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Original Article

Does length-weight equation fit clupeid fishes? An evaluation of LWRs for six clupeids from Iran (Teleostei: Clupeiformes)

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Abstract: This study investigates length–weight relationships of six clupeid species (*Alosa braschnikowi*, *Alosa caspia*, *Dussumieria acuta*, *Nematalosa nasus*, *Sardinella albella* and *Tenualosa ilisha*) captured from three main water bodies of Iran (Persian Gulf, Oman Sea and Caspian Sea), to evaluate if the LWR parameters fit for these fishes having specific morphological characteristics. Based on the obtained results, i) the *b* value was influenced by recorded length (TL, SL, FL) and body shape, ii) it was within the expected range of 2.27–3.48, iii) length–weight relationships were highly correlated and significant (r^2>0.82-0.98, *P*<0.001), and hence length-weight equations fit well with six clupeid species in the Iranian water bodies. The results presented here, would be useful for fishery biologists and fisheries stake-holders in the study area.

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Introduction

Length-weight relationships (LWRs) have been implemented to assess status of fish populations in fisheries since the beginning of the 20th century (Froese, 2006; Jellyman et al., 2013). LWR presents how fish weight changes as a function of length, and it provides essential information for fisheries scientists trying to infer age structure (Jellyman, 1997), to estimate growth rates (Hansen and Closs, 2009), to model bioenergetics (Hayes et al., 2000; Booker et al., 2004) or to quantify some other aspects of fish population dynamics (Safran, 1992). It also provides suitable data to determine breeding season, feeding state, fatness, the suitability of environment and gives knowledge of species ecology (Al-Jebory et al., 2018). Moreover, LWRs are required for assessing biomass of a fish community using only length and species data (Greig et al., 2010), estimating fish condition factor (Hiddink et al., 2011) and constructing comparisons of life history characteristics of fish (Fonseca and Cabral, 2007). Length and weight of fishes are related to each other and can be estimated by having one in hand. Therefore, these equations are useful during field studies to convert length into weight (Esmaeili and Ebrahimi, 2006; Valinassab et al., 2012; Esmaeili et al., 2014, 2015; Sayyadzadeh and Esmaeili, 2016; Jafari-Patcan et al., 2018) or any measured length to another (e.g. TL to SL) (Zareian et al., 2018; Mouludi-Saleh et al., 2019). Fish length is often more quickly and reliably measured than fish weight (Le Cren, 1951).

Some previous studies have provided LWRs for some clupeid species (see Samsun, 1995; Tarkan et al., 2006; Erguden et al., 2011; Yılmaz and Polat, 2011; Saç, 2012; Aydoğan and Özuluğ, 2020). The family Clupeidae with about 198 species (Fricke et al., 2020), with many important food fishes in the world, are commonly caught for production of fish oil and fish meal. Here, the objective of this paper is to provide LWRs of six species of this family from the

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Persian Gulf, Oman Sea and Caspian Sea to evaluate if the LWR parameters fit for these fishes with specific morphological characteristics.

Materials and Methods

Fish specimens were caught from 2016 to 2019 from three main water bodies, including the Persian Gulf, Oman Sea (both in the south) and the Caspian Sea in the north of Iran (Fig. 1). Specimens washed with freshwater and dried with paper. Total length (TL), fork length (FL), and standard length (SL) were measured to the nearest 0.05 mm, and weight (W) was measured to the nearest 0.001 g. Then they were preserved in 5% formaldehyde solution and deposited in ZM–CBSU, Zoological Museum, Collection of Biology Department, Shiraz University.

The parameters of the length–weight relationship $W = aL^b$ were estimated by linear regression of the log-transformed weight and length, where W is weight and L is length (TL, FL or SL), *a* the intercept, and *b* the regression slope (Koutrakis and Tsikliras, 2003). Firstly, log-log plots of length and weight values were conducted for visual inspection of outliers (Froese, 2006). In addition, 95% Confidence Intervals (CI) for *a* and *b* were estimated. Based on the slope (*b*) of the LWR, one can estimate whether fish growth is isometric ($b=3$, all fish dimensions increase at the same rate), hypoallometric ($b<3$) or hyperallometric ($b>3$). Exploring which growth (i.e., isometric or allometric) is presented by a provided species gives assumption on how fish body proportions may differ at a given geographic zone or throughout a specific season (Froese, 2006).

Materials used for LWR: *Alosa braschnikowi* ZM-CBSUX013-1 to 23, X029-1 to 14, X032-1 to 5, X034-1 to 3, X061-1 to 8; 3.83-394.5 g, 7.91-33.70 cm (Fig. 1A); *Alosa caspia* ZM-CBSUX015-1 to 8, X035-1 to 9, X063-1 to 2; 12.16-385.70g, 11.96-34.70cm (Fig. 1B); *Dussumieria acuta* ZM-CBSUX047-1 to 9, X042-1 to 31; 10.41-36.75 g, 11.75-17.75 cm (Fig. 1C); *Nematalosa nasus* ZM-CBSUX010-1 to 19, X011-1 to 17, X016-1 to 8, X046-1 to 7; 35.30-91.50 g, 15.24-21 cm (Fig. 1D); *Sardinella albella* ZM-CBSUX001-1 to 9, X018-1 to 12; 5.82-18.79 g, 9.12-13.70 cm (Fig. 1E); *Tenualosa ilisha* ZM-CBSUX003-1 to 10, X012-1 to 13; 66.20-205.20 g, 19.90-28.80 cm (Fig. 1F).

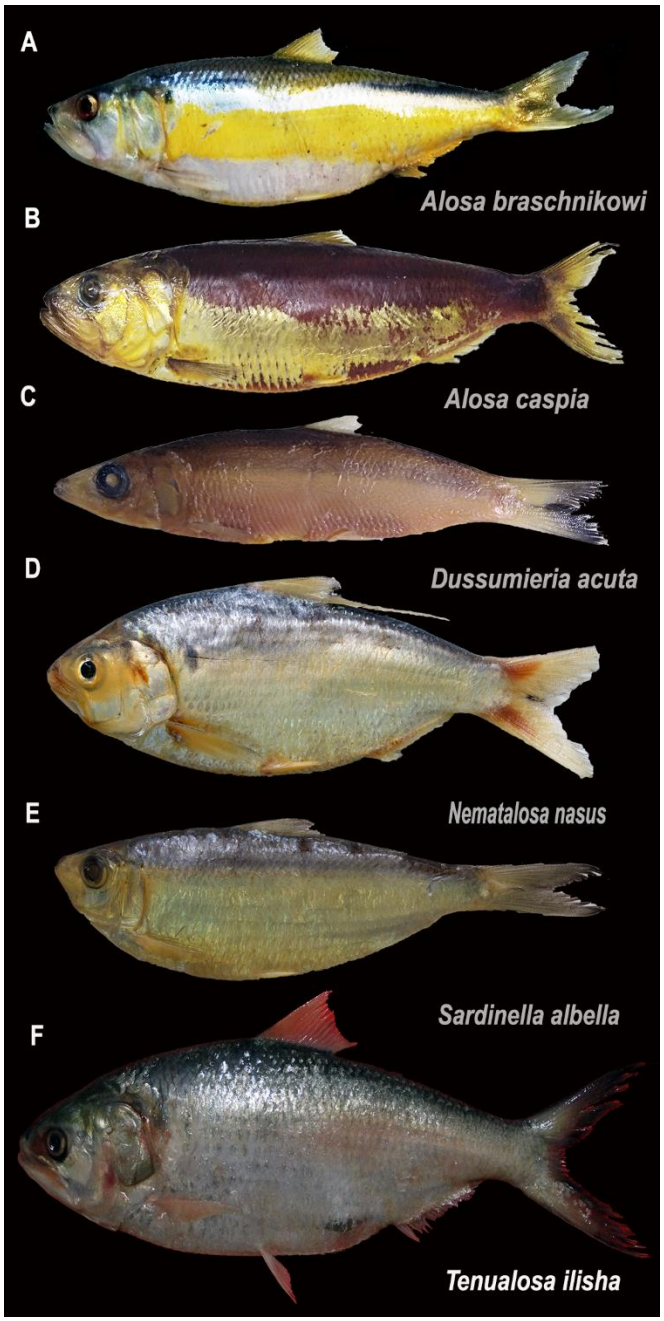

Figure 1. Six studied clupeid species from the Persian Gulf, Oman Sea and Caspian Sea.

Results

A total of 194 fishes with TL ranging from 7.91 to34.8 cm (19.26±6.56) and W from 3.83 to 394.50 g (82.96±78.18 SE) were studied for LWRs (Table 1). Principal estimated parameters of LWRs between fish

Table 1. Principal parameters and linear relations (y = a + bx) between total length and whole wet weight for the 6 clupeids, from Iran. (TL = total length; FL= fork length; SL= standard length; W = fish wet weight, a = intercept value; b = regression slope; r^2 = coefficient of determination; N = number of fish sampled; min = minimum; max = maximum, 95% CI= 95% confidence limit).

Species	Locality	N	W (g), (min – max)	Length (min-max)		Regression parameters			95% CL of *b*	95% CL of *a*
						a	*b* (se)	r^2		
Alosa braschnikowi (Borodin, 1904)	Caspian Sea, Anzali	51	128.95 (3.83-394)	SL	18.10 (6.42-28.10)	0.01148	3.08 (0.09)	0.95	2.90-3.27	0.006-0.019
				TL	22.55 (7.91-33.70)	0.00549	3.11 (0.06)	0.98	2.98-3.23	0.003-0.007
				FL	20.02 (7.15-30.40)	0.00691	3.15 (0.06)	0.98	3.02-3.28	0.004-0.010
Alosa caspia (Eichwald, 1838)	Caspian Sea, Anzali	18	109.37 (12.16-385.7)	SL	18.28 (9.37-27.7)	0.01047	3.11 (0.12)	0.97	2.84-3.38	0.004-0.022
				TL	22.51 (11.69-34.8)	0.00467	3.16 (0.14)	0.96	2.85-3.47	0.001-0.012
				FL	19.90 (10.48-30.6)	0.00537	3.25 (0.14)	0.96	2.93-3.56	0.002-0.013
Dussumieria acuta Valenciennes, 1847	Persian Gulf, Bandar Abbas	32	19.03 (10.41-36.75)	SL	11.44 (9.20-14.64)	0.07079	2.27 (0.11)	0.93	2.04-2.51	0.040-0.125
				TL	14.31 (11.75- 17.75)	0.01479	2.68 (0.10)	0.95	2.46-2.90	0.008-0.026
				FL	12.49 (10.10-15.60)	0.04786	2.36 (0.11)	0.92	2.11-2.60	0.025-0.087
Nematalosa nasus (Bloch 1795)	Persian Gulf, Bandar Abbas and Bushehr	49	64.82 (35.3-91.50)	SL	14.22 (11.07- 16.31)	0.10715	2.41 (0.0.16)	0.82	1.77- 2.62	0.043-0.254
				TL	18.40 (14.16- 21)	0.02137	2.75 (0.12)	0.91	2.70- 3.27	0.010- 0.043
				FL	15.74 (13.32-18.20)	0.01548	3.01 (0.19)	0.83	2.62-3.41	0.005-0.046
Sardinella albella (Valen ciennes 1847)	Persian Gulf, Bandar Abbas	21	12.37 (5.82-18.89)	SL	8.86 (6.88-10.81)	0.01949	2.93 (0.12)	0.96	2.67-3.18	0.011-0.033
				TL	11.56 (9.12- 13.70)	0.00660	3.05 (0.12)	0.97	2.80- 3.30	0.003-0.011
				FL	9.67 (7.42-11.36)	0.01096	3.07 (0.13)	0.96	2.78-3.35	0.005-0.021
Tenualosa ilisha (Hamilt on 1822)	Persian Gulf, Abadan	23	152.35 (66.2-199.70)	SL	20.05 (15.04-23.80)	0.03801	2.75 (0.18)	0.91	2.12-3.19	0.011-0.12
				TL	25.16 (19.90-28.80)	0.00194	3.47 (0.18)	0.94	2.94-3.67	0.001-0.0067
				FL	21.91 (17.42-24.90)	0.00316	3.48 (0.19)	0.95	3.07-3.87	0.009-0.010

lengths (TL, FL and SL) and wet weight for the 6 clupeids are presented in Table 1. The results indicated that the length-weight relationships for all studied species were highly correlated and significant (r^2>0.82-0.98, P<0.001). In the present study, the mean *b* value (based on TL) varied from a minimum of 2.68 for *D. acuta* to 3.47 for *T. ilisha*. In all fishes, except *D. acuta* the mean *b* values (based on FL) are greater than those for SL and TL (Table 1).

Discussion

This work provides LWR for 6 clupeid fishes of the genera *Alosa*, *Dussumieria*, *Nematalosa, Sardinella* and *Tenualosa* from Iran. For all species investigated during this study, the coefficient (*b*) of LWR is within the expected range of 2.27-3.48 as supposed by Froese (2006). The slope (*b*) of the length-weight relationships for all 6 species fell within the expected range of 2.68–3.47 for TL, varying from a minimum of 2.68 for *D. acuta* to a maximum of 3.47 for *T. ilisha*; 2.36–3.48 for FL, varying from a minimum of 2.36 for *D. acuta* to a maximum of 3.48 for *T. ilisha*; 2.27–3.11 for SL, varying from a minimum of 2.27 for *D. acuta* to a maximum of 3.11 for *A. caspia*. The *b* parameter of the length-weight relationships of fishes are influenced by a number of factors, including health, nutrition, habitat, area, environmental conditions (such as salinity and temperature), season, sex, gonad development, level of stomach fullness, variations in the length range of the caught specimen and fishing

gear (Tesch, 1971; Froese, 2006; Moradinasab et al., 2012; Keivany et al., 2016).

LWR is also related to fish body shape. There is great variation in body shape and depth (round-bodied to strongly compressed and deep) of clupeid fishes. As a general rule, eel-like fishes show smaller *b* value. According to Jellyman et al. (2013) based on 285,124 fish records, Anguillidae and Geotriidae were classified as 'eel-like', Pleuronectidae as 'compressed' body shape, Cyprinidae and Poeciliidae as 'short and deep' and the remaining studied families were considered to have 'fusiform' shape. In study of LWR for the spiny eel, *Macrognathus pancalus,* the pool data for the co-efficient of regression (*b*) was recorded as 1.408 in juveniles; 2.977 in males and 3.034 in females (Abujam and Biswas, 2016). In the present study, minimum mean *b* value (based on TL) belongs to *D. acuta* (2.68) with fusiform body shape, and maximum belongs to *T. ilisha* (3.47) with short, deep and almost laterally compressed body form (Fig. 1) revealing relationship of *b* value and body shape. According to Erguden et al. (2011), in some other clupeid fishes, the coefficient *b* ranged from a minimum 2.97 for females of *Alosa immaculata* to a maximum 3.75 for both sexes *A. c. caspia*. The mean *b* values for two other clupeid fishes were also in the expected range of 2.4-3.5 (varied from 3.177 to 3.496, for different populations of *C. cultriventris* and 3.258 for *C. muhlisi*) (see Aydoğan and Özuluğ, 2020).

For all species, r^2 values were high (r^2>0.82-0.98, *P*<0.001). It has been reported that r^2 values less than 0.8 are associated with either low numbers of individuals or a limited size range (see Jellyman et al., 2013) which was not observed for the studied species here.

Based on the results of present study, i) the *b* value is influence by recorded length (TL, SL, FL), ii) the *b* value is influence body shape, iii) it is within the expected range of 2.27–3.48 as supposed by Froese (2006), iv) length–weight relationships were highly correlated and significant (r^2>0.82-0.98, *P*<0.001), and hence length-weight equations fit with for six clupeid species in the Iranian water bodies. The results presented here would be useful for fishery biologists and managers in the studied area.

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