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LENGTH-WEIGHT RELATIONSHIPS OF THREE FRESHWATER MUSSEL SPECIES FROM THE AMAZON (UNIONIDA, HYRIIDAE)

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Abstract

Length-weight relationships of three freshwater mussel species (Hyriidae), Eastern Amazon: the length-weight relationships allow important biological estimates for the fisheries management of species. Through this relationship, it is possible to estimate the weight of the individuals by their lengths, from which the biomass of the studied population can be determined. In addition, it gathers important data to assess the ecological patterns of different populations. The aim of this study was to analyze the length-weight relationships and their respective meat yields of three species of freshwater mussels: *Castalia ambigua*, *Triplodon corrugatus* and *Paxyodon syrmatophorus* from Capim River Bay, Pará, Brazil. For this, the total length, visceral weight, and total weight of 1,057 individuals were determined. All three relationships were considered strong, with determination coefficients greater than 0.9. The species *C. ambigua* showed negative allometric growth, while the other species *P. syrmatophorus* and *T. corrugatus* showed isometric growth. The species with the highest meat yield was *P. syrmatophorus* with 14.8%. The study presents the first parameter record of weight-length relationships for these three freshwater mussel species.

Keywords: Bivalvia. Benthos. Morphometry. Mollusk. Meat Yield.

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1 Introduction

Hyriidae is one of the most speciose families of freshwater mussels in South America, comprising 64 species distributed in six genera. Among them, the species *Castalia ambigua* Lamarck, 1819; *Paxyodon syrmatophorus* (Gmelin, 1791); and *Triplodon corrugatus* (Lamarck, 1819) (GRAF; CUMMINGS, 2021) are found in muddy, clay, and even sandy-silt substrate environments, being restricted to shallow marginal (AQUINO-ALMEIDA, 2006). They are dependent on their association with fish species, using them as hosts, in which the glochidium - larvae denomination - develops (MANSUR; VOLKMER-RIBEIRO; CARVALHO, 1997). These organisms are long-lived, growing fast in the first stages of life and slowly as they reach adulthood, since their energy is reverted to reproduction and maintenance, but such patterns vary widely among species (HAAG, 2009; HAAG; RYPEL, 2009).

Several studies with the family Hyriidae have been developed in recent decades; many of them are on new distribution records (SILVA et al., 2020), taxonomy (MIYAHIRA; MANSUR; SANTOS, 2019; PIMPÃO; MANSU, 2009), larval morphology description (PIMPÃO et al., 2012), molecular analyses (SANTOS-NETO et al., 2016), pearls' characterization (BARROS et al., 2019), feeding behavior (LARA; PARADA; PEREDO, 2002), reproductive cycle (MEYER et al., 2014) and larval growth description (BEASLEY et al., 2005; MANSUR, 1999). However, these species lack studies on weight-length relationships.

Freshwater mussels are of great ecological importance due to their high diversity and wide distribution, inhabiting a great variety of substrates (e.g., muddy, clayey, or sandy) (AGOSTINHO; THOMAZ; GOMES, 2005). In addition, freshwater mussels are part of the diet of riverine populations that exploit them through extractive fishing, increasing the income of local residents through the sale of their shells for the production of buttons and handicrafts (BARROS et al., 2020; BARROS; CHAGAS, 2019; BEASLEY, 2001). Weight-length relationships (WLR) are basic biometric parameters measured during the monitoring process of a particular fishery. This information allows us to estimate indirect growth, body condition, and biomass based on the length frequency distribution reflecting population conditions (OLENTINO et al., 2021). Monitoring these data and comparing them across populations in different habitats can be very important for better fisheries management and to estimate the possible effects of exotic species invasions (ONSOY; SALMAN, 2022). This happens because the weight of organisms is exponentially related to their length, and the slope (coefficient *b*) of the relationship between length and weight indicates the type of growth of the organism: isometric when b = 3, negative allometric when b < 3, and positive allometric when b > 3 (VASCONCELOS; GASPAR, 2017).

Estimations of WLRs are essentially useful for fisheries ecology as well as the dynamics of populations and, mainly, aiding the management of these fishery resources (VASCONCELOS; GASPAR, 2017). Based on the above, this study aims to perform the first record of the weight-length relationships of the three freshwater mussel species: *C. ambigua*, *P. syrmatophorus* and *T. corrugatus* from Capim River Bay, Eastern Amazon, aiming to contribute to the knowledge of currently poorly known native species.

2 Material and Methods

Study Area

The study area comprises the natural bank of freshwater mussels on the banks of Tabatinga Island (1°41'41.94"S, 48°53'2.22"W), located in the Capim River Bay (Figure 1), Abaetetuba, Pará, Eastern Amazon, Brazil (RIBEIRO et al., 2014).

The individuals used in the present study were collected under a license granted by the Chico Mendes Institute for Biodiversity Conservation - ICMBio (Biodiversity Authorization and Information System - SISBIO no. 60204-1).

Species characterization and collection of freshwater mussels

Of the three species that were used in this study, *C. ambigua* is the only one that presents a robust, highly inflated shell with a triangular contour, a tapered or rounded anterior margin, and an obliquely truncated posterior margin. *T. corrugatus* has a robust, poorly inflated shell with a subtriangular outline, a rounded oblique anterior margin, and a truncated posterior, usually with short wings (PIMPÃO; MANSU, 2009). *P. syrmatophorus* has a relatively large, elongated, triangular-shaped, and thick shell with short anterior and elongated posterior sides. Its umbo is low and eroded, with a smooth and shiny outer surface of a light to dark brown color (BEASLEY et al., 2000).

They were collected monthly during low tide from September 2016 to September 2017. We used a qualitative collection method, which consisted of an active and random manual search for the three species of freshwater bivalves on the natural freshwater bivalves bank (BARROS et al., 2020; MIYAHIRA; MANSUR; SANTOS, 2019; OLIVIER; SCHNEIDERMAN, 1956).

We tried to clean the impurities adhered to the shells, e.g., sponges and dirt materials (muddy sediment), before taking the biometric measurements in order to minimize biometric errors (Figure 2).

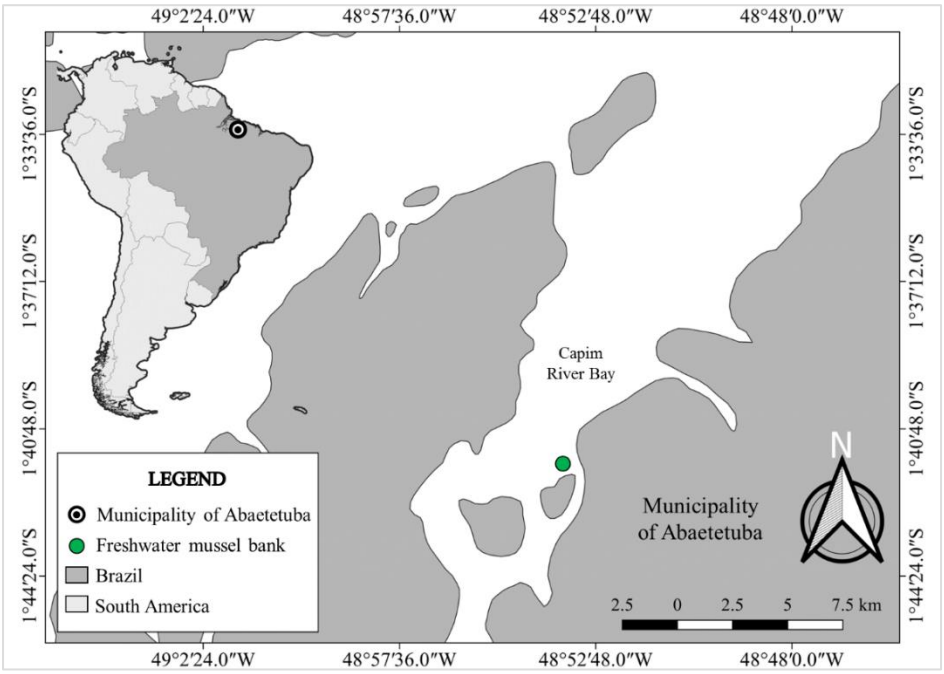

Figure 1. Collection sites of three species studied *Castalia ambigua*, *Paxyodon syrmatophorus* and *Triplodon corrugatus* on Tabatinga Island, Capim River Bay, Abaetetuba, Pará, Eastern Amazon.

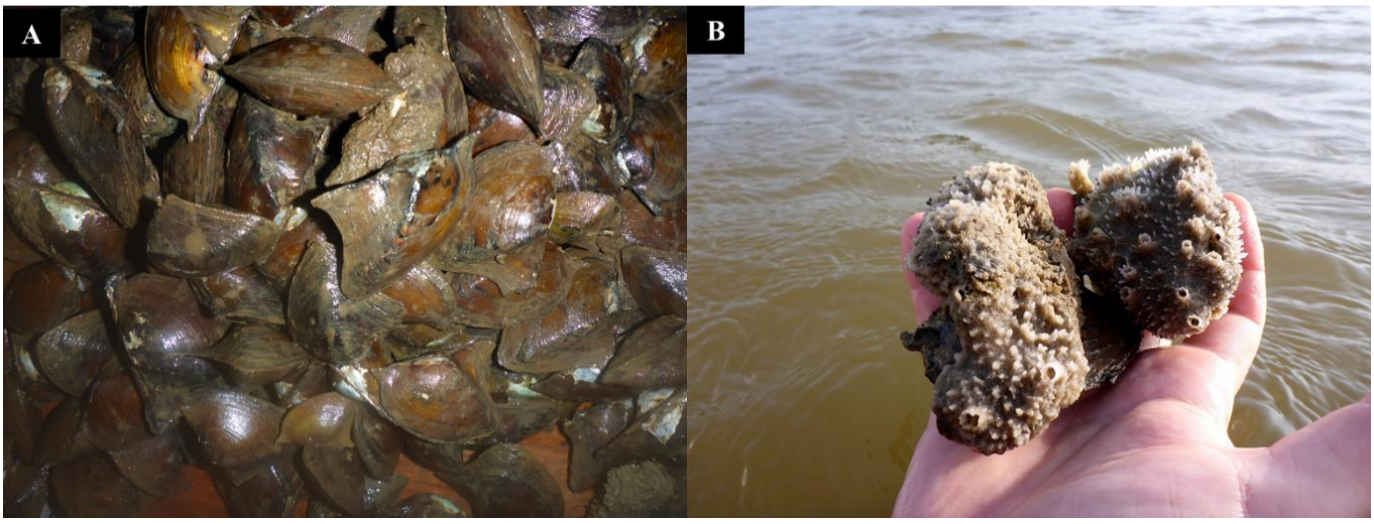

Figure 2. Freshly collected freshwater mussel mollusks from Capim River Bay still covered by (A) unconsolidated substrates and (B) freshwater sponges.

Biometric characterization

The total length was measured using a digital caliper to the nearest 0.01 mm (Tesa, DATAdirect). The total weight was determined in grams using an analytical digital balance to the nearest 0.001 g (MARTE, model AL 500c). The wet weight was determined using the visceral mass only, using the protocol according to VASCONCELOS et al. (2016). The potential model follows the formula $W = a.LT^b$, where *W is* the visceral mass weight in grams, *LT* is the total length in millimeters, *a* is the regression intercept, and *b is* the allometric coefficient (GASPAR; SANTOS; VASCONCELOS, 2001).

The relationship parameters were estimated after a logarithmic transformation of the weight and length values. The data were previously analyzed to explore the presence and removal of outliers (FROESE; TSIKLIRAS; STERGIOU, 2011).

The degree of association between the variables was calculated by the coefficient of determination (r^2) and submitted to an analysis of variance (ANOVA) to estimate the level of significance at 5% of r^2 (GASPAR; SANTOS; VASCONCELOS, 2001).

The type of growth of each species was classified and determined from the values of each angular coefficient *b* (VASCONCELOS; GASPAR, 2017). Additionally, the t-Student test was applied to see if the allometric coefficient differed statistically from the isometric value (GASPAR; SANTOS; VASCONCELOS, 2001). Subsequently, the edible meat yield in percent was obtained using the formula R = (*W* *100)/ *Wt*, where *W* is the visceral mass weight in grams and *Wt* is the total weight of the closed freshwater mussel (visceral mass + shell) in grams (SANTOS et al., 2020).

3 Results

386 *C. ambigua*, 335 *P. syrmatophorus*, and *336 T. corrugatus* were collected, totaling 1,057 individuals. Among the species, the smallest was *C. ambigua* with 13.12 mm (34.94 ± 8.69 mm), and the largest was *T. corrugatus* with 96.17 mm (63.52 ± 14.88 mm). The species with the lowest weight was *P. syrmatophorus* with 0.07 g (3.91 ± 2.41 g), and the species with the highest weight was *T. corrugatus* with 17.07 g (6.02 ± 3.94 g). These as well as its other descriptors are presented in Table 1 and Figure 3.

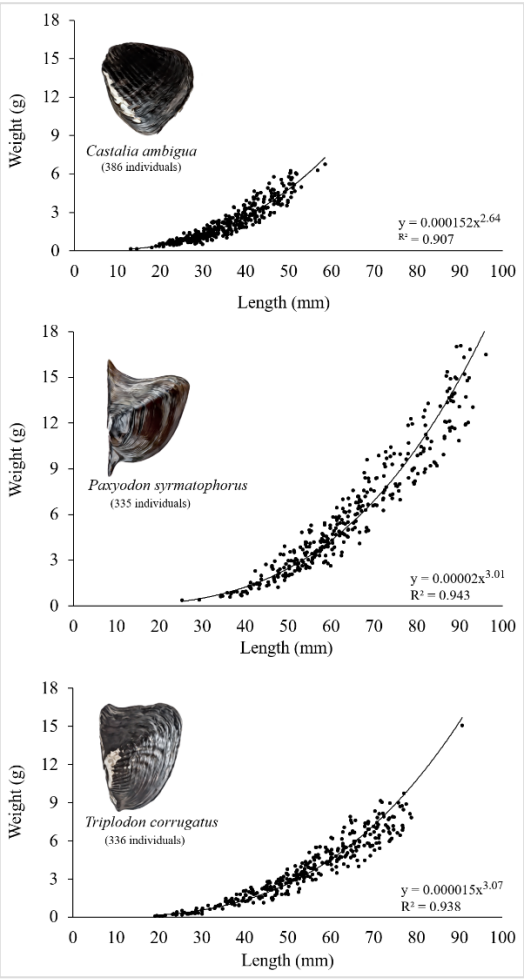

Figure 3. Dispersion of the weight-length relationships of the *Castalia ambigua*, *Paxyodon syrmatophorus* and *Triplodon corrugatus* collected from Capim River Bay, Eastern Amazon, Brazil.

The measurements of weight in grams and shell length in millimeters reveal the close relationship between these two variables. In this case, the coefficients of determination found ranged from 0.907 (*C. ambigua*) to 0.943 (*P. syrmatophorus*), being significant for all three species of Hyriidae (ANOVA $p < 0.05$). Thus, shell length can be used as a reliable measure for body weight under standard conditions. The values of the constant parameter *a* ranged from 0.000015 (*T. corrugatus*) to 0.000152 (*C. ambigua*). The allometric coefficient *b* ranged from 2.64 (*C. ambigua*) to 3.06 (*T. corrugatus*).

The total weight for each species was 6,798 g for *C. ambigua*, 8,863 g for *P. syrmatophorus*, and 15,665 g for *T. corrugatus*. The total visceral weight for each species was 834.4 g for *C. ambigua*, 1,310 g for *P. syrmatophorus*, and 2,024 g for *T. corrugatus*. The results obtained for the weights of the animals were used to evaluate the percentage of meat yield (R). Thus, the yield found for each species was 12.27% for *C. ambigua*, 12.85% for *T. corrugatus*, and 14.78% for *P. syrmatophorus*. Thus, to obtain 1 kilo of freshwater mussel meat, an average of 463 individuals of *C. ambigua*, 256 individuals of *P. syrmatophorus*, and 166 individuals of *T. corrugatus* must be collected.

4 Discussion

This is the first record of a weight-length relationship for these three species of Hyriidae. Within the range of biometric studies, studies focused on freshwater mussel mollusks are scarce, especially when compared to studies of bivalves in marine environments (e.g., (CHAGAS et al., 2019; GASPAR; SANTOS; VASCONCELOS, 2001; GASPAR et al., 2002). This is mainly due to the greater diversity of marine species and their commercial interests (e.g., oysters, clams, and mussels).

The species studied show distinct differences in their shell shape since their larval stage (CUEZZO et al., 2020; PEREIRA; MANSUR; PIMPÃO, 2012). The variation between different body parts is called allometric growth or relative growth, and it is considered that the shell growth of mollusks has a unique pattern for each species, which is responsible for the high pattern of distinction between species (VANZOLINI, 1993).

In this study, the relationships among the biometric variables were classified as strong, showing the positive dependence of body length on weight for the three species. For some species, there may be weak or moderate relationships since the great diversity of life habits may be reflected in a wide morphological variation, both in the individual's shell and in its anatomy (HARPER; TAYLOR; CRAME, 2000).

Table 1. Parameters of length-weight relationships of the three freshwater mussel species collected between September 2016 and September 2017 from Capim River Bay, Eastern Amazon, Brazil.

Species	N	LT (mm)		W (g)		Regression Parameters				
		Min	Max	Min	Max	*a*	95% CL (*a*)	*b*	95% CL (*b*)	r^2
Castalia ambigua	386	13.12	58.55	0.15	6.75	0.000152	0.000113-0.000206	2.64	2.563-2.733	. 907
Paxyodon syrmatophorus	335	19.14	90.68	0.07	15.07	0.000020	0.000015-0.000028	3.01	2.928-3.087	. 943
Triplodon corrugatus	336	25.34	96.17	0.38	17.07	0.000015	0.000011-0.000022	3.07	2.979-3.150	. 938

LT, total length; *W*, weight; N, number of analyzed individuals; *a* and *b*, parameters of the relationship; CL, confidence limits; r^2, Pearson r-squared for logarithmic regression. All relationships were significant at $p<0.05$.

For VASCONCELOS e GASPAR (2017), the allometric coefficient (*b*) defines the type of relative growth within a population, indicating whether there is greater investment in weight or length increase. Therefore, of the species studied, *T. corrugatus* and *P. syrmatophorus* showed isometric allometry, i.e., individuals of these species grow in size in the same proportion as they gain weight, while *C. ambigua* showed negative allometry, i.e., individuals of this species grow faster than they gain weight.

The negative allometry found for *C. ambigua* shows that the weight of the freshwater mussel increases at a slower rate than the size of the body, which may be more pronounced in females than in males and may also be related to the need for a larger abdominal cavity to accommodate its marsupium and larvae (SIMEONE et al., 2022).

Estimating the yield of edible meat from fishery resources is widely studied. These data for freshwater mollusks are important, as in addition to being a resource used in the diet of the native population, they can also be used to estimate the biomass of a population of bivalves (Barros et al., 2020).

In this sense, it is evident that the visceral biomass yields of the freshwater mollusks studied here are low when compared to other aquatic resources, such as fish, which have 30 to 50% of the visceral biomass (MACEDO-VIEGAS; SOUZA, 2004), and shrimp which have around 50% (LIMA et al., 2007).

However, they have percent edible meat yields similar to other invertebrates, such as crabs, from 11 to 18 % (OGAWA et al., 2008) and marine bivalves such as the oyster *Crassostrea tulipa* (Lamarck, 1819), with 20% (CHAGAS et al., 2019).

5 Conclusions

In short, studies related to the ecology, biology, and sustainable management of a resource, such as its morphometric relationships and profitability, are of vital importance since they broaden ecological interactions and evaluate the potential for exploitation, mainly due to its socioeconomic importance for local communities, besides serving as a basis for the elaboration of sustainable management plans.

We also emphasize that their contribution is best made when combined with the investigation of abiotic parameters.

We emphasize, therefore, the importance of our results for conservation and possible strategic planning. And we recommend further studies in the future since the freshwater bivalve population in the region may suffer interference, causing possible alterations in its growth and reproduction due to the extraction of ore and the construction of a waterway port near the study area.

We therefore hope that this work will stimulate new studies to increase knowledge of freshwater bivalves since there is currently little information available in the literature, especially for the Amazon region.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

In order to recognize the participation of the authors, we highlight each contribution: M.R.F.B., designed the study, performed the experiments, and developed the writing of the manuscript; V.S.A., contributed to the collection of material; L.M.Q., made contributions in logistics and material collection; R.A.C., made contributions to logistics, material collection, and revision of the manuscript; M.H., assisted in the logistics of collecting material and revising the essay; L.L.A., helped with writing and translating the manuscript, and M.C.A. helped with writing, revising, and translating the manuscript.

DECLARATION OF INTEREST

The authors disclose that they have no known competing financial interests or personal relationships that could have appeared to influence this manuscript.

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