		
CHAPTER 2.2.1.9: GREAT HAMMERHEAD	AUTHORS: FORSELLEDO R., DOMINGO A., MAS F. and MILLER P.	LAST UPDATE: August 2022 Original: Spanish

2.2.1.9 Description of Great Hammerhead (SPK)

1. Name

1.a. Classification and taxonomy

Species name: *Sphyrna mokarran* (Rüppell, 1837)

Etymology: The name of the genus *Sphyrna* is derived from the Greek “*sphyrna*” which means "hammer" while the name of the species *mokarran* is a name of Arabic origin which means "large".

Synonyms: *Zygaena vulgaris* (Cloquet, 1830) *Zygaena mokarran* (Rüppell, 1837), *Zygaena subarcuata* (Storer, 1848), *Zygaena dissimilis* (Murray, 1887), *Sphyrna ligo* (Fraser-Brunner, 1950).

ICCAT species code: SPK

ICCAT names: Great hammerhead (English), Grand requin marteau (French), Cornuda gigante (Spanish).

According to the ITIS (Integrated Taxonomy Information System), the great hammerhead is classified as follows:

- Phylum: Chordata
- Subphylum: Vertebrata
- Superclass: Gnathostomata
- Class: Chondrichthyes
- Sub-class: Elasmobranchii
- Superorder: Euselachii
- Order: Carcharhiniformes
- Family: Sphyrnidae
- Genus: *Sphyrna*

1.b. Common names

List of vernacular names used according to ICCAT, FAO, Fishbase (www.fishbase.org) and Compagno (1984). The list of countries is not exhaustive and some local names might not be included.

Australia: Great hammerhead, Hoe-head shark.

Brazil: Cação-martelo, Cação-panã, Cambeva, Martelo, Panã, Peixe-martelo.

Cabo Verde: Cornuda-gigante, Martelo, Tubarão-martelo-gigante.

China: 双过仔, 双髻鲨, 牦头沙, 八鳍丫髻鲨, 无沟双髻鲨, 無溝雙髻鯊.

Chinese Taipei: 八鳍丫髻鲨.

Colombia: Pez martillo, Tiburón martillo gigante.

Cuba: Cornuda de ley, Great hammerhead.

Denmark: Stor hammerhaj.

Ecuador: Cachona.

Finland: Isovasarahai.

France: Grand requin marteau.

French Polynesia: Grand requin marteau.

Germany: Großer Hammerhai.

- Greece:** Μεγαλοζύγαινα, Megalozygena.
India: Great hammerhead.
Indonesia: Hiu bingkoh, Hiu capil, Hiu caping.
Japan: Hira-shumokuzame, Hirashumoku zame, Nami-shumokuzame.
Italy: Grande squalo martello, Squalo martello maggiore.
Madagascar: Akio viko, Viko palapalandoha.
Malaysia: Great hammerhead, Jerong tenggiri, Kad suar, Yu bengkong, Yu mata jauh, Yu palang, Yu parang, Yu sambaran, Yu sanggul, Yu sanggul lintang, Yu tanduk, Yu tukul, Yu-tukul parang.
Mauritius: Requin marteau.
Mexico: Cornuda gigante.
Micronesia: Great hammerhead shark, Matefaaib.
Mozambique: Tubarão martelo gigante.
Netherland Antilles: Great hammerhead, Tribon 'i krus, Tribon'i krus.
Netherlands: Grote hamerhaai.
New Caledonia: Cionaa, Grand requin marteau, Requin-marteau.
Oman: Abu-garn, Jarjur, Jarjur al garam.
Palau: Ulach.
Papua New Guinea: Great hammerhead.
Peru: Gran tiburón martillo.
Poland: Glowomlot olbrzymi.
Portugal: Tubarão-martelo-gigante.
Puerto Rico: Cornuda, Great hammerhead, Martillo.
Qatar: Akran.
Somalia: Cawar.
Spain: Cachona, Cachona grande, Cornúa, Cornuda gigante, Cornudo, Martell gegant, Martillo, Pez martillo, Pez martillo gigante, Tollo cruz.
Sweden: Stor hammarhaj.
Tahiti: Ma'o tuamata.
Tanzania: Papa mbingusi, Papa-pingusi.
Thailand: Chalrm Hua-kon-yai, Great hammerhead.
United Kingdom: Great hammerhead, Squat-headed hammerhead shark.
United States: Great hammerhead.
Venezuela: Cornúa gigante.
Vietnam: Cá Nhám búa không rãnh.

2. Identification (Mainly based on Gilbert 1967 and Compagno 1984).

Characteristics of *Sphyrna mokarran* (Figure 1).



Figure 1. Great hammerhead (*Sphyrna mokarran*) (Rüppell 1837). Image taken from Domingo *et al.*, 2010. Photograph credit: William B. Driggers, National Marine Fisheries Service, USA.

Lengths

References to size throughout this document consistently relate to total length (TL), unless otherwise specified (e.g., fork length: FL, and precaudal length: PCL).

It is one of the largest species in the order Carcharhiniformes and the largest in the family Sphyrnidae. Maximum sizes of almost 610 cm have been reported, although individuals over 400 cm are rarely found (Compagno, 1984; Last & Stevens 1994; Ebert *et al.* 2013). In the Northwest Atlantic and the Gulf of Mexico, Clark & von Schmidt (1965) reported a 414 cm female and Springer (1963) measured an individual of 548 cm. The maximum sizes reported by Cliff (1995) in the Western Indian Ocean are 326 cm PCL (~353 cm FL) for females and 263 cm PCL (~287 cm FL) for males. Stevens and Lyle (1989) reported values of 445 and 409 cm for males and females, respectively, in the north of Australia. In the Mexican Pacific, a female measuring 424 cm and weighing 550 kg was captured by artisanal longline (Tovar-Ávila and Gallegos-Camacho, 2014).

Colour

It can vary from dark brown to light grey on the back and flanks, and lighter or white on the belly. The fins do not have any markings, but the tip of the second dorsal fin may be darker in juvenile individuals (French *et al.*, 2018).

External characteristics

It is the largest of all the hammerhead shark species. The front edge of the head is almost straight in adults and slightly arched in juveniles. Both have a slight notch in the centre. The eyes are located on the external sides of the head and the nostrils on the front side near the ends. It does not have spiracles. The mouth is located on the ventral side. The width of the head represents between 23 and 27% of the total length, and the preoral snout is less than 1/3 of the head width. Very tall and falcate first dorsal fin, especially the upper part. The origin of the first dorsal fin is located on the pectoral fin insertions, while the free rear tip is located before the origin of the pelvic fins. Strongly falcate, tall second dorsal fin with a short internal edge. Large and very falcate pelvic fins. The anal fin is of equal size or larger than the second dorsal fin and the trailing edge is strongly V-shaped. The very falcate fins, like the virtually straight front edge of the head can be characteristics that are not very distinguishable in neonates, being easily confused with *S. lewini* (Baker *et al.*, 2017). Diamond-shaped, overlapping dermal denticles with a smooth base. In small individuals, the denticles have 3 to 5 ridges that go from the centre to the rear margin, while in larger individuals they have 5 to 6 ridges. The teeth on the rear margin of the denticles are short and the middle one is the longest.

Internal characteristics

Almost triangular teeth with broad and curved tips and highly-serrated edges on both jaws, acquiring a more oblique shape towards the edges of the mouth. On the upper jaw, 2 to 3 symphyseal teeth and 17 teeth on each side. On the lower jaw, 1 to 3 symphyseal teeth and 16 to 17 teeth on each side. The total number of vertebrae varies between 197 and 212.

3. Distribution and population ecology

3.a. Geographic distribution

It is found in all oceans in tropical and temperate coastal waters, approximately from 40°N to 35°S (Compagno, 1984; Last and Stevens, 1994; Fowler and Cavanagh, 2005; Ebert *et al.*, 2013). In the western Atlantic it is found from North Carolina in the United States to Rio Grande do Sul in southern Brazil, including the Gulf of Mexico and the Caribbean Sea. There are some reports of individuals caught to the north of North Carolina, but these records seem to be occasional or due to misidentifications. Confirmed reports further north were made by Hammerschlag *et al.* (2011) at 38°15'N, 69°31'W, in addition to some individuals tagged to the south of the state of New Jersey (Kohler *et al.* 1998). In the eastern Atlantic, there are records stretching from the Strait of Gibraltar in Morocco to the south of Angola. The species is cited in the ichthyofauna of Portugal and Madeira, but there are no confirmed records have been found of the species for either of the two areas (Carneiro *et al.*, 2014; Bischoito *et al.*, 2018; Carneiro *et al.*, 2019). Records in South African waters are limited to the province of KwaZulu-Natal (Cliff, 1995; Ebert *et al.*, 2021). This species is occasionally present in the Mediterranean Sea, (Bauchot, 1987; Serena, 2005; Zenetos *et al.*, 2012), with records on the south coast from Morocco, Algeria,

Tunisia and Libya (UNEP-MAP RAC/SPA, 2005) to Egypt. Its presence is occasional on the north coast, with a single record in the Ligurian Sea (Boero and Carli, 1977; Celona and De Maddalena, 2005; Psomadakis *et al.*, 2012; Sperone *et al.*, 2012). The map in **Figure 2** was modified in the Mediterranean Sea region to represent the distribution of the species detailed in this section.

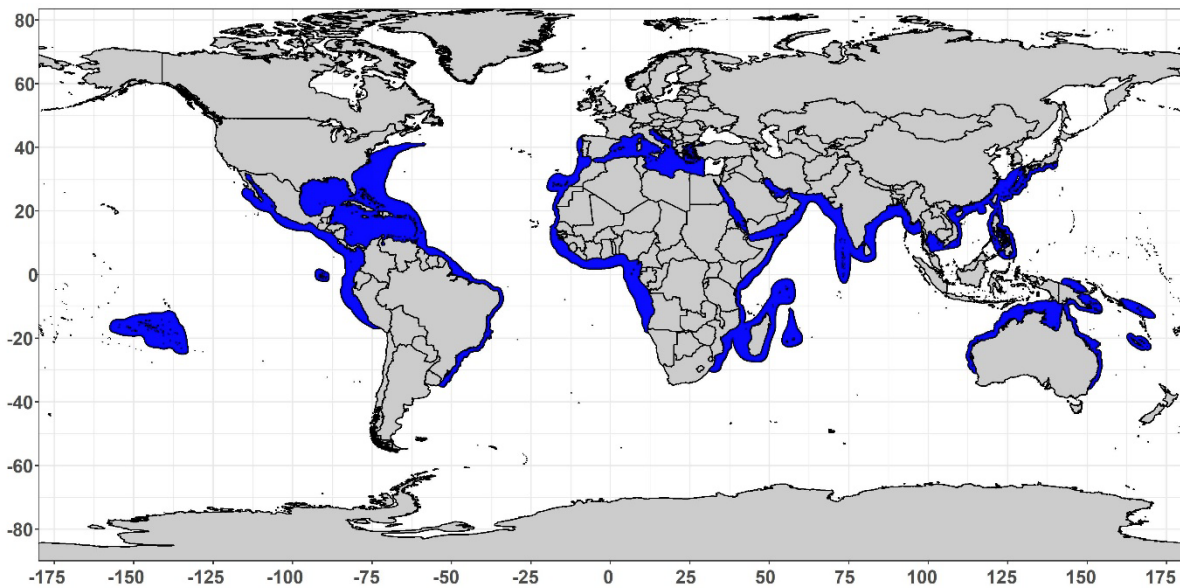


Figure 2. Map showing the distribution of the great hammerhead (*Sphyrna mokarran*). Taken and modified from the International Union for Conservation of Nature (IUCN) (IUCN SSC Shark Specialist Group 2018. *Sphyrna mokarran*. The IUCN Red List of Threatened Species. Version 2021-1).

3.b. Habitat preferences

It is a coastal-pelagic and semi-oceanic species that is present near the coast and in bays, estuaries, coral reefs and lagoons, and far from the coast on the continental shelf or near oceanic islands. It generally prefers shallow coastal waters, although it lives between the surface and depths of 300 m, preferably in waters above 20°C (Compagno, 1984; Ebert *et al.*, 2013; Miller *et al.*, 2014; Weigmann, 2016). Queiroz *et al.* (2016) observed, based on 12 individuals tagged with satellite transmitters, that the distribution of the species is generally restricted to coastal waters of the shelf, and that it has a preference for areas with discontinuities in temperature and high productivity. According to a satellite telemetry study in the northwest Atlantic based on a single individual, the average temperature of the transmissions was $21.9 \pm 0.4^\circ\text{C}$ (range $17.0\text{--}27.9^\circ\text{C}$) (Hammerschlag, *et al.* 2011). On the east coast of South Africa, catches were recorded in waters with surface temperatures of between 18.5 and 26.1°C ($n=158$, average= 23.1°C). It was also observed that the species is present during the summer months when the water is warmer and starts to become less frequent in April and May (Cliff, 1995). Males seem to have a higher tolerance to low temperatures as no females were recorded at temperatures below 22°C (Cliff, 1995).

3.c. Migrations

It is generally a solitary species and considered to be migratory, although there are not enough studies to provide a detailed description of its movements. Currently, the majority of the studies related to movements and migrations of the species have been carried out in the Northwest Atlantic. It appears that some populations move towards higher latitudes during the summer following warm water currents, such as those found off the coast of Florida, where it reaches its distribution limits (Heithaus *et al.*, 2007; Hammerschlag *et al.*, 2011), while other populations are more residential (Stevens and Lyle, 1989; Cliff, 1995). Hammerschlag *et al.* (2011) observed an individual with a satellite transmitter in the Northwest Atlantic that moved at least 1,200 km towards the northeast, apparently following the warm waters of the Gulf Stream. This is a known migratory route for many species, and it is therefore possible that these movements are related to the movement of some of its prey such as *Coryphaena hippurus*, which is known to move towards the North during the spring due to the Gulf Stream (Oxenford and Hunte, 1986; Farrell, 2009; Hammerschlag *et al.*, 2011). More recently, a telemetry-based study carried out in the Bahamas and waters of the State of Florida, United States, found that the central areas of habitat use are found in the waters of the economic exclusive zone (EEZ) of the United States, remaining

91.57% of the time in these waters, and just 8.43% in the waters of the Bahamas EEZ (Graham *et al.*, 2016). Queiroz *et al.* (2016) also observed a high level of residence in the coastal areas of Florida, with movements associated with the fronts. In the same area, a study carried out by Guttridge *et al.* (2017) provides the first evidence of philopatric behaviour for the species, documenting return migrations, seasonal residence and long-term fidelity to the site, with some individuals observed in four consecutive seasons. Based on satellite telemetry, acoustic tags and photo identification, they recorded that some individuals tagged in the Bahamas and Florida carried out migrations of approximately 3,000 km reaching Virginia, the United States. The movements recorded outside the area of study were typically carried out towards the end of the winter season, and many individuals remained during winter. The results suggest that the main objective of site fidelity in the great hammerhead is food, since the area of study are highly productive systems (Guttridge *et al.*, 2017). Also in the Northwest Atlantic, based on information obtained from 282 individuals tagged by the *Cooperative Shark Tagging Program* of the NMFS, 5 individuals were recaptured and a maximum distance travelled of 1,202 km (649 nm) was observed and a maximum recapture time of 3.4 years (Kohler *et al.*, 1998; Kohler and Turner, 2001; Kohler and Turner, 2019). In northern Australia, 48 individuals were tagged with conventional tags and two recaptures were reported, with a time at liberty and maximum distance of 4.2 years and 385 km recorded, respectively (Stevens *et al.*, 2000).

4. Biology

4.a. Growth

There are very few studies on age and growth for this species throughout its entire range (**Table 1**). The hypothesis that just one vertebral ring is formed per year in *S. mokarran* has been validated by the marginal increment trend, radiocarbon dating and tagging and recapture (Passerotti *et al.*, 2010; Piercy *et al.*, 2010; Harry *et al.*, 2011). The species grows rapidly during the first 10 years of life. After this point, the growth rate decreases considerably in males and to a lesser extent in females (Piercy *et al.*, 2010). In the Northwest Atlantic and the Gulf of Mexico, the species was seen to have a similar growth rate (based on the von Bertalanffy k value) to *S. lewini* in the Northwest Atlantic and *S. zygaena* in the Pacific Ocean. Despite having a similar growth rate to other species, the highest age of all hammerhead shark species has been observed in *S. mokarran*: 42 years for males and 44 years for females (Passerotti *et al.*, 2010; Piercy *et al.* 2010). The maximum ages reported by Harry *et al.* (2011) for both sexes (31.7 years for males; 39.1 years for females) in Northeast Australia are lower than those reported by Piercy *et al.* (2010), but this could be due to the low number of large individuals used in the analysis. A female measuring 424 cm and with a total weight of 550 kg caught in the Mexican Pacific was determined to be 45 years old by counting growth rings. This was the longest-living specimens of this species recorded worldwide (Tovar-Ávila and Gallegos-Camacho, 2014). Many shark species are long-living, but the maximum observed for *S. mokarran* is one of the highest reported.

Compared to other hammerhead shark species, the great hammerhead has a greater growth rate and, therefore, reaches maturity earlier (Piercy *et al.*, 2010, Harry *et al.*, 2011). According to the observations of Piercy *et al.* (2010), males grow a little faster than females but are smaller. This difference has been observed in other species and could be related to the energy involved in reproductive development. Upon comparing their results with those obtained by Piercy *et al.* (2010), Harry *et al.* (2011) observed that individuals in the Atlantic grow faster in the first year of life.

Table 1. Growth parameters for *Sphyrna mokarran* according to the Von-Bertalanffy growth model. L_{∞} : asymptotic maximum (cm), k: growth rate (years⁻¹), t_0 : theoretical age at size 0 (years).

Growth Parameter			Area	Reference	Sex	Method
L_{∞}	k	t_0				
264 (FL)	0.16	-1.99	Northwest Atlantic and Gulf of Mexico	Piercy <i>et al.</i> (2010)	Males	Vertebrae
308 (FL)	0.11	-2.86	Northwest Atlantic and Gulf of Mexico	Piercy <i>et al.</i> (2010)	Females	Vertebrae
402 (TL)	0.079	70 (TL)*	West Pacific	Harry <i>et al.</i> (2011)	Both	Vertebrae

* Uses a Von Bertalanffy equation reparametrized with a fixed size at birth of 70 cm TL.

4.b. Length-weight relationship

To date, there are no published length-weight relationships for this species in the Atlantic Ocean for this species. **Table 2** therefore shows the relationships published for other regions.

Table 2. Length-weight relationships published for *Sphyrna mokarran*. N, number of individuals. The same column details if the relationship is for both sexes combined (C), males (M), or females (F). TW: total weight (kg); TL: total length (cm); PCL: precaudal length (cm); FL: fork length (cm).

Equation	N	Length range	R ²	Area	Reference
TW* = 1.23x10 ⁻³ x (TL) ^{3.24}	117 (C)		0.991**	North Australia	Stevens & Lyle (1989)
TW = 8.91 x 10 ⁻⁷ x (TL) ^{3.308}	100 (C)***			Persian Gulf	Hsu <i>et al.</i> (2021)
TW = 1.71 x 10 ⁻⁵ x (PCL) ^{2.9435}	153 (C)	106 – 326 (PCL)	0.958	Southwest	Cliff (1995)
		18 – 400 (TW)		Indian Ocean	
TW = 2.93 x 10 ⁻⁶ x (FL) ^{3.23475}	143 (C)			Indian Ocean	Romanov & Romanova (2012)
TW = 2.74 x 10 ⁻⁵ x (FL) ^{2.8046}	102 (M)			Indian Ocean	Romanov & Romanova (2012)
TW = 3.80 x 10 ⁻⁶ x (FL) ^{3.21084}	39 (F)			Indian Ocean	Romanov & Romanova (2012)

* Total weight in grams; ** Coefficient of determination (R²) based on lineal regression of ln(W) against ln(TL); *** No significant differences were observed between the sexes (X² = 1.858, W = 0.395).

4.c. Conversion factors

The published length-length relationships for the different regions are shown in **Table 3**.

Table 3. Length-length relationships published for *Sphyrna mokarran*. N, number of individuals. The same column details if the relationship is for both sexes combined (C), males (M) or females (F). TL: total length (cm); FL: fork length (cm); PCL: precaudal length (cm); UCL: length of upper lobe of the caudal fin (cm).

Equation	N	Length range	R ²	Area	Reference
TL = 1.253 x (FL) + 3.472	24 (C)		0.98	Northwest Atlantic	Piercy <i>et al.</i> (2010)
TL = 1.290 x (FL) + 3.580	261 (C)		0.99	North Australia	Stevens & Lyle (1989)
TL* = 1.290 x (FL) + 49.01	146 (C)		0.99	Northeast Australia	Harry <i>et al.</i> (2011)
TL* = 1.390 x (PCL) + 74.19	146 (C)		0.99	Northeast Australia	Harry <i>et al.</i> (2011)
FL = 1.064 x (PCL) + 6.090	40 (C)	133 – 306 (PCL)	0.98	Western Indian Ocean	Cliff (1995)
UCL = 0.350 x (PCL) + 17.10	140 (C)	106 – 306 (PCL)	0.93	Western Indian Ocean	Cliff (1995)
TL = 1.30 (FL) + 3.43	105 (C)		0.99	Persian Gulf	Hsu <i>et al.</i> (2021)
TL = 1.43 (PCL) + 3.43	105 (C)		0.99	Persian Gulf	Hsu <i>et al.</i> (2021)

* Stretched total length taken according to Compagno (1984).

4.d. Reproduction

Information on the reproductive biology of *S. mokarran* is scarce in both the Atlantic Ocean and the rest of the species' distribution area.

Gestation and pupping

It is a placental viviparous species and, as in other shark species, only the right ovary is functional (Wourms, 1977). The reproductive cycle is biennial, with a gestation period that lasts for approximately 11 months, after which between 6 and 42 individuals between 46 and 70 cm in length are born (Sadowsky, 1971; Stevens and Lyle, 1989; Fowler and Cavanagh, 2005; Denham *et al.*, 2007; Harry *et al.*, 2011; Rigby *et al.*, 2019).

Clark and von Schmidt (1965) combined their data with those reported by Springer (1940) and estimated that pupping in Florida, United States, occurred towards the end of spring and the beginning of summer. The presence of neonate individuals and young of the year (64 - 89 cm) in the months of June and July coincides with the pupping season already proposed, and it is suggested that pupping grounds occur in areas far from the coast (Hueter and Tyminski, 2007). Two neonates of the species were observed off the coasts of South Carolina and in the northern area of the Gulf of Mexico, United States, these being the two most northern areas where they have been recorded (Barker *et al.*, 2017), in addition to that there had not been any records to date of juvenile individuals (<200 cm) in coastal waters of the East coast of the United States (Castro, 2011). Recently, the area of Biscayne Bay, Florida, was identified as a possible nursery ground for the species, since it meets two of the three criteria described by Heupel *et al.* (2007), as individuals less than 200 cm have not been observed in other areas, and the juveniles are found in this area over the course of 12 months (Macdonald *et al.*, 2021). In southern

Belize, an area of mangroves was identified as a pupping and nursery ground for this species (Denham *et al.* 2007). The first gravid female in Brazilian waters was recorded in Sao Paulo in 1971, and was carrying 40 embryos (Sadovsky, 1971). According to Amorim *et al.* (2011), *S. mokarran*, *S. lewini* and *S. zygaena* all complete their life cycle in areas of South Brazil. In waters off West Africa, Cadenat and Blache (1981) observed that this species may have an annual reproductive cycle, with the mating season taking place between July and September, embryos reaching sizes of between 3 and 9 cm in September and pups of approximately 67 cm being born towards the end of August after 11 months of gestation. Based on studies carried out on the coast of Australia, the species does not seem to use coastal areas as nursing grounds, and pupping probably takes place far off the coast (Stevens and Lyle, 1989; Harry *et al.*, 2011).

According to a gonadosomatic index (GSI) study carried out by Stevens and Lyle (1989) in northern Australia and observations of males, the mating season takes place between October and November. In contrast, the GSI of females did not show a clear trend over the course of the year, but an analysis of the maximum oocyte diameter (MOD) showed that they grow in February and March. In any case, oocytes were observed in the uterus in February, April and July, which means that ovulation could span over an extensive time period. It was observed that embryos measure close to 8 cm in March and grow to reach almost 64 cm in December, and that pupping takes place in December and January, with a gestation period of 11 months. In contrast, Harry *et al.* (2011) reported that the pupping season was slightly earlier on the northeast coast of Australia, during October and November. In accordance with the observations of Stevens and Lyle (1989), the reproductive cycle of females lasts two years as only 59% of female individuals over 220 cm were gravid, and none of those that were carrying almost at-term embryos had mature oocytes in their ovaries. On the other hand, and based on the high GSI values observed during the mating season, males reproduce every year.

Fecundity

The overall fecundity observed is between 6 and 42 embryos per litter (Compagno, 1984; Stevens and Lyle, 1989; Fowler and Cavanagh, 2005). In northern Australia, based on the analysis of 30 gravid females, litters of between 6 and 33 embryos were observed, with a median of 15.4 and a significant relationship between the size of the female and number of embryos of the litter ($R^2 = 0.56$, $P < 0.01$) (Stevens and Lyle, 1989).

Maturity

Size-at-maturity is reported to be between 225 and 293 cm for males and between 210 and 337 cm for females (Compagno, 1984; Stevens and Lyle, 1989; Cliff, 1995; Fowler and Cavanagh, 2005; Rigby *et al.*, 2019). The smallest size at maturity of the range reported correspond, for both sexes, to Australia (Stevens and Lyle, 1989). While the largest sizes of the reported range correspond, for both sexes, to the East coast of South Africa (Cliff, 1995). The sizes reported by Cliff (1995) correspond to the value $L_{50\%}$, 217 cm PCL (~293 cm TL) for males and 237 cm PCL (~337 cm TL) for females. In both sexes, a large overlap of sizes between large immature individuals and smaller mature individuals is observed (Cliff, 1995).

According to an age and growth study carried out in the Northwest Atlantic and the Gulf of Mexico, taking the sizes at maturity observed, and using the growth parameters determined for this species, the suggested age of maturity is between 5 and 6 years (Piercy *et al.*, 2010). In northern Australia, no significant differences in the age of maturity_{50%} were observed between males and females, at 8.3 years (Harry *et al.*, 2011).

Sex ratio

The sex ratio of embryos in a single litter is approximately 1:1 (Compagno, 1984; Stevens and Lyle, 1989; Denham *et al.*, 2007). There are no reports on segregation by sex or size for this species. In northern Australia, Stevens and Lyle (1989) observed a significantly higher proportion of males, with females representing 45.7% of a total of 1,334 individuals. On the East coast of South Africa, significant differences were not observed in the overall catches between males and females. In spite of this, females dominated in the northern area of the field study, while males dominated in the southern area. Likewise, very few females were recorded between the months of July and October (Cliff, 1995).

4.e. Diet

The giant hammerhead is an opportunistic top predator that feeds on a large variety of prey, including crustaceans, molluscs, and cartilaginous and bony fish. They seem to prefer batoids and Siluriformes. Venomous spines are not a problem for great hammerheads as individuals have been found with as many as 50 spines stuck

in different parts of the mouth (Compagno, 1984). In northern Australia, an analysis of this species' diet based on the observation of 347 stomachs showed that 87.5% contained fish, including numerous species of (mainly demersal) sharks and rays, 17.1% contained crustaceans, 4.6% contained cephalopods and 12.4% were empty. Gasteropods, bivalve molluscs, holothuroidea, and mammal and tortoise remains were also found (Stevens and Lyle, 1989). Unlike other species of the genus *Sphyrna*, cephalopods would not be important food items in the species' diet (Smale and Cliff, 1998). In a recent study carried out in eastern Australia, the species was observed to mainly prey on sharks and rays, with a preference for resources that live on the seabed such as the ray *Rhinoptera neglecta*, while other resources such as bony fish, cephalopods and crustaceans were not an important part of its diet. It was also observed that *R. neglecta* was the largest component of *S. mokarran*'s diet in the summer months, when this prey is most abundant (Raoult *et al.*, 2019). This study observed ontogenic changes in the use of resources; however, these changes could not be explained by the sizes of the analysed individuals (Raoult *et al.*, 2019). Cliff (1995) observed that 83.2% of the stomachs analysed contained elasmobranchs, mainly from the superorder Batoidea, and two families of sharks, Scyliorhinidae and Carcharhinidae.

The persecution, attack and capture behaviour of *S. mokarran* was described by Strong *et al.* (1990), who directly observed how an individual of approximately 400 cm preyed on a *Hypanus americana* individual with a disk width of 150 cm. The observation of this behaviour showed that the laterally expanded shape of the head can be directly used to handle prey, pressing it against the seabed. This behaviour has also been recorded on other occasions (Chapman and Gruber, 2002; Roemer *et al.*, 2016; O'Connell, 2018). Chapman and Gruber (2002) also documented the behaviour of this species attacking an *Aetobatus narinari* individual. However, unlike the observations of Strong *et al.* (1990), the attack took place on the surface. In all cases, the shark ultimately used the shape of its head to take the prey to the seabed and eat it. Roemer *et al.* (2016) observed that the species, in pursuing and hunting prey, uses shallow waters less than 1.5 m deep in areas of tidal flats. On these occasions, the species was observed preying on bony fish, as well as sharks (*Ginglymostoma cirratum* and *Negaprion brevirostris*), by making rapid circular movements known as "grasp-turning"; this leaves a very small space, and facilitates eating of prey. The use of warm, shallow waters with a low oxygen concentration implies high metabolic expenditure for large species such as *S. mokarran*. In addition, the authors (Roemer *et al.* 2016) observed in one of the individuals a behaviour which possibly acts as an energy recovery and oxygenation mechanism. After the prey event, it positioned itself in facing a strong current, and remained there for 15 minutes with minimal movement. This hunting behaviour in shallow areas has also been recorded by Doan and Kajiura (2020) who analysed videos taken with drones, in which *S. mokarran* can be observed pursuing specimens of *Carcharhinus limbatus*. In any case, the great hammerhead, which is found in beach coastal areas, due to its size, cannot catch *C. limbatus*, as these smaller individuals go closer to the beach, escaping from *S. mokarran*.

In a review of the diet and trophic level of several shark species based on 5 studies, with 458 individuals analysed, 43.5% contained bony fish, 41.7% chondrichthyans, 11.2% crustaceans and 3.3% cephalopods. According to these data, this species' trophic level is calculated at 4.3 (Cortés, 1999).

4.f. Physiology

The characteristic shape of the head and body of the hammerhead has been studied in different works, most of which take one of the species as the model for all the species of the family Sphyrnidae. Various sensory advantages related to the shape of hammerhead sharks' head have been described, including the hypothesis of an increased olfactory capacity; it has been demonstrated that the width of their head allows them to explore a larger proportion of waters tracking smells. In addition, the distance between their nostrils helps them identify where smells come from, right or left, although it has not been confirmed whether they have greater olfactory acuity (Kajiura *et al.*, 2005). It has also been demonstrated that they have a large number of electroreceptors, with a high density in the ventral area of the head, which results in a higher probability of tracking prey compared to other carcharhinidae species of a similar size (e.g., *Carcharhinus plumbeus*) (Kajiura, 2001; Kajiura and Holland, 2002).

In addition to the sensorial advantages associated with the shape of their head, hammerhead sharks have a series of morphological innovations related to manoeuvrability, greater lateral flexion of the body and the ability to turn sharply. These characteristics appear to be critical for the manner in which this species searches and hunts for food. Kajiura *et al.* (2003) compared the manoeuvrability of two species of hammerhead shark with the sandbar shark (*Carcharhinus plumbeus*), and observed that both of the hammerhead shark species were more agile and had higher manoeuvrability, performing sudden turns at an angle of over 90° almost 50% more than *C. plumbeus* and twice as fast. It was also observed that sandbar sharks roll their entire body in almost half of the turns analysed, whereas hammerhead sharks only roll by an angle of under 10° in opportunities that turn the

body. Consequently, Kajiura *et al.* (2003) suggest that the shape of the head does not help the shark to turn, but provides hydrodynamic stability during turns. As mentioned in the previous point (4.e Diet), it has also been observed that the laterally expanded shape of the head can be directly used to handle prey, pressing it against the seabed (Strong *et al.*, 1990).

The morphological innovations associated with manoeuvrability, agility, and hunting behaviour in this group of species could also have selected enlargement of the dorsal fin in the great hammerhead to generate the lateral forces required to perform such manoeuvres (Payne *et al.*, 2016). The large size of the fin has also possibly led to a unique adaptation in the traditional form of locomotion. By fitting cameras and accelerometers on the dorsal fin, Payne *et al.* (2016) observed that individuals spend up to 90% of the time swimming at roll angles of between 50° and 75°. Once this behaviour had been observed, the authors used hydrodynamic modelling to demonstrate that swimming in this position reduces resistance and transport energy expenditure by approximately 10% compared to traditional vertical swimming.

4.g. Mortality

As regards natural mortality, given the large size of this species, it is not likely to have any natural predators and this could be a factor in its abundance (Miller *et al.*, 2014). In any case, it is known that other species of larger sharks, and including great hammerhead adult individuals, feed on injured or smaller individuals (Myers *et al.*, 2007; French *et al.*, 2018).

As regards catch mortality, in the US bottom longline shark fishery, mortality is estimated at 56% for the great hammerhead, with 50% dying 3.8 hours after being caught (Gulak *et al.*, 2015). For demersal longlines in western Australia, mortality is estimated at 30.8% (Braccini and Waltrick, 2019). Gallagher *et al.* (2014) suggested a post-release mortality of 50%, probably due to a pronounced behavioural and physiological stress response caused by struggles in a fishing line, even during relatively short periods of time, and the great hammerhead is one of most vulnerable species to mortality on the boat and following release. Morgan and Burgess (2007) also observed that 93.8% of great hammerhead individuals were dead when taken on board in commercial bottom longline vessels in the Northwest Atlantic and Gulf of Mexico. Size did not appear to influence susceptibility, while fishing gear soak time had a positive effect on the probability of death, while the water temperature on the sea floor had a negative effect. Between 2005 and 2017, the European purse seine fleet (EU-Spain and EU-France) recorded the catch of 212 individuals of this species, with a mortality rate of 58.96% (Clavareau *et al.*, 2020).

5. Fisheries biology

5.a. Populations/Stock structure

Information on this species' migrations and genetic studies that contemplate the populational structure are scarce. In a molecular analysis performed with samples from the western Atlantic, the Indian Ocean and the East and West coasts of Australia, strong differentiation was observed between the Atlantic and Australian populations, and there was a hybrid presence in the Indian Ocean (Testerman, 2014). Another study based on samples from the Northwest Atlantic and Indian Ocean suggested that there are two distinct groups of great hammerhead, one in the Atlantic and another in Australia and Borneo. The authors acknowledge that the study is based on a small number of samples that are not very representative of the species' distribution. However, despite this and the fact that it is not one of the most divergent hammerhead sharks, there is no haplotype overlap between specimens from the Atlantic and Indian Oceans, which supports recognition of these as distinct allopatric species (Naylor *et al.*, 2012). These studies suggest the existence of two subpopulations, one in the Atlantic Ocean and the other in the Indo-Pacific. However, both studies are based on a small number of samples and only part of the species' global distribution, meaning that integrated studies contemplating these aspects in various stock and management units are necessary (Naylor *et al.*, 2012; Testerman, 2014; Rigby *et al.*, 2019).

5.b. Description of the fisheries

Due to the difficulties associated with correct identification, hammerhead shark species are generally recorded in an aggregate manner in fishing reports, which results in reduced availability of records on great hammerhead catches (Camhi *et al.*, 2009; Miller *et al.*, 2014; Bezerra *et al.*, 2016; Gallagher and Klimley, 2018).

The great hammerhead is fished in a large number of artisanal and industrial fisheries around the world, pelagic and bottom longline, purse seine, pelagic and bottom trawling, and bottom and drift gillnet fisheries, among others (Schneider, 1990; Zeeberg, 2006; Miller *et al.*, 2014; Rigby *et al.*, 2019). This species is mainly taken as bycatch. However, due to the large size of its fins and the high cartilaginous fibre content, it is highly coveted in the shark fin trade and, therefore, it is generally retained due to its high value on the Hong Kong market (Abercrombie *et al.*, 2005; Chapman *et al.*, 2009). The shark fin market is one of the main causes of the decrease in populations of this species (Clarke *et al.*, 2006a), and hammerhead shark (*S. lewini*, *S. mokarran* and *S. zygaena* combined) fins are the second most abundant species group on the international Hong Kong market, representing approximately 6% of the total (Clarke *et al.*, 2004; 2006b).

East Atlantic

It is taken in bycatch in industrial and artisanal driftnet, bottom gillnet, longline and pelagic and bottom trawl fisheries (Schneider, 1990). An artisanal fishery specialised in catching sharks from the families Carcharhinidae and Sphyrnidae has existed in Sierra Leone since 1975 (Denham *et al.*, 2007). The fishing and trade of sharks has grown rapidly in the region since the beginning of the 1970s. Mainly for the fin market, it is calculated that Guinea-Bissau alone exports 250 t of dried fins every year (Walker *et al.*, 2005). In the European fleet's industrial pelagic trawl fisheries in Northwest Africa, the various species of *Sphyrna* combined represent 42% of bycatch (Zeeberg, 2006). The most recent information regarding this region corresponds to purse seine fisheries targeting tropical tunas. This fishery takes various elasmobranch species as bycatch, including *S. mokarran* (Lezama-Ochoa *et al.*, 2018; Escalle *et al.*, 2019; Clavareau *et al.*, 2020). Between 2005 and 2017, the European purse seine fleet (EU-Spain and EU-France) recorded the capture of 212 individuals of this species, most of which were juveniles (98.52%) (Clavareau *et al.*, 2020).

S. mokarran used to be abundant between November and January in Senegal and in October in Mauritania (Cadenat and Blache, 1981), but very low numbers appeared in Guinea and only one individual in Senegal during recent research campaigns (Denham *et al.*, 2007). The regional plan of action for West Africa determined that great hammerhead landings had plummeted and mentioned this species as one of the four most threatened that requires the most attention in the region (Ducrocq, 2002). Despite the fact that there is very little information at the species level and a lack of recent records and recognition that populations are dwindling, the great hammerhead population in this area is assumed to have decreased by 80% in the last 25 years. As a result of scarce regulation and low levels of monitoring in fisheries in this region, the IUCN classified this species as "Critically endangered" in the East Atlantic in 2007 (Denham *et al.*, 2007).

West Atlantic

Jiao *et al.* (2009) observed that the abundance of the hammerheads group – composed of *S. lewini*, *S. mokarran* and *S. zygaena* – has decreased by 70% since 1981 in the Northwest Atlantic, while Myers *et al.* (2007) reported that the same group of species decreased by 89% between 1986 and 2000. In the Northwest Atlantic and the Gulf of Mexico, the great hammerhead is mainly taken as bycatch in pelagic and bottom longline fishing, in gillnets, and in sport fishing. In pelagic longline fishing in the United States, the great hammerhead has decreased by almost 90%, although some of these data are inaccurate due to the difficulties associated with identifying the species (Beerkircher *et al.*, 2002). In addition, due to the size of their fins and their high commercial value, there are still cases of finning where the carcasses are discarded, meaning that these catches are not reported. There is little information about catches and landings of this species in Central America and the Caribbean. The various hammerhead species were caught in large quantities during the 1980s and 1990s off the coast of Belize, causing a dramatic decrease in abundance (Denham *et al.*, 2007). The difficulties associated with identifying the species make it difficult to evaluate. Due to the life history traits of this species, the low catch survival rate, and the high population decrease values estimated at 50% the great hammerhead was classified as an "Endangered" species by the IUCN in the Northwest Atlantic in 2007 (Denham *et al.*, 2007).

This species is rarely caught by the longline fleet that operates out of the Port of Santos in Brazil, and it is included in the hammerhead group (Amorim *et al.*, 1998). According to Amorim *et al.* (2011), hammerhead sharks (*S. lewini* and *S. zygaena*) represented 6.3% of the total shark catch of longline fleets in the South of Brazil between 2007 and 2008. Kotas (2004) reported a higher value (8.3%) between 2000 and 2002 for longline vessels operating out of the Port of Santa Catalina. Recently, Bezerra *et al.* (2016) analysed catch and effort data from the Brazilian chartered and national longline fleets during the 2004–2011 period and found that hammerhead sharks (*S. lewini*, *S. mokarran* and *S. zygaena* combined) accounted for 0.40% of all individuals caught. Likewise, this study observed that the mean catch per unit effort of hammerhead sharks of surface longline fleets was approximately double that of deep-setting longline fleets. A recent study on the marketing of sharks in North Brazil that used genetic studies to identify species determined the presence of 17 species in the 427 samples analysed. *S. mokarran* was the fourth most abundant species overall (9.34%) and the most abundant species from the genus *Sphyrna* (Feitosa *et al.*, 2018).

5.c. State of the stocks

There are currently no stock assessments for this species. In the Atlantic Ocean, Cortes *et al.* (2015) carried out an ecological risk assessment for 15 shark species and 1 ray species, based on industrial pelagic longline fisheries. The results of this study place *S. mokarran* in a situation of intermediate vulnerability compared to the other species (Cortés *et al.*, 2015). This result is partly due to the fact the population parameters and life history traits of the great hammerhead are intermediate as compared to other pelagic shark species. These parameters place the great hammerhead as a shark with moderate growth, meaning that they generally have moderate potential to recover from exploitation (Miller *et al.*, 2014). An Extinction Risk Analysis performed by the NMFS (National Marine Fisheries Service, NOAA, the United States), observed certain uncertainty regarding the species' extinction risk, mainly due to data limitations. However, low risk is the most likely (Miller *et al.*, 2014). During discussions and the elaboration of this extinction risk analysis, it was reiterated that the abundance of the great hammerhead is probably naturally low, and that the lack of fishing data is partly due to the fact that this species is not found in fishing grounds. Consequently, the authors conclude that the general level of extinction risk over the next 50 years would be “no or very low risk” and “low risk” (Miller *et al.*, 2014).

In any case, it has been estimated that the global population of this species has decreased by over 50%. Large decreases were observed in the Indian and Atlantic Oceans prior to the implementation of some management measures, and a slow recovery may currently be taking place in the Northwest Atlantic. In addition to the observed decreases, the lack of information on this species and catches in several regions increase uncertainty regarding stock status. Consequently, this species was recently reclassified by the IUCN from “Endangered” (Denham *et al.*, 2007) to “Critically endangered” (Rigby *et al.*, 2019).

This species can be found in Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), in accordance with paragraph 2, Article II of the Convention, which refers to “similar species”. The criterion of “similar species” refers to species that resemble those included in the list for conservation purposes. Consequently, *S. mokarran* is included due to its likeness to the scalloped hammerhead (*Sphyrna lewini*), a species that is also included in Appendix II of CITES (Vincent *et al.*, 2013). Since 2014, the species has also been listed in Appendix II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS).

In accordance with ICCAT Recommendation 10-08, it is prohibited to retain onboard, transship, land, store, sell, or offer for sale any part or whole carcass of hammerhead sharks of the family Sphyrnidae (except for *S. tiburo*) taken in the Convention area in association with fisheries managed by ICCAT (Rec. 10-08).

6. Bibliography

- Abercrombie, D.L., Clarke, S.C., Shivji, M.S. 2005. Global-scale genetic identification of hammerhead sharks: application to assessment of the international fin trade and law enforcement. *Conservation Genetics* 6: 775–788.
- Amorim, A.F., Arfelli, C.A., Fagundes, L. 1998. Pelagic elasmobranchs caught by longliners off Southern Brazil during 1974-97: an overview. *Marine and Freshwater Research* 49: 621–632.
- Amorim, A.F., Della-Fina, N., Piva-Silva, N. 2011. Hammerhead sharks, *Sphyrna lewini* and *S. zygaena* caught by longliners off southern Brazil, 2007-2008. *ICCAT Collective Volume of Scientific Papers* 66 (5): 2121–2133.
- Barker, A.M., Frazier, B.S., Bethea, D.M., Gold, J.R., Portnoy, D.S. 2017. Identification of young-of-the-year great hammerhead shark *Sphyrna mokarran* in northern Florida and South Carolina. *Journal of Fish Biology* 91 (2): 664-668.
- Bauchot, M.L. 1987. Requins. In: Fischer, W., M. L. Bauchot et M. Schneider (rédacteurs 1987). Fiches FAO d'identification des espèces pour les besoins de la pêche. (Révision 1). Méditerranée et mer Noire. Zone de pêche 37. Volume II. Vertébrés. Publication préparée par la FAO, résultat d'un accord entre la FAO et la Commission des Communautés Européennes (Projet GCP/INT/422/EEC) financée conjointement par ces deux organisations. Rome, FAO, Vo1.2: pp 767-843.
- Beerkircher, L.R., Cortés, E., Shivji, M. 2002. Characteristics of Shark Bycatch Observed on Pelagic Longlines off the Southeastern United States, 1992–2000. *Marine Fisheries Review* 64: 40–49.

- Bezerra, N.P.A., Travassos, P., Hazin, F.H.V. 2016. Vulnerability to longline fisheries of three hammerhead shark *Sphyrna* species in the south-western and equatorial Atlantic Ocean. *Journal of Fish Biology* 89: 1419–1433.
- Biscoito, M., Ribeiro, C., Freitas, M. 2018. Annotated checklist of the fishes of the archipelago of Madeira (NE Atlantic): I-Chondrichthyes. *Zootaxa*, 4429 (3): 459–494.
- Boero, F., Carli, C. 1977. Prima segnalazione Mediterranea di *Sphyrna mokarran* (First report on *Sphyrna mokarran* in the Mediterranean) (Rüppel, 1837) (Selachii, Sphyrnidae). *Boll. Mus. Ist. Univ. Genova*, 45: 91–93.
- Braccini, M., Waltrick, D. 2019. Species-specific at-vessel mortality of sharks and rays captured by demersal longlines. *Marine Policy* 99: 94–98.
- Cadenat, J., Blache, J. 1981. Requins de Méditerranée et d' Atlantique (plus particulièrement de la Côte Occidentale d'Afrique). Ed. OSTROM, Faune Tropicale (21).
- Camhi, M.D., Valenti, S.V., Fordham, S.V., Fowler, S.L., Gibson, C. 2009. The Conservation Status of Pelagic Sharks and Rays: Report of the IUCN Shark Specialist Group Pelagic Shark Red List Workshop. IUCN Species Survival Commission Shark Specialist Group. Newbury, UK.
- Carneiro, M., Martins, R., Landi, M., Costa, F.O. 2014. Updated checklist of marine fishes (Chordata: Craniata) from Portugal and the proposed extension of the Portuguese continental shelf. *European Journal of Taxonomy* 73: 1–73.
- Carneiro, M., Martins, R., Reiner, F., Batista, I. 2019. Ichthyofauna of Portugal: Taxonomic diversity, common and scientific names of marine fishes. IPMA, I.P., Vol. I, 376 p.
- Castro, J.I. 2011. The sharks of North America. New York, NY: Oxford University Press.
- Celona, A., Maddalena, A. 2005. Occurrence of hammerhead sharks (Chondrichthyes: Sphyrnidae) in waters off Sicily (central Mediterranean): Historical and recent data. *Annales, Series Historia Naturalis* Vol. 1, no. 15, p. 57–64.
- Chapman, D.D., Gruber, S.H. 2002. A further observation of the prey-handling behavior of the great hammerhead shark, *Sphyrna mokarran*: Predation upon the spotted eagle ray, *Aetobatus narinari*. *Bulletin of Marine Science*, 70(3): 947–952.
- Chapman, D.D., Pinhal, D., Shivji, M.S. 2009. Tracking the fin trade: genetic stock identification in western Atlantic scalloped hammerhead sharks *Sphyrna lewini*. *Endangered Species Research* 9: 221–228.
- Chin, A., Kyne, P.M., Walker, T.L., McAuley, R.B. 2010. An integrated risk assessment for climate change: analyzing the vulnerability of sharks and rays on Australia's Great Barrier Reef. *Global Change Biology* 16: 1936–1953.
- Clark, E., von Schmidt, K. 1965. Sharks of the central gulf coast of Florida. *Bulletin of Marine Science* 15 (I), 13–83.
- Clarke, S., McAllister, M.K., Michielsens, C.G.J. 2004. Estimates of shark species composition and numbers associated with the shark fin trade based on Hong Kong auction data. *Journal of Northwest Atlantic Fishery Science* 35: 453–465.
- Clarke, S.C., McAllister, M.K., Milner-Gulland, E.J., Kirkwood, G.P., Michielsens, C.G.J., Agnew, D.J., Pikitch, E.K., Nakano, H., Shivji, M.S. 2006a. Global estimates of shark catches using trade records from commercial markets. *Ecology Letters* 9: 1115–1126.
- Clarke, S.C., Magnussen, J.E., Abercrombie, D.L., McAllister, M.K., Shivji, M.S. 2006b. Identification of Shark Species Composition and Proportion in the Hong Kong Shark Fin Market Based on Molecular Genetics and Trade Records. *Conservation Biology* 20: 201–211.
- Clavareau, L., Sabarros, P.S., Escalle, L., Bach, P., Abascal, F.J., Lopez, J., Murua, H., Pascual-Alayon, P.J., Ramos, M.L., Ruiz, J., Mérigot, B. 2020. Elasmobranch bycatch distributions and mortality: Insights from the European tropical tuna purse-seine fishery. *Global Ecology and Conservation* 24: e01211.
- Cliff, G. 1995. Sharks caught in the protective gill nets off KwaZulu-Natal, South Africa. 8. The great hammerhead shark *Sphyrna mokarran* (Rüppel). *South African Journal of Marine Science* 15: 105–114.
- Compagno L.J.V. 1984. FAO species catalogue. Sharks of the world: an annotated and illustrated catalogue of shark species known to date. Part 2. Carcharhiniformes. *FAO Fishery Synopsis* 4: 251–655.

- Cortés, E. 1999. Standardized diet compositions and trophic levels of sharks. *ICES Journal of Marine Science* 56: 707–717.
- Cortés, E., Domingo, A., Miller, P., Forselleo, R., Mas, F., Arocha, F., Campana, S., Coelho, R., Da Silva, C., Hazin, F.H.V., Holtzhausen, H., Keene, K., Lucena, F., Ramirez, K., Santos, M.N., Semba-Murakami, Y., Yokawa, K. 2015. Expanded ecological risk assessment of pelagic sharks caught in Atlantic pelagic longline fisheries. *Collective Volume of Scientific Papers ICCAT* 71: 2637–2688.
- Denham, J., Stevens, J., Simpfendorfer, C.A., Heupel, M.R., Cliff, G., Morgan, A., Graham, R., Ducrocq, M., Dulvy, N.D., Seisay, M., Asber, M., Valenti, S.V., Litvinov, F., Martins, P., Lemine Ould Sidi, M., Tous, P., Bucal, D. 2007. *Sphyrna mokarran*. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 30 April 2012.
- Doan, M.D., Kajiura, S.M. 2020. Adult blacktip sharks (*Carcharhinus limbatus*) use shallow water as a refuge from great hammerheads (*Sphyrna mokarran*). *Journal of Fish Biology* 96 (6): 1530–1533.
- Domingo, A., Cortés, E., Forselleo, R., Driggers, W. 2010. Guía para la identificación de tiburones del océano Atlántico. Publicación de la Comisión Internacional para la Conservación del Atún Atlántico. https://www.iccat.int/Documents/SCRS/Guide_ID_Sharks_SPA-1.pdf.
- Ducrocq, M. 2002. Rapport de la première réunion de coordination du Plan Sous-Régional d'Action pour la Conservation et la Gestion des populations de Requins. Commission Sous Régionale des Pêches, Secrétariat Permanent. Saly-Portudal, du 27 au 29 mai 2002.
- Ebert, D.A., S. Fowler, Compagno, L.J.V. 2013. *Sharks of the world: A fully illustrated guide*. Devon, England: Wild Nature Press.
- Ebert, D.A., Wintner, S.P., Kyne, P.M. 2021. An annotated checklist of the chondrichthyans of South Africa. *Zootaxa* 4947 (1): 001–127.
- Escalle, L., Gaertner, D., Chavance, P., Murua, H., Pascual-Alayón, P.J., Ménard, F., Ruiz, J., Abascal, F., Mérigot, B. 2019. Catch and bycatch captured by tropical tuna purse-seine fishery in whale and whale shark associated sets: comparison with free school and FAD sets. *Biodiversity and Conservation* 28: 467–499.
- Farrell, E.R. 2009. The habitat, movement, and management of dolphin, *Coryphaena hippurus*, in the western North Atlantic, Caribbean, and Gulf of Mexico. MS thesis, Duke University, Durham, NC.
- Feitosa, L.M., Martins, A.P.B., Giarrizzo, T., Macedo, W., Monteiro, I.L., Gemaque, R., Silva Nunes, J.L., Gomes, F., Schneider, H., Sampaio, I., Souza, R., Bráullio Sales, J., Rodrigues-Filho, L.F., Tchaicka, L., Carvalho-Costa, L.F. 2018. DNA-based identification reveals illegal trade of threatened shark species in a global elasmobranch conservation hotspot. *Scientific Reports* 8: 3347.
- Fowler, S.L., Cavanagh, R.D. 2005. Species Status Reports. In: Fowler, S.L., Cavanagh, R.D., Camhi, M., Burgess, G.H., Cailliet, G.M., Fordham, S.V., Simpfendorfer, C.A., Musick, J.A. (comp. and ed.). 2005. *Sharks, Rays and Chimaeras: The Status of the Chondrichthyan Fishes*. Status Survey. IUCN/SSC Shark Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. x + 461 pp.
- French, L., Dorrian, J., Naylor, G. 2018. Biological Profiles: Great Hammerhead. Florida Museum of Natural History. Ichthyology Department. Available at: <https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/sphyrna-mokarran/>.
- Gallagher, A.J., Serafy, J.E., Cooke, S.J., Hammerschlag, N. 2014. Physiological stress response, reflex impairment, and survival of five sympatric shark species following experimental capture and release. *Marine Ecology Progress Series* 496: 207–218.
- Gallagher, A.J., Klimley, A.P. 2018. The biology and conservation status of the large hammerhead shark complex: the great, scalloped, and smooth hammerheads. *Reviews in Fish Biology and Fisheries* 28: 777–794.
- Gilbert, C.R. 1967. A revision of the hammerhead sharks (family Sphyrnidae). *Proceedings of the United States National Museum*. Smithsonian Institution, Washington D.C. vol. 119. 98p.
- Guttridge, T.L., Van Zinnicq Bergmann, M.P.M., Bolte, C., Howey, L.A., Finger, J.S., Kessel, S.T., Brooks, J.L., Winram, W., Bond, M.E., Jordan, L.K.B., Cashman, R.C., Tolentino, E.R., Grubbs, R.D., Gruber, S.H. 2017. Philopatry and Regional Connectivity of the Great Hammerhead Shark, *Sphyrna mokarran* in the U.S. and Bahamas. *Frontiers in Marine Science* 4: 3.

- Hammerschlag, N., Gallagher, A.J., Lazarre, D.M., Slonim, C. 2011. Range extension of the Endangered great hammerhead shark *Sphyrna mokarran* in the Northwest Atlantic: preliminary data and significance for conservation. *Endangered Species Research* 13: 111–116.
- Harry, A.V., Macbeth, W.G., Gutteridge, A.N., Simpfendorfer, C.A. 2011. The life histories of endangered hammerhead sharks (Carcharhiniformes, Sphyrnidae) from the east coast of Australia. *Journal of Fish Biology*, 78: 2026–2051.
- Heithaus, M.R., Burkholder, D., Hueter, R.E., Heithaus, L.I., Pratt, H.L., Carrier, J.C. 2007. Spatial and temporal variation in shark communities of the lower Florida Keys and evidence for historical population declines. *Canadian Journal of Fisheries and Aquatic Sciences* 64(10): 1302–1313.
- Heupel, M.R., Carlson, J.K., Simpfendorfer, C.A. 2007. Shark nursery areas: Concepts, definition, characterization and assumptions. *Marine Ecology Progress Series* 337: 287–297.
- Hsu H.H, Nazeer, Z.M., Lin, Y.J., Panickan, P., Al-Abdulkader, K., Loughland, R., Qurban, M.A. 2021. Biological aspects of juvenile great hammerhead sharks *Sphyrna mokarran* from the Arabian Gulf. *Marine and Freshwater Research* 72: 110-117.
- Hueter, R.E., Tyminski, J.P. 2007. Species-specific distribution and habitat characteristics of shark nurseries in Gulf of Mexico waters off Peninsular Florida and Texas. *American Fisheries Society Symposium* 50: 193–223.
- Jiao, Y., Hayes, C., Cortés, E. 2009. Hierarchical Bayesian approach for population dynamics modelling of fish complexes without species specific data. *ICES Journal of Marine Science* 66, 367–377.
- Kajiura, S.M. 2001. Head Morphology and Electro sensory Pore Distribution of Carcharhinid and Sphyrnid Sharks. *Environmental Biology of Fishes* 61 (2): 125–133.
- Kajiura, S.M., Holland, K.M. 2002. Electroreception in Juvenile Scalloped Hammerhead and Sandbar Sharks. *Journal of Experimental Biology* 205 (23): 3609–3621.
- Kajiura, S.M., Forni, J.B., Summers, A.P. 2003. Maneuvering in juvenile Carcharhinid and Sphyrnid sharks: the role of the hammerhead shark cephalofoil. *Zoology* 106, 19–28.
- Kajiura, S.M., Forni, J.B., Summers A.P. 2005. Olfactory Morphology of Carcharhinid and Sphyrnid sharks: Does the cephalofoil confer a sensory advantage? *Journal of Morphology* 264: 253–263.
- Kohler, N.E., Casey, J.G., Turner, P.A. 1998. NMFS cooperative shark tagging program, 1962–1993: an atlas of shark tag and recapture data. *Marine and Fisheries Review* 60: 1–87.
- Kohler, N.E, Turner, P.A. 2001. Shark tagging: a review of conventional methods and studies. *Environmental Biology of Fishes* 60: 191–223.
- Kohler, N.E, Turner, P.A. 2019. Distributions and movements of Atlantic shark species: a 52- year retrospective atlas of mark and recapture data. *Marine Fisheries Review* 81: 1–93.
- Last, P.R., Stevens, J.D. 1994. *Sharks and Rays of Australia*. CSIRO, Australia. 513p.
- Lezama-Ochoa, N., Murua, H., Ruiz, J., Chavance P., de Molina, A.D., Caballero A., Sancristobal, I. 2018. Biodiversity and environmental characteristics of the bycatch assemblages from the tropical tuna purse seine fisheries in the eastern Atlantic Ocean. *Marine Ecology* 39(3): e12504.
- Macdonald, C., Jerome, J., Pankow, C., Perni, N., Black, K., Shiffman, D., Wester, J. 2021. First identification of probable nursery habitat for critically endangered great hammerhead *Sphyrna mokarran* on the Atlantic Coast of the United States. *Conservation Science and Practice* 3 (8): e418.
- Miller, M.H., Carlson, J., Hogan L., Kobayashi, D. 2014. Status review report: great hammerhead shark (*Sphyrna mokarran*). Final Report to National Marine Fisheries Service, Office of Protected Resources. June 2014. 116 pp.
- Morgan, A., Burgess, G. 2007. At-vessel fishing mortality for six species of sharks caught in the northwest Atlantic and Gulf of Mexico. *Proceedings of the 59th Annual Conference of the Gulf and Caribbean Fisheries Institute*. v. 19(2):123-130.
- Myers, R.A., Baum, J.K., Shepherd, T.D., Powers, S.P., Peterson, C.H. 2007. Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science* 315: 1846–1850.

- Naylor, G.J.P., Caira, J.N., Jensen, K., Rosana, K.A.M., White, W.T., Last, P.R. 2012. A DNA sequence-based approach to the identification of shark and ray species and its implications for global elasmobranch diversity and parasitology. *Bulletin of the American Museum of Natural History* 367, 262 pp.
- O'Connell, C.P. 2018. The utilization of prey-simulating electrodes to analyze the predatory behavior of the great hammerhead shark (*Sphyrna mokarran*). *Zoology and Ecology* 28 (2): 75-85.
- Oxenford, H.A., Hunte, W. 1986. A preliminary investigation of the stock structure of the dolphin, *Coryphaena hippurus*, in the western central Atlantic. *Fishery Bulletin* 84:451–460.
- Passerotti, M.S., Carlson, J.K., Piercy, A.N., Campana, S.E. 2010. Age validation of great hammerhead shark (*Sphyrna mokarran*), determined by bomb radiocarbon analysis. *Fishery Bulletin* 108: 346–351.
- Payne, N., Iosilevskii, G., Barnett, A., Fischer, C., Graham, R.T., Gleiss, A.C., Watanabe, Y.Y. 2016. Great hammerhead sharks swim on their side to reduce transport costs. *Nature Communications* 7: 12289.
- Petersen, S.L., Honig, M.B., Ryan P.G., Underhill, L.G., Compagno, L.J.V. 2008. Pelagic shark bycatch in the pelagic longline fishery off southern Africa. In: Petersen S.L., Nel D.C., Ryan P.G., Underhill, L.G. (Eds.). *Understanding and Mitigating Vulnerable Bycatch in southern African Trawl and Longline Fisheries*. WWF South Africa Report Series - 2008/Marine/002.
- Piercy, A.N., Carlson, J.K., Passerotti, M.S. 2010. Age and growth of the great hammerhead shark, *Sphyrna mokarran*, in the north-western Atlantic Ocean and Gulf of Mexico. *Marine and Freshwater Research* 61: 992–998.
- Psomadakis, P., Giustino, S., Vacchi, M. 2012. Mediterranean fish biodiversity: an updated inventory with focus on the Ligurian and Tyrrhenian seas. *Zootaxa*, 3263(1), 1–46.
- Raoult, V., Broadhurst, M.K., Peddemors, V.M., Williamson, J.E., Gaston, T.F. 2019. Resource use of great hammerhead sharks (*Sphyrna mokarran*) off eastern Australia. *Journal of Fish Biology* 95: 1430– 1440.
- Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Herman, K., Jabado, R.W., Liu, K.M., Marshall, A., Pacoureaux, N., Romanov, E., Sherley, R.B., Winker, H. 2019. *Sphyrna mokarran*. The IUCN Red List of Threatened Species 2019: e.T39386A2920499. <https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T39386A2920499.en>. Downloaded on 02 June 2021.
- Roemer, R.P., Gallagher, A.J., Hammerschlag, N. 2016. Shallow water tidal flat use and associated specialized foraging behavior of the great hammerhead shark (*Sphyrna mokarran*). *Marine and Freshwater Behaviour and Physiology* 49 (4): 235-249.
- Romanov, E.V., Romanova, N.V. 2012. Size distribution and length-weight relationships for some large pelagic sharks in the Indian Ocean. Communication 2. Bigeye thresher shark, tiger shark, silvertip shark, sandbar shark, great hammerhead shark, and scalloped hammerhead shark. IOTC-2012-WPEB08-22.
- Sadowsky, V. 1971. First record of the occurrence of an adult hammerhead shark (*Sphyrna mokarran*) in the southern Brazilian waters. *Inst. Ocean. USP*, no. 305 ,1971.
- Schneider, W. 1990. Field guide to the commercial marine resources of the Gulf of Guinea. FAO species identification sheets for fishery purposes. Prepared and published with the support of the FAO Regional Office for Africa (RAFR), Rome, Italy.
- Serena, F. 2005. Field identification guide to the sharks and rays of the Mediterranean and Black Sea. FAO Species Identification Guide for Fishery Purposes. Rome, FAO. 2005. 97p.
- Smale, M.J., Cliff, G. 1998. Cephalopods in the diets of four shark species (*Galeocerdo cuvier*, *Sphyrna lewini*, *S. zygaena* and *S. mokarran*) from KwaZulu-Natal, South Africa. *South African Journal of Marine Science* 20 (1): 241-253.
- Sperone, E., Parise, G., Leone, A., Milazzo, C., Circosta, V., Santoro, G., Paolillo, G., Micarelli, P., Tripepi, S. 2012. Spatiotemporal patterns of distribution of large predatory sharks in Calabria (central Mediterranean, southern Italy). *Acta Adriatica*, 53 (1), 13-23.
- Springer, S. 1940. The sex ratio and seasonal distribution of some Florida sharks. *Copeia* 1940 (3): 188–194.
- Springer, S. 1963. Field observations on large sharks of the Florida– Caribbean region. In 'Sharks and Survival'. (Ed. P. W. Gilbert.) pp. 95–113. (Heath y Co.: Boston, MA).
- Stevens, J.D., Lyle, J.M. 1989. Biology of three hammerhead sharks (*Eusphyra blochii*, *Sphyrna mokarran* and *S. lewini*) from Northern Australia. *Marine y Freshwater Research* 40: 129–146.

- Stevens, J.D., West, G.J., McLoughlin, K.J. 2000. Movements, recapture patterns, and factors affecting the return rate of Carcharhinid and other sharks tagged off northern Australia. *Marine and Freshwater Research* 51: 127–41.
- Strong, W.R., Snelson, F.F., Gruber, S.H. 1990. Hammerhead shark predation on stingrays: an observation of prey handling by *Sphyrna mokarran*. *Copeia* 1990(3): 836–840.
- Testerman, C.B. 2014. Molecular ecology of globally distributed sharks. Dissertation. Nova University.
- Tovar-Ávila, J., Gallegos-Camacho, R. 2014. Oldest estimated age for *Sphyrna mokarran* (Carcharhiniformes: Sphyrnidae) in the Mexican Pacific. *Hidrobiológica* 24 (2): 163-165.
- UNEP-MAP RAC/SPA, 2005. Chondrichthyan fishes of Libya: Proposal for a research programme. By Seret, B. Ed. RAC/SPA, Tunis. 31pp.
- Vincent, A.C.J., Sadovy de Mitcheson, Y.J., Fowler, S.L., Lieberman, S. 2013. The role of CITES in the conservation of marine fishes subject to international trade. *Fish and Fisheries* 15: 563 – 592.
- Walker, P., Cavanagh, R.D., Ducrocq, M., Fowler, S.L. 2005. Regional Overview: Northeast Atlantic (including Mediterranean and Black Sea). In: Fowler, S.L., Cavanagh, R.D., Camhi, M., Burgess, G.H., Cailliet, G.M., Fordham, S.V., Simpfendorfer, C.A., Musick, A. (eds). *Sharks, rays and chimaeras: the status of the chondrichthyan fishes*, pp. 71–95. IUCN SSC Shark Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.
- Weigmann, S. 2016. Annotated checklist of the living sharks, batoids and chimaeras (Chondrichthyes) of the world, with a focus on biogeographical diversity. *Journal of Fish Biology* 88(3): 837-1037.
- Wourms, J. P. 1977. Reproduction and Development in Chondrichthyan Fishes. *American Zoologist* 17: 379–410.
- Zeeberg, J., Coorten, A., Graaf, E. 2006. Bycatch and release of pelagic megafauna in industrial trawler fisheries off Northwest Africa. *Fisheries Research* 78: 186–195.
- Zenetos, A., Gofas, S., Morri, C., Rosso, A., Violanti, D., García Raso, J.E., Cinar, M.E., Almogilabin, A., Ates, A.S., Azzurro, E., Ballesteros, E., Bianchi, C.N., Bilecenoglu, M., Gambi, M.C., Giangrande, A., Gravili, C., Hyams-Kaphzan, O., Karachle, P.K., Katsanevakis, S., Lipej, L., Mastrototaro, F., Mineur, F., Pancucci-Papadopoulou, M.A., Ramos Espla, A., Salas, C., San Martín, G., Sfriso, A., Streftaris N., Verlaque, M. 2012. Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union’s Marine Strategy Framework Directive (MSFD). Part 2. Introduction trends and pathways. *Mediterranean Marine Science*, 13(2), 328-352.