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Sexual Dimorphism and Length–Weight Relationship of the Hairy Conger Eel *Bassanago albescens* (Anguilliformes: Congridae)[1]

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Abstract—The present study reports the first reference on length-weight relationships (LWR) and sexual dimorphism for *Bassanago albecens*, caught as bycatch in the commercial fishery in the Argentine continental shelf. A total of 91 conger eels were examined. Female specimens (ranged from 371 to 661 mm total length—*TL*) have body length larger than males (from 396 to 537 mm *TL*), but the length-weight relationships allometry coefficient was 3.76 for both sexes. Three out of seven morphometric measurements differed between sexes, in particular head size characteristics. These biometric data and their relationships are relevant to the management and conservation of fish diversity and fisheries.

Keywords: size distribution, allometry, biometric data, Congridae, Southwest Atlantic shelf

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INTRODUCTION

The hairy conger eel *Bassanago albescens* is an iteroparous species (Figueroa, 1999) whose leptocephalus larva was described in 2006 (Figueroa and Ehrlich, 2006). Regarding the iteroparity of *B. albescens*, Figueroa (1999) analyzed histological sections of ovaries in advanced ripening, and observed until four oocyte batches, together with postovulatory follicles. This fact allowed the author to assume that this species is a batch spawner, suggesting that spawning of hairy conger is repeated every year throughout it life span (Murua and Saborido-Rey, 2003). *B. albescens* inhabits the Southeastern Pacific (Chile), the Southeastern Atlantic (Namibia to South Africa) and the Southwestern Atlantic, from South Brazil to Argentina (45°S) on the outer continental shelf and upper slope (Nakamura et al., 1986; Figueroa and Ehrlich, 2006; Caires and Figueiredo, 2011; Eschmeyer et al., 2017). In the Southwestern Atlantic, it presents a high biomass, an enclosed environmental niche (Figueroa, 1999) and is captured as bycatch in trawling fisheries targeting Argentine hake, *Merluccius hubbsi* (Renzi and Castrucci, 1998).

Length weight relationships (LWR) prove to be very helpful in fisheries research for estimating the weight corresponding to a given length and the biomass, and also for allowing life history and morphological comparisons between different fish species and/or populations (Froese, 2006; Joyeux et al., 2009). In addition, the LWR indicate the degree of stabilization of taxonomic characters in fish species and is very useful in the management and exploitation of fish populations (Pervin and Mortuza, 2008). In many fishes sexual dimorphism is recorded, usually females are larger than males of the same age (Parker, 1992). This implies that there can be distinct allometries in their morphological features and, at the same time, sexual differences in morphometric characteristics (Kim et al., 2008). Thus, this study provides length-weight data and examines the possible sexual dimorphism in morphometric characteristics of the Southwestern Atlantic *B. albescens*. This represents a contribution for future studies on the ecology of the species, its management and conservation.

MATERIALS AND METHODS

Samples were obtained from research cruises conducted in the region north of the Southwest Atlantic shelf (36°–41° S) by the National Institute for Fisheries Research and Development (INIDEP) in autumn 2009 (Table 1). A bottom trawl was used during the campaign. After collection, the specimens were stored at −20°C for transfer to the laboratory where the total

[1] The article is published in the original.

Table 1. Details of the fishing hauls performed; Females and Males: number of *Bassanago albescens* collected in the Southwest Atlantic shelf

Latitude	Longitude	Depth, m	Females	Males	Size range, mm
36°04.2′ S	53°29.3′ W	148	18	15	371–655
36°43.2′ S	53°59.8′ W	120	21	10	418–661
39°45.6′ S	56°07.2′ W	142	13	14	396–642

Table 2. Statistical tests performed to compare the total length of *Bassanago albescens* in the Southwest Atlantic shelf

Test	Statist	*d.f.*	*p*-value
Kolmogorov–Smirnov	$D = 0.859$		0.0014
Test to compare two means	$t = 11.22$	88.83	0.0162
Test to compare two variances	$F = 0.958$	51 and 38	0.0327

Table 3. Regression equations and estimated parameters of length–weight relationships for *Bassanago albescens* in Southwest Atlantic shelf

N	*TL* range, mm	*W* range, g	Regression equation	*a*	*b*	r^2
91	371–661	50–510	$\log W = -7.957 + 3.757 \log TL$	1×10^{-8}	3.757	0.954

N—number of individuals, *TL*—total length, *W*—total weight, *a*—intercept, *b*—slope, r^2—coefficient of determination.

length (*TL*) measured to the nearest mm, the total weight (*W*) weighed on an electronic balance to the nearest 0.01 g and the sex of each animal were recorded.

A comparison by sexes of the *TL* frequency distribution was carried out using the Kolmogorov-Smirnov test (Crawley, 2007). The length-weight relationships (LWR) were estimated according to the equation $W = aTL^b$ (Ricker, 1973) by linear regression after a logarithmic transformation of the variables $\log W = \log a + b \log TL$ (Froese, 2006). The degree of association between *W*–*TL* was calculated by the determination coefficient (r^2). Parameters *a* and *b* were also estimated. The hypothetical isometry values ($b = 3$) were checked using the Student's t-test at the level of 95% confidence limit (Zar, 1999). An analysis of covariance (ANCOVA) (Crawley, 2007) was performed to test significant differences in regression gradients between sexes ($p = 0.05$).

For each specimen, seven measures were obtained following to Böhlke (1989), Smith (1989), and Lopez and Castello (1975): 1) eye diameter (ED); 2) pre-anal distance (PAD); 3) head length (*HL*); 4) mouth length (*ML*); 5) tip of snout—lower base of pectoral fin (SBP); 6) snout-beginning of dorsal fin distance (SDD); 7) tip of snout—posterior margin of eye (SPE) (Fig. 1). All measurements were obtained using a Mitutoyo gage (0.01 mm). Size-dependent differences were eliminated following Cussac et al. (1998) and Milano et al. (2002). All measurements were adjusted to the mean *TL* using the relationship: $AM_i = \log(OM_i) - b[\log(TL_i) - \mathrm{mean}(\log(TL))]$, where AM_i and OM_i are the adjusted and original measures, respectively, of the $\mathrm{individual}_i$ character; TL_i is the total length of the $\mathrm{individual}_i$; and *b* is the regression coefficient of the logarithms of OM and *TL*. The constancy of b over the size range was assessed through double logarithmic scatter plots of AM vs. *TL*. Discriminant Function Analyses (DFA) were used in order to identify the morphological variation between sexes. This multifactorial analysis allowed the determination of variable combinations that best discriminated between sexes and detected which one was the most different (Rencher, 2002). The assumptions of DFA were previously tested according to Zuur et al. (2007).

RESULTS

A total of 91 eels were examined and in all of them was possible to distinguish their sexual identity. Females ($n = 52$) ranged from 371 to 661 mm *TL*, with a mean ± SD of 578.8 ± 52.6 mm *TL*, while males ($n = 39$) were smaller, with a size range of 396 to 537 mm *TL* and a mean ± SD of 472.6 ± 37.6 mm *TL* (Fig. 2, Table 2). LWR for males and females did not differ significantly (ANCOVA, d.f. = 1, $p = 0.596$). Therefore, all specimens were pooled to estimate LWR parameters of *B. albescens* (Table 3, Fig. 3) and a positive allometry was detected ($t = 8.667$, $p = 0.00002$).

DFA performed on seven morphometric variables, showed highly significant interspecific differentiation between sexes (Wilk's $\lambda = 0.151$; $F(6, 84) = 79.179$; $p = 0.0001$). The overall correct classification into

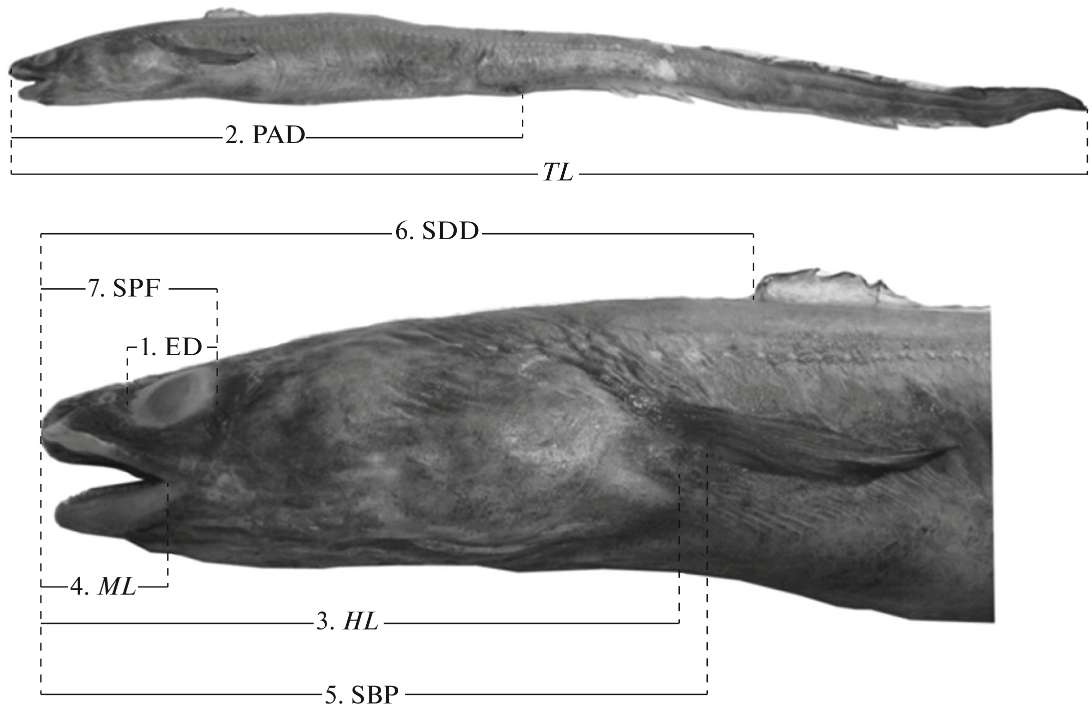

Fig. 1. Measures obtained for *Bassanago albescens* specimens. *TL*—total length; 1. ED—eye diameter; 2. PAD—pre-anal distance; 3. *HL*—head length; 4. *ML*—mouth length; 5. SBP—tip of snout-lower base of pectoral fin; 6. SDD—snout-dorsal fin beginning distance; 7. SPE—tip of snout-posterior margin of eye.

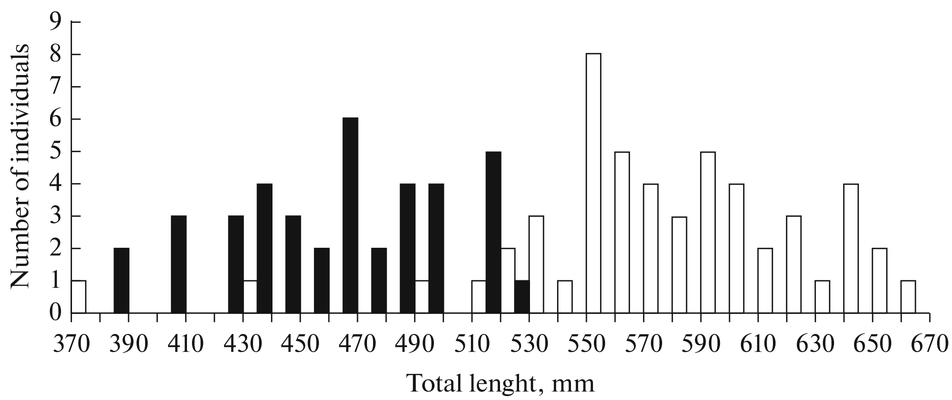

Fig. 2. Size distributions for *Bassanago albescens* in Southwest Atlantic shelf: (■)—males, *n* = 39; (□)—females, *n* = 52.

their originals groups was 100% and the morphometric variables most correlated with the canonical function were HL, tip of snout—lower base of pectoral fin (SBP) and snout—beginning of dorsal fin distance (SDD), corresponding all to the head size (Table 4).

DISCUSSION

Fish dimensions and weight are used to characterize growth, sexual maturation, maximum size, population structure and, in addition, for specific identification and differentiation between sexes of a species (Francis, 2006). In relation to *Bassanago albescens*, Meyer and Smale (1991) and Cousseau et al. (2004) mentioned that individuals measure not more than one meter total length and only females reach the maximum size of the species. Results of present study agree with these authors and statistically prove that there is sexual difference in the total length of *B. albescens*. Parameter b value was higher than the expected range of $2.5 < b < 3.5$ (Froese, 2006). The possible reason could be that the *b* value is affected by many factors, such as the length ranges used, study seasons, habitat, sex, diet, health and annual differences in

Table 4. Morphometric variable differences between males and females of *Bassanago albescens* in the Southwest Atlantic shelf

Morphometric variable	DF1	R^2
Eye diameter, ED	0.003	0.127
Pre-anal distance, PAD	0.450	0.114
Head length, *HL*	0.531	0.570
Mouth length, *ML*	0.010	0.272
Tip of snout-lower base of pectoral fin, SBP	0.351	0.605
Snout-beginning of dorsal fin distance, SDD	0.176	0.470
Tip of snout- posterior margin of eye, SPE	0.132	0.192
Eigenvalue	6.894	
Variance explained, %	100	
Total variance explained, %	100	
Wilks' Lambda	0.151	
p-level	<0.001	
Canonical correlation	0.923	

Standardized canonical discriminant function (DF1), variance explained, Wilks' Lambda, significance (*p*-level), canonical correlation and variables correlation with DF1 is 1-Tolerance (R^2).

environmental conditions (Moutopoulos and Stergiou, 2002; Oscoz et al., 2005; Ye et al., 2007), all of which were not considered in the Froese (2006) study, where the estimated parameters were regarded as mean values and they are not representative of any particular condition. Sexual dimorphism was detected in the morphometric characteristics related to both head size and total length. This sexual dimorphism may reflect the outcome of sexual selection in this species (Parker, 1992). The present study provides length-weight data and sexual dimorphism for *B. albescens* not yet represented in FishBase (Froese and Pauly, 2017); hence, these findings are important contributions for future studies on this species and are relevant to the management and conservation of fish diversity.

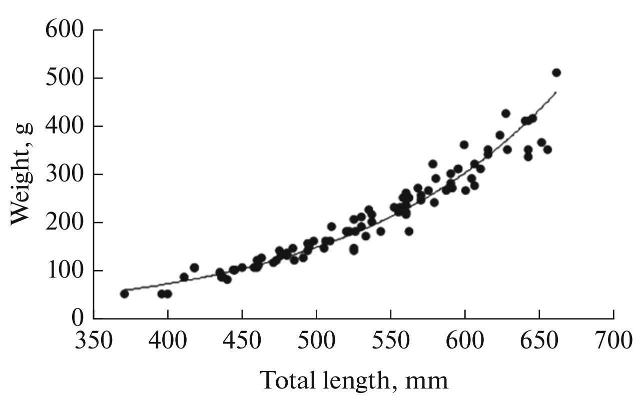

Fig. 3. Length-weight relationship for *Bassanago albescens* caught in Southwest Atlantic shelf. Total length, *TL*; Total weight, $W = 1/23 \times 10^{-8}\ TL^{3.76}$; Regression coefficient, $R^2 = 0.95$; sample size, $n = 91$.

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