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Morphometry and shell shape stabilization indicator (IEF) of the mussel *Mytella charruana* (d'Orbigny, 1842) (Bivalvia, Mytilidae)

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ABSTRACT

The mussel *Mytella charruana* (d'Orbigny, 1842) – bivalve popularly known as "sururu" –, is an important fishing resource on the North and Northeast coast of Brazil. This study aimed to characterize the morphometric relationships and the shell shape stabilization indicator (IEF) of the *M. charruana* collected in November 2018 in the Urindeua River (Salinópolis - PA, Eastern Amazon). Altogether, the external measures (length, width and height) of the shell of 460 individuals were obtained, making simple regressions between these measures, subsequently applying a t-Student test to assess the existence of statistical dependence between the variables at a level 95% significance level (α = 0.05) and the IEF was described through ratios between the shell morphometry. The results indicate positive correlations in all morphometric relationships performed, classifying them as "strong" and negative allometric coefficients. In addition, it was found that *M. charruana* has excellent morphometric relationships, which makes it possible to estimate the external measures of the shell of the species and, based on the IEF, there is a smooth stabilization in the shape of the shell throughout its growth. In addition, this study will serve as a basis for the morphometric standardization of mytilids, considering the largest dimension of the shell as its total length. Studies related to the population dynamics of *M. charruana* are recommended, aiming at a future cultivation of the species in consortium with the cultivation of oysters already practiced in the region.

Keywords: Amazon; Bivalve mollusk; Morphology; Morphometric aspects.

Morfometria e indicador de estabilização da forma da concha (IEF) do mexilhão *Mytella charruana* (d'Orbigny, 1842) (Bivalve, Mytilidae)

RESUMO

O mexilhão *Mytella charruana* (d'Orbigny, 1842) - bivalve conhecido popularmente por "sururu" –, é um importante recurso pesqueiro no litoral Norte e Nordeste do Brasil. Neste estudo objetivou-se caracterizar as relações morfométricas e o indicador de estabilização da forma (IEF) da concha de *M. charruana* coletadas em novembro de 2018 no rio Urindeua (Salinópolis – PA, Amazônia Oriental). Ao todo, foram obtidas as medidas externas (comprimento, largura e altura) da concha de 460 indivíduos, efetuando-se regressões simples entre essas medidas, aplicando posteriormente um teste t-Student para avaliar a existência de dependência estatística entre as variáveis a um nível de significância de 95 % (α = 0,05) e descreveu-se o IEF através de razões entre a morfometria da concha. Os resultados indicam correlações positivas em todas as relações morfométricas realizadas, classificando-as como "fortes" e alometrias negativas. Além disso, verificou-se que *M. charruana* apresenta excelentes relações morfométricas, o que possibilita a estimação das medidas externas da concha da espécie e, com base no IEF, destaca-se uma suave estabilização no formato da concha ao longo de seu crescimento. Adicionalmente, este estudo servirá como base para a padronização morfométricas de mitilídeos, considerando a maior dimensão da concha como o seu comprimento total. Recomenda-se estudos relacionados a dinâmica populacional de *M. charruana*, almejando um futuro cultivo da espécie em consórcio com o cultivo de ostras já praticado na região.

Palavras-chave: Amazônia, Molusco bivalve, Morfologia, Aspectos morfométricos.

Introduction

The species of the family Mytilidae, known worldwide as "mussels", have economic importance in both fishing and cultivation (ARAÚJO et al., 2009). In 2016, mussel farming represents 6% (1.1 million ton.) of the total production of bivalve mollusks farmed in the world (FAO, 2018). In Brazil, five subfamilies, 14 genera and 24 species of mytilids occur, such as *Mytella charruana* (d'Orbigny, 1842), which presents socioeconomic importance in the North and Northeast Brazilian coast, mainly because it is a source of low-cost animal protein and high nutritional value (CORREIA, 1996; RIOS, 2009; CHRISTO; FERREIRA-JR; ABSHER, 2016).

The mussel *M. charruana*, popularly known as "sururu", "bacucu", "sutinga", "estuary mussel" or "bico-de-ouro", is a bivalve mollusk that inhabits estuarine waters (up to 10 m adhered to the substrate of rock or mud, forming colonies (RIOS, 2009; PUYANA; PRATO; DIAZ, 2012). It is native to Central and South America along the Pacific coast of Guay-mas in Mexico, south of Ecuador and the Galapagos Islands and along the Atlantic coast from Colombia to Argentina (COSTA; NALESSO, 2002; RIOS, 2009). It has an equivalent shell, mytiliform, with soft angle dorsally and concavity on the ventral side. Its umbo is anterior, almost terminal and the posterior border is rounded. It has a yellowish brown color in the anteroventral and greenish part in the dorsal part (NARCHI; GALVÃO-BUENO, 1983; COSTA; NALESSO, 2002; RIOS, 2009).

In numerous studies *M. charruana* was considered as synonymy of *Mytela guianensis* (LAMARCK, 1819), however, the current taxonomy distinguish these two species (HORTON et al., 2018). One of the first studies carried out with *M. charruana* in Brazil analyzed the functional anatomy of the species (NARCHI; GALVÃO-BUENO, 1983). Subsequently, several studies were proposed, among them: aspects of fishing (ARAÚJO et al., 2009), growing culture environment (COSTA; NALESSO, 2002), reproductive biology (MACIEL, 2011; CHRISTO; FERREIRA-JR; ABSHER, 2016), effects of Tributyltin (TBT) (MACIEL, 2011), heavy metal concentrations (RAMOS, 2011; HIGINO et al., 2012), population density (PEREIRA et al., 2003; PUYANA, PRATO;DIAZ, 2012), population structure (SOUZA et al., 2014), mortality (ONODERA; HENRIQUES, 2017), mitochondrial analysis (ALVES et al., 2012; SOUZA et al., 2014), abundance in biofouling (CHAGAS, 2016), soft body yield (REIS

JÚNIOR et al., 2016) and biomorphometric relationships (CHRISTO, FERREIRA-JR; ABSHER, 2016; REIS JÚNIOR et al., 2016; CHAGAS et al., 2017).

The studies on the morphology of the shell of mollusks, as well as the respective biomorphometric relationships, are important since they allow taxonomic identifications, a comparison between species or interpopulation and sexual dimorphisms (GASPAR et al., 2002; VASCONCELOS; GASPAR, 2017). According to the authors, such studies are effective in using models for assessment and management of fishery resources. Thus, the present study aims to characterize the morphometric relationships and the Shell Shape Stabilization Indicator (IEF) of the mussel *Mytella charruana* (d'Orbigny, 1842) collected in the Urindeua River (Salinópolis-PA, Eastern Amazon).

Material and methods

The study area was delimited by the oyster farming of the Association of Farmers, Pecuaristas and Aquicultores (Associação de Agricultores, Pecuaristas e Aquicultores – ASAPAQ), located in the estuarine zone of the Urindeua River basin (0°41'50.39"S, 47°22'12.45"W), located in the village of Santo Antônio de Urindeua (Figure 1), municipality of Salinópolis, State of Pará, Eastern Amazonia, North of Brazil.

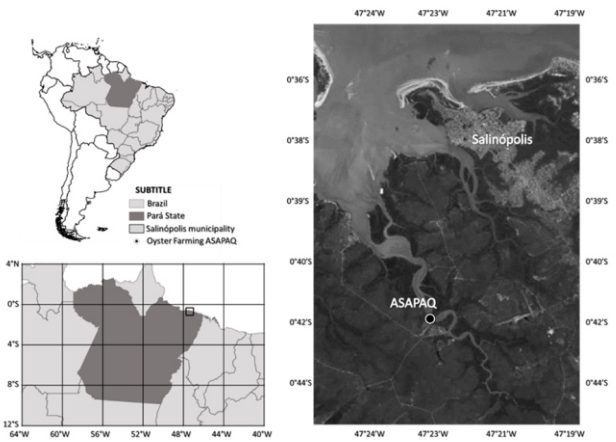

Figure 1. Location of ASAPAQ oyster farming in the Urindeua river, located in the municipality of Salinópolis, where the artificial substrates were inserted. Source: adapted from Chagas et al. (2018).

The collection was carried out in November 2018, and for this study 460 mussels of the *M. charruana* species were used which were fixed in the structures (e.g., bags and lanterns) of the ASAPAQ oyster farming. After the management, the mussels were extracted from the culture structures, performing the washing, according Chagas (2016), keeping them on the ice and transported to the Tropical Benthic Ecology Laboratory (LEBT), located at the Universidade Federal Rural da Amazônia (UFRA), Belém campus (UFRA/Belém), for further morphometric analysis.

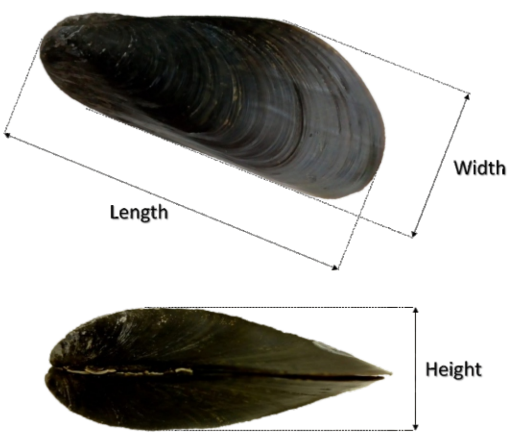

Figure 2. Morphometric measurements of *Mytella charruana* collected in the Urindeua river (Salinópolis, Pará).

To describe the morphometric aspects of *M. charruana*, the methodology used by Gaspar, Santos and Vasconcelos (2001). In this way, morphometric relationships were performed between the external measurements (total length, width and height) (Figure 2) of the mussel shell using linear equations, described in equation 1 below:

$$Y = a + b.X$$

Subsequently, the equations were classified according to the values of the coefficient (*b*) according to Vasconcelos and Gaspar (2017). According to the authors, the equations with $b<1$ are classified by "negative allometry", when $b>1$ are classified by "positive allometry" and when $b=1$, classified by "isometry".

The Pearson correlation coefficient (*r*) was used to test the existence of statistical dependence among the morphometric variables, performing a Student t-test to verify the significance of the values of r according to Rodrigues (2010), at a level of significance of 95% ($\alpha = 0.05$) (Zar, 2010).

To determine the size in which *M. charruana* reaches the defined shape of the shell, the method proposed by Gil, Troncoso and Thomé (2007), which is called Shell Shape Stabilization Indicator (IEF). This method consists of simple analysis and consists of calculating the ratios, expressed as a percentage, between the three linear measurements of the shell. For this, the sampled samples were divided into length classes, calculated through the square root rule ($k = \sqrt{n}$ where *k* is the number of classes and *n* is the number of mussels) and the class interval calculated by the equation $IC = (Ls - Li)/k$, where *IC* is the class interval and *Ls* and *Li* are the largest and smallest total length values sampled. The average of the linear measurements for each interval was determined by determining the following morphometric ratios: H/L , W/L and H/W, where *H* is the height, *L* is the total length and *W* is the shell width.

Results and discussion

The raw data set of *M. charruana* morphometry is available in Mendes, Barros and Chagas (2019), on the digital platform Data Publisher for Earth & Environmental Science – PANGAEA. The individuals collected had a total length of 29.62±5.43mm (mean±SD), ranging from 10.57 to 43.77mm, width of 13.14±2.22mm, between 5.48 and 19, 09mm, and height of 11.43±1.91 mm, between 4.37and17.65 mm.

The maximum total length found in this study is higher than that of Maciel (2011), with 33,08 mm in the Capibaribe River (Pernanbuco, Brasil), and Puyana, Prato and Diaz (2012), with 36 mm in the bay of Cartagena, Colombia. However, it is similar to those found by Pereira et al. (2003), of 46 mm in the estuary of Comprida island (São Paulo, Brasil), Araújo et al. (2009) of 44,3 mm in the coast of Sergipe (Brasil) and 54,80±1,09 mm by Christo, Ferreira-Jr and Absher (2016) in the Estuarine Complex of Paranaguá (Paraná – Brasil). However, much lower than that found by Reis Júnior et al. (2016), of 55 mm found in the Sal river (Sergipe, Brasil).

In the Urindeua river, the shellfish gather the mussels with a total length of more than 20 mm. This commercial size is lower than that practiced in the Ilha Comprida - SP estuary, where *M. charruana* is collected with a total length of more than 30 mm (PEREIRA et al., 2003). However, in both places, shellfish breed adult individuals (>15mm) (STENYAKINA et al., 2010), which does not cause a wide impact on the population, since, according to these authors, in this size individuals have reproduced at least once, renewing the population. It is noteworthy that, from the sampled mussels, it is understood that more than 94% of the individuals presented commercial size (Figure 3).

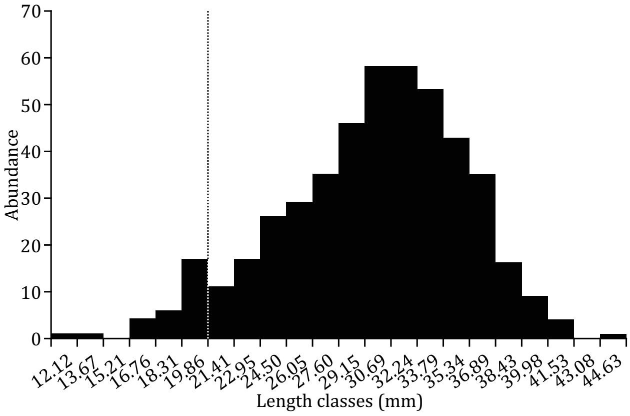

Figure 3. Abundance of mussel *Mytella charruana* by length classes. Dashed lines indicate the minimum commercial size practiced by fishermen on the Urindeua River (Salinópolis, State of Pará).

Positive correlations were found in the three morphometric relationships, classified as "strong" (0.71 ≤ *r* ≤ 0.9) (Figure 4), according Rodrigues (2010). The results of the correlation between total length and shell width of *M. charruana* in this study is close to that found by Reis Júnior et al. (2016), in the Sal river (Sergipe, Brasil), classified as "extremely strong" (*r* > 0.9), and higher than that found by Christo, Ferreira-Jr and Absher (2016) in the Emboguaçu river (Paraná, Brasil), presenting a correlation classified as "weak" (0.21 ≤ *r* ≤ 0.4) (Table 1). We highlight the same classifications when comparing the length and width ratios and between the width and height of *M. charruana*. Comparing the correlations between the morphometric measurements of *M. charruana* in this study, a similarity with another mussel of the Mytilidae family, *Mytella guyanensis* (Lamarck, 1819) (CHRISTO, FERREIRA-JR; ABSHER, 2016; REIS JÚNIOR et al., 2016) (Table 1).

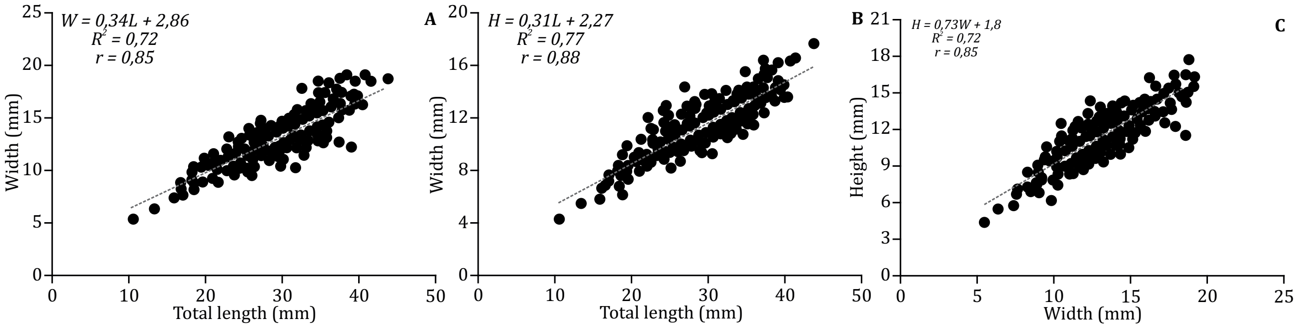

Figure 4. Morphometric relationships of the *Mytella charruana* mussel collected in the Urindeua River (Salinópolis, Pará).

Table 1. Morphometric data of *Mytella charruana* and *Mytella guyanensis* mytilids on the Brazilian coast. Legend: morphometric relationship (**R**), number of individuals used in the study (**n**), correlation coefficients (***R***^{2}), Pearson correlation coefficient (***r***), allometry (***A***).

Species	R	n	Total length (mm) (min - max)	Equation	R²	r	p	A	Sites	Reference
M. charruana	L x W	460	29.62±5.43 (10.5 – 43.7)	W = 2.86 + 0.34L	0.72	0.85	**	-	Urindeua River, PA	Present study
M. charruana	L x H	460	29.62±5.43 (10.5 – 43.7)	H = 2.27 + 0.30L	0.77	0.88	**	-	Urindeua River, PA	Present study
M. charruana	W x H	460	29.62±5.43 (10.5 – 43.7)	H = 1.81+ 0.73W	0.72	0.85	**	-	Urindeua River, PA	Present study
M. charruana	L x W	335	47.83±6.19	W = 11.16 + 0.18L	0.12	0.35	**	-	Emboguaçu River, PR	Christo, Ferreira -Jr and Absher (2016)
M. charruana	L x H	335	47.83±6.19	H = 6.18 + 0.17L	0.25	0.5	**	-	Emboguaçu River, PR	Christo, Ferreira -Jr and Absher (2016)
M. charruana	W x H	335	47.83±6.19	H = 11.09+ 0.19W	0.009	0.29	**	-	Emboguaçu River, PR	Christo, Ferreira -Jr and Absher (2016)
M. charruana	L x W	435	39±6.4 (20 – 55)	W = 3.79 + 0.33L	0.88	0.94*		-	Sal River, SE	Reis Júnior et al. (2016)
M. charruana	L x H	435	39±6.4 (20 – 55)	H = -1.91 + 0.35L	0.82	0.91*		-	Sal River, SE	Reis Júnior et al. (2016)
M guyanensis	L x W	335	46.93±5.02	W = 0.96 + 0.46L	0.75	0.86	*	-	Emboguaçu River, PR	Christo, Ferreira -Jr and Absher (2016)
M guyanensis	L x H	335	46.93±5.02	H = 0.48 + 0.34L	0.50	0.70	**	-	Emboguaçu River, PR	Christo, Ferreira -Jr and Absher (2016)
M guyanensis	W x H	335	46.93±5.02	H = 2.52+ 0.61W	0.47	0.68	**	-	Emboguaçu River, PR	Christo, Ferreira -Jr and Absher (2016)
M guyanensis	L x W	300	47±5.9 (31 – 63)	W = 5.13 + 0.39L	0.77	0.88*		-	Cotinguiba River, SE	Reis Júnior et al. (2016)
M guyanensis	H x L	300	39±6.4 (20 – 55)	H = 1.12 + 0.29L	0.70	0.84*		-	Cotinguiba River, SE	Reis Júnior et al. (2016)

*Valores estimados; ** Valores de $p < 0.001$

All the morphometric relationships in this study presented negative allometry, as well as the studies performed by Christo, Ferreira-Jr and Absher (2016) and Reis Júnior et al. (2016). This allometric classification is evidenced with the *M. guyanensis* mytilide by the same authors.

The shell shape stabilization indicator (IEF) of *M. charruana* showed that the species presents variation in the morphometric ratios throughout its growth. However, the H/L ratio has a rise up to ~20 mm and subsequently tends to a slight stabilization up to ~40 mm, then undergoing a new rise (Figure 5). These two ascents, both initial and final, may be related to the number of individuals sampled in these classes (Figure 3). However, stabilization evidenced at ~20 mm may be related to the first maturation size of the species (>15mm) (STENYAKINA et al., 2010). The IEF of the W/L ratio presents a slight negative slope along the length classes (Figure 5). Such behavior is different from the H/W ratios (mentioned above) and H/L indicating a tendency to stabilization. These characteristics in the IEF of the shell of *M. charruana* may be related to its population aspect, forming large clusters of individuals (RIOS, 2009; PUYANA, PRATO; DIAZ, 2012), which affects space competition.

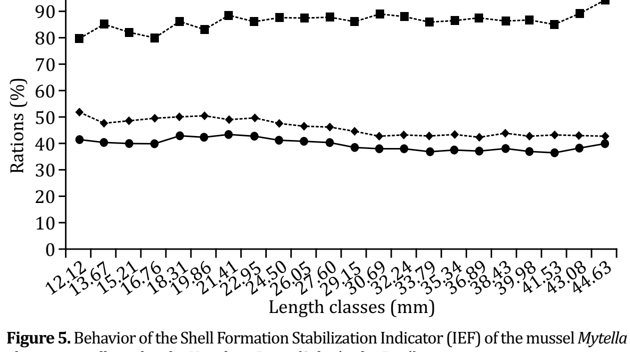

Figure 5. Behavior of the Shell Formation Stabilization Indicator (IEF) of the mussel *Mytella charruana*, collected in the Urindeua River (Salinópolis, Pará).

The IEF proposed by Gil, Troncoso and Thomé (2007) is one of the most effective methods to compare allometric growth among species/populations, being a reference for many studies with bivalve molluscs in Brazil, such as: cockle *Anomalocardia flexuosa* (Linnaeus, 1767) (MARINHO et al., 2018) and the mangrove oyster *Crassostrea tulipa* (Lamarck, 1819) (CHAGAS et al., 2019). In addition, this method is already used in studies with gastropod mollusks (CHAGAS, BARROS; BEZERRA, 2018).

According to Peres-Neto (1995), morphometry is a study of form and its relation to size, therefore, related to growth. In this sense, it is verified that there is a need for standardization of the morphometric measurements of the studied organisms, as well as in bivalve mollusks. However, it is verified that the morphometry of the mussel shell differs in some studies, which may lead to an inconsistency in the comparison of data, or even in fishery management and management measures since they are based on results of growth studies, meat yield and/or reproductive aspects, since the morphometric aspects, are essential in these cases.

According to Marques (1997), the biometry of the shell in mytilids is different from the other marine bivalves. This difference is remarkable because of the morphology of its shell, which presents umbo near or in the umbonal region. Because of this, some studies consider the largest dimension of the shell as its height (OLIVEIRA; OLIVEIRA, 1974; MARQUES, 1997; CHRISTO, FERREIRA-JR; ABSHER, 2016) and others, as in the current study, which consider their largest dimension as the total shell length (CORREIA, 1996; COSTA; NALESSO, 2002; PEREIRA et al., 2003; ARAÚJO et al., 2009; PUYANA, PRATO; DIAZ, 2012; REIS JÚNIOR et al., 2016; CHAGAS et al., 2017; MENDES, BARROS; CHAGAS, 2019).

Due to the divergence in the morphometric measurement of the mytilids and based on the current study, it is suggested to standardize the use of the largest shell size of the mussels as their total length. This will avoid errors in biometric data of the species.

Conclusions

It is concluded that the mussel *Mytella charruana* presents excellent morphometric relationships, which allows the estimation of the size of the species. In addition, based on the Shell Shape Stabilization Indicator (IEF), it was found that the species exhibits a mild stabilization in the shape of the shell throughout its growth. In addition, this study will serve as a basis for the morphometric standardization of mytilids, considering the largest dimension of the shell as its total length.

The mussel is one of the important resources for the community of village of Santo Antônio de Urindeua, which in large part has a source of income in the fishing resources of the region. In this sense studies with the species *M. charruana* are suggested, among them the study of growth, reproductive period, meat yield, centesimal analysis, among others. On the basis of these data, it is possible to verify the possibility of a consortium cultivation with oyster farming, already carried out on the Urindeua River by ASAPAQ, strengthening the seafood trade in the region, which would contribute to the development of community income.

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