Compilation of information on blue shark (*Prionace glauca*), silky shark (*Carcharhinus falciformis*), oceanic whitetip shark (*Carcharhinus longimanus*), scalloped hammerhead (*Sphyrna lewini*) and shortfin mako (*Isurus oxyrinchus*) in the Indian Ocean

A working paper

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At the Ninth Session of the Indian Ocean Tuna Commission in 2005, the commission adopted the resolution 05/05 , arising from the work of the Compliance Committee, concerning the conservation of sharks caught in association with fisheries managed by IOTC. It is stipulated that Contracting Parties and Cooperating non-Contracting Parties (CPCs) shall annually report their data for shark catches, require that their fishermen use their entire catches of shark (fin-body ratio less than 5%), encourage the release of sharks incidentally caught, promote research on sharks; the Commission requires the working party on By-catch (WPBy) to provide preliminary advice on the stock status of key shark species and provide a research plan and timeline for a comprehensive assessment of these stocks.
The purpose of this document is to present some basic biological data needed for assessment of characteristics of the following pelagic sharks species under the management mandate of IOTC. Blue shark (*Prionace glauca*), silky shark (*Carcharhinus falciformis)*, oceanic whitetip shark (*Carcharhinus longimanus*), Scalloped hammerhead shark (*Sphyrna lewini)* and Shortfin mako sharks (*Isurus oxyrinchus*) are , in the Indian Ocean, the species most commonly taken by semi-industrial and artisanal fisheries in many countries and also taken as bycatch, by the pelagic longline fisheries and in a less extent by the purse-seine fishery.
This document is based primarily on information from literature and studies carried out in Indian Ocean, but when the literature available is scarce we will mention studies available from other oceans. The information pertaining to each species is arranged by paragraphs. Nevertheless, accurate information is sometimes difficult to find. General descriptive characters, illustrations of diagnostic features for each species are given in appendix.

1 Distribution and Habitat

Prionace glauca

Blue shark is oceanic and epipelagic and probably the species with the widest range of all sharks, found up to 40º S. latitude in Indian Ocean. It may be found close inshore where the continental shelf is narrow. Therefore blue shark is a very significant component of pelagic oceanic ecosystems throughout the tropical and temperate oceans worldwide
It prefers relatively cool water at 7 to 16°C but can tolerate warmer temperature. In the tropical Indian Ocean, the greatest abundance of blue sharks occurs at depths of 80 to 220 m, with temperatures about 12 to 25°C. Gubanov and Grigor'yev (1975) described the western part of the equatorial zone of the Indian Ocean as where the living conditions for blue sharks are evidently most favorable.

They make vertical excursions between the surface and depths of several hundred meters during the day and confine to depths near the thermocline at night, thus they appear to show a fair degree of niche overlap with swordfish (Bigelow *et al.*, 1999).

Carcharhinus falcifomis

The silky shark is one of the most abundant large sharks in the world. It inhabits warm tropical and subtropical waters throughout the world. It is occasionally found inshore where the water is as shallow as 18 m. It is found in the western Indian Ocean and the Red Sea from Tanzania to Mozambique, including Madagascar and the Comoros and in the mid and eastern Indian ocean from the Maldives and Sri Lanka to western Australia In the open ocean it occurs from the surface down to at least 500 m depth and has been caught over water as deep as 4000 meters.

Carcharhinus longimanus

The oceanic whitetip (*Carcharhinus longimanus*) is one of the most common large sharks in warm oceanic waters. It is circumtropical and it is nearly ubiquitous in water deeper than 180 m and temperatures above 21°C. It has also been reported in shallower waters near land, usually near oceanic islands.

***Sphyrna* spp.**

There are three main species of hammerhead sharks caught commercially in Indian Ocean waters. *Sphyrna lewini*, *Sphyrna* zygaena and *Sphyrna mokarran* can be identified by the shape of their "hammer", their first dorsal fin, and their color. Scalloped hammerhead (*Sphyrna lewini*) is a very commonest hammerhead in the tropics. It can be found in estuarine and inshore to offshore and semi-oceanic from the very surface down to about 275 m. Both migrating and stationary populations are known.

***Isurus* spp.**

Shortfin mako (*Isurus oxyrinchus*) is one of two species in the genus Isurus and one of five species in the family Lamnidae comprising the genera Isurus, Carcharodon, and Lamna *italics*. This species is widely distributed in tropical and warm temperate waters, rarely found in waters below temperatures of 16°C. Makos prefer epipelagic and littoral waters from the surface down to depths of 500 meters.

Longfin mako (*Isurus paucus*) widely distributed in tropical to warm temperate seas, but records are spotty due in part to confusion with the Shortfin Mako. The species was not described until 1966 and it is very poorly known. It is definitively less common and has been identified in Indian Ocean off Madagascar. Nevertheless, in the Maldives *Isurus paucus* appears to be the commoner of the two, but identification still to be finally confirmed]

Unlike its congener the shortfin mako, its flesh is of lesser quality. Thus, it is often discarded at sea.

2 Behaviour - Feeding habits

Prionace glauca

The blue shark is found in large aggregations, not tightly organized schools, and often close to or at the surface in temperate waters. Males and females live segregated and all-male or all-female schools contain sharks that are about the same size. In general, larger fish of both sexes are caught over a wider temperature range than smaller sharks (Nakano and Nagasawa, 1996).

In the vicinity of the Maldives juvenile males predominate in catches (Gubanov and Grigor'yev, 1975; Anderson and Ahmed, 1993). Gubanov and Grigor'yev (1975) also noticed this segregation off the east coast of Africa.

This shark feed on squids, pelagic red crabs and many types of fish including small sharks, tunas and swordfish. It is opportunistic and has been known to feed on dead whales and occasional sea birds and garbage. Also regional and seasonal differences in diet have been reported (Kohler, 1987). Fish caught on longlines during fishing are often attacked and consumed by blue sharks. Subadults and juveniles are taken by both shortfin makos and white sharks as well as by sea lions, fishing is the single largest source of adult mortality. Killer Whale (*Orcinus orca*) has been identified as a predator for Adult blue sharks (Fertl et al., 1996; Visser and Bonoccorso, 2003)

Carcharhinus falcifomis

Studies show no strong tendency for sexual segregation in the silky shark however, they often travel with others of their own size indicating that size segregation is present within the species. Young individuals can be found in coastal nurseries and adults further offshore over deeper water. Small silky shark are often associated with schools of tuna and with drifting objects. Silky shark feeds preferably on fishes, but also squid, and pelagic crabs.

Carcharhinus longimanus

Distribution appears to depend on size and sex (Seki et al. 1998). Larger individuals are caught deeper than smaller ones and there is geographic and sexual segregation (Anderson and Waheed , 1990). The oceanic whitetip shark feeds on bony fishes including lancetfish, oarfish, barracuda, jacks, dolphinfish, marlin, tuna, and mackerels. Other prey consists of stingrays, sea turtles, sea birds, gastropods, squid, crustaceans, and mammalian carrion (dead whales and dolphins). It has been observed in "feeding frenzies" when a food source is present. Large sharks are potential predators of the oceanic whitetip shark, especially immature individuals.

Reports have described swimming behavior in open waters at or near the surface of the water as moving slowly with the huge pectoral fins spread widely and often accompanied by remoras, dolphin fishes, and pilot fishes. An unusual behavior of the oceanic whitetip shark is its association with the shortfin pilot whale (*Globicephala macrorhynchus*) in Hawaiian waters as reported by Stafford-Deitsch (1988). They are often observed swimming along with pods of pilot whales. Although the reason for such behavior , never reported in Indian Ocean, is unknown, it is suspected to be food-related. Pilot whales are efficient at locating squid upon which the oceanic whitetip sharks also feed.

To the best of my knowledge swimming with Pilot Whales has not been reported from the IO

Sphyrna lewini

Scalloped hammerheads can live solitary or form seasonal aggregations. Thus, they can form very large schools in coastal areas. Scalloped hammerhead feed on pelagic fishes, other sharks and rays, squids, lobsters, shrimps and crabs.

Isurus oxyrinchus

Schooling behaviour has not been reported for this species. Shortfin makos are apex opportunistic predators with a wide prey base. They feed mainly upon squid and bony fishes including mackerels, tunas, bonitos and swordfish, but may also eat other sharks, marine mammals and sea turtles. Stillwell and Kohler (1982) estimated that a 68 kg mako might consume about 2 kg of prey per day, and could eat about 8 to 11 times its body weight per year.

They have few natural predators due to their relatively large size and ability for high speed.

As all lamnids, mako sharks are large and active pelagic sharks that can regulate their body temperature (Carey and Teal, 1969), thanks to the ability that has to maintain the temperature of its muscles of 7-10 superior °C to that of the environment that surrounds. This explains their very fast swimming speed (the fastest among the known sharks) and their ability to leap out of the water when hooked. Shortfin makos are often found in the same waters as swordfish, as they are a source of food, and both fish prefer similar environmental conditions.

Off California, small sharks were found to stay near the surface above 20 m depth and in waters near 21°C (Holts and Bedford, 1992). Recent data from eight juvenile shortfin makos radio tagged

off southern California confirms previous studies that juveniles spend most of their time (around 80%) within 12 m of the surface (Sepulveda *et al.* 2004).
Shortfin makos have few natural predators due to their relatively large size and ability for high speed. Evidence of predation by white sharks has been observed off California, in the Mediterranean Sea and off South Africa. Makos have been caught with visible scars and injuries from interactions with sailfish and swordfish.

3 Migration-Unit stock

Prionace glauca
Blue sharks have complex migratory habits that span great distances but are poorly understood. Distribution and movements of the blue shark are strongly influenced by seasonal variations in water temperature, reproductive condition, and availability of prey (Kohler *et al.*, 2002).
They make frequent trans-Atlantic movements between the western and eastern regions, utilizing the major North Atlantic current systems (Stevens, 1976, 1990; Casey, 1982, 1985; Kohler *et al.*, 2002). Mejuto et al (2005) indicate that these sharks migrate between temperate and warm-water zones, with an apparent border curbing these migratory movements around regions of the Equator. There is no evidence of movement between ocean basins. In the Indian Ocean, No information is available about their movement.
From tagging data and catch records, scientists concluded that blue sharks in the North Atlantic constitute a single stock (Kohler *et al.*, 2002). Moreover, mitochondrial DNA d-loop sequence and nuclear microsatellite analyses indicate no differences between blue sharks from the eastern and western North Atlantic. No information is available on stock structure in Indian Ocean for this species.

Carcharhinus falcifomis
This species is definitely highly migratory, therefore we could work on assumption of single unit stock for IO

Carcharhinus longimanus
According to Mejuto *et al*. (2005), oceanic whitetip shark exhibits a trans-equatorial migration in the Indian Ocean.

Sphyrna lewini
This species is less migratory that Blue, Silky or Oceanic Whitetip Sharks. Huge schools of small migrating individuals move polewards in the summer in certain areas. Large schools are present year-round at some reef-side locations in Maldives.

Isurus oxyrinchus
Differents tagging studies indicate that makos are highly migratory. They have the tendency to follow warm water currents in their most northern and southern parts of their range during summer months and can migrate over long distances. This suggests that there is a single well-mixed population in the North Atlantic (Casey and Kohler, 1992). Long distance mixing was also consistent with a recent genetics analysis of microsatellite DNA, which found no differentiation within the Atlantic Ocean (schrey and Heist, 2003).

4 Reproduction

It is widely recognized that elasmobranches are unproductive compared with teleosts , as a result of their low fecundity and late age of maturation. Sharks reproduced via internal fertilization with males using modified pelvic fin elements called claspers.
There are three types of reproductive strategies commonly employed in this group:

Oviparity – in which large, leathery eggcases are laid and the young continue to develop for several months to a year and hatch outside the female. This is the most primitive mode of reproduction.

Ovoviviparity or aplacental viviparity, is the most common mode of shark reproduction.
Embryos in the female's uterus are nourished by yolk stored in a yolk sac. There is no placental connection to the mother. Young are born after development is completed. Among the interesting variations in ovoviviparity is foetal cannibalism.

Viviparity is the most advanced mode of reproduction and is the type employed by most commercially important species. Embryos are attached to a placenta and embryonic development is nourished by the maternal blood supply. Resulting embryos usually reach a quite large size at birth. The requiem (Carcharhinidae) and hammerhead (Sphyrnidae) sharks are the chief viviparous groups

4.1 Mode of reproduction, spawning season and areas

Prionace glauca

The blue shark is a viviparous species, with a yolk-sac placenta. After copulation the females may retain and nourish the spermatozoa in the oviducal gland for months or even years while it awaits ovulation. Once the eggs have been fertilized there is a gestation period of between 9 and 12 months. Litter size is quite variable ranging from four to 135 pups and may be dependent on the size of the female. The new-born pups measure 40 to 51 cm in length. The generation time for blue shark is about 8.1 years.
Gubanov and Grigor'yev (1975) during their scientific cruises carried out between on the equator between 12º N and 10º S, observed pregnant females concentrated mainly in the region from east coast of Africa to longitude 55 º E , between latitude 2 º N and 6 º S. They found pregnant females nearly all the year round. They recorded the biggest embryo in July (8.5 to 35 cm) but they never observed near time of delivery embryos. They assumed that birth occurs outside the limits of the area investigated.
Mejuto and Garcia-Cortes (2006) analysed biological observations collected onboard Spanish surface longline fleet in the Indian Ocean in different zones between 35ºE-75ºE and 25ºN-40ºS. Thus the April-November period revealed a greater presence of gravid females in most of the zones. In the areas covered, 70% of the females analysed exhibited fecundation signs (internal or external), 41% of which had mating injures and only 29% of the females examined were found to have embryos (mean litter size =38). The authors found that the highest mean embryo sizes were attained in the third quarter, which might mark the time of birth.

Carcharhinus falcifomis

There is a strong possibility that different populations across the oceans may vary in their reproductive potential. Broods range from six to fourteen young which measure 75-80 cm TL at birth (Castro 1983). According to Bonfil *et al.* (1993), the silky shark in the Campeche Bank, Mexico, has a twelve month gestation period, giving birth to 10-14 young with average of 76 cm TL during late spring and early summer, possibly every two years. Males mature at 225 cm TL (about 10 years) and females at 232-245 cm TL (> 12 years old).
Fourmanoir (1961, in Bonfil *et al.*, 1993) found with his observations (n=9) collected in Aldabra Atoll, larger size at birth (78-87 cm TL) and mature specimen of both sexes at larger total length (males at 240 cm TL, females at 248-260 cm TL). Anderson and Ahmed (1993) suggested smaller than average size at birth in Maldivian waters (56-63 cm TL).

Carcharhinus longimanus
Oceanic whitetip sharks are viviparous, with the young being nourished by a placental yolk sac. Litter sizes range from 1-15, with increasing numbers being proportional to the size of the mother. Each pup is approximately 60-65 cm in length upon birth. In Southwestern Indian Ocean, it appears whitetips mate and give birth in the early summer, with a gestation period which lasts about one year (Compagno, 1984). The reproductive cycle is believed to be biennial.

Sphyrna lewini
Scalopped hammerhead is viviparous with yolksac-placenta. The number of young can be up to 30. The young are born at 38-45 cm TL. The reproductive cycle is annual and the gestation period is 9-10 months (Stevens and Lyle, 1989).

Isurus oxyrinchus
Female shortfin makos are ovovivipours. Developing embryos feed on unfertilized eggs in the uterus during the gestation period of 15-18 months. Litter size ranges from 4 to 25, increasing with maternal size. Pups grow very fast to reach 70 cm (TL) at birth. After parturition, females may rest 18 months therefore the breeding cycle may be three years (Mollet *et al*, 2000). Nurseries are apparently in deep tropical waters. shortfin makos females mature at about 7 years of age.

4.2 Size and age at first maturity- Sex ratio

Prionace glauca
Skomal and Natanson (2003) age and growth study of blue sharks indicates that full maturity is attained by 5 years of age in both sexes although there may be regional differences in growth.
Females reach sexual maturity at a size of 2.2 to 3.2 meters, while for males it is achieved at lengths of 1.8 to 2.8 meters.
Mejuto and Garcia-Cortes (2006) pointed out the predominance of males in different zones covered between 35ºE-75ºE and 25ºN-40ºS.
In Maldives, 95% of catch immature males, 232-273 cm TL (Anderson and Ahmed, 1993)

Carcharhinus falcifomis
According to Branstetter (1987), males *C. falciformis* mature at 210–220 cm TL (6–7 yr); females at a size higher than 225 cm TL (7–9 yr).
In their study conducted in the Gulf of Mexico Bonfil *et al* . (1993) found that the sex ratio (M:F) of pre-adults and adults sharks (TL > 200 cm; n=211) was 1:1.37.
In Maldives, sex ratio (M:F) varies with size (Anderson and Ahmed, 1993); Small, 56-169 cm TL (n=101) : 0.49:0.51 ; Intermediate, 170-239 cm TL (n=122) :0.68:0.32; Large, 240-260 cm TL (n=11): 0.18:0.82; Total, 56-260 cm TL (n=234) : 0.58:0.42.

Carcharhinus longimanus
Seki et al (1998) gave the size at maturity for both males and females in the Pacific Ocean as 175-189 cm TL which correspond to an age of 4-5 years.

Sphyrna lewini
Scalloped hammerhead males in the Indian Ocean mature at 140-165 cm TL (Bass *et al.,* 1973). Females mature about 200 cm TL (Stevens and Lyle, 1989). The young are born at 38-45 cm TL, and broods consist of 15-31 young (Compagno, 1984). The reproductive cycle is annual and the gestation period is 9-10 months (Stevens and Lyle, 1989). The nurseries are in shallow coastal waters.
Branstetter (1987) in his study in northwestern Gulf of Mexico found male outnumbered adult females in catches because of differences in the distributions of the sexually segregated population

Isurus oxyrinchus

Mollet *et al.* (2000) found significant differences in the length at maturity of female shortfin makos between the Northern and Southern hemispheres. Females mature at lengths of 2.7-3.0 m (TL) and males at 2.0-2.2 m (TL), corresponding to a minimum age at maturity of 7-8 years.

Sex ratios from beach-meshed sharks off KwaZulu-Natal, South Africa, varied monthly, with male-female ratios ranging from 0.6:1 to 2.5:1 and with males more abundant than females for most of the year except January and August; with a sample of 171 sharks, males were significantly more abundant than females with an overall ratio of 1.4:1. Birth occurs mostly in late winter to midsummer in both hemispheres. Off KwaZulu-Natal birth occurred offshore in late spring (November), and mating occurs in autumn (March to June) (Castro *et al.*, 1999).

5 Early stage

Elasmobranches nurseries are habitats where females give birth to their young and juveniles spend their early life history. These habitats provide the young a better source of food and protection against predation. According to Branstetter hypothesis, slow growing species are either born at relatively large sizes or use protected nursery grounds, whereas faster growing species tend to rely more on growth rates than others factors.

Prionace glauca

According to Litvinov (2006), at the earliest age, at a length under 70 cm, sexes separate into individual schools; females stay nearer to the coast. In the eastern Atlantic, two regions of juvenile habitats are recorded: to the north and to the south of the equator, with a typical gap between them in tropical waters. On reaching a length of 160–190 cm, sharks leave for oceanic waters; immature females follow dense aggregations of adult males situated in oceanic waters where their first mating takes place with a delayed fertilization until reaching sexual maturity. A similar pattern of distribution is traced in the eastern Pacific and other regions of the World Ocean.

Carcharhinus falcifomis

C. falciformis apparently makes use of the end of inner continental shelf and the outer continental shelf as a primary nursery (Springer, 1967; Yokota and Lessa, 2006).The juvenile silky shark venture inshore during the summer.

Carcharhinus longimanus

The location of nurseries has not been reported, but very young oceanic whitetip sharks have been found well offshore along the south-eastern US, suggesting offshore nurseries over the continental shelves (Seki *et al*. 1998).

Sphyrna lewini

The Scalloped hammerheads nurseries are in shallow coastal waters.

Isurus oxyrinchus

The location of nurseries has not been reported

6 Growth and Age

Prionace glauca

Age and growth of the blue shark have been described by a number of studies one in Atlantic and Pacific Ocean but never in Indian Ocean. Table 1 presents summaries of the estimated parameters of Von Bertalanffy growth equation from studies carried out on blue shark. Skomal and Natanson

(2003) derived a validated age curve for the blue shark in the North Atlantic. They aged males and females at 16 and 13 years, respectively and estimated longevity to be between 20-26 years of age.

Table 1: Van Bertalanffy growth function parameters and maximum age derived from vertebral band in the blue shark (*Prionace glauca*) separated by location and sex (source: Skomal and Natanson , 2003)

Sex	Ocean	Region	n	L∞	K	T0	Max.age	Authors
Male	North Atlantic	All	287	282.3	0.18	-1.35	16	Skomal and Natanson (2003)
		East	112	309.0	0.12	-1.07	5	Silva et al. (1996)
	North Pacific	East	38	246.7	0.18	-1.11	9	Cailliet et al.(1983)
		West	43	308.1	0.10	-1.37	7	Tanaka et al. (1990)
		All	148	319.5	0.13	-0.76	10	Nakano (1994)
Female	North Atlantic	All	119	286.8	0.16	-1.56	15	Skomal and Natanson (2003)
		East	82	353.0	0.11	-1.04	6	Stevens (1975)
		East	170	382.0	0.09	-1.19	5	Silva et al. (1996)
	North Pacific	East	88	202.6	0.25	-0.80	9	Cailliet et al.(1983)
		West	152	254.1	0.16	-1.01	8	Cailliet et al.(1983)
		All	123	268.9	0.14	-0.85	10	Nakano (1994)
Combined	North Atlantic	All	411	285.4	0.17	-1.41	16	Skomal and Natanson (2003)
		East	336	284.0	0.14	-1.08	5	Silva et al.(1996)
		East	159	314.4	0.12	-1.33	6	Henderson et at (2001)
	North Pacific	East	130	222.1	0.22	-0.80	9	Cailliet et al.(1983)

According to Skomal and Natanson (2003), both sexes grew similarly to age seven, when growth rates decreased in males and remained constant in females. Females could theoretically attain larger sizes than males. This species can reach a length of 380 cm FL.

Carcharhinus falcifomis

According to Branstetter (1987), application of age at length data for combined sexes produced von Bertalanffy growth model parameter estimates of L∞ = 291 cm TL, K = 0.153, t0 = −2.2 yr. Shungo *et al* (2003) estimated the age and growth of the silky shark in the Pacific Ocean using Vertebra. Combined sex von Bertalanffy growth equations were obtained as follows: Lt = 216.4(1 − e−0.148(t+1.76) where Lt is precaudal length in cm at age t. A mature size for males was considered to be approximately 135–140 cm (precaudal length), with an estimated age of 5–6 years, whereas corresponding values for females were 145–150 cm and 6–7 years, respectively. Birth size ranged from 48 to 60 cm. There was no remarkable difference in growth, birth size and age at maturity between the Pacific and Atlantic Oceans. The life history parameters of the silky shark are approximately the same in both oceans.

Carcharhinus longimanus

Oceanic whitetip sharks grow to large sizes, with some individuals reaching 3.5-4 m. However, most specimens are less than 3 m in length. The maximum recorded weight for this species is 167.4 kg.

Branstetter (1990) estimated the von Bertalanffy growth parameter K as 0.04-0.09 $year^{-1}$, and considered it a species with slow growth (a species with a growth parameter K < 0.1). Seki *et al.* (1998) estimated K to be 0.103 $year^{-1}$, and using the same criterion, called it as a fast growth species. However, we will consider here, according to Castro *et al.* (1999), that the oceanic whitetip shark is a slow growing species. Females reach greater maximum lengths than males.

Sphyrna lewini
Von Bertalanffy parameter estimates for combined sexes of this species in northwestern Gulf of Mexico were $L\infty$ = 329 cm TL, K = 0.073, to = −2.2 yr (Branstetter, 1987). In the north-west Atlantic Ocean and from the Gulf of Mexico, the von Bertalanffy growth model resulted in growth parameters of $L\infty$ = 214.8 cm fork length (FL), k = 0.13 year–1, t0 = –1.62 year for males and $L\infty$ = 233.1 cm FL, k = 0.09 year–1, t0 = –2.22 year for females (Piercy *et al*, 2007) . The oldest age estimates obtained for this population were 30.5 years for both males and females, which corresponded to FL of 234 cm and 241 cm respectively. Piercy *et al* (2007) also found that marginal increments were significantly different between months with a distinct trend of increasing monthly increment growth beginning in January. It can grow up to 4.2 m.

Isurus oxyrinchus
Longevity of shortfin makos in Northwest Atlantic based on vertebral crosssections has been estimated by Campana *et al.* (2002) to be at least 24 years, with a theoretical maximum age using von Bertalanffy's growth equation of 28 years (Smith et al. 1998), and 45 years (Cailliet et al.1983). Cailliet et al. (1983) estimated the Von Bertalanffy parameters for the shortfin as: $L\infty$ = 321 cm, K = 0.072 year-1, t0 = -3.75 years (from 44 observations).
There is no evidence of sexually dimorphic growth for the first 13 years of life. The maximum total length about 400 cm, reaching 570 kg.

7 Size at capture

Prionace glauca
Males are slightly smaller than the female. The length of males caught in Indian Ocean by Gubanov and Grigor'yev (1975) during their study was between 170 cm and 330 cm (mean 242.4 cm) and the length of females between 130 and 330 cm (mean 245.8 cm).
The authors reported maximum abundance, size, and weight of the blue shark between latitudes 10N and 10S and the east coast of Africa and 60 E. Scientists in other oceans have supported the fact that blue shark size increased when latitude decreases. Usually size caught is between 180 - 240 cm fork length for a weight range from 30 to 52 kg. In other respects, the number of large females is low thus the occurrence of severe lacerations on female blue sharks incurred during courtship may act as a source of increased mortality in females of the species and shortened their life-span. Whether it is well known that female Blue Sharks have very much thicker skin than males

Isurus oxyrinchus
Size composition of mako caught by recreational fishery is larger than that seen in the commercial fisheries (campana *et al.* , 2004)

8 Mortality and productivity

Prionace glauca

Adult blue sharks have no known predators; however, subadults and juveniles are taken by both shortfin makos and white sharks as well as by sea lions, fishing is the single largest source of adult mortality. There are various published estimates of natural mortality (M) reported in the literature, which vary from as low as 0.07 to a high of 0.48 with a mean of 0.23 (i.e., approximately 23% of the population is dying from natural causes each year) (Campana *et al.* 2004). The same authors estimated that the generation time of blue sharks in the North Atlantic is 8.1 years using life table

analysis. Overall, blue sharks have a high natural mortality and high intrinsic population growth rate in comparison to other sharks.
Blue shark is one of the most abundant, widespread, fecund, and fast growing shark species worldwide. This species is a relatively productive shark (maximum age 16-20 years, mature at 4-6 years, generation time 8 years, 25-50 pups every two years).

Carcharhinus falciformis
Silky sharks are bycatch of many fisheries. It is widely recognized that elasmobranches are unproductive compared with teleosts. Due to its long gestation period, low number of offspring and slow growth rate silky shark can be especially vulnerable to overfishing, besides the fact that they are also fished in their nursery area.

Carcharhinus longimanus
because of its slow growth, limited reproductive potential, and because it is taken as bycatch in large numbers in various unrestricted pelagic fisheries and in directed fisheries, oceanic whitetip shark can be especially vulnerable to overfishing.

Sphyrna lewini
Scalloped hammerheads are generally described as large, slow-growing and long lived. It is widely recognized that elasmobranches are unproductive compared with teleosts. They exhibit a long gestation period and a low number of offspring. For all this reasons, scalloped hammerhead can be especially vulnerable to overfishing.

Isurus oxyrinchus
The instantaneous rate of natural mortality has been estimated at 0.16 (Smith *et al.* 1998). Using the combination of natural mortality rate and age of first reproduction (8 years), a conservative (minimum) generation length of 14 years is estimated (GL=8+1/0.16=14).
Shortfin mako sharks have few natural predators due to their relatively large size and ability for high speed. The shortfin mako is subject to significant bycatch and targeted fisheries in some areas. Most catches are inadequately or un-recorded. The slow intrinsic growth rate and low fecundity of the shortfin mako mean that this species can be especially vulnerable to overfishing.

9 Consumption

Shark flesh is utilized fresh and dried-salted and smoked for human consumption. The oil is extracted for vitamins; fins are used for shark-fin soup, the skin is used for leather, the jaws and teeth used for ornaments. In recent years, sharks have been considered as a promising resource for anti-cancer treatment, artificial skin and anti-blood coagulation medicine (Seki *et al*, 1998).
Shortfin makos' meat is prized as one of the greatest game fishes in the world.
Urea stored in their blood system quickly turns to ammonia when the shark dies which affects the meat quality. Due its low commercial value, blue shark carcasses are not always kept on board but as other shark stocks have declined, blue sharks have become used also for meat in some fisheries. Beside the blue shark fins are particularly appreciated in the Asian market for their culinary use in the dish of the soup. Depending of the fleet sharks are either "finned" at sea, and the fins are then sold to Asian markets or simply released alive.

10 Length- weight conversion

10.1 Fin-to body weight ratio

"Finning" has been a traditional practise in several countries since centuries but a real global demand has been noticed early 80's to provide the Asian market. A great amount of vessels hold the fins onboard for the specific markets and the amount of corresponding captured body weight has been ignored. Historic catches and landing levels are generally difficult to estimate.
Accurate conversion factors between fin weight and landed or whole body weight is very useful in future scientific efforts to estimate levels of catches of some of these species from fin landings and fin markets.
Several studies have been conducted in all oceans of the world but the available data show that there are considerable differences in the fin to body weight ratios among species (Cortés and Neer, 2006).
The finning procedure (selection of cutting points) and the choice of the set of fins used in the calculation have an obvious effect on the ratios obtained. There are also obvious differences in selection of cutting points by fishermen from different fleets. Even within a fishing fleet, the selection of cutting points may vary, as is the case for the caudal fin in the Spanish surface fleet (Mejuto and Garcia-Cortés, 2004).
Fin-to-body weight ratios do not seem to vary considerably with shark size in most species examined. Blue shark and shortfin mako ratios did not vary appreciably across a wide size range (Mejuto and García-Cortés 2004). Pectoral fin size to total length (TL) ratios do change with growth in Oceanic Whitetip (Anderson, pers. com.).
Statistical significant intra-specific differences were found in fin to body weight ratios between juvenile and adult sharks in the scalloped hammerhead shark, *Sphyrna lewini* (Cortés and Neer, 2006). Beside, the ratios obtained suggest important difference among species (Mejuto and García-Cortés 2004).
For blue shark, the study conducted by Neves dos Santos and Garcia (2005), including the whole caudal tail in addition to all the shark fins, found a FW:RW[1] ratio of 6.564% for blue shark, essentially the same as found by Mejuto and García-Cortés (2004) (Tables 2 and 3). Experimental survey conducted by Ariz et al. (2006) obtained a ratio FW: DW[2] close to one the presented by Mejuto and García-Cortés (2004), 14.9 *vs* 14.72.

[1] RW : Round weight
[2] DW : Dress weight

Table 2: fin wet weight- round weight relationships parameters for blue shark. N – sample size; RWT – round weight (Kg); min- minimum; max – maximum; Equation refer to the linear regression: RWT=a=b?F, FF – for overall fins; DF – for dorsal fins; PecF – for pectoral fins; PelF – for Pelvic fins; AF – for anal fins; CF – for caudal fins and Mean % of fin weight. all fins were included (1st and 2nd Dorsal fins, both pectoral, anal, pelvic and entire caudal fin (source: Neves dos Santos and Garcia, 2005)

Relationship	**N**	**RWT mean (RWTmin-max)**	**Equation**	**Coefficient r^2**	**Mean % of fin weight**
RWT-FF Weight	99	20.3 ±11.8 (3.8-98.0)	RWT=-0.315+14.09*FF	0.929	6.564
RWT-DF Weight	66	20.7 ±13.8 (3.8 - 98.0)	RWT=0.386+147.39*DF	0.870	0.663
RWT-pecF weight	66	20.3 ±11.8 (3.8-98.0)	RWT=0.339+43.387*pecF	0.941	2.319
RWT-pelF weight	66	20.7 ±13.8 (3.8 - 98.0)	RWT=0.874+275.723*pelF	0.735	0.354
RWT-AF weight	66	20.3 ± 11.8 (3.8-98.0)	RWT=3.742+790.176*AF	0.841	0.104
RWT-CF weight	66	20.7 ±13.8 (3.8 - 98.0)	RWT=-2.070+35.863*CF	0.953	3.124

Table 3: fin weight to dressed weight and round weight for sharks species caught by Spanish surface longline fleet in Atlantic , Pacific and Indian Ocean. The crew processed sharks according to standard fishery practises. Though, the caudal, first dorsal and both pectoral fins were a least used but in some cases other fins as pelvic were also taken, fins were wet weighed immediately after removal. (source : Mejuto and Garcia-Cortés, 2004)

Species	**% FW: DW**				**% FW: RW**			
	N	**Mean**	**Min**	**Max**	**N**	**Mean**	**Min**	**Max**
Carcharhinus falciformis	11	11.09	10.00	12.73	2	6.50	5.33	7.67
Carcharhinus longimanus	39	21.55	9.30	31.43	7	9.60	7.92	11.67
Prionace glauca	736	14.72	5.79	30.00	184	6.53	4.63	10.00
Isurus oxyrinchus	101	5.81	3.00	7.89				

The difference could come from the fact that Ariz *et al* (2006) did not include the pelvic fins in their calculation. This shows that there is a general consistence in all studies done in all EU surface longline fleets until now.

As Commercial vessels from USA and Australia keep only the first dorsal fin, both pectoral fins, and the lower lobe of the caudal fin, the fin to dressed carcass weight ratio are varying as well (Cortés and Neer, 2006)(Table 4). The analysis of the published documents published up to 2005 (Cortés and Neer, 2006) presenting complete protocols and results obtained by different programs aiming at developing ratio to convert fin weight into weight shows that it would be inaccurate to apply a single, universal numerical ratio without full knowledge of the methods used by each fleet, particularly when this ratio is defined in terms of weights that have already been processed. Therefore, further research to explore potential variation of fin to body weight ratios with size in additional shark species is needed and ratios should be established according to the fleet considered.

Table 4: wet fin weight to dressed carcass weight ratio from the fishery –independent research conducted in USA (Florida). Dorsal fin, both pectoral fins, and the lower lobe of the caudal fin were wet weighed immediately after removal. (source : Cortés and Neer, 2006).

Species	First set of data			Second set of data				
	%	N	SD		%	N	SD	
Carcharhinus falciformis	2.53	18	0.73		-	-	Na	
Isurus oxyrinchus	2.99	9	0.89		4.22	5	Na	
Prionace glauca	4.46	12	0.53		3.74	8	Na	
Sphyrna Lewini	2.85	25	0.78		2.39	9	Na	

10.2 L-W relationships, conversion factors

The following table (table 5) gives total length and fork length relationships and length/weight relationships for the four species in order to estimate the weight of the catches from length (total length: TL or fork length: FL) frequency distributions recorded on board of fishing boats or at landing sites.

Table 5: Some allometric conversion factors, TL = total length; FL = fork length; SL = Standard length; DW = dressed/gutted weight; W = total weight (Weight in kg, length in cm).

Species	TL/FL relationships	Sex	TL/W relationships	References
Carcharhinus falciformis	FL=0.8388 TL -2.6510	Both	$W= 1.54E\text{-}05 * FL^{2.92}$	Kholer *et al.*,1995
			$W= 8.174E\text{-}06 * FL^{2.914}$	Anderson and Ahmed, 1993
Carcharhinus longimanus		Both	$W = 1.822E\text{-}05 * TL^{2.78}$	Anderson and Ahmed, 1993
Isurus Oxyrinchus	FL = 0.9286 *TL - 1.7101	Both	$W=5.2432E\text{-}06 * FL^{3.1407}$	Kholer *et al.*, 1995
	TL = 1.134* FL-1.811		$TL= 66.7584\, DW^{0.323385}$	97/50 DG XIV
Prionace glauca				
	TL = 1.175* FL + 4.103	Both	$DW= 1.787E\text{-}06\, TL^{3.096}$	97/50 DG XIV
	FL = 0.8313 *TL + 1.3908	Both	$W= 3.1841E\text{-}06 * FL^{3.1313}$	Kholer *et al.*, 1995
Sphyrna Lewini				
	FL =0.7756*TL - 0.3132	Both	$W=7.7745E\text{-}06\, FL^{3.07}$	Kholer *et al.*,1995

11 CONCLUSION

Identify and summarize existing life history data available is needed before comprehensive stock assessments can be performed. Life history information should include data on distribution of species by age and sex, genetic structure of the population for stock identification, data on movement rates, data on rates of growth and natural mortality, and data on reproductive rates and age/size at sexual maturity.

This work reveals that very little effort has been devoted in Indian Ocean to study these species and collect basic biological information. Efforts must be made to collect species specific data on the shark biology parameters. This document is an initial attempt at providing information on five major shark species caught in Indian Ocean which will be updated periodically.

12 Websites

Canadian shark research Laboratory:
http://www.marinebiodiversity.ca/shark/english/publications.htm

Florida Museum of Natural Ichthyology Department :
http://www.flmnh.ufl.edu/fish/

Apex Predators Investigation:
http://na.nefsc.noaa.gov/sharks/index.html

International Union for Conservation of Nature and Natural Resources:
http://www.iucnredlist.org/

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