Journal of Applied Biological Sciences 10 (1): 55-60, 2016
ISSN: 1307-1130, E-ISSN: 2146-0108, www.nobel.gen.tr

Length-Weight and Length-Length Relationships of Fish Species in Kirmir Stream and its Tributaries (Suveri and Ilhan Stream) of Sakarya River, Turkey

Özge Zencir[1]* Ahmet Şeref Korkmaz[2]
[1]Erzincan University Rectorate, Office of Scentific Research Project, 24000, Erzincan, Turkey
[2]Department of Fisheries and Aquaculture, Faculty of Agriculture, Ankara University, 06000, Ankara, Turkey

*Corresponding author:
E-mail:zencir06@hotmail.com

Received: January 27, 2016
Accepted: March 07, 2016

Abstract

This study was conducted to determine length-weight (LWR) and length-length (LLR) relationships for 10 fish species caught by electrofishing between August 2005 and July 2006 in Kirmir Stream and its tributaries (Suveri and Ilhan Stream) of Sakarya River, Central Anatolia, Turkey. The length-weight relationships (LWR) exponent b values ranged from 1.940 in Cobitis taenia (Linnaeus, 1758) to 3.377 in Gobio gobio (Linnaeus, 1758). The b values of the length-weight relationships (LWR) for Capoeta sieboldi (Steindachner, 1864) and Alburnus orontis (Sauvage, 1882) were close to 3 indicating the isometric growth ($b=3$, $p<0.05$). The b values of the length-weight relationships (LWR) exhibited a positive allometric growth in Squalius cephalus, Barbus plebejus (Heckel, 1843), and Gobio gobio (Linnaeus, 1758) ($b>3$, $p<0.05$), versus a negative allometric growth in Capoeta baliki (Heckel 1843), Alburnoides bipunctatus (Bloch, 1782), Chondrostoma regium (Heckel, 1843), Cobitis taenia (Linnaeus, 1758) and Oxynoemacheilus angorae (Steindachner, 1897) ($b<3$, $p<0.05$). All the length-weight relationships (LWR) and length-length relationships (LLR) were statistically significant ($r2>0.550$, $p<0.05$ and $r2>0.754$, $p<0.05$).

Keywords: Fish growth, Fresh water fish species, IUCN Red List, Kirmir Stream, Turkey

INTRODUCTION

Fishes especially those of inland water systems are known to experience growth fluctuations due to many factors such as environmental changes, food composition changes, competition within the food chain, changes in the physical and chemical properties of the aquatic medium [1, 2, 3]. The length-weight (LWR) and length-length (LLR) relationships can be used to assess the influence of these factors in fish populations. In addition, length-length (LLR) relationships are also important in fisheries management for comparative growth studies [4, 5].

In fisheries studies, fish length can often be measured more rapidly and easily than mass [6]. The general length-weight relationships (LWR) provide a mathematical relationship between the two variables, length and weight, so that the unknown variable can be easily calculated from the known variable [7, 8]. This expression has been extensively used in the study of fish population dynamics for estimating the unknown weights from known lengths in yield assessments [6].

The length-weight relationships (LWR) are studied to give information on the growth condition of fish and to find out whether the fish grows isometrically or allometrically [9]. Length and weight data of fish are very important parameters in the estimation of the length and age structures, population dynamic [10], growth and mortality rates, and well-being of the fish [11, 12]. It is also used to estimate fish biomass from length frequency distributions [13, 14], calculate fish condition [15, 16], and to compare life history and morphological aspects of fish populations inhabiting different region. Like other morphometric measurements, length-weight relationships (LWR) may change during the events of life cycle like metamorphosis, growth and onset of maturity [11]. Length-weight relationships (LWR) can be used as character for differentiation of taxonomic units [17].

The aim of this study was to provide data on the length-weight (LWR) and length-length relationships (LLR) of 10 fish species. A total of 10 fish species representing 2 families Cyprinidae and Cobitidae were recorded. Fish species identified were followed as: Squalius cephalus (Linnaeus, 1758) [18], Barbus plebejus (Heckel, 1843), Capoeta baliki (Heckel 1843) [19], Alburnoides bipunctatus (Bloch, 1782), Capoeta sieboldi (Steindachner, 1864), Chondrostoma regium (Heckel, 1843), Alburnus orontis (Sauvage, 1882), Cobitis taenia (Linnaeus, 1758), Gobio gobio (Linnaeus, 1758) and Oxynoemacheilus angorae (Steindachner, 1897) [20], caught by electrofishing from the Kirmir Stream and its tributaries of Sakarya River, Turkey. Seven fish species, including Squalius cephalus, Barbus plebejus, Chondrostoma regium, Oxynoemacheilus angorae, Capoeta baliki and Capoeta sieboldi, included on least concern (LC) species and Alburnus orontis included on vulnerable (VU) species in the 2015 IUCN Red List of Threatened Species, were recorded in Turkey. There are many studies for the length-weight relationships (LWR) regarding these species in freshwater of different geographic regions of Turkey (Table 3). Apart from this study, there are three reported studies on the length-weight (LWR) relationships parameters for Squalius cephalus and Capoeta baliki from Kirmir Stream [21, 22, 23]. This study provides the first comprehensive description of the length-weight (LWR) and length-length (LLR) relationships of species from Kirmir Stream and its tributaries, except for Squalius cephalus and Capoeta baliki.

MATERIAL and METHODS

This study was carried out in Kirmir Stream and its tributaries (Suveri and Ilhan Stream) in the Sakarya River Basin (Figure 1). Kirmir Stream is located in the northwestern part of the Central Anatolian region of Turkey at 40-41° N and 32-33° E, and the basin lies within the boundaries of Ankara Province. The depth of the stream is generally shallow (30-50 cm), but reaches 2- 3 m at some points. The bottom structure varies between sandy, stony and muddy [24].

Fish samples were caught in every quarter at 10 selected sampling sites between August 2005 and July 2006 by

electrofishing. A pulsed DC current of 2 amperes at 500-750 volts was used in electrofishing, the current being supplied by a generator. All fish caught were immediately preserved in a plastic barrel containing 4% formalin solution for later analysis in the laboratory. The total length (TL), fork length (FL) and standard length (SL) of each fish species were measured to the nearest 0.1 cm. Individual weights (W) were taken using a digital balance with a precision of 0.01 g.

The length-weight relationship (LWR) was calculated using the equation, W=a*Lb, where W is the total weight (g), L is the total length (cm), a is the intercept and b is the slope of relationship [25]. The degree of association between the variables was computed by the determination coefficient r2. The parameters a and b of LWR were estimated by linear regression on the transformed equation, log W = log a+ b log TL. All length-length (LLR) relationships were established using linear regression analysis. Relationships between TL-FL, FL-SL, and SL-TL were estimated separately for overall samples. The significance of the regression was assessed by analysis of variance (ANOVA), and the b values for each species was tested by t-test to verify that it was significantly different from the predictions for isometric growth (b=3).

RESULTS

In total, 18824 specimens of 10 fish species belonging to the families Cyprinidae, Cobitidae and Balitoridae were caught and examined from the Kirmir Stream and its tributaries. The sample size (n), ranges (minimum and maximum) of total length and total weight, parameters a and b of the length-weight relationships (LWR), 95% confidence intervals of a and b, the determination coefficient (r2), and growth type of these 10 fishes are given in Table 1. Values of the coefficient of determination (r2) varied between 0.550 (Cobitis taenia) and 0.993 (Gobio gobio). All the length-weight relationships (LWR) were statistically significant ($r2>0.550$, $p<0.05$).

The length-weight relationships (LWR) exponent b values ranged from 1.940 in Cobitis taenia (Linnaeus, 1758) to 3.377 in Gobio gobio (Linnaeus, 1758) (Table 1). The b values of the length-weight relationships (LWR) for Capoeta sieboldi (Steindachner, 1864) and Alburnus orontis (Sauvage, 1882) were close to 3 indicating the isometric growth ($b=3$, $p<0.05$). The b values of the length-weight relationships (LWR) exhibited a positive allometric growth in Squalius cephalus, Barbus plebejus (Heckel, 1843), and Gobio gobio (Linnaeus, 1758) ($b>3$, $p<0.05$), versus a negative allometric growth in Capoeta baliki (Heckel 1843), Alburnoides bipunctatus (Bloch, 1782), Chondrostoma regium (Heckel, 1843), Cobitis taenia (Linnaeus, 1758) and Oxynoemacheilus angorae (Steindachner, 1897) ($b<3$, $p<0.05$).

The sample size, morphometric relationships between total length (TL, cm), fork length (FL, cm) and standard length (SL, cm) of 10 fish species and the coefficient of determination r2 are given in Table 2. All length-length relationships (LLR) were statistically significant ($r2 > 0.754$, $p<0.05$).

DISCUSSION

The length-weight relationships (LWR) are studied to give information on the growth condition of fish and to find out whether the fish grows isometrically or allometrically [9]. The length-weight relationships (LWR) exponent b values provide useful information on fish growth. It shows isometric growth when b=3, while it indicates positive allometry when b>3, and negative allometry when b<3. Positive or negative allometry indicates a rounder or slimmer body, respectively, whereas isometric growth shows that the body grows in the same proportion in all dimensions [25].

In this study, the length-weight relationships (LWR) exponent b values ranged from 1.940 in Cobitis taenia (Linnaeus, 1758) to 3.377 in Gobio gobio (Linnaeus, 1758). The length-weight relationships (LWR) exponent b values for all the species were within the limits (2-4) reported by [9, 25] for most fishes. In many studies carried out in Turkey (Table 3), both isometric and allometric growth types for these species were reported. Differences in b values can be affected by several factors including number of specimens examined, habitat, area, seasonal effect, degree of stomach fullness, gonad maturity, sex, health and general fish condition, preservation techniques and differences in the observed length ranges of the specimen caught [9], all of these were not accounted in this study.

The correlation coefficient (r2) for the length-weight relationship of the fishes is high which indicate increase in length with increase in weight. This agreed with earlier studies involving fish species from different water bodies (Table 3). Species having the lowest coefficient of determination (r2) were Cobitis taenia (0.550), because of a probably the lower number of individuals captured [26]. To the date we were not able to find any references dealing with length-length (LLR) relationships for the studied species therefore it was not possible to compare the present results with previous studies.

CONCLUSION

This study provides the first basic and baseline information of the length-weight (LWR) and length-length (LLR) relationships of species from Kirmir Stream and its tributaries that would be beneficial for fishery biologists to impose adequate regulations for sustainable fishery management and conservation of biodiversity for these streams as well as useful spatial temporal comparison in the future.

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Table 1. Descriptive statistics and estimated parameters of length–weight relationship for 10 fish species caughted from the Kirmir Stream and its tributaries

Family	Species	n	FL (cm)		W (g)		Regression parameters		95% CI of a	95% CI of b	r2	p	GT
			Min	Mak	Min	Mak	a	b					
Cyprinidae	Squalius cephalus	1298	3.9	28.4	0.72	389.17	0.011	3.076	-1.963 to -1.911	3.050 to 3.101	0.977	p<0.05	A+
	Barbus plebejus	750	3.4	31.3	0.38	379.57	0.008	3.134	-2.108 to -2.031	3.097 to 3.172	0.973	p<0.05	A+
	Capoeta baliki	9582	3.0	31.3	0.49	498.03	0.019	2.855	-1.729 to -1.702	2.841 to 2.868	0.946	p<0.05	A-
	Alburnoides bipunctatus	1901	3.1	11.0	0.32	23.75	0.021	2.840	-1.716 to -1.627	2.786 to 2.893	0.851	p<0.05	A-
	Capoeta sieboldi	73	5.4	34.0	2.86	611.67	0.015	2.996	-1.914 to -1.711	2.882 to 3.050	0.985	p<0.05	I
	Chondrostoma regium	501	3.7	16.3	1.21	56.94	0.035	2.529	-1.530 to -1.365	2.444 to 2.614	0.872	p<0.05	A-
	Alburnus orontis	4497	2.8	14.1	0.14	40.32	0.010	2.992	-1.996 to -1.935	2.957 to 3.028	0.858	p<0.05	I
	Gobio gobio	4	5.6	7.4	2.14	5.57	0.006	3.377	-3.298 to -1.105	2.053 to 4.701	0.983	p<0.05	A+
Cobitidae	Cobitis taenia	21	6.0*	11.8*	3.29	19.96	0.113	1.940	-1.757 to -0.131	1.098 to 2.782	0.550	p<0.05	A-
Balitoridae	Oxynoemacheilus angorae	197	3.9	8.8	0.61	6.67	0.015	2.734	-1.922 to -1.689	2.593 to 2.876	0.881	p<0.05	A-

n: sample size; **L:** total length (cm); **W:** total weight (g); **a:** intercept; **b:** slope; **CI:** confidence intervals; **r^2:** coefficient of determination; **p:** p-value for t-test comparing differences for isometric growth (b = 3); **GT:** growth type; **I:** isometric, **A+:** positive allometric, **A-:** negative allometric; ***Length**= Standard length; others fork length.

Table 2. Morphometric relationships between total length (TL, cm), fork length (FL, cm) and standard length (SL, cm) for 10 fish species caughted from the Kirmir Stream and its tributaries

Family	Species	n	Equation	Regression parameters		95% Cl of a	95% Cl of b	r 2
				a	b			
Cyprinidae	Squalius cephalus	1298	SL = a + b × TL; TL = a + b × FL; FL = a + b × SL	-0.199 0.379 0.075	0.839 1.042 1.120	-0.276 to -0.122 0.320 to 0.437 -0.0004 to 0.150	0.833 to 0.845 1.037 to 1.047 1.113 to 1.127	0.983 0.992 0.986
	Barbus plebejus	750	SL = a + b × TL; TL = a + b × FL; FL = a + b × SL	0.030 -0.037 0.133	0.814 1.093 1.109	-0.004 to 0.104 -0.108 to 0.032 0.057 to 0.209	0.808 to 0.820 1.087 to 1.099 1.102 to 1.111	0.990 0.994 0.991
	Capoeta baliki	9582	SL = a + b × TL; TL = a + b × FL; FL = a + b × SL	0.957 0.139 0.073	0.717 1.081 0.877	0.864 to 1.050 0.058 to 0.220 -0.001 to 0.149	0.709 to 0.725 1.073 to 1.089 0.869 to 0.884	0.754 0.883 0.852
	Alburnoides bipunctatus	1901	SL = a + b × TL; TL = a + b × FL; FL = a + b × SL	-0.359 0.326 0.321	0.839 1.063 1.083	-0.413 to -0.304 0.283 to 0.368 0.279 to 0.363	0.832 to 0.846 1.057 to 1.069 1.076 to 1.089	0.967 0.984 0.981
	Capoeta sieboldi	73	SL = a + b × TL; TL = a + b × FL; FL = a + b × SL	-0.410 0.244 0.512	0.834 1.076 1.094	-0.941 to 0.121 -0.079 to 0.568 0.080 to 0.943	0.807 to 0.861 1.058 to 1.094 1.067 to 1.121	0.981 0.995 0.989
	Chondrostoma regium	501	SL = a + b × TL; TL = a + b × FL; FL = a + b × SL	-0.101 0.307 0.213	0.826 1.063 1.092	-0.258 to 0.054 0.141 to 0.473 0.121 to 0.304	0.812 to 0.840 1.047 to 1.080 1.081 to 1.102	0.962 0.969 0.988
	Alburnus orontis	4497	SL = a + b × TL; TL = a + b × FL; FL = a + b × SL	-0.170 0.202 0.676	0.823 1.077 1.024	-0.234 to -0.107 0.177 to 0.227 0.614 to 0.739	0.816 to 0.831 1.074 to 1.080 1.015 to 1.033	0.913 0.989 0.916
	Gobio gobio	4	SL = a + b × TL; TL = a + b × FL; FL = a + b × SL	-0.437 0.112 0.782	0.893 1.046 0.998	-2.963 to 2.087 -6.388 to 6.612 -2.590 to 4.155	0.543 to 1.243 0.088 to 2.003 0.438 to 1.559	0.983 0.917 0.967
Cobitidae	Cobitis taenia	21	SL = a + b × TL	-0.480	0.899	-0.958 to -0.002	0.856 to 0.943	0.990
Balitoridae	Oxynoemacheilus angorae	197	SL = a + b × TL; TL = a + b × FL; FL = a + b × SL	0.957 0.139 0.073	0.717 1.081 0.877	0.864 to 1.050 0.058 to 0.220 -0.001 to 0.149	0.709 to 0.725 1.073 to 1.089 0.869 to 0.884	0.807 0.978 0.819

n: sample size; **a:** intercept; b: slope; **C^{l}:** confidence intervals; **r^{2}:** coefficient of determination.

Table 3. Comparison of length-weight relationships parameters for fish species obtained by some researchers

Species	Area	n	Length	Ref.	L (cm)		Regression parameters		r2	GT
					Min	Mak	a	b		
S.cephalus	Kirmir Stream	192*; 203**	FL	[21]	9.8*; 10.7**	30.9*; 30.7**	0.00002*; 0.00002**	2.91*; 3.01**	-	I
	Karasu Stream (Muş)	374	FL	[27]	10.2	30.2	0.00844	3.156	0.98	A+
	Sakarya River	32	TL	[28]	21.1	29.3	0.0079	3.1875	0.89	A+
	Kirmir Stream	192*; 175**	FL	[23]	6.2*; 5.8**	20.2*; 20**	0.0012*; 0.0122**	3.06*; 3.06**	0.90*; 0.91**	I
B. plebejus	Sakarya River	187	FL	[29]	11.8	32.5	0.0103	3.054	-	I
	Kara Stream	-	-	[30]	-	-	0.0756	2.494	-	A-
	Oltu Stream	627	FL	[31]	9.01*; 9**	24.5*; 21.5**	0.0152*; 0.0189**	2.911*; 2.843**	0.97*; 0.96**	I
C. baliki	Kirmir Stream	-	-	[22]	-	-	0.000016	2.820	-	A-
	Delice Stream	246	FL	[32]	4.7	31.0	0.000039	2.811	-	A-
	Samsun Provience	427	FL	[33]	7.2	33.5	0.0043*; 0.0434**	3.3517*; 2.5444**	0.97	A+;A-
	Western Part of Anatolian	55	TL	[34]	9.7	32.2	0.009	3.017	0.98	I
	Sakarya River	1024	TL	[28]	18.0	51.7	0.0408	2.6339	0.81	A-
A. bipunctatus	Çoruh River	353	FL	[35]	7.9	15.9	0.0249	2.79	-	A-
	Western Black Sea, Great Menderes. ect.	2191	TL	[36]	3.2	13.0	0.0830	3.147	0.97	A+
C. sieboldi	Sakarya River	173	FL	[29]	10.2	31.5	0.0104	3.058	-	I
	Delice Stream	537	FL	[37]	7.8	34.1	0.000065	2.710	-	A-
	Çoruh River	404	FL	[38]	-	-	0.0012	3.039	-	I
	Western Part of Anatolian	126	TL	[37]	7.1	43.9	0.009	3.032	0.98	I
	Sakarya River	24	TL	[34]	22.4	33.4	0.1356	2.4440	0.92	A-

C. regium	Savur Stream	289	-	[39]	2.8	29.0	0.0057	1.844	0.98	A-
	River Euphrates	281	-	[40]	11.5	29.2	0.000008	3.038	-	I
	Hatay Province	128	TL	[41]	18.4	33.8	0.0010	3.282	0.71	A+
A. orontis	Karasu River (Erzurum) (***C. mossulensis)	850	FL	[42]	9.36	18.45	0.0073*; 0.0129**	3.082*; 2.913**	0.96*; 0.99**	-
	Karasu River (Erzurum) (C. mossulensis)	375	-	[43]	8.5	18.5	0.008*; 0.01**	3.082*; 2.828**	0.95*; 0.94**	-
G. gobio	Melendiz Stream (G. gymnostethus)	544	FL	[44]	3.9	14.5	-	-	-	-
	Yeşildere Stream (G.hettitorum)	498	FL	[45]	3.0	16.1	-	-	-	-
C. taenia	Darıözü Creek (C.simplicispina)	67	SL	[46]	-	-	0.0000067	3.009	0.92	I
O. angorae	Western Part of Anatolian	30	TL	[34]	4.7	7.3	0.006	3.237	0.88	A+

*values belong to female; **values belong to male; ***Chacalburnus chalcoides (Gueldenstaedti, 1772) is now considered as phenotypic variant of Alburnus chalcoides (www.fishbase.org).

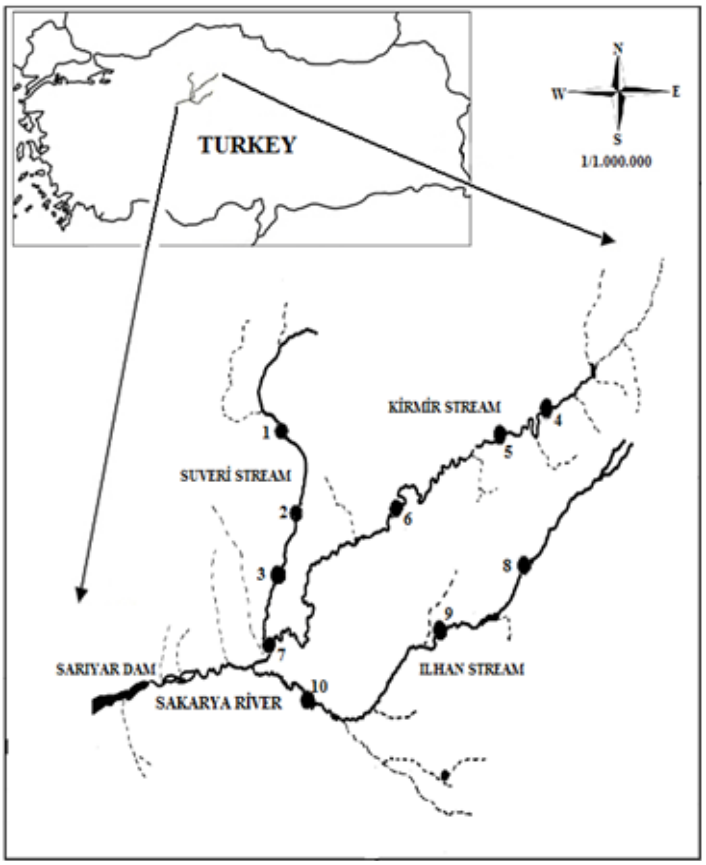

Figure 1. Study area and sampling sites in the Kirmir Stream and its tributaries