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Original Article

# Factors regulating the distribution and abundance of estuarine bivalves in a hypersaline ecosystem of the Brazilian semi-arid region

## Fatores reguladores da distribuição e abundância de bivalves estuarinos em um ecossistema hipersalino do semiárido brasileiro

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**Abstract**

This study aimed to analyze factors that regulate the spatial-temporal distribution of *Anomalocardia flexuosa* (Linnaeus, 1767) in a hypersaline estuary on the coast of the Brazilian semiarid region. From November 2015 to October 2017, rainfall data were consulted and samples of biological material and sediment for granulometric analysis were collected, and abiotic parameters (salinity and temperature) were measured in 3 different areas (A, B, C) of the Apodi/Mossoró estuary. Salinity showed an inverted decreasing pattern within the estuary, with the highest values recorded in A. The granulometric characterization differed between areas and showed a higher percentage of silt and clay in area B and a higher percentage of sand in area C. The density of *A. flexuosa* differed between areas, with A always showing the highest values, recording up to 4,728 ind/m2, and C the lowest, with an average of 370 ind/m2. Significant differences in density were observed between transects in areas A and B. The abiotic variables temperature and percentage of sand in the sediment showed negative correlations with the density of *A. flexuosa*, and salinity, silt+clay and precipitation showed positive correlations. Hypersalinity did not limit the distribution and abundance of the species, and rainfall regulated temporal variations. Competition for space with a meadow of *Halodule wrightii*, located in C, restricted the establishment and density of *A. flexuosa*. Intraspecific competition was also important for adjustments in the abundance of juveniles and adults. Therefore, the species presents broad tolerance to variations in several abiotic factors, however, biotic factors, such as competition, may be influencing the structure of this population.

**Keywords:** salinity, pluviosity, density, competition, *Anomalocardia flexuosa*.

**Resumo**

O presente trabalho foi desenvolvido com o objetivo de analisar fatores que regulam a distribuição espaço-temporal de *Anomalocardia flexuosa* (Linnaeus, 1767) em um estuário hipersalino do litoral do semiárido brasileiro. Durante o período de novembro de 2015 à outubro de 2017 foram consultados dados de pluviosidade e recolhidas amostras de material biológico, sedimento para análises granulométricas, e aferidos os parâmetros abióticos (salinidade e temperatura) em 3 diferentes áreas (A, B, C) do estuário Apodi/Mossoró. A salinidade apresentou um padrão invertido decrescente dentro do estuário, onde os maiores valores foram registrados em A. A caracterização granulométrica diferiu entre áreas e apresentou maior percentual de silte e argila na área B e maior percentual de areia na área C. A densidade de *A. flexuosa* diferiu entre áreas, onde A apresentou sempre os maiores valores, registrando até 4.728 ind/m$^2$, e C os menores, com em média 370 ind/m$^2$. Foram constatadas diferenças significativas de densidade entre os transectos nas áreas A e B. As variáveis abióticas temperatura e percentual de areia no sedimento apresentaram correlações negativas com densidade de *A. flexuosa*, e salinidade, silte+argila e precipitação positivas. A hipersalinidade não limitou a distribuição e abundância da espécie e a pluviosidade regulou variações temporais. A competição por espaço com uma pradaria de *Halodule wrightii,* situada em C, restringiu o estabelecimento e densidade de *A. flexuosa.* Assim como também a competição intraespecífica foi importante para ajustes na abundância de juvenis e adultos. Portanto, a espécie apresenta ampla tolerância as variações de diversos fatores abióticos, porém, fatores bióticos, como competição podem estar influenciando a estrutura desta população.

**Palavras-chave:** salinidade, pluviosidade, densidade, competição, *Anomalocardia flexuosa*.

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## 1. Introduction

Many species of bivalve mollusks play a significant ecological role in the trophic characterization of ecosystems (Silva-Cavalcanti, 2011; Pinto, 2012). Additionally, they hold substantial dietary and economic importance for human populations within their areas of occurrence. Among these species, the Carib pointed venus *Anomalocardia flexuosa* (Linnaeus, 1767) is a bivalve mollusk highly accepted for human consumption due to its high-density occurrence and ease of capture. Consequently, it is intensively exploited for commercial and subsistence purposes in various regions of Brazil (Pezzuto and Echternacht, 1999).

*Anomalocardia flexuosa* is characterized by its broad tolerance to diverse environmental conditions (Boehs, 2000). The species can withstand salinity variations ranging from 17 to 42, with optimal levels around 22 (Leonel et al., 1983) and tolerate prolonged exposure periods to anoxic conditions (Schaeffer-Novelli, 1980; Boehs, 2000). These adaptations enable the formation of high-density beds in bays, estuaries, and intertidal regions (Boehs et al., 2008) and contribute to its wide geographic distribution and underscores its ecological, dietary, and economic relevance.

Environmental parameters, such as temperature and salinity, are known to regulate the distribution and abundance of mollusks on local and regional scales. In particular, salinity has been identified as the primary factor limiting species distribution in estuarine environments (Gosling, 2003). For *A. flexuosa*, lower salinity tolerance has been observed in specific estuarine contexts, such as in northeastern Brazil (Barroso and Matthews-Cascon, 2009). The species has also been recorded in a hypersaline lagoon in Rio de Janeiro, with salinities exceeding 60 (Silva et al., 2005).

In northeastern Brazil's semi-arid regions, hypersaline estuarine environments often develop due to local climatic conditions, such as high temperatures, low precipitation, and reduced river flow caused by damming (Largier, 2010). In such environments, tidal action facilitates exchange between ocean waters and continental interior areas. However, as freshwater inflow remains minimal, seawater dilution is limited, resulting in elevated salinity levels in estuarine water bodies (Pinheiro and Morais, 2010). Hypersaline areas (lakes, streams) can also be found in other regions of Brazil (e.g. Araruama Lagoon in Rio de Janeiro) (Silva et al., 2005), as well as in regions of Europe (e.g. Iberian Peninsula) (Velasco et al., 2006).

Salinity can act as a controlling agent of the distribution, richness and/or diversity of macrofauna (Bassler-Veit et al., 2013; Mariano and Barros, 2015; Medeiros et al., 2010), and the hypersalinity condition can interfere much more in the structure of the community (Velasco et al., 2006). Trindade Junior and Ferreira (2015) state that the hypersalinity of the estuaries interferes in the development of mangrove vegetation and consequently limits animal biodiversity, so these environments are occupied by animals that can resist these conditions. It can also alter the aquatic organisms metabolism, growth, reproduction (Fraga, 1972), abundance (Abrahão et al., 2010) and survival (Lima et al., 2009). More expressive variations in salinity can interfere with the animals' osmoregulation capacity, thus interfering with their physiology (Lima et al., 2009). However, little is known about how hypersalinity influences the distribution, density, and development of estuarine bivalve species, particularly *A. flexuosa*.

In this context, two research questions arise: (1) Does density variation of *A. flexuosa* occur as salinity progressively increases in hypersaline estuarine zones? (2) What factors regulate these spatial and temporal density variations? To address these questions, the study tests the null hypothesis ($H_0$): hypersalinity interferes with the population density of *A. flexuosa* in a hypersaline estuary of the Brazilian northeastern semi-arid region.

This study was undertaken to address existing knowledge gaps by analyzing the influence of hypersalinity on the abundance and spatial-temporal distribution of *A. flexuosa* in a hypersaline estuary in northeastern Brazil.

## 2. Material and Methods

The present study was conducted in the Apodi/Mossoró estuary, located on the western coast of Rio Grande do Norte State in Brazil's semi-arid northeastern region. The Costa Branca region, encompassing the estuary, is characterized by a semi-arid climate with low rainfall and consistently high temperatures, creating intense evaporation conditions (Diniz and Vasconcelos, 2017). The rainy season typically lasts from February to May and contributes limited rainfall. Minimal river inflow, coupled with strong tidal influence, renders the estuary predominantly tidal-driven (Rocha et al., 2011; Medeiros et al., 2018a). These conditions favor hypersalinization of the soil and water (Rocha et al., 2009). For most of the year, the estuary receives little to no freshwater input, resulting in persistently hypersaline conditions year-round (Pinheiro and Morais, 2010; Medeiros et al., 2018b).

Monthly field samplings were conducted between November 2015 and October 2017 at three distinct locations within the estuary, selected based on salinity gradients, species occurrence, and accessibility. Specially seeking to verify density variations according to the inverted salinity pattern in this estuarine zone. Sampling sites included: **Area A** (inner estuary, ~9 km from the river mouth), **Area B** (intermediate estuary, ~1 km upstream from Area A), and **Area C** (river mouth, intertidal zone with seagrass meadows) (Figure 1).

Sampling was performed at three 50-m transects per area, parallel to the river course and spaced 10 m apart. Each transect was subdivided into three equidistant collection points. Using a 50x50 cm quadrant and a shovel to a depth of 10 cm, specimens of *A. flexuosa* were sampled, along with sediment for grain-size analysis. Salinity and temperature of percolating water were recorded in situ, and precipitation data were retrieved from the Rio Grande do Norte Agricultural Research Corporation (EMPARN), with the aim of identifying possible influences of these factors on variations in abundance.

Statistical analyses included exploratory tests for normality (Kolmogorov-Smirnov), homoscedasticity (Levene's test), and residual plots. Nonparametric analyses were used, including the Kruskal-Wallis test, Spearman's

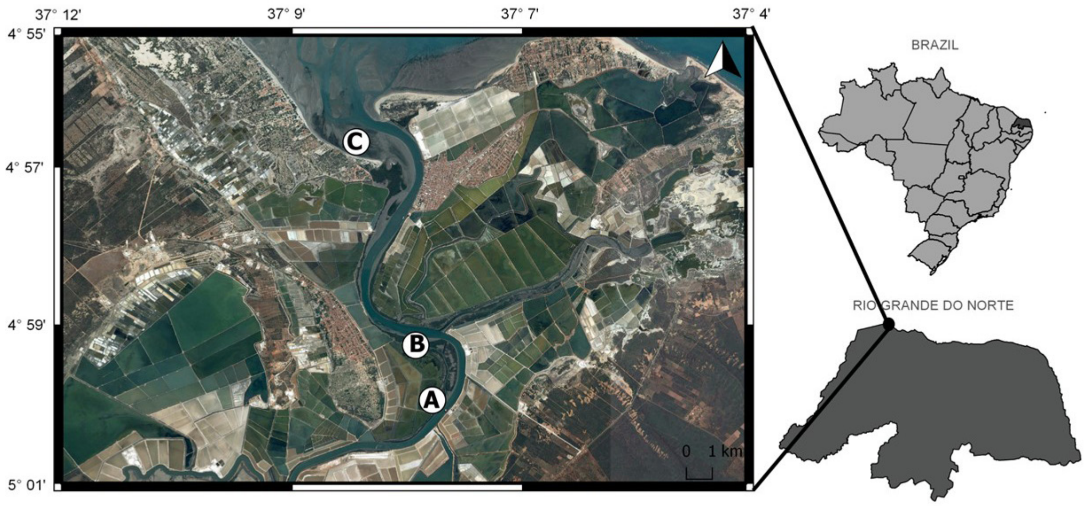


**Figure 1.** Geographic location of the Apodi-Mossoró estuary, municipality of Grossos, state of Rio Grande do Norte (4º 56' 51" S and 37º 08' 55" W) indicating the sampling areas set for this study (A, B, C).

correlation coefficient, and cross-correlation analyses to evaluate temporal relationships between rainfall and species density. Statistical analyses were conducted using PAST (Hammer, 1999) and R 3.5.0 (R Core Team, 2018). Temporal correlation with precipitation events was evaluated using cross-correlation to establish temporal lags.

## 3. Results

### *3.1. Abiotic data*

Throughout the study period, salinity exhibited a variation range of 24-59 in area A, 27-50 in area B, and 35-46 in area C. Minimum values were found at the beginning of the first semester (JAN-JUN), and maximum values in the second semester (JUL-DEZ) in all analyzed areas (Figure 2), with significant differences ($p<0.05$; $H = 22.59$) in the mean values between areas (Table 1), as well as between months (Area A: $p = 0.0006$ $H = 35.89$; Area B: $p = 0.0008$ $H = 35.1$; Area C: $p = 0.0006$ $H = 35.64$). An increasing salinity gradient was established from the river mouth towards the upper regions of the estuary, with salinity values above seawater salinity during most of the study period (Table 1, Figure 2).

Regarding the first year of study, rainfall was concentrated between the months January to June 2016. In the second year, the highest rainfall records were obtained from February to April 2017, with mean values of up to 239 mm (Figure 2). This rainfall occurred after an extensive 5-year drought period.

Characterization of the sediment particle size for the three analyzed areas indicated differences in terms of percentages of sand ($p<0.0005$ $H = 22.32$) and silt + clay ($p<0.0005$ $H = 22.59$). Areas A and B presented higher percentages of silt and clay, and area C showed a greater percentage of sand, especially fine and very fine sand during the first year of study. In the second year, the percentage of muddy sediment (silt and clay) increased in area C and became predominant (Table 1).

### *3.2. Biotic data*

A total of 135,713 individuals of *Anomalocardia flexuosa* were sampled throughout the study period, with 65,625 in area A, 56,041 in area B, and 14,047 individuals in area C. For the entire dataset, the mean density differed between areas ($p = 0.021$, $H = 7.714$), where C differed from A and B ($p = 0.0004$), and A did not differ from B ($p = 0.251$) (Table 1, Figure 3). The highest density values always occurred in area A, with up to 4,728 individuals/m$^2$.

Significant monthly variations in the density of *A. flexuosa* were observed in the three areas (A: $p = 0.007$ $H = 24.06$; B: $p = 0.021$ $H = 22.46$ and C: $p = 0.02$ $H = 22.56$). For area A, the highest monthly means were verified in May and June 2016, with 1,484 individuals/m$^2$ and 1,086 individuals/m$^2$, respectively, in the first study year. In area B, the highest mean density was found in October 2016, with 1,040 individuals/m$^2$, and in area C, in May 2016, with 615 individuals/m$^2$. Areas A and C showed more similar monthly variations in mean density in the first study year, with more expressive differences in the first months of collection, and from the second half of 2016, the density remained stable. In area B, an increasing trend was registered in the mean density of *A. flexuosa* from April 2016, reaching and surpassing the mean densities of area A from July to October 2016 (Figure 4a).

During the second sampling year, an increasing trend in density was observed in areas A and B in the first half of 2017, with average peaks of 3,305 individuals/m$^2$ in July 2017 in area A, and 2,540 individuals/m$^2$ in April 2017 in area B. For the second half of 2017, both areas showed a decrease in the average density of *A. flexuosa*. Throughout 2017, area C remained with the same density pattern, presenting small oscillations in abundance, reaching average values of up to 246 individuals/m$^2$ in May 2017 (Figure 4b).

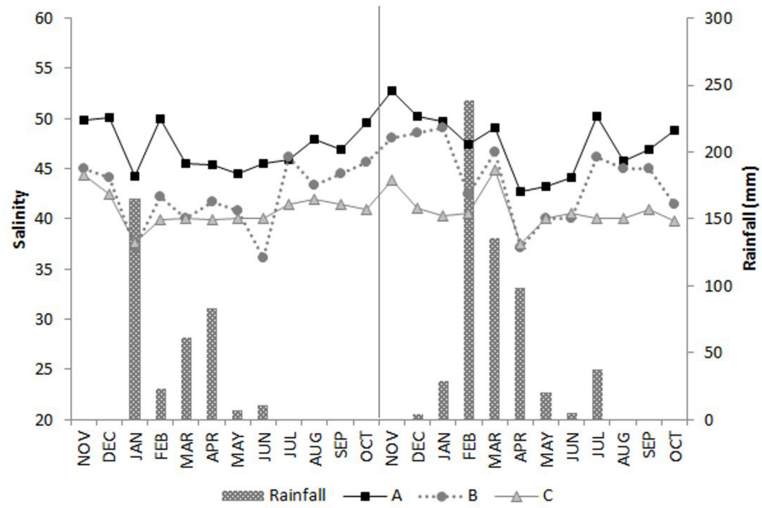


**Figure 2.** Monthly salinity means, for the three sampled areas, and rainfall for the region influenced by the Apodi-Mossoró estuary, during the period from November 2015 to October 2017. Source: EMPARN.

**Table 1.** Mean values of abiotic variables and *Anomalocardia flexuosa* population density ($m^2$) in the three studied areas in the Apodi-Mossoró estuary during the period from November 2015 to October 2017.

| Variable | Area | | | | | |
|---|---|---|---|---|---|---|
| | A | | B | | C | |
| | 2015-2016 | 2016-2017 | 2015-2016 | 2016-2017 | 2015-2016 | 2016-2017 |
| Salinity | 47.6 ± 4.9 | 47.5 ± 4.4 | 42.7 ± 4.3 | 44.1 ± 4.1 | 41.1 ± 2.0 | 40.8 ± 2.1 |
| Temperature (°C) | 29.2 ± 1.3 | 29.3 ± 1.3 | 28.2 ± 1.2 | 28.1 ±1.2 | 31.3 ± 2.0 | 30.6 ± 1.9 |
| Sands (%) | 32.5 ± 10.6 | 27.1 ± 12 | 20.0 ± 11.4 | 13.5 ± 5.9 | 53.1 ± 21.3 | 27.0 ± 18.2 |
| Silt + Clay (%) | 66.7 ± 10.3 | 71.7 ± 12.1 | 79.4 ± 11.3 | 84.4 ± 7.0 | 45.6 ± 21.9 | 71.3 ± 18.0 |
| Density (ind./$m^2$) | 805 ± 937 | 2,015 ± 1,597 | 784 ± 394 | 1,523 ± 843 | 370 ± 211 | 161 ± 108 |

Within each sampling area, the density of *A. flexuosa* varied between the two study years. Significant differences in density were detected between transects in areas A ($p = 0.03$, $H = 7.2$) and B ($p = 0.04$, $H = 6.49$) for the first year (November 2015 to October 2016). Area A exhibited a zonation in substrate occupation by *A. flexuosa* from the waterline, where the first transect, closest to the river course, had the highest mean density, and the third, farthest away, had the lowest mean density. In area B, the highest density was found in the intermediate transect (Figure 5a).

During the second year of data collection (November 2016 to October 2017), the differences in mean density between zones were not significant in any of the three areas analyzed (A: $p = 0.051$, $H = 5.956$; B: $p = 0.733$, $H = 0.6222$; C: $p = 0.43$, $H = 1.689$) (Figure 5b), thus diminishing the zonation pattern found in the first year for A and B.

Abiotic variables temperature and sand percentage in the sediment showed negative correlations with *A. flexuosa* density, while salinity and silt + clay, and rainfall had positive correlations. Rainfall was the variable with the most significant Spearman's correlation coefficient (Table 2).

**Table 2.** Correlations Spearman's between abiotic variables and *A. flexuosa* population density in the Apodi-Mossoró estuary, state of Rio Grande do Norte.

| Variable | p-value | $r_s$ |
|---|---|---|
| Salinity | 0.0000 | 0.31 |
| Temperature | 0.0000 | -0.29 |
| Gravel | 0.0000 | 0.23 |
| Sands | 0.0000 | -0.28 |
| Silt + Clay | 0.0000 | 0.26 |
| Rainfall | 0.04 | 0.42 |

The months with the lowest values of species abundance were concentrated in the dry season for the region (Figure 6). An increasing trend in density can be observed throughout the first sampling months, with stabilization and/or decline in the second half of each year evaluated.

To better investigate the temporal variations in density associated with rainfall, the best lag values that maximized

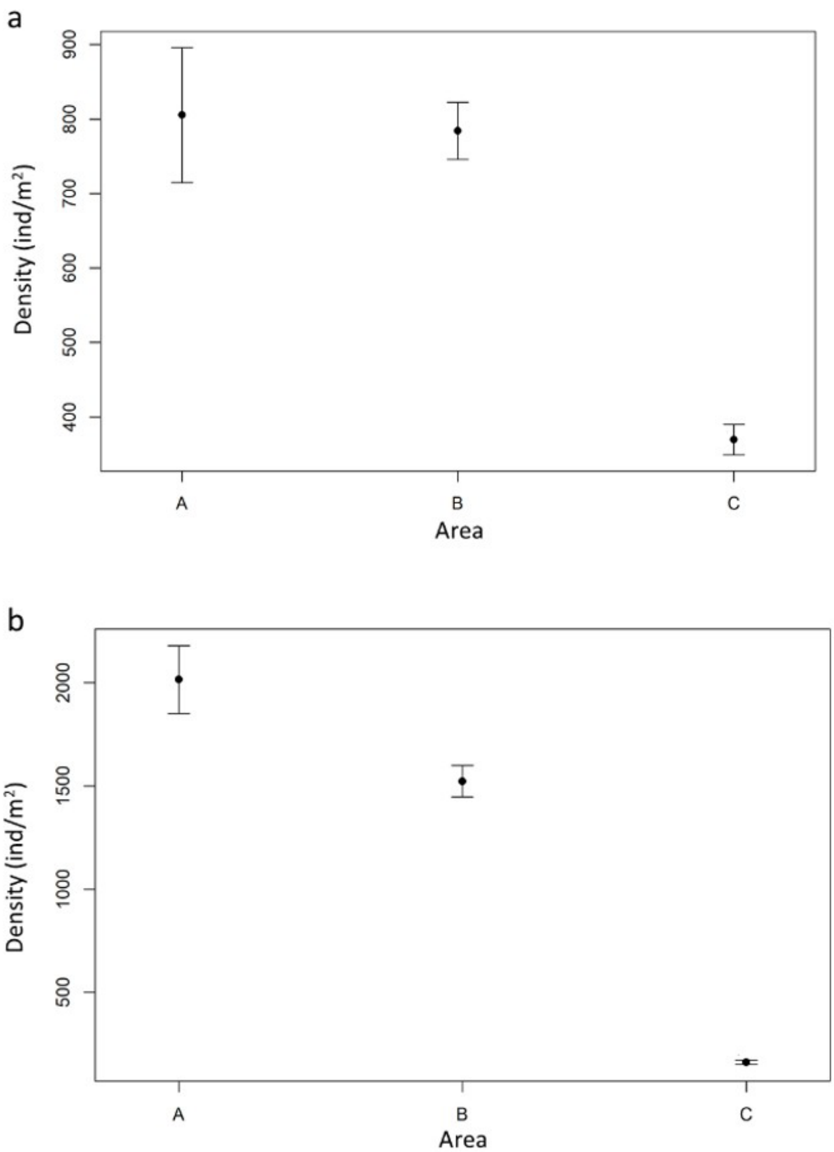


**Figure 3.** Mean population density of *Anomalocardia flexuosa* in the studied areas (A, B, C) in the Apodi-Mossoró estuary during two years of sampling (a = 2015/2016, b = 2016/2017). Bars indicate the confidence interval obtained from the standard error.

the cross-correlation were obtained near lag 2 (Figure 7), indicating that density values are directly and positively influenced two months after rainfall events.

Significant differences in mean length per zone were detected only in area A ($p = 0.027$, $H = 7.2$), where the first transect (T1) concentrated individuals of larger size, and the transect furthest from the water (T3) concentrated individuals of smaller size (Figure 8).

## 4. Discussion

The distribution of benthic invertebrates in unconsolidated environments can be regulated by biological factors (e.g. reproduction, ecological relationships of predation or competition, and even extractive fishing), as well as by abiotic environmental factors such as sediment particle size, available organic matter, local hydrodynamics, among others (McLachlan, 1996). These local abiotic factors can, in many cases, become limiting and regulating conditions for the distribution of the individuals present there (Pinto, 2012).

Regarding the estimates of *Anomalocardia flexuosa* density, although the differences between the three analyzed areas, values are still higher than the estimates obtained for other regions on the Brazilian coast (Boehs et al., 2008; Santos et al., 2014; Corte, 2015). Lima and Andrade (2018) determined points of maximum aggregations of up to 4,058 individuals/m$^2$, whereas,

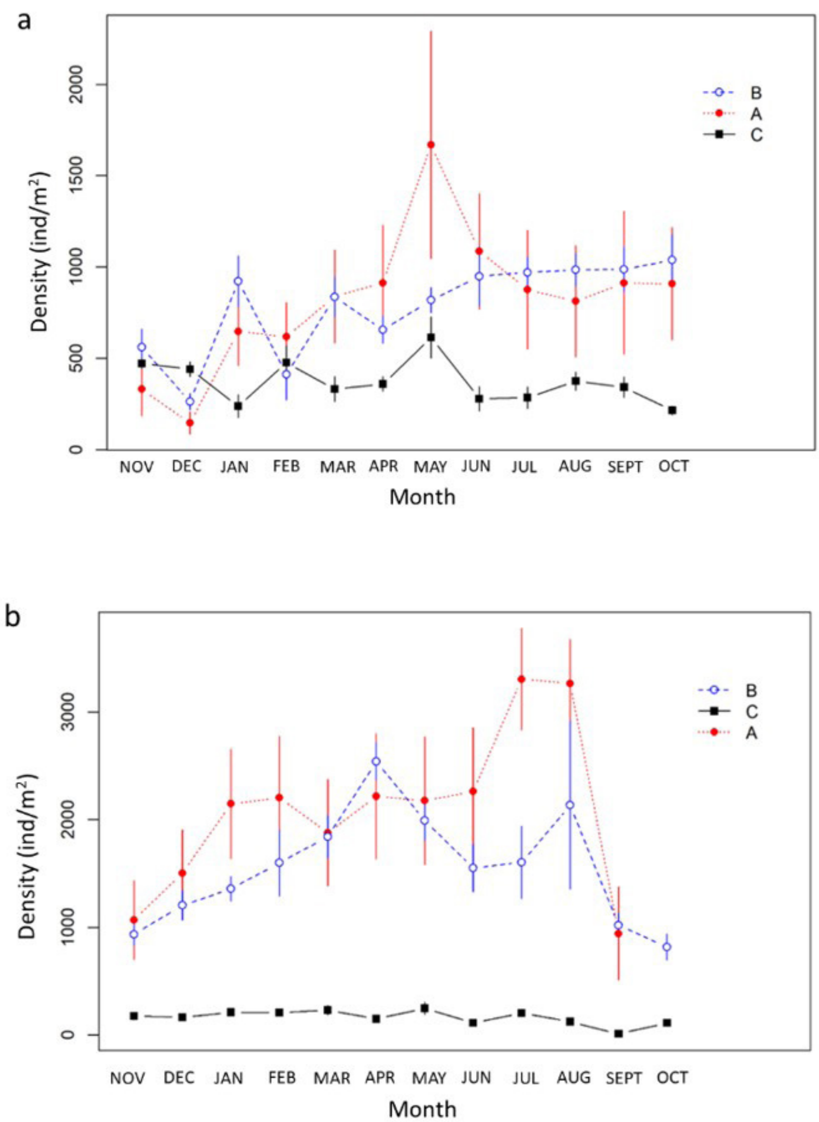


**Figure 4.** Monthly variations in the mean population density of *Anomalocardia flexuosa* in the three areas (A, B, C) studied in the Apodi-Mossoró estuary in 2015/2016 (a) and 2016/2017 (b). Bars indicate the confidence interval obtained from the standard error.

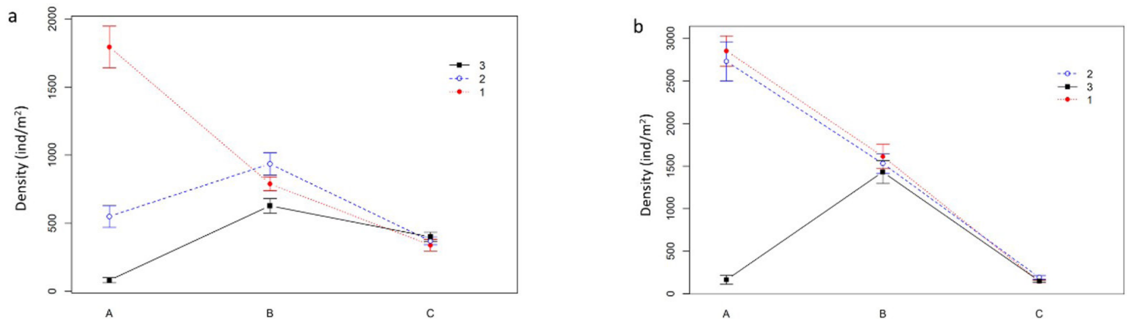


**Figure 5.** Mean population density of *A. flexuosa* between zones/transects (1, 2, 3) in the three areas studied (A, B, C) in the Apodi-Mossoró estuary during two sampling years (a = 2015/2016, b = 2016/2017). Bars indicate the confidence interval obtained by the standard error.

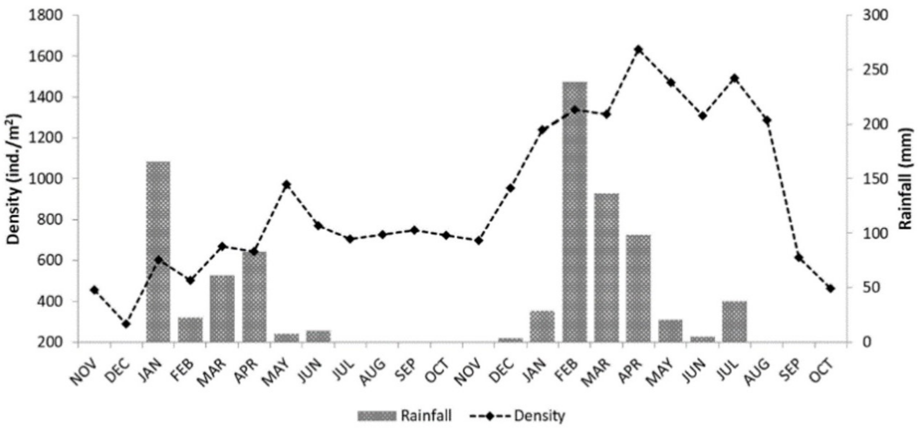


**Figure 6.** Monthly relationship between Rainfall mean in the Apodi-Mossoró estuary and the mean *A. flexuosa* population density from November 2015 to October 2017. Source: EMPARN.

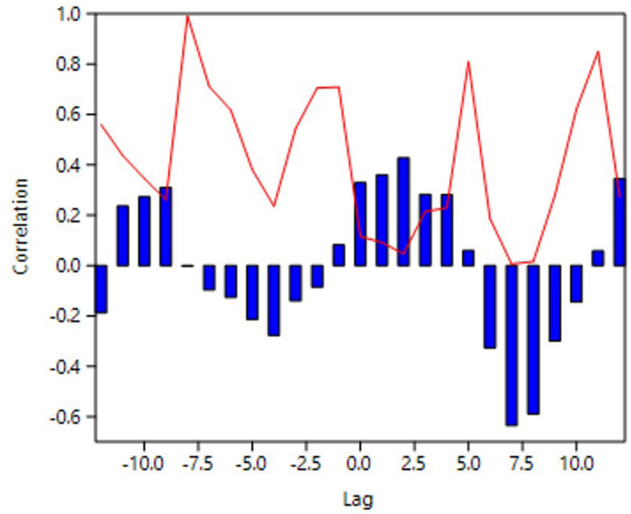


**Figure 7.** Cross-correlation between the mean population density of *A. flexuosa* and rainfall in the Apodi-Mossoró estuary during two years of sampling.

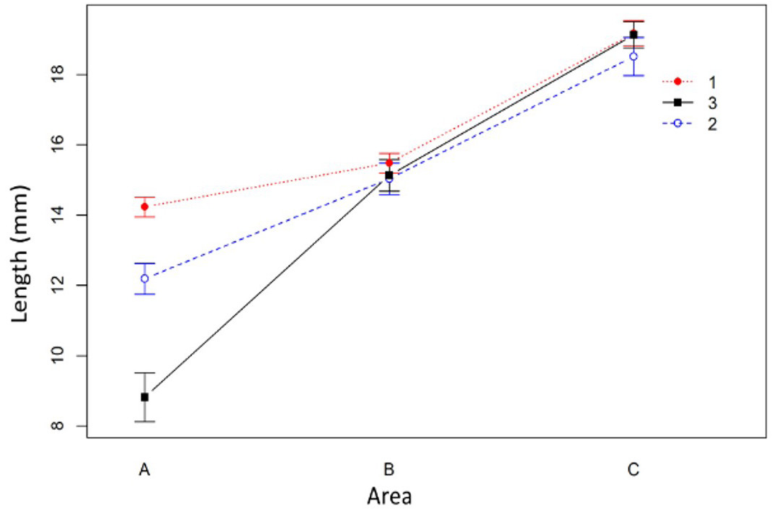


**Figure 8.** Mean shell length of *A. flexuosa* between transects in the three sampling areas in the Apodi-Mossoró estuary in the period from November 2015 to October 2017. Bars represent the confidence interval obtained from the standard error.

in the present study, the density of *A. flexuosa* reached up to 4,728 individuals/m$^2$. Substrate characterization is a preponderant factor in the development of infaunal organisms (Araújo, 2004). *A. flexuosa* preferentially inhabits sandy-muddy sediment, areas with higher food availability, and low hydrodynamic conditions, especially due to its filter-feeding habit (Boehs, 2000). This type of substrate was observed in the three areas analyzed and is therefore considered ideal for the establishment of the species, which may also justify the high densities of this estuarine region. However, in area C, the species did not present a wide distribution as in the other areas. Area B concentrates quite high percentages of fine sediments, which are not the most suitable for filter-feeding organisms; however, this is a low-turbulence region that does not favor particle resuspension, which could cause animal asphyxiation, facilitating the establishment of the species.

Previous studies conducted at the mouth of the Apodi-Mossoró estuary in 2007 and 2008 showed a mean density of around 1,215 individuals/m$^2$ (Rodrigues et al., 2013a), which is much higher than that found in the present study for this same area (area C). During 2009 and 2010, the mean densities in this same location suffered expressive reductions. The high rainfall that allowed the transport of finer sediments to the mouth and reduced the salinity during the study period were probable causes of these changes (Belém et al., 2013). The mean density recorded in the present study for area C was lower than the estimates made for 2007 and 2008, and higher than those for the years 2009 and 2010. This demonstrates that there was a recovery of abundance after the 2009 and 2010 rainfall events but the species has not yet been able to return to the values registered in 2007.

Biological factors can also interfere with these processes of abundance decline and density control, especially competition and/or predation (Wilson, 1990). During this study, a meadow of the marine angiosperm *Halodule wrightii* was also recorded in wide expansion in this area (C) of the estuary (personal observation). The plant's roots also establish up in the sediment in areas of the natural occurrence of *A. flexuosa*, which can lead to competition for space. In addition, the occurrence of the plant modifies the local environmental characteristics, such as hydrodynamics.

On the spatial distribution of the *Erodona mactroides* bivalve in areas with *Ruppia maritima* meadow, Geraldi (2002) found a reduction in bivalve abundance in vegetated areas compared to adjacent areas. This was mainly caused by the modifications the plant made in the local hydrodynamics, which interfered with food availability and consequently the establishment and development of the species. This has also been observed in areas with *Spartina alterniflora* (Addino et al., 2015). The presence of the meadow in these areas also interferes with the abundance of natural predators, allowing the better establishment of other species, such as crabs and gastropods, which are efficient predators of bivalves and can cause a reduction in prey abundance (Geraldi, 2002). Likewise, the presence of the meadow in area C may have influenced the establishment and higher abundance records of *A. flexuosa*, as previously reported for other filter-feeding bivalves that are surface diggers.

Monthly variations in density in areas A and B showed increasing trends during the first months of this study. They evidenced a general pattern of higher values at the end of the first and beginning of the second semester of 2016, which represents the end of the rainy season and the beginning of the dry season for the region. This pattern becomes even more evident in the second year of sampling, with higher values of density and rainfall. Thus, rainfall, which showed a positive correlation with density, seems to play an important role in the monthly changes in *A. flexuosa* density. Silva-Cavalcanti et al. (2018) also report a higher density of this species on the coast of the state of Pernambuco, during the beginning of the rainy season. As also occurred in the state of Maranhão (Santos et al., 2014), this reality seems to be common in some places on the coast Northeast Brazilian. However, under hypersaline conditions, rainfall appears to be an even more efficient factor influencing the temporal variation in *A. flexuosa* abundance.

In area B, the highest values were found after the rainy season of the first collection year, even surpassing, in some months, the mean density obtained in area A. The cross-correlation indicated a period of up to two months for density increase after the occurrence of rainfall events, which may explain the variations in abundance of the specie during this period in area B. This is further reinforced by the overall density of the estuary during the second sampling year, where the highest precipitation levels during the second year were recorded between February and April 2017. Lima et al. (2022) also recorded effects of precipitation on *A. flexuosa* density for up to two months after rain events in Pernambuco, reporting especially a progressive increase in intermediate-sized individuals. Small and large individuals are probably influenced by other factors, such as fishing or natural mortality. Young recruits may have difficulty establishing themselves in the sediment during rainy events due to changes in local characteristics, turbulence, salinity, etc., which may cause natural mortality during this period. However, individuals that are already established in the environment during the rainy season may benefit from the significant increase in organic matter from the rains (Almeida et al., 2021). In the present study, rainfall records were not so significant as to cause sudden changes in salinity records, which causes mortality for the species (Belém et al., 2013). Additional analyses of primary productivity are also needed to better understand these effects.

Regarding the spatial distribution of organisms within each sampled area, the greater density differentiation between transects/zones observed in area A, during the first sampling year, may be related to humidity, time and range of exposure and tidal range, as well as food supply. This area had an apparently higher slope than the others, which may interfere with sediment humidity and resource availability in the last transect located in the upper portion of the bank. The location of the first transect, close to the waterline, allows longer submersion time, and thus oxygenation and food availability, increasing the chances of survival (Boehs, 2000). Additionally, the presence of smaller individuals in the upper transect of area A probably occurred due to the reduced density of this zone, which allowed successful settlement. The differentiation of individual length between zones is a characteristic already reported for *A. flexuosa* in other studies (Araújo, 2004; Boehs et al., 2008; Rodrigues et al., 2013b). Likewise, the action of waves and currents, which are less intense in this region, may facilitate occupation by juveniles, as also observed by Boehs (2000). There is intraspecific competition and a density-related limitation for this species that regulates the abundance of juveniles and adults (Monti et al., 1991).

Anthropogenic predation processes, such as harvesting, can interfere with the abundance of this bivalve (Oliveira et al., 2013). However, this does not seem to be the case in this estuarine region, since the species is widely exploited in both areas C and B. The latter registers high densities and the processes that regulate abundance oscillations in C seem to be much more related to the occurrence of the prairie, as mentioned previously. Additional studies on population dynamics are needed to better assist in the understanding of these aspects. Area A does not have any records of fishing productivity, but it would be an interesting region for directing fishing. This would reduce fishing effort in other areas, allowing rotation and recovery, through the species' own population dynamics processes. In addition, it could be a stimulus for self-regulation of the population, since fishing would remove older individuals, which are no longer interesting in reproductive processes for the stock, with better chances of establishing young individuals (Fonteles-Filho, 2011), especially for *A. flexuosa*, where there is already strong evidence of intraspecific competition.

The hypersalinity of this estuarine region was not a limiting factor for the distribution and abundance of *A. flexuosa*, since even in areas with higher salinity records, the species presented high densities, tolerating and developing well. This probably occurs due to its ability to occupy different environments. However, given the context of climate change, where the occurrence of extreme events with significant temperature increases are already a global reality and a concern for the development of marine animals, hypersaline environments may also be directly impacted by these changes. Additionally, we also include the environmental impacts of mangrove areas, such as significant production of sea salt and shrimp farming, which modify estuarine zones. All this justifies the continuous monitoring of these hypersaline environments and the effects of hypersalinity on the distribution of *A. flexuosa* in the Apodi/Mossoró estuary.

## 5. Conclusion

Therefore, in hypersaline environments, *Anomalocardia flexuosa* is able to establish itself and form high-density beds. Precipitation is an important factor that regulates temporal variations in the abundance of this bivalve under hypersaline conditions. The tolerance limits were wide for most of the abiotic variables analyzed here, which demonstrates that the species appears to be quite resistant to variations in several environmental factors, reversing the imposed pressures. However, biotic factors, such as competition for space and resources, both interspecific and intraspecific, may be limiting for the distribution and abundance of this bivalve and need to be better evaluated.

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