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Length–weight relationships of 9 commercial fish species from the North Aegean Sea

Athanasios EVAGELOPOULOS*, Ioannis BATJAKAS and Drosos KOUTSOUBAS

Department of Marine Sciences, University of the Aegean, 81100, Mytilene, Greece

****Corresponding author, e-mail: tevagelo@marine.aegean.gr***

Length-weight relationships are presented for 9 commercial fish species from Psara Island (North Aegean Sea). The species studied are Boops boops, Dentex maroccanus, Helicolenus dactylopterus, Merluccius merluccius, Mullus surmuletus, Pagrus pagrus, Raja clavata, Scyliorhinus canicula *and* Trachurus picturatus*. To our knowledge, there are no published data on the fish stocks of the study area. Estimates of LWR parameters are provided for* Dentex maroccanus, Trachurus picturatus *and* Helicolenus dactylopterus*, for which reliable LWR datasets are few in the literature, while none has been published for the Greek seas. The samples were collected from the continental shelf and the upper slope, by using non-selective fishing gear (with a research vessel and a commercial bottom trawler), during two seasonal sampling periods: November 2009 and May 2010. The growth pattern of* Boops boops *and* Scyliorhinus canicula *was found to be positive allometric, whereas an isometric growth pattern was determined for the other species in the study. We hope that the LWR obtained here will be used in future fisheries management or conservation research in the study area, for example, to convert lengths to weights, determine fish condition and assess spatial or temporal variability in fish growth.*

Key words: life history, animal growth, fishery management, demersal fisheries, bottom trawling

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). The LWR is related to fish condition and is affected by life-history stage, sex, nutritional state, season and area (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 relationship can be calculated from subsamples and are commonly used in fisheries management or conservation research to convert lengths to weights, determine fish condition and assess spatial or temporal variability in fish growth (FROESE *et al.*, 2011).

The aim of this study is to present novel information for the length-weight relationships and growth patterns for 9 commercial fish species from Psara Island (North Aegean). The species studied are *Boops boops*, *Dentex maroc-*

canus, *Helicolenus dactylopterus*, *Merluccius merluccius*, *Mullus surmuletus*, *Pagrus pagrus*, *Raja clavata*, *Scyliorhinus canicula* and *Trachurus picturatus*.

MATERIAL AND METHODS

Length and weight data for 9 commercial fish species from the southernmost part of the North Aegean Sea (Greece) were used to describe the LWR of the species. The study area extends from the west of Psara and Antipsara Islands to the north of Chios Island (Fig. 1).

The samples were collected with bottom trawling from the continental shelf and the upper slope (depths 30 - 500 m), onboard R/V Philia of HCMR and the Venus II commercial trawler, in November 2009 and May 2010. Trawling methodology was kept similar between vessels and all trawls had the same cod end mesh size of 20 mm and trawling speed of 3 knots. Total Length (TL) to the nearest mm and weight in g of the individuals in the catches were measured onboard. Where large numbers of individuals from a species were caught, the length and weight measurements were carried out in subsamples of the catches (100 specimens following FROESE *et al.*, 2011). The parameters a and b of the LWR were estimated by applying ordinary least squares linear regression. Following the guidelines of FROESE *et al.* (2011), we 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). This was accomplished by calculating Cook's distance D for each observation, 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 = logW, x = logL, β_0 = loga and β_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, 2017; https://www.r-project.org/). The taxonomy and nomenclature are in accordance with FishBase (FROESE & PAULY, 2017; http://www.fishbase.org).

RESULTS AND DISCUSSION

A total of 755 individuals were sampled to provide estimates of LWR (see Table 1). The coefficient of determination for the majority of the regressions was ≥ 0.94 and all slopes were significant ($p < 0.001$). b values ranged from 2.905 to 3.559 and growth was found to be positive allometric for *Boops boops* and *Scyliorhinus canicula* ($p < 0.05$), whereas an isometric growth pattern was determined for the other species.

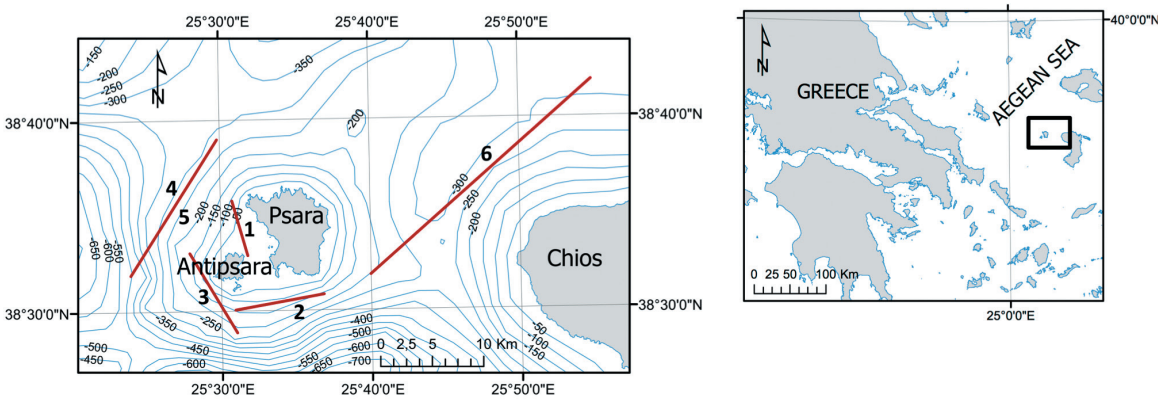

Fig. 1. Map of the study area, indicating with red lines the geographic locations of the hauls

Table 1. Length–weight relationships and growth patterns for 9 commercial fish species from Psara Island (N. Aegean Sea, Greece). 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		
Carangidae	*Trachurus picturatus* (Bowdich, 1825)	75	25.4	42.0	120	560	0.011	2.905	0.153	0.83	I
Merlucciidae	*Merluccius merluccius* (Linnaeus, 1758)	152	17.0	66.4	40	1950	0.006	3.048	0.065	0.94	I
Mullidae	*Mullus surmuletus* (Linnaeus, 1758)	96	13.0	27.5	23	200	0.012	2.945	0.107	0.89	I
Sebastidae	*Helicolenus dactylopterus* (Delaroche, 1809)	92	11.1	25.4	20	254	0.017	2.933	0.078	0.94	I
Sparidae	*Boops boops* (Linnaeus, 1758)	48	15.5	23.3	22	103	0.001	3.559	0.102	0.96	A+
Sparidae	*Dentex maroccanus* (Valenciennes, 1830)	67	11.0	21.1	70	470	0.047	3.017	0.042	0.99	I
Sparidae	*Pagrus pagrus* (Linnaeus, 1758)	23	21.4	48.2	139	1580	0.018	2.927	0.053	0.99	I
Rajidae	*Raja clavata* Linnaeus, 1758	42	32.5	68.5	189	1880	0.004	3.097	0.088	0.97	I
Scyliorhinidae	*Scyliorhinus canicula* (Linnaeus, 1758)	160	16.0	48.0	8	450	0.001	3.382	0.063	0.95	A+

n = sample size. OLS linear regression: a est = estimate of the intercept, b est, SE, p = estimate of the slope, its standard error and the associated p-value, R^2 = coefficient of determination. Growth: A+ = positive allometric, I = isometric

Overall, the estimated b values for the species studied were close to the mean b values given in FishBase, with one exception; the estimated b value for *B. boops* was much higher than the mean value given by FishBase (b = 3.08, SD = 0.1594). Similarly high b values have been reported for *B. boops* from the Aegean Sea by KARAKULAK *et al.* (2006) for the area of Gökceada Island and KARA & BAYHAN (2008) for Izmir Bay (b = 3.258 and 3.419, respectively), as well as by CAMPILLO (1992) for the Gulf of Lions, Western Mediterranean (b = 3.298). Conversely, the b values reported for *B. boops* for the Greek seas Evvoikos Gulf (PETRAKIS & STERGIOU, 1995), the Cyclades archipelago (MOUTOPOULOS & STERGIOU, 2002), and Korinthiakos Gulf (MOUTOPOULOS *et al.*, 2013), were much lower than the estimate here (b = 3.093, 2.877 and 3.098, respectively), as were the b values reported in studies for the Western Mediterranean (e.g. VALLE *et al.*, 2003; b = 2.812) or the Northeastern Atlantic (e.g. TORRES *et al.*, 2012; b = 2.842). Generally, differentiations in the b parameter of the LWR between studies could be attributed to factors such as the area and season that the fish were caught, the life-history stage of the fish, or the nutritional state of the fish (FROESE, 2006), but they could also be due to sample differences in the length ranges of the fish.

To our knowledge, there are no published data on the fish stocks of the study area. In this contribution, estimates for the LWR parameters for 9 commercial species are provided. The species studied included *Dentex maroccanus*, *Trachurus picturatus* and *Helicolenus dactylopterus*, for which reliable LWR estimates are few in the literature, while none has been published for the Greek seas (FROESE & PAULY, 2017). There is a total of only five LWR estimates available for *D. maroccanus* in FishBase: two from the Eastern Atlantic (NGUYEN & WOJCIECHOWSKI, 1972; MENNES, 1985) and three from the Aegean Sea (KARAKULAK *et al.*, 2006; CEYHAN *et al.*, 2009; GUL *et al.*, 2014). LWR estimates for *D. maroccanus* from the Aegean Sea were also presented by ISMEN *et al.* (2007). Moreover, except for the

studies of ISMEN *et al.* (2007) and GUL et al. (2014), the sample sizes in the aforementioned datasets are very small, <10 individuals. Our estimates for the LWR parameters for *D. maroccanus* are similar to those of GUL et al. (2014) for Saros Bay, which is located at the northernmost part of the Aegean Sea. Concerning *T. picturatus,* there are only five datasets available in FishBase: four from the Eastern Atlantic (ISIDRO, 1990; BORGES *et al.*, 2003; MENDES *et al.*, 2004; TORRES *et al.*, 2012) and a single dataset from the Western Mediterranean (MERELLA *et al.*, 1997). To our knowledge, there are no LWR estimates for *T. picturatus* from the Eastern Mediterranean published in the literature. Furthermore, although the maximum length recorded for this species in this study is smaller than the known L_{max} = 60 cm TL (FROESE & PAULY 2017), it is still higher than in any of the aforementioned datasets. Lastly, LWR estimates for *Helicolenus dactylopterus* from the Western Mediterranean have been published by CAMPILLO (1992) and MERELLA (1997) and from the Aegean Sea by FILIZ & BILGE (2004). The present study contributes with a dataset with a wider size range and a higher maximum length.

We consider the main limitations of the present study to be the sampling period not extending over a full year cycle, the sample sizes not being optimal for some of the species studied and the non-differentiation between sexes. Nevertheless, our results provide new information about the LWR of nine fish species of commercial interest from the southernmost part of the North Aegean Sea, while our results for *Dentex maroccanus*, *Trachurus picturatus* and *Helicolenus dactylopterus* are of a broader interest.

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Dužinsko-maseni odnos za 9 komercijalnih vrsta riba iz sjevernog Egejskog mora

Athanasios EVAGELOPOULOS*, Ioannis BATJAKAS i Drosos KOUTSOUBAS

**Kontakt e-adresa: tevagelo@marine.aegean.gr*

SAŽETAK

Prikazani su dužinsko-maseni odnosi za 9 komercijalnih vrsta riba s otoka Psara (sjever Egejskog mora). Istraživane vrste su bukva *(Boops boops),* marokanski zubatac *Dentex maroccanus,* bodečnjak veliki *(Helicolenus dactylopterus),* oslić *(Merluccius merluccius),* trlja kamenjarka *(Mullus surmuletus),* pagar *(Pagrus pagrus),* raža kamenica *(Raja clavata),* mačka bljedica *(Scyliorhinus canicula)* i šarun golemi *(Trachurus picturatus)*. Prema saznanjima, nema objavljenih podataka o ribljem fondu ovog istraživanog područja. Procjena parametara dužinsko-masenog odnosa (LWR) iznesena je za zubaca *Dentex maroccanus*, šaruna golemog *(Trachurus picturatus)* i bodečnjaka velikog *(Helicolenus dactylopterus)*, za koje u literaturi postoje malobrojni pouzdani podaci o dužinsko-masenom odnosu, dok nema nikakvih objavljenih podataka za mora oko Grčke. Uzorci su prikupljani iz epikontinentalnog pojasa i gornjeg nagiba koristeći neselektivne ribolovne alate (istraživačko plovilo i komercijalna pridnena koćarica) tijekom dva sezonska razdoblje uzorkovanja u studenom 2009. i svibnju 2010. godine. Rast bukve i mačke bljedice alometrijski je pozitivan, dok je izometrični uzorak rasta uočen kod drugih istraživanih vrsta. Smatra se da će dužinsko-maseni odnos koji je ovdje uočen biti ubuduće korišten prilikom upravljanja ribarstvom ili prilikom konverzacijskih istraživanja u istraživanom području, primjerice pretvorbom dužine u širinu, određivanja stanja ribe i procjene prostornih i vremenskih varijabilnosti u rastu riba.

Ključne riječi: povijest života, rast životinja, upravljanje u ribarstvu, pridneno ribarstvo, pridneno koćarenje, marokanski zubatac