PANAMJAS
Pan-American Journal of Aquatic Sciences

Morphometric relationships for non-target shrimp marine species off northeastern Brazil

JOSAFÁ REIS-JÚNIOR* & KÁTIA MEIRELLES FELIZOLA FREIRE

Universidade Federal de Sergipe, Departamento de Engenharia de Pesca e Aquicultura, Laboratório de Ecologia Pesqueira, Av. Marcelo Deda Chagas, S/N, Jardim Rosa Elze, CEP 49107-230, São Cristóvão–Sergipe–Brazil.

** Corresponding author:* josafajunior13@hotmail.com

ORCID numbers: JRJ: 0000-0002-0791-2673, KMFF: 0000-0002-6190-3532.

Abstract: We estimated morphometric relationships for four shrimp species (*Exhippolysmata oplophoroides*, *Nematopalaemon schmitti*, *Rimapenaeus constrictus*, and *Sicyonia dorsalis*) caught as bycatch by the shrimp fishery in Sergipe, northeastern Brazil. Allometry in growth differed among species.

Key words: Allometric growth, Lysmatidae, Palaemonidae, Penaeidae, Sicyoniidae.

Relações morfométricas para espécies de camarões marinhos não alvo da pesca no nordeste do Brasil. Resumo: Estimamos relações morfométricas para quatro espécies de camarões (*Exhippolysmata oplophoroides*, *Nematopalaemon schmitti*, *Rimapenaeus constrictus* e *Sicyonia dorsalis*) capturados como fauna acompanhante pela pesca de camarão em Sergipe, nordeste do Brasil. A alometria no crescimento diferiu entre as espécies.

Palavras-chave: Crescimento alométrico, Lysmatidae, Palaemonidae, Penaeidae, Sicyoniidae.

The shrimp fishery is considered predatory due to the capture method, where bottom trawls with low selectivity are used, resulting in a high capture of non-target species that are discarded (Hall *et al*. 2000). In Brazil, the target of this fishery are shrimps of economic importance belonging to the superfamily Penaeoidea (Dias-Neto 2011), however the participation of other shrimp species of no commercial interest is frequent in different states of Brazil: Santa Catarina (Branco *et al*. 2015), Paraná (Robert *et al*. 2007), São Paulo (Bochini *et al*. 2019), Rio de Janeiro (Costa *et al*. 2016), and Sergipe-Alagoas (Santos *et al*. 2016). Many species present in the bycatch of shrimp fisheries are more vulnerable than target species (Lira *et al*. 2022), mainly because most of them do not have their catches reported and basic information on their biology is missing, which prevents researchers and decision makers to assess the real impact of this activity on the ecosystem, representing a threat to its future sustainability (Andrew *et al*. 2007).

Morphometric relationships are important tools that help understanding essential biological aspects of populations of aquatic organisms. Allometry of growth from length-length relationships has been used to understand ecology and reproductive changes in several crustacean species, such as in crabs (e.g., Bertini *et al*. 2007, Reis-Júnior *et al*. 2020) and shrimps (e.g., Rosa *et al.* 2021, Reis-Júnior *et al.* 2023), where the analysis of the slope of these relationships are directly linked for example to energy investments during the reproductive processes. In addition, estimating weight from size is important in ecosystem modeling, especially when only length data is available and estimating biomass is required (Kimmerer *et al*. 2005). Finally, *b* values from weight-length relationships have been used to establish a relationship between a metabolism ratio and the constancy between size at first maturity and maximum size (see, e.g., Pauly *et al*. 2022, for crustaceans).

Among the shrimp species of no economic interest caught by bottom trawlers in Sergipe, we can mention four (Freire *et al.* 2020): *Exhippolysmata oplophoroides* (Holthuis, 1948), which belongs to the family Lysmatidae and has a wide geographical distribution in the Western Atlantic, from North Carolina (USA) to Texas (USA) and from English Guyana to Uruguay (Christoffersen 2016); *Nematopalaemon schmitti* (Holthuis, 1950), a Palaemonidae distributed from Venezuela to Rio Grande do Sul (Brazil) (Mantelatto *et al.* 2016); *Rimapenaeus constrictus* (Stimpson, 1871), a Penaeidae also widely distributed in Western America, occurring from Nova Scotia (Canada) to Santa Catarina (Brazil) (Boos *et al.* 2016); and *Sicyonia dorsalis* Kingsley, 1878 of the family Sicyoniidae, occurring from North Carolina (USA) to Santa Catarina (Brazil) (Costa & Simões 2016). Studies exploring morphometry are scarce or non-existent for these species at a global level and especially for Northeastern Brazil where they are frequently exploited by shrimp fisheries. Therefore, aiming at filling these existing gaps, we estimated length-length and weight-length morphometric relationships and evaluated the growth allometry for *E. oplophoroides*, *N. schmitti*, *R. constrictus*, and *S. dorsalis*.

Samples were obtained monthly between May 2015 and May 2016 from commercial shrimp trawlers based in the ports of Aracaju and Pirambu and operating off the state of Sergipe (10°44'16"S and 36°51'22"W to 11°31'09"S 37°30'42"W), in Northeastern Brazil (Fig. 1a). Samples obtained from boats based on Pirambu were complete (shrimp + bycatch) and obtained before landing from four different boats (6 kg samples from each boat). Samples obtained from boats based on Aracaju contained only shrimps, separated into size categories after landing (one sample of 3 kg from each category): small ('espigão'), medium ('escolha'), and large ('pistola'). The four shrimp species analyzed here were found in both types of samples: shrimp + bycatch (in Pirambu) and separated into size categories (in Aracaju). For more details of the sampling procedures used in this study, see Freire *et al*. (2020) and Reis-Júnior *et al.* (2023). All samples were frozen and stored in the *Laboratório de Ecologia Pesqueira – Departamento de Engenharia de Pesca e Aquicultura – Universidade Federal de Sergipe* (LEP/DEPAQ/UFS) for further analysis. In all samples, non-target shrimps fished in Sergipe (i.e., all species not belonging to the Penaeidae family reported in Freire *et al.* 2020) were separated and identified according to Carpenter (2002) and Costa *et al.* (2003). Each individual was measured: total length (distance from the tip of the rostrum to the tip of the telson, TL, mm), rostrum length (distance from the tip of the rostrum to the postorbital margin, RL, mm), and carapace length (distance from the postorbital margin to the mid-dorsal posterior edge of the carapace, CL, mm) using a digital caliper (precision: 0.01 mm). The total weight (TW, g) was obtained using a scale (precision: 0.0001 g).

The TL vs. CL and RL vs. CL relationships were fitted using a linear model (Y=a+bX), and the relationships TW vs. CL were fitted using a power model ($Y=a \cdot X^b$) (Froese 2006, Zar 2010). Confidence intervals for the parameters *a* and *b* were estimated for all relationships. For the TW vs. CL relationships, the natural logarithm of TW and CL were calculated before estimating *a* and *b*, and their respective confidence intervals. The isometry hypothesis was tested for the TL vs. CL and RL vs. CL relationships (b = 1) and for the TW vs. CL relationships (b = 3) using t-tests (Froese 2006, Zar 2010). The significance of these relationships was tested using analyses of variance (ANOVA). All statistical tests were performed at a 5% significance level using the R software version 4.2.1 (R Core Team 2022).

A total of 622 shrimps were analyzed: 55 specimens of *Exhippolysmata oplophoroides*, 502 of *Nematopalaemon schmitti*, 32 of *Rimapenaeus constrictus*, and 33 of *Sicyonia dorsalis*. The range of size and weight for each shrimp species was: *E. oplophoroides* (7.30–13.79 mm CL, 0.2298–1.7779 g TW), *N. schmitti* (6.47–13.45 mm CL, 0.2013–2.2297 g TW), *R. constrictus* (8.95–18.77 mm CL, 0.3928–4.0513 g TW), and *S. dorsalis* (4.51–14.14 mm CL, 0.0619–2.5327 g TW). *Rimapenaeus constrictus* was the largest and heaviest amongst the species analyzed (Figs. 1b-c), with mean CL (13.61 ± 2.45 mm) and TW (1.4533 ± 0.7701 g) larger than the others: *E. oplophoroides* (10.36 ± 1.51 mm CL, 0.8561 ± 0.3739 g TW), *N. schmitti* (9.96 ± 1.22 mm CL, 1.0349 ± 0.3709 g TW), and *S. dorsalis* (9.41 ± 2.19 mm CL, 0.6480 ±0 .4617 g TW). Based on the size at which these species enter the adult stage (CL, mm) in Southeastern-Southern Brazil (*E. oplophoroides*: smallest ovigerous specimen = 6.3 mm CL (Fransozo *et al.* 2005); *N. schmitti*: smallest

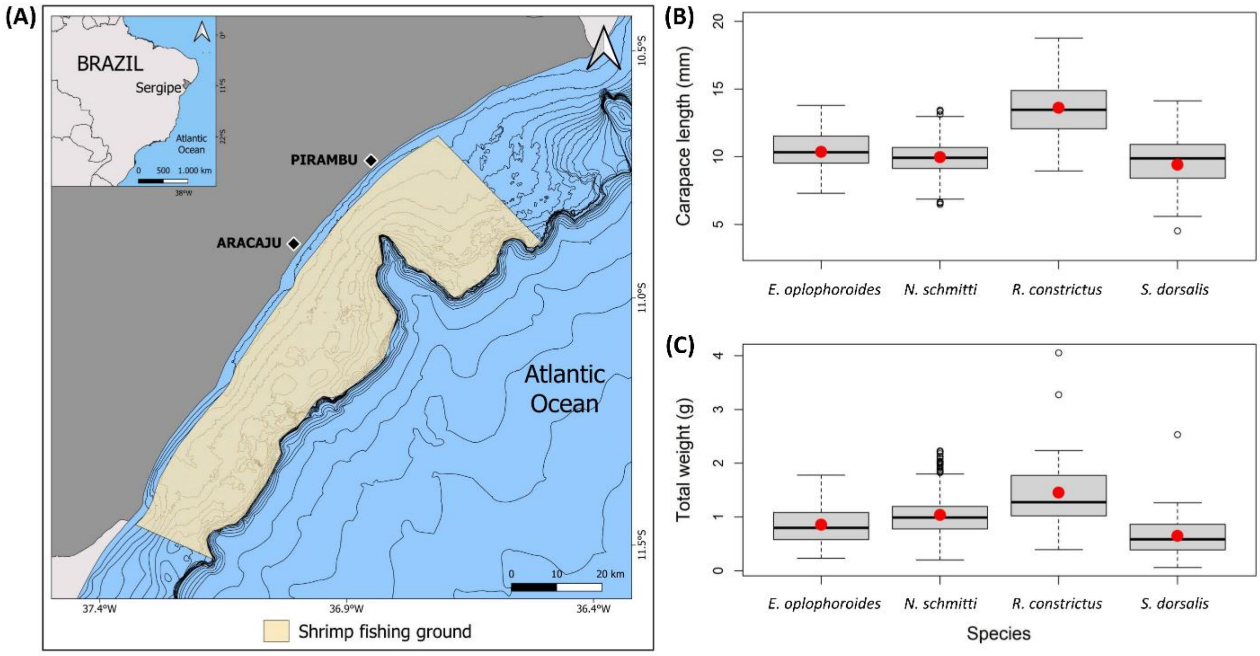

Figure 1. Study area off the state of Sergipe (Northeastern Brazil), indicating the location of the ports of Aracaju and Pirambu, and the shrimp fishing ground (Thomé-Souza *et al*., 2014) (A). Carapace length (B) and total weight (C) for the four species analyzed: *Exhippolysmata oplophoroides*, *Nematopalaemon schmitti*, *Rimapenaeus constrictus*, and *Sicyonia dorsalis*. Red dots represent mean values. The horizontal lines correspond to the 1st, 2nd (median), and 3rd quartiles. The white dots represent outliers.

adult = 9.7 mm and 8.5 mm CL for females and males, respectively (Almeida *et al.* 2011); *R. constrictus*: smallest mature specimen = 6.5 mm CL for both sexes (Garcia *et al.* 2016); and *S. dorsalis*: smallest adult = 9.2 mm and 6.8 mm CL for females and males, respectively (Castilho *et al.* 2008)), we hypothesize that mostly adults were analyzed here due to the size range of the specimens sampled in our study. All morphometric relationships were significant (Table I). The relationships between TL and CL indicated positive allometric growth for all species ($b > 1$). The relationships between RL and CL had the lowest coefficients of determination ($r^2 = 0.24-0.58$), indicating a lower fit between rostrum length and carapace length, and the allometry of growth varied among species: negative ($b < 1$, *R. constrictus* and *S. dorsalis*), isometric ($b = 1$, *E. oplophoroides*), and positive ($b > 1$, *N. schmitti*). Finally, the TW-CL relationships indicated negative allometric growth ($b < 3$) for *N. schmitti* and *R. constrictus*, and isometric growth ($b = 3$) for *E. oplophoroides* and *S. dorsalis* (Table I). The four species analyzed here have been studied in Southern-Southeastern Brazil through several projects focusing mainly on population structure, reproduction, distribution and abundance, and growth (e.g., Castilho *et al.* 2008, Baeza *et al*. 2010, Almeida *et al*. 2011, Garcia *et al*. 2016). However, studies evaluating morphometric relationships are less frequent. Most of the weight-length relationships available are for *R. constrictus*, with a negative allometric growth for females and positive for males off the state of Rio de Janeiro, even though some variation among years was observed (Oliveira-Souza & Lavrado 2017). Studies conducted off the coast of São Paulo found negative allometry in this relationship for both sexes (Santos *et al*. 2020a, Silva *et al*. 2021), corroborating our result for grouped sexes for this species. Conversely, *N. schmitti* and *E. oplophoroides* were evaluated regarding relative growth for relationships between carapace length and secondary structures related to sexual dimorphism and reproductive changes, such as length of the male appendix and the second pleuron length, in populations off Southeastern Brazil (see Herrera *et al*. 2017, Pescinelli *et al*. 2017). For *N. schmitti*, TL-CL and TW-CL relationships were estimated for the state of Sergipe (Santos *et al*. 2020b), but the growth allometry was not statistically evaluated. Their *b* values corroborate with those found in the present study: positive allometry for TL-CL relationships and negative for TW-CL relationships. In fact, Pauly *et al.* (2022) analyzed the relationship between weight and length

Table I. Morphometric relationships estimated for *Exhippolysmata oplophoroides*, *Nematopalaemon schmitti*, *Rimapenaeus constrictus*, and *Sicyonia dorsalis* caught by shrimp trawlers in Sergipe (Northeastern Brazil) from May 2015 to May 2016. TL = total length, CL = carapace length, RL = rostrum length, TW = total weight, *a* = intercept, *b* = slope, n = sample size, CI = 95% confidence interval, r² = coefficient of determination. F refers to the results of the analysis of variance for the regression. For the TW-CL relationships, TW and CL were linearized before the estimation of *a* and *b*. *indicate statistically significant results ($p < 0.05$).

Species	TL-CL relationships					
	a **(CI for** ***a*****)**	***b*** **(CI for** ***b*****)**	**r²**	**n**	**F**	**t-test for allometry**
E. oplophoroides	9.131 (0.439 – 17.823)	4.669 (3.861 – 5.479)	0.88	22	145.0*	9.46* (Positive)
N. schmitti	7.862 (4.329 – 11.395)	5.490 (5.144 – 5.837)	0.88	135	981.4*	25.62* (Positive)
R. constrictus	14.572 (8.321 – 20.823)	3.079 (2.626 – 3.532)	0.87	29	194.7*	9.42* (Positive)
S. dorsalis	3.709 (-0.604 – 8.024)	3.504 (3.094 – 3.914)	0.96	14	347.0*	13.31* (Positive)
	RL-CL relationships					
	a **(CI for** ***a*****)**	***b*** **(CI for** ***b*****)**	**r²**	**n**	**F**	**t-test for allometry**
E. oplophoroides	9.218 (2.525 – 15.910)	1.015 (0.393 – 1.637)	0.35	24	11.5*	0.05 (Isometry)
N. schmitti	0.334 (-2.429 – 3.099)	1.893 (1.621 – 2.165)	0.58	141	189.6*	6.49* (Positive)
R. constrictus	3.189 (-0.172 – 6.552)	0.320 (0.069 – 0.571)	0.24	25	6.9*	5.61* (Negative)
S. dorsalis	1.569 (-0.090 – 3.237)	0.163 (-7×10^{-4} – 0.328)	0.25	16	5.5*	10.88* (Negative)
	TW-CL relationships					
	ln ***a*** **(CI for** ***a*****)**	***b*** **(CI for** ***b*****)**	**r²**	**n**	**F**	**t-test for allometry**
E. oplophoroides	-7.147 (-8.005 – -6.289)	2.959 (2.590 – 3.326)	0.83	55	260.1*	0.22 (Isometry)
N. schmitti	-6.239 (-6.488 – -5.989)	2.708 (2.599 – 2.816)	0.84	465	2407.0*	8.04* (Negative)
R. constrictus	-6.417 (-7.331 – -5.503)	2.570 (2.218 – 2.921)	0.88	32	223.2*	2.49*(Negative)
S. dorsalis	-7.212 (-7.770 – -6.653)	2.951 (2.700 – 3.202)	0.94	33	575.3*	0.39 (Isometry)

for about 370 species of crustaceans and found a tendency toward negative allometry. Finally, for *S. dorsalis,* the morphometric relationships presented here were the first to be estimated.

Growth allometry in TL-CL relationships for shrimps has been associated with differential metabolism between juveniles and adults (Dall *et al*. 1990), where juveniles have steeper slopes due to higher metabolism (see difference between juveniles and adults in *Farfantepenaeus subtilis* in Reis-Júnior *et al*. 2023). Another characteristic evaluated is usually the difference between sexes. Females tend to direct part of the energy investment into the reproductive process, a process known as 'reproductive drain', which makes it possible to observe differences in allometry when compared to males (Dall *et al*. 1990, Reis-Júnior *et al*. 2019, 2023). The weight-length relationships follow the same pattern: even though the sex differences in allometry for the parameter *b* is well-known and associated with differentiated reproductive investment (Leite-Jr & Petrere-Jr 2006, Reis-Júnior *et al.* 2023), it is also possible to observe a monthly variation in *b* for some species (see, e.g., *Xiphopenaeus kroyeri* in Reis-Júnior *et al*. 2019) and an annual variation, suggesting changes in competition for food resources in these populations (see *Rimapenaeus contrictus* in Oliveira-Souza & Lavrado 2017). Pauly *et al.* (2022) added a new element to this discussion, stating that limiting oxygen for water breathing organisms, including crustaceans, may be the most limiting factor responsible for some of observed sexual differences (known as the 'gill oxygen limiting theory' or simply GOLT).

The conservation status for *E. oplophoroides* is Data Deficient (DD) according to the assessment prepared by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) (Christoffersen 2016), indicating the need for further research. Although *N. schmitti*, *R. constrictus,* and *S. dorsalis* have been considered of Least Concern (LC) by ICMBio (Pinheiro & Boss 2016), there is still a lack of biological information regarding morphometric relationships for these species. Length–weight relationships are important as they allow for the conversion of growth-in-length into growth-in-weight for use in stock assessments, and their parameters represent one of the tools used to differentiate stocks. Considering that these species represent part of the by-catch of the shrimp fishery in the region, we recommend that future studies on shrimp trawling place some effort into producing basic information for these and other species of no economic importance caught by shrimp fisheries, accessing also other population differences, e.g., juveniles vs. adults and males vs. females that we could not be understood with the present work, especially in Northeastern Brazil, where studies in general are scarcer and non-target species may be at higher risk.

Ethical statement

The present investigation did not involve the manipulation of regulated animals and did not require approval by an Ethical Committee.

Acknowledgements:

We would like to thank M. Morais and D. Lopes for collaborating with sample acquisition, L. C. Rosa for identifying all shrimps, T. M. R. R. Barreto, A. A. S. Dias, A.C. Gaspar, and S. Lima for helping with laboratory processing. This study was supported by the *Projeto de Monitoramento Participativo de Desembarque Pesqueiro* (PMPDP) and *Fundação de Apoio à Pesquisa e Extensão de Sergipe* (FAPESE) (Grant numbers 2600.0094374.14.4 and 2600.0099827.15.4). J. J. C. Reis Jr thank FAPESE/PMPDP for his scholarship.

References

Almeida, A. C., Fransozo, V., Teixeira, G. M., Furlan, M., Hiroki, K. A. N. & Fransozo, A. 2011. Population structure and reproductive period of whitebelly prawn *Nematopalaemon schmitti* (Holthuis 1950) (Decapoda: Caridea: Palaemonidae) on the southeastern coast of Brazil. **Invertebrate Reproduction & Development**, 55(1): 30-39.

Andrew, N. L., Béné, C., Hall, S. J., Alisson, E. H., Heck, S. & Ratner, B. D. 2007. Diagnosis and management of small-scale fisheries in developing countries. **Fish and Fisheries**, 8(3): 227–240.

Baeza, J. A., Braga, A. A., Lópes-Greco, L. S., Perez, E., Negreiros-Fransozo, M. L. & Fransozo, A. 2010. Population dynamics, sex ratio and size at sex change in a protandric simultaneous hermaphrodite, the spiny shrimp *Exhippolysmata oplophoroides*. **Marine Biology**, 157: 2643-2653.

Bertini, G., Braga, A. A., Fransozo, A., Corrêa, M. O. D. A. & Freire, F. A. M. 2007. Relative growth and sexual maturity of the stone crab *Menippe nodifrons* Stimpson, 1859 (Brachyura, Xanthoidea) in Southeastern Brazil. **Brazilian Archives of Biology and Technology**, 50(2): 259–267.

Bochini, G. L., Stanski, G., Castilho, A. L. & Costa, R. C. 2019. The crustacean bycatch of seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862) fisheries in the Cananéia region, southern coast of São Paulo, Brazil. **Regional Studies in Marine Science**, 31: 100799.

Boos, H., Costa, R. C., Santos, R. A. F., Dias-Neto, J., Severino-Rodrigues, E., Rodrigues, L. F., D'Incao, F., Ivo, C. T. C. & Coelho, P. A. 2016. Avaliação dos camarões peneídeos (Decapoda: Penaeidae). Pp. 300-317. In: Pinheiro, M. A. A. & Boos, H. (Eds.). **Livro Vermelho dos Crustáceos do Brasil: Avaliação 2010-2014**. Sociedade Brasileira de Carcinologia, Porto Alegre, Brazil, 466 p.

Branco, J. O., Freitas-Júnior, F. & Christoffersen, M. L. 2015. Bycatch fauna of seabob shrimp trawl fisheries from Santa Catarina State, southern Brazil. **Biota Neotropica**, 15(2): 1–14.

Carpenter, K. E. 2002. **The living marine resources of the Western Central Atlantic. Volume 1: Introduction, molluscs, crustaceans, hagfishes, sharks, batoid fishes, and chimaeras.** Food and Agriculture Organization of the United Nations, Rome, 600 p.

Castilho, A. L., Furlan, M., Costa, R. C. & Fransozo, V. 2008. Reproductive biology of the rock shrimp *Sicyonia dorsalis* (Decapoda: Penaeoidea) from the southeastern coast of Brazil. **Invertebrate Reproduction & Development**, 52(1-2): 59-68.

Christoffersen, M. L. 2016. Avaliação de *Exhippolysmata oplophoroides* (Holthuis, 1948) (Decapoda: Lysmatidae). Pp. 203-211. In: Pinheiro, M. A. A. & Boos, H. (Eds.). **Livro Vermelho dos Crustáceos do Brasil: Avaliação 2010-2014**. Sociedade Brasileira de Carcinologia, Porto Alegre, Brazil, 466 p.

Costa, R. C. & Simões, S. M. 2016. Avaliação dos camarões sergestídeos (Decapoda: Sergestidae). Pp. 366-376. In: Pinheiro, M. A. A. & Boos, H. (Eds.). **Livro Vermelho dos Crustáceos do Brasil: Avaliação 2010-2014**.

Sociedade Brasileira de Carcinologia, Porto Alegre, Brazil, 466 p.

Costa, R. C., Carvalho-Batista, A., Herrera, D. R., Pantaleão, J. A. F., Teodoro, S. S. A. & Davanso, T. M. 2016. Carcinofauna acompanhante da pesca do camarão-sete-barbas *Xiphopenaeus kroyeri* em Macaé, Rio de Janeiro, Sudeste Brasileiro. **Boletim do Instituto de Pesca**, 42(3): 611–624.

Costa, R. C., Fransozo, A., Melo, G. A. S. & Freire, F. A. M. 2003. Chave ilustrada para identificação dos camarões Dendrobranchiata do litoral norte do estado de São Paulo, Brasil. **Biota Neotropica**, 3: 1−12.

Dall, W., Hill, B. J., Rothlisberg, P. C. & Staples, D. J. 1990. The biology of the Penaeidae. Pp. 1-487. In: Blaxter, J. H. S. & Southward, A. J. (Eds.). **Advances in Marine Biology**. Academic Press, San Diego, 596 p.

Dias-Neto, J. 2011. **Proposta de plano nacional de gestão para o uso sustentável de camarões marinhos do Brasil.** Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA), Brasília, 242 p.

Fransozo, V., Costa, R. C., Bertini, G. & Cobo, V. J. 2005. Population biology of spine shrimp *Exhippolysmata oplophoroides* (Holthuis) (Caridea, Hippolytidae) in a subtropical region, São Paulo, Brazil. **Revista Brasileira de Zoologia**, 22: 1078-1084.

Freire, K. M. F., Rosa, L. C., Reis-Júnior, J. & Barreto, T. M. R. R. 2020. Understanding what is what in marine shrimp fisheries. **Ocean and Coastal Research**, 68: e20322.

Froese, R. 2006. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. **Journal of Applied Ichthyology**, 22: 241–253.

Garcia, J. R., Wolf, M. R., Costa, R. C. & Castilho, A. L. 2016. Growth and reproduction of the shrimp *Rimapenaeus constrictus* (Decapoda: Penaeidae) from the southeastern coast of Brazil. **Regional Studies in Marine Science**, 6: 1–9.

Hall, M., Alverson, D. L. & Metuzals, K. I. 2000. By-catch: problems and solutions. **Marine Pollution Bulletin,** 41: 204–219.

Herrera, D. R., Davanso, T. M. & Costa, R.C. 2017. Relative growth and morphological sexual maturity of the caridean shrimp *Nematopalaemon schmitti* (Decapoda: Caridea: Palaemonidae) in an upwelling region in the Western Atlantic. **Invertebrate Reproduction & Development**, 62(1): 56-62.

Kimmerer, W., Avent, S. R., Bollens, S. M., Feyrer, F., Grimaldo, L. F., Moyle, P. B., Nobriga, M. & Visintainer, T. 2005. Variability in length–weight relationships used to estimate biomass of estuarine fish from survey data. **Transactions of the American Fisheries Society**, 134(2): 481–495.

Leite-Jr, N. O. & Petrere-Jr, M. 2006. Growth and mortalities of the pink-shrimp *Farfantepenaeus brasiliensis* Latreille, 1970 and *F. paulensis* Pérez-Farfante, 1967 in southeast Brazil. **Brazilian Journal of Biology,** 66: 523−536.

Lira, A. S., Le Loc'h, F., Andrade, H. A. & Lucena-Frédou, F. 2022. Vulnerability of marine resources affected by a small-scale tropical shrimp fishery in northeast Brazil. **ICES Journal of Marine Science**, 79(3): 633–647.

Mantelatto, F. L., Pileggi, L. G., Magalhães, C., Carvalho, F. L., Rocha, S. S., Mossolin, E. C., Rossi, N. & Bueno, S. L. S. 2016. Avaliação dos camarões palemonídeos (Decapoda: Palaemonidae). Pp. 252-267. In: Pinheiro, M. A. A. & Boos, H. (Eds.). **Livro Vermelho dos Crustáceos do Brasil: Avaliação 2010-2014**. Sociedade Brasileira de Carcinologia, Porto Alegre, Brazil, 466 p.

Oliveira-Souza, W. & Lavrado, H. P. 2017. Population structure and temporal variation of the roughneck shrimp *Rimapenaeus constrictus* (Decapoda: Penaeoidea) in a coastal bay of the Southwestern Atlantic. **Marine Biology Research**, 13(10): 1073-1083.

Pauly, D., Amarasinghe, U. S., Chu1, E., Freire, K. M. F., Vázquez, E. & Butler IV, M. J. 2022. The growth, respiration, and reproduction of crustaceans: a synthesis through the Gill-Oxygen Limitation Theory (GOLT). **Journal of Crustacean Biology**, 42(4): ruac059.

Pescinelli, R. A., Davanso, T. M., Pantaleão, J. A. F., Carvalho-Batista, A., Bauer, R. T. & Costa, R. C. 2017. Population dynamics, relative growth and sex change of the protandric simultaneous hermaphrodite *Exhippolysmata oplophoroides* (Caridea: Lysmatidae) close to an upwelling area. **Journal of the Marine Biological Association of the United Kingdom**, 98(4): 727-734.

Pinheiro, M. A. A. & Boos, H. 2016. **Livro Vermelho dos Crustáceos do Brasil:**

Avaliação 2010-2014. Sociedade Brasileira de Carcinologia, Porto Alegre, Brazil, 466 p.

R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at https://www.R-project.org/. Accessed on 10 December 2022.

Reis-Júnior, J., Dias, A. A. S., Rosa, L. C., Barreto, T. M. R. R. & Freire, K. M. F. 2023. Assessing the population structure of the southern brown shrimp *Farfantepenaeus subtilis* (Pérez-Farfante 1967) using different sampling methods. **Thalassas,** 39: 77–91.

Reis-Júnior, J., Freire, K. M. F., Rosa, L. C. & Barreto, T. M. R. R. 2020. Population structure of *Hepatus pudibundus* (Decapoda: Aethridae) off the coast of Sergipe State, northeastern Brazil. **Nauplius**, 28: e2020008.

Reis-Júnior, J. J. C., Freire, K. M. F., Rosa, L. C., Barreto, T. M. R. R. & Pauly, D. 2019. Population dynamics of Atlantic seabob *Xiphopenaeus kroyeri* (Decapoda: Penaeidae) off the state of Sergipe, north-eastern Brazil. **Journal of the Marine Biological Association of the United Kingdom**, 99: 143−153.

Robert, R., Borzone, C. A. & Natividade, C. D. 2007. Os camarões da fauna acompanhante na pesca dirigida ao camarão-sete-barbas (*Xiphopenaeus kroyeri*) no litoral do Paraná. **Boletim do Instituto de Pesca**, 33(2): 237-246.

Rosa, L. C., Reis-Júnior, J., Freire, K. M. F. & Barreto, T. M. R. R. 2021. Biometric relationships and sex ratio for red-spotted shrimp *Farfantepenaeus brasiliensis* (Latreille, 1817) (Decapoda, Penaeidae) from the coast of Sergipe, northeastern Brazil. **Nauplius**, 29: e2021002.

Santos, H. L., Santana, F. S., Gonçalves, F. D. S., Araújo, A. R. R. & Deda, M. S. 2020b. Estrutura populacional do *Nematopalaemon shimitti* (Holthuis 1950), Pirambu, Sergipe. Pp. 147-154. In: Santos, A. S. et al. (Eds.). **Transversalidade da Engenharia de Pesca – Anais da IV Semana Acadêmica de Engenharia de Pesca IFES**. Latin American Publicações, São José dos Pinhais, 212 p.

Santos, M. C. F., Silva, K. C. A. & Cintra, I. H. A. 2016. Carcinofauna acompanhante da pesca artesanal do camarão-sete-barbas ao largo da foz do rio São Francisco (Alagoas e Sergipe, Brasil). **Acta of Fisheries and Aquatic Resources**, 4: 1-10.

Santos, R. A. P., Silva, A. R., Moraes, I. R. R., Antunes, M., Lopes, A. E. B., Costa, R. C. & Castilho, A. L. 2020a. Gonadosomatic index and weight/length relationship in females of three penaeoidean shrimps impacted by fisheries on the southeastern Brazilian coast. **Nauplius**, 28: e2020045.

Silva, A. R., Lopes, A. E. B., Grabowski, R. C. & Castilho, A. L. 2021. Weight/carapace length relationship and condition factor of the roughneck shrimp, *Rimapenaeus constrictus* (Stimpson, 1874), on the southeastern Brazilian coast. **Anais da Academia Brasileira de Ciências**, 93(2): e20190570.

Thomé-Souza M. J. F., Carvalho, B. L. F., Garciov-Filho, E. B., Silva, C. O., Deda, M. S., Félix, D. C. F. & Santos, J. C. 2014. **Estatística pesqueira da costa do Estado de Sergipe e Extremo Norte da Bahia – 2013**. Editora UFS, São Cristóvão, 107 p.

Zar, J. H. 2010. **Biostatistical analysis**. Fifth ed. Pearson Prentice Hall, Englewood Cliffs, NJ, 944 p.

Received: July 2022
Accepted: December 2023
Published: May 2024