

RESEARCH ARTICLE

**Exploring a possible nursery ground of white shark
(*Carcharodon carcharias*) in Edremit Bay (northeastern
Aegean Sea, Turkey)**

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Abstract

Between 1 July 2008 and 14 April 2018, five young-of-the-year (YOY) (TL range 85-175 cm) and six juvenile (TL range 180-300 cm) white sharks (*Carcharodon carcharias*) were caught off the Turkish coast of the Aegean Sea. The mean length \pm standard deviation of YOY and juvenile white sharks were 138.1 ± 34 cm and 206.6 ± 46 cm, respectively. The YOY white sharks were caught only in Edremit Bay and juveniles were captured in several localities outside of the mentioned region. Based on the findings of previous studies, it is suggested that Edremit Bay may serve as a nursery ground for *C. carcharias* in the northern Aegean Sea and the surrounding insular marine area outside of the bay waters, may serve as a growing and feeding ground for juveniles until maturity. The white shark population in the Mediterranean may be considered at greater risk of local extirpations than previously thought, and effective management of Edremit Bay as a nursery ground is crucial regarding the overall survival of white sharks in the Mediterranean.

Keywords: Nursery ground, white shark, *Carcharodon carcharias*, Aegean, conservation, survival

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Introduction

Nursery areas, which have been recognized as a concept in the scientific literature for nearly a century, are widely considered to be essential habitats for sharks (Heithaus 2007; Heupel *et al.* 2007). Since shark nurseries have been defined as essential habitats for breeding of a given shark species (Heithaus 2007), the development of appropriate management for nursery areas relies on the ability to

accurately identify those areas that are of greatest importance (Heupel *et al.* 2007).

White shark, *Carcharodon carcharias* (Linnaeus, 1758), is one of the four species of the family Lamnidae, occurring in the Mediterranean Sea. It is an epipelagic shark, inhabiting coastal and off shore waters, from surface down to a depth of 1300 m (Serena 2005). Its distribution range includes the whole Mediterranean, but currently absent in the Marmara and Black Seas (De Maddalena and Heim 2012; Kabasakal 2014). Global distribution of *C. carcharias* extends in temperate oceans of both hemispheres, and rarely found in tropical waters (Serena 2005). White sharks can be defined as ‘nomads’ of the oceans, because of their two-year long-distance migrations between widely separated nursery areas (Domeier and Nasby-Lucas 2013). Male and female white sharks are known to have site fidelity, which is termed as ‘philopatry’ (Domeier and Nasby-Lucas 2013; Gubili *et al.* 2010), which means that adults will return to the areas for breeding, where they were born.

In the recent Red List assessment by Rigby *et al.* (2019), global conservation status of *C. carcharias* was evaluated as vulnerable; however, according to Dulvy *et al.* (2016) and Otero *et al.* (2019), *C. carcharias* is critically endangered in the Mediterranean Sea. Therefore, effective management of its nursery grounds is crucial for the survival of the species in the Mediterranean, where it has little or no contemporary immigration from the Atlantic (Gubili *et al.* 2010). Due to the occurrence of young-of-the-year (YOY) and pregnant female white sharks, Tunisian and Sicilian neritic waters have been historically and contemporarily considered as the main nursery area of *C. carcharias* in the Mediterranean Sea (Boldrocchi *et al.* 2017; Bradai *et al.* 2012; De Maddalena and Heim 2012; Fergusson 1996; Saidi *et al.* 2005). According to Boldrocchi *et al.* (2017), between the second half of the 19th and the beginning of the 20th century, Sibenik Bay and the nearby Kvarner Gulf area might also serve as a nursery ground for *C. carcharias*.

Following the incidental captures of two newborn specimens in Edremit Bay (Figure 1), in early July 2008 (Kabasakal and Gedikoğlu 2008), three more YOY white sharks were also incidentally captured in the same area (Kabasakal 2014; Kabasakal *et al.* 2018). Occurrence of five YOY specimens in a close vicinity in different years suggests that Edremit Bay may serve as a nursery area for *C. carcharias* in the northern Aegean Sea. Since appropriate management of nursery areas relies on accurate identification and mapping of these essential habitats (Heupel *et al.* 2007), it is crucial to determine the approximate boundaries of this possible nursery ground in Edremit Bay. In the present study, based on available data, attempts to draw a preliminary map of this nursery ground are made, and the implications of commercial fisheries, continuing in the same region are discussed.

Materials and Methods

Study Area

The Aegean Sea is topographically divided into two basins by (approximately) the 38° parallel, *i.e.* into the north and south Aegean (Papaconstantinou 1992). Mean monthly sea surface temperatures vary from 8°C in the north during winter, up to 26°C in the south during summer (Poulos *et al.* 1997). The Aegean archipelago is a typical archipelago of continental islands, which are forming groups of minor islands in wide marine space (Türküstün 2015).

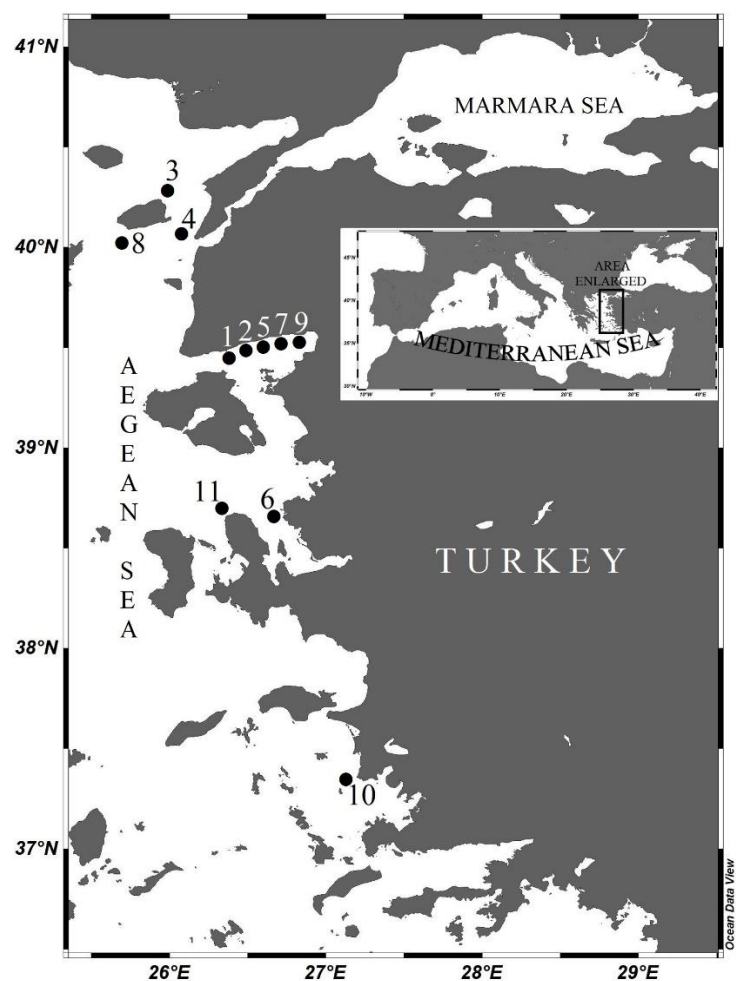


Figure 1. Map showing the capture localities of YOY and juvenile white sharks, off Turkish coast of Aegean Sea. Numbers are same with those in Table 1.

Data Collection

Since the white shark is a critically endangered species and protected in certain parts of the Mediterranean (Otero *et al.* 2019; Serena 2005), the selection of an appropriate sampling method for the present study was an instance of typical opportunistic research, consisting in dead animal sampling (Jessup 2003). A regular screening of scientific literature, social media, local newspaper - both printed and online - provided information on the YOY and juvenile white sharks, incidentally captured off Turkish coast of Aegean Sea (Figure 1). Nine out of 11 white sharks were previously published and relevant information of these specimens were extracted from Kabasakal (2014), Kabasakal and Gedikoğlu (2008), Kabasakal and Kabasakal (2015), and Kabasakal *et al.* (2009, 2018). Two specimens are new records (Table 1). Capture data (type of fishing gears, date and locality of captures, total length (TL) in cm and weight (W) in kg) were recorded for new specimens. Age distribution of YOY and juvenile white sharks was assessed using the following length categories (Boldrocchi *et al.* 2017): YOY (≤ 1.75 m TL) and juvenile (> 1.75 -3.0 m TL).

Results and Discussion

Between 1 July 2008 and 14 April 2018, five YOY (TL 85-175 cm) and six juvenile (TL 180-300 cm) white sharks were caught off Turkish coast of Aegean Sea (Figure 1). These specimens are depicted on Figures 2 and 3, and relevant information are presented in Table 1. The mean length \pm standard deviation of YOY and juvenile white sharks were 138.1 ± 34 cm and 206.6 ± 46 cm, respectively. YOY white sharks (specimens 1, 2, 5, 7 and 9) were caught only in Edremit Bay and juveniles were captured in several localities outside of the bay (Gökçeada, specimens 3 and 8; Çanakkale, specimen 4; Yeni Foça, specimen 6; Karaburun, specimen 11; and Didim, specimen 10; Table 1; Figure 1). One of the YOY white sharks (specimen 5) was released alive (Figure 3). Two specimens (18.1%) were captured in purse-seining fishery, and eight specimens (72.7%) were incidentally captured by artisanal fishermen deploying coastal stationary-, gill- or trammel-nets, and one specimen (9.09%) was captured by means of a bottom-trawler. Thus, nearly 82 % (n=9) of the YOY and juvenile white sharks were captured in demersal fisheries.

Umbilical scars were seen in three newborns (specimens 1, 2 and 5; Figure 4), which were captured in early July (Table 1), and other two YOY white sharks were captured in January and April. Juvenile white sharks were captured in April (n=2), June (n=1), September (n=1), January (n=1) and February (n=1) (Table 1). Most of the young white sharks were recorded in spring and summer months.

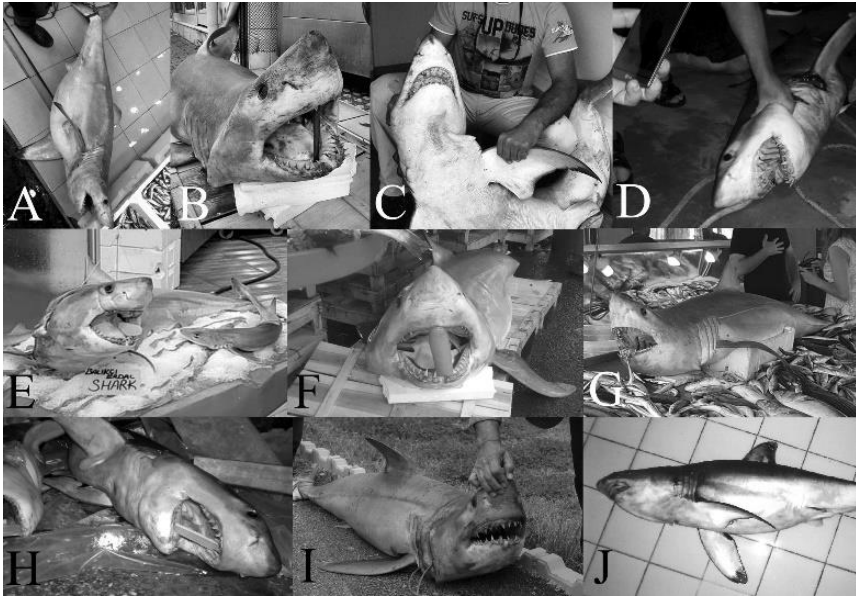


Figure 2. YOY and juvenile white sharks examined in the present study. (A) specimen 7; (B) specimen 4; (C) specimen 6; (D) specimen 10; (E) specimen 9; (F) specimen 8; (G) specimen 11; (H) specimen 1; (I) specimen 3; and (J) specimen 2. Specimen numbers are same with the numbers accompanying the bold dots (●) seen on Figure 1. Capture details of the specimens are presented on Table 1.

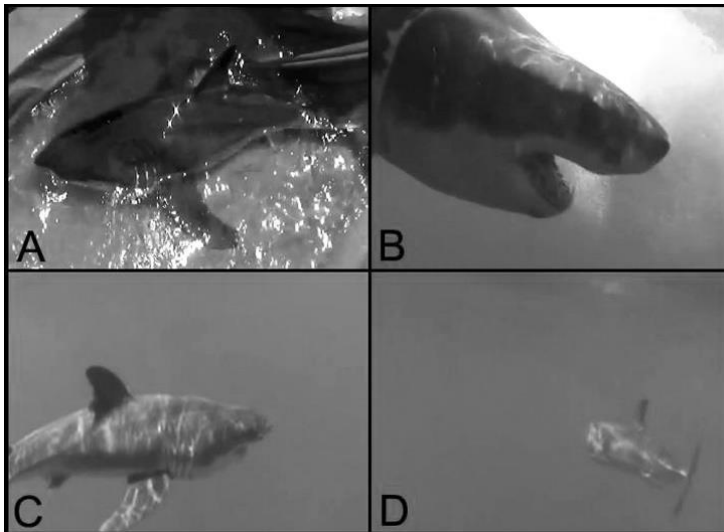


Figure 3. Captured images from the video of releasing a YOY white shark (specimen 5 in Table 1, Figure 1), off the coast of Altınoluk (Video footage: Cenk Balkan).

Table 1. Capture data and relevant references of YOY and juvenile white sharks examined in the present study

No*	Date	Locality	TL (cm)	W (kg)	Gear	References
1	1 July 2008	Altınoluk	125,5	-	Gill-net	Kabasakal and Gedikoğlu (2008)
2	4 July 2008	Altınoluk	145	-	Gill-net	Kabasakal and Gedikoğlu (2008)
3	21 Feb. 2009	Gökçeada	180	47.5	Bottom-trawl	Kabasakal <i>et al.</i> (2009)
4	15 April 2009	Çanakkale	300	102	Purse-seine	Kabasakal <i>et al.</i> (2009)
5	6 July 2011	Altınoluk	85	-	Trammel-net	Kabasakal (2014)
6	19 Sept. 2014	Yeni Foça	200	40	Stationary-net	Kabasakal and Kabasakal (2015)
7	2 January 2016	Altınoluk	175	-	Stationary-net	Kabasakal <i>et al.</i> (2018)
8	January 2017	Gökçeada	180	-	Stationary-net	This study
9	April 2017	Altınoluk	160	-	Gill-net	This study
10	4 June 2017	Didim	200	60	Purse-seiner	Kabasakal <i>et al.</i> (2018)
11	14 April 2018	Karaburun	180	-	Stationary-net	Kabasakal <i>et al.</i> (2018)

*Numbers seen in 'No' column are same with the numbers in Figure 1.

In a recent study on distribution, ecology and status of the white shark in the Mediterranean Sea, Boldrocchi *et al.* (2017) reported on the captures of 29 YOYs in several locations, including the Aegean Sea where six out of 29 Mediterranean YOYs were captured. Furthermore, Boldrocchi *et al.* (2017) stated that juvenile white sharks have been recorded in all regions of the Mediterranean, except in the Marmara Sea. Available data on the occurrence of *C. carcharias* in Turkish waters reveal that YOY or juvenile white sharks have not been historically or contemporarily occurred in the Marmara Sea (Kabasakal 2003, 2014). Movements of white sharks in the Mediterranean Sea is closely associated with the migrations of the bluefin tuna, *Thunnus thynnus* (Linnaeus, 1758) (De Maddalena and Heim 2012). Majority of the historical catch records of *C. carcharias* in the Marmara Sea consisted of adult specimens (≥ 450 cm TL), which have been the bycatch of tuna handliners (Kabasakal 2003, 2016). Presently it can only be speculated that the Marmara Sea might have served as a historical feeding ground for adult white sharks. The mean length of YOYs recorded in several parts of the Mediterranean Sea ranged from 104 ± 24.9 cm (Aegean Sea) to 151 ± 14.1 cm (Sicilian Channel) (Boldrocchi *et al.* 2017). With the addition of recent captures of specimens with TL 160 and 175 cm (specimens 7 and 9), however, mean TL of YOYs in the Aegean Sea should be updated as 138.1 ± 34 cm.

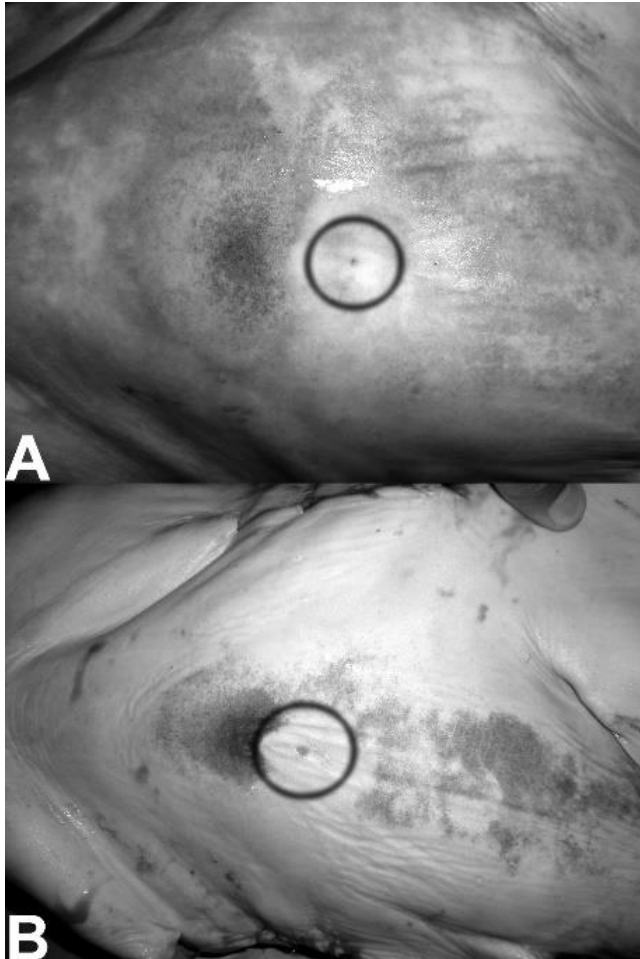


Figure 4. Umbilical scars (birth marks) on the ventral surfaces of neonates; (A) specimen 1, and (B) specimen 2 in Table 1.

The seasonality of occurrence of YOYs and juveniles in the Turkish Aegean Sea well coincides with the seasonality data presented by Boldrocchi *et al.* (2017), Santana-Morales *et al.* (2012), De Maddalena and Heim (2012), and White *et al.* (2019), who reported a close affinity of the high numbers of occurrences with the warmer months of the year. According to Boldrocchi *et al.* (2017) and De Maddalane and Heim (2012), YOYs were captured in spring and summer months in the Mediterranean. In the present study, four out of five YOYs were captured in summer (early July, specimens 1, 2 and 5) and mid-spring (April, specimen 9), and one YOY was captured in winter (January, specimen 7) (Table 1). Total length of the specimen 7 YOY was 175 cm, when it was captured in January, and at that time no birth mark (umbilical scar) was seen. Thus, it can be supposed that,

the specimen 7 was born in the preceeding summer, and remained in Edremit Bay nursery ground for further growing. According to Santana-Morales *et al.* (2012), the umbilical scar was still visible in the white shark specimens of 150 and 163 cm TL.

Although juvenile white sharks are known to frequent inshore water (Harasti *et al.* 2017), they are also known to travel for relatively long distances beyond the perimeters of their nurseries (see eg. Bruce *et al.* 2019; Weng *et al.* 2007). Weng *et al.* (2007) reported on a YOY, which moved 700 km away from its nursery between late September and mid October. In a recent survey dealing with the broad-scale movements of juvenile white sharks in eastern Australia, Bruce *et al.* (2019) found that juveniles can travel for 1800 km, crossing from Bass Strait to New Zealand. Southward and northward occurrences of juveniles in remote regions outside of Edremit Bay nursery were also observed (Figure 1). In the northward of Edremit Bay, three juveniles were captured off Çanakkale and Gökçeada coasts (specimens 3, 4 and 8), and in the southward, two juveniles (specimens 6 and 11) were captured off İzmir coast, and one juvenile (specimen 10) was captured off Didim coast. As it is clearly seen on Figure 1, Aegean seabord of Turkey has a peninsular coastline and assuming that specimen 11 was born in Edremit Bay, then it should have been travelled more than 500 km before it was captured off Didim. For the moment, on the basis of available data, it is not possible to answer the question, whether specimen 11 was born in Edremit Bay or in another unidentified nursery in the southern Aegean Sea. Despite the uncertainties about the provenance of specimen 11, it had enough potential for travelling from Edremit Bay to Didim, as suggested by the movement data of juveniles given by Bruce *et al.* (2019) and Weng *et al.* (2007).

Offshore and coastal islands appear to offer several advantages to YOYs and juveniles, as revealed, for example, by the studies of Curtis *et al.* (2018), Hoyos-Padilla *et al.* (2016) and Klimley (1985). The preference for coastal and insular water of the YOY and juvenile white sharks is reflected by the relatively shallow depths at which these sharks were captured in the present study. Depth of the bottom where the juvenile white sharks were captured was less than 150 m and YOYs were captured in water as shallow as 10 m. As suggested by Hoyos-Padilla *et al.* (2016), insular marine areas provides juvenile white sharks with an opportunity to start their first offshore migrations, probably for feeding on demersal prey and then coming back to their nursery grounds to avoid predators. From this perspective, Edremit Bay nursery ground, which is surrounded by offshore and coastal islands, provides a habitat for growing juveniles to gain experience of movement between offshore islands and nearshore before departing for long-distance migrations. Hoyos-Padilla *et al.* (2016) found that tagged juvenile white sharks remained near Guadalupe Island for 12 to 14 months before departing distant regions.

Throughout its global distribution range, survival of young white sharks is threatened by the pressure of coastal artisanal fisheries with stationary nets, such as gill-net or trammel-net fishery (Klimley 1985; Santana-Morales *et al.* 2012). According to Santana-Morales *et al.* (2012), highest incidental captures of juvenile white sharks were recorded in the artisanal bottom-set gill-nets, with nearly 75% of sharks caught using this fishing gear in western Baja California (Mexico). Curtis *et al.* (2018) also stated that bycatch of juvenile and YOY white sharks in the New York Bight (western north Atlantic) occurs in gill-net fishery. In an extensive research on the interactions of juvenile white sharks with gill-net fishery, Lyons *et al.* (2013) reported that gill-net fishery is significantly and positively correlated with the incidence of white shark captures. In the present study, nearly 73% (8 out of 11) of white sharks were incidentally captured by bottom-set nets, including stationary- (36.3%), gill- (27.2%) and trammel-nets (9.09%). The addition of one specimen (9.09%), which was captured by a bottom-trawler, reveals that nearly 82% (9 out of 11) of juveniles and YOYs of the present study were captured in demersal fisheries (Table 1).

Previous studies revealed that, juvenile white sharks feed primarily on bottom dwelling fishes (White *et al.* 2019), and nursery grounds in their coastal habitats may overlap with areas highly impacted by fisheries (Boldrocchi *et al.* 2017). According to Domeier and Nasby-Lucas (2013), YOY and juvenile white sharks do not have the mass and strength for breaking through most commercial fishing gear, thus they represent the most vulnerable stage of *C. carcharias*.

In conclusion, based on incidental captures of YOY white sharks between 2008 and 2018, it is suggested that Edremit Bay may serve as a nursery ground for *C. carcharias*, in the northern Aegean Sea, and the surrounding insular marine area from northward to southward outside of bay waters, may serve as a growing and feeding ground for juveniles until maturity. Since juvenile fish abundance in nursery areas, including YOYs, may provide an estimate of recruitment trends (Harasti *et al.* 2016), an extensive in situ survey with nondestructive methods is required to investigate the habitat use, site fidelity, relative abundance, seasonal occurrence and movements of YOY and juvenile white sharks, occurred in the Edremit Bay and surrounding marine area. Since the white shark is critically endangered in the Mediterranean Sea (Otero *et al.* 2019), the use of stereo-BRUVs (Baited Remote Underwater Video) may provide a viable and nondestructive method to obtain estimates of the size and presence of white sharks, as proposed by Harasti *et al.* (2016). Based on available genetic data (Gubili *et al.* 2010), Mediterranean white shark population may be considered at greater risk of local extirpations than previously thought, and effective management of Edremit Bay as a possible nursery ground is crucial regarding the overall survival of Mediterranean white sharks.

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Edremit Körfezi'nde (kuzeydoğu Ege Denizi) büyük beyaz köpekbalığının (*Carcharodon carcharias*) olası üreme alanı

Öz

1 Temmuz 2008 ve 14 Nisan 2018 tarihleri arasında, Ege Denizi'nin Türkiye kıyılarında 5 tane yenidoğan (TB aralığı 85-175 cm) ve 6 tane juvenil (TB aralığı 180-300 cm) büyük beyaz köpekbalığı yakalanmıştır. Yenidoğan ve juvenil büyük beyaz köpekbalıklarının ortalama tam boyları (TB), sırasıyla, 138.1±34 cm ve 206.6±46 cm'dir. Yenidoğanlar sadece Edremit Körfezi'nde yakalandıkları halde, juveniller körfez dışında kalan farklı ve körfeze uzak bölgelerde yakalanmışlardır. Eldeki veriler, Edremit Körfezi'nin kuzey Ege Denizi'nde *C. carcharias*'ın üreme alanı olduğunu akla getirmektedir. Ayrıca, körfezin yakın ve uzak çevresindeki adaları kuşatan deniz alanları, görünüşe göre juvenil büyük beyaz köpekbalıklarına olgunluğa erişinceye kadar beslenme ve gelişme alanı sağlamaktadır. Akdeniz'de büyük beyaz köpekbalığı popülasyonunun karşı karşıya olduğu yok olma riski düşünüldüğünden daha fazla olabilir. Bu bakımdan, Edremit Körfezi'ndeki üreme alanında etkin bir yönetim planı uygulanması, Akdeniz'de büyük beyaz köpekbalıklarının genel sağkalımları açısından kritik önemdedir.

Anahtar kelimeler: Üreme alanı, büyük beyaz köpekbalığı, *Carcharodon carcharias*, Ege Denizi, koruma, sağkallım

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