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From rarity to reality: the hidden abundance of critically endangered deep-sea little gulper shark (*Centrophorus uyato*) in the southern Adriatic Sea

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Abstract

The little gulper shark, *Centrophorus uyato* (Rafinesque, 1810), is a critically endangered and poorly known deep-sea shark that is considered very rare in certain parts of the Mediterranean, particularly the Adriatic Sea. Between June and August 2023, a total of 47 individuals (25 females and 22 males) were documented 3 to 4.5 NM off Grama Bay in Vlorë, Albania, at depths ranging from 400 to 450 meters. All the recorded individuals were adults, measuring in average 90.53 cm total length and weighting 4.26 kg. Detailed examinations were performed on 10 individuals (5 males and 5 females), while the remaining specimens were retained by fishermen and subsequently sold for consumption. Local ecological knowledge revealed a consistent presence of the species in the longline catches in the studied area. The findings presented in the current manuscript indicate that the species may be more common in the southernmost Adriatic Sea than previously thought. Moreover, data herein support the postulation that the species prefer submarine canyons within the upper slopes.

Keywords: Mediterranean; deep sea; elasmobranch; sharks; abundance.

Introduction

Gulper sharks (*Centrophorus* Müller & Henle, 1837) are small to medium-sized bathydemersal shark species exhibiting global distribution (Compagno, 1984) and inhabiting outer continental shelves and upper slopes (Ebert & Mostarda, 2013). Until recently, *Centrophorus* species found in the Mediterranean and Adriatic Sea have been predominantly reported as *Centrophorus granulosus* (Bloch & Schneider, 1801) (i.e., Capapé *et al.* 2003; D'Onghia *et al.*, 2015). However, doubts regarding its validity have arisen (McLaughlin & Morrissey, 2005; Bañón *et al.*, 2008; Graham & Daley, 2011) and the genus has undergone significant taxonomical revisions (i.e., White *et al.*, 2013, 2017, 2022; Bellodi *et al.*, 2022). Recent revisions have indicated the complete absence of *Centrophorus granulosus* in the Mediterranean Sea (White *et al.*, 2022), indicating that *Centrophorus uyato* is actually the only species found in the region (Barone *et al.*, 2022) for which a taxonomical redescription was performed (White *et al.*, 2022).

The little gulper shark, *Centrophorus uyato* (Rafinesque, 1810), is a deep-sea species with a global distribution, inhabiting specific regions of the Atlantic, Indian, and Pacific Oceans (Last & Stevens, 1994). It is typically found near the ocean floor at depths ranging from 50 to 1400 meters (Geraci *et al.*, 2017), with a preference for the upper slopes (Compagno, 1984). Despite its wide-ranging global distribution, biology of this species remains poorly known (Watson *et al.*, 2004; Morato *et al.*, 2006; García *et al.*, 2008; Kyne & Simpfendorfer, 2010). Presumed biological traits of the species include slow growth, late maturity, and low reproductive output (Stevens *et al.*, 2000; García *et al.*, 2008). Data thus far suggests adults attain 80 to 110 cm in total length (Reiner, 1996; White *et al.*, 2013) and can weigh up to 7.3 kilograms (IGFA, 2001). Reproduction is lecithotrophic viviparous, with a proposed gestation period ranging from two to three years (Guallart & Vincent, 2001; Hamlett, 2011).

The species is classified as rare and critically endangered in the Mediterranean Sea, particularly in its eastern regions (Serena *et al.*, 2020). A recent checklist of chondrichthyans in the Adriatic Sea underscores the species' rarity, with sightings documented after a prolonged absence spanning decades (Soldo & Lipej, 2022). The updated checklist of Croatian chondrichthyans further emphasizes this rarity by indicating that the last docu-

mented record dates back to 1952 (Balaka *et al.*, 2023). Additionally, recent surveys conducted by Ćetković *et al.* (2024) found the species to be absent from Montenegrin waters in the southern Adriatic Sea during recent official commercial fishery and citizen science surveys. In Albanian waters, historical records account for a total of 25 individuals reported by the end of the last century (Storelli *et al.*, 2002). However, these records lack critical details such as sampling locations and depths, as well as additional biological information beyond total length and weight. As a result, our current comprehension of the species' occurrence and distribution in the Adriatic Sea is predominantly based on limited anecdotal reports (e.g., D'Onghia *et al.*, 2015; Carluccio *et al.*, 2021).

Given the scarcity and outdated nature of data on its occurrence in the Adriatic Sea, this paper aims to describe the frequency, catch disposition, and preferred habitats of the critically endangered little gulper shark in the southernmost Adriatic Sea off Albania.

Material and Methods

Field Research

Between June and August 2023, the authors conducted extensive monitoring of longline and trawl fisheries in the outer continental shelves and upper slopes of the southern Adriatic Sea, off the coast of Vlorë, Albania (Fig. 1). This encompassed both onboard surveys at sea and observations of the catch upon landing in Triport Harbour (Vlorë, Albania). During the study, the authors passively observed overall catch and recorded species without any interfering with the fishing activities.

In Albania, longline fisheries primarily target bluefin tuna and swordfish, yet elasmobranch species are frequently encountered. Throughout the study, a total of 25 longline sets were monitored, typically at depths ranging from 150 to 600 meters. The fishermen utilize a monofilament mainline spanning between 11 to 15 km in length. Each line was equipped with single hooks spaced at in-

Fig. 1: Studied area: (A) investigated locality off Vlorë on a macro-regional scale, (B) trawl survey, (C) longline survey, (D) approximate locations where little gulper sharks were both recorded and reported during the study. Map prepared by: A. Gajić.

tervals of 5 to 6 meters, totalling 2,600 hooks deployed during each set. Each set was left to soak for a period of six to eight hours. Additionally, the study monitored commercial bottom trawlers, examining a total of 278 tows at depths between 150 and 550 meters. The researchers directly observed deep-sea trawling aboard a single commercial vessel, undertaking 14 trips, each lasting three to four days during which 87 of 278 hauls were examined. The trawling targeted flat, muddy bottoms at depths ranging from 300 to 550 meters. The average tow duration ranged from six to seven hours, with an average speed of 2 knots, covering transects of 12 to 14 NM per tow. Additionally, 11 other commercial trawlers were monitored upon their arrival in Triport Harbour (Vlorë) during the study period. These vessels operated on the outer shelf off Vlorë at depths between 100 and 250 meters, leading to the examination of the remaining 191 (out of 278) hauls. Key variables were meticulously recorded for each surveyed vessel, including precise geographic locations obtained through GPS devices and mapping software, depths determined via fishermen interviews and accurate nautical charts, and the type of gear used.

Biological sampling

During the field research, longline fishermen captured a total of 47 individuals, of which 10 (comprising 5 males and 5 females) were sampled by authors for further research. All sampled individuals were already deceased upon retrieval, and no individuals were killed nor harmed for this research. The remaining recorded individuals (n=37, supplementary material S1) were retained by fishermen and subsequently sold for consumption. Individuals were identified as *Centrophorus uyato* following Barone *et al.* (2022). The sampled individuals were transported to Sharklab ADRIA for subsequent morphological, pathological, and radiological (MRI) examinations, as a part of another study.

A comprehensive set of 50 morphological measurements was taken following Compagno (2001) and Ebert & Stehmann (2013). The condition factor (CF) was used to assess the relative well-being of individuals (Datta *et al.*, 2013; Logan *et al.*, 2018) and was calculated a CF = (TW x 10^3) / $(TL)^3$, wherein TW is total weight (g) and TL is total length (cm) following Tanaka & Mizue (1977). The hepatosomatic index (HSI) was utilized as an indicator for both nutritional status (Hattori *et al.*, 2009) and physiological responses to environmental stress (Okoboshi *et al.*, 2022); and was calculated using the formula HSI = (LW/TW) x 100, where LW represents liver weight (g) and TW signifies total weight (g). Two specimens were prepared using standard taxidermic procedures (Manton, 2022) and are currently housed in the Sharklab ADRIA collection in Vlorë, catalogued under the number CEN/01/0106/23A(B).

Local ecological knowledge

To complement the field study data, we conducted extensive questionnaires involving longline (n=11) and trawl (n=34) fishermen in Vlorë. These surveys aimed to gather insights into elasmobranchs occurring in the study area leveraging local ecological knowledge, which has been recognized as a valuable approach (Johannes *et al.*, 2000; Brook & McLachlan, 2005; Sáenz-Arroyo *et al.*, 2005; Bender *et al.*, 2014; Tesfamichael *et al.*, 2014; Giovos *et al.*, 2019; Almojil, 2021), especially for less commonly encountered deep-sea species (Gajić *et al.*, 2022) such as the little gulper shark. In addition to inquiries about fishing practices, fishing locations (which were marked directly on a map), depths, and overall catch, our questionnaire (supplementary material S2) included clear images of species known to occur in the area. Fishermen were tasked with identifying each species and to additionally explain their reasoning behind the identification. Such approach ensured the credibility and validity of the information provided (Gibson *et al.*, 2019), as it relied on the firsthand knowledge and expertise of the fishermen, supplemented by visual aids for accurate species identification. Reports from fishermen who captured and reported the species during the study period were deemed credible, as they already demonstrated the proper identification.

Results

During the study, a total of 47 little gulper sharks (25 females and 22 males) were captured by longline fishermen approximately 3 to 4.5 NM off Grama Bay (coordinates: 40.143608° N, 19.422701° E and 40.189860° N, 19.373482° E), within an area characterized by submarine canyons, at depths ranging from 400 to 450 meters. Gulper sharks were observed in 10 out of the 12 longlines examined off Grama Bay, with an average of four to five individuals recorded per longline (Fig. 2). Notably, the species was completely absent from the catches of all the monitored bottom trawlers. All the recorded sharks during the study were adults, with males averaging 84.42 ± 1.27 cm TL and 3.31 ± 0.39 kg TW, and females 96.83 ± 2.93 cm TL and 5.20 ± 0.61 kg TW. Sex ratio of observed individuals was nearly 1:1, and no differences were observed in terms of the male and female distributions according to the depth. The largest recorded female was measured 100.4 cm TL and weighted 6.01 kg TW, while the largest male had 97.7 cm TL and 5.37 kg TW. The females exhibited a condition factor (CF) of 0.576 ± 0.02, whereas the males showed a slightly lower value of 0.558 ± 0.05. Additionally, the hepatosomatic index (HSI) in females was 26.299 ± 0.17, whereas in males, it was somewhat lower at 25.62 ± 0.88. Detailed morphometric measurements of two males and two females (n=4) are given in Table 1, while the full measurements of the remaining examined individuals (n=6) are given in supplementary (material 3). The stomachs of all ten examined individuals were found to be devoid of any content, including bait

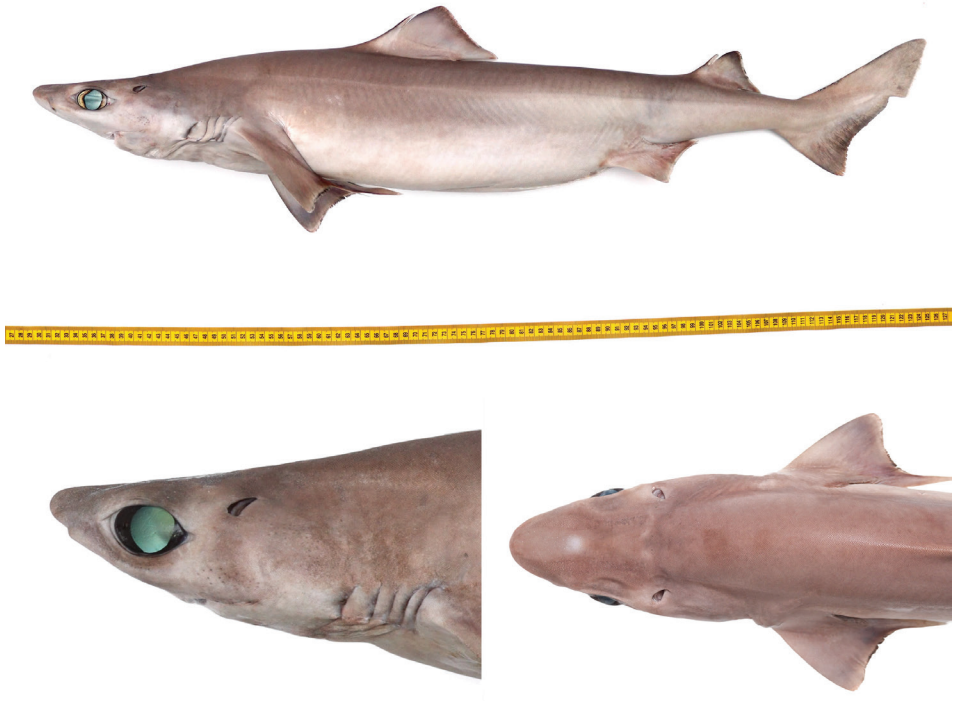

Fig. 2: Adult gulper sharks (*Centrophorus uyato*) captured on 3.5 NM off Grama bay, at a depth of 450 m. Photo credits: A. Gajić.

from the longlines. However, one male individual had a 71 ml of an oil-like substance, which did not float in the water.

The local ecological knowledge revealed the presence of several deep-sea species in the surveyed area, including the little gulper shark. While longline fishermen successfully identified the species, those employing bottom trawls struggled to distinguish between the deep-sea sharks captured, except for the angular rough shark. Consequently, data provided by fishermen employing bottom trawlers was excluded from the study. All the longline fishermen highlighted key diagnostic traits for the species such as large green eyes, dorsal spines, brown coloration, and size (Ebert & Stehmann, 2013; Barone *et al.*, 2022). Moreover, two fishermen discerned differences in the sharpness and shape between the upper and lower jaws (Ebert & Stehmann, 2013). Interviewed longline fishermen revealed a consistent presence of the species in their catches, with an estimation that the species is recorded in over 90% of instances when engaged in fishing activities off Grama Bay, particularly in depths exceeding 350 m. They further reported an average of 3 to 5 individuals per line, with occasional occurrences surpassing 15 individuals. However, the fisherman who caught six of ten individuals examined herein, indicated that in mid-June of 2022, over 110 individuals (weighting approx. 5 to 8 kg.) were captured on a single longline about 4 NM off Grama bay, at the depths of about 400 m. No declines in catch rates over the years were reported. Additionally, fishermen stated that gulper sharks are retained and sold when the overall catch is relatively low, a practice confirmed during fieldwork. However, during periods of abundant catch, the gulper sharks are discarded due to their low economic value. The sharks are released by simply cutting the line, making it impossible to assess their condition or actual post-capture survival during this study. All interviewed fishermen confirmed that they are unaware of the species' critically endangered status and have not had any opportunities to learn more about it.

Discussion

Recent checklists of chondrichthyans (Serena *et al.*, 2020; Soldo & Lipej, 2022; Balaka *et al.*, 2023) indicate the rarity of the little gulper shark throughout the Adriatic Sea. Soldo and Lipej (2022) postulated that sightings of the species in the Adriatic Sea occur after extended periods of absence, spanning decades. However, our findings suggest that the species may be far more prevalent than previously believed, especially in the upper slope of the southernmost Adriatic Sea. These results align with the proposition that adult specimens exhibit a preference for submarine canyons and steeper slopes over flat bottoms (D'Onghia *et al.*, 2014). Such preferences could explain the absence of records in bottom trawls, which target flat muddy bottoms instead. Data obtained through local ecological knowledge directly support this conclusion. Whether the findings presented in this study are an artifact of timing (i.e., an aggregation of the species) or if the previous abundance of the species (at least in the southern Adriatic Sea of Albania) was related to a lack of fisheries monitoring rather than the actual rarity of the species, needs also to be further investigated. Worth to emphasize, several other deep-sea species, including the critically endangered rough shark (*Oxynotus centrina*)

Table 1. Measurements (given in millimeters) and percents of total length determined for two males and two females from Vlorë, Albania.

Observed measurement	MALE 1		MALE 2		FEMALE 1		FEMALE 2	
	mm	%TL	mm	%TL	mm	%TL	mm	%TL
Total length	815	100	806	100	1004	100	925	100
Fork length	728	88.71	686	85.22	894	89.04	804	86.92
Head length	192	23.56	178	22.11	235	23.40	213	23.03
Head height	86	10.55	75	9.32	114	11.35	79	8.54
Precaudal length	667	81.54	637	79.13	827	82.37	719	77.73
Prebranchial length	145	17.79	145	18.01	202	20.12	169	18.27
Interdorsal space	215	26.38	205	25.47	262	26.10	247	26.70
Eye length	41	5.03	40	4.96	44	4.38	43	4.65
Mouth width	59	7.23	55	6.83	86	8.57	73	7.89
Pectoral fin length	148	18.16	145	18.01	151	15.04	168	18.16
Pectoral fin height	80	9.82	79	9.81	79	7.87	83	8.97
Pectoral fin anterior margin	99	12.15	96	11.93	103	10.26	119	12.86
Pectoral fin posterior margin	86	10.55	82	10.19	106	10.56	117	12.65
Pectoral fin base length	33	4.05	43	5.34	56	5.58	47	5.08
Pectoral fin inner margin	102	12.52	106	13.17	127	12.71	119	12.86
First dorsal fin total length	143	17.55	154	19.13	170	16.93	172	18.59
First dorsal fin base length	94	11.53	92	11.43	113	11.25	106	11.46
First dorsal fin height	49	6.01	39	4.84	60	5.98	65	7.03
First dorsal fin anterior margin	97	11.90	89	11.06	78	7.77	117	12.65
First dorsal fin posterior margin	73	8.96	75	9.32	107	10.66	82	8.86
First dorsal fin inner margin	50	6.13	49	6.08	64	6.37	58	6.27
Second dorsal fin total length	87	10.67	91	11.30	96	9.56	99	10.70
Second dorsal fin base length	55	6.75	50	6.21	55	5.48	61	6.59
Second dorsal fin height	36	4.41	42	5.22	51	5.08	49	5.30
Second dorsal fin anterior margin	64	7.85	68	8.45	66	6.57	69	7.46
Second dorsal fin posterior margin	46	5.64	51	6.34	60	5.98	61	6.59
Second dorsal fin inner margin	31	3.80	30	3.73	37	3.67	32	3.46
Pelvic fin total length	91	11.17	85	10.56	97	9.66	107	11.57
Pelvic fin height	50	6.13	54	6.71	56	5.58	53	5.73
Pelvic fin base length	29	3.56	27	3.35	48	4.78	54	5.84
Pelvic fin anterior margin	59	7.24	52	6.46	69	6.87	63	6.81

Continued

Table 1 continued

Observed measurement	MALE 1		MALE 2		FEMALE 1		FEMALE 2	
	mm	%TL	mm	%TL	mm	%TL	mm	%TL
Pelvic fin posterior margin	64	7.85	63	7.83	87	8.67	77	8.32
Pelvic fin inner margin	61	7.48	59	7.33	79	7.88	73	7.89
Clasper length	59	7.24	64	7.95	-	-	-	-
Caudal fork length	88	10.80	102	12.67	105	10.46	96	10.38
Dorsal caudal margin	144	17.67	158	12.63	176	17.53	160	17.23
Preventral caudal margin	87	10.67	89	11.06	116	11.55	103	11.14
Terminal caudal margin	51	6.26	62	7.70	78	7.77	70	7.57
Subterminal caudal margin	21	2.58	22	2.73	21	2.09	21	2.27
Caudal fin form width	61	7.48	62	7.70	69	6.87	61	6.59
Interspiracular	55	6.75	56	6.95	84	8.37	62	6.70
Interorbital	61	7.48	67	8.31	87	8.67	73	7.89
Preoral	75	9.20	45	5.56	94	9.36	91	9.84
Prenasal	25	3.07	24	2.98	35	3.49	28	3.03
Distance 1st and 5th gill slit	30	3.68	34	4.22	42	4.18	38	4.11
Predorsal	270	33.13	254	31.51	324	32.27	306	33.1
Spine total length	42	5.15	47	5.83	58	5.78	48	5.19
Spine length	19	2.33	20	2.48	21	2.09	18	1.95

and the elusive sharpnose sevengill shark (*Heptranchias perlo*), were recently found to be more common in the Adriatic Sea than previously thought after increased monitoring and direct engagement with fishermen (Gajić *et al.*, 2022; Montesanto *et al.*, 2022; Lipej & Mavrič, 2022; Gajić, 2024).

While Ćetković *et al.* (2024) emphasize the absence of recent records in the southern Adriatic Sea of Montenegro, it's essential to recognize the limitations of the conducted surveys, as the majority of fishing activities in Montenegro primarily target depths up to 100 meters (Joksimović *et al.*, 2019). Therefore, the absence of recent records in Montenegro could be attributed to absence of fishing efforts in the preferred habitats of the species, rather than the actual rarity of the species - which necessitates further systematic research.

The condition factor of examined individuls were lower compared to Lebanese waters (Lteif *et al.*, 2017), and as such may suggest certain challenges in nutrient acquisition (Nehemia *et al.*, 2012; Famoofo & Abdul, 2020), as well as potential influences from various factors including stress and water quality parameters (Khallaf *et al.*, 2003). These findings warrant further investigations in this region. Notably, the CF values observed in our study are notably lower compared to those of another recently studied deep-sea squalimorph shark, *Oxynotus centrina*, in the eastern Adriatic Sea, which displayed an average CF of 1.61 and a maximum CF of 3.45 (Gajić *et al.*, 2022). Conversely, the hepatosomatic index (HSI) values were slightly higher than those reported for *O. centrina* in the study by Gajić *et al.* (2022), yet significantly lower than those described by Dragičević *et al.* (2009). However, given the small sample size and limited period of sample collection, drawing conclusions requires additional research in the region.

Despite being critically endangered (Serena *et al.*, 2020), the little gulper shark is not protected under Albanian national legislation (Bakiu & Soldo, 2021), nor in any other Adriatic country (Gajić, 2023). Little gulper shark have low commerical value in Albania, but it is usually sold once caught (2-3 EUR/kg) and utilized for human consumption (mostly fish food, soup and fish burgers). In contrast, based on fisherman interviews in the current study, the commercial value of gulper sharks is so low that they are discarded as by-catch and not landed for commecial sale. It is not known whether the sharks are being released alive or discarded dead in such cases. However, even if released alive, Talwar *et al.* (2017)

noted high post-capture mortality for *Centrophorus sp*., which highlights the necessity of further research in the southern Adriatic given the critically endangered status of the species. The absence of proper fishery monitoring in Albania and the lack of data on the current status and post-capture survival of critically endangered sharks impede the establishment of effective conservation measures (Shiffman & Hammerschlag, 2016; Dulvy *et al.*, 2017; Gajić, 2024). Systematic research on deep-sea sharks and enhancing fishery monitoring in the Adriatic Sea should be imperative across all countries, providing essential data for informing effective long-term conservation measures.

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Supplementary Data

The following supplementary information is available online for the article:
Supplementary material 1: Some of catches containing the little gulper sharks, sold during the study period.
Supplementary material 2: An example of the interview used for assessing LEK.
Supplementary material 3: Full sets of technical measurements of the remaining (n=6) examined individuals.