LENGTH–WEIGHT RELATIONS OF EIGHT FISH SPECIES FROM A SMALL CARIBBEAN COASTAL LAGOON, MEXICO

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Abstract. Due to the importance of the estuarine fish fauna in Mexico and the implications of length–weight relation (LWR) for management and conservation, we present the estimates of the LWR for eight fish species from Rio Huach, a small estuarine system of the Mexican Caribbean. Fishes were caught in five sampling points during an annual cycle (1998) and in November of 2000, were measured with a digital calliper and weighed with a digital balance to obtain the standard length (SL) and weight (*W*). The LWR were obtained with two estimation methods: standardized major axis (SMA) and ordinary least squares (OLS). A total of 678 specimens were suitable for analysis. The estimates of LWR for *Bathygobius soporator* (Valenciennes, 1837) and *Cyprinodon artifrons* Hubbs, 1936 are presented here for first time, and for four species statistical differences with previous estimations of LWR were found (considering one or both estimation methods). With these results, the knowledge of LWR for tropical fish species is increasing and the importance of considering the estimation of LWR parameters using the standardized major axis method is discussed.

Keywords: Estuarine fishes, length–weight relations, regression methods, Mexican Caribbean

Coastal lagoons of Mexico are inhabited by a wide variety of organisms including fish. The latter are important not only for their diversity and the numbers but also for their ecological role in this type of environments (Castro-Aguirre et al. 1999). Despite the importance of estuarine fish fauna of Mexico and the implications of the knowledge of the length–weight relation (LWR) in areas related to the management and conservation of fish species (Froese 2006, Froese et al. 2011), the information available to the Mexican species is still limited (Gonzalez et al. 2004, Velázquez-Velázquez et al. 2009, De La Cruz Agüero et al. 2011, Vega-Cendejas et al. 2012).

In this paper we present the LWR for eight selected species in Rio Huach, a small estuarine lagoon system of southern Quintana Roo (Mexico), bordered to the east by the Caribbean Sea and to the west by the Bay of Chetumal. Its permanent channel, 1.5 km long, connects the lagoon with the Caribbean Sea between 18°24′07″N and 87°46′41″W. The approximate area of the lagoon is 148 058 m^2 and the only freshwater supply system is through rainfall (Avilés-Torres unpublished[**]).

Eight fish species were selected for this study: Hardhead silverside, *Atherinomorus stipes* (Müller et Troschel, 1848); frillfin goby, *Bathygobius soporator* (Valenciennes, 1837); Yucatan pupfish, *Cyprinodon artifrons* Hubbs, 1936; silver mojarra, *Eucinostomus argenteus* Baird and Girard, 1855; slender mojarra, *Eucinostomus jonesii* (Günther, 1879); ocellated killifish, *Floridichthys polyommus* Hubbs, 1936; redear herring, *Harengula humeralis* (Cuvier, 1829); scaled herring, *Harengula jaguana* Poey, 1865. The fish were collected during an annual cycle (1998), but the months of October and November of 2000 were also included. Five fixed sampling points along the lagoon system were considered and fish were sampled with the help of a beach seine (20 m long, 1.5-m drop, and 1-cm mesh) and a cast net (3 m in diameter, one high and 25-mm mesh). The fish collected were fixed with 10% formalin (neutralized with local water) for their later transfer to the laboratory.

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For each individual fish, the size (standard length, SL) was recorded with a digital calliper to the nearest 0.01 mm, while the weight (*W*) was measured using a 0.01-g precision electronic balance. The LWR was estimated according to recommendations given by Froese (2006) and Froese et al. (2011). Only species represented by more than 30 individuals in the total sample were considered in the analyses.

In order to estimate the regression parameters, first the two variables: SL [cm] and *W* [g] were transformed to logarithmic scale (base 10) and the presence of influential points (outliers) was detected through inspection of the corresponding scatter plot, which allowed to exclude these values from subsequent analysis.

The estimation of the regression parameters for the line of best fit was performed through the standardized major axis (SMA) method, rather than ordinary least squares (OLS), for the following reasons: the measured fish comprise a random sample, instead of a representative one of the size range of the included species; both variables (SL and *W*) are subject to natural variation and/or measurement error, which means that SL is not under the control of the observer; the purpose of the regression is to estimate the parameters of the structural relation between SL and *W*, rather than predicting *W* from SL and the slope (*b*) is used to interpret patterns of change in *W* with changes in SL (Laws and Archie 1981, Warton et al. 2006, Smith 2009).

Calculations of the slope (*b*), the intercept (*a*) and their 95% confidence limits, were performed using the program PAST version 2.17 (Hammer et al. 2001), using bootstrapping in the case of SMA.

A total of 678 specimens (all juveniles), comprising eight species, representing five families, were suitable for analysis. Tables 1 and 2 provides information on sample sizes, the coefficient of determination as a measure of goodness of fit, the regression parameters and their 95% confidence intervals. In this work, the LWR was obtained in an unconventional way: first, we used a model II regression method (SMA) to estimate the parameters of the line of best fit; second, 95 % bootstrapped confidence intervals were used to estimate the slope and the intercept. However, the estimates obtained with ordinary least squares were also included to facilitate comparison with previous estimations.

Length–weight regressions were significant in all cases ($P < 0.001$), with a goodness of fit between 81% and 98%. For two species (*Cyprinodon artifrons*, *Bathygobius soporator*) the parameters of the LWR are presented for first time (Table 2). For four species (*Atherinomorus stipes*, *Eucinostomus jonesii*, *Floridichthys polyommus*, and *Harengula humeralis*) the coefficient *b* was statistically different from 3.0, considering both estimation methods, thus indicating an allometric relation between *W* and SL.

The cases of *A. stipes* and *E. jonesii* stand out in the presently reported study, because their corresponding 95% confidence intervals of parameter *b* enclose higher

Table 1

Basic information on eight fish species from Rio Huach, Mexico

Species	*n*	SL [cm]	*W* [g]
Atherinomorus stipes	246	2.1–4.2	0.10–1.50
Bathygobius soporator	43	2.9–7.2	0.50– 6.70
Cyprinodon artifrons	52	2.4–3.4	0.60–1.90
Eucinostomus argenteus	58	3.4–9.7	0.60–18.30
Eucinostomus jonesii	46	2.9–6.1	0.40–4.50
Floridichthys polyommus	89	2.1–5.1	0.30–4.90
Harengula humeralis	112	3.7–4.5	0.70–1.60

n = sample size, SL = standard length, *W* = weight.

values in comparison to those found in scientific literature and electronic databases (De La Cruz-Agüero et al. 2011, Froese and Pauly 2012). The differences indicated here could be related to ontogenetic changes in the LWR for these species, since we used only juvenile specimens in the analysis.

For *H. humeralis* we found statistical differences with previous reports (Froese and Pauly 2012) with the estimates produced by SMA method only, while for *F. polyommus* the estimates provided here are lower than those reported by Vega-Cendejas et al. (2012), although the statistical differences are only appreciated with OLS estimates. In this last case, differences in size, physiological conditions, and other biological and sampling factors between our specimens and those previously reported may explain the discrepancy in the estimates.

As a common practice, OLS method has been used for the estimation of regression parameters in LWR studies (Froese 2006, Froese et al. 2011). However, this method must be applied when the main interests are on the significance of the relation between SL and *W* (*P*- value), the prediction of *W* from SL values (interpolation) or the goodness of fit (strength) of the linear relation (Warton et al. 2006). Moreover, inference about the parameters produced by OLS estimation method have assumptions that rarely are evaluated in LWR: error term (log e) is normally distributed, with mean of zero and a constant variance; the distribution of log *W* is normal at each value of log SL; the variance of log *W* is constant across the range of log SL values and log SL is treated as an independent variable, which means that it has been measured without error (Zar 1968, LaBarbera 1989). In particular, the last point is not the usual case in allometric studies, where the LWR is included.

Therefore we recommend that, although OLS is widely used in LWR, the SMA method should be considered for the estimation of regression parameters, as well as in other allometric studies (Gould 1975, de L. Brooke et al. 1999, Hochcheid et al. 2007). The estimated values produced by OLS method can also be included (only for comparative purposes with previous studies), once their assumptions have been evaluated properly.

Table 2

Estimated parameters of length–weight relation (LWR) for eight fish species from Rio Huach,
Mexico according to ordinary least squares (OLS) and standardized major axis (SMA) estimation methods

Species	OLS				SMA				r^2	PE
	a	CI [95%]	b	CI [95%]	a	CI [95%]	b	CI [95%]		
Atherinomorus stipes	0.007	0.006–0.008	3.697	3.544–3.858	0.006	0.005–0.007	3.837	3.678–3.990	0.928	3.049 [C]
Bathygobius soporator	0.025	0.021–0.031	3.195	2.874–3.004	0.023	0.012–0.029	2.913	2.764–3.039	0.973	First time
Cyprinodon artifrons	0.041	0.034–0.051	3.009	2.883–3.280	0.037	0.030–0.041	3.191	2.972–3.381	0.940	First time
Eucinostomus argenteus	0.015	0.011–0.020	3.152	2.999–3.344	0.014	0.011–0.017	3.207	3.077–3.355	0.967	3.301 [A]
										3.380 [B]
										2.910–3.196 [C]
Eucinostomus jonesii	0.014	0.012–0.018	3.147	3.003–3.297	0.014	0.011–0.017	3.181	3.027–3.342	0.979	2.650 [B, C]
Floridichthys polyommus	0.029	0.026–0.033	3.179	3.070–3.287	0.028	0.024–0.032	3.223	3.103–3.333	0.973	3.318 [A]
Harengula humeralis	0.009	0.006–0.014	3.350	3.048–3.648	0.005	0.004–0.008	3.721	3.419–4.031	0.811	3.006–3.190 [C]
Harengula jaguana	0.011	0.006–0.019	3.200	2.831–3.583	0.008	0.005–0.015	3.410	3.040–3.760	0.881	3.550 [A]
										3.150–3.280 [C]

CI = confidence intervals, r^2 = coefficient of determination, PE = previous estimates, [A] = Vega-Cendejas et al. (2012), from Yucatan Peninsula, [B] = De La Cruz-Agüero et al. (2011), from the Atlantic versant of Mexico, [C] = Froese and Pauly (2012), from Cuba and several other areas in the Atlantic coast.

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