		
<b>CHAPTER 2.2.1.5.</b> <b>BIGEYE</b> <b>THRESHER</b>	<b>AUTHORS:</b> <b>MAS F., DOMINGO A., FORSELLEDO R.</b> <b>and MILLER P.</b>	<b>LAST UPDATE:</b> <b>August 2022</b> <b>Original: Spanish</b>

## 2.2.1.5 Description of Bigeye Thresher (BTH)

### 1. Names

#### 1. a. Classification and taxonomy

**Species name:** *Alopias superciliosus* (Lowe, 1841)

**Etymology:** According to Castro (2011), *Alopias* is an abbreviation of the Greek word *alopekias*, derived from *alopex*, the name of the thresher shark, which in turn is derived from *alopos*, meaning fox. In addition, *superciliosus* comes from the Latin for arrogant or “with an eyebrow raised”, derived from *supercilius*, meaning eyebrow, which alludes to the defined groove above the eyes to the rear of the head.

**Synonyms:** *Alopias profundus* (Nakamura, 1935)

**ICCAT species code:** BTH

**ICCAT names:** Bigeye thresher (English), Requin renard à gros yeux (French), Tiburón zorro ojón (Spanish).

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

- Phylum: Chordata
- Subphylum: Vertebrata
- Superclass: Gnathostomata
- Class: Chondrichthyes
- Sub-class: Elasmobranchii
- Superorder: Euselachii
- Order: Lamniformes
- Family: Alopiidae
- Genus: *Alopias*

#### 1. b. Common names

List of vernacular names used according to ICCAT, FAO, Fishbase ([www.fishbase.org](http://www.fishbase.org)) and Compagno (2001). The list of countries is not exhaustive and some local names might not be included.

**Angola:** Peixe-rato

**Australia:** Bigeye thresher

**Azores:** Tubarão raposo, Bigeye thresher

**Brazil:** Cação-raposa-olho-grande, Tubarão-raposa de olho grande

**China:** 三娘鲨, 长尾沙, 深海狐鲛, 大眼长尾鲨, 大眼长尾鲨, 深海长尾鲨, 深海长尾鲨

**Chinese Taipei:** 深海狐鲛

**Cuba:** Zorro ojón, Big-eyed thresher, Zorro

**Czech Republic:** Žralok mlatec velkooký

**Denmark:** Storøjet rævehaj

**Finland:** Karibiankettuhai

**France:** Renard à gros yeux

**Germany:** Großäugiger Drescherhai, Großäugiger Fuchshai

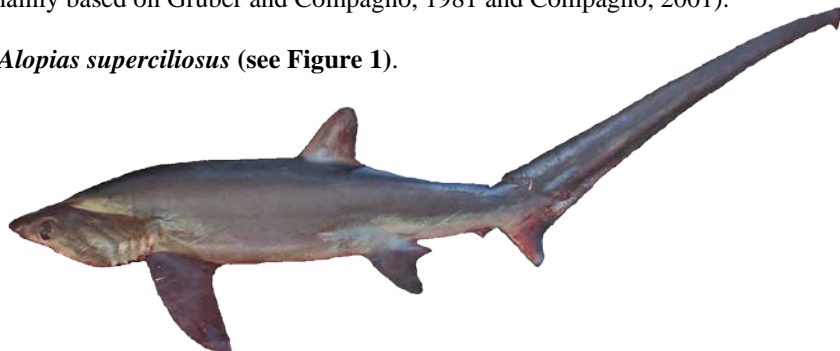
**Greece:** Αλωπίας μεγαλόματος, *Alopias megalomatos*

**Hawaii:** Mano hi'uka, Mano laukahi'u

**Indonesia:** Hiu lancur, Hiu monyet, Hiu tikus, Paitan  
**Italy:** Pesce volpe occhio grosso  
**Japan:** Deepsea bigeye thresher, Bigeye, Bigeyed thresher shark, Big-eyed thresher, Hachiware  
**Madagascar:** Tomanimanente  
**Malaysia:** Bigeye thresher, Terng boi suar, Thresher shark, Yu ekor panjang, Yu mata besar  
**Malta:** Big eye thresher shark  
**Mexico:** Coludo cebucano, Zorro ojón  
**Mozambique:** Zorro olho grande  
**Netherlands:** Grootoogvoshai  
**New Zealand:** Bigeye thresher  
**Oman:** Jarjur, Qatwa albahar  
**Peru:** Tiburón zorro de ojo grande  
**Portugal:** Raposo-de-olhos-grandes, Tubarão-raposo-olhudo, Zorro-de-olhos-grandes  
**South Africa:** Bigeye thresher, Grootoog-sambokhaai  
**Spain:** Tiburón zorro, Zorro ojón, Guilla d'ulls grossos  
**Sweden:** Storögd Rävhaj  
**United Kingdom:** Thresher shark, Big-eyed thresher, Bigeye thresher, Long-tailed shark  
**United States:** Bigeye thresher  
**Uruguay:** Zorro de ojo grande, Azotador  
**Vietnam:** Cá Nhàm đuôi dài mắt to

**2. Identification** (mainly based on Gruber and Compagno, 1981 and Compagno, 2001).

**Characteristics of *Alopias superciliosus* (see Figure 1).**



**Figure 1.** Bigeye thresher (*Alopias superciliosus*) (Lowe, 1841). 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). For specimens caught in the Atlantic Ocean whose size is reported in FL, the corresponding TL is indicated in brackets, calculated using the conversion equation of Fernández-Carvalho *et al.* (2011) (**Table 2**).

The maximum size recorded for this species is a female of 484 cm that was taken as bycatch near the British Isles (51°N-13°W) in a drift net (Thorpe, 1997). In the Northeast Atlantic, Moreno and Morón (1992) reported a maximum size of 410 and 444 cm for males and females, respectively. In the Mediterranean Sea, Kabasakal *et al.* (2011) reported a maximum size of 450 cm, corresponding to a female caught in Turkish waters. Stillwell and Casey (1967) observed maximum sizes of 352 and 399 cm for males and females, respectively, in the Northwest Atlantic. In Southeast Brazil, Mancini (2005) reported the catch of an individual with a gutted weight of 259 kg (without the head, guts or fins) and estimated the size to be 492 cm based on a length-weight relationship. Nonetheless, given that this relationship (see **Table 2**) was constructed using a range of gutted weights between 34 and 126 kg, this size estimation should be considered with caution. Berrondo *et al.* (2007) reported a maximum size of 458 cm in the South Atlantic, based on the Uruguayan pelagic longline fleet observer programme (PNOFA). In the Atlantic, Fernández-Carvalho *et al.* (2015a) reported maximum sizes of 300 and 305 cm FL (~ 509 and 518 cm TL) for females and males, respectively. These lengths converted to TL would correspond to ~ 509 and 518 cm, exceeding the maximum length of 484 cm reported by Thorpe (1997).

### Colour

Greyish-violet to grey-brown on the back and flanks, and white or grey underside.

### External characteristics

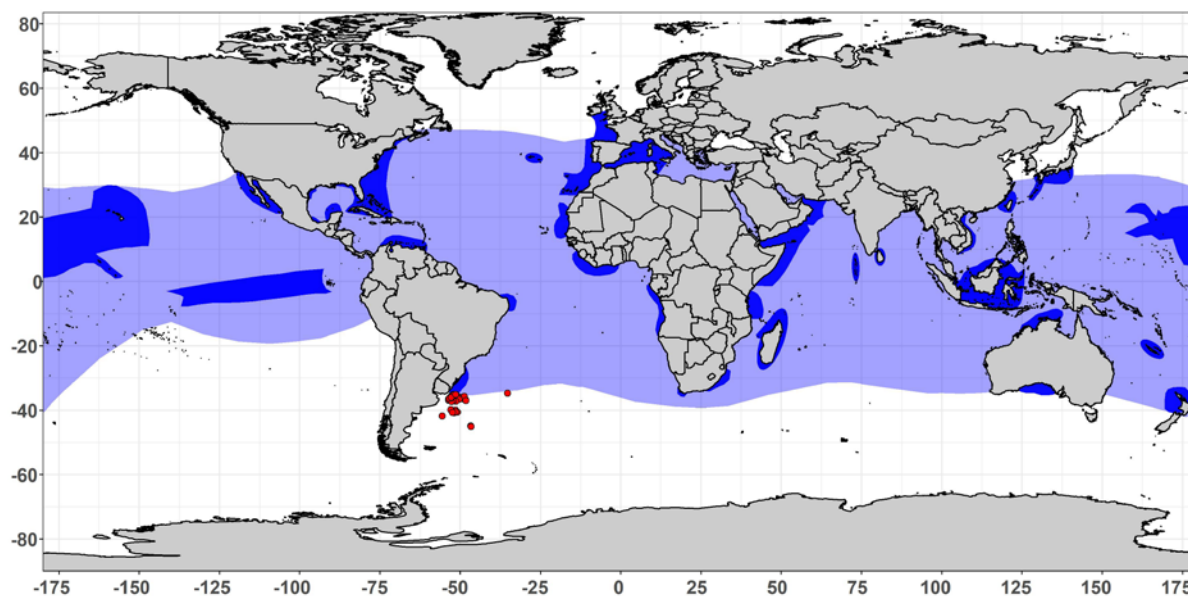
*A. superciliosus* can be easily distinguished from other species in the same genus due to the particular shape of its head (**Figure 1**). It has two deep lateral grooves on the dorsal side over the gill region, which join behind the eyes to give the appearance of a great dorsal ridge. It has large oval eyes that extend onto the dorsal part of the head. The interorbital space is almost flat. The snout is more rounded, relatively more elongated, and less pointy than the other thresher shark species. Labial furrows absent. The first dorsal fin is located further back on the body compared to other threshers, and the midbase is much closer to the pelvic fin origin than the pectoral fin origin. The free rear tip of the first dorsal fin is slightly ahead of or on the origin of the pelvic fins. Curved pectoral fins with relatively broad tips. Caudal fin as long as rest of body. Relatively slender claspers. According to Cadenat (1956), the shape, size and arrangement of the dermal denticles varies with the age and size of individuals. In this study, the author reported that embryos (63 and 68 cm) have small denticles that are spaced out, while an adult female (400 cm) had larger denticles that were much closer and even overlapped.

### Internal characteristics

*A. superciliosus* has the largest teeth in its genus, but the lowest number: from 22 to 27 rows in the upper jaw and 20 to 24 in the lower jaw. No symphyseal teeth. Spinal column composed of a variable number of vertebrae (219 to 319). Apparently, specimens from the east Pacific and Indian Ocean have a higher number of vertebrae than those from the Northwest Atlantic. Spiral valve with 43 to 45 turns. Unlike *Alopias vulpinus*, aerobic red muscle is positioned subcutaneously, as in *A. pelagicus* (Patterson *et al.*, 2011).

## 3. Distribution and population ecology

### 3.a. Geographic distribution



**Figure 2.** Geographic distribution of *Alopias superciliosus*. Taken and modified from the International Union for Conservation of Nature (IUCN) (IUCN SSC Shark Specialist Group 2018. *Alopias superciliosus*. The IUCN Red List of Threatened Species. The red dots (DINARA, unpublished data) represent confirmed records of the species in waters outside the distribution range proposed by IUCN. The new records outside the IUCN distribution were only reviewed for the Atlantic Ocean and adjacent seas.

*A. superciliosus* has a circumglobal distribution in tropical and temperate waters of the Atlantic, Indian and Pacific Oceans (**Figure 2**). According to Compagno (2001), in the western Atlantic this species is found in the United States (from New York to Florida), the Gulf of Mexico, Mexico (from Veracruz to Yucatán), the Bahamas, Cuba, Venezuela and Brazil. However, Berrondo *et al.* (2007) reported numerous records of this species even further south in Uruguayan and international adjacent waters, according to observations on Uruguay's pelagic longline fleet. Similarly, Cuevas and García (2015) reported the first record of the species in waters off north Argentina. In the eastern Atlantic, it is found in Portugal, Spain, Madeira, the Azores, Morocco, the Canary Islands, Senegal, from Guinea to Sierra Leone, Ghana, Angola and South Africa (Cadenat and Blanche, 1981; Muñoz-Chápuli, 1984; Rey and Muñoz-Chápuli, 1992; Compagno, 2001; Ebert *et al.*, 2013, 2021; Seidu *et al.*, 2022). Thorpe (1997) reported that an individual was caught further north than the area specified by Compagno (2001), near the British Isles (51°N-13°W). It is considered a rare species in the Mediterranean Sea (Megalofonou *et al.*, 2005a; Cavanagh and Gibson, 2007; de Maddalena *et al.*, 2016; Serena *et al.*, 2020), but its presence has been noted in the eastern, western and central region (Moreno and Morón, 1992; Schembri *et al.*, 2003; Megalofonou *et al.*, 2005a; Cavanagh and Gibson, 2007; Clo *et al.*, 2009; Corsini-Foka and Sioulas, 2009; de Maddalena *et al.*, 2016; Farrag, 2017; Gökoğlu *et al.*, 2017; Akyol *et al.*, 2020; Ayas *et al.*, 2020; Kousteni *et al.*, 2022).

### 3.b. Habitat preferences

*Alopias superciliosus* is a mesopelagic species that lives in both the neritic and oceanic zone in tropical and temperate waters (Compagno, 2001; Smith *et al.*, 2008; Fernández-Carvalho *et al.*, 2015a). *A. superciliosus*'s extensive use of the water column has been confirmed by several studies in a number of regions. Weng and Block (2004) and Stevens *et al.* (2010) reported maximum depths of approximately 600 m and Nakano *et al.* (2003) reported a maximum of 723 m, while Aalbers *et al.* (2021) recently recorded the deepest dive to date (1013 m).

Stillwell and Casey (1976) reported catches in the Northwest Atlantic at surface temperatures of between 16 and 25°C. Nonetheless, due to *A. superciliosus*'s extensive use of the water column, this species presents a wide thermal tolerance. Information obtained via satellite telemetry provides greater evidence of this species' eurythermal nature. For the Gulf of Mexico, Weng and Block (2004) reported temperature ranges of between 5 and 26°C. Nakano *et al.* (2003) obtained similar results in the eastern Pacific (4-26°C), while in East Australia Stevens *et al.* (2010) reported a range of between 11.1 and 21.6°C for a single individual (female of 170 cm FL, ~ 285 cm TL), spending most of the time between 12.5-15.0°C and 20.0-21.5°C.

Satellite telemetry studies also show that this species uses the water column differently over time, and generally occupies more superficial zones at night and deeper levels during the day (Nakano *et al.*, 2003; Weng and Block, 2004; Kohin *et al.*, 2006; Musyl *et al.*, 2011, Coelho *et al.*, 2015, Aalbers *et al.*, 2021). This vertical behaviour pattern has been reported for other shark species (e.g. *Alopias vulpinus*, Cartamil *et al.*, 2011; *Cetorhinus maximus*, Sims *et al.*, 2005; *Isurus oxyrinchus*, Vetter *et al.*, 2008; *Lamna nasus*, Pade *et al.*, 2009) and it is thought to be related to the vertical migration of their prey (e.g. Musyl *et al.*, 2004; Bernal *et al.*, 2009). Based on 12 specimens equipped with archival satellite tags, Coelho *et al.* (2015) observed differential use of the water column at different times in the Atlantic. According to the authors, the average depth and temperature experienced during the day were 353 m and 10.7°C, while at night these figures were 72 m and 21.9°C. These authors also reported that juveniles and adults use the water column differently. On average, juvenile individuals occupied more superficial layers than adults at night, and deeper levels during the day. In the Pacific, Kohin *et al.* (2006) reported that *A. superciliosus* has different thermal preferences over time, spending more than 70% of its time at temperatures between 11 and 18°C during the day and more than 55% of its time between 24 and 30°C at night. Musyl *et al.* (2011) tagged 3 individuals with satellite tags in the Pacific and reported average depths and temperatures of 331 m (22-543 m) and 11°C (5-25°C) during the day and 118 m (5-500 m) and 20°C (6-27°C) at night. Sepulveda *et al.* (2019) reported an average depth of between 250 and 439 m during the day, spending 99% of the time between 200 and 500 m; and between 20 and 106 m at night, spending 80% of the time at depths of under 100 m. Average temperatures experienced during the day and at night varied between 7.5 and 8.7°C and between 17.4 and 18.2°C, respectively. Based on all the specimens tagged, the thermal and bathymetric ranges observed were 6-25°C and 0-548 m (Sepulveda *et al.*, 2019). The results of a more recent study carried out in the same region based on 13 specimens tagged with archival tags also reported similar results. Aalbers *et al.* (2021) reported that specimens remained at large depths below the mixed layer during the day (average depth: 386 m), while they used more superficial layers of the water column during the night, above the mixed layer (average depth: 65 m). Specimens experienced a large range of temperatures due to their extensive vertical migrations. The average temperatures were 7.9°C during the day and 19.3°C at night, with a minimum temperature of 4.6°C recorded during a dive to a depth of 1013 m (Aalbers *et al.*, 2021).

Cao *et al.* (2011) studied the environmental preferences of *A. superciliosus* in waters close to the Marshall Islands, west Pacific, based on 69 fishing sets with longline gear targeting bigeye tuna (*Thunnus obesus*). The authors reported optimum depth (240-360 m), temperature (10-16°C), salinity (34.5-34.7) and dissolved oxygen (3.0-4.0 ml/l) ranges for the species. However, considering the gear setting and haulback times during this study, the environmental variable ranges presented by the authors only correspond to the species' daytime habitat use. Also in the Pacific, Matsunaga and Yokawa (2013) reported greater CPUE values for this species corresponding to the Japanese longline fleet at surface temperatures of between 23 and 29°C. Nonetheless, considering the mesopelagic habits of *A. superciliosus*, sea surface temperature is unlikely to play a determining role in the distribution of this species.

### 3.c. Migrations

*A. superciliosus* is considered to be a highly migratory species, but there is little information about its movements. Based on the National Marine Fisheries Service (NMFS) Cooperative Shark Tagging Program database, Kohler and Turner (2019) reported that 3% of all tagged individuals were recaptured (n=400). The maximum distance travelled by this species was 2,067 km and the maximum time at liberty was 10.5 years. The recaptures reported in this study demonstrate movements between the Gulf of Mexico and the Northwest Atlantic, movements from neritic waters to remote oceanic waters and vice versa, and local movements within the Caribbean Sea and the Gulf of Mexico (Kohler and Turner, 2019). Twelve specimens tagged in the central Atlantic by Coelho *et al.* (2015) with archival tags travelled for a minimum of between 95 and 1,440 km during times at liberty of between 30 and 182 days. An individual tracked by satellite in the North Atlantic by Carlson and Gulak (2012) travelled a significant distance to oceanic waters, and subsequently returned to shelf waters near the tagging location in the Gulf of Mexico. Weng and Block (2004) also demonstrated that an individual moved from waters close to the slope towards oceanic waters. In the central Pacific, the same authors reported a movement of 1,125 km from the coast of Kona (Hawaii) to the north of French Frigate Shoals. Sepulveda *et al.* (2019) reported on the movements of 11 specimens tagged in the Northeast Pacific with archival tags, and observed a general trend of movements towards the southwest from the tagging site. After 30 days, 10 of the 11 samples tagged were more than 800 km from the release site, and 8 were over 1000 km away (maximum distance of 1,362 km). More recently in the same region, Aalbers *et al.* (2021) tagged 14 specimens with archival tags and observed very similar results to those reported by Sepulveda *et al.* (2019).

Data from fishers in several locations seem to exhibit the somewhat seasonal nature of catches, which suggests that the species would be making some kind of movement to and from fishing areas. In north Cuba, Guitart Manday (1975) reported that, although this species is caught throughout the year, catches peaked in August and October. Similarly, in the Northwest Atlantic, Stillwell and Casey (1967) reported year-long catches, but also observed aggregations of the species between April and June in Cape Hatteras. Fernández-Carvalho (2015a) analysed catches of this species mostly from the Atlantic Ocean, and observed what appeared to be segregation by size, with larger specimens gathering at higher latitudes, mainly in the Southwest and Northwest Atlantic. Smaller specimens were more frequently caught in the tropical and Northeast Atlantic.

Genetic studies performed show the lowest levels of genetic diversity reported for elasmobranchs to date and a lack of genetic structure between the various regions of the Atlantic and the western Indian Ocean (Trejo, 2005; Morales *et al.*, 2018). These results suggest that the species has a great dispersal and migratory capacity, even between different ocean basins.

## 4. Biology

### 4.a. Growth

To date, knowledge about the age and growth of *A. superciliosus* is scarce, but the few existing studies all coincide that it is a large species with slow growth (**Table 1**).

The annual periodicity of growth ring formation was validated by Liu *et al.* (1998) in Northeast Chinese Taipei via a marginal increment analysis. However, the periodicity of ring formation has not been validated in the Atlantic to date. Mancini and Amorim (2004), Mancini (2005) and Fernandez-Carvalho *et al.* (2011) mentioned that it was hard to perform a marginal increment analysis study due to the small size of the outer rings and the difficulty of clearly identifying separate rings. Assuming annual growth ring formation, Fernandez-Carvalho *et al.* (2011) observed maximum ages of 17 and 22 for males and females, respectively, in the tropical Northeast Atlantic. Similarly, in South Brazil, Mancini (2005) reported ages of up to 19 and 18 years for females and males, respectively, and estimated longevity at 35 years for females and 30 years for males. More recently, Fernandez-Carvalho *et al.* (2015b) updated their previous growth study using a larger number of samples with greater geographical coverage in the Atlantic. The results indicated a lower growth coefficient and a larger size

at birth and asymptotic size for males compared to their previous study, while similar results were obtained for all growth parameters in the case of females. The maximum age observed for both sexes was 25 years. Lastly, although the results suggest that there are different growth patterns in the Northern and Southern Hemispheres, the authors conclude that the limited number of samples from the Southern Hemisphere prevents them from reaching solid conclusions.

For the Pacific, Liu *et al.* (1998) observed that males reach sexual maturity at approximately 9-10 years of age, while females do so at approximately 12.3-13.4 years of age. These ages at sexual maturity are higher than in other species of the same genus: 7-8 and 8-9.2 years for *A. pelagicus* males and females, respectively (Liu *et al.* 1999); 4-5 and 5.3 years for *A. vulpinus* males and females, respectively (Smith *et al.*, 2008).

**Table 1.** Growth parameters for *Alopias superciliosus* according to the Von-Bertalanffy growth model.  $L_{\infty}$ : maximum asymptotic length (cm), k: growth coefficient (years<sup>-1</sup>),  $t_0$ : theoretical age at length 0 (years).

Growth Parameter			Area	Reference	Sex	Method
$L_{\infty}$	k	$t_0$				
385 (TL)	0.088	-4.24	Northeast Chinese Taipei	Liu <i>et al.</i> (1998)	Males	Vertebrae
422 (TL)	0.092	-4.21	Northeast Chinese Taipei	Liu <i>et al.</i> (1998)	Females	Vertebrae
467 (TL)	0.070	-3.86	Southeast Brazil	Mancini & Amorim (2004)	Males	Vertebrae
482 (TL)	0.070	-4.93	Southeast Brazil	Mancini & Amorim (2004)	Females	Vertebrae
485 (TL)	0.064	-5.20	Southeast Brazil	Mancini (2005)	Males	Vertebrae <sup>1</sup>
483 (TL)	0.067	-4.87	Southeast Brazil	Mancini (2005)	Females	Vertebrae <sup>1</sup>
487 (TL)	0.065	-5.04	Southeast Brazil	Mancini (2005)	Both	Vertebrae <sup>1</sup>
451 (TL)	0.073	-4.65	Southeast Brazil	Mancini (2005)	Males	Vertebrae
489 (TL)	0.065	-5.04	Southeast Brazil	Mancini (2005)	Females	Vertebrae
465 (TL)	0.071	-4.27	Southeast Brazil	Mancini (2005)	Both	Vertebrae
347(TL)	0.180	152 (TL)*	Northeast Atlantic	Fernandez-Carvalho <i>et al.</i> (2011)	Males	Vertebrae
497 (TL)	0.060	183 (TL)*	Northeast Atlantic	Fernandez-Carvalho <i>et al.</i> (2011)	Females	Vertebrae
416 (TL)	0.090	178 (TL)*	Northeast Atlantic	Fernandez-Carvalho <i>et al.</i> (2015b)	Males	Vertebrae
418 (TL)	0.060	180 (TL)*	Northeast Atlantic	Fernandez-Carvalho <i>et al.</i> (2015b)	Females	Vertebrae

TL: total length (cm) \* A modified version of the von Bertalanffy curve was used that had been reparametrized to estimate size at birth.  
<sup>1</sup> Parameter estimation using whole vertebrae. The lengths presented for Fernandez-Carvalho *et al.* (2011, 2015b) were converted to TL using the conversion equation established by Fernandez-Carvalho *et al.* (2011).

#### 4.b. Length-weight relationship

Published length-weight relationships for several areas of the Atlantic are shown in **Table 2**.

**Table 2.** Published length-weight relationships for *Alopias superciliosus*. W: weight (kg); GW: gutted weight (without the head, guts or fins - kg); TL: total length (cm); FL: fork length (cm).

Equation	N	Length range	R <sup>2</sup>	Area	Reference
$W = 1.825 \times 10^{-5} \times (PCL)^{3.448534}$	15	90-210*	-	Northwest Cuba	Guitart Manday (1975)
$\text{Log}(P) = 11.1204 + 2.99269 \times \text{Log}(FL)$	16	100-200*	-	Northwest Atlantic	Stilwell & Casey (1976)
$W = 9.1069 \times 10^{-6} \times (FL)^{3.0802}$	56	100-228	0.91	Northwest Atlantic	Kohler <i>et al.</i> (1995)
$GW = 8.61821 \times 10^{-6} \times (FL)^{2.99765}$	29	110-225	0.78	Southwest Atlantic	García-Cortés & Mejuto (2002)
$TL = 87.9361 \times (GW)^{0.3095}$	35	34-126	0.91	Southwest Atlantic	Mancini (2005)

\* Approximate lengths based on study figures.

#### 4.c. Length-length relationships

Published length-length relationships for several areas of the Atlantic are shown in **Table 3**.

**Table 3.** Published length-length relationships for *A. superciliosus*. TL: total length (cm); FL: fork length (cm); PCL: precaudal length (cm).

Equation	N	Length range (cm)	R <sup>2</sup>	Area	Reference
FL = 0.5598 x (TL) + 17.666	56	155 - 371 (TL)	0.89	Northwest Atlantic	Kohler <i>et al.</i> (1995)
TL = 1.773 x (FL) – 14.456	147	-	0.95	Northwest Atlantic	Buencuerpo <i>et al.</i> (1998)
FL = 1.073 x (PCL) + 4.15	166	-	0.99	Northwest Atlantic	Buencuerpo <i>et al.</i> (1998)
FL = 0.58 x (TL) + 4.83	390	-	0.92	Northwest Atlantic	Fernandez-Carvalho <i>et al.</i> (2011)

#### 4.d. Reproduction

Information on the reproductive biology of *A. superciliosus* is scarce for both the Atlantic Ocean and the rest of the globe.

##### *Gestation and pupping*

Oophagy is a common feeding mechanism during embryo development in Lamniformes (Gilmore, 1993; Gilmore *et al.*, 2005) and it has been observed in *A. superciliosus* (Gilmore, 1983; Moreno and Morón, 1992; Chen *et al.*, 1997; White, 2007; Castro, 2009). Based on embryonic morphology and their food source, Chen *et al.* (1997) established 6 different stages in embryo development. In the first 3 stages the embryo is inside a capsule with semi-transparent, membrane-like walls and feeds on the yolk sac. In the last 3 stages, the embryo is outside of the capsule free within the uterus, and feeds on nourishing eggs (oophagy) and possibly uterine fluid (see Chen *et al.*, 1997 for more details). Moreno and Morón (1992) distinguish three types of eggs or capsules: empty (no ovum or yolk), with a germinal disk (containing a single ovum with a germinal disk), and nutritional (containing a large number of unfertilized ova; see Moreno and Morón, 1992 for more details). Although it has been suggested that this species could present intrauterine cannibalism as gravid females carry a single embryo in each uterus (Gruber and Compagno, 1981; Compagno, 1984; 2001), there is no empirical evidence to confirm this behaviour (Gilmore, 1983; Moreno and Morón, 1992; Chen *et al.*, 1997). Gilmore (1983) mentions the presence of a fine and smooth epithelium surrounding the embryos' body, which could prevent potential damage to the uterus walls caused by pointy denticles and/or facilitate parturition.

*A. superciliosus* embryos reach a large final size before birth and show many of the diagnostic anatomical characteristics of this species (Gilmore, 1983). According to Moreno and Morón (1992), birth size in the Atlantic is at least 100 cm, which is very similar to the size of at least 105 cm reported by Gilmore (1983). In Southeast Brazil, Amorim *et al.* (1998) reported maximum embryo sizes of up to 103 cm. Size at birth appears to be larger in the Indo-Pacific (135-160 cm). Chen *et al.* (1997) reported a size at birth of 135 to 140 cm for the northwestern Pacific, while Fogacho (2015) observed embryos of up to 126 cm in the northeastern Pacific. In Indian waters, Benjamin *et al.* (2015) reported the catch of two gravid females measuring 340 and 346 cm, each carrying two embryos of 126 and 130 cm and of 155 and 158 cm, respectively. In the Andaman Sea, Das *et al.* (2016) reported the catch of a gravid female measuring 353 cm, carrying a 140 cm male embryo and a 143 cm female embryo. According to Castro (2011), the difference in reported sizes at birth for the Atlantic and Indo-Pacific could in reality not exist. This author indicates that *A. superciliosus* embryos do not have distended stomachs like other Lamniform sharks and are completely developed and practically pigmented at relatively small sizes (60 cm), which could have led researchers to underestimate the true size at birth. In accordance with his observations, this author reported that two embryos inside a female measuring 395 cm caught in Florida (United States) had sizes of 124 and 129 cm, while Fernandez-Carvalho *et al.* (2015a) observed a maximum embryo size of 90 cm FL (~ 147 cm TL) in the Atlantic. These are the largest recorded sizes in this Ocean and are within the range reported for the Indo-Pacific.

The gestation period of the bigeye thresher is probably 12 months (Holden, 1974; Compagno, 2001), but this is uncertain due to the apparent lack of reproductive seasonality. In Northeast Chinese Taipei, it was not possible to estimate the gestation period due to the great variability found in embryo size within a single month (between 20 and > 130 cm in January and February; Chen *et al.*, 1997). Several studies mention that most adult females are pregnant throughout the year, which suggests that copulation and pupping occur continuously and that there are no specific periods for these two reproductive events (Guitart Manday, 1975; Gruber and Compagno, 1981;



Chen *et al.*, 1997). However, Moreno and Morón (1992) mentioned that a large number of females carrying embryos in the late stages of development were caught between the end of September and the beginning of October near the Strait of Gibraltar. These authors also suggested that the pupping season could take place in this region between autumn and winter. In the Northeast Atlantic, gestating females have also been reported in Senegal (Cadenat, 1956) and the Gulf of Cadiz (Muñoz-Chápuli, 1984). In the Northwest Atlantic, Pratt (1993) reported the catch in May of 3 gravid females, two of which (220 and 227 cm FL; ~371 and 383 cm TL) were in early stages of gestation and one (200 cm FL; ~337 cm TL) was carrying at-term embryos (the author does not specify the size of the embryos). Considering the size at birth of 100 cm proposed by Bass (1975) and the discovery of embryos measuring 79.2 cm in October, 75.4 cm in November, 97.1 cm in December and 103 cm in March, Amorim *et al.* (1998) suggested that the pupping season of *A. superciliosus* in South Brazil could occur from March onwards. Furthermore, in the same region as studied by Amorim *et al.* (1998), Mancini (2005) reported the presence of embryos with sizes of 20, 108 and 111 cm in July 2003. The same study also reports the size of 12 embryos collected by the *Núcleo de Pesquisa e Estudo em Chondrichthyes* (NUPEC) in the same region. These sizes were 66.3 cm in April, 41.8 cm in May, 63.4 cm in June, 50 cm in October and 66 cm in November. Two females carrying embryos at different stages of development were caught in Uruguayan waters in March. One measured 200 cm PCL and was carrying at least one embryo in the early stages of development, still within the capsule. The embryo measured approximately 6 cm and the capsule almost 11 cm longitudinally. The other female measured 405 cm and was carrying 2 embryos (a male and a female) that both measured approximately 68.5 cm (Fernandez-Carvalho *et al.*, 2015a; PNOFA, unpublished data). These data support the view of several authors that the reproductive period of *A. superciliosus* does not appear to be very defined in time (Guitart Manday, 1975; Gruber and Compagno, 1981; Chen *et al.*, 1997). It remains to be determined whether the apparent defined reproductive period found by Moreno and Morón (1992) in the Strait of Gibraltar is an exceptional case or represents a real difference in the life history of different *A. superciliosus* populations, or if it is due to the fact that no other specific pupping areas have been identified in other regions. Stillwell and Casey (1976) mentioned an aggregation of this species near Hatteras Cape, North Carolina, United States, between April and June, but it is not known whether it is related to reproduction. Guitart Manday (1975) mentioned gravid females carrying embryos close to size at birth were commonly caught in North Cuba. However, the author did not specify at what point in the year these females were caught. However, based on low catches of small juveniles, the author also suggested that the pupping site would be outside of the study area, or the fishing gear analysed was not selective for this size class. More recently, Fernandez-Carvalho *et al.* (2015a) analysed *A. superciliosus* catches in a large area of the Atlantic, as part of a joint study involving several countries and fishing fleets. The results of this study provide new evidence on potential pupping and/or nursery areas of this species, confirming the areas proposed by Moreno and Morón (1992) in the Strait of Gibraltar, but extending them southwards to tropical waters of Northeast Africa. Additionally, the authors suggest that the waters of Florida and the Caribbean Sea in the Northwest Atlantic and South Brazil and Uruguay in the Southwest Atlantic could also be pupping and nursery areas. Lastly, based on the low occurrence of small juveniles in the catch of longline fleets, Fernandez-Carvalho *et al.* (2015a) present the hypothesis that parturition could take place in more coastal waters. Moreno and Morón (1992) proposed a similar theory, and even report that gillnets catch a large number of juveniles and gravid females in areas close to the coast in the Strait of Gibraltar, while longline vessels operating in the same areas record no catches. Buencuerpo *et al.* (1998) also observed differences between gillnets and longline catches in the same area. Occasional reports of beaching by small *A. superciliosus* individuals (136-144 cm) have been recorded between February and June on the oceanic coast of Uruguay (DINARA, unpublished data).

Matsunaga and Yokawa (2013) reported the presence of 267 gravid females in the Pacific Ocean between the equator and 36°N. The authors reported the presence of gravid females between 10 and 20°N during winter and spring and between 20 and 30°N during summer and autumn. A total of 36 females carrying at-term embryos (60 cm PCL) were caught between 10 and 35°N, while neonates (< 80 cm PCL) mainly occurred between 10 and 15°N and between 150 and 180°W in winter and spring. As there are no differences in the distribution of neonate and juvenile catches, Matsunaga and Yokawa (2013) suggested that this area could act simultaneously as a pupping and nursery area where neonates spend the first years of their life, without migrating to other regions. This finding is in contrast to the proposed hypothesis for the Atlantic, where the species would use more coastal areas as pupping sites

### *Maturity*

The size at maturity of *A. superciliosus* varies by sex and is greater in females than in males. In the Northwest Atlantic, Stillwell and Casey (1976) reported a size at maturity of between 290 and 300 cm for males and 350 cm for females. These estimations are similar to the values mentioned by Moreno and Morón (1992) in the Northeast Atlantic, > 276 cm and 340 cm for males and females, respectively. A more recent study carried out in the Atlantic reports a median size-at-maturity ( $L_{50}$ ), corresponding to 159.2 cm FL (~ 266 cm TL) for males and



208.6 cm FL (~ 351 cm TL) for females (Fernandez-Carvalho *et al.*, 2015a). According to the growth model proposed for the Atlantic by Fernandez-Carvalho *et al.* (2015b) males and females would reach  $L_{50}$  at 6-7 and 13-14 years of age, respectively. In waters off Northeast Cuba, Ruiz-Abierno *et al.* (2021) observed mature females of between 169 and 285 cm PCL, and only one immature female of 137 cm PCL. The authors also observed just one mature male of 178 cm PCL and nine immature specimens of between 167 and 180 cm PCL.

Sizes at maturity in other oceans are similar to those reported for the Atlantic. Chen *et al.* (1997) reported an  $L_{50}$  of 270-288 cm for males and 332-341 cm for females in Northeast Chinese Taipei. In eastern Indonesia, White (2007) reported a size at maturity of between 279 and 283 cm for males. For Ecuador, Fogacho (2015) reported a median size at maturity of 252 and 273 cm for males and females, respectively. The estimated size for females is considerably lower than in other studies carried out in the Indo-Pacific and Atlantic. In the same region, Briones-Mendoza *et al.* (2021) estimated an  $L_{50}$  of 138.7 cm PCL for males.

#### *Sex ratio*

The sex ratio between embryos of a single litter is not significantly different from 1:1 (Gruber and Compagno, 1981; Gilmore, 1993; Chen *et al.*, 1997; Moreno and Morón, 1992). However, there appears to be evidence of significant differences between the North and South Atlantic in terms of both the size distribution and sex ratios of this species. According to Fernandez-Carvalho *et al.* (2015a), males were particularly dominant particularly in the Northwest, Northeast, and Southeast Atlantic, while females were slightly more dominant in tropical waters of the North Atlantic. In waters off Northwest Cuba, Ruiz-Abierno *et al.* (2021) reported that females were dominant in the catch of artisanal longline vessels throughout the year, especially from November to February. Moreno and Morón (1992) reported an aggregation of mainly female individuals near the Strait of Gibraltar between the end of September and beginning of October.

#### *Fecundity*

Like many sharks, only the right ovary is functional in *A. superciliosus* (Gilmore, 1993). In general, the litter size of *A. superciliosus* is 2 embryos (one in each uterus), but there are records of one, three and up to four embryos in a single litter (Cadenat, 1956; Guitart Manday, 1975; Gruber and Compagno, 1981; Gilmore, 1983, 1993; Moreno and Morón, 1992; Chen *et al.*, 1997; Amorim *et al.*, 1998; Buencuerpo *et al.*, 1998; Benjamin *et al.*, 2015; Fernandez-Carvalho *et al.*, 2015a; Fogacho, 2015; Moazzam and Osmany, 2022). At birth, individuals are large and have a good energy reserve stored in the liver. This could strengthen their ability both to search for and capture prey and to escape from predators, therefore increasing their chances of survival (Gilmore, 1983; Chen *et al.*, 1997). The minimum size reported for a gravid female in the Atlantic is 341 cm (Moreno and Morón, 1992).

#### **4.e. Diet**

Thresher sharks use the length of the dorsal lobe of their caudal fin to disorientate and stun their prey (Compagno, 2001; Smith *et al.*, 2008; Aalbers *et al.*, 2010), and this is probably why it is relatively common to see specimens hooked by this fin in longline fisheries (Strasburg, 1958; Gubanov, 1972; Stillwell and Casey, 1976; Gruber and Compagno, 1981; Smith *et al.*, 2008).

In general, the diet of *A. superciliosus* mainly consists of bony fish and cephalopods, although crustaceans have been found on some occasions (Stillwell and Casey, 1976; Gruber and Compagno, 1981; Cortés, 1999; Bowman *et al.*, 2000; Polo-Silva *et al.*, 2007, 2009; Preti *et al.*, 2008; Rossi, 2010). The most detailed and comprehensive studies on *A. superciliosus*'s diet took place in the waters of the Pacific Ocean. Preti *et al.* (2008) describe *A. superciliosus* as an opportunistic species with a wide spectrum that feeds on regional, temporarily available prey, including epipelagic, mesopelagic and epibenthic species. Polo-Silva *et al.* (2007, 2009) studied the composition of *A. superciliosus*'s diet in equatorial waters during the dry and wet seasons. These authors discovered that females have a more diverse diet than males in both the dry (22 taxa, n=57; 14 taxa, n=50; females and males, respectively) and wet seasons (22 taxa, n=58; 13 taxa, n=63; females and males, respectively). Based on their results regarding diet, Polo-Silva *et al.* (2009) also suggested that females and males migrate between coastal and oceanic waters in search of food, and this phenomenon is less notable in males due to their preference for coastal species. A study carried out in the Southwest Atlantic (Rossi, 2010) reported a significantly lower taxonomic diversity (7 taxa) than the previous studies. According to this study, the diet of *A. superciliosus* mainly consists of cephalopods from the order Teuthida and bony fish from the families Trichiuridae and Scombridae. Based on an analysis of 20 stomachs, Cortés (1999) also reported that the diet was mainly dominated by cephalopods (65.2%) and bony fish (34.8%). Bowman *et al.* (2000) found that the diet of individuals in the Northwest Atlantic (n=18) was mainly composed of bony fish (83.5%), and the rest was accounted for by cephalopods (15.1%) and other dietary components (1.4%). Bass *et al.* (1975) observed chondrichthyan remains in the stomach of an adult male measuring 363 cm caught in South Africa; however, the relative importance of chondrichthyans in this species' diet is unknown.

Below is a list of the species mentioned in the diet of *A. superciliosus* based on the literature reviewed (Stillwell and Casey, 1976; Gruber and Compagno, 1981; Bowman *et al.*, 2000; Polo-Silva *et al.*, 2007, 2009; Preti *et al.*, 2008; Rossi, 2010):

**Teleosts:** *Ablennes hians*, *Alepisaurus* sp., *Auxis thazard*, *Benthoosema panamense*\*, *Brotula clarkae*, Clupeidae spp., *Cololabis saira*\*, *Coryphaena hippurus*, *Engraulis mordax*\*, *Etrumeus teres*, *Exocoetus* sp.\*; *Fistularia corneta*, *Fistularia* sp., *Fodiator acutus*, *Hemanthias signifier*, *Istiophorus* sp., *Lagocephalus lagocephalus*, *Larimus argenteus*\*, *Merluccius gayi*\*, *Merluccius productus*\*, *Ophichthus* sp., *Oxyporhamphus micropterus*, Paralepididae sp.\*, *Paralichthys* sp., *Remora remora*, *Sardinops sagax*, Sciaenidae sp., Scombridae sp.\*, *Scomber colias*\*, *Scomber scombrus*, Scorpaenidae spp.\*, *Sebastes paucispinis*, *Trachipterus altivelis*, *Trachurus symmetricus*, Trichiuridae spp.\*; **Cephalopods:** *Abraliopsis affinis*, *Ancistrocheirus lesueurii*, *Cranchia scabra*, *Dosidicus gigas*\*, *Gonatopsis borealis*, *Gonatus* sp.\*, *Histioteuthis dofleini*, *Histioteuthis* sp., *Illex* sp., *Illex illecebrosus*\*, *Loligo opalescens*, *Mastigoteuthis dentata*, *Octopodoteuthis sicula*, *Octopoteuthis* sp., *Teuthida* spp.\*; **Crustaceans:** *Pleuroncodes planipes*, *Solenocera agassizi*.

\* Dominant species in diet composition (by weight or number).

#### 4.f. Physiology

Existing evidence that several sharks of the order Lamniformes are capable of maintaining their body temperature above that of the surrounding water through generation of metabolic heat (regional endothermy; Carey and Teal, 1969; Block and Carey, 1985; Block and Finnerty, 1994; Bernal *et al.*, 2001, 2005) historically suggested the possibility that this ability is shared by thresher sharks (Alopiidae) (for example, Gruber and Compagno, 1981; Weng and Block, 2004; Smith *et al.*, 2008; Amorim *et al.*, 2009). However, detailed studies of the physiology of these sharks show that only *A. vulpinus* possess the physiological specialisations necessary to generate heat metabolically and maintain it, thus enabling generation of a regional endothermy (Bernal and Sepulveda, 2005; Sepulveda *et al.*, 2005; Patterson *et al.*, 2011). Unlike *Alopias vulpinus*, aerobic red muscle is located subcutaneously in *A. superciliosus* and *A. pelagicus* (Patterson *et al.*, 2011), which implies a low capacity to retain the heat generated due to heat exchange between the skin and the surrounding water.

For *A. superciliosus* in particular, Weng and Block (2004) reported the presence of a network or plexus of arteries and veins that almost run in contact and in the opposite direction in the cephalic region and suggested that this species could be capable of generating a cranial endothermy, maintaining only the eye and brain temperatures above the ambient temperature. This capacity would enable the species to forage more efficiently even at low temperatures during their extensive vertical migrations (Weng and Block, 2004). In a previous paper, Block and Carey (1985) located this network in *A. superciliosus* and *A. pelagicus*, but not in *A. vulpinus*. In sharks in which the cranial endothermy has been observed (e.g. *I. oxyrinchus* and *Lamna nasus*), the internal carotid artery is narrow, while in sharks lacking this ability this artery is the main blood supply to the brain (Block and Carey, 1985). The internal carotid artery does not pass through the network or plexus, and therefore sends cold blood to the brain (Block and Carey, 1985). According to the paper by Block and Carey (1985) none of the thresher species has a narrow internal carotid artery. Therefore, in the absence of *in vivo* measurements of cranial temperature, it is not yet possible to confirm the cranial endothermy in this family (Weng and Block, 2004).

*Alopias superciliosus* has laterally expanded branchial chambers and the largest gill surface area documented in elasmobranchs to date. This implies high tolerance to hypoxic waters for prolonged periods (Wootton *et al.*, 2015). The large gill surface area combined with a particularly thin water-blood barrier, fine lamellae, and long total filament length allow this species to efficiently absorb oxygen, even in hypoxic conditions. These adaptations are not seen at this level of development in either of the two remaining thresher shark family species (*A. vulpinus* and *A. pelagicus*), and this is probably one of the reasons why *A. superciliosus* is able to exploit a much greater vertical niche than its closest relatives.

#### 4.g. Mortality

Due to this species' large size-at-birth and the large size of adult and sub-adult specimens, *A. superciliosus* probably has few natural predators over the course of its life. Nonetheless, there are occasional previous reports of shortfin mako (*I. oxyrinchus*) and orcas (*Orcinus orca*) preying on *A. vulpinus* (Bedford, 1985; Visser, 2005), which means that it cannot be ruled out that something similar occurs in the case of *A. superciliosus*.

Knowledge regarding catch and post-catch mortality is limited for this species. Beerkircher *et al.* (2002) reported that 53.7% (n=82) of specimens caught by the United States longline fleet were dead at haulback. Coelho *et al.* (2012) analysed the condition (alive or dead) of a wide variety of elasmobranchs at haulback in longline vessels operating in a wide area of the Atlantic. According to these authors, *A. superciliosus* had one of the highest at-haulback mortality rates (50.6%, n=1061), together with *Sphyrna zygaena* (71.0%, n=372) and *Carcharhinus falciformis* (55.8%, n=310). For its part, Pan *et al.* (2022) reported a mortality at haulback of 31.1% in the Chinese longline fleet targeting bigeye tuna (*Thunnus obesus*) in the Atlantic, and a further 6.1% of species were classified as “moribund” at haulback. Sepulveda *et al.* (2019) fitted 14 archival transmitters to assess post-catch mortality in specimens caught by experimental fishing in California, United States, designed to selectively target swordfish (*Xiphias gladius*) during the day and at great depths. The results of this study showed low mortality, with just one specimen dying following release. A second specimen showed clear signs of having been preyed on 6 hours after being released. The remaining 12 specimens continued to be alive 30 days after catch and release (end of the monitoring period). Similarly, Aalbers *et al.* (2021) reported high post-catch survival for another specific swordfish fishing method during the day in the same region. Of the 14 specimens caught and tagged, all apart from one survived for 30 days after being caught, which indicates a mortality rate of 7%. Nonetheless, the only specimen that did not survive was gravely tangled in the fishing gear, which could have potentially compromised its survival. This therefore suggests that post-catch mortality could be even lower in normal catching conditions.

## 5. Fisheries biology

### 5. a. Populations/Stock structure

Based on mitochondrial DNA studies (control region), Trejo (2005) suggested that there would be at least two different stocks or management units of *A. superciliosus*, one in the Indo-Pacific and another in the Atlantic Ocean. Nonetheless, the presence of haplotypes that are shared by both the Indo-Pacific and Atlantic populations, the species’ great migratory capacity, and its occurrence in waters to the south of South Africa suggest the possibility of a certain degree of genetic exchange between populations from different ocean basins (Trejo, 2005). Within the Atlantic, Trejo (2005) did not find any significant differences in the population structure of the different areas sampled, which suggests that the species has a strong dispersal capacity. Nonetheless, the number of samples was low and restricted to just the North Atlantic, which means it is not yet possible to guarantee the existence of a single stock in the Atlantic Ocean. In turn, the absence of samples from the South Atlantic makes it impossible to confirm whether there is genetic exchange between the Indo-Pacific and South Atlantic populations. Nonetheless, a certain degree of exchange is to be expected due to the presence of the species in South African waters (Trejo, 2005). More recently, Morales *et al.* (2018) analysed the same genetic marker, but with a more representative number of samples from the Atlantic basin and the western Indian Ocean. The results of this study coincide with those of Trejo (2005), demonstrating a lack of population structure between the different areas sampled, or even between the Atlantic and western Indian Ocean.

### 5.b. Description of the fisheries

*A. superciliosus* is caught throughout practically its whole distribution range in the Atlantic (Fernandez-Carvalho *et al.*, 2015a), including the United States (Stillwell and Casey, 1976; Beerkircher *et al.*, 2002; Lynch *et al.*, 2018), the Gulf of Mexico and the Caribbean Sea (Arocha *et al.*, 2002; Cortés *et al.*, 2007; Tavares and Arocha, 2008; Ruiz-Abierno *et al.*, 2021), Brazil (Amorim *et al.*, 1998, 2002; Mourato *et al.*, 2008), Uruguay (Berrondo *et al.*, 2007; Forselledo and Domingo, 2015), South Africa (Compagno and Smale, 1986; Basson *et al.*, 2007; Petersen *et al.*, 2008), the Gulf of Guinea (Castro and Mejuto, 1995; Fernandez-Carvalho *et al.*, 2011), North Africa (Buencuerpo *et al.*, 1998; Fernandez-Carvalho *et al.*, 2011; Seidu *et al.*, 2022), the Iberian Peninsula (Moreno and Morón, 1992; Buencuerpo *et al.*, 1998), the Mediterranean Sea (Megalofonou *et al.*, 2005a,b; Clo *et al.*, 2009) and the British Isles (Thorpe, 1997). This species is caught by different fishing methods such as trawl and drift net, gillnets, rod and reel, and bottom-set longline, but it is mainly taken as bycatch by pelagic longline fleets (Compagno, 2001; Rigby *et al.*, 2009) targeting tunas (Scombridae) and billfishes (Xiphidae and Istiophoridae). Thresher sharks (*A. pelagicus*, *A. superciliosus* and *A. vulpinus*) are traded internationally for their meat, skin and fins (Camhi *et al.*, 2008; Dent and Clarke, 2015).

In the longline fishery, catches of *A. superciliosus* vary between regions, but rarely constitute a substantial proportion of the total shark catch. In Venezuela, this species represents 2.2% of the total shark catch of the Venezuelan longline fleet between 1994 and 2000 (Arocha *et al.*, 2002). In Southeast Brazil, *A. superciliosus* constituted more than 5% of the total shark catch of the Santos longline fleet between 1974 and 1997 (Amorim *et al.*, 1998). Within the Uruguayan Exclusive Economic Zone, and based on information obtained through the Observers Programme, this species represented less than 0.2% of total shark catch of the pelagic longline fleet between 1998 and 2009 (Mas, 2012). Between 1998 and 2005, 0.3% of the total shark catch of the South African longline fleet comprised *A. superciliosus* (Petersen *et al.*, 2008) while the species accounted for 3.6% of the Chinese Taipei fleet's total shark catch taken between 5°N and 15°S from 1999 to 2003. In the United States, this species represented 1.6% of total catch of the pelagic longline fleet between 1981 and 1983 (Berkeley and Campos, 1988) and 1.8% between 1992 and 2000 (Beerkircher *et al.*, 2002). In Northeast Cuba, *A. superciliosus* was the sixth most caught shark species by artisanal longline, accounting for 6% of all sharks caught between 2011 and 2019 (Ruiz-Abierno *et al.*, 2021). Matsunaga and Yokawa (2013) analysed shark catch taken by the Japanese tuna fleet between 1992 and 2006 in the Pacific Ocean. *Alopias superciliosus* was the second most frequent shark species caught by this fleet, only behind *Prionace glauca*, accounting for 10.9% of total shark catch. These results are in contrast to previous findings regarding several surface longline fleets, but are consistent with the species' habits and the deep-setting longlines used by the Japanese fleet. Based on information collected by archival satellite tags, Coelho *et al.* (2015) concluded that the vertical distribution of juveniles and adults of this species overlaps with the operative depth of the Portuguese longline fleet at night, while they occupy deeper layers out of reach of the fleet during the day. The data collected indicate a vertical overlap with this fishing gear of between 56 and 60% for juveniles and 25 to 34% for adults. This study clearly shows that this species' susceptibility to being taken by longline fleets not only depends on the size of individuals, but also on the time of day.

### 5.c. Stock status

In general, pelagic sharks, including *A. superciliosus*, tend to use their energy initially in somatic growth, delaying sexual maturity and living longer than small coastal sharks. In addition, they grow at a faster rate, reach maturity earlier and live shorter than the large coastal species (Cortés, 2000, 2002; Smith *et al.*, 2008). In particular, *A. superciliosus* is considered to be one of the least productive pelagic shark species and has similar life history characteristics to large coastal sharks (Cortés, 2008; Smith *et al.*, 2008). To date, there are no stock assessments for this species in waters of the Atlantic Ocean. However, in an Ecological Risk Assessment carried out by Cortés *et al.* (2015), *A. superciliosus* was identified as one of the least productive pelagic species and the most vulnerable to longline fishing in the Atlantic, followed by *Isurus paucus*, *Isurus oxyrinchus* and *Lamna nasus*. These authors mentioned the need to increase biologic knowledge of *A. superciliosus* to enable a more robust assessment of its productivity. Given this reality, the fact that the species is essentially caught over the whole spectrum of age and size classes by various fishing modalities and that the magnitude of unreported catches in uncertain to date, it is prudent to consider that this species is fully exploited or even overexploited globally (Maguire *et al.*, 2006).

In the Northwest Atlantic, Baum *et al.* (2003) reported a massive decrease in the abundance of many shark species compared to levels prior to the expansion of industrial fishing, indicating a reduction of approximately 80% for thresher sharks (*A. superciliosus* and *A. vulpinus* combined). Although these results have caused great controversy (e.g. Burgess *et al.*, 2005a, b; Maunder *et al.*, 2006), there is a consensus that the abundance of many shark species has fallen to a greater or lesser extent compared to previous levels (e.g. Cortés *et al.*, 2007). Mourato *et al.* (2008) standardise the time series of *A. superciliosus* CPUE between 1978 and 2006 based on the pelagic longline fisheries of South Brazil, and concluded that fishing had only caused a slight decrease in the CPUE over the course of this time series. In the Northwest Atlantic, Cortes *et al.* (2007) reported that the CPUE of *A. superciliosus* appeared to have stabilised and even slightly increased between the late 1990s and 2005, depending on the source of the data used. A more recent study performed in the same region reports a sustained decrease in catches of the U.S. longline fleet from the early 1990s, followed by an apparent increase from 2000 to 2005, to then follow a downwards trend until the end of the period analysed in 2013 (Lynch *et al.*, 2018). More recently, Pacoureaux *et al.* (2021) analysed abundance trends for 18 pelagic chondrichthyan species. According to the authors, global abundance of these pelagic species would have decreased by 46.1% in the Atlantic Ocean, 67.0% in the Pacific Ocean, and 84.7% in the Indian Ocean between the 1970s and 2018. At the global level, the estimations of Pacoureaux *et al.* (2021) indicate a 65% decrease in the relative abundance of *A. superciliosus*.

Globally, *A. superciliosus* is classified as “Vulnerable” in the International Union for Conservation of Nature’s red lists (IUCN; Rigby *et al.*, 2009). More local assessments have classified the species as “Endangered” for the Mediterranean Sea and Northeast Atlantic (Walls and Soldo, 2015, 2016). In accordance with the [Recommendation by ICCAT on the conservation of thresher sharks caught in association with fisheries in the ICCAT Convention area \(Rec. 09-07\)](#), it is prohibited to retain onboard or subsequently sell any part of *A. superciliosus*, with the exception of some small-scale Mexican fisheries with a catch below 110 individuals. In U.S. waters of the Atlantic, the retention and sale of *A. superciliosus* has been prohibited since 2000 under the “Fishery Management Plan of the Atlantic tunas, swordfish and sharks” (NMFS 2010).

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