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Technical contribution

First length–weight relationships of 11 fish species in the Aegean Sea

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Summary

Weight-length relationships were established for eleven marine fish species caught in the SE Aegean Sea, Turkey. Additionally, a bibliographic review of such relationships for these species was conducted. Based on the results, the values of *b* parameter varied between 2.477 and 3.496, with one species having isometric growth, five negative and six positive allometric growth. Furthermore, for *Aulopus filamentosus* there exist no information in the literature, whilst for *Callanthias ruber* and *Gnathophis mystax,* there are no such information available from the Mediterranean.

Introduction

Weight–length relationships (WLR) are widely used in fisheries science for (i) the estimation of the weight for a given length for individual fish, (ii) the estimation of biomass when the length–frequency distribution is known, and (iii) the estimation of condition indices (Anderson and Gutreuter, 1983; Petrakis and Stergiou, 1995; Froese, 2006; Tarkan et al., 2006; Froese et al., 2011). Additionally, such relationships are of high importance for comparing life histories of fishes between different areas of a species distribution (Moutopoulos and Stergiou, 2002; Froese and Pauly, 2014) and hence for fisheries management (Froese et al., 2011).

In present study, we report WLR for 11 fish species from the SE Aegean Sea, Turkey. For *Aulopus filamentosus*, there is no WLR available in the relevant literature. Additionally, with the exception of *Trisopterus capelanus,* for all the remaining species, there is no WLR reported in FishBase (www.fishbase.org; Froese and Pauly, 2014), and for two species, namely *Callanthias ruber* and *Gnathophis mystax,* there is no such information available from the Mediterranean in the relevant literature.

Materials and methods

During October and December 2011, experimental trawl surveys were carried out in the area of South Aegean Sea (Fig. 1). Samplings were performed using the traditional Ottoman bottom trawl (cod end 40-mm-stretched mesh size), by R/V Akyarlar (22.6 m LOA, 485 HP). Sampling depth varied from 30 to 225 m. A towing duration was 45 min for all hauls, and the average towing speed ranged between 2.4 and 2.8 knots (mean 2.5 knots). Fish species were identified based on Whitehead et al. (1986) and validated with FishBase (Froese and Pauly, 2014). Collecting individuals were measured to 0.1 cm total length (TL) and weighed (*W*) to the 0.01 g in the laboratory. All WLRs were estimated using the allometric model, that is $W = a\mathrm{TL}^b$, where *a* is the coefficient of shape and *b* is the power fulfilling the dimensional balance (Lleonart et al., 2000). In cases where *b*-values equal 3, then the growth of fish is isometric, whereas when *b* is smaller or larger than 3, the growth is considered as negative or positive allometric (Lleonart et al., 2000; Froese, 2006).

Following, available WLR for the eleven species were gathered from the relevant literature, using online search engines (i.e. Google Scholar, Web of Science and Scopus). Literature retrieved was tabulated and the following information was extracted: (i) study area; (ii) number of individuals; (iii) length range of the sample; (iv) *a* and *b* parameters of the WLR; and (e) standard error of *b* (SE_b) and coefficient of determination (r^2).

Fig. 1. Map of South Aegean Sea indicating sampling areas (in circles)

Table 1
Weight–length relationships for 11 fish species from the SE Aegean Sea, Turkey, and from other areas of their distribution

Area	LR	N	Sex	*a*	*b*	SE_b	r^2	Reference
Aulopus filamentosus								
SE Aegean Sea, Turkey	23.7–32.8	11	C	0.0065	3.099	0.125	0.99	Present study
Apogon queketti								
Iskenderun Bay, Turkey	7.1–12.3	48	C	0.0157	3.059	0.100	0.95	Erguden et al. (2009)
SE Aegean Sea, Turkey	10.7–11.4	11	C	0.0869	3.061	0.018	0.92	Present study
Callanthias ruber								
North Atlantic		31		0.0517	2.250			Hirch (2009)
SE Aegean Sea, Turkey	5.7–13.5	44	C	0.0243	2.477	0.085	0.99	Present study
Champsodon nudivittis								
Ekincik Bay, Turkey	4.7–13.3	99	C	0.003	3.280		0.95	Filiz et al. (2014)
SE Aegean Sea, Turkey	6.2–12.7	111	C	0.0049	3.146	0.029	0.97	Present study
Gnathophis mystax								
Gulf of Cadiz, Spain	17.5–39.2	115	C	0.001	3.058		0.95	Torres et al. (2012)
SE Aegean Sea, Turkey	17.3–39.7	466	C	0.0015	2.919	0.044	0.97	Present study
Hymenocephalus italicus								
Balearic Islands and Iberian Coast	2.2–5.1	69	C	0.1277	2.796	0.120	0.97	Morey et al. (2003)
Sigacik Bay, Turkey	6.7–16.8	98	C	0.0069	2.510		0.88	Filiz and Taskavak (2008)
Antalya Bay, Turkey	8.2–15.5	76	C	0.0077	2.450		0.77	Deval et al. (2013)
SE Aegean Sea, Turkey	7.4–14.9	91	C	0.0034	2.891	0.158	0.86	Present study
Lagocephalus suezensis								
Iskenderun Bay, Turkey	10.2–16.7	86	C	0.0236	2.749	0.063	0.96	Erguden et al. (2009)
Israel	6.0–19.5	128	C	0.012	2.990	0.004	0.97	Edelist (2012)
Iskenderun Bay, Turkey	6.5–17.1	979	C	0.0198	2.795	0.001	0.86	Başusta et al. (2013)
Iskenderun Bay, Turkey	7.1–17.1	485	F	0.0145	2.914	0.002	0.88	Başusta et al. (2013)
Iskenderun Bay, Turkey	6.5–16.7	494	M	0.027	2.676	0.003	0.83	Başusta et al. (2013)
SE Aegean Sea, Turkey	11.5–14.1	15	C	0.0189	2.751	0.028	0.94	Present study
Lesueurigobius suerii								
Thracian Sea, Greece	3.9–7.5	23	C	0.0155	2.561	0.201	0.89	Lamprakis et al. (2003)
N. Aegean Sea, Greece	5.8–9.4	141	C	0.0086	2.928	0.099	0.86	Karachle and Stergiou (2008)
SE Aegean Sea, Turkey	3.9–4.4	13	C	0.0096	2.933	0.091	0.91	Present study
Rostroraja alba								
Saros Bay, Turkey	9.5–93.0	43	C	0.00662	3.201	0.038	0.99	Ismen et al. (2007)
Izmir Bay, Turkey	25.2–53.4	11	C	0.009	3.478	0.142	0.99	Özaydin et al. (2007)
Izmir Bay, Turkey	16.1–35.2	5	C	0.0083	3.130		0.99	İlkyaz et al. (2008)
SE Aegean Sea, Turkey	26.1–52.0	12	C	0.0021	3.214	0.133	0.99	Present study
Symphurus nigrescens								
Thracian Sea, Greece	4.7–13.0	406	C	0.0029	3.452	0.049	0.92	Lamprakis et al. (2003)
Balearic Islands and Iberian Coast	6.0–12.0	34	C	0.0091	2.833	0.243	0.72	Morey et al. (2003)
Izmir Bay, Turkey	7.3–12.2	182	C	0.0088	2.980		0.96	İlkyaz et al. (2008)
Izmir Bay, Turkey	7.7–12.2	130	F	0.0101	2.920		0.94	İlkyaz et al. (2008)
Izmir Bay, Turkey	7.3–11.8	52	M	0.0083	3.000		0.95	İlkyaz et al. (2008)
N. Aegean Sea, Greece	6.4–11.9	10	C	0.0024	3.416	0.123	0.99	Karachle and Stergiou (2008)
Gulf of Cadiz, Spain	6.2–24.9	123	C	0.0077	2.983		0.97	Torres et al. (2012)
SE Aegean Sea, Turkey	7.8–10.6	10	C	0.0027	3.496	0.071	0.96	Present study
Trisopterus capelanus								
G. Evvoikos and Pagassitikos, Greece	5.0–27.0	2314	C	0.00376	3.274		0.96	Papaconstantinou et al. (1989)[a]
G. Evvoikos and Pagassitikos, Greece	6.0–27.0	2205	C	0.005916	3.170		0.96	Papaconstantinou et al. (1989)[a]
G. Evvoikos, Greece	5.0–31.0	4519	C	0.00586	3.217		0.96	Politou and Papaconstantinou (1991)[a]
Southern Tuscan Archipelago		101	M	0.0049	3.250	0.1	0.90	Biagi et al. (1992)
Southern Tuscan Archipelago		414	F	0.0065	3.160	0.028	0.96	Biagi et al. (1992)
Southern Tuscan Archipelago		954	M	0.0064	3.150	0.022	0.94	Biagi et al. (1992)
Southern Tuscan Archipelago		1492	F	0.0045	3.290	0.015	0.96	Biagi et al. (1992)
Southern Tuscan Archipelago		439	M	0.0076	3.100	0.024	0.96	Biagi et al. (1992)
Southern Tuscan Archipelago		712	F	0.0076	3.110	0.013	0.98	Biagi et al. (1992)
Southern Tuscan Archipelago		740	M	0.0083	3.050	0.025	0.94	Biagi et al. (1992)
Southern Tuscan Archipelago		764	F	0.0053	3.240	0.024	0.96	Biagi et al. (1992)
Italy			F	0.0051	3.365			Campillo (1992)[b]
Italy			M	0.006	3.186			Campillo (1992)[b]
C. Aegean Sea, Greece	4.4–21.9	882	C	0.0056	3.230		0.93	Papaconstantinou et al. (1993)[a]
C. Aegean Sea, Greece		306	M	0.005721	3.226		0.94	Papaconstantinou et al. (1993)[a]
C. Aegean Sea, Greece		291	F	0.004215	3.346		0.96	Papaconstantinou et al. (1993)[a]
C. Aegean Sea, Greece		106	M	0.006765	3.149		0.90	Papaconstantinou et al. (1993)[a]
C. Aegean Sea, Greece		157	F	0.007611	3.118		0.91	Papaconstantinou et al. (1993)[a]
C. Aegean Sea, Greece	5.4–19.4	614	C	0.005051	3.272		0.90	Papaconstantinou et al. (1993)[a]
N. Aegean Sea, Greece	6.0–29.0	2522	C	0.00715	3.147		0.94	Papaconstantinou et al. (1994)[a]
N. Aegean Sea, Greece		888	F	0.006365	3.191		0.97	Papaconstantinou et al. (1994)[a]
N. Aegean Sea, Greece		772	M	0.007244	3.144		0.93	Papaconstantinou et al. (1994)[a]

Table 1
(Continued)

Area	LR	N	Sex	*a*	*b*	SE_b	r^2	Reference
Eastern Adriatic, Croatia	11.2–24.3	109	C	0.01095	3.220	0.06	0.96	Dulčić and Kraljevic (1996)
Balearic Islands, Spain	8.4–15.6	61	C	0.0075	3.060		0.99	Merella et al. (1997)
Balearic Islands and Iberian Coast	8.7–20.6	56	C	0.0042	3.343	0.15	0.94	Morey et al. (2003)
Izmir Bay, Turkey		141	F	0.0047	3.323	0.0673	0.97	Metin et al. (2006)
Izmir Bay, Turkey		125	F	0.0052	3.265	0.0775	0.98	Metin et al. (2006)
Izmir Bay, Turkey		208	F	0.0064	3.185	0.0735	0.95	Metin et al. (2006)
Izmir Bay, Turkey		626	F	0.007	3.156	0.0838	0.97	Metin et al. (2006)
Izmir Bay, Turkey		152	F	0.0092	3.049	0.0806	0.98	Metin et al. (2006)
Izmir Bay, Turkey		143	M	0.0085	3.081	0.0876	0.94	Metin et al. (2006)
Izmir Bay, Turkey		168	M	0.0089	3.049	0.0669	0.94	Metin et al. (2006)
Izmir Bay, Turkey		809	M	0.0094	3.038	0.0699	0.94	Metin et al. (2006)
Izmir Bay, Turkey		275	M	0.0102	3.006	0.0592	0.94	Metin et al. (2006)
Izmir Bay, Turkey		223	M	0.0103	3.006	0.0681	0.94	Metin et al. (2006)
Izmir Bay, Turkey	10.6–24.8	1527	C	0.0072	3.140	0.0792	0.97	Metin et al. (2006)
Saros Bay, Turkey	10.2–20.6	229	C	0.00563	3.203	0.05	0.95	Ismen et al. (2007)
Izmir Bay, Turkey	8.4–22.6	780	C	0.0071	3.166	0.017	0.98	Özaydin et al. (2007)
Izmir Bay, Turkey	6.8–20.5	980	C	0.0065	3.180		0.98	İlkyaz et al. (2008)
Izmir Bay, Turkey	6.8–20.5	554	F	0.0067	3.170		0.98	İlkyaz et al. (2008)
Izmir Bay, Turkey	9.8–18.8	426	M	0.0074	3.120		0.97	İlkyaz et al. (2008)
N. Aegean Sea, Greece	5.7–24.5	174	C	0.0056	3.246	0.024	0.99	Karachle and Stergiou (2008)
North Sicily	4.5–22.5	299	C	0.0076	3.128	0.025	0.98	Giacalone et al. (2010)
E. Adriatic Sea, Croatia	12.4–17.1	40	M	0.0087	3.021	0.169	0.91	Šantić et al. (2010)
E. Adriatic Sea, Croatia	12.3–25.5	66	F	0.0082	3.100	0.059	0.97	Šantić et al. (2010)
E. Adriatic Sea, Croatia	12.3–25.5	106	C	0.008	3.076	0.119	0.97	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.3–15.0	46	M	0.0062	3.181	0.163	0.93	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.8–19.5	67	F	0.005	3.381	0.085	0.95	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.3–19.5	113	C	0.0041	3.322	0.123	0.95	Šantić et al. (2010)
E. Adriatic Sea, Croatia	12.6–16.0	40	M	0.0016	3.179	0.267	0.84	Šantić et al. (2010)
E. Adriatic Sea, Croatia	12.0–18.6	70	F	0.003	3.370	0.153	0.84	Šantić et al. (2010)
E. Adriatic Sea, Croatia	12.0–18.6	110	C	0.002	3.276	0.102	0.86	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.7–20.1	41	M	0.0134	3.030	0.145	0.92	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.3–18.1	71	F	0.008	3.219	0.089	0.95	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.3–20.1	112	C	0.0064	3.133	0.092	0.95	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.3–15.0	35	M	0.0067	2.899	0.072	0.99	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.7–19.3	65	F	0.0201	3.104	0.086	0.94	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.3–19.3	100	C	0.0099	3.07	0.076	0.96	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.7–20.4	38	M	0.0109	2.892	0.291	0.85	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.8–21.3	63	F	0.0131	2.957	0.109	0.91	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.7–21.3	101	C	0.0513	2.921	0.111	0.90	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.5–20.3	37	M	0.0087	2.724	0.21	0.95	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.7–22.6	62	F	0.0213	2.788	0.087	0.93	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.5–22.6	99	C	0.0177	2.788	0.096	0.93	Šantić et al. (2010)
E. Adriatic Sea, Croatia	8.9–21.5	40	M	0.0117	2.740	0.14	0.96	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.4–19.5	63	F	0.0266	2.802	0.921	0.93	Šantić et al. (2010)
E. Adriatic Sea, Croatia	8.9–21.5	103	C	0.018	2.772	0.135	0.94	Šantić et al. (2010)
E. Adriatic Sea, Croatia	9.2–17.2	38	M	0.007	2.907	0.126	0.95	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.2–22.5	70	F	0.0101	2.984	0.079	0.95	Šantić et al. (2010)
E. Adriatic Sea, Croatia	9.2–22.6	108	C	0.008	2.932	0.115	0.95	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.0–16.2	35	M	0.0163	2.930	0.216	0.91	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.1–19.2	65	F	0.0096	2.976	0.095	0.93	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.0–19.2	100	C	0.0082	2.941	0.129	0.92	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.4–15.2	36	M	0.0181	2.994	0.236	0.88	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.7–20.8	68	F	0.0173	3.030	0.095	0.92	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.4–20.8	104	C	0.0146	2.975	0.102	0.91	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.2–14.9	37	M	0.0199	2.963	0.149	0.89	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.4–18.1	70	F	0.0098	3.005	0.129	0.91	Šantić et al. (2010)
E. Adriatic Sea, Croatia	11.2–18.1	107	C	0.0096	3.011	0.104	0.90	Šantić et al. (2010)
E. Adriatic Sea, Croatia	8.9–21.5	463	M	0.001	2.930	0.14	0.93	Šantić et al. (2010)
E. Adriatic Sea, Croatia	10.3–22.5	800	F	0.0012	3.090	0.112	0.94	Šantić et al. (2010)
E. Adriatic Sea, Croatia	8.9–22.5	1263	C	0.0011	2.981	0.218	0.90	Šantić et al. (2010)
SE Aegean Sea, Turkey	8.5–22.2	695	C	0.0071	3.167	0.0185	0.98	Present study

LR, length range (in cm); N, number of individuals; M, males; F, Females; C, both sexes combined; *a* and *b*, parameters of the weight–length relationship; SE_b, standard error of *b*; r^2, coefficient of determination.
[a]Data from Stergiou and Moutopoulos (2001).
[b]Data from FishBase (Froese and Pauly, 2014).

Results and discussion

Overall, 1479 specimens, belonging to 11 species and 11 families, were collected. All relationships were significant (P > 0.001), with values of r^2 ranging from 0.86 (for *Hymenocephalus italicus*) to 0.99 (for *A. filamentosus*, *C. ruber and Rostroraja alba*). The descriptive statistics and calculated WLR parameters are given in Table 1. Review of the relevant literature revealed that there were no previously established WLR for *A. filamentosus*, whereas for *C. ruber* and *G. mystax*, such relationships have been established only for their Atlantic populations [Hirch (2009) for the former species and Torres et al. (2012) for the latter; Table 1]. With the exception of *T. capelanus,* for the remaining seven species, such information is rather limited. In the case of *T. capelanus*, due to the fact that it was only identified as a valid species recently (Delling et al., 2011) and till then it was in synonymous with *T. minutus*, all available information in FishBase is listed under *T. minutus*. According to Delling et al. (2011), apart from molecular and morphological differences, the two species have different geographical distribution, with *T. capelanus* being present in the Mediterranean and *T. minutus* in the Atlantic. Based on the above, in the present study, all available information on *T. minutus* within the Mediterranean was considered to refer to *T. capelanus*. Under this scope, literature search yielded 82 different estimates of WLR (Table 1), the vast majority of which are from the Adriatic Sea (Dulčić and Kraljevic, 1996; Šantić et al., 2010). The *b*-values of the relationship ranged from 2.724 to 3.381 [mean ± standard deviation (SD) = 3.0943 ± 0.154; median = 3.11]. In 54 cases, WLR were estimated for the two sexes separately (27 cases per sex; Table 1), with females having a statistically significant higher *b*-value than males (♀: mean ± SD = 3.140 ± 0.160; ♂: mean ± SD = 3.035 ± 0.134).

For the eleven species studied here, the values of parameter *b* ranged between 2.477 (*C. ruber*) and 3.496 (*Symphurus nigrescens*) (Table 1). Only one species showed isometric growth (*Apogon queketti*), whilst negative allometric growth was observed in five species (*C. ruber*, *G. mystax*, *H. italicus*, *Lagocephalus suezensis* and *Lesuerigobius suerii*) and positive allometric growth in six species (*A. filamentosus*, *Champsodon nudivittis*, *R. alba*, *S. nigrescens*, *T. capelanus*). In general, there were no differences observed between previously reported *b*-values and those estimated in the present study (Table 1).

In this study, WLR were presented for eleven species from SE Aegean Sea, as well as an overview of such relationships in the relevant literature. The estimation of WLR parameters may be influenced by a series of factors, such as seasonality, habitat, sex and maturity of a species (e.g. Petrakis and Stergiou, 1995; Dulčić and Kraljevic, 1996; Gonçalves et al., 1997; Karachle and Stergiou, 2008). Yet, the fact that samplings were conducted only in one season, as well as the low number of individuals in the majority of species studied here, did not allow separate estimations of WLR by season or sex. Nevertheless, given the lack of such information for the species presented here, WLR estimated are of high importance for fisheries research in the area. However, further use of WLR should be limited to the size ranges used for the estimation of the parameters (Petrakis and Stergiou, 1995; Dulčić and Kraljevic, 1996).

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