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Length-Weight and Length-Length Relationships of the Salema *Sarpa salpa* (Linnaeus, 1758) in Izmir Bay (Aegean Sea of Turkey)

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Abstract.- A total of 927 specimens of salema, *Sarpa salpa*, were collected by commercial gillnet and trammel net fishing between October 2004 and September 2005 from the Izmir Bay. Fish size ranged in total length (TL)15.6 - 42.6 cm in all sexes. The parameters a and b of the length-weight relationships (LWRs) were calculated as $W=aL^b$ are presented LWRs for males, females, hermaphrodite and the total sample population was determined as $W=0.0294L^{2.750}$, $W=0.0216L^{2.840}$, $W=0.0115L^{3.058}$ and $W=0.0189L^{2.894}$, respectively. Length-length relationships (LLRs) were measured as TL=a+bFL, FL=a+bSL and SL=a+bTL equations in all sexes and combined. In all the samples together, LLRs are as follows: TL=0.088+1.1255FL, FL=0.043+1.0608SL and SL=0.000+0.8414TL. The results further indicated that LLRs were highly inter correlated ($r^2 < 0.90$, $p < 0.01$).

Key words: Salema**,** *Sarpa salpa,* allometric coefficients.

INTRODUCTION

Length-weight relationships (LWRs) are useful for both applied and basic uses in fishery management (Pitcher and Hart, 1982; Başusta *et al.*, 2014) to (i) estimate weight from length observations; (ii) calculate production and biomass of fish population; and/or (iii) provide information on stock or organism condition at the corporal level. Length-length relationships (LLRs) are also important for comparative growth studies in fisheries management (Moutopoulos and Stergiou, 2002; Hossain *et al.*, 2006; Soomro *et al.*, 2007).

In fisheries studies, fish length can often be measured more rapidly and easily than mass. Knowledge of the LWR makes it easier to determine the mass where only length is known. In the field concerned, the tail flukes are often cut, which makes it difficult to measure the total length (TL) accurately. Knowing the standart length (SL) will enable us to figure out the TL (Froese and Pauly, 2000; Lalèyè, 2006).

The aim of the present study is to determine the LWR and LLR of females, males and and hermaphrodites of the species, *Sarpa salpa* caught in Izmir Bay. Data of LWRs and LLRs of *S. salpa* in Izmir Bay was presented in this study for the first time. The present study provides baseline information on LWRs and LLRs for *S. salpa*, which will be useful for fish biologists and fishery managers in future.

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MATERIALS AND METHODS

The samples were collected monthly during commercial fishing trials conducted with gillnets and trammel nets between October 2004 to September 2005 from Izmir Bay (38º22' N 26º40' E - 38º28' N 26º40' E and 38º28' N 26º46' E - 38º26' N 26º50' E). The specimen of *Sarpa salpa* were taken from commercial boats, kept in wooden boxes and brought to the laboratory without delay. Fish were measured to the nearest 1 mm (TL, FL and SL), and weighed to the nearest 1g. The relationships between TL, fork length (FL) and SL were determined according to LWR and $W=aTL^b$, was transformed into its logarithmic expression;

$$\text{Log } W=\log (a)+b*\log (TL).$$

The parameters a and b were monthly calculated by the least squares regression for males, females and hermaphrodites. Furthermore, relationships between (i) TL and FL, (ii) FL and SL, and (iii) SL and TL were also estimated by using the above least square linear regression equation.

The coefficient a is the intercept and the regression of coefficient b and exponent, indicating isometric growth when equal to 3.0. A value b larger or smaller than 3.0 shows allometric growth (Bagenal and Tesch, 1978; Soomro *et al.*, 2007). The slopes of length-weight regressions were compared using t-test to ascertain if species grew isometrically or not. All analyses were performed using SPSS 13.0 software and all statistical analyses were considered significant at $p<0.01$.

RESULTS AND DISCUSSION

A total of 927 individuals were sampled during the study period. The shortest individual (15.6 cm TL) was obtained in February, 2005 and the longest (42.6 cm TL) in December, 2004. It was determined that 25.24% of the samples were females (n=234), 32.68% males (n=303) and 42.0% hermaphrodites (n=390). The sex ratio was not significantly different from parity ($\chi^2=4.469$; $p<0.01$). Female:male ratio was calculated to be 1:1.29. Erkoyuncu (1995) and Avsar (1998) pointed out that female:male ratio may vary between 1:1 and 1:1.3 in a typical population. The values obtained in our study were within the reasonable range expected for a natural population. The b value was used in the length-weight relationship as the indicator of the growth type of *S. salpa* to find out whether there had been any variations from isometric growth between the sexes and among the sampling times.

Monthly LWRs of *S. salpa* for males, females, hermaphrodite and the total sample population were determined as $W=0.0294L^{2.750}$, $W=0.0216L^{2.840}$, $W=0.0115L^{3.058}$ and $W=0.0189L^{2.894}$ respectively. Monthly LWRs of *S. salpa* presented in Table I showing range between 2.723 (January 2005) and 3.080 (November 2004) in females, from 2.203 (May 2005) to 3.452 (September 2005) in males and from 2.738 (May 2005) to 3.232 (July 2005) in hermaphrodites. In overall samples, however, value b was mean 2.894. Although b values of male and female individuals did not vary in winter and spring months, a significant difference was found during summer and autumn months in particular. Slope values (b) of males were highest remarkably in summer and autumn months. On the other hand, girth of males increased due to gonadal development in summer months, with a more positive allometric growth and a intercept value of males in summer was found to be lower than in the rest of the year. Length-weight index than indicates reproduction occurs during summer months and therefore condition is then on minimum. An allometric relationship was observed between length and weight of the species concerned. Allometry was closer to isometry in hermaphrodite individuals, while negative allometry was found in both sexes and total populations. Gonadal development positively influenced the relationship between length and weight. The value b was calculated by cubic value of length with t-test and significant variation between slope values (b) was compared. All allometric coefficient (b) estimated in this study were within the expected range and accordingly allometric coefficients may range from 2-4 (Benegal and Tesch, 1978; Koutrakis and Tsikliras, 2003).

There have been some studies on the LWRs of *S. salpa* in Turkish seas and other localities and the b values reported in these studies presented in Table II. It is clear from Table II that we did not conduct any comparison since there is not any study conducted on *S. salpa* in this area. However, our results indicated a negative allometric growth manifested both in males and females in Izmir Bay, with only hermaphrodite individuals showed positive allometric growth. Karakulak *et al.* (2006), in a study conducted in northern Aegean sea of Turkey found negative and positive allometric growths in female and male individuals respectively. However, the studies made in other parts of Mediterranean sea by some researchers observed both negative and positive allometric growths in *S. salpa* show in Table II.

Finally this change may be caused by various factors which effect the growth of fish, such as season, habitat, gonadal maturity, sex, stomach fullness, health, preservation techniques and annual differences in environmental conditions (Tesch, 1971; Begenal and Tesch, 1978; Froese, 2006). Mautopoulos and Stergiou (2002) indicated that differences in b values can be ascrib to one or a combination of more of the factors as follows: (i) differences in the number of specimens examined (ii) area/season effects and (iii) distinctions in the observed length ranges of the specimens caught, to which duration of sample collection can be added as well.

Table I.- **Monthly descriptive statistics and estimated parameters of length-weight relationships for both sexes of *Sarpa salpa* in the Izmir Bay***

Months	Sex	N	Length characteristics		Weight characteristics		Relationship parameters				
			TL Range (cm)	Mean TL (±SD)	W Range (g)	Mean W (±SD)	a	95% CI of a	b	95% CI of b	r^2
October 2004	M	78	25.0 - 30.0	28.00±0.15	183.83-304.96	247.87±3.57	0.05	0.017-0.083	2.56	2.17-2.95	0.86
	F	42	27.3 - 36.6	30.71±0.37	235.85-590.12	347.85±13.75	0.01	0.005-0.027	2.90	2.50-3.29	0.94
November	F	12	26.0 - 28.3	26.50±0.18	216.84-270.12	278.90±10.11	0.00	0.0008-0.001	3.08	2.96-3.20	0.80
December	M	33	18.0 - 38.0	26.82±1.34	76.67-766.81	313.18±45.24	0.01	0.009-0.013	3.04	2.91-3.16	0.99
	F	39	19.2 - 42.6	24.57±1.12	88.64-1084.57	241.31±44.31	0.01	0.099-0.016	2.99	2.84-3.14	0.99
	H	42	20.0 - 38.0	30.37±0.90	106.62-637.62	375.88±28.45	0.01	0.014-0.023	2.87	2.73-3.02	0.99
January 2005	F	51	24.6 - 30.0	27.11±0.21	207.50-330.04	274.37±6.52	0.03	0.001-0.067	2.72	2.13-3.30	0.85
	H	48	22.5 - 29.1	26.17±0.26	156.94-325.80	252.14±6.71	0.03	0.010-0.050	2.76	2.36-3.15	0.93
February	F	72	15.6 - 25.3	19.26±0.28	53.13-206.01	100.42±4.57	0.02	0.014-0.025	2.86	2.68-3.04	0.98
	H	33	18.2 - 23.7	21.34±0.34	77.95-173.01	124.69±5.48	0.02	0.009-0.034	2.81	2.44-3.18	0.96
March	M	99	17.6 - 22.4	20.65±0.10	74.00-162.86	125.08±1.79	0.01	0.006-0.017	3.05	2.75-3.36	0.92
	F	6	23.0 - 24.6	23.80±0.46	168.80-216.38	192.59±13.74	0.02	0.005-0.041	2.83	2.68-2.98	0.90
April	M	21	23.7 - 25.3	24.61±0.12	187.20-218.24	203.36±3.83	0.00	0.000-0.010	3.27	2.71-3.84	0.73
	H	69	23.3 - 29.9	25.73±0.18	168.89-369.81	234.18±5.54	0.00	0.002-0.012	3.18	2.78-3.58	0.92
May	M	15	21.1 - 25.0	22.40±0.40	153.86-216.10	165.02±7.44	0.01	0.002-0.032	2.20	2.09-2.30	0.88
	H	54	21.3 - 29.3	25.79±0.33	131.99-376.81	261.32±9.60	0.03	0.005-0.063	2.73	2.19-3.27	0.79
June	H	45	20.5 - 26.3	23.00±0.22	111.38-242.50	165.10±4.79	0.01	0.000-0.022	2.95	2.51-3.39	0.93
July	M	15	22.3 - 29.0	26.38±0.65	153.75-379.12	265.25±21.80	0.00	0.0004-0.009	3.33	2.71-3.95	0.95
	H	60	24.7 - 29.7	26.45±0.15	219.18-400.59	271.75±5.66	0.00	0.0007-0.012	3.23	2.59-3.87	0.85
August	M	15	28.1 - 30.3	28.94±0.28	333.00-422.44	372.32±10.53	0.02	0.004-0.043	2.87	2.12-3.61	0.95
	H	39	26.5 - 34.0	28.97±0.35	299.75-618.32	397.54±15.57	0.01	0.004-0.018	3.10	2.75-3.44	0.96
September	M	27	25.0 - 30.6	27.94±0.32	192.89-419.16	273.34±13.00	0.00	0.0005-0.001	3.45	2.97-3.93	0.91
	F	12	27.5 - 31.0	29.30±0.44	244.48-349.91	301.39±13.84	0.00	0.001-0.016	3.09	2.57-3.61	0.98
Overall	M	303	17.6 - 38.0	24.90±0.23	74.00-766.81	218.45±6.44	0.02	0.024-0.034	2.75	2.64-2.85	0.96
	F	234	15.6 - 42.6	24.20±0.36	53.13-1084.57	234.22±10.21	0.02	0.018-0.024	2.84	2.74-2.93	0.98
	H	390	18.2 - 38.0	26.02±0.17	77.95-637.62	259.46±5.51	0.01	0.008-0.014	3.05	2.92-3.19	0.93
	All	927	15.6 - 42.6	24.28±0.14	53.13-1084.57	210.98±3.91	0.01	0.016-0.020	2.89	2.81-2.97	0.96

*M, male; F, female; H, hermaphrodite; N, number of individuals; TL, total length; W, weight, a and b: parameters of length-weight relationships; 95% C.I of a and b: 95% confidence intervals of a and b, r^2: regression coefficient.

Table II.- LWRs of *Sarpa salpa* from different localities.

Author(s)	Area	Sex	Length range	Length type	N	a	b	r^2
Torres (1991)	Natal, South Africa	Unsexed	-	-	-	0.059	2.79	-
Dulčić and Kraljević (1996)	Eastern Adriatic, Croatia	Unsexed	13.9 - 41.6	TL	437	0.021	3.12	0.98
Abdallah (2002)	Off Alexandria, Egypt	Unsexed	8.9 – 13.0	TL	39	0.014	2.90	0.97
Moutopoulos and Stergiou (2002)	Kyclades, Greece	Mixed	14.9 - 25.1	TL	48	0.014	2.94	0.98
Koutrakis and Tsikliras (2003)	Stryman estuary, Greece	Mixed	7.9 - 11.7	TL	10	0.010	3.19	0.99
Matić-Skoko *et al.* (2004)	Kornati Archipelago, Adriatic	Juvenile	1.6 - 14.2	TL	1515	-	3.28	0.99
Dulčić and Glamuzina (2006)	Middle Adriatic, Croatian	Unsexed	12.5 - 30.2	TL	77	0.004	3.26	0.93
Karakulak *et al.* (2006)	Northern Aegean Sea, Turkey	Female	24.6 - 31.2	TL	25	0.028	2.77	0.69
		Male	11.1 - 30.8	TL	39	0.011	3.06	0.97
		Female+male	11.1 - 31.2	TL	80	0.008	3.13	0.97
Verdiell-Cubedo *et al.* (2006)	Mar Menor lagoon, Spain	Mixed	35.0 – 59.0	TL	138	0.012	3.00	0.92
Pallaoro *et al.* (2008)	Eastern Adriatic Sea, Croatia	Female	23.7 - 43.9	TL	209	0.007	3.17	0.95
		Male	16.2 - 36.8	TL	601	0.012	3.00	0.98
		Immature	10.3 - 13.8	TL	83	0.001	4.04	0.97
		All fish	10.3 - 43.9	TL	898	0.008	3.10	0.98
Acarlı *et al.* (2014)	Homa Lagoon, Turkey	Juvenile	6.7 - 12.4	TL	67	0.006	3.14	0.99
Present study	Izmir Bay, Turkey	Female	15.6 - 42.6	TL	234	0.021	2.84	0.98
		Male	17.6 - 38.0	TL	303	0.029	2.75	0.96
		Hermaphrodite	18.2 - 38.0	TL	390	0.011	3.05	0.93
		All fish	15.6 - 42.6	TL	927	0.018	2.89	0.96

All the LLRs values are given in Table III. The values for coefficient of determination (r^2) for all the length-length parameters of male, female and combined were < 0.90, and highly significant ($p<0.01$). There are few studies made on length-length relationship in *S. salpa* (Moutopoulos and Stergiou, 2002; Torres, 1991). Fish length can also be estimated from weight. Therefore, knowing LWR makes it convenient to establish weight where only length is known.

Table III.- Length-length relationships between total length (TL=a+b-bFL), fork length (FL=a+bSL) and standard length (SL=a+bTL) of *Sarpa salpa* in the Izmir Bay.

Sex	n	Equation	a	b	r^2
Male	303	TL	0.290	1.117	0.99
		FL	-0.175	1.068	0.99
		SL	0.000	0.834	0.99
Female	234	TL	-0.061	1.132	0.99
		FL	0.090	1.056	0.99
		SL	0.000	0.855	0.99
Hermaphrodite	360	TL	0.059	1.125	0.99
		FL	0.085	1.058	0.99
		SL	0.000	0.821	0.99
All	927	TL	0.088	1.125	0.99
		FL	0.004	1.060	0.99
		SL	0.000	0.841	0.99

Morever, relationships among different length types in LLRs are of great importance for comparative growth studies (Froese and Pauly, 2000). On the other hand, Lalèyè (2006) found that tail flukes of fish are generally cut out, which makes it difficult to calculate TL. Knowledge of SL however enables measurement of TL.

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