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Length-weight relationships of six syngnathid species from Ria Formosa, SW Iberian coast

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Abstract: In this study, the length-weight (LWR) parameters were estimated for six syngnathid species, including 2 seahorses and 4 pipefishes, from Ria Formosa, a temperate lagoon from the south coast of Portugal. A total of 5070 fishes were used to determine the LWR. The estimated *b* value ranged from 2.95 (*Nerophis ophidion*) to 3.36 (*Syngnathus abaster*). To the authors' best knowledge, LWR parameters were estimated for the first time for *Nerophis ophidion* and *Syngnathus typhle* for the Atlantic waters. Data here present are essential for management and conservation of these flagship species.

Résumé: *Relations taille-poids de six espèces de syngnathidés de Ria Formosa, SW des côtes Ibériques.* Dans cette étude, les paramètres taille-poids ont été estimés pour six espèces de syngnathidés, y compris 2 hippocampes et 4 trompettes, de Ria Formosa, une lagune de la côte sud du Portugal. Un total de 5070 poissons a été utilisé pour déterminer les relations taille-poids. La valeur *b* estimée variait entre 2,95 (*Nerophis ophidion*) et 3,36 (*Syngnathus abaster*). A la connaissance des auteurs, les paramètres de *LWR* ont été estimés pour la première fois pour *Nerophis ophidion* et *Syngnathus typhle* dans les eaux atlantiques. Les données présentées ici sont essentielles pour la gestion et la conservation de ces espèces phares.

Keywords: Flagship species ● Length-weight relationship ● Syngnathidae ● Temperate lagoon

Introduction

Length-weight relationships (LWR) concerning syngnathids from the southern European Atlantic waters are scarce or inexistent, despite its importance for estimation of the fish condition, predictions of the biomass from length, conversion of growth-in-length equations to growth-in-weight and geographic comparisons of life histories and morphology of different species (Petrakis & Stergiou, 1995; Gonçalves et al., 1997; Froese & Pauly, 2012).

The Ria Formosa lagoon plays a key role as a syngnathid hotspot (Caldwell & Vincent, 2012), therefore is the target of conservation concerns (Curtis et al., 2007; Shokri et al., 2009). It is well established that coastal lagoons are highly productive habitats and appropriate areas for feeding, protection, reproduction and growth of many fish species with high economic and conservational value (Ribeiro et al., 2012). Ria Formosa is a temperate coastal lagoon in southern Europe (Portugal) formed by several channels and separated from the sea by sand barrier

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islands. This coastal lagoon is integrated in the Natural Park of Ria Formosa and classified as Natura 2000 site of interest and included in the Ramsar Convention (Ribeiro et al., 2008).

Six syngnathid species are a common component of the resident ichthyofauna of Ria Formosa (*Hippocampus guttulatus*, *Hippocampus hippocampus*, *Nerophis ophidion, Syngnathus abaster, Syngnathus acus and Syngnathus typhle*). This coastal lagoon harbour one of the most abundant and dense syngnathid populations (Curtis & Vincent, 2005), but it is also an important nursery and growth area (Ribeiro et al., 2006, 2008 & 2012). In addition, some species have high conservation value at both national and international level (e.g., *Hippocampus guttulatus*, *Hippocampus hippocampus*, *Syngnathus abaster*) (ICN, 1993; CITES, 2012; IUCN, 2012; OSPAR, 2012).

Material and Methods

Sampling was carried out monthly from October 2000 to April 2002, with a beach seine for the margins, and beam trawl for the main channels (both with 9 mm mesh size) from a small vessel (6 m), as well as a pushnet (for the small channels) (1 mm mesh size) in 41, 12 and 6 stations, respectively, in the Ria Formosa lagoon (Fig. 1). Syngnathid species were released after total or height length and wet weight data were recorded to the nearest 0.1 cm and 0.01 g from the specimens collected (Table 1). The estimation of LWR parameters ($W = a \times TL^b$; $W = a \times HL^b$) were made after the logarithmic transformation of the data ($\log W = \log a + b \times \log TL$; $\log W = \log a + b \times \log HL$), where W is wet weight and TL is total length (for pipefishes), HL is height length (for seahorses), *a* is the intercept and *b* is the regression coefficient. The degree of association between the weight and length is given by the coefficient of determination, R^2.

Results

A total of 5070 fishes were used to determine the length-weight relationships of six syngnathid species. Estimated parameters and the coefficient of determination (R^2) are given in Table 1. Samples were mainly represented by *Hippocampus guttulatus* Cuvier, 1829 (n = 2042) and *Syngnathus typhle* Linnaeus, 1758 (n = 1233). The fish total length size ranged from 3.6 cm for *Syngnathus acus* Linnaeus, 1758 to 41.4 cm also for *S. acus*. The wet weight ranged from 0.02 g for *Syngnathus abaster* Risso, 1827 and *S. acus* to 54.57 g for *S. acus*. Linear regressions fitted to estimate the LWR were highly significant ($P < 0.05$) for all species (Table 1). The R^2 values ranged from 0.950 for *H. guttulatus* to 0.980 in *S. acus*. The median value of *b* was 3.23 with a minimum *b* of 2.95 for *Hippocampus hippocampus* (Linnaeus, 1758) and a maximum *b* of 3.36 for *Syngnathus abaster*. In terms of growth, *Nerophis ophidion* (Linnaeus, 1758), *Syngnathus abaster, Syngnathus acus* and *Syngnathus typhle* were positively allometric ($b > 3$), *Hippocampus guttulatus* showed isometry ($b = 3$), and *H. hippocampus* expressed negative allometry ($b < 3$).

Table 1. Length-weight relationships (LWR) of six syngnathid species from Ria Formosa. HL = height length; TL = total length; Min-Max = minimum and maximum length (cm) and wet weight (g) recorded; SD = standard deviation; N = sample size; *a* and *b* = parameters of the length-weight relationship; CI = 95% confidence interval; r^2 = coefficient of determination. Growth type: Isometric, positive allometry (+), negative allometry (-).

Species	HL (cm)			Weight (g)			Parameters of the LWR						Growth type
	Min-Max	Mean ± SD	Median	Min-Max	Mean ± SD	Median	N	*a*	CI(*a*)	*b*	CI(*b*)	R^2	
Hippocampus guttulatus	7.1-16.6	11.7 ± 1.63	11.7	0.90-15.82	5.42 ± 2.410	5.00	2042	0.00257	0.00238-0.00277	3.09	3.06-3.12	0.950	Isometric
Hippocampus hippocampus	5.0-13.4	8.3 ± 1.32	8.2	0.50-8.20	2.46 ± 1.240	2.22	418	0.00444	0.00391-0.00503	2.95	2.89-3.01	0.958	Allometric -
	TL (cm)			Weight (g)			Parameters of the LWR						Growth type
	Min-Max	Mean ± SD	Median	Min-Max	Mean ± SD	Median	N	*a*	CI(*a*)	*b*	CI(*b*)	R^2	
Nerophis ophidion	10.3-19.3	14.3 ± 2.09	14.1	0.11-0.66	0.32 ± 0.139	0.30	269	0.00007	0.00005-0.00009	3.11	3.03-3.19	0.951	Allometric +
Syngnathus abaster	3.7-11.0	7.7 ± 1.15	7.7	0.02-1.00	0.27 ± 0.143	0.22	579	0.00025	0.00022-0.00028	3.36	3.31-3.43	0.956	Allometric +
Syngnathus acus	3.6-41.4	21.3 ± 6.68	20.6	0.02-54.57	7.63 ± 7.744	4.72	529	0.00020	0.00017-0.00022	3.34	3.30-3.38	0.980	Allometric +
Syngnathus typhle	4.9-32.3	15.7 ± 5.17	15.0	0.03-16.95	1.95 ± 2.128	1.03	1233	0.00013	0.00012-0.00014	3.35	3.32-3.37	0.977	Allometric +

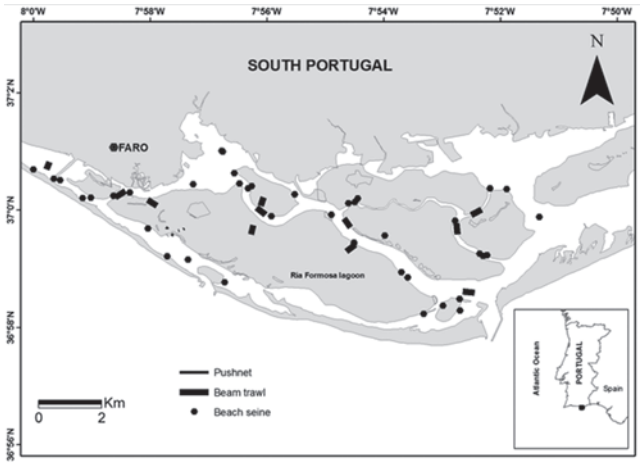

Figure 1. Map of Ria Formosa lagoon showing sampling locations and gear types (seine net, pushnet and beam trawl).

Discussion

Species of the family Syngnathidae are common species of shallow waters, and hence LWR were previously obtained for some of these species in the SW Iberian (Veiga et al., 2009) and Mediterranean coasts (e.g. Verdiell-Cubedo et al., 2006; Gurkan & Taşkavak, 2007) (Table 2). Differences observed for parameters could be due to spatial variation (Sparre et al., 1989). The Mediterranean Sea shows an oligotrophic nature (Crise et al., 1999; Manca et al., 2004), while the Ria Formosa lagoon is a highly productive system (Gamito & Erzini, 2005). Consequently, biotic and abiotic features, that control feeding, reproduction and growth rates, may play an important role in differences found in the length-weight parameters between these regions. Besides that, the estimations here present were applied to a larger number of specimens, which might also have contributed for differences in the LWR parameters in different studies. These results represent a year of sampling and the seasonal variability in fish assemblages and presence or abundance of juvenile migrants in Ria Formosa were taken into account (Froese, 2006). The parameter *b* does not vary significantly during the year, while the parameter *a* could fluctuate seasonally, daily and between habitats (Gonçalves et al., 1997). These relationships are a result of sampling with specific fishing gears; therefore the application of these allometric parameters must be limited to the observed length ranges (Petrakis & Stergiou, 1995; see also Froese et al., 2011).

The data obtained in the present study could be a useful tool in ongoing management and conservation studies (Foster & Vincent, 2004; Vincent et al., 2011 & 2013), and potentially as a reference for comparison of similar parameters estimated in other coastal lagoons. Measuring merely the length would be adequate to estimate biomasses of these syngnathid without impact such vulnerable species in a MPA.

Sampling in different areas, from the margins to channels along the lagoon (see Fig. 1), as well as with different fishing gears allowed to comprise different types of habitats that characterize such complex system as the Ria Formosa coastal lagoon (Curtis & Vincent, 2005; Ribeiro et al., 2012). To the authors' best knowledge, this is the first report of LWRs for *Nerophis ophidion* and *Syngnathus typhle* for the Atlantic Ocean.

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Table 2. Length-weight relationships of syngnathids collected from the SW Iberian and Mediterranean Sea. N = sample size; *a* and *b* = parameters of the length-weight relationship; R^2 = coefficient of determination.

Study	Location	Species	N	a	b	R^2
Verdiell-Cubedo et al. (2006)	Mar Menor coastal lagoon	*Hippocampus guttulatus*	31	0.00248	2.91	0.916
	Mar Menor coastal lagoon	*Syngnathus abaster*	1260	0.00068	2.92	0.970
Gurkan & Taşkavak (2007)	Aegean Sea, Turkey	*Hippocampus guttulatus*	200	0.010	2.47	0.64
	Aegean Sea, Turkey	*Hippocampus hippocampus*	29	0.001	3.14	0.76
	Aegean Sea, Turkey	*Nerophis ophidion*	86	3.00E-06	2.42	0.74
	Aegean Sea, Turkey	*Syngnathus acus*	570	6.00E-08	3.54	0.95
	Aegean Sea, Turkey	*Syngnathus typhle*	125	3.00E-07	3.00	0.96
Veiga et al. (2009)	Arade estuary, Southern Portugal	*Hippocampus guttulatus*	84	0.00724	2.71	0.99
	Arade estuary, Southern Portugal	*Hippocampus hippocampus*	9	0.00640	2.73	0.96
	Arade estuary, Southern Portugal	*Syngnathus abaster*	57	0.00015	3.53	0.96
	Arade estuary, Southern Portugal	*Syngnathus acus*	66	0.00020	3.33	0.99

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