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Records of the critically endangered *Squatina aculeata* and *Squatina oculata* (Elasmobranchii: Squatiniformes: Squatinidae) from the Mediterranean Sea

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Abstract

All three species of angelsharks that inhabit the Mediterranean Sea, *Squatina aculeata* Cuvier, 1829; *Squatina oculata* Bonaparte, 1840; and *Squatina squatina* (Linnaeus, 1758), are classified as Critically Endangered on the IUCN Red List of Threatened Species, since their populations have suffered severe decline and range reduction, mainly due to fishing pressure. The presently reported study aims to further update records of *S. aculeata* and *S. oculata* in the basin in order to achieve a clearer picture of their current status and geographical distribution. In this way, we were able to add a contribution to our knowledge about their biological characteristics. Records on the incidental capture and observation of specimens of *S. aculeata* and *S. oculata* between 2005 and 2022 were collected through the input of alerted professional fishermen, fisher amateurs, and specialist observers on fishery landings or on board in the context of specific surveying programs as well as of citizens' science initiatives. Biological characters such as total length, total weight, sex, and maturity were determined whenever possible. A total of 18 *S. aculeata* and 34 *S. oculata* specimens were recorded. Data corroborate the current occurrence, which is almost rare, of these two Critically Endangered elasmobranchs from the central to the east part of the basin, revealing furthermore the presence of *S. aculeata* in Sardinian waters, in the western part of the basin. Data document the important habitats for both species existing in the Strait of Sicily, especially in the area around Malta, and confirm the occurrence of *S. aculeata* in the southern Aegean Sea. The current presence of both species is also established in Mediterranean Egyptian waters. Our study suggests the urgent need for a wider application and/or reinforcement of existing protection measures for these angelshark species and their habitat, including populations of the southern Mediterranean waters.

Keywords

angelsharks, biodiversity, critically endangered species, elasmobranchs, spatial distribution

Introduction

Three angelshark species dwell in the Mediterranean Sea: *Squatina aculeata* Cuvier, 1829, *Squatina oculata* Bonaparte, 1840, and *Squatina squatina* (Linnaeus, 1758) (see Serena 2005). Some ecological and biological characteristics of angelsharks, i.e., sedentariness, association with coastal locations, slow growth, and low fecundity, render their populations vulnerable to fishing pressures and to other factors, such as habitat perturbation. All three taxa are classified as Critically Endangered on the International Union for the Conservation of Nature's (IUCN) Red List of Threatened Species, since their populations have suffered severe decline and range reduction, mainly due to intense demersal fishing activities (Nieto et al. 2015; Miller 2016; Zava et al. 2016, 2020; Bradai et al. 2018; Gordon et al. 2019; Bargnesi et al. 2020; Lawson et al. 2020).

The sawback angelshark, *S. aculeata*, is a species that prefers temperate and tropical waters and muddy bottoms at depths from 50 to 500 m in the eastern Atlantic and the Mediterranean; similarly, the smoothback angelshark, *S. oculata*, is a warm-temperate and tropical angelshark in the eastern Atlantic, from off southern Portugal and Spain to Morocco and as far as Angola and Namibia, and the whole Mediterranean Sea; it is a bottom dweller on sand and mud, from 10 m to 500 m, mostly between 50 m and 100 m, deeper in tropics (Compagno 1984; Serena 2005; Carpenter and De Angelis 2016; Weigmann 2016).

In order to briefly integrate the distribution of records of *S. aculeata* and *S. oculata* already exhaustively reported by Miller (2016 and references therein) and Lawson et al. (2020 and references therein), a few additions concerning the records of both species in the Mediterranean published in the literature will follow here. The occurrence of *S. oculata* has been recorded from the northern Aegean Sea in 2014–2015 (Yemişken et al. 2016) and 2018 (Yığın et al. 2019) and in the southeastern Aegean Sea in 2003–2004 (Öziç and Yilmaz 2006; Corsini and Zava 2007). The smoothback angelshark has been also recorded from the Mediterranean waters of Turkey by Meriç et al. (2007), Ergüden et al. (2019 and references inside), Özgür Özbek and Kabasakal (2022 and references inside), and Mutlu et al. (2022). In Lebanon, the occurrence of *S. aculeata* and *S. oculata* has been recently confirmed (Lteif et al. 2014; Bariche and Fricke 2020; Lteif unpublished*). In Syria, both species showed an extremely low abundance in 2014–2016 (Alkusairy and Saad 2018). In northern Tunisia *S. oculata* was recorded in 2018 and 2022 (Rafrafi-Nouira et al. 2019, 2022); in the south of the country (Gulf of Gabès), the occurrence of both *S. aculeata* and *S. oculata* was very rare according to surveys of bottom trawler landings carried out between 2004 and 2010 (Enajjar et al. 2015). Only one specimen of *S. oculata* was recorded in the eastern Ionian Sea in the Fisheries Database of the Hellenic Centre for Marine Research obtained in the framework of 15 scientific projects carried out during the period of 1983–2016 (Damalas et al. 2018). Extremely limited data for *S. oculata* as bycatch were obtained between 1991 and 2018 in Levantine waters and none for the Aegean Sea, Turkey (Bengil and Başusta 2018). Also, no landings of angelsharks from the Mediterranean waters of Turkey were observed during the period 1970–2015 (Başusta et al. 2016). Between 2011 and 2020, twenty records of incidentally captured *S. aculeata* specimens from the west to the central sectors of the basin and up to the eastern side, off the south of Crete and in the southeastern Aegean Sea, have been reported by Zava et al. (2020); in this last area, *S. aculeata* has been recorded also in 2009–2010 (Filiz et al. 2018) and very recently (Montesanto et al. 2022). In the Adriatic Sea, *S. oculata* is considered regionally extinct in Croatian waters (Pešić 2020; Pešić et al. 2021).

During the surveys of the MEDITS (Mediterranean Trawl Survey) conducted in the western Mediterranean in the period 1994–2015, no *Squatina* spp. were detected (Ramírez-Amaro et al. 2020). In the whole of the northern Mediterranean, the surveys of the same MEDITS project did not reveal any capture of *S. oculata* during the period 2012–2015, while *S. aculeata* was very rare and found only in the Aegean Sea (Follesa et al. 2019). According to the MEDITS surveys carried out in the Mediterranean between 2016 and 2018, both *S. aculeata* and *S. oculata* were absent (Anonymous 2017, 2019). The database of the Mediterranean Large Elasmobranchs Monitoring (MEDLEM) showed that both angelshark species considered to reside there were very rare throughout the whole basin (Mancusi et al. 2020).

Taking into account the extremely critical situation of Squatinidae populations in the Mediterranean, the occurrence of *S. aculeata*, *S. oculata*, and *S. squatina* was recently assessed as rare in the western Mediterranean and the Adriatic Sea and as occasional in the central and eastern parts of the basin (Serena et al. 2020).

* Lteif M (2015) Biology, distribution and diversity of cartilaginous fish species along the Lebanese coast, eastern Mediterranean. Ecology, environment. PhD Thesis, Université de Perpignan, France, 262 pp.

The need for the documented occurrence of each of the three endangered angelsharks living in the basin is urgent, since the widely diffused grouping of sharks and rays in landing statistics and the misidentification of species or confusion between species, continue to make it difficult to achieve a clear picture of their status and distribution in the Mediterranean Sea (UNEP-MAP 2019; Cashion et al. 2019; Gordon et al. 2019; Lawson et al. 2020).

In the presently reported study, data on the incidental capture or observation of *S. aculeata* and *S. oculata* and specimens collected between 2005 and 2022 in the Mediterranean Sea are reported in order to contribute to a better understanding of the geographical distribution of these taxa in the basin. This may be helpful for the application and widening of existing regulations for the protection of these endangered species to improve conservation actions and boost our knowledge of some of their biological aspects.

Material and methods

Alerted professional fishermen operating prevalently in the eastern and central Mediterranean waters and appropriately trained, promptly provided information to authors on the incidental capture of specimens of *S. aculeata* and *S. oculata* between 2005 and 2022. Other data were collected by fisher amateurs as well as by specialists on fishery landings or on board in the context of specific survey programs. Data from the Malta Archipelago include those from commercial fishery and those obtained from the MEDITS and MEDLEM monitoring programs. Furthermore, the collection of data from Sicily was enriched through the initiative called "Spot the rare fish", launched by the Museo Civico di Storia Naturale di Comiso, Ragusa, Italy (MSNC). This initiative has been active since 2015 and involves citizen science and professional fishermen of Sicily (cf. Zava et al. 2020).

A total of 18 specimens of *S. aculeata* and 34 specimens of *S. oculata* were detected in various Geographical Subareas (GSAs) of the General Fisheries Commission for the Mediterranean (GFCM) (FAO 2018) (Fig. 1) (Table 1). The distribution map of angelshark findings was prepared using Quantum GIS software (QGIS Development Team 2020).

Specimens were identified according to Compagno (1984), Bauchot (1987), and Serena (2005). Identification was carried out through the accurate examination of photos taken on board, immediately after their capture, or taken underwater, or at landing locations or fish markets. The samples stored at the MSNC and in the collections of the Biological Museum of the Department of Biological and Geological Sciences, Faculty of Education, Alexandria University (Table 1), all retrieved dead, were identified directly in the laboratory.

Sex, maturity, total length (TL), and total weight (TW) were determined, whenever possible.

The relation between TW [g] and TL [cm] was calculated for *S. oculata* using the equation

$$TW = aTL^b$$

where a is a constant depending on the species, and b is the allometric parameter. Data of TW and TL collected in the presently reported study were integrated with data of 21 Mediterranean *S. oculata* specimens retrieved from the literature.

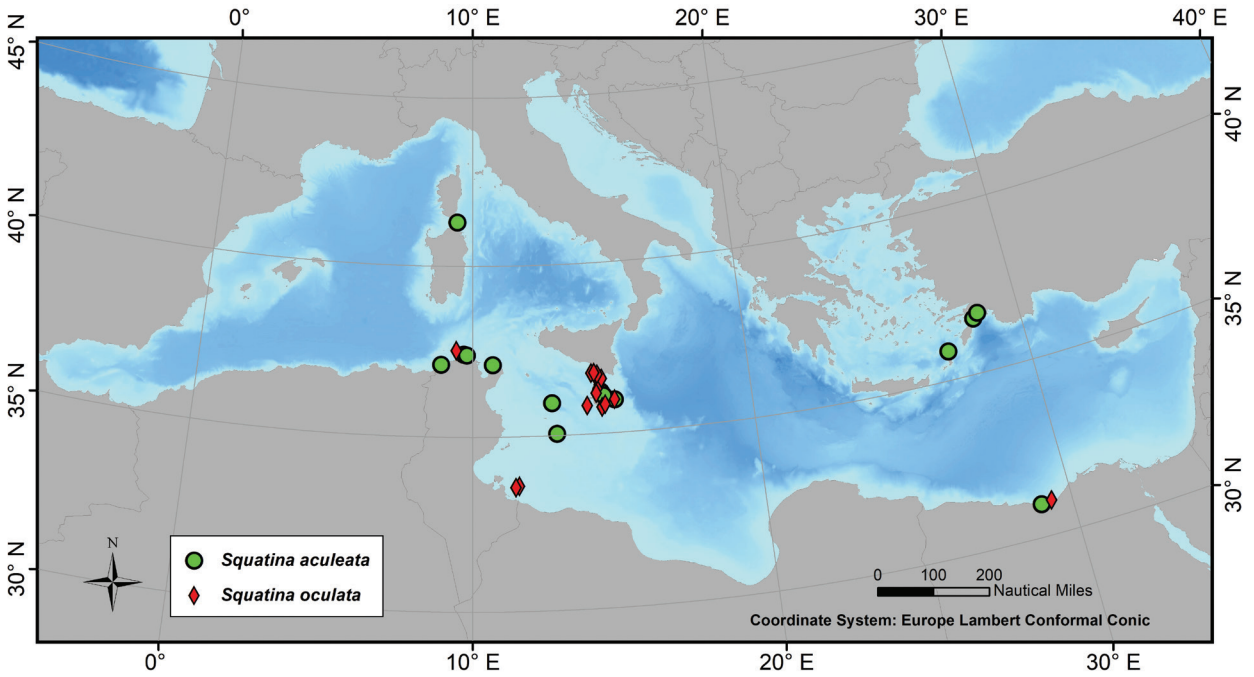

Figure 1. Map of the Mediterranean Sea showing the finding locations of *Squatina aculeata* (green dot) and *Squatina oculata* (red diamond) in the period of 2005–2022.

Table 1. Locations and characteristics of the captures of *Squatina aculeata* and *Squatina oculata* in the Mediterranean Sea (2005–2022).

ID	Date D/M/Y	Country	Place	Coordinates	GSA	Depth [m]	*n*	Sex	M	TL [cm]	TW [g]	Gear/ other	Bottom type	Status	Source of data
Sa1	5/2007	Tunisia	Bizerta	37.4056°N, 9.6836°E	12	120	1	♂	A	>120		BT	Sandy-muddy	Dead and landed, sold	JBS
Sa2	6/2007	Tunisia	Bizerta	37.3808°N, 9.7958°E	12	75	1	♀	A	>130		BT	Sandy-muddy	Dead and landed, sold	JBS
Sa3	1/8/2009	Malta			15		1	♀		128				Dead and landed, sold	AD
Sa4	2/2009	Tunisia	Near Zembra MPA	37.0936°N, 10.7436°E	12	70	1	♂	A	>120		LL	Rocky and sandy	Dead and landed, sold	JBS
Sa5	1/6/2011	Malta		35.9598°N, 15.1013°E	15	105	1	♀	I	49.5	920	BT/MEDITS			MEDITS
Sa6	6/2012	Tunisia	Gulf of Tunis	37.0936°N, 10.7436°E	12	50	1	♂	A	>120		LL	Muddy		JBS
Sa7	3/2013	Tunisia	Tabarka	37.1061°N, 8.8503°E	12	100	1	♂	A	>120		LL	Sandy	Dead and landed, sold	JBS
Sa8	16/12/2014	Malta		36.2125°N, 14.6175°E	15	137	1	♀	I	43	640	BT/ MEDITS			MEDITS
Sa9	31/8/2016	Malta		36.0923°N, 14.7102°E	15	128	1	♀	I	29	200	BT/ MEDITS			MEDITS
Sa10	12/2/2021	Italy	SE of Lampedusa Isl.	35.0500°N, 12.9833°E	13	90	1	♀ + 2 fetuses	P	~150	30000–40000	BT		Released alive	BZ
Sa11	18/4/2021	Egypt	Off El Alamein, Marsa Matruh city	30.9142°N, 28.9742°E	26	55–70	1	♀		113.7	10781	BT	Sandy with coarse grains	Retrieved dead-sold	OMN
Sa12	23/4/2021		Between Rhodes Isl. and Turkey	36.5833°N, 28.3333°E	22	530	1	♀		>130		BT		Released alive	BZ
Sa13	3/5/2021	Greece	Saria Isl., Karpathos	35.8326°N, 27.1796°E	22	80	1	♀		~130		TN		Retrieved dead, sold	GK
Sa14	3/5/2021	Greece	Saria Isl., Karpathos	35.8326°N, 27.1796°E	22	80	1	♀		~120		TN		Retrieved dead, sold	GK
Sa15	7/5/2021	Egypt	Off El Alamein, Marsa Matruh city	30.9142°N, 28.9742°E	26	60–70	1	♀		89	4300	BT	Sandy with coarse grains	Retrieved dead Deposited BMAU	OMN
Sa16	22/5/2021	Italy	Corcelli Isl., Sardinia	41.2970°N, 9.4019°E	11.2	40	1	♂		150	30000	TN		Released alive	BZ
Sa17	11/4/2022	Italy	Linosa Isl., Sicily	35.8548°N, 12.8764°E	16	35	1	♂		~150	40000	TN		Released alive	BZ
Sa18	7/9/2022		Between Rhodes and Turkey	36.7639°N, 25.2220°E	22		1	♀		120		BT		Released alive	BZ
So	6/1980	Italy	Marzamemi, Sicily		19		1			110.0				Dead and landed, sold	GI
So	18/8/1993	Italy	Banco Scalambri, south Sicily		16	250	1	♀	I	29.2		BT		Retrieved dead. Deposited MSNC4769	GI
So1	14/9/2005	Malta		35.8333°N, 14.1000°E	15		1			96.0					MEDLEM AD
So2	28/9/2005	Malta			15		1	♀		156.0					MEDLEM AD
So3	22/6/2006	Malta		35.7658°N, 14.6358°E	15	126	1					BT/ MEDITS			MEDITS
So4	11/2007	Tunisia	Bizerta	37.5203°N, 9.4047°E	12	150	1	♂		>80	~3000	BT	Sandy-muddy	Dead and landed, sold	JBS
So5	11/2007	Tunisia	Bizerta	37.5203°N, 9.4047°E	12	150	1	♀		>80	~3000	BT	Sandy-muddy	Dead and landed, sold	JBS
So6	11/2007	Tunisia	Bizerta	37.5203°N, 9.4047°E	12	150	1	♂		>80	~3000	BT	Sandy-muddy	Dead and landed, sold	JBS
So7	11/2007	Tunisia	Bizerta	37.5203°N, 9.4047°E	12	150	1	♂		>80	~3000	BT	Sandy-muddy	Dead and landed, sold	JBS
So8	11/6/2008	Malta		36.4092°N, 14.5762°E	15	145	1	♀	I	42	430	BT/ MEDITS			MEDITS
So9	12/6/2008	Malta		36.1785°N, 14.4470°E	15	173	1	♀	I	29.5		BT/ MEDITS			MEDITS
So10	12/6/2008	Malta		36.1785°N, 14.4470°E	15	173	1		I	32		BT/ MEDITS			MEDITS
So11	13/6/2008	Malta		35.7613°N, 14.6307°E	15	132	1	♂	I	37.5	520	BT/ MEDITS			MEDITS
So12	13/6/2008	Malta		35.8408°N, 14.7495°E	15	80	1	♀	M	94	7000	BT/ MEDITS			MEDITS
So13	17/6/2013	Malta		35.9690°N, 15.0960°E	15	101	1	♂	I	74	1680	BT/ MEDITS			MEDITS
So14	4/2014	Tunisia	Zarzis	33.5764°N, 11.6125°E	14	47	1	♂	A	>100		BT	Muddy	Dead and landed, sold	JBS

Table 1 continues on next page.

Table 1. cont.

ID	Date D/M/Y	Country	Place	Coordinates	GSA	Depth [m]	*n*	Sex	M	TL [cm]	TW [g]	Gear/ other	Bottom type	Status	Source of data
So15	5/2014	Tunisia	Zarzis	33.5383°N, 11.4928°E	14	26	1	♀	SA	<80		BT	Muddy	Dead and landed, sold	JBS
So16	12/2/2016	Italy	Off Scoglitti Sicily	36.7590°N, 14.4116°E	16	120	1	♀		70.5	3300	BT	Coralligenous, muddy	Frozen MSNC	GI
So17	6/2016	Malta			15		1	♂		77.5		TN		Discards	AD
So18	6/2016	Malta			15		1	♂		77.5		TN		Discards	AD
So19	6/2016	Malta			15		1	♀		97.0		TN		Discards	AD
So20	6/2016	Malta			15		1			71.0		TN		Discards	AD
So21	2/8/2016	Italy	Off Pozzallo, Sicily	36.5930°N, 14.6657°E	16	110	1	♂		74.7	3100	TN	Coralligenous, muddy	Frozen MSNC	GI
So22	15/8/2016	Malta			15	35	1	♀		~100		UW			GI
So23	17/3/2017	Italy	Off Scoglitti Sicily	36.7693°N, 14.3064°E	16	180	1	♂		73.4	2750	BT	Muddy	Frozen MSNC	GI
So24	28/6/2017	Italy	Off Marina di Ragusa Sicily	36.7256°N, 14.5197°E	16	50	1			98.0		TN	Coralligenous, muddy	Released	GI
So25	6/2017	Malta			15		1	♀	I	31.0		BT		Discards	AD
So26	6/2017	Malta			15		1	♀	I	29.5		BT		Discards	AD
So27	6/2017	Malta			15		1	♀	I	29.0		BT		Discards	AD
So28	30/8/2017	Italy	Off Scoglitti Sicily	36.7764°N, 14.4081°E	16	50	1	♀		90.3	6550	BT	*Posidonia* meadows, sandy	Frozen MSNC	GI
So29	5/2018	Malta			15		1	♀		94.5		BT		Discards	AD
So30	3/2019	Malta			15		1	♂		122.0		BT		Discards	AD
So31	3/2019	Malta			15		1	♂		75.0		BT		Discards	AD
So32	10/2019	Malta			15		1	♀	I	29.0		BT		Discards	AD
So33	28/3/2021	Egypt	Off El-Hamam	30.9599°N, 29.3287°E	26	55–70	1	♂		70	2741	BT	Sandy with coarse grains	Retrieved dead Deposited BMAU	OMN
So34	28/3/2021	Egypt	Off El-Hamam	30.9599°N, 29.3287°E	26	55–70	1	♀		49.2	841	BT	Sandy with coarse grains	Retrieved dead Deposited BMAU	OMN

Sa = *Squatina aculeata*; So = *Squatina oculata*; ID = species acronym and specimen identification number; GSA = GFCM geographical subarea; *n* = number of specimens; M = maturity; A = adult; I = immature; M = mature; P = pregnant; TL = total length [cm]; TW = total weight [g]; BT = bottom trawl; TN = trammel net; LL = longline; UW = underwater observation; MSNC = Museo Civico di Storia Naturale di Comiso, Ragusa, Italy; BMAU = Collections of the Biological Museum of the Department of Biological and Geological Sciences, Faculty of Education, Alexandria University, Egypt; MPA = Marine Protected Area; MEDITS = Mediterranean Trawl Survey; MEDLEM: Mediterranean Large Elasmobranchs Monitoring. Bold font denotes samples not considered in Results.

Results

***Squatina aculeata*.** Among the 18 specimens of *S. aculeata* detected between 2007 and 2022, one specimen was incidentally captured in the western basin, off Sardinia (GSA11.2), 11 specimens were incidentally captured in the central Mediterranean, of which five from north Tunisian waters (GSA12), four from Malta (GSA15), one from Lampedusa, and Linosa (Italy) (GSA13) respectively, while the remaining six were found in the eastern basin, four in the Aegean Sea (GSA22), and two in the Egyptian waters (GSA26) (Table 1) (Figs. 1, 2). Ten specimens were caught by bottom trawling, three by longline, and four by trammel net, at depths from 35 m to 530 m, generally on the soft bottom. Apart from two females from Egypt with TL < 120 (Fig. 2B, E) and a juvenile female of 50 cm TL from Malta, the remaining specimens of both sexes had a TL ≥ 120 cm (Fig. 3A) (Table 1). The majority of the sawback angelsharks were captured in spring, followed by summer and winter (Fig. 3B). It must be emphasized that, during the handling of the female caught off Lampedusa Island (Sa10, Table 1), two fetuses of about 15 cm in length were recovered on board (video available at https://youtu.be/6LQTrvzTQTQ). The fetuses carried a yolk sac attached to their ventral side. The live female and fetuses were immediately released.

***Squatina oculata*.** Among the 34 specimens of *S. oculata* incidentally captured or observed between 2005 and 2021, the majority (32 specimens) were found in the central Mediterranean, of which 21 specimens were detected off Malta Island (GSA15) (Fig. 4A1, A2), six off Tunisia (GSA12 and GSA14), and another five off south of Sicily, Italy (GSA16) (Fig. 4B), while the remaining two smoothback angelsharks were fished in the eastern basin, Egypt, GSA26 (Figs. 1, 4C, D) (Table 1).

Sex was determined in 29 smoothback angelsharks, 16 females and 13 males (Table 1). One specimen of *S. oculata* was observed at 35 m of depth during scuba diving, six specimens were caught with trammel nets, and 25 with bottom trawls, at depths from 26 m to 180 m, generally on muddy or muddy sandy bottoms, but also on *Posidonia oceanica* or other vegetated seabeds (Fig. 4A1, A2) (Table 1).

Eleven specimens had a TL between 41 cm and 80 cm and another 12 between 81 cm and 120 cm (Fig. 3A). Total length for both sexes and undetermined sex ranged from 29 cm to 156 cm (69.0 ± 32.4 cm, *n* = 25); total

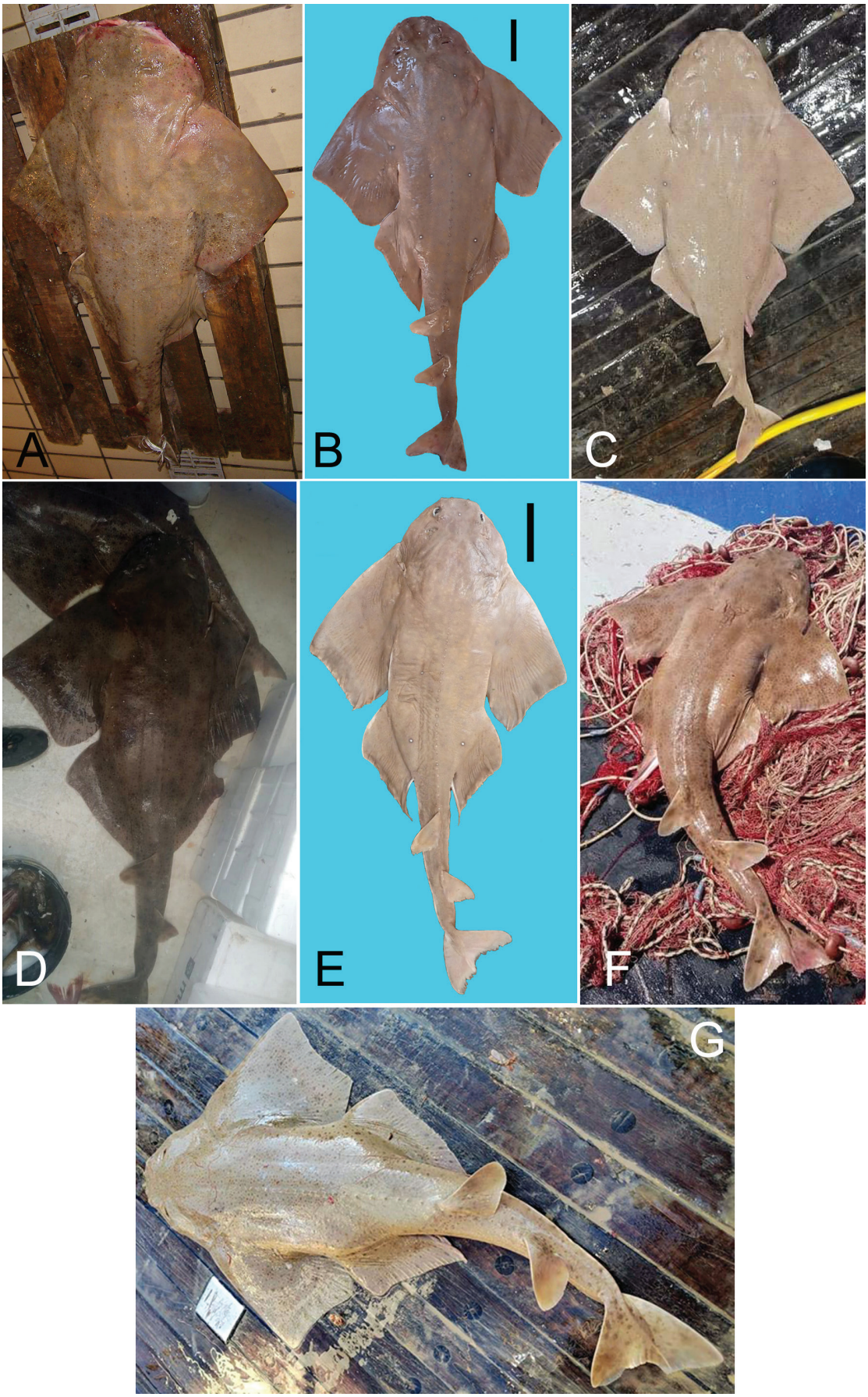

Figure 2. Specimens of *Squatina aculeata* from the Mediterranean Sea. Letters correspond to the following acronyms in Table 1: A = Sa3 (Photo by G. Nowell), B = Sa11, E = Sa15 [Scale bar: 10 cm] (Photos by O.M. Nour), C = Sa12 (Photo by G. Pilla), D = Sa13 and Sa14 (Photo by H. Kioukekli), F = Sa16 (Photo by E. Vitiello), G = Sa18 (Photo by G. Pilla).

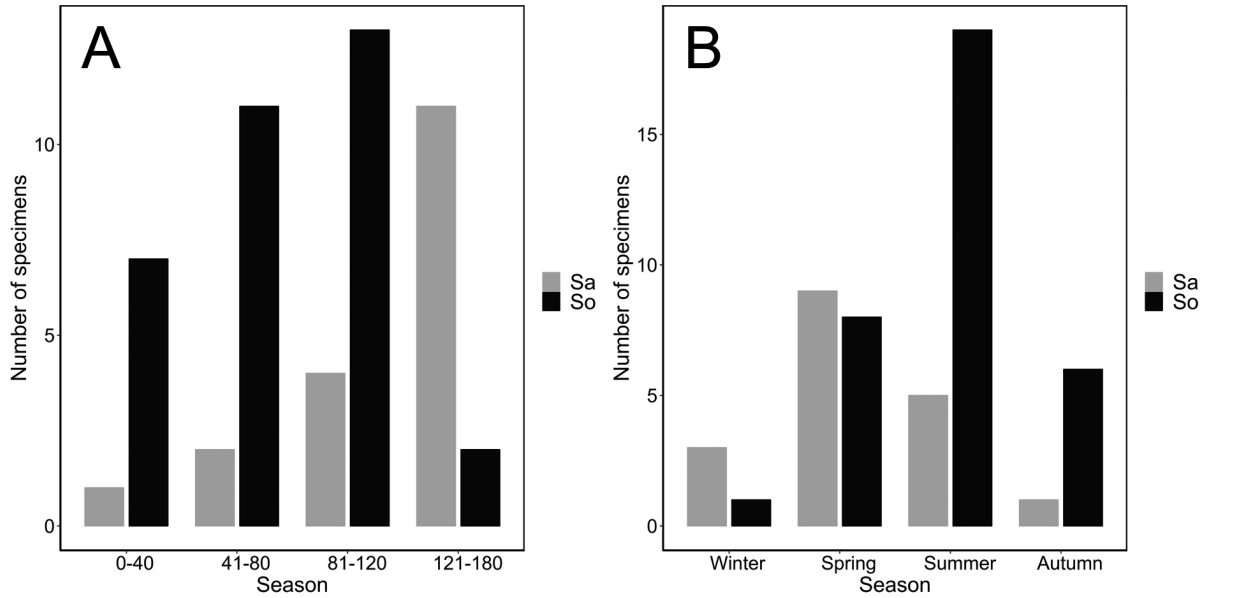

Figure 3. Total length distribution of *Squatina aculeata* (Sa) and *Squatina oculata* (So) detected between 2005 and 2022 in the Mediterranean Sea (**A**) and seasonal distribution of findings (**B**).

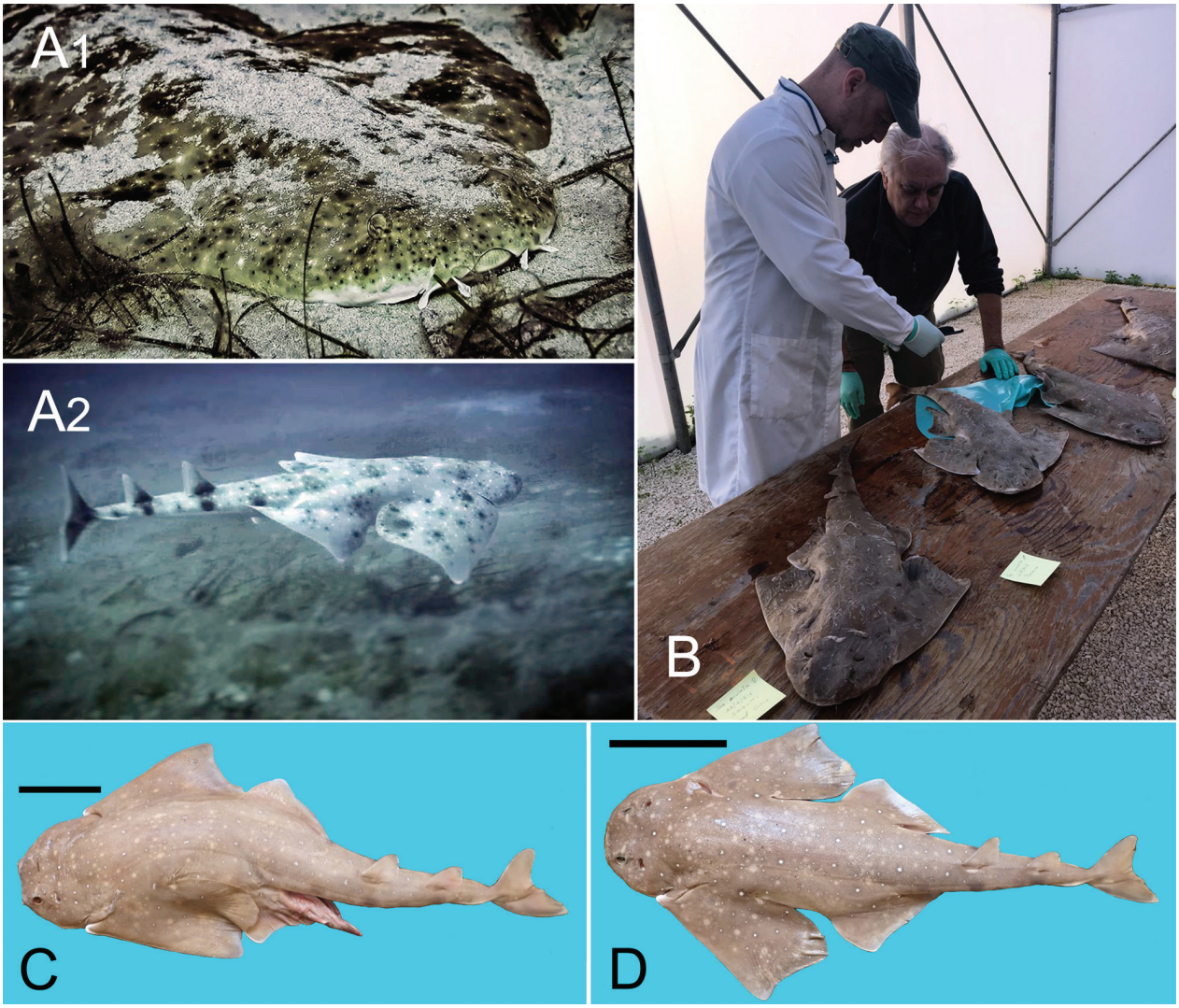

Figure 4. Specimens of *Squatina oculata* from the Mediterranean Sea. Letters correspond to the following acronyms in Table 1: A1 and A2 = So22 (Photos by J. Kuenzel); B = So16, So21, So23, So28 (Photo by G. Polizzi); C = So33, D = So34 (Photos by O.M. Nour) [Scale bars: 10 cm].

length ranged from 29 cm to 156 cm for females (64.7 ± 39.5 cm, n = 13), and from 37.5 cm to 122 cm for males (75.7 ± 21.4 cm, n = 9) (Table 1). The majority of *S. oculata* specimens were captured during the summer, followed by the spring (Fig. 3B).

In addition to the TW and TL measurements determined in 10 specimens of the presently reported study (Table 1), values from 21 Mediterranean specimens were retrieved from the literature for the TW–TL relation (Başusta et al. 1998; Kabasakal and Kabasakal 2004; Corsini and Zava 2007; Zava et al. 2016; Ergüden et al. 2019; Yığın et al. 2019; Özgür Özbek and Kabasakal 2022; Lteif unpublished*). The TW–TL relation for the above 31 specimens (TL 24–95 cm, TW 71–7000 g) resulted in $TW = 0.0038 \cdot TL^{3.1602}$ ($R^2 = 0.974$). The value of the estimated parameter b indicated a positive allometric growth.

During the examination of the stomach content of the 4 specimens stored at the MSNC, only the remains of flatfish eyes were observed, as for *S. aculeata* examined by Zava et al. (2020).

Two records of *S. oculata*, the first reported in 1980 and the second in 1995, are listed in Table 1 for historical reasons, but not considered in the Results.

Discussion

The results showed that *S. aculeata* and *S. oculata* are bycatch species mainly of bottom trawlers, as for *S. squatina*, but they are also impacted by trammel nets and longlines (Serena 2005; Lawson et al. 2020; Zava et al. 2020). The number of specimens released alive was insignificant compared to the number of specimens retrieved dead and sold or discarded. Both species were recorded in relatively shallow waters off Tunisia, south Sicily, Malta, and Egypt regions (26–180 m), apart from one *S. aculeata* from the southeastern Aegean Sea, caught in deep waters (530 m), as for the 60% of the sawback angelsharks listed in Zava et al. (2020). The majority of records of the two angelshark species considered here were reported during summer, followed by spring, both in the central and eastern Mediterranean. These results are probably due to more suitable weather conditions in spring and summer and the consequent intensification of fishery activities during these seasons. In Ragonese et al. (2013) no captures of these species were reported in spring and summer along the bottom trawl surveys carried out off the southern coasts of Sicily (1994 to 2009), while in Zava et al. (2020) the majority of *S. aculeata* were detected in winter.

The records listed in the presently reported study for both species were based predominantly on observations made by fishermen, observers on board, or observers of landings, accompanied in most cases by inaccurate measurements of total length and/or weight that evidently limited the availability of data for further biological study. The parameters obtained for the relation TW–TL of *S. oculata* were comparable to those obtained by Capapé et al. (2002) and Ellis et al. (2021), although the number of Mediterranean *S. oculata* specimens considered (n = 31) (ten of the presently reported study and 21 from literature), was significantly lower than the number of specimens from Senegal (n = 121, females), while it was similar to the number of specimens from the southeast Atlantic (n = 32) studied by the above-mentioned authors. Concerning *S. aculeata*, efforts to build a TW–TL relation for Mediterranean specimens have been recently applied (Zava et al. 2020).

Considering *S. oculata*, and according to Capapé et al. (1990, 2002), Miller (2016), and Ellis et al. (2021), the size of about all males corresponded to mature individuals (TL > 70 cm), while seven females were juveniles (TL < 70 cm), one sub-adult and four females had a size of mature individuals (TL > 90 cm). Almost all specimens of *S. aculeata* of both sexes were adults, apart from two subadult females from Egypt (cf. Capapé et al. 2005).

The occurrence of *S. oculata* juveniles in the waters off Malta and of a pregnant female *S. aculeata* off Lampedusa, as well as the occurrence of adults of both species in the region between the strait of Sicily and Malta, indicate that this area constitutes an important habitat and a nursery ground for both species (Zava et al. 2016, 2020).

Concerning the waters around the Malta Archipelago, it is to be noted that an old taxidermized specimen of *S. oculata* is displayed at the National Museum of Natural History in Mdina, Malta (Fig. 5), testifying that the species also occurred in the past in the area. After the accurate revision of shark and ray species records in the Maltese Islands by Schembri et al. (2003), the occurrence of the smoothback angelshark was considered rare or not frequent and the need for validation was therefore underlined. The findings of all sizes of *S. oculata* in the presently reported study over the last fifteen years ascertain the current presence of the species off Malta, confirming nevertheless that it is uncommon in the area.

Going back to historical documentation on *S. oculata* from Sicily, two stuffed specimens were stored at the Zoological Museum "Pietro Doderlein" of the University of Palermo (catalog numbers P-563 and P-564, Doderlein 1878–1879) (Fig. 6). The label of the display specifies that it was collected in "Mar di Palermo", in the sea of Palermo, northwest of Sicily. Furthermore, a female *S. oculata* could be noted in a postcard showing the fish market of Portopalo di Capo Passero, at the southeastern tip of Sicily, during the 1980s (Fig. 7). Finally, in June 1980, the capture of a large specimen at Marzamemi, southeastern Sicily, was registered by the curator of the MSNC, while a juvenile female *S. oculata* (TL 29.2 cm),

* Lteif M (2015) Biology, distribution and diversity of cartilaginous fish species along the Lebanese coast, eastern Mediterranean. Ecology, environment. PhD Thesis, Université de Perpignan, France, 262 pp.

Figure 5. Stuffed *Squatina oculata* displayed at the National Museum of Natural History in Mdina, Malta (Photo by B. Zava , 2016).

caught on 18 August 1993 by bottom trawl at 250 m of depth off Marina di Ragusa, southeastern Sicily is stored at the MSNC (MSNC4769) (Table 1).

As regards the Italian seas, the range of *S. aculeata* has been reported only for the Ligurian and southern Tyrrhenian waters in Vacchi and Serena (2010). The occurrence of the sawback angelshark in the south Tyrrhenian Sea has, in fact, been recently confirmed (Zava et al. 2020). Due to the lack of data over a long period from the northern Tyrrhenian Sea (Ferretti et al. 2005; Miller 2016), the species has been considered doubtfully present or absent in Sardinian waters (Gordon et al. 2019; Lawson et al. 2020). Consequently, the recent finding of *S. aculeata* in the shallow waters off the northeast of Sardinia, described in the presently reported study, is especially noteworthy. This surprising record probably denotes the existence of a suitable habitat, perhaps hitherto unexplored and unknown for the species.

The records described, substantiate furthermore that populations of *S. aculeata* dwell in the southern Aegean, as observed in Zava et al. (2020 and references therein) and Lawson et al. (2020 and references therein).

All three species of angelsharks are listed among the ichthyofauna of the Mediterranean Egyptian waters (Akel and Karachle 2017), but their presence is considered uncertain or very rare (Morey et al. 2019a, 2019b; Lawson et al. 2020), due to the lack of observations over a long period. In studies conducted off Alexandria in the last decade, the occurrence of *S. squatina* has been documented (Moftah et al. 2011; Azab et al. 2019). The records here described of *S. oculata* and *S. aculeata* in the same area, off Alexandria, are therefore remarkable, not only

Figure 6. Stuffed *Squatina oculata* (female) displayed at the Zoological Museum "Pietro Doderlein", University of Palermo, Italy (catalog number P-563) (Photo by B. Zava, 2014).

Figure 7. *Squatina oculata* at the fish market of Portopalo di Capo Passero, Sicily, in the 1980s. (Postcard) (Dino Oliva, kind permission. https://www.facebook.com/portopalodiunavolta).

because they verify their current occurrence in the Mediterranean waters of the country, but because they contribute furthermore to enrich the poorly known geographical distribution of both species in the southern waters of the Levantine basin.

Conclusions

Understanding the life-history strategies of endangered elasmobranchs and increasing our knowledge about their spatial distribution have important implications for conservation purposes. Given the high risks of extinction of the angelsharks in the Mediterranean Sea, effective protective measures across international boundaries should be adopted through the identification of critical habitats and knowing the period of key life-history events, namely, mating, spawning, and pupping. In addition, it would be advisable to implement protective measures in order to reduce mortality levels stemming from commercial fisheries.

The results of this study could be used to design *ad hoc* spatial protective measures limiting commercial fishing, for example, around the shallow waters in Lampedusa and Maltese Archipelago, preserving crucial habitats and potential nursery areas for *S. oculata* and *S. aculeata*. In parallel, it will be important to carry out awareness campaigns for fishermen by informing them of the vulnerability of the species and how to handle and release safely the captured individuals, so avoiding death and possible sale to the fish market.

Results of this study also indicate that the network of well-trained professional fishermen, and fisher amateurs, along with researchers, can be considered an ever-growing source of data on wildlife, which can fill the gaps of knowledge on the occurrence and distribution of threatened elasmobranch species in poorly known habitats.

Indeed, thanks to this well-structured network of experts, it was possible to update the spatial distribution of Mediterranean angelsharks, reporting for the first time the occurrence of *S. aculeata* in waters off the northeast of Sardinia and confirming the presence of *S. aculeata* and *S. oculata* in the Egyptian waters where they had been hitherto considered uncertain or very rare.

This stressed the necessity of enlarging the Mediterranean network interested in collecting information about angelsharks and activating a long-term monitoring project to obtain a more homogeneous and realistic description of the presence and distribution of these species throughout the whole Mediterranean basin, in order to estimate their relative abundance and to identify critical habitats in nearshore areas in terms of mating and pupping.

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