Preliminary Recovery Plan for Scalloped Hammerhead in the Indian Ocean

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Contents

List of Figures

List of Tables

Summary

This document is a Preliminary Recovery Plan for the Scalloped Hammerhead in the Indian Ocean. It provides summary information on the Scalloped Hammerhead in the Indian Ocean, including biology and ecology, critical habitats, population and stock status, threats, current management measures, and information gaps. The main threat to Scalloped Hammerhead in the Indian Ocean is mortality resulting from fishing, in particular from the gillnet and artisanal fisheries. The Plan considers the conservation needs of the Scalloped Hammherhead in the Indian Ocean and identifies a preliminary set of recommended actions that can be implemented by the IOTC and its CPCs to begin to halt decline and promote recovery of the species. The overarching vision of the Plan is to see the Scalloped Hammerhead population in the Indian Ocean increasing and recovered and thriving in well-managed ecosystems. This Preliminary Recovery Plan describes a range of mechanisms that can be used to halt the decline of the Scalloped Hammerhead in the Indian Ocean and facilitate a recovery, for consideration by the IOTC and its Contracting Parties and Cooperating, Non- Contracting Parties (CPCs). It can form the basis for a full Recovery Plan derived through the normal IOTC processes and consultations with its CPCs. The Scalloped Hammerhead is in dire straits in the Indian Ocean and despite the lack of data, a precautionary approach is needed and management actions are needed without further delay.

1.0 Background

The Scalloped Hammerhead (*Sphyrna lewini*) is on a trajectory to extinction (Rigby *et al.* 2019a). In December 2019, the global status of Scalloped Hammerhead was revised from Endangered to Critically Endangered on the IUCN Red List of Threatened Species. Overfishing is the primary threat, with the species targeted and taken as bycatch in coastal and tuna fisheries. Some of the most severe population declines are in the Indian Ocean (Rigby *et al.* 2019a). There is a paucity of information available on the Scalloped Hammerhead in the Indian Ocean, and this situation is not expected to improve in the short to medium term; catch and effort data are poor and abundance estimates are lacking. As a result, no quantitative stock assessment has been undertaken for Scalloped Hammerheads in the Indian Ocean but rather a qualitative ecological risk assessment which requires less rigorous data was undertaken.

Existing management measures of Regional Fisheries Management Organizations (RFMOs) have been insufficient to prevent dramatic declines in oceanic sharks and rays (Pacoureau *et al.* 2021). Pacoureau *et al.* (2021) notes that species classified as Critically Endangered cannot support fisheries, and that strict prohibitions on landings and other measures to reduce fishing mortality are urgently needed to avert population collapses and rebuild populations. The FAO Code of Conduct for Responsible Fisheries (Article 7.6.10) states that '*regional fisheries management organizations and arrangements, in the framework of their respective competences, should introduce measures for depleted resources and those resources threatened with depletion that facilitate the sustained recovery of such stocks*' In April 2021, WWF updated its advocacy asks for oceanic sharks and rays, calling on major tuna RFMOs, who have a large role to play in safeguarding the health of oceanic shark and ray populations, to implement a set of urgently needed measures in order to prevent extinctions and to support their recovery and are calling for recovery plans by the end of 2023 for all Critically Endangered oceanic shark species (WWF 2021b). The increasing concerns for oceanic sharks and rays has led to the International Commission for the Conservation of Atlantic Tunas (ICCAT) recently adopting the first tuna Regional Fisheries Management Organisation (RFMO) rebuilding plan for any shark or ray, that is, for the North Atlantic Shorfin Mako (*Isurus oxyrinchus*) ((WWF 2021a).

This Preliminary Recovery Plan is the first step towards calling for action on halting the decline of the Scalloped Hammerhead in the Indian Ocean and includes a range of recovery mechanisms that can be implemented by the IOTC and its coastal Nation States. It is a Preliminary Recovery Plan and to draft a full Recovery Plan will require extensive stakeholder consultation with the IOTC and its Contracting Parties and Cooperating, Non- Contracting Parties (CPCs).

1.1 Indian Ocean Tuna Commission

The Indian Ocean Tuna Commission (IOTC) Area of Competence includes the east and west Indian Ocean (Figure 1) and currently 29 Commission Contracting Parties (CPCs) (Table 1) and one Cooperating Non-Contracting Party (Senegal). The IOTC includes Indian Ocean coastal countries and United Nation countries or regional economic integration organisations that fish for tuna in the Indian Ocean. The majority of CPCs are coastal Nation States.

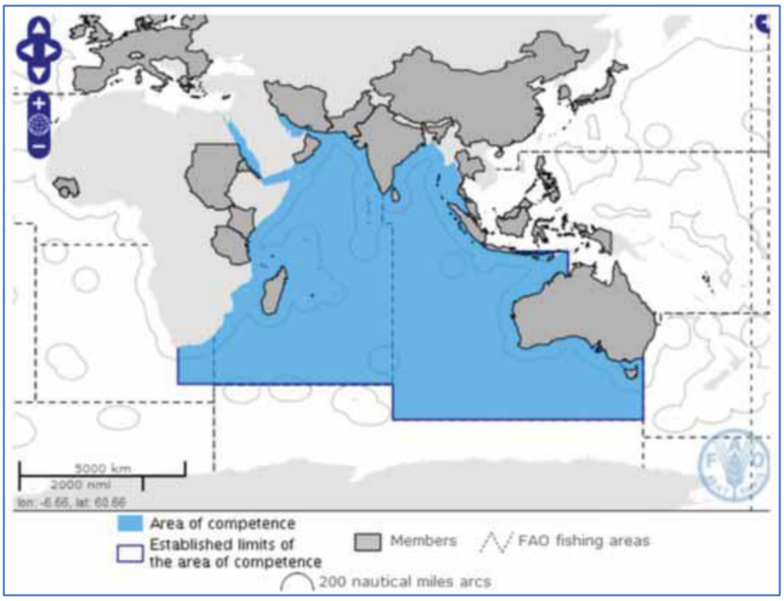

Figure 1: IOTC Area of Competence. Source: (Dunn *et al.* 2013), fig. 1, p6.

Table 1: IOTC Contracting Parties (CPCs)

Country	Country
Australia	Mauritius
Bangladesh, Peoples' Republic of	Mozambique
China	Oman, Sultanate of
Comoros	Pakistan
European Union	Philippines
France (OT)	Seychelles
India	Somalia

Indonesia	Sri Lanka
Iran, Islamic Republic of	South Africa
Japan	Sudan
Kenya	Tanzania
Korea, Republic of	Thailand
Madagascar	United Kingdom
Malaysia	Yemen
Maldives	

1.2 Species distribution, habitat, and ecology

The Scalloped Hammerhead has a global distribution in tropical and warm-temperate seas (Ebert *et al.* 2021). In the Indian Ocean, it occurs throughout all coastal and insular waters (Figure 2).

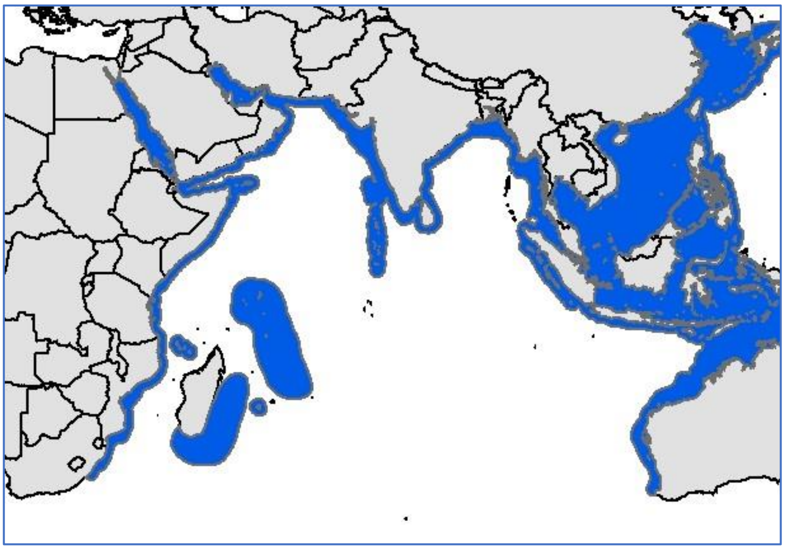

Figure 2: Scalloped Hammerhead distribution in the Indian Ocean. Source: the IUCN Red List of Threatened Species 2021-3.

The Scalloped Hammerhead is a coastal and semi-oceanic pelagic shark, occurring on the continental and insular shelves and adjacent deep water from the surface usually to 275 m depth, though it has been recorded to approximately 1,000 m off Tanzania and in the tropical eastern Pacific (Bessudo *et al.* 2011b; Moore and Gates 2015; Ebert *et al.* 2021). The species migrates from inshore bays to pelagic waters as it grows. Juveniles mostly inhabit shallow inshore areas while adults are mostly offshore in midwater, with females migrating inshore to pup (Rigby *et al.* 2019a). In some areas, such as eastern Australia, neonates are born throughout the year in shallow intertidal areas though a peak in pupping seems to occur in late spring and early summer while in other areas, such as Indonesia, there seems to be seasonal rather than year-round pupping (Harry *et al.* 2011). Neonates and juveniles mostly inhabit large shallow coastal bays and estuaries in turbid waters, that is, nursery areas (Baum *et al.* 2009; Cuevas-Gómez *et al.* 2020; Corgos and Rosende-Pereiro 2021). They can remain in these shallow coastal waters (<25 m depth) for one to two years, with reports of up to one year on oceanic islands and two years in continental bays (Baum *et al.* 2009; Corgos and Rosende-Pereiro 2021).

The Scalloped Hammerhead segregates by sex, with females tending to move offshore at an earlier age and smaller than males; in northern Australia and the Gulf of Mexico, males ranging from less than 1m and up to 2m total length (TL) were more abundant over the continental shelf while females larger than 1.5 m TL were more abundant at the edge of the continental shelf (Baum *et al.* 2009; Harry *et al.* 2011).

It is a seasonally migratory species that occurs in large schools both inshore and around seamounts and offshore islands by day and disperses at night to feed alone or in small groups (Miller *et al.* 2014; Ebert *et al.* 2021). These seasonal aggregations have been mostly recorded from the Pacific and can number into the hundreds (Gallagher and Klimley 2018). Studies during the 1980s reported that large schools of small Scalloped Hammerheads form off Natal, South Africa and elsewhere in the summer and migrate to higher latitudes (Compagno 1984; Stevens and Lyle 1989). The species can also form large resident populations (Baum *et al.* 2009). It rarely occurs in waters cooler than 22°C (Miller *et al.* 2014) and generally remains below the thermocline in cooler waters during the summer and closer to the surface in the winter, possibly related to food availability with upwelling in colder months increasing surface water primary productivity (Bessudo *et al.* 2011b; Ebert *et al.* 2021). The reported diving behaviour appears to vary among studies. In the Red Sea, Scalloped Hammerhead made deep dives during both the day (to 650–700 m) and night (>850 m) likely foraging for prey which contrasts with studies in the Eastern Tropical Pacific, Gulf of California, and Gulf of Mexico that report deep dives only during the night (Spaet *et al.* 2017).

The Scalloped Hammerhead reaches a maximum size of 370–430 cm total length (TL) with males mature at 140–198 cm TL and females mature at 200–250 cm TL (Rigby *et al.* 2019a). It has viviparous reproduction, producing 12–41 pups per litter and breeding every one to two years with the young born at 31–57 cm TL (Rigby *et al.* 2019a). Males mature at ~10 years and females mature at 13–15 years and it reaches a maximum age of 35 years and thus, has a generation length of 24 years (Rigby *et al.* 2019a). Generation length is the turnover rate of breeding individuals, meaning for Scalloped Hammerhead, there are 24 years between consecutive generations. The population intrinsic rate of increase, or population growth rate, for Scalloped Hammerhead is low, with estimates ranging from 0.028–1.21 per year which indicates populations are vulnerable to depletion and slow to recover from overexploitation (Miller *et al.* 2014; Rigby *et al.* 2019a).

1.2.1 Indian Ocean Hammerheads

Four species of hammerheads occur in the Indian Ocean. The Scalloped Hammerhead, Great Hammerhead (*Sphyrna mokarran*), Smooth Hammerhead (*S. zygaena*), and the Winghead Shark (*Eusphyra blochii*). The Great Hammerhead occurs throughout the Indian Ocean with its range similar to that of the Scalloped Hammerhead, although it is less common. The Smooth Hammerhead has a patchier range in the Indian Ocean and is the most oceanic of the hammerhead sharks, while the Winghead Shark only occurs in the northern Indian Ocean on the Asian continent (Clarke *et al.* 2015; Ebert *et al.* 2021).

Identification issues

It can be difficult to differentiate the three *Sphyrna* species that occur in the Indian Ocean, particularly as juveniles, without taking them onboard a vessel (E.U. 2014). If the species is to be released, bringing it on board can reduce its chances of survival. This difficulty in identification can lead to misreporting of species-specific catches or only the generic grouping of ‘hammerhead shark’ being reported.

1.3 Population structure and trends

1.3.1 Global and Indian Ocean Structure

The global pattern of stock structure of the Scalloped Hammerhead varies between males and females, reflecting the strong sexual segregation. Genetic studies of females indicate there are at least four genetically distinct populations: Northwest and Western Central Atlantic, Southwest Atlantic, Eastern Atlantic, and Indo-West Pacific (Duncan *et al.* 2006). In contrast, males do not show these distinct genetic population differences, with no large genetic differences between and within ocean basins. This suggests that males move across oceans and thus enable male-based genetic dispersal while females move only regionally and not between continental coastlines that are discontinuous (Duncan *et al.* 2006; Daly-Engel *et al.* 2012).

Recent genetic analyses of Scalloped Hammerhead within the Indo-Pacific region revealed that Western Australia (eastern Indian Ocean) population has limited connectivity to the rest of the Indo-Pacific (northern and eastern Australia, Indonesia, Papua New Guinea, Philippines, Taiwan, and Fiji) (Heupel *et al.* 2020). However, no evidence of genetic structuring between the Indian and Pacific Ocean has also been reported suggesting long-distance male-biased dispersal (Daly-Engel *et al.* 2012). Further, the population segment within the Arabian Sea region (Red Sea, Arabian Sea, and Gulf) may be distinct from the rest of the Indian Ocean (Spaet *et al.* 2015). This lack of concordance on the genetic structure of Scalloped Hammerhead within the Indian Ocean highlights the need for further work to elucidate the stock structure.

A collaborative 3-year project from 2017–2020 investigating population structure and connectivity of tuna, Scalloped Hammerhead, and Blue Sharks of the Indian Ocean was unfortunately unable to resolve the structure of Indian Ocean Scalloped Hammerhead as CITES restrictions on transport of samples prevented useful data collection. Recommendations were made to conduct future sampling and analysis of Scalloped Hammerheads under appropriate CITES arrangements (Davies *et al.* 2020).

Despite the uncertainty of the stock structure, there is consensus that males disperse long distances but females move only regionally. Thus, on a regional level, females are crucial to rebuilding populations and recovery is dependent on reducing fishing pressure on females (CITES 2013).

1.3.2 Global and Indian Ocean Population Trend

The global population of Scalloped Hammerhead is estimated to have steeply declined across all oceans by >80% over the past 72 years (three generation lengths) (Rigby *et al.* 2019a). In the Indian Ocean, the declines were severe with the population estimated to have undergone a reduction of 93% over the past 72 years. This decline was based on the longest and most robust time-series available for JARA (Just Another Red List Assessment) modelling from the Indian Ocean, which was from the Kwazulu-Natal South Africa beach protection (KZNSBP) that uses midwater gillnets. This revealed a steady decline in catch-per-unit-effort (CPUE) of the Scalloped Hammerhead from 1978–2003 (Figure 3) and an overall population reduction of 93% when modelled and extrapolated using JARA to the past 72 years (three generation lengths) (Rigby *et al.* 2019a).

However, recovery of populations is possible. The implementation of management measures in the Northwest Atlantic and Gulf of Mexico in recent years have had a positive impact on Scalloped Hammerhead populations as they have begun to increase (Rigby *et al.* 2019a). Management measures included: fins naturally attached until landing, reduction in targeted and bycatch effort, gear restrictions for Scalloped Hammerhead, hammerhead shark quotas, minimum size limits and trip limits in recreational fisheries, requirements for permits to retain or sell Scalloped Hammerhead, mandatory logbook reporting, many state water regulations that mirror federal regulations, and management of the small-scale commercial fishing fleet in the U.S. Caribbean region (Miller *et al.* 2014).

The IUCN Red List assessment recommends that to enable recovery of the species across all oceans, all Scalloped Hammerhead retention and landings are prohibited for at least as long as the global population is listed as Critically Endangered or Endangered. It also recommends full implementation of commitments agreed through international treaties, including those of tuna RFMOs, and that initiatives to prevent capture, minimise bycatch mortality, promote safe release, and improve catch (and discard) reporting are urgently needed (Rigby *et al.* 2019a). WWF recommends a number of additional measures for highly threatened oceanic sharks including i) significant increases in observer coverage and ii) the introduction of recovery plans including plans that minimize interactions between fishing gear and sharks, and protection of critical habitats (WWF 2021b).

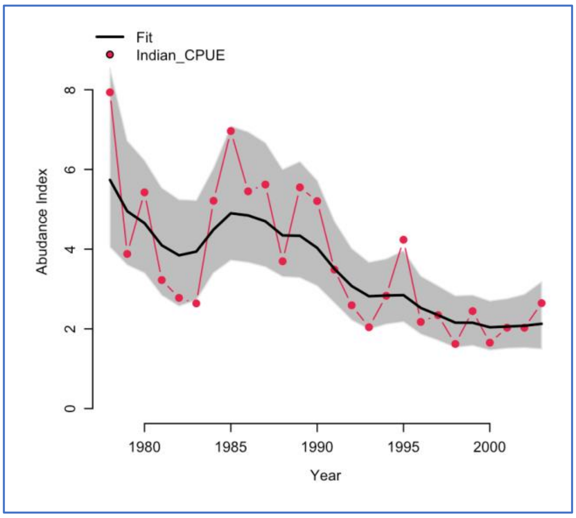

Figure 3: Annual CPUE of Scalloped Hammerhead in the KZNSBP from 1978–2003 modelled by JARA. Source: Rigby et al. 2019a.

1.3.3 Country-specific Population Trends

Population trend data for Scalloped Hammerhead from the Indian Ocean is sparse, other than that from the KZNSBP in South Africa. The status of shark[1] populations in general is estimated to be fully to over-exploited in countries with major fisheries for sharks, that is, in the United Republic of Tanzania, Kenya, Mauritius, Seychelles, Pakistan, Iran, and India Maldives, and Indonesia; declines in Scalloped Hammerheads are also likely to have occurred in these countries (De Young 2006; Baum *et al.* 2009) (U. Shahid pers. comm. 2022).

Across four countries of the Arabian Seas, that is, Kuwait, Bahrain, Oman, and Yemen, fisher interviews revealed that hammerhead shark (*Sphyrna* spp.) abundances have strongly declined by 69–80% (Almojil 2021). Where available, Scalloped Hammerhead trends from countries in the Indian Ocean are reported below.

[1] The term shark is used to refer to sharks and rays throughout the document unless otherwise specified.

Australia

A 50–75% decline in hammerhead shark (*Sphyrna* spp.) catch-per-unit-effort was noted in the Western Australian North Coast Shark Fishery from 1996–2005 (Heupel and McAuley 2007). The North Coast Shark Fishery ceased operating in 2005. Scalloped Hammerhead likely dominated the hammerhead shark catches (Braccini *et al.* 2019).

India

Longline research surveys from 1984–2006 revealed declining nominal catch rates of pelagic sharks, of which Scalloped Hammerhead contributed up to 6% of the catch (John and Varghese 2009). Landings from Cochin Fisheries Harbour from 2007–2011 indicated increasing landings of Scalloped Hammerhead from 71.3 t to 227.1 t. However, concurrently the minimum size decreased from 110 cm TL to 70 cm TL which possibly indicates overexploitation (CITES 2013).

Across India, from 2007–2018, the average annual hammerhead shark catch indicated a declining trend (Thomas *et al.* 2021). The average annual catch was 639 t, of which Scalloped Hammerhead represented 95% of landings. Declines were greater in some areas, for example, the Bay of Bengal east coast exploratory surveys from 2005–2010 revealed a 99% decline in the hooking rate of sharks, with Scalloped Hammerhead the third most dominant species by weight (Thomas *et al.* 2021). Further, the Scalloped Hammerhead fishery in India during 2007–2018 was dominated by juveniles, indicating that the fishing grounds overlap juvenile habitat areas (Thomas *et al.* 2021).

Indonesia

Scalloped Hammerheads catches in the artisanal shark longline fishery of Tanjug Luar, off East Lombok from 2001–2011 declined as a proportion of the total shark catch from 15 to 2% (FAO 2013).

Malaysia

Surveys of fishing communities in Malaysia found >70% of respondents in Perak and Pehang states reported declines in hammerhead sharks (Then *et al.* 2019).

Oman

Catches of Scalloped Hammerhead declined between 2002–2004 although the trend varied among areas (Henderson *et al.* 2007). The Scalloped Hammerhead was one of the dominant species caught in Oman's shark fisheries with juveniles most commonly caught (Henderson *et al.* 2007).

South Africa

Scalloped Hammerhead neonates were reported as the dominant elasmobranch bycatch taken by prawn trawlers operating on the Tugela Banks in the 1990s (Fennessy 1994). These catches declined by 47% in just 3 years from 1989–1992 with an estimated mortality of almost 98% for the neonates (Fennessy 1994; Diemer *et al.* 2011).

1.4 Indian Ocean Stock Status and Ecological Risk Assessment

1.4.1 Stock Status

The stock status of Scalloped Hammerhead in the IOTC is unknown. There is no quantitative stock assessment due to the limited and highly uncertain basic fishery indicators for this species in the Indian Ocean (IOTC 2021a). The IOTC reported nominal catch of Scalloped Hammerhead in 2019 was 51 t which equates to approximately 1,536 individuals (Romanov and Romanov 2012). The Scalloped Hammerhead is also possibly included in the generic unidentified 'shark' catch for 2019 of 21,899 t.

As such, the actual catch of Scalloped Hammerhead in the Indian Ocean is highly uncertain and the IOTC Working Party on Ecosystems and Bycatch (WPEB) recommend it should be investigated further as a priority (IOTC 2021d). This poor quality and highly uncertain data are not expected to improve in the short to medium term. The WPEB conclude that the limited available information indicates considerable risk to the Scalloped Hammerhead stock status at current effort levels (IOTC 2021d). Maintaining or increasing effort can result in declines in biomass and productivity of the Scalloped Hammerhead (IOTC 2021a).

The management advice in the stock status overview refers to the ecological risk assessment where Scalloped Hammerhead was found to be extremely vulnerable to gillnet fisheries (see 1.4.2 Ecological Risk Assessment). The species is vulnerable to overfishing due to its slow life history characteristics and as pups occur in shallow coastal waters that are often heavily fished, this exacerbates the species vulnerability to gillnet fisheries. The outlook for the species refers to piracy in the western Indian Ocean that displaced and concentrated a substantial portion of longline effort into parts of the southern and eastern Indian Ocean. Improved onboard security has since seen some longline effort relocate to the northwest Indian Ocean with the exception of the Japanese fleet. The concentrated effort may have caused localised depletion of the Scalloped Hammerhead in the southern and eastern Indian Ocean. The management advice was that the IOTC take a cautious approach and implement some management actions for the Scalloped Hammerhead and that further implementation of recording and reporting is needed to inform scientific advice for this species.

The IOTC Working Party on Ecosystems and Bycatch plans to undertake an assessment of Scalloped Hammerhead in 2022 with the assessment method to be determined and likely to be a data poor stock assessment method due to the limited and highly uncertain data available (IOTC 2021e; IOTC 2021d). Despite concerns for the status of the species, recognition of the highly uncertain and limited catch and biological data on the species in the Indian Ocean, and the management advice calling for priority on catch data for Scalloped Hammerhead, the Scalloped Hammerhead is not among the priority shark species in the Program of Work for 2022–2026 for the IOTC Science Process (IOTC 2021e). The priority shark species are: Blue Shark (*Prionace glauca*), Shortfin Mako (*Isurus oxyrinchus*), Oceanic Whitetip Shark (*Carcharhinus longimanus*), and Silky Shark (*C. falciformis*).

1.4.2 Ecological Risk Assessment

The ecological risk assessment (ERA) for shark in the Indian Ocean, which included Scalloped Hammerhead, was a semi-quantitative analysis that ranked the vulnerability of species to longline, purse seine, and gillnet fisheries based on their biological productivity and susceptibility to the fishing gear (Murua *et al.* 2018). The Scalloped Hammerhead was most vulnerable to gillnet fisheries, followed by purse seine then longline fisheries. It is also likely vulnerable to artisanal handline fisheries in inshore waters which were not included in the ERA, likely due to a lack of data. The biological productivity of the Indian Ocean Scalloped Hammerhead stock is the same for all fleets, hence the difference in its vulnerability was due to its susceptibility to capture which was the greatest in the gillnet fleets. Susceptibility was estimated by assessing the horizontal overlap between the species distribution and fisheries (availability), the vertical overlap between species and fishing gear (encounterability), gear selectivity, and post-capture mortality (Murua *et al.* 2018).

The Scalloped Hammerhead has a mainly coastal distribution in the IOTC Area of Competence (Figure 1) and hence, has the highest level of availability or overlap with the gillnet fisheries that are mainly coastal fisheries (Figure 4). The longline and purse seine fisheries occur mostly in offshore and high seas waters in the IOTC and hence had relatively lower levels of overlap with the Scalloped Hammerhead's mainly coastal distribution (Figure 5, Figure 6). The other susceptibility parameters were not available for Scalloped Hammerhead, with the exception of selectivity to longlines, and so were all conservatively estimated as the highest value, which can affect the overall vulnerability assessment. This was also the case for many other shark species with a recommendation to revisit the ERA once more regional species-specific information is available (Murua *et al.* 2018).

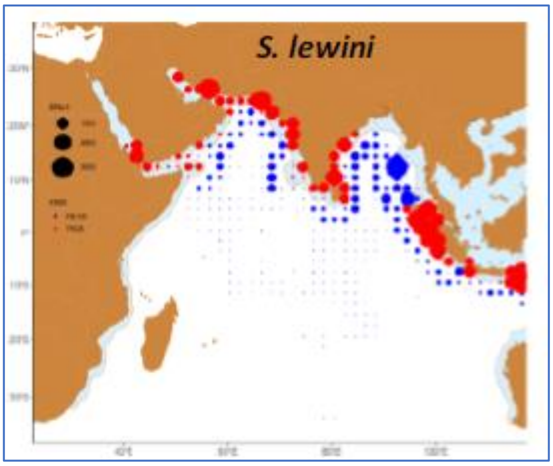

Figure 4: Overlap between Scalloped Hammerhead distribution area and gillnet total effort shape file from Williams et al. (2018) distribution for the gillnet fleet. In red: effort overlapping with species range and in blue: effort outside species range. Source: Murua et al. 2018, fig. 8, p27.

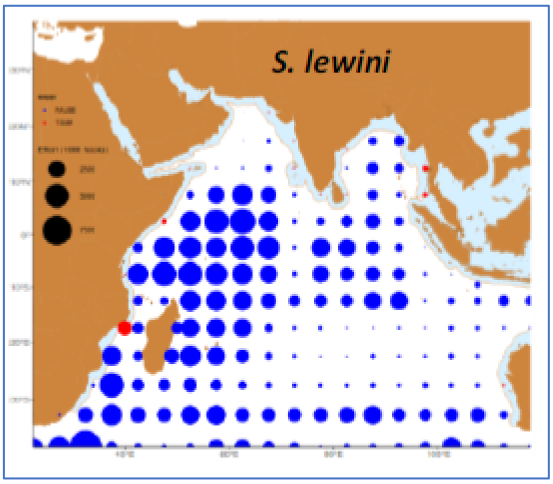

Figure 5: Overlap between Scalloped Hammerhead distribution area and longline effort (number of hooks) distribution for the longline fleet for the period 2011–2017. In red: effort overlapping with species range and in blue: effort outside species range. Source: Murua et al. 2018, fig. 6, p25.

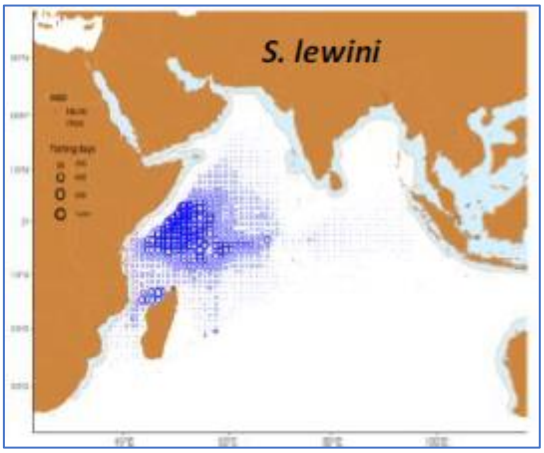

Figure 6: Overlap between Scalloped Hammerhead distribution area and purse seine total effort (total number of days/hours) distribution for the purse seine fleet for the period 2011–2017. In red: effort overlapping with species range and in blue: effort outside species range. Source: Murua et al. 2018, fig. 7, p26.

A semi-quantitative risk assessment is conducted when the available data are poor and the ERA uses some inherently uncertain data. The catch data is uncertain as recording and reporting of shark catches in the IOTC is noted as being very irregular over time, though with some improvements in recent years, possibly due to the IOTC adopting Resolutions 15/01, 15/02 and 17/05 and 11/04 (see 4.1.1 IOTC CMMSs) which make mandatory the reporting of shark catch data for various shark species. However, hammerhead sharks are only required to be reported to genus level and only for longline and gillnet gears (IOTC 2021b).

The information on shark target and bycatch in the IOTC database is considered very incomplete (Murua *et al.* 2018). Most of the shark catch is reported as generic 'shark' and not at a species-specific level. In the IOTC reported nominal catches for 1950–2017, Scalloped Hammerhead are only reported by species in the purse seine fishery where they are noted as accounting for 3% of the shark catch for 1950–2017. The line fishery (distinct from longline fishery) reports two generic groups of hammerheads: 'bonnethead and hammerhead' and 'hammerhead' that account for 8% and 3%, respectively of the shark catch. The longline and gillnet fisheries appear to include Scalloped Hammerhead under the generic 'shark' (Murua *et al.* 2018).

Regionally species-specific data for the Scalloped Hammerhead is not available for the Indian Ocean, reducing the accuracy of the regional productivity estimates. In the purse seine fishery, the bycatch of Scalloped Hammerhead was very low and thus there was no size-frequency data available. In the gillnet fishery, for all shark species, there was no data on size-frequency or any post-capture mortality. The ERA strongly recommended that regionally specific biological information is collected along with observer data on species-specific catches, size-frequency catch data, and post-capture and post-release mortality data (Murua *et al.* 2018).

1.5 Critical Habitats for Scalloped Hammerhead

Critical habitats for sharks in general are areas that play an important role in ensuring their survival, such as nurseries, mating, gestation, feeding, aggregation areas and migratory routes. Implementation of effective management measures, such as spatial protection and/or fisheries management, in critical habitats will improve their conservation (Simpfendorfer in press).

The Scalloped Hammerhead is known to use coastal inshore waters as nursery areas which often include estuaries and bays, form aggregations around seamounts and offshore islands, exhibit philopatry (repeatedly returning to the same area), and use migratory routes (Miller *et al.* 2014; Gallagher and Klimley 2018).

There is limited information on these critical habitat areas for Scalloped Hammerhead within the Indian Ocean and consideration needs to be given to identifying important aggregation areas and migratory routes that could inform spatial protection measures in the future. The Indian Ocean has numerous seamounts with a particular abundance of them between Réunion and Seychelles.

Nursery areas

Scalloped Hammerhead nursery areas are reported for Tulega Banks off northern KwaZulu-Natal, South Africa (Diemer *et al.* 2011). Also in South Africa, tagging studies indicate that the entrance to the Mzimvubu River in Port St Johns in the Transkei is an important coastal habitat for the juveniles and subadult Scalloped Hammerhead (Diemer *et al.* 2011).

Breeding areas

In northeast Madagascar in Antongil Bay target shark fisheries land both Scalloped Hammerhead adults, including pregnant females, and juveniles, suggesting this may be a breeding area for the species (Miller *et al.* 2014).

Aggregation areas

The Transkei was found to be an important area for larger Scalloped Hammerhead with an increased abundance of the species in the region. It was postulated that this may be associated with the narrow continental shelf in the region and the proximity of the Agulhas Current at Transkei (Diemer et al. 2011). An MPA within the Transkei, that is, the Pondoland Marine Protected Area, may provide some protection to juvenile and subadult Scalloped Hammerheads when they are resident in this area (Diemer *et al.* 2011). Elsewhere in the Indian Ocean, in Mayotte, Scalloped Hammerheads are commonly observed near steep reef slopes in the austral winter (van der Elst and Everett 2015).

Migratory routes

Migration along the South African east coast has been observed for Scalloped Hammerhead possibly in response to seasonal changes in sea surface temperatures (Diemer et al. 2011; Hussey et al. 2011).

2.0 Conservation Status

The Scalloped Hammerhead is listed globally as Critically Endangered by the IUCN Red List of Threatened Species (Rigby *et al.* 2019a). In 2009, there were regional IUCN Red List assessments with the species listed as Endangered in the western Indian Ocean based on the declines observed in the Kwazulu-Natal South Africa beach protection (which were 64% over the 26 years of the time-series) (https://www.iucnredlist.org/Scalloped Hammerhead regional). For the updated global assessment, the same KZNSBP time-series was used but the level of decline was extrapolated over the past three generation lengths (72 years). There was no regional assessment for the eastern Indian Ocean. These regional assessments have not been revisited for the 2019 global IUCN Red List assessment.

3.0 Threats

3.1 Global Overview

The Scalloped Hammerhead is taken globally as both target and bycatch in coastal and pelagic commercial and small-scale (including artisanal) fisheries and to a lesser degree, in recreational fisheries. Most of the catch is bycatch in pelagic large-scale commercial fleets using longline, purse seines, and gillnets in offshore and high-seas waters (Rigby *et al.* 2019a). In coastal waters it is taken by a variety of gears including gillnets, trammel nets, longlines, and trawls, especially in regions with a narrow continental shelf (Rigby *et al.* 2019a). Beach protection programs in South Africa and Réunion also capture Scalloped Hammerheads as bycatch (Guyomard *et al.* 2019; Rigby *et al.* 2019a). It is likely that catches in pelagic and coastal fisheries are under-reported (Dent and Clarke 2015).

The Scalloped Hammerhead is an obligate ram ventilator and therefore must swim to breath, and as such, it has a high mortality when brought onboard vessels (at-vessel mortality (AVM)) and mortality is also high once released (post-release mortality (PRM)). The AVM has been reported as 42.3–57.1% on swordfish pelagic longlines in the Atlantic, 62.9–91.4% on United States shark bottom-longlines, and 71.4% on eastern Indian Ocean demersal longlines in Western Australia (Coelho *et al.* 2012; Miller *et al.* 2014; Gulak *et al.* 2015; Braccini and Waltrick 2019). Reduced soak times of bottom-longlines reduced mortality of Scalloped Hammerhead; soak times of >4 hours resulted in >65% AVM, 3.5 hours resulted in 50% AVM, and 1 hour resulted in 12% AVM (Morgan *et al.* 2009; Gallagher *et al.* 2014; Miller *et al.* 2014; Gulak *et al.* 2015). Deeper hook depths (45 m) on pelagic longlines significantly reduced mortality for Scalloped Hammerhead possibly due to deeper, cooler waters improving oxygen availability of captured animals (Gallagher *et al.* 2014). The AVM of Scalloped Hammerhead in purse seines in the equatorial Eastern Pacific was 0% (all alive) but the PRM was 100% (Eddy *et al.* 2016). Hammerhead sharks (*Sphyrna* spp.) have a very high AVM in gillnets of 71.5–98.8%, reported from the Northwest Atlantic and Southeast Australia; no species-specific Scalloped Hammerhead gillnet AVMs were reported (Ellis *et al.* 2017). The high mortality at-vessel and post-release mortality rates of the Scalloped Hammerhead makes it highly vulnerable to fisheries as any prolonged interaction with fishing gear can result in mortality (Gallagher and Klimley 2018).

The Scalloped Hammerhead is vulnerable to local depletions due to their aggregating behaviour and high catch mortality rates. The aggregating behaviour of both juveniles and adults increases their chances of being caught in high numbers and high catches may be reported even when the overall population is depleted (Baum *et al.* 2009). Targeted fishing on Scalloped Hammerhead schools has been frequently reported (Miller *et al.* 2014). Further, the inshore habitat of juveniles and subadults makes them highly susceptible to inshore coastal fisheries.

3.1.2 Use and Trade

Fins are the main product from the species traded, mostly internationally (CITES 2013). Hammerhead fins are one of the species preferred for shark fin soup and are among the top species of fins traded globally (Dent and Clarke 2015; Fields *et al.* 2018). They are the fourth most common fin species traded in Hong Kong and third most commonly traded in China (Cardeñosa *et al.* 2018; Fields *et al.* 2018; Cardeñosa *et al.* 2020a). Even small Scalloped Hammerhead fins, potentially from juveniles, are traded and represented the second most common species of small fins sampled in Hong Kong retail markets (Cardeñosa *et al.* 2020b). Scalloped Hammerhead is also used for its meat which is a globally rising trade (Okes and Sant 2019). The skin, cartilage, liver oil, and jaws are also used.

3.2 Indian Ocean

In the Indian Ocean, similar to the global situation, hammerhead sharks (*Sphyrna* spp.) are taken as both target and bycatch in pelagic and coastal large and small-scale fisheries. They are most frequently captured in coastal fisheries and fisheries operating in national waters where there is limited shark catch data collected (Rice 2017). Coastal and small-scale fisheries target sharks for local consumption and trade (Rice 2017). Hammerhead sharks (*Sphyrna* spp.) account for approximately 6% of the total shark catch in the Indian Ocean, however the species-specific composition of hammerhead shark catches in the IOTC fishing fleet are not well understood, mostly as a result of a lack of species-specific hammerhead shark catch reporting (Murua *et al.* 2012; Rice 2017).

The 2021 IOTC stock status report identified the main gears that captured Scalloped Hammerhead in the IOTC from 2014–2018 as gillnet, ringnet, coastal longline, longline (fresh), and offshore gillnets. As identified in the ERA, the Scalloped Hammerhead is most susceptible to gillnet fisheries, followed by purse seine then longline fisheries. The main fleets that caught Scalloped Hammerhead during 2014–2018 were: Sri Lanka, Kenya, Seychelles with the other main fleets reporting they released it alive or discarded, i.e. EU-France, South Africa, Indonesia, and Japan.

The available data from the longline fishery indicates that hammerhead sharks (Scalloped, Great, and Smooth) are mainly caught in the western Indian Ocean in the east African coastal waters and the equatorial high seas between east Africa and India and the Maldives (Figure 7) (Rice 2017). Consequently, the main countries with hammerhead shark longline catches are South Africa, Mozambique, Tanzania, Kenya, Somalia, Madagascar, Seychelles, Sri Lanka, India, and the Maldives. Longline effort is generally higher in the western than the eastern Indian Ocean and overall reported shark catch is higher in number and weight in the western Indian Ocean (Rice 2017). Nominal catch data extends back to the 1950 as industrial longline fishing commenced in the 1950s in the Indian Ocean and (Rice 2017).

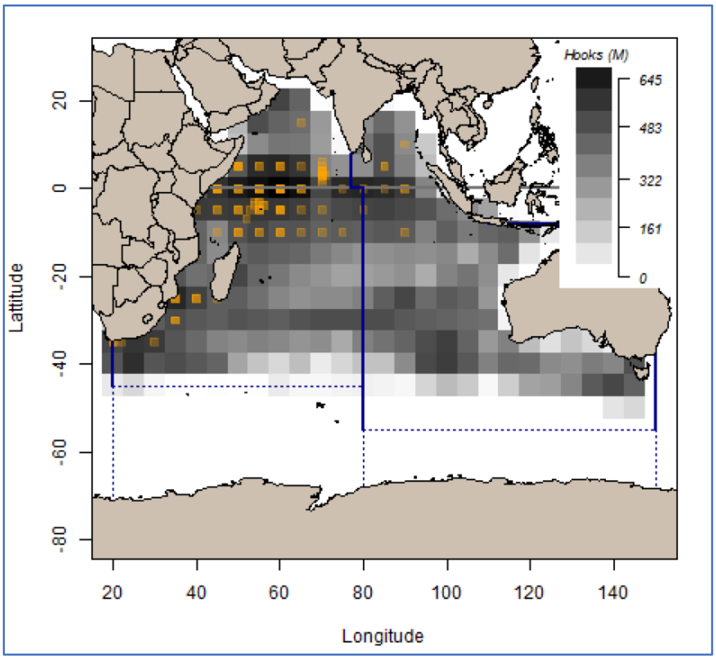

Figure 7: Reported hammerhead shark catch in Indian Ocean longline fisheries 1952–2015. Orange squares indicate reported hammerhead shark catch and grey squares indicate reported effort. Source: Rice 2017, fig. 9, p35.

3.2.1 Artisanal Fisheries

Artisanal fisheries take a large proportion of the tuna catch in the IOTC with catch data suggesting they are expanding (Martin and Shahid 2021). Artisanal refers variously to fisheries for subsistence or local consumption or exclusively operating in their Exclusive Economic Zones (EEZ). However, this has created some confusion as it is not clear whether that also includes large vessels within EEZs and in response, the IOTC Working party on the implementation of Conservation and Management Measures (WPICMM) agreed in 2020 that the term 'artisanal fisheries' be replaced with 'coastal fisheries' in IOTC Resolutions (Martin and Shahid 2021). The 'coastal fisheries' definition includes artisanal fisheries and refers to fisheries that operate exclusively within their EEZs but excludes vessels larger than 24 metres in length (WPICMM03 2020). In this Preliminary Recovery Plan, the terms 'artisanal fisheries' and 'coastal fisheries' will be used as referred to in a cited document, rather than as defined by IOTC.

Artisanal fisheries also take a large proportion of the IOTC shark catch. They were estimated to account for approximately 60% of the total IOTC catch of some pelagic sharks, that is, Oceanic Whitetip Shark (*Carcharhinus longimanus*) and Bigeye Thresher (*Alopias superciliosus*) with the remainder of these species' catches taken in the pelagic large-scale fisheries (Martin and Shahid 2021). No such estimates are available for Scalloped Hammerhead, although it could be higher than 60% capture in the artisanal fisheries as the Scalloped Hammerhead is a more coastal species than the Oceanic Whitetip Shark and Bigeye Thresher.

Scalloped Hammerhead of small and medium size were found to be among the dominant species in artisanal shark catches using drift and bottom-set gillnets, demersal and pelagic longlines, and handlines from Kenya, Zanzibar, and northern Madagascar in the southwestern Indian Ocean during 2016–2017 (Temple *et al.* 2019). Severe underreporting of southwest Indian Ocean regional artisanal elasmobranch landings to FAO were revealed with estimates of landings 73% higher than those reported to FAO in 2016 with the reported FAO landings also including large-scale fisheries (Temple *et al.* 2019).

3.2.2 Country-specific Threats

All national reports provided to the 24th Session of the Scientific Committee (SC24) (IOTC 2021c) were reviewed and any reported hammerhead shark catches noted in the following country sections. More detail on fleet composition and gears used for shark catches within each country are available in some of the national reports. Where available, any other Scalloped Hammerhead catches from countries were included.

Australia

No Scalloped Hammerhead were recorded from 2010–2020 as captured, released/discarded by Australian longline vessels in the IOTC Area of Competence. During this same period, 16 'hammerhead sharks' captures were reported, and 463 'hammerhead sharks' reported as captured and released/discarded by Australian longline vessels (IOTC 2021c).

Bangladesh

The Scalloped Hammerhead catch in artisanal shark fisheries in the Bay of Bengal, Bangladesh was reported to account for approximately 5% by weight of the total shark landings from 2006–2014 (Roy *et al.* 2015).

India

The average annual catch of hammerhead sharks across India was 639 t, of which Scalloped Hammerhead represented 95% of landings (Thomas *et al.* 2021). More details are included in Section 1.3.3 Country-specific Population Trends.

Indonesia

Substantial catches of Scalloped Hammerhead are taken in artisanal and small-scale fisheries with almost all caught by gillnet fisheries immature and most caught by longline also immature (White *et al.* 2008). From 2006–2015 in the Indonesian eastern Indian Ocean, longline vessels reported that Scalloped Hammerhead represented 4% of the total shark catch with most of the animals immature (Rice 2017). Further, from 2014–2017, the shark fishery operating from southern Bali and Lombok down to Northern Australia, Flores Sea, and Makassar Strait reported landing 2,425 Scalloped Hammerhead which represented 15% of the total shark catch with immature and female Scalloped Hammerheads commonly caught (Chodrijah and Setyadji 2015; Simeon *et al.* 2019).

Iran (Islamic Republic of,)

Hammerhead shark (*Sphyrna* spp.) represented 1–2% of the total shark landings in the gillnet fishery, although the accuracy of the data are unknown as all landings data are collected from ports (Rice 2017). In the tuna fleet in 2015, 63 t of hammerhead shark (*Sphyrna* spp.) were reported which represented 0.03% of the total landed catch (Rice 2017).

Kenya

An offshore tuna longline fishery both targets and takes sharks as bycatch, with the Scalloped Hammerhead observed to be the dominant shark species captured, accounting for approximately 47% of the total shark catch by number. The offshore tuna fishery was low effort with only two longline vessels operating in 2016–2017 (Kiilu and Ndegwa 2018). A semi-commercial longline fishery in Mombasa targets sharks including Scalloped Hammerhead (Kiilu and Ndegwa 2018). Semi-industrial prawn trawl fisheries take sharks as bycatch, most of which are discarded (Kiilu and Ndegwa 2018). Scalloped Hammerhead was one of dominant shark species caught in artisanal prawn trawlers operating in Malindi-Ungwana Bay from 2012–2013 with 90% of the Scalloped Hammerheads immature (Kiilu et al. 2019). Hammerhead sharks are caught occasionally in recreational fisheries with less than ten hammerhead sharks reported annually since 2010 (Rice 2017).

Korea

Across the Korean longline and purse seine fleets in the IOTC Area of Competence from 2016–2020 only one hammerhead shark was reported to be captured and that was by longline and was released (IOTC 2021c).

Malaysia

Shark catches were reported from the Malaysia fleet operating in the IOTC Area of Competence from 2016–2020 and during this period there were no hammerhead shark captures (SEAFDEC 2006; IOTC 2021c) . Scalloped Hammerhead was one of the main shark species in key landing ports in the Malaysian Indian Ocean in 2006 with the catch entirely comprised of immature individuals (SEAFDEC 2006). The species was not reported from Malaysian Indian Ocean landing sites in 2015-2016 (Arshad *et al.* 2017).

Maldives

In the Maldives longline fleet operating in the IOTC Area of Competence from 2014–2019, 144 generic 'hammerhead sharks' were released from 2014–2017 with none retained and no hammerhead shark catches reported in 2018–2019 (IOTC 2021c).

Mauritius

In the Mauritius fleet operating in the IOTC Area of Competence from 2014–2019, 29 generic 'hammerhead sharks' with a total weight of 1,243 kg were caught and retained from 2013–2020 (IOTC 2021c).

Mozambique

Scalloped Hammerhead are taken in inshore, artisanal fisheries along the coast (Dudley and Simpfendorfer 2006; Doherty *et al.* 2015).

Madagascar

Scalloped Hammerheads are caught throughout Madagascar. In the southwest Toliar region, substantial catches of immature Scalloped Hammerhead from 2001–2002 were reported from the target shark fisheries and hammerhead sharks (*Sphyrna* spp.) represented 29% of the sharks caught by number (McVean *et al.* 2006). Also in this region, in later years from 2007–2012 , hammerhead sharks were still reported to dominate catches and species-specific data revealed Scalloped Hammerhead accounted for 31% of the shark catch (Humber *et al.* 2017). At least 95% of the Scalloped Hammerheads were juveniles (Humber *et al.* 2017).

Off the east coast, Scalloped Hammerhead are captured in the pole and line fisheries (Cripps *et al.* 2015). In the north, the species is taken in an artisanal fishery that targets sharks with hammerhead sharks (*Sphyrna* spp.) accounting for 24% of the shark catch and Scalloped Hammerhead the dominant species of hammerhead shark. Over 96% of the Scalloped Hammerheads were immature (Miller *et al.* 2014). In Antongil Bay, in the northeast, Scalloped Hammerhead is the dominant shark landed in target shark fisheries with adults, including pregnant females, and juveniles captured, suggesting this may be a breeding area for the species (Miller *et al.* 2014).

Oman

Shark catches were reported from the Oman industrial fleet operating in the IOTC Area of Competence from 2011–2020 and during this period there were no hammerhead shark captures (IOTC 2021c).

Pakistan

An estimated 29 t of hammerhead shark (*Sphryna* spp.) was landed in Pakistan annually from 2013–2015 with most of the catch from the gillnet fishery (Rice 2017).

Seychelles

In the Seychelles fleets operating in the IOTC Area of Competence from 2016–2020, 29 generic 'hammerhead sharks' were caught in the industrial longline fleet, 24 generic 'hammerhead sharks' were caught in the semi-industrial longline fleet, and 2 'hammerhead sharks' were released during 2019–2020 (IOTC 2021c).

Somalia

Hammerhead sharks (*Sphyrna* spp.) was estimated to account for 15% of the small-scale shark and ray catches from 1950–2010 (Persson *et al.* 2015).

Sri Lanka

In the Sri Lankan fleet operating in the IOTC Area of Competence from 2015–2020, 242 kg of Scalloped Hammerhead were retained; no information was reported on Scalloped hammerhead releases (IOTC 2021c). Scalloped Hammerhead catches were elsewhere reported as 110 t, 79 t, and 119 t in 2011, 2012, and 2013 respectively with no concurrent information on retention or discards (Rice 2017). Further, a total of 1,057 t of Scalloped Hammerhead was reported caught in Sri Lankan waters from 2005–2015 (NDF 2016). Hammerhead sharks account for 11% of total shark catches taken within Sri Lankan waters with Scalloped Hammerhead representing most (64%) of the hammerhead shark catch (NDF 2016).

South Africa

Shark catches were reported from the South African fleet operating in the IOTC Area of Competence from 2010–2020 and during this period there were no hammerhead sharks retained. Shark discards in 2020 included the release of 47 Scalloped Hammerheads with 62% of these alive when released (IOTC 2021c).

Thailand

In Rangong Province, Andaman Sea, 25 Scalloped Hammerhead were recorded from two main landing sites from 2014–2015, which represented approximately 1% of total landings (Arunrugstichai *et al.* 2018). A severe decline in Scalloped Hammerhead from 2005 when they represented 20% of the total landings, was postulated. However, the differences may be due to changes in fishing effort and practice and different ports surveyed (Arunrugstichai *et al.* 2018).

United Kingdom

Shark catches were reported from the United Kingdom fleet (only longline vessels) operating in the IOTC Area of Competence from 2009–2020 and during this period only 0.1 t of Scalloped Hammerhead was reported as caught in 2009 (IOTC 2021c).

3.2.3 Gillnet Fisheries

The Scalloped Hammerhead is considered most susceptible to capture in gillnet fisheries in the Indian Ocean and it has very high mortality rates in gillnets (Ellis *et al.* 2017; Murua *et al.* 2018). Gillnets are also the main gear catching all sharks in the IOTC accounting for 56% of the total shark catches (Murua *et al.* 2018). The species composition of the shark catch is not well known however, estimates from Pakistan indicated that Scalloped Hammerhead represents 5% of the total shark catch in gillnets (Shahid *et al.* 2016). Drift gillnets are used by approximately 21 countries in the Indian Ocean and account for approximately 40% of total shark catches, although data are sparse and generally of low reliability (Shahid *et al.* 2021).

Gillnet fisheries effort in the IOTC has increased significantly over the past few decades with the expansion mainly by coastal states including Iran, India, Indonesia, Pakistan, Sri Lanka, and Oman (Martin and Shahid 2021). In 2012, Iran had the largest fleet of drift gillnets with nearly 6,000 vessels ranging in length from 10 m to 40 m (Ardill 2012). Very large nets are used in some areas with lengths of 7–12 km reported by the Pakistan fleet and net lengths up to 30 km reported elsewhere and although IOTC management measures have recently been introduced to limit their length, non-compliance has been reported (Ardill 2012; Martin and Shahid 2021) (see 4.1.1 IOTC CMMS). The gillnets generally used in the Indian Ocean do not have mesh size regulations for their target catch but rather consist of several net panels with varying mesh sizes and low hanging ratios (Martin and Shahid

2021). Low hanging ratio nets have meshes with narrow openings that entangle fish across a wide range of sizes which is one of the major factors affecting catches and thus, makes the gillnets highly non-selective. Gillnet fisheries poses a significant threat not just to Scalloped Hammerheads but to all bycatch in the nets fisheries due to the large nets, long soak times of up to 12 hours, poor catch and effort data, increasing effort, limited observer coverage, and non-compliance with management measures (Moazzam and Khan 2019; Martin and Shahid 2021).

3.2.4 IUU and Piracy

Illegal, unreported, and unregulated (IUU) fishing is at relatively high levels in the Indian Ocean with IUU catches estimated to account for 32% of the Eastern Indian Ocean (FAO Area 57) region's catch (Agnew *et al.* 2009). In the western Indian Ocean, in the early 2000s, approximately 120–200 longline vessels were operating illegally in coastal waters mainly targeting hammerhead sharks (*Sphyrna* spp.) and giant guitarfish (*Rhynchobatus* spp.) (Dudley and Simpfendorfer 2006). Also in the early 2000s, approximately 700 vessels were operating in Somalia waters in unregulated fishing and were targeting sharks among other species (HSTF 2006).

Piracy in the northwest Indian Ocean region caused displacement of a significant portion of the longline fleet effort from that region to the south and east Indian Ocean (IOTC 2021a). Piracy still continues but increased security on board some longline vessels has seen them return to the northwest Indian Ocean tuna fishing areas (IOTC 2021a).

3.2.5 Shark Control Program

Scalloped Hammerheads are taken in shark control programs (SCP) that target large sharks to provide protection for beach users. The Scalloped Hammerhead has high mortality rates in the SCP nets and drumlines. In the Indian Ocean, SCPs are in place in South Africa and Reunion Island. In South Africa, midwater gillnets are used and from 2013–2017, the annual average catch of Scalloped Hammerhead was 68.8 animals with 1.2% of these released alive and an average annual mortality rate of 98.8% (not including post-release mortality) (KZNSBP 2022).

In Reunion Island, the SCP uses a modified drumline known as a SMART drumline (Shark Management Alert in Real Time). These were trialled to reduce the impact of the SCP on non-target and undersized target sharks (Guyomard *et al.* 2019). From 2014–2017, 24 Scalloped Hammerhead were caught with 46% released alive and 54% released dead or in weak condition with some individuals dead within minutes of being hooked (Guyomard *et al.* 2019). The mean response time to enable Scalloped Hammerheads to be released alive was 40 minutes but by a mean of 61 minutes they were either dead or too weak to be released. Scalloped Hammerheads are among the species captured in the Reunion Island SCP with the lowest survival rates (Guyomard *et al.* 2019).

In Western Australia, a Shark Mitigation Strategy has been implemented that includes five beach net enclosures that are not nets but rather a physical barrier that covers the entire water column and prevents sharks from entering the enclosed area. A SMART drumline trial was not found to be satisfactory as a shark mitigation measure in WA and has not been implemented (Western Australian Government 2022).

3.2.6 Habitat Degradation

Inshore, coastal habitats preferred by juvenile and subadult Scalloped Hammerheads are subject to habitat loss and degradation from anthropogenic activities that threatens these animals. The extent of the impact to Scalloped Hammerheads in the Indian Ocean is unknown. Other pollutants and contaminants (e.g. heavy metals) may cause sublethal effects and lower levels of mortality. Scalloped Hammerheads caught in artisanal fisheries in Djibouti in 2016–2018 contained organochlorine compounds and trace elements although the effect of these on the animals is unknown (NOAA 2020b). Total mercury levels at concentrations above those safe for human consumption were found in Scalloped Hammerheads collected from the Kwazulu-Natal South Africa beach protection nets from 2005–2010 (NOAA 2020b).

3.2.7 Climate Change

The Scalloped Hammerhead may be threatened by climate change that may affect water temperatures, currents, and possibly trophic dynamics (NOAA 2020b). For example, in South Africa, a general shift in currents across the southern Cape over the past few decades linked to climate change has reduced available habitat for some elasmobranchs and may have caused changes in their distributions (Riley *et al.* preprint). The threat of climate change was assessed for a range of elasmobranchs, including the Great Hammerhead but not the Scalloped Hammerhead, on Australia's Great Barrier Reef (GBR) (Chin *et al.* 2010). The assessment considered effects of climate change predicted to occur over the next 100 years on the GBR and included climate change factors of water temperature, ocean acidification and circulation, freshwater input, sea level rise, and light and UV radiation. The Great Hammerhead was ranked with a low vulnerability to climate change essentially as it has a wide distribution, occurs in a range of different habitats, and feeds on a variety of prey (Chin *et al.* 2010). This is likely to be similar for the Scalloped Hammerhead as its range and ecology is similar to that of the Great Hammerhead, however, it does not preclude more localised climate change impacts to inshore habitats and pelagic habitat hotspots, and climate change impacts are an area of ongoing research.

4.0 Management Measures and Practices

4.1 Legal Instruments

4.1.1 IOTC CMMS

There are no IOTC Conservation and Management Measures (CMMs) that are specific to hammerhead sharks, however the measures of some other CMMs (in the form of Resolutions) are relevant, notably for the regional observer scheme, the precautionary approach, data collection, mandatory recording and reporting, Fish Aggregation Devices (FADs), shark finning ban, prohibition on large-scale driftnets, mandatory sub-surface setting of gillnets, and optional phasing out of gillnets (Table 2). The IOTC Regional Observer Scheme (ROS) requires 5% coverage for each gear type by fleet (Res. 11/04), however only a limited number of CPCs are reaching this level of coverage (IOTC 2021g) . While there is species-specific reporting mandated for some shark species, hammerheads sharks are not required to be reported at a species-specific level nor for all gear types. The generic level of 'hammerhead sharks (*Sphyrna* spp.)' is only required to be reported and only for longline and gillnet and not for purse seine and pole and line as detailed in Res. 15/01 (IOTC 2021b).

There are retention bans in the IOTC for Thresher Sharks (Res. 12/09), Whale Sharks (Res. 13/05), Oceanic Whitetip Sharks (Res. 13/06), and Mobulids (Res. 19/03). These bans require the prompt release unharmed of the elasmobranchs and that no individuals shall be retained on board, transhipped, landed, stored, sold or offered for sale. Whale Sharks require the use of best practice safe release and handling guidelines developed by the IOTC Scientific Committee. The Oceanic Whitetip Sharks Res. 13/06 specifies that as its easily identified, this species can be released before being taken on board. The Resolution is applicable to all flagged vessels authorised to fish for tuna or tuna-like species managed by the IOTC on the high seas. Exempt from the retention ban are artisanal fisheries which operate entirely in the EEZs and in the case of some CMMs, use the catch for local consumption. There is also a CMM for Blue Shark (Res. 18/02) to encourage recording, reporting and research on life history, critical habitats, post-release mortality, and, guidelines for safe release.

Table 2: IOTC CMMS relevant to Scalloped Hammerhead

Instrument	Description
IOTC Indian Ocean Tuna Commission	**Res. 11/04:** On a regional observer scheme. requires 5% coverage for each gear type by fleet. **Res. 12/01**: On the implementation of the precautionary approach **Res. 12/02:** On data confidentiality policy and procedures for catch and effort, length frequency, and observer data. **Res. 13/06:** On a scientific and management framework on the conservation of shark species caught in association with IOTC managed fisheries. **Res. 15/01 and 15/02**: On mandatory recording and reporting of shark catch data which is for hammerheads is from longline and gillnet gear and at the level of *Sphyrna* spp. **Res. 15/09:** On a fish aggregating devices (FADs) working group. **Res. 16/07:** On the use of artificial lights to attract fish. **Res. 17/05**: On the conservation of sharks caught in association with fisheries managed by IOTC including a ban on shark finning. **Res. 17/07:** On the prohibition to use large-scale (>2.5 km) driftnets on the high seas to be extended to the entire IOTC Area of Competence, including EEZs in 2022. **Res. 18/07**: On measures applicable in case of non-fulfilment of reporting obligations in the IOTC. **Res. 19/02**: On FADs management plan, restriction on total number of FADs and all FADs must be non-entangling and biodegradable by 2022. **Res. 21/01**: On rebuilding yellowfin tuna stocks, includes mandatory sub-surface (2 m depth) setting of gillnets to be fully implemented by 2023, optional phasing out of gillnets or conversion to other gears, increase in observer coverage or field sampling to 10% to be fully implemented by 2023.

4.1.2. IOTC Gillnet Management Measures

In 2017, the IOTC implemented a prohibition on the use of large-scale (>2.5 km) drift gillnets on the High Seas which is to be extended in January 2022 to the entire IOTC Area of Competence, including EEZs (Res. 17/07). Pakistan, which is one of the IOTC CPCs with the highest drift gillnet effort has objected to this Resolution (Shahid et al. 2021). There have been lengthy delays in the objection as well as implementation into national legislation. The IOTC has also mandated gillnets be set sub-surface (2 m) which is to be fully implemented by 2023 (Res. 21/01). This Res. 21/01 also includes optional phasing out of gillnets or conversion to other gears, and an optional increase in observer coverage or field sampling to 10% to be fully implemented by 2023. The implementation of gear restriction measures need to be incorporated into national legislation of most CPCs to enable legal provision (Martin and Shahid 2021).

In Pakistan, the gillnet fleet adopted sub-surface gillnet (1.4–2 m) setting from 2014 with the entire fleet using this method by 2016 (Moazzam 2019). Observed shark catches, including Scalloped Hammerhead, reduced by an average 15% with the use of sub-surface gillnets, with the exception of some species such as Shortfin Mako whose catches increased by 9% (Moazzam 2019). The observed shark catches were compared between 2013 and 2018 with data from crew based observers on 4 tuna gillnet vessels in 2014 and 30 tuna gillnet vessels in 2018 (Moazzam 2019). The effectiveness in reducing bycatch mortality of Scalloped Hammerheads by sub-surface gillnet setting needs further investigation.

4.1.3 IOTC Shark Finning Measures

The IOTC shark finning measure (Res. 17/05) require fins remain naturally attached until the first point of landing for sharks landed fresh and that the total weight of shark fins on board not exceed 5% of the weight of sharks on board for frozen sharks. It also encourages progressive implementation of the fins naturally attached provision to all shark landings. Live release is encouraged for all sharks taken as bycatch while targeting other species.

The implementation of this measure should have helped improve the species-specific identification of fresh landed fins. It would certainly assist with hammerhead shark fin identification if species-specific records of hammerheads were reported. Fins from all hammerhead species have a characteristic shape that is much taller than broad and a dull brown or light grey colour that distinguishes them from fins from other shark species (Abercrombie and Chapman 2008). However, separating the species of hammerhead sharks based on their fins is difficult. Fin identification guides indicate that Scalloped Hammerhead and Smooth Hammerhead first dorsal fins are visually almost indistinguishable while the Great Hammerhead first dorsal fin is distinct from the other two species (Abercrombie and Chapman 2008; Abercrombie *et al.* 2013; Marshall and Barone 2016). The fin traders in Hong Kong can separate hammerhead shark fins from other shark species, and usually group Scalloped and Smooth Hammerhead together and separate from Great Hammerhead (Clarke *et al.* 2006). The Winghead Shark dorsal fins are very similar in height, fin shape, and colour to those of Great Hammerhead and in height and fin shape to Scalloped Hammerhead, and it is difficult to differentiate the three species (Abercrombie and Chapman 2008; Heupel et al. 2016; Marshall and Barone 2016).

The effectiveness of the IOTC measure in preventing shark finning was reviewed with the conclusion that the current reporting requirements were not sufficient to be able to assess the level of compliance with the finning measure (Clarke 2018). The review did suggest that the quantity of fins transhipped has declined in recent years from the maximum quantities reported in 2010–2011 which may reflect the global trend of a decline in the shark fin market that began in 2012 (Clarke 2018).

Landing sharks with fins naturally attached is preferable for data collection and enforcement. The use of the 5% fin-to-carcass ratio can create problems with species identification and thus enforcement of measures such as CITES and retention bans. It can also lead to high grading at sea, that is, replacement of low value fins with high value fins such as those from hammerhead sharks (Cosandey-Godin and Morgan 2011).

4.1.4 Retention Bans

Retention bans are a measure that can help raise awareness of threatened bycatch species and are relatively easy to enforce (Martin and Shahid 2021). However, their effectiveness in reducing shark mortality varies by species. To provide a significant reduction in mortality, the at-vessel mortality (AVM) and post-release mortality (PRM) of the species must both be low, compliance levels need to be high, and any exemption such as artisanal fisheries should not comprise a significant proportion of the catch (Martin and Shahid 2021). The Scalloped Hammerhead has high AVM and PRM for gillnets, longlines, and purse seine gears and thus, while a retention ban may reduce landings it does not prevent capture, and it is more likely to be effective if it is complemented by other measures that reduce Scalloped Hammerhead mortality in the Indian Ocean (Martin and Shahid 2021). These measures include avoidance, catch mitigation, and improvement to PRM through safe handling and release practices, and are discussed in Section 4.2.1 Bycatch Avoidance and Mitigation.

4.1.5 Multilateral Environmental Agreements

IOTC CPCs are also signatory to international conventions and treaties that have implemented measures for sharks and rays, including Scalloped Hammerhead (Table 3).

Table 3: Multilateral Environmental Agreements relevant to Scalloped Hammerhead.

Instrument	Description	IOTC CPCs signatory
Barcelona Convention Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean	**Annex II**: Endangered or threatened species; Parties shall ensure the maximum possible protection and recovery of, while prohibiting the damage to and destruction of, these species.	France, European Union.
CCSBT Commission for the Conservation of Southern Bluefin Tuna	CCSBT encourages both CPCs and Cooperating Non-CPCs to comply with a variety of binding and non-binding measures in order to protect species ecologically related to Southern bluefin tuna, including sharks.	Australia, European Union, Indonesia, Japan, Philippines, Republic of Korea, South Africa.
CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora	**Appendix II**: Species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilization incompatible with their survival.	All IOTC CPCs.
CMS Convention on the Conservation of Migratory Species of Wild Animals	**Appendix II**: Migratory species that have an unfavourable conservation status and need or would significantly benefit from international cooperation; CMS Parties shall endeavour to conclude global or regional agreements to benefit these species.	All IOTC CPCs are Parties or Non-Party range states.
CMS Sharks MOU Memorandum of Understanding on the Conservation of Migratory Sharks	**Annex 1**: Signatories should endeavour to achieve and maintain a favourable conservation status for these species based on the best available scientific information and taking into account their socio-economic value.	All IOTC CPCs are Signatory or Range States.
UNCLOS	**Annex I**: States whose nationals fish in the region for the highly migratory species listed in Annex I shall cooperate	All IOTC CPCs.

United Nations Convention on the Law of the Sea (Implementing Agreement 1994)	directly or through appropriate international organizations to ensure the conservation and optimum utilization of such species throughout the region, both within and beyond the exclusive economic zone.	
EU European Union	**Council Regulation (EU) 2017/127:** prohibits to fish for, to retain on board, to transship or to land both hammerhead species for Union vessels in the ICCAT Convention Area.	European Union.
FAO Food and Agriculture Organization	**IPOA Sharks:** International Plan of Action for Conservation and Management of Sharks based on which states should adopt and implement a national plan of action for conservation and management of shark stocks (NPO Sharks) if their vessels conduct directed fisheries for sharks or if their vessels regularly catch sharks in non-directed fisheries.	All IOTC CPCs.
SWIOFC Southwest Indian Ocean Fisheries Commission	Promote the sustainable utilization of the living marine resources of the Southwest Indian Ocean region	Comoros, France, Kenya, Madagascar, Mozambique, Seychelles, Somalia, South Africa, Tanzania, Yemen.
IORA Indian Ocean Rim Association	Inter-governmental organisation aimed at strengthening regional cooperation and sustainable development within the Indian Ocean region.	Most IOTC CPCs.
GFCM General Fisheries Commission for the Mediterranean	**Rec. GFCM/36/2012/3**: shark species listed under Annex II of the Barcelona Convention cannot be retained on board, transshipped, landed, transferred, stored, sold or displayed or offered for sale and must be released unharmed and alive to the extent possible.	European Union, France.
NAFO Northwest Atlantic Fisheries Organization	In order to safeguard the marine ecosystems in which the Convention Area's fisheries resources are found, NAFO develops and adopts conservation and enforcement measures to protect shark species in its region.	European Union, France, Japan, Republic of Korea.

The only tuna Regional Fisheries Management Organisations to have a specific measure on Scalloped Hammerhead is the International Commission for the Conservation of Atlantic Tunas (ICCAT). In 2010, ICCAT prohibited the retention, transshipment, landing, and sale of Scalloped Hammerheads (and other hammerhead shark species) for ICCAT fisheries operating in the Convention Area (Recommendation 10-08). There are exceptions for local consumption in developing countries, provided they cap catches, meet catch data reporting requirements, and ensure fins are not traded internationally.

As noted in Rigby *et al.* (2019a), the Western and Central Pacific Fisheries Commission (WCPFC) designated the Scalloped Hammerhead as a 'key shark species' in 2010, but has yet to adopt Scalloped Hammerhead catch limits. Several proposals to ban hammerhead shark landings and/or set regional hammerhead shark fishing limits through the Inter-American Tropical Tuna Commission (IATTC) have been defeated. The Indian Ocean Tuna Commission (IOTC) has yet to act on 2018 scientific advice to adopt Scalloped Hammerhead fishery management measures.

CITES

The Scalloped Hammerhead was listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 2014 in recognition of the need to regulate international trade to ensure that such trade does not threaten its survival in the wild. To meet the CITES Appendix II listing provisions, international trade in Scalloped Hammerhead products can only occur if they are legally acquired and a Non-detriment Finding (NDF) has been done and finds that such trade will not be detrimental to the survival of the species (Mundy-Taylor *et al.* 2014). Some IOTC CPCS have completed an NDF for hammerhead sharks, such as Australia, India, Seychelles, and Sri Lanka (Okes and Sant 2022). Senegal has been noted as having hammerhead catches prior to the Scalloped Hammerhead listing in 2014 and has records of hammerhead trade in the CITES Trade Database but there is no NDF publicly available, and while there is no obligation to share NDFs, CITES Parties are encouraged to do make them publicly available (Okes and Sant 2022). Similarly, Scalloped Hammerhead likely originating in Oman are being traded at United Arab Emirates auction sites and it is not known if Oman has a hammerhead NDF (Okes and Sant 2022).

Scalloped Hammerheads taken on the high seas and landed also require an NDF prior to international trade. As all IOTC CPCs share the Scalloped Hammerhead Indian Ocean stock, and there is limited capacity in some CPCs, a regional NDF facilitated by IOTC could enable legal exports of Scalloped Hammerhead products (so long as it finds trade is non-detrimental).

The IOTC has sought to improve the information, implementation, capacity, and regional co-operation for CITES listed elasmobranchs in the Indian Ocean. A IOTC/CITES data mining workshop was held and a data request to all IOTC CPCs was made for their national catch and trade data on CITES listed sharks, including Scalloped Hammerhead with eight of the 31 CPCs responding (Rice 2017). Implementation of CITES shark listings by IOTC CPCs is generally poor and limited by a number of factors in addition to a lack of capacity and resources. These include sub-regional undocumented trade, for example, between Iran and Pakistan, and between Kenya and Somalia; and non-specific reporting of shark exports in some regions, for e.g. shark fin is exported as dried fish (Rice 2017).

National Plans of Action

Half of the IOTC CPCs have produced National Plans of Actions for Sharks (NPOA-Sharks) that aim to ensure the conservation and management of sharks and their long-term sustainable use (IOTC 2021f) (Table 4). Parties with an NPOA-Sharks draft or in preparation are Bangladesh, India, Kenya, Madagascar, Mozambique, Oman (Sultanate of,), Pakistan, Senegal, and Somalia (IOTC 2021f). It is difficult to gauge the effectiveness of an NPOA-Sharks with respect to providing Scalloped Hammerhead protection as it depends not only on whether an IOTC Member has instigated shark protection, such as in the Maldives, but also on the level of compliance and enforcement and social acceptance of the measure.

Table 4: IOTC CPCs with a National Plan of Action-Sharks. Status information extracted from IOTC 2021f.

IOTC CPCs	Comments – latest year of NPOA-Sharks	Status
Australia	2012	2nd NPOA-Sharks (Shark-plan 2) was released in July 2012, along with an operational strategy for implementation.
European Union- RPOA	2009	Approved on 05-Feb-2009 and it is currently being implemented.
France (EU) RPOA	2009	Approved on 05-Feb-2009.
Indonesia	2015	Indonesia has established an NPOA for sharks and rays in 2015-2019.
Japan	2016	NPOA–Shark assessment implementation report submitted to COFI in July 2012 (Revised in 2016).
Malaysia	2014	A revised NPOA-sharks was published in 2014.
Maldives	2015	The NPOA-Sharks is in the finalization process and is expected to be published in November of 2014. The longline logbooks ensure the collection of shark bycatch data to genus level. Maldives would be reporting on shark bycatch to the appropriate technical Working Party meetings of IOTC.
Mauritius	2015	The NPOA-sharks has been finalised; it focuses on actions needed to exercise influence on foreign fishing through the IOTC process and licence conditions, as well as improving the national legislation and the skills and data handling systems available for managing sharks.
Philippines	2009	Under periodic review.
Republic of Korea	2011	Currently being implemented.
Seychelles	2016	Seychelles has developed and is implementing a new NPOA for Sharks for years 2016-2020
Sri Lanka	2018	An NPOA-sharks has been finalized and is currently being implemented.
South Africa	2018	The NPOA-sharks was first approved and published in 2013. A review is now being undertaken with cooperation from several International and National experts in order to update the NPOA.
Taiwan, ROC	2012	No revision currently planned
Thailand	2020	An updated NPOA Sharks has been developed for the years 2020-2024 and has been submitted to the Secretariat and FAO.

4.2 Bycatch Management Approaches

The IOTC has adopted a number of CMMs addressing the management of threatened species taken as bycatch in IOTC target fisheries with most of these focussed on non-retention with some mitigation measures (Martin and Shahid 2021). An extensive and thorough review of these measures, their effectiveness, and approaches to bycatch management has recently been conducted by Martin and Shahid (2021) who provided a series of recommendations to improve their implementation and effectiveness, some of which are included as 'Actions' in Section 6.3 Actions. A summary of recommendations from their discussions on bycatch management approaches are included here as they are relevant to Scalloped Hammerhead and were (Martin and Shahid 2021):

- Direct management approaches should consider incentives for fishery operators to find other ways to reduce bycatch and work towards performance standards for bycatch species which require vessels to meet a standard, e.g. a bycatch quota or rate which tend to create stronger and more direct incentives.
- Fishers should be more actively involved in the management of bycatch species, especially in the development of appropriate mitigation measures as this utilises their in-depth knowledge of the fisheries in which they operate to develop methods that are appropriate, effective, and will be accepted in the long-term; an approach that has proven effective in many areas.
- A combination of approaches beyond direct top-down management should be explored, including an increased focus on voluntary initiatives.

Monitoring, Control, and Surveillance(MCS)

The IOTC has multiple Resolutions related to MSC activities as outlined in IOTC (2019). Res. 15/01 includes the intent to collect bycatch data but the MSC activities related to logbook keeping and reporting have largely not been met as described by IOTC (2019). There appear to be no other MSC measures specified in relation to bycatch and or shark species. The IOTC recently established a Working Group for the development of electronic monitoring programme standards which is focussed on IUU fishing and ensuring transhipments are reduced but it is cross-cutting and could be relevant to bycatch and Scalloped Hammerhead catches in the future (U. Shahid pers. comm. 2022).

4.2.1 Bycatch Avoidance and Mitigation

In the Indian Ocean there have not been many measures applied to mitigate interactions with bycatch (Martin and Shahid 2021). The IOTC has requested CPCs undertake research that can help implement more effective bycatch mitigation measures in Resolution 17/05 on the 'Conservation of Sharks Caught in Association with Fisheries Managed by IOTC' where CPCs are encouraged to '*identify ways to make fishing gears more selective, where appropriate, including research into the effectiveness of prohibiting wire leaders*' and to '*improve handling practices for live sharks to maximise post-release survival*'. It also encourages research to '*identify key shark mating, pupping and nursery areas*' and to '*improve knowledge on key biological/ecological parameters, life-history and behavioural traits, migration patterns of key shark species'*. If this research was undertaken by the CPCs and then the outcomes implemented through gear regulations, improved handling practices, protection of critical habitats, and improved AVM and PRM, it could lead to marked reductions in shark mortality, including mortality of Scalloped Hammerheads.

Martin and Shahid (2021) (page 40) neatly summarised criteria for effective bycatch mitigation measures as: '*effective in reducing unwanted catches to nominal levels, practical, safe, economically viable, require minimal alteration to traditional gear, tolerant of crew behaviour, easy to monitor and enforce, incorporate measurable performance standards and will not cause increased bycatch of another species*.' These criteria are useful for guiding the development and implementation of mitigation measures for Scalloped Hammerheads.

The best strategy for protection of threatened target and bycatch species is to reduce the interaction between the species and fisheries, that is, avoidance measures. However, avoidance is often not possible and thus other mitigation measures are also needed. Scalloped Hammerheads should ideally remain in the water once caught and while released, however, this is often not logistically feasible. Reducing the fight time, for example by using lighter gear, and also reducing the time a Scalloped Hammerhead spends in the gear once caught (soak time) can also reduce stress and improve PRM once released. Proper handling and quick release also improve PRM (Zollett and Swimmer 2019). Along with avoidance, these measures are briefly discussed in the following sections, that is: policy and management measures which include safe handling and release practices; gear changes; and spatial and temporal closures. Bycatch avoidance and mitigation is an area where technological advances are ongoing and can play an important role. This topic has been extensively researched and only a brief summary is provided here.

Avoidance

Avoiding catching Scalloped Hammerheads is the most effective measure to reduce their mortality, however it is difficult to investigate and implement, and has rarely been attempted for pelagic and semi-pelagic sharks and rays. Other than spatial closures which are discussed below, suggested measures are not setting on FADs with high shark densities in purse seines and temperature avoidance in longlines (Cosandey-Godin and Morgan 2011).

Purse seine bycatch mitigation approaches are being tested by the International Seafood Sustainability Foundation (ISSF) with one of them the use of acoustic instruments when arriving at a FAD to avoid setting if there are many sharks present. Additionally, it has been found that bycatch-to-catch ratios were always highest when tuna catches were small, and consequently avoidance of setting on small schools of tuna (e.g. < 10 t) was found to reduce the amount of bycatch by 23-43% and reduce the number of Silky Sharks by 21-41% (Ardill 2012; MADE 2012). Whether this is also the case for Scalloped Hammerheads needs investigation.

Longline fishers have commented that setting gear in certain water temperatures can reduce shark bycatch levels, such as setting on the colder side of fronts. However, this requires significant further investigation of shark species, including Scalloped Hammerhead, water temperature preferences and thermal dynamics (Cosandey-Godin and Morgan 2011).

Policy and Management Measures

These measures include: limiting fishing effort, catch and shark size limits, banning shark finning (see 4.1.3 IOTC Shark Finning Measures), safe handling and release practices, and spatial closures. The latter two are discussed briefly below.

Safe Handling and Release Practices

Improved handing practices for sharks landed live and to be released can maximise survival and lead to high survival rates if the sharks are landed in good condition. Handling and release guidelines for Scalloped Hammerheads in United States fisheries provides general guidelines to improve their survival (NOAA 2020a). The European purse seine fleets implemented these safe handling and release practices in 2014 which has improved the post-release mortality (PRM) for pelagic shark species (Murua *et al.* 2018). A safe handling and release guide for gillnet fisheries in the IOTC, which included

Whale Sharks, was recently released by WWF-Pakistan (WWF-Pakistan 2020). A recent review of safe handling and release guidelines for sharks in tuna fisheries summarises the basic tenets of safe handling for sharks and humans and references available guides (Zollett and Swimmer 2019). Most shark handling guides have been developed for longline and purse seine fisheries with no specific guidelines for gillnets however purse seine guides can be relevant for gill nets. With respect to longlines recent work has focussed on removing as much trailing line as possible from hooked and released sharks (Martin and Shahid 2021). Safe shark handling and release guidelines have been developed for fisheries in other ocean basins and could be adopted in the IOTC for Scalloped Hammerheads. (ABNJ 2018; Murua *et al.* 2021). A good source of guides and information is the Bycatch Management Information System (https://www.bmis-bycatch.org/).

Spatial closures

Spatial closures can be permanent and are often referred to as Marine Protected Areas (MPAS) or seasonal/temporal and/or dynamic closures. Marine Protected Areas (MPAs) can be highly effective in protecting sharks from the major threats of overfishing and habitat loss, and halting population decline, promoting recovery, and long-term sustainability. Improved conservation of sharks can also lead to improved functional food webs and healthy ecosystems. Within the Indian Ocean, there are a wide variety of existing MPAs within national waters ranging in size from small, local MPAs to the very large 640,000 km^2 Chagos Marine Protected Area. In 2021, the Western Indian Ocean Great Blue Wall initiative was launched to establish a network of marine and coastal conserved areas to benefit both biodiversity and local livelihoods. This initiative may encourage and support the implementation of effective MPAs.

Scalloped Hammerheads currently benefit from MPAs in various countries. It is a good candidate for spatial protection as it aggregates in critical habitats at different life stages. For e.g. in Fiji, the Rewa River estuary MPA is an important nursery aggregation site; the Darwin and Wolf Marine Sanctuary no-take marine reserve within the larger Galapagos Marine Reserve protects aggregations of Scalloped Hammerheads; and Malpelo Fauna and Flora Sanctuary, Colombia provides protection for Scalloped Hammerheads that exhibit seasonal site fidelity to the area (Bessudo *et al.* 2011a; Salinas de León *et al.* 2016; Marie *et al.* 2017).

Some of the existing Indian Ocean MPAs may provide protection for Scalloped Hammerheads such as the Pondoland Marine Protected Area in South Africa that provides some protection to juvenile and subadult Scalloped Hammerheads when they are resident in the area (Diemer *et al.* 2011). However, protection of other critical habitats of Scalloped Hammerheads could begin to halt their decline and promote recovery. Some critical habitats have been identified in the Indian Ocean such as nursery areas in Tulega Banks off northern KwaZulu-Natal, South Africa; potential breeding areas in Antongil Bay, Madagascar; and possible migratory routes along the South African east coast (see Section 1.5 Critical Habitats for Scalloped Hammerhead). Seamounts are known aggregation sites for adult Scalloped Hammerheads. These could all be candidates for possible MPAs. Further work is needed to identify other Scalloped Hammerhead critical habitat areas within the Indian Ocean and where possible, to implement and designate appropriate areas as MPAs using best practice guidelines for effective shark and ray MPAs (Rigby *et al.* 2019b).

Habitat hotspots, or predictable areas of occurrence, have been observed for some pelagic sharks, including the Great Hammerhead, in the Atlantic Ocean. These hotspots are in areas of seasonally shifting strong gradients, or fronts, in sea surface temperature and high primary productivity (Queiroz *et al.* 2016). Such hotspots likely also exist in the Indian Ocean. Any spatial closures may incur costs to the tuna fisheries but these may be minimized if habitat hotspots are distinct from high tuna catch areas. For example, in the eastern Pacific, there were areas of temporally persistent high bycatch of small Silky Sharks possibly associated with parturition grounds that were spatially distinct from high tuna catch areas, and thus could be appropriate candidate areas that would reduce the pelagic shark bycatch with the least loss of targeted tuna catch (Watson *et al.* 2009)

In the Indian Ocean, high spatial overlap areas between pelagic sharks and pelagic longline fishing vessels included the Agulhas Current, Mozambique Channel, South Australia, and northwest Australia (Queiroz *et al.* 2019). While generally indicative of areas of concern, the data used for the Indian Ocean did not include hammerhead sharks.

Also in the Indian Ocean, areas of increased pelagic shark biodiversity are apparent off the Somali Peninsula and in the Mozambique Channel and could be potential pelagic MPAs, although more investigation is required to determine if Scalloped Hammerheads occur in these areas and if so, whether they shift seasonally and if seasonal MPAs could be appropriate (MADE 2012). In the South African pelagic longline fishery, temporary spatial closures were more effective than permanent and seasonal closures for reducing shark bycatch and minimizing the cost to the fishery (Grantham *et al.* 2008).

Gear bycatch mitigation

Any potential mitigation measures for Scalloped Hammerheads need to also be considered in relation to the impact on target catches and on other bycatch species, for example, the impacts of sub-surface gillnet setting on mobulids (captured) and circle hooks on turtles (reduces capture rates) (Swimmer *et al.* 2020) (S. Shahid pers. comm. 2022).

Gillnets

Gillnets in the Indian Ocean are mostly panels with varying mesh sizes and low hanging ratios (See Section 3.2.3 Gillnet Fisheries). Mesh size regulation suited to the target species and moving away from low hanging ratios along with twine material that increases its visibility would improve the selectivity of the gillnets and reduce bycatch. They also appear to have long soak times of up to 12 hours which dramatically increases the mortality of bycatch and in particular Scalloped Hammerheads. Much shorter soak times may improve the mortality of Scalloped Hammerhead captured in the nets.

The mandatory sub-surface setting of gillnets has reduced the observed catches of sharks by 15% (Moazzam 2019) but effectiveness in reducing bycatch mortality of Scalloped Hammerheads needs further work.

Bycatch mitigation using gillnet illumination, different gear settings such as tensioning the net, use of acoustic deterrents, and electromagnetic fields have all had varying degrees of success in reducing shark bycatch in gillnets (Cosandey-Godin and Morgan 2011; Aristi *et al.* 2018; Shahid *et al.* 2021; Senko *et al.* 2022). Scalloped Hammerheads were found to avoid magnetic fields from ferrite magnets on gillnets without any reduction in the target teleost catch (Rigg *et al.* 2009). Recently a workshop in the IOTC has been proposed to address bycatch mitigation measures in gillnet fisheries in the Indian Ocean which would be highly beneficial to elucidate effective mitigation measures for Scalloped Hammerheads (Shahid *et al.* 2021).

Purse seine

The mandated requirement for FADs to be non-entangling and biodegradable and the reduction in the number of FADS (Res. 19/02) is significant progress in reducing bycatch mortality in FADs. Research by ISSF and others continues on other mitigation techniques such as acoustic instruments to avoid setting on schools with high densities of sharks or small schools of tuna (associated with high bycatch ratios), removing sharks prior to brailing which greatly reduces the stress and improves survival, and releasing sharks during the loading process (Ardill 2012; MADE 2012; Martin and Shahid 2021). Mitigation research is investigating deterrents such as bait stations and sound and chemicals to lure sharks away from FADs prior to them being set (Cosandey-Godin and Morgan 2011). Temporal and spatial restrictions on setting on FADs to reduce shark bycatch has been in the Atlantic and Pacific Oceans and could be investigated in the Indian Ocean (Cosandey-Godin and Morgan 2011). The effectiveness of these mitigation measures to reduce Scalloped Hammerhead mortality is not yet assessed.

Longline

A wide range of shark bycatch mitigation measures have been investigated and implemented in longline fisheries and include use of circle hooks, a ban on wire leaders, different hook depths, bait restrictions and use of artificial bait, reducing soak time, minimising the length of trailing gear on released sharks, and repellents (Cosandey-Godin and Morgan 2011; MADE 2012; Martin and Shahid 2021).

Specific to Scalloped Hammerheads was a study that found deeper hook depths (at 45 m) on pelagic longlines significantly reduced mortality, possibly due to the deeper, cooler waters providing higher oxygen levels compared to shallower waters (Gallagher *et al.* 2014). A reduction in soak times of bottom longlines was also suggested as a way to reduce Scalloped Hammerhead mortality with a reduction from >4 hours to 1 hour dramatically improving mortality from >65% to 12% AVM (See Section 3.0 Threats). Although this has practical limitations due to the target fishing soak time, any reduction in soak time to less than 4 hours is likely to be beneficial to Scalloped Hammerheads. The use of lanthanide metals on longline hooks was found to significantly reduce the catch of juvenile Scalloped Hammerheads (Hutchinson *et al.* 2012). A global meta-analysis revealed circle hooks significantly reduce AVM of Scalloped Hammerheads in pelagic longline fisheries (Reinhardt *et al.* 2018), and as such could be an effective mitigation measure for Scalloped Hammerheads in the Indian Ocean.

5.0 Information Gaps

5.1 Biology and Ecology

There is a lack of Scalloped Hammerhead Indian Ocean life history information on age and growth, size and age-at-maturity, and reproductive periodicity. The ERA strongly recommended the collection of regionally specific Scalloped Hammerhead biological information (Murua *et al.* 2018). However, while this regionally specific information is lacking and being collected, biological data from other regions can be used.

Diurnal movements of Scalloped Hammerheads appear to vary among oceans and studies. Indian Ocean specific information would be valuable as these movements can inform gear modifications for bycatch mitigation, for example, deeper or shallower sets.

Stock structure

The stock structure is not clear in the Indian ocean and in-relation to other ocean basins. Further work is needed to elucidate the genetic structure of Scalloped Hammerhead within the Indian Ocean.

Critical habitats

There is limited information on Scalloped Hammerhead critical habitat areas within the Indian Ocean and consideration needs to be given to identifying important aggregation areas and migratory routes that could inform spatial protection measures in the future. Consultation with IOTC CPCs is required to ascertain any local knowledge of such critical habitat areas.

Information on pelagic Scalloped Hammerhead hotspots in the Indian Ocean could inform temporal spatial closures that may reduce mortality of Scalloped Hammerhead, ideally without affecting target species catches.

Stock assessment

Data limitations have precluded a full quantitative stock assessment of Scalloped Hammerhead in the Indian Ocean. It is essential that data are collected to enable a stock assessment (E.U. 2014). A stock assessment is planned for 2022 but due to poor data quality it is likely to be a data poor assessment method. For a stock assessment, catch and effort data, discard data, shark species-specific size-frequency data and length-weight data, and mortality data are needed and has been recommended by the IOTC Scientific Committee to be collected (Clarke 2018). Increased levels of observer coverage and better reporting are likely to be needed in the mid- to long-term.

Mortality estimates

Accurate estimates of natural and fisheries mortality are lacking and are needed to inform reliable stock assessments. Logbook and observer-based species-specific catch estimates along with post-release mortality estimates are needed (Clarke 2018).

5.2 Fisheries

The lack of species-specific catch and biological data are the main data limitations identified for Scalloped Hammerheads in the Indian Ocean. The ERA strongly recommended the collection of observer data on species-specific catches, size-frequency catch data, and post-capture and post-release mortality (Murua *et al.* 2018). Most of these are already mandated in CMMS, however, some such as post-release mortality require the establishment of additional research projects.

Historical catches

Historical catch data are considered to be significantly under-reported for most fleets due to lack of fishery statistics data collection in the earlier years of the fisheries. While reporting requirements have improved over the years, the lack of earlier reliable historical data makes evaluation of catch trends difficult (Martin and Shahid 2021). The IOTC Scientific Committee has recommended improved estimations of historical catch and effort data for sharks since 2010 (Clarke 2018).

Gear mitigation

The CMMs for sharks do not require any shark bycatch mitigation for either gillnets, purse seines, or longlines (Martin and Shahid 2021). Such measures are needed to reduce the mortality of Scalloped Hammerheads being caught in these gears.

Observer data

Observer coverage is inconsistent across the fleets. For some fleets, it is exceeding the required level of coverage while others are not meeting the CMM mandated levels of coverage. Observer coverage does not exist for the gillnet fleets and the artisanal fisheries are not required to have onboard observer coverage (IOTC 2020). A priority is to support the major gillnet fleets to develop an observer scheme (e.g. Iran, Indonesia, India, Sri Lanka) (Martin and Shahid 2021). The IOTC Scientific Committee has recommended that observer levels requested by IOTC (5 %) be implemented (Clarke 2018).

Reporting

Hammerhead sharks are not required to be reported at a species-specific level nor for all gear types. The generic level of 'hammerhead sharks (*Sphyrna* spp.)' are only required to be reported and only for longline and gillnet and not for purse seine and pole and line as detailed in Res. 15/01 (IOTC 2021b). Hammerhead sharks have been identified as vulnerable in IOTC fisheries, including purse seines, and while pole and line fishing is very selective it still may take hammerhead sharks, albeit in limited numbers. Consequently, species-specific catch reporting of hammerhead sharks is needed for all fleets and all gear types, at least until it is determined that Scalloped Hammerheads are not threatened by a gear type.

In observer schemes, all species are to be identified to as low a taxonomic level as possible, and thus for fleets with good coverage, species-specific catch data are collected but not all fleets have good observer coverage or good reporting of the observer data (Martin and Shahid 2021).

The CMM requirements for bycatch species monitoring data and reporting are relatively comprehensive. However, there is low compliance with monitoring and reporting particularly in the resource limited developing coastal nations with small-scale fleets. Some fleets are not reporting bycatch, evident from fleets using similar gears reporting high bycatch rates. Further, the bycatch data reported to IOTC is limited and poor quality (Martin and Shahid 2021). As noted by Martin and Shahid (2021), '*for species other than the most commonly caught sharks, data reporting is extremely poor, sparse and unstandardised; not conducive to supporting regional level analyses*.' Alternative methods of monitoring and reporting may be required for small-scale and artisanal fleets, such as self-sampling programs and electronic monitoring systems and applying validation and verification through port sampling or crew based observers (U. Shahid pers. comm. 2022).

Another issue with the shark catch data, and hence data on Scalloped Hammerheads, is unreported catches (Miller *et al.* 2014; Martin and Shahid 2021). This is partly due to the lack of resources for collecting catch data from artisanal fisheries, however these fisheries account for a large proportion of the catch of some shark species in the IOTC (see Section 3.2.1 Artisanal Fisheries). The lack of reporting on discards is also an issue; discard levels are needed for estimates of mortality, particularly with Scalloped Hammerheads that have high mortality levels when caught. The IOTC Scientific Committee has recommended current discard levels and estimates of historic discard levels be monitored for sharks by species and year (Clarke 2018).

The IOTC Scientific Committee has repeatedly considered the issues with data monitoring and reporting and have made recommendations calling for data improvement in shark data since at least 2010, some of which have since been included in Resolutions, for e.g. Res. 17/05 (Clarke 2018).

Mortality reduction

Reducing mortality to a level that halts population decline and allows recovery should be the primary goal. The most effective way to reduce mortality for the Scalloped Hammerhead is to implement measures that avoid capture. Following this are measures that reduce catchability, that is, bycatch mitigation, followed by methods to minimize fishing mortality through improving AVM and PVM, and then spatial protection.

Bycatch mitigation

The main threat to Scalloped Hammerheads in the Indian Ocean are the gillnet fisheries. The requirement for sub-surface setting may reduce the Scalloped Hammerhead interactions but needs further investigation. No other shark mitigation measures for gillnets are implemented (Martin and Shahid 2021). Other than the mandated requirement for non-entangling and biodegradable FADs, no other shark bycatch mitigation measures for other gears have been implemented.

PRM and safe handling

There are IOTC safe release and handling guidelines for Whale Sharks and the recommendation for release of Oceanic Whitetip Sharks before being brought on board. However, the other retention bans resolutions for Threshers and Mobulids do not include specification for safe handling and release. There is also no safe handling and release guidelines for other species of bycatch sharks. Inclusion of such guidelines could improve the post-release mortality of Scalloped Hammerheads.

Bycatch management

The IOTC CMMS for bycatch do not have any performance standards against which they can be evaluated to assess if the measures are achieving the desired aim. That is, they do not have any operational objectives linked to indicators which can be triggered when a threshold is exceeded, for example, such as catch rates or catch levels which could be compared pre- and post-implementation of the CMM (Martin and Shahid 2021). Inclusion of performance standards would allow progress of the effectiveness of a measure to be assessed.

6.0 Vision, Goals, Objectives, and Actions

There is currently sufficient knowledge of the status of the Scalloped Hammerhead in the Indian Ocean which is on a trajectory to extinction to take action now and instigate a recovery plan. Prohibitions on retention are not sufficient to halt the decline of the Scalloped Hammerhead as they have such a high mortality once captured that simply releasing them will not save them. A recovery plan that includes a suite of measures designed to reduce mortality to a level that allows recovery and the data and monitoring, control, and surveillance to achieve this is the appropriate approach. The ICCAT have recognised this and undertaken a rebuilding plan for highly depleted stocks of the North Atlantic Shortfin Mako.

Recovery plans include a vision, objectives, actions, time-frames, and responsibilities, include stakeholder consultation, are reviewed regularly, and include public reporting of progress. Recovery plans for other threatened species of pelagic sharks were reviewed and provided guidance for this Preliminary Scalloped Hammerhead Recovery Plan, that is, the recovery plans for White Shark and Oceanic Whitetip Shark (in development), the rebuilding plan for the North Atlantic Shortfin Mako, and a review of recovery planning for threatened sharks (NOAA Fisheries 2019; Rayns 2019; Australian Government 2022).

6.1 Vision

The Scalloped Hammerhead population in the Indian Ocean is recovered and thrives in healthy, well managed ecosystems, involving IOTC and its CPCs, local communities and other stakeholders, contributing to sustainable development and being a source of pride as a flagship species for the Indian Ocean.

This is a preliminary Vision for consideration by stakeholders during the development of a full Scalloped Hammerhead recovery plan. As stated in the IUCN guidelines for conservation planning: *An overarching Vision outlines, in an inspirational and relatively short statement, the desired future state for the species. Hence, the Vision describes, in broad terms, the desired range and abundance for the species, its ecological roles, and it relationship with humans* (IUCN 2017).

6.2 Objectives

The main objective of this Preliminary Recovery Plan is to enable recovery of the Scalloped Hammerhead in the wild throughout its range in the Indian Ocean. To halt population decline and promote recovery, the current fishing mortality rate must be reduced over the next 10 years. This can be done by:

- Ensuring measures are implemented to enable recovery and that recovery is not hindered by anthropogenic activities such as unsustainable fishing and removal of critical habitats.
- Improving the population status of the Scalloped Hammerhead in the Indian Ocean in the near and long-term to the point where it is no longer threatened (Vulnerable, Endangered, or Critically Endangered).

The specific objectives of the Plan are presented in Table 5 and are numbered for ease of reference but not in order of priority. The objectives are all to be implemented within the next five to ten years. These objectives are preliminary and should be considered and revised if needed, along with their time-frames, through key stakeholder consultation.

Table 5: Objectives of the Preliminary Recovery Plan (not in order of priority).

Objective 1:	Improve data reporting and instigate research on the Scalloped Hammerhead based on existing IOTC requirements.
Objective 2:	Develop and apply quantitative measures to assess and monitor population trends, status and recovery of the Scalloped Hammerhead in the Indian Ocean.
Objective 3:	Quantify and reduce mortality on the Scalloped Hammerhead taken as target and bycatch by fishing throughout its range in the Indian Ocean.
Objective 4:	Minimise the impact of shark control programs on the Scalloped Hammerhead, where practicable.
Objective 5:	Quantify and minimise detrimental impacts of international trade in Scalloped Hammerhead products through implementation of CITES provisions.
Objective 6:	Identify habitat critical to the survival of the Scalloped Hammerhead and minimise fishing mortality and impact of other threatening processes within these areas

Objective 7:	Develop and implement relevant research programs to support the conservation of the Scalloped Hammerhead.
Objective 8:	Promote community and stakeholder education and awareness in relation to Scalloped Hammerhead conservation and management.
Objective 9:	Encourage the development of regional partnerships to enhance the conservation and management of the Scalloped Hammerhead across national and international jurisdictions.

Reference Points

Recovery plans should ideally set reference points in relation to population status to clarify the level of population recovery required to reduce the threatened status (Rayns 2019). With respect to IUCN Red List of Threatened Species, a population is not considered threatened (Vulnerable, Endangered, or Critically Endangered) when the population size reduction is less than 30% over the past three generation lengths, which is 72 years for the Scalloped Hammerhead. Recovery of the Scalloped Hammerhead to a non-threatened Red List status could take decades due to its long generation length.

Alternatively, or in conjunction with the Red List reference points, fishing-mortality reference points for recovery of Scalloped Hammerhead could be used as a recovery criterion. As described for the Oceanic Whitetip Recovery plan that is being drafted, in data poor situations where a full stock assessment is not possible, an ecological risk assessment approach, such as SAFE (Sustainability Assessment for Fishing Effects) or EASI-Fish (Ecological Assessment of the Sustainable Impacts of Fisheries) can be used to estimate F and reference points for vulnerability status of Scalloped Hammerhead such as F (fishing mortality) relative to F_{msy}, F_{limit}, F_{crash}, and SSB (spawning stock biomass) (Zhou and Griffiths 2008; Griffiths *et al.* 2019; NOAA 2019). As an example, the Oceanic Whitetip Shark recovery plan is considering a fishing mortality criteria to delist the species when F is at a risk level equivalent to or less than a medium risk ranking (level below F_{msy} with at least 70% probability (NOAA 2019).

If there are high levels of uncertainty in the data, as is the case for Scalloped hammerhead, this does not preclude the use of reference points but rather, as outlined in the precautionary approach (Resolution 12/01), provisional reference points can be adopted when information for establishing reference points is absent or poor. A review and analysis of the most appropriate reference point for Scalloped Hammerhead is needed and should be considered in key stakeholder consultation.

6.2.1 Criteria for evaluating successful progress

A recovery plan needs to consider appropriate criteria to evaluate successful progress of the plan. Some suggested criteria are below and these should be considered and discussed by stakeholders for the development of a full Scalloped Hammerhead Recovery Plan. The recovery plan will be deemed to achieving successful progress if within 10 years of implementation, the following have been achieved:

- Interactions with, and mortality of, Scalloped Hammerhead is accurately recorded, reported, and assessed and significantly reduced in fisheries (Objectives 1, 2, 3, 6, 7).
- An empirical monitoring program(s) is established to measure population trends with a view to assessing recovery in the long term (i.e. 10 or more years). (Objectives 1, 7).
- Decline halted within 10 years and an upward trend in population size is demonstrated through an empirical monitoring program(s) in the long term (i.e. 10 or more years). (Objectives 1,2).
- Habitat critical to the survival of Scalloped Hammerhead has been identified, mapped, and is protected. (Objective 5).
- Appropriate measures have been put in place to manage key threats to Scalloped Hammerheads. (Objectives 2, 3, 4, 8, 9).

Indicators can be developed to assess progress towards success, such as reference points, total allowable catch, a precautionary harvest strategy and development of programs to provide the relevant information such as tagging programs and close-kin mark-recapture studies.

6.3 Actions

Actions identified for the recovery of the Scalloped Hammerhead in the Indian Ocean are described in Table 6 with priority assigned for each action. Priorities are defined as follows:

Priority 1: Prompt action is necessary to mitigate the key threats to the Scalloped Hammerhead and to provide valuable information to help identify long-term population trends.

Priority 2: Action would provide a more informed basis for the long-term management and recovery of the Scalloped Hammerhead.

Priority 3: Action is desirable, but not critical to the recovery of Scalloped Hammerhead or assessment of trends in recovery.

For consideration in stakeholder consultation, recovery plan actions should be SMART, that is Specific, Measurable, Achievable, Relevant, and Time-Bound. Being specific narrows down exactly what needs to be achieved and removes any ambiguity. Actions need to be measurable so that progress towards the objective can be assessed. While actions may be desirable, they need to be achievable, not just a wish-list. Relevant actions help achieve the overall objectives however it they are time-bound it provides deadlines to measure progress and evaluate success of the recovery plan.

Table 6: Actions of the Preliminary Recovery Plan (within the next five to ten years).

Action	Description	Priority	Performance Criteria	Jurisdiction/responsible agency	Time frame
Objective 1: Improve data reporting and instigate research on the Scalloped Hammerhead based on existing IOTC requirements.					
1.1	Investigate and assess effectiveness of bycatch mitigation methods (Res. 17/05) to reduce Scalloped Hammerhead at-vessel mortality (AVM) in gillnets, purse seines, and longlines, with gillnets a priority. Gillnets: assess effect of mesh size, hanging ratio, and net twine. Longlines: assess hook type and depth effects, bait type, lanthanide metals, bite-offs, and lengths of trailing gear. Purse seine: assess FAD deterrents.	1	• The most effective bycatch mitigation measures implemented and effectiveness of mortality reduction assessed, including o Scalloped Hammerhead avoidance measures reviewed and implemented where possible. o Improved understanding of AVM of Scalloped Hammerhead in all three gears.	IOTC and CPCs.	3–8 years
1.2	Best practice safe handling and release guidelines developed for Scalloped Hammerhead across all fisheries to reduce post-release mortality (Res. 17/05).	1	• Safe handling and release guidelines for Scalloped Hammerhead developed, available, and implemented across all fisheries.	IOTC and CPCs	1–4 years
1.3	Encourage CPCs to report catch, effort, and discards of Scalloped Hammerheads by IOTC Area and type of fishery. (Res. 15/02, 17/05)	1	• Scalloped Hammerhead catch, effort, and discards reported.	IOTC and CPCs.	1–5 years
1.4	Assist observer programs to improve recording of interactions with Scalloped Hammerheads, fate, and corresponding fine scale catch and effort data (Res. 15/01, 15/02, 17/05).	1	• Scalloped Hammerhead interactions, fate, catch, and effort recorded more consistently in the observer programs.	IOTC and CPCs.	3–8 years
1.5	Develop a priority species list, including Scalloped Hammerhead, for observers to collect biological data such as length, sex, length-weight, and take samples for age, growth, and reproduction analysis (Res. 17/05).	1	• Priority list accepted and biological data collected for Scalloped Hammerhead.	IOTC	1-3 years

Action	Description	Priority	Performance Criteria	Jurisdiction/responsible agency	Time frame
1.6	Identify important habitats for all life stages of Scalloped Hammerhead including connectivity between regions and where possible, produce habitat maps detailing pupping, nursery, feeding, aggregation areas, and migratory routes (Res. 17/05).	1	• Important habitats (e.g. pupping, nursery, aggregations, migration areas) for the Scalloped Hammerhead are identified and mapped.	IOTC and CPCs.	3–5 years
Objective 2: Develop and apply quantitative measures to assess and monitor population trends, status and recovery of the Scalloped Hammerhead in the Indian Ocean.					
2.1	Undertake a stock assessment to assess population trends, dynamics, and status. Identify all uncertainties and data requirements to improve stock assessments of Scalloped Hammerhead. Undertake data mining to reconstruct historical catch and effort data for Scalloped Hammerhead in the IOTC.	1	• A data-limited stock assessment method has been used to assess population trends and status.	IOTC.	The first stock assessment currently planned for 2022.
2.2	Develop and implement a monitoring program (including relative abundance estimates) to monitor population trends.	1	• Data and population (e.g. CPUE) trends are reported annually to IOTC and CPCs.	IOTC and CPCs.	1–10 years
2.3	Review and analyse appropriate reference points to enable evaluation of Scalloped Hammerhead recovery (see Reference points description in Objectives section).	2	• Reference points, or initially provisional reference points, have been reviewed, analysed, and assigned.	IOTC and CPCs.	1–5 years
Objective 3: Quantify and reduce mortality on the Scalloped Hammerhead taken as target and bycatch by fishing throughout its range in the Indian Ocean.					
3.1	Improve species level reporting and species identification of Scalloped Hammerhead. Liaise with data providers to ascertain type of assistance (e.g. training workshops, genetics, machine learning approaches) required to improve species identification.	1	• Addition of species-specific reporting of Scalloped Hammerhead to Res. 15/01. • Best methods to improve species identification have been determined.	IOTC.	1–3 years
3.2	Monitor the total fishing effort and fishing mortality (bycatch, target and discard) of Scalloped Hammerheads in gillnet, purse	1	• Bycatch and mortality numbers are monitored by CPCs and reported	CPCs.	3–8 years, report as per Res.

Action	Description	Priority	Performance Criteria	Jurisdiction/responsible agency	Time frame
	seine, longline, and pole and line fisheries (all interactions are recorded) and reported to IOTC.		according to the time frames specified in Res. 11/04 and 15/02.		11/04 & 15/02 timeframes
3.3	Implement the precautionary approach for Scalloped Hammerhead management.	1	• The precautionary approach has been adopted for the management of Scalloped hammerhead and a stock assessment completed.	IOTC and CPCs.	1–3 years
3.4	Consider the effectiveness of implementing a retention ban in concert with mitigation measures (e.g. reduction in AVM and discard mortality) to reduce Scalloped Hammerhead mortality.	1	• Effectiveness determined of a retention ban implemented in concert with mitigation measures.	IOTC and CPCs.	1-4 years
3.5	Prioritise implementation of a gillnet observer program, expand observer coverage, undertake preliminary analysis of observer data, and improve awareness and update discard reporting to species-specific levels for threatened sharks, including Scalloped Hammerhead.	1	• Observer data records include Scalloped Hammerhead interactions. • Gillnet fleet observer program implemented and collecting data on Scalloped Hammerheads. • Increased observer coverage across all fleets to ≥20%. • Preliminary analysis of observer data commenced. • Awareness of discard reporting improved. • Discard reporting resolution improved and includes Scalloped Hammerheads.	IOTC and CPCs.	3–8 years
3.6	Feasibility study of alternative methods (other than observer program) of bycatch (including Scalloped Hammerhead) data collection, e.g. electronic monitoring, crew based data collection, port sampling (in progress).	2	• Feasibility study of alternative bycatch data collection methods completed.	IOTC and CPCs.	Study may be ready in late-2022

Action	Description	Priority	Performance Criteria	Jurisdiction/responsible agency	Time frame
3.7	Compile baseline socioeconomic data on level of dependency on gillnets	2	• Socioeconomic data compiled	IOTC and CPCs.	1–5 years
3.8	Encourage CPCs to phase out or convert gillnets to other gears and ensure compliance with the ban on drift gillnets. This could be by a stepped conversion to low ecosystem impact gear.	2	• Gillnets phased out or converted to other gears and full compliance with ban on drift gillnets.	IOTC and CPCs.	5–8 years
3.9	Implement recommendations of IOTC Assessment of Shark Finning, including, require all fins to remain naturally attached until landing or increase reporting requirements when fins are removed at sea to demonstrate finning is not occurring.	2	• All sharks are landed with fins naturally attached and/or data collected to demonstrate finning is not occurring.	IOTC and CPCs.	1–4 years
Objective 4: Minimise the impact of shark control programs on the Scalloped Hammerhead, where practicable.					
4.1	Shark control programs (SCP) to report Scalloped Hammerhead catches and fate annually to their respective governments.	1	• Collection and assessment of Scalloped Hammerhead catch data.	South Africa, Réunion, Australia (if SCP mitigation involves any Scalloped Hammerhead captures).	Annually
4.2	Review the effect of SCPs on the Scalloped Hammerhead.	2	• Levels of Scalloped Hammerhead mortality/ interaction during SCPS are quantified. • If regular mortality/interaction with Scalloped Hammerheads occur in SCPs, seasonal trends and post-release mortality have been monitored. • Options that may facilitate a reduction in Scalloped Hammerhead captures are identified.	South Africa, Réunion, Australia (if SCP mitigation involves any Scalloped Hammerhead captures).	2–6 years
4.3	Where feasible and practical, undertake biological recording and sampling of Scalloped Hammerheads caught in SCPs.	2	• Protocols for SCP contractors modified to require, where feasible and practical, recording of basic	South Africa, Réunion, Australia (if SCP mitigation	As required

Action	Description	Priority	Performance Criteria	Jurisdiction/responsible agency	Time frame
			biological data and collection of genetic samples and/or retention and delivery of deceased Scalloped Hammerheads to research agencies.	involves any Scalloped Hammerhead captures).	
4.4	Evaluate alternatives to beach gillnets and/or drumlines, including the use of non-lethal methods or alternative strategies.	2	• Alternatives are evaluated and implemented if effective. • Use of beach gillnets and drumlines declines as alternatives are developed.	South Africa, Réunion, Australia (if SCP mitigation involves any Scalloped Hammerhead captures).	3–8 years
Objective 5: Quantify and minimise detrimental impacts of international trade in Scalloped Hammerhead products through implementation of CITES provisions.					
5.1	Investigate and quantify Scalloped Hammerhead products in trade.	1	• Investigation quantified Scalloped Hammerhead shark products traded in the IOTC. Report also provided routes of the products traded.	IOTC and CPCs.	3–5 years
5.2	Refine and implement techniques (DNA and morphological) to identify shark products.	1	• Identification guides for Scalloped Hammerhead products produced and DNA identification methods synthesised into a practical guide.	IOTC and CPCs.	3–6 years
5.3	Undertake market place and landing site testing of Scalloped Hammerhead products to determine the levels of supply.	2	• Develop effective ways of undertaking market place and landing site testing of Scalloped Hammerhead products. • Market place testing undertaken.	IOTC and CPCs.	3–6 years
5.4	Improve reporting of CITES trade permits in Scalloped Hammerhead and review CITES trade database to identify under-reporting.	2	• CITES trade database reviewed and any under-reporting identified.	CPCs.	2–5 years
5.5	Collate existing Scalloped Hammerhead IOTC CPCs Non-Detriment Findings (NDFs) and through sharing of such NDFs, encourage other CPCs to undertake NDFs.	2	• NDFs collated and where permission granted, available to all IOTC CPCs.	IOTC and CPCs.	3–8 years

Action	Description	Priority	Performance Criteria	Jurisdiction/responsible agency	Time frame
			• New NDFs completed.		
5.6	Determine the level of sustainable Scalloped Hammerhead international trade from the IOTC high seas through a regional NDF.	2	• IOTC facilitated a regional NDF	IOTC	1–5 years
Objective 6: Identify habitat critical to the survival of the Scalloped Hammerhead and minimise fishing mortality and impact of other threatening processes within these areas.					
6.1	Monitor Scalloped Hammerhead use of known critical habitats.	1	• Monitoring program developed to determine Scalloped Hammerhead occupancy and use of critical habitats.	IOTC and CPCs.	3–5 years
6.2	Use Scalloped Hammerhead critical habitat maps to help inform appropriate conservation measures where proposed activities may impact these habitats.	2	• Critical habitats for Scalloped Hammerheads are adequately taken into account when assessing the impact of proposed activities in the marine environment and adequately protected.	IOTC and CPCs.	3–8 years
6.3	Identify existing MPAs, KBAs (Key Biodiversity Areas) and EBSAs (Ecologically or Biologically Significant Areas) in the Indian Ocean and review their importance and levels of protection to Scalloped Hammerheads. Suggest modified or new MPAs, KBAs or ESBAs to include Scalloped Hammerheads, if appropriate.	2	• MPAs, KBAs, and EBSAs identified and effectiveness at protecting Scalloped Hammerheads reviewed and presented to MPA, KBA and ESBA appropriate fora.	IOTC and CPCs.	3–8 years
6.4	Consider Scalloped Hammerhead critical habitats in designating and managing spatial closures, including MPAs, to minimize fishing mortality.	2	• Scalloped Hammerhead critical habitats criteria used in designating and managing spatial closures.	IOTC and CPCs.	3–8 years
6.5	Assess historical degradation of Scalloped Hammerhead critical habitats and identify current risks and measures needed to reduce those risks.	2	• Historical degradation assessed and reported, risks identified and mitigation measures recommended.	IOTC and CPCs.	3–8 years

Action	Description	Priority	Performance Criteria	Jurisdiction/responsible agency	Time frame
Objective 7: Develop and implement relevant research programs to support the conservation of the Scalloped Hammerhead.					
7.1	Include Scalloped Hammerhead as a priority shark species in the IOTC Science Process Program of Work.	1	• Scalloped Hammerhead included as a priority shark species in the Program of Work.	IOTC.	1 year
7.2	Assess the effect on Scalloped Hammerhead mortality of sub-surface (2 m) setting of gillnets.	1	• Effectiveness assessed of mortality reduction of sub-surface setting of gillnets on Scalloped Hammerheads.	IOTC and CPCs.	1–3 years
7.3	Evaluate post-release mortality and diving depths of Scalloped Hammerheads by tagging program.	1	• Tagging program implemented and post-release mortality and diving depths of Scalloped Hammerheads determined.	IOTC and CPCs.	3–8 years
7.4	Analyse age, growth, reproduction information to improve understanding of the population dynamics and inform stock assessments.	2	• Knowledge of Indian Ocean specific life history of Scalloped Hammerhead improved.	IOTC and CPCs.	3–5 years
7.5	Investigate and determine the proportion of life history stages being captured by the artisanal, coastal, and industrial fleets.	2	• An understanding of the fleet dynamics in terms of which fleets are catching the most juveniles, sub-adults and pregnant females.	IOTC and CPCs.	1–3 years
7.6	Determine the stock structure of the Scalloped Hammerhead in the Indian Ocean through genetic analyses. Ensure Scalloped Hammerheads sampling conducted under appropriate CITES arrangements.	2	• Genetic material collected, transported, and processed. • Scalloped Hammerhead stock structure clarified in the Indian Ocean.	IOTC and CPCs.	1–5 years
7.7	Apply the genetic close-kin mark-recapture method to determine the population abundance of Scalloped Hammerhead in the Indian Ocean.	2	• The use of close-kin mark-recapture genetics has been used to determine population abundance.	IOTC and CPCs.	3–8 years
Objective 8: Promote community and stakeholder education and awareness in relation to Scalloped Hammerhead conservation and management.					

Action	Description	Priority	Performance Criteria	Jurisdiction/responsible agency	Time frame
8.1	Promote education and awareness of the highly threatened status of Scalloped Hammerheads, particularly among artisanal and coastal fishers.	1	• Community education strategy and initiatives developed and implemented.	IOTC and CPCs.	3 years
8.2	Strengthen awareness of, and compliance with, the requirement to report Scalloped Hammerhead bycatch and mortality in fisheries, including artisanal and coastal fisheries.	2	• Scalloped Hammerhead educational material made available to IOTC fishers through the most appropriate method for each of large-scale, small-scale and artisanal fishers.	IOTC and CPCs.	3–5 years
8.3	Ensure effective communication by IOTC with relevant stakeholders in regards to any changes in CMMs or other arrangements concerning Scalloped Hammerheads.	2	• As appropriate, community education strategy and initiatives developed and implemented.	IOTC.	1 year
Objective 9: Encourage the development of regional partnerships to enhance the conservation and management of the Scalloped Hammerhead across national and international jurisdictions.					
9.1	Assess the information on regional threats to Scalloped Hammerheads.	2	• Information on threats is available across regional jurisdictions.	IOTC.	3–5 years
9.2	Identify synergies and promote opportunities for regional collaboration both within the Indian Ocean and adjacent regions to promote the recovery of Scalloped Hammerheads.	2	• Within appropriate fora, such as tFRMOs, CITES, and CMS meetings, side-events are held to encourage a coordinated approach to Scalloped Hammerhead management and conservation.	IOTC.	3–8 years

7.0 Socioeconomic considerations

The socioeconomic impact of implementation of the recommended actions of a Recovery Plan must be considered, particularly in light of the IOTC's Article V.2d requirement that the '*Commission to keep under review the economic and social aspects of the fisheries based on the stocks covered by this Agreement bearing in mind, in particular, the interests of developing coastal States. This includes ensuring that conservation and management measures adopted by it do not result in transferring, directly or indirectly, a disproportionate burden of conservation action onto developing States, especially Small Island Developing States'*. Coastal communities in the Indian Ocean rely heavily on fisheries resources as a main source of protein and for livelihoods and food security. Some nations in the Indian Ocean have significant socio-economic challenges and rank in the lowest quartile of the Human Development Index (UNDP 2020) which limits their capacity to effectively regulate and manage their marine resources.

To assess the socioeconomic impact of the Scalloped Hammerhead recommended preliminary actions and of the implementation of bycatch measures in general, baseline socioeconomic data needs to be compiled to determine the level of dependency on marine resources caught, in particular by gillnets. Such collected information in concert with stakeholder engagement and participation will help determine the optimal management of bycatch sharks, including Scalloped Hammerhead, that ensures coastal communities are not disadvantaged. These issues are complex and must be given a high priority during stakeholder consultation for development of a full Scalloped Hammerhead Recovery Plan.

8.0 Biodiversity and ecosystem benefits

The Scalloped Hammerhead is an ecologically important apex marine predator. They are an integral and vital part of functioning marine ecosystems exerting top-down control through predation with their removal from the marine environment likely to cause trophic cascades and major issues for the long-term health of ecosystems (Bessudo *et al.* 2011b). This can have dire consequences for food security and income in developing nations; the loss of apex predators mean not only that sharks are no longer available as a food source and income but their loss also affects the entire marine food web meaning the loss of other marine food sources and income (Pacoureau *et al.* 2021). This crucial role in marine ecosystems also means that any measures that improve mortality for Scalloped Hammerheads and remove threats in their habitats will have positive ramifications for a range of other bycatch and marine species that occur in the same habitats. Thus, Scalloped Hammerhead management and conservation will provide much broader biodiversity and ecosystem benefits.

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