

Article



# Identifying Potential Critical Angel Shark Areas in Türkiye, Eastern Mediterranean Based on New Records of *Squatina* spp. Identified through Fisher Engagement

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Abstract: This study presents new records of three Critically Endangered angel shark species (Family: Squatinidae) occurring in the Eastern Mediterranean—Smoothback Angelshark S. oculata Bonaye, 1840, Sawback Angelshark S. aculeata Cuvier, 1829, and Angelshark S. squatina (Linnaeus, 1758). The supporting data serves to highlight three potential Critical Angel Shark Areas (CASAs) in Türkiye: Fethiye Bay, Çanakkale Strait (i.e., Dardanelles), and Antalya Bay. These data also demonstrate that female S. oculata may mature at a smaller size than prior published estimates of length at first maturity. This new dataset provides details of 23 S. squatina specimens, 52 S. oculata specimens, and 5 S. aculeata specimens, totalling 80 recent angel shark specimens found in Turkish waters mostly sent to us from small-scale fishers who had incidentally caught angel sharks. Also presented are four capture-induced parturition events in Turkish waters onboard fishing vessels, thus providing details on internal yolk sacs, reproductive habitats, and indications of spawning season. Our dataset presented here spans from 2018 to 2023 and suggests that mature adults of S. squatina and S. oculata still occur in Turkish waters, in Fethiye Bay and Çanakkale, respectively. Due to elevated chances of fishers encountering Critically Endangered angel sharks in Türkiye, we suggest that fishers are trained in handling and safe-release methods, to ensure reduced incidents of capture-induced parturition, and improved post-release survival. This study demonstrates that bottom set nets set by small-scale fishers pose less risk to mortality for angel sharks as they are almost always encountered alive after a usual 12 h soak time, suggesting that bottom trawling in critical habitats should be better regulated (or phased out) to help improve national angel shark conservation initiatives.

**Keywords:** Critical Angel Shark Areas (CASAs); Eastern Mediterranean Sea; elasmobranch; reproduction; Important Shark and Ray Areas (ISRAs); Squatinidae; capture induced parturition

**Key Contribution:** Angel shark populations are facing considerable range restrictions in the Mediterranean Sea. Here, we provide evidence for three potential new Critical Angel Shark Areas (CASAs) in Türkiye based on preliminary findings.

## 1. Introduction

Shark and ray populations are rapidly declining globally, with an estimated onethird of all Chondrichthyan species now threatened as a consequence of overfishing [1]. Declines are even more pronounced in the Mediterranean Sea, where between 1985 and 2015, the number of threatened elasmobranchs increased from nearly half of all species to two-thirds [2]. While many species are classified within a threat category on the International Union for the Conservation of Nature's (IUCN) Red List of Threatened Species (www.iucnredlist.org, accessed on 22 October 2023), their classifications on these lists do not



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**Copyright:** © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). provide for their direct protection. Despite regional prohibitions, angel sharks are caught and retained for sale or local consumption in countries which have failed to implement protection at the national level.

Angel sharks (Family: Squatinidae) are amongst the most threatened families of elasmobranchs globally (given substantial population declines and range restrictions), along with the sawfishes (Family: Pristidae), giant guitarfishes (Family: Glaucostegidae), and wedgefishes (Family: Rhinidae) [1,3–5]. The species within these families share similar benthic ecologies and traits (including being large, dorso-ventrally flattened coastal species) that make them vulnerable to capture in demersal fishing gear, particularly bottom trawls and bottom set gillnets [5]. Angel sharks are demersal "lie-and-wait" ambush predators [5,6]. Their broad pectoral fins enable them to bury themselves in soft sediment, where they can remain hidden, before extruding their trap-like jaws to catch unsuspecting prey that may swim by [6]. As ambush predators, this implies a low oxygen requirement [7,8] and they appear to be able to survive for a number of hours when entangled in fishing nets, as reported to the first author by several artisanal fishers, unlike ram-ventilated sharks that need to swim constantly to breathe.

Angel sharks exhibit sexual dimorphism (the females grow to be larger than the males), are aplacental, lecithotrophic, viviparous species, i.e., they give birth to live young that are solely nourished via yolk sacs, which first are externally attached to the embryos, then internally absorbed by the embryos before birth [9]. Studies on their reproduction are rare, but it is generally thought that they have a long population generation time as they mature late and produce few young every one to two years [5].

There are now 24 accepted valid species of angel sharks inhabiting tropical and temperate seas [10–13]. Of these described species, over half (n = 13) are listed in a threat category on the IUCN Red List (eight Critically Endangered, four Endangered, and one Vulnerable, www.iucnredlist.org (accessed on 23 October 2023), https://www.iucnssg. org/angelsharks-strategy.html (accessed on 23 October 2023), while one remains Data Deficient and two more recently discovered species are Not Evaluated. Many of these species have overlapping ranges and can be challenging to distinguish due to similarities in morphology [5]. Three species occur in the Mediterranean Sea—the Sawback Angelshark Squatina aculeata Cuvier, 1829, Smoothback Angelshark Squatina oculata Bonaparte, 1840, and Angelshark Squatina squatina (Linnaeus, 1758). These three species were reassessed in 2017 and all retained their Critically Endangered status on the IUCN Red List, indicating a high risk of extinction in the wild. Based on historical declines, suspected declines in the extent of occurrence and area of occupancy, and the contemporary rarity of these species, it is suspected that population reductions of at least 80% (but likely closer to 90%) have occurred over the past three generations [14–16]. The Squatinidae family is highly vulnerable to population declines owing to its low fecundity, late maturation, and sedentary lifestyle making them especially prone to demersal fishing activities [12].

## 1.1. Regional and National Conservation Strategies

The three Mediterranean *Squatina* species are listed as Critically Endangered species under IUCN's Redlist [17–19], and listed on the General Fisheries Commission for the Mediterranean (GFCM) binding Recommendation GFCM/42/2018/2 (https://www.fao. org/gfcm/decisions/en/, accessed on 23 October 2023), amending GFCM/36/2012/3. This was recast in 2023 in ELI: http://data.europa.eu/eli/reg/2023/2124/, accessed on 23 October 2023). This recommendation prohibits the retention, landing and sale of 24 elasmobranch species listed in Annex II of the Barcelona Convention. The European Union transposed GFCM/36/2012/3 into EU law in 2015: EU 2015/2102 (https://www.fao.org/faolex/results/details/en/c/LEX-FAOC150974/, accessed on 23 October 2023), strengthening the protection for Mediterranean angel sharks. While the GFCM Shark measure has not been fully transposed into law in Turkish waters, all three *Squatina* species are protected under the National Fisheries Law (Communiqué 2016/35), which was updated in 2018 to include angel sharks, among other vulnerable species, and places

angel sharks under Article 5 of the Turkish Prohibited Species list, prohibiting targeting, retention, and sale [20].

Since 2017, the Angelshark *Squatina squatina* has been listed in Appendix I and II of the Convention on the Conservation of Migratory Species (CMS), and Annex I of the CMS Memorandum of Understanding on the Conservation of Migratory Species (CMS Sharks MoU). In 2024, a Single Species Action Plan was adopted by CMS for *Squatina squatina* in the Mediterranean (https://www.cms.int/sites/default/files/document/cms\_cop14\_doc.27.7.1\_ssap-angelshark-med\_e.pdf, accessed on 23 October 2023). These listings should stimulate full protection from the CMS Parties who are Range States. Türkiye is not, however, a Party to CMS or the CMS Sharks MoU.

The Mediterranean Angel Sharks: Regional Action Plan [6] was developed to focus efforts to help restore angel sharks in the region to robust populations. It calls for stakeholders to work together to address the challenges faced by these Critically Endangered species. The threats, goals, and objectives specific to the Mediterranean were later used as a basis for the development of more localised SubRegional Action Plans covering Türkiye (GFCM Geographical Subarea (GSA) 22 for the Aegean Sea, GSA 23 for Crete in collaboration with Greek partners, and GSA 24 for the Northern Levant Sea). The objective is to protect, conserve, and rebuild angel shark populations using a tailored approach [6,21]. This study was performed within the framework of these SubRegional Action Plans [21–23].

Understanding the habitat preferences of the two lesser-studied angel shark species (the Smoothback Angelshark *Squatina oculata* and the Sawback Angelshark *Squatina aculaeta*) in the Mediterranean is vital for their survival [24]. The first step is identifying their Critical Angel Shark Areas (CASAs). CASAs are defined as "An area that contains essential features necessary for the conservation of angel sharks. This may include an area that is not currently occupied by the species that will be needed for its recovery or conservation e.g., Nursery, mating, aggregation and foraging areas [25–27]". Particularly, where known, their critical habitats should be defined and mapped, enabling the identification of CASAs.

In 2023, the IUCN Shark Specialist Group launched a new initiative to identify Important Shark and Ray Areas (ISRAs) using an expert-driven innovative approach (sharkrayareas.org, accessed on 23 October 2023). This was in response to the global crisis facing elasmobranchs, as they are now the second most threatened taxon in the marine realm. This new project is evidence-based and delineates areas that are critical for the survival of vulnerable sharks and rays. Although these areas are not destined for stand-alone protection through their creation, they can serve to support and improve local, regional, and national conservation and management strategies.

#### 1.2. Range Restriction and Rarity of Angel Shark Data

A recent study that compiled angel shark records from across the Mediterranean using a variety of data sources from 2005 to 2022 revealed 34 *S. oculata* and 18 *S. aculeata* records in total [24]. A Mediterranean Trawl Survey from MEDITS that sampled the northern Mediterranean from 2012 to 2015 did not report any *S. oculata* and only found *S. aculeata* in the Aegean Sea [25]. Subsequent trawl surveys from 2016 to 2018 did not find any *S. aculeata* or *S. oculata* [26,27]. The Angel Shark Sightings Map (ASSM) collates global angel shark records (see https://angelsharksmap.zsl.org/, accessed on 23 October 2023). Both *S, oculata* and *S. aculeata* have mainly been reported from the Central Mediterranean (Tunisia, Croatia, Malta, and Italy), and Aegean Sea [9,24,25,28] in the Mediterranean, and also from Egypt [24].

Giovos et al. (2022) [29] made a predictive distribution map of the three angel shark species encountered in the Aegean Sea, based on a number of database records from Crete, Aegean Sea, and Marmara Sea (GSAs 22, 23 and 28) from 2000 to 2021. In total, over a 21-year period, this study revealed 64 angel shark records—23 *S. squatina*, 26 *S. aculeata*, and 10 *S. oculata*, plus 5 records which could only be identified to the Squatinidae family. Through this data, Critical Angel Shark Areas (CASAs) were mapped in the region through a systematic spatial conservation planning analysis using various predictors. Giovos

et al. (2021) [30] illustrated that *S. squatina*'s most suitable area based on prior records and habitat matching in the Turkish region of the Aegean Sea extends from the Izmir province to Marmara Sea in the north, whereas *S. oculata* and *S. aculeata* are more commonly encountered in Türkiye's southern Aegean Sea extending to the Antalya province. However, with all three species still occurring in Turkish waters, identification of Critical Angel Shark Areas (CASAs) offers a valuable opportunity to study their life-history traits and help aid their recovery within the Eastern Mediterranean basin.

Angel sharks have been reported in Turkish seas from the early 1900s [31–33], when they were seemingly common based on reported schooling behaviour [31], and they were even fished by harpoon during the 1960s–1970s. Angel sharks are the only shark family that were reported separately in the Turkish fisheries statistics, separating them from the Turkish 'dogfish' umbrella term accounting for all other sharks (TUIK 1967–2020). While common until the 1960s in Turkish waters (including Marmara, Aegean, and Levantine waters), there follows a sudden decline in their reported catch levels. A historical review of *S. squatina* records in Turkish waters [34] revealed that *S. squatina* was common in Marmara Sea up to the 1970s and used to be found in aggregations up until around 1975. Kabakasal [35] recorded a few specimens from the Western Black Sea in the late 1990s, but *S. squatina* has not been sighted there ever since. Interestingly, in southern Türkiye, *S. oculata* was not formally reported for 20 years until 2017 [36]. Angel sharks are considered rare in Turkish waters [37,38]. From the 2000s onwards, angel shark records [36–46] for all three species in Turkish waters average approximately one per year in peer-reviewed publications in Turkish waters.

The penalties for the targeted catch and retention of prohibited species generally increase each year in Türkiye, and in 2023 the penalty was equivalent to approximately USD 850 (https://tokat.tarimorman.gov.tr/Duyuru/467/Su-Urunleri-2023-Idari-Para-Cezalari, accessed on 23 October 2023). Due to these fines, fishers are unwilling to report any prohibited species. Thus, it is challenging to gather angel shark bycatch records from fishers. However, once fishers are aware that they are only liable for a fine if they transport or try to sell the fish, some can be motivated to share their bycatch records, albeit privately.

These records, presented here in some detail, contribute to improving the scant knowledge of the biology of angel sharks, in the hope that this additional knowledge may also help toward the delivery of conservation objectives of the Sub-Regional Action Plan aiding regional angel shark species recovery. Due to the scarcity of recent angel shark data in the Mediterranean, the data presented here, specifically from the parturition events and maximum lengths, was also used to improve knowledge of life history traits such as spawning season and length at first maturity of *S. oculata*, as these are important parameters for fisheries science and management.

This study improves the knowledge of angel sharks in Türkiye under the SubRegional Action Plan for the Aegean and Levantine Seas by publishing additional angel shark records, outlining four capture-induced parturition events detailed from 2023, three potential CASAs, a new ISRA in Türkiye based on *S. oculata*, and an update of the length of first maturity for *S. oculata*.

## 2. Materials and Methods

In 2023, a directed research study was developed in Türkiye focusing on angel shark conservation. This study aims to educate fishers about the critical status of angel shark populations, teach them the importance of safe handling, gather data on angel shark distribution and habitat usage, and identify Critical Angel Shark Areas in Türkiye. The identification of CASAs is based here on angel sharks' known habitat usage such as nursery, mating, aggregation, and foraging areas.

The data collection methods used here to gather angel shark records stem from a variety of sources to better inform the pattern of distribution. Many records were first collated through the Turkish Facebook Citizen Science Page: Sharks and Rays in Turkey which is managed by the first author (https://www.facebook.com/groups/sharksinTurkey,

accessed on 23 October 2023). Most verified records were gathered from local fishers, supplemented by a few online news portals, in which the published media allowed for species verification, from 2018 to 2023. Other records were collected by directed outreach campaigns to small-scale fishers encouraging their future reporting of angel shark sightings, notably from their incidental captures detailed below. Local fishery cooperative managers were also recruited to support the project by informing their local fishers about the study's aims and inviting local fishers to share their angel shark records. Historical angel shark sighting records from fisher surveys were not incorporated into the dataset since these did not have accompanying photographic or video evidence that could enable the verification of species, but the survey data was used to support the Local Ecological Knowledge (LEK) amassed by these fishers.

## 2.1. Angel Shark Species Identification

Identification of the three angel shark species was identified based on key diagnostic features as found in Ebert and Dando's Field Guide to Sharks, Rays & Chimearas of Europe and the Mediterranean [10], presented in Figure 1. Species-specific identification was generally completed by the first co-author in clear cases, and in unclear cases, two more angel shark experts aided in the identification. All the records presented in Table 1 were verified to species.

#### 2.2. Directed Outreach to Small-Scale Fishers

As an action of the Subregional Action Plans for Türkiye [22], between March and June 2023, approximately 120 local small-scale fishers from Muğla and Antalya provinces in Fethiye, Marmaris, Bozburun, Datça, Finike, and Antalya were informed of the status of protected elasmobranch species in the country, and particularly the Critically Endangered status of the three Mediterranean species of angel sharks and their regional range-restriction patterns. Fishers were shown how to prioritize the safe release of sharks and encouraged to report details of any incidental captures, leading to improved knowledge of the distribution of these species in the region. All records are summarised in the results. Of these 120 smallscale fishers, 98 of them were interviewed (March to July 2023) for their recent and historical interactions with angel sharks. The survey questions were aimed at gathering details on recent and historical catches of angel sharks, such as areas, depth, seasons, mean caught sizes, and number of individuals, as well as changes in the relative abundances of angel sharks encountered throughout the duration of their fishing career, ensuring traditional historical knowledge was captured (in Supplementary Materials). The study also encouraged the future reporting of angel shark catches by opening chat groups and social media channels for fishers to send in their photos and details of angel shark catches. Respondents were recruited through snowball sampling. The lead author and one smallscale fisher lead the interviews.

The majority of these records were provided by small-scale fishers. Small-scale fishers generally release angel sharks when they are caught alive, in line with Turkish law. These set-net fishers generally cast their bottom nets before sunset and retrieve them shortly after sunrise resulting in an 8–12 h soak time (depending on the season). However, local ecological fisher knowledge indicates that angel sharks in particular are predominantly alive when disentangled, with only extreme cases resulting in mortality when fishers have to leave their gear for longer durations due to mechanical issues or bad weather. All records presented here (aside from one parturition event from Bozburun) were verified to species using photographic or video documentation.



**Figure 1.** Scientific illustrations of the three angel shark species found in the Mediterranean. (A) *Squatina squatina*, (B) *Squatina oculata*, and (C) *Squatina aculeata*. Illustration credit: Marc Dando, scientific illustrator.

Four accounts are provided here of the capture-induced parturition of angel sharks in Türkiye in 2023, along with one record from Italy in 2021, to collate the recent Mediterranean records for improved knowledge. Measurements were taken for the gravid females (see Table 2 and Figure 4). Measurements for the pups were then estimated based on the known length of the gravid female. Due to the positioning of the pups in the photos, the sizes reported here are approximate. The initial measurements were calibrated using the online software program Eleif (https://eleif.net/photomeasure, accessed on 23 October 2023; Table 1).

#### 2.3. Length at First Maturity

Mean length at first maturity ( $L_m$ ), i.e., the length where 50% of iteroparous individuals in a fish population become mature, is strongly related to the maximal length attained by the oldest individuals in that population ( $L_{max}$ ), particularly when the different sizes that females and males can attain is taken into account [47–49]. However, the ratio  $L_m/L_{max}$ , often viewed as constant or 'invariant' [50], is not constant, as shown empirically by Froese and Binohlan [51] and Pauly [48]. Rather, what is constant among bony fish and a wide number of invertebrate taxa is the relationship [47,48]:

$$L_{\rm max}{}^{\rm D}/L_{\rm m}{}^{\rm D} \approx 1.35 \tag{1}$$

Here, the parameter D is defined by D = 3(1 - d), where d is the exponent of the relationship linking the area of the respiratory surface (S, e.g., the gill surface) of bony fish or water-breathing invertebrates and their body weight, i.e.,  $S \propto Wd$  [7,48].

However, Warren [52], based on a database of 1500+  $L_m$  and  $L_{max}$  values assembled for Chondrichthyes (chimaera, rays, and sharks, including *Squatina* spp.), shows that for marine species, the relationship between  $L_m$  and  $L_{max}$  is

$$L_{max}{}^{D}/L_{m}{}^{D} = 1.14 \ (\pm 0.13) \tag{2}$$

This indicates that sharks and marine rays mature at a size that is a larger fraction of their maximum length (see also [53,54]).

Thus, their mean length at first maturity can be estimated from

$$L_{\rm m} = L_{\rm max} / 1.14^{1/D}$$
(3)

Here, this will be solved with D = 0.48, the mean value for the three *Squatina* species in the compilation by Warren [52].

## 3. Results

The outreach and data collection campaign used in this study generated a substantial number (n = 80) of new individual records, many of which were first incorporated into the Turkish citizen science Facebook Page: Sharks and Rays in Turkey (https://www.facebook. com/groups/sharksinTurkey, accessed on 23 October 2023).

## 3.1. Angel Shark Records Details and the Potential CASAs

Table 1 presents 61 recent angel shark records for Türkiye reported between August 2018 and December 2023, with a total of 80 individuals, suggesting three potential CASAs utilised by angel sharks: Fethiye Bay (n = 38), Northern Aegean Çanakkale District (n = 18), and Antalya Bay Region, extending just outside to Patara (n = 17), with the remaining records pertaining to other regions. Figure 2 shows the three potential CASAs with the number of specimens found in each.



**Figure 2.** Map of Southern and Eastern Türkiye with the three potential CASAs shown, with the number of specimens found there recently.

**Table 1.** New records of angel sharks in Türkiye in Antalya Bay (AB), Çanakkale Strait (ÇS); Dalyan (DY), Fethiye Bay (FB), Gökçeada Island (GI), Iskenderun Bay (IB), Kaş (KA), Marmaris (MA), and Patara (PA); # = number of specimens; P = photo available; V = video available, pertaining to adults (ad.), subadults, young-of-the-year (YOY), and neonates (neon.).

| Site (Depth in m) and Date | #/P/V | Stage               | Sex | Status | TL (cm)   |
|----------------------------|-------|---------------------|-----|--------|-----------|
| Squatina aculeata          |       |                     |     |        |           |
| ÇS () 16.08.2018           | 1/P/V | Adult               |     | Alive  | 100       |
| AB () 06.02.2021           | 1/P   | Adult               |     | Dead   |           |
| FB () 21.04.2021           | 1/P   | Juvenile            | Μ   | Alive  | 58        |
| AB () 07.11.2021           | 1/P   | Adult               |     | Dead   | -         |
| IS () 16.05.2023           | 1/P   | Adult               | F   | Dead   |           |
| Squatina oculata           |       |                     |     |        |           |
| FB () 01.02.2020           | 1/P   | Adult               |     | Dead   |           |
| FB () 10.04.2020           | 1/P   | Adult               |     | Alive  | 79.8      |
| FB () 04.10.2020           | 1/P   | Adult               | F   | Dead   | 80        |
| ÇS () 07.11.2022           | 1/P   | Adult               |     | Alive  | 100       |
| ÇS () 07.11.2022           | 1/V   | Adult               |     | Alive  |           |
| ÇS () 05.01.2023           | 1/V   | Adult               |     | Alive  | 60-80     |
| FB (120, 135) 06.01.2023   | 2/V   | Adult               | F&M | Alive  |           |
| MA (60) 09.01.2023         | 1/P   | Adult               |     | Dead   | 72        |
| FB () 09.01.2023           | 1/V   | Pups and ad.        |     | Alive  | 110       |
| FB (188, 194) 18.01.2023   | 1/V   | 3 embryos and adult | -   | Alive  | -         |
| FB (190) 20.01.2023        | 1/P   | Adult               |     | Alive  | 65        |
| FB () 20.01.2023           | 1/P   | Subadult and ad.    | Μ   | Alive  | 55        |
| FB (200) 29.01.2023        | 2/V   | Sub-adult and ad.   | F&M | Alive  | 50-60,65+ |
| DY () 01.03.2023           | 1/P   | Adult               | F   | Dead   |           |
| FB () 13.02.2023           | 1/P   | Adult               |     | Alive  |           |
| FB (91) 07.03.2023         | 2/P   | Adult               | F&M | Both   | 67,83     |
| FB () 15.03.2023           | 1/V   | Adult               | F   | Dead   |           |
| FB (160) 26.03.2023        | 4/V   | Neon. and ad.       | F   | Alive  | 20–23, 69 |

| Site (Depth in m) and Date | #/P/V | Stage               | Sex | Status | TL (cm) |
|----------------------------|-------|---------------------|-----|--------|---------|
| AB () 13.05.2023           | 1/V   | Adult F             |     | Alive  | 150     |
| PA () 13.05.2023           | 1/V   | YOY                 |     | Alive  | 38      |
| KA (17) 16.05.2023         | 1/P   | Adult M             |     | Alive  | 57      |
| KA (111) 23.05.2023        | 1/P   | Adult               | F   | Alive  | 77      |
| PA (39) 29.07.2023         | 1/V   | Sub-adult           | F   | Alive  | 50-60   |
| FB () 16.06.2023           | 2/V   | Sub-adult and Adult |     | Alive  | 38, 150 |
| FB (183) 26.08.2023        | 1/V   | Sub-adult           | F   | Alive  | 48      |
| AB (93) 13.09.2023         | 1/P   | Sub-adult           | F   | Alive  | 61      |
| AB (89) 19.09.2023         | 1/V   | Sub-adult           | Μ   | Alive  | 81      |
| AB (108) 19.09.2023        | 1/V   | Adult               | F   | Alive  | 78      |
| AB (100) 19.09.2023        | 1/V   | Adult               | F   | Alive  | 82      |
| AB (108) 24.09.2023        | 1/V   | Sub-adult           | F   | Alive  | 69      |
| FB (110) 26.09.2023        | 1/V   | YOY                 | F   | Alive  | 39.5    |
| FB (110) 08.10.2023        | 1/PV  | Sub-adult           | Μ   | Alive  | 55      |
| AB (130) 22.10.2023        | 1/V   | Sub-adult           | F   | Alive  | 55      |
| FB (167) 24.11.2023        | 1/PV  | Sub-adult           | F   | Alive  | 50,5    |
| FB (160) 02.12.2023        | 1/V   | Sub-adult           | Μ   | Alive  | 60      |
| FB (185) 02.12.2023        | 1/V   | Adult               | F   | Alive  | 75      |
| FB (169) 02.12.2023        | 1/V   | Sub-adult           | Μ   | Alive  | 55      |
| FB (239) 09.12.2023        | 1/V   | Sub-adult           | Μ   | Alive  | 60      |
| FB (210) 09.12.2023        | 1/V   | Sub-adult           | М   | Alive  | 62      |
| FB (204) 09.12.2023        | 1/V   | Sub-adult           | Μ   | Alive  | 62      |
| FB (210) 09.12.2023        | 1/V   | Sub-adult M         |     | Alive  | 70      |
| FB (200) 09.12.2023        | 1/V   | Sub-adult M         |     | Alive  | 67      |
| FB (150) 12.12.2023        | 1/V   | YOY F               |     | Alive  | 42.5    |
| FB (162) 12.12.2023        | 1/V   | Sub-adult N         |     | Alive  | 60      |
| FB (171) 12.12.2023        | 1/V   | Sub-adult           | F   | Alive  | 62      |
| Squatina squatina          |       |                     |     |        |         |
| ÇS () 27.07.2022           | 1/V   | YOY                 |     | Alive  | 30-40   |
| GI () 23.01.2023           | 6/V   | Subadult and ad.    |     | Alive  |         |
| FB (35) 26.01.2023         | 1/P   | Adult               |     | Alive  |         |
| ÇS () 01.06.2023           | 1/V   | Adult               |     | Alive  |         |
| ÇS () 03.03.2023           | 6/V   | Pups and ad.        | F   | Alive  |         |
| IB (35) 13.04.2023         | 1/V   | Adult               |     | Alive  |         |
| AB () 13.05.2023           | 1/V   | Adult F Ali         |     | Alive  | 150     |
| PA () 13.05.2023           | 1/V   | YOY                 |     | Alive  | 38      |
| KA (17) 16.05.2023         | 1/P   | Adult               | М   | Alive  | 57      |
| KA (111) 23.05.2023        | 1/P   | Adult               | F   | Alive  | 77      |
| MB (60) 09.01.2023         | 1/P   | Adult               |     | Dead   | 72      |

Table 1. Cont.

Three potential CASAs are shown here (Figure 2) based on the habitat usage showing the number of specimens found. The Çanakkale and Fethiye Bay potential CASAs are based on hosting spawning habitats evidenced by mature females that underwent capture-induced parturition events. The Finike Bay potential CASA is based on a known feeding area, as LEK (n = 6 fishers) states that *S. oculata* are normally encountered in fishing nets targeting shrimp. Once shrimp are caught in the net, then the angel sharks come to feed on them. Additionally, angel sharks are reported between the Fethiye Bay and Finike Bay regions, indicating the importance of this stretch of coastline to these species. This southern region from Fethiye to Antalya Bay hosts all life stages of *S. oculata* (from 10 cm foetuses to 150 cm maximum length females).

Of the 80 individuals for Türkiye, 23 were *S. squatina*, 52 were *S. oculata*, and 5 were *S. aculeata. Squatina squatina* was found mainly in the Çanakkale District but was also found in Antalya and Iskenderun Bay (Table 1). Please note these records in Table 1 only include data with photograph or video evidence allowing for species identification. Also in the compiled data is an account of one large female in Fethiye Bay in March 2023, with video evidence of the shark being butchered for meat portions. All species presented in Table 1 were identified to species level due to the high quality of the photographs and video footage.

## 3.2. Capture-Induced Parturition Events

There were four reported capture-induced parturition events, all induced by fishing gear entanglement (three from small-scale fishers and one from a recreational fisher), for angel sharks from three localities in Türkiye in 2023, shown in Figure 3.



**Figure 3.** Map of Western and Southern Türkiye showing the localities of the records of the angel shark parturition events as listed above: Fethiye Bay, Aegean Sea (1 and 4), Nara Burnu, Çanakkale Strait (2), and Bozburun Peninsula, Aegean Sea (3), with other cities mentioned shown here.

Each event is presented here, with details more succinctly summarized in Table 2.

- 1. On 9 January 2023, a gravid *Squatina oculata* was caught by a small-scale fisher using bottom set nets at a depth of 110 m in Fethiye Bay, then brought onboard to disentangle prior to release. Capture-induced parturition occurred with three pups (pers comms, O. Orhan). All were dead. One had a large external yolk sac still attached, and the other two yolk sacs became detached from the embryo as the nets were hauled in (Figure 4A); these were returned to the sea along with the female, which survived. The three foetuses were estimated by the fisher to be between 10 and 15 cm in total length (TL).
- 2. On 9 March 2023, a gravid *Squatina squatina* was captured by hook and line from about 20 m in depth by a recreational vessel operating near Nara Burnu, Çanakkale Strait (Figure 5). Capture-induced parturition resulted in the premature birth of seven pups which appeared near term and were released alive along with the female. It was noted that the bottom habitat was a *Posidonia oceanica* meadow.
- 3. On 23 March 2023, a gravid *Squatina* species was caught off of Bozburun Peninsula by set nets from 120 m. Capture-induced parturition resulted in the premature birth of five pups, which were reportedly released alive. There are no photos of this event as the fisher was alone (M. Özçılik, pers. obs.). This is the only account reported here without media.

4. On 26 March 2023, a gravid *Squatina oculata* was caught in Fethiye Bay. Captureinduced parturition resulted in the premature birth of one pup while the net was being hauled in, while another pup had emerged halfway from the cloaca, and a third remained internally. The female was measured at 69.6 cm, then released alive with the pups, all of which appeared alive at the time of release (Figure 6).



**Figure 4.** (**A**) Three *S. oculata* pups born from capture-induced parturition onboard a fishing vessel in Fethiye Bay, Türkiye on 9 January 2023, one pup with yolk sac still attached. (**B**) An example of a mature female *S. oculata* measuring 88 cm. Photo credits: Oben Orhan (**A**) and Aylin Ulman (**B**).



**Figure 5.** *Squatina squatina* pup (in the middle) and the female from the Dardanelles on 9 March 2023. Source: https://www.canakkaleyorum.com/haber/canakkalede-yakalanan-kopek-baligi-teknede-dogum-yapti-27256, accessed on 23 October 2023.



**Figure 6.** Female *S. oculata* measured at 69.6 cm and the three pups measuring approximately 20, 21.5, and 23 cm (estimated from software), captured in Fethiye Bay on 26 March 2023. Photo credit: Aylin Ulman.

5. On 2 December 2022, a gravid *Squatina aculeata* approximately 150 cm in total length was caught by gillnetters south of Lampedusa Island reported in Zava et al. [24]. Capture-induced parturition resulted in the premature birth of two pups. The pups were estimated to be about 15 cm in length and had visible yolk sacs attached to their abdomen. They were released alive [24]. The accompanying video can be found here: https://www.youtube.com/watch?v=6LQTrvzTQTQ, accessed on 23 October 2023.

**Table 2.** Details of capture-induced parturition events in angel sharks (*Squatina* spp.) from Türkiye in 2023, and Italy (2021).

| Location<br>and Date                            | Depth<br>(m) | Species      | Gear         | TL<br>(cm) | Pups Number (and<br>Length in cm) | Yolk Sacs           | Status of Pups    |
|---|--------------|--------------|--------------|------------|-----------------------------------|---------------------|-------------------|
| 1. Fethiye Bay<br>9 January 2023                | 110          | S. oculata   | Net          | 75–85      | 3<br>(8–12)                       | External            | Dead              |
| 2. Nara Burnu, 9 March 2023                     | 30           | S. squatina  | Hook         | 150        | 7<br>(20–30)                      | Not seen            | Released<br>alive |
| 3. Bozburun Peninsula<br>23 March 2023          | 120          | Squatina sp. | Net          | ~80        | 5                                 | None                | Released alive    |
| 4. Fethiye Bay 26 March 2023                    | 160          | S. oculata   | Net          | 67.6       | 3<br>(19.5, 21.5, 23)             | Internal, 2–4<br>cm | Released<br>alive |
| 5. Lampedusa Island, Sicily 12<br>February 2021 | 90           | S. aculeata  | Bottom trawl | ~150       | 2<br>(~15)                        | External            | Released alive    |

## 3.3. Incidental By-Catch Records from Fethiye Region

A total of 38 *S. oculata* were encountered in 28 out of 35 normal commercial fishing trips using bottom set nets conducted in this region (from Fethiye Bay southwards to Patara, Antalya) from January 2023 until the end of December 2023, as reported by one local fisher (Table 1). Since 2020, a range of size classes from *S. oculata* records have been confirmed from this region. Specimens from a number of life history stages were reported in this region (10–15 cm for embryos with yolk-sac attached externally, 18–21.5 cm for foetuses or survived pups, 37 cm for young-of-the-year (YOY), 50–70 cm for juveniles and 70–150 cm for mature individuals; see Table 1 for details).

## 3.4. Local Ecological Knowledge (LEK) from Surveys

From the fisher interviews, it was revealed that Finike Bay in Antalya Bay hosts a resident population of sub-adult to adult *S. oculata*. Interview responses lead to the understanding that select small-scale fishers using bottom set nets targeting shrimp from 70 to 80 m in a certain area of muddy substrates encountered from 2 to >50 angel sharks per vessel (n = 4) in 2022. Angel sharks have also been found in these fishing grounds from depths of 20 m. The LEK indicates that catches peak in summer from July to September in Finike Bay. The lengths of the *S. oculata* caught in this locality are mostly juveniles to sub-adults ranging from 30 to 70 cm. Note that these historical records were not integrated into Table 2 as a lack of photo or video evidence prevented verification. Incidental catches reported since September 2023 were registered as they were accompanied by the evidence needed to identify the species.

Fisher surveys from Fethiye Bay revealed that over 30 years ago, angel sharks were commonly caught in shallow waters within the bay, but the inner bay was protected from commercial fishing in 1988 when the area became a Specially Environment Protected Area (SEPA). Since then, fishers began encountering angel sharks less frequently in the middle bay—with the grounds open to fishing, it is locally understood that the adult population moved to deeper habitats. This LEK is supported by data as the small-scale local fishers from Fethiye (n = 15) that fish in shallower waters (30–60 m) each caught between zero to two angel sharks in the last year from the fishable regions, whereas the one small-scale fisher who fishes regularly in deeper waters (100–300 m) in Fethiye Bay has been encountering *S. oculata* on approximately 40% of his regular fishing trips. Angel sharks are generally caught by bottom set nets with a larger mesh size (25–34 mm) targeting larger fish, and are not generally retained on longlines, as they seemingly are able to break the lines (according to LEK).

Table 3 presents maximum length along with reported and estimated mean length at first maturity for the three Mediterranean angel shark species, to serve as a basis for interpreting the data in Tables 1 and 2.

The data from Tables 1 and 2 were used to create an update on the mean length at first maturity for the three Mediterranean angel shark species.

**Table 3.** Mean length at first maturity, maximum length (TL; cm) of angel sharks (*Squatina* spp.); adapted from Tables 1 and 2 and Warren ([53]), based on data in Ebert et al. [54] and Capapé et al. [55,56].

| Species and Sex            | L <sub>max</sub><br>(Türkiye) | L <sub>max</sub><br>(W. 2023) | L <sub>m</sub> **<br>(W. 2023) | L <sub>m</sub><br>Equation (3) | %<br>Deviation |
|----------------------------|-------------------------------|-------------------------------|--------------------------------|--------------------------------|----------------|
| S. aculeata ♀              | 100 *                         | 188                           | 137                            | 143                            | -4             |
| S. aculeata 🕈              |                               | 152                           | 120                            | 116                            | 3              |
| S. oculata ♀               | 150                           | 157                           | 89                             | 119                            | -25            |
| S. oculata ♂               | 150                           | 145                           | 82                             | 110                            | -25            |
| S. squatina $\mathfrak{P}$ | 150                           | 169                           | 123                            | 128                            | -4             |
| S. squatina 🕈              |                               | 132                           | 79                             | 100                            | -21            |

\* assumed to be a female; \*\* bold estimates are considered less reliable; see text.

## 4. Discussion

The dataset presented here reveals an abundance of recent Local Ecological Knowledge about Critically Endangered angel shark populations, habitats, and their reproduction in three areas of the Turkish coast. Since an average of only one angel shark record has been officially published each year or two since the late 1990s (see [34,37]), this study reporting 80 records of angel sharks in Turkish waters in recent years (2018–2023) suggests that Türkiye holds several Critical Angel Shark Areas that could be important for the survival of these species in the Mediterranean Sea. It also stresses the importance of directed studies to better understand the threats these species face. This study revealed the existence of three potential CASAs in Türkiye in Fethiye Bay, Antalya Bay, and Çanakkale Strait based on reproductive events, feeding areas, and specimens found in many life-history stages. The majority of data from this study was used as evidence to list an area in the Southeastern Aegean Sea as an IUCN Important Shark and Ray Area (ISRA), which passed external review in July 2023. Key information (such as MPAs, fishing activities, tourism activities, marine traffic, and oceanographic data) should then be layered onto these CASAs to understand how areas are being utilised and who the interested Parties are in order to facilitate better decision-making for the future protection of these areas.

The designation on the Turkish Prohibited Species list means that fishers no longer report their incidental catches of angel sharks for fear of penalties, which implies an awareness of the regulation. Although penalties only apply to the transport or sale of listed species, fishers are uncomfortable sharing records of incidental capture or discards (whether deceased or alive) (Pers comm A. Ulman). This study, along with its outreach efforts, educates fishers that they will only be penalized for transporting or selling angel sharks, which reduces their apprehension about reporting sightings.

## 4.1. Critical Habitat

Prior research on the three Mediterranean angel shark species shows their minimum and maximum depths, which served as a basis for understanding where to look for their critical habitats. For example, S. squatina has a reported depth range of 0 to 150 m, S. aculeata from 30 to 500 m, and S. oculata from 5 to 500 m [54]. The results of this study showed that S. oculata used to be caught in relatively shallow coastal waters a few decades ago in Fethiye Bay, but they have seemingly relocated to deeper habitats there from 100 to 300 m, particularly in winter. Fethiye Bay has suffered from increasing pollution from wastewater from hotels in recent decades, which has likely depleted the oxygen content in shallow waters. Meanwhile, in Finike Bay, they are sometimes encountered in shallower waters from 20 to 60 m, but most are found from 60 to 80 m in muddy bottom habitats. No data on depths were recorded for S. squatina or for S. aculeata here, aside from one S. squatina record close to Gokçeada Island from 27 February 2023 which reported five specimens (juvenile and adults) within a 500 m length bottom set net from a 20-25 m depth in a *Posidonia oceanica* habitat. *Posidonia oceanica* meadows are identified as a priority habitat type for conservation under the Habitats Directive (Dir 92/43/CEE) [57]. One other record from Türkiye from trawl surveys conducted in Saros Bay from 2005 to 2008 reported a 23.5 cm female S. squatina specimen, providing further support that the northern Aegean also hosts important nursery habitats for Angel sharks [58]. Since the data presented here is solely based on small-scale fisher observations, it would be beneficial to examine the deeper waters in Finike Bay via other survey techniques, such as baited remote-operated cameras, to explore areas that the fishers do not frequent and so clarify the maximum depths and distribution.

## 4.2. Reproduction and Capture-Induced Parturition

A subject warranting closer investigation relates to stress-induced reproductive events in elasmobranchs from fishing gear interactions. Adams et al. [58] found from a review that an average of one-quarter of viviparous elasmobranchs caught in fishing trips resulted in capture-induced parturition of either foetuses or live pups. The observations documented in Table 1, besides being indicative of stress, suggest (conscious of the limited sample size) that springtime in Turkish waters is the season that angel sharks give birth to their young. The specimens encountered in January were too underdeveloped to have survived, as evidenced by the presence of external yolk sacs, which would be completely absorbed by the pups before they were born [56]. We do not exclude the possibility that external yolk sacs can become dislodged when hauling in the fishing net. However, by late March, the pups appeared fully developed. S. oculata are reported to have smaller litter sizes than the other two species, ranging from 3 to 8 pups on average [56], while S. aculeata have between 8 and 12 pups [56], and S. squatina 7 and 25 pups [10]. From these accounts, the two S. oculata events (one with embryos that did not survive and one event where the foetuses seemed near full term and alive) each had three pups, while the unidentified angel shark species from a third locality nearby (but most likely S. oculata from Bozburun) had five pups and the other *S. squatina* parturition event had seven pups. However, these pup numbers should be treated conservatively, as some pups may have been released while the shark was still in the water, or remained inside the female as they are generally quickly released. The measured size at birth for S. oculata from prior research from Tunisia shows that pups ranged from 22 to 27 cm [56], whereas here they were between 20 and 22 cm. Although slightly smaller, they were apparently nearly ready to be released from the cloaca, as evidenced by the total re-absorption of the yolk sac.

#### 4.3. New Frameworks for Improved Future Angel Shark Conservation

In addition to the identification of CASAs, the IUCN's ISRAs initiative has recently been developed with a view to helping facilitate decision-making with regard to areabased management for ISRAs [59]. Within this process, one criterion for proposing ISRAs includes life history, referencing "areas that are important to sharks for carrying out vital functions across their life-cycle (i.e., reproduction, feeding, resting, movement, or undefined aggregations)", with reproductive areas "that are important for sharks to mate, give birth, lay eggs, or provide refuge and other advantages to the young" explicitly stated as a sub-criteria. A workshop initiated in May 2023 saw experts convene to map critical habitats across the Mediterranean and Black Seas. Using this angel shark data as a basis, along with other records of qualifying endangered species in the region, such as Sandbar Shark *Carcharhinus plumbeus*, a new ISRA named the Southeastern Aegean Sea was proposed and accepted in July 2023 [60], which can be found at https://sharkrayareas.org/portfolio-item/southeastern-aegean-sea-isra/, accessed on 23 October 2023. This ISRA extends from Datça to Olüdeniz, Fethiye in Türkiye, and includes the northern portion of Rhodes Island, Greece (IUCN Shark Specialist Group, 2023P).

Both the Mediterranean Angel Shark Regional Action Plan [6] and Subregional Action Plans for the Ionian Sea, Aegean Sea/Crete, Northern Levant Sea, and Cyprus GSAs 21, 22, 23, 24, and 25 [21,22,30,61,62] provide detailed guidance towards improving the angel shark knowledge needed to help their populations rebuild. Once data from all these plans are gathered, the regional distribution knowledge and habitat use will become clearer. Additionally, all stakeholders, including decision-makers such as fishery managers, scientists, and fishers, should collaborate to help design an improved conservation strategy for angel sharks.

#### 4.4. Mortality Threats from Small-Scale vs. Large-Scale Fishing

While comparing the Mediterranean review of bycaught angel sharks from Zava et al. [24] with our dataset, one difference is clear. From the data stemming mainly from the central Mediterranean basin, bottom trawling was listed as the biggest threat for angel sharks and resulted in many of these records being fatal to these Critically Endangered species, although an exact number was not provided for the percentage of mortalities. Zava et al. explain that "The number of specimens released alive was insignificant compared to the number of specimens retrieved dead and sold or discarded". From our dataset from Türkiye, 10 out of 80 records reported deceased specimens, which is more optimistic than Zava et al.'s findings. In addition, it shows that national protection and awareness campaigns appear to be changing the habits of informed small-scale fishers. In cases where fishers share the data with social media, angel shark campaigns or researchers, the regional understanding of their populations can be greatly improved upon. However, it is understood that the hauling in of bottom trawl nets causes more opportunities for the crushing and asphyxiation of species, which also supports the different results in these two studies.

Since angel sharks generally survive in the trammel nets, regionally, bottom trawling seems to be the largest threat to angel shark conservation in cases where the nets are set for long periods and individuals are badly tangled upon retrieval (pers comm. Oben Orhan). There are no ports with bottom trawlers close to Fethiye, but one to two trawlers are known to operate in Fethiye Bay for a couple of weeks each year, whereas the other potential CASA located in Finike Bay of Antalya Bay is open to bottom trawling from September until April 15th each year. Other angel shark reviews support this claim that bottom trawling is likely the largest threat for angel sharks, followed by bottom set nets and longlines [5,24,63].

## 4.5. Life-History Traits

Table 2 summarizes the recent data presented here on 61 records of 80 individuals for the three species of angel sharks in Turkish waters. Jointly with the length records in Table 1, these data indicate that both juveniles and large specimens of all three *Squatina* species still occur in Turkish waters (see Table 3).

While this study is limited by a relatively small sample size, Table 3 suggests that some published values of  $L_m$  are underestimated, likely due to  $L_m$  being based on the length at which a few specimens of a population first become mature as opposed to an estimate of mean length at first maturity at which 50% become mature, with the 50% that became mature at lengths <  $L_m$  compensating for the 50% that become mature at length >  $L_m$ .

Thus, while the female *S. squatina* in Table 1 was, at 150 cm, well above the  $L_m$  estimates in Table 3, the female *S. oculata* of 67 cm, and even some of those ranging from 75 to 80 cm (Table 1) are below the reported  $L_m$  value of 82 cm in Table 3. Moreover, the latter value may itself be an underestimate, as it strongly differed from the predicted value of 110 cm.

Finally, it should be considered that in the last two to three decades, both the mean length at first maturity and the maximum length of angel shark species may have declined due to the strong increase in water temperature given the mechanisms in Cheung et al. [64] and Pauly [48]. However, the available field data are too sparse to distinguish whether the  $L_m$  values of angel sharks in the Eastern Mediterranean were underestimated and/or whether their mean length at first maturity has actually declined due to warming.

## 5. Conclusions

The updated angel shark records suggest three likely CASAs in Türkiye, two (Fethiye Bay and Çanakkale Strait) based on reproductive events, and the other (Finike Bay) being a known feeding ground. Fethiye Bay is identified as an Important Shark and Ray Area in Türkiye (Southeastern Aegean Sea), while Finike Bay lies just outside the lineations of the Antalya Bay ISRA, and Çanakkale is an Area of Interest for a potential ISRA (Truva Shelf, containing the entrance to Çanakkale). Details of each area can be found here: https://sharkrayareas.org/e-atlas/, accessed on 23 October 2023. Now that three potential CASAs and ten ISRAs have been identified in Türkiye (one based on angel sharks named the southwestern Aegean Sea), it is highly recommended that spatial management be strengthened in these areas to reduce the main threats to angel shark mortality. Bottom trawl fishing is already prohibited in the Çanakkale, the inner Fethiye Bay, and a portion of Finike Bay (Turkish Fishing Regulation 5/1, 2020/20) [65], providing a strong basis for improved protection.

This study shows the importance of informing fishers and linking them with scientists and conservationists so that Local Ecological Knowledge can be used to contribute to the conservation of threatened species. While the identification of likely CASAs and ISRAs does not offer any protection at this time, the identification of these areas can help direct future management measures. In particular, these areas should be further investigated to learn more details on angel shark usage of the area, its delineations, its seasons, and its connectivity to other subregions. Widescale outreach and training to teach fishers the critical statuses, handling, and safe-release techniques for angel sharks should be undertaken to limit impacts on and help rebuild their populations in the Eastern Mediterranean Sea.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fishes9070270/s1, Supplementary Data 1: Angel shark survey in English.

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**Institutional Review Board Statement:** Ethical review and approval were waived for this study due to the capture records being forwarded from local fishers via incidental capture events or captured from social media. Outreach education events in line with this study instructed local fishers on the safe handling and prioritized urgent live release of elasmobranchs in line with national Turkish law.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are contained within this article and supplementary materials.

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