Population structure of the invasive bivalve *Isognomon bicolor* (C.B. Adams, 1845) on rocky beaches in northeastern Brazil

Estrutura populacional da bivalve invasora *Isognomon bicolor* (C.B. Adams, 1845) nas praias rochosas do nordeste do Brasil

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**ABSTRACT**
The invasive bivalve *Isognomon bicolor* is native to the Caribbean and had its first record for the Brazilian coast published in 2002. The objective of this study was to compare the population structure of *I. bicolor* in two rocky beaches of the coast of Paraíba and verify its temporal variation. Six samples (20 x 20 square cm) were collected on each beach, three in the dry season and three in the rainy season and at two levels of the mid-coastal zone (Bottom and High). Nine samples were obtained for each beach per month, totaling 108 samples. 2,196 specimens of *I. bicolor* were collected and measured. The highest densities occurred at Carapibus beach. Considering the size structure, there was a significant difference in the length of the nacreous layer between beaches, mid-littoral zones and seasons, with most recruits and smaller individuals occurring on Jacumã beach.

**Keywords:** marine bioinvasion, population structure, rocky shores.

**RESUMO**
A bivalve invasiva *Isognomon bicolor* é nativa das Caraíbas e teve o seu primeiro registro para a costa brasileira publicado em 2002. O objectivo deste estudo foi comparar a estrutura populacional de *I. bicolor* em duas praias rochosas da costa da Paraíba e verificar a sua variação temporal. Foram recolhidas seis amostras (20 x 20 cm quadrados) em cada praia, três na estação seca e três na estação chuvosa e em dois níveis da zona média costeira (Fundo e Alto). Foram obtidas nove amostras para cada praia por mês, totalizando 108 amostras. Foram...
recolhidas e medias 2.196 amostras de I. bicolor. As densidades mais elevadas ocorreram na praia de Carapibus. Considerando a estrutura de tamanho, houve uma diferença significativa no comprimento da camada nacarada entre praias, zonas de meio-litoral e estações do ano, com a maioria dos recrutas e individuos mais pequenos a ocorrerem na praia de Jacumã.

**Palavras-chave:** bioinvasão marinha, estrutura populacional, costas rochosas.

### 1 INTRODUCTION

Exotic species can become invasive when they threaten native biological diversity, as their high population density can cause these species to disappear (Erro! Fonte de referência não encontrada. Teixeira et al., 2010; Breves-Ramos et al., 2010).

Some species have a great capacity to invade and colonize environments due to biological, genetic, physiological and ecological characteristics that confer tolerance to most environmental factors (Machado & Oliveira, 2009). Routes of introduction such as ballast water, fouling on oil platforms or on the hulls of ships, are considered the main forms of introduction of exotic species around the world (Astudillo, 2006; Ferreira et al., 2004).

Marine environments have for several decades suffered a constant increase in biological invasions, either by the natural flow of organisms through climate change and currents, or by the flow mediated by human activity and the importance of these areas for world maritime navigation (Teixeira et al., 2010). An exotic species can establish itself both in conditions very similar to its habitat of origin, and in environments that have been altered by anthropic factors (Tyrrell & Byers, 2007).

Originating from the central western Atlantic coast, the bivalve *Isognomon bicolor* prevails on steep rocky coasts exposed to moderate waves (Breves-Ramos et al., 2010). On the Brazilian coast, *I. bicolor* has a wide distribution, extending from the Northeast to the Southeast coast (Domaneschi & Martins, 2002).

This bivalve was classified as an invasive species on the Brazilian coast with potential for a high impact on resident species (Junqueira, 2009).

Given the large number of exotic species occupying estuarine coastal areas and marine habitats, little is known about invasions in these environments. And this results in a lack of understanding about the indirect effects of invaders, their
impacts on species at different trophic levels and impacts on food chain properties and ecosystem processes (Grosholz, 2002).

Ecological studies on biological invasions can be essential for understanding the main driving forces of community dynamics, since the damage generated by the invasion can be irreversible ecological changes, damages to public health and economic losses (NISC, 2004; Silva et al., 2012).

However, there are relevant studies in some places around the globe, regarding the biological introduction and its vectors, as well as the monitoring of several introduced species (Oricchio, et al. 2019; Castro, et al., 2016).

Studies with information on the evolution and interactions of invasive species and native species in invaded communities can lead to a better understanding of the susceptibility of ecosystems subject to invasion, understand which factors influence the dispersion of exotic species, in addition to contributing to the understanding of propagation and management of invasive species (Sakai et al., 2001).

The trend, in all habitats, is that the impacts caused by invasive species increase over time, and therefore it is important to recognize the threat of biological invasions and adopt measures for prevention and control (Leão et al., 2011).

In this context, it is very important to deepen the knowledge about the ecology of I. bicolor and to understand how its populations are reacting in the different regions and places invaded and different environmental conditions to which it is exposed on the Brazilian coast.

Considering the ecological importance that an invasive species can assume and the probable modifications and impacts it can cause in coastal ecosystems in Brazil, this study aimed to analyze the population structure of the invasive bivalve *Isognomon bicolor*, based on its distribution, density and size structure in two sandy beaches in Paraíba, Northeastern Brazil, to provide information on the species in places not yet studied, helping to know the status of the invasion and contributing to future monitoring.

The present work was carried out on two structurally similar rocky beaches (Figure 1):

Jacumã (7°17’38.36”S; 34°48’3.21”W) and Carapibus (7°17’58.62”S, 34°47’56.50” O) located in the municipality of Conde, south coast of Paraíba,
Northeast Brazil. The municipality is located in the Conde Microregion and Mata Paraibana Mesoregion, with an AS’ climate (hot and humid), according to the Köppen classification, with dry summers with a drought period of 5 to 6 months and rainy winters (PDDM, 2001).

The two beaches have similar structural characteristics, with sandstone rock formations, and both have an intertidal zone composed of rocky material and unconsolidated sandy material. However, Carapibus beach has a longer rocky strip than Jacumã, and the intertidal zone is exposed for longer periods during low tide. (Suguiu, 1998).

Figure 1 . Location of the State of Paraíba on the Brazilian coast and the municipality of Conde, southern coast of the State of Paraíba, Northeast Brazil. Highlight for the beaches of Jacumã and Carapibus, with the sandstone reefs

2 METHODS

The study was developed during six months of sampling, with three samplings in the rainy season (July to September 2013) and three in the dry season (December 2013 to February 2014). For the sampling, two levels of the beaches’ mid-littoral were defined, dividing this zone into two parts: Bottom mid-littoral and High mid-littoral (Figure 2). Each level of the midlittoral was divided into three longitudinal bands, where three samples were obtained in each band of each level, nine samples for the upper mesolittoral and nine samples for the lower mesolittoral, totaling eighteen samples per month of collection.
The samples were delimited by squares of 20 x 20 cm, thrown at random, and then the substrate components (including Isognomon bicolor) were scraped and removed with the aid of spatulas, chisels and mallet, being packed in plastic bags and taken to the laboratory where were preserved in 70% alcohol for later screening and measurement.

After sorting, the specimens of *I. bicolor* were measured with the aid of a caliper (accuracy 0.01 mm), verifying the following measurements: Total length (TL); Length of the pearly layer (LPL); Hinge length (HL); Hinge point thickness (HPT); Edge stitch thickness (EST).

### 2.1 DATA ANALYSIS

Total length (TL) is understood as the distance between the apex of the hinge to the margin of the lower part of the shell; Length of the nacreous layer (NL) comprises the inner face of the valves in the region that houses the body, which is coated with shiny nacre; Hinge point thickness (HPT) is the thickness at the hinge region of a valve; Edge stitch thickness (EST) is the thickness of the margin opposite the hinge of the same valve; Shell width comprises the measure of the greatest width of the individual with the valves closed; and the shell height is determined by the distance between the upper dorsal margin and the ventral part of the shell.

These parameters were established with the purpose of analyzing the population structure, verifying the density of recruits and adults, and through that detect possible differences in the classes of size and shell thickness between the variables season, beach and zone.

To analyze the size distributions of *Isognomon bicolor*, the size classes were established based on the length of the pearly layer, comprising five classes: (1st) those individuals that reached a length less than or equal to 4 mm, in this case they were classified as recruits; (2nd) from 4 mm to 8 mm; (3rd) from 8 mm to 12 mm; (4th) from 12 mm to 16 mm; (5th) and individuals that reach a length greater than 16 mm (Figure 5).

The average density (ind/m²) on the beaches, zones and stations was calculated, considering that the total sampling area in this study was 8.64 m². The differences between the mesolittoral zones and seasons were also analyzed.
3 RESULTS
3.1 SIZE STRUCTURE

Considering the average densities of *I. bicolor* found on the beaches of Carapibus (300 ind./m²) and Jacumã (203.7 ind./m²) it was seen that on the beach of Jacumã there was no difference in the density and abundance of *I. bicolor* between the zones, however, it can be seen that in Carapibus the density of *I. bicolor* differed between the zones, with a higher average density in the upper zone, indicating greater affinity with this area (Figure 2).

However, when analyzing between the zones and seasons of each beach, the highest density was found in the upper mid-littoral zone, Carapibus beach. Jacumã beach had its highest density in the rainy season and an average of 266 ind./m². Only the lower mid-littoral zone of Carapibus had an average density greater than 500 ind./m² and greater abundance, with just over 1000 individuals found.

Figure 1. Data on abundance, density (ind./m²) of individuals of *Isognomon bicolor* in the seasons and zones of the midlittoral in each beach by area (4.32m²).

The number of individuals in size classes between 8 and 12 mm (436 ind./m²) was higher at Carapibus beach. Jacumã beach presented a high frequency of size classes between recruits (233 ind./m²) and 4 to 8 mm (383 ind./m²) and no occurrence of individuals of the class above 16 mm. The maximum length recorded in this study was 18.85 mm, with only one individual, and it occurred in the upper mid-littoral zone in Carapibus, during the dry season. The smallest size, 0.03 mm, was found in the lower mid-littoral, in the rainy season at Jacumã beach. The measurements of the individuals of *I. bicolor* indicated the occurrence of the five size classes established in all the analyzed factors. (Figure
There was a significant variation in the size structure of *I. bicolor* between beaches, mid-littoral zones and seasons. The results indicate that the population structure of the invasive bivalve is well distributed in the two studied areas, but with a greater abundance of recruits and younger individuals, which suggests an intense recruitment. The data showed that both the rainy season and the dry season had a higher frequency of individuals from the lower classes. In Jacumã there were more recruits in the upper zone, while in Carapibus the recruits were more abundant in the lower zone.

![Figure 2. Measurements obtained for analysis of the size structure of *I. bicolor*: (a) (NL) nacreous layer; (LH) length of the hinge; (LPL) length of the pearly layer; (TL) total length; height. (b) width; (EST) edge stitch thickness; (HPT) hinge.](image)

The age group of the recruits (less than 4 mm) occurred on both beaches and was present in all factors studied (zones and seasons). Regarding the abundance of *Isognomon bicolor* among the size classes, recruits and younger individuals (between 4 and 8 mm) were more abundant overall. There was a predominance of individuals of the size class between 4 and 8 mm in both beaches and seasons and in the mid-littoral zones. The greatest abundance of this age group occurred at Carapibus beach, during the dry season (Figure 4).

Although the Jacumã beach has a greater abundance of recruits in the zones and seasons, it was observed that in this area the size classes greater than
8 mm decreased by more than half the amount of recruits and the class between 4 mm and 8 mm. In Carapibus, there was a decrease in the number of individuals as the population grew, however, there was a higher frequency of larger individuals.

Regarding seasonality, Carapibus beach recorded a higher average of individuals during the dry season. With these results, it is likely that in Carapibus the presence of individuals of higher age groups indicates a greater capacity for survival and with physical and environmental conditions more favorable to the development of the population.

Although the data do not show an influence of seasonality on population recruitment, the results indicate a decrease in the number of individuals from the larger size classes in the two study areas. Carapibus recorded the highest size averages between zones and seasons, indicating a greater number of individuals from higher classes. In the upper range, the size class between 12 and 16 mm was more abundant, with 25 individuals being recorded. The age group above 16 mm was less expressive, but found both in the upper and lower ranges.

In the upper range of the mesolittoral, organisms are more susceptible to thermal stress and desiccation, suffering greater action of sunlight, variations in temperature and humidity.

4 DISCUSSION

From these results, we can indicate that the populations of *Isognomon bicolor* are well established in rocky beaches of the coast of Paraíba, in which the species presents itself in high densities, with individuals of different sizes and life...
Considering the number of individuals and the sampled area, the average densities found on the beaches of Carapibus and Jacumã were lower than the densities observed in other locations in Brazil (López, 2010; Fernandes et al., 2004), however, this difference may be related to various factors, such as benthic composition, climatic regime and time of establishment.

The two beaches differ in many structural aspects and it is likely that the characteristics of the rocky substrate are determinant in the population density, among other aspects. In this study, there was a significant difference in the abundance of *I. bicolor* between the beaches, with higher density and abundance at Carapibus beach. Despite having similar topographic characteristics, the sandstone reef strip at Carapibus beach has a greater extension and is composed of larger rocks and with more heterogeneity than that of Jacumã beach, and structural factors such as this can influence the pattern of colonization of the area and in the resistance of individuals.

On Jacumã beach, smaller and smoother rocks were observed, providing a more homogeneous substrate and that the upper rocky strip is submerged for a longer period, offering protection and helping to avoid desiccation, which is likely to influence recruitment and resistance of younger individuals on this beach. The invasive bivalve *I. bicolor* mainly needs low-relief structures to recruit more efficiently (Moysés, 2005).

It is likely that these differences in density also reflect different stages of invasion, in which the beaches studied in this study would be in early stages and in other studies would be in more advanced stages of invasion, since *I. bicolor* selects the crevices that favor its establishment, as these substrates offer refuge against predators, protect against wave action and extreme environmental conditions, resulting in greater survival in these microhabitats, local environmental characteristics can influence the recruitment and zonation of intertidal benthic organisms (Zamprogno et al., 2010; Osman & Whitlatch, 2004).

Environmental factors may also indicate the reasons for the higher density of this invasive bivalve in the lower mesolittoral zone, abiotic factors are more stable and the population distribution is more influenced by biological interactions that are more suitable for feeding, growth and reproduction (Moreno & Rocha,
Among the physical and environmental factors, wave action and desiccation have been highlighted among the most important (Griffiths & Branch, 1991; Bustamante et al., 1997).

The dominance pattern of the population of I. bicolor is not maintained by the intensity of its recruitment, but by the stability of the bank, the longevity of adults, and a recruitment associated with low mortality and morphological plasticity (Rocha, 2002).

Due to these physical effects, the population of I. bicolor seems to be occupying a well-defined region of greater tidal influence, a dominance of the species in this range and a low coverage in places more exposed to the effect of upwelling and areas with intense beating (López, 2010).

In other studies, this type of population structure was observed on rocky shores in southeastern Brazil, with lower densities of recruits and a high number of larger individuals (López, 2010; Breves-Ramos et al., 2010; Zamprogno et al., 2012).

There are still few studies that show the reproductive investment of the species, as such information is essential to assess recruitment strategies and probable causes of mortality (López, 2010). In this study, the size classes occurred in both zones and in the seasons of the year, indicating a stable establishment in the studied region. However, the absence of previous studies in these sampled areas prevents a more accurate assessment of the population structure and the impact caused by an invasive species on native communities.

It is expected that the results of this study on the population of I. bicolor off the coast of Paraíba may allow future monitoring of the species in these areas. It is of great importance to carry out future research in these areas and in other locations, in order to add the scientific knowledge necessary for monitoring and diagnosis of bioinvasions by I. bicolor. It is known that populations are widely distributed throughout the coastal zone of Brazil, making it possible to carry out prevention and control activities in possible places of establishment and population development of this invasive species.
5 FINAL CONSIDERATIONS

The results obtained in the present study allow us to conclude that:

- The invasive bivalve *Isognomon bicolor* has a higher density of individuals in the rainy season of the two beaches, occupying mainly the lower area of Carapibus beach, less subject to desiccation, and in the upper area of Jacumã.

- The abundance and density of *I. bicolor* are related to the structural differences of the beaches, such as the size of the occupied rocks and the degree of emergence and exposure to desiccation.

- The distribution of size classes is defined by the places with the best conditions for recruits and younger individuals and also by the range in which *I. bicolor* is more physiologically adapted.

- The presence of recruits in both the dry and rainy seasons indicates that *I. bicolor* can reproduce throughout the year, which would increase its capacity for bioinvasion.

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