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Length-weight and length-length relations for 21 fish species caught in Izmir Bay

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This study exhibits relationships between length-weight and length-length for 21 fish species caught in Izmir Bay. Coefficients a and b for the length-weight relationships (LWRs) and length-length relationships (LLRs) were calculated with W=aLb formulae and as equations of TL=a+bFL and TL=a+bSL respectively. Equations of length-length for converting standard length and fork length into total length and vice versa were proven linear. The involved relationships were significantly interrelated (R2>0.942). Values b in the LWRs varied from 2.21 to 3.96 (mean ± SE: 3.15 ± 0.08). The student's t-test showed that 87.9% of values b were significantly different from 3.

Key words: Fish species, length-length relationships, length-weight relationships, Izmir Bay

INTRODUCTION

Both LWRs and LLRs are extensively employed in fisheries research and management (WANG *et al.*, 2012; KEIVANY *et al.*, 2015b). LWRs of fishes are widely used to weight a sample via its length and vice versa (BEYER, 1987; BINOHLAN & PAULY, 1998; KEIVANY *et al.*, 2015a). The LWRs study for a species can provide important insights into the biology (SARKAR *et al.*, 2008) and the ecology (FROESE, 2006) of the species. LLRs are beneficial in a standardizing type of length when data has been outlined (FROESE, 1998) and are also functional for similar population areas (MOUTOPOULOS & STERGIOU, 2002).

The aim of this study was to provide basic data on length-weight relationship and length-length relationship for 21 fish species sampled from Izmir Bay. The estimated LWRs and LLRs of the species could present valuable database for future researches to make comparisons between years and locations. .

MATERIAL AND METHODS

Izmir Bay (38°32'09''N and 26°45'18''E) is one of the most significant basin concerning maritime processes and fisheries covering an area of 960 km^2 with a shoreline of 464 km (YUCEL-GIER *et al.,* 2010). It is a hot-spot fishing area with 83.4 % of the bay allotted to fisheries (PAZI *et al.,* 2010).

The bay is the region composed of natural reef areas, seagrass in and around Gediz flowing into the bay and related lagoons suitable for fish to spawn and feed and for some species to reproduce. It has fisheries areas and seagrass beds where fishing is conducted all year round (OZAYDIN & TASKAVAK, 2006).

The samples of the study were collected from local commercial fishermen using gillnets, trammel nets, purse seines, longlines and hand lines and from visits to the local (i.e., Urla, Güzelbahçe and Şemikler) fishing ports between January and December 2015.

Fishes collected or bought from commercial fishing boats and auctions were made in the lab when they were freshly caught. Measurements were occasionally made by using the digital balance and measurement scale that available and ready for usage in the cooperative building at the port. Lengths (TL, SL and FL) of specimens were measured in mm with their weight (W) in g.

A relationship between length and weight of the species was calculated by $W=a\times L^b$ where W is the weight (g) at a given L length (cm), *a* (intercept) and *b* (slope) the regression coefficient (RICKER, 1979). Parameters of the regression coefficient were calculated through linear regression analysis on converted weight and length data and the growth type was identified by Student's t-test. Relationships of TL vs FL and TL vs SL were also computed by linear regression.

RESULTS

Analyses for regressions of LW and LL were performed on 5728 individuals from 21 species in 10 families included in the study. Table 1 presents the number of the sampling (n), minimal and maximal length-weight ranges, LW and LL relations, factors *a* and *b*, determination (R^2).

All relations were significant ($P<0.05$). The determination coefficient R^2 was higher than 0.900, ranging from 0.941 to 0.999. The allometric parameter coefficient *b* ranged from a minimum of 2.21 for *Sphyraena sphyraena* to a maximum of 3.96 for *T. capelanus* with a mean value of 3.15 ± 0.08 (mean ± SE), which was significant difference from 3 (P<0.05, t-test=1.86). Concerning kind of growth, 3, 5 and 13 species exhibited an isometric growth (b=3) negative allometric growth (b<3) and positive allometric growths (b>3), respectively (Table 1).

DISCUSSION

Sampling times are different as the sampled fishes that are collected from commercial fishermen. Fishes have been collected during the months caught by commercial fishermen, that is, during the catching periods of the fish. The sample time is shown in Table 1 by numbering the months. The estimated LWR and LLR values represent the sampling time. It should not be considered as an annual average value.

The exponent values reported for "b" in different fishes ranged from 2.5 to 4.0 (HILE, 1936; MARTIN, 1949). FROSE (2006) declared that *b* prime should normally be between 2.5 and 3.5 and TESCH (1971); BAGENAL, T. & F. W. TESCH (1978); KOUTRAKIS & TSIKLIRAS (2003) stated that it was between 2 and 4. The calculated allometric coefficient *b* varied among the species from a minimum of 2.21 for *S. sphyraena*, to a maximum of 3.96 for *T. capelanus*. These values are within the limits (2 and 4) reported by TESCH (1971) and BAGENAL & TESCH (1978) and KOUTRAKIS & TSIKLIRAS (2003).

Variations of values *b* are based on the anatomic and morphological characteristics as well as on abiotic and biotic factors of their habitation when the sampling has been made (STERGIOU & MOUTOPOULOS, 2001; MOUTOPOULOS & STERGIOU, 2002; FROESE *et al.*, 2011).

The factors above (abiotic and biotic factors) were out of the scope of the present study. Their effects have not been studied. It was only reported which types of different fishing gears were used and in which months the fishes were caught, thus providing the opportunity to make comparisons for further studies in the same study area (in Izmir Bay).

The *b* value of *S. sphyraena* specimens, which were collected from the bay between September and October, was found as 2.21. PETRAKIS & STERGIOU (1995) determined their *b* value as 2.32 in the South Euboikos Gulf – which is almost in the same latitude and climate as Izmir Bay-with similar *b* values at the same period of

Table 1. Length-length and length-weight relationship parameters for 21 fish species from Izmir Bay

Family		Species		*n*	($TL_{min-max}$)	*Equation*	SE_b	R^2	*P*	*GT*	*FG*	*ST*
1	Carangidae	1	*Caranx rhonchus*	180	TL=21.09±0.12 (17.4-27.0)						TN	5
					FL=18.58±0.11 (15.3-23.8)	FL=0.8804TL+0.0087	0.0054	0.998				
					SL=17.70±0.10 (14.5-22.7)	SL=0.8545TL–0.3250	0.0058	0.998				
					W=138.94±2.38 (77.5-285.0)	$W=0.0170TL^{2.95}$	0.0234	0.997	*s*	–A		
		2	*Trachurus trachurus*	389	TL=17.64±0.28 (11.0-30.8)						TN PS CN	10-12
					FL=15.92±0.25 (10.1-27.4)	FL=0.8750TL+0.4870	0.0047	0.997				
					SL=15.09±0.24 (9.4-26.5)	SL=0.8628TL–0.1276	0.0039	0.998				
					W=60.37±3.17 (10.0-237.0)	$W=0.0075TL^{3.03}$	0.0254	0.993	*s*	+A		
2	Centracanthidae	3	*Spicara maena*	209	TL=17.48±0.11 (15.7-21.2)						TN	4-5
					FL=16.06±0.11 (14.2-19.6)	FL=0.9737TL–0.9598	0.0161	0.986				
					SL=14.74±0.10 (13.0-18.0)	SL=0.9124TL–1.2088	0.0178	0.980				
					W=67.19±1.86 (38.0-132.0)	$W=0.0008TL^{3.94}$	0.1357	0.941	*s*	+A		
3	Clupeidae	4	*Sardinella aurita*	208	TL=20.94±0.11 (16.0-25.5)						GN	10-12
					FL=18.48±0.10 (14.2-22.4)	FL=0.8377TL+0.9468	0.0134	0.987				
					SL=17.61±0.09 (13.5-21.5)	SL=0.8254TL+0.3308	0.0163	0.980				
					W=80.13±1.45 (31.0-160.0)	$W=0.0027TL^{3.37}$	0.0762	0.974	*s*	+A		
4	Merlucciidae	5	*Merluccius merluccius*	581	TL=25.57±0.23 (13.7-36.4)						GN TN	10-12
					SL=23.13±0.22 (12.0-33.7)	SL=0.9234TL–0.4819	0.0060	0.994				
					W=147.28±3.80 (13.6-488.3)	$W=0.0030TL^{3.28}$	0.0329	0.985	*s*	+A		
5	Gadidae	6	*Trisopterus capelanus*	78	TL=18.43±0.20 (13.8-21.0)						TN CN	2-3
					SL=16.65±0.19 (12.9-19.5)	SL=0.9232TL–0.3624	0.0340	0.975				
					W=73.21±3.03 (23.1-122.0)	$W=0.0007TL^{3.96}$	0.1204	0.983	*s*	+A		

	Family		Species	*n*	($TL_{min-max}$)	*Equation*	SE_b	R^2	*P*	*GT*	*FG*	*ST*
6	Mugilidae	7	*Chelon ramada*	107	TL=33.41±0.36 (28.3-42.7)						TN	11
					FL=30.24±0.33 (25.8-38.8)	FL=0.9121TL–0.2328	0.0041	0.999				
					SL=28.11±0.31 (23.9-36.1)	SL=0.8554TL–0.4676	0.0054	0.999				
					W=359.78±12.44 (210.0-727.0)	$W=0.0094TL^{3.00}$	0.0213	0.999		I		
		8	*Chelon saliens*	101	TL=24.29±0.25 (20.0-29.0)						TN	6-7
					FL=21.99±0.23 (18.1-26.3)	FL=0.9056TL–0.0021	0.0049	0.999				
					SL=21.05±0.22 (17.3-25.2)	SL=0.8717TL–0.1244	0.0046	0.999				
					W=134.05±4.17 (70.5-225.7)	$W=0.0102TL^{2.96}$	0.0408	0.995		I		
		9	*Mugil cephalus*	219	TL=36.75±0.61 (27.4-68.0)						TN	8-10
					FL=33.56±0.55 (25.0-62.0)	FL=0.8992TL+0.5168	0.0043	0.999				
					SL=30.92±0.52 (23.0-57.6)	SL=0.8446TL–0.1216	0.0051	0.998				
					W=587.80±33.54 (196.0-2912.0)	$W=0.0136TL^{2.91}$	0.0475	0.985	*s*	–A		
7	Mullidae	10	*Mullus barbatus barbatus*	476	TL=13.90±0.14 (5.7-23.2)						GN TN	9-10
					FL=12.28±0.13 (5.0-20.7)	FL=0.8819TL+0.0205	0.0076	0.991				
					SL=11.18±0.12 (4.6-19.0)	SL=0.8221TL–0.2418	0.0057	0.994				
					W=33.79±1.20 (1.6-141.1)	$W=0.0058TL^{3.23}$	0.0287	0.990	*s*	+A		
		11	*Mullus surmuletus*	182	TL=16.54±0.16 (11.8-23.0)						GN TN	10-12
					FL=14.62±0.14 (10.5-20.2)	FL=0.8946TL–0.1819	0.0096	0.995				
					SL=13.56±0.13 (9.6-19.3)	SL=0.8292TL–0.1572	0.0101	0.993				
					W=62.05±2.07 (20.5-161.2)	$W=0.0063TL^{3.26}$	0.0685	0.980	*s*	+A		
8	Scombridae	12	*Sarda sarda*	107	TL=39.71±0.21 (36.0-43.9)						GN	10-11
					FL=36.66±0.19 (33.3-40.5)	FL=0.9214TL+0.0626	0.0042	0.999				
					SL=34.98±0.19 (31.5-38.7)	SL=0.8841TL–0.1320	0.0061	0.999				
					W=699.78±11.44 (510.0-950.0)	$W=0.0071TL^{3.12}$	0.0242	0.998	*s*	+A		

Family		Species		*n*	($TL_{min-max}$)	*Equation*	SE_b	R^2	*P*	*GT*	*FG*	*ST*
9	Sparidae	13	*Diplodus annularis*	549	TL=11.84±0.07 (8.5-19.2)						TN	5
					FL=10.82±0.06 (8.0-17.7)	FL=0.9239TL–0.1232	0.0094	0.985				
					SL=9.61±0.06 (6.8-16.2)	SL=0.8427TL–0.3732	0.0086	0.986				
					W=29.70±0.63 (8.9-122.0)	$W=0.0101TL^{3.21}$	0.0508	0.966	*s*	+A		
		14	*Diplodus sargus*	103	TL=21.49±0.24 (15.9-25.5)						TN LL	5-6
					FL=19.09±0.22 (14.2-23.0)	FL=0.9260TL–0.8092	0.0216	0.986				
					SL=17.00±0.20 (12.5-20.5)	SL=0.8241TL–0.7110	0.0212	0.983				
					W=197.49±6.07 (77.0-320.0)	$W=0.0286TL^{2.87}$	0.0884	0.976	*s*	–A		
		15	*Diplodus vulgaris*	460	TL=14.15±0.13 (9.9-25.8)						TN LL	5-8
					FL=12.29±0.11 (8.3-23.2)	FL=0.8788TL–0.1511	0.0101	0.984				
					SL=11.01±0.11 (7.5-21.1)	SL=0.8228TL–0.6355	0.0072	0.991				
					W=49.62±1.70 (12.7-278.0)	$W=0.0118TL^{3.10}$	0.0359	0.984	*s*	+A		
		16	*Lithognathus mormyrus*	131	TL=19.27±0.21 (12.4-24.1)						TN LL	9
					FL=17.22±0.19 (11.1-21.6)	FL=0.8997TL–0.1200	0.0097	0.996				
					SL=15.80±0.18 (10.1-20.2)	SL=0.8314TL–0.2244	0.0124	0.993				
					W=96.95±2.96 (24.9-179.8)	$W=0.0132TL^{2.99}$	0.0772	0.979		I		
		17	*Oblada melanura*	111	TL=20.68±0.24 (17.0-26.2)						LL HL	5-6
					FL=18.08±0.21 (14.7-22.9)	FL=0.8655TL+0.1775	0.0103	0.996				
					SL=16.83±0.20 (13.8-21.4)	SL=0.8161TL–0.0501	0.0080	0.997				
					W=122.72±4.48 (62.2-241.4)	$W=0.0113TL^{3.05}$	0.0203	0.999	*s*	+A		
		18	*Pagellus acarne*	525	TL=13.75±0.06 (9.5-18.2)						LL HL	5-6
					FL=12.33±0.06 (8.4-16.3)	FL=0.8693TL+0.3803	0.0122	0.974				
					SL=11.31±0.05 (7.8-15.4)	SL=0.7948TL+0.3836	0.0097	0.980				
					W=33.37±0.45 (10.5-78.1)	$W=0.0083TL^{3.15}$	0.0443	0.974	*s*	+A		

Family		Species	n	$(TL_{min-max})$	Equation	SE_b	R^2	P	GT	FG	ST
9 Sparidae	19	*Pagellus erythrinus*	734	TL=15.87±0.09 (11.6-23.8)						TN LL	1-3
				FL=13.89±0.08 (10.1-21.0)	FL=0.8646TL+0.1688	0.0060	0.991				
				SL=12.72±0.08 (9.0-19.5)	SL=0.8365TL–0.5472	0.0080	0.983				
				W=55.07±1.04 (18.8-173.6)	$W=0.0139TL^{2.97}$	0.0257	0.986	*s*	–A		
	20	*Sparus aurata*	221	TL=24.18±0.23 (18.5-32.6)						TN LL HL	10-12
				FL=21.57±0.21 (16.5-29.1)	FL=0.8930TL–0.0288	0.0050	0.998				
				SL=19.63±0.19 (15.0-26.6)	SL=0.8238TL–0.2876	0.0074	0.995				
				W=229.23±8.18 (78.4-585.6)	$W=0.0019TL^{3.65}$	0.0702	0.980	*s*	+A		
10 Sphyraenidae	21	*Sphyraena sphyraena*	57	TL=39.77±0.49 (34.7-48.0)						PS	9-10
				FL=36.68±0.45 (31.8-44.5)	FL=0.9092TL+0.5183	0.0285	0.987				
				SL=35.19±0.41 (30.5-42.6)	SL=0.8396TL+1.8034	0.0389	0.971				
				W=242.72±7.35 (184.0-395.0)	$W=0.0702TL^{2.21}$	0.1400	0.948	*s*	–A		

n: Number of examined specimens. *min-max*: Minimum and maximum range of *x* and *y* axis. : Average total length (*TL*, cm), fork length (*FL*, cm), standard length (*SL*, cm) and total weight (*W*, g). *SE*: Standard error. $TL_{min-max}$: Minimum and maximum total lengths (length range). SE_b: Standard error of the slope (*b*) with 95% confidence interval (*t*-test). R^2: Coefficient of determination. *P*: significance level of *b* versus 3 for length-weight relationship (*s*: significant (*t*-test, $P < 0.05$)). *GT*: The growth type (I: isometry, –A: negative allometry, +A positive allometry). *FG*: Fishing Gear (TN: Trammel net, GN: Gillnet, PS: Purse seine, LL: Longline, HL: Handline, CN: Combined net (Trammel net + Gillnet)). *ST*: Sampling time (months, -: from to till).

time, that could be explained by the fact that its body shape shows a negative allometric growth. In addition, the fact that data of *S. sphyraena* PETRAKIS & STERGIOU (1995) was collected in the period from August to November which was longer than the present sampling period should be taken into account when the assessment is performed. As known from AVSAR (1998), body shape of any fish could determine its type of growth. Species with thinner and longer body form often show a negative allometric growth since its height grows greatly than its weight.

The high *b* value in *S. aurata* was probably caused by the samples that having a narrow range of length. November and December, when the sampling was performed, were the periods in which sea bream was mostly fished in Izmir Bay, as they approached the shore in schools and migrated to spawning areas along the coastline. High condition factor could then influence an increase in the *b* value. The *b* values of most of the species presented in the present study are in general agreement with those observed from previous studies in Izmir bay and other adjacent areas.

The LWRs and LLRs for the 21 species are in FishBase (FROESE & PAULY, 2016). However, there are only a few examples and one reference each for LL regressions of *C. rhoncus* and *S. sarda* in FishBase. The current study is believed to be likely to contribute greatly to increase in the number of references and samples.

Although some studies have been performed on the LWRs of fish in Izmir Bay, there are only two on LLRs. These are KARA & BAYHAN (2008) for *Boops boops* and BAYHAN & KARA (2015) for *Sarpa salpa.* The current study will be important especially for length-length relationships of 21 fish species in Table 1. There is only one length-weight relationship found for the species *Trisopterus capelanus* in FishBase. However, there are no length-length relationships for it. This study will thus provide length-length relationships for the first time on the species *T. capelanus*. Although FishBase provides relationships between SL and FL measurements for the species *Sarda sarda*, there are no values for correlation between measurements of TL and FL and those between TL and SL length. Likewise, FishBase presents relationships between TL and FL for *Sparus aurata*, but there are no values for the relationship between TL and SL for the species. Moreover, FishBase has only one fish length-length relationships value for *Chelon saliens* and *Caranx rhonchus*. This study provided increasing the number of length-length relationship values for the above-mentioned species.

In conclusion, the study provides us with a basic knowledge of LW and LL relationships involving 21 species, which are greatly likely of use for fisheries biologists and managers to study in Izmir Bay.

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Dužinsko-maseni i dužinsko-dužinski odnos za 21 vrstu riba ulovljenih u Izmirskom zaljevu

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SAŽETAK

U ovom radu se prikazuje povezanost dužinsko-masenog odnosa i dužinsko-dužinskog odnosa za 21 vrstu riba ulovljenih u Izmirskom zaljevu. Koeficijenti a i b za odnos dužinsko-masenog (LWR) i odnos dužinsko-dužinskog (LLR) izračunati su s formulama W = a/b i kao jednadžbom TL = a + bFL i TL = a + bSL. Jednadžbe za pretvaranja standardne duljine i vilične duljine u ukupnu duljinu i obrnuto, pokazale su se linearnima. Uključeni odnosi bili su značajno međusobno povezani (R2> 0,942). Vrijednosti b u LWR varirale su od 2,21 do 3,96 (srednja vrijednost ± SE: 3,15 ± 0,08). Studentov t-test pokazao je da se 87,9% vrijednosti *b* značajno razlikuje od 3.

Ključne riječi: riba, dužinsko-dužinski odnos, dužinsko-maseni odnosi, Izmirski zaljev