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Preliminary observations on gastropod predation naticids in the eastern Amazon

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Preliminary observations on gastropod predation naticids in the eastern Amazon

Resumo: Os gastrópodes naticídeos vivem na zona intermareal sendo comumente conhecidos por se alimentarem de moluscos bivalves. Neste contexto, compreender a relação predatória interespecífica dos moluscos é importante para a caracterização funcional da cadeia trófica. O objetivo deste estudo foi estudar a predação de gastrópodes naticídeos da espécie *Natica marochiensis* sobre o bivalve *Donax striatus*. Foi evidenciada a atração de gastrópodes pela locomoção dos bivalves no substrato, bem como uma provável percepção olfativa pelos rastros no sedimento provenientes da locomoção dos bivalves. Após a percepção da presa, os gastrópodes passam gradativamente a forragear, cobrindo a presa com a sola pediosa para sufocá-la. Não houve marcas de perfuração nos bivalves consumidos por *N. marochiensis* após o experimento. No entanto, foi demonstrado que grandes gastrópodes forrageiam tanto pequenos quanto grandes bivalves. Assim, a hipótese de que os gastrópodes predadores atacam apenas pequenos bivalves é refutada. Observações *in situ* destacam que um indivíduo pequeno de *N. marochiensis* forrageia *D. striatus* com maior estrutura corporal, mas "hipoteticamente" por instinto acaba desprezando a presa pois o gasto de energia durante o forrageamento não seria compensatório.
Palavras-chave: Amazônia; Relação interespecífica; moluscos; *Natica marochiensis*; *Donax striatus*.

Abstract: Naticid gastropods live in the intertidal zone and are commonly known for feeding on bivalve molluscs. Understanding the interspecific predatory relationship of mollusks is important for the functional characterization of the trophic chain. The objective was to study the predation among the naticid gastropod *Natica marochiensis* on the bivalve *Donax striatus*. The attraction of gastropods through the locomotion of the bivalves in the substrate was evidenced,as well as a probable olfactory perception through the trails in the sediment from the locomotion of the bivalves. After the prey is perceived, gastropods gradually move on to foraging, covering the prey to suffocate it. There were no perforation marks in the bivalves consumed by *N. marochiensis* after the experiment. However, it was shown that large gastropods forage both small and large bivalves. Thus, the hypothesis that predatory gastropods prey on only small bivalves is refuted. In situ observations stand out that a small *N. marochiensis* forages *D. striatus* with greater body structure, but "hypothetically" by instinct it ends up despising the prey as the energy expenditure during the foraging would not be compensatory.
Keywords: Amazon; Interspecific relationship; shellfish; Natica marochiensis; Donax striatus.

Introduction

Biotic interactions, such as competition, parasitism, mutualism and predation play a crucial role in the formation of the community structure, being determined by the dynamics of the populations (POLIS; STRONG, 1996). The eating habit of an organism is limited by several factors, such as the abundance of resources and morphological and physiological characteristics for the search, handling and capture of food (RICKLEFS, 1996).

Marine neogastropods live and forage in the coastal area (TAYLOR; TAYLOR, 1977; RUPPERT; BARNES, 1996) and are considered specialized predators of mollusks, mainly bivalves (DÁVID, 1995; HENCKES; CUNHA, 2007; CHIBA; SATO, 2013; CHAGAS et al., 2020), gastropods (BERRY, 1982; HUGHES, 1985; CHATTOPADHYAY et al., 2014), crustaceans (HUELSKEN, 2011), echinoderms (KABAT, 1990), annelids (KABAT, 1990) between others. The morphology of these gastropods assist in movement within the sediment, facilitating the capture and manipulation of prey (CARRIKER, 1981; CHAGAS; HERRMANN, 2021). Among the families with predatory habits, the Naticidae and Muricidae stand out, which have a greater amount of information in the scientific literature.

Naticidae includes four genera on the Brazilian coast: *Natica* Scopolli, 1777, *Polinices* Montfort, 1810, *Sinum* Röding, 1798 and *Sigatica* Meyer & Aldrich, 1886 (RIOS, 2009). These gastropods feed through fixation in the visceral mass of the bivalve or through perforations in the shell of the prey, using the specialized radula that contains chemical substances capable of dissolving calcium carbonate (BERG; NISHENKO, 1975; CARRIKER, 1981; BERRY, 1982; ANSELL; MORTON, 1987; RUPPERT; BARNES, 1996). They are considered one of the largest and oldest groups of shell drillers with strong influences on community structure and species diversity (WILTSE, 1980; KABAT; KOHN, 1986). The characteristic holes of predation by naticids are characteristic, which makes them identifiable and can be traced in shells of fossil mollusks over time (KELLEY; HANSEN, 1993; DIETL; KELLEY, 2006).

Naticid gastropods are recognized as pests (HANCOCK, 1960) and this causes several works to be carried out on these organisms, mainly on the characteristics of the predatory relationship between gastropods and their prey, ranging from paleontological studies to the present day (WILTSE, 1980; KABAT; KOHN, 1986; ANSELL; MORTON, 1987; ARONOWSKY; LEIGHTON, 2003; HUELSKEN, 2011; MALLICK et al., 2014; MONDAL et al., 2014). The gastropod *Natica marochiensis* (Gmelin, 1791) presents a series of studies, including to understanding of the relationship between the size of the shell and the size of the radula (MEIRELLES; MATTHEWS-CASCON, 2003), aspects of reproductive biology (MARTINS, 1996), spawning and larval development (VASCONCELOS et al., 2013), predatory relationship (HENCKES; CUNHA, 2007; CHAGAS; HERRMANN, 2021) or eating aspects and habits (MARTINS, 1996).

Among the studies cited, the results of Martins (1996), Henckes e Cunha (2007) and Chagas e Herrmann (2021) make this current work possible because they mention the bivalve *Donax striatus* Linnaeus, 1767 as one of the main prey for *N. marochiensis* and the occurrence of this predation on the

Brazilian coast. Thus, the objective was to characterize the predatory relationship between the gastropod *N. marochiensis* on the bivalve *D. striatus* on the beach of Ajuruteua (Amazon coast, North region of Brazil) and to test the hypothesis of preference in the foraging of gastropods based on the size of the prey.

Materials and Methods

The study area is bordered by Ajuruteua beach (0°49'41.58 "S, 46°36'11.50" O), located in the Bragantina Coastal Plain, 36 km from the Municipality of Bragança, located in the Eastern Amazon region (Fig. 1). It has a length of 2.5 km, with a gentle slope towards the sea, being described as a tip of land between mangroves and the sea (PEREIRA et al., 2006). According to these authors, for presenting this location, for its peculiar hydrodynamics and for the erosive action of the sea, its area has been decreasing progressively in recent years.

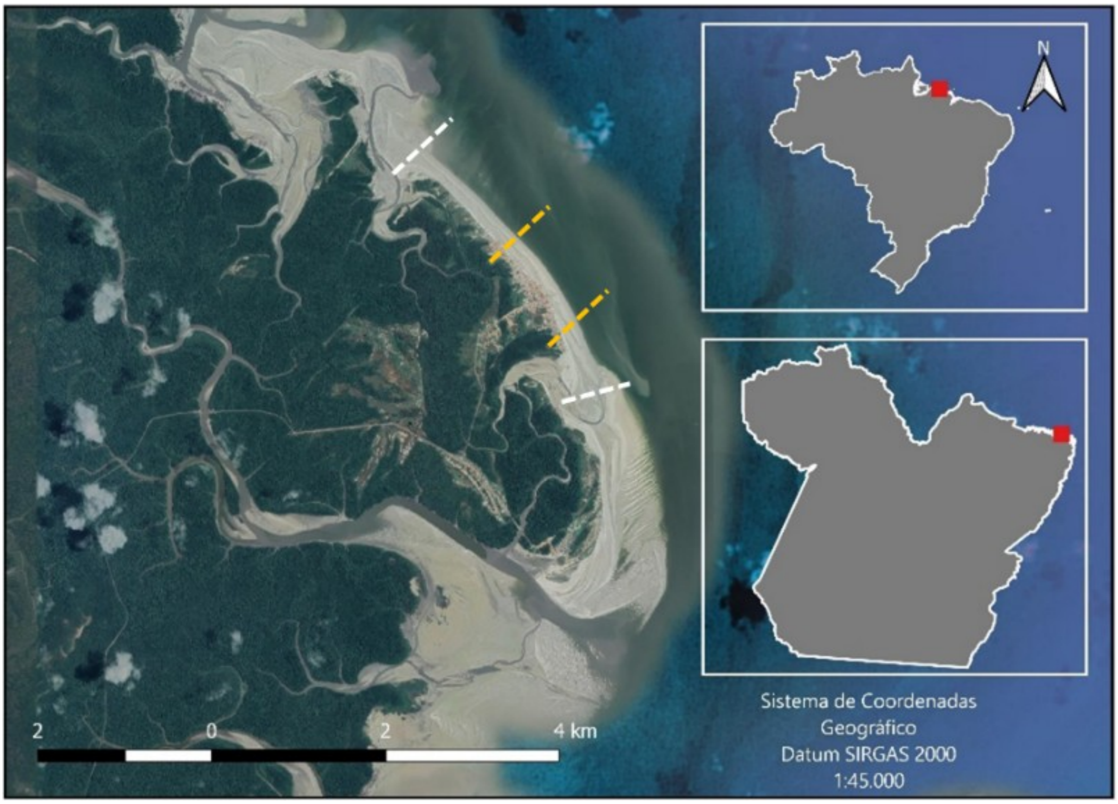

Figure 1 – Sampling and experiment area, located on Ajuruteua beach delimited by the white dashed line. Tourist area bounded by the dashed line in orange.

The area's climate is equatorial, hot and humid, and is characterized by a very rainy season between the months of December and May, and a dry season, in the other months of the year (PEREIRA et al., 2006). Martorano et al. (1993) found that the average annual rainfall is between 2,500 and 3,000 mm/year, the relative humidity varies between 80 and 91%, with an average air temperature of 25.7°C, ranging between 20.4°C and 32.8°C. According to these authors, in the region the regime of semi-daytime macro tides prevails, with an amplitude of four to six meters.

The characterization of the predation of *N. marochiensis* on *D. striatus* was carried out in October 2013, for five consecutive days, with samples in the morning and night periods. The instruments used for the execution of the collection and experiments, are: global positioning system (GPS) for the marking of places where predation is evident; digital pachymeter (TESA DATA Direct model, accurate to 0.01mm) for the morphometry of mollusks (gastropods and bivalves); gardening shovel to dig the sediment in search of organisms; measuring tape to determine the length of gastropod tracks; basketballs measuring 56x36 cm to perform the experiment; 10 m of ropes to mark areas in the intertidal region; flashlights for checking predation at night in the intermareal region; and stopwatch for determining the gastropod speed.

The verification of a location containing *N. marochiensis* buried in the sediment was carried out by observing the marking in the sand, forming a path originating from the locomotion of these mollusks when they drag their prey (Fig. 2). Thus, in order to limit the species distribution on Ajuruteua beach, observations were made during the day and night. When found, the location coordinates were marked, the lengths of the locomotion paths were measured and the biometrics (total length, width and height) of the gastropod shell were performed. In addition, gastropods found in containers were stored for use in the experiment for testing the hypothesis of preference in foraging based on prey size (described below).

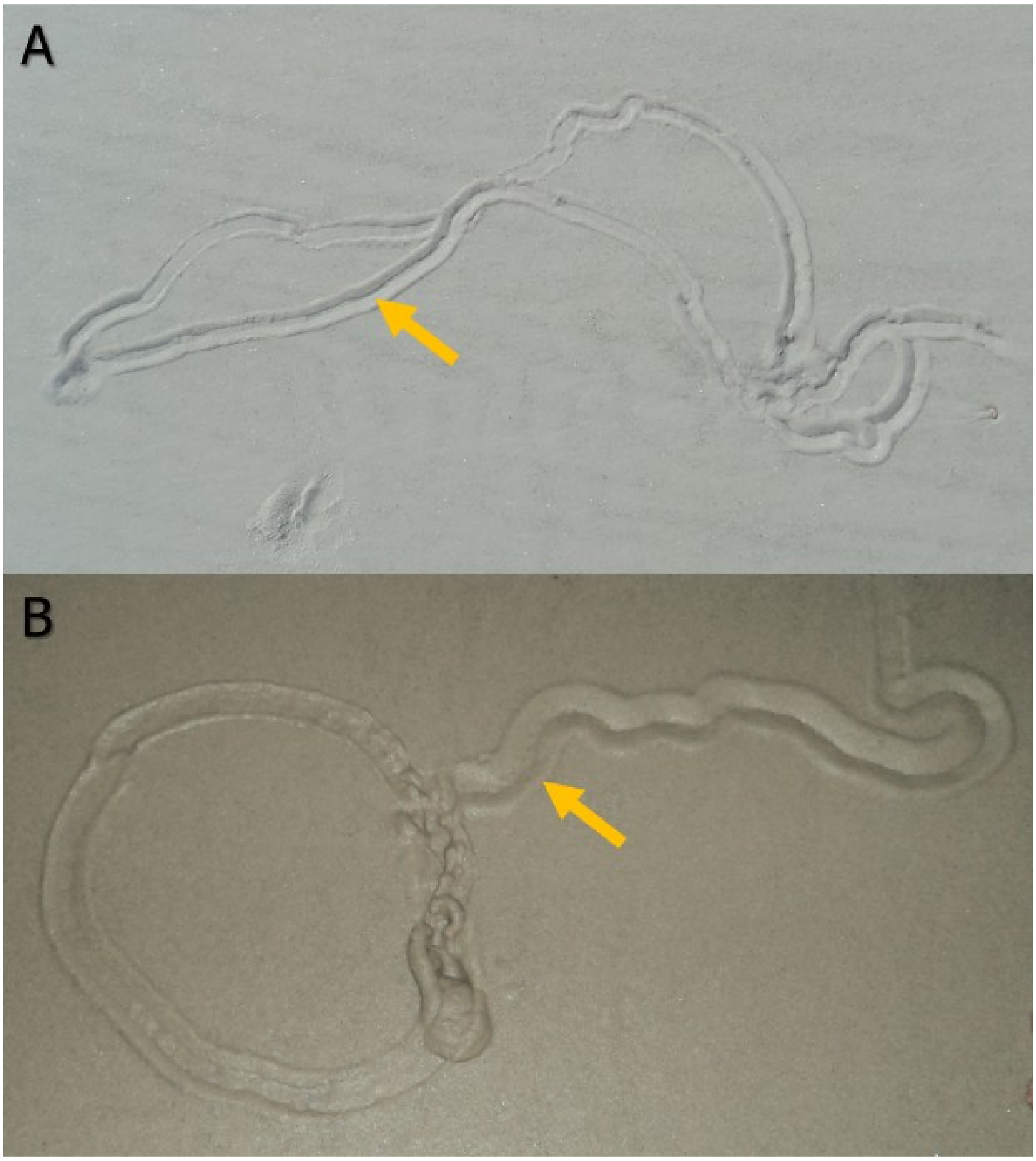

Figure 2 – Locomotion marks (orange arrows) made by *Natica marochiensis* on the sand of Ajuruteua beach during the day (a) and night (b).

To describe the predation of *N. marochiensis* on *D. striatus*, two experiments were organized: (1) predation characterization and (2) gastropod foraging time. For the experiments, 39 predators (*N. marochiensis*) found along Ajuruteua beach and 61 prey (*D. striatus*) of different sizes were used. For the execution of both experiments, an artificial environment was created capable of simulating the natural environment characteristic of these animals. Therefore, sand from the beach was poured into the inside of the basquettes so that it covered the bottom to a depth of 5 cm, inserting seawater to moisten the area to the point of making it similar to the intermareal zone. During the experiment it was necessary to add more water due to evaporation. Both experiments were observed for a total period of 24 hours

In the first experiment, based on the description of predation and the possible factors that lead to the choice of prey, 12 *N. marochiensis* and 24 *D. striatus* were used, which were arranged in four bars measuring 28x14 cm, in a 3:8 ratio (predator:prey). The second experiment, of foraging observation, used a basketball with a size of 56x36 cm, randomly distributed, 27 *N. marochiensis* and 37 *D. striatus.*

Additionally, the mean displacement speed of the predator *N. marochiensis* was characterized, in order to estimate the locomotion time towards the prey and/or in common movements. To determine this average speed, 10 individuals of different sizes were chosen at random from the predators captured for the predation characterization experiments, calculating the average time spent by each individual to cover a space of 10 cm.

To verify the relationship between the variables analyzed (biomorphometry of *N. marochiensis* and *D. striatus*; length of *N. marochiensis* and speed; length of *N. marochiensis* and the length of the locomotion trail), simple regressions were performed using linear equations of the type: $Y = a + b.X$. To test for the existence of statistical dependence between the related variables of the morphometric relationships, Pearson's correlation coefficient (r) was used, with significance of the r values, sequentially applying a t-Student test to assess the existence of statistical dependence between variables at a 95% significance level ($\alpha = 0.05$) (ZAR, 2010). The linear (a) and angular (b) coefficients of the regressions were estimated using the least squares method. There was also a correlation between the biomorphometry of predators and the path left by this mollusk when moving in the sediment. For statistical analysis, the statistical program was used using the software PAleontological STatistics – PAST, version 4.0 (HAMMER, 2020).

Results and Discussion

The raw data of the morphometry carried out on the molluscs captured on the beach of Ajuruteua are available on the digital platform *Data Publisher for Earth & Environmental Science* – PANGAEA (www.pangaea.de/). The gastropod *N. marochensis* had a total length of 14.07±1.58 mm (mean±SD), ranging from 10.5 to 17.68 mm, width 11.74±1.58 mm, between 9.19 and 14 , 78 mm and height 7.40±0.94 mm, between 5.56 and 9.37 mm, available online at Chagas et al. (2016b). The bivalve *D. striatus* had a total length of 21.19±2.71 mm, ranging from 10.60 to 27.73 mm, width of 17.55±1.81 mm, between 9.72 and 21.49 mm and height of 12.68±1.37 mm, ranging from 6.48 to 13.74 mm, available online at Chagas et al. (2016a).

In the observations of the locomotion trails of *N. marochensis*, the greatest amount was found during the night. Such paths were always arranged in the mesolitroral region. This is due to the gastropod's need to bury itself in the sand during the low tide period, otherwise it would make it difficult to enter the sediment, which would cause a greater energy expenditure.

A total of 37 locomotion trails were found along the entire length of the beach, however a total of 39 *N. marochiensis*, that is, in two paths, more than one gastropod was found. This occurred during the night and the additional gastropod probably must have “carried” its prey in the previous tide cycle.

The locomotion trails were 1.84 ± 1.45 m long, ranging from 0.2 to 6 m. In addition, it should be noted that there is no correlation between the total length of *N. marochiensis* and its respective locomotion trail left on the beach (Fig. 3). The length of the trail can be associated with the time of encounter with the prey. Of this, an expressive number of paths was observed in the regions furthest from the tourist area, probably due to the trampling of sand by bathers who frequent the beach. It is noteworthy that all gastropods found were foraging the bivalve *D. striatus.*

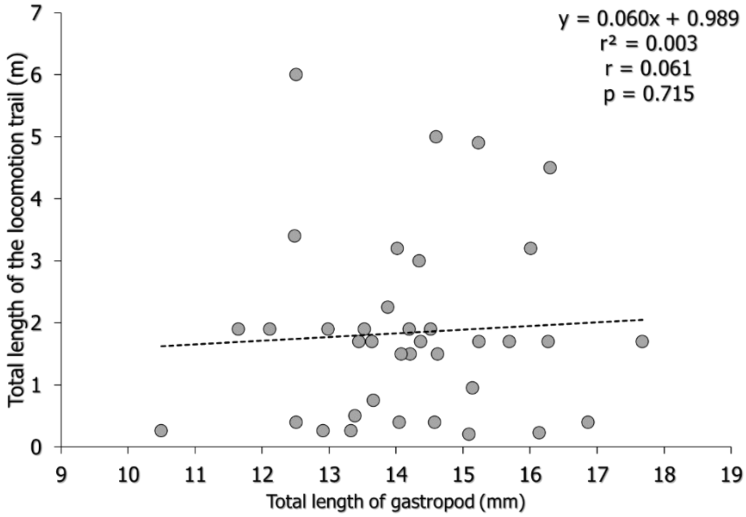

Figure 3 – Total length ratio of the gastropod *Natica marochiensis* and the length of the trail left on the sand at Ajuruteua beach.

The speed at which the gastropod *N. marochiensis* moves is an important data to verify, for example, how long it takes the predator to search for its prey, as well as to move with it until it buries. Given the importance of knowledge about predator locomotion, the speed of this gastropod is being documented in the literature. The average gastropod displacement speed is 33 mm.s-1, with no significant differences in locomotion speed in relation to the gastropod length (Fig. 4).

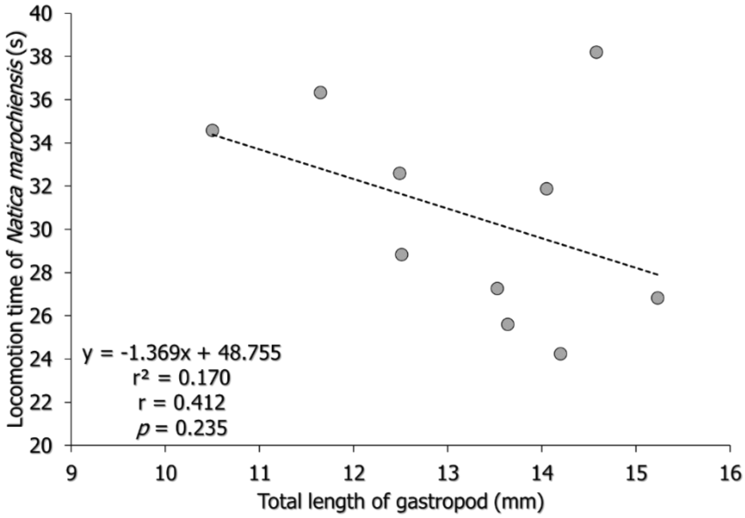

Figure 4 – Relationship between the total length of the gastropod *Natica marochiensis* and its locomotion time.

Through the observations in the two experiments, it was found that gastropods travel towards the prey when they receive some stimulus, that is, when they perceive the bivalve moving in the sand, as this way the energy expenditure in search of food is possibly lower. The perception of prey *by N. marochiensis* is due to the characteristic odor of the locomotion trails of *D. striatus* or to the vibrations during the movement of the bivalves in the sediment.

In this study, there was no evidence of predator drilling on bivalves, both in experiments and in locu observations. However, there was an expressive number of perforated valves along the entire length of Ajuruteua beach. The type of death seen in the experiments was due to suffocation, in this case, gastropods encompass their prey with their mantle, for a certain time until the animal's death. Through the observations made in the experiments, it was verified that there is no preference of gastropods for prey size. Thus, that is, there is no prior choice but meetings through the aforementioned stimuli

The result of the analysis of the relationship between the total length of gastropod *N. marochiensis* and bivalve *D. striatus* indicates a weak positive but significant correlation (p = 0.035) (Figure 5). This weak correlation stems from the fact that large gastropods forage both small and large bivalves. Thus, the hypothesis that predatory gastropods prey on only small bivalves is refuted. However, it was observed in situ that a small *N. marochiensis* forages *D. striatus* with greater body structure, but “hypothetically” by natural instinct it ends up despising the prey since the energy expenditure during the foraging would not be compensatory.

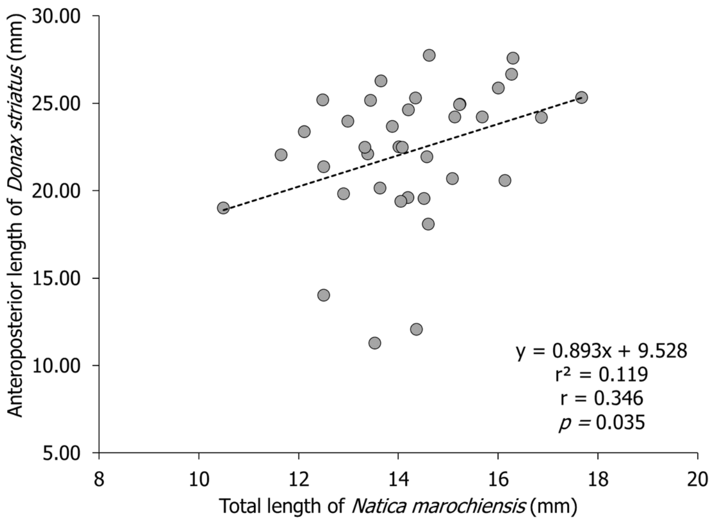

Figure 5 – Total length ratio of the gastropod *Natica marochiensis* and the bivalve *Donax striatus*.

Naticid predation occurs during low tides, and it may take several tidal cycles to deal with prey. In addition, during the night the frequency of predation is much higher due to low temperatures and during the day it can be reduced according to the increasing risks of desiccation due to overheating and predation of birds (HUGHES, 1985; HENCKES; CUNHA, 2007).

The greater presence of predators foraging at night, found in this study was also verified by Henckes e Cunha (2007). These authors also comment on the disposition of gastropods in the mesolittoral zone due to the ease of grounding in the substrate, thus reducing energy expenditure. Henckes e Cunha (2007) mention that each path is characteristic of the movement of individuals of *N. marochiensis*, therefore the presence of two gastropods foraging inside the sediment may occur, but only the path of the gastropod most recently buried in the sediment is clear.

As verified in this study, Hughes (1985) mentions that naticid gastropods go to the bivalves due to stimuli, either by vibrations in the sediment or by the sharp smell of gastropods of the genus *Natica*, capable of detecting their prey at a distance of 5 cm, mainly due to the characteristic smell of locomotion of the bivalves left on the trail.

In this study, there was no evidence of drilling by predators on the bivalves, both in experiments and in locu observations, but there was an expressive number of valves spread over the extension of Ajuruteua beach. It is worth mentioning that drilling is characteristic evidence of the predation of these marine gastropods (ANSELL, 1960; CARRIKER, 1981; BERRY, 1982; RUPPERT; BARNES, 1996; CHAGAS et al., 2020). According to KOWALEWSKI (2002), the identity and efficiency of predators, behaviors as stereotypical for the position of the holes and size of prey, food preference and its morphology can be well understood from the perforation. Mallick et al. (2014) mentions that predation by perforation of naticid gastropods is ubiquitous in the fossil record since the Cretaceous and well documented in the literature that indicate a considerable variation in the spatial and temporal distribution in perforation of naticids, both on bivalves and gastropods.

The type of death seen in the experiments was due to suffocation. In this case, gastropods encompass their prey with their mantle, for a certain time until the animal's death. This type of manipulation is highly questioned in the literature, since the bivalves can stay for a long time with their valves closed. However, this alternative manipulation can be a change aimed at lower energy expenditure during consumption, spending as little energy as possible on handling (MACARTHUR; PIANKA, 1966), given the availability of resources and the ability of the prey to avoid predation (RICKLEFS, 1996).

Through the observations made in the experiments, it was found that there is no preference for size, that is, the choice is made through eventualities. It was noted that a small *N. marochiensis* forage *D. striatus* with greater body structure, but hypothetically by natural instinct it ends up despising the prey since the energy expenditure during the foraging would not be compensatory. Segundo Berg e Nishenko (1975), predatory marine gastropods there is a determination in choosing their prey by size, that is, small gastropods prey only on small bivalves while large gastropods prey on both large and small bivalves. Thus, for the same type of prey, predators tend to select them by the sizes in which the energy return is more favorable. (KREBS; DAVIES, 1996; BEGON et al., 2007). Drilling predators often show the preferred size of prey that can be explained from the cost-benefit analysis (KITCHELL et al., 1981; CAMPBELL, 1987; CHATTOPADHYAY; BAUMILLER, 2009)

The results of this study confront the hypothesis that the choice of prey is mainly determined by size (BERG; NISHENKO, 1975). Additionally, it considers the positions on the possible cost-benefit ratio to be valid, but there is a need for more specific works on the subject, in order to verify and describe the energy compensation (KREBS; DAVIES, 1996). That is, how does this interaction between the energy expenditure in handling the prey and the energy obtained with the consumption of the prey.

Conclusion

Studies on biological interactions are important because it allows us to understand and describe, for example, the processes arising from the determining factors for choosing a prey by its predator. These studies can be used to verify the impact of the presence of one organism on the other, thus enabling mitigating actions.

In this study, it was found that the gastropods *N. marochiensis*, predators of *D. striatus* bivalves from Ajuruteua beach, have characteristics regarding predatory behavior, very similar to what is reported in previous literature. We approach a descriptive analysis of the action and behavior of these gastropods, bringing information that does not exist in the literature, such as the verification of the locomotion speed of these organisms, before the capture of their prey.

It was not verified in this study the presence of holes in the bivalves consumed in the experiment, however, an expressive number was found along the extension of the beach, of bivalve valves drilled totally or partially. Therefore, indicate that there is predation by perforation on *D. striatus*, however in the in situ experiment, there was no evidence of perforation, and all bivalves were consumed after the act of suffocation applied by gastropods.

We also bring to the discussion about the cost-benefit ratio practiced naturally by gastropod predators of bivalves. this is something to be evaluated because there was a low correlation taking into account the choice by size among the individuals found with their prey. Thus, we report that small individuals consuming a bivalve of larger proportions.

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