species' status conducted to ensure that the listing classification of a species as threatened or endangered on the List of Endangered and Threatened Wildlife and Plants (List) (50 CFR 17.11 – 17.12) is accurate. The 5-year review is required by section 4(c)(2) of the Endangered Species Act of 1973, as amended (ESA). The review was prepared pursuant to the joint National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife 5-year Review Guidance and template (NMFS and USFWS 2018). The NMFS Office of Protected Resources led the 5-year review with input from the Southeast Fisheries Science Center, NMFS regional offices, and science centers. We updated information from the status review (Miller et al. 2014) based on peer-reviewed publications, government and technical reports, conference papers, dissertations, and theses. We gathered information *through January 2020*. The 5-year review is on the scalloped hammerhead shark (*Shyrna lewini)* four distinct population segments (DPS): endangered Eastern Atlantic DPS, endangered Eastern Pacific DPS, threatened Central and Southwest Atlantic DPS, and threatened Indo-West Pacific DPS. We summarized and analyzed the biology and habitat, threats, and conservation efforts in light of the ESA section 4(a)(1) factors (see Section 2.3.2.1) to determine whether a reclassification or delisting may be warranted (see Section 3.0).

NMFS initiated a 5-year review of the four scalloped hammerhead shark DPSs and solicited information from the public on September 6, 2019 (84 FR 46938). We received three comment letters and incorporated information as appropriate in this review.

1.3 Background

1.3.1 FRN Notice citation announcing initiation of this review

84 FR 46938; September 6, 2019

1.3.2 Listing History

<u>Original Listing</u>

FR notice: 79 FR 38213 July 3, 2014

Date listed: July 3, 2014; effective September 2, 2014

Entities listed: endangered Eastern Atlantic DPS, endangered Eastern Pacific DPS, threatened Central and Southwest Atlantic DPS, and threatened Indo-West Pacific DPS

1.3.3 Associated rulemakings

NMFS found there were no marine areas within the jurisdiction of the United States that met the definition of critical habitat for three of the DPSs: the Central and Southwest Atlantic DPS, Indo-West Pacific DPS, or Eastern Pacific DPS. The fourth DPS—the Eastern Atlantic DPS—only occurs outside of U.S. jurisdiction, and critical habitat cannot be considered for that DPS (80 FR 71774, November 17, 2015).

Because we listed the Eastern Pacific DPS and Eastern Atlantic DPS of scalloped hammerhead sharks as endangered, all of the take prohibitions of section 9(a)(1) of the ESA (16 U.S.C. 1538(a)(1)) were applied. These include prohibitions against importing, exporting, engaging in foreign or interstate commerce, or "taking" of the species. "Take" is defined under the ESA as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct." These prohibitions apply to all persons, organizations and entities subject to the jurisdiction of the United States, including in the United States and its territorial seas, or on the high seas. In the case of threatened species—in which case two of the DPSs are listed as threatened—ESA section 4(d) requires the Secretary to issue regulations deemed necessary and appropriate for the conservation of the species. In the listing rule (79 FR 38213, July 3, 2014), NMFS evaluated the needs of and threats to the Central and Southwest Atlantic DPS and Indo-West Pacific DPS and determined that protective regulations pursuant to section 4(d) were not necessary or appropriate for the conservation of either DPS.

1.3.4 Review History

Miller et al. (2014) found that the four DPSs were either at a moderate or high level of extinction risk.

1.3.5 Species' Recovery Priority Number at start of 5-year review

N/A (NMFS 2016)

1.3.6 Recovery Plan or Outline

N/A (NMFS 2016)

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate?

__X_ **Yes**, *go to section 2.1.2*
_____**No**, *go to section 2.2*

2.1.2 Is the species under review listed as a DPS?

__X_**Yes**, *go to section 2.1.3.*
____ **No**, *go to section 2.1.4*

2.1.3 Was the DPS listed prior to 1996?

_____Yes, *give date and go to section 2.1.3.1*
___X_**No**, *go to section 2.1.4*

2.1.4 Is there relevant new information for this species regarding the application of the DPS policy?

_____Yes
___X_**No**, *go to section 2.2., Recovery Criteria*

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan[1] containing objective, measurable criteria?

____Yes, *go to section 2.2.2*
_X__**No**, *(see NMFS 2016).*

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

This section is not divided into the respective DPSs because much of the information on the species' biology and life history is applicable across geography. This section only contains new information since the status review (Miller et al. 2014).

2.3.1.1 New information on the species' biology and life history:

Trophic Position
The scalloped hammerhead shark is a high trophic-level predator, and most sharks are classified as generalists that feed around trophic position 4, but this classification may be an oversimplification of the trophic structure of these top-level predators. Several recent studies have used isotope analysis to understand the trophic position and inter and intra-specific foraging relationship of large sharks.

Off southern Africa, 13 species of sharks (n = 271) were sampled for isotope analysis (δ15N and δ13C) values from captures in beach protection nets along the KwaZulu-Natal between 2005 and 2009 (Hussey et al. 2015). A range of intraspecific variation in isotope values among species was observed including scalloped hammerheads showing the largest range in δ15N values (3.1‰: 13.3 to 16.5‰) and the largest δ13C (2.8‰: −14.3 to −17.1‰) range. Absolute trophic position for scalloped hammerheads was 4.7 ± 0.44. The data on scalloped hammerheads and the other 12 species suggest large sharks are feeding at a higher trophic position and across a broader trophic range (Hussey et al. 2015).

[1] Although the guidance generally directs the reviewer to consider criteria from final approved recovery plans, criteria in published draft recovery plans may be considered at the reviewer's discretion.

Stable isotope analysis of δ13C and δ15N in samples of the silky shark (*Carcharhinus falciformis*) and scalloped hammerhead shark caught illegally in Malpelo Island, Colombia, indicated that both shark species co-occur, but do not share similar food sources and feeding areas. The trophic position of both species was similar suggesting that both species occupy a high position in the marine food chain. However, the scalloped hammerhead shark showed a wider trophic niche than the silky shark, with low trophic overlap (5%) between the two species. The δ15N values of the scalloped hammerhead (15.9 ± 0.11‰) were higher than those of the silky shark (14.9 ± 0.09‰) (Estupiñán-Montaño et al. (2017).

Stable isotope analysis of scalloped hammerheads sampled (n = 6; June to November 2014) from the bycatch of tuna longline fishing vessels operating in the northeast central Pacific had a mean trophic position of 5.4 (SD ± 0.4). Minimal inter-specific (i.e., smooth hammerhead, *Sphyrna zygaena*) variation in δ15N and δ13C values were found. Although these shark species had a similar trophic niche width according to the corrected standard δ15N-δ13C ellipses areas (smooth hammerhead, 0.73; scalloped hammerhead, 0.67), they showed low niche overlap (Li et al. 2016). These results are similar to Loor-Andrade et al. (2015) who found similar trophic niche and low overlap in scalloped hammerheads (n = 41) and smooth hammerheads (n = 64) collected from the artisanal fishery operating off Ecuador. The differences are likely linked to individual foraging strategies—the two hammerhead shark species consumed prey with different isotopic compositions in different foraging areas (Loor-Andrade et al. 2015).

Reproduction

Little new information is available on reproduction in scalloped hammerheads since the 2014 status review. Miller et al. (2014) reported that the scalloped hammerhead shark is viviparous (i.e., give birth to live young), with a gestation period of 9–12 months, which may be followed by a one-year resting period. Females attain maturity around 200–250 cm (TL) while males reach maturity at smaller sizes (range 128 – 200 cm (TL); however, the age at maturity differs by region. See Miller et al. (2014) for citations and further details.

Since the 2014 status review, a mating event was recorded at Isla del Coco National Park, Costa (Salinas-de-León et al. 2017). The mating sequence was observed with one male and one female and was characterized by an open water encounter followed by pre-copulatory biting, grabbing of the pectoral fin/copulation. During mating, the pair fell (at a rate of approximately 0.75–1 meters per second) in a spiral trajectory from close to the surface, over 40 m above the seafloor, to the seabed where they separated. The authors state that the mating behavior was similar to other reef sharks, such as the nurse (*Ginglymostoma cirratum*), blacktip (*Carcharhinus melanopterus*), and whitetip reef sharks (*Triaenodon obesus*) (see Salinas-de- León et al. 2017).

Multiple paternity was found in two studies. Off the east coast of Africa, multiple paternity was found in 46% of scalloped hammerhead litters (n = 13 litters; range 3–16 pups) sampled (Rossouw et al. 2016). Off Papua New Guinea, 100% of the sampled litters (n = 5 litters; average litter size 17.2 pups) had multiple paternity (Green et al. 2017).

2.3.1.2 Abundance, population trends (e.g., increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

Population Trends

Systematic monitoring of population abundance does not exist for any of the scalloped hammerhead DPSs. Thus, we rely on data from shark deterrent programs, diver and fishermen surveys, and catch per unit effort (CPUE) from fisheries-dependent monitoring.

The IUCN's most recent assessment designated the scalloped hammerhead as Critically Endangered and described the global population as decreasing at a median of 76.9–97.3%, with the highest probability of >80% reduction over three generation lengths (Rigby et al. 2019). It is important to note that the IUCN estimate was based on only four datasets encompassing the North Atlantic and Gulf of Mexico, South Pacific, and Indian Ocean. Some of the data were over a decade old and the more recent data (1994–2017) from the North Atlantic and Gulf of Mexico showed a population increase after fisheries management measures were enacted.

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

Rigby et al. (2019) reported data from the Queensland, Australia, shark bather protection program from 1964 through 2004, indicating an annual rate of decline of 8.4%. The shark control program off South Africa indicated a 4.0% annual rate of decline from 1978 through 2003 (Rigby et al. 2019). Miller et al. (2014) also included these datasets in their risk analysis and concluded significant declines to this DPS from the Queensland and South Africa shark bather protection programs.

<u>Eastern Pacific DPS</u>

Based on diver observations collected from January 1993 to December 2013 in Cocos Island, Costa Rica, scalloped hammerhead relative abundance declined 45% during the period (White et al. 2015). Although dives were not entirely standardized (e.g., there was no defined field of view), the protocols were consistent throughout the study. Each dive averaged 60 minutes and was led by an experienced professional divemaster. Dive depth ranged from 10 to 40 m depending on the site (n = 17), but depth was consistent within sites. A standardized data sheet was used for all dive sites (White et al. 2015). Peñaherra-Palma et al. (2018) used divers' perceptions about changes in relative abundance of sharks in the Galapagos Marine Reserve (GMR). Based on divers' categorical trend scores and percentage of abundance change from the 1980s through the early 2010s, the authors developed a semi-quantitative virtual abundance change model based on an initial value of 1 then calculated the increase or decrease in subsequent decades. Divers' perceived a 50% decline in hammerhead shark abundance across the decades (Peñaherra-Palma et al. 2018).

Pérez-Jiménez (2014) examined fishery-dependent, fishery-independent, and museum records from the west coast of Mexico from the late 1880s through 2010. The author found that scalloped hammerhead sharks were once common.

Eastern Atlantic DPS

In the Mediterranean Sea, scalloped hammerheads have declined at a rate of -0.17 over almost two centuries and biomass of -0.36 over the last century (see Miller et al. 2014; Rigby et al. 2019). A 61.7% decline in CPUE of hammerheads was estimated for longline vessels operating in the south Atlantic from 1998 to 2007 (Rigby et al. 2019 Table S11; citing Barreto *et al.* 2016). The majority of the fleet effort was concentrated in the area of the Central and Southwest Atlantic DPS, so the information is repeated below.

Central and Southwest Atlantic DPS

A 61.7% decline in CPUE of hammerheads was estimated for longline vessels operating in the south Atlantic from 1998 to 2007 (Rigby et al. 2019 Table S11; citing Barreto *et al.* 2016). The majority of the fleet effort overlapped with the Central and Southwest Atlantic DPS, but some effort also was within the boundaries of the Eastern Atlantic DPS (see above). Miller et al. (2014) considered Brazilian longline catch data in their extinction risk analysis and reported peak catches in 2002 (508 tonnes) with significant declines by 2009 (88 tonnes).

Age and Growth

Rigby et al. (2019) summarized the literature on age and growth from various populations. Scalloped hammerheads reach a maximum size of 370–420 cm total length (TL). Males mature at smaller sizes between 140–198 cm TL compared to females at 200–250 cm TL. Females mature at 13.2 years (see below) and live up to 35 years. They give birth annually with a litter size from 12-41 pups and generation length is 24.1 years (see Rigby et al. 2019).

Age and growth parameters were estimated from growth-band counts of thin-cut vertebral sections collected from three Indonesian fish markets between April 2001 and March 2006. A multi-model analysis was used to estimate growth parameters for each sex. Age at maturity was calculated to be 8.9 and 13.2 years for males (n = 23) and females (n = 72), respectively (Drew et al. 2015). The age of juvenile scalloped hammerhead sharks (n = 296) caught by fisheries in the Mexican Pacific Ocean from March 2007 to September 2017 was estimated from growth band counts in thin-sectioned vertebrae (Coiraton et al. 2019). Estimated ages ranged from 0 to 10+ years for females and 0 to 7+ years for males. In the Mexican Pacific, growth bands were opaque during summer (July–September), a period of faster growth, and translucent during winter months (November–March), a period of slower growth. A similar pattern of growth has been reported from other studies in the Atlantic Ocean and Australia (see Coiraton et al. 2019).

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

The NMFS status review (Miller et al. 2014) provided an overview of the population structure, indicating genetic discontinuity within oceans, associated with oceanic barriers, but little population structure along continental margins. An exception was within the western Atlantic where females may display natal homing or remain close to their natal region of origin. Only a few studies were found on population structure since the 2014 status review.

The scalloped hammerhead mitochondrial deoxyribonucleic acid (mtDNA) has been completely mapped, which may be useful in future examinations of population structure. The genome is

16,726 base pairs in length with the typical gene composition and orders in vertebrates (Chen et al. 2015).

Spaet et al. (2015) found five novel haplotypes in samples (n = 233) collected at fish markets throughout the Red and Arabian Seas. The authors used a parsimony network analysis indicating the scalloped hammerhead in this area is distinct from other populations in the Indian Ocean. Two possible explanations exist. First, scalloped hammerheads in the Arabian Seas may have evolved to breed differently from populations in the Indian Ocean. Over the last several thousands of years, the Arabian region lost permanent estuaries to desertification. Thus, the sharks may no longer rely on estuaries for nurseries and do not undertake reproductive migrations, thereby reducing gene flow with other populations in the Indian Ocean. Second, regional oceanography and upwelling zones may form temporary barriers between Arabian and other Indian Ocean populations. Additional data on migration routes, migration times, and breeding cycles are needed to understand why novel haplotypes are present in the Arabian Seas population (Spaet et al. 2015).

Based on tissue samples (n = 30) taken from scalloped hammerheads landed in the fishing port in Tanjung Luar, Lombak, Indonesia, haplotype diversity was low ((Hd) = 0.40; nu π = 0.0018), indicating the population may be at risk of inbreeding and loss of adaptive traits (Hadi et al. 2019).

2.3.1.4 Taxonomic classification or changes in nomenclature:

No changes since the status review (Miller et al. 2014).

2.3.1.5 Spatial distribution, trends in spatial distribution, or historic range:

Miller et al. (2014) describe the scalloped hammerhead shark as 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. Scalloped hammerhead sharks are highly mobile and partly migratory, making migrations along continental margins as well as between oceanic islands in tropical waters. See Miller et al. (2014) for further details. Only a few studies were found on spatial distribution since the 2014 status review.

Rooker et al. (2019) assessed movement of scalloped hammerheads electronically tagged in the U.S. waters of the Gulf of Mexico (GOM) from 2012 to 2016. They found that scalloped hammerheads displayed prolonged periods of residency (99% of daily positions) in the northern GOM in U.S. waters with limited displacement to Mexico (~ 1% or less) and none to Cuba.

Using a qualitative assessment framework based on genetic and tagging data as well as expert elicitation, Chin et al. (2017) determined that scalloped hammerheads occurring across northern Australia, Indonesia, and Papua New Guinea (PNG) were connected with movement across all areas. Australian populations were dominated by juveniles and small adult males, while Indonesian and PNG populations included large adult females.

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

General Movement
Satellite tracks from 23 pelagic shark species (n = 1,804), including scalloped hammerheads (n = 31) tagged from 2002 to 2017 in the Atlantic, Indian, and Pacific Ocean indicate the pelagic shark species occupy predictable habitat hotspots (Queiroz et al. 2016, 2019). They preferred fronts characterized by strong seasurface-temperature and high productivity gradients.

Vertical partitioning was observed among shark assemblages in the central Indian Ocean within the British Indian Ocean Territory Marine Reserve. Scalloped hammerhead sharks were observed associated with deep (70–80 meter) seamounts. Whereas shallower (<40 meter) reefs and lagoons supported white tip and blacktip reef sharks, tawny nurse sharks, and tiger sharks (Tickler et al. 2017). A scalloped hammerhead was observed during oil exploration in the Ruvuma basin off Tanzania 1 meter off the seabed at 1,042 meter–depth (Moore and Gates 2015).

A female scalloped hammerhead that was tracked for 182 days in the Red Sea did not exhibit the diel foraging pattern (i.e., nighttime foraging) found in other studies (Spaet et al. 2017). The shark travelled approximately 1,000 km from the waters off central Saudi Arabia southeastward into Sudanese waters, then returned to the tagging location toward the end of the tracking period. Excursion depths ranged between 650 and 971 meters for the majority of the days tracked (174 of the 182 days). Spaet et al. (2017) found deep diving behavior during both daytime and nighttime over the entire tracking period. The diving patterns indicated the shark was likely foraging on mesopelagic fish and squid. The authors acknowledge that an individual's behavior may not be extrapolated to the species level, but the consistency of the behavior over time indicates it was not an anomaly.

The Darwin and Wolf Islands within the GMR in the Eastern Tropical Pacific harbor the largest fish biomass reported to date on a reef worldwide. Diver operated stereo-video surveys were conducted in the cold season spanning July to December when shark abundance peaks. Approximately 73% of the total biomass (12.4 ± 4.01 t ha^1) consisted of sharks, of which nearly half were scalloped hammerheads (Salinas-de-León et al. 2016). Ketchum et al. (2014a) tracked seven scalloped hammerheads for 19–96 hours at Wolf Island between 2007 and 2009 using ultrasonic transmitters with depth and temperature sensors. Movements of individual hammerheads fell in two classes: constrained (remaining near the island) and dispersive (moving offshore to pelagic environments). The hammerheads were highly selective of location (i.e., habitat on up-current side of island) and depth (i.e., base of mixed layer) while refuging and diving the width of the mixed layer or at times below the thermocline while moving offshore, most likely for foraging. The central activity space off the southeast side of Wolf Island was small, but varied among individuals (mean ± SE 0.25 ± 0.2 km^2), not exceeding 0.6 km^2 and not changing significantly between seasons (Ketchum et al. 2014a). Using pinger tags, Ketchum et al. (2014b) tracked hammerheads (n = 134) from July 2006 to July 2010 in the northern Galapagos at listening stations around four islands in the GMR and two isolated islands in the Eastern Tropical Pacific, 700 and 1,200 km away. Hammerheads formed schools at specific locations during the day, but dispersed at night. They exhibited 24-hour diel excursions amongst the islands. Inter-island connectivity was greatest in the northern GMR with almost no movement to the central area within the GMR. Currents are warmer and stronger in the northern GMR, which is likely a factor in why hammerheads chose this area over the central GMR. During the height of the warm season (December–January), hammerheads spent more days at the northern islands, but their presence began to taper off in the later part (March–June) of the warm season when the sharks began to make longer migrations (>300 km; 15–52 days) to the other islands in the Eastern Tropical Pacific (Ketchum et al 2014b).

Although ESA–listed scalloped hammerheads do not occur in the northern GOM, we cite several studies of habitat preferences that may help inform how listed scallop hammerheads use habitat in other localities. In the northern GOM, satellite data indicate that scalloped hammerheads associate with the continental shelf with limited evidence of open ocean habitat use beyond the shelf edge (Wells et al. 2018; Rooker et al. 2019). Females (n = 5) displayed shelf-edge movements (>200 m isobath) and males displayed shallower mid-shelf use (Wells et al. 2018). Scalloped hammerheads also occurred at close proximities to both artificial and hard-bottom habitat with low chlorophyll a concentrations (~0–4 mg $m^{-}3$) and moderate salinities (33–35.5; unit of measurement not given, but assumed to be parts-per-thousand). The species did not appear to be influenced by oceanographic processes such as sea surface temperature and sea surface height anomaly (Wells et al. 2018). Fisheries independent surveys using gillnets (n = 21,597 sets) from 1985 to 2014 in the northern GOM recorded 10 elasmobranch species of which the scalloped hammerhead was the fewest (2.1%; n = 429) of the total caught (Plumlee et al. 2018). Salinity, temperature, depth, and month (summer) are predictors for scalloped hammerhead abundance in the northern GOM (Ward-Page et al. 2015; Plumlee et al. 2018).

Potential Parturition and Nursery Areas

Since the 2014 status review (Miller et al. 2014), the new information on potential parturition and nursery areas comes from the Pacific Ocean and is relevant to the Eastern Pacific and Indo-West Pacific DPSs.

The Rewa Delta, Fiji, potentially is an important nursery area for scalloped hammerheads (Brown et al. 2016; Marie et al. 2017). A fisheries-independent survey conducted in the Rewa Delta from September 2014 to March 2016 captured 1,054 scalloped hammerhead sharks. The study found that sharks, primarily neonates and young-of-the-year (99.8%), use the delta year-round. Parturition occurred in the warm and wet months of the austral summer (Marie et al. 2017). Vierus et al. (2018) conducted a fisheries-independent shark survey in the fishing grounds of the Ba Estuary, Fiji Islands. The authors set gillnets and longlines (n = 196.13 fished hours) from December 2015 to April 2016. In addition to other shark species, 35 scalloped hammerhead sharks were captured, tagged, and released. Mean size was 51.8 ± 4.8 cm TL and open or semi-healed umbilical scars were noted on majority (n = 21) of the sharks. The data indicate that birthing occurs at least during the survey period and likely the Ba Estuary serves as a nursery area (Vierus et al. 2018).

The Great Barrier Reef, Australia, likely is an important nursery area for scalloped hammerheads (Yates et al. 2015a,b,c). Fishery-independent surveys using bottom set gillnets and longlines were undertaken between 2012 and November 2014 to investigate shark communities along 400 km of the tropical eastern coast of Australia (Yates et al. 2015a). Five bays were surveyed

(Rockingham, Bowling Green, Upstart, Edgecumbe and Repulse Bays), which are shallow (about 15 meters) and sheltered from ocean swells by the Great Barrier Reef. Nineteen species were reported of which Carcharhiniformes species contributed 99.2% of the total shark catch. Of the 1,806 sharks captured, 567 were immature, including 336 young-of-the-year individuals. Scalloped hammerheads were moderately abundant comprising 5% of the total catch. The majority (83%) were young-of-the-year. Their distribution was patchy with 71% caught in Rockingham Bay, none recorded in Edgecumbe Bay and was relatively scarce elsewhere (Yates et al. 2015a,c). The Spatial variations detected for the juvenile scalloped hammerheads suggest that their occurrence along tropical coastlines is dynamic and some bays may provide nursery habitat for these species while others may not (Yates et al. 2015c). Data on the ecological factors that influenced distribution amongst the bays were also analyzed. Scalloped hammerhead abundance (n = 73) decreased with decreased turbidity at salinities greater than 31 ppt and increased with temperature (Yates et al. 2015b).

Based on mtDNA and paternity analyses, Quintanilla et al. (2015) found high genetic connectivity between Malpelo Island and the Colombian Pacific coast, suggesting that these two areas are nurseries for scalloped hammerhead sharks.

Other possible nursery areas include Golfo Dulce and Wafer Bay, Isla del Coco, Costa Rica (Zanella and López-Garro 2015; Zanella et al. 2016; Zanella et al. 2019). Ten juvenile scalloped hammerheads were tagged in June 2011 in the southwestern part of Golfo Dulce and tracked by passive acoustic telemetry (Zanella et al. 2019). The sharks were detected up to 372 days and were resident in the area for the first month after tagging. Although residency declined exponentially after the first month, it remained high for eight consecutive months on two of the tagged sharks. One juvenile female shark, remained in the vicinity of the acoustic array for 9 months, returned after 11 months, and traveled greater than 500 km offshore to adult habitat where it was caught by a longline vessel 3.5 years after tagging. This suggests that Golfo Dulce represents important habitat for juvenile survival and recruitment into adult populations in the Eastern Tropical Pacific (Zanella et al. 2019).

The El Tecuán Estuary off the Pacific coast of Jalisco, Mexico, was identified as a nursery. Seven young-of-the year scalloped hammerhead sharks were tagged with ultrasonic transmitters from October through December 2014 in waters off the estuary (Rosende-Pereiro and Corgos 2018). More than 99% of the detections during active tracking were located at a depth of less than 30 meters (less than 1.5 km from the shore), and approximately 70% were located between 10- and 20-meter depth. The sharks spent the daytime between 1–3 km north or south of the Purificación River, which is part of the estuary system. At dusk, the sharks moved from their location to the vicinity of the river mouth, where they stayed for up to 8 hours, probably feeding, and then moved to zones further away from the river mouth (Rosende-Pereiro and Corgos 2018). The coastal waters of Oaxaca, Mexico are likely also an important parturition and/or nursery area. Scalloped hammerheads (n = 822) collected from artisanal fleets operating in the Pacific off Oaxaca coast from August 2001 to December 2007 were mostly (66.5%) neonates or juveniles (Alejo-Plata et al. 2018). Of the total, 37 were gravid females with litters ranging from 15–42 embryos. These females were caught April to August each year of the study.

The Gulf of California contains important nursery habitat. Based on isotope analysis, Rojes et al. (2013) concluded the southeastern Gulf of California was a nursery area offering abundant food for juvenile scalloped hammerhead sharks. Juveniles were predominant in the area and 80% of the sample (n = 554) had food in their stomachs. Isotopic composition was similar between seasons, sexes, and exhibited a linear isotopic relationship ($\delta 13C$ and $\delta 15N$) with their prey in the area indicating foraging residency. Hoyos-Padilla et al. (2014) tracked a juvenile female scalloped hammerhead tagged January 26, 2007, in La Paz Bay, Mexico. The female measured 95 cm TL when tagged and was recaptured in the same area 10.5 months later at a size of 123 cm TL, which is equivalent to a 4-year-old female. The shark traveled northward to the central Gulf of California before returning to La Paz Bay—a total distance of approximately 3,350 km. During the migration the shark shifted from coastal waters to deeper offshore waters. In the deeper waters, the shark remained in waters less than 30 meters depth during the day and made repeated dives to depths up to 250 meters during the night. The authors concluded this behavior demonstrated an ontogenetic shift from a juvenile inhabiting an inshore nursery to a sub-adult maximizing foraging opportunities in deeper offshore waters.

2.3.1.7 Other:

No other information was found since the 2014 status review (Miller et al. 2014).

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

In terms of effects to habitat, the 2014 status review (Miller et al. 2014) discussed pollution and degradation of water quality as possible serious threats to the scalloped hammerhead nursery and juvenile habitats over continental and insular shelves, but the cumulative anthropogenic effects on the species' continued existence are difficult to quantify. Because scalloped hammerheads' range includes 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' habitat. New information on habitat degradation related to pollution and contaminants is outlined below. Several studies examined bioaccumulation in scalloped hammerheads because of concern over transferring contaminants during human consumption (Bergés-Tiznado et al. 2015, McKinney et al. 2016, Mohammed and Mohammed 2017, Boldrocchi et al. 2019). For climate change impacts see Miller et al. (2014).

<u>Indo-West Pacific DPS</u>
An untreated sewage spill in Laucala Bay, Fiji in 2014 may have led to diseased juvenile scalloped hammerheads (Juste-Poinapen et al. 2019). Fourteen juvenile scalloped hammerheads that were bycaught by fishermen operating in the Rewa Delta, Fiji, were examined for their intestinal microbiome. The authors found microorganisms common to marine species, including sharks. However, two bacterial species (*A. salmonisidas* and *K. pneumonia*) dominated the intestinal microbiota of two individual sharks sampled. Both microbes are described as opportunistic pathogens associated with respiratory and urinary tract infections in humans. A

possible explanation for the infection is that during the study a major sewage spill occurred in Laucala Bay. This discharge continued unabated for 18 days, until temporary control measures were implemented. Although Laucala Bay and the Rewa Delta are separated by about 6 km, contaminated prey may have moved from Laucala Bay to the Rewa Delta via the Vunidawa River that connects these waters or, alternately, newly born and juvenile individuals moved in search of prey and fed in areas contaminated by the sewage (Juste-Poinapen et al. 2019).

Scalloped hammerheads caught (n = 11; November 2016 to February 2017 and from October 2017 to January 2018) in artisanal fisheries operating from Djibouti in the Gulf of Aden, had organochlorine compounds (OCs) and trace elements concentrations with the highest burdens in livers compared with muscles and fins (Boldrocchi et al. 2019).

Scalloped hammerheads (n = 34) collected from beach protection nets along the east coast of South Africa between 2005 and 2010 had high levels of total mercury (12.45 $\pm$ SE 1.84 mg kg^{-1} of dry weight) at concentrations above guidelines for safe human consumption (McKinney et al. 2016).

Eastern Pacific DPS

Scalloped hammerheads caught (n = 40; November to December 2011 and in October 2012) in artisanal fisheries operating in the Gulf of California, Mexico were evaluated for selenium and mercury concentrations (Bergés-Tiznado et al. 2015). The highest concentration of mercury was found in muscle tissue, followed by kidney, liver, and brain, suggesting that mercury is accumulated through diet. Selenium was higher in the kidney, followed by liver, brain, and muscle (Bergés-Tiznado et al. 2015).

Eastern Atlantic DPS

No new information since the status review (Miller et al. 2014).

Central and Southwest Atlantic DPS

Liver tissue samples from scalloped hammerheads captured off the southeastern U.S. Atlantic coast showed that pregnant females transferred a substantial amount of contaminants (0.48–0.66 g of PCBs and 0.14–0.39 g of DDTs representing approximately 0.03–2.3% of the concentration in the hepatic tissue) to their offspring. Potential health impacts are unknown and further research is needed to understand potential effects on shark physiology (Lyons and Adams 2015).

Scalloped hammerheads collected (n = 10) from two commercial fish landing sites in Trinidad had levels of mercury, arsenic, cadmium, and lead in vertebrae, muscle, fin, and liver tissue that would pose a health risk to consumers over long term exposure (Mohammed and Mohammed 2017). The effect, if any, of these contaminants to scalloped hammerheads needs further research.

Summary: Present or threatened destruction, modification or curtailment of its habitat or range

In addition to the threats outlined in the status review (Miller et al. 2014), new information indicates that scalloped hammerhead DPSs are exposed to pollutants and contaminants, but the cumulative anthropogenic effects on the species' continued existence are difficult to quantify. The findings in these studies were directly relevant to three DPSs (Indo-West Pacific, Eastern Pacific, and Central and Southwest Atlantic), but are also likely apply to the Eastern Atlantic

DPS as well. As an apex predator, scalloped hammerheads likely bioaccumulate contaminants wherever they occur. Until further data become available on the possible threats to the species' habitat and/or range, we conclude the extinction risk analysis in Miller et al. (2014) remains valid.

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Targeted Fisheries and Fisheries Interactions
Miller et al. (2014) identified commercial, recreational, and artisanal fisheries, including at-vessel mortality as a major threat to all four DPSs. New information indicates these factors remain a threat to the scalloped hammerhead DPSs.

A global scale of overlap between fisheries and pelagic sharks was conducted and applies to all four listed scalloped hammerheads. Geolocation data from thousands of pelagic longline fishing vessels were examined from 2012 to 2016 to derive the spatial overlap of the vessel activity with shark presence from 23 pelagic shark species, including the scalloped hammerhead, that were tagged from 2002 to 2017 in the Atlantic, Indian, and Pacific Ocean (Queiroz et al. 2016). Overlap was calculated as the number of grid cells that sharks (shark track length) and fishing effort (in days) occurred in the same 1° × 1° (1° = 110.6 km) grid cells in an average month. Shark presence and fishing effort overlapped in 24% of the mean monthly space, although exposure to fishing vessels was as high as 76% in some of the hotspot areas (Queiroz et al. 2019). Major hotspots in the Atlantic Ocean include the Gulf Stream, Caribbean Sea, Gulf of Mexico, and around oceanic islands such as the Azores. In the Indian Ocean, hotspots included the Agulhas Current, Mozambique Channel, South Australian Basin, and northwest Australia. In the Pacific Ocean, hotspots included the California Current, Galapagos Islands, and New Zealand (see Figure 1: *source* Queiroz et al. 2019).

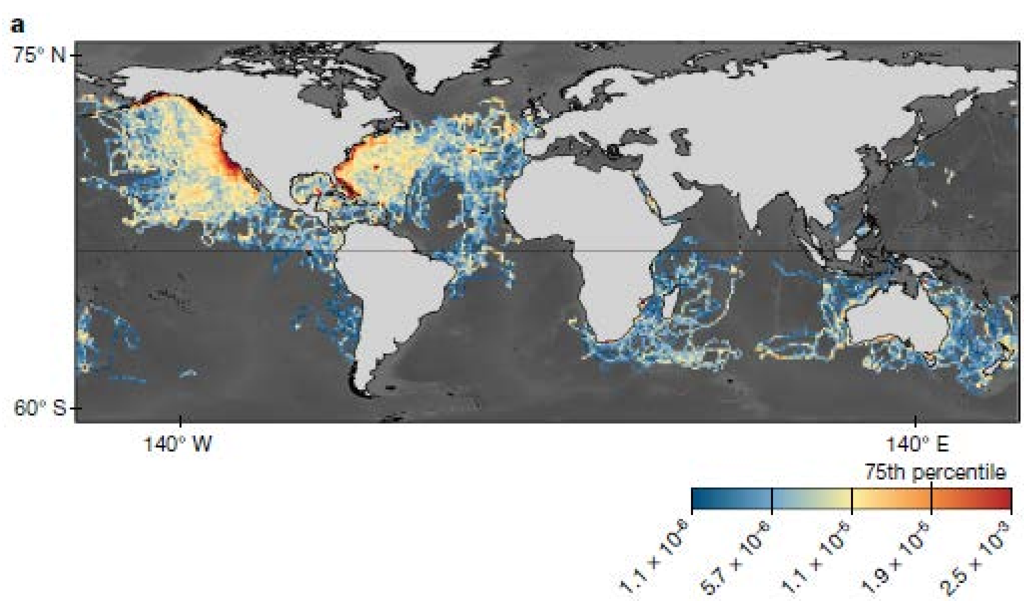

*Figure 1***.** *Relative density of sharks. Distribution of the mean monthly weighted normalized location density of tracked sharks in 1° × 1° grid cells (shark hotspots were defined by cells with* $\geq$ *75th percentile of relative density).* Source: *Queiroz et al. 2019 Figure 2a.*

The remainder of this section is divided by the DPSs, but it is important to note that for some of the high seas fisheries studies, multiple DPSs may be affected.

Indo-West Pacific DPS

In Queensland Australia, the majority of commercial shark product comes from the East Coast Inshore Fin Fish Fishery and the Gulf of Carpentaria Inshore Fin Fish Fishery. An observer program operated from 2006 to 2012, and the scalloped hammerhead was the third most frequent species observed (n = 1,654; observer coverage was voluntary and percent coverage was not reported; Leigh 2015). Jaiteh et al. (2014) estimated bycatch of protected species, including scalloped hammerheads, in the Pilbara Fish Trawl Interim Managed Fishery operating in northeastern Australia in 2008–2009 to be 8,109 (standard error $\pm$ 910) individuals. Sharks and rays dominated the interactions, comprising 66% recorded on video and 92% reported by observers. Overall, bycatch reduction devices (BRDs) reduced the landings of all species by 34%, whereas 66% of animals that interacted with the BRDs were retained in the net and landed on deck. Of these, 90 individuals (77%) were dead and 39 (23%) were alive when discarded. The study did not report estimates for specific species (Jaiteh et al. 2014). Elasmobranch catch by two commercial longline vessels operating off New South Wales during 17 days in 2013 were examined to determine contributing factors for at-vessel mortality. Sixty-five hammerhead sharks (52 scalloped, 2 smooth, and 11 great) were caught during the fishing trips and had among the highest mortality rate among 18 elasmobranch species. All hammerhead sharks died within 5 hours of capture and mortality started to occur after 60 minutes of being hooked (Butcher et al. 2015). High at-vessel mortality was reported off western Australia during research vessel sets (n = 267) using 500 m long demersal longlines with 50 12/0 J-hooks and metal snoods. Depth fished was between 40 and 90 m. Twenty-eight scalloped hammerheads were caught, of which 20 were dead and soak time was found to be a major factor (Braccini and Waltrick 2019).

Scalloped hammerhead sharks are targeted by Indonesian fisheries using pelagic and demersal longlines, purse seines, and gillnets. Several studies reported scalloped hammerhead catch generally from landings data. However, sampling dates overlap in some of the studies and it is unclear whether some of the data collected is duplicative.

In the waters of Aceh Barat and Aceh Jaya from January to July 2014, 311 hammerhead sharks were collected from fishermen. Males (n = 206; $\leq$ 111.5 cm) and juvenile females (n = 57) less than 91.5 cm total length dominated the catch. Approximately 70% were caught in the months of March and April (Jaliadi et al. 2017). Scalloped hammerheads comprised about 10% of the total sharks (n = 2,986) caught in the directed shark fishery operating off Banda Aceh from October 2013 to June 2014. About half of the scalloped hammerheads measured were immature (approximately 110 of 208 measured) (Dharmadi and Kasim 2016). The shark fishery operating from Southern Bali and Lombok down to Northern Australia, Flores Sea, and Makassar Strait reported landing 16,098 sharks between 2014 and 2017, of which 2,425 were scalloped hammerheads. The study used an index of fishing gear and season to determine catch-per-unit-effort, which ranged from about 5 to 8 sharks (15 IUCN vulnerable and endangered species combined) per trip (Simeon et al. 2019). Landings at East Lombok from the targeted shark fishery (52 vessels and 595 trips) from January 2014 through December 2015 reported 1,103 (8.7% of total catch) scalloped hammerheads (Yulianto et al. 2018). Survey data from 2010 and landings data from 2013 collected (n = 852 total) at Tunjung Luar Fish Landing Centre in Indonesia indicate immature and female scalloped hammerheads are commonly caught in the shark fishery operating in coastal waters (Chodrijah and Setyadji 2015).

In eastern Indonesia, Jaiteh et al. (2017) collected catch data from elasmobranch fishing trips (n = 56 trips; 1,912 sharks) and interviewed 186 fishermen (95 active, 91 retired) about their perceptions of changes in their fishery over the last two decades (1993–2012/13). Catch data revealed that *Sphyrna lewini* and *S. mokarran*, were the 5th most numerous combined taxon in the catch. Fishermen's perception (80% of respondents) reported that the numbers and/or sizes of sharks they catch, including the scalloped hammerhead, have decreased over the time they had been fishing. The respondents felt that overfishing was a major factor because historically they were able to catch large mature sharks—a size rarely encountered in the last decade. Despite the apparent impact on several harvested species, there is currently no effective management of the eastern Indonesian shark fishery. Protection mainly is enacted through export bans, which are enforced through spot checks of shipments at a main airport. According to Jaiteh et al. (2017), Indonesia lacks enforcement resources and catches and exports of hammerhead sharks likely will continue unhindered in eastern Indonesia.

An assessment of shark landings at 6 fishing ports in Malaysia (Sarawak and Sabah in eastern Malaysia; Kelantan, Johor, Terrengganu, and Pahang in western Malaysia) conducted from 2014–2017 reported 4,742 sharks, of which 184 (4%) were scalloped hammerheads. Total length size ranged from 40 – 245.3 cm, of which many were newly born, suggesting the fisheries were operating in nursery areas (Arai and Azri 2019). Highest percent of total catch was reported for Sarawak (~33%) followed by Sabah (~5%) and Terengganu and Pahang (~2%). Scalloped hammerheads were not reported from Kelantan and Johor. Fisheries deploying drift gill nets, bottom trawl nets, and hook and line target commercially important species such as mackerel, scad, sardine and tuna and do not target sharks in the area (Arai and Azri 2019).

In Rangong Province of Thailand, a survey conducted between December 2014 and April 2015 at two major landing locations recorded 25 scalloped hammerheads of which all but two were neonates (Arunrugstrichai et al. 2018). This more recent survey shows a drastic decline of percent landings (down to ~1% of landings) for scalloped hammerheads from an earlier study conducted by Krajangdara (2005; cited by Arunrugstrichai et al. 2018), which reported the scalloped hammerhead at about 20% of the landings. The decline in landings may be attributed to overexploitation, but also may be because different ports were surveyed between the studies. Also, possible changes in fisheries effort and practices need to be examined (Arunrugstrichai et al. 2018).

From 2006 to 2014, artisanal shark fisheries in Bangladesh reported scalloped hammerheads as about 5% (total number not reported) of total shark landings by weight (Roy et al. 2015).

Interviews and landings data (n= 68 site visits at 12 landing ports; April 2007–May 2014) in the Balochistan region of southwest Pakistan, reported two mature scalloped hammerheads from fisheries using set nets and longlines. The Pakistan elasmobranch fishery was listed as eighth globally in its landings of sharks and other elasmobranchs during the 1990s, but landings have declined by up to a tenth of peak catch (Gore et al. 2019).

In the southwestern Indian Ocean, catch landings from artisanal fisheries were recorded from drift and bottom set gillnets, dermersal and pelagic longlines and handlines at landings sites in Kenya (n = 8), Zanzibar (n = 8) and northern Madagascar (n = 5) from June 2016 through June 2017. Hammerheads were among the most common and scalloped hammerheads were reported, but the study combined the data within the Family Sphyrnidae (Temple et al. 2019). This study indicated severe underreporting of landings to the FAO. Despite the study covering only select gear types, landings estimates were 72.6% higher than the cumulative total of 20,547 t reported by southwest Indian Ocean nations (which included large-scale fisheries) to the FAO in 2016 and 129.2% more than the 10-year average of 15,468 t (2006–16) (Temple et al. 2019).

In coastal waters off Kenya, catch by weight per unit effort for scalloped hammerheads was 0.73 kg h^{1} $trawl^{1}$ (SD ± 1.6; n = 78 sharks) in the artisanal prawn trawlers operating in Malindi-Ungwana Bay from June 2012 to May 2013. Scalloped hammerheads were one of the dominant shark species caught and consisted largely (>90%) of immature sharks (Kiilu et al. 2019).

Catch data from 2007–2012 collected in a non-motorized, small-scale shark fishery operating in the Toliara region of Madagscar showed 31% (n = 3,505) of the estimated 20 species of shark were scalloped hammerheads (Humber et al. 2017). A significant decrease in the average size of sharks (all species) caught were recorded for the period. The mean and range of recorded size of scalloped hammerheads were 63.6 cm (20–270 cm), which was strongly skewed towards smaller individuals. The dominant size class was 51–60 cm for both male and female scalloped hammerheads and it was estimated that at least 95.3% (n = 1998) of females and 10.6% (n = 1,211) of males were juveniles (Humber et al. 2017).

Eastern Pacific DPS

In the Golfo Dulce, Costa Rica, the artisanal bottom longline caught 872 sharks from May 2010–2011, of which juvenile (74.31 cm ± 17.4 cm) scalloped hammerheads were the majority caught (51.8%) (López-Garro and Zanella 2015). Clarke et al. (2018) assessed susceptibility and vulnerability of scalloped hammerhead catch in the Costa Rica shrimp trawl fishery, which operates exclusively along the Pacific coast between 3.5 and 1,000 meters deep. Based on an analysis of fishery-independent and fishery-dependent surveys conducted between 2008 and 2012, scalloped hammerheads were among the most vulnerable with a score of 2.3 (scale low 1.0 to high 3.0) for both susceptibility and vulnerability. Scalloped hammerheads are also highly vulnerable to incidental catch in the eastern Pacific Ocean tuna purse-seine fishery. Based on observer data from 2005–2013, scalloped hammerheads were among the most vulnerable elasmobranch species caught in the fishery (Duffy et al. 2019). The Eastern Pacific purse-seine fishery operates in areas where scalloped hammerheads occur and the gear are generally set around 200 meters, which is within the vertical distribution for scalloped hammerheads. The vertical and horizontal overlap with the fishery renders scalloped hammerheads susceptible to high catch and mortality rates (Duffy et al. 2019).

The Ecuadorian artisanal fishery, which has the capacity to fish offshore, targets large pelagic fish using longline and surface and bottom gillnets to target coastal fish, as well as shellfish and mollusks. From 2008 to 2012, 106,963 trip-landing inspection reports showed 7,404 scalloped hammerheads were caught. This number is an underestimate because it is a subset of the total fleet (Martínez-Ortiz et al. 2015). Two Ecuadorian tuna purse-seine vessels operating in the eastern Pacific Ocean from May to July 2011, recorded six scalloped hammerheads caught in the seine. All were brought onboard alive; however, when released, these sharks were observed struggling at the surface, floating upside down, and sinking. PSAT data indicated they died post-release (Eddy et al. 2016).

Eastern Atlantic DPS

Observer data from the French tropical tuna purse-seine fishery operating in the eastern Atlantic (n = 8,673 sets; 2005 through 2017) showed scalloped hammerheads were the second most frequently caught elasmobranch (n = 929; 6.0%). The majority of scalloped hammerhead catch (70.2%) consisted of juveniles and overall mortality was 41.66%. When combined with all elasmobranchs, mortality on fish aggregating devices (FAD; 51%) was higher than free swimming tuna schools (FSC; 40%) likely due to higher juvenile catches in FADs (71%) compared to FSC sets (35%) (Clavereau et al. 2018).

Central and Southwest Atlantic DPS

Combined *Sphyrna* spp. catch data from 29,418 longline sets from Brazilian tuna longline vessels operating in the southwestern and equatorial Atlantic Ocean between 2004 and 2011 were analyzed to investigate the distribution, catch rate, and size (Bezerra et al. 2016). During that period, 6,172 hammerhead sharks were caught. The highest percentage of hammerhead sharks were caught in 2007 (3.9% of elasmobranchs) and the lowest in 2010 (0.4% of elasmobranchs). In general, the spatial distribution of the mean CPUE by years and quarters showed a trend of higher catches near the equatorial region and in southern Brazil. Nominal CPUE was 0.12 *Sphyrna* spp. per 1,000 hooks, with the highest value recorded in 2007 (0.30 *Sphyrna* spp. per 1,000 hooks). Females were the dominant catch (n = 205 sexed sharks; 117 were females and 88 were males). Of the sexed sharks, 82% were juvenile females and 54% were juvenile males (Bezerra et al. 2016). A molecular analysis of shark specimens (n = 427) taken from fish markets and landing ports in northern Brazil from 2014–2016 revealed 18 (4.2%) were scalloped hammerhead sharks (Feitosa et al. 2018). A similar study in Guyana, found scalloped hammerheads to be the second most common shark of 14 species found in samples sold in fish markets (17.4%; n = 132; Kolmann et al. 2017).

Fishermen operating off Rio Grande do Norte in northwestern Brazil were interviewed between December 2017 and February 2018 to determine their perception of shark catch. *Sphyrna* spp. was the most common species (n = 172 identifications of which almost half were scalloped hammerheads) identified as bycatch from commercial fisheries targeting snappers, flying fish, and tuna using handline, gillnet, and longlines (Carvalho et al. 2018).

We present several studies of bycatch in the U.S. pelagic longline fishery operating in the northern Atlantic and Gulf of Mexico. In addition, NMFS completed an ESA section 7 consultation on the operation of the Highly Migratory Species (HMS) Fisheries (Excluding

Pelagic Longline) under the Consolidated Atlantic HMS Fishery Management Plan (NMFS 2020). Although scalloped hammerheads are not listed under the ESA in this region, the fishermen operating in in the Atlantic HMS fisheries fish in both the northern Atlantic and Gulf of Mexico. Therefore, the Atlantic HMS fisheries may overlap with the Central and Southwest Atlantic DPS. Thus, the findings of these studies and the NMFS ESA section 7 consultation could inform fisheries management decisions in areas where scalloped hammerhead DPSs occur.

The U.S. shark bottom longline fishery allows landings of scalloped hammerheads in addition to other shark species (e.g., blacktip shark, *Carcharhinus limbatus*, and bull shark, *C. leucas*) in the Atlantic Ocean and Gulf of Mexico. From January to December 2017, a total of 83 trips on 12 vessels with a total of 150 bottom longline hauls were observed. None of these observed trips occurred in the area where the Central and Southwest Atlantic DPS occurs. In the commercial fishery (n = 46 hauls), 13 scalloped hammerhead sharks were caught of which 30.8% were kept, 53.9 % were discarded alive, and 15.4% were discard dead. The shark research fishery has a limited number of vessels (generally around five per year), 100% observer coverage, specific requirements on which species can be kept, and targets sandbar sharks. In the shark research fishery, 186 scalloped hammerhead sharks were caught (n = 104 hauls) of which 74.7% were kept, 20.4% were discarded alive, 4.3% were discarded dead, and 0.5% were of unknown disposition (Mathers et al. 2018).

Gallagher et al. (2014) assessed survival and vulnerability of 12 shark species bycaught in the U.S. pelagic longline fishery targeting swordfish (*Xiphius gladius*), yellowfin tuna (*Thunnus albacares*), and bigeye tuna (*T. obesus*) in the western Atlantic Ocean and Gulf of Mexico from 1995 to 2012. A total of 3,431 swordfish and 1,596 tuna sets were analyzed. Scalloped hammerhead survival significantly increased with deeper hook depths (45.9 m $\pm$ 0.61). However, mean survival rate (45.9%) was among one of the lowest of the 12 species assessed. Gallagher et al. (2014) integrated the survival results with reproductive potential to understand the relative vulnerability of each species to bycatch in the pelagic longline fishery. They found that the scalloped hammerhead exhibited one of the highest vulnerabilities (7.3; range 1.7–9.7) to bycatch. Cortés et al. (2015) conducted an ecological risk assessment of scalloped hammerheads to pelagic longline fleets operating in the North and South Atlantic and found an overall low susceptibility likely due to reduced interactions with the gear in coastal waters and low vulnerability based on moderate productivity.

Gulak et al. (2015) found a 62.9% rate of at-vessel mortality for scalloped hammerheads in 273 bottom longline sets (479, 648.9 hook hours) made between June 2010 and December 2013 in coastal waters off the southeast of the United States. Soak times varied from 1.5 to 22.6 h (mean = 9.4 h; SD 5.8), the mainline length averaged 7.2 km (0.9–22.2 km; SD 4.0) and number of hook timers used per set ranged from 10 to 601 (mean = 199 per set; SD 188). Hooking mortality was influenced by both time on the hook and fishing depth. Median hooking times were 3.5 h and 50% mortality was predicted at 3.5 h and 3.8 h. Gulak et al. (2015) suggest soak time limits as a possible means to reduce hammerhead shark mortality in bottom longline fisheries.

The U.S. Atlantic HMS fisheries (excluding pelagic longlines) operate in the U.S. Exclusive Economic Zone (EEZ) including areas in the Caribbean around Puerto Rico and the U.S. Virgin Islands. In addition to targeting tuna, swordfish, sailfish, marlin and spearfish, the fisheries can catch and land 42 species of shark in the management unit, including the scalloped hammerhead. Because the fisheries can occur in the Caribbean, fisheries overlap with the range of the Central and Southwest Atlantic DPS. NMFS (2020) determined that vertical hook-and-line gear (rod and reel, bandit rigs, buoy gear, and handlines) are likely to adversely affect the Central and Southwest Atlantic DPS. Based on the Marine Recreational Information Program data from Puerto Rico from 2001 through 2016, NMFS expanded the Puerto Rico estimate to all areas fished in territorial and federal waters in the U.S. Caribbean. The expanded estimate was 43 scalloped hammerheads are anticipated to be taken annually. Of these takes, NMFS estimated the federal HMS recreational fishery interacts with 2 to 3 Central and Southwest Atlantic DPS scalloped hammerheads each year of which approximately 50% die (NMFS 2020). In 2004, NMFS completed a consultation on the pelagic longline portion of the Consolidated Atlantic HMS Fishery Management Plan, which .was reinitiated in 2014. Because a final biological opinion on the pelagic longline component was not available for this 5-year review, we present preliminary findings from the consultation and rely on Miller et al. (2014) who provided scalloped hammerhead catch and mortality data from the Atlantic HMS pelagic longline fishery.

NMFS (in prep) analyzed observed take data and observer coverage levels from the observer program along with effort data for the fishery from 2005-2018. These years capture the first full year of the new circle hook and bait requirements imposed on the fishery in 2005, under which the fishery still operates, as well as similar levels of effort. Only 7 of the years from 2005-2018 had observed takes, so estimates could only be derived for those years. Estimated take of the Central and Southwest Atlantic DPS in the HMS pelagic longline fishery was an average of 137 individuals per year alive on retrieval (954.66/7 = 136.38 rounded up to 137) out of an estimated average of 192 total interactions per year (1,339.63/7 = 191.38 rounded up to 192). Of those released alive, NMFS estimated that 28 sharks would die after release based on an estimated 20% mortality rate. An estimated average of 55 individuals per year were dead on retrieval (384.97/7 = 55) annually (NMFS in prep).

Landings and dead discards of sharks by U.S. pelagic longline fishermen in the Atlantic are monitored every year and reported to the International Commission for the Conservation of Atlantic Tunas (ICCAT). From 1992–2000, elasmobranchs represented 15% of the total catch by the pelagic longline fishery, with *S. lewini* comprising 4.3% of the shark bycatch (only 200 individuals over the 9-year period). Analysis of HMS 2005–2009 logbook data indicated that an average of 25 vessels landed 181 hammerhead sharks per year on pelagic longline gear. An additional 1,130 sharks (annual average) were caught and subsequently discarded, with 780 individuals discarded alive and 350 discarded dead (see Miller et al. 2014). NMFS (2019) reported the number of releases and the status of the scalloped hammerhead (ICCAT-prohibited species) from Atlantic HMS pelagic longline vessels in 2017 to be 76 released dead and 140 released alive (NMFS 2019).

Shark Fin Trade

This section is not divided by DPS because it is difficult to know which DPSs are being traded in the market. Illegal shark finning continues to occur in many countries and tracking the source is not always possible. DNA barcoding is an important method for accurately identifying the shark product by species, but its use may not be feasible for compliance inspections.

Hong Kong is a major hub for the shark fin trade and scalloped hammerheads are a major contributor to the market. Cardeñosa et al. (2018a) collected processed fin trimmings (n = 9,200) from Hong Kong retailers (75 randomly selected vendors out of approximately 300 total) from February 2014 to December 2016. Scalloped hammerheads were found in 100% of the sampling events and collectively with smooth hammerheads made up 7.9% of the raw trimmings. In relative abundance, scalloped hammerheads ranked 4th in over 80 species detected. However, it is important to note that trimmings do not necessarily equal number of shark fins, thus the relative abundance may not provide an understanding of the overall prevalence of scalloped hammerheads in the shark fin trade. In a related study, Cardeñosa et al. (2019) sampled small fins (n = 475; average fin base of 3.18 cm, SD = 0.93 cm) in five bags purchased from Hong Kong vendors between December 2018 and January 2019. Scalloped hammerheads were the second most common species indicating juveniles are also a part of the contemporary fin trade. The retail market findings matched the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) records (https://trade.cites.org) of Hong Kong imports in terms of hammerhead sharks (Family Sphyrnidae) being commonly imported, but according to Cardeñosa et al. (2018a), the volume of trade appeared to be underreported in CITES. DNA-based identification of fin trimmings (n = 4,800) from China trade market identified only 8 species or complexes that represented >1% of the trade in 2014–2015, including scalloped hammerheads, which represented 4.08% (Fields et al. 2017).

Based on national import and export data, the shark fin trade in China declined approximately 20% overall from 2003–2011 in concert with a reduction in FAO-reported total production. This was unexpected because China's economy was expanding at the same time and many consumers would have been able to afford shark fins (Eriksson and Clarke 2015). In contrast, shark meat import and quantities rose at an average rate of 4.5% annually from 2000 to 2011 (Dent and Clarke 2015). Causal factors are unknown, but may be driven by the increasing global demand for seafood or by the finning regulations that require shark carcasses be landed together with their fins, which may have prompted markets to sell the meat (Dent and Clarke 2015).

Although Hong Kong remains a major hub in the trade of shark fins, other countries have increased exports in shark fins. For example, in addition to Hong Kong, Thailand, Japan, and Malaysia may be among the world's top four export markets for shark fins (Dent and Clarke 2015).

Information on the shark fin market from other countries has become available since the NMFS 2014 status review (Miller et al. 2014), but the percentage, in most cases, is low. Hammerhead shark fins were a component of the fin trade in United Arab Emirates, Dubai, and Oman (Jabado et al. 2015). Scalloped hammerheads (n = 365) made up 5.42% of the 33 shark species sampled. Shark fin traders confirmed that the most lucrative business was the trade in large shark fins, which were considered of the highest quality, and, therefore, the most expensive. The United Arab Emirates is the fourth largest exporter in the world of raw dried shark fins to Hong Kong and is a major hub in the North Indian Ocean region for the trade in shark products. The Emirati fishery contributes minimally to this trade (Jabado et al. 2015). Samples from retail stores (n = 316) between 2012 and 2014 showed 6.3% were scalloped hammerheads that likely came from domestic Taiwanese fisheries and not from international trade (Chuang et al. 2016). In Costa Rica, 4% of 637 tissue samples collected between June 2013 and September 2014 from the central markets (n = 15) were scalloped hammerheads (O'Bryhim et al. 2017). Identification of illegal shark fins seized in Brazil identified scalloped hammerheads to represent about 1% of 747 shark fins (Ferrette et al. 2019). In the southeastern coastal region of Bangladesh, Haque et al. (2019) collected tissue samples (n = 556) from three landings and nine shark processing centers between 2016 and 2017. A total of 21 species of elasmobranchs were identified through DNA barcoding analysis, including the scalloped hammerhead (n = 2; 5.88% of shark species sampled). In addition to being a signatory to CITES, Bangladesh has identified scalloped hammerheads as a schedule I species protected by the Wildlife (protection and security) Act, 2012 of Bangladesh. The collection of scalloped hammerhead products is a punishable crime (i.e., financial penalties and imprisonment). However, lack of public awareness and sufficient monitoring and enforcement of trade restrictions contribute to illegal trade (Haque et al. 2019). DNA barcoding analysis of shark fins (n = 10) purchased from wholesalers in the United Kingdom in 2016 revealed scalloped hammerheads (n = 2; 37.5% of species) were being sold (Hobbs et al. 2019). The wholesalers stated that they did not have CITES permits and the fins had been imported from Asia in 2015, suggesting the import was not in compliance with CITES (Hobbs et al. 2019). Although still under investigation and not identified to species, a seizure of a shipment on January 24, 2020, at the port of entry in Miami, Florida, revealed 18 boxes of dried shark fins. The shipment was falsely declared and commingled with nonprotected and nonregulated species (M. Doyle E&E news, February 3, 2020), indicating improper CITES documentation.

Summary: Overutilization for commercial, recreational, scientific, or educational purposes
Miller et al. (2014) and the listing rule (79 FR 38213; July 3, 2014) identified overutilization for commercial and/or recreational purposes as a significant threat contributing to the extinction risk of the four scalloped hammerhead shark DPSs. Scalloped hammerhead sharks are targeted by industrial, commercial, artisanal, and recreational fisheries, and caught as bycatch in many other fisheries, including pelagic longline tuna and swordfish, gill net, and purse-seine fisheries. The information in this 5-year review is consistent with fisheries being a major threat to all four DPSs. However, the new information does not indicate a change in the scope, intensity, or severity of impacts of fisheries on the four scalloped hammerhead DPSs that was considered in Miller et al. (2014). See Section 2.4 Synthesis.

2.3.2.3 Disease or predation:

Miller et al. (2014) reported no information had been found to indicate that disease is a factor in scalloped hammerhead shark abundance. In addition, predation was not considered a factor outside of human consumption and use (see Section 2.3.2.2). The only new information since the 2014 status review was a study on fungi infection in captive sharks. Scalloped hammerheads held in the Adventure Aquarium, Camden, New Jersey, were infected (n = 3) with a deleterious fungi—the *Fusarium solani* species complex or *Fusarium*-like species. The fungi cause hemorrhagic and ulcerative lesions. Causal factors included water temperature, exhibit size and design, substrate and decor, and co-exhibiting animal interactions leading to increased susceptibility to opportunistic infections (Desoubeaux et al. 2017). The study cites only 15 cases of the fungi in scalloped hammerheads, including the three in the study, have been reported since the 1980s. Thus, it is unlikely that the fungi infection resulting from aquaria captivity poses a threat to any of the DPSs.

2.3.2.4 Inadequacy of existing regulatory mechanisms:

Miller et al. (2014) examined domestic and international regulatory mechanisms. Their analysis is intact with only a few updates on specific mechanisms described below. This section is not divided by DPS because many of the mechanisms may affect multiple DPSs.

Domestic

Shark Finning Prohibition Act; Shark Conservation Act

Miller et al. (2014) reported that the passage of the Shark Finning Prohibition Act (which was enacted in December 2000 and implemented by final rule on February 11, 2002; 67 FR 6194), significantly decreased U.S. exports of dried Atlantic shark fins. Exports dropped again by 58%, to 15 mt, in 2011 with the passage of the U.S. Shark Conservation Act and closure of loopholes from the previous Act. States have also enacted shark finning bans, including Hawaii (2010), California (2011), Oregon (2011), Washington (2011), the Commonwealth of the Northern Mariana Islands (2011), Guam (2011), American Samoa (2012), Illinois (2012), Maryland (2013), Delaware (2013), New Hampshire (2018), New York (2013), Nevada (2017), Massachusetts (2014), Rhode Island (2016), and Texas (2015) (NMFS 2017; HSI 2019 updated; see Table 1 below).

Magnuson-Stevens Fishery Conservation and Management Act

In 2016, NMFS published a Magnuson-Stevens Fishery Conservation and Management Act (MSA) rule that prohibits any person from removing fins of a shark at sea, possessing shark fins on board a fishing vessel unless they are naturally attached to the corresponding carcass, transferring or receiving fins from one vessel to another at sea unless the fins are naturally attached to the corresponding carcass, landing shark fins unless they are naturally attached to the corresponding carcass, or landing shark carcasses without their fins naturally attached (81 FR 42285; June 29, 2016). In January 2020, NMFS clarified that the MSA requires NMFS to prevent overfishing in shark fisheries regardless of whether fins are allowed to be sold, and that a ban on the sale of shark fins (see section above) would only regulate which parts of a sustainably harvested shark can be used.

Also in 2016 (81 FR 88975), NMFS published an MSA rule to address issues regarding illegal, unreported, and unregulated (IUU) fishing or seafood fraud. The rule established permitting, reporting, and recordkeeping procedures relating to the importation of certain fish and fish products, including sharks, identified as being at particular risk of IUU fishing or seafood fraud. The rule provides additional protections for the sustainability of sharks. It requires the importer of record to provide and report key data from the point of harvest to the point of entry into U.S. commerce (NMFS 2017). During 2016, shark fins were imported through the following U.S. Customs and Border Protection districts: Los Angeles, Miami, and New York. In 2016, countries of origin were China, Hong Kong, the Netherlands, and New Zealand. The mean value of U.S. imports per metric ton has somewhat stabilized with a mean of $12,000/mt in 2016, the same mean value seen in 2015 and 2013. The majority of shark fins exported in 2016 were sent from the United States to Hong Kong, with smaller amounts going to China. The mean value of U.S. exports per metric ton has generally declined since 2012, but average value increased to $71,000/mt in 2016 compared to $57,000/mt in 2015 (NMFS 2017).

International
Miller et al. (2014) reported on the strong provisions adopted by ICCAT (recommendation 10-08) in 2010, which prohibited 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. In addition, all of the tuna regional fishery management organizations (RFMOs) have implemented requirements that the weight of shark fins on board fishing vessels up until the point of landing can be no more than 5% the weight of the shark carcasses on board. Table 1 (below) provides updates since Miller et al. (2014) on international and domestic mechanisms on shark protection and shark finning. Unlike the ICCAT prohibition on hammerhead shark retention, the requirement to land no more than 5% weight of shark fins to shark carcasses does not address mortality or prevent the use of shark fins. The requirements only govern whether the fins are separated and the carcass disposed of at sea. Enforcement of finning controls is lacking in many cases. For example, observer data from the Western and Central Pacific Fisheries Commission (WCPFC) suggest that although finning controls have been in place since 2008, the proportion of sharks finned is still 15–25% in the purse seine fishery (100% observer coverage) and 30–40% in the longline fishery (<2% observer coverage) (Clarke 2013). According to Eriksson and Clarke (2015), transnational cooperative management approaches are required to regulate shark fin trade sources, reinforce national policies across regions including the high seas, and implement rigorous monitoring (e.g., universally implemented product-specific and species-level commodity codes, effective border inspection systems, catch documentation, and other traceability schemes).

Table 1 is from the Humane Society International 2019 update of national laws, multi-lateral agreements, regional and global regulations on shark protection and shark finning (https://www.hsi.org/wp-content/uploads/2019/06/2019-Shark-Fishing-and-Finning-Regulations.pdf). It includes new mechanisms enacted since the 2014 status review (Miller et al. 2014) and includes which DPSs are most likely to be affected. However, an assessment of the effectiveness of these mechanisms at reducing mortality of scalloped hammerheads was not found.

Table 1. Update (2015-2019) of national laws, multi-lateral agreements, regional and global regulations on shark protection and shark finning. See Miller et al. (2014) for earlier mechanisms on shark protection and shark finning.

Country/Origin	Year	Mechanism	DPS
General Fisheries Commission of the Mediterranean	2018	Adopted an European Union-led proposal that requires all sharks to be landed with the fins naturally attached to their bodies	Eastern Atlantic
China	2019	Shark finning banned per IOTC-2019-CoC16-IR03 - Legal Reference: Official Notice on Tuna Management	Indo-West Pacific, Eastern Pacific
Comoros	2015	Shark finning banned per IOTC 2019 Compliance Report: Banned since 2015; Legal reference Articles 35 & 36, Decree No 15_050/PR of 15/04/2015	Indo-West Pacific

Country/Origin	Year	Mechanism	DPS
Iran	2017	Shark finning banned per IOTC-2019-CoC16-CQ10	Indo-West Pacific
Japan	2017/2018	2017 shark finning banned for sharks landed fresh; 2018 shark finning banned for landed frozen per source IOTC-2019-CoC16-CQ11	Indo-West Pacific, but possibly all DPSs
Pakistan	2017	IOTC 2019 Compliance Report: Fisheries Departments, Government of Sindh & Government of Balochistan have issued Notification dated 18-05-2016 under Sindh Fisheries Ordinance 1980 & Notification dated 08-09-2016 under Balochistan Sea Fisheries Ordinance, 1971, received by email 10.05.19.	Indo-West Pacific
Peru	2016	Sharks must be landed with the head and all fins totally or partially attached naturally to the body. Landing of detached fins or trunks without fins is prohibited. (Decreto Supremo No. 021-2016-PRODUCE).	Eastern Pacific
Kiribati	2015/2016	Commercial fishing of any kind was banned in the Phoenix Islands Protected Area and in the area around the southern Line Islands beginning January 2015 and in November 2016, commercial shark fishing was banned in its 3.4 million-square-kilometer (1.3 million-square-mile) EEZ. It also bans the possession, trade, and sale of shark products and the use of wire leaders. Kiribati’s sanctuary expands the Micronesia Regional Shark Sanctuary, completed in 2015, to more than 9 million square kilometers (3.5 million square miles). In all, 15 shark sanctuaries now provide more than 19 million square kilometers (7.34 million square miles) of ocean free of commercial shark fishing	Indo-West Pacific
Micronesia	2015	Sharks are protected in the EEZ of the Federated States of Micronesia (Public Law 18- 108).	Indo-West Pacific
Turks and Caicos	2015	Banned exports of sharks (amendment to territorial fishing regulations)	Central and Southwest Atlantic
India	2015	Export of all shark fins prohibited	Indo-West Pacific
U.S. Nevada	2017	Possession, sale and purchase of shark fins prohibited along with products from other species as part of an anti-wildlife trafficking bill	All DPSs
U.S. New Hampshire	2018	Possession, sale and trade of shark fin products of CITES-listed species, part of an anti-wildlife trafficking law	All DPSs
U.S. Rhode Island	2016	Possession, sale and trade of shark fins was prohibited (with an exception for dogfish)	All DPSs
U.S. Texas	2015	Possession, sale and trade of shark fins was prohibited	All DPSs

Marine Protected Areas

Mackeracher et al. (2019) assessed the effectiveness of marine protected areas (MPAs) in conserving sharks and rays. The authors interviewed scientists, managers, fisheries experts, conservation practitioners, advocates, and policy experts (n = 53) from September 2017 through February 2018 to determine: (a) the effectiveness of MPAs as a tool for shark and ray conservation; (b) which factors influence the success of MPAs for sharks and rays; and (c) the desired outcomes of these MPAs. Thirty-four MPAs from 20 countries were discussed during the interviews, including seven Shark Sanctuaries (Federated States of Micronesia, Cayman Islands, French Polynesia, St. Maarten, Bonaire, Saba, Kiribati). Overall, perceptions were that MPAs were somewhat effective for shark and ray conservation, especially when the MPA was shark and ray-focused. Challenges to effective MPAs were the highly mobile and migratory nature of many shark and ray species. MPA boundaries may be too small and most do not cover the species' home range. Conversely, some are too large, which hinders adequate monitoring and enforcement. Many MPAs are biologically focused and do not consider the importance of socioeconomic characteristics such as the level of community reliance on the resource. Thus, local support for the MPA suffers (Mackeracher et al. 2019). Other studies described below are relevant to the Eastern Pacific DPS.

Nalesso et al. (2019) used passive acoustic monitoring to determine the residency and site preference of scalloped hammerhead sharks at Cocos Island National Park Marine Protected Area (MPA), Costa Rica, in the Eastern Tropical Pacific. Between 2005 and 2012, 84 sharks were tagged of which 62% were female, one was a known male, and the remainder were of unknown gender. Overall, the sharks were strongly associated with Cocos Island, especially at Alcyone, a shallow seamount located 3.6 km offshore from the main island. However, individuals did not remain at Cocos constantly throughout the year and absences of nine months or more were recorded. A diel pattern was observed with sharks moving away from the receiver locations around dusk and returning generally around dawn. These nightly excursions sometimes exceeded the 22 km radius protected area of Cocos MPA. In those cases, the Cocos MPA would only offer protection during daytime hours and not during the night when the sharks move offshore to forage. This increases their vulnerability to longline fishing in the region, which generally operates from dusk to dawn (Nalesso et al. 2019). Hammerhead abundance at Cocos has declined by 45% over the past two decades (White et al. 2015), probably due to a combination of illegal fishing within and legal fishing beyond the boundaries the Cocos MPA. Nalesso et al. (2019) suggested a more regional approach to MPAs is needed to encompass foraging areas, migratory corridors, and nursery areas. In 2012, Costa Rica expanded the Cocos MPA by establishing the Seamounts Marine Management Area (SMMA), consisting of a 9,640 km^2 rectangle surrounding Cocos Island National Park. Within this area, take of scalloped hammerhead sharks is prohibited around a group of seamounts approximately 74 km to the southwest of the Cocos. However, industrial fishing is still permitted within the rest of the SMMA and it is unclear how the area will be enforced (Nalesso et al. 2019).

In May 2018, Costa Rica announced the designation of more than 10,000 acres of nursery habitat in Golfo Dulce for the scalloped hammerhead shark. It established a new level of protection and is part of the 172,974-acre Marine Management Area and Shark Sanctuary planned for the Golfo Dulce ecosystem. No-take zones are also planned for the wetlands of Coto River. In 2016, Ecuador established the Darwin and Wolf Marine Sanctuary together with 21 smaller conservation areas scattered through the volcanic archipelago, protecting over 18,000 m^2 (47,000 km^2), or about one third of the water around the Galápagos Islands. The new sanctuary alone encompasses 15,000 m^2 (40,000 km^2) and extends around the northern Galápagos Islands of Darwin and Wolf. In 2015, Madagascar established a shark sanctuary in the Indian Ocean, which restricts international fishing boats in the bay, establishes locally managed marine areas, and grants exclusive use and management rights to local communities (HSI 2019 update: https://www.hsi.org/wp-content/uploads/2019/06/2019-Shark-Fishing-and-Finning-Regulations.pdf).

Pañaherrera-Palma (2016) modeled habitat utilization by scalloped hammerheads within the GMR and found that nearly 90% of the GMR boundary covers scalloped hammerhead habitat use during the cold season (June–October), but only about 30% during warm season (December–April).Thus, the GMR likely is providing only partial protection for a certain life stage and the sharks are still susceptible to fishing operations outside the reserve.

Convention on the Conservation of Migratory Species of Wild Animals (CMS) Memorandum of Understanding on the Conservation of Migratory Sharks (Sharks MoU)

The Second Meeting of Signatories (MOS2) was held February 15–19, 2016, in San Jose, Costa Rica, with over 30 countries participating in the meeting. Twenty-two species of sharks and rays were added to the Annex of the MoU, including the scalloped hammerhead shark. The MOS2 also established a Conservation Working Group that will develop a strategy for cooperation with fisheries-related bodies and organizations. At the Third Meeting of Signatories held in December 10–14, 2018, in Monaco, the Conservation Working Group reported on their progress. The Conservation Working Group developed a definition of bycatch ('Sharks that interact with but are not the targets of fishing operations') for the MoU, committed to develop a comprehensive best practices guidelines on mitigating bycatch, perform a gap analysis of conservation activities under relevant fisheries bodies, and synthesize priorities for research, conservation, and management measures (https://www.cms.int/sharks/en/CWG1#documents).

Summary: Inadequacy of existing regulatory mechanisms

Miller et al. (2014) identified the inadequacy of existing regulatory mechanisms as a significant threat contributing to the extinction risk of the four scalloped hammerhead shark DPSs. New information indicates expansion of domestic and international mechanisms to conserve sharks (e.g., Table 1 above); however, many measures have only recently been enacted and long-term monitoring is needed before determining the effectiveness of these mechanisms for conserving scalloped hammerhead DPSs. Existing bans on shark finning are not always complied with. For example, observer data from WCPFC suggest that although finning controls have been in place since 2008, the proportion of sharks finned is still 15–25% in the purse seine fishery and 30–40% in the longline fishery. Additional MPAs and shark sanctuaries have been established, but challenges remain. For example, some of these areas do not encompass foraging areas, migratory corridors, and nursery areas. For these reasons, the inadequacy of existing regulatory mechanisms remains a significant threat for the four scalloped hammerhead shark DPSs.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

Shark Deterrent Programs
Shark deterrent programs exist in areas where the Indo-West Pacific DPS and Central and Southwest Atlantic DPS are present. The program in Recife, Brazil, uses drumlines and longlines to deter shark attacks. Sharks caught in the lines are transported to the continental slope, tagged and released. Once released, the sharks tend to continue their migration northward and do not return to the area at risk of shark attacks (Bornatowski et al. 2014). In a shark deterrent program from 2014–2017 along the west coast of Reunion Island in the southwestern Indian Ocean, modified conventional drumlines were deployed. These modified drumlines alert fishermen when bait is taken and can respond quickly to release untargeted species. During 58,770 hours of fishing effort, there were 269 catches comprised of 14 species and scalloped hammerheads were one of the more vulnerable with 54.2% (n = 24) released dead or in weak condition (Guyomard et al. 2019). In Queensland, Australia, a shark deterrent program has operated since 1962 spanning over 1,760 km of coastline (Roff et al. 2018). From 1962 to 2017, nearly 50,000 sharks were caught in the program. Sphyrnidae represented 23% of total catch, which was predominated by *S. mokarran* and *S. lewini*. Based on catch per unit effort, the program has likely depleted the Sphyrnidae population by over 90% (Roff et al. 2018).

Hybridization:
Although not an ESA-listed DPS, scalloped hammerheads were found to breed with the Carolina hammerhead (*S. gilberti*) in the Northwest Atlantic and Gulf of Mexico (Barker et al. 2019). We cite the study to indicate the possibility of hybridization within the listed DPSs. From 2010 through 2017, fin clips were collected from 600 individuals identified as scalloped hammerheads from North Carolina south through Texas. Samples included 506 young-of-the-year, 83 juveniles and 11 adults. Of the 600 samples, Barker et al. (2019) assigned a hybrid class to 4.5–4.9%, which included 10 first-generation hybrids and 15–17 backcrosses indicating the hybrids were viable. All hybrids were young-of-the-year and, with the exception of one case, were the result of female Carolina hammerheads mating with male scalloped hammerheads. It is unknown whether this hybridization would have a negative or positive impact on scalloped hammerheads. More likely, repeated hybridization and backcrossing with scalloped hammerheads could lead to the loss of endemic Carolina hammerheads (Barker et al. 2019).

Summary: Other natural or manmade factors affecting its continued existence
Miller et al. (2014) identified other natural factors, such as the species' high at-vessel fishing mortality and schooling behavior, as contributing to the risk of extinction for each DPS when combined with other threats such as overutilization and illegal fishing. Information in this 5-year review indicates those factors still exist. For example, because the scalloped hammerhead exhibits schooling, fisheries catch can be high (see Section 2.3.2.2). New information on other natural or manmade factors include the possible adverse effects of some shark deterrent programs on local populations in the Indo-West Pacific DPS. However, the effect of the depletion of these populations on the viability of the Indo-West Pacific DPS is unknown. Hybridization occurs with scalloped hammerheads and Carolina hammerheads, but it is unknown whether this will pose a threat in the foreseeable future.

2.4 Synthesis

Systematic monitoring of population abundance does not exist for any of the scalloped hammerhead DPSs. However, data from shark deterrent programs, as well as diver and fishermen surveys indicate all four DPSs have declined. For example, scalloped hammerheads have likely declined up to 50% over the last several decades in Costa Rica. For the threatened Indo-West Pacific DPS and Central and Southwest Atlantic DPS, data from shark deterrent programs and fisheries catch data, respectively, are consistent with the 2014 status review (Miller et al. 2014). The IUCN's most recent assessment designated the scalloped hammerhead as Critically Endangered and described the global population as decreasing at a median of 76.9–97.3%, with the highest probability of >80% reduction over three generation lengths (Rigby et al. 2019). See Section 2.3.1.2 for details.

Threats identified by Miller et al. (2014) remain a concern. Fisheries are a major threat for the scalloped hammerhead. For the Indo-West Pacific DPS, scalloped hammerheads are a major component of targeted fisheries, in some places as high as 33% of the total shark catch. Scalloped hammerheads exhibit high at-vessel mortality when bycaught. Many fisheries report juvenile catch, which may indicate overexploitation. In some places (e.g., Malaysia), young-of-the-year are caught indicating fishing pressure in nursery areas. For the Eastern Pacific DPS, scalloped hammerheads are highly vulnerable and susceptible to catch in shrimp trawl, purse-seine, and artisanal fisheries. For the Eastern Atlantic DPS, the French tropical tuna purse-seine fishery operating in the eastern Atlantic reported scalloped hammerheads as the second most frequently caught elasmobranch of which the majority of catch (70.2%) consisted of juveniles and overall mortality was high—over 40%. For the Central and Southwest Atlantic DPS, fisheries operating off South America reported up to ~4% scalloped hammerheads in their total shark catch. Many were juveniles.

The shark fin trade remains a threat. Based on shark fin trimmings, scalloped hammerheads were the 4th most abundant shark species found in the Hong Kong market. When compared to CITES records, the volume of trade in the Hong Kong market appears to be underreported. Although China's shark fin trade declined approximately 20% overall from 2003–2011, scalloped hammerheads represented about 4.0% of the overall trade. In addition, other countries (e.g., United Arab Emirates, Dubai, and Oman) continue to trade scalloped hammerheads. Some of this trade is likely illegal. For example, analysis of shark fins purchased from wholesalers in the United Kingdom in 2016 revealed scalloped hammerheads (n = 2; 37.5% of species) were being sold without a CITES permit. Although still under investigation, a seizure of a shipment on January 24, 2020, in Miami, Florida, revealed 18 boxes of dried shark fins that were not identified to species. The shipment was not declared as shark fins. Additionally, while the species were not identified, there were multiple species involved, likely some that required CITES documentation, which was not provided.

In addition to apparent non-compliance with CITES, the inadequacy of existing regulatory mechanisms remains a significant threat contributing to the extinction risk of the four scalloped hammerhead shark DPSs. New information indicates an expansion of domestic and international mechanisms to conserve sharks; however, many measures have only recently been enacted and long-term monitoring is needed before determining the effectiveness of these mechanisms for conserving scalloped hammerhead DPSs. In addition measures that have been in place for over a decade show poor compliance. For example, observer data from the WCPFC suggest that although finning controls have been in place since 2008, the proportion of sharks finned is still 15–25% in the purse seine fishery and 30–40% in the longline fishery. Additional MPAs and shark sanctuaries have been established, but challenges remain. For example, some of these areas do not encompass foraging areas, migratory corridors, and nursery areas. See Section 2.3.2 for details.

The above information indicates all four DPSs are declining and significant threats identified in the status review (Miller et al. 2014) and listing rule (79 FR 38213; July 3, 2014) remain a factor in the extinction risk of each of the four DPSs. For the demographic risk, we only found information on population trends.

The decline in the threatened Indo-Pacific DPS is based on two limited shark control programs in Australia and South Africa. These datasets were considered in the Miller et al. (2014) extinction risk analysis. Therefore, we have no new information on population trends for this DPS that would alter the previous results of the extinction risk analysis. Additionally, while significant threats remain a factor for decline, based on the fisheries data, scalloped hammerhead sharks still appear to be fairly common throughout the Indo-Pacific, as represented by their proportions in the bycatch and landings data. As a result, we conclude that the original risk assessment in Miller et al. (2014) for the Indo-Pacific DPS that the Indo-Pacific DPS is threatened remains valid at this time.

For the threatened Central and Southwest Atlantic DPS, the new information on rate of decline is based on the CPUE of all hammerhead sharks for the longline fishing vessels operating in the western and central South Atlantic Ocean up through 2007 (data not available at the time of the 2014 status review and listing rule). Miller et al. (2014) also considered catch data from the Brazilian fleet through 2009 and acknowledged the decline in abundance of this DPS is mainly due to commercial and artisanal fisheries. The new information does not appear to significantly change these conclusions. As noted in Miller et al. (2014) and confirmed again in Cortés et al. (2015), the DPS may have low productivity rates but is also one of the least vulnerable shark species to the pelagic longline fisheries common within the range of this DPS. They are also afforded significant protection in the ICCAT fisheries (i.e., prohibited from being retained, transshipped, landed, sorted, or sold). As a result, we conclude that the original risk assessment in Miller et al. (2014) for the Central and Southwest Atlantic DPS that the Central and Southwest Atlantic DPS is threatened remains valid at this time.

For the endangered Eastern Pacific DPS as well as the endangered Eastern Atlantic DPS, the information on demographic risk gathered in this review is consistent with the Miller et al. (2014) and listing rule (79 FR 38213; July 3, 2014) that both of these DPSs are endangered. The new information provides further support of the significant threats posed by commercial (and in particular purse-seine) fisheries operating throughout the range of these DPSs. And while new MPAs and shark sanctuaries have been established, protection from threats is not guaranteed as some of these areas do not include important foraging areas, migratory corridors, and nursery areas for the species.

For the aforementioned reasons, we recommend no reclassification for any of the DPSs. That is, the Eastern Atlantic DPS and Eastern Pacific DPS should remain listed as endangered, and the Central and Southwest Atlantic DPS and Indo-West Pacific DPS should remain listed as threatened species under the ESA.

3.0 RESULTS

3.1 Recommended Classification

_____Downlist to Threatened
_____Uplist to Endangered
_____Delist
__X_ **No change is needed**

4.0 RECOMMENDATONS FOR FUTURE ACTIONS

NMFS should continue to work through international mechanisms to strengthen measures to protect sharks, including the four scalloped hammerhead shark DPSs.

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NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
Sphyrna lewini

Current Classification:

Recommendation resulting from the 5-Year Review

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__X_No change is needed

LEAD OFFICE APPROVAL:

Director, Office of Protected Resources, NOAA Fisheries

Approve____ Date: ________

HEADQUARTERS APPROVAL:

Assistant Administrator, NOAA Fisheries

_____Concur   _____ Do Not Concur

Signature____ Date_______