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Length-weight relationship of 104 demersal fish species from the continental shelf of the South Brazilian Bight captured in bottom trawl shrimp nets

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Abstract

This study encompasses the description and evaluation of the length-weight relationship of 104 demersal fish species caught by bottom trawlers targeting shrimps on the southeast continental shelf of Brazil from 2004 to 2006. The regression criteria describing the length-weight relationship for each species were classified as approved (met the criteria), approved with reservations (partially met the criteria), and not approved (did not meet the criteria) based on linear regression parameters to determine whether length is a viable predictor of weight. A total of 141,433 individual fish, comprising 44 families and 104 species, were sampled; the beta parameter (± se) varied from 0.22 ± 0.12 to 3.94 ± 0.19, and the alpha parameter varied from -4.09 ± 0.04 to 0.89 ± 0.02. In total, 22 species were not identified by a recent large survey (2019) conducted in the study area. The results of this study are significant for the management of fishery resources, mainly due to the occurrence of unusual species, the economic importance and enormous effort exerted by the trawling fleet in the region, and the substantial sample size, in which a large number of individuals per species were caught.

Keywords: Reproducible analysis, Linear regression, Alpha parameter, Beta parameter

Species-specific length-weight relationships (LWRs) are valuable in fisheries science because fish size is often measured in terms of body length (Froese et al., 2014). For example, fish length estimates from non-destructive sampling methods (e.g., underwater visual census and remote underwater videos) are converted into weight using LWRs to provide fish biomass estimates (Daros et al., 2018; Wilson and Graham, 2018; Soeth et al., 2020). Moreover, detailed information on LWRs and their uncertainties allows us to investigate fisheries and their environmental impacts (Lehodey et al., 2008; Philippsen et al., 2019), to estimate the regional and global active carbon flux of fish (Saba et al., 2021), to estimate trophic interactions (Machado et al., 2020), and to calculate body condition indices and

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behavioral shifts from allometric growth variation (Correia et al., 2009; Soeth et al., 2019). Ultimately, LWRs helps maximize fishing yield along with sustainability (Kolding et al., 2016); however, LWR data specific to important species and fishing grounds in the southwestern Atlantic Ocean are still scarce (Haimovici and Velasco, 2000; Passos et al., 2012; Vaz-dos-Santos and Rossi-Wongtschowski, 2013; Dias et al., 2014; Eduardo et al., 2020).

Bottom trawling is a widespread method for demersal fishery worldwide (Amoroso et al., 2018). It plays a major role in the overexploitation of target and non-target (i.e., bycatch) fishery resources (Gustavsson et al., 2011; FAO, 2020, 2018). In Brazil, the bycatch of demersal fish by bottom trawling, along with the decline in shrimp populations, has caused certain fishing fleet to exclusively catch demersal fish, increasing the pressure on these stocks (D'incao et al., 2002). It is therefore important to evaluate these fish and provide information related to them. In this study, weight and length data from 141,433 demersal fish were used to determine the LWR of 104 species caught by bottom trawlers in the fishery grounds of southern Brazil.

The fish were captured by the Soloncy Moura Research vessel, equipped with a balloon-shaped bottom trawl aiming at shrimp, which had a total length of 24.4 m. The length of the top and bottom panels was 18.6 m and 24 m, respectively. The mesh size of the trawl body was 50 mm (between opposite knots) and 30 mm for the cod end (between opposite knots). The trawl door weighed 90 kg (two), and the length of the horizontal opening of the net was 12.25 m.

Fish sampling was conducted seasonally from June 2004 to May 2006 on the southeastern continental shelf of Brazil. A total of 294 30-minute trawls were performed from 26°S to 26°30´S, at three radial distances perpendicular to the coast, and from depths of 9 to 103 m (Figure 1). The specimens collected were preserved in a cold chamber until they were transported to the laboratory. The total length (TL, 1 mm) and weight (W, 0.1 g) of all fish were measured and identified to the lowest taxonomic level based on specialized literature (Barletta and Corrêa, 1992; Figueiredo and Menezes, 1978, 1980a, 1980b, 2000).

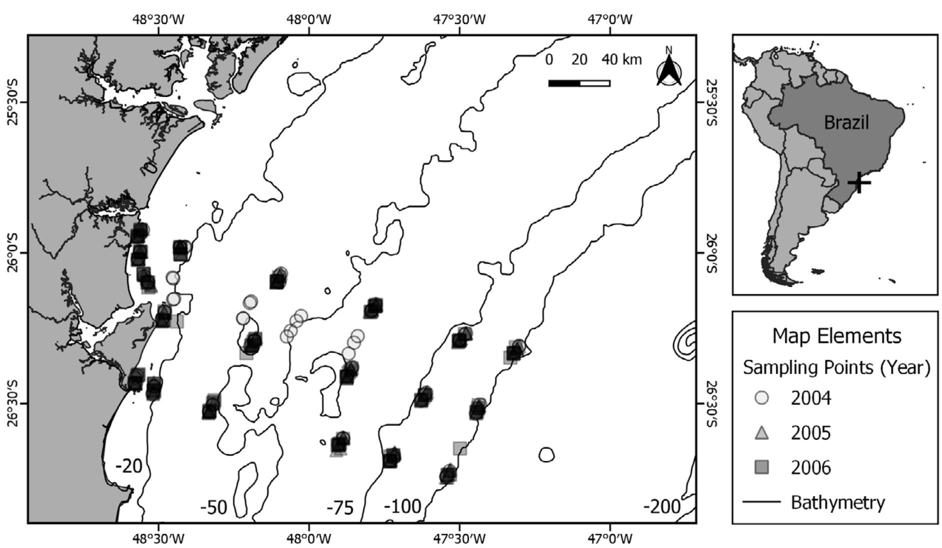

Figure 1. Map showing the sampling points in each year surveyed (2004, 2005, and 2006).

The LWR of each species was described in accordance with the methodology proposed by Ogle (2016). First, a linear regression of the log-transformed (log10) weight and total length (TL) measurements was performed, and all significant outliers were eliminated from the analysis. The slope of the regression is an estimate for beta and the intercept is an estimate for *log10*(*alpha*). The equation *log 10*(*weight*)=*log10*(*alpha*) + (*beta* x *log10*(*length*)) was generated for each species, predicting *log10*(*weight*) at a specific *log10*(*length*). The weight value (*log 10*(*weight*)) estimated for a specific length value (*log 10*(*length*) can be transformed from the logarithmic scale to the original scale (anti-log) by multiplying the correction factor generated for each species (Ogle, 2016).

Each regression was assessed using the criteria and techniques proposed by Ogle (2016) to determine whether TL is a good predictor of fish weight. The criteria included a high F-statistic from the analysis of variance (stipulated > 100 in this study), a high coefficient of determination (stipulated > 0.6 in this study), a small P-value (< 0.05), a non-zero slope, a normal frequency distribution of the values, and a uniform distribution of the variance along the regression line (Ogle, 2016). Based on these criteria, each regression was classified as follows: approved (met the criteria), approved with reservations (partially met the criteria), and not approved (did not meet the criteria) (Figure 2).

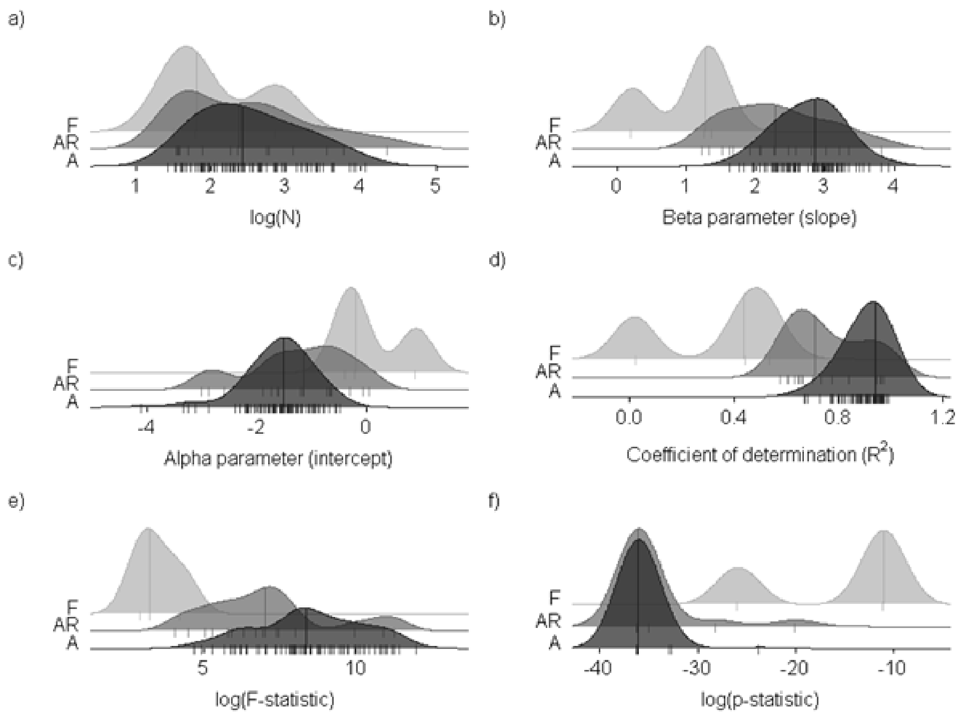

Figure 2. Kernel density from the linear regression estimates. Summary of the variability between species from linear regression and analysis of variance in classifying the LWR as approved (A), approved with reservations (AR), and not approved (F). Parameters included: (a) fish abundance [log(N)]; (b) Alpha parameter; (c) Beta parameter; (d) Coefficient of determination; (e) F-statistic value; (f) P-statistic from the analysis of variance.

The Supplementary Material (1 and 2) includes the reproducible analysis with the calculations that generated the coefficients for each regression (i.e., alpha and beta parameters, the estimated variability along the regression line, and the coefficient of determination), the residual plots used to verify the homoscedasticity requirements, the regression plots for all species and years of collection, and the tests used to verify whether weight predicts length. R software (R Core Team, 2020) was used to perform all statistical analyses.

Each species was examined to determine if it had been identified in an extensive survey of trawl fisheries in Brazil conducted by Rotundo et al. (2019). Table S1 shows the LWR parameters for each species, ordered based on the phylogenetic order of Eschmeyer's Catalog of Fishes (Betancur-R et al., 2017; Fricke et al., 2023), the classification of each regression based on the criteria of Ogle (2016), and whether the species had been identified in the survey conducted by Rotundo et al. (2019).

In total, 141,433 fish from 44 families and 104 species were sampled (Table S1). The most abundant species were: *Stephanolepis hispida* (N = 23,197); *Dactylopterus volitans* (N = 11,421); *Chirocentrodon bleekerianus* (N = 8,930); *Trachurus* *lathami* (N = 8,085); and *Stellifer rastrifer* (N = 7,324); while the least abundant species was *Bothus robinsi*, totaling 28 individuals. The TL measurements of the fish ranged from 1 cm to 135 cm, with a mean and standard deviation of 11.37 and 9.26 cm, respectively. The weight measurements of the fish ranged from 1 g to 3345.76 g, with a mean and standard deviation of 33.85 and 84.55 g, respectively.

Among all the species, the beta parameter (± standard error) varied from 0.22 ± 0.12 (*Cynoscion microlepidotus*) to 3.94 ± 0.19 (*Scomber japonicus*), while the alpha parameter varied from -4.09 ± 0.04 (*Fistularia petimba*) to 0.89 ± 0.02 (*C. microlepidotus*). The beta parameter corresponds to the regression slope that represents the LWR in logarithmic form, which reflects the growth pattern and possible condition of the populations sampled (Froese, 2006). The alpha parameter corresponds to the regression intercept that represents the LWR in logarithmic form (Froese, 2006) and is inversely proportional to any increase in the beta parameter. The interrelation between these parameters (alpha and beta) linearized in a by plot can possibly identify LWRs (Figure 2) that are questionable for different reasons, such as a small sample size, a small sample number with high variation, or the presence of outliers in the sample (Froese, 2006).

In this study, the species *Anchoviella lepidentostole*, *Cathorops spixii*, *Chirocentrodon bleekerianus*, *Chloroscombrus chrysurus*, *Cynoscion microlepidotus*, *Diapterus rhombeus*, *Eucinostomus gula*, *Pellona harroweri*, *Peprilus paru*, *Rypticus randalli*, *Selene vomer*, *Stellifer brasiliensis*, *Stephanolepis hispida*, and *Trichiurus lepturus* showed evidence in the regression parameters, such as beta and alpha outside the expected range for the species, a coefficient of determination incompatible with a high sample number, or groupings that are visually identified in the regression plot, denoting possible groupings and therefore indicating that there are factors that predict weight in addition to length. These factors may be related to sample structure, season, or population characteristics such as growth stanzas, sex ratio, and gonad maturity (Froese, 2006; Franco et al., 2013; Nobile et al., 2015). Therefore, further investigation of the species mentioned above is recommended.

In total, 22 species had not been identified by Rotundo et al. (2019), and, of these 22, *Citharichthys dinoceros* and *Cynoscion microlepidotus* did not meet the criteria for approval in the regression analysis (Table S1). Of the other 82 species, only one failed to meet the criteria for approval in the regression analysis (Table S1).

Due to the substantial number of individuals caught per species and the occurrence of unusual species in the region, the results of this study are of interest for the management of fishery resources. Therefore, they are expected to be used to support decision-making processes and as a technical source for publications seeking to estimate the characteristics of demersal fish populations on the southern continental shelf of Brazil.

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AUTHOR CONTRIBUTIONS

G.D.M.: Conceptualization, Methodology, Software, Validation, Formal analysis, Data Curation, Writing - Original Draft, Visualization.

H.L.S.: Resources, Writing - Review & Editing, Supervision.

J.A.A.: Methodology, Investigation, Writing - Review & Editing.

P.C.P.: Methodology, Validation, Investigation, Resources, Data Curation, Writing - Review & Editing, Supervision, Project administration, Funding acquisition.

M.S.: Methodology, Writing - Review & Editing, Supervision.

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