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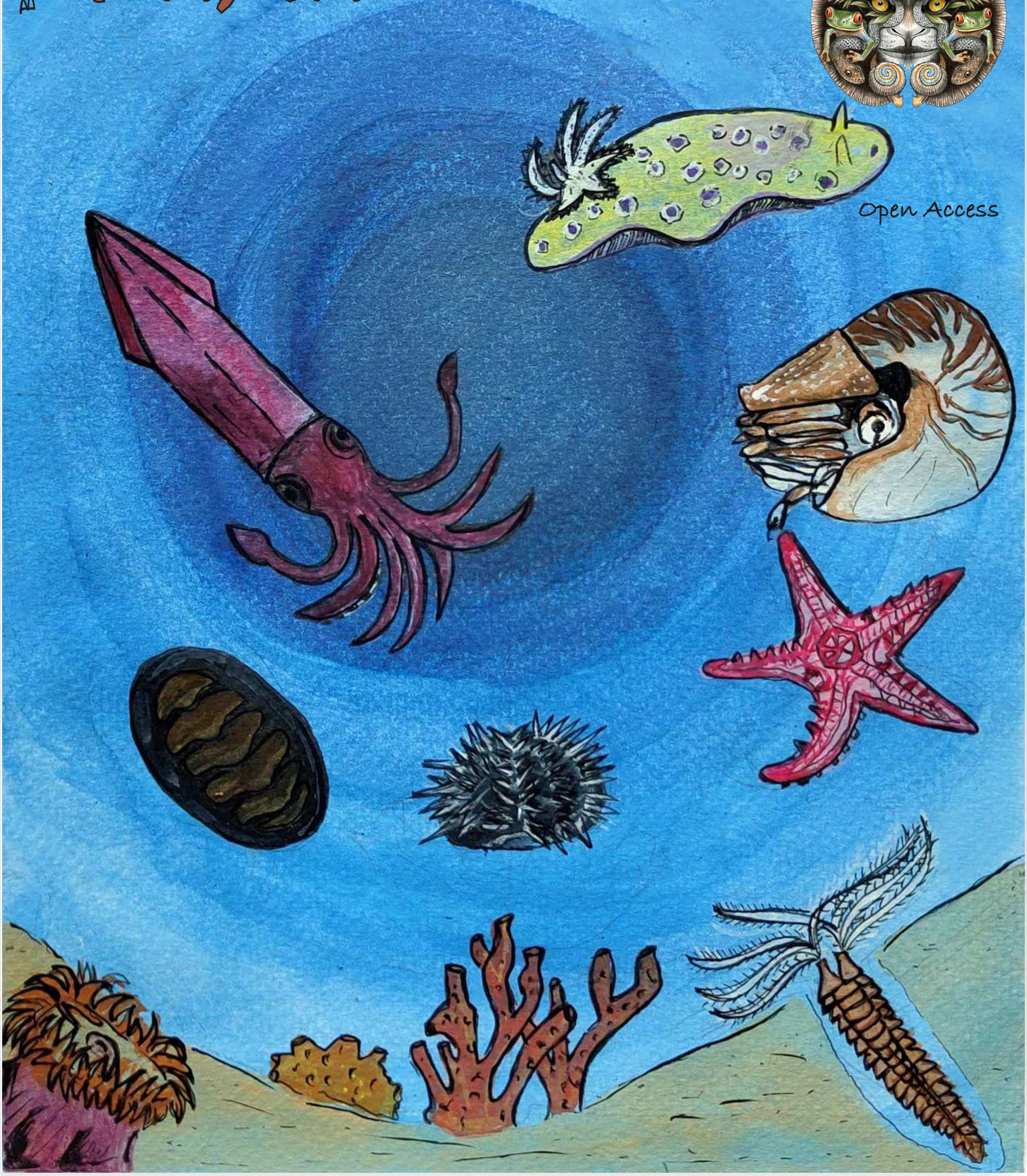

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COMMUNICATION

Trace elements in *Penaeus* shrimp from two anthropized estuarine systems in Brazil

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Abstract: This study measured concentrations of trace elements (Al, As, Cd, Cu, Fe, Mn, Ni, and Pb) in the muscle of pink shrimps (genus *Penaeus*) from two anthropized estuarine systems in Brazil: Guanabara Bay (GB) and Sepetiba Bay (SB). Concentrations were highest in the less anthropized SB site, where shrimps showed higher assimilation rates that can be explained by their higher trophic position compared to shrimps from GB. These results reinforce the role of food sources as the main route of trace elements for the aquatic animals.

Keywords: Coastal systems, metals, metalloid, pink shrimps, stable isotope.

Portuguese abstract: Este estudo verificou que a concentração de elementos traço (Al, As, Cd, Cu, Fe, Mn, Ni e Pb) no músculo de camarões-rosa (gênero *Penaeus*) é variável entre dois sistemas estuarinos antropizados no Brasil (Baía de Guanabara - BG e Baía de Sepetiba - BS), sendo maior no local menos antropizado (BS). As regressões entre as concentrações de elemento traço e os valores de $\delta^{15}N$ mostraram maiores taxas de assimilação nos camarões da BS, o que pode ser explicado pela sua posição trófica mais elevada em relação aos camarões da BG. Os resultados reforçam o papel das fontes alimentares como a principal rota de elementos traço para os animais aquáticos.

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Author contributions: Di Beneditto, A.P.M.: project administration, funding acquisition, conceptualization, investigation, writing - original draft, writing - review & editing. Pestana, I.A.: formal analysis, writing - review & editing. de Carvalho, C.: shrimps sampling, writing - review & editing.

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INTRODUCTION

Trace elements such as metals and metalloids can accumulate in all compartments of aquatic environments (Brown & Depledge 1998), where their concentrations reflect both natural levels and anthropogenic contamination. When they enter human food chains, elements such as Cd, Hg, and Pb can cause neurological and kidney damage (WHO 2019), while As (metalloid) is linked to several types of cancers (Palma-Lara et al. 2020). Shrimps and other crustaceans accumulate trace elements from water, sediment, and food sources at levels beyond those necessary for nutrition and metabolism (Rainbow 2002; Boudet et al. 2019). Food is the main route of trace elements for both invertebrates and vertebrates (Rainbow 2002; Di Beneditto et al. 2021; Kehrig et al. 2022)

The pink shrimps *Penaeus brasiliensis* Latreille, 1817 and *P. paulensis* Perez Farfante, 1967 are sympatric in the southwestern Atlantic, where juveniles inhabit estuaries while adults live in marine waters (Neto 2011). Carvalho et al. (2021) investigated the stomach contents and the niche breadth of juvenile pink shrimps in two anthropized estuarine systems located in Sepetiba Bay and Guanabara Bay, southeastern Brazil (~23°S) (Figure 1). These areas are proximal coastal nurseries and fishing sites for both species. Niche analysis revealed pink shrimps from Guanabara Bay occupied a lower trophic position and showed greater trophic diversity in comparison to pink shrimps from Sepetiba Bay (Carvalho et al. 2021). The authors verified that interspecific differences in feeding preferences are negligible within the same estuarine system.

Based on findings of Carvalho et al. (2021) and the premise that food sources are the main route of trace elements for the animals, we made two predictions: i) the concentration of trace elements in shrimps *Penaeus* is variable between the two estuarine systems, following the spatial difference of the trophic niche, and ii) pink shrimps from Sepetiba Bay have higher trace element concentrations, since their trophic position is higher than in Guanabara Bay.

METHODS

Since *P. brasiliensis* and *P. paulensis* have similar feeding habits and niches in estuarine systems, we grouped them as *Penaeus* shrimps. Juvenile pink shrimps were sampled through fisheries inside Guanabara Bay (n = 80 individuals) and Sepetiba Bay (n = 67 individuals); herein referred as GB and SB, respectively (Figure 1). The samplings were done in 2021—2022. In GB, shrimps were caught in a fishing site in the central portion of the bay (8 km^2, 12—15 m deep), 10 km from the bay entrance (Figure 1). In SB, the fishing site included an area of approximately 6 km^2 and 10 m deep, 20 km from the bay entrance and 3 km from its northeastern shore, in front of the Guandu River mouth (Figure 1).

GB is more anthropized than SB. It comprises 384 km^2 with a drainage basin of 4,080 km^2 (55 small-river inputs). In surrounding areas, there are almost 12 million inhabitants, 6,000 industries and intensive inputs of domestic sewage and industrial effluents (Cordeiro et al. 2021). The SB comprises 450 km^2 with a drainage basin of 2,065 km^2. The SB surrounding areas have 400 industries, mainly chemical and metallurgic plants, and a population of approximately 2.0 million (Costa et al. 2011).

After sampling, shrimps were stored in transparent clean plastic bags and kept in cold storage during transportation. In the laboratory, the abdominal muscle (edible portion) of each shrimp was removed, stored in a dry sterile bottle, frozen (-20ºC), freeze-dried and homogenized to a fine powder using a mortar and pestle.

The trace elements considered in this study are Al, As, Cd, Cu, Fe, Mn, Ni, and Pb, which were determined using ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry) 720 ES (Varian Liberty Series II). Briefly, freeze-dried muscle (0.5 g) was solubilized in 10 mL of 65% HNO_3 and heated in a digester block. The samples were resuspended in 5 mL of 0.5% HNO_3 at 60 °C, filtered and brought to a final volume of 20 mL with 0.5% HNO_3. An analytical control solution was prepared to check for contamination. A reference material (*DORM-4* fish protein, National Research Council of Canada) was analyzed to test the precision and accuracy, and the recovery values were above 95%. The coefficients of variation among analytical replicates were < 10%. The concentrations were determined in mg kg^{-1} of dry weight.

We used the ratio of nitrogen stable isotope ($\delta^{15}N$) to evaluate the trophic position of the pink shrimps. Dry muscle sample (0.4 mg) of each shrimp was analysed using an organic elemental analyzer (Flash 2000, Thermo Scientific) coupled to a mass spectrometer (Delta V Advantage Isotope Ratio Mass Spectrometer, Thermo Scientific) through the ConFlo-VI interface (Model BR30140, Thermo Scientific). The reference value for nitrogen was the atmospheric nitrogen. Samples were analyzed using analytical blanks and urea analytical standards (IVA Analysentechnik-330802174). Analytical control and reproducibility were done for every 10 samples using a certified isotopic standard (Elemental

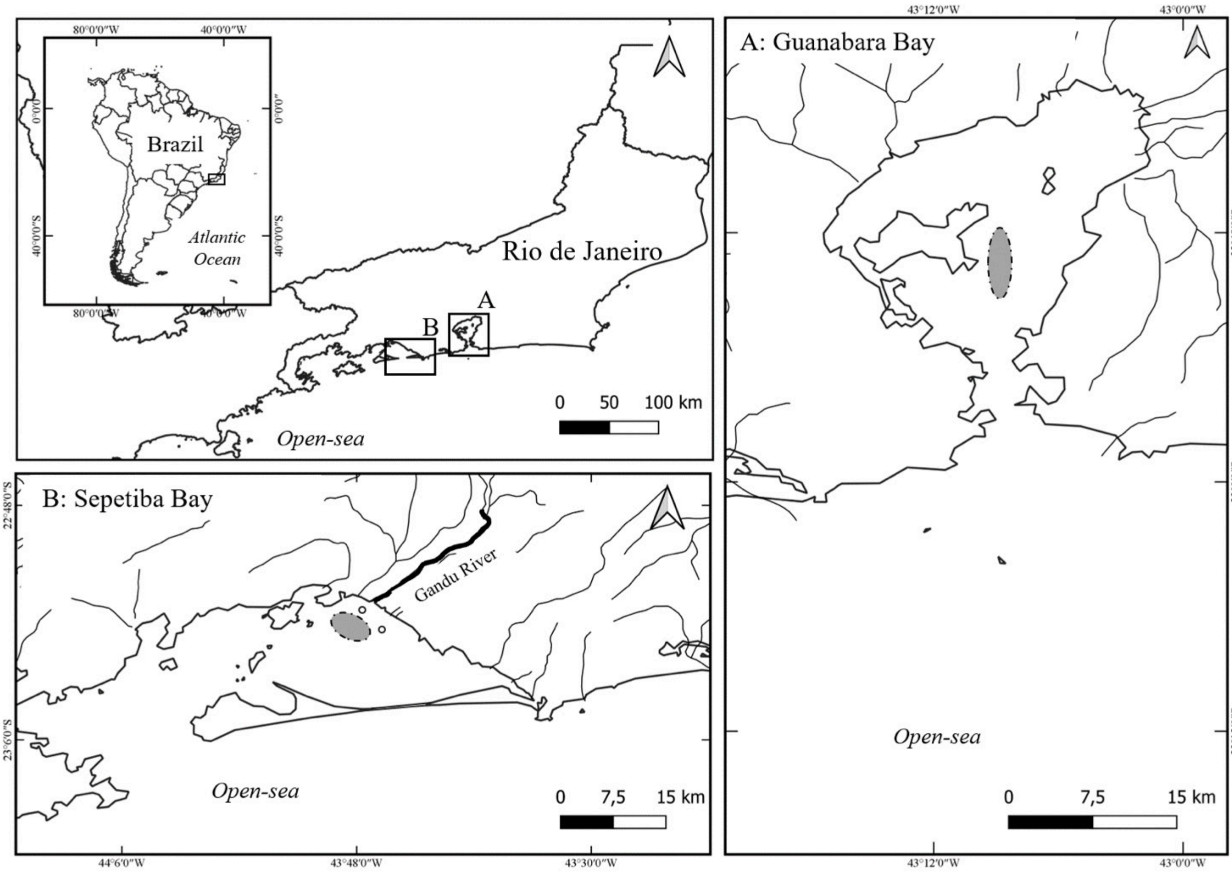

Figure 1. Guanabara Bay (A) and Sepetiba (B) Bay, southeastern Brazil, and the fishing sites of the pink shrimps inside the bays (gray ellipse areas). Extract from Di Beneditto et al. (2021).

Microanalysis Protein Standard OAS) and based on triplicates for every 10 samples (± 0.3‰ for $\delta^{15}N$). The isotopic result was presented as parts per thousand (‰).

RESULTS AND DISCUSSION

The concentrations of Al, As, Cd, Cu, Fe, Mn, Ni, and Pb, and the values of $\delta^{15}N$ in the muscle of the pink shrimps were greater in SB than GB (Table 1). This finding was statistically supported by the ANOVA results (R Core Team 2022) for most elements (Table 1). ANVISA (2021) and FAO/WHO (1991) have established the maximum tolerable limits of some trace elements (e.g., As, Cd, Cr, Cu, Hg and Pb) for food products. In this study, the trace elements determined in the pink shrimps were below these limits.

The difference in $\delta^{15}N$ values reinforces the findings of Carvalho et al. (2021): pink shrimps from SB are in higher trophic position than GB (p <0.001). The isotopic difference between the pink shrimps from the two estuarine systems was 4.7%, which is high enough to distinguish different trophic levels between them. According to Post (2002), differences in $\delta^{15}N$ values ranged from 2 to 5% indicate different trophic levels.

Table 1. Median ± interquartile range values of Al, As, Cd, Cu, Fe, Mn, Ni, and Pb (mg·kg-1 dry weight), and δ15N (‰) in the muscle of pink shrimps from two anthropized estuarine systems in Brazil. Lowercase letters a and b indicate ANOVA differences at at *p* <0.05.

Estuarine system Elements	Guanabara Bay (GB)	Sepetiba Bay (SB)
Al	16.8 ± 25.5^{b}	42.2 ± 47.3^{a}
As	3.1 ± 2.1^{b}	5.1 ± 3.6^{a}
Cd	0.02 ± 0.01^{a}	0.02 ± 0.01^{a}
Cu	8.5 ± 4.8^{a}	9.6 ± 6.2^{a}
Fe	10.8 ± 16.9^{b}	35.8 ± 31.4^{a}
Mn	0.8 ± 1.0^{b}	1.5 ± 1.3^{a}
Ni	0.1 ± 0.2^{b}	0.2 ± 0.3^{a}
Pb	0.1 ± 0.04^{a}	0.1 ± 0.1^{a}
$\delta^{15}N$	7.5 ± 6.6^{b}	12.2 ± 0.9^{a}

Regressions between trace element concentrations

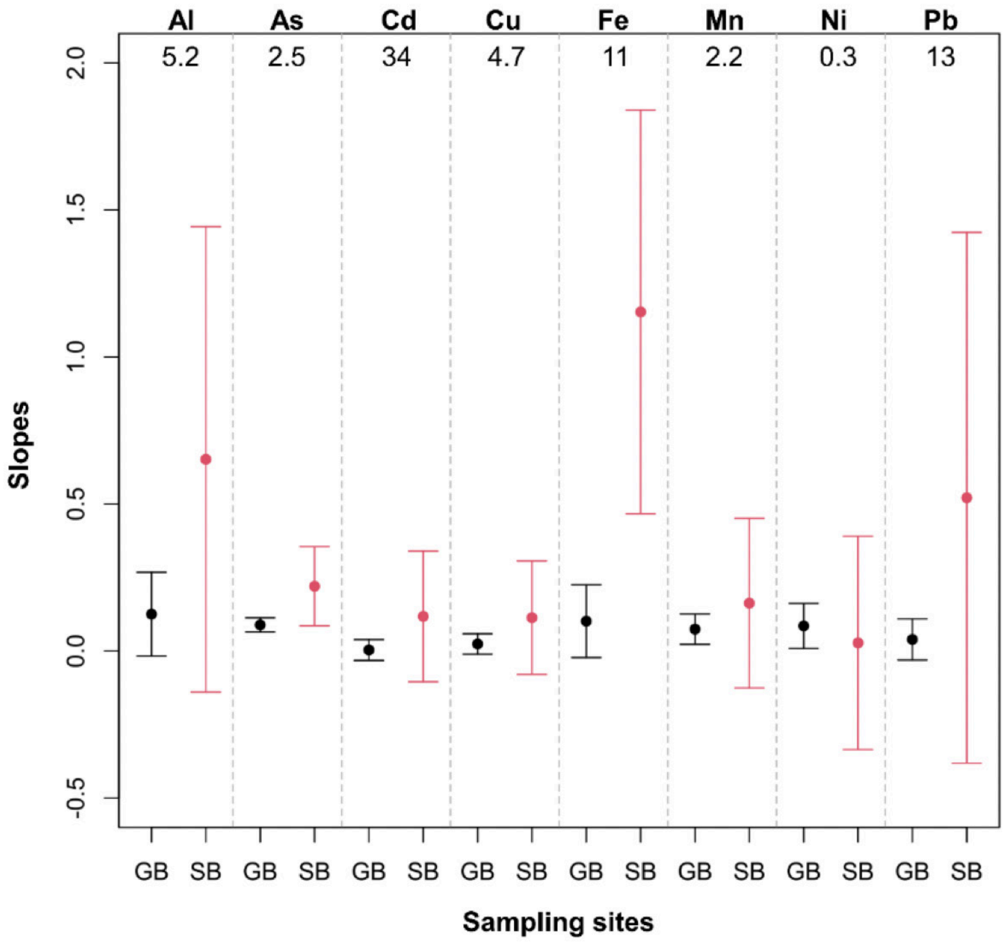

Figure 2. Slopes obtained from regressions between trace elements concentrations and δ15N values in pink shrimps from two anthropized estuarine systems in Brazil. The symbols (black circle to Guanabara Bay - GB, and red circle to Sepetiba Bay - SB) and bars represent each slope and its 95% confidence interval, respectively. Numbers below the trace elements are the slope ratio between the estuarine systems (SB/GB).

and $\delta^{15}N$ values were adjusted (R Core Team 2022) to verify the assimilation rate of each element according to the trophic position (i.e., their slopes). Mathematical transformations were done whenever necessary to meet the regression assumptions (normality, linearity, homoscedasticity) using a maximum likelihood function (Venables & Ripley 2002). The absence of overlapping in the 95% confidence intervals of the slopes can be interpreted as a significant difference between the two estuarine systems (p <0.05). Meanwhile, the high variance in the regressions associated with SB, as showed by the confidence intervals (Figure 2), made it difficult to detect significant differences (except for Fe). Since this is a statistical problem and not a conceptual one, the data interpretation was based on the magnitude of difference in slopes (numbers at the top of Figure 2). The slope ratios between the estuarine systems (SB/GB) were greater than 1 (except for Ni), revealing a greater assimilation rate of the elements in SB. Considering all elements, the average assimilation rate was 9.2 ± 11.0 times greater in SB compared to GB (Figure 2). The results confirmed the two-hypothesis: the concentration of trace elements is variable between the pink shrimps, following the spatial difference of their trophic niches; and pink shrimps from SB have higher trace element concentrations than in GB due to their higher trophic position.

Trace elements have different availability in the environment and different physiological pathways in the consumers (Boudet et al. 2019; Kolarova & Napiórkowski 2021), which may explain different concentrations in the pink shrimps between and within estuaries. The level of anthropization is higher in GB than SB (Costa et al. 2011; Cordeiro et al. 2021); thus, it could be expected that both the trace element concentrations and assimilation rates are higher in the pink shrimps from GB. However, the trophic position drove the assimilation rates, reinforcing the role of food sources as the main route of trace elements to the aquatic animals (Rainbow 2002; Di

Beneditto et al. 2012; Kehrig et al. 2022).

Carvalho et al. (2021) recommended attention to monitoring the pink shrimps from SB due to their smaller trophic breadth and lower $\delta^{15}N$ range, which may increase their sensitivity to changing habitat. The data on trace elements in the shrimps' muscle reinforce this recommendation, once their exposure to trace elements, including hazardous elements, can increase in a changing habitat.

REFERENCES

ANVISA (2021). Estabelece os limites máximos tolerados (LMT) de contaminantes em alimentos. Diário Oficial [da] República Federativa do Brasil. Agência Nacional de Vigilância Sanitária. https://www.in.gov.br/en/web/dou/-/instrucao-normativa-in-n-88-de-26-de-marco-de-2021-311655598 Accessed 23 November 2021.

Boudet, L.C., J. Mendieta, M.B. Romero, A.D. Carricavur, P. Polizzi & J.E. Marcovecchio (2019). Strategies for cadmium detoxification in the white shrimp *Palaemon argentines* from clean and polluted field locations. *Chemosphere* 236: 124–224. https://doi.org/10.1016/j.chemosphere.2019.06.194

Brown, M.T. & M.H. Depledge (1998). Determinants of trace metal concentrations in marine organisms, pp. 185–217. In: Langston, W.J. & M.J. Bebianno (eds.). *Metal Metabolism in Aquatic Environments*. Chapman and Hall, London, 800 pp.

Carvalho, C., L.R. Monteiro, K.A. Keunecke, H.P. Lavrado & A.P.M. Di Beneditto (2021). Trophic assessment and isotopic niches of the sympatric penaeids species *Penaeus brasiliensis* and *P. paulensis* in SW Atlantic estuarine systems. *Marine Biology Research* 17(7–8): 658–668. https://doi.org/10.1080/17451000.2021.2011320

Cordeiro, R.C., F.F. Monteiro, R.E. Santelli, L.S. Moreira, A.G. Figueiredo, E.D. Bidone, R.S. Pereira, L.C. Anjos & M.F.G. Meniconi (2021). Environmental and anthropic variabilities at Guanabara Bay (Brazil): A comparative perspective of metal depositions in different time scales during the last 5,500 yrs. *Chemosphere* 267: 128895. https://doi.org/10.1016/j.chemosphere.2020.128895

Costa, L.C., A.P. Ferreira & E.B. Neves (2011). Aplicação do sistema de projeção de poluição industrial (modelo IPPS) na bacia hidrográfica da baía de Sepetiba (Rio de Janeiro, Brasil): estudo de caso. *Cadernos de Saúde Coletiva* 19: 66–73.

Di Beneditto, A.P.M., V.T. Bittar, P.B. Camargo, C.E. Rezende & H.A. Kehrig (2012). Mercury and nitrogen isotope in a marine species from a tropical coastal food web. *Archives of Environmental Contamination and Toxicology* 62: 264–271. https://doi.org/10.1007/s00244-011-9701-z

Di Beneditto, A.P.M., I.A. Pestana, B.C.V. Oliveira, C.E. Rezende & C. Carvalho (2021). Titanium in commercial shrimp from anthropized tropical bays and estimated quantities of TiO_2. *Revista Ibero Americana de Ciências Ambientais* 12: 144–156. https://doi.org/10.6008/CBPC2179-6858.2021.010.0013

Neto, J.D. (2011). Proposta de Plano Nacional de Gestão para o uso sustentável de camarões marinhos do Brasil. Série Plano de Gestão Recursos Pesqueiros, Brasília, Brasil, 242 pp.

FAO/WHO - Food and Agriculture Organization of the United Nations/ World Health Organization (1991). Report of the Nineteenth Session of the Joint FAO/WHO Codex Alimentarius Commission. https://www.fao.org/3/t0490e/T0490E01.htm Electronic version accessed 20 October 2022.

Kehrig, H.A., R.A. Hauser-Davis, M.C. Muelbert, M.G. Almeida, A.P.M. Di Beneditto & C.E. Rezende (2022). Mercury and stable carbon and nitrogen isotopes in the natal fur of two Antarctic pinniped species. *Chemosphere* 288: 132500. https://doi.org/10.1016/j.chemosphere.2021.132500

Kolarova, N. & P. Napiórkowski (2021). Trace elements in aquatic environment. Origin, distribution, assessment and toxicity effect for the aquatic biota. *Ecohydrology & Hydrobiology* 21: 655–668. https://doi.org/10.1016/j.ecohyd.2021.02.002

Palma-Lara, I., Martínez-Castillo, M., Quintana-Pérez, J.C., Arellano-Mendoza, M.G., Tamay-Cach, F., Valenzuela-Limón, O.L., García-Montalvo, E.A. & Hernández-Zavala, A. (2020). Arsenic exposure: a public health problem leading to several cancers. *Regulatory Toxicology and Pharmacology* 110: 104539. https://doi.org/10.1016/j. yrtph.2019. 104539

Post, D.M. (2002). Using stable isotopes to estimate trophic position: models, methods, and assumptions. *Ecology* 83: 703–718. https://doi.org/10.1890/0012-9658(2002)083[0703:USITET]2.0.CO;2

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/

Rainbow, P.S. (2002). Trace metal concentrations in aquatic invertebrates: why and so what? *Environmental Pollution* 120(3): 497–507. https://doi.org/10.1016/S0269-7491(02)00238-5

Venables, W.N. & B.D. Ripley (2002). *Modern Applied Statistics with S.* Springer, New York, 497 pp.

WHO - World Health Organization (2019). Food safety fact sheet. https://www.who.int/news-room/fact-sheets/detail/foodsafety. Electronic version accessed 20 October 2022.

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