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Length – Weight Relationships of 12 Commercial Fish Species Caught with Static Fishing Gear in the N. Ionian Sea (Greece)

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Abstract

This study presents the length-weight relationships (LWR) for 12 commercial fish species from coastal waters off South Corfu Island (N. Ionian Sea, Greece). All fish originated from the catches made by a single artisanal fisherman during April – September 2009. Multiple types of predominantly static fishing gear were used, mainly gillnets (mesh size: 28 mm) operated at depths of 10–40 m and trammel nets (mesh sizes: 22, 24, 28, 32, 34, 36, 40 mm) operated at depths of 7–70 m. Moreover, bottom longlines and trolling lines were occasionally used, at depths of 20–50 m and 35 m, respectively. Length (TL) in cm and weight in g of all the individuals in the catches were measured in the laboratory. Estimates of the b parameter ranged between species from 2.652 to 3.593. For none of the fish species examined in the present paper has LWR information been published before for the N. Ionian Sea, and for six of them (i.e. for *Epinephelus costae, Labrus viridis, Oblada melanura, Sarda sarda, Scomber colias* and *Scorpaena porcus*) there is no LWR information for the Ionian Sea as a whole. The results of this study may thus contribute in fisheries management and marine conservation in the Ionian Sea by providing baseline LWR information for several commercial fish species based on samples of local populations. Moreover, this study contributes in complementing the few LWR datasets that exist in the international literature for *E. costae* and *L. viridis*.

Keywords Life history · Animal growth · Fisheries management · Artisanal fisheries · Marine conservation

Introduction

The Length - Weight Relationship (LWR) in fish is described by the power function $W = aL^b$, where W is weight, L is length and a and b are the species-specific parameters of the function, which can be estimated by regression analysis (Le Cren 1951). LWR is related to fish condition, and sex, life-history stage, geographic area and the seasonal or annual variations in environmental conditions are among the most important factors that also affect within-species LWR variability (Le Cren 1951; Jennings et al. 2001; Froese 2006). Even after fish obtain adult body shape during their ontogenetic development, their shape may vary during growth in relation to size (positive or negative allometric growth, $b > 3$ or $b < 3$, respectively), or not (isometric growth, $b = 3$). The parameters of the LWR function can be calculated from subsamples and are commonly used in fisheries or conservation research to conveniently convert lengths to weights, determine fish condition and assess spatial or temporal variability in fish growth (Froese et al. 2011). Moreover, LWR parameters estimated from local populations are generally preferable when estimating fish weights from lengths (Harmelin-Vivien and Francour 1992; Giakoumi and Kokkoris 2013).

LWR is among the best-studied biological characteristics of fish species in the Mediterranean, but this is true to a lesser extent for the Central Mediterranean Sea (Dimarchopoulou et al. 2017). In particular, very few studies exist for the Ionian Sea, especially if the adjacent Patraikos and Korinthiakos Gulfs are not considered. The aim of this study is to present new information for the LWR and growth patterns for 12 commercial fish species caught in the coastal waters off South Corfu Island (N. Ionian Sea, Greece): *Dentex dentex* (Linnaeus, 1758), *Diplodus sargus* (Linnaeus, 1758), *Epinephelus costae* (Steindachner, 1878), *Labrus viridis* Linnaeus, 1758, *Oblada melanura* (Linnaeus, 1758), *Phycis phycis* (Linnaeus, 1766), *Sarda sarda* (Bloch, 1793), *Scomber colias* Gmelin, 1789, *Scorpaena porcus* Linnaeus, 1758, *Scorpaena scrofa* Linnaeus, 1758, *Spicara maena* (Linnaeus, 1758) and *Trachinus radiatus* Cuvier, 1829.

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Materials and Methods

Length and weight data for 12 commercial fish species caught in the coastal waters off South Corfu Island (N. Ionian Sea, Greece) were used to describe the LWR of the species for the study area. The latter extended from the southwest (off Gardenos) to the southest (off Petritis) of Corfu. All fish originated from the catches made by a single artisanal fisherman during April – September 2009. Multiple types of predominantly static fishing gear were used, mainly gillnets (mesh size: 28 mm) operated at depths of 10–40 m and trammel nets (mesh sizes: 22, 24, 28, 32, 34, 36, 40 mm) operated at depths of 7–70 m. Moreover, bottom longlines and trolling lines were occasionally used, at depths of 20–50 m and 35 m, respectively. Length (TL) in cm and weight in g of all the individuals in the catches were measured in the laboratory. The parameters a and b of the LWR were estimated with Ordinary Least Squares linear regression (Le Cren 1951). Following the guidelines of Froese et al. (2011), we systematically removed from the data influential observations, i.e. outliers (data points whose response y values did not follow the general trend of the remaining data) and high leverage observations (data points that had particularly high or low predictor x values). We accomplished this by first calculating Cook's distance D for each observation, and then deleting influential observations using the following cut-off rule: $D_i > 4 / (n - k - 1)$, where D_i is Cook's distance for observation i, n is the total number of observations and k is the number of independent variables (Fox 1997). In order to check for allometric growth, i.e. test the regression slope against the value 3, we reparameterized the original regression model $y = \beta_0 + \beta_1 x$ (where $y = \log W$, $x = \log L$, $\beta_0 = \log a$ and $\beta_1 = b$) into $y - 3x = \beta_0 + \theta x$. A test of significance for the new model against the null hypothesis H_0: $\theta = 0$ is equivalent to a test of significance for the original model against H_0: $\beta_1 = 3$. All data analyses were carried out with R (R Core Team 2019). The taxonomy and nomenclature are in accordance with FishBase (Froese and Pauly 2019).

Results

In this survey, length and weight were measured in a total of 541 specimens, belonging to 12 species and 9 families. The results of the Ordinary Least Squares linear regression analysis that was carried out for the estimation of the LWR parameters of the studied species are presented in Table 1. Sample sizes ranged from 9 for *E. costae* and *S. sarda* to 163 for *S. scrofa*. The coefficient of determination was ≥0.87 and all slopes were significant ($p < 0.001$). b values ranged between species from 2.652 to 3.593. The growth of *D. dentex* and *S. sarda* was found to be positive allometric, while the growth of *S. porcus* and *S. scrofa* was found to be negative allometric. The growth of the rest of the species was isometric.

Discussion

The only paper on fish LWR that we are aware of for the N. Ionian is that of Liousia et al. (2012), where fish LWR parameters were estimated for the port of Igoumenitsa, as well as for Amvrakikos Gulf (E. Ionian). For the S. Ionian Sea information is similarly limited (Papacostantinou et al. 1988a, b; Dimitriadis and Fournari-Konstantinidou 2018), while for the adjacent Patraikos and Korinthiakos gulfs LWR information can be found in Papacostantinou et al. (1988b), Mytilineou and Papacostantinou (1991), and Moutopoulos

Table 1 Descriptive statistics and Length - Weight Relationships parameters for 12 commercial fish species caught with multiple types of fishing gear from the coastal waters off South Corfu Island (N. Ionian Sea, Greece), during April – September 2009. *p* values for all species were < 0.001

Family	Species	n	Length (cm)		Weight (g)		a	b		R^2	Growth
			min	max	min	max	est	est	SE		
Sparidae	*Dentex dentex (Linnaeus, 1758)*	24	20	68	93	6200	0.003	3.390	0.104	0.98	A+
	Diplodus sargus (Linnaeus, 1758)	89	12	36	25	718	0.015	3.034	0.084	0.94	I
Serranidae	*Epinephelus costae (Steindachner, 1878)*	9	25	37	167	571	0.013	2.942	0.210	0.97	I
Labridae	*Labrus viridis Linnaeus, 1758*	44	14	33	39	428	0.024	2.760	0.131	0.92	I
Sparidae	*Oblada melanura (Linnaeus, 1758)*	19	19	30	93	354	0.013	3.001	0.231	0.91	I
Phycidae	*Phycis phycis (Linnaeus, 1766)*	16	23	47	114	930	0.015	2.888	0.087	0.99	I
Scombridae	*Sarda sarda (Bloch, 1793)*	9	39	66	580	3600	0.001	3.593	0.184	0.98	A+
	Scomber colias Gmelin, 1789	71	25	37	133	520	0.012	2.925	0.140	0.87	I
Scorpaenidae	*Scorpaena porcus Linnaeus, 1758*	42	12	26	43	305	0.061	2.652	0.160	0.88	A-
	Scorpaena scrofa Linnaeus	163	13	38	36	824	0.024	2.915	0.041	0.97	A-
Centracanthidae	*Spicara maena (Linnaeus, 1758)*	26	16	23	49	139	0.031	2.696	0.190	0.90	I
Trachinidae	*Trachinus radiatus Cuvier, 1829*	29	19	36	47	543	0.006	3.12	0.24	0.87	I

et al. (2013). Data on fish LWR for the Ionian Sea was also reviewed by Stergiou and Moutopoulos (2001).

For none of the fish species examined in the present paper has LWR information been published before for the N. Ionian Sea, and for six of them (i.e. for *E. costae, L. viridis, O. melanura, S. sarda, S. colias, S. porcus*) there is no LWR information for the Ionian Sea as a whole. The LWR for *D. dentex, D. sargus, P. phycis, S. scrofa, S. maena, T. radiatus* have been described in the S. Ionian Sea by Dimitriadis and Fournari-Konstantinidou 2018, and the LWR for *D. dentex*, *D. sargus*, *O. melanura*, *S. porcus*, *S. scrofa* have been reported for the adjacent to S. Ionian Sea Korinthiakos Gulf by Moutopoulos et al. (2013). Moreover, this study contributes in complementing the few LWR datasets that exist in the international literature for *E. costae* and *L. viridis* (Froese and Pauly 2019).

Our b parameter estimates were within one SD of the mean b estimate given in FishBase for all species except for *D. dentex, S. porcus,* and marginally also for *P. phycis*. Compared to our b values, the estimates given for the S. Ionian Sea by Dimitriadis and Fournari-Konstantinidou 2018 were significantly different for *D. dentex* and *P. phycis* (b ± 95%CI: 2.861 ± 0.13 and 3.240 ± 0.065, respectively). Moreover, our b values were significantly different from those given by Moutopoulos et al. (2013) for *D. dentex* and *S. porcus* for the Korinthiakos Gulf (b ± SE: 2.987 ± 0.053 and 2.965 ± 0.076, respectively).

Generally, differentiations in the b parameter of the LWR between studies can be attributed to a range of ecological factors such as the geographic area and season that the fish were caught, the nutritional state of the fish (Froese 2006), and disease and parasite loads (Ricker 1975). Moreover, the accuracy of b estimates may become compromised due to sampling bias, e.g. due to small sample sizes, or unrepresentative samples in respect to size distributions. The latter may result as an undesirable effect of the habitat type sampled: For example, younger individuals may be more prevalent at shallower depths than in deeper waters. Sample representativeness in terms of size distribution may also be affected by the sampling method: Indeed, due to the selective type of the fishing gear used in the present study, small-sized individuals were not caught for all species sampled. The use of the LWR presented here should thus be limited to the length ranges presented in Table 1. We consider other comparatively less important limitations of the present study to be the sampling period not extending over a full year cycle (it excluded winter), and the non-differentiation between sexes. Still, we believe that the results of this study contribute in filling an important knowledge gap and offer local LWR information to fisheries management and marine conservation in the Ionian Sea.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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