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Spatial and temporal distribution of the shellfish *Anomalocardia brasiliana* (Gmelin, 1791) on Mangue Seco beach, Pernambuco, Brazil

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Abstract

This study aims to analyze the spatial and temporal distribution of the mollusc, *Anomalocardia brasiliana* along the Mangue Seco beach (Igarassu, PE, Brazil). The 1,800 meters beach line was divided into three sections (S) of 600 meters each; S1: 0 to 600, S2: 600 to 1200m and S3: 1200 to 1800m. Totally, 540 samples were taken at different levels, sections and during different seasons. A total of 1,016 specimen were collected during the two periods; January (summer) and August (winter) 2009. In January, 636 clams were collected of which 55% were smaller than 15 mm. In winter 380 samples were collected, 57% being of adult size, between 21 and 25 mm in length. The maximum density recorded in the summer period was 414.91 ± 82.48 ind.m^{-2} at S3 and 323.49 ± 90.11 ind.m^{-2} at S1respectively, which were significantly different from S2 (156.12 ± 28.72 ind.m-²). The lowest density was found during the winter with 102.67 ± 5.07 ind.m^{-2} and 122.37 ± 36.86 ind m^{-2} for S1 and S2 respectively, which largely differed from S3 (296.76 ind.m^{-2} ± 45.20). Among the stations, S3 obtained the highest rate of biomass with 1,248.47 ± 305.82 g.m^{-2} during the summer and 1,136 ± 191.14 g.m^{-2} during the winter, which was significantly different from two other stations' sections. The rain exerts an influence on the distribution of the bivalve *A. brasiliana*, which was shown through the decreasing of the molluscs' density, however, they also increased in size (>20mm) due to increase of food availablity in the rainy season.

Keywords: Season, Density, Biomass, *Anomalocardia brasiliana*

Introduction

Clams are extensively collected from exposed beaches throughout the world as part of recreational, artisanal or commercial fishery activities (McLachlan et al., 1996). The authors cited define recreational fishery as the collection of bait or food without sale or

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dependence on the resource; artisanal fishery as collection for subsistence or sale by individuals or groups using traditional methods; and commercial fishery as collection for sale by corporate or collective organizations.

A number of species of mollusc in estuarine regions are extensively exploited by traditional communities in Brazil, with no management measures to ensure the sustainable use of these resources (Araújo, 2001). *Anomalocardia brasiliana* is easy to locate and extract and is therefore commonly consumed. Harvesting both for subsistence and sale is carried out in various regions of the country (Pezzuto and Echternacht, 1999). This species is found along the coasts and provides the livelihood for a large number of economically and socially underprivileged families. The meat is sold and represents the main (often the only and irreplaceable) source of monetary income for entire small traditional communities (Silva-Cavalcanti and Costa, 2009). The clam fishery has considerable socioeconomic importance in the state of Pernambuco (northeast Brazil) as a source of income and also as a part of the family diet.

Biological factors (reproductive behaviour and food availability) and physiochemical factors (hydrodynamics, particle size, amount of organic matter and rainfall) have been used to study the abundance and diversity patterns of molluscs (McLachlan, 1983; Soares-Gomes and Pires-Vanin, 2003). The studies demonstrate how bivalves can be accurately used to represent the structure of the benthic community. The ability of these species to cope with physical and biological changes associated with major environmental gradients, such as tidal influence, exposure rate and water and substrate characteristics (Rodil et al., 2008), is demonstrated by the temporal and spatial patterns of these inter-tidal invertebrate communities. Biological and ecological studies on *A. brasiliana* have been carried out on the coast of the states of São Paulo (Narchi, 1972 and 1974; Schaeffer-Novelli, 1976; Pereira-Smith et al., 1982), Santa Catarina (Rosa, 1989) and Paraná (Lana *et al.,* 1989; Netto and Lana, 1994; Boehs, 2000). Observations have also been made regarding the demographic distribution, growth and spawning of this species in the Caribbean (Monti et al., 1991).

The aim of the present study was to analyze the spatial and temporal distribution of the mollusc *Anomalocardia brasiliana* along Mangue Seco beach (Igarassu, Brazil), which is one of the most popular areas for catching shellfish in the state of Pernambuco.

Materials and Methods

Study area

The city of Igarassu which is located on the northern coast of the state of Pernambuco (Brazil), 28 km of the state capital (Recife), has an area of 302.9 km², a population of 86,519 a tropical climate with a rainy winter and dry summer. There are three protected areas in the city: the Santa Cruz Estuary Environmental Protection area (EPA), Timbó River Estuary EPA and Nova Cruz EPA. The most famous beach of the city, Mangue Seco, is located in Nova Cruz (S 07°49' 44.19'' and W 035° 50' 03.06''). This shallow beach is approximately 2 km in length, with small waves and an intensive tide, with tide variation greater than 500 m (Fig. 1). Mangue Seco Beach consists of a multitude of highly productive ecosystems and is considered as a green region, where one can find areas covered with coconut trees, extensive mangrove estuaries, coral sands, islands and reefs.

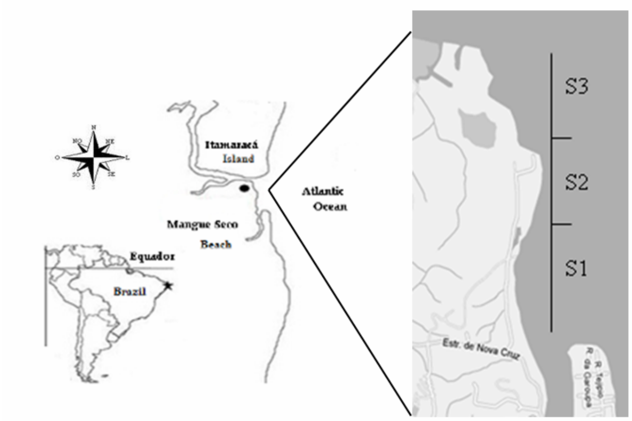

Figure 1: Map showing location of study area in Mangue Seco Beach north coast of Pernambuco. The vertical line indicates the sections of 600 meters (S1. S2 and S3) analyzed along the beach.

Sampling methods

The 1800-meter stretch of beach was divided into three 600-meter sections (S), each with differences regarding the number of fishermen exploiting the section: S1 – 0 to 600; S2 – 600 to 1200 m; and S3 – 1200 to 1800 m. Three levels (L) were established parallel to the beach at intervals of 20 m from the beach line: L1 – 20 m; L2 – 40 m; and L3 – 60 m. Ninety imaginary transversal lines were established along the beach. The collection points were the intersections between the transversal lines and levels. Sampling was carried out at low tide in January and August 2009, representing summer (dry season), and winter (rainy season) respectively.

Specimens were collected using a cylindrical tube 20 cm length and 10 cm diameter (0.0079 m²), excavating the sediment down

1016 specimens were collected, 636 (63%) to a depth of 10 cm. The sediment was sieved using a 2-mm mesh net. The collected material was analyzed at the Sustainable Mariculture Laboratory of the *Universidade Federal Rural de Pernambuco* (Brazil).

The maximal Shell Length (SL) of the anterior-posterior axis of each individual was measured to the nearest 0.01 mm using digital callipers. Weight was determined using an analogue scale with an accuracy of 0.25 g. The specimens were distributed among five size classes: C1 (≤ 15 mm), C2 (16 - 20 mm), C3 (21 - 25 mm), C4 (26 - 30 mm) and C5 (> 30 mm). Individuals with SL of 20 mm or lower were classified as juveniles and those with SL greater than 20 mm were classified as adults (Arruda-Soares et al., 1982).

Sea surface temperature and salinity were recorded *in situ* at each sampling point. Water temperature was determined using a mercury thermometer and salinity was determined using a refractometer (Model S10 – Atago). Sediment samples from the sampling sites were also collected, using a cylindrical tube 5 cm in diameter and excavating down to a depth of 10 cm; the samples were stored in plastic bags for the subsequent analysis of particle size.

Data analysis

The data were analyzed in terms of the number of individuals, abundance (individuals per m²) and biomass ($g.m^{-2}$). These data were analyzed by factor analysis of variance (ANOVA), followed by Duncan's Multiple Range Test to determine differences between stations, levels and seasons.

Results

Water temperature at the time of collection ranged from 27° C to 32° C and from 25° C to 30° C in January (summer) and August (winter) respectively. There was a significant difference in mean salinity values between seasons, which ranged from 38 to 40‰ and from 26 to 35‰ in January and August respectively (Table 1). Rainfall (mm) in the city of Igarassu from January to December 2009 is shown in Figure 2 (data obtained from the Meteorological Laboratory of Pernambuco and Technology Institute of Pernambuco).

Mean grain size differed among stations: S1 had 70.15% coarse sand and 16.74% medium sand; S2 had 85.80% and 6.29% coarse sand and gravel, respectively; and S3 had 60.83%, 17.35% and 13.05% coarse, medium and fine sand, respectively.

A total of 540 samples were taken from different levels of the sections and in different seasons. A total of of which were collected in summer and 380 (37%) were collected in winter. The size of the clams differed with regard to the season: C1 (≤ 15 mm) was the most abundant size class in summer, with 347 specimens captured (approximately 55%); the C2, C3 and C4 size classes were represented by 96, 114 and 76 specimens, respectively. In winter C3 (21 to 25 mm) was more abundant size class, with 218 individuals (57%); the C1, C2 and C4 size classes were represented by 64, 48 and 47 specimens, respectively. C5 (> 30 mm) was the lowest class in both seasons, with only three animals per season: 0.5% in summer and 0.8% in winter.

Table 1: Mean (± SD) water temperature (° C) and salinity (‰) in Mangue Seco (Pernambuco - Brazil). During the summer and winter. The three sections (S1 to S3)

	Summer			Winter		
	Mean ± SD			Mean ± SD		
	S1	S2	S3	S1	S2	S3
Temperature	29.1±1.38[a*]	28.5±1.07[a]	28.9±0.59[a]	27.3 ±1.2[a]	28.3 ±3.9[a]	28.3 ±1.0[a]
Salinity	39.8 ±0.36[a]	38.3±0.76[b]	37.5 ±0.51[b]	30.4 ±1.8[b]	38.3 ±0.76[a]	34.0 ±3.3[b]

* Different letters among lines indicate significant differences (p<0.05)

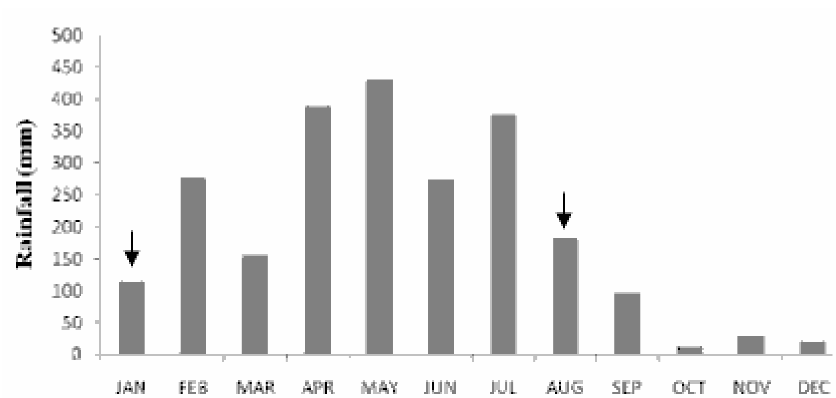

Figure 2: Rainfall (mm) recorded for the period January to December 2009. Arrows indicate the months of collection. Source: LAMEPE.

The difference in tide level (L1, L2 and L3) did not significantly affect the mean biomass and density values (Table 2). However, the summer data revealed a trend, indicating differences in biomass (L2> L3> L1) and density (L2> L1> L3) between levels. The same biomass pattern was found in winter, whereas a different density pattern occurred

(L2> L3> L1).

Table 2: Mean (± SE) density (ind.m^{-2}) and biomass (g.m^{-2}) for levels (L1. L2 and L3) in summer and winter.

	Summer		Winter	
Tidal Level	g.m^{-2}	ind.m^{-2}	g.m^{-2}	ind.m^{-2}
L1	430.37 ± 124.28[a*]	289.73 ± 110.52[a]	526.00 ± 197.49[a]	132.21 ± 42.91[a]
L2	995.70 ± 385.79[a]	354.53 ± 98.98[a]	864.63 ± 326.33[a]	192.67 ± 89.31[a]
L3	765.13 ± 288.67[a]	250.35 ± 94.31[a]	796.77 ± 119.36[a]	196.91 ± 60.92[a]

* Different letters among columns indicate significant differences ($p<0.05$)

There were no statistically significant differences in the population density of *A. brasiliana* in the study area between the summer and winter periods (298.17 ± 53.00 ind.m^{-2} and 173.93 ± 35.17 ind.m^{-2}, respectively). However, significant differences were found when comparing the sections (S1, S2 and S3) and section/season interactions (Table 3). The maximum density recorded in the summer was 414.91 ± 82.48 ind.m^{-2} in S3 and 323.49 ± 90.11 ind.m^{-2} in S1, both of which differed substantially from S2 (156.12 ± 28.72 ind.m^{-2}). In winter, the minimal density was 102.67 ± 5.07 ind.m^{-2} in S1 and 122.37 ± 36.86 ind.m^{-2} in S2, both of which different substantially from S3 (296.76 ± 45.20 ind.m^{-2}). The variation in density demonstrated the seasonal fluctuations, with higher values in summer and lower values in winter (Figure 3).

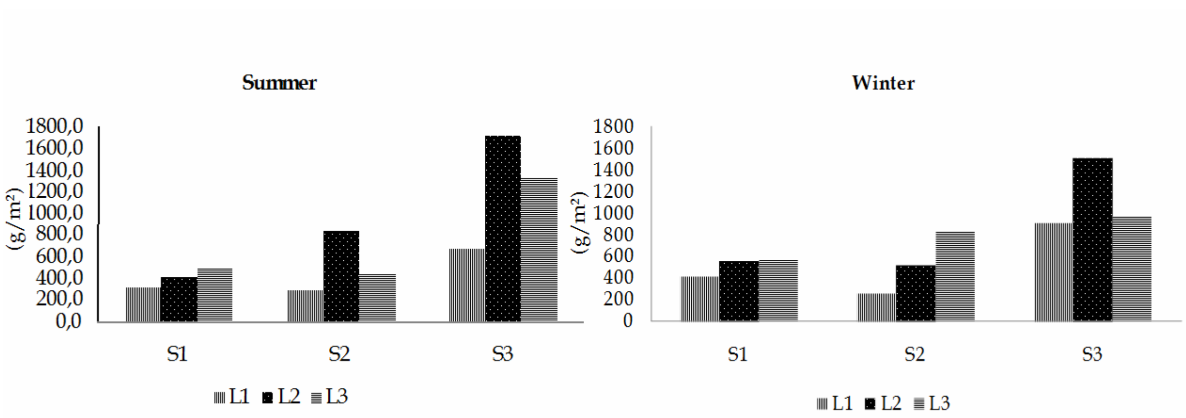

Figure 3: Population density of *A. brasiliana* by sections (S1. S2 and S3) levels (L1. L2 and L3) of Mangue Seco beach. During the summer and winter.

Season had little impact on biomass, with values of 730.40 $g.m^{-2}$ and 729.13 $g.m^{-2}$ in summer and winter respectively (Fig. 4). However, the results revealed that biomass varied among sections and with regard to section/season interactions (Table 3). S3 differed between seasons and had a greater number of clams and, consequently, greater biomass in comparison to S1 and S2.

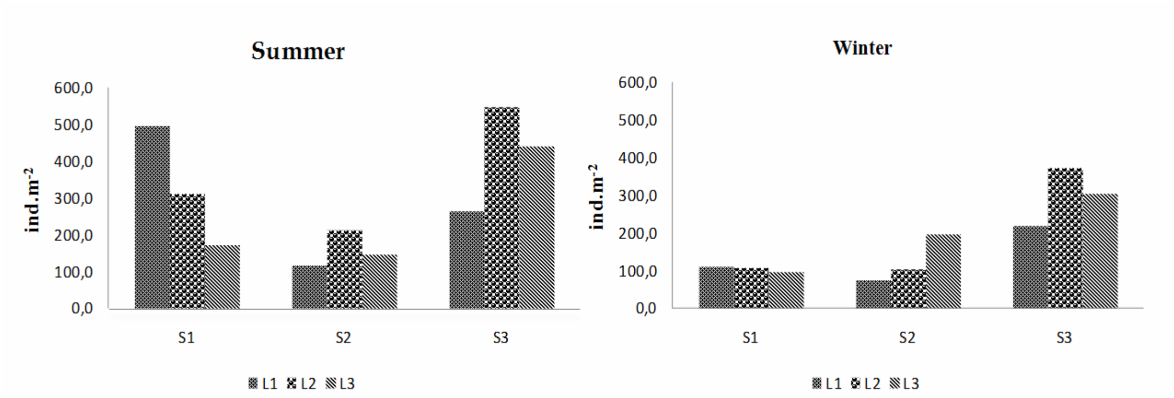

Figure 4: Biomass of *A. brasiliana* by sections (S1. S2 and S3) and levels (L1. L2 and L3) of Mangue Seco beach. During the summer and winter

Discussion

Mean salinity varied greatly over the two seasons. The drop in salinity in winter was related to the increased rainfall in the months prior to the sampling campaign. Filho (2001) reported that drastic changes in salinity (daily, seasonal, annual) greatly influenced the distribution of benthic associations in estuaries. Leonel et al. (1983) experimentally demonstrated that *A. brasiliana* tolerates variations in salinity from 17 to 42‰. Monti et al. (1991) reported the occurrence of *A. brasiliana* in the Guadeloupe archipelago (Caribbean) in areas with salinity ranging from 17 and 38‰.

There were no significant differences in standard grain size between the three stretches of beach. Magalhães et al. (1998) reported the absence of this species in locations with a substrate composed of coarser sand and higher densities in substrates composed of fine-grained sand with a large amount of organic matter. Boehs et al. (2008) observed this same pattern predominantly in the population of *A. brasiliana* in the inter-tidal non-vegetated estuarine complex of Paranaguá Bay in the state of Paraná (southern Brazil).

Rainfall influenced the distribution pattern of *A. brasiliana* in 2009. There were more clams larger than 20 mm in August than in January, the latter of which typically followed a period of drought that caused the majority of clams to be smaller than 20 mm. Terrestrial runoff, river discharge and the re-suspension of bottom sediments by tidal currents are the principal sources of nutrients in tropical estuarine ecosystems (Von Prahl et al., 1990; Cantera and Blanco 2001; Medeiros et al. 2001). Thus, it can be assumed that greater primary productivity (and consequently food availability) is associated with the rainy season. The same has been observed by Gocke et al. (2001) in a tropical estuary in Costa Rica and Hernández and Gocke (1990) in a coastal lagoon on the Caribbean coast of Colombia. According to Riascos (2006), the reproductive cycle of the tropical bivalve *Donax dentifer* on the Pacific coast of Colombia was associated to the availability of food in the rainy season. This same conclusion may be drawn for *A. brasiliana*.

Table 3: Biomass and population density (Mean ± SE) of *A. brasiliana* one way S1 (0-600m). S2 (600-1200) and S3 (1200-1800m). the season (S = Summer and W = Winter) and the interaction between section and the seasons in the Beach Mangue Seco. Pernambuco - Brazil.

Sections	**Biomass** ($g.m^{-2}$)	**Density** ($ind.m^{-2}$)
S1	462.71 ± 40.07^{a}	213.08 ± 64.92^{ab*}
S2	533.95 ± 105.01^{a}	139.24 ± 22.22^{a}
S3	1192.63 ± 163.21^{b}	355.84 ± 49.67^{b}
Seasons	**Biomass** ($g.m^{-2}$)	**Density** ($ind.m^{-2}$)
S	730.40 ± 165.43^{a}	298.17 ± 53.00^{a}
W	729.13 ± 126.44^{a}	173.93 ± 35.17^{a}
Sections × Seasons	**Biomass** ($g.m^{-2}$)	**Density** ($ind.m^{-2}$)
S1× S	412.10 ± 51.79^{a}	323.49 ± 90.11^{c}
S2 ×S	530.63 ± 165.53^{a}	156.12 ± 28.72^{ab}
S3 ×S	1248.47 ± 305.82^{b}	414.91 ± 82.48^{c}
S1 ×W	513.33 ± 52.76^{a}	102.67 ± 5.07^{a}
S2 ×W	537.27 ± 166.53^{a}	122.37 ± 36.86^{a}
S3 ×W	1136.80 ± 191.14^{b}	296.76 ± 45.20^{bc}

* Different letters among columns indicate significant differences ($p<0.05$)

An analysis of the density and biomass of *A. brasiliana* in relation to the tide level revealed a more frequent distribution pattern at Level 2 (L2>L1>L3). Rodil et al (2008) analyzed the distribution pattern of a macrobenthic community and found a greater density of molluscs at the inter-tidal level (L2>L3>L1).

August precedes the summer, in which the greater regional demand for this product leads to an increase in fishing efforts, which could suggest why the density of *A. brasiliana* was lower in winter. Rodil et al (2008) reached the same conclusion for an estuarine beach in Spain on which bivalves were scarce in April, likely due to local clam gathering activities in the previous months. These molluscs are used by fishing communities for both subsistence consumption and sales to the consumer market (Pezzuto & Echternacht, 1999; Rosa, 1989). Another factor that may have influenced the lower density was the increased rainfall in winter, which altered the salinity of the sea, leading to increased mortality rates and, consequently, a lower density of individuals collected in this period (Moueza et. al., 1988; 1999; Monti, 1991; Bezerra, 1998; Estrada, 2001; Barreira and Araújo, 2005; Boehs et al., 2008). In areas with considerable density, a natural self-limitation was experienced due to the reduced amount of space and food, causing the density value to be reduced (Pezzuto and Echternacht, 1999).

Rainfall exerted an influence over the distribution of the bivalve *A. brasiliana*, leading to a decrease in density. However, the animals were larger (> 20 mm) in the rainy season due to the increase in the availability of food sources. These results can serve as a basis for future management programs for the species through the maintenance of natural stocks and control of fishing activity in the region.

Acknowledgments

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