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Occurrence of *Audacallichirus mirim* (Rodrigues, 1971) in the coast of southeastern Brazil: first record in southern Espírito Santo and northern Rio de Janeiro

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Abstract

The ghost shrimp *Audacallichirus mirim* had been previously recorded along the Brazilian coast. However, this study marks its first report in southern Espírito Santo and northern Rio de Janeiro, in southeastern Brazil. Two male specimens were collected at Piúma Beach (Espírito Santo) and Guaxindiba Beach (Rio de Janeiro) in March 2023, using a steel suction pump in the intertidal zone. The individuals were identified in a laboratory based on taxonomic characteristics. Abiotic factors such as salinity, temperature, and dissolved oxygen were measured at the collection sites, revealing distinct environmental conditions between the two beaches. Granulometric analysis showed significant differences in sediment composition, with Piúma characterized by finer sands and Guaxindiba by a more poorly sorted sediment, with a higher contribution of coarser grains. This record contributes to understanding the biogeographical distribution of *A. mirim*, emphasizes its ecological role, and highlights the need for further research on its population dynamics and habitat preferences in southeastern Brazil.

Introduction

Members of the infraorder Axiidea represent a significant component of the macroinfauna in sandy intertidal and subtidal environments, exhibiting a cosmopolitan distribution. Over recent decades, taxonomic revisions of burrowing decapods have been driven by molecular genetic investigations, as well as studies exploring their morphological nuances, physiology, behaviour, reproductive biology, and population dynamics (Kornienko, 2013). Despite these advancements, identifying and documenting species distributions remain crucial for elucidating biogeographical patterns and ecological dynamics.

Audacallichirus mirim (Rodrigues, 1971) was first described by Sérgio de Almeida Rodrigues as *Callianassa* (*Callichirus*) *mirim*. During the 1990s, it was reclassified as *Sergio mirim* (Pezzuto, 1998), and its current scientific nomenclature, *Audacallichirus mirim*, is now widely accepted (Hernáez *et al.*, 2022*b*). *Audacallichirus mirim* belongs to the group commonly known as 'burrowing shrimps' which inhabit soft sediments mainly in intertidal and subtidal regions, although some species extend to deeper habitats (Kensley, 1996; Felder and Kensley, 2004; Dworschak *et al.*, 2012). These ghost shrimps are notable for constructing burrows that vary in shape and depth (Griffis and Suchanek, 1991; Pereyra and Carvalho, 2020) and for their significant influence on community structure (Pillay, 2019). Their burrowing activities, involving the removal of water and sediment, contribute to bioturbation, thereby enhancing the suspension of organic matter and pollutants, nitrogen fixation, and food availability across trophic levels (Ziebis *et al.*, 1996; Bertics *et al.*, 2010).

The ghost shrimp *A. mirim* has previously been recorded along the Brazilian coast, from Bahia to Rio Grande do Sul, by Hernáez *et al.* (2022*b*). However, these authors did not record this species in certain mesoregions of southeastern Brazil. This study marks the first report of the species in southern Espírito Santo and northern Rio de Janeiro.

Materials and methods

The fieldwork was conducted in March 2023. Initially, the focus of the study was to investigate the populations of *Callichirus corruptus* (Hernáez *et al.*, 2020*a*) along the southeastern coast of Brazil. During our campaigns, we captured two male specimens of *Audacallichirus mirim* at two different beaches: Piúma Beach, located in Piúma municipality in the southern Espírito Santo state (20°50′42.11″S and 40°44′16.04″W) and

Guaxindiba Beach, located in São Francisco do Itabapoana municipality in the northern Rio de Janeiro state (21°28′42.41″S and 41°3′24.57″W). This marks the first record of the species in both the regions (Figure 1).

At each locality, burrowing shrimp specimens were collected from their burrows using a steel suction pump (diameter = 80 mm, length = 100 cm) within the intertidal zone (depth ~80 cm). The pump was applied up to five times in each burrow for extraction. After collection, each specimen was carefully rinsed with seawater, placed in a plastic bag, preserved in ice, and subsequently examined. Abiotic conditions were measured at both the surface water and within the galleries, including temperature, pH, conductivity, salinity, and dissolved oxygen using a multiparameter probe (U-50 series, Horiba, Japan).

In a laboratory, each specimen was identified, and its sex was determined based on the morphology of the first pair of pleopods. In cases where this criterion failed to allow definitive sex determination, the location of gonopores and life stage (adult or juvenile) was revisited (Hernáez, 2018). Systematic identification was based on studies of Poore *et al.* (2019) and Hernáez *et al.* (2022*b*), supplemented by taxonomic classification resources available at https://www.marinespecies.org/index.php. The biometric measurements recorded for each specimen included total length (mm), cephalothorax length (mm), left cheliped length (mm), left cheliped width (mm), right cheliped length (mm), right cheliped width (mm), and total weight (g).

Sediments of each sandy beach were collected using a shovel, stored in plastic bags and transported to the laboratory. Aliquots of each sample (<2.0 mm) was dried in an oven at 60°C and then separated for granulometric measurements without removing carbonates and organic matter. This determination was performed using a Shimadzu Series SALD-3101 laser diffraction particle size analyzer. The diameter of grain size (mm) was classified according to the scale of the Massachusetts Institute of Technology (Wentworth, 1922): very coarse sand (2 to 1 mm); coarse sand (1 to 0.5 mm); medium sand (0.5 to 0.25 mm); fine sand (0.25 to 0.125 mm), very fine sand (0.125 to 0.063 mm); silt (0.063 to 0.004 mm); and clay (grain size <0.004 mm).

Photographs of the collected organisms were captured using a Canon EOS Sl3 camera with an EF-s 18-55 IS STM lens. Specimens were positioned on a black clipboard using a tape measure for scale reference. The photos documented key morphological characteristics for accurate identification of these individuals. All laboratory analyses were performed at Laboratório de Ciências Ambientais of Universidade Estadual do Norte Fluminense Darcy Ribeiro.

Results

Abiotic characterization of the recording sites

The environmental conditions of both beaches are summarized in Table 1. Physical–chemical parameters in surface water suggest saline waters in Piúma (salinity = 31.0 and conductivity = 47.6 mS cm^{-1}), while indicating brackish waters in Guaxindiba (salinity = 23.0 and conductivity = 39.2 mS cm^{-1}). Guaxindiba also shows lower concentrations of dissolved oxygen compared to Piúma (5.9 and 7.5 ppm, respectively), along with higher water temperatures (30.5 and 25.7°C, respectively). In contrast, abiotic conditions measured inside the galleries show an inverse pattern: Piúma had lower salinity and conductivity (19.7 and 31.7 mS cm^{-1}, respectively) compared to Guaxindiba (23.5 and 36.8 mS cm^{-1}, respectively). Dissolved oxygen concentrations inside the galleries were lower than that of surface water in both areas (4.9 and 2.2 ppm, respectively).

The granulometric composition of the beaches was primarily composed of fine sand (approximately 31%) and very fine sand (approximately 41%) at Piúma Beach, with coarser fractions making up the remaining 28%. At Guaxindiba Beach, the composition included fine sand (approximately 57%) and very fine sand (approximately 20%), with coarser fractions constituting the remaining 23%.

Description of species characteristics and specimens

These collections represent the first record of this species in southern Espírito Santo and northern Rio de Janeiro, southeastern Brazil

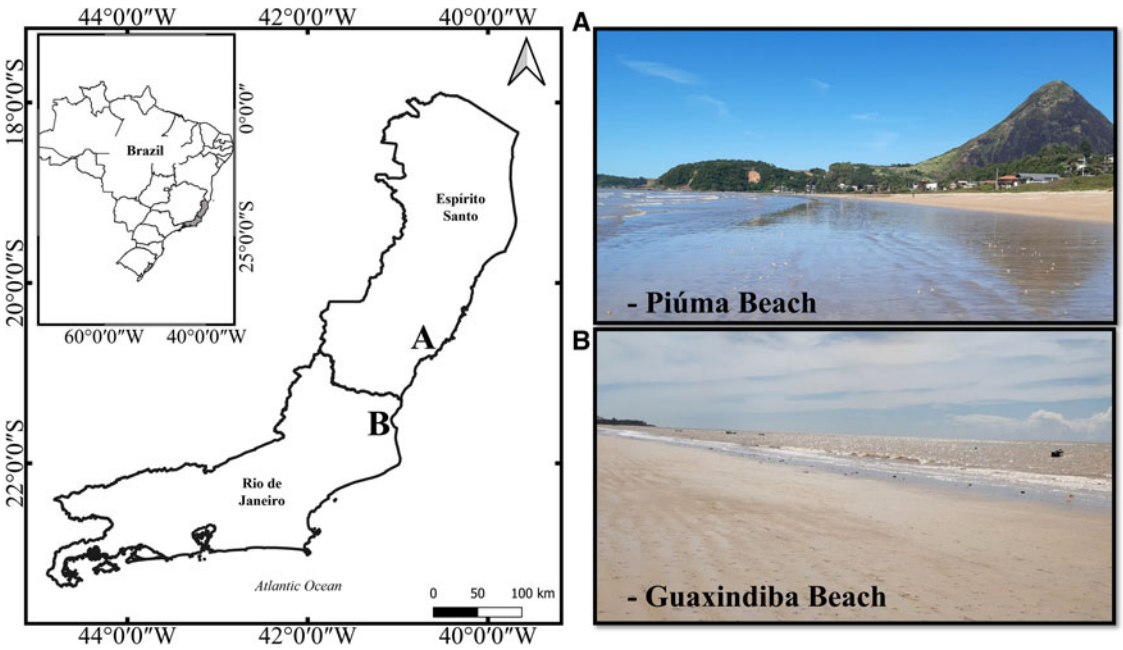

Figure 1. *Audacallichirus mirim* collection area in southern Espírito Santo (Piúma Beach (A)) and northern Rio de Janeiro states (Guaxindiba Beach (B)).

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Table 1. Morphometric measurements and abiotic conditions for two adult male specimens of *Audacallichirus mirim* collected from Piúma and Guaxindiba

	Piúma Beach		Guaxindiba Beach	
Biotic conditions				
Sex	M		M	
Age	Adult		Adult	
TL (mm)	4.1		7.4	
LC (mm)	1.0		1.9	
LCL (mm)	1.0		1.8	
LCW (mm)	0.3		0.4	
RCL (mm)	1.1		–	
RCW (mm)	0.2		–	
Total weight (g)	0.5		5.7	
Abiotic conditions	Surface Water	Galleries	Surface Water	Galleries
Temperature (°C)	25.7	30.3	30.5	29.7
pH	6.8	6.8	9.0	8.4
Conductivity (mS cm^{-1})	47.6	31.7	39.2	36.8
Salinity	31.0	19.7	23.0	23.5
DO (ppm)	7.5	4.9	5.9	2.2
DO (%)	97.9	80.2	88.4	42.3

Measurements include total length (TL), cephalothorax length (CL), left cheliped length (LCL) and width (LCW), right cheliped length (RCL) and width (RCW), and total weight (TW). Abiotic conditions were measured at both the surface water and within the galleries, including temperature, pH, conductivity, salinity, and dissolved oxygen (DO) in both ppm and percentage.

(Figures 2 and 3, respectively). Biometric measurements of the specimens are provided in Table 1.

Taxonomy

Kingdom ANIMALIA
Phylum ARTHROPODA von Siebold, 1848
Subphylum CRUSTACEA Brünnich, 1772
Class MALACOSTRACA Latreille, 1802
Order DECAPODA Latreille, 1802
Suborder PLEOCYEMATA Burkenroad, 1963
Infraorder AXIIDEA de Saint Laurent, 1979
Family CALLICHIRIDAE Manning and Felder, 1991
Genus *Audacallichirus* Poore, Dworschak, Robles, Mantelatto & Felder, 2019
Species *Audacallichirus mirim* Rodrigues, 1971

Material Examined

Diagnosis was adapted from Hernáez *et al.* (2022*b*). The carapace exhibits a small triangular rostrum along with two rounded anterolateral projections (Figures 2A and 3A). The ocular peduncles are contiguous, except for a separated blunt apical portion, which fails to reach the second article of the antennular peduncles. Notably, the antennular peduncle appears longer and stouter than the antennal peduncle, with the second article of the antennular peduncle slightly exceeding the fourth article of the antennal peduncle. The third merus of the maxilliped displays non-parallel distal and proximal margins, featuring a strong distal obliquity without projecting beyond the carpo-meral articulation. The male major cheliped merus is characterized by a prominent hook on the lower margin, while the fixed finger bears a small triangular tooth at the midpoint of the cutting edge. The dactylus exhibits a strong arcuate shape with a downwardly curved tip, bifid and longer than the fixed finger. Its cutting edge showcases a large bifid tooth proximally, otherwise remaining unarmed. The male second pleopod presents well-developed endopod and exopod. The telson is slightly broader than long, tapering distally, and emarginate posteriorly.

Discussion

The ghost shrimp *Audacallichirus mirim* constitutes one of 46 species of burrowing shrimp documented along the Brazilian coast (Hernáez *et al.*, 2022*b*), although it is not always the most abundant. The number of *Callichirus corruptus* individuals captured on the beaches of Guaxindiba and Piúma was significantly higher (a 30:1 ratio) compared to the records of *A. mirim* on each beach. Despite its wide geographic distribution, spanning from the coast of Bahia to Rio Grande do Sul, *A. mirim* is often underrepresented in field collections. This discrepancy can be explained by several factors, including differences in habitat preference, niche partitioning, and abiotic filtering of species based on environmental conditions. For example, *C. corruptus* typically inhabits higher intertidal zones, which may make it more accessible during sampling. In contrast, *A. mirim* is more often associated with subtidal zones, estuaries, or tidal flats, making it more difficult to capture using the same sampling methods (Pezzuto, 1998).

The environmental conditions at Piúma and Guaxindiba beaches, where *A. mirim* was found, align with previous reports on its habitat. The known ranges for this species include temperatures from 12 to 27°C, salinity from 12 to 36, and preferred grain size composed by fine sands (median = 2.88Ø) (Pezzuto, 1998). These conditions were previously measured in the surf zone in southern Brazil and suggest that *A. mirim* may be better adapted to cooler environments (Pezzuto, 1998). Our recorded temperatures, ranging from 25.7 to 30.5°C, were measured in the swash zone and within the inhabited burrows of *A. mirim*, suggesting a higher temperature tolerance for the species in southeastern Brazil.

Although our salinity measurements, ranging from 19.7 to 31.0, were consistent with those reported in southern Brazil by

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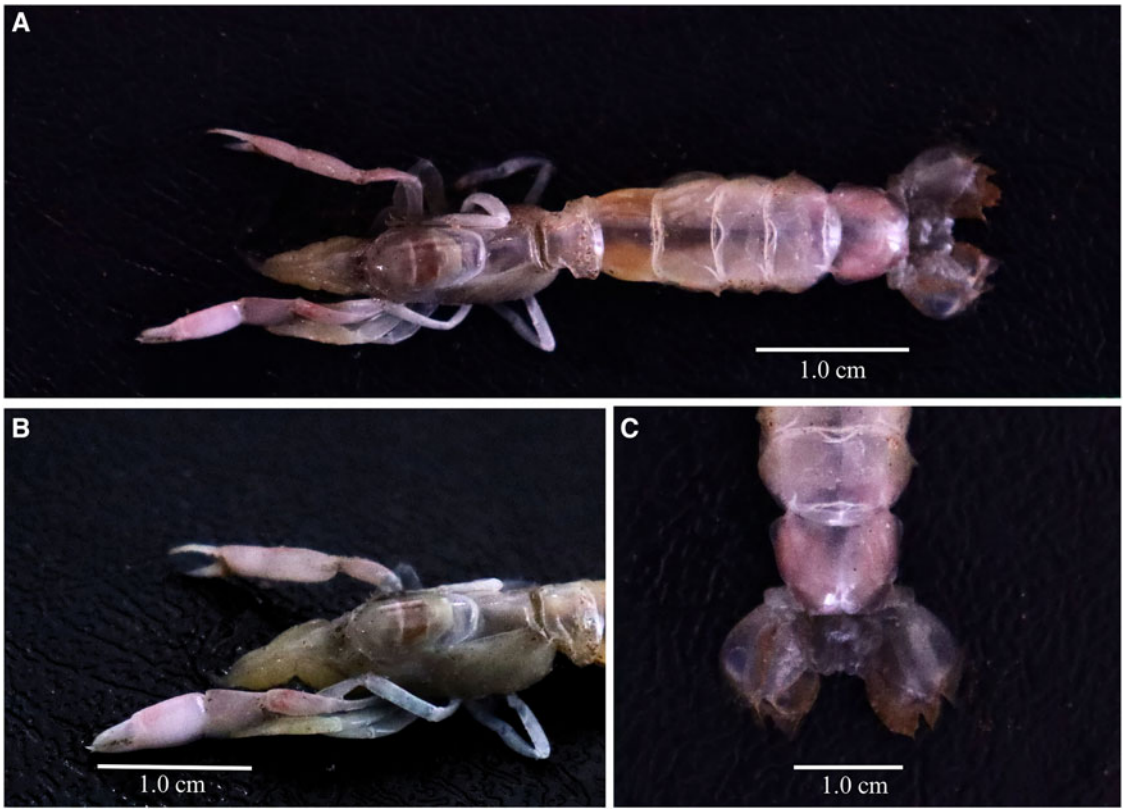

Figure 2. Specimen of *A. mirim* from Piúma Beach, Espírito Santo state: (A, B), dorsal view and (C), telson, dorsal view (scale = 1.0 cm).

Pezzuto (1998), ocean salinity values were more prominent in the surface waters of Piúma, in contrast to the brackish surface waters observed at Guaxindiba. Thus, the species also appears to have wide tolerance limits for salinity variations, corroborating its occurrence in tidal flats. Therefore, the low number of *A. mirim* individuals captured in our study may reflect the natural rarity of this species in terms of abundance rather than local environmental filter. In addition, the low abundance may be linked to

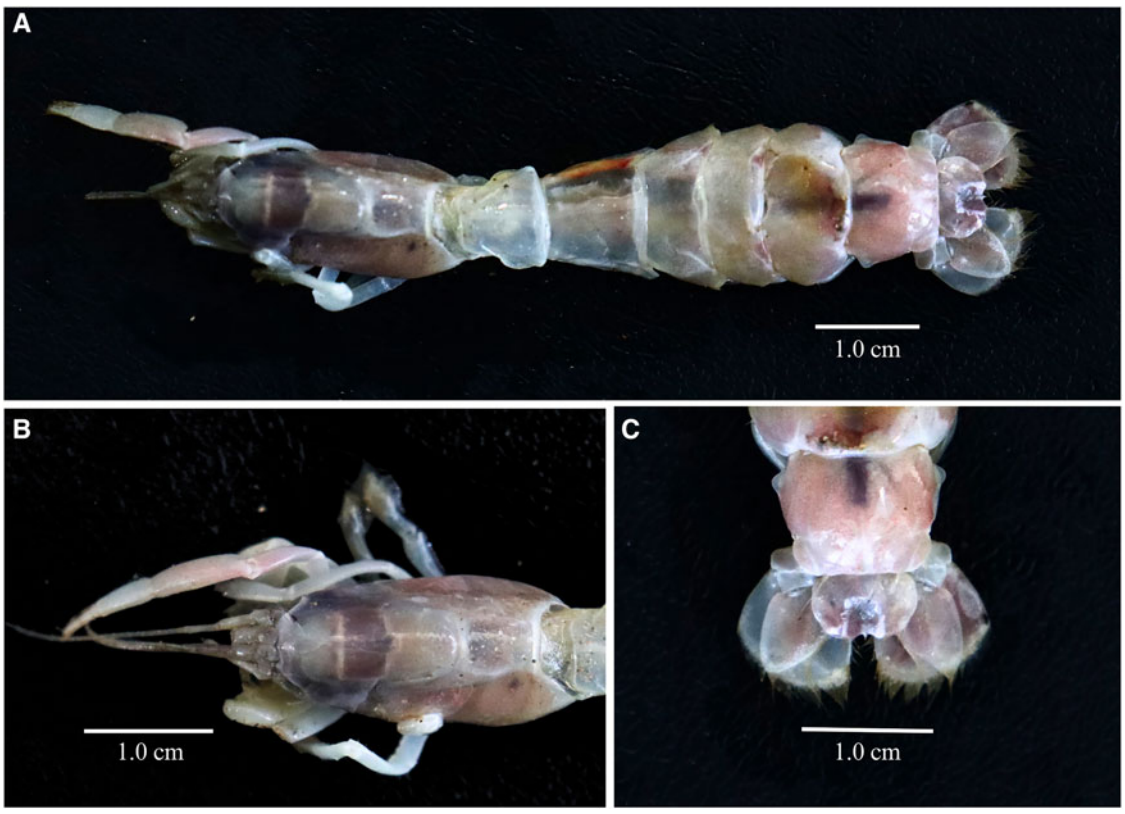

Figure 3. Specimen of *A. mirim* from Guaxindiba Beach, Rio de Janeiro state: (A, B), dorsal view and (C), telson, dorsal view (scale = 1.0 cm).

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seascape features, including ocean currents that affect larval dispersal and recruitment patterns.

Nonetheless, this record is historically significant, providing evidence of a spatial overlap between *A. mirim* and *C. corruptus*, which has not been previously documented, even in states such as Bahia and São Paulo, where both species occur (Hernáez *et al.*, 2022*b*). This overlap is especially intriguing and raises questions about subtle environmental similarities between the sampled beaches that may support both species. Such findings highlight the importance of understanding species-specific habitat preferences, which are crucial for future conservation efforts.

We acknowledge that our sampling efforts did not specifically target *A. mirim*, and thus it may have affected the species' representativeness. Thus, future studies on its distribution at a finer scale and its habitat are necessary for more efficient sampling. This could confirm its natural rarity and increase our knowledge of the species ecological role and population dynamics. This research will be essential for developing conservation strategies and ensuring the conservation of this potentially important fishery resource and its habitats.

Data. All relevant data are available in the paper. Additional data are available from the corresponding author on reasonable request.

Author contributions. K. A. F. and L. L. C. conceived the study. K. A. F., L. M. S. V., P. V. G., M. E. A. S. S., and L. L. C. performed the investigations. K. A. F., L. M. S. V., and L. L. C. performed the statistical analyses. K. A. F. wrote the manuscript. L. L. C. supervised the project and reviewed the draft manuscript. All authors reviewed and approved the manuscript.

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Competing interests. None.

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