

Filling in knowledge gaps: Length–weight relations of 46 uncommon sharks and rays (Elasmobranchii) in the Mediterranean Sea

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<http://zoobank.org/723A6A19-43A5-45B0-AC11-C18EC1710540>

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Academic editor: Rodolfo Reyes Jr. ♦ **Received** 30 December 2020 ♦ **Accepted** 17 February 2021 ♦ **Published** 9 September 2021

Citation: Tsikliras AC, Dimarchopoulou D (2021) Filling in knowledge gaps: Length–weight relations of 46 uncommon sharks and rays (Elasmobranchii) in the Mediterranean Sea. *Acta Ichthyologica et Piscatoria* 51(3): 249–255. <https://doi.org/10.3897/aiep.51.65858>

Abstract

Large sharks and rays are generally understudied in the Mediterranean Sea, thus leading to a knowledge gap of basic biological characteristics that are important in fisheries management and ecosystem modeling. Out of the 76 sharks and rays inhabiting the Mediterranean Sea, the length–weight relations (LWR) are available for 28 (37%) of them, usually for common small-sized species that are not protected and may be marketed. The aim of the presently reported study was to fill in the knowledge gap through the estimation of LWR of rare and uncommon sharks and rays in the Mediterranean Sea using the information from single records or few individuals. The analysis was based on a Bayesian hierarchical method for estimating length–weight relations in fishes that has been recently proposed for data-deficient species or museum collections and uses the prior knowledge and existing LWR studies to derive species-specific LWR parameters by body form. The use of this method was applied to single records of rare and uncommon species and here we report the LWR of 46 uncommon sharks and ray species, 14 of which are first reported LWR at a global scale and 21 are the first reported LWR for the Mediterranean Sea; the remaining 11 species are first time records for the western or eastern Mediterranean regions. Museum collections and sporadic catch records of rare emblematic species may provide useful biological information with the use of appropriate Bayesian methods.

Keywords

gap analysis, fisheries management, ecosystems, Mediterranean Sea

Introduction

According to a recent gap analysis on the biology of Mediterranean fishes, sharks and rays (Class Elasmobranchii) are among the least studied species in the Mediterranean Sea and the lack of knowledge is higher for the less abundant large sharks and rays that are protected and rarely collected in a commercial catch or even scientific surveys (Dimarchopoulou et al. 2017). Despite their conservation status, many sharks are still illegally targeted for their fins

and these records are not officially reported (Clarke et al. 2006). Due to the scarcity of samples, the records on the biology of sharks and rays in the Mediterranean are sporadic (Dulvy et al. 2016; Dimarchopoulou et al. 2017), however, because of the importance of large sharks and rays in marine ecosystems and their conservation status (Dulvy et al. 2014), there are several single-catch records available of emblematic species such as the great white shark *Carcharodon carcharias* (Linnaeus, 1758) (see Kabasakal 2020). The majority of Mediterranean records

originate from Tunisia and Turkey owing to the lifetime commitment of a few scientists (e.g., Capapé et al. 2006; Kabasakal 2020 among others) and also, in the case of Tunisia, to the higher species richness of sharks and rays in the western Mediterranean Sea (Dulvy et al. 2016). The majority of biological characteristics of small and common sharks—e.g., lesser spotted dogfish, *Scyliorhinus canicula* (Linnaeus, 1758)—and rays—e.g., thornback ray, *Raja clavata* Linnaeus, 1758—that are marketed and not protected in the Mediterranean Sea are better studied (Froese and Pauly 2020).

Length–weight relations (LWR) of fishes (Froese 2006) are important in stock assessments for converting length measurements to weight and estimation of stock biomass (Froese et al. 2011). The LWR is the most studied biological characteristic and studies are available for a large proportion of fish stocks and the majority of finfish in the Mediterranean Sea (Dimarchopoulou et al. 2017). However, rare sharks and rays are underrepresented (Froese and Pauly 2020) and some of the existing LWR records deviate from the cube law dynamics (Froese 2006) because of the small sample size and narrow length and weight distributions (Froese et al. 2011).

A Bayesian hierarchical method for estimating length–weight relations in fishes has been proposed for data-deficient species that uses the prior knowledge and existing LWR studies to derive species-specific LWR parameters by body form (Froese et al. 2014). According to this method, the approximate values of the slope (b) and the intercept (a) of LWR have been estimated for all fish species and are available in FishBase (Froese and Pauly 2020). Recently, a new approach for estimating LWR from single the length and weight records has been proposed and applied to preserved museum specimens for species for which LWR are not available in the literature (Hay et al. 2020). Based on this approach the LWR of several uncommon fish species, for which museum records are available but their LWR were not, were generated (Hay et al. 2020).

Overall, out of the 43 species of sharks and 33 species of rays that are present in the Mediterranean Sea (Dulvy et al. 2016), LWR are available for 28 species (37%) based on FishBase records (Froese and Pauly 2020) and the literature (updated dataset of Dimarchopoulou et al. 2017). The aim of the presently reported study was to combine these two approaches and generate LWR for 46 rare shark and ray species in the Mediterranean Sea based on single records (or records of a few individuals) that were available in the literature and for which LWR are lacking at a global or regional scale. Thus, the gap between available and desired knowledge on the LWR of Mediterranean marine fishes will be minimized to only a handful of species.

Methods

We collected the single specimen records (or few specimens) of total length (L) [cm] and total weight (W)

[g] data for 46 uncommon shark and ray species in the Mediterranean Sea that belong to 10 orders and 16 families from the literature. Then, we estimated their LWR (Table 1) using the Bayesian estimate available for the species based on LWR of taxonomically related species (Froese and Pauly 2020). The number of specimens ranged from a single (17 cases) and double specimens (10 cases) to 27 specimens of the great white shark that are available in a recently published book (Kabasakal 2020). The mean number of specimens was 3.65. All length data were converted to cm of total length and all weight data to g of total weight.

In species for which a range of sizes was not available to estimate the parameters of LWR, such as with museum specimens, Hay et al. (2020) assumed that the LWR were isometric, i.e., that the parameter $b = 3$, which is a good approximation in the majority of cases (Froese 2006). A similar approach was followed in the presently reported study with b approximated based on related species or species with similar body form (Froese and Pauly 2020) following a Bayesian hierarchical method (Froese et al. 2014).

When total length (L) and total weight (W) measurements from single specimen were available, the parameter a was estimated as (Hay et al. 2020):

$$a = \frac{W}{L^b}$$

where b is the approximation based on the Bayesian estimate available for the species based on LWR of related species (Froese and Pauly 2020) or body form when a Bayesian estimate was not available (Froese et al. 2014).

When several specimens (n) were available, but not enough to support a valid LWR, because of a small sample size or narrow length range, the mean value of parameter a was estimated as (Hay et al. 2020):

$$a = \frac{\sum_{i=1}^n \frac{W}{L^b}}{n}$$

where b is the approximation based on the Bayesian estimate available for the species based on LWR of related species (Froese and Pauly 2020) or body form when a Bayesian estimate was not available (Froese et al. 2014).

Results

The LWR of 46 uncommon sharks and ray species are reported for the Mediterranean Sea based on published sources of stranded or incidentally caught animals; none of the specimens was preserved or in a museum collection. For 14 species this is the first reported LWR at a global scale and for 21 species this is the first reported LWR for the Mediterranean Sea (Table 1). The remaining 11 species are first-time LWR records for the western (nine species), eastern Mediterranean (one species) regions, and Aegean Sea (one species).

Table 1. Selected biometric data for 46 species of sharks and rays in the Mediterranean Sea.

Scientific name	N	Total length [cm]	Total weight [g]	b	b source	a	a range	First LWR	Country	Reference
CARCHARHINIFORMES										
Carcharhinidae										
<i>Prionace glauca</i> (Linnaeus, 1758)	1	288.0	174000	3.11	BFB	0.0039	—	Mediterranean	—	Kohler et al. 2002
<i>Carcharhinus altimus</i> (Springer, 1950)	2	65.2–68.0	2200–3100	3.12	BFB	0.0054	0.0048–0.0059	Mediterranean	Turkey	Ayas et al. 2020, Turan et al. 2020
<i>Carcharhinus brachyurus</i> (Günther, 1870)	1	253.0	200000	3.09	BFB	0.0075	—	Mediterranean	Italy	Storai et al. 2007
<i>Carcharhinus brevipinna</i> (Müller et Henle, 1839)	1	115.0	11500	3.07	BFB	0.0054	—	Mediterranean	Turkey	Ayas et al. 2019
<i>Carcharhinus falciformis</i> (Müller et Henle, 1839)	1	209.0	48000	3.09	BFB	0.0033	—	Mediterranean	Italy	Garibaldi and Orsi-Relini 2012
<i>Carcharhinus plumbeus</i> (Nardo, 1827)	6	89.0–300.0	3500–70000	3.17	BFB	0.0019	0.0010–0.0023	Mediterranean	Tunisia	Capape et al. 2018, Soufi et al. 2018
<i>Galeocerdo cuvier</i> (Péron et Lesueur, 1822)	2	95.8–97.4	2750–2840	3.15	BFB	0.0016	0.0015–0.0016	Mediterranean	Libya	Tobuni et al. 2016
ECHINORHINIFORMES										
Echinorhinidae										
<i>Echinorhinus brucus</i> (Bonnaterre, 1788)	6	170.0–254.0	45000–300000	3.12	BFB	0.0074	0.0031–0.0147	Global	Algeria, Turkey	Hemida and Capape 2002, Kabasakal and Bilecenoglu 2014
HEXANCHIFORMES										
Hexanchidae										
<i>Heptranchias perlo</i> (Bonnaterre, 1788)	5	70.0–110.0	1000–5000	3.11	BFB	0.0022	0.0016–0.0035	western Med	Tunisia, Spain	El Kamel-Moutalibi et al. 2014, Guallart et al. 2019
<i>Hexanchus griseus</i> (Bonnaterre, 1788)	17	250.0–600.0	200000–1000000	3.04	BF	0.0062	0.0034–0.0123	Global	Turkey	Kabasakal 2006
<i>Hexanchus nakamura</i> Teng, 1962	1	230.0	85000	3.11	BFB	0.0038	—	Mediterranean	Albania	Bakiu et al. 2018
LAMNIFORMES										
Alopiidae										
<i>Alopias vulpinus</i> (Bonnaterre, 1788)	1	395.0	180000	2.86	BFB	0.0067	—	Mediterranean	Turkey	Erguden et al. 2015
<i>Alopias superciliosus</i> Lowe, 1841	7	151.0–450.0	10000–180000	2.91	BFB	0.0051	0.0027–0.0068	Mediterranean	Many countries	Kabasakal and Karhan 2007, Clo et al. 2008, Damalas and Megalofonou 2012, Kabasakal et al. 2011, Lanteri et al. 2017
Cetorhinidae										
<i>Cetorhinus maximus</i> (Gunnerus, 1765)	1	236.0	70000	3.04	BF	0.0043	—	Mediterranean	Turkey	Bilecenoglu et al. 2013
Lamnidae										
<i>Isurus oxyrinchus</i> Rafinesque, 1810	1	69.8	2285	3.03	BFB	0.0059	—	Mediterranean	Turkey	Bilecenoglu et al. 2013
<i>Lamna nasus</i> (Bonnaterre, 1788)	5	91.0–236.0	35000–120000	3.03	BFB	0.0240	0.0077–0.0753	Mediterranean	Italy	Storai et al. 2005
<i>Carcharodon carcharias</i> (Linnaeus, 1758)	27	132.0–642.0	27650–2500000	3.05	BFB	0.0074	0.0043–0.0108	Mediterranean	Tunisia	Saidi et al. 2005, Morey et al. 2003
Odontaspidae										
<i>Carcharias taurus</i> Rafinesque, 1810	1	99.7	3318	3.03	BFB	0.0029	—	Mediterranean	Turkey	Ismen et al. 2009
<i>Odontaspis ferox</i> (Risso, 1810)	2	190.0–250.0	34000–180000	3.04	BF	0.0066	0.0040–0.0092	Mediterranean	Turkey	Kabasakal and Bayri 2019
MYLIOBATIFORMES										
Dasyatidae										
<i>Bathytoshia centroura</i> (Mitchill, 1815)	1	60.1	5200	3.07	BFB	0.0180	—	western Med	Croatia	Dulcic et al. 2003
<i>Dasyatis chrysonota</i> (Smith, 1828)	1	36.9–44.5	149–445	3.07	BFB	0.0030	0.0023–0.0039	Global	Israel	Golani and Capape 2004
<i>Dasyatis marmorata</i> (Steindachner, 1892)	1	33.0	171.8	3.07	BFB	0.0037	—	Global	Greece	Chatzispayrou et al. 2020
<i>Himantura leoparda</i> Manjaji-Matsumoto et Last, 2008	2	26.0–135.2	722–55000	3.17	BFB	0.0166	0.0097–0.0236	Global	Turkey	Yucel et al. 2017
<i>Himantura uarnak</i> (Gmelin, 1789)	3	140.0–148.6	40000–150000	3.17	BFB	0.0117	0.0047–0.0195	Mediterranean	Turkey	Basusta et al. 1998, Ali et al. 2010
<i>Taeniura grabata</i> (Geoffroy Saint-Hilaire, 1817)	4	60.0–117.8	1681–16600	3.17	BFB	0.0040	0.0033–0.0045	Global	Turkey	Basusta et al. 1998, Ali et al. 2013
Mobulidae										
<i>Mobula japonica</i> (Müller et Henle, 1841)	2	97.5–120.0	67000–100000	3.04	BFB	0.0540	0.0478–0.0602	Global	Tunisia	Capape et al. 2015
<i>Mobula mobular</i> (Bonnaterre, 1788)	3	200.0–291.5	100000–105000	3.04	BFB	0.0052	0.0022–0.0101	Global	Italy, Turkey	Scacco et al. 2009, Basusta and Ozbek 2017
Myliobatidae										
<i>Aetomylaeus bovinus</i> (Geoffroy Saint-Hilaire, 1817)	2	152.7–160.0	14800–16200	3.04	BF	0.0033	0.0032–0.0034	Western Med	Tunisia	El Kamel et al. 2010
<i>Myliobatis aquila</i> (Linnaeus, 1758)	4	50.0–114.0	2000–29400	3.09	BFB	0.0111	0.0096–0.0130	Western Med	France	Capape et al. 2006
RAJIFORMES										
Rajidae										
<i>Leucoraja melitensis</i> (Clark, 1926)	1	27.0	80.2	3.13	BFB	0.0027	—	Global	Tunisia	Ben Amor et al. 2018
<i>Dipturus nidarosiensis</i> (Storm, 1881)	4	24.0–148.2	20.12–13783	3.24	BFB	0.0010	0.0009–0.0013	Global	Italy	Follesa et al. 2012
<i>Dipturus oxyrinchus</i> (Linnaeus, 1758)	1	48.0	443	3.25	BFB	0.0015	—	Western Med	France	Capape et al. 2006
<i>Leucoraja circularis</i> (Couch, 1838)	6	61.9–101.0	1250–5650	3.08	BFB	0.0052	0.0038–0.0087	Western Med	Tunisia	Mnasri et al. 2009
<i>Leucoraja fullonica</i> (Linnaeus, 1758)	11	19.0–76.0	191–2300	3.13	BFB	0.0065	0.0019–0.0240	Global	Italy	Zupa et al. 2010
<i>Leucoraja naevus</i> (Müller et Henle, 1841)	2	22.0–52.0	59–864	3.10	BFB	0.0041	0.0041–0.0041	Mediterranean	Spain	Valls et al. 2011
<i>Raja brachyura</i> Lafont, 1871	1	91.5	5450	3.27	BFB	0.0021	—	Eastern Med	France	Capape et al. 2006
<i>Raja undulata</i> Lacepède, 1802	2	48.4–58.0	765–1356	3.20	BFB	0.0031	0.0031–0.0031	Mediterranean	France	Capape et al. 2006
RHINOPRISTIFORMES										
Glaucoptegidae										
<i>Glaucoptegus halavi</i> (Forsskål, 1775)	1	102.3	3005	2.99	BFB	0.0029	—	Global	Tunisia	Ben Souissi et al. 2007

Table 1 continues on next page.

Table 1. cont.

Scientific name	<i>N</i>	Total length [cm]	Total weight [g]	<i>b</i>	<i>b</i> source	<i>a</i>	<i>a</i> range	First LWR	Country	Reference
Rhinopteroidea										
<i>Rhinoptera marginata</i> (Geoffroy Saint-Hilaire, 1817)	5	38.5–87.4	104–9980	3.10	BFB	0.0044	0.0010–0.0096	Western Med	Turkey	Basusta et al. 2012
SQUALIFORMES										
Oxynotidae										
<i>Oxynotus centrina</i> (Linnaeus, 1758)	4	53.3–79.0	1649–5020	3.04	BF	0.0087	0.0080–0.0093	Aegean Sea	Greece	Kousteni and Megalofonou 2016
SQUATINIFORMES										
Squatinae										
<i>Squatina aculeata</i> Cuvier, 1829	1	79.9	3690	3.04	BFB	0.0061	—	Global	Turkey	Basusta 2002
<i>Squatina oculata</i> Bonaparte, 1840	6	29.1–79.5	173–3750	3.04	BFB	0.0067	0.0061–0.0076	Global	Greece, Italy	Corsini and Zava 2007, Zava et al. 2016, Erguden et al. 2019
<i>Squatina squatina</i> (Linnaeus, 1758)	2	38.0–156.0	1900–32600	3.02	BFB	0.0200	0.0078–0.0322	Mediterranean	Turkey	Akyol et al. 2015, Cavallaro et al. 2015
TORPEDINIFORMES										
Torpedinidae										
<i>Tetronarce nobiliana</i> (Bonaparte, 1835)	4	17.0–102.0	150–20000	2.96	BFB	0.0256	0.0133–0.0342	Western Med	France	Capape et al. 2006
<i>Torpedo marmorata</i> Risso, 1810	4	16.0–50.0	40–3500	2.94	BFB	0.0241	0.0115–0.0354	Western Med	France	Capape et al. 2006
<i>Torpedo torpedo</i> (Linnaeus, 1758)	2	25.0–39.0	300–1012	2.90	BFB	0.0255	0.0246–0.0265	Mediterranean	France	Capape et al. 2006

N = sample size, *b* and *a* are LWR parameters of information; BFB = Bayesian FB, BF = Body form.

A Bayesian estimate of parameter *b* based on LWR of related species was available for 41 species (Froese and Pauly 2020), while for the remaining 5 ones—*Hexanchus griseus* (Bonnaterre, 1788), *Cetorhinus maximus* (Gunnerus, 1765), *Odontaspis ferox* (Risso, 1810), *Aetomylaeus bovinus* (Geoffroy Saint-Hilaire, 1817), *Oxynotus centrina* (Linnaeus, 1758)—an estimate based on their body form was used (Froese et al. 2014). In cases where more than one specimen was available, the range of length, weight, and parameter *a* is provided (Table 1).

Discussion

Although isometric growth ($b = 3$) is the most common type of growth in the majority of families (Froese 2006), strong deviations from isometry have been observed due to a narrow range of sizes and/or low sample size (Froese et al. 2011; Hay et al. 2020). In addition, as the seasonality in *b* values is strong along with the corresponding estimates of *a* (Froese 2006), a limited sampling period, even with a large sample size of the entire somatic range of the species may lead to varying LWR (Hay et al. 2020). This effect of seasonality is partly related to the spawning period of fishes and it is especially strong for the female viviparous sharks that deviate a lot in somatic weight during their gestation period (Castro 2000).

Length data for a few specimens of some other very rare shark species exist in the literature—pigeon shark, *Carcharhinus amboinensis* (Müller et Henle, 1839) (see Da Maddalena and Della Rovere 2005); common sawfish, *Pristis pristis* (Linnaeus, 1758) (see Capape et al. 2006);

dusky shark, *Carcharhinus obscurus* (Lesueur, 1818) (see Bilecenoglu et al. 2013)—but weight data are lacking as those specimens were spotted at fish markets, where only part of the body was “available” usually the head, or are based on photos or anecdotal records from newspapers and magazines. Anecdotal evidence and historical records may be really valuable in reconstructing the history of these iconic predators (Ferretti et al. 2016) and gaining insight into the previous status of marine ecosystems and ecosystem effects of fishing (Pauly 1995; Pauly et al. 1998).

This work extends the approach of gaining valuable information from museum collections (Hay et al. 2020) to rare and sporadic catch records of emblematic species such as large sharks and rays for which biological information is lacking, at least in the Mediterranean Sea. The importance of the Bayesian approach to data-deficient areas and species is highlighted along with the need for recording the basic biological information (length, weight, and sex) even from single specimens of rare and uncommon sharks and rays. As the majority of these species are rare and protected (although illegally landed in many areas of the Mediterranean Sea), sometimes such data are only available in fish markets and newspapers/magazines; nowadays also through social media (Kabasakal and Bilecenoglu 2020).

Acknowledgments

The authors would like to thank Daniel Pauly and Rainer Froese for their insightful suggestions and two anonymous reviewers for their helpful comments.

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