BLUE SHARK (*PRIONACE GLAUCA*)

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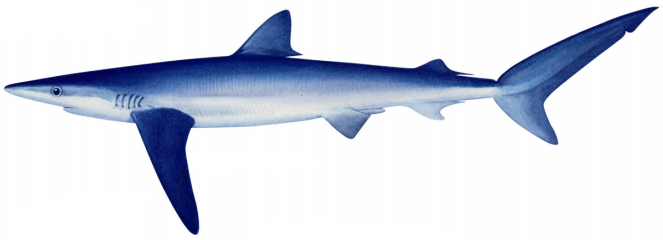

Taxonomy

Blue shark (*Prionace glauca*) is a species in the Kingdom Animalia. Blue shark was named *Prionace glauca* in 1758 by Carl Linnaeus and is the only species of the genus *Prionace* within the Carcharhinidae family. The name is derived from the Latin '*glauca*' meaning blue in reference to the distinct blue dorsal surface of the shark.

Table 1. Taxonomic hierarchy and nomenclature (source: ITIS)

Kingdom	Animalia
Subkingdom	Bilateria
Infrakingdom	Deuterostomia
Phylum	Chordata
Subphylum	Vertebreta
Infraphylum	Gnathostomata
Superclass	Chondrichthyes
Class	Chondrichthyes - cartilaginous fishes, rays, sharks
Subclass	Elasmobranchii - cartilaginous fishes, rays, sharks, skates, torpedoes
Superorder	Euselachii
Order	Carcharhiniformes
Family	Carcharhinidae
Genus	Prionace
Species	Prionace glauca

Synonyms:

- *Carcharias gracilis Philippi, 1887*
- *Carcharias hirundinaceus* Valenciennes in Müller and Henle, 1839
- *Carcharias pugae* Perez Canto, 1886
- *Prionace mackiei* Phillipps, 1935
- *Squalus caeruleus* Blainville, 1816
- *Squalus glaucus* Linnaeus, 1758
- *Thalassinus rondelettii* Moreau, 1881

Common names: Blue shark [English]; Requin bleu [French]; Tiburón azul [Spanish]

Distribution & habitat

Geographic range

Blue shark is the most common shark in pelagic oceanic waters throughout the tropical and temperate oceans worldwide (**Fig. 1**). It has one of the widest ranges of all the shark species and may also be found close inshore. Adult blue sharks have no known predators; however, subadults and juveniles may be preyed upon by shortfin makos, great white sharks, and adult blue sharks. Fishing is a major contributor to adult mortality.

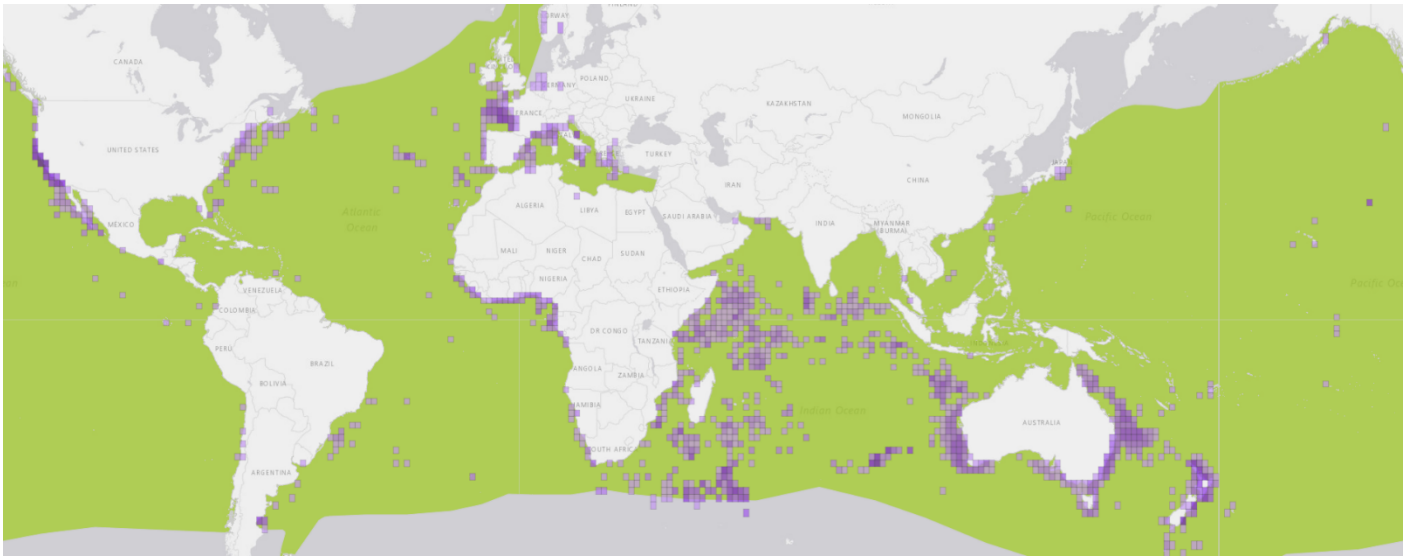

Fig. 1. Global distribution of the blue shark according to IUCN expert range maps (green envelope) and observations recorded in the Global Biodiversity Information Facility (purple squares). Source: www.mol.org

In the tropical Indian Ocean, the greatest abundance of blue sharks occurs at depths of 80 to 220 m, in temperatures ranging from 12 to 25°C but the species has also been recorded diving as deep as 1,000 m (Campana et al. 2011). The distribution and movements of blue shark are strongly influenced by seasonal variations in water temperature, reproductive condition, and availability of prey but tend to lie between 62°N and 54°S (Coelho et al. 2018).

Movements & migrations

Blue shark has been shown to undertake long-distance migrations including transoceanic routes from Australia to South Africa (Silva et al. 2010, Campana et al. 2011, Queiroz et al. 2019). The oceanic species is mostly found in offshore areas, although it has also been reported in areas close to coasts, in particular in areas where there is a narrow continental shelf (Last & Stevens 2009).

Movement patterns of blue shark are thought to relate mostly to migratory and habitat segregation patterns which relate to spatio-temporal changes in growth and reproductive stages (Coelho et al. 2018). Juvenile blue sharks may remain in nursery areas until they reach around 130 cm in length and do not take extensive migrations until reaching

that size (Nakano & Stevens 2008). While a large number of satellite tags have been deployed in the Atlantic Ocean, little information is available in the Indian Ocean (**Fig. 2**).

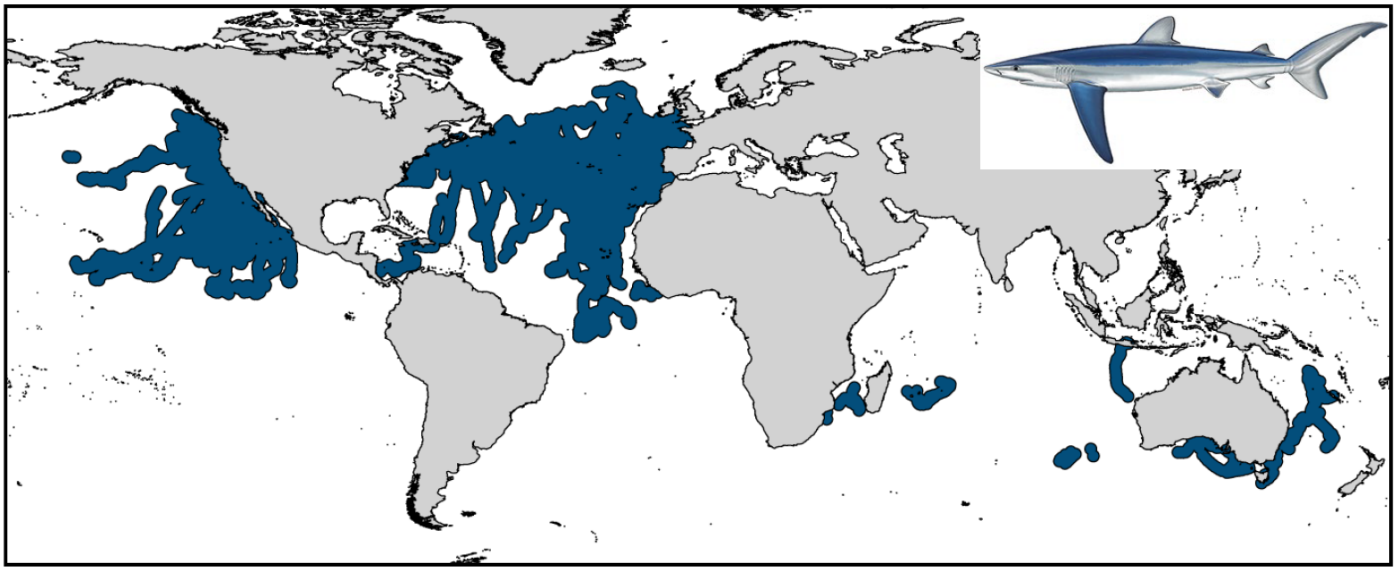

Fig. 2. Extent of the space use areas of blue shark derived from the movements of sharks tagged with satellite transmitters (Queiroz et al. 2019)

Population structure

Recent information derived from single nucleotide polymorphisms (SNPs) on the population genetic structure of blue shark at global scale suggests the existence of two main genetic clusters: (1) the northern Atlantic Ocean region, including the Mediterranean Sea and (2) the Indo-Pacific region (Nikolic et al. 2020). This SNPs-based approach did not provide any evidence of genetic structure within the Indian Ocean. However, this study did suggest that while there is a distinct genetic group in the Indian-Pacific Oceans which differs to that in the Atlantic Ocean, there is thought to be some mixing around South Africa which needs further investigation to determine whether there is mixing of the two groups in the southern regions of the Indian and Atlantic Oceans (Nikolic et al. 2020).

Blue shark is often found in large single sex schools containing individuals of similar size. Subtropical waters south of 20°S and temperate waters such as in the south-west off the coast of South Africa and the south-east off the coast of Australia appear to be nursery grounds where small blue sharks dominate (Coelho et al. 2018), but where all range of sizes from 55 to 311 cm fork length (FL) are recorded. In contrast mature fish (FL > 185 cm) dominate in the offshore equatorial waters. Overall, the area of overlap with the IOTC management area is high.

Spatial segregation has been observed between male and female blue sharks (in general more females were recorded in southern latitudes both in the southwest and southeast of the Indian Ocean) with an additional variation in sex-ratios in different seasons (Castro & Mejuto 1995, Coelho et al. 2018). However, females in the early stages of pregnancy have also been found in the north-west Indian Ocean, particularly in the first half of the year suggesting that this may be a mating area (Gubanov & Grigor'yev 1975).

Biology

Growth & morphometrics

The maximum size observed for blue sharks in the Indian Ocean is around 380 cm fork length (FL), corresponding to a total length (TL) of more than 400 cm. Bomb radiocarbon dating of Indian Ocean blue sharks showed that males of 270 cm FL may attain 25-27 years of age (Romanov & Campana 2011). Growth studies based on annual increments deposited in vertebrae confirmed that males may reach 25 and females 21 years old (Andrade et al. 2019).

In the Indian Ocean, embryos have been shown to be in the size range 12-36 cm FL, with a mean of around 26 cm (Mejuto & García-Cortés 2005). In the Atlantic Ocean, information on embryo growth suggests that fork length at birth could be around 41 cm following a gestation period of ~11 months (Mejuto & Garcia-Cortés 2005). This is consistent with the observations of six free-swimming neonates of 34-36 cm precaudal length (i.e. 37-39 cm FL) in the North Pacific (Fujinami et al. 2017).

Length (cm) – length (cm) and length (cm) - weight (kg) relationships have been developed for Indian Ocean blue shark from samples at sea onboard longliners during commercial and scientific cruises (**Table 2**).

Table 2. Morphometric relationships for Indian Ocean blue shark. Dressed weight (aka carcass weight) corresponds to headed and caudal peduncle-off weight (PD), i.e. the body without head, gills, guts, tail, and fins

Source measure	Target measure	Equation type	a	b	N	Source
Fork length FL	Total length TL	$TL = a \times FL + b$	1.1681	5.3197	6,485	Ariz et al. 2007
Fork length	Round weight RW	$RW = a \times FL^{b}$	2.7968e-6	3.1697	2,279	Ariz et al. 2007
Total length	Round weight RW	$RW = a \times TL^{b}$	1.3307e-6	3.2043	2,311	Ariz et al. 2007
Fork length	Dressed weight PD	$PD = a \times FL^{b}$	4.0189e-7	3.362	2,129	Ariz et al. 2007
Total length	Dressed weight PD	$PD = a \times TL^{b}$	1.6877e-7	3.4163	2,137	Ariz et al. 2007
Fork length	Round weight RW	$RW = a \times FL^{b}$	1.59e-5	2.84554	2,842	Romanov & Romanova 2009

Reproduction

Blue shark is a viviparous species, with a yolk-sac placenta. Once the eggs have been fertilised there is a gestation period of between 9 and 12 months (Pratt 1979). Litter size is quite variable, ranging from four to 135 pups and may be dependent on the size of the female (Mejuto & García-Cortés 2005). The average litter size observed from the Indian Ocean is 38, very similar to the one reported in the Atlantic Ocean (37). In the Indian Ocean, pregnant females are present for most of the year between latitude 2ºN and 6ºS (Gubanov & Grigor'yev 1975).

- Annual reproductive cycle
- Fecundity: relatively high (mean litter size = 38 in the Indian Ocean) (Mejuto & Garcia-Cortés 2005))
- Generation time: 8–10 years
- Gestation period: 9–12 months (Carrera- Fernández et al. 2010)
- Sex ratio: close to 1:1 (Coelho et al. 2018)
- Maturity (Jolly et al. 2013):
    - Females mature at 194 cm TL and males at 201 cm TL
    - At about 4–7 years for males and 5–7 years for females.

Trophic ecology

Blue shark has a diverse diet, feeding on a range of teleost fish as well as cephalopods (mainly squid) (Andrade et al. 2019). Studies on the stomach content of the species found that epi and mesopelagic teleost species made up a large proportion of the fish species found in the digestive tract (Henderson et al. 2001) while cephalopod consumption is believed to be seasonal (McCord & Campana 2003). Blue shark is thought to show a preference for slow-moving prey due to its morphological characteristics, meaning it is not a fast swimming predator (Vaske-Júnior et al. 2009).

Studies analysing stomach contents of blue shark have estimated the trophic level to be between 4.05-4.4 (i.e., tertiary consumers) confirming that blue sharks are among the top consumers in the marine ecosystem (Vaske-Júnior & Rincon-Filho 1998, Cortés 1999, Henderson et al. 2001, Kubodera et al. 2007, Froese & Pauly 2015, Hernández-Aguilar et al. 2016).

Blue shark itself is also considered to be an important source of food for large marine predators including other shark species as well as billfish (Amaratunga 1983, Cortés 1999, Galván-Magaña et al. 2013, Froese & Pauly 2015).

Fisheries

Blue sharks are caught by a large diversity of fishing gears because of their wide habitat and occurrence in coastal and offshore areas (see section Distribution & Habitat). Most blue sharks are taken as bycatch in pelagic longline fisheries targeting tuna and tuna-like species, although a few fleets may specifically target this species (Clarke et al. 2014). Bycatch rates are particularly high in swordfish-targeted longline fisheries since the two species share very similar habitats (Petersen et al. 2009). In the Indian Ocean, blue sharks are also caught as bycatch in gillnet fisheries targeting tunas while they constitute an anecdotal part of purse seine fisheries catches. Historical information available from sport fishery clubs in the Indian Ocean suggests that some oceanic sharks, possibly including blue shark, were caught in the past during competitions but they now very seldomly occur in the catches (Pepperell et al. 2017).

The practice of shark finning is considered to be regularly occurring for blue sharks with the species comprising the main component of the international shark fin trade (Clarke et al. 2006, Cardeñosa et al. 2018, Fields et al. 2018). Little information is available on bycatch/release injury rates in the Indian Ocean but they are probably high. Preliminary estimations of at-haulback mortality showed that 24.7% of the blue shark specimens captured in longline fisheries targeting swordfish are captured dead at time of haulback (Coelho et al. 2011). Specimen size seems to be a significant factor, with larger specimens having a higher survival at-haulback (Coelho et al. 2011). Experiments conducted in other oceans with satellite tags have shown that the mortality of blue shark discarded at sea varies around 10-17%, with major effects of the condition of the fish when released at sea (Campana et al. 2009, 2016, Musyl & Gilman 2018).

Catch trends & distribution

The catches reported to IOTC for blue shark, and sharks in general, are highly uncertain. Overall, very little information on shark catches is reported for coastal fisheries. Also, the information on catch mainly includes nominal (i.e. retained) catches while most blue sharks were discarded at sea prior to the 2000s. Also, more than 80% of the nominal catches of sharks prior to the mid-1990s were reported to the IOTC in aggregate form (i.e. as part of the "*various sharks NEI*" aggregate) preventing the accurate monitoring of blue shark catches over time.

With the advent of finning regulations (e.g. FAO Code of Conduct for Responsible Fisheries, IOTC Res. 17/05) and the increased demand for blue shark meat, retention of blue shark catches has increased over the last two decades with improved reporting by CPCs in the Indian Ocean (**Fig. 3a**). After a steady increase from the mid-1990s to about 30,000 t in the mid-2000s, the nominal catches of blue shark have significantly dropped to about 25,000 t in 2019. In recent years (2015-2019), more than 20 CPCs reported nominal catch data for blue shark, with industrial longline representing 40% of the total reported catches while coastal longliners from Indonesia have been estimated to take about 50% of the total catches (**Fig. 3b**). Overall, the nominal catches of blue shark are considered widely

under-estimated. Furthermore, almost no information is available on discards for most fisheries. However, information collected from observers at sea showed that blue shark is the dominant shark taken in the Indian Ocean Taiwanese longline fishery targeting bigeye tuna, with about one third being discarded (Huang & Liu 2010). Also, blue shark widely dominated the bycatch of the South-African longliners targeting swordfish during 1998-2005, with a catch rate of about 12 individuals caught per 1,000 hooks (Petersen et al. 2009).

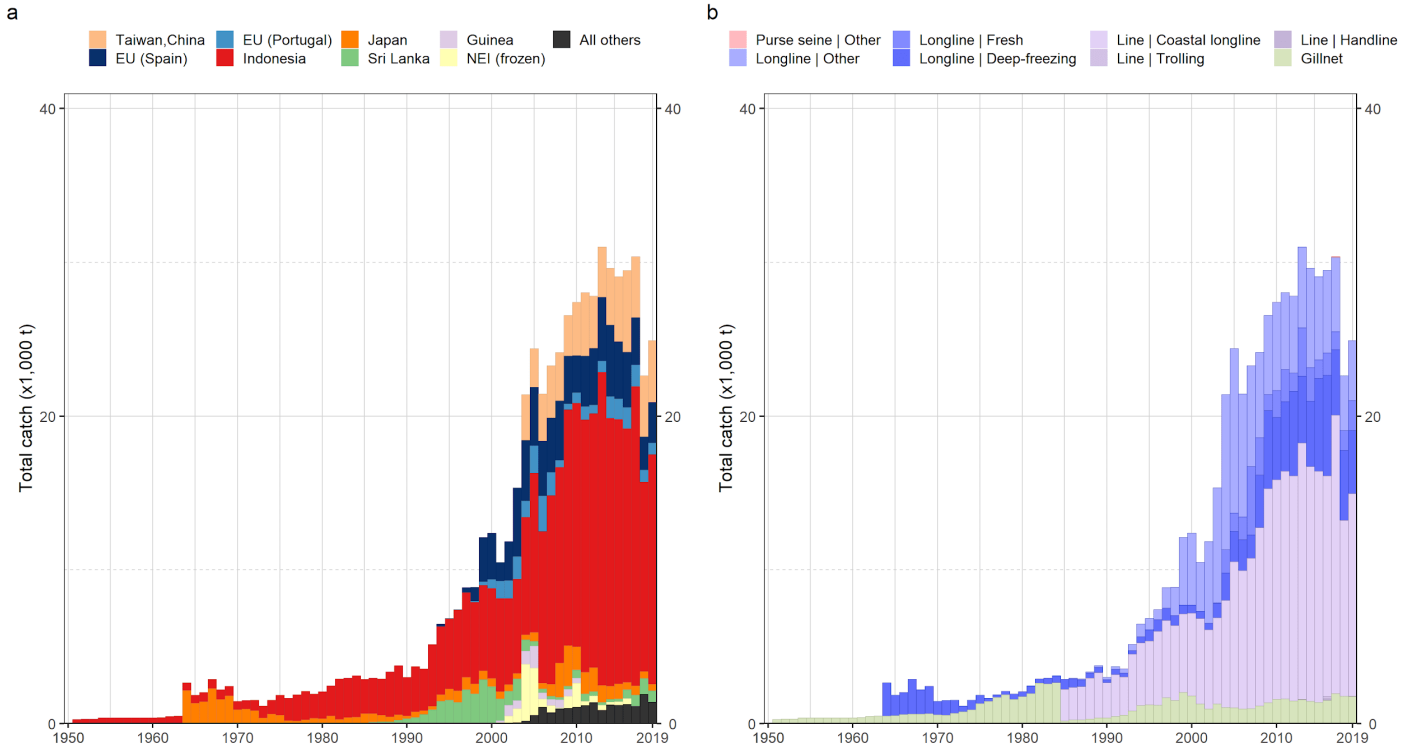

Fig 3. Annual time series of nominal catches (t) of blue shark (a) by main fishing fleet and (b) fishery during 1950-2019

During the last decade, the catches of blue shark reported to the IOTC were distributed all over the Indian Ocean, with higher levels in the western part of the ocean where longline fishing effort is more intense (**Fig. 4**). Important levels of catch by coastal fisheries have also been reported around Sri Lanka while no geo-referenced catch data are available from the Arabian Sea region and Indonesian waters, despite their importance for shark populations, including blue shark (Sembiring et al. 2015, Jabado & Spaet 2017).

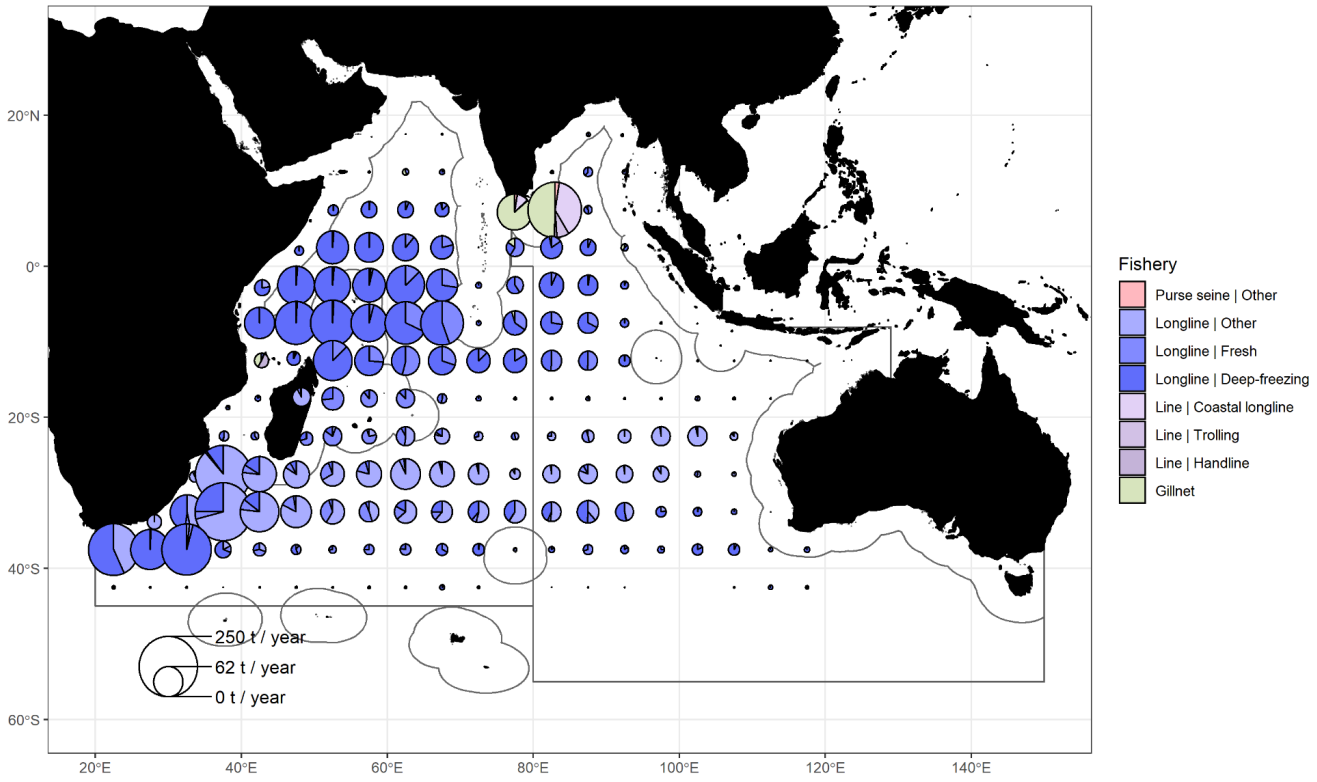

Fig. 4. Spatial distribution of the mean annual catches (t) of blue shark by fishery as reported for the period 2010-2019

Length composition of the catch

Blue shark is the elasmobranch species of the Indian Ocean for which the most size data have been collected, including onboard fishing vessels by fishers and scientific observers and at landing places by national research and fisheries administrations (n >225,000 samples). The fork length (FL) distributions of blue shark catches highlight the difference in selectivity and show that longline fisheries targeting swordfish and sharks (Longline|Other) catch larger blue sharks (median of about 200 cm FL) than the deep-freezing and fresh longline fisheries (median of about 175 cm FL) (**Fig. 5**). Size data from Sri Lankan and Indonesian coastal longliners suggest these fleets catch smaller blue sharks, with most fish caught in the fork length range 110-140 cm.

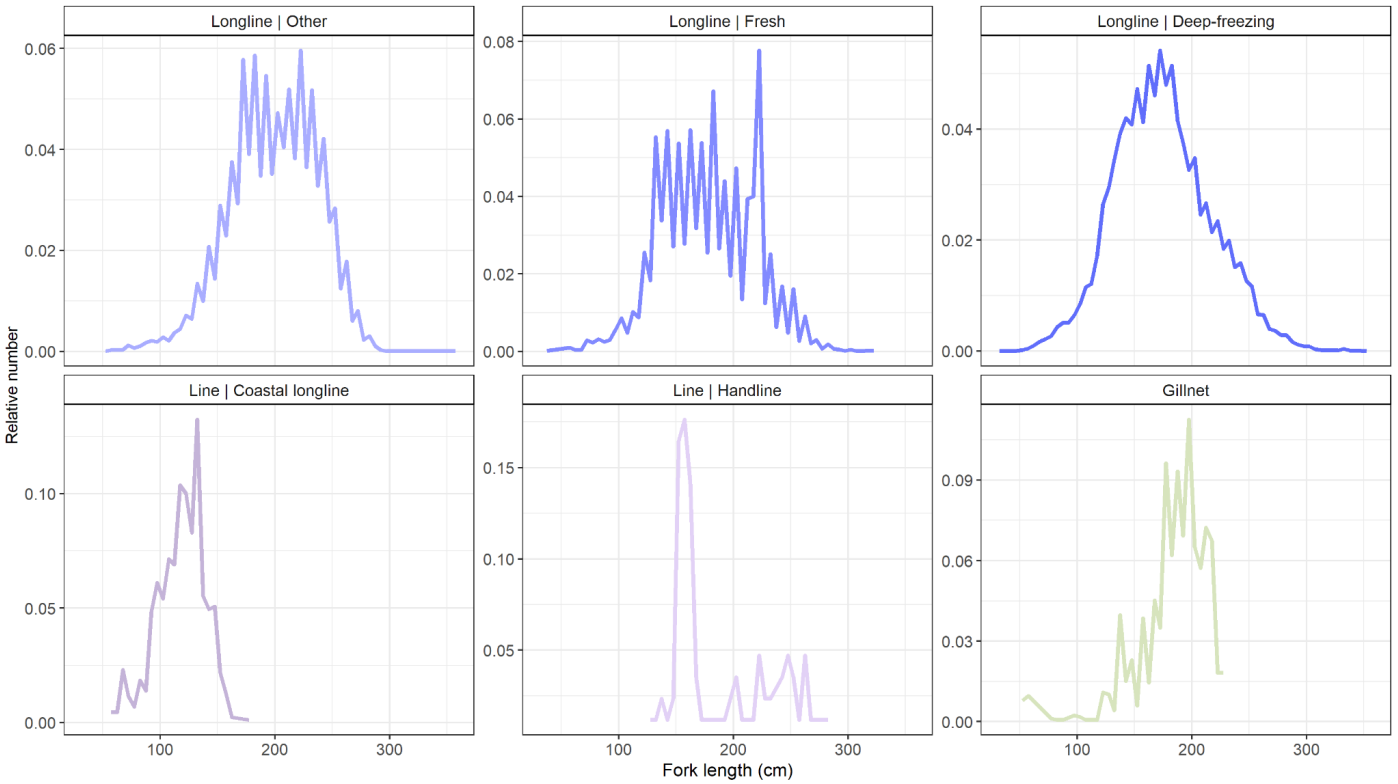

Fig. 5. Relative fork length frequency distributions (%) of blue shark derived from the samples reported for the longline fleets between 2005 and 2019 in 5 cm length classes

Markets

The markets for sharks have previously been mostly focused around shark fins but since the relatively recent introduction of various anti-finning regulations around the world, which aim to encourage the full utilization of sharks, the market for shark meat has risen considerably. This has led to an increase in targeting of shaks rather than them only being caught as bycatch in other fisheries including tuna fisheries (Dent & Clarke 2015). However, shark fins (which are among the most expensive seafood items globally) have retained a considerably higher value than shark meat.

Internationally, there are largely distinct markets for meat and fins. However, due to the aggregation of both products, there is a paucity of trade data to distinguish the two product types, meaning that separate analysis of the markets is challenging (Dent & Clarke 2015). The vast majority of shark fins end up in countries in East and Southeast Asia while for shark meat there is a broader range of destinations for the products, with the largest consumers of the meat found in South America and Europe (Dent & Clarke 2015).

Blue sharks are thought to be a preferred species for shark fin soup as well as an important part of the shark meat trade (Dent & Clarke 2015). In addition to the global trade of shark products, there are also important elasmobranch subsistence fisheries in parts of the Indian Ocean such as along the coasts of Madagascar and Indonesia (McVean et al. 2006, Robinson & Sauer 2013).

Stock status

Blue sharks are one of the most abundant, widespread, fecund, and fast-growing shark species worldwide and as such are considered to be more resistant to fishing than other shark species. In absence of clear information on stock structure, one single stock unit is considered for stock assessment in the Indian Ocean. The current IUCN threat status of ‘Near Threatened’ applies to blue sharks globally.

The ecological risk assessment (ERA) conducted for the Indian Ocean by the WPEB and SC in 2018 consisted of a semi-quantitative risk assessment analysis to evaluate the resilience of shark species to the impact of a given fishery

by combining the biological productivity of the species and their susceptibility to each fishing gear type. Blue sharks received a medium vulnerability ranking (No. 6) in the ERA rank for longline gear because it was estimated as the most productive shark species, but was also characterised by the third highest susceptibility to longline gear . Blue shark was estimated as not being susceptible thus not vulnerable to purse seine gear (Murua et al. 2018).

Information available on this species has been improving in recent years. Several models have been used in 2017 to assess the stock status. On the weight-of-evidence available in 2017, the Indian Ocean stock of blue shark was determined to be not overfished and not subject to overfishing.

Management Measures

Conservation and Management Measures

Blue shark in the Indian Ocean are currently subject to a number of Conservation and Management Measures adopted by the Commission:

- Resolution 18/02 *On management measures for the conservation of blue shark caught in association with IOTC fisheries* includes reporting requirements for catch, effort, size and discard data for the species in full accordance with Resolution 15/02. The Resolution also states that the SC will provide advice (if possible) on options for candidate limit, threshold and target reference points based on the stock assessment to be conducted in 2021.
- Resolution 15/01 *On the recording of catch and effort data by fishing vessels in the IOTC area of competence* sets out the minimum logbook requirements for purse seine, longline, gillnet, pole and line, handline and trolling fishing vessels over 24 metres length overall and those under 24 metres if they fish outside the EEZs of their flag States within the IOTC area of competence. As per this Resolution, catch of silky sharks must be recorded by longline and purse seine fleets (retained and discarded)
- Resolution 15/02 *Mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPCs)* indicated that the provisions, applicable to tuna and tuna-like species, are applicable to shark species
- Resolution 11/04 *On a Regional Observer Scheme* requires data on shark interactions to be recorded by observers and reported to the IOTC within 150 days. The Regional Observer Scheme (ROS) started on 1st July 2010
- Resolution 17/05 *On the conservation of sharks caught in association with fisheries managed by IOTC* includes minimum reporting requirements for sharks, calls for full utilisation of sharks and includes a ratio of fin-to-body weight for frozen shark fins retained onboard a vessel and a prohibition on the removal of fins for sharks landed fresh.

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