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Artisanal fisher ecological knowledge with morphometric measurements of Angel Sharks form Libya, Central Mediterranean

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ABSTRACT

Background: Angel sharks (*Squatina* spp.) in the Mediterranean Sea are critically endangered, and there is a significant knowledge gap regarding their populations in Libyan waters.

Aim: This study aimed to assess the status of Angel sharks in Libyan waters by integrating local ecological knowledge (LEK) from artisanal fishers with novel morphometric data.

Methods: Structured interviews were conducted with 53 artisanal fishers at the Tripoli fishing port (April–May 2022) to gather LEK on Angel shark distribution, abundance, and threats. Morphometric measurements were collected from seven Angel shark specimens that landed during the study period.

Results: Fishers encountered all three Mediterranean Angel shark species (*Squatina squatina*, *Squatina aculeata*, and *Squatina oculata*) across several Libyan coastal areas (Tripoli, Misurata, Zuwara, Tajoura, and Qarabuli). Annual catch estimates of five or more Angel sharks per fisher were reported, primarily from depths of 10–300 m (mean: 124.02 m). Reported total lengths ranged from 15 to 200 cm, with the majority being between 15 and 100 cm. Trawling (43%), bottom gillnets (36%), and longlines (21%) were the main fishing methods associated with Angel shark captures. A significant positive correlation was found between distance from the coast and fishing depth (Spearman's $r_{\text{sub}} = 0.69$, $p < 0.001$). Morphometric data included: *S. squatina* ($n = 3$; TL: 46–80 cm; weight: 884.0–6395.0 g), *S. aculeata* ($n = 1$; TL: 66 cm; weight: 1,884.0 g), and *S. oculata* ($n = 3$; TL: 44–52 cm; weight: 634.0–959.0 g). Fishers identified marine pollution, overfishing, illegal fishing practices, and inadequate enforcement as major threats to the Angel shark population.

Conclusion: This study provides critical baseline information on the abundance and distribution of angel sharks in Libyan waters, highlighting their continued presence and vulnerability. The findings underscore the urgent need for targeted conservation actions. This includes stock assessments, habitat protection, and fisheries management measures to ensure the long-term survival of these critically endangered species in the region.

Keywords: Angel sharks, *Squatina* spp., Libya, Local Ecological Knowledge, Morphometrics, Conservation, Fisheries, Mediterranean Sea.

Introduction

Angel sharks (*Squatina* spp.) represent a unique and critically endangered group of benthic elasmobranchs, which are characterized by flattened bodies, cryptic coloration, and ambush predation strategies. (Compagno et al. 2005). These adaptations made them highly efficient predators in their marine habitats (Ellis et al., 2021). Globally, 23 species of Angel sharks have been identified, all facing significant threats from bycatch in bottom-fishing gear, habitat degradation, and overfishing (Dulvy et al., 2021; Long et al., 2021). In the Mediterranean Sea, the three species of the Angel shark—the common Angel shark (*Squatina squatina*), the smooth-back Angel shark (*Squatina oculata*), and the sawback Angel shark (*Squatina aculeata*)—have experienced dramatic population declines, leading to

their classification as critically endangered on the IUCN red list (Gordon et al., 2019). Once common across Mediterranean fisheries, these species now persist in only a few localized areas, with records becoming increasingly scarce (Damalas and Vassilopoulou, 2011; Fortibuoni et al., 2016).

The Mediterranean Angel Shark exemplifies the challenges facing regional marine biodiversity. Historical records indicate that these sharks were once widespread throughout the northern Adriatic, Aegean, and Tyrrhenian Seas. However, over the past six decades, targeted fisheries and incidental bycatch have significantly decimated populations of these species (Ligas et al., 2013; Follesa et al., 2019). Today, isolated reports from regions such as the Gulf of Gabès and the Tyrrhenian Sea indicate small, remnant populations,

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highlighting the need for urgent conservation measures (Saidi *et al.*, 2023). These patterns mirror broader trends in global elasmobranch decline driven by unsustainable fishing practices, habitat loss, and insufficient management frameworks (Dulvy *et al.*, 2021).

Libyan waters, located within area 21 of the Southern Ionian Sea in the GFCM subregion, host a significant proportion of Mediterranean elasmobranch diversity, with over 74 species reported (UNEP-MAP RAC/SPA, 2005). However, systematic data on *Squatina* species in this region are (SOS, 2020) scarce. Earlier records identified *S. squatina* and *S. aculeata* (Hureau and Monod, 1973; Zupanovic and El-Buni, 1982), while later studies confirmed the presence of *S. oculata* (Sogreah, 1977). A recent national checklist documented 59 elasmobranch species in Libya (Shakman *et al.*, 2023). The absence of detailed studies hampers efforts to understand population trends, spatial distributions, and threats. However, anecdotal evidence from local artisanal fishers suggests that Angel sharks continue to inhabit Libyan waters, albeit under growing pressure from marine pollution, illegal fishing practices, and bycatch.

Local ecological knowledge (LEK) is a promising approach to address data gaps in regions with limited scientific monitoring (Figus *et al.*, 2017). By integrating Fisher observations with direct biological measurements, LEK provides a cost-effective and community-driven method for assessing species distribution, abundance, and threats (Berkström *et al.*, 2019; Colloca *et al.*, 2020). This study combines LEK with morphometric measurements to present the first comprehensive assessment of Angel sharks in Libya. The findings will inform conservation strategies and establish baseline data crucial for the sustainable management of critically endangered species.

Materials and Methods

Data collection through interviews

LEK was collected through structured interviews with fishers at the Tripoli fishing port between April 15 and May 15, 2022. A total of 53 fishers were interviewed, all of whom were regularly engaged in fishing activities using either artisanal fishing vessels or trawlers. Before each interview, participants were provided with an information sheet outlining the research objectives and were assured of the confidentiality of their responses. Informed consent was obtained verbally from all participants.

The interviews were conducted in person using a standardized questionnaire that included both closed and open-ended questions. Questions focused on fishing practices, including fishing seasons, gear used, primary fishing grounds, and economic aspects related to Angel sharks. Participants were also asked about their encounters with Angel sharks, including their frequency, location (distance from shore and depth),

size of captured individuals, bottom type, and perceived trends in abundance. Color illustrations were used to confirm the identification of the three Mediterranean Angel shark species (*S. squatina*, *S. aculeata*, and *S. oculata*). Recreational fishers were excluded from the study.

Morphometric analysis

Morphometric measurements were taken from seven Angel shark specimens: *S. squatina* ($n = 3$), *S. aculeata* ($n = 1$), and *S. oculata* ($n = 3$). These specimens represent the first morphometric data of Angel sharks in Libya. Twenty-two standard body measurements were recorded for each specimen, following the methods outlined by Bass *et al.* (1975) (Table 1). All measurements were made to the nearest millimeter using calipers. The mouth width was measured as the distance between the inner edges of the labial furrows.

Data analysis

Quantitative data obtained from the questionnaires were analyzed using descriptive statistics to summarize trends in fisher-reported observations. In contrast, open-ended responses were analyzed qualitatively to provide context and explore fishers' perceptions of Angel shark populations and the threats they face. Additionally, Spearman's rank correlation was used to assess the relationship between the distance from the coast and fishing depth. Statistical analyses were performed using MS Excel[®] and the R software environment (R Core Team, 2024) ensuring reproducibility and accuracy of findings.

Ethical approval

Not needed for this study.

Results

Fisher's encounters and perceptions

All the interviewed fishers ($n = 53$) reported encountering Angel sharks in their fishing areas. While all respondents were able to identify *Squatina squatina*, the other two species, *S. aculeata* and *S. oculata*, were

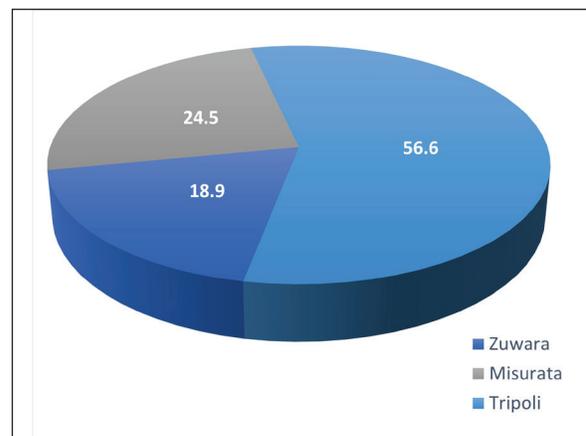


Fig. 1. Fishing areas used in fishing Angel sharks in Tripoli port, Libya.

not consistently recognized, likely due to their lower capture frequency. The primary fishing areas where Angel sharks were encountered were Tripoli (56.6%), Misurata (24.5%), and Zuwara (18.9%) (Fig. 1).

The majority of fishers (69.8%, $n = 37$) reported capturing five or more Angel sharks in the 12 months preceding the interviews. However, all reported captures were incidental bycatch because there are no targeted fisheries for angel sharks in Libya.

Fishers reported that encounter depths varied depending on the fishing gear used. Users of Artisanal gear encountered Angel sharks at shallow depths as little as 10 m, while trawlers reported encounters at depths of up to 200–300 m. The overall average capture depth was 124.02 m. Similarly, distances from the coast where Angel sharks were encountered ranged from 3 nautical miles (for artisanal gear) to 200 nautical miles (for trawlers), with an overall average of 60.27 nautical miles. A strong positive correlation was found between distance from the coast and fishing depth (Spearman's $r_s = 0.69$, $p < 0.001$), indicating that Angel sharks are more frequently encountered in deeper, offshore waters.

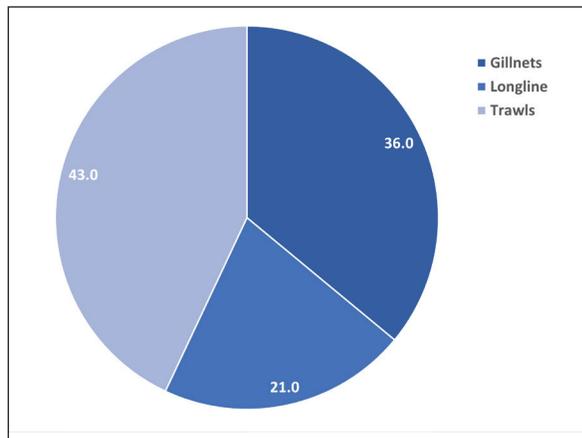


Fig. 2. Fishing gear types used for Angel Shark fishing in Tripoli, Libya.

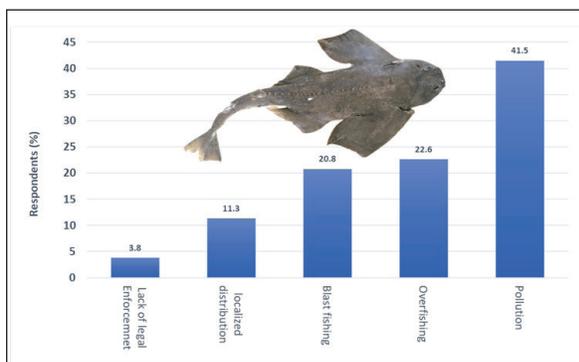


Fig. 3. Causes of Angel Shark decline based on Fisher's opinion.

The total length (TL) of the captured angel sharks ranged from 15 to 200 cm. The most frequently reported size class was 15–100 cm (64.2%), followed by 101–110 cm (18.9%) and 110–200 cm (17.0%).

Fishers reported encountering Angel sharks most frequently over rocky-sandy substrates, followed by sandy bottoms. Among fishing gears, trawling was the most cited method associated with the capture of Angel sharks (43.2%), followed by bottom gillnets (35.8%) and longlines (20.9%) (Fig. 2).

Perceived decline in Angel Sharks

All respondents reported a perceived decline in Angel shark catches in recent years. The primary factors attributed to this decline included increased land-based marine pollution (41.5%), particularly untreated sewage along the Tripoli coast, which intensified over the past decade. Other contributing factors cited were overfishing (22.6%), destructive practices like dynamite fishing (20.8%), localized distribution of Angel sharks (11.3%), and insufficient enforcement of fisheries regulations (3.8%) (Fig. 3). Two fishers provided photographs of *S. squatina* specimens they had captured (Fig. 4).



Fig. 4. Some common Angel sharks were photographed by fishers in Tripoli waters.

Morphometric data

Morphometric measurements were obtained from seven Angel shark specimens captured in Tripoli waters, including *S. squatina* (n = 3), *S. aculeata* (n = 1), and *S. oculata* (n = 3) (Table 1).

- The TL of *S. squatina* specimens ranged from 46 to 80 cm (mean = 65.0 cm, SD = 17.3), with weights ranging from 884.0 to 6395.0 g (mean = 3454.7 g, SD = 2774.0).
- The *S. aculeata* specimen had a TL of 66 cm and a weight of 1884.0 g.
- *S. oculata* specimens ranged in TL from 44 to 52 cm (mean = 48.3 cm, SD = 4.0) and in weight from 634.0 to 959.0 g (mean = 847.0 g, SD = 184.5).

Variations in body proportions, such as the distance from the snout to the first dorsal fin and from the snout to the pelvic fin, were observed among the three species, reflecting interspecific differences in body morphology within the *Squatina* genus. *S. squatina* consistently

exhibited larger body dimensions compared to the other two species. The number of tooth rows was relatively consistent among the species. Notably, all measured specimens were juveniles or sub-adults, suggesting that ongoing trawling activities disproportionately impact younger age classes and pose a significant threat to the population structure of these species.

Discussion

This study provides one of the first insights into the status of the Angel shark (*Squatina* spp.) in Libyan waters by integrating LEK with fisheries data. The findings reveal key information about their distribution, catch characteristics, and threats, highlighting the Tripoli region as a potential hotspot for Angel sharks, particularly *S. squatina*, which was the most frequently identified species by the interviewed fishers. The reported encounters in Misrata, Zuwara, Tajoura, and Garabulli further

Table 1. Morphometric measurements of seven Angel shark specimens caught off the Tripoli coast, Libya.

Morphometric measurements	Sample 1 <i>S. squatina</i>	Sample 2 <i>S. squatina</i>	Sample 3 <i>S. squatina</i>	Sample 4 <i>S. aculeata</i>	Sample 5 <i>S. oculata</i>	Sample 6 <i>S. oculata</i>	Sample 7 <i>S. oculata</i>
Total length (TL)	80	69	46	66	52	49	44
Standard length (SL)	71	59	39	57	45	41	38
Total weight (g)	6,395.0	3,085.0	884.0	1,884.0	948.0	959.0	634.0
Disc length (cm)	52	41	26	38	29.5	25	23
Eye diameter (cm)	1	1	0.9	1.6	1.4	1	1
Preorbital length (cm)	9	2.5	1.7	9.5	2	6	5.5
Spiracle length (cm)	2	1.9	1.7	1.5	1.3	1	0.5
Snout to mouth (cm)	1.2	0.9	0.6	1	0.4	0.5	.25
Snout to first gill-slit (cm)	13	10.2	6.7	9.5	7.4	6.1	5.5
Snout to the first dorsal fin (cm)	53	43	29	41	33	33	28
Snout to pelvic (cm)	35	29	18	28	21	20	18.5
Snout to the spiracle (cm)	8	5	3.5	6.5	4	4.4	4
The first to second dorsal (cm)	11	5	3.9	7.5	4.2	5.6	5
Between dorsal bases (cm)	6.5	8	6.1	5	6.1	4	3.5
Second dorsal to upper caudal (cm)	9.1	4.9	3.2	7.5	5	5.5	5.2
Upper caudal (cm)	8.7	9	6.2	7.1	6.5	4.4	3.9
Lower caudal (cm)	8.2	10.5	6.7	6.6	7	3.6	3.3
Mouth width (cm)	11.5	7	5.8	8.8	5.6	6.5	5.5
Internasal width (cm)	5.6	4.5	3.3	4.1	3.5	3.1	2.8
Inter-spiracular width (cm)	7.6	5.5	3.4	5	4	4	3.6
Total tooth row in upper/lower jaws	3-3	2-3	2-3	3-3	3-3	3-3	3-3
Total number of teeth in upper/lower jaws	20/20	20/20	20/20	20/20	18/18	16/16	14/14

indicate the widespread distribution of these species along the Libyan coast. Similar patterns have been observed in neighbouring Tunisia, where *S. oculata* has been reported in the north (Rafrafi-Nouira *et al.*, 2022). In the Gulf of Gabès, surveys indicated the rare occurrence of *S. aculeata* and *S. oculata* (Saidi *et al.*, 2023). Given the shared continental shelf between Libya and Tunisia, the conservation status of these species is likely similar in both countries, which could inform conservation strategies across the region.

One of the most concerning findings is the prevalence of juvenile Angel sharks in the reported catches. The majority of captured individuals fell within the 15–100 cm TL size class, suggesting that immature individuals dominate the population in these areas. This, along with the observed correlation between fishing depth and distance from the shore, indicates that coastal areas may serve as important nursery habitats for these species. The capture of juveniles before reproductive maturity could severely impact population recruitment and long-term viability (Awruh *et al.*, 2008). Similarly, concerns regarding the impact of fishing on juvenile Angel sharks have been raised in other parts of the Mediterranean (Giovos *et al.*, 2022).

The preference for rocky and sandy bottom habitats of Angel sharks aligns with previous studies on their habitat associations (Bakiu *et al.*, 2020; Barker *et al.*, 2022). This information can aid in the identification of critical habitats and the establishment of marine protected areas (MPAs) to safeguard key Angel shark grounds. Additionally, the predominance of trawling as the primary fishing gear associated with the capture of Angel sharks highlights the significant risk of bycatch, which could negatively impact these vulnerable species. Although there is no targeted fishery for Angel sharks in Libya, the incidental capture of these species in bottom trawls, gillnets, and longlines still contributes to population decline, as observed in other Mediterranean regions (Dulvy *et al.*, 2017).

Fishers' perceptions of the declining abundance of Angel sharks, attributed primarily to marine pollution, overfishing, and illegal fishing practices, align with broader threats to marine biodiversity in the Mediterranean (Coll *et al.*, 2010; FAO, 2020). The increase in land-based pollution, particularly the discharge of untreated sewage along the Tripoli coast, is a serious concern that requires urgent attention. Moreover, destructive fishing practices, such as dynamite fishing, not only directly harm Angel shark populations and degrade their habitats. The lack of effective fisheries regulations and enforcement exacerbates these threats, making it imperative to improve governance and monitoring mechanisms.

Although the morphometric data presented in this study are based on a small sample size, they provide valuable baseline information for future assessments of the Angel shark populations in Libya. The observed variations in

body proportions among the three *Squatina* species are consistent with known interspecific differences within the genus. The capture of these specimens in trawls, particularly juvenile or subadult size, highlights the potential threat that fishing activities pose to the population structure of these species. While Libya's relatively small fishing fleet has historically maintained robust fish stocks, the increasing use of unsustainable fishing methods, such as extensive bottom trawling, threatens to undermine this stability (Bradai *et al.*, 2022).

Conservation concerns and actionable recommendations

The findings of this study underscore the urgent need for targeted conservation measures to protect Angel sharks in Libya. A crucial first step is the development and implementation of a national elasmobranch conservation plan, created in collaboration with local fishers and other relevant stakeholders. This plan should include tested measures to reduce bycatch, such as gear modifications (e.g., bycatch-reducing devices) and spatial or temporal closures in areas of high Angel shark abundance. In addition, addressing the threats posed by marine pollution and illegal fishing practices is crucial. Strengthening the enforcement of existing regulations and raising awareness among fishers and the general public about the importance of Angel shark conservation are essential components of a comprehensive strategy. In particular, enforcement should focus on halting the sale of endangered species at fish markets (Fig. 5).

Establishing well-managed MPAs along the Libyan coast, particularly in areas identified as important habitats for Angel shark and other elasmobranch species, is also a priority. Two candidate areas, the Tripolitania coast and the Gulf of Sirte (Sidra) waters, have recently been proposed as important shark and ray areas (IUCN SSC Shark Specialist Group, 2023), which would help the national authorities to declare them as MPAs. These MPAs not only protect Angel shark populations but also support local fishers by providing refugia. This could allow for the potential spillover of



Fig. 5. Common Angel shark *Squatina squatina* on display at Tripoli fish market (A Hamza ©).

adults into adjacent fish areas. Future research should focus on expanding the collection of morphometric and biological data, including reproductive biology and feeding ecology. This will help us better understand the population dynamics and ecological requirements of Angel sharks in the region.

Integrating ongoing LEK monitoring with scientific surveys can provide a comprehensive understanding of the status of Angel sharks, enabling more adaptive and effective management strategies.

Conclusion

This study confirms that critically endangered Angel sharks persist in Libyan waters and face severe threats. Local fishers' knowledge, combined with our morphometric data, reveals that all three Mediterranean species are present, mainly juveniles caught as bycatch. Tripoli appears to be a key area, underscoring this for effective protection. Declining catches, linked to pollution and destructive fishing, demand immediate action. The national elasmobranch action plan must be effectively implemented and strengthened, focusing on these threats. The key priorities are bycatch reduction, habitat protection, and prohibition of illegal fishing practices. Community engagement remains crucial. The identified Important Shark and Ray Areas must be legally protected as a priority.

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Conflicts of interest

The authors declare no conflicts of interest.

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Authors' contributions

Abdulmaula Hamza led the conceptualization, data curation, formal analysis, and supervision of the study and was responsible for writing, review, and editing. Amal Abdel-Aziz Abunaqassa, Nusalba Adel Al-Qrew, and Noura Milad Saleh contributed to the field and lab investigations, methodology development, and visualization of the research results. All authors have reviewed and approved the final manuscript.

Data availability

The manuscript contains all the data supporting the findings of this study. Any additional information needed is obtainable from the corresponding author upon justifiable request.

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