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ECOLOGY

Temporal variability of the invasive Asian clam *Corbicula fluminea* (Müller, 1774) in the Poxim-Açu River, northeastern Brazil

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ABSTRACT. In this study we analyze the temporal variability in the density and the size classes of the *Corbicula fluminea* (Müller, 1774) at Poxim-Açu River, northeastern Brazil. Densities ranged from 60 ± 103 to 500 ± 240 individual m^{-2}, but this variability was not statistically significant. There was no significant relationship between densities and water parameters (depth and flow). The population was mainly composed of young individuals, with 10-14 mm of shell length. Lower densities and predominance of juveniles suggest a recent invasion event. However, *C. fluminea* was firstly recorded at Poxim-Açu River three years before this study. Thus, these results might reflect a mortality followed by a reinvasion event. A continuous monitoring program is needed to better evaluate whether this population is growing and spreading as well as to determine which environmental variables could be driving the temporal variability of this species.

Keywords: density; size class; non-indigenous species; mollusks; freshwater.

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Introduction

The Asian clam *Corbicula fluminea* (Müller, 1774) (Bivalvia: Cyrenidae) is one of the most successful invasive species in freshwater environments worldwide (Sousa et al., 2008; Crespo et al., 2015). This species is native from Southeast Asia but currently has spread to American and European freshwater systems (Mansur et al., 2004; Crespo et al., 2015). The high invasive capacity of Asian clam is associated to its rapid growth, earlier sexual maturity, short life span, high fecundity, self-fertilize through androgenesis and its association with human activities (Sousa et al., 2008; Robb-Chavez et al., 2022).

In its invaded range, *C. fluminea* is responsible for several ecological and economical damages. This species might cause phytoplankton depletion due to its high filtration rates and, thus, promote changes in the local food web (McMahon, 1982; Sousa et al., 2008; Robb-Chavez et al., 2022). Also, competition for food and space can result in decrease in population size or even displacement of native species (Darrigran, 1992, 2002; Sousa et al., 2008; Robb-Chavez et al., 2022). As for economic impacts, the macrofouling caused by Asian clam can clog water piping systems (Darrigran, 2022) resulting in over a billion dollars in remediation costs annually (Robb-Chavez et al., 2022).

In South America, its introduction occurred via ballast water probably during the 1960’s in the Plata River (Ituarte, 1981). Then, the species spread northward upstream through Uruguay and Paraná-Paraguay rivers and, finally, to eastern and northeastern Brazilian basins (Mansur et al., 2016). Its rapid spreading was facilitated mainly by human activities such as transporting water and sand among rivers, construction of transposition channels, transplantation of species and related aquaculture materials (Mansur et al., 2016). In the State of Sergipe, this species was firstly recorded to Caatinga biome along the São Francisco River (Santana et al., 2013) and then, to Sergipe River Basin, more precisely to Poxim-Açu River (Rosa & Dantas, 2020) and Jacarecica River (Rosa & Freitas-Filho 2023).

Besides previous records in Sergipe and its potential damage for local environments, there is no study analyzing any ecological aspects of *C. fluminea* on the local rivers invaded by them. Thus, in this work we sought to evaluate the temporal variability in abundance and size classes of this invasive species on the Poxim-Açu River, State of Sergipe, northeastern Brazil.

Material and methods

The Poxim-Açu River is part of the Poxim River sub-basin, which belongs to the Sergipe River basin (Figure 1). The sub-basin comprises an area of 128 km^2, 10% winding index, 4th order river hierarchy and compactness coefficient of 1.76, with elongated, practically straight form and low tendency to flood peaks (Rocha et al., 2014). The Poxim River basin contributes to about 30% of the water supply of Aracaju city, state capital and a dam was built by the Sanitation Company of State to provide water supply for human consumption, which started to operate in 2013. Two sampling sites were established downstream the dam (Figure 1). The Site 1 (10°55’183” S, 37°11’264” W) presents preserved riparian forest on both banks, presence of erosion on the right bank of the river. The riverbed is characterized by the presence of pebbles and coarse sand, with less than 5% silt deposited at the bottom of the river and in the backwaters. Site 2 (10°55’188” S, 37°11’180” W) presented a narrow riparian forest (less than 10 m), with erosion on both banks of the river. The substrate is composed mainly of coarse sand and pebbles, and approximately 30% of the habitats were stable.

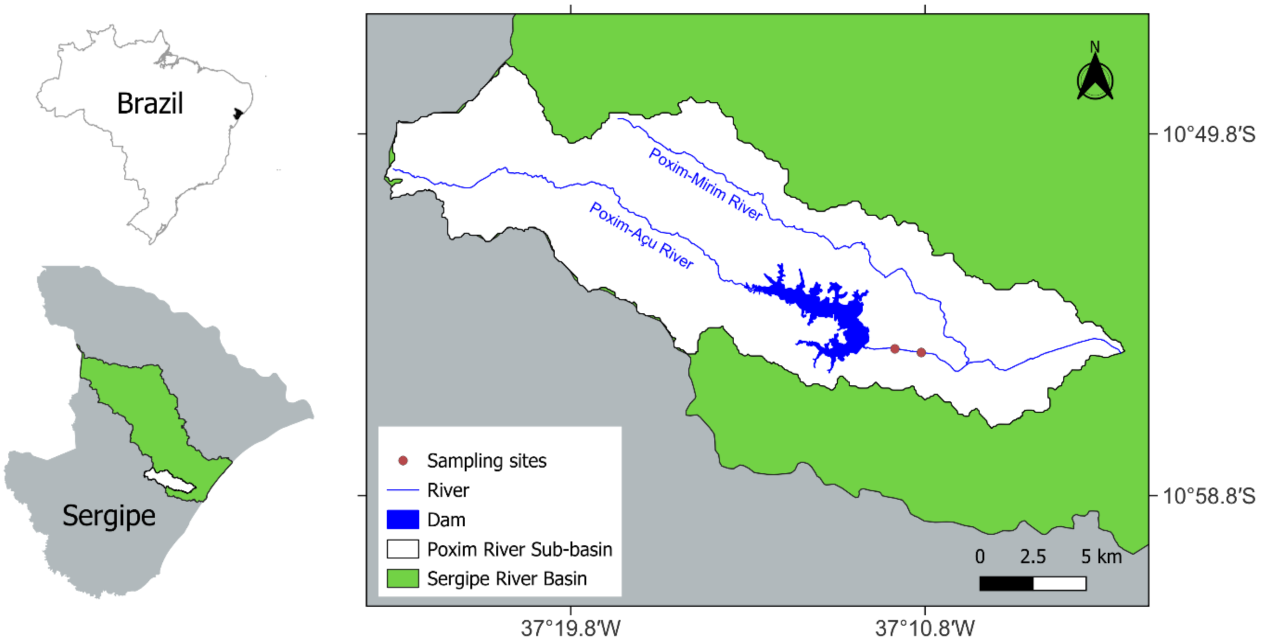

Figure 1. Map of the Poxim River Sub-basin indicating the sampling sites.

Samplings were carried out monthly from May 2019 to February 2020, except in July and August 2019. Three samples were taken at each site using a PVC core of 0.25 m of diameter which was pushed 10 cm into the sediment. All individuals found inside were taken by hand, stored in plastic bags properly identified and sent to the lab for further analysis. During each sampling period, the water depth and flow were also measured. At the lab, individuals were identified according to Pereira et al. (2012), counted and their shell length were measured with a digital pachymeter.

Differences in the bivalve abundance between sites and sampling period were tested by a two-way analysis of variance, after first testing for normality (Kolmogorov–Smirnov test) and homogeneity of variance (Cochran test) (Zar, 2009). All individuals were grouped into 1-mm shell length intervals for frequency distribution analyses and possible relationships between bivalve abundances and water parameters (depth and flow) were accessed by a Spearman Correlation test.

Results

The water depth ranged from 0.11 (October) to 0.38 m (September), while water flow ranged from 0.22 (June) to 1.03 $m^3\ s^{-1}$ (May) (Figure 2).

The mean densities of *C. fluminea* ranged from 60 ± 103 (September 2019, Site 2) to 500 ± 240 individuals m^{-2} (June 2019, Site 1; Figure 3). However, these differences were no statistically significant neither between sites (F = 0.044; p = 0.835), nor among sampling periods (F = 1.424; p = 0.230), nor for the interaction between both factors (F = 1.361; p = 0.255). Also, there was no significant relationship between the *C. fluminea* abundance and both water depth (r_s = -0.266; p = 0.308) and water flow (r_s = -0.274; p = 0.298).

Regarding the size class, the smallest individual was 5 mm and the largest one was 18 mm of shell length, but most individuals were between 10-12 and 12-14mm size classes (Figure 4).

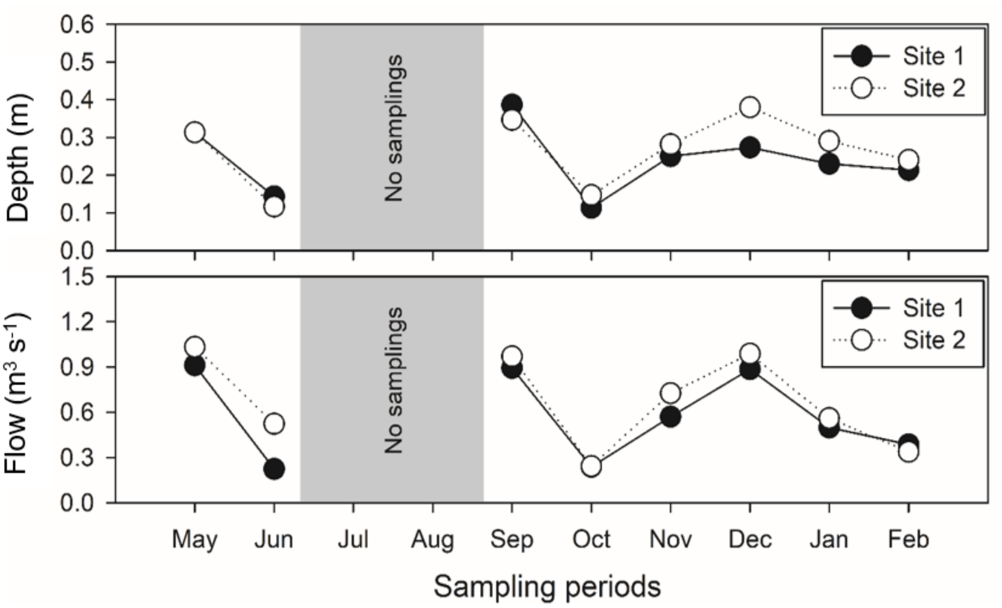

Figure 2. Absolute values of water depth and flow at each site of the Poxim-Açu River along the sampling periods.

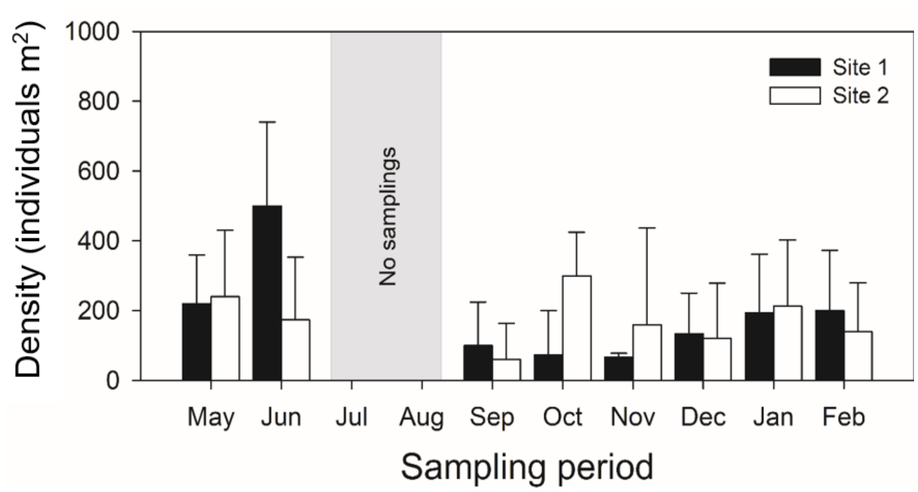

Figure 3. Mean densities (+ standard deviation) of *Corbicula fluminea* at each site of the Poxim-Açu River along the sampling periods.

Discussion

In general, oscillations in the abundance of *Corbicula fluminea* are related to changes in the environmental variables such as sediment composition (Sousa et al., 2008; Silveira et al., 2016), temperature and oxygen concentration (Mansur et al., 1994; Bagatini et al., 2007; Rodriguez et al., 2020), water level (or depth) and flow (Paschoal et al., 2015; Castañeda et al., 2018; Kelley et al., 2022).

In the Poxim-Açu River there was no significant relationship between *C. fluminea* abundances and neither water depth or flow. Also, the observed changes in abundance were not significant, suggesting a temporal stability over time. However, the observed densities in this study (maximum of 500 individuals m^{-2}) were lower than in the previous record. *Corbicula fluminea* was previously recorded at Poxim-Açu river in 2016 with densities ranging from 412 to 1692 individuals m^{-2} (Rosa & Dantas, 2020). Although uncommon, retractions in *Corbicula* densities have been recorded along Prata River after 25 years of invasion but the reasons behind this phenomenon are unclear (Reshaid et al., 2017).

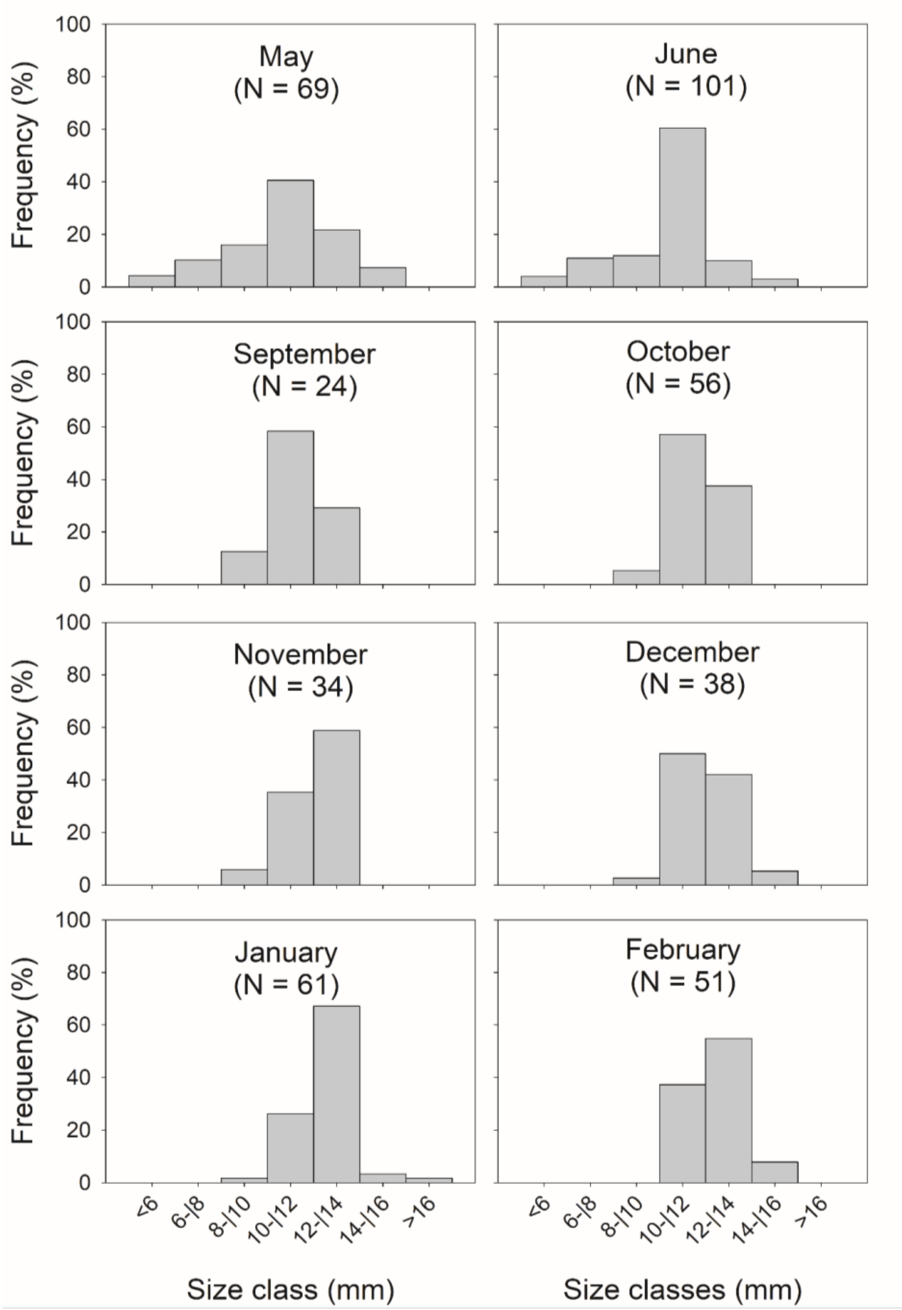

Figure 4. Size class histograms of the *Corbicula fluminea* shell length collected at Poxim-Açu River.

Moreover, according with age estimates carried out by Cataldo and Boltovskoy (1998), individuals of *C. fluminea* smaller than 15.3 mm of shell length are juvenile, while individuals from 15.4 to 22.4 mm of shell length are one year old; from 22.5 to 27.0 mm are two-year-old and those bigger than 27 mm of shell length are three-year-old. Based on these estimates, the population in the Poxim-Açu River is composed mainly of juveniles. Only 6 individuals (ca. 1.5% of total of individuals collected) were bigger than 15.3 mm of shell length, which would correspond to one year old.

Curiously, population with lower densities and composed mainly by juvenile organisms are attributed to recent invasion events of *C. fluminea* (Callil & Mansur, 2002; Oliveira et al., 2014) and it was unexpected such population after three years of its first record in the Poxim-Açu River. Probably this scenario is the result of a massive mortality event followed by a new recruitment (i.e., a secondary invasion). However, apparently there is no natural cause for this mortality. There were no changes in the river bottom as well as there was no drought event along this period.

Seasonal fluctuations with decline in abundance of *C. fluminea* during rainy seasons has been attributed to increase in water turbidity and sedimentation (Avelar et al., 2014). Increased river flow and current velocity are observed during the rainy season, resulting in re-suspension of sediment and, then, increasing water turbidity (Christofoletti, 1981). Manipulative experiments have corroborated with effects of turbidity increasing on reduction of *C. fluminea* densities, resulting in 50% of mortality rates when submitted to 150 NTU turbidity levels over 96hs (Avelar et al., 2014). In Sergipe, the rainy season is from April to August (Alvares et al., 2013). Indeed, during July and August the water level of Poxim-Açu was so high that it was impossible to carry out the samplings. Also, the lower densities were recorded in September but it was not significantly different from other sampled periods. However, it is possible that the mortality event had been the result of a prolonged period of high turbidity occurred in the past years. Moreover, we must also take into account the presence of the dam ~2 km upstream sampling sites. Besides controlling the water flow, some management activity carried out in the dam could be responsible for the mortality event observed here.

Since population of the *C. fluminea* with densities above 200 ind. m^{-2} are capable of generating potential ecological and economic damages (Mansur & Garces, 1988), a continuous monitoring program is need to evaluate the grow and spread of *C. fluminea* populations on Poxim-Açu River. Besides, a more accurate monitoring of the environmental parameters is essential to understand which variables could be driving the temporal variability of this species.

Conclusion

Even after three years of its first record, the population of the *C. fluminea* in the Poxim-Açu River was composed mainly by juveniles (one-year old) and showed lower densities than previous records. There was no significant temporal variation on abundances. A continuous monitoring program is needed to better evaluate whether this population is growing up and spreading as well as to determine which environmental variables could be driving the temporal variability of this species.

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