CHAPTER 2.2.1.8: SMOOTH HAMMERHEAD	**AUTHORS: MILLER P., DOMINGO A., FORSELLEDO R. and MAS F.**	**LAST UPDATE: August 2022 Original: Spanish**

2.2.1.8 Description of Smooth Hammerhead (SPZ)

1. Name

1.a. Classification and taxonomy

Species name: *Sphyrna zygaena* (Linnaeus, 1758)

Synonyms: *Squalus zygaena* (Linnaeus, 1758), *Squalus malleus* (Shaw & Nodder, 1796), *Squalus* (*Cestrorhinus*) *caroliniensis* (Blainville, 1816), *Squalus* (*Cestrorhinus*) *pictus* (Blainville, 1816), *Zygaena malleus* (Valenciennes, 1822), *Zygaena vulgaris* (Cloquet, 1830), *Zygaena subarcuata* (Storer, 1848).

ICCAT species code: SPZ

ICCAT names: Smooth hammerhead (English), Requin marteau commun (French), Cornuda cruz (Spanish).

According to the ITIS (Integrated Taxonomy Information System), the smooth 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 (2001). The list of countries is not exhaustive, and some local names might not be included.

Albania: Peshk çekiç, Peshk karabinier, Peshkkarabinier, Peshku çekan, Peshku çekiç
Australia: Common hammerhead shark, Hammerhead shark, Smooth hammerhead, Smooth hammerhead shark
Azores: Cornuda, Peixe martelo, Smooth hammerhead, Tubarão-martelo
Brazil: Cação-martelo, Cambeba, Cambeva, Cambeva-preta, Chapéu-armado, Cornuda, Cornudo, Martelo, Pata, Peixe-canga,Peixe-martelo, Tubarão-martelo
Cabo Verde: Martelo, Peixe-cornudo, Peixe-martelo, Tubarão-martelo
China: 丫髻鲛, 双过仔, 双髻鲨, 牦头沙, 錘頭雙髻鯊, 锤头双髻鲨
Chinese Taipei: 丫髻鮫.
Colombia: Cachona, Pez martillo, Sarda de cachas
Croatia: Jaram
Cuba: Cabeza de martillo, Common hammerhead, Cornuda, Pez martillo, Smooth hammerhead
Cyprus: Zygaena
Denmark: Almindelig hammerhaj, Hammerhaj
Ecuador: Cachona
Egypt: Abou bornita

Finland: Vasarahai
France: Cagnole, Lou peï judiou, Marteau, Pantouflier lavaco, Peï jouziou, Peï martel, Peïs judieú, Requinmarteau, Requin-marteau commun, Scroesna
Germany: Gemeiner hammerfisch, Gemeiner hammerhai, Glatter hemmerhai, Hammerhai, Meerschlägel, Schlägelfisch
Greece: Αγριόψαρο, Ζύγαινα, Προπέλα, Πατερίτσα, Δεκανίκι, Paterítsa, Pateritza, Σφύρνα, Zygaena, Zygaina, Zygena
Hawaii: Mano kihikihi
Hong Kong: Hammerhead shark, Tai tse sha
India: बतू, कान मुशी, કાન મસુ ી, कनीर, कनीरर, ചടയന്, கொம்பன் சுரொ, കൊമ്പന് സ്റൊവ്, കൊന്പന് സുരവ്, கொம்பன் சுறொ, ചട്ടിത്തലയന് സ്റൊവ്, ചൊടയന്, ವರಿಓಛ, કનેર, Boat, Boot, Chadayan, Chattithalayan sravu, Kan moosi, Kan mushi, Kaner, Kaneri, Koma sorrah, Komban-sorrah, Kombansurav, Shark, Variocha
Indonesia: Hiu bingkoh, Hiu capil, Hiu caping
Israel: Patishan
Italy: Capa a martiello, Magniusa, Magnosa, Magnose, Magnusa, Martello, Pei judiu, Pesca martello, Pesce carabiniere, Pesce martello, Pesce martiello, Pescio scrossua, Pisci carabbineri, Pisci crozza, Pisci marteddu, Pisci matteddu, Ribello, Squalo martello, Stampella
Japan: Shiro-shumokuzame
Korea: 귀상어
Lebanon: Iskandar
Madagascar: Viko
Madeira Island: Cornuda
Malasia: Jerong tenggiri, Yu bengkong, Yu mata jauh, Yu palang, Yu parang, Yu sanggul, Yu tukul
Malta: Kurazza, Kurazza komuni, Pesce martello, Pixximartell, Smooth hammerhead
Mauritania: Diarandoye, Pez martillo, Requin marteau, Smooth hammerhead
Mauritius: Hammerhead shark, Requin marteau, Requin marteau lisse
Mexico: Cornuda cruz, Cornuda prieta
Montenegro: Jaram mlat
Mozambique: Tubarão martelo liso
Myanmar: Nga-man-than-woot
Netherlands: Gladde hamerhaai, Hamerhaai
Netherlands Antilles: Common hammerhead, Hamerhaai, Hammerhead shark, Tribon di cruz
New Zealand: Hammerhead shark, Kakere, Mango-pare, Mangopare, Smooth hammerhead, Smooth hammerhead shark
Norway: Hamerhai
Oman: Abu-garn, Jarjur, Jarjur al graram
Pakistan: Bodher-buther
Palaos: Ulach
Peru: Tiburón martillo
Philippines: Awal, Balagbagan, Bingkungan, Binkugan, Buntok martillo, Kodosan, Korsan, Krusan, Kuros na pating, Pating, Sarikan, Tampugan
Polond: Rekin Plot a. glowomlot pospolity
Portugal: Cornuda, Tubarão-martelo
Puerto Rico: Cornuda, Pez martillo
Rumania: Rechin ciocan
Russia: молот-рыба
Samoa: Mata'italiga
Serbia: Jaram, Mlat
South Africa: Gladde hamerkop, Smooth hammerhead
Spain: Cachona, Carnuda, Corna, Cornúa, Cornuda, Cornudilla, Cornuilla, Leunada, Martell, Martillo, Medialuna, Pez martillo, Sarda de cachas, Tailandano, Tollo cruz
Suriname: Hamerhaai, Hammerhead, Sartji
Sweden: Hammarhaj, Hammerhaj
Trinidad and Tobago: Hammerhead shark, Pantouflier, Smooth hammerhead
Türkiye: Çekiç, Cekiç baligi, Çekiç baliği
United Kingdom: Common hammerhead shark, Common smooth hammerhead shark, Hammerhead shark, Smooth hammerhead
United States: Common hammerhead, Smooth hammerhead

Uruguay: Tiburón martillo, Cornuda
Vietnam: Cá Nhám búa

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

Characteristics of *Sphyrna zygaena* (see Figure 1).

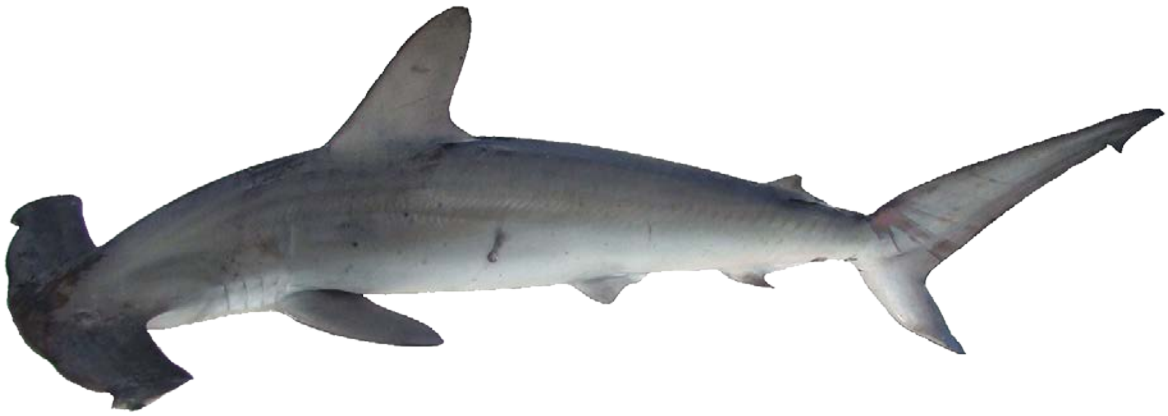

Figure 1. Smooth hammerhead (*Sphyrna zygaena*) (Linnaeus, 1758). Photo: National on-board observer programme of the Uruguayan tuna fleet (PNOFA-DINARA-Uruguay).

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).

The smooth hammerhead is one of the largest species of the family Sphyrnidae, reaching maximum sizes of between 370 and 400 cm. The most observed sizes are around 256 cm for males and 304 cm for females (Compagno, 1984).

Colour

Dark olive or greyish-brown coloured back and lighter or white coloured belly. The ventral side of the pectoral fins have dark tips in some individuals.

External characteristics

This species can be easily recognised by its large size and hammer-shaped head, which is supported by enlarged pre-and post-orbital cartilages. The front edge of the head is curved and, unlike other species of the genus, has no central notch. The eyes are located on the external part of the head and the nostrils on the front side near the ends. It has no spiracles. The mouth is found on the ventral side and has a very strong curved shape. The width of the head represents between 26 and 29% of the total length, and the distance between the anterior edge and the insertion of the posterior edge is less than 1/2 of the head width. Slightly curved first dorsal fin, with origin in front of the pectoral fin insertion and the free rear tip well ahead of the pelvic fins. Small second dorsal fin with a slightly curved trailing edge. The internal margin of the free rear tip is almost twice the height of the fin. The trailing edge of the pelvic fins is straight, and the trailing edge of the anal fin is notably V-shaped. It has densely distributed dermal denticles with a W-shaped rear margin. Denticles are as broad as they are long. In small individuals, the denticles have 3 ridges that go from the centre to the posterior margin. Larger individuals have 5 to 7 crests that go from the centre to the anterior margin and 3 to 5 teeth across the posterior margin, with the largest in the middle.

Internal characteristics

It has 13 to 15 triangular teeth with smooth edges on each side of the upper jaw, and there may be a small symphyseal tooth in some cases. It has 12 to 14 smooth or slightly serrated teeth on each side of the lower jaw, with a single symphyseal tooth. The total number of vertebrae varies between 193 and 206.

3. Distribution and population ecology

3.a. Geographic distribution

The smooth hammerhead is found in all oceans in tropical and temperate waters. In the West Atlantic it can be found from Nova Scotia (Canada) to the Gulf of Mexico (United States), Cuba, Haiti, the Virgin Islands, Venezuela and the Guianas, Brazil, Uruguay, and Argentina (Compagno, 1984; Menni, 1976; Casper *et al.*, 2005; Bezerra *et al*., 2017; Deacy *et al*., 2020; Logan *et al*., 2020; Martinazzo *et al.*, 2022). Records further north in Canada mainly correspond to catches of small individuals during the summer (Vladykov, 1935; Castro, 2011). In the East Atlantic, it can be found in the British Isles and Ireland, France, Spain, Portugal, Morocco, the Canary Islands, Cabo Verde, Azores, Mauritania, Senegal, Guinea and Côte d'Ivoire, with reports in the Gulf of Guinea, Sao Tomé and Príncipe, Gabon, Angola, Namibia and South Africa (Afonso *et al.*, 2022; Compagno, 1984; Casper *et al.*, 2005; Zaera & Alcalá, 2005; Clavareau *et al.*, 2018; Couto *et al*., 2018; Santos & Coelho, 2018; Santos & Coelho, 2019). Reports further north correspond to the British Isles, but it is a rare species in this area with just 6 confirmed records between 1829 and 2004 (Southall & Sims, 2005). The species is present along the whole Mediterranean Coast, with one record in the Black Sea (Serena, 2005). Knowledge on the general distribution of this species - mainly in tropical areas - is incomplete due to the fact that it can be confused with *S. lewini* and catch and landing data is often aggregated for both of these species (Casper *et al.*, 2005; Kotas *et al*., 2008; Bezerra *et al*., 2016; Miller, 2016; Gallagher & Klimley, 2018).

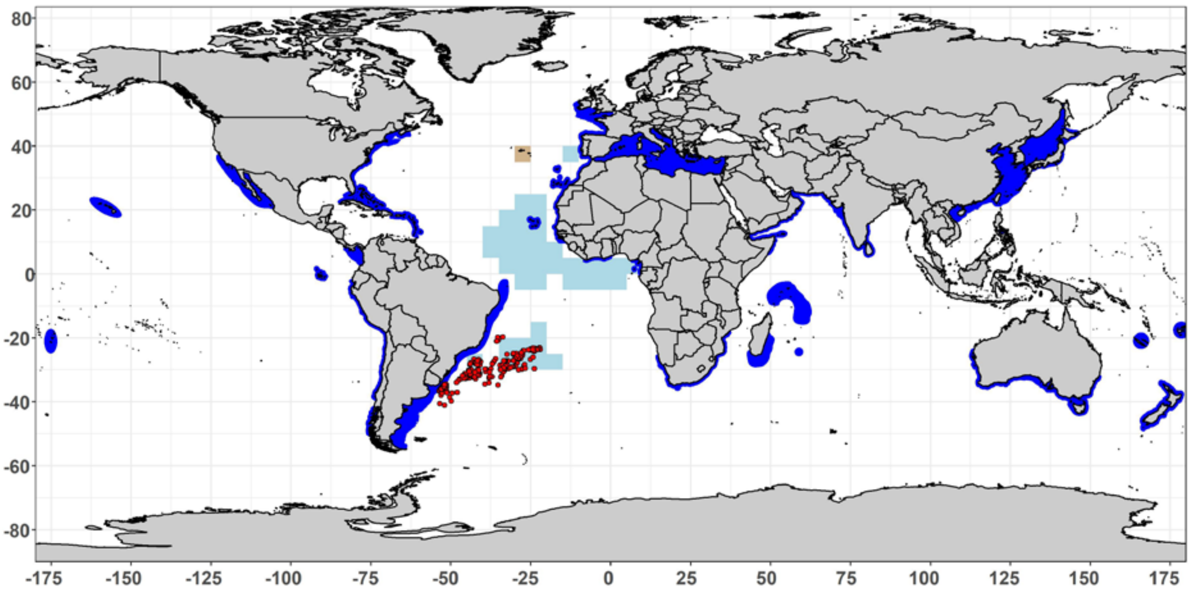

Figure 2. Map showing the distribution of the smooth hammerhead (*Sphyrna zygaena*). Taken and modified from the IUCN (IUCN SSC Shark Specialist Group, 2018. *Sphyrna zygaena*. The IUCN Red List of Threatened Species. Version 2021-1). The red dots (DINARA, unpublished data) and the light blue polygons (Santos & Coelho, 2019) and brown polygon (Afonso *et al.*, 2022) refers to confirmed records of the species in waters outside the distribution range proposed by the IUCN. The review of the new records outside the IUCN distribution range was only carried out for the Atlantic Ocean.

3.b. Habitat preferences

Sphyrna zygaena is a semipelagic species with global distribution in tropical, sub-tropical and temperate waters and is particularly abundant in temperate zones due to its high tolerance of cold temperatures compared to other species of the same genus. Throughout its range, it is often found both close to the coast and on the continental shelf, the slope and in oceanic waters, with records ranging from the surface to depths of 200 m (Compagno, 1984; Compagno *et al.,* 2005). This species has been observed in the Indian River, Florida, the United States, (Casper *et al.,* 2005) and both in the mouth of and in River Plate, Uruguay (Menni, 1967; Menni & Garcia, 1985; Doño, 2008). Several studies agree that the smooth hammerhead is characterised by a marked age class segregation, and it is extremely rare to find adult individuals in coastal areas, where juveniles and neonates are found. In South Brazil, Amorim *et al.* (2011) observed the highest abundances of *S. zygaena* during the autumn and spring. In a subsequent study that analyses the catches of *S. zygaena* in Southeast and South Brazil, Kotas *et al.* (2012) reported that while the species was found at a wide range of depths (33-3100 m), most catches were taken around the shelf break. It was also reported that for a total of 354 individuals landed, the average catch site depth was 226 m. Mas (2012) reached similar findings and observed that the relative abundances of sets carried out in waters of the upper continental slope were much higher than those observed at depths of over two thousand metres. In the same study, it was observed that in the EEZ of Uruguay this species is caught by pelagic longlines operating in waters with a relatively wide range of surface temperatures (13-24.5°C), but catches mostly took place in sets in waters with a surface temperature between 18.5 and 22°C. Similar results were observed in South Africa by Smale (1991), who found higher abundances of *S. zygaena* during the first half of the year when the temperature between the surface and the first 10 m was between 19 and 22°C on average. The occurrence of neonates and small juveniles was recorded between November and March (spring and summer) over the course of several years in the coastal waters of Uruguay at depths of under 20 metres in various areas from Río de la Plata to the Atlantic coast, which means that *S. zygaena* uses this zone as a nursery area (Doño, 2008). The same study indicates that water temperatures in the area under study during this period range from 17 to 24°C, while salinity varies between 7.5 and 32.5 due to the discharge of the Río de la Plata. The presence of this species in cold water areas, such as the British Isles, could be exceptional and may be owing to the occasional intrusion of warmer bodies of water (Southall & Sims, 2005).

Based on an analysis of data obtained by observers on the Portuguese longline fleet targeting swordfish in the Atlantic Ocean, Santos & Coelho (2019) found that a greater proportion of larger individuals was found in oceanic waters far from the coast, while smaller individuals were generally found in oceanic waters closer to the African continent and groups of islands.

Based on an extensive series of historical *S. zygaena* catch data in very shallow waters off the East coast of South Africa, Dicken *et al*. (2018) found that catches were higher in winter and spring, while the lowest catches were recorded in summer. The authors indicated that this seasonal pattern in catches is probably related to the sea temperature (which is higher in summer). In this same study, 1,073 males and 1,322 females were dissected, and it was determined that all were juveniles or adolescents, which demonstrates a clear spatial segregation in the use of this habitat.

Although the use of electronic tags together with satellite telemetry has generated a substantial amount of information on habitat use and the environmental preferences of several large shark species, few studies have been carried out on *S. zygaena*. In the first of these, Francis (2016) analysed data obtained from three juvenile individuals equipped with satellite tags in coastal areas of North New Zealand and found that two remained very close to the coast throughout the entire period (6 and 55 days, respectively), in the same bay where they were initially caught. The third individual was monitored for 250 days with an archival tag, and although the reconstruction of its horizontal movements was not very precise, it was estimated that it spent the majority of this period on the continental shelf. During the first 70 days of monitoring, this individual spent 90% of the time in the first 10 metres of the water column (96.3% during the day and 89.9% at night). Subsequently, its behaviour suddenly changed and for the next six months it was at depths of between 40 and 60 metres for 55.2% of the time, and only remained in the first 10 metres of the water column for 12.7% of the time. During the summer months, the range of water temperatures where this individual was located varied by up to 5-6°C daily, while in winter the daily variation range in temperature was very small as the water column is less stratified. Minimum temperatures reached around 15°C.

Based on an analysis of data obtained from seven individuals equipped with archival tags in oceanic waters of the central region of the equatorial North Atlantic, Santos & Coelho (2018) determined that individuals spent most of the time near the surface at depths of less than 50 metres, where temperatures were above 23°C. The authors observed that there was no cyclical daily pattern in vertical movements and found that there was little difference between daytime and night-time periods. The mean depth for all individuals monitored was 13.62 ± 19.77 m, and the mean temperature was 26.28 ± 2.06°C. Dives to greater depths followed by rapid reascents were occasionally observed. The maximum depth recorded was 260.9 m, and the minimum temperature was 12.80°C. The top 10 metres of the water column were the most used range, regardless of the time of day and the maturity of the individuals. Adults remained within this range for 67.9% of the time during the day and 63.9% of the time at night, while in the case of juveniles these figures were 74.8% and 47.8%, respectively.

Logan *et al.* (2020) analysed the areas used by six juvenile females caught in coastal waters off the East of the USA (NW Atlantic) and found that all the individuals remained in coastal waters and did not abandon the continental shelf during the monitoring period, which lasted between 49 and 441 days. The individuals spent most of the time in zones where the surface temperature was between 17 and 25°C. This study found that individuals made seasonal movements between the most used areas and characterized distinct residence areas during the summer and at the end of winter and early spring. When analysing how often four of the individuals surfaced, Logan *et al*. (2020) found that they generally surfaced more frequently during periods just before sunrise and just after sunset. This is in contrast with the observations of Francis (2016), who performed a similar analysis on one individual and found that it mostly surfaced during the night-time.

Based on data obtained using different satellite and acoustic tags to track 18 individuals, Alfonso *et al.* (2022) analysed the habitat use and behaviour of smooth hammerhead juveniles off the North coast of Faial (Azores). Having obtained an extensive data series, including eight individuals tracked for more than two years (reaching a maximum of 4 years), the authors were able to determine that, while almost all the individuals travelled between Faial and Pico Islands, the areas of greatest use for all of them were clustered in coastal waters located off North Faial, with very low or no use of other coastal areas around the two islands. The results of this study indicate that these juvenile individuals are permanent residents in the habitat of the coastal shelf of the islands, and also show that the individuals aggregate seasonally in discreet areas in the first years of life, with high seasonal residence and annual fidelity to the location, making up what is generally known as breeding areas. A daily pattern was found in the use of the breeding areas, it being observed that the individuals used areas very close to the coast mainly during the day, moving to the more remote areas in the proximity of the shelf break at night. This daily oscillation in the movements was accompanied by an increase in the night-time activity, demonstrated by the horizontal movements.

3.c. Migrations

To date, little is known about migratory aspects of *S. zygaena*, and it is therefore not possible to provide a detailed description. Bass *et al.* (1975) reported that large aggregations of juveniles from this species travelling together have been recorded in South Africa, but no significant movements were observed. Studies based on tag and recapture are still too limited to explain smooth hammerhead migrations. Kohler *et al.* (1998) reported that individuals of this species that were tagged in the Northwest Atlantic were generally recaptured close to the tagging site. Based on 64 tagging studies with conventional tags, Kohler & Turner (2001) subsequently observed that only 6 of these involved *S. zygaena*, in which a total of 1,427 individuals were tagged and only 6 were recaptured. The maximum reported distance travelled was 1,122 km and the maximum time at liberty was 2.1 years. Within the framework of the *National Marine and Fisheries Service's Cooperative Shark Tagging Program* a total of 269 specimens were tagged between 1962 and 2013 in the Atlantic, of which only 7 were recaptured. The maximum reported distance travelled was 919 km and the maximum time at liberty was 2.1 years (Kohler & Turner, 2020).

A total of 1,342 individuals were tagged off the East coast of South Africa between 1984 and 2009, with a recapture rate of 1.5% (Diemer *et al*., 2011). The average distance travelled by recaptured individuals was 141.8 ± 20.4 km, while the maximum distance was 384 km. The mean time at liberty was 603.5 ± 192.9 days. One individual was recaptured at the tagging site after 80 days, while six individuals were recaptured between 1-100 km from the initial site after between 293 and 3,075 days, nine were recaptured between 101-200 km after between 45 and 2,963 days, and four were recaptured at a distance of over 200 km after between 52 and 601 days. The minimum distance travelled per day was estimated at a movement rate of 5.1 km per day, which corresponded to an individual of 109 cm PCL that was captured 384 km from the tagging site after 75 days.

Recently, it was determined by electronic tagging that *S. zygaena* is able to travel long distances in the oceanic environment of the Atlantic (Santos & Coelho, 2018). This study recorded a maximum transfer of 6,610 km over a duration of 150 days. It corresponded to an adult female that travelled from south of Cabo Verde to waters located off the south edge of the Angolan EEZ, which demonstrates that the species engages in large scale trans-equatorial transfers. For the total of the individuals monitored, all of which departed from international waters of the central region of the northern Equatorial Atlantic, it was calculated that they travelled an average distance of 33.4 km per day.

In a subsequent study focused on researching the movements and habitat use of juvenile individuals caught and tagged in shallow waters on the East coast of the United States (NW Atlantic), Logan *et al.* (2020) found that all the individuals monitored remained almost exclusively in waters on the continental shelf, not venturing into the oceanic environment. The same study determined that juvenile individuals of *S. zygaena* are able to travel long distances even while they remain in coastal waters. Average daily transfers of between 16 and 23 km per day were recorded for five individuals that were monitored during periods of between 4 and 14 months. The maximum transfer recorded was for a juvenile female that travelled a total of 7,320 km over a period of 441 days. During this time, the individual carried out seasonal migrations in the area approximately between 35°N and 41°N. For the set of individuals, a seasonality pattern was observed in terms of similarity of the areas of greatest use. They occupied higher latitudes during summer, and during autumn, they travelled towards an area located in lower latitudes, which was used during winter. The same study indicated that based on the environmental characteristics of the areas of greatest use, surface temperature of the sea and productivity appear to be important drivers of the pattern of seasonal movements that was observed. The fact that all these individuals, monitored over several months, have displayed extensive periods of residence in coastal waters, is an interesting complement to the findings of Santos & Coelho (2018), which determined that juvenile individuals occur and remain in the oceanic environment for several weeks.

4. Biology

4. a. Growth

To date, there are two studies that analyse the age and growth of the smooth hammerhead in the Atlantic (**Table 1**). In the first of these studies, Coelho *et al.* (2011) began by determining the best technique to read the vertebrae and found that the growth rings could be easily observed using a dying technique. The estimated age was 4 to 21 years for males and 4 to 18 years for females. Individuals of 4 years measured between 136 and 140 cm FL. Consequently, considering the size at birth proposed by Compagno (1984) of 29 to 39 cm FL (50-61 cm TL), the authors estimated that the growth rate of this species is approximately 25 cm per year. This growth can be observed at least during the first years of life, as growth rates decrease as the individuals grow. The hypothesis that a growth ring is formed each year was not validated in this study (Coelho *et al.*, 2011). Subsequently, Rosa *et al.* (2017) carried out an analysis on a wider sample of individuals. An even larger quantity of individuals was added to the samples used by Coelho *et al*. (2011), to cover a larger size range representing a more extensive area of the Atlantic. It estimated ages from 4 to 25 years for males, and from 3 to 24 years for females. The growth curves of both sexes were similar up to 10 years, from when the growth rate for males decreased considerably, while the decrease in growth rate for females was smaller, manifesting at a later age. The authors indicate that the young individuals must have a very high growth rate in the first years, since the youngest individual was assigned an age of 3 years, measuring 126 cm FL. Wray-Barnes (2016) analysed samples of individuals caught off the East coast of Australia (Southwest Pacific) and discovered slow growth, similar to the findings of Rosa *et al*. (2017) for the Atlantic. In addition, he reported that the oldest female was estimated to be 34 years old at a length of 279 cm, while the oldest male reached an age of 17 years at 257 cm.

Table 1. Growth parameters for *Spyrna zygaena* according to the Von-Bertalanffy growth model. L_{oo}: maximum asymptotic length (cm), k: growth coefficient (years^{-1}), t_o: theoretical age at length 0 (years).

Growth Parameter						
L_∞	k	t_0	Area	Reference	Sex	Method
272 (FL)	0.060	-9.4	Central West Atlantic	Coelho *et al.* (2011)	Males	Vertebrae
285 (FL)	0.070	-7.3	Central West Atlantic	Coelho *et al.* (2011)	Females	Vertebrae
212 (FL)	0.220	29 (FL)[a]	Central West Atlantic	Coelho *et al.* (2011)	Males	Vertebrae
229 (FL)	0.180	29 (FL)[a]	Central West Atlantic	Coelho *et al.* (2011)	Females	Vertebrae
214 (FL)	0.200	39 (FL)[a]	Central West Atlantic	Coelho *et al.* (2011)	Males	Vertebrae

231 (FL)	0.170	39 (FL)[a]	Central West Atlantic	Coelho *et al.* (2011)	Females	Vertebrae
284.6 (FL)	0.09	52.2 (FL) [b]	Atlantic	Rosa *et al.* (2017)	Males	Vertebrae
293.9 (FL)	0.09	52.7 (FL) [b]	Atlantic	Rosa *et al.* (2017)	Females	Vertebrae
288.2 (FL)	0.09	52.4 (FL) [b]	Atlantic	Rosa *et al.* (2017)	Both	Vertebrae
301 (TL)	0,139	-2.45	Northwest Pacific	Garza (2004)	Both	Vertebrae
340.7 (TL)	0,06	102 (TL) [c]	Southwest Pacific	Wray-Barnes 2016	Males	Vertebrae
302.2 (TL)	0,06	112 (TL) [c]	Southwest Pacific	Wray-Barnes 2016	Females	Vertebrae
298.5 (TL)	0,07	106.2 (TL) [c]	Southwest Pacific	Wray-Barnes 2016	Both	Vertebrae

TL: total length (cm); FL: fork length (cm). [a] A modified version of the von Bertalanffy was used with a fixed size at birth. [b] A re-parametrized version of the von Bertalanffy was used to estimate L_0 instead of t_0 and retrocalculated data (Dahl-Lea). [c] A re-parametrized version of von Bertalanffy was used to estimate L_0 instead of t_0.

4. b. Length-weight relationship

There are few length-weight relationships in the literature for this species. Those found in this literature review are presented in **Table 2**.

Table 2. Published length-weight relationships for *Sphyrna zygaena*. TW: total weight (kg); GW: gutted weight (without the head, guts or fins; kg); TL: total length (cm); CL: carcass length (cm).

Equation	N	Length range (cm)	R^2	Area	Reference
$GW = 8.00 \times 10^{-6} (CL)^{3.23}$	62	-	0.87	Southwest Atlantic	Amorim *et al.* (2011)
$GW = 5.00 \times 10^{-6} (CL)^{3.34}$	29	-	0.93	Southwest Atlantic	Amorim *et al.* (2011) [1]
$GW = 2.00 \times 10^{-6} (CL)^{3.08}$	33	-	0.84	Southwest Atlantic	Amorim *et al.* (2011) [2]
$TW = 0.008508 \times (TL)^{2.84}$	97	66-140.5	0.901	Southwest Atlantic	Motta *et al.* (2014) [1]
$TW = 0.016206 \times (TL)^{2.70}$	113	70-115.5	0.837	Southwest Atlantic	Motta *et al.* (2014) [2]
$TW = 0.011697 \times (TL)^{2.77}$	210	66-140.5	0.869	Southwest Atlantic	Motta *et al.* (2014) [3]
$TW = 2.183 \times 10^{-8} \times (PCL)^{2.90}$	776	54-150	0.88	Western Indian Ocean	Dicken *et al.* (2018)[1]
$TW = 1.083 \times 10^{-8} \times (PCL)^{3.0}$	894	48-143	0.91	Western Indian Ocean	Dicken *et al.* (2018)[2]
$TW = 1.455 \times 10^{-8} \times (PCL)^{2.96}$	1.674	48-150	0.90	Western Indian Ocean	Dicken *et al.* (2018)[3]

[1] and [2] conversion equations for males and females, respectively. [3] equation for both sexes combined.

4. c. Conversion factors

Below are the length-length relationships found for the smooth hammerhead (*S. zygaena*) in this literature review.

Table 3. Published length-length relationships for *Sphyrna zygaena*. TL: total length; FL: fork length; PCL: precaudal length; DDC: insertion distance of the first dorsal fin till the precaudal pit.

Equation	N	Length range	R^2	Area	Reference
FL = 0.5598 x (TL) + 17.666	56	155-371	0.890	Northwest Atlantic	Kohler *et al.* (1995)
TL = 1.280 x (FL)	194	95-165	0.983	Southwest Atlantic	Mas *et al.* (2014) [1]
TL = 1.280 x (FL) - 0.616	344	90-255	0.983	Southwest Atlantic	Mas *et al.* (2014) [2]
TL = 1.3597 x (PCL) + 5.8532	272	83-228	0.983	Southwest Atlantic	Mas (2012)[1]
TL = 1.3627 x (PCL) + 5.1988	505	80-232	0.982	Southwest Atlantic	Mas (2012)[2]
FL = 1.063 x (PCL) + 4.908	199	83-150	0.988	Southwest Atlantic	Mas *et al.* (2014) [1]
FL = 1.063 x (PCL) + 5.222	351	80-232	0.988	Southwest Atlantic	Mas *et al.* (2014) [2]
TL = 2.10 x (DDC) + 30.52	33	-	0.99	Southwest Atlantic	Kotas *et al.* (2012)
FL = 0.972 × (PCL) + 49.765	1.697	48-170	0.86	Western Indian Ocean	Dicken *et al.* (2018)
TL = 1.2225 x (FL) + 9.0821	71	114-262	0.983	Western Indian Ocean	Ariz *et al.* (2007)
FL = 0.8039 x (TL) – 4.3490	71	135-328	0.983	Western Indian Ocean	Ariz *et al.* (2007)
TL = 1.261 x (FL) + 1.922	144	64-284	0.98	South-western Pacific	Wray-Barnes (2016)
TL = 1.323 x (PCL) + 7.260	144	64-284	0.95	South-western Pacific	Wray-Barnes (2016)

[1] and [2] conversion equations for males and females, respectively.

4.d. Reproduction

Gestation and pupping

It is a placental viviparous species and, as in other shark species, only the right ovary is functional (Wourms, 1977). The gestation period lasts from 10 to 11 months, after which parturition takes place in very shallow waters. Compagno (1984) reported a size at birth of between 50-61 cm. Based on the observation of neonates with an open umbilical scar, the size at birth would be between 49 and 55 cm in the region of the Southwest Atlantic off the coasts of Uruguay (Doño, 2008). Subsequently, two gravid females were analysed in Uruguay, which were carrying embryos with a mean size of 54 and 52 cm, respectively (Mas 2012). For South Brazil, Voren *et al.* (2005) reported a size at birth of between 49 and 55 cm. Smale (1991) reported that sizes at birth ranged from 59 to 63 cm in South Africa. In the Atlantic Ocean, the coasts of South Brazil and Uruguay have been reported to be pupping and nursery areas (Vooren *et al.,* 2005; Doño, 2008). In Southeast Brazil, Gadig *et al*. (2002) reported that artisanal fishing with gillnets operating between 5 and 19 miles off the coasts at depths of between 8 and 15 metres catches juvenile individuals with an average size of 86 cm in the winter months. In the same line, Kotas *et al.* (2012) reported that 100% of *S. zygaena* individuals landed by vessels operating with bottom gillnets in coastal waters off South Brazil were juveniles. According to Amorim *et al.* (2011), in South Brazil gravid females migrate to coastal areas between October and February to give birth. This migration pattern towards coastal areas could protect pups and provide them with a better feeding area. On the coast of São Paulo, they do so between November and February (Bittencourt *et al.,* 2003). On the coast of South Africa, Bass *et al.* (1975) observed a *S. zygaena* female in February that appeared to have pupped recently, and a female with at-term embryos in November. According to Stevens (1984), on the East coast of Australia the pupping season is between January and March, with ovulation occurring approximately in the same period.

In the East Pacific, Pérez-Jiménez and Venegas-Herrera (1997) analysed 11 gravid females and found that maximum embryo sizes were 55.3 and 55.7 cm for males and females, respectively.

Francis (2016) found that the occurrence of neonates and small juveniles in coastal waters of North New Zealand reaches maximum levels during summer and autumn and reported that the occurrence of juvenile individuals in this region was recorded throughout all seasons over a period of several years, pointing out that there are possibly several nursery areas in various bays and gulfs along the North coast of this country.

Maturity

According to Compagno (1984), size at maturity is between 210 and 240 cm for both sexes. In the Gulf of Guinea, Castro and Mejuto (1995), reported gravid females of between 220 and 225 cm fork length (FL). In Australia, Stevens (1984) reported that males reach maturity at a size of between 250 and 260 cm and females at approximately 265 cm.

In the East Pacific, Pérez-Jiménez and Venegas-Herrera (1997) found that the minimum size of gravid females was 196.3 cm, which corresponded to the female carrying the lowest number of embryos (9 individuals) of the total analysed.

Sex ratio

In South Brazil, females were slightly more frequent than males, with a sex ratio of 0.9:1. Although no significant differences were observed in the seasonal analysis, Amorim *et al.* (2011) observed more females in spring and more males in winter. Kotas *et al.* (2012) found that for a set of 261 individuals that measured less than 110 cm TL and caught in South and Southeast Brazil, the sex ratio was very close to 1:1. In the waters of the EEZ of Uruguay, 37.2% of all individuals caught by the longline fleet between 1998 and 2009 were males and 62.8% were female, which gives a sex ratio (male:female) of 1:1.7. In terms of months, there was a significantly lower proportion of males compared to females between April and August and a higher proportion in November, but no differences were found in the remaining months (Mas, 2012). Based on the analysis of data obtained by observers on the Portuguese pelagic longline fleet operating in the Atlantic, Santos and Coelho (2019) found a sex ratio of 1.4 males: 1 female for a total of 562 individuals, which were mostly caught in the equatorial and tropical Northeast Atlantic.

Francis (2016) reported a sex ratio of 1:1 for coastal waters of North New Zealand. González-Pestana (2019) reported a general sex ratio of 1:1.2 males to females in a sample of 7,485 individuals caught by the drift gillnet fleet in Peru. Specifically for neonates and juveniles, the proportion was also 1:1.2 in favour of females, while there was a very strong predominance of females in the case of adults with 1 male:7 females.

Based on an analysis of 2,395 juvenile individuals caught in very shallow waters on the East coast of South Africa, Dicken *et al*. (2018) found a sex ratio biased towards females (1.23 females: 1 male).

The sex ratio in embryos of a single litter is approximately 1:1 (Stevens, 1984; Castro and Mejuto, 1995; Pérez-Jiménez and Venegas-Herrera, 1997). In the regions of Southeast and South Brazil, Bittencourt *et al.* (2003) reported an embryo ratio of 1:0.8 males to females. In two litters observed in Uruguay, the embryo ratio was 1:1 (Mas, 2012).

Fecundity

According to Compagno (1984), the litter size of *S. zygaena* ranges from 29 to 37 individuals. In the Gulf of Guinea, Castro and Mejuto (1995) reported the average number of pups in a litter to be 33.5. Litters of 18 and 27 individuals were observed in two gravid females in Uruguay (Mas, 2012). In the East Pacific, Pérez-Jiménez and Venegas-Herrera (1997) analysed 11 gravid females and found that litter size varied between 9 and 35 individuals, with an average of 23.4 individuals. Except for two females, all were carrying at least 20 embryos. In East Australia (West Pacific), Stevens (1984) observed that litter size varied between 20 and 49 individuals, with an average of 32.

4.e. Diet

The smooth hammerhead feeds on a wide variety of prey, including some small chondrichthyans, crustaceans, cephalopods and bony fish, with the latter forming the majority of their diet (Compagno, 1984; Smale, 1991; Cortés, 1999; Casper *et al.*, 2005). In a review of the diet and trophic level of several shark species, Cortés (1999) analysed the stomach contents of 243 individuals and found that cephalopods were the main dietary item in 68.9% of individuals, while bony fish constituted the main item in 29.8% of individuals. Chondrocytes and crustaceans were the main item in a very low proportion of the individuals analysed (0.9% and 0.4%, respectively) (Cortés, 1999). According to these data, this species' trophic level is calculated at 4.3 (Cortés, 1999). According to Levin's index, in Ecuadorian waters *S. zygaena* is a specialised predator as its diet is based on some species of cephalopods (Bolaño, 2009). Although there are several reports of chondrichthyans consumption by this species, mainly by larger individuals, only 0.7% of individuals contained remains thereof in a study carried out in South Africa (Dudley and Cliff, 1993).

In a study based on individuals caught on the continental shelf of South Brazil, an analysis of these individuals' stomach contents showed that this species' diet is mainly composed of cephalopods (*Illex argentinus* and *Chiroteutis* sp.) small bony fish (*Balistes* sp., *Diodon* sp. and *Aluterus* sp.) (Bornatowski and Schwingel, 2009). Also in South Brazil, Bornatowski *et al.* (2007) observed the presence of squids from the *Loligo* sp. genus in the majority of the stomachs analysed, and these squids could be considered an extremely important food source for this species. Additionally, Bornatowski *et al.* (2007) considered that the amount of squid consumed by this species may be underestimated as squid musculature is digested quickly and, therefore, a lower quantity than the actual amount consumed is observed in stomachs. These squids are nektonic and represent approximately 80% of the cephalopods found in South Brazil. A subsequent study, in which the stomachs were analysed of 77 juvenile individuals caught by gillnet in coastal waters (<30 m deep) of Southeast Brazil, again found that *S. zygaena* preys mainly on cephalopods (61.4% IRI), in particular the squids *Doryteuthis* sp. and *Lolliguncula brevis* (Bornatowski *et al*., 2014). The same paper informs that while teleosts were relatively less important, they accounted for almost 81% in terms of consumed weight. On the coast of South Africa, it was observed that the diet of *S. zygaena* is mainly composed of squid (*Loligo v. reynaudii*) and bony fish such as hake, Atlantic horse mackerel, mackerel and individuals from the family Trachipteridae (Smale, 1991).

Similar observations have been reported for Australia, where a study showed that 76% of the stomachs analysed contained squid and 54% contained bony fish (Stevens, 1984). On the coasts of Baja California, Mexico, the smooth hammerhead's main prey are cephalopods such as *Dosidicus gigas*, *Onychoteuthis banksii*, *Ancistrocheirus lesueurii* and *Sthenoteuthis oualaniensis* (Ochoa-Díaz, 2009; Galván-Magaña *et al.*, 2013). Based on the results of stomach content analyses, this species consumes prey in both the coastal and oceanic areas and travels to the surface at night to feed on cephalopods in the oceanic area (Ochoa-Díaz, 2009). Similar observations were made on the coast of Ecuador, where the diet of this species was composed of cephalopods, bivalvia and penaeids. The largest group included the cephalopods *D. gigas* (coastal-oceanic habitat), *Lollinguncula diomedeae* (coastal habitat) and *S. oualaniensis* from oceanic habitats (Bolaño, 2009). This author (Bolaño, 2009) observed that, as it increased in size, *S. zygaena* changed its dietary preferences, consuming less *L. diomedeae* and more *D. gigas*. This could be due to the fact that size increases swimming capacity and nutritional needs. Subsequent studies also carried out in Ecuador (Galván-Magaña *et al*., 2013; Estupiñán-Montaño *et al*., 2019), which analysed the stomachs of 127 and 335 individuals, respectively, found that cephalopods were the main item, which coincided with the findings previously reported by Bolaño (2009). The most significant species also coincided in the three studies (*D. gigas*, *S. oualaniensis*, and *A. lesueurii*).

Based on analysis of 485 specimens landed in different ports of North Peru, González-Pestana *et al.* (2017) found that *S. zygaena* consumes at least 14 species of teleost and 11 of cephalopod. According to the IRI, the most important species were the cephalopods *Doryteuthis gahi* (37%) and *Dosidicus gigas* (27%). The authors also report that they found significant differences in the diets of the individuals on analysing separately different size classes. In a subsequent study, González-Pestana *et al*. (2021) once again reported that off the North coast of Peru, *S. zygaena* mainly feeds on cephalopods in the pelagic environment. Furthermore, the authors reiterated that the main species consumed were *D. gahi* and *D. gigas*, and stated that the prey-specific index of relative importance (PSIRI) was 31% and 30%, respectively. In addition, they indicated that Peruvian anchoveta (*Engraulis ringens*) could also be an important dietary item for *S. zygaena*, as observed by Castañeda (2001), particularly during years when lower water temperatures predominate, where *E. ringens* and another species of Engraulidae were the most important items. A recent study carried out by Segura-Cobeña *et al*. (2021) compared the carbon and nitrogen isotopic composition and the essential fatty acid concentration of three groups of *S. zygaena* caught in different nursery areas located in the North of Peru. The results indicated that the individuals' trophic niches differ significantly between the different nursery areas. The authors indicated that these differences are principally determined by the influence of the Humboldt current and the associated upwelling, which facilitate a differentiating productivity increase between the three nursery areas. In addition, they recommended that conservation and management efforts for this species consider each of these areas as separate juvenile stocks associated with different ecosystems.

Based on an analysis of the stomach contents of 933 individuals caught in very shallow waters off the East coast of South Africa, Dicken *et al*. (2018) determined that teleosts were the most important functional group of prey (IRI%) and were recorded in 93.7% of the stomachs analysed. In total, 61 species of teleosts (representing 28 families) were found. The most significant were small pelagic species including sardine (*Sardinops sagax*), anchovy (*Pomatomus saltatrix*) and mackerel (*Scomber japonicus*). Cephalopods were the second most important functional group in terms of relative importance, being found in 23.1% of the stomachs analysed, consisting of cuttlefish, at least 19 species of squid and 5 species of octopus. The occurrence of elasmobranchs and crustaceans was very low (0.3% IRI).

4.f. Physiology

The various sensory advantages related to the shape of hammerhead sharks' head have been described, but none are specific to *S. zygaena* to date. These sensory advantages include the hypothesis of 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. In any case, these olfactory advantages, together with a larger number of electroreceptors over the width of the head, increase the probability of finding prey (Kajiura *et al.*, 2005). It has also been suggested that the shape of the head provides hydrodynamic stability on curves, enabling better manoeuvring, which can be important in effectively catching prey (Gaylord *et al*., 2020)

According to a study carried out by Escobar-Sánchez *et al.* (2010) in the Pacific Ocean of Mexico, the mercury levels found in the smooth hammerhead are within acceptable levels for human consumption. The results show that the concentrations are low compared to those found by García-Hernández *et al.* (2007) in the Gulf of California, where *S. zygaena* presented the highest values of the 11 shark species observed. In contrast, Besnard *et al*. (2021) reported that the muscle mercury concentration found in *S. zygaena* was lower than in *Prionace glauca* and *Isurus oxyrinchus*. In both studies, the relationship between total length and mercury bioaccumulation was not significant for this species, which means that mercury concentration does not increase with the size of the shark (García-Hernández *et al.*, 2007; Escobar-Sánchez *et al.*, 2010). On the coasts of South Baja California, the smooth hammerhead's main prey are cephalopods (Ochoa-Díaz, 2009). According to Bustamante *et al.* (2006), cephalopods have a special ability to accumulate heavy metals in different levels of tissue. Accordingly, these prey could be *S. zygaena*'s main source of mercury (Escobar-Sánchez *et al.*, 2010).

Some of the most frequently caught shark species in the Gulf of California (*S. zygaena*, *Alopias pelagicus*, *Rhizoprionodon longurio*, *Carcharhinus obscurus*, *S. lewini*, *Nasolamia velox*) have the highest mercury concentrations. Consequently, García-Hernández *et al.* (2007) recommend that information about the consumption of these species be disseminated.

In South Brazil, the smooth hammerhead presented the highest average mercury concentration of the three species analysed (*Prionace glauca, Isurus oxyrinchus* and *S. zygaena*) (Mársico *et al.,* 2007). These values are lower than those found in the Northeast Pacific (García-Hernández *et al.,* 2007; Escobar-Sánchez *et al.,* 2010; Besnard *et al*., 2021). By contrast, this species has high mercury concentrations in the Mediterranean, and the concentration in the liver is double the values found for muscle. This is due to the liver's role in contaminant biotransformation (Storelli *et al.,* 2003). In this study, the presence of other contaminants was also observed, and from a toxicological viewpoint, more attention should be paid to high arsenic levels and the presence of polychlorinated biphenyl (PCB) (Storelli *et al.,* 2003).

5. Fisheries biology

5.a. Populations/Stock structure

Various studies agree that there are several *S. zygaena* populations across its distribution range (Testerman *et al*., 2008; Testerman, 2014; Bolaño-Martínez *et al*., 2019; Félix-López *et al*., 2019; Kuguru *et al*., 2019; Ferrette *et al*., 2021). Evidence indicates that the reproductive philopatry of females is one of the elements explaining the high level of genetic structuring between different populations (Testerman, 2014; Félix-López *et al*., 2019, Ferrette *et al*., 2021).

Based on genetic analyses of the mtCR of individuals caught in the Atlantic, North Pacific, Southeast Pacific and Indo-Pacific, Testerman *et al*. (2008) found a strong geographical subdivision into four separate populations, with no evidence of gene flow between the populations and little to no detectable genetic structure within these populations. Although the study was carried out on a relatively modest sample, the authors indicate that the data obtained suggest a possibly extensive genetic subdivision, meaning that a multi-regional approach would be necessary to ensure proper management.

In a subsequent study carried out on a larger number of samples and with a broader approach that also considered nuclear markers, Testerman (2014) found that both markers reveal a strong genetic division between the Atlantic and the Indo-Pacific, with no sharing of haplotypes or genotypes. Mitochondrial data showed structuring within each of the oceanic basins, with at least 8 genetically different regional populations (at least two in the West Atlantic, one in the West Indian Ocean, and five in the Pacific). Contrasting results from nuclear and mitochondrial markers could indicate female reproductive philopatry and gene flow mediated by males (Testerman, 2014).

Based on a genetic study of individuals coming from various regions of the Atlantic, Pacific and Indian Oceans, Ferrete *et al*. (2021) determined that there are at least 6 *S. zygaena* populations and found that the species has a strong populational genetic structure between the three oceans. The same study indicates that there is a moderate distinction in the Atlantic between the SW and the Gulf of Guinea, specifying that there are three populations in this ocean (one in the SW and two in the central East Atlantic). The authors also indicated that there is one population in the SW Indian Ocean and two in the Pacific. The high level of genetic structure of *S. zygaena* populations, which is higher than the level determined for *S. lewini*, demonstrated a lower level of gene flow between distant regions, which could indicate that it is necessary to consider different management units for the conservation of this species throughout its distribution range (Ferrete *et al*., 2021). In the same study, the authors determined that there were historical migratory connections between very distant populations, which coincides with the species' ability to travel long distances (Santos and Coelho, 2018). These elements suggest that the strong structure found in *S. zygaena* could be explained by reproductive behaviours such as female philopatry, as previously suggested for this species by Testerman (2014) and Félix-López *et al*. (2019), similar to what has been indicated for *S. lewini* (Duncan and Holland, 2006; Daly-Engel *et al*., 2012).

5.b. Description of the fisheries

Due to the difficulties for its correct identification, hammerhead sharks are frequently recorded in aggregate form in fishing reports, and sometimes even in landing sampling and observer programmes. As a result, fewer records are available on smooth hammerhead catches (Kotas *et al*., 2008; Camhi *et al.,* 2009, Bezerra *et al.*, 2016, Miller, 2016; Gallagher and Klimley, 2018).

The smooth hammerhead is caught by a wide variety of fisheries, from artisanal coastal to pelagic industrial ones using a variety of gears, including pelagic longline, demersal longline, handline, gillnets, purse seine and pelagic and bottom trawl (Casper *et al.*, 2005; Kotas *et al*., 2008; Kotas *et al*., 2012; Francis, 2016; Reed *et al*., 2017; Gallagher and Klimley, 2018; Rigby *et al*., 2019). Catches of this species have been reported in fisheries targeting sharks in the United States, Brazil and Spain, and also as bycatch in a large number of fisheries not targeting sharks (Bonfil, 1994; Kotas *et al*., 2012; Francis, 2016). Apparently, catches in pelagic fisheries correspond to larger individuals, while juveniles are more commonly caught in more coastal fisheries (Casper *et al.*, 2005; Francis, 2016; Gallagher and Klimley, 2018; Kotas *et al*., 2012).

The fins of this species are increasingly coveted in some areas due to the increase in demand and their commercial value. Hammerhead shark fins are the second most abundant group on the international market (Clarke *et al.*, 2004). According to Clarke *et al.* (2006a), the shark fin trade is one of the main causes of decreases in shark populations, and it is estimated that between 1.3 and 2.7 million *S. zygaena* and/or *S. lewini* are represented on the shark fin market. According to Clarke *et al.* (2006b), large species of hammerhead (*S. lewini*, *S. mokarran* and *S. zygaena* combined) represent approximately 6% of the Hong Kong market.

At present, *S. zygaena* is classified globally as *Vulnerable* in the IUCN's red lists (Rigby *et al.*, 2019), and it was included in Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) along with *S. lewini* and *S. mokarran*. Based on ecological risk assessments, the smooth hammerhead was classified as having low vulnerability (compared to other chondrichthyans) to pelagic longline fleets operating in the Atlantic Ocean (Cortés *et al*., 2010; Cortés *et al*., 2015), mainly due to its relatively high productivity and medium-low susceptibility to the fleets considered. Despite this, and 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 ICCAT fisheries (ICCAT, 2010).

Northeast Atlantic and Mediterranean Sea

In the Northeast Atlantic and the Mediterranean, the smooth hammerhead is mainly incidental catch in longline fisheries targeting swordfish and tuna, and in gillnets (Casper *et al.*, 2005). Buencuerpo *et al.* (1998) reported the highest catch values for this species in Spanish fisheries operating off the coast of Africa near Gibraltar. According to Ferretti *et al.* (2008), the *Sphyrna* sp. group has suffered the most drastic population decreases (approximately 99.99% in terms of both abundance and biomass) of all large shark populations living in the Mediterranean Sea.

In a study based on data obtained between 2003-2016 by observers on the Portuguese longline fleet targeting swordfish in the Atlantic Ocean, Santos and Coelho (2019) analysed a data set corresponding to approximately 2.5 million hooks, in which a total catch of 638 individuals of *S. zygaena* was recorded. *S. zygaena* occurred in 15% of the sets observed. The results indicated that the relative abundances of *S. zygaena* in areas close to the African continent (mainly between the Gulf of Guinea and Cabo Verde) were higher than those observed in waters located further away from the continent in the same latitudinal range.

Purse seine fleets targeting tropical tunas in the eastern Atlantic took several elasmobranch species as bycatch, including *S. zygaena* (Clavareau *et al.*, 2018, Lezama-Ochoa *et al.*, 2018). From 2005 to 2017, observers on board the French fleet recorded a total catch of 532 individuals (3.4% of the elasmobranch total) (Clavareau *et al.*, 2018). The authors of this study estimated that 99.8% were juvenile individuals and the mortality rate reached 54.7%. Lezama-Ochoa *et al.* (2018) reported that a catch of 52 individuals was observed in a total of 1,591 sets performed by the French and Spanish fleets operating in the tropical East Atlantic between 2003 and 2011.

Northwest Atlantic

In the Northwest Atlantic, it has been estimated that the abundance of the hammerheads group (*S. lewini*, *S. mokarran* and *S. zygaena*) has fallen by 89% since 1986 due to intense fishing pressure (Baum *et al*., 2003). Although the smooth hammerhead is within this group, based on the Virginia Institute of Marine Science's sampling programme, *S. lewini* was observed to be the most abundant species of the group, with a ratio of more than 10:1 compared to *S. zygaena* (Ha, 2006). Nonetheless, part of the data and methods used by Baum *et al*. (2003) to determine this fact have been seriously called into question (Burgess *et al*., 2005) and, therefore, the real situation of the *S. zygaena* population(s) is uncertain in this period. Based on an exhaustive review of the available information on smooth hammerhead catches in the NW Atlantic, Miller (2016) indicated that this species has a relatively low occurrence in the catches of US fisheries. Miller (2016) indicated that the pelagic longline fleet landed an average of 181 hammerhead sharks annually between 2005 and 2009. *S. lewini* probably accounted for the majority, and *S. zygaena* represented the minority. The same study indicated that, based on data from the observer programme in the demersal longline fishery targeting sharks, only 6 *S. zygaena* were caught from 2005 to 2014, in a total of 3,032 sets performed in 833 fishing trips.

Southwest Atlantic

In the Southwest Atlantic, the species is facing intense fishing effort in all stages of its lifecycle as neonates and juveniles are caught in coastal areas by gillnet and bottom trawl fisheries (Kotas and Petrere, 2002; Kotas, 2004; Vooren *et al.*, 2005; Doño, 2008; Kotas *et al*., 2012; Bernasconi *et al.*, 2018), as well as by recreational fisheries in coastal waters of Southeast Brazil (Martinazzo *et al.*, 2022), while juveniles and adults are caught on the continental shelf and in oceanic areas by trawl and pelagic longline fisheries (Kotas and Petrere, 2002; Kotas, 2004; Kotas *et al*., 2008; Kotas *et al*., 2012; Mas, 2012). São Paulo's pelagic longline fleet catches *S. lewini* and *S. zygaena* in a proportion of 60% and 40%, respectively. Catch figures for this species have varied over time, with an upward trend from 1971 (7 t) to 1990 (290 t) and a falling trend from 1991 (Amorim *et al.*, 1998). More recent work in the same area mentions approximate catches of 9 t in 2002 and 55 t in 2005 with seasonal variations in abundance and *S. lewini* being the most abundant (Vooren *et al.*, 2005; Silveira, 2007). Kotas (2004) reported similar patterns and observed that, although *S. zygaena* were caught in Santa Catarina, Brazil, throughout the year, there were seasonal variations and catches were more abundant in summer (associated with colder waters). Amorim *et al.* (2011) discovered that the hammerhead shark catches of the longline fleet in South Brazil between 2007 and 2008 mainly took place on the slope and reported that *S. zygaena* and *S. lewini* combined represented 6.3% of total shark catch in weight. In total, *S. zygaena* represented 65% of the hammerheads caught, while *S. lewini* accounted for the remaining 35%. Kotas *et al.* (2012) observed that for the fleet that operated in South and Southeast Brazil with bottom gillnet, targeting whitemouth croaker (*Micropogonias furnieri*), out of the two main ports of Santa Catarina *S. zygaena* represented 19.6% of the total hammerheads landed in the period 2008-2009, and *S. lewini* constituted the remaining 80.4%. For all the industrial fisheries that land into those ports, the same study reports that following a peak of 381 t of hammerhead shark offloaded in 2005, catches decreased significantly reaching a minimum of 43 t in 2012. In the waters of the EEZ of Uruguay, Mas (2012) found that *S. zygaena* accounted for 3.6% of all sharks caught by the pelagic longline fleet from 1998-2009, making it the fourth most abundant species. In addition, the author observed that more than 99% of the individuals caught were juveniles in the case of both males and females, and that the highest CPUE values were observed in autumn and the lowest in winter. As regards the spatial distribution of catches, Mas (2012) indicated that most catches were taken during fishing sets performed near the shelf break, and very few catches were taken in sets carried out at depths of over 2,000 m. Bezerra *et al.* (2016) analysed catch and effort data of Brazil's chartered and national longline fleets for the period 2004-2011, and found that hammerhead shark catches (*S. lewini*, *S. mokarran* and *S. zygaena* together) reached a total of 6,172 individuals in 29,418 sets, representing 0.40% of the total individuals caught. The study also indicates that the average catch per unit effort for all surface longline sets was almost double that of bottom longlines. The species was also reported as incidental catch taken by Asian fleets operating in the area (Matsushita and Matsunaga, 2002; Joung *et al.*, 2005).

Coelho *et al.* (2012) recently analysed catch mortality for a wide variety of elasmobranchs in longline vessels operating in the Atlantic. According to these authors, *S. zygaena* had the highest mortality (71.0%, n=372) of the most frequently caught species, followed by *Carcharhinus falciformis* (55.8%, n=310) and *Alopias superciliosus* (50.6%, n=1.061). According to this study, the smooth hammerhead is a particularly vulnerable species as a high percentage of the individuals caught die. Consequently, a discard recommendation would not be very efficient and should be evaluated at the species level (Coelho *et al.*, 2012).

Other regions

Data obtained between 1998 and 2005 by observers in the South African longline fisheries targeting large pelagic fish indicate that hammerhead sharks represent 0.6% of the total shark catch (Petersen *et al.*, 2009). The authors indicate that this value corresponds to *S. zygaena, S. lewini* and *S. mokarran* combined, with no separate values provided for each species. Based on an analysis of catches in bather protection programme nets on the East coast of South Africa, Dicken *et al*. (2018) found that 2,512 *S. zygaena* were caught between 1978 and 2014. Most of these catches, which took place in very shallow waters near the coast, were juvenile and adolescent individuals with estimated ages between 2 and 4 years (93.1% of all individuals caught) (Dicken *et al.*, 2018). Reed *et al*. (2017) reported that *S. zygaena* is taken as bycatch in waters to the south of the EEZ of South Africa by the pelagic trawling fishery targeting mackerel (*Trachurus capensis*), which mainly operates near the continental shelf break.

In the East Pacific, *S. zygaena* has been one of the species landed by several fisheries. Based on landing samples performed between 1995 and 1996 in La Cruz de Huanacaxtle (Nayarit, Mexico), Pérez-Jiménez and Venegas-Herrera (1997) determined that *S. zygaena* accounted for almost 35% of all sharks landed (n = 2,004), and was the main species landed with a total of 700 individuals landed by 20 vessels over a period of less than 5 months. In Peru, González-Pestana (2019) monitored the fleet operating with drift gillnets from the ports of Máncora, Bayovar, San José and Salaverry, and reported that at least 7,485 individuals were caught from 2009 to 2017. In Ecuador, López-Martínez *et al*. (2020) monitored the landings of a number of artisanal and industrial fleets operating from several ports and reported that annual *S. zygaena* catches varied between 62 and 582 in the 2007-2013 period, peaking in 2011.

In New Zealand, *S. zygaena* catches with various fishing gears have been recorded, including bottom gillnet, bottom longline, demersal trawling and surface longline (Francis, 2016). Most catches were recorded in coastal waters at depths of between 9 and 110 metres, although some catches with pelagic longline were recorded in oceanic waters outside of the 1,000-metre isobath.

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