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Length-Weight Relationships for the Benthic Invertebrates of a Mountain River in the Southern Caspian Sea Basin, Iran

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ABSTRACT

Biomass is an important parameter in studying a variety of energetic processes in food webs, community structure, and composition of aquatic organisms. Biomass determinations are based on direct weighing of animals, biovolume determination, and length-weight conversion. Although direct weighing of individual organisms is the most accurate methodology, its application is not very common due to its time consuming nature. Length-weight regressions are the most widely used approach for estimating benthic invertebrate biomass because they are less time consuming and more precise than other methods. In this research, length-weight relationships are evaluated for the most common benthic invertebrates found in an Iranian mountain river in the Southern Caspian Sea Basin by fitting the power function (linearized by logarithmic transformation) to data of wet and dry weights against body length of aquatic invertebrates at both family and order level. A general predictive equation was also obtained for all individuals measured in this study. Regressions obtained were significant at a *P* value of < 0.05 and explained a high proportion of variation of the dependent variable, as expressed by the correlation coefficient (r= 0.82-0.99). Regression equations obtained in this study for three major orders of aquatic invertebrates were also compared to those in previous studies from different geographical locations. Relationships developed in this study, can be useful for future assessments of benthic community structure and for understanding the importance of these invertebrates in the energy flux of the river.

Keywords: Aquatic insects, Biomass, Body length, Energy flux of river.

INTRODUCTION

Benthic invertebrates are one of the most important communities of rivers and streams, and aquatic insects are the major group in these communities (Nakagawa and Takemon, 2015; Rajabei Nezhad, 2007). Aquatic insects are a group of organisms that live on, in, or near the substratum of the streams and rivers in their larval and pupal life stages and mountainous rivers that have clean and unpolluted water are suitable for a wide range of aquatic insects (McCafferty, 1981). These organisms are an important component of aquatic (and sometimes terrestrial) food webs because they break down and process organic matter and provide food for invertebrates and vertebrates (e.g. fish, birds) (Kiyak *et al*., 2007; Bouchard, 2012). Biomass is a key factor in quantifying a variety of energetic processes in food webs, ranging from individual consumption and bioenergetics to the spatial transfer of energy between habitats (Sabo *et al*., 2002). Biomass of aquatic macro-invertebrates is also important to determine growth rates and secondary production, as well as to understand life histories, seasonal patterns, and trophic relationships between functional feeding

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groups (Becker *et al*., 2009; Burgherr and Meyer, 1997).

There are three main approaches to biomass determination: (1) Direct weighing of fresh, frozen, or preserved animals; (2) Biovolume determination; and (3) Length- weight conversion (Burgherr and Meyer, 1997; Benke *et al*., 1999). Despite its accuracy, direct weighing of individual organisms is not the most applicable method due to its time consuming nature, while length-weight conversions usually are considered more suitable than other approaches because they are less time consuming and more precise (e.g. Burgerr and Meyer, 1997; Becker *et al*., 2009; Miserendino, 2001). The length-weight relationships of stream invertebrates have been reported in several regions, such as North America (Smock 1980; Benke *et al*., 1999; Johnston and Cunjak, 1999), Europe (Meyer, 1989; González *et al*., 2002) and New Zealand (Towers *et al*., 1994).

Length-weight regressions can be used for many purposes in ecological studies where measuring length (or some other linear dimension) is easier and less time consuming than obtaining weight (Benke *et al*., 1999): (1) They are useful for estimating biomass in the laboratory, where growth rates or other bioenergetics variables are measured; (2) They enable estimation of population or community biomass, given length-frequency data from the field; (3) They are useful in establishing size-specific weight for most secondary production methods; and (4) They allow for more comprehensive comparisons of invertebrate populations within and between habitats and ecosystems.

A parabolic or power curve has most often been used to estimate Weight (W) from Length (L) in studies of freshwater macro-invertebrates, and a power function usually provides a better fit to the data than most other mathematical formulations (e.g. Smock, 1980; Burgherr and Meyer, 1997; Towers *et al*., 1994; Benke *et al*., 1999).

Although different biological studies have been carried out on the benthic invertebrates of the Iranian running waters (e.g. Abdoli *et al*., 2016; Rajabi Nezhad, 2007; Salavatian, 2012), studies on length-weight relationships for benthic invertebrates from Iranian river ecosystems are scarce. Indeed, prior to the present study, no length-weight relationship has been reported for benthic invertebrates in streams and rivers of Iran, except the one study that was carried out for determining length-weight relationships for aquatic beetles in a marsh in Iran (Heydarnejad, 2010). In general, researchers should make their own regressions for a target taxon in the local area.

In this research, length-weight relationships are developed for the most common benthic invertebrates found in an Iranian mountain river in the Southern Caspian Sea Basin. Most of the studies that have examined these relationships for aquatic invertebrates are restricted to dry weight of the organisms. However, wet weight is used in some ecological and bioenergetics models (e.g. *inSTREAM*, Railsback *et al*., 2011). We therefore present dry-to-wet weight ratios for the benthic organisms to enable conversion from wet weight to dry weight values and vice versa. It should be noted that this study is part of a comprehensive ecohydraulics research that has been going on since 2014 (Hajiesmaeili *et al*., 2014) with a focus on fish species and developed with considering benthic invertebrates and bioenergetics modeling approaches. To our knowledge, this paper presents the first published length-weight relationships for benthic invertebrates in an Iranian river ecosystem. These relationships are required and useful for future assessments of benthic community structure and of the feeding ecology of benthivorous fishes.

MATERIALS AND METHODS

Study Area

This study was carried out in the Elarm River, Lar National Park (LNP), Iran. In the southern Caspian Sea Basin, the LNP system, including the Lar Lake, and the

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rivers of Dalichay, Absefid, Elarm, Kamardasht, Khoshkehrud and Lar, provide a unique habitat for the brown trout (Figure 1). Elarm River is considered one of the main and unique habitats of brown trout in LNP and a research site for this fish as well. This river was selected for this study because it had diverse hydrological, morphological and hydraulic conditions in a relatively small length of the river. LNP is located in the north of Iran between Tehran and Mazandaran Provinces. Because the water resources of the park are exploited to supply the drinking water for the city of Tehran and because of the protected nature of the park, no industrial or agro-aquaculture activities are permitted in the area. Consequently, wildlife and especially brown trout populations have ample habitat, which is hard to find in other parts of the Caspian Sea Basin (Esteve *et al*., 2018).

Sample Collection

Benthic invertebrate samples were collected from 36 cross sections along the river. These organisms were collected from two different points on each cross section. A total of 72 samples were collected from about 2 km of river. Field data collection and sampling were carried out in August 2017. Benthic invertebrate samples were collected using a Surber sampler (30×30 cm, 250 µm mesh size). Organisms were collected by stirring and removing the substratum by hand to a depth of a few centimeters. The samples were packed in plastic containers, labeled, fixed in a 4% formalin solution, and transported to the laboratory for processing. We assumed that formalin-preserved invertebrates provided weight estimates very close to those of fresh invertebrates (Ross, 1982; Leuven *et al*., 1985), unlike estimates from ethanol-preserved invertebrates, which lose a substantial portion of their dry weight through leaching (Howmiller, 1972; Dermott and Paterson, 1974; Leuven *et al*., 1985).

In the laboratory, each sample was transmitted to a white tray for separation, counting, and identification. Samples were sorted in Petri dishes, using a stereomicroscope. Benthic invertebrates were identified to the family level using specific identification keys (Usinger, 1956; Needham and Needham, 1941; Haney, 2013; Adams and Vaughan, 2003; Beauchene, 2016; Bouchard, 2004). After identification, the organisms were counted and the weight of the identified families was determined. In order to determine biomass of benthic invertebrates in terms of wet weight, organisms of each taxon were placed on a blotting paper for a few minutes to remove excess moisture and then weights of each family were measured to the nearest 0.001 g.

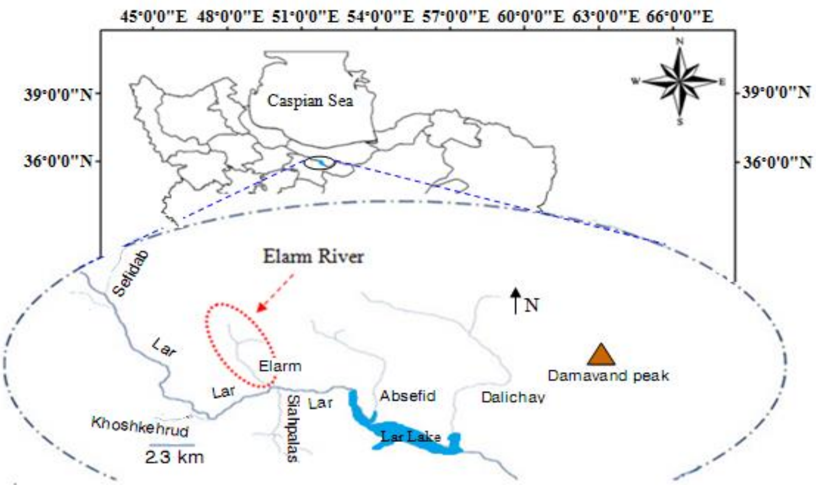

Figure. 1. Elarm River (Lar National Park).

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To determine dry weight, organisms were dried at 60˚C for 24 hours, and then weighed on a KERN PB balance. In order to determine a length-weight relationship for each family and order, body length and weight of individuals of each family were determined. Body length was measured as the distance from the anterior of the head to the end of the last abdominal segment. Table 1 provides information on the number of individuals used in each family for the statistical analysis and building the relationships, the range and mean values of the body length, and weight of these individuals.

Data Analysis

Regression analysis was employed to determine lines of best fit relating individual Body Length (BL) and wet (or dry) weight at both the family and order level. Power functions of the form $W = aL^b$ were fit by log transforming weights and length so that linear equations of the following form could be used to estimate weight:

$$\ln W = \ln a + b \ln L \quad (1)$$

Where, W is dry or wet Weight (mg), L is body Length (mm), "a" and "b" are regression constants. In practice, when interpreting a length–weight regression equation, ''b'' values represent the rate of increase (i.e. slope) of weight against length in a linear relationship, whereas the constant ''a'' only represents the weight of an organism at a unit length (i.e. 1 mm). The fit of the regression equations was judged by the correlation coefficient (r), the significance level (P, obtained from regression ANOVA) and residual analysis.

The goodness of fit of a regression model is dependent on the combination of variables, the distribution of the measured organisms over the range of the linear body dimensions and the range itself (Burgherr and Meyer, 1997). The logarithmic transformation of the power equation will

Table 1. Number of individuals (n), ranges and mean values of body length and wet (and dry) weight of identified families.

Taxon	*n*	Length (mm)		Wet weight (mg)		Dry weight (mg)	
		Range	Mean±*SD*[a]	Range	Mean±*SD*	Range	Mean±*SD*
Diptera	511						
Simuliidae	121	2-11	5.65±1.97	1-40	8.05±7.21	0.07-2.8	0.56±0.51
Chironomidae	150	3-16	6.01±2.48	1-31	6.56±7.10	0.06-1.86	0.39±0.43
Tipulidae	99	4-21	11.67±3.23	2-58	21.42±13.49	0.38-11.02	4.07±2.56
Pupae of Diptera	115	2-9	4.48±1.16	1-38	6.73±6.54	0.07-2.66	0.47±0.46
Adult Diptera	26	2.5-6	3.75±1.01	2-25	7.31±6.67	0.44-5.5	1.61±1.47
Ephemeroptera	196						
Baetidae	141	3-18	6.74±1.94	1-51	13.60±9.68	0.07-3.57	0.95±0.68
Heptageniidae	55	4-18	9.29±3.91	4-105	39.89±29.18	0.6-15.75	5.98±4.38
Trichoptera	183						
Caseless Trichoptera	83	5-18	10.42±2.97	4-111	46.18±22.76	0.76-21.09	8.77±4.32
Cased Trichoptera	100	6-19	11.91±2.68	18-413	125.05±71.22	8.28-189.98	57.52±32.76
Coleoptera	74						
Larvae	51	4-7	5.63±0.89	1-48	6.55±9.25	–	–
Adult	23	2-9	3.09±1.40	2-61	6.74±12.32	–	–

[a] SD: Standard Deviation.

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have effect on the confidence limits. According to Wenzel *et al*. (1990), a difference of up to 20% between the actual and calculated biomass can be expected.

Regression functions were generated at both family and order level. The Coleoptera organisms were separated into adults and larvae, and regression equations for these two groups are only presented in terms of wet weight. For the predictive equations at the order level, all data of an order were pooled and computed again. A general predictive equation was also obtained by pooling data from all individuals measured in this study. These relationships were first developed in terms of Wet Weight (WW) and then Dry Weight (DW) of the organisms. Knowing the proportion of Dry-to-Wet Weight (PDW) and developing the relationship based on one measure of weight allows easy conversion to the other.

RESULTS

Information on the number of individuals used to calculate each regression at the order level, the range and mean values of the body length, and weight of these individuals are presented in Table 2. All the organisms of these orders are in their larval life stage, except for Diptera that contains also pupae and adult life stages.

Parameters for the regression equations relating body length to wet and dry weight for each order and family are presented in Table 3. Predictive equations were obtained for the most frequent and abundant invertebrates found in the river. All regression equations were significant at the *P*< 0.05 level.

The equations indicate a high difference in intercepts among the orders, reflecting their different average sizes (Table 3).

For Trichoptera, those families with a significant number of individuals are considered for length-weight regression analysis. Trichoptera are usually collected with their cases and we thought it would be interesting to determine if some relationship exists between length of the case and body weight. We have therefore provided parameters for weight determination for Trichoptera based on case presence or absence in Table 3. Since Oligochaeta and Amphipoda were not identified to family level, regression equations at the family level are only presented for aquatic insects.

There was no significant linear correlation between ln *W* and ln *L* for larvae of Coleoptera (P> 0.05), and a quadratic regression model yielded a better fit, suggesting a curvilinear relationship between body length and wet weight.

Whether regression equations at the order level had better goodness of fit than equations for the family level differed among taxon (Table 3). We obtained a general predictive equation by pooling data from all individuals measured in this study (Table 4).

Mean values of the *PDW* for identified benthic organisms in the study river are presented in Table 5. Mean value of *PDW* for benthic organisms was 0.16, with a range 0.06 to 0.47 among different families.

Table 2. Number of individuals (n), ranges and mean values of body length, wet weight and dry weight of the identified orders.

Taxon (Order)	***n***	Length (mm)		Wet weight (mg)		Dry weight (mg)	
		Range	Mean±*SD*	Range	Mean±*SD*	Range	Mean±*SD*
Diptera	511	2-21	6.56 ± 3.43	1-58	9.87 ± 10.30	0.12-6.96	1.18 ± 1.24
Ephemeroptera	196	3-18	7.46 ± 2.88	1-105	20.97 ± 21.06	0.11-11.55	2.31 ± 2.32
Trichoptera	183	5-19	11.23 ± 2.90	4-413	89.28 ± 67.40	1.32-136.29	29.46 ± 22.24
Oligochaeta	38	14-74	39.76 ± 11.87	25-404	144.21 ± 88.11	4.25-68.68	24.52 ± 14.98
Amphipoda	67	3-12	7.81 ± 2.23	2-59	22.21 ± 12.91	0.24-7.08	2.67 ± 1.55

[a] *SD*: Standard Deviation.

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Table 3. Values for the constants ln "a" and "b", obtained from Equation (1) for Wet (and Dry) Weight (WW and DW, mg) and Body Length (BL, mm) of selected taxa of benthic invertebrates in Elarm River.[a]

Taxon	Conversion	Regression constants		*r*
		ln *a*±*SE*	*b*±*SE*	
Diptera	$BL \rightarrow WW$	-0.277±0.263	1.318±0.116	0.93
	$BL \rightarrow WW$	-2.397±0.263	1.318±0.116	0.93
Simuliidae	$BL \rightarrow WW$	0.019±0.506	1.124±0.282	0.82
	$BL \rightarrow WW$	-2.641±0.505	1.125±0.282	0.82
Chironomidae	$BL \rightarrow WW$	-0.626±0.398	1.192±0.185	0.89
	$BL \rightarrow WW$	-3.456±0.400	1.198±0.186	0.89
Tipulidae	$BL \rightarrow WW$	-1.573±0.271	1.838±0.110	0.98
	$BL \rightarrow WW$	-3.233±0.271	1.838±0.110	0.98
Pupae of Diptera	$BL \rightarrow WW$	0.188±0.239	0.895±0.149	0.94
	$BL \rightarrow WW$	-2.475±0.239	0.897±0.149	0.94
Adult Diptera	$BL \rightarrow WW$	0.923±0.294	0.631±0.211	0.87
	$BL \rightarrow WW$	-0.591±0.294	0.631±0.211	0.87
Ephemeroptera	$BL \rightarrow WW$	-1.305±0.350	2.055±0.155	0.96
	$BL \rightarrow WW$	-3.512±0.349	2.055±0.155	0.96
Baetidae	$BL \rightarrow WW$	-0.122±0.550	1.281±0.271	0.86
	$BL \rightarrow WW$	-2.781±0.551	1.280±0.271	0.86
Heptageniidae	$BL \rightarrow WW$	-0.764±0.271	1.907±0.117	0.98
	$BL \rightarrow WW$	-2.660±0.271	1.906±0.117	0.98
Trichoptera	$BL \rightarrow WW$	-0.939±0.403	2.182±0.165	0.96
	$BL \rightarrow WW$	-2.048±0.403	2.182±0.165	0.96
Caseless Trichoptera	$BL \rightarrow WW$	0.502±0.364	1.379±0.151	0.93
	$BL \rightarrow WW$	-1.157±0.364	1.379±0.152	0.93
Cased Trichoptera	$BL \rightarrow WW$	-0.373±0.358	2.083±0.144	0.97
	$BL \rightarrow WW$	-1.148±0.358	2.083±0.144	0.97
Coleoptera				
Adult	$BL \rightarrow WW$	-1.084±0.230	2.318±0.169	0.99
Oligochaeta	$BL \rightarrow WW$	-2.649±0.570	2.035±0.156	0.91
	$BL \rightarrow WW$	-4.420±0.570	2.035±0.156	0.91
Amphipoda	$BL \rightarrow WW$	-1.271±0.279	2.059±0.141	0.98
	$BL \rightarrow WW$	-3.390±0.279	2.059±0.141	0.98

[a] *r*: Correlation coefficient, *SE*: Standard Error of the estimate.

Table 4. Results of the general regression equations for benthic invertebrates of Elarm River.

Taxon	Conversion	Regression constants		***r***
		ln *a*±*SE*	*b*±*SE*	
All taxa	$BL \rightarrow WW$	-0.073±0.24	1.365±0.078	0.93
	$BL \rightarrow WW$	-2.062±0.295	1.431±0.096	0.96

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Table 5. Mean values of the proportion of Dry-to-Wet Weight (PDW) for selected taxa of benthic invertebrates in Elarm River.

Taxon	$PDW \pm SD^a$
Diptera	0.12±0.07
Simuliidae	0.07±0.06
Chironomidae	0.06±0.05
Tipulidae	0.16±0.14
Pupae of Diptera	0.07±0.08
Adult Diptera	0.22±0.19
Ephemeroptera	0.11±0.08
Baetidae	0.08±0.05
Heptageniidae	0.15±0.10
Trichoptera	0.33±0.16
Caseless Trichoptera	0.19±0.10
Cased Trichoptera	0.47±0.07
Oligochaeta	0.17±0.07
Amphipoda	0.12±0.11

[a] *SD*: Standard Deviation.

DISCUSSION

Length-weight relationships are a useful tool in ecological research. Estimating weight indirectly from linear body measurements is less time consuming than direct weight determination, particularly for smaller invertebrates. Body length is widely used for determining length–weight relationships of aquatic invertebrates (Smock, 1980; Towers *et al*., 1994; Burgherr and Meyer, 1997) mainly because it has a larger measuring range than other linear body dimensions like head capsule width and interocular distance, and allows to analyze size distribution pattern of invertebrate taxa (González *et al*., 2002).

In our study, relationships between body length and weight (both wet and dry weight) for the most common benthic invertebrates of a mountain river in the LNP of Iran were obtained for the first time (Tables 3 and 4). We found that Diptera, Ephemeroptera and Trichoptera orders were the most important faunal groups in terms of both abundance and weight in Elarm River, which is consistent with findings from previous studies (Abdoli *et al*., 2016; Salavatian, 2012).

Our estimate for the mean value of *PDW* supports that of Seiz (2011) who suggested that, for benthic invertebrates, dry weight is 15% of wet weight.

In this study, the value of b for different orders and families of benthic invertebrates was less than the expected value 3 (Table 3), which means that body weight of these invertebrates is more influenced by surface than by volume (Engelmann, 1961). It has been suggested that b is likely to be closer to a value of 2 for organisms that are relatively flattened; i.e., those that are more 2-dimensional than 3-dimensional (Wenzel *et al*., 1990; Towers *et al*., 1994). For all benthic invertebrates of this study, including insects and non-insects, we found no marked difference in regression slope (b value) and r values between regressions in terms of wet and dry weight. Regression equations obtained in this study for three major orders of aquatic invertebrates were compared to those in previous studies from different geographical locations (Table 6).

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The "b" values we obtained were most similar to those found for New Zealand (Towers *et al*., 1994). The direct between-study comparisons in Table 6 suggest that sample size, body length range, differences in the physical-chemical environment and trophic conditions can influence the outcome of the length–weight relationship considerably, as also argued elsewhere (Giustini *et al*., 2008; Benke *et al*., 1999). Variation among length-weight relationships may also be attributable to methodological differences in the development or application of the relationships; and true spatio-temporal or taxonomic variation in weight at length (Johnston and Cunjak, 1999).

The variability among model predictions indicate that relationships obtained for aquatic invertebrates in a specific area are not transferable to other study sites and length-weight equations should be developed for the taxon and habitat under study. Our equations will enable river ecologists to derive biomass estimates for benthic invertebrates of similar Iranian running waters rapidly and economically. The taxa found in Elarm River are representative of the benthos of rivers in LNP in the Southern Caspian Sea Basin and regression equations developed in this study may be used for ecological studies of rivers in the Southern Caspian Sea Basin. Further investigation is needed on length-weight relationships within aquatic families and orders not studied here.

Table 6. Regression coefficients for the relationships between body length and dry weight of individuals grouped according to the three major orders of aquatic invertebrates in the present and previous studies.[a]

Order	Regression constants		Range	*n*	Region	Reference
	ln *a*	*b*				
Diptera	-2.397±0.263	1.32±0.12	2.0-21.0	511	Iran	This research (2018)
	-5.221±0.588	2.43±0.15	2.3-68.1	136	North America	Smock (1980)
	-6.210±0.210	2.52±0.01	1.2-46.7	133	Europe	Burgherr and Meyer (1997)
	-4.730±0.170	2.36±0.09	2.0-23.0	118	South America	Miserendino (2001)
	-2.878±0.180	1.24±0.10	2.1-16.8	62	New Zealand	Towers *et al*. (1994)
Ephemeroptera	-3.512±0.349	2.06±0.16	3.0-18.0	196	Iran	This research (2018)
	-5.021±0.095	2.88±0.07	1.1-24.1	459	North America	Smock (1980)
	-6.560±0.210	3.41±0.10	1.2-16.0	122	Europe	Burgherr and Meyer (1997)
	-6.980±0.280	3.51±0.14	2.5-15.0	128	South America	Miserendino (2001)
	-4.645±0.215	2.70±0.09	3.9-19.5	195	New Zealand	Towers *et al*. (1994)
Trichoptera	-2.048±0.403	2.18±0.17	5.0-19.0	183	Iran	This research (2018)
	-6.266±0.693	3.12±0.29	3.2-25.0	232	North America	Smock (1980)
	-6.037±0.390	2.82±0.16	3.7-24.8	80	Europe	Burgherr and Meyer (1997)
	-5.040±0.260	2.72±0.13	1.5-13.0	92	South America	Miserendino (2001)
	-4.894±0.268	2.44±0.12	1.3-25.0	133	New Zealand	Towers *et al*. (1994)

[a] Values for the constants ln a and b were reported with standard error of the estimate in all references except Smock (1980) who reported regression constants with 95% confidence intervals. Range= Range of body length; n= Number of individuals used to calculate each regression, *SE*: Standard Error of the estimate.

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REFERENCES

1. Abdoli, A., Azizi, Z., Kiabi, B., Mashhadi Ahmadi, A. A. and Golzarianpour, K. 2016. Study of Summer Food Habits of the Brown Trout, *Salmo trutta fario,* in Lar Dam Lake and Streams in Lar National Park. *J. Fish. Sci. Tech*., **5(3):** 1-17. (in Persian)
2. Adams, J. and Vaughan, M. 2003. *Macroinvertebrates of the Pacific Northwest. A Field Guide*. The XERCES Society, Portland.
3. Beauchene, M. 2016. *Macroinvertebrate Field Identification Cards, CT DEEP Riffle Bioassessment by Volunteers (RBV) Program*. CT Dept. of Energy and Environmental Protection, Hartford, Connecticut.
4. Becker, B., Moretti, M. S. and Callisto, M. 2009. Length-Dry Mass Relationships for a Typical Shredder in Brazilian Streams (Trichoptera: Calamoceratidae). *Aquat. Insects*, **31(3**): 227-234.
5. Benke, A. C., Huryn, A. D., Smock, L. A. and Wallace, J. B. 1999. Length-Mass Relationships for Freshwater Macroinvertebrates in North America with Particular Reference to the Southeastern United States. *J. N. Am. Benthol. Soc.*, **18(3):** 308-343.
6. Bouchard, R. W. Jr. 2004. *Guide to the Aquatic Macroinvertebrates of the Upper Midwest*. Water Resources Center, University of Minnesota, St. Paul, MN.
7. Bouchard, R. W. Jr. 2012. *Guide to Aquatic Invertebrates Families of Mongolia*. Saint Paul, Minnesota, USA.
8. Burgherr, P. and Meyer, E. I. 1997. Regression Analysis of Linear Body Dimensions vs. Dry Mass in Stream Macroinvertebrates. *Arch. Hydrobiol.,* **139:** 101-112.
9. Dermott, R. M. and Paterson, C. G. 1974. Determining Dry Weight and Percentage Dry Matter of Chironomid Larvae. *Can. J. Zool.,* **52:** 1243-1250.
10. Engelmann, M. D. 1961. The Role of the Soil Arthropods in the Energetic of an Old Field Community. *Ecol. Monogr.,* **31(3):** 221-238.
11. Esteve, M., Abdoli, A., Hashemzadeh Segherloo, I., Golzarianpour, K. and Ahmadi, A. A. 2018. Observation of Male Choice in Brown Trout (Salmo trutta) from Lar National Park, Iran. In: "*Brown Trout: Biology, Ecology and Management*", (Eds.): Lobón-Cerviá, J. and Sanz, N. John Wiley and Sons Ltd. PP.165-178.
12. Giustini, M., Miccoli, F. P., Luca, G. D. and Cicolani, B. 2008. Length-Weight Relationships for Some Plecoptera and Ephemeroptera from a Carbonate Stream in Central Apennine (Italy). *Hydrobiologia*, **605:** 183-191.
13. González, J. M., Basaguren, A. and Pozo, J. 2002. Size-mass Relationships of Stream Invertebrates in a Northern Spain Stream. *Hydrobiologia*, **489:** 131-137.
14. Hajiesmaeili, M., Ayyoubzadeh, S. A., Sedighkia, M. and Kalbassi, M. R. 2014. Physical Habitat Simulation of Rainbow Trout in Mountainous Streams of Iran. *J. Bio. Env. Sci.*, **5(4):** 497-503.
15. Haney, J. F. 2013. *An Image-Based Key to Stream Insects, Beta Version 1.0 Released 2013*. University of New Hampshire Center for Freshwater Biology <cfb.unh.edu> 5 Jan. 2018.
16. Heydarnejad, M. S. 2010. Length-Weight Relationships for Aquatic Beetles (Coleoptera) in a Marsh in Iran. *Acta. Entomol. Sinica*, **53(8):** 932-935.
17. Howmiller, R. I. 1972. Effects of Preservatives on Weights of Some Common Macrobenthic Invertebrates. *Trans. Am. Fish. Soc.*, **101:** 743-746.
18. Johnston, T. A. and Cunjak, R. A. 1999. Dry Mass-length Relationships for Benthic Insects: A Review with New Data from Catamaran Brook, New Brunswick, Canada. *Freshwat. Biol.,* **41:** 653-674.

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19. Kiyak, S., Canbulat, S. and Salur, A. 2007. Nepomorpha (Heteroptera) Fauna of South-Western Anatolia (Turkey). *Bol. Soc. Entomol. Aragonesa*, **40:** 548-554.
20. Leuven, R. S. E. W., Brock, T. C. M. and Van Druten, H. A. M. 1985. Effects of Preservation on Dry- and Ash-free Dry Weight Biomass of Some Common Aquatic Macro-invertebrates. *Hydrobiologia*, **127(2):** 151-159.
21. McCafferty, W. P. 1981. *Aquatic Entomology*. Jones and Bartlett Publishers, USA, 449 PP.
22. Meyer, E. 1989. The Relationship between Body Length Parameters and Dry Mass in Running Water Invertebrates. *Arch. Hydrobiol.*, **117:** 191-203.
23. Miserendino, M. L. 2001. Length-Mass Relationships for Macroinvertebrates in Freshwater Environments of Patagonia (Argentina). *Ecol. Austral.*, **11:** 3-8.
24. Nakagawa, H. and Takemon, Y. 2015. Length-Mass Relationships of Macro-Invertebrates in a Freshwater Stream in Japan. *Aquat. Insects: Int. J. Freshwat. Entomol.* **36**: 53-61
25. Needham, J. G. and Needham, P. R. 1941. *A Guide to the Study of Fresh-Water Biology*. Fourth Edition, Comstock Publishing Company, INC, New York.
26. Railsback, S. F., Harvey, B. C. and Sheppard, C. 2011. *inSTREAM: The Individual-Based Stream Trout Research and Environmental Assessment Model, Version 5.0*.
27. Rajabei Nezhad, R. 2007. Study of Density, Distribution and Yield on Benthic Fauna and Brown Trout (*Salmo trutta fario*) Feeding in Lar Reservoirs. PhD. Thesis, Research and Science Branch, Islamic Azad University. (in Persian).
28. Ross, D. H. 1982. Production of Filter-Feeding Caddisflies (Trichoptera) in a Southern Appalachian Stream System. PhD. Dissertation, University of Gorgia, Athens.
29. Sabo, J., Bastow, J. L. and Power, M. E. 2002. Length-Mass Relationships for Adult Aquatic and Terrestrial Invertebrates in a California Watershed. *J. N. Am. Benthol. Soc.*, **21(2):** 336-343.
30. Salavatian, S.M. 2012. Identification of Benthic Macroinvertebrates in Rivers Entering to Lar Dam Lake. *Lahijan J. Env. Sci.*, **1(4):** 67-78. (in Persian)
31. Seiz, A. 2011. *Benthic Invertebrate Community Composition in Four Stream across a Restoration Intensity Gradient.* Department of Biology, Clark University, Worcester, MA, USA 01610.
32. Smock, L. A. 1980. Relationships between Body Size and Biomass of Aquatic Insects. *Freshwat. Biol.*, **10:** 375-383.
33. Towers, D. J., Henderson, I. M. and Veltman, C. J. 1994. Predicting Dry Weight of New Zealand Aquatic Macroinvertebrates from Linear Dimensions. *N. Z. J. Mar. Freshwat. Res.*, **28:** 159-166.
34. Usinger, R. L. 1956. *Aquatic Insects of California*. University of California Press, Berkeley and Los Angeles, California.
35. Wenzel, F., Meyer, E. and Schwoerbel, J. 1990. Morphometry and Biomass Determination of Dominant Mayfly Larvae (Ephemeroptera) in Running Waters. *Arch. Hydrobiol.*, **118:**31-46.

روابط طول- وزن بی‌مهرگان کفزی رودخانه‌ای کوهستانی در حوضه جنوبی دریای خزر، ایران

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چکیده

زیست‌توده پارامتری مهم در مطالعه فرآیندهای انتقال انرژی زنجیره‌های غذایی و همچنین ساختار اجتماعی و ترکیب موجودات آبزی می‌باشد. تعیین زیست‌توده بر اساس اندازه‌گیری مستقیم وزن جانوران، روش حجمی، و تبدیل طول-وزن می‌باشد. اگرچه اندازه‌گیری مستقیم وزن هر یک از ارگانیسم‌ها صحیح‌ترین روش می‌باشد، اما به دلیل زمان‌بر بودن آن کاربرد این روش رایج نیست. روابط رگرسیونی طول- وزن به دلیل سرعت و دقت آن‌ها نسبت به سایر روش‌ها، رایج‌ترین رویکرد مورد استفاده برای برآورد زیست‌توده بی‌مهرگان کفزی می‌باشند. در این تحقیق روابط طول- وزن رایج‌ترین کفزیان شناسایی‌شده در رودخانه‌ای کوهستانی در ایران واقع در حوضه جنوبی دریای خزر با استفاده از برازش تابعی توانی (خطی‌شده از طریق تبدیل لگاریتمی) بر داده‌های وزن تر و خشک در برابر طول بدن بی‌مهرگان آبزی در دو سطح خانواده و راسته توسعه داده شده‌اند. یک رابطه عمومی نیز بر اساس داده‌های کل کفزیان شناسایی شده در تحقیق توسعه داده شده است. روابط توسعه داده شده در سطح $P<0.05$ معنی‌دار بودند و ضریب همبستگی روابط در محدوده ۰/۹۹- ۰/۸۲ بود. روابط رگرسیونی حاصل از تحقیق حاضر برای سه راسته عمده از بی‌مهرگان آبزی با روابط سایر تحقیقات انجام شده در مناطق جغرافیایی مختلف مورد مقایسه قرار گرفت. روابط توسعه داده شده در این تحقیق در بررسی‌های آینده ساختار جمعیت کفزیان و نیز درک اهمیت این بی‌مهرگان در انتقال انرژی رودخانه مفید خواهد بود.

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