Endangered Species Act Status Review Report: Shortfin Mako Shark (*Isurus oxyrinchus*)

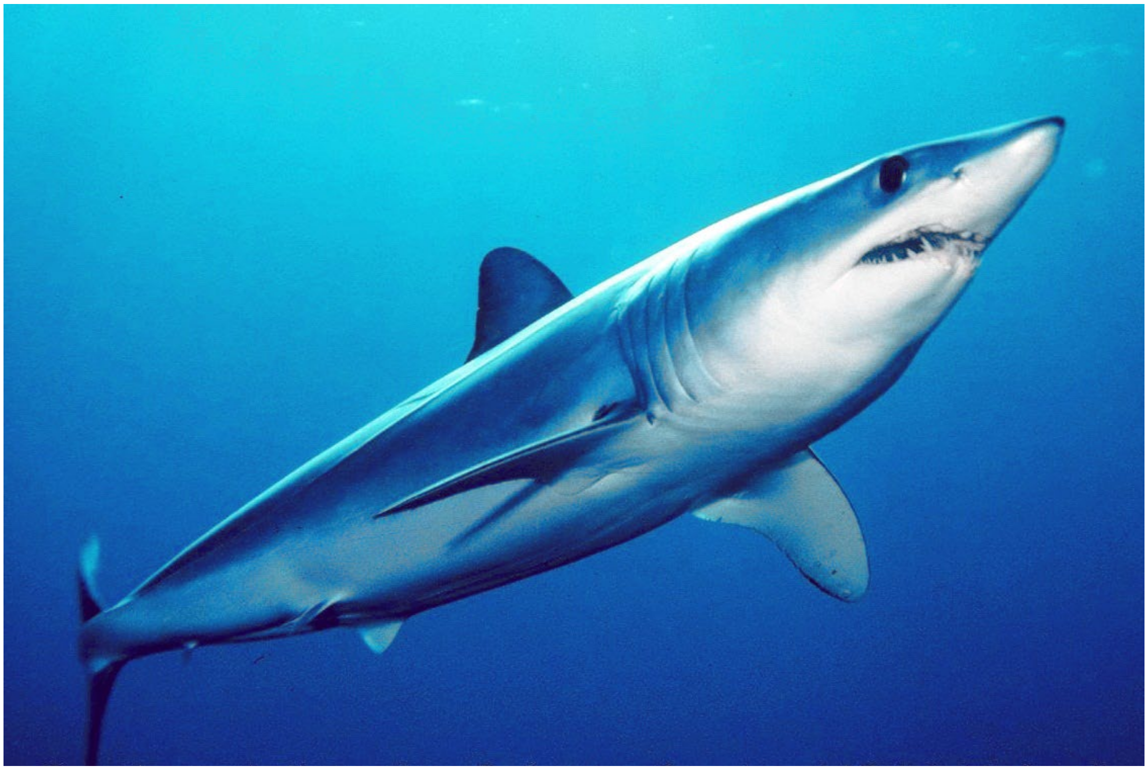

Photo credit: Mark Conlin, NOAA Fisheries, SWFSC Large Pelagics Program

2022
National Marine Fisheries Service
National Oceanic and Atmospheric Administration

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Executive Summary

This report was produced in response to a petition received from Defenders of Wildlife on January 25, 2021, to list the shortfin mako shark (*Isurus oxyrinchus*) as endangered or threatened under the Endangered Species Act (ESA). Under the ESA, if a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. 1533(b)(3)(A)). On April 15, 2021, the National Marine Fisheries Service (NMFS) announced in the Federal Register that the petition presented substantial information in support of the petitioned action and that a status review would be conducted (86 FR 19863). This report summarizes the best available scientific and commercial information on the shortfin mako shark and presents an evaluation of its status and extinction risk.

The shortfin mako is a large pelagic shark that occurs across all temperate and tropical ocean waters. While the species is highly migratory and travels long distances in the open ocean, it is also known to display fidelity to small geographic areas on or near continental shelves and coastal areas of high productivity. The species has a broad thermal tolerance and is able to exploit a high diversity of prey resources. It is a long-lived, late-maturing, and slow-growing species with low productivity.

Abundance trends for the species vary by ocean basin. Significant historical and ongoing population declines are apparent in the North Atlantic Ocean with high certainty, and declines in the Indian Ocean and South Atlantic Ocean are also indicated, though there is very low certainty in available data. The population trend for the species in the North Pacific appears to be stable based on a robust stock assessment, and the population in the South Pacific is increasing based on several abundance indicators.

The greatest threats to the shortfin mako shark are the overutilization of the species for commercial purposes and the inadequacy of existing regulatory mechanisms to address the threat of overutilization. While the species is typically not targeted in commercial fisheries, it is a common bycatch species that is opportunistically retained for its meat and fins that are highly valued for human consumption. Risk assessments have repeatedly found the shortfin mako shark to be at high risk of overexploitation by pelagic longline fisheries given the species' low productivity and high susceptibility to capture. Several regulatory measures aimed at conserving the species have recently become effective, including its listing under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and retention prohibitions in the North Atlantic. It is too soon to evaluate the effect of these measures, however, based on available information, they may be inadequate to protect the shortfin mako shark from overutilization.

Based on the best available scientific and commercial information, we conclude that while overutilization will continue to be a threat to the shortfin mako shark in certain parts of its range through the foreseeable future (25 years), the species is at a low risk of extinction based on available abundance projections, the species' high adaptability and wide spatial distribution, and the existence of genetically and ecologically diverse, sufficiently well-connected populations. We did not find that the species is at a high or moderate risk of extinction in any portions of its range, and we did not find that any distinct population segments (DPS) of the species exist.

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1. INTRODUCTION

Scope and Intent of the Present Document

On January 25, 2021, the National Marine Fisheries Service (NMFS) received a petition to list the shortfin mako shark (*Isurus oxyrinchus*) as either threatened or endangered under the U.S. Endangered Species Act (ESA). Under the ESA, if a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. 1533(b)(3)(A)). NMFS determined the petition presented substantial information for consideration and that a status review was warranted for the species (see following link for the Federal Register notice for shortfin mako shark: https://federalregister.gov/a/2021-07714). This document is the status review of the shortfin mako shark.

The ESA stipulates that listing determinations should be based on the best available scientific and commercial information. NMFS appointed a biologist in the Office of Protected Resources Endangered Species Conservation Division to undertake a scientific review of the biology, population status and trends, threats, and outlook for the shortfin mako shark. Using this scientific review, NMFS convened a team of biologists and shark experts to conduct an extinction risk analysis for the shortfin mako shark and make conclusions regarding the biological status of the species.

Therefore, this document reports the scientific review as well as the Team's conclusions regarding the extinction risk of the shortfin mako shark. The conclusions in this status review are subject to revision should important new information arise in the future. Where available, we provide literature citations to review articles that provide more extensive citations for each topic. Data and information were reviewed through May 2022.

2. LIFE HISTORY AND ECOLOGY

2.1 Taxonomy and Distinctive Characteristics

The shortfin mako shark was first described in 1810 by naturalist Constantine Rafinesque. It is a relatively large (up to ~4 meters (m) in length) pelagic shark that is highly migratory and distributed throughout all temperate and tropical oceanic waters. The species belongs to the family Lamnidae in the order Lamniformes, the mackerel sharks (ITIS 2021). Lamnid sharks are littoral to epipelagic with broad distributions in tropical to cold-temperate waters (Compagno 1984). They are fast-swimming sharks and have a modified circulatory system to maintain internal temperatures warmer than the surrounding water (Compagno 1984).

The species has a moderately slender, spindle-shaped body with a conical snout (Figure 1; Compagno 1984; Compagno 2001). Its pectoral fins are narrow-tipped and moderately broad and long (considerably shorter than the length of the head) as compared to the very long pectoral fins of its single congeneric, the longfin mako shark (*Isurus paucus)*, which also has a less pointed snout and dusky underside (Compagno 1984; Compagno 2001; Ebert *et al*. 2013). The first dorsal fin is large, and the second is very small and pivoting (Compagno 1984). The upper and lower lobes of the caudal fin are of nearly equal size, which is reflected in the genus name *Isurus* from the Greek words for "equal tail." The teeth are large and bladelike without serrations, and the tips of the anterior teeth are strongly reflexed (Compagno 1984). Teeth of the longfin mako shark are relatively more robust and taper to a less fine point (Ebert *et al*. 2013). The dorsal surface of the body is dark blue, and the ventral side is white. The species reaches a maximum total length of about 445 centimeters (Weigmann 2016).

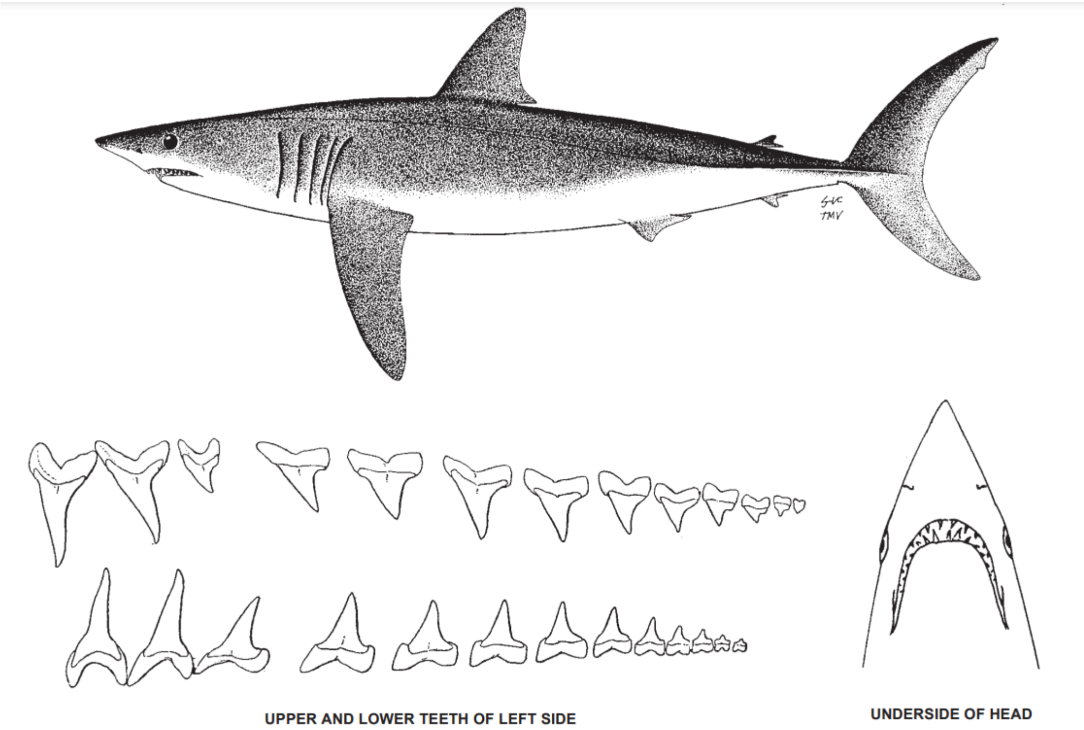

Figure 1. Shortfin mako shark illustrations (reprinted from Compagno 2001).

2.2 Distribution and Habitat Use

The shortfin mako shark is a globally distributed pelagic species, occurring across all temperate and tropical ocean waters from about 50°N (up to 60°N in the northeast Atlantic) to 50°S and across a range of marine habitats (Rigby *et al.* 2019; Santos *et al.* 2020). Compagno (2001) provides the following description of the species' global distribution: in the western Atlantic, the species occurs from the Gulf of Maine to southern Brazil and possibly northern Argentina, including Bermuda, the Caribbean, and the Gulf of Mexico. In the eastern Atlantic, the range spans from Norway, the British Isles, and the Mediterranean to Morocco, Azores, Western Sahara, Mauritania, Senegal, Côte d'Ivoire, Ghana, southern Angola, probably Namibia, and the west coast of South Africa. In the Indo-Pacific basin, the species is found from the east coast of South Africa, Mozambique, Madagascar, Mauritius and Kenya north to the Red Sea, and east to Maldives, Iran, Oman, Pakistan, India, Indonesia, Viet Nam, China, Taiwan, North Korea, South Korea, Japan, Russia, Australia (all states and entire coast except for Arafura Sea, Gulf of Carpentaria and Torres Strait), New Zealand (including Norfolk Island), New Caledonia, and Fiji. In the central Pacific the shortfin mako shark occurs from south of the Aleutian Islands to the Society Islands, including the Hawaiian Islands, and in the eastern Pacific, from southern California (and sometimes as far north as Washington State) south to Mexico, Costa Rica, Ecuador, Peru and central Chile. Rare observations outside of this range have also been made, for example in waters of British Columbia (Gillespie and Saunders 1994). See Figure 2 below for an updated map of the species' distribution.

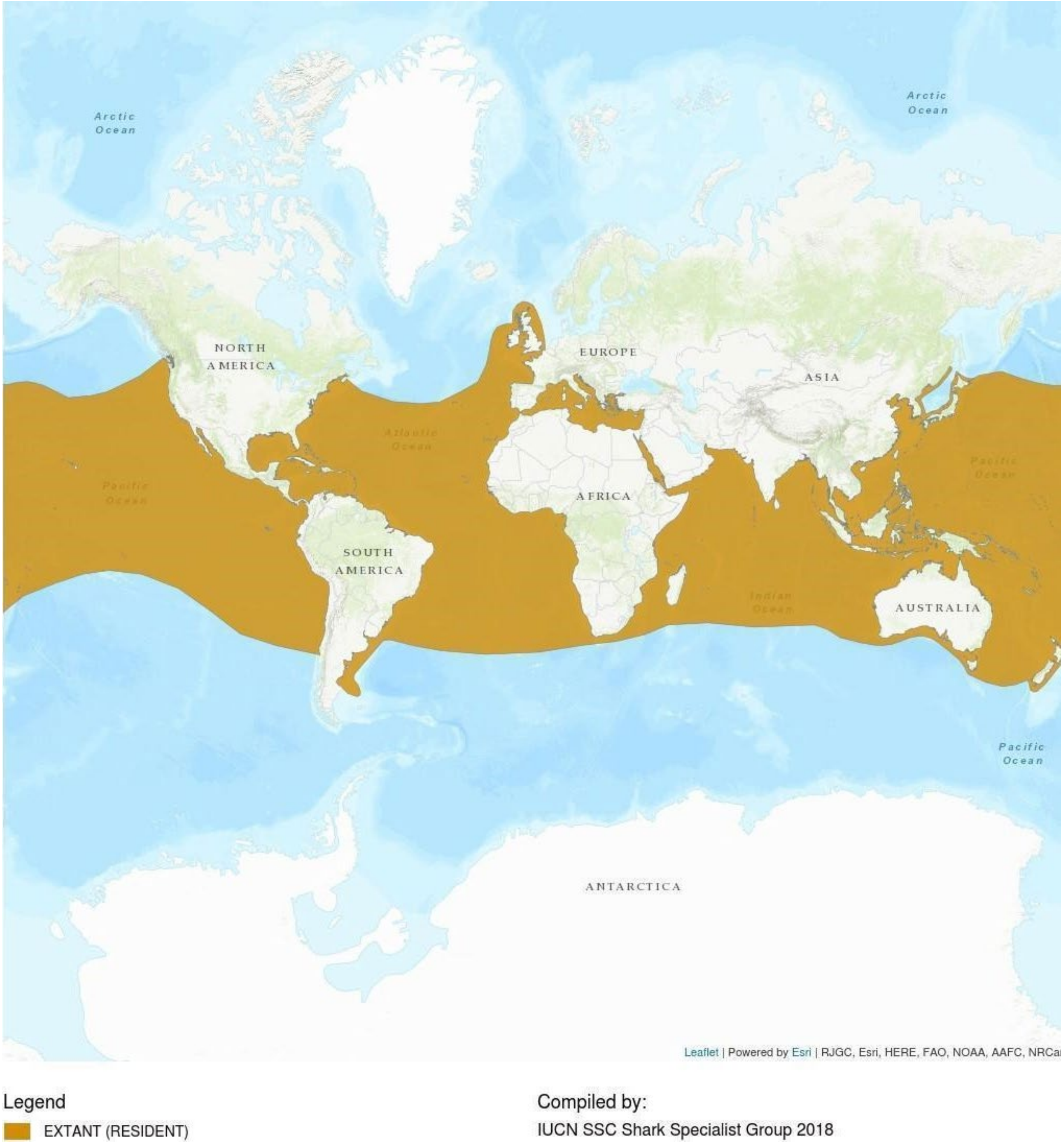

Figure 2. Shortfin mako shark range map (reprinted from IUCN SSC Shark Specialist Group 2018).

The shortfin mako shark is known to travel long distances in and between open ocean, continental shelf, shelf edge, and shelf slope habitats (Rogers *et al.* 2015b; Santos *et al.* 2021), making extensive long distance straight-line movements of several thousand kilometers (km) (Francis *et al.* 2019). From traditional dart and fin tagging data, maximum recorded time at liberty is 12.8 years, and the maximum straight-line distance between tag and recapture localities is 3,043 nautical miles (5,636 km) (Kohler and Turner 2019). Shorter-term electronic tagging results from several studies indicate that the species commonly makes roundtrip migratory movements of more than 20,000 km, with one individual found to undertake an extended migration of 25,550 km over a period of 551 days (Rogers *et al*. 2015b; Francis *et al.* 2019). While the species has also been shown to exhibit fidelity to small geographic areas on or near continental shelves and coastal areas of high productivity, this fidelic behavior is rarely observed in the open ocean (Rogers *et al.* 2015b; Corrigan *et al.* 2018; Francis *et al.* 2019; Gibson *et al.* 2021). Recent research demonstrates that the species regularly switches between these states of activity (i.e., resident or fidelity behavior state and traveling state), spending nearly half their time (44–47%) in residency and slightly less than half their time (35–42%) in transit (Rogers *et al.* 2015b; Francis *et al.* 2019). It is unknown whether these behavioral states are tied to specific behaviors as both states were observed to last for several months, meaning that sharks were more than likely feeding in both states; further, results came from immature males and females and therefore breeding behavior was not a factor (Francis *et al.* 2019). Furthermore, this behavioral switching may be affected by factors including environmental variation, spatial areas of sampling, or biotic factors; therefore, these findings may not be representative of the entire species, especially across time and space. As Francis *et al.* (2019) deployed tags on juveniles, it is possible that the observed patterns would not be consistent across developmental stages, with mature individuals displaying unique spatial movements relative to their juvenile counterparts.

The vertical distribution of shortfin mako sharks is related to numerous environmental variables, including water temperature, dissolved oxygen (DO) concentration, time of day, prey availability, and lunar phase. The species typically occupies waters ranging between 17°C and 22°C (Casey and Kohler 1992; Nasby-Lucas *et al.* 2019; Santos *et al.* 2020, 2021), though it has a broad thermal tolerance and has been shown to also occupy waters from 10°C (Abascal *et al.* 2011) to 31°C (Vaudo *et al.* 2017). Like other lamnid sharks, the shortfin mako shark has counter-current circulation and is a red muscle endotherm, meaning that it can maintain the temperature of its slow-twitch, aerobic red muscle significantly above ambient temperature (Watanabe *et al.* 2015). Red muscle endothermy allows the species to tolerate a greater range of water temperatures, cruise faster, and have greater maximum annual migration lengths than fish without this trait (Watanabe *et al.* 2015). The high energetic cost of endothermy is suggested to be outweighed by benefits such as increased foraging success, prey encounter rates, and access to other seasonally available resources (Watanabe *et al.* 2015). The routine metabolic rate and maximum metabolic rate of shortfin mako sharks is among the highest measured for any shark species (Sepulveda *et al.* 2007), which may explain why the shortfin mako shark typically inhabits waters with DO concentrations of at least 3 milliliters per liter and avoids areas of low DO (Abascal *et al.* 2011). Individuals primarily occupy the upper part of the water column, but dive to depths of several hundred meters (as deep as 979.5 m reported by Santos *et al.* (2021)), allowing them to forage for mesopelagic fishes and squid, though dives may have other functions including navigation (Holts and Bedford 1993; Francis *et al.* 2019). There is evidence that illumination from a full moon causes shortfin mako sharks to move into deeper water, likely in pursuit of prey (Lowry *et al*. 2007). “Bounce” or “yo-yo” diving behavior, in which individuals repeatedly descend to deeper water and then ascend to shallow depths, has been regularly observed in both adults and young-of-the-year (YOY) (Sepulveda *et al.* 2004; Abascal *et al.* 2011; Vaudo *et al.* 2016; Santos *et al.* 2021). This type of diving behavior may be associated with feeding, behavioral thermoregulation, energy conservation, and navigation (Klimley *et al.* 2002; Sepulveda *et al.* 2004). Tagging studies have shown that the species typically spends more time in deeper, colder water during the daytime, and moves to shallower, warmer waters at night (Holts and Bedford 1993; Klimley *et al.* 2002; Sepulveda *et al.* 2004; Loefer *et al.* 2005; Stevens *et al.* 2010; Abascal *et al.* 2011; Nasby-Lucas *et al.* 2019). These diel vertical migrations are typically attributed to the pursuit of prey. However, other studies indicate no significant changes in vertical distribution between daytime and nighttime (Abascal *et al*. 2011, Santos *et al*. 2020). Larger individuals can dive to deeper depths than smaller individuals (Sepulveda *et al.* 2004), and juveniles specifically tend to spend much of their time in shallower, warmer water (Holts and Bedford 1993; Nosal *et al.* 2019).

There is some evidence that certain ocean currents and features may limit movement patterns, including the Mid-Atlantic ridge separating the western and eastern Atlantic (Casey and Kohler 1992 using conventional tagging data from 231 recaptured shortfin mako sharks over a 28-year period; Santos *et al.* 2020 using satellite telemetry for 41 shortfin mako sharks over a period of between 30 and 120 days, see Figure 3 below), and the Gulf Stream separating the North Atlantic and the Gulf of Mexico/Caribbean Sea (Vaudo *et al.* 2017 using satellite telemetry for 26 shortfin mako sharks over a period of 78–527 days). However, conventional tagging data indicates that movement does occur across these features. Data from the NMFS Cooperative Shark Tagging Program (n=1,148 recaptured shortfin mako sharks) over a 52-year period show evidence of the species crossing the Mid-Atlantic Ridge demonstrating exchange between the western and eastern Atlantic (see Figure 4 below; Kohler and Turner 2019). In fact, shortfin mako shark individuals that made long distance movements (> 1,000 nautical miles) at liberty for less than one year (n=104) were primarily tagged off the coast of the U.S. Northeast and were recaptured in the Gulf of Mexico, Caribbean Sea, mid-Atlantic Ocean, and off Portugal, Morocco, and Western Sahara (Kohler and Turner 2019). In the Pacific, tagging data supports east-west mixing in the north and minimal east-west mixing in the south (see Figure 5 below; Sippel *et al.* 2016; Corrigan *et al.* 2018). Trans-equatorial movement appears to be uncommon based on tagging studies (Sippel *et al.* 2016; Corrigan *et al.* 2018), though tagged shortfin mako sharks have been recorded crossing the equator (Rogers et al. 2015a; Santos *et al.* 2021).

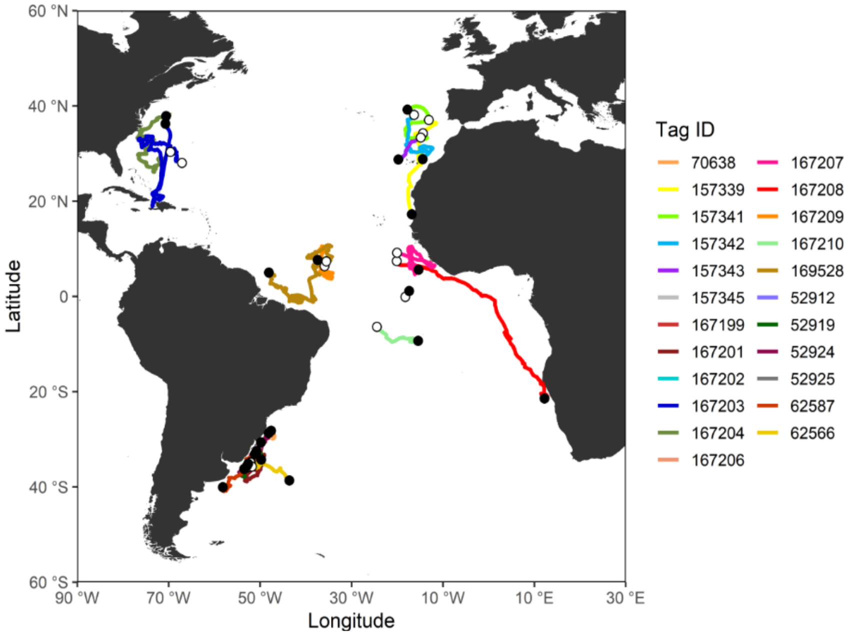

Figure 3. Most likely tracks of shortfin mako sharks tagged with miniPAT pop-up archival transmittal tags in the Atlantic Ocean. White circles represent tagging locations and black circles represent the pop-up locations (reprinted from Santos et al. 2020).

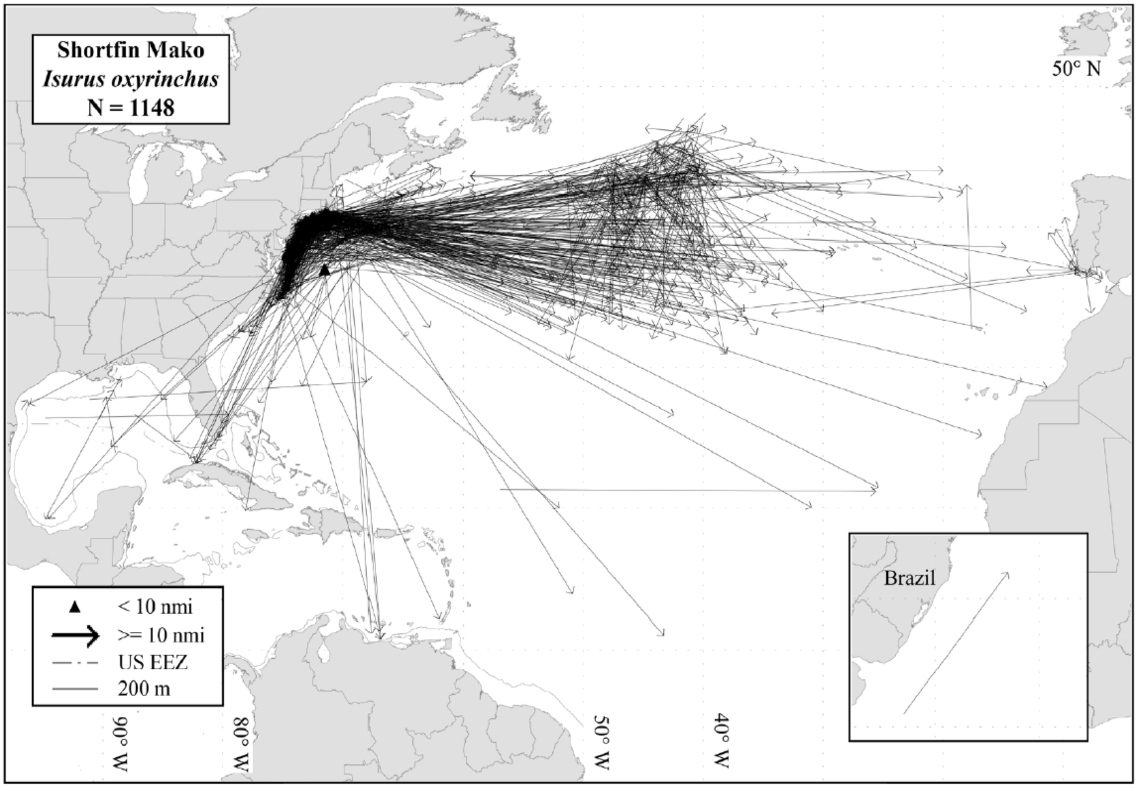

Figure 4. Shortfin mako shark mark-recapture data in the North Atlantic from the NOAA Fisheries Cooperative Shark Tagging Program (reprinted from Kohler and Turner 2019).

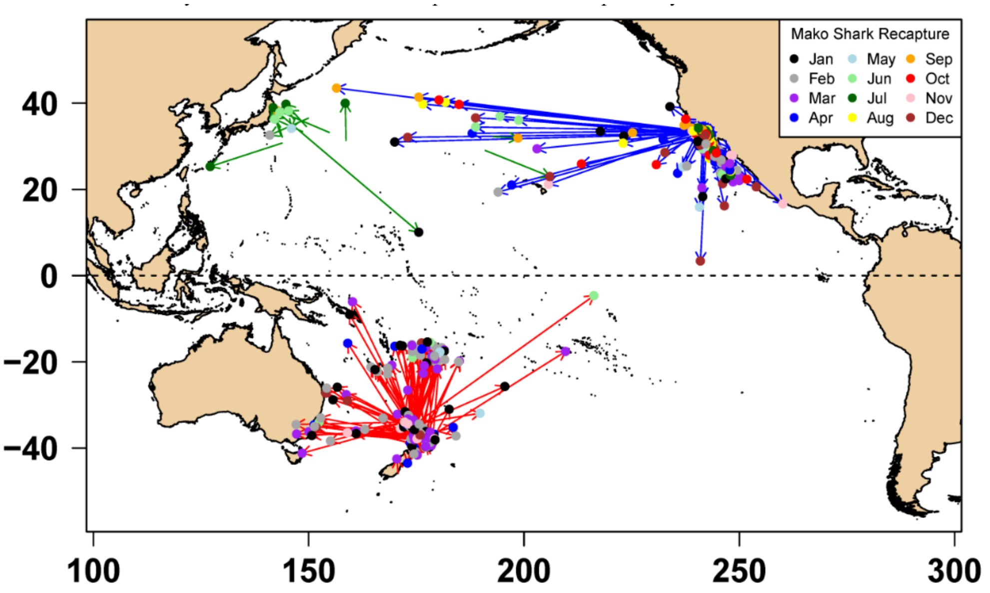

Figure 5. Shortfin mako shark tag recaptures in the Pacific Ocean (reprinted from Sippel et al. 2016).

The location of mating grounds and other reproductive areas are not well known for the shortfin mako shark, although the distribution of the youngest age classes may indicate potential pupping and nursery areas. Casey and Kohler (1992) observed YOY shortfin mako sharks offshore in the

Gulf of Mexico, hypothesizing that pups are born offshore in the Northwest Atlantic to protect them from predation by large sharks, including other makos. Bite marks observed on mature females caught in the Gulf of Mexico may have resulted from mating behavior, indicating that the area may also be a mating ground (Gibson *et al.* 2021). The presence of mature and pregnant females in the Gulf of Mexico provides further support that this is a gestation and parturition ground for the species. However, fisheries data suggests that pupping is geographically widespread in the Northwest Atlantic given that neonates are widely distributed along the coast of North America and largely overlap with the distribution of older immature sharks and adults (Natanson *et al.* 2020). Excursions of tagged shortfin mako sharks towards the shelf and slope waters of the Subtropical Convergence Zone, the Canary archipelago, and the northwestern African continental shelf, as well as aggregations of YOY shortfin mako sharks in these areas, may indicate that they serve as pupping or nursery grounds in the Northeast Atlantic (Maia *et al.* 2007; Natanson *et al.* 2020; Santos *et al.* 2021). In the Eastern North Pacific, the Southern California Bight has been suggested as a nursery area as roughly 60% of the catch here is made up by YOY and two- to four-year-old juveniles (Holts and Bedford 1993; Rodríguez-Madrigal *et al*. 2017; Nasby-Lucas *et al.* 2019). Further south, the presence of many juveniles and some neonates near fishing camps in Baja California, Mexico, suggests that the area between Bahía Magdalena and Laguna San Ignacio may also be a nursery ground for the shortfin mako shark (Conde-Moreno and Galvan-Magana 2006). Presence of small immature shortfin mako sharks off Caldera, Chile, suggests that this may be a pupping or nursery area for the Southeastern Pacific (Bustamante and Bennett 2013). The temperate waters of the south-west Indian Ocean have been shown to host high concentrations of neonates and adults, suggesting that this area may be a nursery ground (Wu *et al.* 2021). Further, pregnant females have been observed in coastal waters off South Africa, strengthening the evidence that this area may be used for pupping or as a nursery (Groeneveld *et al.* 2014).

2.3 Feeding and Diet

The shortfin mako shark is a large, active predator that feeds primarily on teleosts and also consumes cephalopods, other elasmobranchs, cetaceans, and crustaceans (Stillwell and Kohler 1982; Cortés 1999; Maia *et al.* 2006; Gorni *et al.* 2012). It is estimated that shortfin mako sharks must consume 4.6% of their body weight per day to meet their high energetic demands (Wood *et al.* 2009). Based on the shortfin mako shark's diet, the species has a trophic level of 4.3 (tertiary consumers have a trophic level over 4.0, while plants have a trophic level of one), one of the highest of 149 species examined by Cortés (1999) and comparable to other pelagic shark species such as common and bigeye thresher sharks (*Alopias vulpinus* and *A. superciliosus*), the salmon shark (*Lamna ditropis*), and the oceanic whitetip shark (*Carcharhinus longimanus*) (Bizzarro *et al*. 2017). Rogers *et al.* (2012) found evidence that the species targets specific prey despite high prey diversity; however, stable isotope analysis indicates that the species is a generalist predator (Maya Meneses *et al*. 2016). The degree of prey selectivity in any given individual's diet is likely strongly correlated with prey availability, with prey being consumed as encountered.

The specific diet of the shortfin mako shark varies by life stage, geographic location, season, and oceanic habitat. In the Northwest Atlantic, bluefish (*Pomatomus saltatrix*) are a major inshore prey item for the species and have been estimated to make up 77.5% of diet by volume (Stillwell and Kohler 1982), and more recently, 92.6% of diet by weight (Wood *et al.* 2009). In the northeast Atlantic, teleosts made up over 90% of the species' diet by weight, and Clupeiformes and garpike (*Belone belone*) are common prey (Maia *et al.* 2006). In the South Atlantic, teleosts are also dominant in the shortfin mako shark's diet (including *Lepidocibium flavobruneum*, *Scomber colias*, and Trichiruridae), while cephalopods of the orders Teuthida and Octopoda are also consumed (Gorni *et al.* 2012). In the northeast Pacific along the west coast of the United States, jumbo squid (*Dosidicus gigas*) and Pacific saury (*Cololabis saira*) are the two most important prey items, and other frequent teleost prey includes Pacific sardine (*Sardinops sagax*), Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*), and striped mullet (*Mugil cephalus*) (Preti *et al.* 2012). By contrast, YOY and juvenile shortfin mako sharks off Baja California Sur, Mexico, largely consume whitesnout searobin (*Prionotus albirostris*), chub mackerel (*Scomber japonicus*), and a variety of small squids (Velasco Tarelo 2005). As they age, larger teleost species and squids more commonly found in offshore pelagic waters become increasingly important, as evidenced by stable isotope analysis (Velasco Tarelo 2005). A large female shortfin mako shark recreationally caught off the coastline of the Southern California Bight was found to have eaten a California sea lion, *Zalophus californianus,* an event that does not appear uncommon based on previously documented pinnipeds in the stomachs of large shortfin mako sharks (Lyons *et al*. 2015). Shortfin mako sharks in the Indian Ocean prey on teleosts (*Trachurus capensis* and *S. sagax*), elasmobranchs (*Rhizoprionodon acutus* and *Carcharhinus obscurus*), and cephalopods (*Loligo* spp.) (Groeneveld *et al.* 2014). The dominant prey of shortfin mako sharks caught in coastal bather protection nets in the southwest Indian Ocean were elasmobranchs, while the diet of shortfin mako sharks caught in offshore longlines was dominated by teleosts (Groeneveld *et al.* 2014). As the size of individuals caught in coastal bather nets was significantly greater than those caught in offshore longlines, Groeneveld *et al.* (2014) suggest that larger prey attracts larger mako sharks to coastal waters.

2.4 Growth, Reproduction, and Longevity

Shortfin mako sharks are long-lived and are estimated to reach maximum ages of at least 28–32 years based on vertebral band counts validated by bomb radiocarbon and tag-recapture studies (Natanson *et al.* 2006; Dono *et al.* 2015). Longevity in the Pacific has been estimated as high as 56 years (Chang and Liu 2009; Carreon-Zapiain *et al*. 2018). There is uncertainty in the use of vertebral band pair counting to determine age as some authors find evidence for or assume annual growth band deposition periodicity (Cailliet *et al.* 1983; Campana *et al.* 2002; Ardizzone *et al.* 2006; Bishop *et al.* 2006; Semba *et al.* 2009; Dono *et al.* 2015; Liu *et al.* 2018) while others find evidence for the deposition of two growth band pairs each year for either all (Pratt Jr. and Casey 1983) or their first five years of life (Wells *et al.* 2013). Kinney *et al.* (2016) used the recapture of an oxytetracycline-tagged adult male to validate annual band deposition in adult shortfin mako sharks, inferring that juveniles experience more rapid growth and, therefore, exhibit biannual band pair deposition. In addition, there is evidence that vertebral band pair counts do not accurately reflect age in older, large individuals (Harry 2018; Natanson *et al.* 2018). Due to inconsistent information on vertebral band deposition in the Pacific, the International Scientific Committee for Tuna and Tuna-like Species (ISC) Shark Working Group's 2018 stock assessment of shortfin mako sharks in the North Pacific treated data from the western North Pacific as having a constant band pair deposition rate and data from the eastern North Pacific as having a band pair deposition rate that changes from two to one band pairs per year after age five. The 2017 stock assessment of North and South Atlantic shortfin mako sharks conducted by the International Commission for the Conservation of Atlantic Tunas (ICCAT) assumed annual band pair deposition based on Natanson *et al*. (2006).

Shortfin mako sharks exhibit slow growth rates, defined by Branstetter (1990) as having a K-value of less than 0.1 (see Table 1 for K-value estimates). Males and females have similar growth rates until a certain point, when male growth slows down compared to female growth. This has been estimated to occur at seven years of age in the western and central North Pacific (Semba *et al.* 2009), 11 years of age in the Northwest Atlantic (Natanson *et al.* 2006), and 15 years of age (217 cm fork length (FL)) in the western South Atlantic (Dono *et al.* 2015). Females ultimately attain larger sizes than males, as has been documented in other shark species (Natanson *et al.* 2006). Maximum theoretical length in females is reported to be 370 centimeters (cm) total length (TL) in the western and central North Pacific (Semba *et al.* 2009) and 362 cm TL in the eastern North Pacific (Carreon-Zapiain *et al.* 2018). Other estimates are detailed in Table 1. The maximum observed length for the species is 445 centimeters TL (Weigmann 2016), although Kabasakal and de Maddalena (2011) used photographs to estimate the length of a female caught off Turkey at 585 cm TL.

Age and size at maturity vary by geographic location. In general, males and females reach maturity at approximately 6–9 and 15–21 years (Natanson *et al.* 2006; Semba *et al.* 2009), and at sizes of 180–222 cm TL and 240–289 cm TL (Conde-Moreno and Galvan-Magana 2006; White 2007; Varghese *et al.* 2017), respectively (see Table 1 below for additional information and citations).

Shortfin mako sharks reproduce through oophagous (meaning ‘egg eating’) vivipary, wherein, after depletion of their yolk-sac, the embryos develop by ingesting unfertilized eggs and are born as live young (Stevens 1983; Mollet *et al.* 2000). Estimates of gestation time vary from nine months to 25 months (Mollet *et al.* 2000; Duffy and Francis 2001; Joung and Hsu 2005; Semba *et al.* 2011) and litter sizes typically range from four to 25 pups (Mollet *et al.* 2000; Joung and Hsu 2005; Semba *et al.* 2011). Several studies find that litter size increases with maternal size (Mollet *et al.* 2000; Semba *et al.* 2011), though others find no evidence of this relationship (Joung and Hsu 2005; Liu *et al.* 2020). Size at birth is approximately 70 cm TL (Mollet *et al.* 2000). The reproductive cycle is estimated to take up to three years, with a potential resting period of 18 months (Mollet *et al.* 2000). There is evidence that parturition occurs in late winter to mid-spring in both the Northern and Southern Hemisphere based on embryonic growth estimates (Mollet *et al.* 2000; Semba *et al.* 2011; Bustamante and Bennett 2013), though Duffy and Francis (2001) found evidence of parturition in summer. With regard to mating strategy, two studies have found genetic evidence for polyandry and multiple paternity within litters, though other mating strategies (e.g., polygyny or monogamy) cannot be ruled out (Corrigan *et al*. 2015; Liu *et al*. 2020).

Table 1. Growth and reproduction parameters for shortfin mako sharks from available literature (m = male, f = female, c = combined sexes, $L\infty$ = mean asymptotic length, K = von Bertalanffy growth constant, t_0 = theoretical age at zero length, L0 = length at birth, PCL = pre-caudal length, CFL = curved fork length).

Parameter	Estimate	Region	Reference
Theoretical Longevity	29 years (m), 28 years (f)	SW Pacific	(Bishop *et al.* 2006)
	29 years (m), 32 years (f)	NW Atlantic	(Natanson *et al.* 2006)

Parameter	**Estimate**	**Region**	**Reference**
	56 years (c)	NE Pacific	(Carreon-Zapiain *et al.* 2018)
Growth rate (von Bertalanffy growth function)	$L_\infty = 302$ cm FL, $K = 0.266$ year^{-1}, $t_0 = -1$ years (m)	NW Atlantic	(Pratt Jr. and Casey 1983)
	$L_\infty = 345$ cm FL, $K = 0.203$ year^{-1}, $t_0 = -1$ years (f)	NW Atlantic	(Pratt Jr. and Casey 1983)
	$L_\infty = 253.3$ cm FL, $K = 0.125$ year^{-1}, $L_0 = 71.6$ cm FL (m)	NW Atlantic	(Natanson *et al.* 2006)
	$L_\infty = 432.2$ cm FL, $K = 0.043$ year^{-1}, $L_0 = 81.2$ cm FL (f)	NW Atlantic	(Natanson *et al.* 2006)
	$L_\infty = 411$ cm TL, $K = 0.05$ year^{-1}, $t_0 = -4.7$ years (c)	NE Pacific	(Ribot-Carballal *et al.* 2005)
	$L_\infty = 302.16$ cm FL, $K = 0.0524$ year^{-1}, $t_0 = -9.04$ years (m)	SW Pacific	(Bishop *et al.* 2006)
	$L_\infty = 732.41$ cm FL, $K = 0.0154$ year^{-1}, $t_0 = -10.79$ years (f)	SW Pacific	(Bishop *et al.* 2006)
	$L_\infty = 296.60$ cm TL, $K = 0.087$ year^{-1}, $t_0 = -3.58$ years (m)	SE Pacific	(Cerna and Licandeo 2009)
	$L_\infty = 325.29$ cm TL, $K = 0.076$ year^{-1}, $t_0 = -3.18$ years (f)	SE Pacific	(Cerna and Licandeo 2009)
	$L_\infty = 231.0$ cm PCL, $K = 0.16$ year^{-1}, $L_0 = 59.7$ cm PCL (m)	Central and Western N Pacific	(Semba *et al.* 2009)
	$L_\infty = 308.3$ cm PCL, $K = 0.090$ year^{-1}, $L_0 = 59.7$ cm PCL (f)	Central and Western N Pacific	(Semba *et al.* 2009)
	$L_\infty = 251.6$ cm CFL, $K = 0.15$ year^{-1}, $t_0 = -2.488$ years (m)	S Indian	(Liu *et al.* 2018)

Parameter	**Estimate**	**Region**	**Reference**
	L_∞ = 323.8 cm CFL, K = 0.075 year^{-1}, t_0 = −4.360 years (f)	S Indian	(Liu *et al.* 2018)
	L_∞ = 285 cm FL, K = 0.113 year^{-1}, L_0 = 90 cm FL (c)	SW Indian	(Groeneveld *et al.* 2014)
Maximum length	270 cm FL (m), 347 cm FL (f) observed	SW Pacific	(Bishop *et al.* 2006)
	370 cm TL (f) theoretical	Western and Central N Pacific	(Semba *et al.* 2009)
	445 cm TL observed	Mediterranean	(Weigmann 2016)
Length at maturity	165 cm PCL (m), 256 cm PCL (f)	Western and Central N Pacific	(Semba *et al.* 2011)
	180 cm FL (m)	NE Atlantic	(Maia *et al.* 2007)
	180 cm TL (m)	NE Pacific	(Conde-Moreno and Galvan-Magana 2006)
	189–222 cm TL (m), 266–289 cm TL (f)	N Indian	(Varghese *et al.* 2017)
	180.2 cm TL (m)	SE Pacific	(Bustamante and Bennett 2013)
	186 cm TL (m), 240–250 cm TL (f)	Indo-Pacific	(White 2007)
	180–185 cm FL (m), 275–285 cm FL (f)	SW Pacific	(Francis and Duffy 2005)
	185 cm FL (m), 275 cm FL (f)	NW Atlantic	(Natanson *et al.* 2006)
	182 cm FL (m), 280 cm FL (f)	N Atlantic	(Natanson *et al.* 2020)

Parameter	**Estimate**	**Region**	**Reference**
	190 cm TL (m)	NE Pacific	(Carreon-Zapiain *et al.* 2018)
	190 cm FL (m), 250 cm FL (f)	SW Indian	(Groeneveld *et al.* 2014)
	195 cm TL (m), 280 cm TL (f)	Indo-Pacific	(Stevens 1983)
	210 cm TL (m), 278 cm TL (f)	NW Pacific	(Joung and Hsu 2005)
Age at maturity	6 years (m), 16 years (f)	Central and Western N Pacific	(Semba *et al.* 2009)
	7 years (m), 15 years (f)	SW Indian	(Groeneveld *et al.* 2014)
	7–9 years (m), 19–21 years (f)	SW Pacific	(Bishop *et al.* 2006)
	8 years (m), 18 years (f)	NW Atlantic	(Natanson *et al.* 2006)
Gestation period	9–13 months	Central and Western N Pacific	(Semba *et al.* 2011)
	12 months	NW Atlantic	(Pratt Jr. and Casey 1983)
	15–18 months	Global	(Mollet *et al.* 2000)
	23–25 months	NW Pacific	(Joung and Hsu 2005)
Litter size	4–15	NW Pacific	(Joung and Hsu 2005)
	4–16	Indo-Pacific	(Stevens 1983)
	8–17	Western and Central N Pacific	(Semba *et al.* 2011)

Parameter	**Estimate**	**Region**	**Reference**
	9–14	SW Indian	(Groeneveld *et al.* 2014)
	4–25	Global	(Mollet *et al.* 2000)
	Up to 20	SW Atlantic	(Costa *et al.* 2002)
Length at birth	64.5–72.0 cm TL	SW Atlantic	(Costa *et al.* 2002)
	70 cm TL	Indo-Pacific	(Stevens 1983)
	70 cm TL	Global	(Mollet *et al.* 2000)
	70 cm TL (m), 79.3 cm TL (f)	SE Pacific	(Cerna and Licandeo 2009)
	74 cm TL	NW Pacific	(Joung and Hsu 2005)
Parturition timing	Late winter – mid-spring	Global	(Mollet *et al.* 2000)
	Summer	SW Pacific	(Duffy and Francis 2001)
	Winter through mid-summer	NW Pacific	(Joung and Hsu 2005)
	Winter and spring	Central and Western N Pacific	(Semba *et al.* 2011)
Reproductive cycle timing	2 years	NW Pacific	(Tsai *et al.* 2014)
	3 years (18 month resting period)	Global	(Mollet *et al.* 2000)
	3 years (12 month resting period)	NW Pacific	(Joung and Hsu 2005)

2.5 Population Structure and Genetics

Although certain ocean currents and features may limit movement patterns between different regions as discussed in section 2.2 Distribution and Habitat Use, several genetic studies indicate a globally panmictic population with some genetic structuring among ocean basins.

Heist *et al.* (1996) investigated genetic population structure using restriction fragment length polymorphism analysis of maternally inherited mitochondrial DNA (mtDNA) from shortfin mako sharks in the Northwest Atlantic (n=21), central North Atlantic (n=24), western South Atlantic (n=23), eastern North Pacific (n=30), and western South Pacific (n=22). The North Atlantic samples showed significant isolation from other regions ($p<0.001$) and differed from other regions by the relative lack of rare and unique haplotypes and high abundance of a single haplotype (Heist *et al.* 1996). Significant differences in haplotype frequencies were not detected between the samples from Brazil, Australia, and California (Heist *et al.* 1996). Haplotypes did not seem to be confined to specific regions, and the three most common haplotypes were found in all samples (Heist *et al.* 1996). Clustering of mtDNA haplotypes did not initially support the presence of genetically distinct stocks of shortfin mako shark (Heist *et al.* 1996); however, reanalysis of the data found significant differentiation between the South Atlantic and North Pacific samples (Schrey and Heist 2003) in addition to isolation of the North Atlantic.

A microsatellite analysis of samples from the North Atlantic (n=152), South Atlantic (Brazil; n=20)), North Pacific (n=192), South Pacific (n=43), and Atlantic and Indian coasts of South Africa (n=26) found very weak evidence of population structure ($F_{ST} = 0.0014$, $P = 0.1292$; $R_{ST} = 0.0029$, $P = 0.019$) (Schrey and Heist 2003). Pairwise F_{ST} comparisons were not statistically significant after Bonferroni correction, though one pairwise R_{ST} value (North Atlantic vs. North Pacific) showed significant differentiation ($R_{ST} = 0.0106$, $P = 0.0034$). These results were insufficient to reject the null hypothesis of a single genetic stock of shortfin mako shark, suggesting that there is sufficient movement of shortfin mako sharks, and therefore gene flow, to reduce genetic differentiation between regions (Schrey and Heist 2003). The authors note that their findings conflict with the significant genetic structure revealed through mtDNA analysis by Heist *et al.* (1996). They suggest that as mtDNA is maternally inherited and nuclear DNA is inherited from both parents, population structure shown by mtDNA data could indicate that female shortfin mako sharks exhibit limited dispersal and philopatry to parturition sites, while male dispersal allows for gene flow that would explain the results from the microsatellite data (Schrey and Heist 2003).

Taguchi *et al.* (2011) analyzed mtDNA samples from the central North Pacific (n=39), western South Pacific (n=16), eastern South Pacific (n=10), North Atlantic (n=9), eastern Indian Ocean (n=16), and western Indian Ocean (n=16), finding evidence of significant differentiation between the North Atlantic, and the central North Pacific and eastern South Pacific (pairwise $\Phi_{ST} =$ 0.2526 and 0.3237, respectively). Interestingly, significant structure was found between the eastern Indian Ocean and the Pacific Ocean samples (pairwise Φ_{ST} values for Central North Pacific, Western South Pacific, Eastern South Pacific are 0.2748, 0.1401, and 0.3721, respectively), but not between the eastern Indian and the North Atlantic (Taguchi *et al*. 2011).

Corrigan *et al.* (2018) also found evidence of matrilineal structure from mtDNA data, while nuclear DNA data provide support for the existence of a globally panmictic population. Although there was no evidence of haplotype partitioning by region and most haplotypes were found across many (sometimes disparate) locations, Northern Hemisphere sampling locations were significantly differentiated from all other samples, suggesting reduced matrilineal gene flow across the equator (Corrigan *et al.* 2018). The only significant differentiation indicated by microsatellite data was between South Africa and southern Australia (pairwise $F_{ST} = 0.037$, $\Phi_{ST} = 0.043$) (Corrigan *et al.* 2018). Clustering analysis showed only minor differences in allele frequencies across regions and little evidence of population structure (Corrigan *et al.* 2018). Overall, the authors conclude that although spatial partitioning exists, the shortfin mako shark is genetically homogenous at a large geographic scale. Taken together, results of genetic analyses suggest that female shortfin mako sharks exhibit fidelity to ocean basins, possibly to utilize familiar pupping and rearing grounds, while males move across the world's oceans and mate with females from various basins, thereby homogenizing genetic variability (Heist *et al*. 1996; Schrey and Heist 2003; Taguchi *et al*. 2011; Corrigan *et al*. 2018).

Haplotype diversity in shortfin mako sharks has been found to be high in several studies. Heist *et al.* (1996) found 25 haplotypes among 120 individuals for an overall haplotype diversity of 0.755 and a nucleotide diversity of 0.347. Taguchi *et al.* (2011) found haplotype and nucleotide diversity to be 0.92 and 0.0070, respectively, across the global range of the species. Corrigan *et al.* (2018) detected 48 unique haplotypes among 365 individuals for a haplotype diversity of 0.894 ± 0.013 and found very low nucleotide diversity of 0.004 ± 0.003.

2.6 Demography

Natural mortality for shortfin mako sharks is low and was estimated by Bishop *et al*. (2006) at 0.14 and 0.15 year^{-1} for males and females, respectively. Chang and Liu (2009) calculated natural mortality at 0.077–0.244 year^{-1} for females and 0.091–0.203 year^{-1} for males in the Northwest Pacific. In the North Atlantic, natural mortality was estimated at 0.101 year^{-1} (Bowlby *et al*. 2021). The generation time is estimated at 25 years (Cortés *et al*. 2015; Rigby *et al*. 2019).

In an analysis of productivity and susceptibility to longline fisheries in the Indian Ocean, Murua *et al*. (2012) calculated a population finite growth rate (λ) for shortfin mako sharks of 1.061 year^{-1} (1.040–1.081). In an updated risk analysis, these values became 1.049 year^{-1} (1.036–1.061; Murua *et al*. 2018). Liu *et al*. (2015) estimated values for λ of shortfin mako sharks off California to be 1.1213 ± 0.0635 year^{-1} and 1.0300 ± 0.0763 year^{-1} for those in the Northwest Pacific. As the species displays sexual dimorphism in size, growth rates, and size at maturity, Tsai *et al*. (2015) argue that the use of a two-sex demographic model more accurately estimates the probability of decline risk and, therefore, better informs management decisions. Further, as the mating mechanism of shortfin mako sharks affects the proportion of breeding females and has not been conclusively established, these scenarios (monogamous, polyandrous, polygynous) should be modeled as well (Tsai *et al*. 2015). The authors report that in the Northwest Pacific, without fisheries-related mortality, values for λ were 1.047, 1.010, and 1.075 year^{-1} for females and 1.056, 1.011, and 1.090 year^{-1} for males in monogamous, polyandrous, and polygynous mating scenarios, respectively. Under fishing conditions at the time of the study, all values for λ dropped to less than 1 (0.943, 0.930, and 0.955 year^{-1} for females and 0.918, 0.892, and 0.939 year^{-1} for males in monogamous, polyandrous, and polygynous mating scenarios, respectively). Thus, population declines were expected regardless of the mating system modeled.

Productivity for the shortfin mako shark is quite low. In a recent analysis using six methods, Cortés (2016) determined that the intrinsic rate of population increase (r_{max}) for Atlantic shortfin mako sharks ranged from 0.036–0.134 yr^{-1}. These values were among the lowest calculated from 65 populations and species of sharks (Cortés 2016).

3. GLOBAL AND REGIONAL ABUNDANCE ESTIMATES AND TRENDS

3.1 Global Population Trends

Currently, there is no estimate of the absolute global abundance of the shortfin mako shark; however, based on the age-structured assessments conducted by ICCAT (2017) and the ISC Shark Working Group (2018), current abundance is estimated at one million individuals in the North Atlantic and eight million individuals in the North Pacific (FAO 2019). Comprehensive analyses based on regional stock assessments and standardized catch-per-unit-effort (CPUE) data have been used by the International Union for Conservation of Nature (IUCN) to approximate trends for the species globally.

In the 2019 IUCN Red List assessment, Rigby *et al*. estimated a global population trend using the following data sources: (1) the 2017 stock assessments conducted by ICCAT for the North and South Atlantic, (2) the 2018 stock assessment conducted by the ISC Shark Working Group for the North Pacific, (3) standardized CPUE data for the South Pacific from Francis *et al.* (2014), and (4) a preliminary stock assessment in the Indian Ocean by Brunel *et al.* (2018). Individual trends by region are discussed in section 3.2 Regional Population Trends, below. Using Just Another Red List Assessment (JARA) (Winker *et al*. 2018; Sherley *et al*. 2019), a Bayesian state-space tool for trend analysis of abundance indices, Rigby *et al.* (2019) found that the species is declining in all oceans other than the South Pacific, where it is increasing, with the steepest population declines indicated in the North and South Atlantic. Due to the unreliable stock assessment in the South Atlantic (discussed further below), the North Atlantic stock assessment was considered as representative of the South Atlantic for the trend analysis, which may have overestimated the extent of decline in this region. A global trend was estimated by weighting each region's trend by the relative size of each region. To standardize the time period over which the trends were calculated, JARA projected forward the amount of years without observations that it would take to reach three generation lengths. The overall median population reduction was estimated at 46.6%, with the highest probability of 50–79% reduction over three generation lengths (72–75 years). Trends indicated by Rigby *et al.* (2019) do not always align with abundance and trend indicators from other sources, as discussed below in section 3.2 Regional Population Trends. The JARA framework used by Rigby *et al*. (2019) has been described as inappropriate for this long-lived, sexually dimorphic species as it only uses mean annual trends in the population over the assessment period and does not consider size or age structures of the population over recent decades (Kai 2021a).

3.2 Regional Population Trends

North Atlantic Ocean

The most recent stock assessment by ICCAT indicates a combined 90% probability that the North Atlantic stock is in an overfished state and is experiencing overfishing (see Figure 7 below; ICCAT 2017). The nine model runs used in this assessment (which included Just Another Gibbs Sampler emulating the Bayesian production model [BSP2-JAGS], Just Another Bayesian Biomass Assessment [JABBA], Catch-only Monte-Carlo method [CMSY], and Stock Synthesis 3 [SS3]) generally agreed, indicating that stock abundance in 2015 was below biomass at maximum sustainable yield (B_{MSY}), though the production models provided a more pessimistic result than the age-structured model (ICCAT 2017). The age-structured stock assessment model (SS3) estimates historical declines in spawning stock fecundity from 1950 (unfished condition) to 2015 at 50% and recent declines (from 2006 to 2015) at 32% (FAO 2019). All assessment models were consistent, and together indicated that the North Atlantic shortfin mako shark has experienced historical declines in total biomass of between 47–60% and recent declines in total biomass of between 23–32% (FAO 2019). Projections conducted in the 2017 assessment using a production model (BSP2-JAGS) found that for a total allowable catch (TAC) of 1,000 metric tons (t), the probability of being rebuilt and not experiencing overfishing (biomass (B)>B_{MSY}, and fishing mortality (F)<fishing mortality at MSY (F_{MSY})) was estimated to be only 25% by 2040 (one generation length).

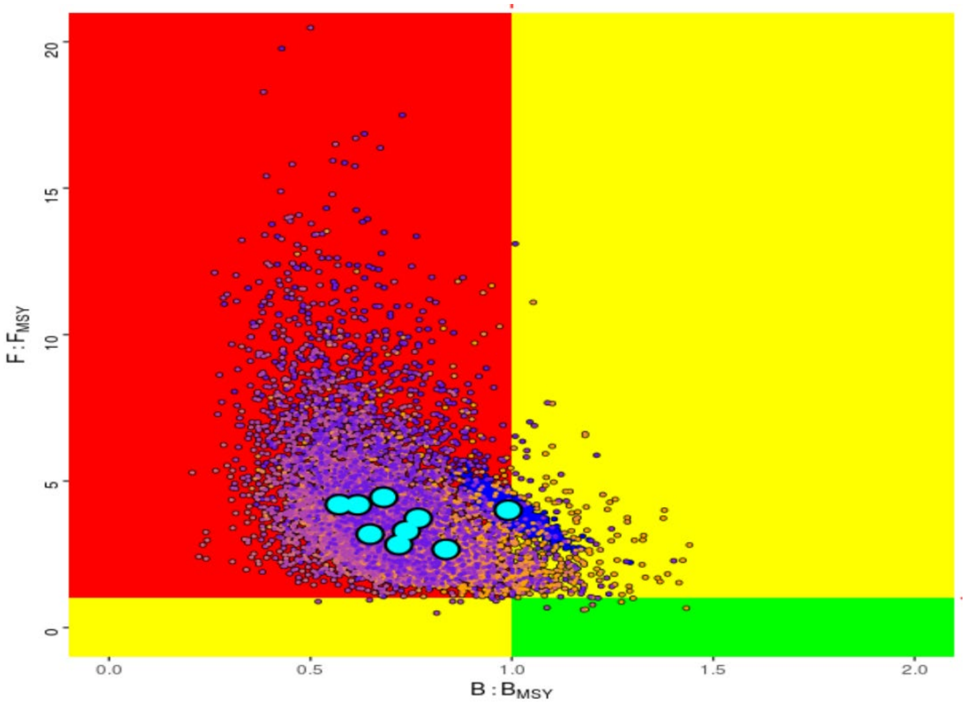

Figure 6. Kobe phase plot showing status (2015) of North Atlantic shortfin mako shark based on all assessment models used. The top left (red) quadrant represents overfishing occurring and an overfished stock, while the bottom right (green) quadrant represents a stock that is not overfished and in which overfishing is not occurring. Large points show the medians for each assessment scenario; small points show the individual simulations (reprinted from ICCAT 2017).

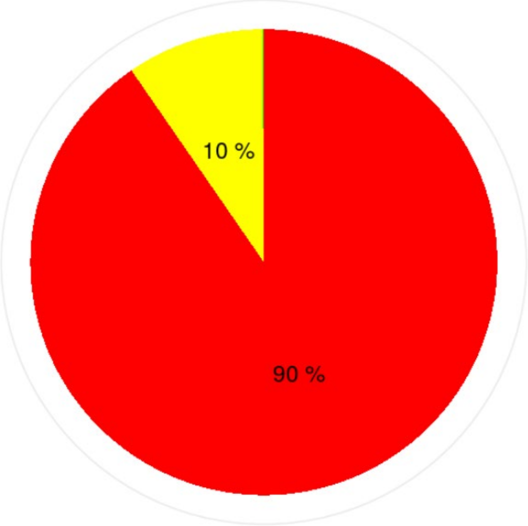

Figure 7. Kobe Pie Chart for combined runs in the North Atlantic showing a combined 90% probability that the stock is in an overfished state and is experiencing overfishing. Green indicates a healthy stock, yellow indicates a stock that is either overfished or experiencing overfishing, and red indicates overfishing and an overfished stock (reprinted from ICCAT 2017).

In 2019, the ICCAT Standing Committee on Research and Statistics (SCRS) carried out new projections for North Atlantic shortfin mako shark through 2070 (two generation lengths) using an integrated model (Stock Synthesis (SS)) at the Commission's request. The 2019 update to the stock assessment projected that even with a zero TAC, the North Atlantic stock will be rebuilt and not experiencing overfishing by 2045 with a 53% probability, and that regardless of TAC (including a TAC of 0 t), the stock will continue declining until 2035 (ICCAT 2019). In this case, TAC refers to all sources of mortality and is not limited to landings data. Projections showed that a TAC of 500 t has a 52% probability of rebuilding the stock without overfishing in 2070. To be in the green quadrant of the Kobe plot (rebuilt and without overfishing, see Figure 6) with at least a 60% probability by 2070, the projections indicate that realized TAC must be 300 t or less (ICCAT 2019). These TAC options with associated time frames and probabilities of rebuilding were presented to the Commission; however, given the vulnerable biological characteristics of this stock and these pessimistic projections, to accelerate the rate of recovery and to increase the probability of success, the SCRS recommended that the Commission adopt a non-retention policy without exception.

The 2017 stock assessment and 2019 update to the stock assessment present more accurate and rigorous results than the prior 2012 assessment. The 2012 assessment overestimated stock size, underestimated fishing mortality, and suggested a low probability of overfishing (ICCAT 2019). Input data and model structure changed significantly between the 2012 and 2017 ICCAT stock assessments: catch time series start earlier (in 1950 vs. 1971 in the 2012 assessment), some biological inputs have changed and are sex-specific in the 2017 assessment, and additional length composition data became available (ICCAT 2017). In addition, the CPUE series have been decreasing since 2010, which was the last year in the 2012 assessment models (ICCAT 2017). Finally, the age-structured model in the 2017 stock assessment more accurately captured the time-lags in population dynamics of a long-lived species than the production models used in 2012.

The IUCN's JARA trend analysis for the North Atlantic region relied on the 2017 ICCAT stock assessment. Trend analysis of modeled biomass estimated a median decline of 60% in the North Atlantic between 1950 and 2017 (Rigby *et al.* 2019), which is consistent with the decrease in total biomass (60%) obtained from SS model run 3 from the 2017 ICCAT stock assessment. In the western North Atlantic, fisheries mortality for shortfin mako sharks was estimated at 0.33 (0.19–0.56 95% CI), which was 5–18 times higher than estimates of F_{MSY}, suggesting that the species is in a state of overfishing in this region (Byrne *et al.* 2017). However, ICCAT soon adopted Recs. 17-08 (available at https://www.iccat.int/Documents/Recs/compendiopdf-e/2017-08-e.pdf) and later 19-06 (available at https://www.iccat.int/Documents/Recs/compendiopdf-e/2019-06-e.pdf), which both encourage release of live sharks, which would be expected to reduce fishing mortality. Thus, the 2017 estimates are likely higher than what actually occurred under the two new recommendations.

There is no stock assessment available for shortfin mako sharks in the Mediterranean Sea. Ferretti *et al*. (2008) compiled data from public and private archives representing sightings, commercial fisheries, and recreational fisheries data in the western Mediterranean Sea and used generalized linear models to conduct a meta-analysis of encounter trends. Long-term combined trends for shortfin mako shark and porbeagle (*Lamna nasus*) in the Mediterranean Sea indicate up to a 99.99% decrease in abundance and biomass since the early 19th century, though considerable variability among datasets as a result of geography and sample size was noted (Ferretti *et al.* 2008). While shortfin mako sharks spanning a broad range of sizes are occasionally reported as bycatch in swordfish and albacore longline fisheries (Megalofonou *et al*. 2005), or in other artisanal or commercial fisheries (Kabasakal 2015) from the eastern Mediterranean Sea, no reliable estimates of abundance are available for this region.

Overall, the best available evidence indicates that the North Atlantic shortfin mako shark population has experienced significant historical declines in biomass of 47–60%, and declines will continue until at least 2035 regardless of fishing mortality.

South Atlantic Ocean

Results of the most recent ICCAT stock assessment for shortfin mako sharks in the South Atlantic indicate a high degree of uncertainty (ICCAT 2017). The BSP2-JAGS model estimated that the stock was not overfished (B_{2015}/B_{MSY}=1.69 to 1.75) but that overfishing may be occurring (F_{2015}/F_{MSY}=0.86 to 1.07). Two runs from this model indicate a 0.3–1.4% probability of the stock being overfished and overfishing occurring (red quadrant in Kobe plot), a 29–47.4% probability of the stock not being overfished but overfishing occurring, or, alternatively, the stock being overfished but overfishing not occurring (yellow quadrants in Kobe plot), and a 52.3–69.6% probability of the stock not being overfished and overfishing not occurring (green quadrant in Kobe plot; see Figure 8 below) (ICCAT 2017). The JABBA model results indicated an implausible stock trajectory and were, therefore, not considered for management advice. The CMSY model estimates indicate that the stock could be overfished (B_{2015}/B_{MSY}= 0.65 to 1.12) and that overfishing is likely occurring (F_{2015}/F_{MSY}=1.02 to 3.67). Considering catch scenarios C1 (catches from the data preparatory meeting starting in 1950 in the north and 1971 in the south) and C2 (alternative estimated catch series based on ratios (Coelho and Rosa 2017), starting in 1971), CMSY model estimates indicated a 23–89% probability of the stock being overfished and overfishing occurring (red quadrant in Kobe plot), a 11–48% probability of the stock not being overfished but overfishing occurring, or alternatively, the stock being overfished but overfishing not occurring (yellow quadrants in Kobe plot), and only a 0–29% probability of the stock not being overfished and overfishing not occurring (green quadrant in Kobe plot) (Figure 8). Generally, while CPUE exhibited an increasing trend over the last 15 years, both catches and effort increased, contrary to the expectation that the population is expected to decline with increasing catch (FAO 2019). This inconsistency caused the ICCAT working group to consider the assessment highly uncertain, and they conducted no projections for the stock. Nevertheless, the combined assessment models found a 19% probability that the population is overfished and is experiencing overfishing (ICCAT 2017). The assessment also notes that, despite uncertainty, in recent years the stock may have been at, or is already below, B_{MSY} and fishing mortality is already exceeding fishery mortality at MSY (F_{MSY}). Based on the uncertainty of the stock status, combined with the species' low productivity, the ICCAT working group concluded that catches should not increase above average catch for the previous 5 years, about 2,900 t (ICCAT 2017; FAO 2019). There is a significant risk that the South Atlantic stock could follow a trend similar to that of the North Atlantic stock given that fishery development in the South Atlantic predictably follows that in the North, and that the biological characteristics of the stock are similar. The 2019 update to the stock assessment (ICCAT 2019) therefore reiterates the recommendation that at a minimum, catch levels should not exceed the minimum catch in the last five years of the assessment (2,001 t with catch scenario C1).

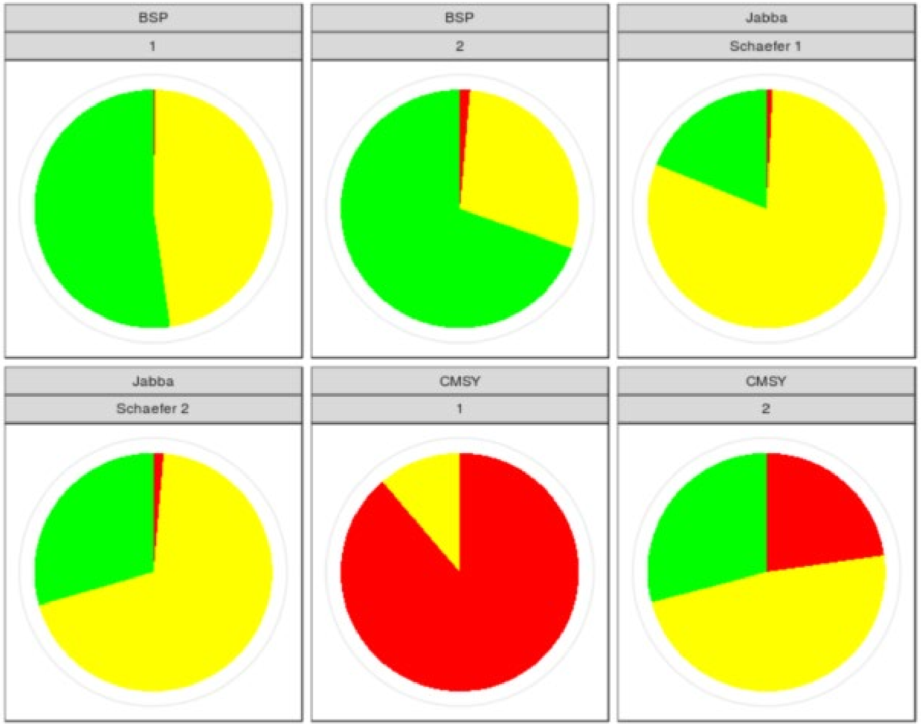

Figure 8. Kobe Pie Charts for individual runs in the South Atlantic. From left to right, models are: BSP1=BSP2JAGS, Catch 1, Schaefer; BSP2= BSP2JAGS, Catch 2, Schaefer; JABBA Schaefer with Catch 1; JABBA Schaefer with Catch 2; CMSY with Catch 1; CMSY with Catch 2. Green indicates a healthy stock, yellow indicates a stock that is either overfished or experiencing overfishing, and red indicates overfishing and an overfished stock (reprinted from ICCAT 2017).

In addition to the ICCAT stock assessment, standardized catch rates in South Atlantic longlines indicate steep declines in the average CPUE of shortfin mako shark between 1979–1997 and 2007–2012 (Barreto *et al.* 2016). However, the methodologies used in this study have several caveats and limitations, including the standardization analysis being applied individually to each of the time series and the use of different variables. Therefore, the results are not directly comparable between the different time periods and cannot be used to infer the total extent of decline over the entirety of the time series (FAO 2019).

Overall, despite high uncertainty in abundance and trends for the species in this region, the best available data indicate that there is a 19% probability that the population is overfished and is experiencing overfishing, and in recent years the stock may have been at, or is already below, B_{MSY} and fishing mortality is already exceeding F_{MSY}.

North Pacific Ocean

The most comprehensive information for shortfin mako sharks in the North Pacific comes from the 2018 ISC Shark Working Group stock assessment, which found that the North Pacific stock was likely not in an overfished condition and was likely not experiencing overfishing between 1975 and 2016 (42 years) (ISC Shark Working Group 2018). This analysis used an SS model that incorporated size- and age-specific biological parameters and utilized annual catch data from 18 fleets between 1975 and 2016, annual abundance indices from five fleets for the same period, and annual size composition data from 11 fleets between 1994 and 2016 (Kai 2021a). This assessment determined that the abundance of mature females was 860,200 in 2016, which was estimated to be 36% higher than the number of mature females at maximum sustainable yield (MSY) (ISC Shark Working Group 2018). Future projections indicated that spawning abundances were expected to increase gradually over a 10-year period (2017–2026) if fishing mortality remains constant or is moderately decreased relative to 2013–2015 levels (ISC Shark Working Group 2018). Using results from the ISC stock assessment, historical decline in abundance (1975–1985 to 2006–2016) is estimated at 16.4%, and a recent increase (2006–2016) is estimated at 1.8% (CITES 2019).

The IUCN Red List Assessment for global shortfin mako shark also used the ISC assessment to model the average trend in the North Pacific stock over three generation lengths (72 years) and indicated a median decline of 36.5% based on annual declines of 0.6% (Rigby *et al.* 2019). A comprehensive comparison of the assessments by the ISC and the IUCN (Kai 2021a) describes JARA (applied by Rigby *et al.* 2019) as a useful tool in extinction risk assessments for data-poor pelagic sharks, but inappropriate for the relatively data-rich North Pacific shortfin mako shark. The assessment by IUCN used only the mean annual trends in the population over the assessment period estimated from SS and did not consider size or age structure of the population over recent decades. Kai (2021a) concludes that the results of the ISC's assessment of current and future status of North Pacific shortfin mako shark are more robust and reliable than those of the IUCN and finds a median decline of the population trajectory of 12.1% over three generation lengths with low uncertainty.

The ISC Shark Working Group's 2021 report of indicator-based analysis for shortfin mako shark in the North Pacific used time series of catch, indices of relative abundance (CPUE), and length-frequency data from multiple fisheries over the time period 1957–2019 to monitor for potential changes in stock abundance since the 2018 benchmark assessment. Catch of shortfin mako shark in 2019 was the second highest value for the last decade, and the scaled CPUEs indicated a stable and slightly increasing trend in the four major fleets (U.S. Hawaii longline shallow-set, Taiwan longline large-scale, Japan research and training vessels, and Mexico observer for longline) (ISC Shark Working Group 2021). The Working Group concluded that there were no signs of major shifts in the tracked indicators that would suggest a revision to the current stock assessment schedule for shortfin mako shark is necessary (ISC Shark Working Group 2021). The next stock assessment is scheduled for 2024.

Observer data from the Western and Central Pacific Fisheries Commission (WCPFC) indicate that longline catch rates of mako sharks in the North Pacific declined significantly by an average of 7% (95% confidence interval (CI): 3–11%) annually between 1995 and 2010 (Clarke *et al.* 2013). However, these data represent trends for both longfin and shortfin mako sharks combined, and the performance of the standardization model was poorer than for other studied shark species, making the estimated trend less reliable. There were also variable size trends for mako sharks in the North Pacific, with females showing significant increases in median length in one region (Clarke *et al.* 2013). In an updated indicator analysis using the same data, Rice *et al.* (2015) noted that the standardized CPUE trend looked relatively stable between 2000 and 2010, but no inference was possible for the last four years (2010–2014) due to data deficiencies in some years.

Kai *et al.* (2017) analyzed catch rates in the Japanese shallow-set longline fishery in the western and central North Pacific from 2006–2014, finding an increasing trend since 2008. However, fishery-independent logbook data collected from Japanese research and training vessels in the western and central North Pacific (mainly 0–40°N and 130°E–140°W) from 1992–2016 showed a decreasing catch rate since 2008 (Kai 2019). The opposing trends indicated by fishery-dependent and -independent data in this region may be due to factors such as differing areas of operation, differing gear types, underreporting by both data sources, and differing model structures applied to the data (Kai 2019). Additionally, standardized CPUE estimates from 2011–2019 in the Japanese longline fleet operating in the North Pacific Ocean showed a stable trend from 2011 to 2016, with a slight decline after 2016 (Kanaiwa *et al.* 2021). The authors note that observer coverage in the fleet is low (1.7%–3.0% in certain areas) and that these results may not represent the overall trend for the North Pacific stock of shortfin mako shark (Kanaiwa *et al.* 2021).

Results from stock assessments and standardized CPUE trends from observer data are more comprehensive, robust, and reliable than trends from fishery logbook data. Therefore, we find that the best scientific information available indicates that shortfin mako sharks in the North Pacific are neither overfished nor experiencing overfishing, and the population is likely stable and potentially increasing despite evidence of historical decline and indications of recent decline in fishery-independent datasets.

South Pacific Ocean

In the South Pacific, longline catch rates reported to WCPFC did not indicate a significant trend in abundance of mako shark (shortfin and longfin combined) between 1995 and 2010 (Clarke *et al.* 2013). In an updated indicator analysis, standardized CPUEs for the mako shark complex show a relatively stable trend in relative abundance, with low points in 2002 and 2014, though the 2014 point is based on relatively few data and should be interpreted with caution (Rice *et al.* 2015). In New Zealand waters, logbook and observer data from 1995–2013 analyzed by Francis *et al.* (2014) indicate that shortfin mako sharks were not declining, and may be increasing, over the period from 2005–2013. More recently, an analysis of the data by the FAO Expert Advisory Panel for the Assessment of CITES Proposals did not find statistically significant trend fits for two of the data series; those that were significant were increasing (Japanese South 2006–2015, Domestic North 2006–2013, and Observer Data 2004–2013) (FAO 2019). Trend analysis of modeled biomass indicates a median increase of 35.2% over three generation lengths based on an estimated annual rate of change of 0.48% from 1995–2013 (Rigby *et al.* 2019). In sum, the best scientific information available indicates that shortfin mako sharks in the South Pacific have an increasing population trend.

Indian Ocean

Only preliminary stock assessments using data-limited assessment methods have been conducted for the shortfin mako shark in the Indian Ocean, with few other stock indicators available. Catch data are thought to be incomplete for several reasons: landings do not reflect the number of individuals finned and discarded at sea, shortfin mako sharks are not sufficiently specified in catch data and are often aggregated with other species, shortfin mako shark may be misidentified as longfin mako shark, and recorded weight may often refer to processed weight rather than live weight (Bonhommeau *et al.* 2020). With these caveats in mind, a preliminary assessment by Brunel *et al.* (2018) was carried out based on CPUE estimates from Portuguese (2000–2016) and Spanish (2006–2016) swordfish and tuna longline fleets operating in the IOTC convention area. Results from two models (a Bayesian Schaefer-type production model and another model analyzing the trends of catches) indicate that the stock is experiencing overfishing (F_{2015}/F_{MSY}= 2.57) but is not yet overfished (B_{2015}/B_{MSY} close to one) (Brunel *et al.* 2018). However, there were considerable uncertainties in the estimates and conflicting trends in biomass between the two models used. Nonetheless, trajectories showed consistent trends toward both overfished and subject to overfishing status (Brunel *et al.* 2018). Using the results of the Schaefer model from Brunel *et al.* (2018), historical decline (1970–1980 to 2005–2015) was estimated at 26%, recent decline (2005 to 2015) was estimated at 18.8%, and future 10-year decline was projected at 41.6% from the historic baseline (1970–1980 to 2015–2025) (CITES 2019). A trend analysis for modeled biomass in the Indian Ocean using Brunel *et al.*'s assessment indicates a median decline of 47.9% over three generation lengths (Rigby *et al*. 2019).

A more recent preliminary assessment using updated catch and CPUE indices also indicates that the shortfin mako shark in the Indian Ocean is experiencing overfishing but is not overfished (Bonhommeau *et al.* 2020). This assessment uses nominal catch of shortfin mako shark as reported to the IOTC (1964–2018) and scaled CPUEs from Japan (1993–2018), Spain (2001–2018), Taiwan (2005–2018), and Portugal (2000–2018). Bonhommeau *et al.* (2020) used JABBA and CMSY models, both of which gave results that were generally consistent with the previous assessment: that the stock is currently undergoing overfishing and is not overfished (Figure 9).

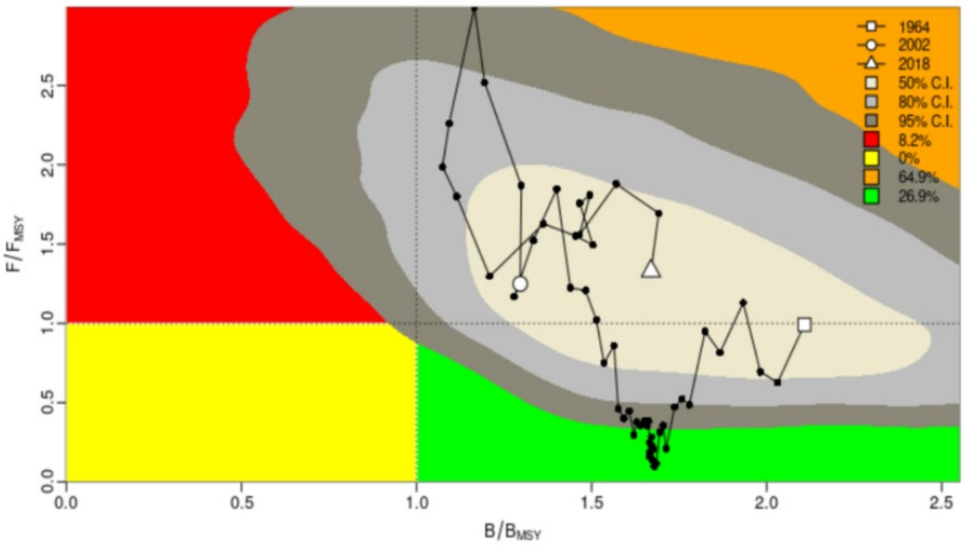

Figure 9. Kobe phase plot showing estimated trajectories (1963–2018) of B/BMSY and F/FMSY for the JABBA model for the Indian Ocean shortfin mako shark without the Japanese CPUE time series. Different gray shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legends (reprinted from Bonhommeau et al. 2020).

In a separate study, Wu *et al*. (2021) analyzed standardized CPUE trends using observer records and logbook data from 2005–2018 for the Taiwanese longline fishery in the Indian Ocean, which was the second largest shortfin mako shark-catching nation in the region in 2019. The standardized CPUEs indicate a gradual decrease between 2005 and 2007, followed by a sharp increase in 2008, a slow decline between 2008 and 2015, and another increase between 2015 and 2018 (Wu *et al.* 2021). However, Wu *et al*. (2021) note that the rapid increases in CPUEs between 2007 and 2008 and later between 2015 and 2017 may be unrealistic for the stock biomass of such a long-lived species and suggest that the results may be due to increased reporting by skippers and observers. Logbook data from Japanese longliners operating in the Indian Ocean from 1993–2018 indicates that abundance of shortfin mako shark decreased from 1993–2009 and increased slightly since then (Kai and Semba 2019). Standardized CPUE has risen after 2008 in Portuguese and Spanish longline fleets as well (Coelho *et al*. 2020b; Ramos-Cartelle *et al*. 2020), though these data sets were included in the preliminary stock assessment conducted by Bonhommeau *et al*. (2020). In the Arabian Sea, the shortfin mako shark was assigned near threatened status by the IUCN Shark Specialist Group, with CPUE data suggesting variable abundance and little evidence of significant population reduction (Jabado *et al.* 2017). Fishing pressure in this region is high, and because the species has high susceptibility to pelagic fisheries, Jabado *et al.* (2017) estimated that over the past 3 generations the population has declined 20–30%, with future declines expected. Results from these studies may reflect partial stock status in the Indian Ocean, but may not have sufficient spatial coverage to be indicative of the entire stock status.

In sum, preliminary assessments in the Indian Ocean indicate that the population is experiencing overfishing but is not yet overfished, and recent increasing CPUE trends are indicated in Spanish, Portuguese, and Taiwanese longline fleets. Catch data have the potential to be substantially underestimated and the recent increases in CPUE from these fleets may not reflect trends in abundance.

Summary

Overall, while abundance estimates for the shortfin mako shark are not available for all regions, the stock assessments available for the North Atlantic and North Pacific Oceans indicate current numbers of about one million and eight million individuals, respectively (FAO 2019). These estimates were generated by the FAO Expert Advisory Panel, which extracted these numbers from the full computer outputs available for the age-structured assessments conducted by ICCAT (2017) and the ICS Shark Working Group (2018). Rigby *et al.* (2019) conducted a trend analysis of shortfin mako shark abundance indices using the 2017 ICCAT stock assessment in the Atlantic, the 2018 ISC Shark Working Group stock assessment in the North Pacific, a preliminary stock assessment for the Indian Ocean (Brunel *et al.* 2018), and a CPUE indicator analysis from New Zealand for the South Pacific (Francis *et al.* 2014). Due to the unreliable stock assessment in the South Atlantic, the North Atlantic stock assessment was considered as representative of the South Atlantic for the trend analysis, which may have overestimated the extent of decline in this region. This assessment indicates that the global shortfin mako shark population has experienced an estimated median population reduction of 46.6%, with the highest probability of 50–79% reduction over three generation lengths (72–75 years) (Rigby *et al.* 2019), although the JARA framework used by Rigby *et al*. has been described as inappropriate for this species as it extrapolates mean annual trends in the population from the assessment period over three generations and does not consider size or age structure of the population over recent decades (Kai 2021a).

Population decline has been indicated in the North Atlantic with high certainty, and abundance is likely to continue declining until at least 2035 even in the absence of fishing mortality. In the North Pacific there is evidence of historical decline, although recent assessments indicate that the stock is neither overfished nor experiencing overfishing, and the population is likely stable or potentially increasing. Although a stock assessment has not been completed for shortfin mako sharks in the South Pacific, the best available scientific data and analyses indicate an increasing population trend. Abundance of the shortfin mako shark in the South Atlantic and Indian Oceans is not as clear, given significant uncertainties in the data in these regions. The most recent stock assessments of shortfin mako sharks in the South Atlantic has a high degree of uncertainty, and indicate a combined 19% probability that the stock is overfished and experiencing overfishing. Preliminary assessments in the Indian Ocean indicate that the population is experiencing overfishing but is not yet overfished (Brunel *et al*. 2018; Rigby *et al*. 2019).

4. ANALYSIS of ESA SECTION 4(a)(1) FACTORS

The ESA requires NMFS to determine whether a species is endangered or threatened due to any one of the five factors specified in section 4(a)(1) of the ESA: (A) the present or threatened destruction, modification, or curtailment of a species' habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; and (E) other natural or manmade factors affecting the species' continued existence. The following sections provide information on each of these factors as they relate to the current status of the shortfin mako shark.

4.1 (A) Present or Threatened Destruction, Modification or Curtailment of Habitat or Range

The shortfin mako shark is a highly migratory, pelagic species of shark that spends time in several habitat types including in the open ocean and on or near the continental shelf. The species is globally distributed from about 50°N (up to 60°N in the northeast Atlantic) to 50°S. While distribution is influenced by environmental variables including water temperature, DO concentration, and prey distribution, the shortfin mako shark is highly adaptable and able to use a wide variety of prey resources. There is no evidence that range contractions have occurred.

Threats of pollution and environmental contaminants, as well as climate change, are addressed in section 4.5 (E) Other Natural or Manmade Factors Affecting the Species' Continued Existence.

4.2 (B) Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Commercial and artisanal fisheries

The best available information indicates that the primary threat facing the shortfin mako shark is overutilization in fisheries. The majority of the catch is taken incidentally in commercial fisheries throughout the species' range, and the species is often opportunistically retained due to the high value of its meat and fins (Camhi *et al.* 2008; Dent and Clarke 2015). The species is targeted in semi-industrial and artisanal fisheries in the Indian and Pacific Ocean, and as a sportfish in several recreational fisheries. Recreational fisheries are thought to have minimal contribution to the species' overutilization in comparison to effects from commercial fisheries.

Global reported catches of shortfin mako shark have risen substantially since 1980 (see Table 2 and Figure 10). According to the Food and Agriculture Organization of the United Nations (FAO) global capture production statistics (accessible at https://www.fao.org/fishery/statistics-query/en/capture/capture_quantity), reported catch for shortfin mako shark in the period 2010–2019 totaled 128,743 t. Throughout this time period, landings in the Atlantic Ocean and adjacent seas totaled 61,673 t (~48% of global reported catch), in the Pacific Ocean totaled 43,927 t (~34% of global reported catch), in the Indian Ocean totaled 23,143 t (~18% of global reported catch) (see Figure 10). Reported landings, however, represent a substantial underestimate of actual catch and do not fully account for mortalities that result from fisheries interactions, including sharks that are discarded dead, finned, or that experience post-release mortality. For instance, Clarke *et al*. (2006) estimated that shark biomass in the fin trade alone is three to four times higher than catch reported in the FAO capture production data. Therefore, effects of commercial fishing fleets on the shortfin mako shark are much greater than reported catch numbers suggest.

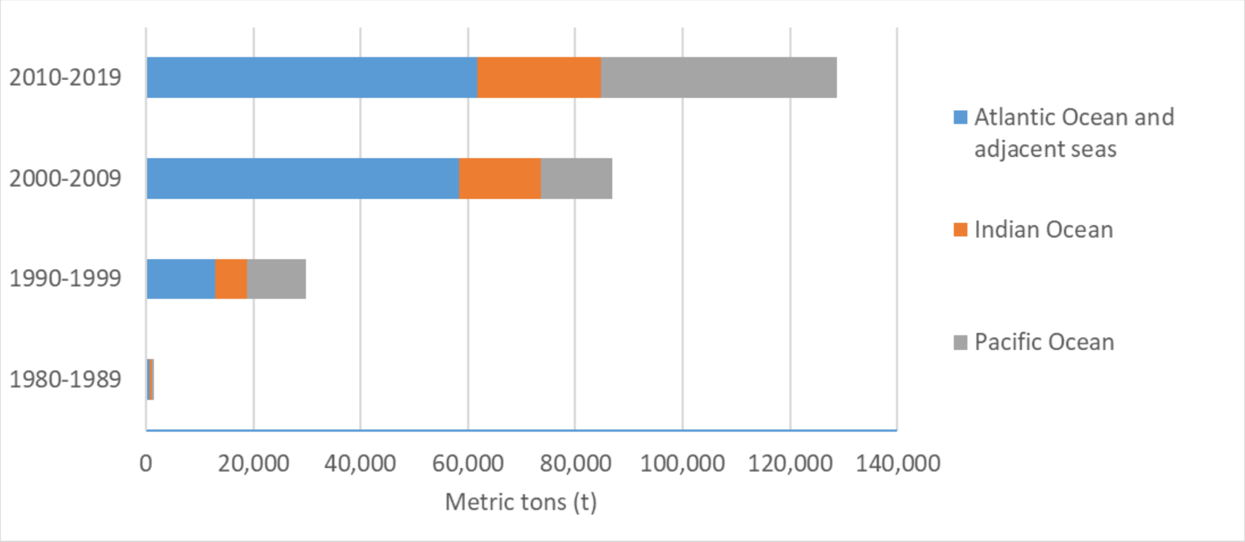

Figure 10. Global reported catch of shortfin mako shark from 1980–2019 by ocean basin (data from FAO global capture production statistics accessed February 2022).

Table 2. Global reported catch of shortfin mako shark (t) from 1980–2019 by ocean basin (data from FAO global capture production statistics accessed February 2022).

	1980-1984	**1985-1989**	**1990-1994**	**1995-1999**	**2000-2004**	**2005-2009**	**2010-2014**	**2015-2019**
Atlantic Ocean and adjacent seas	435	262	755	12,095	27,588	30,720	33,721	27,952
Indian Ocean	0	452	1,738	4,162	6,289	8,910	10,951	12,192
Pacific Ocean	0	452	5,435	5,569	5,893	7,512	23,605	20,322
Total	435	1,166	7,928	21,826	39,770	47,142	68,277	60,466
Yearly Average	87	233	1,586	4,356	7,954	9,428	13,655	12,093

Data from across the species' range indicate that much of the catch of shortfin mako sharks in longline fisheries is composed of the immature individuals (N Atlantic: Biton-Porsmoguer 2018, Coelho *et al*. 2020a; S Atlantic: Barreto *et al*. 2016; NW Pacific: Ohshimo *et al*. 2016, Semba *et al*. 2021; E Pacific: Furlong-Estrada *et al*. 2017, Saldaña-Ruiz *et al*. 2019, Doherty *et al*. 2014; Indian: Winter *et al*. 2020, Wu *et al*. 2021). Exploitation of the juvenile life stage reduces the proportion of the population that survives to maturity to reproduce. Due to the late age-at-maturity of the species, many years are required before conservation actions may influence the spawning population. Additionally, abundance indices based on the part of the population that is most vulnerable to fisheries mortality (immature individuals) can be out of phase with those based on the abundance of the spawning stock (e.g., CPUE and age-structured population models, respectively) for decades. For these reasons, the delay between identifying overutilization and addressing it can limit the effectiveness of mitigation and can make fisheries management for the shortfin mako shark difficult.

Rates of at-vessel mortality, or mortality resulting from interactions with fishing gear prior to being brought onboard (also known as hooking or capture mortality), vary by fishing practice and gear type. Campana *et al.* (2016) estimated fisheries mortality of shortfin mako sharks in Northwest Atlantic pelagic longline fisheries targeting swordfish and tuna, in which the majority (88%) of hooks used were circle hooks. The types of leaders or branch lines were not reported. Shortfin mako sharks were found to experience a mean at-vessel mortality rate of 26.2%, and another 23% of incidentally caught shortfin mako sharks were injured at haulback (Campana *et al.* 2016). The proportion of shortfin mako sharks that experienced at-vessel mortality in pelagic longlines was significantly higher than that of blue sharks (*Prionace glauca*), likely because shortfin mako sharks have very high oxygen requirements, and their ability to ram ventilate—or continuously force water across their gills to breathe, typically by swimming at speed—is compromised once hooked (Campana 2016; Campana *et al.* 2016). Data from Portuguese longline vessels targeting swordfish in the North and South Atlantic indicate at-vessel mortality rates of 35.6% for shortfin mako shark (Coelho *et al.* 2012). This fleet uses stainless steel J hooks and both monofilament and wire branch lines (Coelho *et al.* 2012). In the North Pacific, shortfin mako sharks incidentally caught in the Hawaii deep-set and American Samoa longline fisheries targeting tuna were found to experience an at-vessel mortality rate of 22.7% (Hutchinson *et al*. 2021). Prior to May 2022, the Hawaii deep-set fishery used circle hooks, stainless steel braided wire leader, and monofilament; the American Samoa longline fishery uses circle hooks and all monofilament branch lines (Hutchinson *et al*. 2021). However, in May 2022, NMFS issued a final rule that prohibits the use of wire leader in the Hawaii deep set longline fishery.

Post-release (or discard) mortality rates are more difficult to accurately assess, although tag-recapture and telemetry studies indicate that they can be relatively low for shortfin mako sharks depending on factors such as hook type, hooking location, and handling. Reported estimates of post-release mortality rate also depend on the duration over which survival is assessed. Any mortality related to capture and handling that occurs after the monitoring period would cause post-release mortality rates to be underestimated (Musyl *et al*. 2009, Musyl and Gilman 2019). Campana *et al.* (2016) estimated that shortfin mako sharks (n=26) caught incidentally in Northwest Atlantic pelagic longlines have post-release mortality rates of 30–33% over ~50 days. Bowlby *et al.* (2021) also investigated post-release mortality in North Atlantic pelagic longline fleets, estimating a rate of 35.8% for the species over the first 30 days from 104 tagging events. The post-release mortality rate of tagged shortfin mako sharks (n=35) after capture and release by pelagic longliners in the Northeast, Northwest, Equatorial, and Southwest Atlantic was estimated at 22.8% over the first 30 days (Miller *et al.* 2020). A telemetry study on post-release mortality rates of five shark species captured in the Hawaii deep-set and American Samoa tuna longline fisheries found relatively low post-release mortality rates for shortfin mako shark (6%), with only one mortality observed out of 18 tags that reported (Hutchinson *et al*. 2021). A Bayesian analysis of the post-release mortality rates from all sharks tagged (including shortfin mako shark) found that post-release fate was correlated with the animal's condition at the vessel, handling method, and the amount of trailing gear left on the animals, whereby animals that were left in the water and had most of the gear removed had the lowest mortality rates (Hutchinson *et al*. 2021). Another telemetry study conducted by the WCPFC in three longline fisheries in the South Pacific (New Caledonia, Fiji, and New Zealand) with much larger sample sizes (n = 57 shortfin mako shark tags) also found low post-release mortality rates for shortfin mako sharks:

11.6% of the tagged, uninjured shortfin mako sharks died within the 60-day monitoring period of the tags, and this estimate increased to 63.2% for injured shortfin mako sharks (Common Oceans (ABNJ) Tuna Project 2019). Similar to conclusions from Hutchinson *et al*. 2021, survival rates were higher when trailing gear was minimized, particularly in relation to the size of the animal. Although the practice of hauling sharks on deck was not found to have contributed to mortality, the probability of injury is higher when sharks are hauled onboard, and injured sharks are less likely to survive (Common Oceans (ABNJ) Tuna Project 2019). This suggests that improvements to handling and release methods can help reduce post-release mortality in shortfin mako shark and other shark bycatch species.

A review of available data on the use of circle hooks to reduce bycatch mortality, versus the use of J-hooks, indicates that circle hooks either decrease or have no effect on at-vessel mortality of shortfin mako sharks, but significantly increase the likelihood of mouth hooking, which is associated with lower rates of post-release mortality when compared to gut or foul hooking (Keller *et al.* 2020). However, Semba *et al.* (2018) found that estimated total mortality of incidentally caught shortfin mako sharks was 1.6 times higher with circle hooks compared to J-hooks. Domingo *et al.* (2012) found that significantly more shortfin mako sharks were caught using circle hooks than J-hooks (39 vs. 20, p=0.03) in the Uruguayan pelagic longline fleet using American-style longlines, and Bowlby *et al.* (2021) found a significant increase in recovery time following capture on circle hooks. A meta-analysis of 24 publications on effects of hook, bait, and leader type in pelagic longline fisheries indicated that the catch rate increased significantly by 20% with the use of circle hooks vs. J-hooks for shortfin mako sharks (Rosa *et al.* 2020). It is also noted that sharks are able to bite off and escape when caught by a J-hook, spending much less time hooked, likely leading to a higher survival rate (Rosa *et al.* 2020). This suggests that further study is needed to determine how effectively circle hooks reduce mortality, and whether the use of circle hooks is an appropriate mitigation measure. In 2021, however, Keller *et al.* (2021) discovered statistical and data treatment errors in previous meta-analyses, including Rosa *et al*. (2020), concerning statistical tests on retention rates. These meta-analyses were referenced by Semba *et al*. (2018) and provided the foundation for this research. Upon correcting for these errors, the results presented by Keller *et al*. (2021) demonstrate that there is no significant difference in shortfin mako shark retention due to hook type. Furthermore, at-haulback mortality decreases by 10% due to circle hook use, a result that is statistically significant. Based on the best available science, total mortality is likely lower due to circle hook use, especially when considering the reduced injury rates and at-haulback mortality associated with circle hook use.

Beyond hook type, several other factors influence the catch and mortality rates of shortfin mako sharks. Bringing incidentally caught shortfin mako sharks on deck to remove gear has recently been shown to reduce survival and increase recovery times (Bowlby *et al.* 2021). Increased catches of shortfin mako shark have been observed with the use of mackerel bait instead of squid (Coelho *et al.* 2012; Amorim *et al.* 2015; Fernandez-Carvalho *et al.* 2015). Additionally, larger shortfin mako sharks have been shown to have lower odds of dying due to the fishing process (Coelho *et al.* 2012).

In sum, commercial, artisanal, and sport fisheries that allow retention of shortfin mako sharks operate in the Atlantic, Pacific, and Indian Oceans, with landings increasing from 1980 to the present (see Table 2 and Figure 9). The majority of harvest has occurred in the Atlantic, though in 2019, FAO global capture production statistics indicate that the Pacific landed 5,458 t, surpassing the 3,955 t landed in the Atlantic. Post-release mortality makes up a substantial amount of total fishery mortality, but is not captured in reported landings data. Total non-landed fishery mortality for shortfin mako sharks in the Canadian pelagic longline fishery was estimated at 49.3% (95% CI: 23–73%), indicating that even if retention of the species is prohibited, about half of shortfin mako sharks hooked by this fleet would die during or after fishing (Campana *et al.* 2016). Given that other nations targeting swordfish and tuna in the Northwest Atlantic and other ocean basins use similar gear configurations as used in the study by Campana *et al.*, similar un-reported mortality levels may be expected if landings of shortfin mako shark were prohibited throughout its global range. The degree to which fisheries mortality threatens the shortfin mako shark is analyzed below by ocean basin.

North Atlantic Ocean
Across the North Atlantic, shortfin mako sharks are incidentally caught mainly in pelagic and surface longlines, and to a lesser extent, purse seines, bottom trawls, and gillnets. There are no commercial fisheries targeting shortfin mako sharks in this region. Since 2017, ICCAT CPCs have been required to release live North Atlantic shortfin mako sharks in a manner that causes the least harm. Retention of dead North Atlantic shortfin mako sharks remained acceptable in many cases, and harvest of live individuals was only permitted under very limited circumstances. Reported landings for all CPCs in the North Atlantic (including dead discards) remain high, and are presented in Table 3.

Table 3. Reported landings and dead discards (t) of North Atlantic shortfin mako shark by all ICCAT CPCs (data from SCRS 2021).

2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
3,603	3,467	3,281	3,356	3,119	2,373	1,882	1,709

Over 90% of recent shortfin mako shark catch in the North Atlantic is attributable to Spain, Morocco, and Portugal, with Spain harvesting nearly half of the North Atlantic catch in 2019 (866 t reported). The Spanish longline fleet targeting swordfish (*Xiphias gladius*) used traditional multifilament surface longline gear for decades; however, monofilament was introduced and broadly implemented in the late 1990s (Fernández-Costa *et al.* 2017). Due to the marketable nature of the species, the Spanish fleet has retained the vast majority of shortfin mako shark bycatch, and discards have been negligible since the beginning of this fishery (Mejuto *et al.* 2009). In fact, Spain has not reported any discards for this stock and given the mandatory reporting imposed by ICCAT Recommendations 17-08 and 19-06, this is incredibly concerning, especially as live shortfin mako sharks are required to be released except in very limited circumstances. In the last 10 years of catch data reported to ICCAT, Spain has landed 15,735 t of shortfin mako shark for an average of 1,574 t per year (Table 4). In early 2021, however, Spain announced a moratorium on the landing, sale, and trade of North Atlantic shortfin mako shark. The retention ban reportedly applies to 2021 catches from all Spanish vessels, whether operating in domestic water or on the high seas, and the ban on sale and trade extends to a 90 t stockpile of mako shark fins landed by Spanish vessels in 2020. Due to at-vessel and post-release mortality, retention bans will not eliminate fishery mortality. However, because approximately 50% of catches would be expected to survive as discussed above, this retention ban may significantly reduce shortfin mako shark mortality in the Spanish pelagic longline fleet operating in the North Atlantic, and therefore overall mortality in this region.

Table 4. Reported catches (t) of shortfin mako shark by Spain in the North Atlantic (data from ICCAT SCRS).

2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
2,019	1,667	2,308	1,509	1,481	1,362	1,574	1,784	1,165	866	870

Morocco is another major contributor to fishery mortality in the North Atlantic. The swordfish longline fleet in Morocco ranked second in catches in the North Atlantic, comprising 19.21% of catches from 2011–2016 (Baibbat *et al.* 2018). Morocco also catches shortfin mako sharks in its purse seine fleets, though at lower levels. Reported catch data presented in the SCRS catalog indicates that in 2019, Moroccan longline fleets were responsible for roughly 70% of the country's total landings, while the remaining 30% of shortfin mako shark catch came from Morocco's purse seine fleets. Morocco's total landings of shortfin mako shark have increased over time from 420 t in 2011 to 1,050 t in 2016 (Baibbat *et al.* 2020). More recently, Morocco's total landings of the species have gone down relative to previous years (this may be due to management actions as required by ICCAT Recs. 17-08 and 19-06): reported catches totaled 450 t in 2017, 594 t in 2018, 501 t in 2019, and 382 t in 2020 (SCRS 2021). In February 2022, the government of Morocco announced a five-year national prohibition on the fishing, storage, and trade of shortfin mako shark. While at-vessel and post-release mortality are not mitigated by this measure, this retention ban may significantly reduce shortfin mako shark mortality in the North Atlantic if strictly enforced.

Portugal is also a major contributor to shortfin mako shark catch. According to analysis of commercial landings data from major Portuguese fishing ports, between 1986 and 2017 Portugal contributed mean annual landings of 179.9 t (Alves *et al.* 2020). There were three distinct trends during this 32-year period as seen in Figure 11: mean annual landings of 59 t from 1986 until 2002, a marked increase to 420 t between 2003 and 2013, and an extremely sharp decrease in 2014, with the lowest value recorded (27 t) occurring in 2017 (Alves *et al.* 2020).

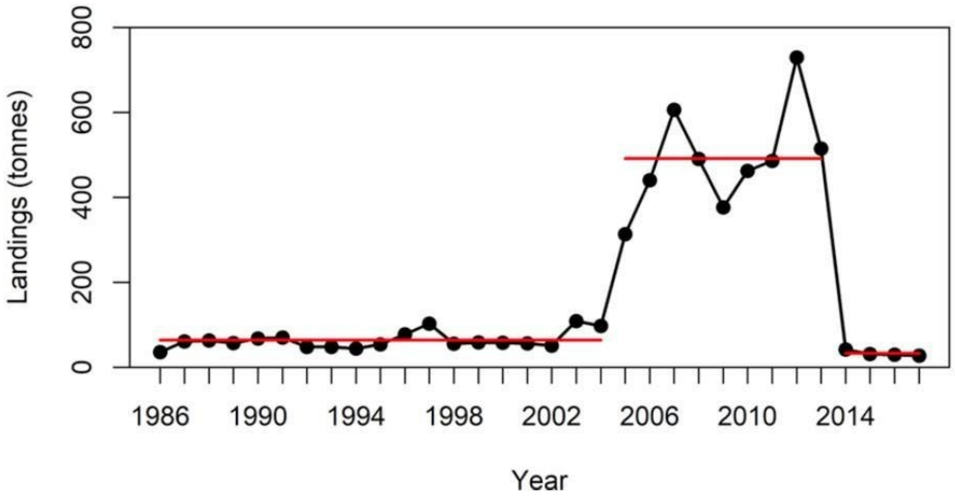

Figure 11. Landings of shortfin mako shark in Portuguese fishing ports between 1986 and 2017; red lines are relative to periods that differ in terms of mean and variance that resulted from a non-parametric change points assessment (reprinted from Alves et al. 2020).

ICCAT SCRS data shows a similar trend in Portuguese landings of shortfin mako shark. Between 1990 and 2002, annual landings averaged 432 t; from 2003–2013, annual landings averaged 1,077 t; and from 2014–2019, annual landings averaged 257 t (SCRS 2020). In the Azores, the shortfin mako shark is one of four species captured in significant numbers, typically in the swordfish pelagic longline (PLL) fishery (Torres *et al.* 2016). Though the Azores PLL fishing fleet is small (5 vessels), several vessels from mainland Portugal and other EU fleets frequently fish in the Azores Exclusive Economic Zone (EEZ) (Torres *et al.* 2016). Typically, a longline set (1000 hooks) catches an average of 0.04 t of shortfin mako shark (Pham *et al.* 2013) and annual landings have been relatively stable between 1993 and 2013 (Torres *et al.* 2016).

Shortly after Spain's retention ban in 2021, Portugal announced a new moratorium on landings of shortfin mako sharks caught in the North Atlantic high seas fisheries, the source of the majority of Portugal's mako shark catch. This ban may substantially reduce mortality of shortfin mako sharks, though as with retention bans announced by Spain and Morocco, at-vessel and post-release mortality would still need to be addressed.

In the Northwest Atlantic, shortfin mako sharks are incidentally caught by the U.S. PLL fleets targeting swordfish and tuna (*Thunnus* spp.), including in the Gulf of Mexico and the Caribbean Sea. Between 1986 and 2008, total reported fishing effort by the U.S. pelagic longline fleet was 291,568 sets and ranged from 2,055 (~1,410,809 hooks) in 1986 to 19,409 (~13,324,762 hooks) in 1989, with a mean of 13,321 sets (~8,672,626 hooks) year^{-1} (Levesque 2013). Annual shortfin mako shark CPUE ranged from 0.23 kg per 100 hooks in 1987 to 2.66 kg per 100 hooks in 1993, with a mean of 1.27 kg per 100 hooks (Levesque 2013). A total of 2,406 t of shortfin mako shark were landed and sold by this fishery between 1985 and 2008, valued at $4,562,402 (Levesque 2013). Commercial landings of shortfin mako shark ranged from 17.6 t in 1985 to 266.8 t in 1993, with a mean of 100.24 t year^{-1} (Levesque 2013). As described below in section 4.4 (D) Inadequacy of Existing Regulatory Mechanisms, after the 2017 ICCAT stock assessment indicated that North Atlantic shortfin mako sharks were overfished and experiencing overfishing, the United States took immediate action to end overfishing and work towards rebuilding of the stock through emergency rulemaking. These measures led to a reduction in North Atlantic shortfin mako shark landings by the U.S. longline fleet, with 112 t landed in 2017, 42 t landed in 2018, and 33 t landed in 2019 (NMFS 2021). Shortfin mako shark catch in U.S. pelagic longlines represented only 0.8% of total international longline catch of the species across the entire Atlantic Ocean in 2019 (NMFS 2021), and due to the poor reporting of other ICCAT Contracting Parties and Cooperating Non-Contracting Parties (CPCs), this percentage is likely significantly lower.

The Canadian PLL fleet also incidentally catches shortfin mako sharks in the Northwest Atlantic, with reported landings under 100 t each year between 1993 and 2007 (Fowler and Campana 2009). ICCAT SCRS catalogs (available at https://www.iccat.int/en/accesingdb.html) indicate that the fleet continued to catch less than 100 t each year through 2019 (except 109 t in 2017), with 62 t reported in 2019. Total fishing mortality from all Canadian fleets was 55 t in 2018 and 64 t in 2019, with a requirement to release all live animals. In April 2020, Canada prohibited retention of shortfin mako sharks in Atlantic Canadian waters; however, as discussed above, the combination of at-vessel and post-release mortality still led to 20 t of shortfin mako mortality in 2020 (18 t from PLL).

Risk assessments have repeatedly found shortfin mako sharks to be at high risk of overexploitation by pelagic longline fisheries in the North Atlantic. Using an ecological risk assessment, the inflection point of the population growth curve (a proxy for B_{MSY}), and IUCN Red List status, Simpfendorfer *et al.* (2008) found the shortfin mako shark to have the highest risk for pelagic shark species taken in Atlantic longline fisheries. Similar results were found by Cortés *et al.* (2010) in an ecological risk assessment of 11 pelagic elasmobranchs across the North and South Atlantic, which incorporated estimates of productivity (intrinsic rate of increase, r) and susceptibility to the fishery (a product of the availability of the species to the fleet, encounterability of the gear given the species' vertical distribution, gear selectivity, and post-capture mortality). The authors found the shortfin mako shark to be at high risk of overexploitation (Cortés *et al.* 2010). In an expanded assessment, the shortfin mako shark's low productivity ($r=0.058$ $year^{-1}$) and high susceptibility to capture (0.220, calculated as the product of four factors: availability of the species to the fleet, encounterability of the gear given the species' vertical distribution, gear selectivity, and post-capture mortality) continued to give the species one of the highest risks of overexploitation of sharks caught by Atlantic pelagic longline fleets (Cortés *et al.* 2015).

In summary, based on the results of the 2017 ICCAT Stock Assessment and the 2019 Update to the Stock Assessment for shortfin mako shark as discussed in section 3.2 Regional Population Trends, the shortfin mako shark has experienced historical declines in the North Atlantic Ocean, which are projected to continue until at least 2035. Combined with the continued high level of fishing effort, high catches, and low productivity, we conclude that overutilization of shortfin mako shark is occurring in the North Atlantic Ocean. ICCAT recently adopted Rec. 21-09, which will influence future mortality levels in the North Atlantic. This regulatory measure is discussed in section 4.4 (D) Inadequacy of Regulatory Mechanisms under Regional Fisheries Management Organizations.

South Atlantic Ocean

Shortfin mako sharks are frequently caught in pelagic longlines in the South Atlantic, where fishing effort has been increasing since the 1970s (Barreto *et al.* 2016). Important contributors to South Atlantic shortfin mako shark landings as reported by the ICCAT SCRS are Spain, Namibia, Brazil, Portugal, South Africa (Figure 12). Reported landings for all CPCs in the South Atlantic (including dead discards) are presented in Table 5.

Table 5. Reported landings and dead discards (t) of South Atlantic shortfin mako shark by all ICCAT CPCs (data from SCRS 2021).

2013	2014	2015	2016	2017	2018	2019	2020
2,183	3,274	2,774	2,765	2,786	3,158	2,308	2,855

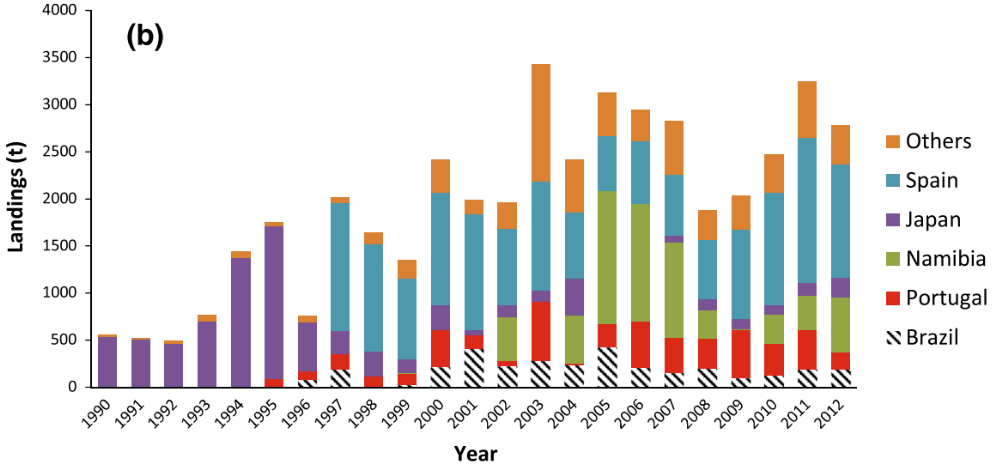

Figure 12. Annual catches of South Atlantic mako shark using Task 1 ICCAT data (reprinted from Lucena Frédou et al. 2015).

An analysis of historical catches in longline fishing fleets in the South Atlantic found three distinct phases of fishery exploitation: phase A (1979–1997), characterized by the use of deep multifilament line with J hooks to target tunas; phase B (1998–2007), during which monofilament lines and circle hooks were used to target sharks and tunas, and phase C (2008–2011), during which several measures regulating shark fishing came into effect (Barreto *et al.* 2016). The authors found that standardized catch rates of shortfin mako shark from a zero-truncated model increased 8-fold in phase A (1979–1997), decreased by 55% in phase B (1998–2007), and increased 1.3-fold in phase C (2008–2011; Figure 13), even though nominal catch rates for all sharks combined were highest in phase B. Dramatic catch rate declines in phase B coincided with significant fishing effort increases as well as a lack of regulatory measures, and Barreto *et al.* (2016) conclude that shortfin mako sharks are depleted in the South Atlantic.

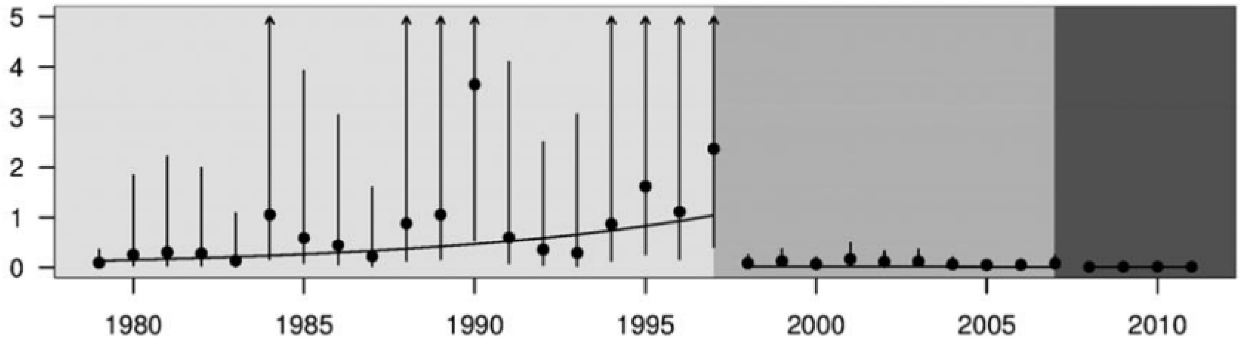

Figure 13. Trend in standardized catch rates of shortfin mako sharks in the South Atlantic. Y-axis displays catch per 1000 hooks. Solid lines indicate overall trends with year as continuous variable; dots indicate individual year estimates with year as factor; vertical lines indicate 95% CI; arrows indicate CIs are larger than the y-axis scale in a particular year (reprinted from Barreto et al. 2016).

Spanish longline fleets in the South Atlantic reported shortfin mako shark catches of 1,049 t in 2017, 1,044 t in 2018, 1,090 t in 2019, and 799 t in 2020 (SCRS 2021). As described above, the Spanish fleet has retained the vast majority of shortfin mako shark bycatch due to the high value of the species. Therefore catches and landings have been roughly equivalent since the beginning of this fishery (Mejuto *et al*. 2009).

In Brazil, pelagic longline vessels targeting tuna have been fishing since 1956, and part of the longline fleet shifted to targeting swordfish in 1994 (Lucena Frédou *et al.* 2015). Though there are no directed fisheries for shortfin mako shark in the South Atlantic, the species is frequently retained due to its high value and is one of eight shark species commonly caught in the Brazilian longline fleet (Lucena Frédou *et al.* 2015). Data from 2004–2010 indicate that mako sharks (shortfin and longfin combined, though longfin are rarely caught) were the second most common shark, making up 5.4% of all individuals caught (Lucena Frédou *et al.* 2015). Standardized CPUE of shortfin mako shark in Brazilian tuna longline fisheries (domestic and foreign chartered) was relatively stable from 1978–2016, with the most recent years showing unusual stability (1.4 to 1.6), with a drop in 2016 to 0.85 (Hazin *et al.* 2018). Reported catch has been increasing in Brazil over the past few years: 124 t in 2016, 275 t in 2017, 399 t in 2018, 739 t in 2019, and 542 t in 2020 (no discards have been reported) (SCRS 2021).

The South African PLL fleet targeting tuna and swordfish operates in the South African EEZ where the Southeast Atlantic meets the Southwest Indian Ocean. Based on landings, logbook, and observer data, the South African pelagic longline fleet was estimated to catch 50,000 shortfin mako sharks in 2015, with less than 1,000 estimated to have been released in good condition (Jordaan *et al.* 2020). In total, 96% of hooked shortfin mako sharks were retained, and of those discarded, 82% were dead (Jordaan *et al.* 2020). Most of the shortfin mako shark catch occurred in waters of the Indian Ocean and was, therefore, reported to the IOTC; smaller quantities of the species are caught in Atlantic waters (Jordaan *et al.* 2020). There have been steep increases in fishing effort (from 0.45 million hooks set in 2000 to 1.7 million hooks set in 2015) as well as shortfin mako shark fishing mortality in the South African PLL fleet (Jordaan *et al.* 2018). Reported landings increased from 869 sharks in 2000 to 37,946 in 2015, although the earlier landings were likely under-reported (Petersen *et al*. 2009; Jordaan *et al*. 2020). Despite being officially considered bycatch since 2005, shortfin mako sharks remained a primary target species of parts of this fleet (Jordaan *et al.* 2020). Foreign fleets targeting tuna also operate in the South

African EEZ, outnumbering local fleets (an estimated 31 million hooks vs. 21 million hooks set between 2000–2015, respectively) (Jordaan *et al.* 2018). Foreign fleets mostly operate in the SW Indian Ocean, with only 9% of hooks in the SE Atlantic. Foreign vessels set an average of 2,493 hooks per line, compared to only 1,282 hooks per line used by local vessels, though retention and landings of sharks are much higher in local fleets (Jordaan *et al.* 2018).

In summary, based on the results of the 2017 ICCAT Stock Assessment and the 2019 Update to the Stock Assessment for shortfin mako shark as discussed in section 3.2 Regional Population Trends, the shortfin mako shark may be experiencing declines in abundance in the South Atlantic Ocean. Combined with the continued high level of fishing effort, high catches, and low productivity, we conclude that overutilization of shortfin mako shark may be occurring in the South Atlantic Ocean, though status is highly uncertainty.

Western and Central Pacific Ocean

Shortfin mako sharks commonly interact with the longline fisheries in the Western and Central Pacific Ocean. Fisheries information and catch data for this region are available from the Western and Central Pacific Fisheries Commission (WCPFC). Like other regions, there is a historical lack of shark reporting on logbooks for most fleets in the Pacific, although this has improved in recent years with the implementation of Conservation Management Measures (CMM 2019-04) that require reporting of catches of key shark species. These measures are described in further detail in section 4.4 (D) Inadequacy of Existing Regulatory Mechanisms. Despite reporting requirements, recent catches of key shark species have not been provided to the WCPFC for several longline fleets, including Indonesia, which is the top shark fishing nation in the world (Dent and Clarke 2015; Okes and Sant 2019). Fleets with the highest reported numbers of shortfin mako sharks caught in recent years (as reported in WCPFC data catalogs available at https://www.wcpfc.int/data-catalogue) include Taiwan, the United States (Hawaii), Japan, Spain, and New Zealand.

In the western North Pacific, Taiwanese coastal and offshore longline fishing vessels mainly target dolphinfish (also known as mahi mahi; *Coryphaena hippurus*), tunas, and billfishes from April to October, and switch to targeting sharks by changing gear configuration from November to March (Liu *et al.* 2021a). Liu *et al.* (2021a) carried out a productivity-susceptibility analysis for these Taiwanese fleets, where intrinsic rate of population growth (r) was used to express productivity, and susceptibility was estimated by multiplying catchability, selectivity, and post-capture mortality. Based on the shortfin mako shark's low productivity (r=0.0300) and high susceptibility (1.1754), the authors found the species to be at highest ecological risk. However, when conducting an integrated ERA (incorporating the ERA, IUCN Red List index, annual body weight variation trend, and the inflection point of population growth curve), Liu *et al.* (2021a) found the species to be in the least risk group, possibly because the average body weight of the species in the western North Pacific hasn't experienced significant decline. The authors find this result to be reasonable as the latest stock assessment for North Pacific shortfin mako shark indicates that the stock is not overfished and overfishing is not occurring.

The shortfin mako shark is one of the most commonly caught shark species in the Taiwanese large-scale tuna longline fleet. Logbook data from this fleet are considered reliable records of actual catch as all shortfin mako sharks were retained due to the species' high market value.

Catch in this fleet peaked at 156 t in 2015, after which catch decreased for three years before reaching 142 t in 2019 (Liu *et al.* 2021b). Taiwan's catch of mako sharks (shortfin and longfin) in all longline fleets as reported in WCPFC data catalogs are high in the most recent six years of data: 1,216 t in 2015; 1,073 t in 2016; 1,088 t in 2017; 1,146 t in 2018; 1,680 t in 2019; and 1,665 t in 2020.

While there are no directed commercial fisheries for shortfin mako sharks in Hawaii, the species is caught relatively frequently in the Hawaii-based PLL fishery targeting swordfish in the shallow-set sector, and bigeye tuna (*Thunnus obesus*) in the deep-set sector (Walsh *et al.* 2009; Carvalho 2021). Substantially higher numbers of shortfin mako sharks are caught in the deep-set sector than the shallow-set sector. Detailed catch data are available for these fisheries thanks to the Pacific Islands Regional Observer Program (PIROP), initially established in 1994. In 2001, high interaction rates with leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) sea turtles in the shallow-set sector led to a closure of this fishery until 2004 (Walsh *et al.* 2009). When the swordfish fishery reopened, observer coverage was mandated at 100%, up from less than 5% in the years prior to the fishery closure (Carvalho *et al.* 2014). Observer coverage in Hawaii's deep-set PLL fishery also increased from below 5% to approximately 20% each year beginning in 2001 (Carvalho *et al.* 2014). From 1995–2006, shortfin mako sharks made up 2.9% of all observed shark catch in Hawaii-based PLL fisheries, with higher nominal CPUE rates in the shallow-set sector than the deep-set sector (Walsh *et al.* 2009). Between 1995–2000 and 2004–2006, catch rates for shortfin mako sharks were stable for the deep-set sector, and increased 389% in the shallow-set sector to 0.911 sharks per 1000 hooks (Walsh *et al.* 2009). Comparing the same two time periods, minimum estimates of shortfin mako shark mortality decreased in both the deep-set and shallow-set sectors (from 80.6 to 47%, and from 68 to 31.6%, respectively) (Walsh *et al.* 2009). This reduction in mortality may be a result of the prohibition of shark finning in 2000, and the requirement of the use of relatively large circle hooks rather than traditional J-hooks in the shallow-set sector beginning in 2004 (Walsh *et al.* 2009; Carvalho *et al.* 2014). Data from Hawaii and California-based Pelagic Longline Vessels Annual Reports (available at https://www.fisheries.noaa.gov/resource/data/hawaii-and-california-longline-fishery-logbook-summary-reports) indicate that from 2008 to 2019, Hawaii longline fisheries have steadily increased the portion of mako catch that is released alive, with 58% being released alive in 2008 and 89% being released alive in 2019. Data from the report also shows that from 2008 to 2019, mako sharks comprised, on average, only 0.71% of all species landed in the shallow-set and deep-set fisheries combined.

Estimated annual standardized CPUE of shortfin mako shark caught in the Japanese offshore and distant-water shallow-set longline fishery from 1994–2019 indicated that the species had a gradually increasing trend until 2011, and then remained stable, except in 2016 (Kai 2021b). The authors note that the increasing trend until 2004 was caused by gradually increasing catch with a slight increase of fishing effort, the steep increase from 2004 to 2011 was mainly caused by decreasing fishing effort and stable annual catches, and the stable trends in recent years are the result of consistent catch and fishing efforts (Kai 2021b).

The New Zealand tuna longline fishery is composed of foreign-licensed vessels (which ceased fishing after the 1994–1995 season), foreign chartered vessels, and domestic vessels (Francis *et al.* 2001). After foreign-licensed vessels ceased fishing in the New Zealand EEZ, the number of hooks set by longline vessels in New Zealand declined from a maximum of 27 million in 1980–1981 to less than four million (Griggs *et al*. 2021). Total effort dropped to a low of 2.2 million hooks in 2007–2008 (Griggs *et al*. 2021). During the 2015–2016 to 2017–2018 time period, domestic vessels are the only fleet to fish with surface longlines in New Zealand waters, setting an average of 2.2 million hooks annually (Griggs *et al*. 2021). Shortfin mako sharks are a common bycatch species, and between the 1988–1989 and 1997–1998 seasons, an estimated 25,000 individuals were caught when observed CPUE was multiplied by total effort (Francis *et al*. 2001). In the 2015–2016 season, 484 shortfin mako sharks were observed caught in the domestic fleet making up 1.9% of the catch (Griggs *et al*. 2021). Only 2.5% of the observed caught shortfin makos were retained and 37% were discarded dead (Griggs *et al*. 2021). In the 2017–2018 season, 286 shortfin makos were observed caught making up 1.5% of the observed catch (Griggs *et al*. 2021).

Shortfin mako sharks are incidentally caught in the American Samoa longline fleet targeting mainly albacore tuna (*Thunnus alalunga*). According to the American Samoa Longline Limited-entry Fishery Annual Report for 2019, 154 makos were caught, but only one was kept and the other 153 were released (PIFSC 2020). From 2006–2018, observed interactions with shortfin makos in the American Samoa longline fishery didn't have a clear trend, but peaked in 2011 and declined after 2015 (PIROP unpublished data).

In Australian waters, shortfin mako sharks are a protected species and may not be retained, though they are caught as bycatch in other fisheries. In 2019, 1,659 shortfin mako sharks were caught in the Eastern Tuna and Billfish Fishery (7 were alive, 574 were dead, and 1,078 were released in unknown condition), 127 were caught in the Western Tuna and Billfish Fishery and released in unknown condition, 3 were caught in the Small Pelagic Fishery (one alive and two dead), and 92 were caught in the gillnet, hook, and trap sector (2 alive; 82 dead; 8 in unknown condition) (Patterson *et al.* 2020).

Although historical catch data for the Western and Central Pacific is lacking, reporting has improved in recent years with the implementation of Conservation Management Measures that require reporting of catches of key shark species. A noteworthy exception are catches from Indonesia, recognized as the top shark fishing nation in the world. Interactions with shortfin mako shark commonly occur in pelagic longline fleets in this region. The latest stock assessment for shortfin mako sharks in the North Pacific indicates that the stock is not overfished and overfishing is not occurring, and CPUE trends from the South Pacific indicate increasing shortfin mako shark abundance. Based on available data, it does not appear that overutilization is occurring in this region.

Eastern Pacific Ocean

While an experimental longline fishery targeted shortfin mako sharks in California from 1988–1992, the species is now mainly taken as bycatch in Eastern Pacific commercial longline, drift gillnet, and purse seine fleets (Read 2008). According to the Inter-American Tropical Tuna Commission's (IATTC) Report on the tuna fishery, stocks, and ecosystem in the Eastern Pacific Ocean (EPO) in 2020, purse seine fisheries have contributed very little to the take of mako sharks (*Isurus* spp.) in the EPO from 1993–2020 (estimated <3 t each year on average). Longline vessels are a more important source of fishery mortality for the genus in the EPO. Estimated catch of mako sharks (*Isurus* spp.) was 2,882 t in 2018 and 1,927 t in 2019, and the total estimated catch in longlines from 1993–2019 was 36,036 t (IATTC 2020).

The California/Oregon drift gillnet fishery targeting swordfish and thresher sharks incidentally catches shortfin mako sharks, the large majority of which are retained. Annual landings of the species ranged from 278 t in 1987 to 31 t in 2006 and have annually declined since the late 1990s (Read 2008; Sippel *et al*. 2014). Most recently, observer records (available at https://www.fisheries.noaa.gov/west-coast/fisheries-observers/west-coast-region-observer-program) indicate that catches have decreased: 41 shortfin mako sharks were caught and 39 were kept in the 2017–2018 season (36 per 100 sets), 95 were caught and 85 kept in the 2018–2019 season (76.61 per 100 sets), 136 were caught and 135 were kept in 2019–2020 season (158.14 per 100 sets), and 3 shortfin mako sharks were caught and kept in the 2020–2021 season (13.64 per 100 sets). Analysis of NMFS observer records from 1990–2015 indicates that shortfin mako sharks make up only 4.92% of the total catch in this fishery (Mason *et al*. 2019).

Within the Mexican EEZ in the Pacific, shortfin mako sharks are taken in the artisanal fishery and the pelagic longline fishery, and were historically taken in the drift gillnet fishery until 2010 (Sosa-Nishizaki *et al.* 2017). The majority of shortfin mako shark landings come from Baja California Sur (BCS), where the artisanal longline fleet is responsible for most of the catch on both the Pacific coast and the Gulf of California coast (Sosa-Nishizaki *et al.* 2017). The artisanal fleet in BCS represents an important source of food and employment in coastal communities, and is carried out on small boats (up to 10.5 m length) with outboard motors (Furlong-Estrada *et al.* 2017). Smaller sharks in coastal areas are caught using monofilament gillnets, while larger pelagic sharks are captured in deeper water with longlines (Furlong-Estrada *et al.* 2017). A productivity and susceptibility analysis for shark species caught in the BCS artisanal fishery revealed that shortfin mako sharks have one of the highest vulnerabilities to the fishery based on their low productivity and high susceptibility (Furlong-Estrada *et al.* 2017). Reported catches from the states of Baja California, Baja California Sur, Sinaloa, Nayarit, and Colima totaled 660 t (live weight) in 2016, down from 1,653 t in 2015 and 1,467 t in 2014 (Sosa-Nishizaki *et al.* 2017). In 2019, however, shortfin mako shark catch peaked at 1,795 t (González-Ania *et al.* 2021). As shortfin mako sharks are the second most common shark species in longline catches off the west coast of BCS, with juveniles strongly dominating landings, the effect of this fishery is of concern for the early life stages found in this area (Furlong-Estrada *et al.* 2017; Saldaña-Ruiz *et al*. 2019).

In Ecuador, artisanal fisheries are also major sources of food production and employment. Over the period from 2008–2012 in the five principal ports of the fishery (Esmeraldas, San Pablo de Manta, Puerto Daniel López, Santa Rosa de Salinas, and Anconcito), 846.6 t of shortfin mako shark were landed by the pelagic longline and surface gillnet fleets combined, making up 0.2% of the fishery (Martinez-Ortiz *et al.* 2015).

Shortfin mako sharks are caught in Peruvian small-scale longline fisheries targeting dolphinfish (mahi mahi) from December through February, and sharks from March through November (Doherty *et al.* 2014). Observer data from the Port of Ilo collected in 2005–2010 indicates that of 16,610 sharks landed, shortfin mako sharks made up 28.4% of the catch (Doherty *et al.* 2014). An average of 93.3% of those were immature individuals below legal minimum landing size

(Doherty *et al.* 2014). The authors calculated a CPUE of 1.9 ± 3.1 and 33.6 ± 10.9 sharks (all species) per 1000 hooks for the dolphinfish season (in which shortfin mako sharks are taken incidentally and retained) and the shark season, respectively. The number of longline vessels in the Peruvian small scale fishing fleet increased by >350% between 1995 and 2005, and has been estimated to set 80 million hooks per year (Alfaro-Shigueto *et al.* 2010; Doherty *et al.* 2014). Despite being defined as small-scale, the magnitude of fishing effort and the high proportion of juvenile shortfin mako sharks landed may have a large effect on the population off of Peru.

To summarize, shortfin mako sharks are mainly taken in longline and drift gillnet gear in the Eastern Pacific. Stock assessments in the North Pacific and standardized CPUE data in the South Pacific indicate stable and potentially increasing abundance trends. Therefore, shortfin mako sharks in the Eastern Pacific are not likely subject to overutilization.

Indian Ocean

In the Indian Ocean, shortfin mako sharks are caught in pelagic longline, gillnet, and purse seine fleets, with the majority of catch coming from longlines targeting swordfish and sharks. Nominal reported catches of sharks in the IOTC convention area have generally been increasing since the 1950s, though reporting of shark catches has been very irregular and information on shark catch and bycatch is considered highly incomplete (Murua *et al.* 2018). Fisheries catch data for the Indian Ocean are available from the IOTC, which requires CPCs to annually report shortfin mako shark catch data (see IOTC Resolutions 17/05, 15/01, and 15/02). However, prior to the adoption of resolution 05/05 (superseded by resolution 17/05), there was no requirement for sharks to be recorded at the species level in logbooks. It was not until 2008 that some statistics became available on shark catch, mostly representing retained catch and not accounting for discards (IOTC 2018). Several countries continually do not report on their interactions with bycatch species, as evidenced by high rates of bycatch reported by other fleets using similar gear configurations (IOTC 2018). When catch statistics are provided, they may not represent total catches of the species, but those simply retained on board, with weights that likely refer to processed specimens (IOTC 2018). Misidentification of shark species is also a common problem, and reporting by species is very uncommon for gillnet fleets where the majority of shark catches are reported as aggregates (IOTC 2020). Reported shark catches dropped significantly after 2017 when India stopped reporting aggregated shark catches and did not replace that reporting with detailed reports by species. Decreases in reported shark catches by Mozambique and Indonesia are thought to represent similar reporting issues (IOTC 2020). In sum, although reporting has improved substantially in recent years, current reported catches continue to be incomplete and largely underestimated. Given the conservation life history of the species and long generation time, the lack of historical data is concerning and establishing long-term trends is not feasible.

The major contributors to mako shark (longfin and shortfin combined) catch reported to IOTC are Japan, Madagascar, Indonesia, Spain, Sri Lanka, Pakistan, Taiwan, South Africa, Portugal, and Guinea (Figure 14).

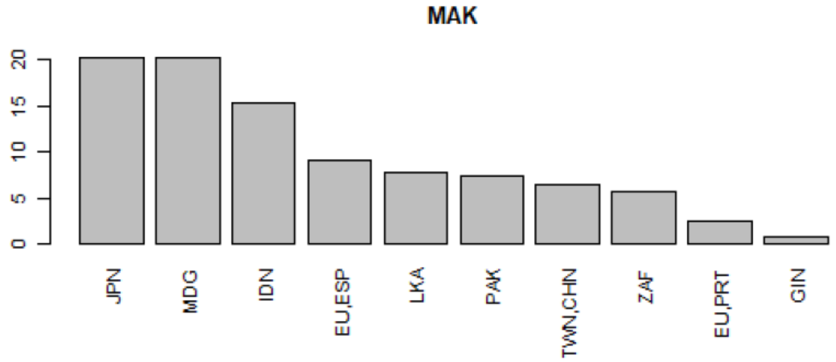

Figure 14. IOTC CPC contribution by percentage to mako shark catch (JPN=Japan; MDG=Madagascar; IDN=Indonesia; EU, ESP=Spain; LKA=Sri Lanka; PAK=Pakistan; TWN,CHN=Taiwan; ZAF=South Africa; EU,PRT=Portugal; GIN=Guinea) (reprinted from IOTC 2020).

The Japanese longline fishery targeting southern bluefin tuna (*Thunnus maccoyii*) in the Indian Ocean is limited in area and season of operation, but generally overlaps with shortfin mako shark distribution (Kai and Semba 2019). Increasing fishing effort in the early 1990s led to high and increasing annual catch in this fishery, which peaked in 1996 (Figure 15; Kai and Semba 2019). Fishing effort decreased more over time than annual catch, leading to slight increases in a standardized CPUE index of abundance (Kai and Semba 2019).

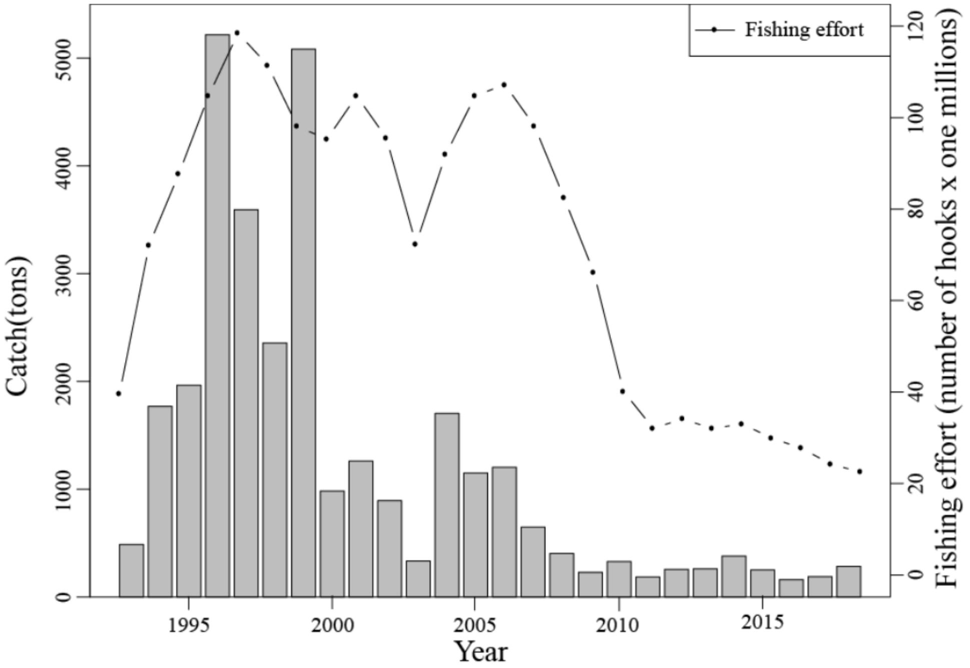

Figure 15. Estimated shortfin mako shark catch and fishing effort in the Japanese tuna longline fishery operating in the Indian Ocean from 1993–2018 (reprinted from Kai and Semba 2019).

Indonesia is currently the leading elasmobranch fishing nation in the world, though data on Indonesian fisheries are scarce (Winter *et al*. 2020). Dent and Clarke (2015) estimate that annual total captures of chondrichthyan fishes from 2000–2011 averaged 106,034 t. Shark meat is consumed domestically and provides an affordable source of protein, while fins are traded internationally as a luxury item (Winter *et al.* 2020). Most of the sharks landed in Indonesia are taken as bycatch in artisanal fisheries using gillnets, longlines, seines, and bottom trawls (Fahmi and Dharmadi 2015). Available recent studies assessing shark fisheries in southern Indonesia are limited to a few major landing ports. The largest pelagic fisheries that take elasmobranchs as bycatch operate from Benoa (Bali) and Cilacap (Central Java), and smaller pelagic fisheries that frequently target sharks and rays operate from Tanjung Luar (Lombok) and Kedonganan (Bali) (Blaber *et al.* 2009). When characterizing elasmobranch fisheries at six landing sites (Cilacap (Central Java), Kedonganan (Bali), Muara Angke (Jakarta), Muara Baru (Jakarta), Pelabuhanratu (West Java), and Tanjung Luar (Lombok)), Blaber *et al.* (2009) found that shortfin mako sharks were the third most common shark bycatch species in Indonesian tuna longline fisheries. A study of landings at Cilacap (representative of Indonesian shark bycatch fisheries) from 2006–2013 provided similar results, and indicated that shortfin mako sharks were caught in the Indonesian tuna gillnet fisheries, although the species made up a smaller percentage contribution (Fahmi and Dharmadi 2015). Elasmobranch fisheries in the Bali strait were examined using survey data from Muncar, a major port in East Java, indicating that shortfin mako sharks caught in industrial longlines made up about 1.2% of the catch between 2017 and 2018, and most of these (75%) were juveniles (Winter *et al.* 2020).

The shortfin mako shark is one of the most common bycatch species in the Taiwanese tuna longline fleet operating in the Indian Ocean, which reported the second highest catch of shortfin mako sharks to the IOTC in 2019. Based on logbook data for this fishery over the period 2005–2018, Wu *et al.* (2021) found that the Taiwanese tuna longline fleet catches were largely made up of juvenile shortfin mako sharks: 97% of females and 74% of males were immature. This could be due to bait and gear selectivity favoring the catch of juveniles, or scarcity of adults in this ocean basin (Wu *et al.* 2021). Analysis of standardized CPUE data from 2005–2018 indicates a stable and slightly increasing trend for the species (Figure 16; Tsai *et al.* 2019; Wu *et al.* 2021).

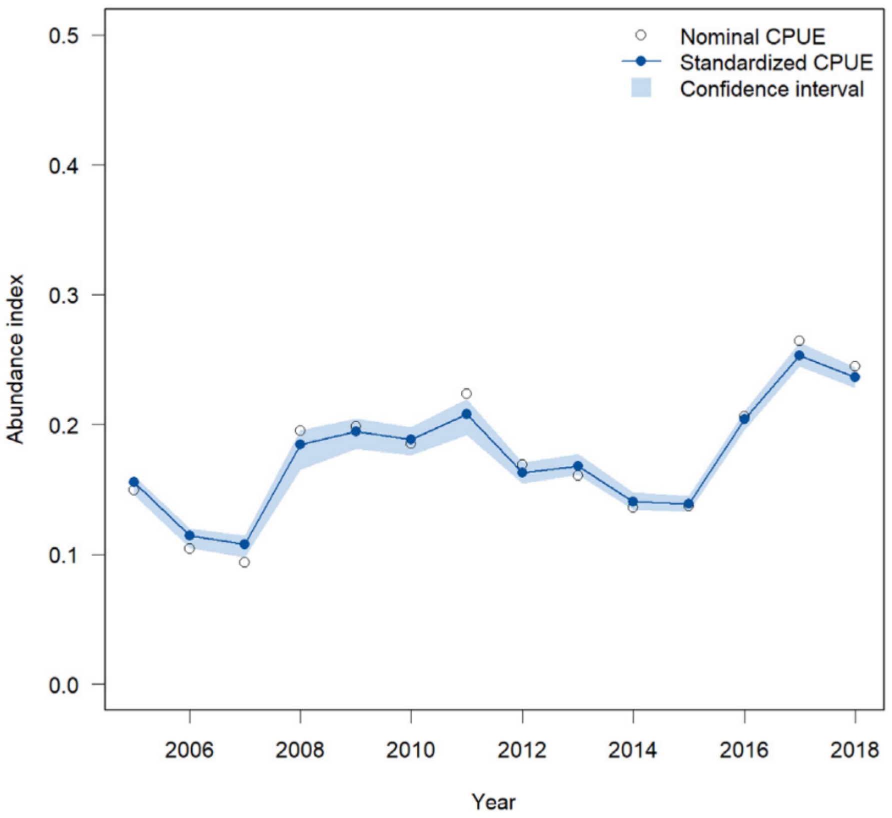

Figure 16. Nominal and standardized CPUEs per 1000 hooks for shortfin mako shark bycaught in Taiwanese large-scale tuna longline fleet, with 95% confidence interval (reprinted from Wu et al. 2021).

The Spanish surface longline fishery targeting swordfish began operating in the Indian Ocean in 1993 and expanded in geographical range since 2001 (Ramos-Cartelle *et al.* 2020). From the 2001–2018 period, shortfin mako shark catch by weight in this fleet represented an average of 5.35% of the total annual round weight of species combined, and shortfin mako shark was the third most prevalent species landed after swordfish and blue shark (Ramos-Cartelle *et al.* 2020). Using Generalized Linear Modeling, standardized CPUE data from this period indicates an increasing trend, especially after 2008 (Ramos-Cartelle *et al.* 2020).

As discussed above, shortfin mako sharks are caught and landed in substantial numbers by the South African PLL fleet. Though the fleet operates in both the Southeast Atlantic and Southwest Indian Oceans, shortfin mako sharks dominate the catch to the south of South Africa over the Agulhas Bank, an area under the management of the IOTC (Jordaan *et al.* 2020). Increasing CPUE indices are thought to reflect increased targeting and retention of the species, as well as improved reporting of landings, possibly combined with greater abundance (Jordaan *et al.* 2018).

The Portuguese PLL fishery targets swordfish and is mainly concentrated in the southwest Indian Ocean (Coelho *et al.* 2020b). The number of active vessels increased since the beginning of the fishery in 1998 until 2006, rising to 17 vessels, and has decreased to as low as 3 vessels in recent years (Coelho *et al.* 2020b). Fishing effort remained relatively constant between 1999 and 2004, increased in 2006–2007, and dropped in 2008. In recent years, effort increased to similar levels as in 2006–2007. Catch of shortfin mako shark seems to have followed this trend as well (Figure

17). The standardized CPUE index was highly variable until 2008 and shows a generally increasing trend in recent years (Coelho *et al.* 2020b).

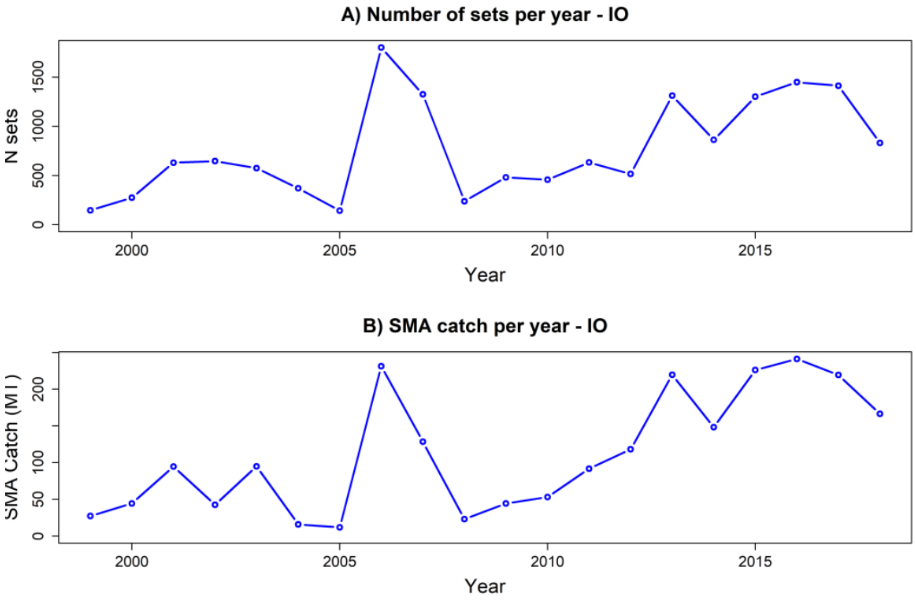

Figure 17. Plot of total effort (A) and catch of shortfin mako shark (B) for the Portuguese longline fleet operating in the Indian Ocean (reprinted from Coelho et al. 2020b).

Using the methodology of Cortés *et al.* (2010), a preliminary Productivity-Susceptibility Analysis for sharks caught in IOTC longline fisheries revealed that shortfin mako sharks have among the highest vulnerability to overexploitation in this fishery due to the species' low productivity (λ=1.061) and high susceptibility (0.929) (Murua *et al.* 2012). In an updated ecological risk assessment of IOTC longline, gillnet, and purse seine fisheries, Murua *et al.* (2018) found that the most vulnerable species to the IOTC pelagic longline fleet is the shortfin mako shark based on its low productivity (λ=1.049) and high susceptibility (0.867) (Figure 18).

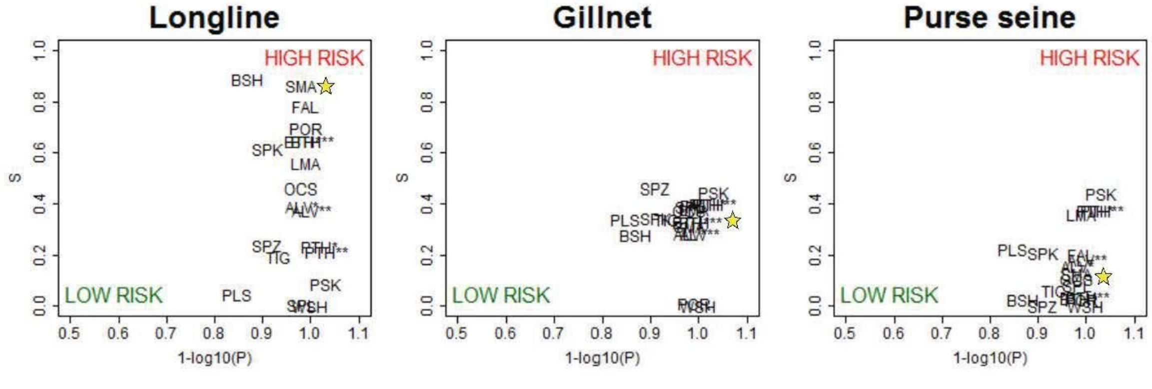

Figure 18. Productivity-susceptibility analysis for species caught by IOTC longline, gillnet, and purse seine fleets, including shortfin mako shark, indicated as SMA with a yellow star. Productivity is shown on the x-axis and susceptibility is shown on the y-axis (adapted from Murua et al. 2018).

Shortfin mako sharks had lower susceptibility to catch in the purse seine and gillnet fisheries (0.129 and 0.318, respectively) and were therefore found to be less vulnerable to overexploitation by these fleets (Murua *et al.* 2018). The post-capture mortality rate in Indian Ocean purse seine fleets was reduced between the 2012 and 2018 assessments due to the

European fleet implementing safe release best practices in 2014, but it is still quite high for shortfin mako sharks (approximately 55%) (Murua *et al.* 2018). Post-capture mortality represents the proportion of captured animals that die as a result of interaction with the gear, calculated as the sum of landings and dead discards (Cortes *et al*. 2010).

Overall, the best available scientific and commercial information from the Indian Ocean indicates some conflicting results with regard to whether the species is experiencing overutilization in this region. Results of preliminary stock assessments for shortfin mako sharks in the Indian Ocean indicate that the stock is subject to overfishing, but is not yet overfished (as discussed in section 3.2 Regional Population Trends). However, there is a high degree of uncertainty in the results due to data limitations. Additionally, several recent examinations of standardized CPUE data from various fleets indicate generally increasing trends, as discussed above. Therefore, while overutilization in commercial fisheries may be affecting shortfin mako sharks in this region, the severity of impact is highly uncertain.

Recreational fisheries

Shortfin mako sharks are a common target of recreational fisheries for several reasons. As previously mentioned, the meat is considered high quality for human consumption. In addition, the shortfin mako shark is considered a strong fighter, is challenging to catch, and often displays spectacular leaps out of the water, which also motivates anglers (French *et al.* 2019a). Available data on recreational fishing on shortfin mako sharks is summarized below.

Atlantic Ocean

Recreational fishing for shortfin mako shark takes place along the east coast of the United States. In all regions examined, including north of Virginia, south of Virginia, and the Gulf of Mexico, shortfin mako shark recreational catch was estimated at 17,973 individuals and 1,222 metric tons (t) in 1978 (Casey and Hoey 1985). ICCAT SCRS data indicates that U.S. recreational rod and reel catch peaked in 1995 at 1,422 t. Though U.S. recreational catch in the North Atlantic was estimated at 816 t as recently as 2014, 2018 regulations on recreational fishing for the species (discussed in section 4.4 (D) Inadequacy of Regulatory Mechanisms) reduced catch from 192 t in 2017 to 125 t in 2018, 25 t in 2019, and 24 t in 2020.

Offshore recreational fishing in the Mediterranean was recently assessed based on social media videos, which indicated that between 2010 and 2019, nine shortfin mako sharks were caught, only 3 of which were known to be released (Panayiotou *et al.* 2020). Though data on recreational fishing in this region is limited, the study indicates that the species is retained more frequently than other sharks and teleosts caught recreationally in this area and that reporting via ICCAT likely does not include recreationally caught specimens.

Pacific Ocean

In California, shortfin mako sharks have been recreationally fished since at least the 1950s. Reliable data on catch are available since 1957 from charter vessels and since the 1980s from private vessels (Kinney *et al*. 2017). California's commercial passenger fishing vessel database (CFPV) and the RecFIN database, used to estimate catch from private recreational vessels, are two sources for recreational fishing data (Figure 19). Recreational catch has been minimal since the early 2000s (Sippel *et al.* 2014; Kinney *et al*. 2017), and targeted effort for shortfin mako sharks in the private recreational fishery has been declining, dropping especially low after 2013

(E. Hellmers, California Department of Fish and Wildlife, personal communication on April 13, 2022). Shortfin mako sharks are also targeted opportunistically in the recreational albacore tuna fisheries off Oregon and Washington, but most are released at the boat without being brought aboard. Because these sharks are not landed in ports, records of catch are considered spotty and unreliable.

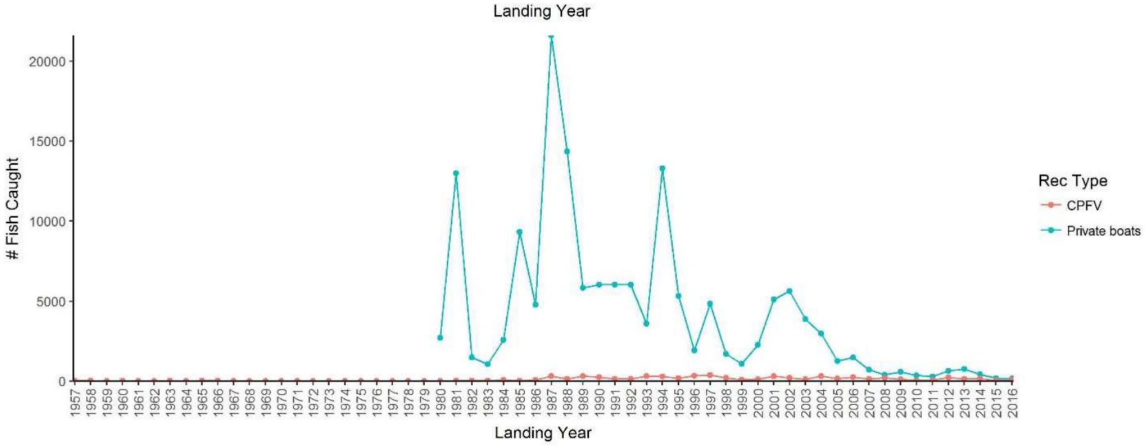

Figure 19. Annual recreational catch of shortfin mako sharks (data from 1990 – 1992 for private recreational boats are an average of the catch from 1993 – 1996 since no catch data were available for those three years; reprinted from Kinney et al. 2017).

Shortfin mako sharks are also targeted by recreational fishermen in Australia both for harvest and catch-and-release. While shortfin mako sharks are a protected species under Australia's Environment Protection and Biodiversity Conservation (EPBC) Act, recreational harvest is allowed in Australian waters based on the assumption that the sharks are frequently released and, therefore, the fishery has a negligible impact (French *et al.* 2015). Respondents to a survey of recreational anglers residing in Tasmania, Victoria, and New South Wales indicated that 636 of 871 shortfin mako sharks (73%) caught in a 12-month period were released (French *et al.* 2019a). Although angling events can be lengthy and energetically costly, post-release survival for recreationally caught shortfin mako sharks off southeastern Australia is high (90%) (French *et al.* 2015). French *et al.* (2015) did not find the length of fight time to be associated with decreased survivorship, and concluded that the species is highly resilient to capture-induced stress. It is possible that injury from foul hooking, which was significantly more common with J-hooks than with circle hooks, decreased post-release survival given that 2 of 3 mortalities were foul-hooked animals caught on J hooks (French *et al.* 2015). Another survey of recreational anglers in southeastern Australia revealed significantly different gear use between those aiming to retain the species (most commonly using J-hooks and offset J-hooks) and those releasing the sharks (most commonly using circle and offset circle hooks) (French *et al.* 2019b).

<u>Trade</u>

Demand for shark products, specifically meat and fins, has rapidly increased over the last four decades and has led to the overexploitation of shark populations worldwide. While trade in shark fins appears to have decreased slightly since the early 2000s, the trade in shark meat has grown over the last decade or so (Dent and Clarke 2015). In fact, domestic shark meat consumption in India is indicated to be the main driver of local shark harvest rather than the global fin trade (Karnad *et al*. 2020). The vast majority of shark fins in international trade are imported into and consumed in East and Southeast Asia, including China, Hong Kong, Taiwan, Singapore, Malaysia, and Vietnam, while the largest importers and consumers of shark meat include Italy, Brazil, Uruguay, and Spain (Dent and Clarke 2015). Spain, Indonesia, Taiwan, and Japan are the major shark fin exporting producers, and as the trade in shark meat has increased in recent years, these producers have also begun exporting large volumes of shark meat to the markets in Italy and Brazil (Dent and Clarke 2015). While available data on the trade in shark products are incomplete due to inconsistent identification of species and tracking of product types and volumes, FAO statistics conservatively estimate the average declared value of total world shark fin imports at $377.9 million per year from 2000–2011, with an average annual volume imported of 16,815 t (Dent and Clarke 2015). Annual average figures for shark meat from 2000–2011 were 107,145 t imported, worth $239.9 million (Dent and Clarke 2015). Quantifying the number of individual sharks harvested for the international shark trade is more difficult given that a substantial proportion of harvest is illegal, unregulated, or unreported (IUU) (Clarke *et al.* 2006b). Using shark fin trade data to estimate the total number of sharks traded worldwide, Clarke *et al.* (2006b) found that between 26 and 73 million individual sharks are traded annually (median = 38 million each year), with a median biomass estimate of 1.70 million t per year (range: 1.21–2.29 million t each year).

Due to the high value of both their meat and fins, shortfin mako sharks are more frequently retained when caught as bycatch than other pelagic shark species (CITES 2019). In fact, shortfin mako sharks are more highly valued for their meat, with fins often kept as a by-product (Fowler *et al*. 2021). The meat is utilized fresh, frozen, smoked, dried, and salted for human consumption (CITES 2019; Dent and Clarke 2015). Shortfin mako shark liver oil, teeth, jaws, and skin are also traded, though most of these products are of lower value and are not traded in significant quantities (CITES 2019).

The shortfin mako shark is a preferred species in the Hong Kong fin market, one of the largest fin trading markets in the world (Fields *et al.* 2018). Clarke *et al.* (2006a) analyzed 1999–2001 Hong Kong trade auction data in conjunction with species-specific fin weights and genetic information to estimate the annual number of globally traded shark fins. The authors estimated that the shortfin mako shark makes up approximately 2.7% (95% probability interval: 2.3–3.1%) of the Hong Kong shark fin trade, the fourth highest proportion of auctioned fin weight after blue (17.3%), hammerhead (*Sphyrna zygaena* or *S. lewini*, 4.4%), and silky (*Carcharhinus falciformis*, 3.5%) sharks. This translates to an estimated 300,000–1,000,000 individual sharks utilized in the global shark fin trade each year, totaling between 20,000 and 55,000 t in biomass (Clarke *et al*. 2006b). Although these data are fairly dated, more recent studies demonstrate the continued prevalence of shortfin mako shark fins in international trade. Fields *et al.* (2018) found shortfin mako shark to be the ninth most commonly traded species in Hong Kong based on random samples of fin trimmings from retail markets, making up 2.77% of fin trimming samples and comprising 0.6% of modeled trimmings. In another recent study, shortfin mako shark fins made up 4.16% and 2.37% of samples taken in the fin markets of Guangzhou, the largest fin trade hub in mainland China, and Hong Kong, respectively (Cardeñosa *et al*. 2020).

Shortfin mako sharks were listed under Appendix II of CITES effective November 26, 2019. As such, exports of the species must be found to be non-detrimental to the survival of the species in the wild, and the specimen must have been legally acquired. As the numbers presented above predate the CITES listing of shortfin mako sharks, current levels of exploitation for the international trade in meat and fins may be lower than levels prior to the listing (this regulatory measure is discussed further in 4.4 (D) Inadequacy of Existing Regulatory Mechanisms). With the trade in shark meat on the rise, the preference for shortfin mako shark meat in addition to their continued prevalence in the fin trade presents a concern for overexploitation of the species.

4.3 (C) Disease or Predation

Disease

The shortfin mako shark has been documented to host several parasites including cestodes, nematodes, blood flukes, and copepods (Benz 1980; Rokicki and Morozinska 1995; Caira and Bardos 1996; Benz *et al.* 2002; Gonzalez-Armas *et al.* 2012; Jacobsen *et al.* 2013; Orelis-Ribeiro *et al.* 2013; Penades-Suay *et al.* 2017; Caira *et al.* 2020). Infection by the copepod *Anthosoma crassum* can cause skin lesions around the jaws and gill arches of Lamniformes, and severe infections may lead to mortality (Benz *et al.* 2002). Parasitism by copepods is typical in sharks, however (Benz 1980). We found no information to indicate that disease is impacting the status of the shortfin mako shark.

Predation

Predation is not known to influence the status of shortfin mako sharks. Although killer whales (*Orcinus orca*) have been observed preying on a shortfin mako shark in New Zealand (Visser *et al.* 2000), as have white sharks (*Carcharodon carcharias*) (Fergusson *et al*. 2000), adult shortfin mako sharks are an apex predator and have few other natural predators. Adult shortfin mako sharks are known, however, to be cannibalistic (Horn *et al*. 2013) and other large sharks may also consume YOY and juvenile mako sharks. Given their high trophic position (see section 2.3 Feeding and Diet) and capacity to grow to a size that prohibits predation by most sea creatures (see section 2.4 Growth, Reproduction, and Longevity), we conclude that predation is not a threat to the shortfin mako shark.

4.4 (D) Inadequacy of Existing Regulatory Mechanisms

Inadequate regulatory mechanisms can leave the shortfin mako shark vulnerable to overharvest based on its high commercial value. As the shortfin mako shark is a highly migratory species with a global distribution, regulatory and conservation mechanisms at several different spatial and temporal scales are needed for adequate management. Below is a summary of regulatory measures that currently apply to the species, and an analysis of whether these are inadequate to protect the species from identified threats. Details of additional regulatory mechanisms are identified by jurisdiction in Appendices 1–3.

U.S. Domestic Regulatory Mechanisms

Tuna Conventions Act of 1950 (TCA)

Originally enacted in 1950, the TCA provides for the representation of the United States in the IATTC. Additionally, it authorizes the U. S. Secretary of Commerce to promulgate regulations for U.S. vessels that fish for tuna or tuna-like species in the IATTC Convention area.

Atlantic Tunas Convention Act of 1975 (ATCA)

The ATCA was originally enacted in 1975 and authorizes the U.S. Secretary of Commerce to administer and enforce all provisions of ICCAT, to which the United States is a party. As discussed further below, ICCAT conducts stock assessments for species in the convention area, and CPCs negotiate quotas and binding management recommendations. If ICCAT adopts recommendations, the United States must implement them under the ATCA. Regulations may be issued by the Secretary of Commerce to implement the Convention and, to the extent practicable, regulations promulgated under the ATCA are to be consistent with fishery management plans (FMPs) prepared and implemented under the MSA.

Magnuson-Stevens Fishery Conservation and Management Act (MSA)
The MSA was originally enacted in 1976. It is the primary law governing marine fisheries management in U.S. federal waters (3–200 miles offshore) and aims to prevent overfishing, rebuild overfished stocks, increase long-term economic and social benefits, and ensure a safe and sustainable supply of seafood. The MSA created eight regional fishery management councils, whose main responsibility is the development and subsequent amendment of FMPs for managed stocks. The MSA requires NMFS to allocate both overfishing restrictions and recovery benefits fairly and equitably among sectors of the fishery. In the case of an overfished stock, NMFS must establish a rebuilding plan. The FMP or amendment to such a plan must specify a time period for ending overfishing and rebuilding the fishery that shall be as short as possible, taking into account the status and biology of the stock, the needs of fishing communities, recommendations by international organizations in which the United States participates, and the interaction of the overfished stock within the marine ecosystem. The rebuilding plan cannot exceed ten years, except in cases where the biology of the stock, other environmental conditions, or management measures under an international agreement in which the United States participates dictate otherwise.

Shark Finning Prohibition Act of 2000
The Shark Finning Prohibition Act was enacted in December 2000 and implemented by final rule on February 11, 2002 (67 FR 6194). Section 3 of the Shark Finning Prohibition Act amended the MSA to prohibit any person under U.S. jurisdiction from: (i) engaging in the finning of sharks; (ii) possessing shark fins aboard a fishing vessel without the corresponding carcass; and (iii) landing shark fins without the corresponding carcass. In addition, Section 3 of the Shark Finning Prohibition Act contains a rebuttable presumption that any shark fins landed from a fishing vessel or found on board a fishing vessel were taken, held, or landed in violation (of the Act) if the total weight of shark fins landed or found on board exceeds 5% of the total weight of shark carcasses landed or found on board. Section 9 of the Shark Finning Prohibition Act defines finning as the practice of taking a shark, removing the fin or fins from a shark, and returning the remainder of the shark to the sea. The Shark Finning Prohibition Act also requires NMFS to provide Congress with an annual report describing our efforts to implement the law. The 2018 Shark Finning Report indicates that the mean value of shark fin imports dropped from $12,000 to $5,000 per metric ton from 2016 to 2017, and the mean value of exports decreased from $71,000 per metric ton in 2016 to $8,000 per metric ton in 2017 (NMFS 2018). U.S. participation in the fin trade therefore appears to be decreasing, although this could also be driven by reduced demand for shark fins worldwide (Dent and Clarke 2015).

Western and Central Pacific Fisheries Convention Implementation Act
Originally enacted in 2007, this Act authorizes the U.S. Secretary of Commerce to promulgate regulations needed to carry out the United States' obligations under the Convention on the

Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean. This includes implementing the decisions of the WCPFC, to which the United States is a party.

Shark Conservation Act of 2010

The Shark Conservation Act was signed into law on January 4, 2011, and amended the High Seas Driftnet Fishing Moratorium Protection Act and the MSA to improve existing domestic and international shark conservation measures. To address concerns over the practice of shark finning, the Shark Conservation Act, among other things, prohibits any person from removing shark fins at sea (with a limited exception for smooth dogfish); or possessing, transferring, or landing shark fins unless they are naturally attached to the corresponding carcass.

Management in the Atlantic Ocean

The U.S. Secretary of Commerce has the authority to manage highly migratory species (HMS) in the U.S. EEZ of the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea (16 U.S.C. 1811 and 16 U.S.C. 1854(f)(3)). The Atlantic HMS Management Division within NMFS develops regulations for Atlantic HMS fisheries and primarily coordinates the management of HMS fisheries in federal waters (domestic) and the high seas (international), while individual states establish regulations for HMS in state waters. However, federally permitted shark fishermen are required to follow federal regulations in all waters, including state waters, unless the state has more restrictive regulations. For example, the Atlantic States Marine Fisheries Commission (ASMFC) developed an interstate coastal shark FMP that coordinates management measures among all states along the Atlantic coast (Florida to Maine) in order to ensure that the states are following federal regulations. This interstate shark FMP became effective in 2010.

Shortfin mako sharks in the Atlantic are managed under the pelagic species complex of the Consolidated Atlantic HMS FMP. The first Atlantic Shark FMP of 1993 classified the status of pelagic sharks as unknown because no stock assessment had been conducted for this complex. At that time, the Maximum Sustainable Yield (MSY) for pelagic sharks was set at 1,560 t dressed weight (dw), which was the 1986–1991 commercial landings average for this group. However, as a result of indications that the abundance of Atlantic sharks had declined, commercial quotas for pelagic sharks were reduced in 1997. The quota for pelagic sharks was then set at 580 t. In 1999, the U.S. FMP for Atlantic Tunas, Swordfish, and Sharks implemented the following measures affecting pelagic sharks: (1) a reduction in the recreational bag limit to one Atlantic shark per vessel per trip, with a minimum size of 137 cm fork length for all sharks; (2) an increase in the annual commercial quota for pelagic sharks to 853 t dw, apportioned between porbeagle (92 t), blue sharks (273 t dw), and other pelagic sharks (488 t dw), with the pelagic shark quota being reduced by any overharvest in the blue shark quota; and (3) making bigeyed sixgill (*Hexanchus nakamurai*), bluntnose sixgill (*Hexanchus griseus*), broadnose sevengill (*Notorynchus cepedianus*), bigeye thresher, and longfin mako sharks, among other species, prohibited species that cannot be retained.

The implementing regulations for the conservation and management of the domestic fisheries for Atlantic swordfish, tunas, sharks, and billfish are published in the 2006 Consolidated HMS FMP (71 FR 58058, NMFS 2006). Since 2006, this FMP has been amended twelve times, with four additional amendments currently under development. Amendment 2, finalized in June 2008, requires that all shark fins remain naturally attached through landing in both the commercial and recreational fisheries (73 FR 35778, June 24, 2008; corrected version 73 FR 40658, July 15, 2008). Limited exceptions to this requirement allowed by Amendment 9 (80 FR 73128; November 24, 2015) do not apply to shortfin mako sharks.

Any fisherman who fishes for, retains, possesses, sells, or intends to sell, Atlantic pelagic sharks, including shortfin mako sharks, needs a Federal Atlantic Directed or Incidental shark limited access permit. Generally, directed shark permits allow fishermen to target sharks while incidental permits allow fishermen who normally fish for other species to land a limited number of sharks. The permits are administered under a limited access program and NMFS is no longer issuing new shark limited access permits. To enter the directed or incidental shark fishery, fishermen must obtain a permit via transfer from an existing permit holder who is leaving the fishery. Until recently, under a directed shark permit, there was no numeric retention limit for pelagic sharks, subject to quota limitations (see below for a description of a recent final rule regarding the retention limit for shortfin mako sharks). An incidental permit allows fishermen to keep up to a total of 16 pelagic or small coastal sharks (all species combined) per vessel per trip. Authorized gear types include: pelagic or bottom longline, gillnet, rod and reel, handline, or bandit gear. All fins must remain naturally attached. The annual quota for pelagic sharks (other than blue sharks or porbeagle sharks) is currently 488.0 t dw (Amendment 2 to the 2006 Consolidated Atlantic HMS FMP (73 FR 35778, June 24, 2008; corrected version 73 FR 40658, July 15, 2008)).

NMFS monitors the different shark quota complexes annually and will close the fishing season for each fishery if landings reach, or are projected to reach, an 80 percent threshold of the available quota and are also projected to reach 100 percent of the available quota before the end to the fishing year. Atlantic sharks and shark fins from federally permitted vessels may be sold only to federally permitted dealers; however, all sharks, with a limited exception for smooth dogfish sharks, must have their fins naturally attached through offloading. The head may be removed and the shark may be gutted and bled, but the shark cannot be filleted or cut into pieces while onboard the vessel. Logbook reporting is required for selected fishermen with a federal commercial shark permit. In addition, fishermen may be selected to carry an observer onboard, and some fishermen are subject to vessel monitoring systems depending on the gear used and locations fished. Since 2006, bottom longline and gillnet fishermen fishing for sharks have been required to attend workshops to learn how to release sea turtles and protected species in a manner that maximizes survival. In 2017, these workshops were modified to include a section on releasing prohibited shark species. Additionally, NMFS published a final rule on February 7, 2007 (72 FR 5633), that requires participants in the Atlantic shark bottom longline fishery to possess, maintain, and utilize handling and release equipment for the release of sea turtles, other protected species, and prohibited shark species. In an effort to reduce bycatch, NMFS has also implemented a number of time/area closures with restricted access to fishermen with HMS permits who have pelagic longline gear onboard their vessel.

The HMS Management Division also published an amendment to the Consolidated HMS FMP that specifically addresses Atlantic HMS fishery management measures in the U.S. Caribbean territories (77 FR 59842; Oct. 1, 2012). Due to substantial differences between some segments of the U.S. Caribbean HMS fisheries and the HMS fisheries that occur off the mainland of the United States (including permit possession, vessel size, availability of processing and cold storage facilities, trip lengths, profit margins, and local consumption of catches), the HMS Management Division implemented measures to better manage the traditional small-scale commercial HMS fishing fleet in the U.S. Caribbean Region. Among other things, this rule created an HMS Commercial Caribbean Small Boat (CCSB) permit, which: allows fishing for and sales of big-eye, albacore, yellowfin, and skipjack tunas, Atlantic swordfish, and Atlantic sharks within local U.S. Caribbean market; collects HMS landings data through existing territorial government programs; authorizes specific gears; is restricted to vessels less than or equal to 45 feet (13.7 m) length overall; and may not be held in combination with any other Atlantic HMS vessel permits. Until 2021, fishermen who held the CCSB permit were prohibited from retaining any Atlantic sharks. In 2021, NMFS modified the regulations to allow fishermen who hold the CCSB permit to retain up to three non-prohibited smoothhound sharks, non-blacknose small coastal sharks, or large coastal (other than hammerhead, silky, and sandbar) sharks (combined) per vessel per trip (86 FR 22882, April 30, 2021). CCSB permit holders are restricted to fishing with only rod and reel, handline, and bandit gear. Both the CCSB and Atlantic HMS regulations will help protect shortfin mako sharks while in the Northwest Atlantic Ocean, Gulf of Mexico, and Caribbean Sea.

After the 2017 ICCAT stock assessment indicated that North Atlantic shortfin mako sharks were overfished and experiencing overfishing, the United States took action to end overfishing and take steps toward rebuilding the stock through emergency rulemaking in March 2018. The measures immediately required release of all live shortfin mako sharks caught by commercial pelagic longliners with a minimum of harm while giving due consideration to the safety of crew members, and only allowed retention in pelagic longline gear if the shortfin mako shark was dead at haulback. The measures required commercial fishermen using non-pelagic longline gear (e.g., bottom longline, gillnet, handgear) to release all shortfin mako sharks, alive or dead, with a minimum of harm while giving due consideration to the safety of crew members. For recreational fisheries, the emergency rulemaking increased the minimum size limit for both male and female shortfin mako sharks to 83 inches FL. These temporary measures were replaced by long-term management measures finalized as Amendment 11 to the 2006 Consolidated HMS FMP in March 2019. The final management measures for commercial fisheries allowed retention of shortfin mako sharks caught with longline or gillnet gears if sharks were dead at haulback. Further, vessels with pelagic longline gear were required to have a functional electronic monitoring system to verify catch condition for compliance purposes. For recreational fisheries, the minimum size limit was increased from 54 inches to 71 inches FL for males and 83 inches FL for females, and the use of circle hooks was required for all recreational shark fishing. These measures led to the reduction of the U.S.'s total landings of North Atlantic shortfin mako shark (commercial and recreational) from 302 t in 2017, to 165 t in 2018, to 57 t in 2019, with 2 t of dead discards, an 81% reduction from 2017. In 2020, U.S. recreational landings of North Atlantic shortfin mako shark were 24 t, reduced by over 90% from the 2013–2017 average.

Following the adoption of Rec. 21-09 at the November 2021 ICCAT annual meeting (described further below), NMFS published a final rule to implement a flexible shortfin mako shark retention limit with a default limit of zero in all commercial and recreational HMS fisheries (87 FR 39373; July 1, 2022). The rule meets domestic management objectives, implements Recommendation 21-09, and acknowledges the possibility of future retention (limited retention of shortfin mako sharks may be allowed in 2023 and future years if ICCAT determines that fishing mortality is at a low enough level North Atlantic-wide to allow retention consistent with the conservation objectives of the recommendation). The rule, effective July 5, 2022, requires that all commercial and recreational fishermen release all shortfin mako sharks, whether dead or alive, at haulback. Any sharks released alive must be released promptly in a manner that causes the least harm to the shark.

Management in the Pacific Ocean
In the U.S. Pacific, HMS fishery management is the responsibility of adjacent states and three regional management councils that were established by the MSA: the Pacific Fishery Management Council (PFMC), the North Pacific Fishery Management Council (NPFMC), and the Western Pacific Regional Fishery Management Council (WPRFMC). Based on the range of the shortfin mako shark, only the PFMC and WPRFMC directly manage the species.

The PFMC's area of jurisdiction is the EEZ off the coasts of California, Oregon, and Washington. Prior to the development of a West Coast-based FMP for HMS, the fisheries were managed by the states of California, Oregon, and Washington, although some federal laws also applied. In late October 2002, the PFMC adopted its FMP for U.S. West Coast HMS Fisheries. This FMP’s management area also covers adjacent high seas waters for fishing activity under the jurisdiction of the HMS FMP. The final rule implementing the HMS FMP was published in the Federal Register on April 7, 2004 (69 FR 18443). Since its implementation, this FMP has been amended five times, most recently in 2018. The FMP requires a federal permit for all commercial HMS vessels that fish for HMS off of California, Oregon or Washington, or land HMS in these states. The permit is endorsed with a specific endorsement for each gear type to be used, and any commercial fisherman may obtain the required gear endorsements. Legal HMS gear includes harpoon, surface hook and line, large mesh drift gillnet, purse seine, and pelagic longline; however, the use of these gears are subject to state regulatory measures. For commercial passenger recreational fishing vessels, a federal permit is required by the FMP, though existing state permits or licenses for recreational vessels can meet this requirement. Legal recreational gear includes rod-and-reel, spear, and hook and line. Per the FMP, due to the stock’s vulnerability, possible importance of the U.S. West Coast EEZ as nursery habitat, and poorly known total catches and extent of the stock, the recommended harvest guideline for shortfin mako sharks is 150 t round weight. This harvest guideline is a general objective, not a quota. Although attainment of a harvest guideline doesn’t require management action such as closure of the fishery, it does prompt a review of the fishery.

The WPRFMC’s area of jurisdiction is the EEZs of Hawaii, Territories of American Samoa and Guam, Commonwealth of the Northern Mariana Islands, and the Pacific Remote Island Areas, as well as the domestic fisheries that occur on the adjacent high seas. The WPRFMC developed the Fishery Ecosystem Plan for Pacific Pelagic Fisheries of the Western Pacific Region (FEP; formerly the Fishery Management Plan for the Pelagic Fisheries of the Western Pacific Region) in 1986 and NMFS, on behalf of the U.S. Secretary of Commerce, approved the Plan in 1987. Since that time, the WPRFMC has recommended, and NMFS has approved, numerous amendments to the Plan as necessary for conservation and management purposes. The WPRFMC manages HMS fisheries pursuant to the FEP, and species that are managed under FMPs or FEPs are called Management Unit Species (MUS), and typically include those species that are caught in quantities sufficient to warrant management or specific monitoring by NMFS and the Council. In the FEP, shortfin mako sharks are designated as a Pelagic MUS and, thus, are subject to regulations under the FEP. These regulations are intended to minimize impacts to targeted stocks as well as protected species. Fishery data are also analyzed in annual reports and used to amend the FEP as necessary.

Adequacy of existing U.S. domestic regulatory measures

The United States manages 12 of 16 sustainable shark fisheries globally (Ferretti *et al*. 2020). As of 2017, of the 38 shark stocks or stock complexes in U.S. fisheries, 15 (39%) were listed as not subject to overfishing and 10 (26%) were listed as not overfished, 4 (11%) were listed as subject to overfishing and six (16%) were listed as overfished, and 19 (50%) had an unknown overfishing status and 22 (58%) had an unknown overfished status (NMFS 2018). Management measures implemented in response to the status of the North Atlantic shortfin mako shark stock were finalized in March 2019, and have been effective in reducing U.S. landings of the species in this region (both recreationally and commercially) as discussed above. NMFS recently published a final rule to implement ICCAT Rec. 21-09, requiring that all U.S. commercial and recreational fishermen release all shortfin mako sharks, whether dead or alive, at haulback. The adequacy of this retention prohibition cannot be assessed at this time. In the Pacific, the available stock assessment for the North Pacific region indicates that the species is neither overfished nor experiencing overfishing (ISC Shark Working Group 2018). For the foregoing reasons, it is likely that U.S. domestic fisheries management measures are adequate to address threats of overfishing to the species in U.S. waters. With regard to the fin and meat trade, declines in U.S. exports of shark fins followed implementation of both the Shark Finning Prohibition Act and the Shark Conservation Act, and recent declines in the mean value of U.S. exports per metric ton have been reported by NMFS. Additionally, 14 U.S. states and three U.S. territories have enacted legislation controlling shark finning by banning possession and sale of shark fins (see details in Appendix 2). These state laws have reduced U.S. landings of sharks and therefore U.S. trade and consumption of shark fins, although it is important to note that the United States has traditionally played a relatively minimal role in the global shark fin trade (0.3 and 0.4% of global imports and exports in U.S. dollars according to Ferretti *et al*. 2020). Measures that prohibit the possession and sale of shark fins may provide some limited conservation benefit to sharks, including the shortfin mako shark, by discouraging the landing of any sharks.

International Conventions and Agreements

United Nations Convention on the Law of the Sea (UNCLOS)

UNCLOS is an international treaty that was adopted and signed in 1982 in Montego Bay, Jamaica. The Law of the Sea Convention defines the rights and responsibilities of nations with respect to their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources. The importance of collaborative management for highly migratory species is addressed in Article 64, which states: The coastal State and other States whose nationals fish in the region for the highly migratory species listed in Annex I shall cooperate directly or through appropriate international organizations with a view to ensuring conservation and promoting the objective of optimum utilization of such species throughout the region, both within and beyond the exclusive economic zone. The shortfin mako shark is listed on Annex I, Highly Migratory Species, of UNCLOS.

FAO Port State Measures Agreement (PSMA)

The PSMA was adopted in 2009 as a tool to combat IUU fishing. It aims to prevent illegally caught fish from entering international markets through ports. Under the terms of the treaty, foreign vessels will provide advance notice and request permission for port entry, countries will conduct regular inspections in accordance with universal minimum standards, offending vessels will be denied use of port or certain port services, and information sharing networks will be created. As IUU fishing is also a threat to elasmobranch species, implementation of the PSMA can have a positive effect on the conservation of elasmobranchs.

Convention on the Conservation of Migratory Species of Wild Animals (CMS)

CMS is an environmental treaty of the United Nations that aims to conserve migratory species, their habitats, and their migration routes. CMS establishes obligations for each State joining the Convention, promotes collaboration among range states, and provides the legal foundation for coordinating international conservation measures throughout a migratory range. Shortfin mako sharks were listed on Appendix II of CMS in 2008, thereby obligating Parties to work regionally to promote their conservation. The CMS defines Appendix II species as "those that have an unfavorable conservation status and that require international agreements for their conservation and management, as well as those that have a conservation status which would significantly benefit from the international cooperation that could be achieved by an international agreement."

The species is also included in Annex 1 of the CMS Memorandum of Understanding on the Conservation of Migratory Sharks (Sharks MOU) as of 2010. The CMS Sharks MOU is non-binding and aims to achieve and maintain a favorable conservation status for migratory sharks based on the best available scientific information and taking into account the socio-economic value of these species for the people in various countries. Annex 1 lists species that have an unfavorable conservation status and which require international agreements for their conservation, or would benefit significantly from such an agreement. The work of the MOU is built on an international conservation plan, which has the following objectives: to improve understanding of migratory shark and ray populations through research, monitoring, and information exchange; to ensure that directed and non-directed fisheries are sustainable; to protect critical habitats, migration corridors, and critical life stages of sharks, skates, and rays; to increase public awareness of threats and participation in conservation activities; and to enhance national, regional, and international cooperation. As of September 27, 2021, there are 49 signatories to the CMS Sharks MOU, including the United States.

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

CITES is an international convention that aims to ensure that international trade in animals and plants does not threaten their survival. CITES affords varying degrees of protection to over 37,000 species, which are classified into three appendices: Appendix I includes species threatened with extinction, and trade in specimens of these species is permitted only in exceptional circumstances; Appendix II includes species not necessarily threatened with extinction, but trade must be controlled to ensure utilization is compatible with their survival; and Appendix III contains species that are protected in at least one country that has asked other CITES Parties for assistance in controlling the trade in specimens of that species. CITES only regulates international trade and does not regulate take or trade within a country. CITES measures are legally binding for Parties.

The shortfin mako shark was included on Appendix II of CITES effective November 26, 2019. International trade in specimens of the species is allowed with an export permit, re-export certificate, or introduction from the sea (IFS) certificate granted by the proper management authority. The above permits or certificates may be granted if the trade is found to be non-detrimental to the survival of the species in the wild and the specimen was found to have been legally acquired. An IFS certificate applies when a specimen is taken on the high seas (not under the jurisdiction of any state) and is landed in a state. Several countries have taken a reservation to the listing (Botswana, Democratic Republic of the Congo, Eswatini, Japan, Namibia, Norway, South Africa, United Republic of Tanzania, Zambia, and Zimbabwe) meaning they have made a unilateral decision to not be bound by the provisions of CITES relating to trade in this species.

An analysis of trade data and fin trimmings from a Hong Kong market led Cardeñosa *et al.* (2018) to conclude that compliance with reporting and permitting requirements for CITES-listed shark species listed at the 16th CITES Conference of the Parties (2013) was low in 2015–2016. Therefore, the CITES listing may not have a strong impact on the number of shortfin mako sharks harvested for the international fin and meat trades.

International Shark Fishing and Finning Regulations

Finning bans have been implemented by several entities or countries including the European Union (EU), as well as nine Regional Fishery Management Organizations (RFMOs) (see Appendix 3). These finning bans range from requiring fins remain attached to the body, to allowing fishermen to remove shark fins if the weight of the fins does not exceed 5% of the total weight of shark carcasses landed or found onboard. This type of measure limits shark finning while allowing processing flexibility to the fishing industry (Shiffman and Hammerschlag 2016). In fact, all of the relevant RFMOs prohibit fins onboard that weigh more than 5% of the weight of sharks to curb the practice of shark finning. Although fin-to-carcass ratios have the potential to reduce the occurrence of shark finning, a number of issues associated with reliance on the 5% ratio have been identified, including the lack of clear scientific basis for the 5% ratio as a conservation measure, and the fact that the ratio varies widely by species, fin types used in calculation, type of carcass weight used (whole or dressed), and fin cutting techniques (Lack and Sant 2009). Under the fin-to-carcass ratio measure, landing sharks that do not have fins attached to the body make it difficult to match fins to a carcass (Lack and Sant 2009). This can allow for switching the fins of prohibited but more valuable species for those of the species they legally land the carcasses of, a practice called ‘high grading” (Shiffman and Hammerschlag 2016). Controls on finning also lack the capacity to provide differential protection to those shark species most at risk from overfishing and have no impact on the mortality of sharks that are discarded because their fins have either no or very low market value (Lack and Sant 2009). With the rise in the shark meat market in recent years (Dent and Clarke 2015), retention of the full carcass for commercial purposes may be an advantage for fishermen, as the product is worth keeping on board for landing. Overall, despite their existence, laws and regulations intended to curb finning are rapidly changing and are not always effectively enforced by countries and RFMOs (Biery and Pauly 2012).

Several countries have enacted complete shark fishing bans (i.e., bans on retention and possession of sharks and shark products), with the Bahamas, Marshall Islands, Honduras, Sabah (Malaysia), and Tokelau (an island territory of New Zealand) adding to the list in 2011, the Cook

Islands in 2012, and the Federated States of Micronesia in 2015 (see Appendix 2). So-called "shark sanctuaries" (i.e., locations where harvesting sharks is prohibited) can also be found in the Eastern Tropical Pacific Seascape (which encompasses around two million km^2 and includes the Galapagos, Cocos, and Malpelo Islands), in waters off the Maldives, Mauritania, Palau, French Polynesia, New Caledonia, and Raja Ampat, Indonesia. However, it should be noted that sharks can still be caught as bycatch and discarded in these areas. See Appendices 2 and 3 for a description of the existing regulatory mechanisms in place for shark fishing and finning, respectively, throughout the range of the shortfin mako shark beyond the U.S. EEZ.

Several countries and territories also prohibit the sale or trade of shark fins or products, including:

- Bahamas
- Canada
- Commonwealth of the Northern Mariana Islands
- American Samoa
- Cook Islands
- Egypt
- French Polynesia
- Guam (with an exception for subsistence fishing)
- Republic of the Marshall Islands
- Sabah, Malaysia

Regional Fisheries Management Organizations

ICCAT

ICCAT is the main international regulatory body for managing shortfin mako sharks on the high seas in the Atlantic Ocean. In 2004, following the development and implementation of the International Plans of Action for Conservation and Management of Sharks, ICCAT adopted Recommendation 04-10 requiring CPCs to annually report data for catches of sharks, including available historical data. Recommendation 04-10 specifically calls for the SCRS to review the assessment of shortfin mako sharks and recommend management alternatives for consideration by the Commission, and to reassess the species no later than 2007. In 2005, ICCAT adopted Recommendation 05-05, which amended Recommendation 04-10 by requiring CPCs to annually report on their implementation of the Recommendation and instructing those that have not yet implemented this recommendation to reduce North Atlantic shortfin mako shark mortality to implement it and report to the Commission. In 2006, ICCAT adopted Recommendation 06-10, which further amended Recommendation 04-10 and called for a shortfin mako shark stock assessment in 2008. A supplemental Recommendation by ICCAT (07-06) calls for CPCs to submit catch data including estimates of dead discards and size frequencies in advance of SCRS assessments, to take appropriate measures to reduce fishing mortality for the North Atlantic shortfin mako shark, and to implement research on pelagic sharks in the Convention area to identify potential nursery areas. Recommendation 10-06 instructed CPCs to report on how they have implemented the three recommendations described above, particularly steps they have taken to improve data collection for direct and incidental catches. It also recommended that CPCs that do not report catch data for shortfin mako sharks be prohibited from retaining the species, and that the SCRS conduct a stock assessment for shortfin mako sharks in 2012. Recommendation 14-06 replaces and repeals Recommendations 05-05 and 06-10, calls for CPCs to improve data collection for shortfin mako shark and report information on domestic catch of shortfin mako shark to ICCAT, and encourages CPCs to undertake research on biology and life history of the shortfin mako shark.

Based on the 2017 shortfin mako shark stock assessment, which concluded a 90% probability of the stock being in an overfished state and experiencing overfishing, the Commission adopted Recommendation 17-08, requiring CPCs to release North Atlantic shortfin mako shark in a manner that causes the least harm. Retention of dead North Atlantic shortfin mako sharks remained acceptable in many cases, and harvest of live shortfin was only permitted under very limited circumstances. In 2019, the SCRS carried out new projections for North Atlantic shortfin mako shark through 2070 (two generation lengths) at the Commission's request (projections described in section 3.2 Regional Population Trends). Multiple TAC options with associated time frames and probabilities of rebuilding were presented to the Commission. Based on the resulting pessimistic projections and high susceptibility of the species to overexploitation, and to accelerate the rate of recovery and to increase the probability of success, the SCRS recommended that the Commission adopt a non-retention policy without exception. While a non-retention policy would ostensibly reduce mortality, shortfin mako shark frequently interact with surface longline fisheries and the potential inability for fishermen to avoid the species may not lead to sufficient decreases in mortality; therefore, the SCRS noted that other management measures such as time-area closures, reduction of soak time, safe handling, and best release practices may also be required (ICCAT 2019).

In 2019, the United States and Curaçao presented a proposal that was designed to end overfishing immediately and rebuild the stock by 2070 with a greater than 50% probability. The proposal would have accounted for mortality that would occur even under a no retention proposal by establishing a TAC, including dead discards, of 700 t to end overfishing in 2020 with a step-down to 500 t by 2022. It also proposed requiring gear modifications to assist in reducing at-vessel and post-release mortality, namely circle hooks and nylon monofilament leaders. Individual CPCs would be required to reduce their catches by 80% in 2020 and by 85% by 2022 from the average of 2013–2015 catches in order to end overfishing and begin rebuilding. All retention would be prohibited until a CPC achieves its required reductions; even then, retention would be permitted only under limited conditions, including 100% observers or electronic monitoring, minimum size requirements, or a landings obligation with no commercial profit. This proposal would have required CPCs to report their total dead discards and live releases of mako shark, estimated based on the total fishing effort of their relevant fleets.

In a separate proposal, Senegal and nine co-sponsors, including Canada, sought to prohibit the retention and sale of North Atlantic shortfin mako shark. The proposal included an exemption for CPCs whose domestic law requires that any dead fish be landed, that fishermen cannot draw any commercial profit from such fish, and that includes a prohibition against shortfin mako shark fisheries. The EU presented a proposal to require release of all North Atlantic shortfin mako sharks alive at haulback with a TAC of 500 t, and new reporting requirements for in-season monitoring and reporting. CPCs could land shortfin mako sharks that are dead at haulback if the vessel has an observer or electronic monitoring on board; live release would be required for recreational fisheries.

The United States, Senegal, Canada, EU, and Morocco met several times to discuss the three shortfin mako shark proposals, but were unable to reach agreement on the elements of a combined measure. In a proposal presented by the Chair and adopted (Rec. 19-06), it was agreed to extend and update the existing provisions in Rec. 17-08. Recommendation 19-06 also urged the Commission to adopt a new management recommendation for the North Atlantic shortfin mako shark at its 2020 annual meeting in order to establish a rebuilding plan with a high probability of avoiding overfishing and rebuilding the stock to B_{MSY} within a timeframe that takes into account the biology of the stock. Due to the COVID-19 pandemic, however, ICCAT did not host an annual meeting in 2020 and management decisions were made through a correspondence process. Due to the difficulty associated with this process, no consensus could be made on a new measure and Rec. 19-06 remained in place.

In 2021, the ICCAT annual meeting was conducted virtually, and the conservation of the North Atlantic shortfin mako shark stock was a priority. Commission members reached consensus on Rec. 21-09, which puts into place a two-year retention ban that aims to reduce mortality and establishes a process to evaluate if and when retention may be allowed in the future, in line with scientific advice. The measure contains strong provisions to improve data reporting, and particularly, the catch reporting of live releases and fish discarded dead, by all ICCAT parties. This measure entered into force on June 17, 2022, and as data for each fishing year is not reported until the following calendar year, the management effect of Rec. 21-09 will not be easily assessed until 2024 when the landings and discard data from 2023 can be analyzed. Despite this important step forward, ICCAT's work to end overfishing and rebuild North Atlantic shortfin mako shark is not complete; within Rec. 21-09 a provision exists to revisit the measure "no later than 2024 to consider additional measures to reduce total fishing mortality." Future efforts will likely be focused on reducing the at-haulback and post-release mortality of North Atlantic shortfin mako shark unintentionally captured alongside target species.

IATTC

The IATTC is responsible for the conservation and management of tuna and other pelagic species in the Eastern Pacific. There are currently no specific resolutions related to the management of shortfin mako shark; however, IATTC does have resolutions relating to sharks in general. Resolution C-16-05 on the management of shark species requires that purse-seine vessels promptly release any shark that is not retained as soon as it is seen in the net or on deck and includes provisions for safe release of such sharks. Resolution C-05-03 requires vessels to have onboard fins that total no more than 5% of the weight of sharks onboard. The IATTC requires 100% observer coverage onboard the largest purse seine vessels, and 5% observer coverage on larger longline vessels.

WCPFC

The WCPFC was established by the Convention for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (WCPF Convention), which aims to address issues related to the management of high seas fisheries resulting from unregulated fishing, over-capitalization, excessive fleet capacity, vessel re-flagging to escape controls, insufficiently selective gear, unreliable databases, and insufficient multilateral cooperation with respect to conservation and management of highly migratory fish stocks. There are currently no management measures specific to shortfin mako sharks in the WCPFC;

however, their management is addressed under the Conservation and Management Measure for Sharks (CMM 2019-04). This measure prohibits finning, requires that vessels land sharks with their fins naturally attached, and calls for vessels to reduce bycatch and practice safe release of sharks. In order to reduce bycatch mortality, the measure calls for longline fisheries targeting billfish and tuna to either not use wire branch lines or leaders, or not use shark lines (i.e., branch lines running directly off longline floats or drop lines).

IOTC

In Indian Ocean waters, the IOTC serves to promote cooperation among CPCs to ensure, through appropriate management, the conservation and optimum utilization of stocks, and encourage sustainable development of fisheries based on such stocks. The United States is not a member. Conservation and Management Measures are adopted in the form of either resolutions, which require a two-thirds majority of Members present and voting to adopt them and are binding for contracting parties, or recommendations, which are non-binding and rely on voluntary implementation. While several measures have been adopted by IOTC parties that apply to sharks and bycatch in general, there are currently no specific resolutions related to the management of shortfin mako shark (see IOTC 2019). In Resolution 15/01 on the recording of catch and effort by fishing vessels in the IOTC area of competence, all purse seine, longline, gillnet, pole and line, handline, and trolling fishing vessels are required to have a data recording system and provide aggregated data to the Secretariat each year. Resolution 15/02 mandates statistical reporting requirements for IOTC CPCs by species and gear for all species under the IOTC mandate as well as the most commonly caught elasmobranch species and lays out requirements for observer coverage. IOTC Resolution 17/05 on the conservation of sharks caught in association with fisheries managed by IOTC requires that sharks landed fresh not have their fins removed prior to first landing, and for sharks landed frozen, CPCs must abide by the 5% fins-to-carcass weight ratio. Further, CPCs must report data for catches of sharks including all available historical data, estimates and life status of discards (dead or alive), and size frequencies under this resolution. Despite these requirements, reporting of shark catches has been very irregular and information on shark catch and bycatch is considered highly incomplete (Murua *et al.* 2018). Several countries continue to not report on their interactions with bycatch species as evidenced by high rates of bycatch reported by other fleets using similar gear configurations (IOTC 2018). The lack of reliable records of catch and lack of a formal stock assessment make it difficult to determine whether the regulatory mechanisms described above are adequate to address overutilization of the species in the Indian Ocean.

4.5 (E) Other Natural or Manmade Factors Affecting the Species' Continued Existence

Pollutants and environmental contaminants

As top predators with high longevity and large size, sharks are susceptible to bioaccumulation and biomagnification of heavy metals and other contaminants in their tissues (Gelsleichter and Walker 2010). Several studies have quantified the concentration levels of these pollutants and toxins in shortfin mako shark tissues, but with a focus on human consumption and safety (Suk *et al.* 2009; Lopez *et al.* 2013; Nalluri *et al.* 2014; McKinney *et al.* 2016; Biton-Porsmoguer *et al.* 2018; Mirlean *et al.* 2019). As such, many of the results from these studies may indicate either "high" or "low" concentrations in sharks, but this is primarily in comparison to recommended safe concentrations for human consumption and does not necessarily provide information on physiological impacts to individual sharks, their offspring, or shark populations. For example, shortfin mako sharks in the Northeastern Pacific were found to have muscle mercury (Hg) levels ranging from 0.15 to 2.90 micrograms per gram (µg/g), increasing with body size (Suk *et al.* 2009). The study reported that all analyzed shortfin mako sharks over 150 cm FL had muscle Hg levels exceeding the U.S. Food and Drug Administration's established action level of 1.00 µg/g for human consumption of commercial fish, but did not assess or discuss how mercury contamination affects the sharks' physiology or behavior (Suk *et al.* 2009). In the Southeastern Pacific, shortfin mako shark tissues (liver, stomach, and muscle) had a mean mercury and lead concentrations of 0.034 ± 0.023 and 0.922 ± 0.44 µg/g, respectively (Lopez *et al.* 2013). In the Northeast Atlantic, mercury levels in shortfin mako shark muscle tissue ranged from 0.12 to 2.57 mg/kg (Biton-Porsmoguer *et al.* 2018), and in the South Atlantic, muscle tissue had a mean mercury concentration of 0.502 µg/g (Mirlean *et al.* 2019). In addition to metals, shortfin mako sharks were found to have the highest accumulation potential of other organic contaminants (polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT) and metabolites, and non-DDT pesticides) when compared to two other pelagic sharks: blue and common thresher (Lyons *et al.* 2019). This result is explained by the shortfin mako shark's high trophic level and its high potential to transfer accumulated contaminants to offspring via maternal offloading (Lyons *et al.* 2019).

While shortfin mako sharks are exposed to environmental pollutants and have been shown to accumulate high concentrations of toxins, the effects are not well resolved. Alves *et al.* (2016) found a correlation between contaminant levels (persistent organic pollutants and metals) and biochemical responses in blue sharks, with higher levels of these contaminants associated with greater DNA damage and inhibition of an antioxidant enzyme. The authors report that these negative effects might impact the metabolism of blue sharks, as well as behaviors such as swimming, feeding, and reproduction (Alves *et al.* 2016). Adverse effects of high mercury concentrations in tissues have also been documented in several freshwater teleosts, including impairment of gonadal development and reproduction (Scheuhammer *et al.* 2007), though it is hypothesized that sharks have higher thresholds for mercury-associated effects than freshwater fish (Gelsleichter *et al.* 2020). Results of available studies provide some evidence that sharks may experience negative physiological impacts and potentially reduced fitness as a result of contaminant exposure, though further study is needed.

Climate change

The impacts of climate change on shortfin mako sharks, and pelagic sharks in general, have not been well studied. However, large-scale impacts of climate change such as ocean warming and acidification have the potential to threaten the species and its prey base in open ocean and continental shelf habitats, given projected impacts to these environments. The IPCC (2019) reports that the global ocean has warmed unabated since 1970 and has taken up more than 90% of the excess heat in the climate system (high confidence). It is virtually certain that the ocean will continue warming throughout the 21st century and by 2100, the top 2000 m of the ocean will very likely take up 5–7 times more heat under RCP8.5 than observed heat uptake since 1970 (IPCC 2019). It is very likely that the ocean has taken up 20–30% of total anthropogenic carbon dioxide emissions since the 1980s, leading to ocean acidification rates of 0.017–0.027 pH units per decade since the late 1980s (IPCC 2019). It is virtually certain that continued carbon uptake through 2100 will exacerbate ocean acidification, and under RCP8.5, open ocean surface pH is projected to decrease by around 0.3 pH units by 2081–2100, relative to 2006–2015 (IPCC 2019).

Available studies indicate that warming and acidification can have adverse effects on shark survival, fitness, and behavior. A study on the tropical brownbanded bamboo shark (*Chiloscyllium punctatum*) indicated that early acclimation to projected climate scenarios of ocean acidification and warming for 2100 (pH drop of 0.5 and increase in temperature of 4°C to 30°C) caused significant reductions in juvenile survival and fitness (Rosa *et al.* 2014). The authors report that under these future conditions, the study animals showed decreased metabolic and ventilatory capabilities (Rosa *et al.* 2014). As the brownbanded bamboo shark is a relatively inactive bottom-dwelling shark, potential impacts on metabolism may be more pronounced in active pelagic species with greater energy demands (Rosa *et al.* 2014), such as the shortfin mako shark. Climate change-induced acidification has also been shown to impact feeding behavior in sharks. Smooth dogfish sharks (*Mustelus canis*) exposed to acidification conditions consistent with projections for the year 2100 showed impairment in their ability to track food odors and attack a food source (Dixson *et al.* 2015). Pistevos *et al.* (2015) found similar effects of increased temperature and carbon dioxide levels on the Port Jackson shark, *Heterodontus portusjacksoni*, resulting in increased energetic demands, decreased metabolic efficiency, and reduced ability to locate food through olfaction. Though these studies show susceptibility of smaller benthic sharks to ocean warming and acidification, future studies should be carried out on pelagic ram-ventilators across a range of sizes and developmental stages.

Habitat suitability and prey distribution of the shortfin mako shark will also likely be impacted by climate change, although it remains to be determined to what degree this will impact the species and how quickly the species may be able to adapt to changing oceanic conditions. In a climate change risk assessment for sharks and rays in the Great Barrier Reef, pelagic species were found to have relatively low risk, with moderate to high exposure to only two of the ten climate change factors considered: oceanographic changes, which could affect productivity, migration patterns, and phenology; and rising temperatures, which could affect the physiochemical environment (Chin *et al.* 2010). Additionally, pelagic sharks generally had low sensitivity (i.e., rarity and habitat specificity) and rigidity (i.e., physical-chemical intolerance, immobility, and latitudinal range), which lowered their vulnerability to climate change factors (Chin *et al.* 2010). However, as evidence supports the shortfin mako shark's use of and fidelity to coastal areas (see section 2.2 Distribution and Habitat Use), their adaptive capacity may be lower than that suggested by this study. The consumption of diverse prey types by shortfin mako sharks across their life history (see section 2.3 Feeding and Diet) suggests a capacity to adapt to changing prey base, provided sufficient quantities of prey are available to meet metabolic needs.

Projected climate change-induced habitat shifts for predators in the Eastern North Pacific through 2100 indicated that the shortfin mako shark may lose the greatest amount of habitat of the species analyzed (Figure 20) (Hazen *et al.* 2013). In contrast, a study of future habitat suitability in the Australian EEZ found that suitable habitat for mackerel sharks was predicted to increase under RCP4.5 and RCP8.5 by 2100 (Birkmanis *et al.* 2020). Off the east coast of Australia, poleward shifts of core habitat for shortfin mako sharks were projected to move at a greater rate at the trailing edge than at the leading edge, implying that habitat availability for the species may shrink over time (Robinson *et al.* 2015).

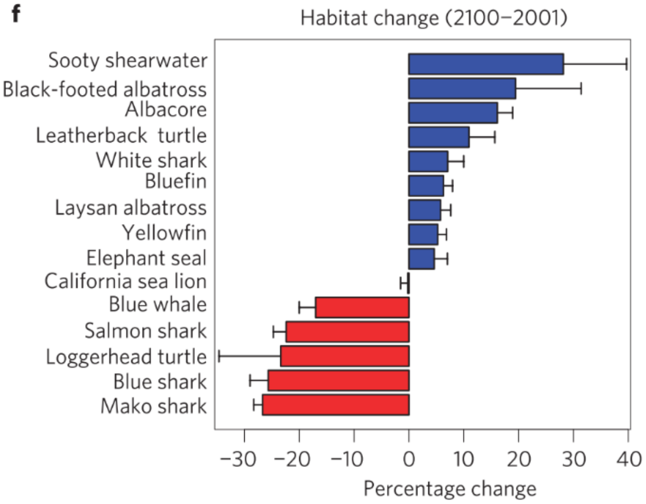

Figure 20. Total predicted mean habitat change for predators in the Eastern North Pacific from 2001 to 2100 with 1 standard deviation error bars (reprinted from Hazen et al. 2013).

Overall, climate change has the potential to adversely impact shortfin mako sharks, though there is high uncertainty regarding the specific impacts to the species, and how it might be able to adapt to changing conditions. While some studies project that the species may be subject to significant habitat loss and behavioral and fitness impairments by 2100, their broad prey base and thermal tolerance, among other factors, may give them a high adaptive capacity.

Bather protection and shark control

Small numbers of shortfin mako sharks are incidentally caught in bather protection programs in South Africa and Australia, which aim to reduce the risk of shark attacks on humans through the use of gillnets and baited drumlines near public beaches. The New South Wales Shark Meshing Program began in 1937 and targeted shortfin mako sharks until 2017, but continues to catch them incidentally. In the 2018–2019 season, eleven shortfin mako sharks were caught, making up 2.8% of the total catch (NSW Department of Primary Industries 2019). Just one of these individuals was found alive and released, while others were found dead (NSW Department of Primary Industries 2019). The Queensland Shark Control Program was established in 1962 and currently targets shortfin mako sharks with both nets and drumlines. From 1992–2008, fifteen shortfin mako sharks were caught with drumlines and eight were caught in nets in southern Queensland; survival rates for the species were 26.7% and 12.5% in each gear type, respectively (Sumpton *et al.* 2011). Catch of mako sharks in the program totaled 62 individuals from 2001–2021 (Queensland Department of Agriculture and Fisheries 2021). Shark-control programs at KwaZulu-Natal off the eastern coast of South Africa began in 1952 using large-mesh gillnets and baited drumlines beginning in 2007. Mean annual catch of shortfin mako sharks was fifteen from 1978–1989, twelve from 1990–1999, eight from 2000–2009, and one from February 2007 to February 2010 (Cliff and Dudley 2011). The percentage of shortfin mako sharks released alive increased from 1%, 10%, and 8% in the first three time periods, respectively, to 50% with the use of drumlines (Cliff and Dudley 2011). While mortality to shortfin mako sharks incidentally caught in shark control gillnets and drumlines appears high, the number of individuals impacted is low enough that we do not find shark control programs in Australia and South Africa to appreciably threaten the species.

5. EXTINCTION RISK ANALYSIS

5.1 Introduction

Section 3 of the ESA defines an endangered species as “any species which is in danger of extinction throughout all or a significant portion of its range.” A threatened species is defined as “any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” In many previous NMFS status reviews, a team has been convened to compile the best available information on the species and conduct a risk assessment through evaluation of the demographic risks and threats facing the species. They then provide an evaluation of overall extinction risk, accompanied by a detailed narrative justifying their conclusion. This information is ultimately used by the NMFS Office of Protected Resources, after consideration of the legal and policy dimensions of the ESA standards and benefits of ongoing conservation efforts, to make a listing determination. For purposes of this risk assessment, an Extinction Risk Analysis (ERA) Team, composed of fishery biologists, managers, and shark experts, was convened to review the best available information in this Status Review document and evaluate the overall extinction risk for the shortfin mako shark.

5.2 Rangewide Extinction Risk Analysis

The ability to measure or document risk factors impacting a marine species is often limited, and quantitative estimates of abundance and life history information are often lacking altogether. Therefore, in assessing extinction risk of a species with limited data available from certain regions, it is important to include both qualitative and quantitative information. In previous NMFS status reviews, Biological Review and ERA Teams have used a risk matrix method to organize and summarize the professional judgment of members. This approach is described in detail by Wainwright and Kope (1999) and has been used in Pacific salmonid status reviews, as well as in reviews of thresher sharks, hammerhead sharks, and oceanic whitetip sharks (see http://www.nmfs.noaa.gov/pr/species/ for links to these reviews). In the risk matrix approach, the condition of the species is summarized according to four demographic risk criteria: abundance, growth rate/productivity, spatial structure/connectivity, and diversity. These viability criteria, outlined in McElhany *et al.* (2000), reflect concepts that are well-founded in conservation biology and that individually and collectively serve as strong indicators of extinction risk. Using these concepts, the ERA Team estimated the extinction risk of the shortfin mako shark after conducting a demographic risk analysis. Likewise, the ERA Team performed a threats assessment for the species by scoring the severity of current threats and their likely impact on the species through the foreseeable future. The summary of demographic risks and threats obtained by this approach was then considered by the ERA Team to determine the species’ overall level of extinction risk both currently and in the foreseeable future. Specifics on each analysis are provided below.

Foreseeable future – ERA team discussion

According to regulations implementing section 4 of the ESA that were in place during the ERA Team’s deliberations, the foreseeable future extends only so far into the future as we can reasonably determine that both the future threats and the species' responses to those threats are likely. These regulations instructed us to describe the foreseeable future on a case-by-case basis, using the best available data and taking into account considerations such as the species' life-history characteristics, threat-projection timeframes, and environmental variability. This approach is also consistent with NMFS's longstanding interpretation of this term in use prior to the issuance of these regulations in 2019. On July 5, 2022, the U.S. District Court for the Northern District of California issued an order vacating the ESA section 4 implementing regulations that were revised or added to 50 CFR part 424 in 2019 ("2019 regulations," see 84 FR 45020, August 27, 2019) without making a finding on the merits. On September 21, 2022, the U.S. Court of Appeals for the Ninth Circuit granted a temporary stay of the district court's July 5 order. As a result, the 2019 regulations are once again in effect, and we are applying the 2019 regulations here.

In determining an appropriate foreseeable future timeframe for the shortfin mako shark, we first considered the species' life history. The species matures late in life, with females estimated to mature at an age of 15–21 years and males at 6–9 years of age (Bishop *et al.* 2006; Natanson *et al.* 2006; Semba *et al.* 2009; Groeneveld *et al.* 2014). The species has high longevity of at least 28–32 years (Bishop *et al.* 2006; Natanson *et al.* 2006), and exhibits relatively slow growth rates and low productivity (Cortés *et al.* 2015). We also considered generation time for the shortfin mako shark, which is defined as the average interval between the birth of an individual and the birth of its offspring and has been estimated at 25 years (Cortés *et al.* 2015). Given the life history characteristics of the shortfin mako shark, it would likely take several decades for any conservation management actions to be realized and reflected in population abundance indices.

As the main threats to the species are overutilization in commercial fisheries and the inadequacy of regulatory measures that manage these fisheries, we then discussed the time period over which we could reasonably predict the likely impact of these threats on the biological status of the species. Several projections for shortfin mako shark abundance are available: the 2019 ICCAT update to the stock assessment for the North Atlantic carried out projections over 2 generation lengths, or 50 years; the ISC Shark Working Group's 2018 stock assessment for North Pacific shortfin mako sharks used 10-year projections; and the IUCN Red List Assessment carried out projections based on available data to achieve a 3 generation length (GL) time frame using JARA, a Bayesian state-space tool for trend analysis of abundance indices.

In examining these projections and their respective confidence intervals, the ERA Team noted that uncertainty increased substantially after about one generation length in all cases across multiple regions of the species' range. In the IUCN JARA projections conducted for shortfin mako sharks by region, uncertainty (i.e., the difference between the median and confidence intervals) increased to 50% by 2030 for the South Pacific population (about 18 years projected), and 40% by 2040 for the Indian and North Pacific populations (about 25 years projected). Additionally, ICCAT's report of the 2019 shortfin mako shark stock assessment update meeting emphasizes that the Kobe II Strategy Matrix (K2SM) used to provide scientific advice for the North Atlantic stock does not capture all uncertainties associated with the fishery and the species' biology. Specifically, ICCAT's SCRS noted that "the length of the projection period (50 years) requested by the Commission significantly increases the uncertainty of the results. Therefore, the Group advised that the results of the K2SM should be interpreted with caution," (ICCAT 2019). As a result of this statement, the ERA Team considered the 50-year projection period to be questionable on its scientific merit, with estimates over that time frame only provided because the Commission requested them. Given the concerns about uncertainty that were repeatedly highlighted by the SCRS (ICCAT 2019), the ERA Team concluded that such a duration is not an appropriate time period for the foreseeable future.

In addition to uncertainty in projected abundance trends, the Team discussed the uncertainty associated with future management measures and fishing behavior across regions. ICCAT is currently the only major RFMO with management measures specific to shortfin mako sharks, and recently adopted a two-year retention ban for the species in the North Atlantic. The conservation benefit of this measure is uncertain, however, as it does not require fishermen to modify gear or fishing behavior that would reduce at-vessel or post-release mortality of the species. Further, management of the species after this two-year ban expires is unknown. Some of the top shortfin mako shark-catching nations in this region (Spain, Portugal, and Morocco) have very recently announced unilateral retention prohibitions for North Atlantic shortfin mako shark, although the effect these bans will have on the species is again unknown, even if well implemented. Although projections carried out in 2019 by ICCAT's SCRS indicate that the North Atlantic stock will continue declining until around 2035 regardless of fishing mortality, the effect on stock status beyond this varies greatly with fishing mortality levels. Beyond the North Atlantic and North Pacific (where fishing data is also considered robust), fishing harvest and, especially, at-vessel and post-release mortality data are less thoroughly documented, introducing considerable uncertainty in projections of fishery impacts past a few decades.

After considering the best available information on the shortfin mako shark's life history, projected abundance trends, and current and future management measures and fishing behaviors, the Team concluded that a biologically reasonable foreseeable future timeframe would be 25 years, or one generation length, for the shortfin mako shark. As the main threats to the species are overutilization in commercial fisheries and the inadequacy of existing regulatory mechanisms, this timeframe would allow for reliable predictions regarding the likely impact of these threats on the future biological status of the species.

Methods

Demographic Risk Analysis

The Team reviewed all relevant biological and commercial information for the species, including: current abundance of the species in relation to historical abundance, and trends in abundance based on indices such as catch statistics; the species' growth rate and productivity in relation to other species and the effect on population growth rate; its spatial and temporal distribution; possible threats to genetic integrity; and natural and human-influenced factors that cause variability in survival and abundance. Each ERA Team member then assigned a risk score to each of the four Viable Population (VP) factors (abundance, productivity, spatial distribution, and diversity). Risks for each VP factor were ranked on a scale of 0 (unknown risk) to 3 (high risk). Below are the definitions that the Team used for each ranking:

> 0 = Unknown: The current level of information is either unavailable or unknown for this demographic factor, such that the contribution of this factor to the extinction risk of the species cannot be determined.
>
> 1 = Low risk: It is unlikely that the particular factor directly contributes or will contribute significantly to the species' risk of extinction currently or in the foreseeable future.
>
> 2 = Moderate risk: It is likely that the particular factor directly contributes or will

contribute significantly to the species' risk of extinction in the foreseeable future, but does not in itself constitute a danger of extinction currently.

3 = High risk: It is highly likely that the particular factor directly contributes or will contribute significantly to the species' risk of extinction currently.

Team members were given a template to fill out and asked to rank each factor's contribution to extinction risk. After scores were provided to the team lead, they were anonymized and shared with the entire team, who then discussed the range of perspectives for each of the demographic risks, and the supporting data upon which they were based. Team members were then given the opportunity to revise scores after the discussion, if they felt their initial analysis had missed any pertinent data discussed in the group setting. The scores were reviewed by the ERA Team and considered in making the overall risk determination, which is presented at the end of this section. Although this process helps to integrate and summarize a large amount of information, there is no simple way to translate the risk matrix scores directly into a determination of overall extinction risk. Thus, it should be emphasized that this exercise was simply used as a tool to help the ERA Team members organize the information and assist in their thought processes for determining overall risk of extinction for the species. Other descriptive statistics, such as mean, variance, and standard deviation, were not calculated as the ERA Team felt these metrics would add artificial precision or accuracy to the results.

Table 6. Template for the demographic risk analysis scoring used in ERA team deliberations. The matrix is divided into four sections that correspond to the parameters for assessing population viability (McElhany *et al*. 2000).

Viable Population Factor	**Contribution to Species' Risk of Extinction**	**Justification**
ABUNDANCE		
PRODUCTIVITY		
SPATIAL DISTRIBUTION		
DIVERSITY		

Threats Assessment

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

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

Similar to the demographic risk analysis, the ERA Team members were given a template to fill out and asked to rank each threat in terms of its contribution to the extinction risk of the species. Specific threats falling within the five categories provided in Section 4(a)(1) were identified from sources included in this Status Review Report, and included as line items in the scoring template (Table 7). Below are the definitions that the Team used for each ranking:

> 0 = Unknown: The current level of information is either unavailable or unknown for this particular threat, such that the contribution of this threat to the extinction risk of the species cannot be determined.
>
> 1 = Low: It is unlikely that this threat is significantly contributing or will contribute to the species' risk of extinction currently or in the foreseeable future.
>
> 2 = Moderate: It is likely that this threat will contribute significantly to the species' risk of extinction in the foreseeable future, but does not in itself constitute a danger of extinction currently.
>
> 3 = High: It is highly likely that this threat contributes significantly to the species' risk of extinction currently.

After scores were provided and anonymized, the Team discussed the range of perspectives for each of the threats and the supporting data upon which they were based. Team members were then given the opportunity to revise scores after the discussion, if they felt their initial analysis had missed any pertinent data discussed in the group setting. The scores were then reviewed by the ERA Team and considered in making the overall risk determination that is presented at the end of this section. Again, it should be emphasized that this exercise was used simply as a tool to help the ERA Team members organize the information and assist in their thought processes for determining the overall risk of extinction for the shortfin mako shark.

Table 7. Template for the threats analysis scoring used in ERA team deliberations.

4(a)(1) Factor	Threat	Contribution to Species' Risk of Extinction	Interaction with other threats or demographic factors (list)?	Justification
Habitat destruction, modification, or curtailment	*Habitat destruction, modification, or curtailment*			
Overutilization	*Commercial and artisanal fisheries*			
Overutilization	*Recreational fisheries*			

4(a)(1) Factor	Threat	Contribution to Species' Risk of Extinction	Interaction with other threats or demographic factors (list)?	Justification
Overutilization	*Trade*			
Disease or Predation	*Disease*			
Disease or Predation	*Predation*			
Inadequacy of existing regulatory mechanisms	*Inadequacy of existing regulatory mechanisms*			
Other natural or manmade factors affecting the species' continued existence	*Pollutants and environmental contaminants*			
Other natural or manmade factors affecting the species' continued existence	*Climate change*			
Other natural or manmade factors affecting the species' continued existence	*Bather protection and shark control*			

Overall Extinction Risk

Guided by the results from the demographics risk analyses as well as the threats assessments, the ERA Team members used their informed professional judgment to make an overall extinction risk determination for the species. For this analysis, the ERA Team used three levels of extinction risk as defined in the NMFS Guidance on Responding to Petitions and Conducting

Status Reviews under the Endangered Species Act (updated February 1, 2021):

> 1 = Low risk: A species, subspecies, or DPS is at low risk of extinction if it is not at moderate or high level of extinction risk (see "Moderate risk" and "High risk" below). A species, subspecies, or DPS may be at low risk of extinction if it is not facing threats that result in declining trends in abundance, productivity, spatial structure, or diversity. A species, subspecies, or DPS at low risk of extinction is likely to show stable or increasing trends in abundance and productivity with connected, diverse populations.
>
> 2 = Moderate risk: A species, subspecies, or DPS is at moderate risk of extinction if it is on a trajectory that puts it at a high level of extinction risk in the foreseeable future (see description of "High risk" below). A species, subspecies, or DPS may be at moderate risk of extinction due to current and/or projected threats or declining trends in abundance, productivity, spatial structure, or diversity. The appropriate time horizon for evaluating whether a species, subspecies, or DPS is more likely than not to be at high risk in the foreseeable future depends on various case- and species-specific factors.
>
> 3 = High risk: A species, subspecies, or DPS with a high risk of extinction is at or near a level of abundance, productivity, spatial structure, and/or diversity that places its continued persistence in question. The demographics of a species, subspecies, or DPS at such a high level of risk may be highly uncertain and strongly influenced by stochastic or depensatory processes. Similarly, a species, subspecies, or DPS may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create present and substantial demographic risks.

To allow individuals to express uncertainty in determining the overall level of extinction risk facing the shortfin mako shark, the ERA Team adopted the "likelihood point" (FEMAT) method (see Table 8 below for template). This approach has been used in previous status reviews (e.g., oceanic whitetip shark, Pacific salmon, southern resident killer whale, Pacific herring, and black abalone) to structure the Team's thinking and express levels of uncertainty in assigning threat risk categories. For this approach, each Team member distributed 10 'likelihood points' among the three extinction risk levels. After scores were provided and anonymized, the Team discussed the range of perspectives for the species and the supporting data on which scores were based, and was given the opportunity to revise scores if desired after the discussion.

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

Table 8. Template for overall extinction risk scoring used in ERA Team deliberations.

Species is at low risk	Species is at moderate risk	Species is at high risk	Total
			10

ERA Team's Extinction Risk Results and Conclusion for Shortfin Mako Shark

Evaluation of Demographic Risks

Of the four VP factors evaluated by the ERA Team, we identified productivity as the greatest contributor to the species' extinction risk. The Team also expressed some concern with regard to the abundance factor, and found both spatial distribution and diversity to be of little concern with regard to the shortfin mako shark's extinction risk. Below is a brief summary of the rationale for the Team's conclusions regarding demographic risks to the shortfin mako shark.

Abundance

The ERA Team assessed available abundance and trends information by region, including formal stock assessments, preliminary stock assessments using data-limited assessment methods, and standardized CPUE trends. There are no global abundance estimates available; however, using the formal stock assessments available for the North Atlantic and North Pacific, current abundance has been estimated at one million and eight million individuals, respectively (FAO 2019). Using the regional rates of change weighted by an area-based estimate of the size of each region as a proportion of the species' global distribution, the IUCN red list assessment estimated global decline at 46.6% over three generation lengths (Rigby *et al*. 2019). Historical declines of varying degrees are evident across all oceans, though current trends are mixed.

The most recent stock assessment for shortfin mako shark in the North Atlantic indicates a combined 90% probability that the stock is in an overfished state and is experiencing overfishing (ICCAT 2017). The age-structured stock assessment model estimates historical declines in spawning stock fecundity from 1950 (unfished condition) to 2015 at 50%, and recent declines (from 2006–2015) at 32% (ICCAT 2017, FAO 2019). All nine assessment model runs were consistent, and together indicated that shortfin mako sharks in the North Atlantic have experienced historical declines in total biomass of 47–60%, and recent declines in total biomass of 23–32% (ICCAT 2017, FAO 2019). The 2019 update to the stock assessment projects that even with a zero TAC, the North Atlantic stock will be rebuilt and not experiencing overfishing by 2045 with a 53% probability, and that regardless of TAC (in this case, TAC refers to all sources of mortality and is not limited to landings), the stock will continue declining until 2035 (ICCAT 2019). Overall, the Team agreed that the findings from the stock assessment and projections were concerning. The Team discussed how to appropriately interpret the stock assessment's focus on being rebuilt ($SSF/SSF_{MSY} > 1$) and without overfishing ($F/F_{MSY} < 1$) in the context of assessing extinction risk. While recovery as defined by these criteria is likely to take decades, this does not indicate that the stock is at risk of becoming extirpated now or in the foreseeable future (25 years). Additionally, the Team weighed the potential reduction in fishing mortality (and associated effects on abundance) that may result from the recent two-year retention prohibition (ICCAT Rec. 21-09), which entered into force on June 17, 2022. As data for each fishing year is not reported until the following calendar year, the management effect of this measure will not be easily assessed until 2024 when the landings and discard data from 2023 can be analyzed. While this retention prohibition will likely reduce shortfin mako shark mortality to some degree, there is uncertainty concerning the effect of the measure and the future management of the species after the two-year time period. As noted above, the low productivity and slow population growth of shortfin mako shark may also mean that measurable impacts of this measure do not manifest for several years, when a new cohort enters the fishery.

The 2017 stock assessment for shortfin mako sharks in the South Atlantic indicated a high degree of uncertainty. The combined assessment models found a 19% probability that the population is overfished and is experiencing overfishing (ICCAT 2017). The authors conclude that despite high uncertainty, in recent years the South Atlantic stock may have been at, or already below, B_{MSY} and fishing mortality is likely exceeding F_{MSY} (ICCAT 2017). Projections for the stock were not completed in 2019 due to high uncertainty. The ERA Team agreed that some degree of population decline may be occurring, but was cautious about drawing conclusions due to the high degree of data uncertainty.

The most comprehensive information on trends for shortfin mako sharks in the North Pacific comes from the 2018 ISC Shark Working Group stock assessment, which found that the North Pacific stock was likely not in an overfished condition and was likely not experiencing overfishing between 1975 and 2016 (42 years) (ISC Shark Working Group 2018). This assessment determined that the abundance of mature females was 860,200 in 2016, which was estimated to be 36% higher than the number of mature females at MSY (ISC Shark Working Group 2018). Future projections indicated that spawning abundance is expected to increase gradually over a 10-year period (2017–2026) if fishing mortality remains constant or is moderately decreased relative to 2013–2015 levels (ISC Shark Working Group 2018). Using results from the ISC stock assessment, historical decline in abundance (1975–1985 to 2006–2016) is estimated at 16.4%, and a recent increase (2006–2016) is estimated at 1.8% (CITES 2019). While the IUCN used the ISC assessment to model the average trend in the North Pacific stock over three generation lengths (72 years) resulting in a median decline of 36.5% (Rigby *et al.* 2019), Kai (2021a) found a median decline of the population trajectory of 12.1% over three generation lengths with low uncertainty. The ERA Team concluded that despite evidence of historical decline, shortfin mako sharks in the North Pacific are neither overfished nor experiencing overfishing, and the population is likely stable and potentially increasing.

Although a stock assessment is not available for shortfin mako sharks in the South Pacific, available information indicates that the population is increasing. Standardized CPUEs for the mako shark complex (i.e., both shortfin and longfin mako shark) show a relatively stable trend in relative abundance, with low points in 2002 and 2014, though the 2014 point is based on relatively few data and should be interpreted with caution (Rice *et al.* 2015). In New Zealand waters, logbook and observer data from 1995–2013 analyzed by Francis *et al.* (2014) indicate that shortfin mako sharks were not declining, and may be increasing, over the period from 2005–2013. More recently, an analysis by the FAO Expert Advisory Panel for the Assessment of CITES Proposals did not find statistically significant trend fits for two of the data series; those that were significant were increasing (Japanese South 2006–2015, Domestic North 2006–2013, and Observer Data 2004–2013) (FAO 2019). Trend analysis of modeled biomass indicates a median increase of 35.2% over three generation lengths (Rigby *et al.* 2019). In sum, the ERA Team agreed that the best available data for shortfin mako sharks in the South Pacific indicate an increasing population trend.

Finally, in the Indian Ocean, preliminary stock assessments using data-limited assessment methods are available for shortfin mako sharks and indicate that the stock is experiencing overfishing, but is not yet overfished (Brunel *et al*. 2018; Bonhommeau *et al*. 2020). Both preliminary assessments are considered highly uncertain due to limitations in catch data. Using the results of the Schaefer model from Brunel *et al.* (2018), historical decline (1970–1980 to 2005–2015) was estimated at 26%, recent decline (2005 to 2015) was estimated at 18.8%, and future 10-year decline was projected at 41.6% from the historic baseline (1970–1980 to 2015–2025) (CITES 2019). A trend analysis for modeled biomass in the Indian Ocean using Brunel *et al.*'s assessment indicates a median decline of 47.9% over three generation lengths (Rigby *et al.* 2019). Recent increases in CPUE trends are indicated in Spanish, Portuguese, and Taiwanese longline fleets (Coelho *et al*. 2020b; Ramos-Cartelle *et al*. 2020; Wu *et al.* 2021), though it should be noted that these datasets were included in the assessment by Bonhommeau *et al.* (2020). Overall, the ERA Team felt that the data support some level of historical population decline and indicate that shortfin mako sharks are currently experiencing overfishing in this region. The Team agreed that the available data were highly uncertain and incomplete. However, the majority of the group did not conclude that the species is at risk of extirpation in this region at present or within the foreseeable future.

The ERA Team considered the risk associated with abundance of the global species using the information summarized above. Reported landings represent a substantial underestimate of mortality resulting from fisheries interactions, and therefore there is some level of uncertainty in all available stock assessments and abundance indices, particularly so in the South Atlantic and Indian Oceans. However, stock assessments in the North Atlantic and North Pacific were considered robust by the ERA Team. Some degree of historical decline is indicated in all ocean basins, and population declines are ongoing in the North Atlantic. In the South Pacific, there are no available stock assessments, so the positive trends indicated here are based on available studies with limited geographic scope. Overall, there is no indication that global abundance has declined so low that reproductive success of the species has declined or inbreeding has resulted, nor is there evidence of other depensatory processes associated with small populations. All Team members agreed that this information indicates that the species' abundance does not currently put it at risk of extinction. Several Team members were of the opinion that declining abundance trends would likely contribute to the species' risk of extinction in the foreseeable future; however, the majority of Team members felt that global abundance is unlikely to contribute significantly to the species' risk of extinction currently or in the foreseeable future.

Productivity

The shortfin mako shark exhibits high longevity (at least 28–32 years; Natanson *et al.* 2006; Dono *et al.* 2015), slow growth rates (K<0.1; see Table 1), late age at maturity (6–9 for males and 15–21 years for females; Natanson *et al*. 2006; Semba *et al.* 2009), long gestation (9–25 months; Mollet *et al.* 2000; Duffy and Francis 2001; Joung and Hsu 2005; Semba *et al.* 2011), and long reproductive cycles (3 years; Mollet *et al.* 2000; Joung and Hsu 2005). Cortés (2016) determined that the intrinsic rate of population increase (r_{max}) for Atlantic shortfin mako sharks ranges from 0.036–0.134 yr^{-1}. This was among the lowest values calculated from 65 populations and species of sharks. The Team therefore concluded that the productivity of the species is quite low. The species also exhibits low natural mortality (0.075–0.244 yr^{-1}; Cortés 2016) and a long generation time (25 years; Cortés *et al.* 2015). Together, the species' life history characteristics indicate that it is highly susceptible to depletion from exploitation or other high-intensity sources of mortality, and will recover slowly from declines brought on by such stressors. The ERA Team was largely in agreement that although this factor doesn't constitute a risk of extinction for the species currently, this factor would likely contribute significantly to the species’ risk of extinction in the foreseeable future, especially as exacerbated by impacts of fishing mortality and resulting declines in abundance.

Spatial distribution

Shortfin mako sharks are globally distributed across all temperate and tropical ocean waters and utilize numerous habitat types including open ocean, continental shelf, shelf edge, and shelf slope habitats (Rogers *et al.* 2015b; Corrigan *et al.* 2018; Francis *et al.* 2019; Rigby *et al.* 2019; Santos *et al.* 2020; Gibson *et al.* 2021). This highly migratory species is capable of undertaking movements of several thousand kilometers (Kohler and Turner 2019; Francis *et al.* 2019) and is able to make vertical migrations in the water column to several hundred meters depth (Santos *et al.* 2021). As a red muscle endotherm, the species is able to regulate its body temperature, allowing it to tolerate a broad range of water temperatures (Watanabe *et al.* 2015). Connectivity among ocean basins has been demonstrated by several genetic studies. Taken together, results of available genetic analyses suggest that female shortfin mako sharks exhibit fidelity to ocean basins, while males readily move across the world’s oceans and mate with females from various basins to produce a single population (Heist *et al.* 1996; Schrey and Heist 2003; Taguchi *et al.* 2011; Corrigan *et al*. 2018). The ERA Team unanimously agreed that, based on the information summarized above, this demographic factor is not likely to contribute significantly to the species’ risk of extinction now or in the foreseeable future.

Diversity

In our consideration of the degree to which diversity contributes to the extinction risk of the shortfin mako shark, the Team evaluated available information on genetic diversity as well as diversity of distribution and ecology. Available genetic studies do not indicate that the species has experienced a significant loss of diversity that would contribute to extinction risk. In fact, haplotype diversity has been found to be high in several studies: 0.755 by Heist *et al*. (1996), 0.92 by Taguchi *et al*. (2011), and 0.894 by Corrigan *et al*. (2018). Nucleotide diversity has been found to be lower: 0.347 by Heist *et al*. (1996), 0.007 by Taguchi *et al*. (2011), and 0.004 by Corrigan *et al*. (2018). Genetic studies indicate a globally panmictic population, meaning that there is sufficient movement of shortfin mako sharks, and therefore gene flow, to reduce genetic differentiation among regions (Heist *et al*. 1996; Schrey and Heist 2003; Taguchi *et al*. 2011; Corrigan *et al*. 2018). We found no evidence that gene flow, migration, or dispersal has been reduced. The species occurs across a variety of habitats and regions (Rogers *et al.* 2015b; Rigby *et al.* 2019; Santos *et al.* 2020), and is able to consume a diversity of prey (Stillwell and Kohler 1982; Cortés 1999; Maia *et al.* 2006; Gorni *et al.* 2012); these characteristics protect against catastrophic events that may impact a certain region or prey species. For these reasons, the Team unanimously agreed that it is not likely that this factor significantly contributes to the species' risk of extinction now or in the foreseeable future.

Evaluation of ESA Section 4(a)(1) Factors

Of the five ESA Section 4(a)(1) factors, the group identified overutilization and inadequacy of existing regulatory mechanisms as most concerning in terms of their contribution to the species’ risk of extinction. The other factors, including habitat destruction, modification, or curtailment; disease and predation; and other natural or manmade factors affecting the species' continued existence, were not identified as contributing significantly to the species' risk of extinction now or in the foreseeable future. Below is a summary of the rationale for the ERA Team's conclusions regarding threats to the shortfin mako shark.

Habitat Destruction, Modification, or Curtailment
The shortfin mako shark is a highly migratory, pelagic species that spends time in a variety of open ocean and nearshore habitat types. The species is globally distributed from about 50°N (up to 60°N in the northeast Atlantic) to 50°S. While distribution is influenced by environmental variables including water temperature, prey distribution, and DO concentration, the shortfin mako shark is able to tolerate a broad thermal range and use a wide variety of prey resources. The Team agreed that because shortfin mako sharks have high adaptive capacity and do not rely on a single habitat or prey type, they are able to modify their distributional range to remain in an environment conducive to their physiological and ecological needs. Additionally, there is no evidence that range contractions have occurred, or that destruction or modification of their habitat on a global scale has occurred to such a point that it has impacted the status of the species. Therefore, the Team concluded that the loss or degradation of habitat are not likely to be contributing significantly to the extinction risk of the shortfin mako shark now or in the foreseeable future.

Overutilization
When considering the overutilization of the species, the Team evaluated the contribution of commercial and artisanal fisheries, recreational fisheries, and international trade to the extinction risk of the shortfin mako shark.

While the shortfin mako shark is generally not targeted in commercial fisheries, it is highly susceptible to being incidentally caught by PLL fleets in all regions. When bycaught, the species is often opportunistically retained due to the high value of its meat and fins. The species is known to experience moderate levels of at-vessel mortality (roughly 23–36%; Bowlby *et al.* 2021, Hutchinson *et al*. 2021), and if released alive, post-release mortality rates of up to 36% have been reported (Bowlby *et al.* 2021). Therefore, even if retention of the species is prohibited, the Team recognized the potential for a significant proportion of shortfin mako sharks hooked by commercial PLL vessels to die during or after fishing, depending on gear, handling, and other factors.

In the North Atlantic, fisheries mortality has led to serious population declines, and the stock is currently both overfished and experiencing overfishing. ICCAT Recommendations 17-08 and 19-06 have required live shortfin mako sharks to be released except in very limited circumstances since 2017, though reported landings are still high (1,709 t in 2020, inclusive of dead discards (SCRS 2021)). The Team discussed whether the newly adopted retention prohibition (Rec. 21-09) would be adequate to reduce fishing mortality and allow the stock to begin to rebuild, given that at-vessel mortality will not be addressed by this measure. Given the status of the stock, the continued high level of fishing effort, high catches, and low productivity, we concluded that overutilization of shortfin mako shark is occurring in the North Atlantic Ocean.

Available data do not indicate that shortfin mako sharks in other regions are subject to such a level of overutilization with high certainty. In the South Atlantic, fishing effort has been increasing since the 1970s, and the stock has an overall 19% probability of being overfished with overfishing occurring. Data quality in the South Atlantic is poor, and the stock assessment in this region has high uncertainty. Therefore, given the high fishing effort and low productivity of the species, we conclude that overutilization may be occurring in the South Atlantic. In the Western and Central Pacific, although historical catch data are lacking, reporting has improved in recent years with required reporting of catches of key shark species. Interactions with shortfin mako sharks commonly occur in PLL fleets in both the WCPO and the EPO. The latest stock assessment for shortfin mako shark in the North Pacific indicates that the stock is not overfished and overfishing is not occurring. CPUE trends available from a variety of fisheries in the South Pacific indicate population increases, although a stock assessment is not available for this region. Despite this lack of a cohesive population model, all available data indicate flat or increasing abundance trends. Based on available data, the Team concluded that overutilization is not demonstrably occurring in any region of the Pacific Ocean, despite variation in the certainty associated with estimates among regions. In the Indian Ocean, available preliminary stock assessments indicate that overfishing is occurring but the stock is not yet overfished. Underreporting of catch is suspected to be continuing in this region, and we therefore had low certainty that these assessments accurately reflect the status of the species here. However, recent CPUE trends in certain fleets indicate increasing trends in this region. The Team concluded that, while overutilization in commercial fisheries is likely impacting shortfin mako sharks in the Indian Ocean, the severity of impact is highly uncertain.

Recreational fishermen target shortfin mako sharks in certain regions due to the high quality of their meat, and the strong fight experienced by the angler. In the U.S. Atlantic, recreational landings of shortfin mako sharks have been significantly reduced after management measures implemented in 2018 and 2019. In the Pacific, both U.S. and Australian recreational fisheries for the species are largely catch-and-release. Further, population-level impacts of recreational fishing at a global scale are unlikely to occur due to vessel limitations that prevent the vast majority of the "fleet" from accessing the whole of the species’ habitat. For these reasons, the Team unanimously agreed that recreational fishing is unlikely to contribute to the species' risk of extinction now or in the foreseeable future.

Shortfin mako sharks are commonly retained for their highly valued meat when incidentally caught, with fins often kept as a by-product (Fowler *et al*. 2021). Recent studies (Fields *et al*. 2018, Cardeñosa *et al*. 2020) continue to show the prevalence of shortfin mako shark fins in the markets of Hong Kong and China. Several Team members cited the estimation by Clarke *et al*. (2006b) that 300,000–1,000,000 shortfin mako sharks may be utilized in the global shark fin trade each year, totaling between 20,000 and 55,000 t in biomass. Although this is not a recent study, and recent regulatory mechanisms may reduce pressure from the fin trade on this species, this estimate was still cause for concern given the productivity of the species. Considering the recent declines in the fin trade and increases in the meat trade, the Team generally agreed that the preference for shortfin mako shark meat (in addition to fins) presents a concern for overexploitation of the species.

Although catch and mortality data are underreported globally, with very low confidence in both the Indian and South Atlantic Oceans, the Team recognized the ESA’s requirement that we consider the best available scientific and commercial data available, summarized above and in this Status Review Report. The majority of Team members concluded that overutilization of the shortfin mako shark in commercial fisheries and trade will likely contribute to the extinction risk of the species in the foreseeable future, especially when management measures are inadequate. Two Team members did not conclude that overutilization was likely to contribute to the extinction risk of the species rangewide now or in the foreseeable future because despite the evident effects of overfishing in the North Atlantic, they did not find that the level of threat would imperil the species at a global level.

Disease or predation
Shortfin mako sharks are known to host a number of parasites, but the Team found no evidence that disease is impacting the status of the species, nor any indication that disease may influence the species' status in the foreseeable future. The species is a large apex predator with few natural predators. Given current population estimates and distribution, impacts from predation on a global scale are not likely to affect the species' extinction risk. While climate change may cause changes to the marine food web (and therefore, potentially influence predation on juvenile shortfin mako sharks) over the next several decades, at this time there is no way for the Team to accurately predict how these changes may impact the species. Therefore, the Team concluded that neither disease nor predation are factors that will likely contribute significantly to the species' extinction risk now or in the foreseeable future.

Inadequacy of existing regulatory mechanisms
While evaluating whether existing regulatory mechanisms are inadequate for addressing threats to the shortfin mako shark, the Team discussed the need for management across the species' broad geographic range, and at many scales (domestic, regional, international) due to the highly migratory nature of the species. The Team concluded that U.S. domestic regulatory measures were adequate for management of the species in U.S. waters, as evidenced by the reduction in U.S. shortfin mako shark catch (commercial and recreational) in the Atlantic following the 2017 ICCAT stock assessment, stable population status in the North Pacific, and strong prohibitions on shark finning for those subject to U.S. jurisdiction. Despite adequate management in U.S. waters, the Team concluded that regulatory measures to address threats of incidental catch and trade across the species' range may not be adequate in certain areas.

RFMOs that manage HMS play perhaps the most significant role in regulating catch and mortality of shortfin mako sharks in commercial fisheries worldwide. Of the four major RFMOs that manage shortfin mako sharks, only ICCAT has management measures specific to the species, while IATTC, WCPFC, and IOTC have general shark management measures. Based on ICCAT's 2017 stock assessment for the North Atlantic shortfin mako shark, which concluded a 90% probability of the stock being in an overfished state and experiencing overfishing, the Commission adopted Rec. 17-08, requiring CPCs to release North Atlantic shortfin mako sharks in a manner that caused the least harm. Retention of dead North Atlantic shortfin mako sharks remained acceptable in many cases, and harvest of live individuals was only permitted under very limited circumstances. In 2019, ICCAT adopted Rec. 19-06 in response to pessimistic projections for North Atlantic shortfin mako shark. This measure extended the provisions of Rec. 17-08 until in 2021, Commission members reached consensus on Rec. 21-09, which put into place a two-year retention ban for the species and established a process to evaluate if and when retention may be allowed in the future in line with scientific advice. This measure entered into force on June 17, 2022 and the first year that its effects can be assessed will be 2024. Additionally, the low productivity of the shortfin mako shark means that the biological response to the measure will likely not be detectable for several years, despite assessment efforts. Therefore, at this time it is not possible to assess the adequacy of this measure to address the ongoing threat of overfishing in the North Atlantic. The Team did discuss some concerns and uncertainties with regard to Rec. 21-09. The measure does not require changes to fishing behavior or gear, and therefore will not address at-vessel or post-release mortality of incidentally caught shortfin mako sharks. Based on recent reported landings allowed under Rec. 19-06 indicating high numbers of shortfin mako sharks dead at-haulback, it is unclear if Rec. 21-09 will reduce mortality to a point that will allow the North Atlantic stock to rebuild. It is also unclear what measures will be in place after the two-year period ends.

Regarding the general shark conservation measures in place for WCPFC, IOTC and IATTC, the Team had concerns regarding low compliance with reporting requirements, especially in the Indian Ocean and South Atlantic Ocean. The lack of reliable catch data in these regions, as well as a lack of formal stock assessments in the Indian Ocean and South Pacific Ocean, make it difficult to assess whether regulatory mechanisms in these areas are adequate to address threats of overutilization to the species.

As the shortfin mako shark is highly valued for both its meat and fins, regulatory mechanisms ensuring that trade does not lead to overexploitation are critical to the species' survival. Many individual countries and RFMOs have implemented measures to curb the practice of shark finning and the sale of or trade in shark products over the last decade, and the shortfin mako shark was listed on Appendix II of CITES as of November 2019. Although this is a positive step to ensure the sustainability of the trade, it is difficult to assess the effectiveness of this measure over such a short period of time. The Team did note that compliance with reporting and permitting requirements for other CITES-listed shark species has been low in recent years (Cardeñosa *et al.* 2018). While the fin trade has declined, recent increases in the trade of shark meat signify the continued need for regulatory mechanisms to address this threat.

Overall, while the Team recognized the strong regulatory measures in place for shortfin mako sharks in U.S. domestic waters, retention bans that have been put in place for the species in several countries and recently by ICCAT, and increased global efforts to end shark finning, the Team expressed concern about the adequacy of existing regulatory mechanisms to monitor and manage mortality from fisheries interactions on the high seas and the international meat and fin trade. The Team was split on how this factor contributes to the extinction risk of the species, with just over half of the Team concluding that the inadequacy of existing regulatory mechanisms will likely contribute significantly to the species' risk of extinction in the foreseeable future, but is not likely contributing to the species' extinction risk currently. The remaining members found it unlikely that this factor is significantly contributing to the species' extinction risk now or will contribute to the species' risk of extinction in the foreseeable future.

Other natural or manmade factors affecting the species' continued existence
Under this factor, the Team considered potential threats posed by pollutants and environmental contaminants, climate change, and shark control/bather protection efforts.

As high-level predators, shortfin mako sharks bioaccumulate and biomagnify heavy metals and organic contaminants; however, the impacts of these pollutants on the physiology and productivity on the species (and sharks in general) are poorly studied. The Team found no direct evidence that individuals or populations are adversely affected to a degree that would impact the status of the species. Therefore, the Team unanimously agreed that pollutants and environmental contaminants are unlikely to be contributing significantly to the species' extinction risk now or in the foreseeable future.

When considering the potential threat of climate change to the shortfin mako shark, the Team considered projected impacts to the marine environment (including warming waters, acidification, and shifting prey distributions) and the species' potential responses to these impacts. While long-term climate projections (through 2100) are available and considered reliable, the Team found that the species' responses to these projected environmental changes could not be predicted with any certainty. While some studies project that the species may be subject to significant habitat loss and behavioral and fitness impairments by 2100, their broad prey base and thermal tolerance, among other factors, may give them a high adaptive capacity. The majority of the Team considered it unlikely that climate change is currently contributing to the species' extinction risk or will contribute to the species' extinction risk in the foreseeable future. Several Team members concluded that the contribution of climate change to the extinction risk of the species in the foreseeable future could not be determined due to the lack of available information on the species' response to climate change.

A small number of shortfin mako sharks experience mortality as a result of shark control/bather protection programs in South Africa and Australia, which aim to reduce the risk of shark attacks on humans near public beaches. Due to the localized geographic extent of the programs and the very low number of individuals impacted, the Team did not find that shark control programs are likely to contribute significantly to the extinction risk of the species now, and found it unlikely that these programs would contribute significantly to extinction risk in the foreseeable future.

In sum, the Team did not identify any other natural or manmade factors affecting the continued existence of the shortfin mako shark.

Evaluation of Overall Extinction Risk

Guided by the results and discussions from the demographic risk analysis and ESA Section 4(a)(1) factor assessment, we analyzed the overall risk of extinction to the global shortfin mako shark population. In this process, the ERA Team considered the best available scientific and commercial information regarding the shortfin mako shark from all regions of the species' global range and analyzed the collective condition of these populations to assess the species' global extinction risk. The following table gives the results of our likelihood point distributions. Likelihood points were tallied and the totals (n = 90) are presented for the overall level of extinction risk.

Table 9. Results of the ERA Team's overall extinction risk analysis.

	Species is at low risk	Species is at moderate risk	Species is at high risk
Number of likelihood points	60	29	1

The ERA Team was fairly confident in determining the overall extinction risk of the species, placing two-thirds of its likelihood points in the low risk category. Some uncertainty is reflected in the allocation of points to the moderate risk category, largely due to poor reporting of catches and low confidence in abundance and trends in certain regions.

The Team acknowledged that the shortfin mako shark has experienced historical declines of varying degrees in all ocean basins, mainly due to interactions with commercial fishing vessels, however, current abundance trends are mixed. A robust recent stock assessment in the North Pacific indicates that the species is stable and potentially increasing there, and population increases are also indicated in the South Pacific. The recent stock assessment in the North Atlantic, which the Team also considered highly reliable, indicates ongoing declines that will continue into the foreseeable future. However, the Team did not conclude that this region is at risk of extirpation based on available projections carried out by ICCAT's SCRS, information on current fisheries mortality, and predictions about future management and levels of fisheries mortality. The South Atlantic may also have a declining population trend, but this is highly uncertain. Fisheries mortality remains high in the region. In the Indian Ocean, preliminary stock assessments indicate that the shortfin mako shark population is experiencing overfishing, although compliance with reporting requirements is quite low in this region, so the Team felt that the extent of the species' decline in this region is highly uncertain and potentially underestimated. Even with continued declines in the North Atlantic and highly uncertain status in the South Atlantic and Indian Oceans, the stable and potentially increasing population status in the Pacific Ocean, a major segment of the global population, led the majority of the Team to conclude that abundance would not contribute significantly to the extinction risk of the species now or in the foreseeable future. The Team also concluded that the shortfin mako shark's high genetic and ecological diversity, connectivity between populations, and wide spatial distribution reduce the species' extinction risk by providing resilience in the face of stochastic events and threats concentrated in certain regions. The Team did, however, find the low productivity of the species to contribute significantly to the species' risk of extinction in the foreseeable future as the species is highly susceptible to depletion from exploitation, and will recover slowly from such declines.

Overutilization in commercial fisheries and inadequate regulatory mechanisms to manage these fisheries are the main drivers of observed population declines. While regulatory mechanisms have recently been adopted to prohibit retention of the species in the North Atlantic and to ensure the sustainability of the international trade in shortfin mako shark products, it is too soon to accurately assess the adequacy of these measures to address overutilization. The Team did consider the lack of compliance with reporting requirements in the Indian Ocean and South Atlantic Ocean concerning for the species, especially considering the high value of the species in the meat and fin trade. The low confidence in catch data also made it difficult for the Team to assess whether regulatory mechanisms are inadequate to address the threat of overutilization in these regions.

Overall, the Team concluded that the species is not at high or moderate risk of extinction based on the following: (1) the high adaptability of the species based on its use of multiple habitat types, tolerance of a wide range of water temperatures, and generalist diet; (2) the existence of genetically and ecologically diverse, sufficiently well-connected populations; (3) the species' wide spatial distribution with no indication of range contractions or extirpations in any region, even in areas where there is heavy bycatch mortality and utilization of the species' high-value fins and meat; (4) the stable and potentially increasing population trend indicated in the Pacific Ocean, a major segment of the species' range; (5) abundance estimates of one million and eight million individuals in the North Atlantic and North Pacific, respectively; and (6) no indication that the species is experiencing depensatory processes due to low abundance. Based on all of the foregoing information, which represents the best scientific and commercial data available regarding current demographic risks and threats to the species, the ERA Team concluded that the shortfin currently has a low risk of extinction rangewide.

5.3 Significant Portion of its Range Analysis

Under the ESA and our implementing regulations, a species may warrant listing if it is in danger of extinction or likely to become so within the foreseeable future throughout all or a significant portion of its range. Having determined that the shortfin mako shark is not in danger of extinction or likely to become so within the foreseeable future throughout all of its range, we now consider whether the shortfin mako shark is in danger of extinction or likely to become so within the foreseeable future in a significant portion of its range—that is, whether there is any portion of the species' range for which it is true that both (1) the portion is significant and (2) the species, in that portion, is in danger of extinction or likely to become so within the foreseeable future. A joint USFWS-NMFS policy, finalized in 2014, provided the agencies' interpretation of this phrase ("SPR Policy," 79 FR 37578, July 1, 2014) and explains that, depending on the case, it might be more efficient for us to address the "significance" question or the "status" question first. Regardless of which question we choose to address first, if we reach a negative answer with respect to the first question, we do not need to evaluate the other question for that portion of the species' range. We chose to first address the question of the species' status in portions of its range.

Because there are infinite ways to divide up the species' range for an SPR analysis, we only considered portions that have a reasonable likelihood of being in danger of extinction or likely to become so within the foreseeable future, and biologically significant to the species. We considered whether the threats posed by overutilization and inadequate regulatory measures are geographically concentrated in any portion of the species' range at a biologically meaningful scale or whether these threats are having a greater impact on the status of the species in any portions relative to other portions. While the shortfin mako shark is subject to the threat of overutilization in commercial fisheries across its range, fishing mortality is substantially affecting the species in the North Atlantic Ocean, and is projected to continue impacting the species' status in this region over the foreseeable future. Based on highly uncertain data, the Indian Ocean population is considered to be experiencing overfishing but is not yet overfished, and recent CPUE increases have occurred in certain fleets. The South Atlantic population may be both overfished and experiencing overfishing and has highly uncertain stock status. Overutilization of the species does not appear to be occurring in the Pacific Ocean: the North Pacific population appears stable and is neither overfished nor experiencing overfishing based on robust data, and the South Pacific population has been indicated to be increasing with moderate certainty. Because the North Atlantic stock of shortfin mako shark is currently experiencing substantial negative impacts of overfishing and inadequate regulatory mechanisms and will continue to be impacted over the foreseeable future, the Team concluded that there was a reasonable likelihood that the species is at greater risk of extinction in this portion relative to the remainder of the range. The Team also agreed to consider whether the Atlantic Ocean as a whole is a portion that may be at risk of extinction now or in the foreseeable future based on indications of the species' decline in this portion, and to ensure a thorough analysis of the species' status in this ocean basin. While overutilization and inadequacy of existing regulatory mechanisms are impacting the species in the Indian Ocean, the ERA Team did not conclude that the species in the Indian Ocean has a reasonable likelihood of being in danger of extinction or likely to become so within the foreseeable future. The best available information for the species in this region, including two preliminary stock assessments, does not indicate that the species is overfished, and recent increasing CPUE trends are indicated in Spanish, Portuguese, and Taiwanese longline fleets. Although population declines are potentially underestimated due to poor reporting and data problems discussed previously, we do not find that the species is likely to be at risk of extirpation in this region over the foreseeable future based on the best available data. Therefore, the Indian Ocean was not assessed as a portion in the SPR analysis. The Team therefore went on to assess the extinction risk of two portions: the North Atlantic Ocean and the Atlantic Ocean as a whole.

To determine extinction risk in each portion, the Team used the likelihood point method as described in 5.2 Rangewide Extinction Risk Analysis. The Team evaluated the best available information on the demographic threats and ESA Section 4(a)(1) factors for shortfin mako sharks in each portion, beginning with the North Atlantic Ocean portion. The recent stock assessment conducted by ICCAT indicates that the North Atlantic shortfin mako shark has experienced declines in biomass of between 47–60% from 1950–2015, and predicts that the population will continue to decline until 2035 regardless of fishing mortality levels. Despite the species' low productivity and the relatively high level of fishing mortality impacting the species, the Team did not conclude that the current abundance of the species in the portion (estimated at one million individuals by FAO (2019)) and current threats it faces put it at a high risk of extinction. Many of the Team's points were placed in the moderate risk category for the North Atlantic Ocean portion, which is reflective of the species' low productivity, and the considerable uncertainty associated with potential effects of existing and future regulatory mechanisms aimed at rebuilding and ending overfishing of the North Atlantic shortfin mako stock over the next few decades. However, the ERA Team placed the majority of its likelihood points in the low risk category and concluded that the North Atlantic portion has a low extinction risk. Despite its continuing declining trend, the ERA Team did not feel that the rate of decline in the foreseeable future would be great enough to put the species in this portion at high risk of extinction in the foreseeable future.

When conducting the analysis of the status of the species in the Atlantic Ocean, the Team considered the role of the highly uncertain fishing and abundance data available for the South Atlantic. Despite uncertainty, it is likely that the species' abundance in this region is declining with ICCAT's SCRS finding a 19% probability that the stock is overfished and experiencing overfishing. The Team also considered the possible effects of the retention prohibition in the North Atlantic and the potential for a shift in fishing effort for the species to the South Atlantic. Overall, the Team did not find that the species in the Atlantic Ocean portion was at high risk of extinction based on available abundance and threats information. The Team did place many points in the moderate risk category to reflect the species' low productivity, and the uncertainty in data and future regulatory mechanisms. However, the ERA Team placed the majority of its points in the low risk category because the level of fishing mortality and population decline expected within the foreseeable future does not place the species in this portion at high or moderate extinction risk in this timeframe.

Thus, to summarize, the ERA Team did not find the shortfin mako shark to be in danger of extinction or likely to become so within the foreseeable future in either of these portions of its range. As a result, the ERA Team did not continue the analysis to evaluate whether either of these portions constitutes a significant portion of the shortfin mako shark's range.

5.4 Distinct Population Segments Analysis

Criteria for Identification of Distinct Population Segments

Under the ESA, a listing determination may address a "species," which is defined to also include subspecies and, for any vertebrate species, any DPS that interbreeds when mature (16 U.S.C. 1532(16)). The joint policy of the USFWS and NMFS provides guidelines for defining DPSs below the taxonomic level of species (61 FR 4722; February 7, 1996). The policy identifies two elements to consider in a decision regarding whether a population qualifies as a DPS: discreteness and significance of the population segment to the species.

Discreteness

A DPS may be considered discrete if it is markedly separate from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors, or if it is delimited by international governmental boundaries. Genetic differences between the population segments being considered may be used to evaluate discreteness.

Significance

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

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

Distinct Population Segment Analysis – ERA Team Results

The petition to list the shortfin mako shark requested that NMFS list the species throughout its range, or alternatively, as DPSs, should NMFS find that they exist. As part of the ERA team duties, we were asked to examine the best available data to determine whether DPSs may exist for this species. The petition did not provide information regarding potential DPSs of the shortfin mako shark. As previously noted, to meet the definition of a DPS, a population must be both discrete from other populations of the species and significant to the species as a whole (61 FR 4722; February 7, 1996).

To determine whether any discrete populations of shortfin mako sharks exist, we looked at available information on shortfin mako shark population structure, including tagging, tracking, and genetic studies. As discussed in 2.5 Population Structure and Genetics, although certain ocean currents and features may limit movement patterns between different regions, available genetic studies indicate a globally panmictic population with some genetic structuring among ocean basins.

Heist *et al.* (1996) investigated genetic population structure using restriction fragment length polymorphism analysis of maternally inherited mtDNA from shortfin mako sharks in the North Atlantic, South Atlantic, North Pacific, and South Pacific. The North Atlantic samples showed significant isolation from other regions ($p<0.001$), and differed from other regions by the relative lack of rare and unique haplotypes, and high abundance of a single haplotype (Heist *et al.* 1996). Reanalysis of the data found significant differentiation between the South Atlantic and North Pacific samples (Schrey and Heist 2003) in addition to isolation of the North Atlantic.

A microsatellite analysis of samples from the North Atlantic, South Atlantic (Brazil), North Pacific, South Pacific, and Atlantic and Indian coasts of South Africa found very weak evidence of population structure ($F_{ST} = 0.0014$, $P = 0.1292$; $R_{ST} = 0.0029$, $P = 0.019$) (Schrey and Heist 2003). These results were insufficient to reject the null hypothesis of a single genetic stock of shortfin mako shark, suggesting that there is sufficient movement of shortfin mako sharks, and therefore gene flow, to reduce genetic differentiation between regions (Schrey and Heist 2003). The authors note that their findings conflict with the significant genetic structure revealed through mtDNA analysis by Heist *et al.* (1996). They suggest that as mtDNA is maternally inherited and nuclear DNA is inherited from both parents, population structure shown by mtDNA data could indicate that female shortfin mako sharks exhibit limited dispersal and philopatry to parturition sites, while male dispersal allows for gene flow that would explain the results from the microsatellite data (Schrey and Heist 2003).

Taguchi *et al.* (2011) analyzed mtDNA samples from the North and South Pacific, North Atlantic, and Indian Oceans, finding evidence of significant differentiation between the North Atlantic and the Central North Pacific and Eastern South Pacific (pairwise $\Phi_{ST} = 0.2526$ and 0.3237, respectively). Interestingly, significant structure was found between the eastern Indian Ocean and the Pacific Ocean samples (pairwise Φ_{ST} values for Central North Pacific, Western South Pacific, Eastern South Pacific are 0.2748, 0.1401, and 0.3721, respectively), but not between the eastern Indian and the North Atlantic.

Corrigan *et al.* (2018) also found evidence of matrilineal structure from mtDNA data, while nuclear DNA data provide support for a globally panmictic population. Although there was no evidence of haplotype partitioning by region and most haplotypes were found across many (sometimes disparate) locations, Northern Hemisphere sampling locations were significantly differentiated from all other samples, suggesting reduced matrilineal gene flow across the equator (Corrigan *et al.* 2018). The only significant differentiation indicated by microsatellite data was between South Africa and southern Australia (pairwise $F_{ST} = 0.037$, $\Phi_{ST} = 0.043$) (Corrigan *et al.* 2018). Clustering analysis showed only minor differences in allele frequencies across regions, and little evidence of population structure (Corrigan *et al.* 2018). Overall, the authors conclude that although spatial partitioning exists, the shortfin mako shark is genetically homogenous at a large geographic scale.

Taken together, results of genetic analyses suggest that female shortfin mako sharks exhibit fidelity to ocean basins, possibly to utilize familiar pupping and rearing grounds, while males readily move across the world's oceans and mate with females from various basins (Heist *et al*. 1996; Schrey and Heist 2003; Taguchi *et al*. 2011; Corrigan *et al*. 2018). This finding does not support the existence of discrete population segments of shortfin mako sharks.

We also considered whether available tracking data support the existence of discrete population segments of shortfin mako shark. There is some evidence that certain ocean currents and features may limit movement patterns, including the Mid-Atlantic ridge separating the western and eastern North Atlantic, and the Gulf Stream separating the North Atlantic and the Gulf of Mexico/Caribbean Sea (see Figure 3) (Casey and Kohler 1992; Vaudo *et al.* 2017; Santos *et al.* 2020). However, conventional tagging data indicates that mixing does occur across these features (see Figure 4; Kohler and Turner 2019). In the Pacific, tagging data supports east-west mixing in the north and minimal east-west mixing in the south (see Figure 5; Sippel *et al.* 2016; Corrigan *et al.* 2018). Trans-equatorial movement may be uncommon based on some tagging studies, though tagged shortfin mako sharks have been recorded crossing the equator (Sippel *et al.* 2016; Corrigan *et al.* 2018; Santos *et al.* 2021). Therefore, we concluded that there do not appear to be major barriers to the species' dispersal that would result in marked separation between populations.

Overall, we did not find that the best available information supports the existence of discrete populations of shortfin mako shark. We therefore conclude that there are no population segments of the shortfin mako shark that would qualify as a DPS under the DPS policy.

Appendix 1

Current and relevant shark regulations by U.S. state and territory in the Atlantic and Pacific (Source: Adapted from Young *et al*. 2017).

U.S. Atlantic State or Territory	**Regulations**
Maine, New Hampshire	Although part of the Atlantic States Marine Fisheries Commission (ASMFC), both Maine and New Hampshire were granted *de minimis* status for the Interstate FMP for Atlantic Coastal Sharks (see further details below) that was adopted by the ASFMC in 2008 (ASFMC 2008). These states implement the following rules that uphold the goals and objectives of the FMP: require federal dealer permits for all dealers purchasing Coastal Sharks; prohibit the take or landings of prohibited species in the plan; close the fishery for porbeagle sharks when the NMFS quota has been harvest; prohibit the commercial harvest of porbeagle sharks in State waters; require that head, fins and tails remain attached to the carcass of all shark species, except smooth dogfish, through landing.
Massachusetts	Also a part of the ASMFC, and was granted *de minimis* status for the Interstate FMP for Atlantic Coastal Sharks. Granted an exemption from the possession limit for non-sandbar large coastal sharks and closures of the non-sandbar large coastal shark fisheries. As of 2014, it is unlawful to possess, sell, offer for sale, trade, or distribute a shark fin.

U.S. Atlantic State or Territory	Regulations
Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia	Anglers must abide by the Interstate FMP for Atlantic Coastal Sharks adopted by the ASMFC (ASFMC 2008). This FMP requires that all sharks harvested by commercial or recreational fishermen within state waters have the tail and fins attached naturally to the carcass. While there are no set quotas for the pelagic group, ASFMC opens and closes the fishery when NMFS opens and closes the corresponding federal fisheries. Sharks caught in the recreational fishery must have a fork length of at least 4.5 feet (54 inches) and they must be caught using a handline or rod and reel. Each recreational shore-angler is allowed a maximum harvest of one shark from the federal recreationally permitted species per calendar day. Recreational fishing vessels are allowed a maximum harvest of one shark from the federal recreationally permitted species per trip, regardless of the number of people on board the vessel. An annual recreational seasonal closure is imposed in state waters of Virginia, Maryland, Delaware, and New Jersey from May 15 through July 15 during which time fishermen are prohibited from possessing certain species, regardless of where the shark was caught. Fishermen who catch any of these species in federal waters may not transport them through the state waters of Virginia, Maryland, Delaware, and New Jersey during the seasonal closure. New York amended its Environmental Conservation Law to prohibit sharks (excluding spiny dogfish) from being taken for commercial or recreational purposes by baited hooking except with the use of non-stainless steel non-offset circle hooks. New York, Rhode Island, Maryland, New Jersey, and Delaware have shark fin laws that ban the possession, sale, offer for sale, trade, or distribution of shark fins. Laws in these states exempt spiny dogfish and smooth dogfish fins from the ban. Each state law also includes other exceptions including for education, research, and other situations.
North Carolina	Adopted the ASMFC Coastal Shark Interstate FMP. Additionally, the Director may impose restrictions for size, seasons, areas, quantity, etc. via proclamation. The longline in the shark fishery shall not exceed 500 yds or have more than 50 hooks. Requires reporting of all recreationally landed sharks through state administered HMS catch card program.
South Carolina	Adopted the ASMFC Coastal Shark Interstate FMP. Additionally, defers to federal regulations. Gillnets may not be used in the shark fishery in state waters.

U.S. Atlantic State or Territory	Regulations
Georgia	Adopted the ASMFC Coastal Shark Interstate FMP. Additionally, commercial and recreational regulations: 2 sharks/person or boat, whichever is less, with a minimum size of 48 inches FL (122 cm). It is unlawful to have in possession more than one shark greater than 84" TL (213 cm). All sharks must be landed with the head and fins intact. Sharks may not be landed in Georgia if harvested using gillnets.
Florida	Adopted the ASMFC Coastal Shark Interstate FMP. Additionally, commercial and recreational regulations: 1 shark/person per day bag limit, 2 sharks per vessel limit. Shortfin mako sharks have an 83 inch FL (211 cm) minimum size limit. Eight other harvestable species have no minimum size limit, and seven harvestable species have a 54 inch FL (137 cm) minimum size limit. 27 species of shark are prohibited. Gear requirements: hook and line only, must use non-offset non-stainless-steel circle hooks when targeting or harvesting sharks with live or dead natural bait. Harvest prohibited by or with the use of a treble hook or any other multiple hook (any hook with two or more points and a common shaft) in conjunction with live or dead natural bait As of 2020, it is unlawful to import, export, and sell separated shark fins, as well as to possess in or on the waters of this state a shark fin that has been separated from a shark or land a separated shark fin in this state.
Alabama	Recreational and commercial: bag limit – 1 shark/person/day with a minimum size of 54 inches FL (137 cm) or 30 inches dressed (76 cm). State waters close when federal season closes and no shark fishing on weekends, Memorial Day, Independence Day, or Labor Day. Restrictions on chumming and shore-based angling if creating unsafe bathing conditions. Regardless of open or closed season, gillnet fishermen targeting other fish may retain sharks with a dressed weight not exceeding 10% of total catch.
Louisiana	Recreational: bag limit 1 shark/person/day with a minimum size of 54” FL (137 cm). Commercial: 33 sharks/vessel/day limit and no minimum size. Commercial and recreational harvest of sharks prohibited from April 1st through June 30th. Fins must remain naturally attached to the carcass through off-loading. Owners/operators of vessels other than those taking sharks in compliance with state or federal commercial permits are restricted to no more than one shark from either the large coastal, small coastal, or pelagic group per vessel per trip within or without Louisiana waters.
Mississippi	Recreational: bag limit LCS/Pelagics 1 shark/person (possession limit) up to 3 sharks/vessel (possession limit) with a minimum size of 37” TL (94 cm). Finning is prohibited.

U.S. Atlantic State or Territory	**Regulations**
Texas	Commercial/recreational: bag limit – 1 shark/person/day; Commercial/recreational possession limit is twice the daily bag limit (i.e., 2 sharks/person/day). As of 2016, it is unlawful to possess, sell, and purchase shark fins or products derived from shark fins.
Illinois	As of 2013, it is unlawful to possess, sell, offer for sale, trade, or distribute a shark fin.
U.S. Virgin Islands	Federal regulations and federal permit requirements apply in Territorial waters.
Puerto Rico	Federal regulations and federal permit requirements apply in Territorial waters. It is unlawful to fish, possess, sell, or offer for sale nurse shark (*Ginglymostoma cirratum*).

U.S. Pacific State or Territory	**Regulations**
Alaska	Commercial harvest regulated by North Pacific Fishery Management Council (NPFMC). Recreational fishing for sharks is allowed with a limit of 5 spiny dogfish/person/day (no size limit) and one shark of any other species/person/day (no size limit). Harvest of non-dogfish sharks is limited to 2 sharks/person/year and reporting is required.
Washington	Commercial harvest of bottomfish by longline, purse seine, gill net, deep-water set net, and bottom trawl prohibited in greater Puget Sound. Commercial bottom trawling prohibited in state waters (3 NM) along the outer coast. Recreational angling for, retaining, and possessing sixgill, sevengill, and thresher sharks prohibited state-wide. Sixgill sharks may not be removed from the water. All other species of shark included in aggregate bottomfish limit, which varies by region from 0–15 fish/person/day. The sale, trade, or distribution of shark fins or derivative products was banned state-wide in 2011.
Oregon	Sharks are members of two targeted recreational harvest groups: spiny dogfish, leopard shark, and tope shark fall into the General Marine Species (GMS) category; all other sharks fall into the Offshore Pelagic Species (OPS) category. Bag limit varies by region for GMS but is 25 fish in aggregate/person/day for OPS. White, basking, megamouth, and oceanic whitetip sharks are prohibited and must be immediately released unharmed. The fins and tail must remain attached and disposed of with the carcass for all species except spiny dogfish. Possession, sale, offer for sale, trade, or distribution of shark fins is prohibited as of 2012.

U.S. Pacific State or Territory	Regulations
California	California's Shark Fin Prohibition law makes it unlawful to possess, sell, offer for sale, trade, or distribute a shark fin as of 2013. The law exempts licensed shark fishermen that land sharks in California from the possession ban. Includes an education and research exemption. Sharks may not be taken with drift gillnets of mesh size eight inches (20 cm) or greater except under a revocable permit issued by the California Department of Fish and Game.
Hawaii	It is unlawful to possess, sell, offer for sale, trade, or distribute shark fins as of 2010. Includes exemptions for education and research.
Nevada	As of 2018, it is unlawful to purchase, sell, offer for sale, or possess with intent to sell any item made with shark fins.
American Samoa	Prohibits the possession, delivery, carry, shipment, or transport of any shark species or shark body part as of 2012. Includes an exemption for research.
Guam	Bans the possession, sale, offer for sale, take, purchase, barter, transport, export, import, trade, or distribution of shark fins as of 2012. Includes exemptions for research and subsistence fishing.
Commonwealth of the Northern Mariana Islands	Bans the possession, sale, offer for sale, trade, or distribution of shark fins as of 2011. Includes exemptions for research and subsistence fishing.

Appendix 2

Summary of global shark finning regulations, excluding the United States (Source: Adapted from Young *et al*. 2017; https://www.hsi.org/wp-content/uploads/2019/06/2019-Shark-Fishing-and-Finning-Regulations.pdf).

Country	Date	Regulations on Shark Finning
Argentina	2009	Ban on shark finning.
Australia	Various	States and Territories govern their own waters. Central government regulates 'Commonwealth' or Federal waters, from 3 to 200 nautical miles offshore. Most States and Territories ban finning, and some require that sharks be landed with their fins naturally attached.
Belize	2012	Finning banned under Regulation OSP-05-11, adopted by Central American integration System (SICA)'s Fisheries and Aquaculture Sector Organization of the Central American Isthmus (OSPESCA). Applies to domestic and foreign vessels that catch and land sharks in SICA countries, and vessels in international waters flying the flag of a SICA member country.
Brazil	2012	Sharks must be landed with their fins naturally attached to their bodies.
Canada	1994, 2018	Finning in Canadian waters and by any Canadian licensed vessel fishing outside of the EEZ has been prohibited since 1994. In 2018, a 5% fin-to-carcass weight ratio measure was replaced with a requirement that fins must be naturally attached when landed.
Cape Verde	2005	Finning prohibited throughout the EEZ.
Chile	2011	Bans shark finning in Chilean waters. Sharks must be landed with fins naturally attached.
China	2019	Per China's 2019 IOTC Compliance Report (IOTC-2019-CoC16-IR03), under the Ministry of Agriculture and Rural Affairs of China's updated Official Notice on Tuna Management, it is prohibited to remove shark fins and discard the carcass. The fin-carcass ratio shall not exceed 5% before the first point of landing.
Colombia	2007	Sharks must be landed with fins naturally attached to their bodies.
Comoros	2015	Per 2019 IOTC Compliance Report (IOTC-2019-CoC16-CR04), shark finning has been banned since 2015.
Costa Rica	2006	Ban on shark finning.
Dominican Republic	2012	Finning banned under Regulation OSP-05-11, adopted under the SICA-OSPESCA framework.

Country	**Date**	**Regulations on Shark Finning**
El Salvador	2006	Shark finning is prohibited. Sharks must be landed with at least 25% of each fin still attached naturally. The sale or export of fins is prohibited without the corresponding carcass.
European Union (EU)	2003 (finning) 2013 (fins-attached)	Shark finning is prohibited by all vessels fishing in EU waters and on all EU vessels fishing in oceans worldwide since 2003. Sharks must be landed with fins naturally attached since 2013.
Gambia	2004	Ban on finning in all territorial waters. Mandatory to land sharks caught in Gambian waters on Gambian soil.
Guatemala	2012	Finning banned under Regulation OSP-05-11, adopted under the SICA-OSPESCA framework.
Guinea	2009	Ban on finning in all territorial waters.
Honduras	2012	Finning banned under Regulation OSP-05-11, adopted under the SICA-OSPESCA framework.
India	2013	Sharks must be landed with fins naturally attached.
Indonesia	2012	Per 2019 IOTC Compliance Report (IOTC-2019-CoC16-CQ09) finning has been banned since 2012 under Ministerial Regulation No.12/PERMEN-KP/2012.
Iran	2017	Per 2019 IOTC Compliance Report (IOTC-2019-CoC16-CQ10) finning has been banned since 2017.
Japan	2017	Per 2019 IOTC Compliance Report (IOTC-2019-CoC16-CQ11), finning banned since 2017 for sharks landed fresh and 2018 for sharks landed frozen.
Malaysia	2014	Finning has been prohibited since 2014 under Section 8(b) of the Fisheries Act of 1985.
Maldives	2010	Per 2019 IOTC Compliance Report (IOTC2019-CoC16-CQ16), sharks must be landed with fins naturally attached.
Mauritius	2018	Per 2019 IOTC Compliance Report (IOTC-2019-CoC16-CQ17), finning has been banned since 2018.
Mozambique	2019	Per 2019 IOTC Compliance Report (IOTC-2015-CoC12-CR19 Rev 2), finning is banned.
Mexico	2007	Shark finning is prohibited. Shark fins must not be landed unless the bodies are on board the vessel. In 2011, Mexico banned shark fishing from May 1 to July 31 in Pacific Ocean and from May 1 to June 30 in Gulf of Mexico and Caribbean Seas.

Country	Date	Regulations on Shark Finning
Namibia	2003	Generally prohibits the discards of harvested or bycaught marine resources. Prohibits shark finning.
New Zealand	2014	Removal of fins and discarding bodies into the sea is prohibited, even if the shark is dead. For some species, the fins must be naturally attached when landed. For others, the fins can be naturally or artificially attached when landed. If following a fin-to-greenweight (unprocessed weight) ratio, the fins can be unattached when landed.
Nicaragua	2004, 2012	Fins must not weigh more than 5% of the total weight of the carcass. Export of fins allowed only after proof that carcass has been sold as the capture of sharks for the single use of their fins is prohibited. Finning banned in 2012 under Regulation OSP-05-11, adopted under the SICA-OSPESCA framework.
Nigeria	2011	Returning shark carcasses at sea is prohibited under the Nigeria Sea Fisheries Act of 2011.
Oman	1999	Prohibits the throwing of any shark part or shark waste in the sea or on shore. It is also prohibited to separate shark fins and tails unless this is done according to the conditions set by the competent authority.
Pakistan	2017	Per 2019 IOTC Compliance Report (IOTC-2019-CoC16-CR20 Rev 1), finning prohibited under Notification dated 18-05-2016 under Sindh Fisheries Ordinance 1980 & Notification dated 08-09-2016 under Balochistan Sea Fisheries Ordinance, 1971.
Panama	2006	Shark finning is prohibited. Industrial fishermen must land sharks with fins naturally attached. Artisanal fishermen may separate fins from the carcass but fins must not weigh more than 5% of the total weight of the carcass.
Peru	2016	Under Decreto Supremo No. 021-2016-PRODUCE, sharks must be landed with fins totally or partially attached naturally; landing of detached fins or carcass prohibited.
Republic of Korea	2009	Per IOTC Compliance Report 2019 (IOTC-2019-CoC16-CQ13), finning has been banned since 2009.

Country	Date	Regulations on Shark Finning
Seychelles	2006	Fins may not be removed onboard a vessel unless authorized. Must produce evidence that they have the capacity to utilize all parts or the shark. Fins may not be transshipped. Fins must not weigh more than 5% of the total weight of the carcass (after evisceration) or 7% (after evisceration and beheading).
Sierra Leone	2008	Ban on shark finning.
South Africa	1998	Sharks must be landed, transported, sold, or disposed of whole (they can be headed and gutted). Sharks from international waters may be landed in South Africa with fins detached.
Spain	2002	It is illegal to have shark fins onboard without the corresponding carcass.
Sri Lanka	2001	Ban on shark finning.
Taiwan	2012	Enacted a shark finning ban with the exception of vessels not landing in Taiwan.
United Kingdom	2009	All sharks required to be landed with fins naturally attached.
Venezuela	2012	Sharks caught in Venezuelan waters must be brought to port with fins naturally attached.

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