OFFSHORE FISHERIES OF THE SOUTHWEST INDIAN OCEAN:
their status and the impact on vulnerable species







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11. ELASMOBRANCHS (SHARKS AND RAYS)

A review of status, distribution and interaction with fisheries in the Southwest Indian Ocean

Jeremy Kiszka[1] and Rudy van der Elst[2]

Abstract

An overview of available information on sharks and rays in the Southwest Indian Ocean (SWIO) is presented, highlighting their dynamics, role in fisheries and conservation status. Despite their prominence , little directed research and assessment has been undertaken with the exception of studies in KwaZulu-Natal (South Africa), largely attributable to historic problems of shark attack. Additional drivers of research have focussed on charismatic species with tourist value.

Elasmobranchs are targeted or taken as bycatch in a range of SWIO fisheries, including longline, purse seine, pelagic drift net and especially shrimp trawling with high impact on endemic species. Some 188 species have been recorded by 39 nations totalling a catch of > 100,000t in 2012. However, FAO records reveal that shark catches in the western Indian Ocean have almost halved from a peak of 180,000t in 1996.

Analysis of records for coastal waters of 11 SWIO countries provides insight into the scale of fisheries and conservation status of elasmobranchs in different regions. Available information on shark behaviour, ecology, local distribution, aggregations, nursery areas and migrations is interrogated. Significant information gaps remain with knowledge on the ecology, biology and fisheries for elasmobranchs highly fragmented; disconcerting in the light of declining catches in the SWIO. Available data is generally inadequate for the assessment and management of stocks. However, new smart tag technology and genetic profiling is expanding the information on elasmobranchs. In addition, some mitigation measures have been implemented to minimise elasmobranch bycatch through the installation of bycatch reduction devices (BRDs) in several trawl fisheries. A start has also been made with the FAO-promoted National Plans Of Action for sharks (NPOA), with several countries having produced initial reports to underpin the conservation and management of sharks.

Introduction

Elasmobranchii is one of the two subclasses of cartilaginous fish in the class Chondrichthyes, the other being Holocephali (chimaeras). They occur in all oceans, from coastal to oceanic waters, from the surface to depths of more than 3,000 meters (Priede *et al.* 2006). Elasmobranchs range from planktivores to apex predators and exhibit every reproductive mode known in vertebrates, from egg laying to placental viviparity (Shelson *et al.* 2008). Most elasmobranchs (sharks and rays) and the related chimaeras are characterised by low fecundity and productivity, slow growth, late age at maturity, large size at birth, high natural survivorship and a long life. Such biological characteristics have serious implications for the sustainability of shark and ray fisheries (Kiszka & Heithaus 2014). Not surprisingly, these species are dependent on a stable environment, and generally have limited capacity to sustain and recover from heavy fishing pressure.

Among the 1,160 species of cartilaginous fishes known, 188 have been recorded in the Southwest Indian Ocean region (SWIO). Except for South Africa (especially the coast of KwaZulu-Natal province), little effort has been made to assess the status of sharks and rays in the SWIO, although some species have been more investigated than others in the region, notably the larger and emblematic species such as the whale shark (*Rhincodon typus*) and the reef manta ray (*Manta alfredi*).

This chapter provides an overview of available information on the status, fisheries (including directed exploitation and incidental catches, or bycatch) and management of elasmobranchs in the SWIO.

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Regional biodiversity and critical habitats for elasmobranchs in the Southwest Indian Ocean (SWIO)

This section highlights the level of knowledge on diversity and status of elasmobranchs in national waters of the SWIO countries. Generally, information on elasmobranchs is poor in most areas, except for the east coast of South Africa, where research was stimulated largely in response to a spate of shark attacks on bathers in the region. The Annex lists the species that have been recorded in the region, which includes more than 30 endemic species.

COUNTRY OVERVIEWS

South Africa (KwaZulu-Natal)

The most extensive research on the taxonomy, diversity, ecology and behaviour of elasmobranchs in the SWIO has been conducted in South Africa. Research on elasmobranch taxonomy and ecology in South Africa was initiated in the 1960s at the Oceanographic Research Institute by Davies (1964), Bass *et al.* (1973, 1975 a, b, c, 1976) and Wallace (1967 a, b, c). While their research publications remain relevant today, subsequent studies at the KwaZulu-Natal Sharks Board (KZNSB) have enriched the baseline information substantially. Their role in protecting the province's bathing beaches from shark attack for the past 40 years has allowed them to document relative abundance (including inter-annual and seasonal), breeding, feeding ecology and behaviour of sharks in this region. From 1980 to 2010, 216 peer-reviewed papers on elasmobranch ecology, taxonomy, distribution, and abundance have been produced in South Africa (Escobar-Porras & Sauer 2011), a large proportion of papers being based on data generated from net catches made by the KZNSB. The relative occurrence of the most common species caught in the nets is presented in Table 1.

From 1978 to 2003, the population status of 14 species of sharks caught in the KZNSB nets was investigated (Dudley & Simpfendorfer 2006). Catch rates of four species (*Carcharhinus leucas*, *Carcharhinus limbatus*, *Sphyrna lewini* and *Sphyrna mokarran*) showed a significant decline, as did the mean or median length of three species (*Carcharhinus amboinensis*, *C. limbatus* and female *Carcharodon carcharias*). The potential impact of the shark nets was assessed to be high for at least three species (*C. leucas, Carcharhinus obscurus* and *Carcharias taurus*), because of their very low intrinsic rates of population increase (Dudley & Simpfendorfer 2006). Holden (1977) and van der Elst (1979) had earlier concluded that the inshore species of sharks were most susceptible to reduction in numbers through shark netting off KwaZulu-Natal.

Shark abundance and diversity is seasonally influenced by the "Sardine Run", a winter influx of shoals of South American pilchards (*Sardinops sagax*) from the southwest during the austral winter. This spectacular event attracts large numbers of top predators, including seabirds, marine mammals and elasmobranchs to the KwaZulu-Natal coast. The effect of the Sardine Run on shark catches off the coast of KwaZu-

Table 1: Mean annual shark catches in KwaZulu-Natal Sharks Board nets from 2006 to 2010. (Source: http://www.shark.co.za/catchstatistics)

Species		***Mean number of animals caught***		***Percent released***	***Mortality*** (No. of animals)
		Caught	*Released*		
Great white	*Carcharodon carcharias*	28	3	10.7	25
Short-fin mako	*Isurus oxyrinchus*	4.8	0.8	16.7	4
Tiger	*Galeocerdo cuvier*	51.4	18.8	36.6	32.6
Raggedtooth	*Carcharias taurus*	62.8	14.6	23.2	48.2
Common thresher	*Alopias vulpinus*	0.2	<0.1	<0.1	0.2
Bigeye thresher	*Alopias superciliosus*	0.2	<0.1	<0.1	0.2
Pelagic thresher	*Alopias pelagicus*	0.0	<0.1	<0.1	<0.1
Bull (Zambesi)	*Carcharhinus leucas*	15	2.8	18.7	12.2
Pigeye	*Carcharhinus amboinensis*	5.2	0.6	11.5	4.6
Dusky	*Carcharhinus obscurus*	138	19.8	14.3	118.2
Sandbar	*Carcharhinus plumbeus*	4.6	0.2	4.3	4.4
Copper	*Carcharhinus brachyurus*	9.6	0.6	6.3	9
Blacktip	*Carcharhinus limbatus*	67.4	10.2	15.1	57.2
Spinner	*Carcharhinus brevipinna*	54.6	3.4	6.2	51.2
Great hammerhead	*Sphyrna mokarran*	0.6	<0.1	<0.1	0.6
Scalloped hammerhead	*Sphyrna lewini*	64	0.2	0.3	63.8
Smooth hammerhead	*Sphyrna zygaena*	34.4	0.6	0.7	33.8
Unidentified hammerheads	*Sphyrna* spp.	1.2	0.2	16.7	1
Snaggletooth	*Hemipristis elongatus*	0.6	<0.1	<0.1	0.6
Blue	*Prionace glauca*	0.2	<0.1	<0.1	0.2
Species unknown		3.6	0.8	22.2	2.8
Total		***546.4***	***76.6***	***14***	***469.8***

lu-Natal is particularly significant in June and July, with the presence of copper (or bronze whaler) sharks (*Carcharhinus brachyurus*) being strongly associated with sardine shoals. Spinner sharks (*Carcharhinus brevipinna*) and scalloped hammerhead sharks (*S. lewini*) are normally caught in greater numbers in summer than in winter, but they appear to shift their spatial distribution seasonally to feed on sardines (Dudley & Cliff 2010a).

The most charismatic shark species in South Africa, the great white shark (*C. carcharias*) is common, especially in the vicinity of seal colonies (notably Cape fur seals (*Arctocephalus pusillus*) in the Cape region, and has been caught regularly in KZNSB nets (Cliff *et al.*1989). Based on tagging data, the first estimate of great white shark population size off eastern South Africa was 1,279 individuals (95% CI, 839-1,843 sharks; Cliff *et al.*1996). Between 1978 and 2003, 35.8 white sharks were caught annually in the nets (SD=13.5).

From 1984 to 2009, distribution and movement of two hammerhead shark species (*S. zygaena* and *S. lewini*) along the east coast of South Africa were investigated using sport fisher tagging data (Diemer *et al.* 2011). Recapture rates by anglers varied from 1.9% for *S. lewini* to 1.5% for *S. zygaena.* Coastal areas in Transkei have been identified as of importance to juvenile and subadult hammerhead sharks year-round (Bass *et al.* 1975b; Diemer *et al.* 2011).

In the Aliwal Shoal Marine Protected Area and on the nearby Protea Bank, sharks are periodically very abundant and are of major economic importance. Commercial and recreational line fishers endure negative impacts of high levels of predation by sharks of their catches (Mann 2011), primarily involving blacktip sharks (*C. limbatus*). These aggregating sharks may well in part be attracted to fisher activities associated with the capture of certain seasonal shoaling species such as the geelbek (*Atractoscion aequidens*). Catches in the shark nets do not mirror this periodic increase, confirming that these aggregations are indeed localised. (Dudley & Cliff *et al.* 2010b). Also common in this area are tiger (*Galeocerdo cuvier*) and ragged-tooth (*C. taurus*) sharks which support a viable tourism industry based on divers and underwater shark encounters (Dicken & Hosking 2009). The coast of KwaZulu-Natal is a major area for ragged-tooth sharks in South Africa. Pregnant females spend the early part of their gestation in the warmer waters of northern KwaZulu-Natal and possibly southern Mozambique. After parturition further south off the Eastern Cape, many of the females migrate back to KZN (Dicken *et al.* 2006).

Whale sharks occur along the entire South African eastern seaboard with occasional strandings as far south as Cape Town. In the 1990s, whale shark studies were initiated with a comprehensive review of strandings as well as aerial surveys with sightings of 95 and 49 individuals south of Durban (Beckley *et al.* 1997). From 2001 to 2002, the occurrence of the whale shark was further investigated off KZN although only eight whale sharks were seen, with a sighting rate of 0.21 sharks per 100km of coastline. Another 13 surveys were completed during the summers of 2003/2004 and 2004/2005 and a total of 30 sharks were sighted, with a mean sighting rate of 0.69 sharks per 100 km of coastline. The density of sharks was highest in the far north where it averaged 1.05 sharks per 100km between January and May (Cliff *et al.* 2007). Clearly, whale shark abundance is variable in this region.

One group of elasmobranchs of great concern is the sawfishes, family Pristidae, which have been severely depleted globally (Kyne *et al.* 2013) and are now possibly extinct in South African waters (Everett *et al.* in press). Two species are known to occur in the SWIO: *Pristis pristis* and *Pristis zijsron*, both listed as Critically Endangered (IUCN Red List, www.iucnredlist.org). Reasons for their decline include (but are probably not limited to) entanglement in fishing nets and habitat degradation. It appears that sawfish populations have likewise been depleted in other countries of the region. Sawfishes are probably one of the most threatened of the elasmobranchs in the SWIO region.

Mozambique

The highest elasmobranch diversity in the SWIO region has been recorded from Mozambique waters, with 108 species (73 sharks and 35 rays; reviewed by Kiszka *et al.* 2009a). Fishery-dependant data provide the basis for preliminary information on the relative abundance of sharks in this country. From 2006 to 2010, fishery observer data from the long-line fishing boats were collected, and sharks amounted for 11% of the catches by number. Four species were mostly represented: *Carcharhinus sorrah*, *G. cuvier*, *Squalus megalops* and *S. lewini* (Palha de Sousa 2011). No dedicated research on sharks and rays has been undertaken in Mozambique, except on the largest and emblematic species, especially the reef manta ray (e.g. Marshall *et al.* 2009, 2011) and the whale shark (Brunnschweiler *et al.* 2009). In the 1980s, a number of surveys were carried out by both Soviet and German trawlers primarily to estimate the potential nominal catch of fish, crustaceans and molluscs. During these surveys, sharks were recorded and the most commonly caught species were *Carcharhinus falciformis*, *C. obscurus*, *Mustelus manazo* and *S. zygaena* (Sousa *et al.* 1997).

Sport fishers measure dusky shark before tagging and release. (Photo: Rudy van der Elst)

Based on research conducted in Mozambique, a revision of the genus *Manta* has been proposed (Marshall *et al.* 2009). Two species are currently recognised: the giant manta ray (*Manta birostris*) and the reef manta ray (*M. alfredi*). Off southern Mozambique, there is a major reef manta ray aggregation that has been investigated for several years. From 2003 to 2007, annual population size estimates ranged from 149 to 454 individuals and a super-population estimate of 802 individuals (Marshall *et al.* 2011). This species occurs all year round off Inhambane, but higher concentrations are observed from November to January, during the breeding season. Due to high site fidelity and small population size, reef manta rays are highly vulnerable to fisheries in Mozambique (Marshall *et al.* 2011). Around Pt. Tofo, near Inhambane in southern Mozambique, an important whale shark aggregation has been identified (Cliff *et al.* 2007). The animals gather year-round in a narrow corridor close to shore and the high sighting rates and accessibility of the sharks has led to the development of a tourism industry. Although the broader scale movement patterns and behaviour of these fish are unknown, the local population structure (81% males) suggests that these sharks constitute a sub-set of a larger population (Bunnschweiler *et al.* 2009).

Tanzania
Along the coast of Tanzania, at least 51 elasmobranch species have been recorded (Kiszka *et al.* 2009a). Despite the exploitation of sharks in Tanzania, especially off Zanzibar, very little is known on the distribution, diversity and abundance of elasmobranchs in this area. Interview surveys suggest the African angel shark (*Squatina africana*) is commonly caught although these data are limited in quantitative detail. For an in-depth view of local elasmobranch diversity see Shehe & Jiddawi (1997). The whale shark has been recorded seasonally off Zanzibar, especially from August to November (Rowat 2007). White sharks have also been recorded off the coast of Zanzibar (Cliff *et al.* 2000).

Kenya
A total of 41 species of elasmobranchs has been recorded from Kenya (Kiszka *et al.* 2009a). However, almost nothing is documented on their abundance and distribution in Kenyan waters. In November 1994, an aerial survey along the whole coast of Kenya documented the distribution of whale sharks and other large coastal sharks (Wamukoya *et al.* 1997). A total of 37 whale sharks and 15 individuals of other large shark species was recorded during the survey (63 rays of unknown species were also sighted). Noticeable concentrations of elasmobranchs were seen in Ungwana Bay and around the islands of Pate and Manda. Whale sharks appear evenly distributed but more common from July to May, with observed aggregations in the Kikambala-Malindi stretch (Wamukoya *et al.* 1997; Rowat 2007).

Union of the Comoros
Very little research has been specifically directed to the status of sharks and rays in the Comoros (islands of Anjouan, Mohéli and Grande Comoro). Nevertheless, a total of 27 species of elasmobranchs has been recorded around the Comoros (Kiszka *et al.* 2009a). Additionally, fishes of the deep demersal habitats (100-400m) have been investigated and eight species of sharks and rays (Squalidae, Scyliorhinidae, Odontaspididae, Rajidae, Torpedinidae and Narkidae) were recorded (Heemstra *et al.* 2006). Although no scientific information is available on the existence of major aggregations, a number of divers have reported the presence of aggregating reef sharks and rays off Mohéli (National Marine Park), especially off the southeast coast (mostly *Carcharhinus amblyrhynchos* and *Manta* cf. *alfredi*).

Mayotte (including Iris, Zélée and Geyser banks)
Several small-scale initiatives have been undertaken to assess the diversity and occurrence of elasmobranchs around the island of Mayotte and surrounding reef banks (Iris, Zélée and Geyser). Most diversity records have been recorded from a sighting network implemented in 2007 (Jamon *et al.* 2010). A total of 39 species has been recorded (Kiszka *et al.* 2009a), mostly reef-associated and pelagic sharks. No major shark or ray aggregations were identified around the island. However, in the austral winter, reef manta rays (*M. alfredi*) and scalloped hammerhead sharks (*S. lewini*) are commonly observed near steep reef slopes (Wickel *et al.* 2010). On reefs, *C. amblyrhynchos* and *Triaenodon obesus* are the most common species (Jamon *et al.* 2010). In offshore waters, based on pelagic longline data fished over slope areas, *C. falciformis* (CPUE, N/1000hooks = 3.94), *Prionace glauca* (CPUE = 3.28) and *S. lewini* (CPUE = 0.88) are the most common species (Kiszka *et al.* 2010). Adjacent to Mayotte, surveys have been undertaken on Iris, Zélée and Geyser banks to assess elasmobranch diversity (Chabanet *et al.* 2002; Wickel *et al.* 2010). It has been speculated that the Geyser Bank could constitute a nursery area for tawny nurse sharks (*Nebrius ferrugineus*) and that the Zélée Bank could be a nursery for *C. amblyrhynchos* (Jamon *et al.* 2010; Wickel *et al.* 2010).

French dispersed islands (Europa, Bassas da India, Juan de Nova, Glorieuses, and Tromelin)
Around the French scattered islands, little is known on the diversity and use of reef-associated habitats by sharks and rays. A research project, led by IRD (Institute of Research for Development, RequIEP: *Requins des îles Eparses*) was undertaken in 2011 around all of these islands. Elasmobranch diversity was found to be highly variable between islands, attributable in part to the high variability of observation effort: 8 species around Bassas da India, 7 around Europa, 16 around Juan de Nova, 14 around the Glorieuses and 3 around Tromelin (Kiszka *et al.* 2009a). Reef shark diversity, area use and relative abundance have been assessed during short-term diving and fishing surveys (van der Elst & Chater 2001; Kiszka *et al.* 2009b; Wickel *et al.* 2009). Nursery areas have been found in Bassas da India for *C. galapagensis* (Hammerschlag & Fallows 2005), Europa for *C. melanopterus* (Wickel *et al.* 2009) and Juan de Nova for *C. amblyrhynchos* (Kiszka *et al.* 2009). Juan de Nova appears to be the area with the highest reef shark abundance, the dominant species

being *Carcharhinus albimarginatus*, *C. amblyrhynchos* and *N. ferrugineus* (Kiszka *et al.* 2009b).

Madagascar

A total of 83 species of elasmobranchs has been recorded around Madagascar, including 59 sharks and 24 ray species (Kiszka *et al.* 2009a). The bulk of information has been derived from fishery data. In the southwest, in the Toliara region, the most commonly caught elasmobranch species in coastal fisheries (using longlines and gillnets) are *Sphyrna* spp. cf. *lewini*, *C. amblyrhynchos*, *C. limbatus* or *C. melanopterus* and *G. cuvier* (McVean *et al.* 2006). In this region, there is some evidence of population declines due to overfishing for the shark fin market. Along the northwest coast, in the Nosy Be region, whale sharks seem relatively common, especially during planktonic blooms. Their abundance in the region seems particularly high between October and December (Jonahson & Harding 2007). In the northwest region (Boeny-Mahajunga area), shark communities appear slightly different with *C. amblyrhynchos*, *S. lewini*, *C. sorrah*, *L macrorhinus, T. obesus* and *R. acutus* being the most common species (Andriamanaitra 2004; Robinson & Sauer 2013). The scalloped hammerhead shark is still the most abundant species, but shows worrying signs of decline in the region (Andriamanaitra, 2004).

Seychelles

Around the Seychelles, 84 elasmobranch species have been recorded: 62 sharks and 22 rays (Kiszka *et al.* 2009a). In the 1990s, it was estimated that there was between 50,000 and 56,000t of shark biomass on the Mahé Plateau, with an additional 34,000t on the other banks (NPOA Seychelles 2007). However, very little is documented on the ecology of both coastal/reef-associated and oceanic sharks around the Seychelles. Around Aldabra, 10 species of reef sharks have been recorded (belonging to three families), with *C. melanopterus* and *N. acutidens* being the most abundant species inside the lagoon and *C. albimarginatus* the most common species along the outer slope of the reefs (Stevens 1984). Population densities calculated for *C. melanopterus* in some areas varied from 19 to 198 individuals per km^2 (Stevens 1984). While no recent data on elasmobranchs have been documented, recent shark attacks on Praslin have highlighted the need to better understand shark diversity and abundance in Seychelles.

Whale sharks are common around the Seychelles, especially around Mahé, with information on abundance, distribution and ecology of this species available. The earliest report of whale sharks in Seychelles dates back to 1756 (Lionnet 1984), and the first individual ever caught was also reported from these waters in 1805 (Smyth 1829). Whale sharks have been recorded from June to February in this area (Rowat 2007). Tracking data have shown sharks tagged around the Seychelles to migrate eastward towards Africa, then from there southward towards Mozambique, northward to Somalia and westward to Sri Lanka (Rowat & Gore 2007).

Using a combination of photo-identification and marker tags, from 2001 to 2007, a total of 552 individuals was identified (Rowat *et al.* 2009). Around Mahé, abundance estimates

Whale shark research in Mozambique. (Photo: Simon Pierce)

using mark-recapture models for 2004-2007 indicated there to be 348-488 sharks (95% CI). Existing data suggest that whale sharks are transient in the Seychelles, indicating the need for regional research initiatives (Rowat *et al.* 2009). Recently, spatial behaviour of sicklefin lemon sharks (*N. acutidens*) has been investigated in the Amirantes islands (Seychelles), showing that these sharks have a restricted home range, making them particularly vulnerable to anthropogenic impacts such as fishing (Filmalter *et al.* 2013).

La Réunion

Until very recently, no dedicated studies had been undertaken to investigate the diversity, ecology and behaviour of sharks around La Réunion. However, the assessment of bycatch in the pelagic longline fishery and reef fish population studies provide a list of 51 species: 42 sharks and 9 rays (Kiszka *et al.* 2009a). As the number of attacks on bathers, especially surfers and divers, has increased, a dedicated research project on the ecology and behaviour of *G. cuvier* and *C. leucas* has been implemented by IRD, *Institut de Recherche pour le Développement*. However, no results are available yet. In the offshore region of the EEZ, based on pelagic longline surveys, 712 fishes were caught, including 107 elasmobranchs (Romanov *et al.* 2011). The most common elasmobranch species being *P. glauca* (62% of elasmobranch species) and *Pteroplatytrygon violacea* (31%). Other less common species included *I. oxyrinchus*, *C. longimanus*, *C. falciformis* and *S. zygaena* (Poisson 2011; Romanov *et al.* 2011).

Mauritius

No dedicated studies have been undertaken on sharks off Mauritius. A total of 60 elasmobranch species has been recorded, including 43 sharks and 17 rays (Kiszka *et al.* 2009a). No major shark or ray aggregations have been documented, except at “Rocher aux Pigeons”, where grey reef sharks (*C. amblyrhynchos*) were once numerous, especially before the 1990s. However, based on diver interviews, grey reef sharks are now rarely seen, presumably as a result of high fishing pressure (Kiszka *et al.* 2009a). Offshore, the two most commonly caught sharks in longlines are *I. oxyrinchus* and *P. glauca* (Mamode 2011).

SHARKS OF THE OPEN OCEAN IN THE SWIO: OVERVIEW OF BIODIVERSITY

Around 30 species of elasmobranchs spend much of their life away from land masses in oceanic waters (Pitkitch *et al.* 2008). The bulk of knowledge on oceanic sharks in the SWIO region has been derived from longline fishery data. From 1961 to 2009, 46 elasmobranch species/taxa were recorded in the catch of pelagic longliners in the Indian Ocean (Table 2). The most diverse group was the pelagic sharks represented by 28 species, dominated by the family Carcharhinidae with 15 species of the genus *Carcharhinus,* and by two mono-specific genera (*Galeocerdo* and *Prionace*). The number of species recorded has varied from 30 to 40 in the period 1960-80, declining to 22 in the catches of the 2000s (Romanov *et al.* 2010). However, this trend may be partially linked to misidentifications in early years of data collection. Taxonomic Uncertainty (TU), calculated as the percentage of the taxa recorded at a level higher than species, confirms improved identification with a lower value of TU in the last period: 2002-2009. If all species were precisely identified this index would be equal to 0 (Romanov *et al.* 2010).

The most abundant pelagic shark families in the SWIO are Lamnidae, Carcharhinidae and Alopiidae. Among Lamnidae, great white sharks are mostly confined to southern Africa but occasionally make incursions into tropical waters. Large adults have been recorded in the tropical western Indian Ocean, including Zanzibar, northern Madagascar, Mauritius, Kenya (Cliff *et al.* 2000) and on several occasions around Mayotte (Jamon *et al.* 2010). The short-fin mako shark (*Isurus oxyrinchus*) is the most abundant mackerel shark in the SWIO, and this area takes the highest catch rate for this species in the Indian Ocean (Smale 2008, Groeneveld *et al.* 2014). This species is rarely seen on the continental shelf. Between 1978 and 2003, annual catches of this species in KZNSB nets were low (mean=13.4; SD=4.5 sharks), and no trend in catch rate or size of sharks has been detected over the period (Dudley & Simpfendorfer 2006). However, the net catch rates have subsequently decreased to an average of 4.8 in recent years (Table 1), suggesting a possible population decline, similar to that reported in the offshore fisheries. Among requiem sharks (Carcharhinidae), *C. falciformis* and *P. glauca* are the most abundant species. *C. falciformis* is found in open waters, from near the surface to >3,000m (Compagno, 1984). *P. glauca* occurs closer to the surface but can range to depths of ~1000m, and is probably one of the most prolific shark species in the world. However, they are less abundant in equatorial waters and their abundance tends to increase with latitude, including in the SWIO (Nakano & Stevens 2008). All three species of thresher sharks (*Alopias pelagicus*, *A. vulpinus* and *A. superciliosus*) occur in the SWIO, but have probably declined over the decade (Romanov *et al.* 2010).

Table 2: Elasmobranch species recorded in Indian Ocean pelagic catches: 1961-2009 (from Romanov *et al.* 2010).

Order, family, *species*	*1961-1970*	*1971-1980*	*1981-1989*	*2002-2009*
Lamniformes				
Alopiidae				
Alopias pelagicus	x	x	x	x
Alopias superciliosus	x	x	x	x
Alopias vulpinus	x	x	x	x
Alopias spp.	x	x	x	x
Lamnidae				
Carcharodon carcharias	x			
Isurus oxyrinchus	x	x	x	x
Isurus paucus		x	x	x
Isurus spp.	x	x	x	
Lamna nasus		x	x	
Pseudocarchariidae				
Pseudocarcharias kamoharai		x	x	x
Carcharhiniformes				
Carcharhinidae				
Carcharhinus albimarginatus	x	x	x	x
Carcharhinus altimus	x			
Carcharhinus amblyrhynchoides		x		
Carcharhinus amblyrhynchos		x	x	x
Carcharhinus brachyurus		x		
Carcharhinus brevipinna		x	x	
Carcharhinus falciformis	x	x	x	x
Carcharhinus galapagensis		x		
Carcharhinus leucas	x	x	x	
Carcharhinus limbatus	x	x	x	
Carcharhinus longimanus	x	x	x	x
Carcharhinus melanopterus	x	x	x	x
Carcharhinus obscurus	x	x	x	
Carcharhinus plumbeus	x	x	x	x
Carcharhinus sorrah	x	x	x	
Carcharhinus spp.	x	x	x	
Galeocerdo cuvier	x	x	x	x
Prionace glauca	x	x	x	x
Sphyrnidae				
Sphyrna lewini	x	x	x	x
Sphyrna mokarran		x	x	x
Sphyrna zygaena	x	x	x	
Sphyrna spp.	x	x	x	x
Hexanchiformes				
Hexanchidae				
Hexanchus griseus			x	
Squaliformes				
Squalus spp.		x		
Unidentified squalids	x	x	x	x
Rajiformes				
Mobulidae				
Manta birostris	x	x		
Manta spp.		x	x	
Mobula spp.	x		x	x
Dasyatidae				
Pteroplatytrygon violacea	x	x	x	x
Dasyatis spp.		x	x	x
Taeniura lymna	x			
Rajidae	x			
Number of species/taxa recorded	30	40	34	22
Total number of individuals	2928	19312	3830	834
Taxonomic uncertainty	26.6	30	26.4	22.7

MIGRATORY ROUTES AND POPULATION STRUCTURE OF ELASMOBRANCHS

Several species of shark are known to undertake extensive migrations; some having been recorded to cross ocean basins. However, information on movements and migration of elasmobranchs in the SWIO region is still very limited. Most of the information that does exist on shark movements has been collected from fisheries taking bycatch in oceanic ecosystems or from studies of charismatic species, especially the whale shark. Movement patterns (including vertical and horizontal) have been documented for this largest of species. A whale shark tagged and tracked off southern Mozambique showed a highly directional movement across the Mozambique Channel and around the south of Madagascar, a distance of ~1,200km in 87 days. The animal explored both bathypelagic and epipelagic zones (Brunnschweiller *et al.* 2009). In the western Indian Ocean, purse-seine fishery observers report that whale sharks are found between 0°S and 10°S in January. In April and May, they seem to mainly occur between 10°S and 20°S, in the Mozambique Channel. Thereafter, the sharks seem to move in more northerly latitudes and by August, they span between 5°N to 5°S (Rowat 2007). From satellite telemetry data, tagged whale sharks around the Seychelles seem to be influenced by geostrophic currents (Rowat & Gore 2007). Depth recordings show that up to 53% of the time was spent in water shallower than 10m, but dives to depths of 750 – 1 000m were also recorded (Rowat & Gore 2007).

Some information has been documented for a few oceanic shark species, such as *C. falciformis*. Under the MADE project (Mitigating ADverse impacts of open ocean fisheries, www.made-project.eu), a number have been tagged using PAT (Passive Acoustic Transponders) and miniaturized PAT tags. Those tagged under FADs (Fishing Aggregating Devices), have shown they remained associated with the FAD for several days (mean association time with FAD: 5.19 days) but deep dives were recorded at night, believed to be foraging trips (Filmalter *et al.* 2011).

In a SWIOFP-funded study into the population structure of *I. oxyrinchus*, Groeneveld *et al.* (2014) reported on observer-collected data from pelagic longliners between 2005 and 2010, involving 5,819 specimens. Results indicate a demographically structured population with size increasing from temperate to subtropical waters. Reproductively active adults are more common in coastal waters suggesting a preference for pupping closer to the coast.

Information on genetic structure is accumulating and has generally been generated from larger scale studies such as on whale sharks (Castro *et al.* 2007) and scalloped hammerhead sharks (Duncan *et al.* 2006). In general and not surprisingly, large and migratory sharks show limited genetic structural diversity, even at large spatial scales, including at the global level. Based on global sampling of whale sharks, including 18 samples from the SWIO, only limited population division and no evidence for cryptic evolutionary partitions were found (Castro *et al.* 2007). However, significant haplotypes frequency differences were found between the Atlantic and the Indo-Pacific regions. Overall, whale shark population genetic structure highlights the need for development of broad international approaches for management and conservation of this and related vulnerable species (Castro *et al.* 2007).

Species with more sedentary behaviour may display disjunct distribution or reproductive philopatry at some levels of structure, as for example *S. lewini.* From genetic sampling at 20 nursery areas around the world, including the Seychelles and the east coast of South Africa, population subdivisions was seen to be pronounced. (Duncan *et al.* 2006). Although genetic discontinuity is primarily associated with oceanic barriers, site fidelity and philopatry can limit recruitment from other regions in otherwise widely distributed species. Overall, nursery populations linked by continuous coastlines have high connectivity, but oceanic dispersal by females appears to be rare (Duncan *et al.* 2006).

Oceanic Whitetip. (Photo: Julien Wickel)

Relationship with fisheries

Elasmobranchs interact in two main ways with fisheries, either as a targeted resource or as incidental bycatch. Sharks and rays are an increasingly important and valued resource with 39 nations reporting the capture of elasmobranchs in the WIO, totalling about 86,500t in 2009 (FAO 2012). To this must be added a substantial non-reported catch taken by IUU operations. In some countries specific elasmobranch fishery permits are issued for shark fisheries, and some of these are managed accordingly. For example, the soupfin shark (*Galeorhinus galeus*) fishery of South Africa, the demersal gill net fisheries for deep water squalids by Mozambique and Madagascar and artisanal shark fisheries in Seychelles (www.wiofish.org) are legally authorised fisheries.

The trend in declared landings of elasmobranchs is noteworthy. Notwithstanding the improvements and diligence in reporting, the past decade has seen a significant decline of total catches reported from the WIO as depicted in Figure 1. While the underlying causes may not be immediately clear, it seems that Asian nations fishing in the western Indian Ocean have reported the largest decline. That, despite the increased landings reported by African countries and the higher demand for and value of shark products (FAO 2012).

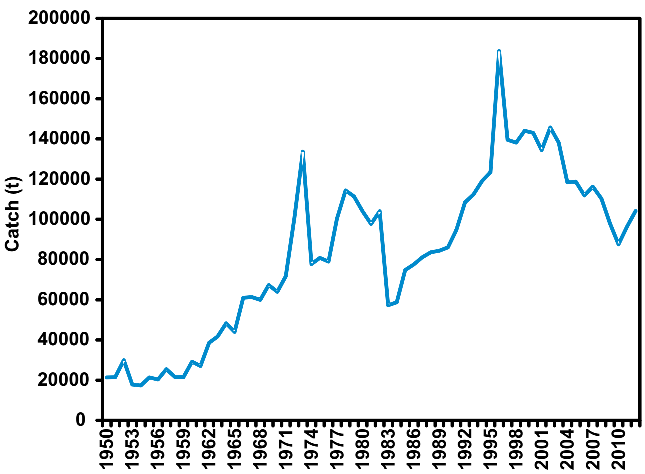


Figure 1. Reported total annual landings of elasmobranchs in the WIO (FAO Area 51) in tons (FAO 2012).

Bycatch of elasmobranchs features in several fisheries, both in coastal and in oceanic ecosystems. While in some cases this bycatch may provide food security and useful income, there is concern that in many cases this may have a negative impact on elasmobranch populations in the SWIO. This may be true for open ocean fisheries, both purse seine and longline, for low resilient coastal/reef-associated species and also for demersal elasmobranchs taken in trawls. Unfortunately, information is scarce and mostly derived from open-ocean fisheries.

COASTAL FISHERIES THAT TAKE ELASMOBRANCHS IN SWIO COUNTRIES

Here, we overview information by country on the exploitation and bycatch of elasmobranchs in the SWIO, especially in coastal waters and adjacent areas. The harvesting and bycatch of sharks in oceanic waters is treated separately. In 1996, TRAFFIC compiled a suite of reports that investigated the capture and trade in sharks around the world. One of the reports focussed on countries of the southeast Atlantic and SWIO. Although there have been substantial changes since that time, it does provide a useful baseline and point of reference (Marshall & Barnett 1996).

South Africa (East Coast region)

Sharks are caught along the coast of KwaZulu-Natal by the KZNSB as part of their bather protection programme. Indeed, since 1952, shark nets have been progressively introduced along the KwaZulu-Natal coastline. By December 2005, there were 38 installations comprising a total of 27.3km of netting (Dudley & Cliff 2010b). A typical shark net measures 213.5m long by about 6.3m deep, is manufactured from black multifilament polyethylene braid and is set about 400m from shore in 12–14m water depth (Dudley & Cliff 2010b). In the period 1970-1980 an average of 1,500 large elasmobranchs was caught in these nets annually. Progressively, there has been a reduction in this catch to levels of around 567 per annum, supplemented by some 15% released alive (Cliff & Dudley, 2011; www.shark.co.za). The relative occurrence of the most common large species is presented in Table 1. The high rate of capture of sharks and bycatch has prompted the KZNSB to implement a drum line capture system in favour of gillnets thereby further reducing mortality on several species of elasmobranchs as well as on marine mammals and sea turtles (Cliff & Dudley 2011).

Industrial fisheries in South Africa legally make moderate catches of elasmobranchs, taken in longline, trawl and line fisheries. Collectively these fisheries declared 1,710t of elasmobranchs in 2009, although this is combined for the east and west coast regions (Fishing Industry Yearbook 2010). These are legally harvested elasmobranchs that are declared and subject to management regulations. However, a number of fisheries take elasmobranchs as bycatch; not always fully declared or recorded. In the pelagic longline fishery, sharks dominate the bycatch. From 1998 to 2005, 26 species were reported caught in this fishery off South Africa. *P. glauca* and *I. oxyrinchus* were the most commonly caught species: 69.2% and 17.2%, respectively (Petersen *et al.* 2009). The catch per unit effort of these two species started to decrease since 2001 and 2000 respectively, accompanied by a decrease in average length for both species over the period 2002-2007 (Petersen *et al.* 2009). A number of other fisheries also catch sharks as bycatch, especially the demersal longline and the trawl fisheries that target Cape hake (*Merluccius capensis*). The overall catch rates are tabulated in Table 3.

Table 3. Catch rates of the four most common elasmobranch species taken by demersal industrial fisheries off the Cape south-west coast (after Petersen *et al.* 2008)

	Demersal longline			*Demersal trawl*
	% of total catch	Catch per 1000 hooks	Kg per 1000 hooks	Kg per nm^2
Squalus mitsukurii	12	10.5	31.5	68.32
Holohalaelurus regani	5.9	2.19	3.3	54.34
Scyliorhinus capensis	3.2	0.46	0.7	12.62
Raja straeleni	1.9	1.46	4.4	358.11

Off the KZN coast there is an industrial fishery for crustaceans with shallow inshore and deeper offshore elements. From 1989 to 1992, Fennessy (1994) analysed the elasmobranch bycatch of the inshore sector. He estimated that 44,600 elasmobranchs were caught in this fishery during the study period, estimated at 357 tons per year and including 26 species of which seven were endemic to the SWIO. Although a high, but variable proportion was returned alive to the water, the total elasmobranch catch was clearly substantial. Moreover, most individuals taken were juveniles. Dominant species were *Sphyrna lewini, Mustelus mosis, Halaelurus lineatus, Gymnura natalensis* and *Himantura gerrardi*. In a later study, Mkhize (2006) calculated elasmobranch catches in 2003 of the same fishery to be only 89 tons, partly attributable to much lower fishing effort. She documented 24 species of elasmobranch, contributing about 5% to the total discarded bycatch by number. Poor catch rates and market competition with cultured shrimp have effectively ceased operations since 2009 of this inshore fishery. It was estimated that the offshore deep-water shrimp trawl fishery discards about 901 tons of fish and invertebrates annually (2003 data). Of this 158 tons (18%) are elasmobranchs, represented by 17 species (Persad 2005). More recent observer data in both these shrimp fisheries has been collected (Tables 4 and 5; S. Fennessy/ORI, unpublished data) (see Chapters 2&3).

Table 4. Common elasmobranchs recorded by observers on 198 inshore (Thukela Bank) trawls from 2003-2006 (total fleet effort ~1000 trawls) (S. Fennessy/ORI, unpublished data).

Species	*Common name*	*No.*	*%*
Sphyrna lewini	Scalloped hammerhead shark	978	49.8
*Gymnura natalensis**	Diamond ray	302	15.4
Hymantura gerrardi	Brown ray	188	9.6
*Rhinobatos annulatus**	Lesser sand shark	113	5.8
Carcharhinus brevipinna	Spinner shark	67	2.7
Dasyatis thetidis	Thorntail ray	45	2.3
Mustelus mosis	Smooth hound shark	44	2.2
*Dasyatis chrysonata**	Blue ray	43	2.2
Pteromylaeus bovinus	Duckbill ray	35	1.8
Himantura uarnak	Honeycomb stingray	30	1.5
Other elasmobranchs		186	12.7

** endemic*

Table 5. Common elasmobranchs recorded by observers on 426 deep water trawls from 2003-2006 (total fleet effort ~6000 trawls) (S. Fennessy/ORI, unpublished data).

Species	*Common name*	*No.*	*%*
Squalus megalops	Spiny dogshark	3053	42.8
Holohalaelurus punctatus	Spotted catchark	573	8
Dalatias licha	Seal sharks	569	8
Pliotrema warreni	Sixgill sawshark	557	7.8
Squalus mitsukurii	Spiny dogshark	517	7.2
Cruriraja triangularis	Triangular legshark	423	5.9
Raja alba	Spearnose ray	400	5.6
Raja springeri	Roughbelly skate	319	4.5
*Squatina africana**	African Angel shark	145	2
Cephaloscyllium sufflans	Balloon shark	112	1.6
Other elasmobranchs		127	5.4

** endemic*

In addition to the industrial fisheries, there are commercial and recreational line fisheries which also take elasmobranchs, though most are released alive. In some cases commercial exploitation has taken place, notably for young dusky sharks (*C. obscurus*) (Dudley 2013) for food and for a variety of species for fins. However, these fisheries are managed and do not represent a threat *per se*. Over the years the attitude of fishers to killing unwanted elasmobranchs has changed so that in most cases the catch is released alive. Indeed, South Africa is well advanced in the development of a National Plan of Action (NPOA) for sharks.

Mozambique

It has been estimated that up to 60% of the Mozambican population is in some way dependent on marine resources. A wide variety of fisheries occur with licenses issued to domestic operators and especially to partnerships with foreign fishing companies. Table 6 reflects the number issued, although some licences may be dormant and thus inactive. The data also reveals a declining trend in license numbers, partly attributable to improved management and rationalization in these fisheries.

Table 6. Total semi- and industrial licences issued by ADNAP for Mozambique fisheries.

Fishing licences	*Peak*	*2011*
Inshore shrimp trawl	45 in 1980	13
Deep water shrimp trawl	90 in 1999	55
Purse seine	51 in 2007	34
Long line	110 in 2005	37
Linefish	43 in 2008	34

There are also a limited number of licensed gill net fisheries that capture line fish and sharks. Sharks are caught in virtually all Mozambican fisheries, either as target, or bycatch: discarded or retained. Elasmobranchs have been reported in industrial, semi-industrial and artisanal fisheries and by all types of boats using all types of gears in the full range of depth intervals, from the coastline to about 1,200m in depth (Sousa *et al.* 1997). In the late 1990s, a few semi-industrial directed shark fisheries using gillnets were established in the Maputo area as well as in Inhambane Bay and in the region of Vilankulos, especially targeting coastal/shelf-associated species (Sousa *et al.* 1997). However, these shark-directed fisheries appear to fluctuate and had effectively been reduced to two operators by 2010. Periodically, elasmobranchs are opportunistically targeted in certain places. One example was the intense pursuit of mantas at Ligogo in 2010, where a large number of mantas *Manta alfredi/birostris* and short-horn devilrays *Mobula kuhlii* were caught in gillnets. As this site is near Inhambane and famed for top manta diving encounters, this created a local management problem.

Most of the elasmobranchs taken in Mozambique waters are part of a bycatch, with shrimp trawlers catching the most significant quantities. However, bycatch reduction devices (BRDs) have been tested in shrimp trawl fisheries in Mozambique. Fennessy & Isaksen (2007) showed that 75% of hauls with reduction grids caught fewer large rays than those without grids, while hauls using grids caught no large sharks at all. Overall, the Nordmøre grid successfully allowed the escape of larger elasmobranchs. Use of the grid, as well as a square-mesh panel sewn into the trawl, substantially reduced the bycatch without significantly reducing shrimp catches (Fennessy & Isaksen 2007).

Tanzania

Fisheries in Tanzania are largely artisanal, and include handline, longline and gillnet operations. In 2008, there were 7,342 and 7,155 small fishing vessels in Tanzania mainland and Zanzibar, respectively (MLFD/MALE 2008). Fishing for elasmobranchs has occurred for centuries, especially in Zanzibar, being mostly seasonal during austral summer. Sharks are important resources for Zanzibar, not only as a valuable and cheap source of dried meat, but more importantly also as a major source of income provided by fins (Schaeffer 2004). Bottom-set gillnets, which particularly target sharks and rays, vary in length up to 450m, with mesh sizes ranging from 20-40cm bar. Longlines are also used to harvest sharks (Barnett 1997).

In Zanzibar, a study on shark fisheries was conducted in April 2004 based on interview data from two landing sites in Stone Town (Schaeffer 2004). Data was gathered through observation of the type and number of sharks landed, fishing gear employed, and sale of shark products, particularly fins. A total of sixteen different shark species was identified during this study, although species identification was problematic. Most abundant species were *Carcharhinus macloti*, *R. acutus* and *C. amblyrhynchos*. *S. africana* and *C. obscurus* were other species mentioned as common in the catches (Schaeffer, 2004). The total catch of fish landed in Zanzibar declined from around 20,000t in the 1980s to about 10,000t in 1995. Shark landings statistics show a similar declining trend (Shede & Jiddawi 1997), although no more up-to-date information appears to be available. Besides a thriving artisanal sector, there is also an industrial inshore shrimp trawl fishery which is known to capture elasmobranchs as bycatch. However, this fishery was closed in 2008, in part due to a high level of turtle bycatch. At the time of closure a total number of 25 vessels was licenced although each year this is reviewed. This fishery is likely to resume operations in the near future, ostensibly with bycatch reduction devices in place.

Kenya

Kenyan fisheries include both artisanal and semi-industrial sectors, and are of major socio-economic importance. Artisanal fisheries are confined to shallow coastal waters but account for 90% of the annual total marine fish landed: 10,000-16,000t taken by about 10,000 fishers. A wide range of gears that can catch elasmobranchs is used by artisanal fishers, including gillnets, beach seines, shrimp trawls and longlines. In 2006, 28 artisanal landing sites were known to exist along the coast of Kenya (Kiszka *et al.* 2008).

There is a significant semi-industrial shallow water shrimp fishery in Ungwana Bay that has experienced high turtle mortalities and was closed accordingly for several years before using BRDs as a matter of course. Research trawling has indicated that these fisheries take an elasmobranch bycatch in moderate numbers, including *Himantura uarnak*, *Dasyatis pastinaca, Raja alba, Raja smithi, Squatina africana and Squalus aspes* (Kimani *et al.* 2010). Unfortunately, sharks taken by foreign pelagic operators and those explicitly directed at sharks, have not been documented (Marshall 1997). Nevertheless, there is an industrial fishery associated with harvesting shark and rays. Mombasa is the centre of a considerable shark fin and meat trade, with a number of dealers licensed to import and export shark fin products. For the period 1986 to 1990, Kenya exported a total of 139t of shark fins, which equates to an average of 28t per year (Marshall, 1997). Until recently, quantities of dried shark meat and fins were imported from Somalia (van der Elst, unpublished data). No recent estimates have been published, but the shark fin trade probably increased during the last two decades.

Union of the Comoros

Very little is known on shark use and exploitation in the Comoros. Fishing in the Comoros is entirely artisanal but licenses are awarded to commercial Asian and European longline and purse-seine fishing vessels. Coastal and artisanal fishing gears include handlines, beach seines, fish traps, and gillnets (Poonian *et al.* 2008). Gillnets targeting sharks have been reported (around 250m long, 2m deep with a bar mesh size of 30cm). However, the extent of their use is undocumented.

In 2009, a dedicated interview survey was conducted to assess the use, bycatch and exploitation of sharks and other elasmobranchs around the Comoros (Maoulida *et al.* 2009). Artisanal fishers were interviewed about the frequency of shark catches, species caught, gear used and market value. A number of shark species was found to be caught in Comorian waters, including *C. longimanus, S. lewini, G. cuvier* and *C. falciformis*.

On Grande Comoro (Ngazija), sharks were caught largely as bycatch, while on Anjouan, sharks were more often intentionally targeted. Shark meat was cheaper (USD 0.5-2 per kg) than other fish, such as tuna (USD 3-5 per kg); but fins and dried meat were an exception, reaching high values at market, up to USD 40 per kg and USD 5 per kg respectively. Local fishers valued sharks as an indicator of the presence of large schools of tuna; the most important fishery resource. Some 42% of the Anjouan fishers confirmed intentionally targeting sharks, indicating that this island should be a priority for elasmobranch fisheries management in the Comoros. Overall, sharks did not appear to be highly valued as a resource in the Comoros. However, the disproportionately high value of shark fins and increasing demand from overseas could result in rapid and unsustainable increases in shark catch (Maoulida *et al.* 2009).

Mayotte and French dispersed islands (Europa, Bassas da India, Juan de Nova, Glorieuses, Tromelin)

Fisheries around Mayotte are mostly artisanal and poorly developed. The most important fishing technique is handline, targeting reef and pelagic fish. In 2006, 1,092 small boats (including pirogues and small vessels less than 7m long) were recorded around the island (Direction des Affaires Maritimes, personal communication). Small seines are also used on the barrier reef to target small reef fish (only around 20 boats). Two small longliners also operate from Mayotte in the territorial waters, targeting billfish and tunas (Kiszka *et al.* 2010).

In a 2010 interview survey, data was collected on the bycatch, exploitation and use of elasmobranchs by small-scale coastal fisheries around Mayotte (Hamada, 2010). Up to 97% of respondents confirmed taking sharks as retained bycatch; meat being consumed but fins not collected. The most commonly caught species were *S. lewini*, *G. cuvier*, *C. amblyrhynchos* and *N. ferrugineus* (Hamada 2010).

In the domestic pelagic longline fishery, sharks make up 20.3% of catches but are generally discarded. The most commonly caught species are, in order of occurrence, *C. falciformis*, *P. glauca*, *S. lewini* and *C. longimanus* (Kiszka *et al.* 2010). Based on data collected during an observer programme (2009-2010), out of a total number of 166 sharks caught, 127 were discarded (76.5%). Most of them were released alive (88.2%), all others being discarded dead. The capture mortality of the sharks was recorded for 137 individuals: 16.1% were observed dead and 83.9% were alive (Kiszka *et al.* 2010).

Around the French scattered islands, no fisheries are allowed. However, illegal fishing occurs, especially around the Glorieuses islands (from Madagascar and possibly other countries, including from Asia) and it has been recently shown that sharks could be targeted, probably for fins (J. Kiszka, unpublished data, Figure 2). Illegal longline fishing boats from Sri Lanka have also been documented with shark fins around Glorieuses islands (*Préfecture des Terres Australes et Antarctiques Françaises*, personal communication).

Madagascar

In Madagascar, fisheries constitute a primary source of income for both coastal communities and foreign revenue for the national economy. The three main types of fisheries in Madagascar, are classified according to the power of vessels' engines: commercial (>50hp), artisanal (<50hp) and traditional (non-motorized). In 2006, 80 commercial longline and trawling vessels exploiting tunas, swordfish, sharks and shrimps were recorded (source: Ministry of Agriculture, Fisheries and Livelihoods). The artisanal fisheries mainly utilize gillnets to target elasmobranchs, fish and crustaceans. Traditional fisheries target a full range of resources, including elasmobranchs, cephalopods, sea turtles, echinoderms and fish in shallow coastal and as well as pelagic waters.

The industrial, artisanal and traditional shark fisheries of Madagascar have been the subject of studies dating back as far as 1930 (Petit 1930). Studies have been mostly undertaken in the north of the country and in the southwest (particularly the Toliara region (Andriamanaitra 2004; McVean *et al.* 2006). Here there is an active export market for the fins resulting from these fisheries, indicating a considerable social and economic importance in this impoverished region of Madagascar. In the Toliara region, results from a total of 1,164 fishing outing records, included at least 13 species of elasmobranchs, with an estimated total wet weight of over 123t. Hammerhead sharks *Sphyrna* spp. represented 29% of sharks caught by number and 24% of the total wet weight (McVean *et al.* 2006). There were 30 longline vessels registered by the ministry of fisheries in 2010, 60% operating along the west coast. Around 23% of their east coast catches comprise sharks, while this proportion is lower at 17% from the western waters. Trolling liners and encircling gillnets (which are called artisanal fisheries in Madagascar) catch sharks at quite low levels (1.13% for the east and 0.74 % for the west; Rahombanjanahary, 2011).

In some cases shrimp fishers have shifted their activity into pelagic fisheries by changing their vessels to small-scale longliners. In the period from 2008 to 2010, there were five such converted longliners; four fishing the west and one the east coast of Madagascar. Shark fisheries are showing signs of decline, possibly as a result of the decline of other established fisheries (Rahombanjanahary, 2011).

Figure 2: Dried shark meat in an illegal fishing camp, Glorieuses islands, April 2011 (*C. amblyrhynchos*). (Photo: Jeremy Kiszka)

Seychelles

There is a long history of shark fishing in Seychelles, considered to have been of significant socio-economic importance. Prior to WWII, sharks were caught as bycatch but retained and mostly dried for local consumption. At the end of the war, the market for dried shark meat was further developed. Consequently, fishing effort was applied across the entire Mahé plateau and its surrounds, the banks beyond and the Amirantes. However, in the late 1950s, the decline of large sharks around the central islands had been noted and by the end of the 1960s, large sharks were almost absent off Mahé (Smith & Smith 1969). A local semi-industrial long-line fishery was initiated in the mid-1990s to target swordfish and tuna; resulting in an increased shark bycatch. In the late 1990s, it was noted that some of the longline vessels were increasingly targeting and finning sharks in order to export this high-value commodity (Bargain 2001). The targeting of sharks increased dramatically when the Seychelles Government banned the export of swordfish (2003-2005) to the EU until issues regarding the cadmium content of the fish exceeding EU recommended levels were resolved in 2005.

Shark stocks of Seychelles have continued to be the subject of increasing exploitation with concern as to their sustainability and in particular the practice of "finning" in some fisheries. Three agencies are known to export fins to the Asian market (Seychelles NPOA 2007). The Ministry of Environment and Natural Resources (MENR) and the Seychelles Fishing Authority (SFA) initiated the process to develop a National Plan of Action for the Conservation and Management of Sharks (NPOA-sharks) to address these concerns (Seychelles NPOA 2007).

One of the most useful sources of information on the species composition of contemporary stocks is restricted to an interview-based stakeholder survey (Nevill 2005). This study highlights the fact that shark diversity in Seychelles coastal waters had decreased significantly (Nevill 2005). Diving with sharks represents a significant component of the tourism industry.

Galapagos shark, *Carcharhinus galapagensis*. A globally distributed pelagic species associated with oceanic islands. (Photo: Chris Fallows www.apexpredators.com)

La Réunion

Two main fisheries occur around La Réunion: longline and handline (coastal, reef-associated). Longlining occurs throughout the year in the EEZ by a fleet of around 30 vessels (2010), targeting tuna and swordfish. Handlines target reef fish, and around 300 boats have been recorded around the island (IFREMER, personal communication). Sharks are seldom targeted, and shark finning is prohibited in accordance with European regulations. Data from voluntary logbooks (5,884 longline sets) collected between 1997 and 2000 were analysed to assess the potential impact of the Réunion-based longline swordfish fishery on sharks (Poisson, 2011). Blue sharks represented between 75% and 88% of shark catches, with variable discard rates between species, ranging from low discards (2.6%) for *Isurus* spp. to high discards for blue shark (86.5%). Estimates by weight of the total catch of sharks (both retained and discarded) ranged from 7% to 9% of the total catch of the major target species caught by the fishery. Of concern is the decline of blue shark CPUE from 2.2 to 1.03 sharks per 1,000 hooks between 1998 and 2000 (Poisson 2011). As a result of a growing number of shark bites on surfers and bathers since 2011, drumlines are currently used to remove coastal sharks along the coast of La Réunion (particularly *C. leucas* and *G. cuvier*).

Mauritius

The Mauritian fleet consists of artisanal, semi-industrial and industrial operations. The artisanal fleet has 1,605 vessels, consisting of 7-9m long boats targeting mainly shallow-water demersal species in the lagoon and outer reefs. Some 1,620 fishers were registered in this fishery in 2010 (Sweenarain 2011). The semi-industrial fleet consists of four vessels, each less than 24m and mostly involved in the shallow-water demersal fishery on offshore reef banks, with some occasionally also involved in the pelagic fishery. The industrial fleet consists of three vessels longer than 24 meters. A small-scale FAD fishery is being developed in order to offset the depleted artisanal lagoon fish stocks, targeting mainly tuna around some 27 FADs.

Although elasmobranchs are seldom targeted around Mauritius, they are frequently taken as bycatch, both in coastal/small-scale and pelagic fisheries. Recently, the shark bycatch in all Mauritian fisheries was investigated (Mamode 2011). From 2006 to 2010, the shark bycatch was recorded in semi-industrial and industrial pelagic fishing boats, although without information on species composition. For the years 2009-2010 a total of 2,349t of sharks was transhipped at Port Louis. The main species of sharks landed from licensed and non-licensed fishing vessels calling at Port Louis consisted of blue (58.1%) and short-fin mako sharks (38.9%) (Mamode 2011).

OVERVIEW OF OPEN-OCEAN SHARK BYCATCH IN THE WIO

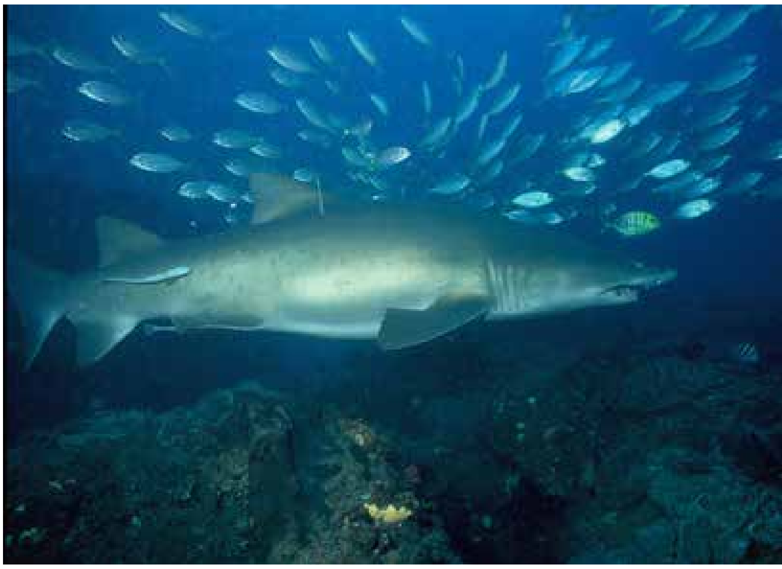
In the western Indian Ocean, longlines, purse seines and occasionally pelagic driftnets are used to harvest tuna, swordfish and elasmobranchs; either as target species or as bycatch. These fisheries are considered one of the most significant sources of shark mortality in the region. In 2009, 33 countries reported elasmobranch landings from the FAO fishing area 51, totalling 86,500t (FAO 2012). This represents about 12% of the total reported global elasmobranchs catch of 721,163t. Significantly, the western Indian Ocean elasmobranch catch is third highest of all the FAO fishing regions. The entire Indian Ocean accounts for the highest ocean catch of elasmobranchs. Although detailed information on shark catch and bycatch in the Indian Ocean is still limited, there have been improvements in data submission to the Indian Ocean Tuna Commission (IOTC) since the early 2000s. These records indicate that 15 species (belonging to 5 families) are regularly taken in the region's fisheries (Smale 2008). However, most of the elasmobranch landings in the IOTC region are still not identified to species and are grouped as "sharks". There are still too few observer programmes in the Indian Ocean and SWIO in particular, and little is known on trends in pelagic shark populations of the region, except from data collected in the South African pelagic longline fishery and the KwaZulu-Natal Sharks Board.

In the Indian Ocean, most shark carcasses are discarded but fins are collected. Overall, elasmobranch catches drastically increased in the western Indian Ocean (FAO fishing area 51), peaking in 1996, partly attributable to higher fishing effort directed at tuna. However, since that peak the reported landings of elasmobranchs subsided significantly as depicted in Figure 1 (Smale 2008). Three main shark families are taken in pelagic fisheries in the SWIO: Lamnidae, Alopiidae and Carcharhinidae.

Among the requiem sharks, *P. glauca*, *C. falciformis* and *C. longimanus* are the most commonly caught species. *C. falciformis* is distributed throughout the region (Fourmanoir 1961; Compagno 1984). Off the Maldives, this is the most important pelagic shark caught (70-80%; Anderson & Hafiz 2002). In the purse seine fishery, for the period 1986 to 1992, the annual bycatch was estimated at 944-2,270t of pelagic oceanic sharks and 53-112t of *Mobula* spp. and *Manta* spp. (Romanov 2002). For the period 2003-2009, silky sharks were the most common bycatch shark species by weight in the purse seine fishery associated with floating objects, as deduced from observer data on European vessels (Amandè *et al.* 2011). The highest catch rates were observed in the northern fishing grounds (2°N, 53°E), north of the Seychelles (Amandè *et al.* 2011). Fishing operations under FADs are characterized by significantly higher bycatch levels (4.3 sharks per set in FAD-associated tuna vs. 0.3 sharks in targeting of free shoaling tuna; Amandè *et al.* 2008).

An extensive and large-scale study on catches in the Taiwanese pelagic longline fishery in the Indian Ocean was conducted by Huang & Liu (2010). Observer data collected from 77 trips on Taiwanese longline vessels from June 2004 to March 2008 were used to estimate the scale of the bycatch. At least 40 species were recorded. Albacore, bigeye, yellowfin, and southern bluefin tuna were the major target species and comprised over 73.3% of the total retained catch. Major bycatch species were *X. gladius*, *P. glauca*, *Istiophorus platypterus*, *Brama brama*, and *Lepidocybium flavobrunneum* (Huang & Liu 2010). Highest bycatch rates were observed in the tropical Indian Ocean (between 10°N and 10°S, i.e. the bigeye tuna fishery), with, in order of occurrence, *P. glauca* (n=2,067 individuals), *C. falciformis* (n=621), *A. superciliosus* (n=439) and *I. oxyrinchus* (n=219) (Huang & Liu 2010). In the albacore tuna fishery, essentially occurring between 10°S and 25°S, bycatch rates were lower and *P. glauca* and *I. oxyrinchus* were the most common bycatch species.

Off South Africa, *P. glauca* is targeted in the pelagic shark-directed longline fishery and is a common bycatch in the tuna and swordfish directed fisheries. Of the total pelagic shark landings in South Africa, including east and west coasts, *P. glauca* comprised 35% of landed mass from 1998 to 2008 (Jolly *et al.* 2011). Recent results highlighted greatest *P. glauca* abundance during summer and autumn off the west coast of South Africa, and standardized CPUE for both fisheries suggests that *P. glauca* catch rates remained relatively stable from 1998 to 2008 (Jolly *et al.* 2011).



Raggedtooth shark, *Carcharias taurus*, shortly after being tagged on a KZN reef. (Photo: Geremy Cliff)

Management of shark fisheries and mitigation of bycatch in the SWIO

COASTAL FISHERIES

In the SWIO, very few mitigation measures have been implemented to minimise elasmobranch bycatch, except in some trawl fisheries where bycatch levels of elasmobranchs are the most significant. Various initiatives have been undertaken to reduce bycatch in shrimp trawl fisheries of the region (Fennessy *et al.* 2008). In Kenya, the use of TEDs (Turtle Excluder Devices), contributing to reduce elasmobranch bycatch, was legislated in 2003. In 2008, a draft discussion paper aimed at developing a shrimp fishery management plan was circulated to stakeholders. This plan includes gear modification, reduced fishing effort and zonation of the fishing grounds in order to reduce user-conflict (Fennessy *et al.* 2008). No concrete mitigation measures were implemented in Tanzania, while in Mozambique; legislation has required the compulsory use of TEDs since 2005. A number of experiments to test various BRD designs have been conducted jointly by South Africa and Mozambique. There are additional initiatives underway to investigate shrimp trawl gear technology including Turtle Excluder Devices (TEDs) (Fennessy *et al.* 2008). In South Africa, the use of Nordmøre grids provided good results, with a reduction by 60% of elasmobranch bycatch. Other legislated measures reducing bycatch in South Africa have also been implemented, including a mesh size limit (50mm), an inshore trawling distance limit of 0.5nm, and the prohibition of the sale of certain bycatch species (Fennessy *et al.* 2008). In Madagascar, a number of mitigation measures have been implemented to reduce bycatch in shrimp trawl fisheries, including mesh size restrictions, trawl gear size limits, closed seasons and areas, partial prohibition of nocturnal trawling, limited number of permits and zonation of effort. The use of TEDs was legislated in 2003 and enforced in 2005 (Fennessy *et al.* 2008).

Shark finning, Comoros. (Photo: Hendrik Sauvignet)

While the industry generally appears amenable to the ultimate implementation of these devices, the actual level of implementation of BRDs has been variable with encouraging levels of implementation in several fisheries, such as in Kenya and Tanzania. Improved legislation and heightened awareness are prerequisites.

OCEANIC FISHERIES

Managing wide ranging oceanic species is highly challenging. Fortunately, the IOTC has greatly improved data collection on shark and other bycatch species in the Indian Ocean. In addition, the number of reports on elasmobranch ecology, behaviour, bycatch and usage has significantly increased over the last ten years, highlighting the increasing interest to manage shark and ray populations in the region. However, information remains inadequate and the scale and extent of the shark bycatch in oceanic realm of the Indian Ocean is probably much higher than reflected in current data.

Baum *et al.* (2003) have suggested that shark populations have drastically declined in the Atlantic Ocean (75% of decline over 15 years). Overall the declining trend in the western Indian Ocean appears equally serious judging by FAO data presented in Figure 1. However, no information is at hand from the Indian Ocean to detect trends in individual shark populations, especially in the SWIO, except for South Africa. Indeed, pelagic shark longline records and shark catches made by the KwaZulu-Natal Sharks Board are the only reliable sources of information to assess long-term trends. As indicated earlier, several species appear to have been substantially depleted, such as hammerhead sharks (*Sphyrna* spp.). In the SWIO, the lack of capacity in specific countries to assess, manage and control access to their EEZ is also a major problem that needs to be addressed. Due to their life history traits, limiting their stock rebuilding potential, management plans for elasmobranchs are urgently needed in the Indian Ocean. It has been suggested that open ocean marine protected areas could assist shark populations. One management approach that is increasingly being considered is fisheries' closures (Grantham *et al.* 2008). In the South African pelagic longline fishery, three closure approaches were tested, suggesting that temporary spatial closures were the most cost effective and considerably reduced bycatch, while purely seasonal closures were ineffective (Grantham *et al.* 2008).

Technical modifications of gears have also been implemented in many fishing areas around the world. While the use of nylon leaders generally lead to lower shark bycatch rates and increase bigeye tuna catches (Ward *et al.* 2008), the use of circle hooks does not really lead to a decrease of bycatch (e.g. Yokota *et al.* 2006). In the SWIO region, the MADE project (Mitigating ADverse impacts of open ocean fisheries, www.made-project.eu) is investigating the effectiveness of certain mitigation measures to decrease shark bycatch, such as the use of "ecological FADs", the implementation of better practices on board vessels, the use of artificial baits or a better vertical distribution of hooks (Dagorn 2011). In addition, it has been recently shown that drifting FADs constitute a major source of mortality for silky sharks in the Indian Ocean (Filmalter *et al.* 2013). In this region, entanglement mortality of silky sharks is about 5-10 times that of other known bycatch shark species taken as bycatch from the region's purse-seine fleet. Estimates from this single ocean (480,000-60,000 individuals) rival those from all world fisheries combined (400,000-2 million individuals). This situation clearly requires immediate management decisions (Filmalter *et al.* 2013).

Member states of FAO that are targeting sharks in its fisheries have to compile a National Shark Assessment Report (SAR). The Seychelles has published their NPOA-Sharks in 2007. Amongst others, this report should take into account issues pertaining to biodiversity, conservation and the management of sharks. There is a shark management plan in South Africa which provides the basis for development of a National Plan of Action for the conservation and management of sharks in South African waters.

Gaps and recommendations

South African-based scientists have generated considerable information on elasmobranchs. In addition, credible information from KZN shark nets is also a useful data set that provides scientific knowledge on elasmobranchs, including on population trends. However, knowledge on the ecology, biology and fisheries of elasmobranchs in the SWIO region remains highly fragmentary and limited. Fortunately, there is an increase in research activities on open ocean sharks and the development of new initiatives in the region, especially under the auspices of IOTC and its active Working Party on Ecosystems and Bycatch (WPEB). Overall, research on sharks and rays has been limited to large and emblematic species, ignoring the assessments of smaller, less charismatic but equally threatened species. The biggest gap relates to assessment of elasmobranchs, their population dynamics and sustainability. There are very few models to assess elasmobranchs. The question posed is: how serious is the bycatch of elasmobranchs in specific fisheries? Which species are vulnerable and why? Such information is not available in most cases.

Here are some recommendations for research and management:

- Better reporting of shark bycatch, in all fisheries, including the use of semi-quantitative approaches in coastal/artisanal/small scale fisheries, having an impact on even less resilient species (e.g. reef sharks).
- Studies on population structure to define elasmobranch management units, at different temporal scales (from populations to individuals, from evolutionary to ecological/behavioural scales). Included should be telemetry on a regional basis (Kiszka & Heithaus 2014).
- Detailed assessment of shark finning in the SWIO region.
- Implementation of Shark Assessment Reports in all SWIO countries, and the development of NPOA-Sharks in all SWIO countries.
- Development of regional management plans for stocks which straddle international boundaries.

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Annex:
Draft list of elasmobranchs species recorded in the West Indian Ocean. Highlighted are endemic to SWIO.

Order	*Family*	*Genus*	*Species*	*Authors*	*IUCN Red list status**
SHARKS					
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*albimarginatus*	Rüppell (1837)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*altimus*	Springer (1950)	DD
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*amblyrhynchos*	Bleeker (1856)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*amboinensis*	Müller & Henle (1839)	DD
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*brachyurus*	Günther (1870)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*brevipinna*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*falciformis*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*galapagensis*	Snodgrass & Heller (1905)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*humani sp. nov.*	White & Weigmann (2014)	NE
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*leucas*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*limbatus*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*longimanus*	Poey (1861)	VU
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*macloti*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*melanopterus*	Quoy & Gaimard (1824)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*obscurus*	Lesueur (1818)	VU
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*plumbeus*	Nardo (1827)	VU
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*sealei*	Pietschmann (1913)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*sorrah*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Galeocerdo*	*cuvier*	Péron & LeSueur (1822)	NT
Carcharhiniformes	Carcharhinidae	*Loxodon*	*macrorhinus*	Müller & Henle (1839)	LC
Carcharhiniformes	Carcharhinidae	*Negaprion*	*acutidens*	Rüppell (1837)	VU
Carcharhiniformes	Carcharhinidae	*Prionace*	*glauca*	Linnaeus (1758)	NT
Carcharhiniformes	Carcharhinidae	*Rhizoprionodon*	*acutus*	Rüppell (1837)	LC
Carcharhiniformes	Carcharhinidae	*Scoliodon*	*laticaudus*	Müller & Henle (1838)	NT
Carcharhiniformes	Carcharhinidae	*Triaenodon*	*obesus*	Rüppell (1837)	NT
Carcharhiniformes	Hemigaleidae	*Hemipristis*	*elongata*	Kluzinger (1871)	VU
Carcharhiniformes	Hemigaleidae	*Paragaleus*	*leucolomatus*	Compagno & Smale (1985)	DD
Carcharhiniformes	Proscyllidae	*Ctenacis*	*fehlmanni*	Springer (1968)	DD
Carcharhiniformes	Proscyllidae	*Eridacnis*	*radcliffei*	Smith (1913)	LC
Carcharhiniformes	Proscyllidae	*Eridacnis*	*sinuans*	Smith (1913)	LC
Carcharhiniformes	Pseudotriakidae	*Pseudotriakis*	*microdon*	Brito Capello (1868)	DD
Carcharhiniformes	Scyliorhinidae	*Apristurus*	*indicus*	Brauer (1906)	NE
Carcharhiniformes	Scyliorhinidae	*Apristurus*	*longicephalus*	Nakaya (1975)	DD
Carcharhiniformes	Scyliorhinidae	*Cephaloscyllium*	*sufflans*	Regan (1901)	LC
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*boesemani*	Springer & D'Aubrey (1972)	DD
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*clevai*	Seret (1987)	NE
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*lineatus*	Bass, D'Aubrey & Kistnasamy (1975)	DD
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*lutarius*	Springer & D'Aubrey (1972)	DD
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*natalensis*	Regan (1904)	DD
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*quagga*	Alcock (1899)	DD
Carcharhiniformes	Scyliorhinidae	*Haploblepharus*	*edwardsii*	Schinz (1822)	NT
Carcharhiniformes	Scyliorhinidae	*Haploblepharus*	*fuscus*	Smith (1950)	VU
Carcharhiniformes	Scyliorhinidae	*Haploblepharus*	*kistnasamyi*	Human & Compagno (2006)	CR
Carcharhiniformes	Scyliorhinidae	*Holohalaelurus*	*grennian*	Human (2006)	NE
Carcharhiniformes	Scyliorhinidae	*Holohalaelurus*	*favus*	Human (2006)	EN
Carcharhiniformes	Scyliorhinidae	*Holohalaelurus*	*melanostigma*	Norman (1939)	DD
Carcharhiniformes	Scyliorhinidae	*Holohalaelurus*	*punctatus*	Gilchrist (1914)	EN

Order	Family	Genus	Species	Authors	IUCN Red list status*
Carcharhiniformes	Scyliorhinidae	*Holohalaelurus*	*regani*	Gilchrist (1922)	LC
Carcharhiniformes	Scyliorhinidae	*Poroderma*	*africanum*	Gmelin (1789)	NT
Carcharhiniformes	Scyliorhinidae	*Poroderma*	*pantherinum*	Müller & Henle (1838)	DD
Carcharhiniformes	Scyliorhinidae	*Scyliorhinus*	*capensis*	Müller & Henle (1838)	NT
Carcharhiniformes	Scyliorhinidae	*Scyliorhinus*	*comoroensis*	Compagno (1988)	DD
Carcharhiniformes	Sphyrnidae	*Sphyrna*	*lewini*	Griffith & Smith (1834)	EN
Carcharhiniformes	Sphyrnidae	*Sphyrna*	*mokarran*	Rüppell (1837)	EN
Carcharhiniformes	Sphyrnidae	*Sphyrna*	*zygaena*	Linnaeus (1758)	VU
Carcharhiniformes	Triakidae	*Galeorhinus*	*galeus*	Linnaeus (1758)	VU
Carcharhiniformes	Triakidae	*Hypogaleus*	*hyugaensis*	Miyosi (1939)	NT
Carcharhiniformes	Triakidae	*Mustelus*	*manazo*	Bleeker (1854)	DD
Carcharhiniformes	Triakidae	*Mustelus*	*mosis*	Hemprich & Ehrenberg (1899)	DD
Carcharhiniformes	Triakidae	*Mustelus*	*palumbes*	Smith (1957)	DD
Carcharhiniformes	Triakidae	*Scylliogaleus*	*quecketti*	Boulenger (1902)	VU
Carcharhiniformes	Triakidae	*Triakis*	*megalopterus*	Smith (1839)	NT
Heterodontiformes	Heterodontidae	*Heterodontus*	*ramalheira*	Smith (1949)	DD
Hexanchiformes	Hexanchidae	*Heptranchias*	*perlo*	Bonnaterre (1788)	NT
Hexanchiformes	Hexanchidae	*Hexanchus*	*griseus*	Bonnaterre (1788)	NT
Hexanchiformes	Hexanchidae	*Hexanchus*	*nakamurai*	Teng (1962)	DD
Hexanchiformes	Hexanchidae	*Notorynchus*	*cepedianus*	Peron (1807)	DD
Lamniformes	Alopiidae	*Alopias*	*pelagicus*	Nakamura (1935)	VU
Lamniformes	Alopiidae	*Alopias*	*superciliosus*	Lowe (1840)	VU
Lamniformes	Alopiidae	*Alopias*	*vulpinus*	Bonnaterre (1788)	VU
Lamniformes	Lamnidae	*Carcharodon*	*carcharias*	Linnaeus (1758)	VU
Lamniformes	Lamnidae	*Isurus*	*oxyrinchus*	Rafinesque, 1810	VU
Lamniformes	Lamnidae	*Isurus*	*paucus*	Guitart (1966)	VU
Lamniformes	Lamnidae	*Lamna*	*nasus*	Bonnaterre (1788)	VU
Lamniformes	Mitsukurinidae	*Mitsukurina*	*owstoni*	Jordan (1898)	LC
Lamniformes	Odontaspididae	*Carcharias*	*taurus*	Rafinesque (1810)	VU
Lamniformes	Odontaspididae	*Odontaspis*	*ferox*	Risso (1810)	VU
Lamniformes	Odontaspididae	*Odontaspis*	*noronhai*	Maul (1955)	DD
Lamniformes	Pseudocarchariidae	*Pseudocarcharias*	*kamoharai*	Matsubara (1936)	NT
Orectolobiformes	Ginglymostomatidae	*Nebrius*	*ferrugineus*	Lesson (1831)	VU
Orectolobiformes	Ginglymostomatidae	*Pseudoginglymostoma*	*brevicaudatum*	Günther (1867)	VU
Orectolobiformes	Hemiscylliidae	*Chiloscyllium*	*plagiosum*	Anonymous [Bennett] (1830)	NT
Orectolobiformes	Rhincodontidae	*Rhincodon*	*typus*	Smith (1828)	VU
Orectolobiformes	Stegostomatidae	*Stegostoma*	*fasciatum*	Hermann (1783)	VU
Pristiophoriformes	Pristiophoridae	*Pliotrema*	*warreni*	Regan (1906)	NT
Squaliformes	Centrophoridae	*Centrophorus*	*granulosus*	Bloch & Schneider (1801)	VU
Squaliformes	Centrophoridae	*Centrophorus*	*lusitanicus*	Bocage & Capello (1864)	VU
Squaliformes	Centrophoridae	*Centrophorus*	*moluccencis*	Bleeker (1860)	DD
Squaliformes	Centrophoridae	*Centrophorus*	*niaukang*	Teng (1959)	NT
Squaliformes	Centrophoridae	*Centrophorus*	*secheyllorum*	Baranes (2003)	DD
Squaliformes	Centrophoridae	*Centrophorus*	*squamosus*	Bonnaterre (1788)	VU
Squaliformes	Centrophoridae	*Deania*	*calcea*	Lowe (1839)	LC
Squaliformes	Centrophoridae	*Deania*	*profundorum*	Smith & Radcliffe (1912)	LC
Squaliformes	Centrophoridae	*Deania*	*quadrispinosum*	McCulloch (1915)	NE
Squaliformes	Dalatiidae	*Dalatias*	*licha*	Bonnaterre (1788)	NT
Squaliformes	Dalatiidae	*Euprotomicrus*	*bispinatus*	Quoy & Gaimard (1824)	LC
Squaliformes	Dalatiidae	*Heteroscymnoides*	*marleyi*	Fowler (1934)	LC
Squaliformes	Dalatiidae	*Isistius*	*brasiliensis*	Quoy & Gaimard (1824)	LC

Order	*Family*	*Genus*	*Species*	*Authors*	*IUCN Red list status**
Squaliformes	Dalatiidae	*Squaliolus*	*laticaudus*	Smith & Radcliffe (1912)	LC
Squaliformes	Echinorhinidae	*Echinorhinus*	*brucus*	Bonnaterre (1788)	DD
Squaliformes	Etmopteridae	*Etmopterus*	*bigelowi*	Shirai & Tachikawa (1993)	LC
Squaliformes	Etmopteridae	*Etmopterus*	*brachyurus*	Smith & Radcliffe (1912)	NE
Squaliformes	Etmopteridae	*Etmopterus*	*compagnoi*	Smith & Radcliffe (1912)	DD
Squaliformes	Etmopteridae	*Etmopterus*	*gracilispinis*	Krefft (1968)	LC
Squaliformes	Etmopteridae	*Etmopterus*	*lucifer*	Jordan & Snyder (1902)	LC
Squaliformes	Etmopteridae	*Etmopterus*	*pusillus*	Lowe (1839)	LC
Squaliformes	Etmopteridae	*Etmopterus*	*sensotus*	Bass, D'Aubrey & Kistnasamy (1976)	LC
Squaliformes	Somniosidae	*Centroscymnus*	*coelolepis*	Bocage & Capello (1864)	NT
Squaliformes	Somniosidae	*Centroselachus*	*crepidater*	Bocage & Capello (1864)	LC
Squaliformes	Somniosidae	*Zameus*	*squamulosus*	Günther (1877)	DD
Squaliformes	Squalidae	*Cirrhigaleus*	*asper*	Merrett (1973)	DD
Squaliformes	Squalidae	*Squalus*	*acanthias*	Linnaeus (1758)	VU
Squaliformes	Squalidae	*Squalus*	*lalannei*	Baranes (2003)	DD
Squaliformes	Squalidae	*Squalus*	*megalops*	Macleay (1881)	DD
Squaliformes	Squalidae	*Squalus*	*mitsukurii*	Jordan & Snyder (1903)	DD
Squaliformes	Squalidae	*Squalus*	*uyato*	Rafinesque (1810)	NE
Squatiniformes	Squatinidae	*Squatina*	*africana*	Regan (1908)	DD
RAYS					
Rajiformes	Anacanthobatidae	*Anacanthobatis*	*marmoratus*	von Bonde & Swart (1923)	DD
Rajiformes	Anacanthobatidae	*Anacanthobatis*	*ori*	Wallace (1967)	DD
Rajiformes	Dasyatidae	*Dasyatis*	*brevicaudata*	Hutton (1875)	LC
Rajiformes	Dasyatidae	*Dasyatis*	*chrysonata*	Smith (1828)	NE
Rajiformes	Dasyatidae	*Dasyatis*	*microps*	Annandale (1908)	DD
Rajiformes	Dasyatidae	*Dasyatis*	*thetidis*	Ogilby (1899)	DD
Rajiformes	Dasyatidae	*Himantura*	*draco*	Compagno & Heemstra (1984)	NE
Rajiformes	Dasyatidae	*Himantura*	*fai*	Jordan & Seale (1906)	LC
Rajiformes	Dasyatidae	*Himantura*	*granulata*	Macleay (1883)	NT
Rajiformes	Dasyatidae	*Himantura*	*imbricata*	Bloch & Schneider (1801)	DD
Rajiformes	Dasyatidae	*Himantura*	*jenkinsii*	Annandale (1909)	LC
Rajiformes	Dasyatidae	*Himantura*	*leoparda*	Manjaji-Matsumoto & Last (2008)	VU
Rajiformes	Dasyatidae	*Himantura*	*uarnak*	Forsskål (1775)	VU
Rajiformes	Dasyatidae	*Neotrygon*	*kuhlii*	Müller & Henle (1841)	DD
Rajiformes	Dasyatidae	*Pastinachus*	*sephen*	Forsskål (1775)	DD
Rajiformes	Dasyatidae	*Pteroplatytrygon*	*violacea*	Bonaparte (1832)	LC
Rajiformes	Dasyatidae	*Taeniura*	*lymna*	Forsskål (1775)	NT
Rajiformes	Dasyatidae	*Taeniura*	*meyeni*	Müller & Henle (1841)	VU
Rajiformes	Dasyatidae	*Urogymnus*	*asperrimus*	Bloch & Schneider (1801)	VU
Rajiformes	Gymnuridae	*Gymnura*	*natalensis*	Gilchrist & Thompson (1911)	DD
Rajiformes	Gymnuridae	*Gymnura*	*poecilura*	Shaw (1804)	NT
Rajiformes	Hexatrygonidae	*Hexatrygon*	*bickelli*	Heemstra & Smith (1980)	LC
Rajiformes	Myliobatidae	*Aetobatus*	*flagellum*	Bloch & Schneider (1801)	EN
Rajiformes	Myliobatidae	*Aetobatus*	*narinari*	Euphrasen (1790)	NT
Rajiformes	Myliobatidae	*Aetomylaeus*	*vespertilio*	Bleeker (1852)	EN
Rajiformes	Myliobatidae	*Manta*	*alfredi*	Krefft (1868)	VU
Rajiformes	Myliobatidae	*Manta*	*birostris*	Walbaum (1792)	VU
Rajiformes	Myliobatidae	*Mobula*	*eregoodootenkee*	Bleeker (1859)	NT
Rajiformes	Myliobatidae	*Mobula*	*japanica*	Müller & Henle (1841)	NT
Rajiformes	Myliobatidae	*Mobula*	*kuhlii*	Müller & Henle (1841)	DD
Rajiformes	Myliobatidae	*Mobula*	*tarapacana*	Philippi (1892)	DD

Order	Family	Genus	Species	Authors	IUCN Red list status*
Rajiformes	Myliobatidae	*Mobula*	*thurstoni*	Loyd (1908)	NT
Rajiformes	Myliobatidae	*Myliobatis*	*aquila*	Linnaeus (1758)	DD
Rajiformes	Myliobatidae	*Pteromylaeus*	*bovinus*	Geoffroy Saint-Hilaire (1817)	DD
Rajiformes	Myliobatidae	*Rhinoptera*	*javanica*	Müller & Henle (1841)	VU
Rajiformes	Plesiobatidae	*Plesiobatis*	*daviesi*	Wallace (1967)	LC
Rajiformes	Rajidae	*Bathyraja*	*smithii*	Müller & Henle (1841)	DD
Rajiformes	Rajidae	*Cruriraja*	*andamanica*	Lloyd (1909)	DD
Rajiformes	Rajidae	*Cruriraja*	*parcomaculata*	von Bonde & Swart (1923)	NE
Rajiformes	Rajidae	*Cruriraja*	*triangularis*	Smith (1964)	NE
Rajiformes	Rajidae	*Dipturus*	*campbelli*	Wallace (1967)	NT
Rajiformes	Rajidae	*Dipturus*	*crosnieri*	Séret (1989)	VU
Rajiformes	Rajidae	*Dipturus*	*johannisdavisi*	Alcock (1899)	DD
Rajiformes	Rajidae	*Dipturus*	*lanceorostratus*	Wallace (1967)	DD
Rajiformes	Rajidae	*Dipturus*	*springeri*	Wallace (1967)	DD
Rajiformes	Rajidae	*Dipturus*	*stenorhynchus*	Wallace (1967)	DD
Rajiformes	Rajidae	*Fenestraja*	*maceachrani*	Séret (1989)	DD
Rajiformes	Rajidae	*Leucoraja*	*wallacei*	Hulley (1970)	LC
Rajiformes	Rajidae	*Okamejei*	*heemstrei*	McEachran & Fechhelm (1982)	NE
Rajiformes	Rajidae	*Raja*	*miraletus*	Linnaeus (1758)	NE
Rajiformes	Rajidae	*Rajella*	*leopardus*	von Bonde & Swart (1923)	LC
Rajiformes	Rajidae	*Rostroraja*	*alba*	Lacepède (1803)	EN
Rajiformes	Rhinobatidae	*Rhina*	*ancylostoma*	Bloch & Schneider (1801)	VU
Rajiformes	Rhinobatidae	*Rhinobatos*	*annulatus*	Müller & Henle (1841)	LC
Rajiformes	Rhinobatidae	*Rhinobatos*	*holcorhynchus*	Norman (1922)	DD
Rajiformes	Rhinobatidae	*Rhinobatos*	*leucospilus*	Norman (1926)	DD
Rajiformes	Rhinobatidae	*Rhinobatos*	*ocellatus*	Norman (1926)	DD
Rajiformes	Rhinobatidae	*Rhinobatos*	*zanzibarensis*	Norman (1926)	NT
Rajiformes	Rhinobatidae	*Rhynchobatus*	*djiddensis*	Forsskål (1775)	VU
Pristiformes	Pristidae	*Anoxypristis*	*cuspidata*	Latham (1794)	EN
Pristiformes	Pristidae	*Pristis*	*pristis*	Linnaeus (1758)	CR
Pristiformes	Pristidae	*Pristis*	*zijsron*	Bleeker (1851)	CR
Torpediniformes	Narcinidae	*Benthobatis*	*moresbyi*	Alcock (1898)	DD
Torpediniformes	Narcinidae	*Electrolux*	*addisoni*	Compagno & Heemstra (2007)	CR
Torpediniformes	Narcinidae	*Heteronarce*	*garmani*	Regan (1921)	NE
Torpediniformes	Narcinidae	*Narcine*	*insolita*	Carvalho, Séret & Compagno (2002)	DD
Torpediniformes	Narcinidae	*Narcine*	*oculifera*	Carvalho, Compagno & Mee (2002)	NE
Torpediniformes	Narcinidae	*Narcine*	*rierai*	Lloris & Rucabado (1991)	DD
Torpediniformes	Narcinidae	*Narke*	*capensis*	Gmelin (1789)	DD
Torpediniformes	Torpedinidae	*Torpedo*	*fuscomaculata*	Peters (1855)	DD
Torpediniformes	Torpedinidae	*Torpedo*	*sinuspersici*	Olfers (1831)	DD

*IUCN RED LIST STATUS ABBREVIATIONS	
Extinct in the wild	EW
Critically endangered	CR
Endangered	EN
Vulnerable	VU
Near threatened	NT
Least concern	LC
Data deficient	DD
Not evaluated	NE