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## Chapter

# Overview of the Genus *Squalus* in the Mediterranean Sea

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## Abstract

In the Mediterranean Sea, in addition to the two historically known species belonging to the *Squalus* genus (*Squalus blainville* and *Squalus acanthias*), a third species, *Squalus megalops*, has been reported. This last species is a subject of debate between authors. *S. acanthias* is quite distinct from the other species of the genus *Squalus*, while *S. blainville* and *S. megalops* are very similar morphologically. This similarity has resulted in considerable confusion over their taxonomy. The lack of a well-preserved holotype for *S. blainville*, misidentifications in databases and in the literature, description, and figure of Risso (1827) not conforming to any known species of *Squalus* are impediments to the proper taxonomic identification and the potential revision of the genus. This chapter aims to clarify the state of the species of the genus *Squalus* in the Mediterranean Sea, taking into account all the studies carried out on this subject.

**Keywords:** sharks' misidentification, *squalus* genus, *Squalus blainville*, *Squalus acanthias*, *Squalus megalops*, Mediterranean Sea

## 1. Introduction

The Mediterranean Sea is a semi-enclosed sea covering less than 1% of the surface of the global oceans, even though it constitutes a general richness hotspot of total species on a global scale [1, 2]. This richness of cartilaginous and bony fishes is likely the result of the recolonization of the Mediterranean basin after the Messinian crisis. As demonstrated for the great white shark [3], pulses of species immigrations occurred during the glacial and interglacial periods of the quaternary [4].

It is a heterogeneous biogeographic area that shows a high level of biological diversity. This sea constitutes a complex marine ecosystem within which elasmobranchs play a basic role in controlling trophic relationships [5]. This is related to multiple factors from its geological history to its peculiar oceanographic and ecological features [6].

The Mediterranean Sea is considered a Chondrichthyes-rich basin. Recently, a total of 88 chondrichthyan species were listed, representing 30 families and 48 genera in the area [6]. This list includes 48 species of sharks, belonging to 18 families and 27 genera, 38 species of batoids, belonging to 11 families and 19 genera, and two chimeras belonging to two different genera.

Despite its richness, it encloses the highest proportion of threatened species in the world [7], in the Mediterranean Sea, where at least 53% of the species are classified

by the IUCN as vulnerable, endangered, and critically endangered [8, 9]. Quite a large proportion of species (13%) are still classified as data deficient [8].

There are information gaps with respect to species richness and abundance of elasmobranchs in the Mediterranean Sea. These gaps often make it hard for international organizations to assess the conservation status of populations. Either the knowledge of the abundance and richness of this group, which has played a crucial ecological part in Mediterranean trophic webs, is also significant to any future strategic plan for the conservation of marine biodiversity in the region [10, 11].

The gaps are due to many reasons, the most important of which is the misidentification of species in databases and in the literature. Generally, elasmobranchs have suffered major taxonomic constraints that have led to misidentification issues related to by-catch and fisheries, which were usually solved by grouping data at higher taxonomic levels, such as genus or family [12, 13], or to morphological and biological similarities among some species, which have led to considerable confusion over their taxonomy such the case of the *Squalus* genus species [14].

Dogfish are scientifically classified as the Squalidae family, categorized under the squaliform order, which encompasses seven families in total, including Squalidae. The latter, more commonly known as dog sharks or spiny dogfish, have two dorsal fins different in shape with long spines without grooves and anal fin, with a cylindrical body and a small mouth. Their jaws are furnished with powerful cutting teeth and sometimes present only on the lower jaw; the upper jaw plays, in this case, only the role of holding the prey. The species of this family are generally small sharks, which frequently generally more or less accentuated bottoms except for the spiny dog *S. acanthias*, which does not descend below 150 meters.

Some species are highly valued and important as a major fish resource for food and liver oil. Some species are threatened due to overfishing and because of their biological characteristics, namely a long lifespan, late maturity, and low fecundity, as is the case with all elasmobranchs.

The Squalidae family itself contains two separate genera: *Cirrhigaleus* and *Squalus*, numbering together 37 species, and has the most species in the group, including *Squaliolus laticaudus*, one of the smallest known sharks with a size of 15 cm.

The genus *Squalus* Linnaeus, 1758 is distributed worldwide [15]. Until 2013, 25 species were known: 14 species documented as valid and 11 species added latterly from the western Indo-Pacific ocean [16–18]. But, this number has recently increased due to the resurrection of *Squalus acutipinnis* (Regan 1908) from South Africa and the description of four new species (*S. albicaudatus*, *S. bahiensis*, *S. lobularis*, and *S. quasimodo*) from the southwest Atlantic [19–21].

It was stated that the species diversity within the group is still poorly characterized [22]. For instance, 20 species have been described or resurrected in the last decade in the Indo-Pacific region [23–25] and the south Atlantic [19, 20].

In fact, cryptic speciation among elasmobranchs is very common [26, 27] and the number of new descriptions, red descriptions, and resurrections of species is growing with the increasing application of molecular tools and integrated taxonomic methodologies. Thus, the number of valid species in the genus was doubled and a significant amount of “hidden” diversity in the group has been revealed. Consequently, about 50% of the *Squalus* species are considered data deficient consistent with the International Union for the Conservation of Nature (IUCN) red list of threatened species [22].

The *Squalus* species inhabit the waters of the continental shelf and upper slope, between 300 and 700 m of depth [28–30], as well as some seamounts and the waters around oceanic islands [22, 31]. They have been divided into four assemblages based on

their morphology: the “*acanthias*” group, the “*blainville*” group, the “*megalops cubensis*” group, and the “*asper-barbifer*” group [32–34]. However, members of the “*asper-barbifer*” group are assigned to the genus *Cirrhigaleus* [17]. Nevertheless, in recent years, different genetic studies have attempted to identify *Squalus* species using mitochondrial COI and NADH2 genes [22, 35–37]. Generally speaking, three well-defined groups within the genus have been described: group I, including *Squalus suckleyi* and *S. acanthias*; group II, including *S. blainville*/*S. megalops*/*Squalus raoulensis*/*Squalus brevirostris*; and a third group, “the *Squalus mitsukurii* complex” including *Squalus edmundsi*, *Squalus japonicus*, *Squalus grahami*, *Squalus clarkae*, and *S. mitsukurii* [22, 38–40].

In the Mediterranean, in addition to the two historically known species the long-nose spurdog *S. blainville* (Risso, 1827) and the spiny dogfish *S. acanthias* (Linnaeus, 1758), a third species, the shortnose spurdog *S. megalops* (Macleay, 1881), has been reported [40–43].

In the following, we try to clarify the state of the species of the genus *Squalus* in the Mediterranean Sea taking into account all the studies carried out on this subject.

## 2. Status of *squalus* genus in the Mediterranean Sea

### 2.1 Ecobiology

As many elasmobranchs, Squalidae are K-selected species with slow growth rates, low fecundity, and late sexual maturation; those species tend to aggregate by sex and size [31, 44, 45]. These features make such a taxon greatly vulnerable to overfishing. Thus, increased understanding of their ecobiology is crucial to develop an assessment for conservation strategies and developing effective fisheries management.

	Maximum TL (cm)	Maturity size (cm TL)	Uterine Fecundity	Size at birth (cm TL)	Location, reference
<i>Squalus blainville</i>	♀89.0	51–65	1–5	21–24	Gulf of Tunis, Tunisia [46]
	♂76.0	45–51			
	♀ 84.0	70	2–6	—	Gulf of Tunis, Tunisia [47]
	♂ 64.0	51			
	♀ 75.0	60	—	20–23.5	Gulf of Tunis, Tunisia [48]
	♂ 62.0	55			
	♀ 92.0	57–58	—	15.5–16.5	Strait of Sicily, Italy [29]
	♂ 73.5	45–46			
	♀78.5	60.1	2–6	19–22	Ionian Sea, Greece [49]
	♂66.4	45–51			
	♀100	62.5	2–6	23.2–24.5	Gulf of Gabès, Tunisia [50, 51]
	♂83.4	52.3			
	♀77.9	65.44	1–6	18–20.9	Eastern Mediterranean Sea [52]
	♂79.9	45.77			
	♀ 95.0	60.3	—	—	Eastern Ionian Sea [53]
	♂ 100.0	41.3			

	Maximum TL (cm)	Maturity size (cm TL)	Uterine Fecundity	Size at birth (cm TL)	Location, reference
<i>S. megalops</i>	♀76	56.41	2–6	18.8–23.6	Gulf of Gabès, Central Mediterranean Sea [50, 51]
	♂69	44.39			
<i>S. acanthias</i>	♀111.0	86–88	4–12	—	Languedocian coast, Northern Mediterranean [54]
	♂80.0	63.5–70			
	♀82.0	51.8	1–6	7.2–22	Eastern Mediterranean Sea [55]
	♂75.5	47.0			
	♀117.5	56.4	1–9	22.3	North Aegean Sea [56]
	♂121.6	52.8			
	♀102.5	57.5			
♂87.5	65.9				

**Table 1.**  
*Studies on Squalus blainville, S. megalops, and Squalus acanthias reproduction carried out in the Mediterranean Sea.*

In the Mediterranean Sea, many investigations on the life history traits of Squalidae were conducted toward filling the information gap and to develop practical conservation strategies for those species in the area. As shown in **Tables 1–4**, a survey of the available published literature was carried out through a bibliographic study.

Until now, the historical traits of the Mediterranean population of *S. megalops* remained poorly studied, which may be attributed to its taxonomic problem in the area.

Generally speaking, Squalidae species are aplacental viviparous, with a long gestation, estimated up to 2 years for *S. acanthias* [81]. Their uterine fecundity was estimated to be from 1 to 12 embryos per litter. Females reach maturity at up to 70 cm,

Species	Prey frequencies							Location, reference
	Chond.	Teleo.	Crus.	Moll.	Ann.	Echino.	Oth.	
<i>Squalus blainville</i>		+++	+++	+	+			Gulf of Gabès, Tunisia [51]
		+++	++	+++		+		Eastern Ionian Sea [53]
		+++	+	+++	+		—	Aegean sea [58]
		++	+	+++				Maltese Islands [59]
		+++	+	++	—			Eastern Mediterranean [60]
<i>S. acanthias</i>		+++		+++		+	+	Eastern Ionian Sea [53]
		++	—	+++				western Mediterranean Sea [61]
		+++	+	++				Adriatic Sea [57]
		+++						Sea of Marmara [62]
<i>Squalus megalops</i>	—	+++	+	+	+	+		Gulf of Gabès, Tunisia [63]

**Table 2.**  
*Studies on Squalus blainville, S. megalops, and Squalus acanthias diet carried out in the Mediterranean Sea (-; +; ++; +++: Increasing gradient of prey importance according to the calculated IRI%/ Chond.: Chondrichthyes; Teleo.: Teleosteans, crus.: Crustaceans; moll.: Mollusks; Ann.: Annelids; Echino.: Echinoderms; Oth.: Others).*

56.41 cm, and 88 cm total length (TL), whereas males matured at up to 55.0 cm, 44.39 cm, and 70.0 cm TL for *S. blainville*, *S. megalops*, and *S. acanthias*, respectively (**Table 1**). The estimated size at maturity differed between males and females confirming the marked sexual size dimorphism of those species.

Concerning the food habits of those species, they are active predators, which feed on similar preys but with different importance according to the index of relevant importance of each prey item consumed (IRI%) calculated (**Table 2**). Species are reported to feed mainly on bony fishes, cephalopods, and crustaceans.

Sexual size and mass dimorphism were observed, with females attaining larger TL and greater mass than males (**Table 3**). This pattern is common among viviparous

	Sex	N	LWRs	GT	Location, reference
<i>Squalus blainville</i>	M	1038	W = 0.0033 L 3.09	+	Strait of Sicily, Italy [29]
	F	812	W = 0.0037 L 3.07	+	
	C	27	W = 0.0012 L 3.37	+	Balearic Islands [64]
	C	88	W = 0.0035 L 3.06	+	Eastern Adriatic Sea [65]
	M	108	W = 0.002 L 3.37	+	Gulf of Gabès, Tunisia [66]
	F	124	W = 0.003 L 3.10	+	
	C	299	W = 0.00345 L 3.06	+	North Aegean Sea [67]
	C	27	W = 0.0030 L 3.07	I	Saros Bay North Aegean Sea [68]
	M	8	W = 0.0145 L 2.68	—	
	F	19	W = 0.0016 L 3.21	+	
	C	18	W = 0.00004 L 2.48	—	Sea of Marmara [69]
	C	177	W = 0.0033 L 3.06	+	Antalya Bay [70]
	M	92	W = 0.0035 L 3.03	I	eastern Mediterranean Sea [52]
	F	85	W = 0.0029 L 3.10	+	
	C	308	W = 0.0048 L 2.96	I	Central Eagean Sea [71]
	M	149	W = 0.0049 L 2.95	I	
	F	159	W = 0.0046 L 2.98	I	
	M	361	W = 2E-06 L 3.16	+	Eastern Mediterranean Sea [72]
	F	445	W = 7E-07 L 3.32	+	
	C	11	W = 0.0819 L 2.89	—	Lebanease marine waters [73]
C	14	W = 0.0053 L 2.95	I	North Eagean sea [74]	
C	184	W = 0.0010 L 3.35	+	the Levantine Sea, eastern Mediterranean Sea [75]	
M	85	W = 0.0009 L 3.40	+		
F	99	W = 0.0014 L 3.29	+		
F	1282	W = 0.003 L 3.08	+	South of Sicily Central Mediterranean Sea [76]	
M	970	W = 0.005 L 2.98	—		
<i>S. megalops</i>	C	630	W = 0.002 L 3.13	+	Gulf of Gabès, Tunisia [77]
	M	323	W = 0.005 L 2.98	—	
	F	307	W = 0.005 L 2.98	—	

	Sex	N	LWRs	GT	Location, reference
<i>S. acanthias</i>	C	32	W = 0.0112 L 2.77	+	North Aegean Sea [78]
	F	16	W = 0.0023 L 3.18	+	
	M	16	W = 0.0014 L 3.29	+	
	C	32	W = 0.0031 L 3.11	+	Aegean Sea [79]
	C	421	W = 0.00201 L 3.15	+	Eastern Adriatic Sea [66]
	F	346	W = 0.0075 L 2.86	—	North Aegean Sea [56]
	M	274	W = 0.003 L 3.11	+	
	C	565	W = 0.0037 L 3.04	+	Saros Bay [68]
	M	253	W = 0.0072 L 2.86	—	
	F	312	W = 0.0027 L 3.12	+	
	C	8	W = 0.00003 L 2.61	—	Sea of Marmara [69]
	M	150	W = 9.54 10 <sup>-7</sup> L 3.20	+	Adriatic Sea [57]
	F	176	W = 9.5 10 <sup>-7</sup> L 3.21	+	

**Table 3.**

*Studies on squalus blainville, S. megalops, and Squalus acanthias mass-length relationship, carried out in the Mediterranean Sea (N: Number of individuals; M: Male; F: Female; L: Length; W: Weight; GT: Growth type; I: Isometry; (+): Positive allometry; (-): Negative allometry).*

sharks since for females, due to their more energetically demanding reproductive mode, there is a strong selection pressure for larger body size [82].

Squalidae are long-lived animals, with females attaining greater age than males, as it is typical of most elasmobranchs. Using the von Bertallonfy model, the investigations were conducted to confirm this pattern of differential growth between males and females (**Table 4**). The maximum ages observed for males were 22 years, 26 years, and 23 years and for females were 28 years, 29 years, and 36 years of *S. blainville*, *S. megalops*, and *S. acanthias*, respectively.

## 2.2 Geographic distribution

*S. acanthias* and *S. blainville* are mostly found in the northern part of the Mediterranean Sea and the Adriatic, including the Black Sea [30, 83–85]. Some authors have reported the spiny dogfish (*S. acanthias*) to be one of the most frequent shark species captured in the Mediterranean [30, 86, 87]. Whereas, its congener *S. blainville* is stated to be one of the most important species of the demersal assemblages in the eastern Ionian Sea [88], as well as throughout the basin, principally in its central-western part (eastern Corsica and southern Sicily) and the eastern Ionian and Aegean seas [87]. The species was found to be more abundant on the slope than on the shelf [89].

The reason for this replacement between those sharks could be related to taxonomic problems afflicting the *Squalus* genus in different areas of the Mediterranean [38, 84]. Indeed, recent studies [53] highlight that *S. acanthias* showed a limited geographic distribution in the past, suggesting an inaccurate classification of these two species [90].

To clarify the real presence of the *Squalus* species in the Mediterranean Sea, numerous scientific studies, such as MEDITS trawl survey, have been conducted.

	Method	Sex	VBGM parameters			Maturity age (years)	Maximum age (years)	Location
			$L_{\infty}$ (cm)	$K$ (years <sup>-1</sup> )	$T_0$ (years)			
<i>Squalus blainville</i>	Dorsal fin spine	F	105.7	0.11	-1.1	7.4	19	Gulf of Gabès, Tunisia [66]
		M	91.1	0.14	-1.4	4.7	15	
	Vertebrate	F	117.9	0.10	-1.3	5.1	8	Strait of Sicily, Italy [29]
		M	96	0.13	-1.3	3.3	8	
	Dorsal fin spine	F	109.7	0.03	-5.58	17	28	eastern Mediterranean Sea [72]
		M	66.55	0.08	-3.35	11.3	22	
<i>S. megalops</i>	Dorsal fin spine	F	82.31	0.06	-3.89	15.38	29	Gulf of Gabès, Tunisia [77]
		M	68.55	0.08	-4.65	8.39	26	
<i>S. acanthias</i>	Dorsal fin spine	F	173.3	0.09	-0.04	20.9	23	Adriatic Sea [80]
		M	103.3	0.09	-0.04	10.5	36	
	Dorsal fin spine	F	113.0	0.18	—	7.5	13	Adriatic Sea [57]
		M	92.0	0.24	—	5.5	9	

**Table 4.** Studies on *Squalus blainville*, *S. megalops*, and *Squalus acanthias* age, carried out in the Mediterranean Sea (VBGM Von Bertallonffy);  $L_{\infty}$ : The asymptotic length at which growth is zero;  $K$  is the growth rate;  $T_0$ : Constant value).

According to those studies, *S. acanthias* and *S. blainville* are mostly found in the northern part of the Mediterranean Sea, Adriatic, and Black Sea [25, 84, 85, 91].

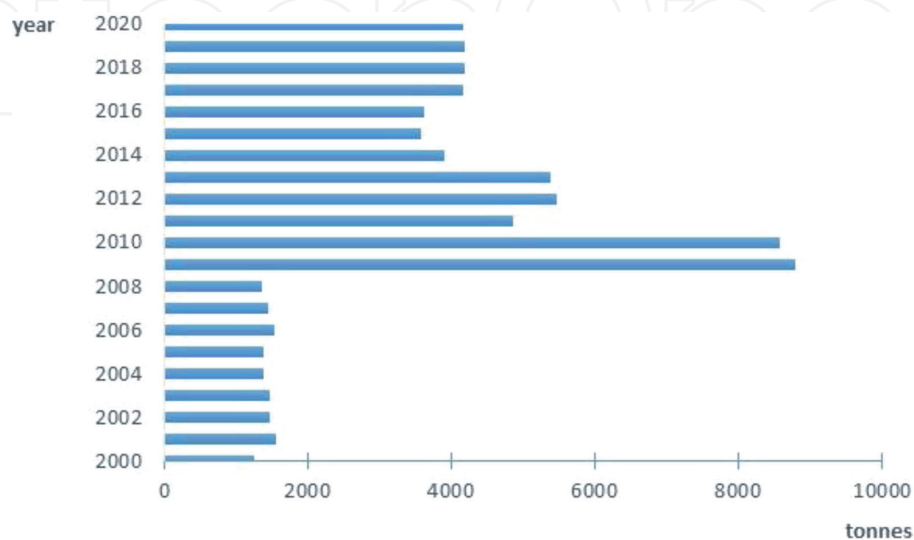
Concerning *S. megalops*, it is recorded from the northern coasts of the Canary Islands, Morocco, and southern Spain (Malaga), but it is present mainly along the African coasts of Tunisia [41].

### 2.3 Catches

Fundamental problems in accurately identifying and classifying species have hampered the collection of robust biological and ecological data. This fact, together with erroneous reports of reported catches (usually lower than actual catches; [30, 92]) makes stock estimates for these fish difficult to assess. This situation is of particular concern in elasmobranchs taken as targets or as bycatch in several fisheries around the globe, as their conservative life history strategies make them extremely vulnerable to overexploitation [93].

Worldwide, Indonesia and Spain remain the top three shark catchers in the world [94]. In the Mediterranean Sea, countries, contributing more to the elasmobranch landings during the last years, are Tunisia and Libya, which contributed more than 70% of production. Tunisian landings did not show any distinguished variations from 1980 to 2015. Those from Libya appear for the first time in FAO statistics and seem to be significant. Turkey and Italy register a dramatic decrease in catch after being known to be the major elasmobranch-fishing countries within the Mediterranean, between 1980 and 2008. It should be noted that the Mediterranean landings of carcharhiniformes, the most represented group among the elasmobranchs and the most commercially fished, recorded a notable decrease [92]. The most commonly caught species are skates (*Rajidae*) and catsharks (*Scyliorhinus spp.* and *Galeus spp.*) [95, 96]. Different species of pelagic sharks, as well as eagle rays (*Myliobatidae*) and stingrays (*Dasyatidae*), are bycatch of pelagic and demersal fisheries [97, 98].

Squalidae, it represents one of the most commercially targeted families among elasmobranchs [24]. Capture production for Squalidae in the Mediterranean and the Black Sea during the last decades is illustrated in **Figure 1** [99].



**Figure 1.** Capture production for Squalidae in the Mediterranean and Black Sea during the last decades.

Indeed, several species belonging to this family are landed by up to 50 countries in direct fisheries or as bycatch [24]. The genus *Squalus* is highly represented in bycatch and several studies have focused on the mitigation of the fishery impact on this group [100–102].

In the Mediterranean Sea, *S. blainville* constitutes an important landing from bottom trawlers, longlines, and gill nets [103, 104]. Moreover, the presence of *S. megalops* and *S. blainville* was reported on African coasts of Tunisia in bycatch of bottom trawl and longline fisheries [41, 92].

Although longlines are considered selective, they bring several nontarget species, including *S. acanthias* [92]. In fact, a significant decline in the bycatch of the former species is perceived according to the fishermen's perception on the evolution of shark populations in the northern Catalan coast (north-western Mediterranean Sea) [105]. The low presence of the piked dogfish (Annex III of the Barcelona Convention) in the subregion's bycatch composition could confirm the recorded decrease in biomass of this species.

The bycatch of elasmobranchs is an issue of global concern, particularly in high-seas pelagic longline fisheries, where 25% of the catch is nontarget sharks and rays [106]. Thus, in order to keep the populations of these fishes in balance, incisive management programs are required to guarantee stability for the populations. Among these management measures, the elimination or at least the reduction of the bycatch cannot be missing.

## 2.4 Taxonomic status

Dependable data on species richness are crucial for any biodiversity study and conservation policies, even though it is every so often difficult to discriminate a species based on extremely similar morphological characters [107]. Therein, reliable species identification is the principal step for the application of conservation policies and maintainable exploitation of natural resources [108], all the more so considering the currently elevated biodiversity crisis induced by human activities [109].

Overall, sharks belonging to the *Squalus* genus exhibit conserved body morphology, making identification based entirely on morphological characters complicated, leading to misidentifications [110]. This complexity is amplified even similarly *via* the high overlap of morphological characters among species, as identification is often based on limited and insufficiently consistent characters, like the number of vertebrae and morphometric data [10, 16, 20, 38, 111, 112]. In fact, morphological and biological similarities among squalids have led to considerable confusion over their taxonomy [14]. Some taxonomic and nomenclatural problems affect the group of species in question. Excluding *S. acanthias*, easily recognizable thanks to its specific pattern, characterized by the presence of white spots on the back or narrowly round to acutely angular rear tips and inner margins of the pectoral fins, which permits an easier identification and discrimination from the other two species [84], and the correct identification of the other two species, which do show a very similar morphology, requires the observations of the dermal denticles, meristic features, or even genetic analysis.

Compared with *Squalus acanthias* and *S. asper*, a close similarity between *S. blainville* and *S. megalops* was pointed out [113, 114]. Moreover, despite that the relationships between the snout tip and nostril distance and the distance from the nostril to the preoral clefts were proposed as the best features for discriminating between species of the genus *Squalus*, and it is proved that they were of little use [115].

The taxonomic status of *S. blainville* is problematical as there are no extant types and the original description and figures do not correspond to any known species of

*Squalus* [42, 116]. Consequently, in a review of the Australian species of *Squalus*, *Squalus griffini* and *Squalus fernandinus* (Molina, 1782) were incorrectly synonymized with *S. blainville* [32]. However, in a review of Japanese *Squalus*, *S. blainville* was defined as a species with high dorsal fins and long dorsal-fin spines [116]. The same review revealed that *Squalus*, referring to *S. fernandinus* and *S. blainville* by some authors, had short dorsal-fin spines and were more similar to *S. mitsukurii* from Japan, and suggested that nominal *S. blainville* from New Zealand could be identical to *S. mitsukurii* [112, 117]. It was also noted that dogfish resembling *S. mitsukurii* occurred in Australia and New Zealand [31]. Outside its main distributional area (Mediterranean Sea and eastern Atlantic), *S. blainville* has also been recorded erroneously in Australia and New Zealand [112]. It was thought to be widespread in the Atlantic, Indian and Pacific Oceans [34, 117] as well as in Japan [116]. The distribution of *S. blainville* was restricted to the Mediterranean Sea and eastern Atlantic, and its records in the Pacific records were questioned [17]. The confusion is due largely to the poor original description and the lack of type material.

Taxonomic research on the genus *Squalus* conducted in the Tunisian waters revealed that *S. blainville* in this zone is not characterized by its high first dorsal fin and spine as was well thought-out by some authors, but rather it is a short-spine species [31, 116]. Comparing their data for *S. blainville* with the measurements of the same species in different regions, they noted that data generally agree despite there being some differences in the morphometrics between populations, and that Tunisian *S. blainville* specimens examined and the specimens studied by some authors [41–43, 114, 115, 118] have similar vertebral counts.

Recently, according to the studies conducted in other areas of the Mediterranean Sea and based on morphological and genetic (COI sequences) analyses, only one spurdog species, *S. blainville*, occurs in the Ionian, Libyan, Aegean Seas, and the Sardinian waters [38, 119].

These findings spotlighted the stretch of sea between Tunisia, southern Sicily, Malta, and Libya, known as the Strait of Sicily, as a more interesting area for spurdog species. The presence of *S. blainville* in the Maltese waters was assessed through the use of the DNA barcoding approach [84]. In the same region, some authors [37] collected and analyzed individuals belonging to the nominal *S. blainville* and genetically clustering within clade B [22], while three individuals were classified as *Squalus* sp. by the authors as clustering in the genetic clade C [22].

Regarding *S. megalops*, it is described for the first time in the Mediterranean in 1984 [43]; its occurrence is still debated and several scientific studies contributed to clarifying the real presence of this species in the area [21, 22, 37, 39, 41, 42, 84, 85, 119].

It was suggested that the southern Australian *S. megalops* might be endemic to Australia [91]. However, the tale can be even extra complex. Morphological research has proven that more than a single form of this species exists in Australian seas [28].

Recently, few research within the context of integrative taxonomy had been successfully accomplished in the genus *Squalus* aiming at the integration of new molecular taxonomy techniques to more classical morphological analyses with the purpose to make clear taxonomic ambiguities among some of the species [41, 84].

To highlight the taxonomic uncertainties in relation to the occurrence of *Squalus* species in the central Mediterranean Sea, a study including other morphometric characters and a molecular study was carried out to confirm that *S. megalops* occurs as a valid species in the Mediterranean Sea [41]. In fact, two species of spurdog of the genus *Squalus* occur in the Gulf of Gabès (southern Tunisia and central Mediterranean): *S. blainvillei* and *S. megalops cubensis* group. Morphometric and

meristic data as well as genetic analyses (DNA inter-simple sequence repeat markers and molecular barcoding methods) support the assignation of this short-snout spurdog to *S. megalops*.

The Tunisian *S. megalops* species are consistent for characters typifying the “*megalops-cubensis*” group and fit the description of *S. megalops* from Australian waters [23], as well as the eastern Atlantic-Mediterranean [42] and Mediterranean waters [43]. Specimens described from other areas clearly agree with the Tunisian samples of *S. megalops* for most of the morphometric characters and had similar vertebral counts to those studied by other authors (Indo-Pacific, [118]; South Africa, [115]; Mediterranean coasts of Spain, [34]; east Atlantic, [42]; south western Australia, Queensland [23]).

Some authors stated that the number of chondrocranial lateral processes is the most important character to discriminate between *S. blainville* and *S. megalops* [34, 42], but they can be discriminated also based on other morphological features, such as teeth and dermic denticles morphology. These findings have been confirmed in the Gulf of Gabès through morphometric, meristic, and genetic analyses, suggesting that *S. megalops* could be even more common than *S. blainville* in these waters (Figures 2 and 3) [41]. In addition to the differences cited between those species, the study of their traits of the life history in the area revealed that they differ also in those terms [50, 51, 63, 66, 77].

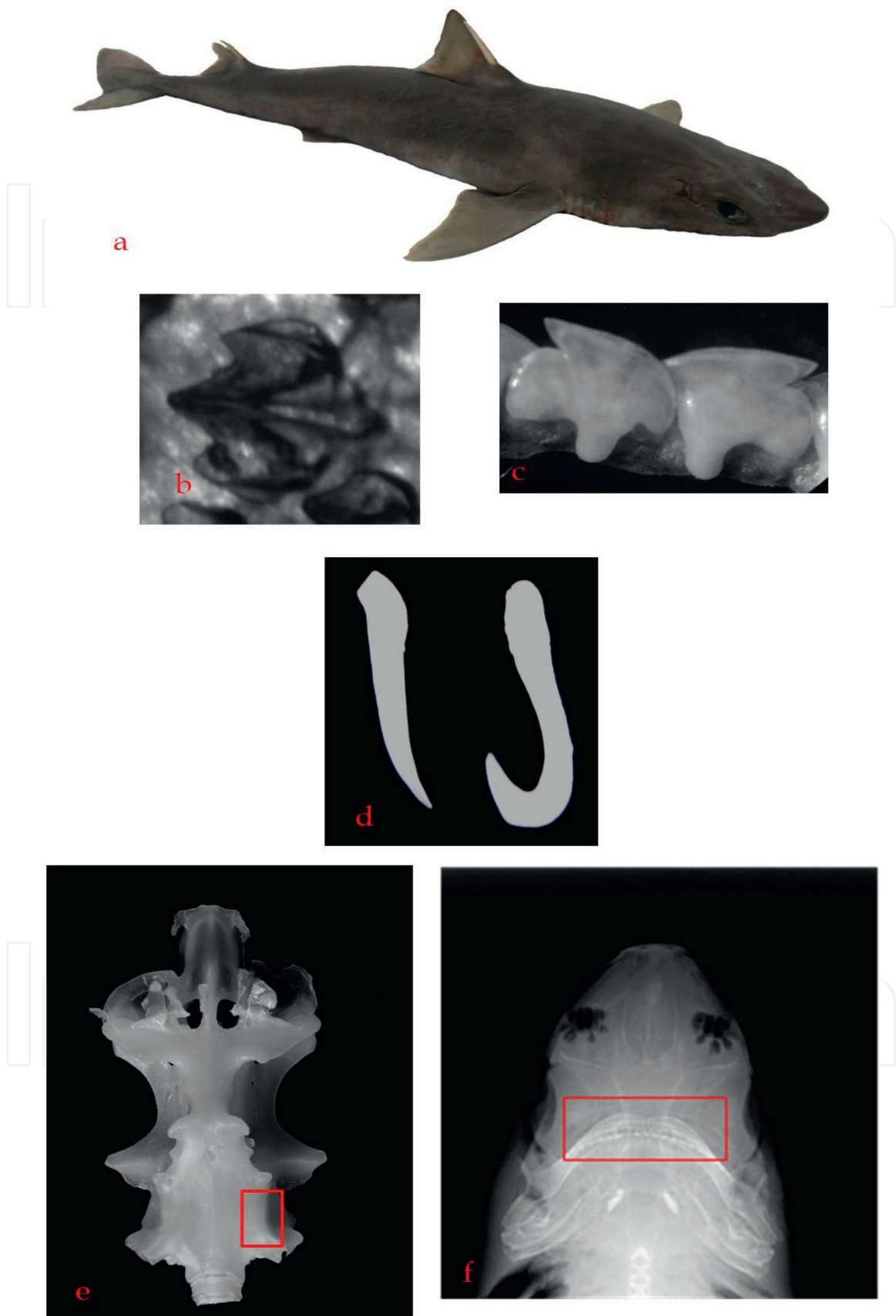
Differently from the former study [41], a study on the intraspecific morphological variability in *S. blainville* did not identify diagnostic features (e.g., dermal denticles), which could effectively discriminate between *S. blainville* and *S. megalops*. The authors asserted that species identification based only on morphological characteristics can easily lead to taxonomic misidentifications, especially when multiple anatomical characters (e.g., skull and teeth morphology) are used [84].

To aid in clarifying the taxonomic status of *Squalus* species in the eastern Atlantic and Mediterranean, some authors assessed species diversity at the molecular level and evaluated the consistency in species identification in the region [22]. They confirmed unreliable species identification in the eastern Atlantic and Mediterranean *Squalus* and reinforced the need to revise the status of *S. megalops* and *S. mitsukurii* as they may include several distinct species distributed around the world. Nonetheless, the results provided by those authors suggest that a different species from the “true Australian” *S. megalops*, which remains unidentified, can occur in the eastern Atlantic and Mediterranean waters [22].

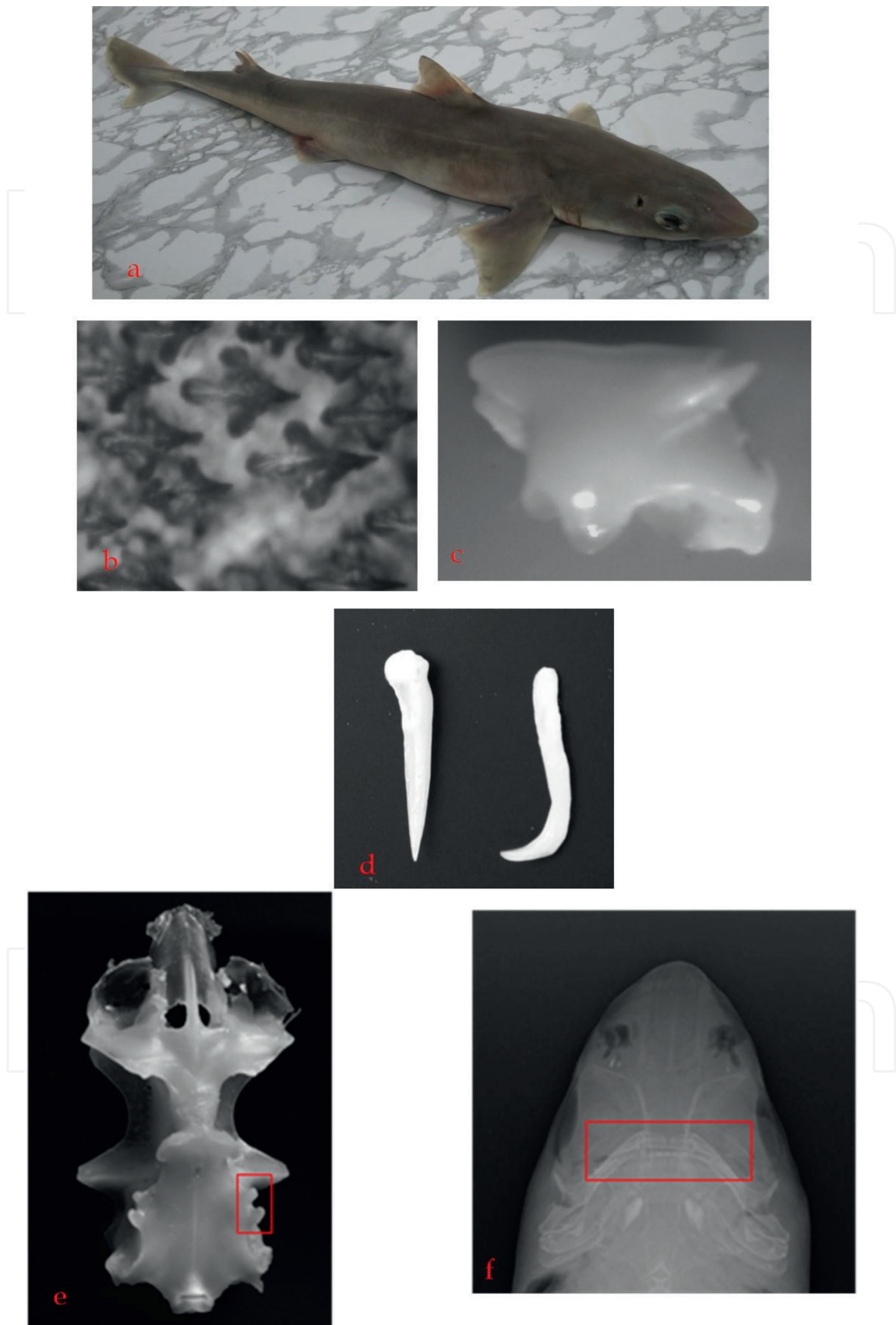
In any case, specimens of *S. megalops* for which the identification is considered feasible were rarely reported in the catches [38, 51]. Most of the catches of these species are recorded from the northern coasts of Canary Islands, Morocco, and southern Spain (Malaga). However, the real presence of *S. megalops* is still unclear not only for the Mediterranean Sea but also for the neighboring Atlantic area [18, 22] and some evidences confirm the inconsistency of the species identification keys to distinguish between the Atlantic and Mediterranean *Squalus*, concerning *S. blainville* and *S. megalops* [22].

Studies conducted in the Sardinian waters showed that morphological and genetic analysis revealed the presence only of *S. blainville* in the region, despite the observation of chondrocranial lateral processes initially allowing the investigated specimens to be subdivided into two groups. Indeed, the comparison of chondrocranial and body morphology of the specimens examined indicated that none of the considered measurements could differentiate the two squalid groups [38].

They noted that considering the brief half-life and fast replacement rate of the dermal denticles [120]. In fact, the different development stages of denticles observed



**Figure 2.** *Squalus blainville* (adult female 96 cm TL) off Tunisian waters (a: Lateral view, b: unicuspid flank denticles, c: teeth with a single cusp deeply notched and outward end strongly oblique d: bent claws and massive spurs, e: two cartilaginous processes in the basal plate, f: sharpen palatoquadrate).



**Figure 3.** *Squalus megalops* (adult female 76 cm TL) off Tunisian waters (a: lateral view, b: unicuspid flank denticles, c: teeth with a single cusp deeply notched and outward end directed strongly laterally, d: bent claws and massive spurs, e: two cartilaginous processes in the basal plate, f: sharpen palatoquadrate).

in the analyzed skin portion could explain this particular aspect [120]. Moreover, dermal denticles, teeth, and dorsal fin spines were reported as common diagnostic morphological structures, which could vary in shape with the ontogenetic development [121, 122]. Consequently, the morphology of the dermal denticles should be further investigated before it can be properly used as a suitable classification tool, as also suggested particularly for the genus *Squalus* [84]. The same authors stated that considering the finding of sporadic divergent sequences [22, 38, 41, 119] different from *S. blainville* and *S. acanthias* but also *S. megalops* from Australia, the occurrence of a third species in the Mediterranean (apart from *S. acanthias* and *S. blainville*) cannot be ruled out.

Similar efforts were undertaken recently for those species [39]; it was noted that *S. megalops* does not occur in the eastern Atlantic and Mediterranean waters and that individuals composing clade C [22] should be considered a new species that needs formal description and proper taxonomic assessment [22, 123]. Besides, the species described as short-snout spurdog by other authors was considered a rare species and an occasional visitor with high morphological similarity to the *S. megalops* and *S. blainville* but is genetically distinct from both [39].

According to some authors [32], molecular data alone do not replace traditional taxonomy in the delimitation of species [124]. This integrative approach has been used over the years and has proven to be quite effective in elasmobranchs [124, 125] and in other groups of organisms [125, 126]. However, because of the difficulty of morphologically defining *Squalus* species, many sequences available in genetic databases indicate misidentifications or identifications only at the genus or family levels, making them not very useful for molecular identification purposes.

On their part, some authors stated that despite *S. acanthias* is the type species of the genus and is one of the most easily distinguished species of *Squalus* some sequences of Mediterranean specimens originally recognized as *S. acanthias* clustered in clade B. This misidentification is surprising but reveals the confused state of *Squalus* taxonomy in the region [22].

These findings further support current inconsistencies in species identification within the genus *Squalus* and the need for an accurate redescription of *Squalus* species, especially in the Mediterranean Sea, to stabilize the systematic and facilitate specimens' identification.

### **3. Conclusions**

The Mediterranean Sea represents some of the most intensively studied regions of the world's oceans; however, this wealth of information does not translate into a good understanding of the species diversity and raises additional concerns regarding accurate identification of elasmobranchs. This concerns, among others, the genus *Squalus*, which the taxonomic confusion on it, is intrinsically related to difficulties in morphologically separating congeners and to incessant applications of synonyms due to the lack of appropriate taxonomic scrutiny with disregard for detailed morphological assessments that are essential for understanding possible variations and defining species.

In conclusion, since the first comprehensive revision on the genus in Africa [115] and after over 40 years gap, it is clear thus that an integrative approach includes both morphological and genetic tools with rigorous participation of taxon experts in the systematics of elasmobranch fishes still need to be strengthened to reduce this "taxonomic obstacle" and to faster actions in conservation and management of target

species that were formerly unknown. Therefore, the establishment of a coordinated international effort to implement a comprehensive and integrated taxonomic assessment of this genus which represents an irreplaceable component of the biodiversity of the area is welcomed.

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## References

- [1] Tortonese T. Osservazioni comparative intorno alla ittiofauna del Mediterraneo e dell'Atlantico occidentale (Florida e isole Bahamas). *Natura*. 1989;**1**:1-20
- [2] Derrick DH, Cheok J, Dulvy NK. Spatially congruent sites of importance for global shark and ray biodiversity. *PLoS One*. 2020;**15**(7):e0235559. DOI: 10.1371/journal.pone.0235559
- [3] Leone A, Puncher GN, Ferretti F, Sperone E, Tripepi S, Micarelli P, et al. Pliocene colonization of the Mediterranean by great White shark inferred from fossil records, historical jaws, phylogeographic and divergence time analyses. *Journal of Biogeography*. 2020;**47**(5):1119-1129. DOI: 10.1111/jbi.13794
- [4] Bianchi CN, Morri C, Chiantore M, Montefalcone M, Parravicini V, Rovere A. Mediterranean Sea biodiversity between the legacy from the past and a future of change. In: Stambler N, editor. *Life in the Mediterranean Sea: A Look at Habitat Changes*. Vol. 1. New York: Nova Science Publishers, Inc; 2012. p. 55. ISBN: 978-1-61209-644-5
- [5] Katsanevakis S, Coll M, Piroddi C, Steenbeek J, Ben Rais Lasram F, Zenetos A, Cardoso AC: Invading the Mediterranean Sea: Biodiversity patterns shaped by human activities. *Frontiers in Marine Science*. 2014;**1**:32. DOI: 10.3389/FMARS.2014.00032
- [6] Serena F, Abella AJ, Bargnesi F, Barone M, Colloca F, Ferretti F, et al. Species diversity, taxonomy and distribution of Chondrichthyes in the Mediterranean and Black Sea. *The European Zoological Journal*. 2020;**87**:497-536. DOI: 10.1080/24750263.2020.1805518
- [7] Dulvy NK, Allen DJ, Ralph GM, Walls RHL. The Conservation Status of Sharks, Rays and Chimaeras in the Mediterranean Sea [Brochure]. Malaga, Spain: IUCN; 2016. p. 14
- [8] Dulvy NK, Fowler SL, Musick JA, Cavanagh RD, Kyne PM, Harrison LR, et al. White WT: Extinction risk and conservation of the world's sharks and rays. *eLife*. 2014;**3**:e00590. DOI: 10.7554/eLife.00590
- [9] Otero M, Serena F, Gerovasileiou V, Barone M, Bo M, Arcos JM, et al. Identification Guide of Vulnerable Species Incidentally Caught in Mediterranean Fisheries. Malaga, Spain: IUCN; 2019. p. 204
- [10] Menesini E. Ittiodontoliti Miocenici di Terra d'Otranto (Puglia). *Palaeontographia Italica*. 1968;**65**:1-61
- [11] Ramírez-Amaro S, Ordines F, Puerto MÁ, García C, Ramon C, Terrasa B, et al. New morphological and molecular evidence confirm the presence of the Norwegian skate *Dipturus nidarosiensis* (storm, 1881) in the Mediterranean Sea and extend its distribution to the western basin. *Mediterranean Marine Science*. 2017;**18**(2):251-259. DOI: 10.12681/MMS.1950
- [12] Zeeberg J, Corten A, Graaf E. Bycatch and release of pelagic megafauna in industrial trawler fisheries off Northwest Africa. *Fisheries Research*. 2006;**78**(2):186-195. DOI: 10.1016/j.fishres.2006.01.012
- [13] Coelho R, Erzini K. Identification of deep water lantern sharks (Chondrichthyes: Etmopteridae) using morphometric data and multivariate analysis. *Journal of the Marine Biological Association of the United Kingdom*. 2008;**88**(1):199-204. DOI: 10.1017/S0025315408000271

- [14] Myakov NA, Kondyurin VV. Dogfishes, *squalus* (Squalidae) of the Atlantic Ocean and comparative notes on the species of this genus from other regions. *Journal of Ichthyology*. 1986;**26**(6):1-18
- [15] Ebert DA, Stehmann M. Sharks, Batoids, and Chimaeras of the North Atlantic. Vol. No. 7. Rome: FAO Species Catalogue of fishery Purpose; 2013. p. 523
- [16] Ebert DA, Fowler S, Compagno LJV. *Sharks of the World: A Fully Illustrated Guide*. London: Wild Nature Press; 2013. p. 528
- [17] Compagno LJV, Dando M, Fowler S. *A Field Guide to the Sharks of the World*. London: Harper-Collins; 2005. p. 496
- [18] Last PR, White WT, Pogonoski JJ. Descriptions of the New Dogfishes of the Genus *Squalus* (Squaloidea: Squalidae). Hobart: CSIRO Marine and Atmospheric Research; 2007. p. 130. DOI: 10.4225/08/58615c42b11ce
- [19] Viana ST, de Carvalho MR. Redescription of *Squalus acutipinnis* Regan, 1908, a valid species of spiny dogfish from southern Africa (Chondrichthyes: Squaliformes: Squalidae). *Copeia*. 2016;**104**:539-553. DOI: 10.1643/CI-14-217
- [20] Viana ST, de Carvalho MR, Gomes UL. Taxonomy and morphology of species of the genus *squalus* Linnaeus, 1758 from the southwestern Atlantic Ocean (Chondrichthyes: Squaliformes: Squalidae). *Zootaxa*. 2016;**4133**:1-89. DOI: 10.11646/ZOOTAXA.4133.1.1
- [21] Bellodi A, Porcu C, Cannas R, Cau A, Marongiu MF, Mulas A, et al. Life-history traits of the longnosed skate *Dipturus oxyrinchus*. *Journal of Fish Biology*. 2017;**90**(3):867-888. DOI: 10.1111/JFB.13205
- [22] Veríssimo A, Zaera-Perez D, Leslie R, Iglesias SP, Seter B, Grigoriou P, et al. Molecular diversity and distribution of eastern Atlantic and Mediterranean dogfishes *squalus* highlight taxonomic issue in the genus. *Zoologica scripta*. 2017;**46**(4):414-428. DOI: 10.1111/zsc.12224
- [23] Last PR, Edmunds M, Yearsley GK: *Squalus crassispinus* sp. nov., a new spurdog of the 'megalops-cubensis' group' from the eastern Indian Ocean. In Last PR, White WT, Pogonoski JJ editors. Descriptions of new dogfishes of the genus *Squalus* (Squaloidea: Squalidae). CSIRO Marine and Atmospheric Research Paper No 14, World Register of Marine Species. 2007; pp. 11-22
- [24] Ebert DA, White WT, Goldman KJ, Compagno LJ, Daly-Engel TS, Ward RD. Resurrection and redescription of *Squalus suckleyi* (Girard, 1854) from the North Pacific, with comments on the *Squalus acanthias* subgroup (Squaliformes: Squalidae). *Zootaxa*. 2010;**2612**(1):22-40. DOI: 10.11646/zootaxa.2612.1.2
- [25] White WT, Iglesias SP. *Squalus formosus*, a new species of spurdog shark (Squaliformes: Squalidae), from the western North Pacific Ocean. *Journal of Fish Biology*. 2011;**79**(4):954-968. DOI: 10.1111/j.1095-8649.2011.03068.x
- [26] Borsa P, Shen KN, Arlyza IS, Hoareau TB. Multiple cryptic species in the blue-spotted maskray (Myliobatoidei: Dasyatidae: Neotrygon spp.): An update. *Comptes rendus biologiques*. 2016;**339**(9-10):417-426. DOI: 10.1016/j.crv.2016.07.004
- [27] Borsa P, Arlyza IS, Hoareau TB, Shen KN. Diagnostic description and geographic distribution of four new cryptic species of the blue-spotted maskray species complex (Myliobatoidei:

Dasyatidae; Neotrygon spp.) based on DNA sequences. *Journal of Oceanology and Limnology*. 2018;**36**(3):827-841. DOI: 10.1007/s00343-018-7056-2

[28] Whitehead PJP, Bauchot ML, Hureau JC, Nielsen J, Tortonese E. Fishes of the North-Eastern Atlantic and the Mediterranean (FNAM). Paris: Unesco; 1984. p. 1473 ISBN 92-3-002308-6

[29] Cannizzaro L, Rizzo P, Levi D, Gancitano S. Age determination and growth of *Squalus blainvillei* (Risso, 1826). *Fisheries Research*. 1995; **23**(1-2):113-125. DOI: 10.1016/0165-7836(94)00333-R

[30] Serena F, Papacostantinou C, Relini G, Gil De Sola L, Bertrand J. Distribution and abundance of spiny dogfish in the Mediterranean Sea based on the Mediterranean international trawl surveys program. *Biology and management of dogfish sharks*. In: Gallucci VF, McFarlane GA, Bargmann GC, editors. American Fisheries Society. Maryland: Bethesda; 2009. pp. 139-149. DOI: 10.47886/9781934874073.ch13

[31] Compagno LJV. Squaliformes-Dogfish sharks. In: Fischer W, Nauen C, editors. *FAO Species Catalogue, Volume 4. Sharks of the World: An Annotated and Illustrated Catalogue of Shark Species Known to Date. Part I. Hexanchiformes to Lamniformes. Vol. 125*. Rome: FAO Fisheries Synopsis; 1984. pp. 111-113

[32] Garrick JAF. Studies on New Zealand Elasmobranchii. Part XII. The species of *squalus* from New Zealand and Australia; and a general account and key to the New Zealand Squaloidea. *The Transactions and Proceedings of the Royal Society of New Zealand*. 1960;**88**:519-557

[33] Garrick JAF, Paul LJ. *Heptranchias dakini* Whitley, 1931, a synonym of *H. perlo* (Bonnaterre, 1788), the

sharpnosed sevengill or perlon shark, with notes on sexual dimorphism in this species. *Zoological Publications from Victoria University of Wellington*. 1971;**54**:1-14

[34] Bigelow HB, Schroeder WC 1957: A study of the sharks of the suborder Squaloidea. *Bulletin of the Museum of Comparative Zoology*. 1957;**117**:1-150

[35] Daly-Engel TS, Koch A, Anderson JM, Cotton CF, Rubbs RD. Description of a new deep-water dogfish shark from Hawaii, with comments on the *Squalus mitsukurii* species complex in the West Pacific. *Zookeys*. 2018;**798**:135-157. DOI: 10.3897/zookeys.798.28375

[36] Ziadi-Künzli F, Soliman T, Imai H, Sakurai M, Maeda K, Tachihara K. Re-evaluation of Deep-Sea dogfishes (genus *squalus*) in Japan using phylogenetic inference. *Deep-Sea Research Part I: Oceanographic Research Papers*. 2020;**160**:103261. DOI: 10.1016/j.dsr.2020.103261

[37] Vella A, Vella N, Schembri S. A molecular approach towards taxonomic identification of elasmobranch species from Maltese fisheries landings. *Marine Genomics*. 2017;**36**:17-23. DOI: 10.1016/j.margen.2017.08.008

[38] Bellodi A, Porcu C, Cau A, Marongiu MF, Melis R, Mulas A, et al. Investigation on the genus *squalus* in the Sardinian waters (Central-Western Mediterranean) with implications on its management. *Mediterranean Marine Science*. 2018;**19**:256-272. DOI: 10.12681/mms.15426

[39] Ferrari A, Di Crescenzo S, Cariani A, Crobe V, Benvenuto A, Piattoni F, et al. Puzzling over Spurdogs: Molecular taxonomy assessment of the *squalus* species in the strait of Sicily. *The European Zoological Journal*.

2021;88:181-190. DOI: 10.1080/  
24750263.2020.1849436

[40] Ward RD, Holmes BH, Zemlak TS, Smith PJ. DNA barcoding discriminates Spurdogs of the genus *squalus*. In: Last PR, White WT, Pogonoski JJ, editors. Descriptions of New Dogfishes of the Genus *Squalus* (Squaloidea: Squalidae). Hobart, Australia: CSIRO Marine and Atmospheric Research; 2007. pp. 117-130. Available from: <http://hdl.handle.net/102.100.100/124477?index=1>

[41] Marouani S, Chaâba R, Kadri H, Saidi B, Bouain A, Maltagliati F, et al. Taxonomic research on *Squalus megalops* (Macleay, 1881) and *Squalus blainvillei* (Risso, 1827) (Chondrichthyes: Squalidae) in Tunisian waters (Central Mediterranean Sea). *Scientia Marina*. 2012;76(1):97-109. DOI: 10.3989/scimar.03440.22B

[42] Muñoz-Chápuli R, Ramos F. Morphological comparison of *Squalus blainvillei* and *S. megalops* in the eastern Atlantic, with notes on the genus. *Japanese Journal of Ichthyology*. 1989;36(1):6-21. DOI: 10.1007/BF02905668

[43] Muñoz-Chápuli R, Ramos F, Garcia-Garrido CM. *Squalus megalops* (McLeay, 1882) en el Mediterraneo. Notas sobre su diagnosis, sistematica y distribucion. *Butlletí de la Societat Catalana d'Ictiologia i Herpetologia*. 1984;9:16-21

[44] King JR, McFarlane GA. Marine fish life history strategies: Applications to fishery management. *Fisheries Management and Ecology*. 2003;10:249-264. DOI: 10.1046/j.1365-2400.2003.00359.x

[45] Dell'Apa A, Bangley CW, Rulifson RA. Who let the dogfish out? A review of management and

socio-economic aspects of spiny dogfish fisheries. *Reviews in Fish Biology and Fisheries*. 2015;25:273-295. DOI: 10.1007/s11160-014-9379-1

[46] Quignard JP. Recherche sur la biologie de *Squalus blainvillei*, (Risso, 1826). *Travaux du Laboratoire de la Biologie Halieutique Université de Rennes*. 1971;5:125-141

[47] Capapé C. Observations sur la sexualité, la reproduction et la fécondité de 8 sélaciens pleurotrêmes vivipares placentaires des côtes tunisiennes. *Archives de l'institut Pasteur de Tunis*. 1974;51:329-344

[48] Capapé C, Quignard JP. Recherche sur la biologie de *Squalus blainvillei*, (Risso, 1826) (Pisces, Squalidae) des côtes tunisiennes: relations taille-poids du corps, du foie et des gonades. Coefficients de condition. *Rapports hépato et gonosomatique. Croissance embryonnaire. Archives de l'institut Pasteur Tunis*. 1980;57(4):385-408

[49] Sion L, D'Onghia G, Tursi A, Mytilineou C. First data on distribution and biology of *Squalus blainvillei* (Risso, 1826) from the eastern Mediterranean Sea. *The Journal of Northwest Atlantic Fishery Science*. 2003;31:213-219. DOI: 10.2960/J.v31.a16

[50] Marouani S, Kadri H, Bradai MN, Saïdi B, Bouain A. Size at maturity of *Squalus blainvillei* and *Squalus megalops* in the Gulf of Gabès (Tunisia). *Rapports des réunions Commission internationale pour l'exploration scientifique de la Mer Méditerranée*. 2013;40:466. DOI: 10.1029/2005PA001169

[51] Marouani S. Systématique et écobio-  
logie de deux requins *Squalus blainvillei* (Risso, 1827) et *Squalus megalops* (Macleay, 1881) (Chondrichthyens, Squalidae) du golfe de Gabès (Méditerranée centrale).

Tunisia: Faculté des sciences de Sfax:  
Université de Sfax; 2013

[52] Kousteni V, Megalofonou P. Reproductive biology and embryonic development of *Squalus blainvillei* in the eastern Mediterranean Sea. *Scientia Marina*. 2011;**75**(2):237-249. DOI: 10.3989/scimar.2011.75n2237

[53] Anastasopoulou A, Mytilineou C, Makantasi P, Smith CJ, Kavadas S, Konstantia EL, et al. Life history aspects of two species of the *squalus* genus in the eastern Ionian Sea. *Journal of the Marine Biological Association of the United Kingdom*. 2018;**98**(4):937-948. DOI: 10.1017/S0025315416001818

[54] Capapé C, Reynaud C. Maturity, reproductive cycle and fecundity of the spiny dogfish *Squalus acanthias* (Chondrichthyes: Squalidae) off the Languedocian coast (southern France, northern Mediterranean). *Journal of the Marine Biological Association of the United Kingdom*. 2011;**91**(8):1627-1635. DOI: 10.1017/S0025315411000270

[55] Chatzisprou A, Megalofonou P. Sexual maturity, fecundity and embryonic development of the spiny dogfish, *Squalus acanthias*, in the eastern mediterranean sea. *Journal of the Marine Biological Association of the United Kingdom*. 2005;**85**(5):1155-1161. DOI: 10.1017/S0025315405012233

[56] Yigin CC, Ismen A. Reproductive biology of spiny dogfish *Squalus acanthias*, in the North Aegean Sea. *Turkish Journal of Fisheries and Aquatic Science*. 2013;**13**:169-177. DOI: 10.4194/1303-2712-v13\_1\_20

[57] Bargione G, Donato F, La Mesa M, et al. Life-history traits of the spiny dogfish *Squalus acanthias* in the Adriatic Sea. *Scientific Reports*. 2019;**9**:14317. DOI: 10.1038/s41598-019-50883-w

[58] Kousteni V, Karachle PK, Megalofonou P. Diet and trophic level of the longnose spurdog *Squalus Blainville* (Risso, 1826) in the deep waters of the Aegean Sea. *Deep Sea Research Part I: Oceanographic Research Papers*. 2017;**124**:93-102. DOI: 10.1016/j.dsr.2017.04.008

[59] Bonnici L, Bonello JJ, Schembri PJ. Diet and trophic level of the longnose spurdog, *Squalus Blainville* (Risso, 1826) in the 25-nautical mile fisheries management zone around the Maltese islands. *Regional Studies in Marine Science*. 2018;**19**:33-42. DOI: 10.1016/j.rsma.2018.03.001

[60] Bengil EGT. Biology and ecology of *squalus Blainville* (Risso, 1827) from the eastern Mediterranean. *Thalassas*. 2022;**124**:93-102. DOI: 10.1007/s41208-022-00482-w

[61] Barria C, Coll M, Navarro J. Unravelling the ecological role and trophic relationships of uncommon and threatened elasmobranchs in the western Mediterranean Sea (supplement). *Marine Ecology Progress Series*. 2015;**539**:225-240

[62] Güzin G, Demirel N. Evaluation of the comprehensive feeding strategy and trophic role of overexploited mesopredator species in the sea of Marmara (northeastern Mediterranean). *Estuarine, Coastal and Shelf Science*. 2021;**259**:107448. DOI: 10.1016/j.ecss.2021.107448

[63] Marouani S, Kadri H, Karaa S. MN Bradai: Feeding ecology of the piked spurdog *Squalus megalops* (Chondrichthyes: Squalidae) in the Gulf of Gabès (Central Mediterranean Sea). *Marine and Freshwater Research*. 2017;**69**(1):48-55. DOI: 10.1071/MF17018

[64] Merella P, Quetglas A, Alemany F, Carbonell A. Length-weight relationship

- of fishes and cephalopods from the Balearic Islands (Western Mediterranean). Naga, The WorldFish Center. 1997;**20**(3/4):66-68
- [65] Pallaoro A, Jardas I, Šantič M. Weight-length relationships for 11 chondrichthyan species in the eastern Adriatic Sea. *Cybium*. 2005;**29**(1):93-96
- [66] Marouani S, Kadri H, Saidi B, Morize E, Bouain A, Bradai MN. Age, growth, longevity, natural mortality and maturity of the longnose spurdog *Squalus blainvillei* (Chondrichthyes: Squalidae) in the Gulf of Gabès (Central Mediterranean Sea). *Cahiers de biologie marine*. 2012;**53**:197-204. DOI: 10.21411/CBM.A.E6C632F8
- [67] Ismen A, Ozen O, Altinagac U, Ozekinci U, Ayaz A. Weight-length relationships of 63 fish species in Saros Bay, Turkey. *Journal of Applied Ichthyology*. 2007;**23**:707-708. DOI: 10.1111/j.1439-0426.2007.00872.x
- [68] Ismen A, Yigin C, Altinagac U, Ayaz A. Length-weight relationships for ten shark species from Saros Bay C (North Aegean Sea). *Journal of Applied Ichthyology*. 2009;**25**:109-112. DOI: 10.1111/j.1439-0426.2009.01263.x
- [69] Bok TD, Gokturk D, Kahraman AE, Alicli TZ, Acun T, Ates C. Length-weight relationships of 34 fish species from the sea of Marmara, Turkey. *Journal of Animal and Veterinary Advances*. 2011;**10**:3037-3042. DOI: 10.3923/javaa.2011.3037.3042
- [70] Güven O, Kebapçioğlu T, Deval MC. Length-weight relationships of sharks in Antalya Bay, eastern Mediterranean. *Journal of Applied Ichthyology*. 2012;**28**:278-279. DOI: 10.1111/j.1439-0426.2011.01823.x
- [71] Eronat EGT, Özaydın O. Length-weight relationship of cartilaginous fish species from Central Aegean Sea (Izmir Bay and Sığacık Bay). *Ege Journal of Fisheries and Aquatic Sciences*. 2014;**31**(3):119-125. DOI: 10.12714/egejfas.2014.31.3.01
- [72] Kousteni V, Megalofonou P. Aging and life history traits of the longnose spiny dogfish in the Mediterranean Sea: New insights into conservation and management needs. *Fisheries Research*. 2015;**168**:6-19. DOI: 10.1016/j.fishres.2015.03.014
- [73] Lteif M, Mouawad R, Jemaa S, Khalaf G, Lenfant P, Verdoit-Jarraya M. The length-weight relationships of three sharks and five batoids in the Lebanese marine waters, eastern Mediterranean. *Egyptian Journal of Aquatic Research*. 2016;**42**:475-477
- [74] Öztekin A, Özekinci U, Daban İB. Lengthweight relationships of 26 fish species caught by longline from the Gallipoli peninsula, Turkey (northern Aegean Sea). *Cahiers de Biologie Marine*. 2016;**57**:335-342
- [75] Grace E, Bengil T. Biology and ecology of *squalus Blainville* (Risso, 1827) from the eastern Mediterranean. *Thalassas: An International Journal of Marine Sciences*. 2022. DOI: 10.1007/s41208-022-00482-w [In press]
- [76] Falsone F, Geraci ML, Scannella D, Gancitano V, Di Maio F, Sardo G, et al. Length-weight relationships of 52 species from the south of Sicily (Central Mediterranean Sea). *Fishes*. 2022;**7**(2):92. DOI: 10.3390/fishes7020092
- [77] Marouani S, Kadri H, Bradai MN. First data on the age, growth and sexual maturity of the piked spurdog, *Squalus megalops* (Chondrichthyes: Squalidae), in the Gulf of Gabès (Central Mediterranean Sea). *Marine and Freshwater Research*. 2015;**67**(5):578-585. DOI: 10.1071/MF14356

- [78] Filiz H, Mater S. Preliminary study on length-weight relationships for seven elasmobranch species from North Aegean Sea. Turkey Journal of Fisheries & Aquatic Sciences. 2002;**19**(3-4):401-409
- [79] Filiz H. G bilge : Length-weight relationships of 24 fish species from the North Aegean Sea. Turkey. Journal of Applied Ichthyology. 2004;**20**(5):431-432. DOI: 10.1111/j.1439-0426.2004.00582.x
- [80] Gracan R, Zavodnik D, Krstinić P, Lazar B. Feeding ecology and trophic segregation of two sympatric mesopredatory sharks in the heavily exploited coastal ecosystem of the Adriatic Sea. Journal of Fish Biology. 2016;**90**(1):167-184. DOI: 10.1111/jfb.13158
- [81] Jones TS, Uglund KI. Reproduction of female spiny dogfish, *Squalus acanthias*, in the Oslofjord. Fishery Bulletin. 2001;**99**:685-690
- [82] Sims CA. Implications of rational inattention. Journal of Monetary Economics. 2003;**50**(3):665-690. DOI: 10.1016/S0304-3932(03)00029-1
- [83] Bat L, Erdem Y, Ustaoglu S, Yardım Ö, Satılmış HH. A study on the fishes of the Central Black Sea coast of Turkey. Journal of the Black Sea/Mediterranean Environment. 2005;**11**:281-296
- [84] Bonello J, Bonnici L, Ferrari A, Cariani A, Schembri P. Not all that clear cut: Intraspecific morphological variability in *Squalus Blainville* (Risso, 1827) and implications for identification of the species. Journal of the Marine Biological Association of the United Kingdom. 2016;**96**(8):1585-1596. DOI: 10.1017/S0025315415001915
- [85] Giarruso ME. Indagini morfologiche e genetiche sul genere *Squalus* nello stretto di Sicilia. Corso di laurea magistrale in biologia marina [thesis]. Italy: Tesi di laurea in struttura e connettività delle popolazioni marine; 2019. p. 31
- [86] Baino R, Serena F, Ragonese S, Rey J, Rinelli P. Catch composition and abundance of elasmobranchs based on the MEDITS program. Rapport de la Commission Internationale pour l'Exploration Scientifique de la Méditerranée. 2001;**36**:234
- [87] Damalas D, Vassilopoulou V. Chondrichthyan by-catch and discards in the demersal trawl fishery of the Central Aegean Sea (eastern Mediterranean). Fisheries Research. 2011;**108**(1):142-152. DOI: 10.1016/j.fishres.2010.12.012
- [88] Tsagarakis K, Mytilineou C, Haralabous J, Lorange P, Politou CY, Dokos J. Mesoscale spatio-temporal dynamics of demersal assemblages of the eastern Ionian Sea in relationship with natural and fisheries factors. Aquatic Living Resources. 2013;**26**:381-397. DOI: 10.1051/alr/2013067
- [89] Marongiu MF, Porcu C, Bellodi A, Cannas R, Cau A, Cuccu D, et al. Temporal dynamics of demersal chondrichthyan species in the central western Mediterranean Sea: The case study in Sardinia Island. Fisheries Research. 2017;**193**:81-94. DOI: 10.1016/j.fishres.2017.04.001
- [90] Follesa MC, Marongiu MF, Zupa W, Bellodi A, Cau A, Cannas R, et al. Spatial variability of Chondrichthyes in the northern Mediterranean. Scientia Marina. 2019;**83**(S1):81-100. DOI: ORG/10.3989/SCIMAR.04998.23A
- [91] Last PR. Stevens JD: Sharks and Rays of Australia. Melbourne, Australia: CSIRO; 1994. p. 513. DOI: 10.1017/S0025315400047858
- [92] Bradaï NM, Saidi B, Enajjar S. Overview on Mediterranean Shark's

- fisheries: Impact on the biodiversity. In: Türkoglu M, Önal U, Ismen A, editors. Marine Ecology - Biotic and Abiotic Interactions. London: Intechopen; 2018. pp. 211-230. DOI: 10.5772/INTECHOPEN.74923
- [93] Musick JA, Burgess GH, Cailliet GM, Camhi M, Fordham SV. Management of sharks and their relatives (Elasmobranchii). Fisheries. 2000;25(3):913. DOI: 10.1577/15488446(2000)025<0009:MOSATR>2.0.CO;2
- [94] FAO: The State of World Fisheries and Aquaculture. Sustainability in Action. Vol. 2020. Rome: FAO; 2020. p. 244. DOI: 10.4060/ca9229en
- [95] Walker JMT, Joan MT, Wilkins AS, Dallaire JR, Sandler HM, Hoover-Dempsey KV. Parental involvement: Model revision through scale development. The Elementary School Journal. 2005;106(2):85-104. DOI: 10.1086/499193
- [96] Cashion MS, Bailly N, Pauly D. Official catch data underrepresent shark and ray taxa caught in Mediterranean and Black Sea fisheries. Marine Policy. 2019;105(7437):1-9. DOI: 10.1016/j.marpol.2019.02.041
- [97] Damalas D, Megalofonou P. Occurrences of large sharks in the open waters of the southeastern Mediterranean Sea. Journal of Natural History. 2012;46:43-44. DOI: 10.1080/00222933.2012.716864
- [98] Echwikhi K, Saidi B, Bradai MN, Bouain A. Preliminary data on elasmobranch gillnet fishery in the Gulf of Gabès Tunisia. Journal of Applied Ichthyology. 2013;29:1080-1085. DOI: 10.1111/JAI.12022
- [99] GFCM (Mediterranean and Black Sea) Capture Production Quantity (1970 - 2020) [https://www.fao.org/fishery/statisticsquery/en/gfcm\\_capture/gfcm\\_capture\\_quantity](https://www.fao.org/fishery/statisticsquery/en/gfcm_capture/gfcm_capture_quantity)
- [100] Mandelman JW, Farrington MA. The physiological status and mortality associated with otter-trawl capture, transport, and captivity of an exploited elasmobranch, *Squalus acanthias*. ICES Journal of Marine Science. 2007;64(1):122-130. DOI: 10.1093/icesjms/fsl003
- [101] Stoner A, Kaimmer SM. Reducing elasmobranch bycatch: Laboratory investigation of rare earth metal and magnetic deterrents with spiny dogfish and Pacific halibut. Fisheries Research. 2008;92(2):162-168. DOI: 10.1016/j.fishres.2008.01.004
- [102] Tallack SML, Mandelman JW. Do rare-earth metals deter spiny dogfish? A feasibility study on the use of electropositive "mischmetal" to reduce the bycatch of *Squalus acanthias* by hook gear in the Gulf of Maine. ICES Journal of Marine Science. 2009;66(2):315-322. DOI: 10.1093/icesjms/fsn215
- [103] Séret B, Serena F. Distribution and abundance of *Squalus acanthias* and *Squalus blainvillei* in the Mediterranean Sea based on the Mediterranean international trawl survey program (MEDITS). In: The Mediterranean Chondrichthyan Fishes (Sharks, Rays, Skates and Chimaeras): Status and Priorities for Conservation. Tunis, Tunisia: United National Environment Programme (UNEP) Regional Activity Centres/Special Protected Areas (RAC/SP) Final Report; 2002
- [104] Marongiu MF, Porcu C, Bellodi A, Cannas R, Carbonara P, Cau A, et al. Abundance, distribution and reproduction of the data-deficient species (*Squalus Blainville*) around Sardinia Island (central western

Mediterranean Sea) as a contribution to its conservation. *Marine Freshwater Resources*. 2020;**72**(1):118-130.

DOI: 10.1071/MF19372

[105] Nuez I, Gazo M. Cardona : A closer look at the bycatch of medium-sized and large sharks in the northern Catalan coast (north-western Mediterranean Sea): Evidence of an ongoing decline? *Aquatic Conservation: Marine and Freshwater Ecosystems*. 2021;**31**(9):2369-2380.

DOI: 10.1002/aqc.3651

[106] Mandelman JW, Cooper PW, Werner TB, Lagueux KM. Shark bycatch and depredation in the U.S. Atlantic pelagic longline fishery. *Reviews in Fish Biology and Fisheries*. 2008;**18**:427-442.

DOI: 10.1007/s11160-008-9084-z

[107] Last PR, White WT, Pogonoski JJ, Gledhill DC, Yearsley GK, Ward RD: Application of a rapid taxonomic approach to the genus *squalus*. In: Last PR, White WT, Pogonoski JJ editors. *Descriptions of New Dogfishes of the Genus Squalus* (Squaloidea: Squalidae). Hobart, Tas.: CSIRO Marine and Atmospheric Research; 2007. p. 1-10.

DOI: <http://hdl.handle.net/102.100.100/124361?index=1>

[108] Díaz-Jaimes P, Bayona-Vásquez NJ, Escatel-Luna E, Uribe-Alcocer M, Pecoraro C, Adams DH, et al. Population genetic divergence of Bonnethead sharks *Sphyrna tiburo* in the Western North Atlantic: Implications for conservation. *Aquatic Conservation, Marine and Freshwater Ecosystems*. 2021;**31**(1):83-98. DOI: 10.1002/aqc.3434

[109] Ceballos G, Ehrlich PR, Barnosky AD, García A, Pringle RM, Palmer TM. Accelerated modern human-induced species losses: Entering the sixth mass extinction. *Science Advances*. 2015;**1**(5):e1400253. DOI: 10.1126/sciadv.1400253

[110] Geraci ML, Ragonese S, Norrito G, Scannella D, Falsone F, Vitale S: A tale on the demersal and bottom dwelling Chondrichthyes in the south of Sicily through 20 years of scientific survey. In: Filho LFDSR, de Luna Sales JR, editors. *Chondrichthyes - Multidisciplinary Approach* [Internet]. London: IntechOpen. 2017. p. 13-37. DOI: 10.5772/intechopen.69333

[111] Pflieger MO, Grubbs RD, Cotton CF, Daly-Engel TS. *Squalus clarkae* Sp. Nov., a new dogfish shark from the Northwest Atlantic and Gulf of Mexico, with comments on the *Squalus mitsukurii* species complex. *Zootaxa*. 2018;**4444**:101-119. DOI: 10.11646/zootaxa.4444.2.1

[112] Ariza AA, Adachi AMCL, Roque P, Hazin FHV, Vianna M, Rotundo MM, et al. DNA barcoding and species delimitation for dogfish sharks belonging to the *squalus* genus (Squaliformes: Squalidae). *Diversity*. 2022;**14**:544. DOI: 10.3390/d14070544

[113] Ledoux JC. Affinités et origines du *Squalus blainvillei* de Méditerranée. *Journées Ichthologique, C.I.E.S.M.* 1970;**3**:65-69

[114] Merrett NF. A new shark of the genus *squalus* (Squalidae, Squaloidea) from the equatorial western Indian Ocean, with notes on the *Squalus blainvillei*. *Journal of Zoology*. 1973;**171**:93-110. DOI: 10.1111/j.1469-7998.1973.tb07518.x

[115] Bass AJ, D'Aubrey JD, Kistnasamy N. Sharks of the east coast of southern Africa. VI the families Oxynotidae, Squalidae, Dalatiidae, and Echinorhinidae, Investigation. *Investigational Report Institute of Oceanographic Sciences*. 1976;**45**:1-103

[116] Chen C, Taniuchi T. Nose: Blainville's dogfish, *Squalus Blainville*,

from Japan, with notes on *S. mitsukurii* and *S. japonicus*. Japanese Journal of Ichthyology. 1979;26:26-42

[117] Bigelow HB, Schroeder WC: Fishes of the western North Atlantic, part I: Lancelets, cyclostomes, sharks. In Tee-Van J, Breder CM, Hildebrand SF, Parr AE, and Schroeder WC, Editors. Fishes of the Western North Atlantic. Part 1. Sears Foundation for Marine Research, Yale University, New Haven; 1948. P 59-576) DOI: 10.1126/science.111.2874.95

[118] Springer VG, Garrick JAF. A survey of vertebral numbers in sharks. Proceedings of the United States National Museum. 1964;116:73-96. DOI: 10.5479/si.00963801.116-3496.73

[119] Kousteni V, Kasapidis P, Kotoulas G, Megalofonou P. Evidence of high genetic connectivity for the longnose spurdog *Squalus Blainville* in the Mediterranean Sea. Mediterranean Marine Science. 2016;17(2):371-383. DOI: 10.12 681/mms.1222

[120] Kemp NE. Integumentary system and teeth. In: Hamlett WC, editor. Sharks, Skates and Rays: The Biology of Elasmobranch Fishes. Chapter 2. The John Hopkins University Press; 1999. pp. 43-68

[121] White WT, Ebert DA, Naylor GJP, Ho HC, Clerkin P, Veríssimo A, et al. Revision of the genus *Centrophorus* (Squaliformes: Centrophoridae): Part 1—Redescription of *Centrophorus granulatus* (Bloch & Schneider), a senior synonym of *C. acus* Garman and *C. niaukang* Teng. Zootaxa. 2013;3752(1):35. DOI: 10.11646/ZOOTAXA.3752.1.5

[122] Veríssimo A, Cotton CF, Buch RH, Guallart J, Burgess GH. Species diversity of the deep-water gulper sharks (Squaliformes: Centrophoridae:

*Centrophorus*) in North Atlantic waters - current status and taxonomic issues. Zoological Journal of the Linnean Society. 2014;172(4):803-830. DOI: 10.1111/zoj.12194

[123] Last PR, Stevens JD. Sharks and Rays of Australia. 2nd ed. Collingwood, Australia: CSIRO; 2009. p. 644

[124] Schlick-Steiner BC, Steiner FM, Seifert B, Stauffer C, Christian E, Crozier RH. Integrative taxonomy: A multisource approach to exploring biodiversity. Annual Review of Entomology. 2010;55:421-438. DOI: 10.1146/annurev-ento-112408-085432

[125] Gabbanelli V, Díaz de Astarloa JM, Gonzalez-Castro M, Vazquez DM, Mabrugaña E: Almost a century of oblivion: Integrative taxonomy allows the resurrection of the longnose skate *Zearaja brevicaudata* (Marini, 1933) (Rajiformes; Rajidae). Comptes Rendus Biologies. 2018;341:454-470. DOI: 10.1016/j.crv.2018.10.002

[126] García-Melo JE, Oliveira C, Silva GJDC, Ochoa-Orrego LE, Pereira LHG, Maldonado-Ocampo JA. Species delimitation of Neotropical characins (Stevardiinae): Implications for taxonomy of complex groups. PLoS One. 2019;14:e0216786. DOI: 10.1371/journal.pone.0216786