Length-weight relationships and condition factor of eight fish species inhabiting the Rocha Lagoon, Uruguay

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Length-weight relationships are commonly used in fisheries biology to convert length measures into weight and to ascertain the growth characteristics related to those variables. On the other hand, length-weight relationships are used for estimating fishes' condition factor, and these values are used for comparing the "condition", "fatness" or "well-being" of fish (LE CREN, 1951; FROESE, 2006). The condition factor could reflect the physiological state of a fish, which is influenced by both intrinsic (gonadal development, organic reserves, presence or absence of food in the gut) and extrinsic (food availability, environmental variability) factors (NIKOLSKY, 1969). The coastal lagoons on the south-eastern Uruguayan Atlantic coast (José Ignacio, Garzón, Rocha, Castillo, and Negra) serve as feeding (NORBIS; GALLI, 2004; OLSSON et al., 2013), reproduction (VIZZIANO et al., 2002), nursery grounds (SANTANA; FABIANO, 1999) and growing areas (BORTHAGARAY et al., 2011) for several marine and estuarine fishes which sustain local artisanal fisheries (SANTANA; FABIANO, 1999; SAONA et al., 2003; FABIANO; SANTANA, 2006). The Rocha Lagoon is a shallow, brackish, microtidal lagoon (area=72 km^2, mean depth 0.58 cm, tide amplitude <40 cm) on the southwestern coast of the Atlantic Ocean (34º33'S, 54º22'W), being part of a MaB / UNESCO Biosphere Reserve. The lagoon is separated from the sea by a sandbar parallel to the coast that opens naturally several times in the course of the year as a consequence of the action of southern storms and/or freshwater discharges due to rain or human action (CONDE et al., 2000). The intermittently open–closed bar creates a marked salinity gradient as a consequence of marine intrusion (CONDE et al., 2000). The Rocha Lagoon is highly productive and land-use changes that have occurred in the basin, as well as ongoing eutrophication and the artificial modification of the frequency of connection with the ocean, may have had a synergistic effect on its ecological functioning (BONILLA *et al.,* 2006). Fish length and weight data are scarce for Uruguayan coastal lagoons and there are no estimates of the condition factor for fishes in these ecosystems. The aim of the present study was to estimate the length-weight relationships of eight fish species of the Rocha Lagoon, caught by artisanal fisheries using different kinds of gear according to the target species, and assess the relative weight (Wr) as a condition factor for each species.

Monthly sampling was carried out in the Rocha Lagoon - Uruguay (34º33'S, 54º22'W), between November 2009 and February 2012. Fishes were caught by five multi-species fisheries that operate in different parts of the lagoon. The silverside fishery (*Odontesthes argentinensis*) used a beach seine (40 mm mesh in the wings and 10 or 20 mm at the cod ends, vertical opening 1 m, and of 200 m or 400 m length) and was directed from the coast using a boat. The mullet fishery (*Mugil liza*) was conducted from the boat, encircling the school of fish with gillnets. In the menhaden (*Brevoortia aurea*) and flatfish (*Paralichthys orbignyanus*) fisheries set gillnets were used and moved by fishermen every 12 or 24 hours (SAONA et al., 2003). The black drum (*Pogonias cromis*) was a bycatch species of the flatfish fishery. The whitemouth croaker (*Micropogonias furnieri*) was a bycatch species of all the above-mentioned fisheries (SAONA et al., 2003) and *Oligosarcus jenynsii* and *Lycengraulis grossidens* were bycatch species of the silverside fishery. Except for *B. aurea* (this species was the subject of monthly sampling to study its reproductive cycle), the remaining species were sampled opportunistically, and the pooled data of all the species were analyzed in order to minimize the effect of season, sex, age and maturity stage. The total

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length (mm) (L_T) and total body weight (g) (W_T) of all the individuals of each species were recorded.

The parameters for the equation $W_T = a\ L_T^{\ b}$ (RICKER, 1973) were estimated by linear regression, after a logarithmic transformation of the variables. Extreme outliers were removed before fitting the linear regression. The statistical significance of the slope (b), the intercept (a) and the correlation coefficient (r) using Student's *t*-test (SOKAL; ROHLF, 1995) were analyzed. In order to check whether fish growth was statistically different from isometric growth (H_0: b=3), a Student *t*-test was performed. The relative weight as condition factor (Wr) was calculated for each fish species by the following expression: $Wr = W_T/a_m L_T^{bm}$, (FROESE, 2006). The median Wr with lower and upper percentiles 25% and 75% respectively, were calculated for each species and the values compared applying the Kruskall – Wallis test non – parametric analysis of variance (SOKAL; ROHLF, 1995). In all the tests, the significance level considered was p=0.05.

A total of 2067 specimens belonging to eight fish species (Table 1) representing seven families (Engraulidae, Clupeidae, Characidae, Mugilidae, Atherinopsidae, Sciaenidae and Paralichthyidae) were used for calculation of the $L_T - W_T$ relationships (Table 1). All the estimated regression coefficients were highly significant (p<0.0001), and ranged from 2.82 for *O. argentinensis* to 3.34 for *B. aurea*. All the b values were within the expected range from 2.5 to 3.5 (FROESE, 2006). In all cases more than the 84% of W_T variability was explained by the models (Table 1). The species *M. furnieri*, *O. argentinensis* and *M. liza* grew more quickly in length than in weight (i.e. negative allometry b<3), while *B.aurea*, *P. cromis* and *P. orbignyanus* grew more rapidly in weight than in length (positive allometry b>3). For *O. jenynsii* and *L. grossidens* the growth was isometric (b=3) (Table 1).

Species such as *L. grossidens* (FROESE; PAULY, 2015), *M. furnieri* (VAZZOLER; IWAI, 1971; YAMAGUTI et al., 1973; MAGRO et al., 2000; NORBIS; VEROCAI, 2002; RODRIGUEZ DA COSTA; ARAÚJO, 2003; CAROZZA et al., 2004; CARNEIRO et al., 2005; JOYEUX et al., 2009; BORTHAGARAY et al., 2011; PASSOS et al., 2012; SEGURA et al., 2012; GURDEK; ACUÑA PLAVAN, 2014; FROESE; PAULY, 2015; GALLI; NORBIS, 2016), *O. jenynsii* (ANTONETTI et al., 2014), and *M. liza* (FROESE; PAULY, 2015) that have several published estimates of slopes, presented values within or near the confidence limits of the present study. On the other hand, *O. argentinensis* and *P. orbignyanus* that inhabit Brazilian coastal waters had comparatively higher values (HAIMOVICI; VELAZCO, 2000) than our estimates for the Rocha Lagoon. The black drum *P. cromis* had higher values than the individuals which inhabit Argentinian (URTEAGA; PERROTA, 2001) and Brazilian coastal waters (HAIMOVICI; VELAZCO, 2000). Comparing regression coefficient estimates of the present study with published values for log a vs b plot (FROESE, 2006), most of the values fell within the ellipse, except for *P. cromis*. However, the estimated parameters of length-weight relationships given in this study should be used with caution as the length ranges of the specimens available were determined by the selectivity of the fishing gear used by the artisanal fisheries that operated in the Rocha coastal lagoon (SAONA et al., 2003). Thus, the use of length-weight relationships to estimate the weight for a given length and convert length observations into weights should be done only for specimens of lengths within the length ranges used in the estimate parameters.

The highest median values of Wr (>1) were recorded for *M. furnieri*, followed by *O. argentinensis* and. *P. orbignyanus.* The lowest values of Wr (<1) were recorded for *L. grossidens,* followed by *M. liza, B. aurea, O. jenynsii* and *P. cromis* (Table 1). The condition factor is influenced by the reproduction and feeding of individuals and during the sampling period (November 2009 to February 2012), springs and summers were more numerous than autumns and winters. However, non-significant differences were found between species for Wr (Kruskall – Wallis test=2.239, p=0.945>0.05), and a high overlap was found between lower and upper percentiles (25% and 75%, respectively) for values of Wr calculated by species (Table 1). This suggests that most individuals of each of the species in the Rocha Lagoon would be found in a similar condition. This is the first study that has estimated the condition factors and length-weight regression coefficients for eight species caught by artisanal fishery in a Uruguayan coastal lagoon. Estimates of length-weight relationships are used for between habitat comparisons of the growth of a specific species as they are considered to provide an index of habitat trophic state (TSOUMANI et al., 2006). The relative weight (Wr) as a condition factor is recommended for use across populations or species (FROESE, 2006) and can provide information on the general condition of fishes in the habitat in which they live and alterations in population density. Thus, the estimated Wr for each species can provide a useful tool

Table 1. Estimated parameters of length-weight relationships and condition factor for fishes collected from Rocha Lagoon – Uruguay (Max=maximum length (cm); Min=minimum length (cm); n=number of individuals included in the analysis; a=intercept; b=slope; CI 95%=confidence interval; (0): Isometry; (+)=significant positive allometry; (-):significant negative allometry); r=correlation coefficient; r^2=coefficient of determination; Wr=Relative weight).

Fish species	Total length			Parameters length - weight relationships				Median	Percentil
	Min	Max	n	a	b ± CI 95%	r	r^2	Wr	25% - 75%
Lycengraulis grossidens	15.5	22.4	220	0.008	3.09±0.20 (0)	0.93	0.86	0.998	0.946 - 1.061
Brevoortia aurea	8.7	32.1	382	0.006	3.34±0.02 (+)	0.98	0.97	0.995	0.947 - 1.052
Oligosarcus jenynsii	12.5	22.1	92	0.011	3.10±0.30 (0)	0.92	0.85	0.987	0.915 - 1.088
Mugil Liza	4.7	37.7	254	0.019	2.87±0.03 (-)	0.99	0.99	0.997	0.959 - 1.041
Odontesthes argentinensis	11.7	26.0	602	0.015	2.82±0.09 (-)	0.95	0.90	1.003	0.945 - 1.061
Micropogonias furnieri	18.0	46.0	258	0.015	2.87±0.10 (-)	0.97	0.94	1.011	0.929 - 1.072
Pogonias cromis	33.0	66.5	46	0.003	3.31±0.30 (+)	0.97	0.94	0.986	0.928 - 1.063
Paralichthys orbignyanus	5.2	62.5	213	0.008	3.09±0,03 (+)	0.99	0.98	1.002	0.940 - 1.065

and constitute an important baseline for future studies for the comparison and examination of overall growth or as an indicator of habitat quality.

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