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Length-weight relationships for 48 fish species of the Gediz estuary, in İzmir Bay (Central Aegean Sea, Turkey)

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Length-weight relationships were calculated for 48 fish species from İzmir Bay in the Aegean Sea, Turkey. A total of 3584 fish specimens were captured with beach seine, handline, fyke net, scoop net, castnet and trammel net in 2010–2014. The sample size ranged from three individuals for Squatina squatina *to 140 for* Mugil cephalus. R^2 *values varied between 0.95 for* Pomatoschistus bathi *and 0.99 for* Argyrosomus regius, Chelon labrosus *and* Mugil cephalus. *All regressions were highly significant* ($P < 0.001$). *Values of the exponent b in the length-weight regression* ($W = aL^b$) *ranged from 2.750 for* S. squatina *to 3.514 for* Syngnathus acus *and the median value was 3.134 with 25–75% of the values ranging between 3.030 and 3.218.*

Keywords: Length-weight relationship, Gediz estuary, İzmir Bay, Aegean Sea

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INTRODUCTION

There are three important rivers in İzmir province, these being the Bakırçay, Güzelhisar and Gediz, which flow from north to south into Çandarlı, Aliağa and İzmir Bays, respectively. İzmir Bay is the largest of these in the centre of the Aegean Sea in Turkey (38°32′09″N 26°45′18″E) (Figure 1). Pazı *et al.* (2010) determined the whole area of the bay to be 960 km² with a total shoreline of 464 km in length. Considered one of the most important fishery grounds of the Aegean region of Turkey (Uçkun *et al.* 2000), İzmir Bay provides a significant proportion of the overall marine fish production in Turkey. The bay is also known as an important spawning and nursery ground for several fish species due to the lagoons serving as sheltered habitats and inflows of nutrients from the Gediz River (Özaydın & Taşkavak 2006).

Estuarine environments are vital habitats for many species of fish, crustaceans and molluscs, serving as spawning grounds, nurseries, feeding grounds and important for early growth and/or physiological preparation for migration. Estuaries are also of great importance in biodiversity. It is important to note that most species found there attract direct and indirect attention in commercial terms (Elie, 1998).

Length-weight relationships are very useful for fisheries research because they: (a) allow growth-in-length equations to be converted to growth-in-weight for use in stock assessment models; (b) help estimate biomass by means of length observations; (c) enable us to obtain an estimate of the condition of the fish; and (d) are useful for interregional comparisons of life histories in certain species (Petrakis & Stergiou, 1995; Dulčić & Kraljević, 1996; Gonçalves *et al.*, 1997; Stergiou & Moutopoulos, 2001). The length-weight relationships are an important component of *FishBase* (Froese & Pauly, 2016). The relationships between length and weight of fish are explained by the equation $W = aL^b$, $b = 3$ with an isometric increase of weight. If b is different from 3, the increase of weight is allometric ($b > 3$; $b < 3$) (Pauly, 1984).

The present study was conducted to measure length-weight relationships of fish caught with various catching gears in the estuary of the Gediz River, which is the longest of the rivers flowing into İzmir Bay. It reports the length-weight relationships for 48 fish species captured from the Gediz estuary in İzmir Bay in the Central Aegean Sea.

MATERIALS AND METHODS

Located between 38°35′57″ N and 26°48′5″ E, the Gediz River originates in the Murat and Şaphane mountains in Kütahya province and flows into İzmir Bay between the Foça and Çamaltı salt marshes. The area of the delta basin is 17,500 km² with a main river arm length of 401 km and mean annual flows of 60.48 m³/s. The river forms a wide delta of 40,000 ha on the east side of İzmir Bay as one of the largest deltas in Turkey, containing abundant nutrients (Bayhan *et al.*, 2008; Süzal *et al.*, 2008; Çağırankaya & Meriç, 2013). There are three lagoons called Küçük, Çalıbaşı (Çilazmak) and Homa, the latter being the only one available for fisheries.

The study was conducted at the river mouth section, where the Gediz River flows into the sea, to sample fish species using various catching gears such as cast nets with pockets, beach seine, handlines, fyke nets, scoop nets and trammel net between 2010 and 2014 and to measure them for length and

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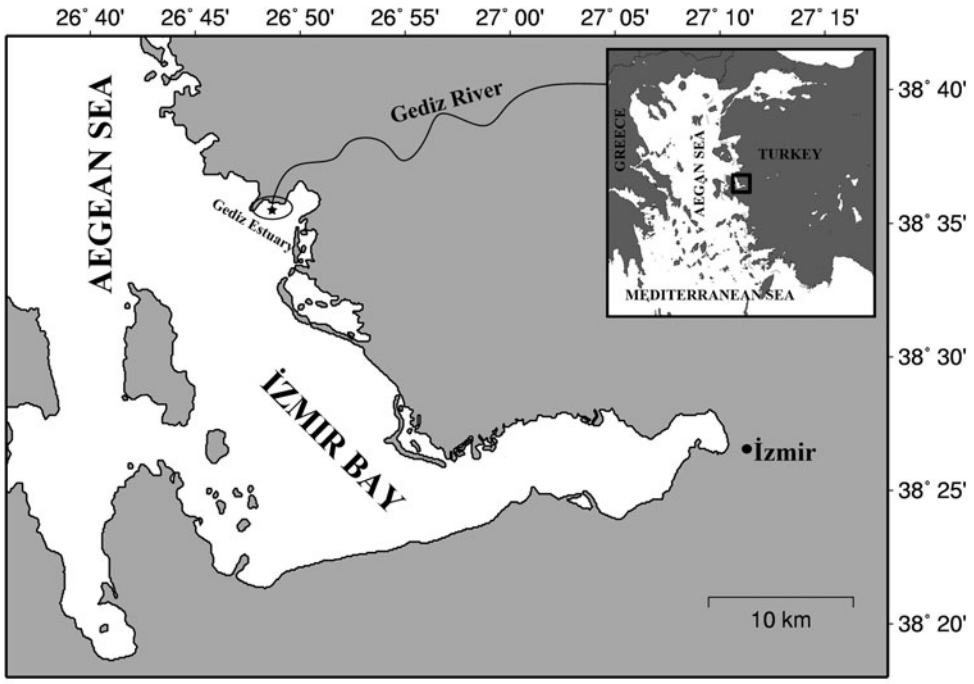

Fig. 1. Sampling area.

weight. Used in the daytime, cast nets (with central line connected with pockets) were thrown manually with a distance of 220 cm between the tap (where the hauling rope is tied) and the skirt section as the final part width of mesh amount of 800. The net is 4 kg in weight with a mesh size of 12 mm and a twin width of 210d/6. The handline used in daytime is composed of a mainline of 0.25 mm, two branchlines of 0.20 mm and 15 cm in length, two hooks of no. 10 size (Mustad SL53UBL), a 25 g lead weight and a small-scale swivel. The handline bait is nereid (*Nereis diversicolor*) in particular. Mesh size is 20 mm in inner net and 100 mm in outer net of trammel net. The length and height of the equipped net were 100 and 1.2 m, respectively. The net was set on the sea bottom of 1–3 m in depth and soaked overnight (about 10 h). The beach seine had a total 20 m wing length with height of 1.20 m. The mesh size of both wing and bag sides was 2 mm in bar length. The bag was 5 m long. Mouth width of the bag was horizontally 1 m. This beach seine used in daytime was set and hauled manually in shallow water of 0–1 m. The net in the bag section of the scoop net is no. 210d/4 with mesh size of 6.5 mm. The hoop of the bag section was made of iron with a diameter of 60 cm with a wooden handle of 2 m in length and 4 cm in diameter. The scoop net was used in daytime.

The values of the mesh sizes for trammel net, scoop net and beach net were given in bar length in the study. Fish captured by each gear in the study area were brought in separate boxes to the lab where measurements were made when fish were still wet. They were measured in the laboratory for total length (TL) to the nearest cm and weighed wet (W) to the nearest g. The length-weight relationships were calculated using the equation $W = aL^b$ (Ricker, 1979). The statistical significance level of R^2 was estimated by a non-linear model ($W = aL^b$) transformed to a linear model ($LogW = loga + b.logTL$). All statistical analyses were evaluated at $P < 0.01$ significance level.

RESULTS AND DISCUSSION

The length–weight relationships of 48 fish species representing 24 families are shown in Table 1, which shows the sample size, the type of catching gears used to catch the fish, length range, length-weight relationship parameters (intercept and slope) for each fish species and related statistical values (95% confidence limits of a and b, and coefficient of determination). The sample size ranged from three individuals for *Squatina squatina* to 140 for *Mugil cephalus*. R^2 values varied between 0.95 for *Pomatoschistus bathi* and 0.99 for *Argyrosomus regius, Chelon labrosus* and *Mugil cephalus*. All regressions were highly significant ($P < 0.01$).

Overall, the values of parameter b varied between 2 and 4 (Tesch, 1971) and mostly remained within the expected range of 2.5–3.5, with extreme values of 2.750 for *S. squatina* and 3.514 for *Syngnathus acus*, which were possibly caused by the small sample size. Median value was 3.134 while 25–75% of the values ranged between 3.030 and 3.218 (Figure 2). Mean value of b was 3.120 ($\pm$ 0.0209), which is not significantly different from 3.0 ($P > 0.01$).

Values of b equal to 3 indicate that the fish grows isometrically; those different from 3 indicates allometric growth. Five species had isometric growth ($b \sim 3$); *Atharina boyeri, Boops boops, Liza saliens, Salaria fluviatilis* and *Sardinella aurita*; four species showed negative allometric growth ($b < 3$): *Argyrosomus regius, Dicentrarchus labrax, Diplodus puntazzo, Engraulis encrasicolus*; all remaining species (39 species) showed positive allometric growth ($b > 3$).

Most of the species were collected over an extended period of time and the data are not representative of a particular season or any time of the year. Accordingly, the estimated parameters should be regarded as mean annual values. Various factors could account for differences in parameters of the length-weight relationships between seasons and years, such as stage of maturity, sex, temperature, salinity,

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Table 1. Fishing gear and estimated parameters of the length-weight relationship for 48 species collected from the Central Aegean Sea of Turkey.

Species	*N*	Length (min-max)	Weight (min-max)	*a*	*b* (95% CI of *b*)	R^2	Fishing gear
Alosa fallax nilotica	41	36.30 ± 0.360 (32.4–40.7)	464.54 ± 15.079 (316.8–660.0)	0.0039	3.251 ± 0.0110 (3.229–3.273)	0.9996	TN
Anguilla anguilla	73	45.05 ± 0.657 (32.8–59.7)	147.89 ± 7.228 (49.0–355.0)	0.0005	3.270 ± 0.0314 (3.207–3.333)	0.9935	FN
Aphanius fasciatus (male)	31	3.50 ± 0.083 (2.60–4.50)	0.66 ± 0.053 (0.23–1.43)	0.0107	3.234 ± 0.0754 (3.083–3.385)	0.9845	BS
Aphanius fasciatus (female)	73	4.33 ± 0.090 (2.70–5.90)	1.34 ± 0.087 (0.25–3.35)	0.0100	3.271 ± 0.0317 (3.208–3.334)	0.9934	
Argyrosomus regius	27	42.46 ± 2.436 (27.0–70.4)	1004.6 ± 172.9 (206–3580)	0.0114	2.976 ± 0.0040 (2.968–2.984)	0.9999	HL, FN
Arnoglossus laterna	83	9.37 ± 0.183 (6.4–12.7)	6.50 ± 0.381 (1.85–15.1)	0.0062	3.066 ± 0.0086 (3.049–3.083)	0.9994	FN
Atherina boyeri	121	5.62 ± 0.171 (3.2–10.1)	1.72 ± 0.160 (0.24–7.29)	0.0073	2.985 ± 0.0075 (2.970–3.000)	0.9993	BS
Atherina hepsetus	83	6.0 ± 0.115 (4.3–9.0)	1.56 ± 0.100 (0.52–4.91)	0.0058	3.069 ± 0.0341 (3.001–3.137)	0.9901	BS
Belone belone	85	20.83 ± 0.366 (15.0–26.4)	10.51 ± 0.533 (3.4–20.2)	0.0007	3.123 ± 0.0062 (3.111–3.135)	0.9997	BS
Boops boops	51	10.85 ± 0.214 (8.5–13.8)	13.13 ± 0.786 (5.9–25.7)	0.0092	3.021 ± 0.0133 (2.994–3.048)	0.9991	HL, BS
Chelon labrosus	113	18.07 ± 0.694 (5.2–34.2)	98.80 ± 10.031 (1.4–458.5)	0.0083	3.090 ± 0.0021 (3.086–3.094)	0.9999	CN, TN
Dicentrarchus labrax	97	21.82 ± 0.556 (11.4–33.6)	149.63 ± 10.765 (19.0–454.8)	0.0134	2.969 ± 0.0045 (2.960–2.978)	0.9998	HL
Diplodus annularis	91	11.39 ± 0.141 (8.0–15.5)	24.39 ± 1.046 (7.7–66.5)	0.0085	3.249 ± 0.0612 (3.127–3.371)	0.9694	P, HL, FN
Diplodus puntazzo	61	9.41 ± 0.311 (4.7–13.5)	16.63 ± 1.430 (1.8–41.3)	0.0177	2.977 ± 0.0086 (2.960–2.994)	0.9995	P
Diplodus sargus	73	8.81 ± 0.223 (5.2–12.4)	12.64 ± 0.929 (2.1–31.9)	0.0122	3.125 ± 0.0049 (3.115–3.135)	0.9998	P
Diplodus vulgaris	87	9.06 ± 0.231 (5.7–13.0)	11.83 ± 0.877 (2.25–31.8)	0.0085	3.202 ± 0.0062 (3.190–3.214)	0.9997	P
Engraulis encrasicolus	47	6.98 ± 0.140 (4.5–9.5)	2.67 ± 0.138 (0.66–5.7)	0.0111	2.775 ± 0.0326 (2.710–2.840)	0.9871	TN, BS
Gambusia affinis	17	2.58 ± 0.077 (2.1–3.2)	0.21 ± 0.020 (0.1–0.4)	0.0101	3.162 ± 0.0662 (3.030–3.294)	0.9935	BS
Gobius cobitis	56	11.91 ± 0.349 (8.4–15.0)	28.49 ± 2.433 (8.9–54.8)	0.0109	3.145 ± 0.0147 (3.116–3.174)	0.9994	FN
Gobius niger	95	6.43 ± 0.167 (3.8–10.2)	3.51 ± 0.288 (0.55–12.1)	0.0082	3.144 ± 0.0094 (3.125–3.163)	0.9992	FN
Gobius paganellus	77	8.09 ± 0.126 (6.1–10.3)	6.92 ± 0.370 (2.46–14.7)	0.005	3.421 ± 0.0163 (3.388–3.454)	0.9983	FN
Lithognathus mormyrus	73	12.61 ± 0.171 (10.0–15.7)	22.04 ± 0.986 (9.9–42.0)	0.0053	3.265 ± 0.0441 (3.177–3.353)	0.9872	P, FN
Liza aurata	81	10.80 ± 0.338 (5.3–16.4)	15.56 ± 1.324 (1.45–44.4)	0.0091	3.035 ± 0.0046 (3.026–3.044)	0.9998	BS, FN, CN
Liza ramada	115	9.39 ± 0.242 (4.6–14.2)	10.13 ± 0.705 (0.95–28.5)	0.0093	3.030 ± 0.0037 (3.023–3.037)	0.9998	BS, FN, CN
Liza saliens	91	14.33 ± 0.433 (6.8–22.4)	34.67 ± 2.690 (3.0–106.6)	0.0098	2.988 ± 0.0064 (2.975–3.001)	0.9996	BS, FN, CN
Mugil cephalus	140	13.87 ± 0.442 (5.5–26.0)	40.22 ± 3.590 (1.6–188.0)	0.0089	3.055 ± 0.0018 (3.051–3.059)	0.9999	BS, CN, TN, P
Mullus barbatus	107	8.18 ± 0.208 (4.5–11.9)	6.25 ± 0.449 (0.75–16.8)	0.0062	3.190 ± 0.0170 (3.156–3.224)	0.9970	BS, FN
Mullus surmuletus	117	6.09 ± 0.100 (4.0–9.2)	2.13 ± 0.124 (0.45–7.5	0.0045	3.344 ± 0.0149 (3.314–3.374)	0.9977	BS, FN
Parablennius sanguinolentus	85	8.43 ± 0.223 (5.8–11.2)	8.68 ± 0.452 (2.79–18.3)	0.0135	2.996 ± 0.0391 (2.918–3.074)	0.9860	FN
Platichthys flesus luscus	103	12.51 ± 0.157 (10.0–15.5)	17.66 ± 0.693 (8.1–33.1)	0.0056	3.165 ± 0.0104 (3.144–3.186)	0.9989	FN
Pomatoschistus bathi	29	2.91 ± 0.056 (2.50–3.60)	0.28 ± 0.019 (0.16–0.55)	0.0075	3.353 ± 0.1334 (3.086–3.620)	0.9590	BS
Pomatoschistus marmoratus	93	3.71 ± 0.103 (2.0–5.5)	0.48 ± 0.038 (0.05–1.39)	0.0056	3.218 ± 0.0216 (3.175–3.261)	0.9959	BS
Pomatoschistus minutus	81	8.08 ± 0.113 (6.3–10.1)	7.92 ± 0.346 (3.52–15.02)	0.0126	3.059 ± 0.0096 (3.040–3.078)	0.9992	BS
Raja clavata	33	32.58 ± 1.146 (22.3–42.7)	186.20 ± 20.187 (47.4–392.0)	0.002	3.251 ± 0.0128 (3.225–3.277)	0.9995	FN
Salaria fluviatilis	17	7.22 ± 0.203 (5.7–8.4)	4.47 ± 0.348 (2.1–6.8)	0.0119	2.982 ± 0.0541 (2.874–3.090)	0.9951	BS
Sardina pilchardus	32	8.07 ± 0.157 (5.8–11.4)	4.62 ± 0.281 (1.5–11.93)	0.0069	3.065 ± 0.0047 (3.056–3.074)	0.9998	BS
Sardinella aurita	67	9.68 ± 0.282 (6.0–14.4)	7.11 ± 0.620 (1.4–20.0)	0.0062	3.033 ± 0.0168 (2.999–3.067)	0.9980	BS, FN
Sarpa salpa	107	9.66 ± 0.167 (6.5–12.7)	9.22 ± 0.474 (2.4–19.8)	0.0066	3.148 ± 0.0092 (3.130–3.166)	0.9991	BS, P
Serranus hepatus	79	9.04 ± 0.231 (5.0–12.4)	13.31 ± 0.937 (1.77–31.0)	0.0105	3.175 ± 0.0102 (3.155–3.195)	0.9992	FN
Solea solea	103	12.03 ± 0.197 (8.5–15.5)	17.62 ± 0.869 (5.0–36.3)	0.005	3.248 ± 0.0115 (3.225–3.271)	0.9987	FN
Sparus aurata	83	15.61 ± 0.127 (13.5–18.2)	54.18 ± 1.408 (32.6–86.9)	0.0096	3.134 ± 0.0892 (2.956–3.312)	0.9385	HL, FN
Spicara maena	75	10.55 ± 0.204 (7.4–13.6)	15.75 ± 0.880 (5.12–32.0)	0.011	3.049 ± 0.0113 (3.026–3.072)	0.9990	HL
Squatina squatina	3	66.47 ± 3.495 (60.0–72.0)	2120.0 ± 298.4 (1580–2610)	0.0203	2.750 ± 0.0177 (2.715–2.785)	0.9999	FN

Continued

Table 1. Continued

Species	*N*	Length (min-max)	Weight (min-max)	*a*	*b* (95% CI of *b*)	R^2	Fishing gear
Syngnathus abaster	21	10.88 ± 0.295 (8.5–12.9)	0.63 ± 0.051 (0.28–1.03)	0.0003	3.135 ± 0.0144 (3.106–3.164)	0.9996	BS
Syngnathus acus	93	12.92 ± 0.399 (5.5–20.7)	1.99 ± 0.196 (0.08–7.38)	0.0002	3.514 ± 0.0150 (3.484–3.544)	0.9983	BS
Syngnatus typhle	45	9.85 ± 0.309 (6.3–13.9)	0.26 ± 0.025 (0.05–0.68)	0.0002	3.135 ± 0.0225 (3.090–3.180)	0.9978	BS
Trachurus mediterraneus	61	11.19 ± 0.246 (8.4–15.6)	12.63 ± 0.849 (5.0–30.6)	0.0105	2.905 ± 0.0085 (2.888–2.922)	0.9995	BS, HL
Uranoscopus scaber	95	16.73 ± 0.500 (8.4–28.0)	96.14 ± 8.444 (8.4–377.8)	0.0101	3.160 ± 0.0047 (3.151–3.169)	0.9998	HL, FN
Zosterisessor ophiocephalus	73	9.82 ± 0.180 (6.7–13.1)	10.20 ± 0.520 (3.0–22.6)	0.0102	2.995 ± 0.0054 (2.984–3.006)	0.9998	FN

BS, Beach seine; CN, Cast net; FN, Fyke-net; HL, Handline; P, Round wire fish pot; TN, Trammel net.

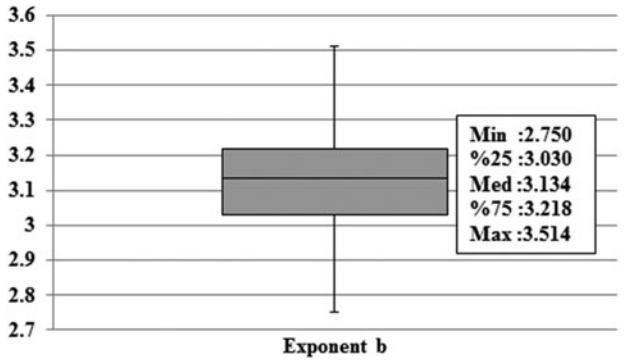

Fig. 2. Box-whiskers plots of exponent *b* of the length-weight relationships ($W = a \times L^b$) for 48 fish species caught in the Gediz Estuary. The central box covers 50% of data values, the vertical line indicates the range of the values, and the horizontal line represents the median.

food quality and quantity and size (Shepherd & Grimes, 1983; Pauly, 1984; Weatherley & Gill, 1987; Dulčić & Kraljević, 1996). According to Tesch (1971), Bagenal & Tesch (1978), Gonçalves *et al.* (1997), Wootton (1998), Taşkavak & Bilecenoğlu (2001), Moutopoulos & Stergiou (2002) Hossain *et al.* (2006a), Karakulak *et al.* (2006), Samsun *et al.* (2007) and Özaydın *et al.* (2007) the parameter *b*, unlike the parameter *a*, may vary seasonally and even daily and between habitats. Therefore, the length-weight relationship of fish is affected by a number of factors including gonad maturity, sex, diet, stomach fullness, health, and preservation techniques as well as season and habitat, none of which was taken into account by the present study.

Bayhan *et al.* (2008) caught 56 fish species of 24 families in total from around lagoons in the Gediz River mouth using beach seine and commercial trawl. In the river mouth, 30 fish species of 17 families were found whereas the present study captured 48 fish species of 24 families. Bayhan *et al.* (2008) reported that beach seine and commercial trawl were used to sample fish species in front of the river mouth and off it in 10–15 m depths, respectively. However, it was not reported which species were caught by beach seine and which fish were captured by trawls there. The present study did not use trawls in the sampling process. On the other hand, the beach seine used was similar to the one in the study by Bayhan *et al.* (2008). However, our study employed trammel net, cast net, fyke net, pots, handline and scoop net as well as beach seine. A possible reason for the difference between the present study and that of Bayhan *et al.* (2008) could be that an excessive number of catching gear types was used. Martin-Smith (1996), Hossain *et al.* (2006a, b) and Cengiz *et al.* (2011) reported that possible reasons for diversity in species in a given area or interregional zone could vary according to environmental conditions and type of catching gear used in the sampling process.

Similar studies have been made involving length-weight relationships of fishes captured in estuary areas. Koutrakis & Tsikliras (2003), Dulčić & Glamuzina (2006) and Veiga *et al.* (2009) measured length-weight of 43 species of 19 families in three estuaries in the northern Aegean sea, 59 species of 32 families in three estuaries along the Croatian Adriatic sea and 54 species of 22 families in the Arade estuary of southern Portugal, respectively. Our study measured LWR of 48 species of 24 families in the estuary of the Gediz River.

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The following fish species were captured in the above-mentioned studies and the Gediz estuary area: *Anguilla anguilla, Belone belone, Chelon labrosus, Dicentrarchus labrax, Diplodus annularis, Engraulis encrasicolus, Liza aurata, Liza ramada, Liza saliens, Mugil cephalus, Mullus surmuletus, Sardina pilchardus, Sarpa salpa, Solea solea, Sprata aurata, Syngnathus acus.* The most abundant families seen in all estuaries (including Gediz) were Gobiidae, Sparidae and Mugilidae. The most abundant species and families in Mediterranean estuaries could be the characteristic feature of estuary regions, in general. Number of fish as individual and species caught in estuaries can change based on various factors, such as types, sizes, number, efficiency and related technical aspects of catching gears, differences in geographic regions, sampling time and daily or seasonal reproduction and feeding migrations.

In addition, new species may be captured other than those listed in Table 1 if the sampling processwere to include additional catching gears as mentioned above for sampling in the area where the study was performed (in the river mouth). For example, liftnets and stow net can be used in the deeper and central sections of the river mouth and during stronger currents, respectively. Moreover, longlines or set lines can be employed to catch bigger individuals in particular. The banks of the Gediz River are occasionally covered with wild weeds where the present catching gears are difficult to use. The present study employed pots and fyke nets. However, more practical and efficient gears could also be developed such as lures to gather and lead fish towards catching gears, optical (light) baits, meats and acoustic baits etc. Morever, fish-frightening processes could be used for the purpose.

The present study determined species composition and length-weight relationships of fishes captured by various catching gears in the estuary of Gediz. The data of species composition established in the study could be a historical record upon which further studies could be based involving this estuary. Additionally, the length-weight parameters hereby reported could be of great use in ongoing studies on catches in commercial fisheries in Turkey.

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REFERENCES

Bagenal T.B. and Tesch F.W. (1978) Age and growth. In T. Bagenal (ed.) *Methods for assessment of fish in fresh waters*, 3rd edition. IBP Handbook No. 3. Oxford: Blackwell Scientific, pp. 101–136.

Bayhan B., Sever T.M. and Kaya M. (2008) Diversity of fish fauna in Gediz Estuary Lagoons (Izmir Bay/Aegean Sea). *Journal of Animal and Veterinary Advances* 7, 1146–1150.

Çağırankaya S.S. and Meriç B.T. (2013) Türkiye'nin Önemli Sulak Alanları: Ramsar Alanlarımız. Orman ve Su İşleri Bakanlığı, Doga Koruma ve Milli Parklar Genel Müdürlüğü, Hassas Alanlar Dairesi Başkanlığı, Ankara, Türkiye, pp. 97–107.

Cengiz Ö., İşmen A., Özekinci U. and Öztekin A. (2011) An investigation on fish fauna of Saros Bay (Northern Aegean Sea). *Afyon Kocatepe Üniversitesi Journal of Science* 11, 31–37.

Dulčić J. and Glamuzina B. (2006) Length–weight relationships for selected fish species from three eastern Adriatic estuarine systems (Croatia). *Journal of Applied Ichthyology* 22, 254–256.

Dulčić J. and Kraljević M. (1996) Weight-length relationships for 40 fish species in the eastern Adriatic (Croatian waters). *Fisheries Research* 28, 243–251.

Elie P. (1998) L'impact d'un barrage d'estuaire sur la migration des poissons amphihalins: solutions de réhabilitation et premiers résultats. In Auger C. and Verrel J.L. (eds) *Les estuaires français, évolution naturelle et artificielle, Actes du séminaire national de travail*, Paris, 26–27 novembre 1997. Plouzané: Ed. Ifremer, pp. 141–156.

Froese R. and Pauly D. (eds) (2016) *FishBase*, version 09/2016. http://www.fishbase.org.

Gonçalves J.M.S., Bentes L., Lino P.G., Riberio J., Canario A.V.M. and Erzini K. (1997) Weight-length relationships for selected fish species of the small-scale demersal fisheries of the south and south-west coast of Portugal. *Fisheries Research* 30, 253–256.

Hossain M.Y., Ahmed Z.F., Leunda P.M., Islam A.K.M.R., Jasmine S., Oscoz J., Miranda R. and Ohtomi J. (2006a) Length-weight and length-length relationships of some small indigenous fish species from the Mathabhanga River, southwestern Bangladesh. *Journal of Applied Ichthyology* 22, 301–303.

Hossain M.Y., Ahmed Z.F., Leunda P.M., Jasmine S., Oscoz J., Miranda R. and Ohtomi J. (2006b) Condition, length-weight and length-length relationships of the Asian striped catfish *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae) in the Mathabhanga River, southwestern Bangladesh. *Journal of Applied Ichthyology* 22, 304–307.

Karakulak F.S., Erk H. and Bilgin B. (2006) Length–weight relationships for 47 coastal fish species from the northern Aegean Sea, Turkey. *Journal of Applied Ichthyology* 22, 274–278.

Koutrakis E.T. and Tsikliras A.C. (2003) Length-weight relationships of fishes from three northern Aegean estuarine systems (Greece). *Journal of Applied Ichthyology* 19, 258–260.

Martin-Smith K.M. (1996) Length/weight relationships of fishes in a diverse tropical fresh-water community, Sabah, Malaysia. *Journal of Fish Biology* 49, 731–734.

Moutopoulos D.K. and Stergiou K.I. (2002) Length–weight and length–length relationships of fish species from the Aegean Sea (Greece). *Journal of Applied Ichthyology* 18, 200–203.

Özaydın O. and Taşkavak E. (2006) Length-weight relationships for 47 fish species from Izmir Bay (eastern Aegean Sea, Turkey). *Acta Adriatica* 47, 211–216.

Özaydin O., Uckun D., Akalın S., Leblebici S. and Tosunoglu Z. (2007) Length-weight relationships of fishes captured from Izmir Bay, Central Aegean Sea. *Journal of Applied Ichthyology* 23, 695–696.

Pauly D. (1984) Fish population dynamics in tropical waters: a manual for use with programmable calculators. *ICLARM Studies and Reviews 8*. Manila, Philippines. 325 pp.

Pazı I., Yucel-Gier G. and Arısoy Y. (2010) The use of marine in the Izmir Bay. *Turkey's marine and coastal area VIII*. National

https://doi.org/10.1017/S0025315416001879 Published online by Cambridge University Press

Congress, Trabzon, April 2010, Turkey Coast, 27–30 April 2010, pp. 317–322.

Petrakis G. and Stergiou K.I. (1995) Weight–length relationships for 33 fish species in Greek waters. *Fisheries Research* 21, 465–469.

Ricker W.E. (1979) Growth rates and models. In Hoar W.S., Randall D.J. and Brett J.R. (eds) *Fish physiology. Vol. VIII, bioenergetics and growth*. London: Academic Press, pp. 677–743.

Samsun N., Kalaycı F. and Samsun O. (2007) Seasonal variation in length, weight, and sex distribution of turbot (*Scophthalmus maeoticus* Pallas, 1811) in the Sinop region (Black Sea) of Turkey. *Turkish Journal of Zoology* 31, 371–378.

Shepherd G. and Grimes C.B. (1983) Geographic and historic variations in growth of weakfish, *Cynoscion regalis*, in the middle Atlantic Bight. *Fishery Bulletin USA* 81, 803–813.

Stergiou K.I. and Moutopoulos D.K. (2001) A review of length-weight relationships of fishes from Greek marine waters. *Naga, the ICLARM Quarterly* 24, 23–39.

Süzal A., Bizsel N., Bizsel K.C. and Hüsrevoğlu Y.S. (2008) Dissolved nutrient behaviour along the estuarine salinity gradient at the Gediz River Mouth (Aegean Sea, Turkey). *Turkish Journal of Engineering and Environmental Sciences* 32, 67–84.

Taşkavak E. and Bilecenoğlu M. (2001) Length-weight relationships for 18 Lessepsian (Red Sea) immigrant fish species from the eastern Mediterranean coast of Turkey. *Journal of the Marine Biological Association of the United Kingdom* 81, 895–896.

Tesch W. (1971) Age and growth. In Ricker W.E. (ed.) *Methods for assessment of fish production in fresh waters*, 2nd edition. Oxford: Blackwell, pp. 97–130.

Uçkun D., Toğulga M. and Taşkavak E. (2000) A preliminary study on the growth of the common hake (*Merluccius merluccius* L., 1758) in Izmir Bay, Aegean Sea. *Acta Adriatica* 41, 25–34.

Veiga P., Machado D., Almeida C., Bentes L., Monteiro P., Oliveira F., Ruano M., Erzini K. and Gonçalves J.M.S. (2009) Weight–length relationships for 54 species of the Arade estuary, southern Portugal. *Journal of Applied Ichthyology* 25, 493–496.

Weatherley A.H. and Gill H.S. (1987) *The biology of fish growth*. London: Academic Press.

and

Wootton R.J. (1998) *Ecology of teleost fishes*, 2nd edition. Dordrecht: Kluwer Academic Publishers.

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