v. 2, n. 7, 2022

International Journal of Biological and Natural Sciences

INFLUENCE OF THE RAIN PERIOD ON THE DISTRIBUTION AND BIOECOLOGY OF BOLACHA-DA-PRAIA *Mellita quinquiesperforata* (LESKE, 1778ON A TROPICAL SANDY BEACH

Camila Chaves Silva
Universidade Federal do Maranhão- UFMA, Departamento de Oceanografia e Limnologia- DEOLI
São Luís, Maranhão, Brasil.
http://lattes.cnpq.br/7746169818978704

Flávia Rebelo Mochel
Universidade Federal do Maranhão- UFMA, Departamento de Oceanografia e Limnologia- DEOLI
São Luís, Maranhão, Brasil.
ORCID 0000-0001-5911-3171

James Werllen de Jesus Azevedo
Universidade Federal do Maranhão- UFMA, (Department of Oceanography and Limnology) - DEOLI
São Luís, Maranhão, Brazil.
ORCID 0000-0002-7034-4592

Abstract: The beach cookie Mellita quinquiesperforata (LESKE, 1778) occurs on the beaches of the State of Maranhão and was analyzed in the rainy season, for four consecutive years, in six collections between the months of December to May, on a sandy beach of Araçagi, municipality of São José de Ribamar. Five profiles were established perpendicular to the coastline with three collection points in each, in a total of 15 collection points. The profiles were located in three bands, according to the distances from the lowest syzygy tide line. The beach area covered by the profiles was 3,000 m², arranged 100 meters long by 30 meters wide. The results showed that, where M. quinquiesperforata was found, the sediment consisted of fine sand, with moderately selected grains. A total of 483 individuals were sampled at 15 collection points. No significant differences were found that could establish patterns in the distribution of animals between different heights and tidal ranges, indicating that they were all in the lower mesolittoral, in the same sediment facies. The average density found for the species was 5.36 ind/m². In periods of greater or lesser rainfall, significant differences ($p < 0.001$) were observed for abundance, density, body size and salinity. The average density (for all profiles) in the period of intense rainfall was 1.28 ind/m² and in the period of lower rainfall it was 9.44 indv/m² as for the size of the endoskeleton, there was a significant variation between the periods of high rainfall and low rainfall. rain, and most of the chicks and juveniles were found in the period when it rained little. The rains indicated to be a determining factor for the population structure of M. quinquiesperforata.

Keywords: Irregular hedgehogs, Echinoidea, environmental sciences, coastal ecosystems, Maranhão.

INTRODUCTION

The species Mellita quinquiesperforata (LESKE, 1778), known as bolacha-da-praia, is an irregular, exclusively marine, armless echinoid, with short spines on the flattened carapace, used in locomotion to replace the tube feet (BRUSCA and BRUSCA, 2006).). It inhabits sandy substrates from the low tide zone to a depth of 180 m and is found from the Gulf of Mexico to Brazil and is distributed in the West Indies (PERRY and LARSEN, 2004). According to Salsman and Tolbert (1965), M. quinquiesperforata is nocturnal, traveling 1 cm to the seafloor every 10 minutes, reducing its activity during the dawn and during the morning, when the entire community is again inactivated. In addition, the species tends to be faster during the action of more turbulent waves. On several sandy beaches, M. quinquiesperforata is a more frequent echinoid, its appearance is dependent on the time of year and its greatest abundance is in the surf zone (MARTINS, 2003).

Sandy beaches are coastal ecosystems formed by sedimentary depositional processes that accumulate grains and particles of pebbles, sand, gravel and shells, on low surfaces of the coast, from the surf band to the upper limit (supralittoral) near the dunes. (CORREIA and SOVIERZOSKI, 2005). This ecosystem has an important biodiversity of taxonomic groups, which make up the macrofauna, meiofauna and microfauna. Among the representatives of the macrofauna, Cnidaria, Annelids, Mollusca, Crustacea, Echinodermata and Hemichordata stand out (BROWN & MCLACHLAN, 1990). Beach benthic macrofauna includes epifauna and infauna (or endofauna) organisms. The beach wafer, M. quinquiesperforata, belongs to the infauna, as it is among those organisms that excavate or are buried in the sediment (WEIHE AND GRAY, 1968). Beach cookies

are important bioindicators of the ecological quality of beaches (LAITANO et al., 2008), as well as being of great importance in estuarine and marine food chains (ROSELLON-DRUKER et al., 2019).

The communities of organisms adapted to the sandy beach environment are subject to extreme environmental conditions, constituted by physical and chemical gradients, such as wave hydrodynamics, variations in temperature, salinity, and biological ones, such as competition and predation (BROWN and MCLACHLAN, 1990; SALDANHA, 2003). In a context in which discussions about the transformations of the coastal zone caused by human action, especially related to climate change and sea level rise (IPCC, 2022), are increasingly emerging, it is necessary to seek to understand the relationships between populations of benthic animals and their environments.

The beach cookie M. quinquiesperforata occurs on the sandy beaches of the State of Maranhão, which is characterized by a macro-tidal regime, climate influenced by the Intertropical Convergence Zone (ITCZ) and other relevant factors that increase the importance of knowing this species and the parameters that influence its bioecology, its population dynamics, etc. The present study seeks to contribute to the understanding of the influence of the rainy season on the bioecology and distribution of M. quinquiesperforata on a sandy beach in the coastal zone of Maranhão.

MATERIAL AND METHODS

STUDY AREA

The study area was located in Praia do Araçagi, municipality of São José de Ribamar, northwest of São Luís Island (Figure 1), at geographic coordinates 02° 26'56" – 2º27' 56" S and 44° 10' 55" – 44º 11' 00" W, next to São Marcos Bay.

Figure 1: Study area at Praia do Araçagi, Golfão Maranhense, Ilha de São Luís, Maranhão., Brazil.

Source: the authors, based on IBGE, (Google Earth and Wikipedia: o Estado do Maranhão.

Praia do Araçagi is located on São Luís Island, State of Maranhão, at coordinates **2°27›56.98»S** and 44°11'53.88"W and is bathed by the estuarine waters of Golfão Maranhense. The climate of the region is tropical, hot and humid, with an average rainfall of 2,000 mm, with a dry period from July to December and a rainy period from January to June (INMET, 2015; NIMER, 1989). The macro-tidal regime is semidiurnal, with heights up to 6.8 meters at high tides and -0.5 at low tides (DHN, 2022)

The sampling area corresponded to a strip of beach 100m long by 30m wide, totaling 3,000 m². In this area, 3 strips were delimited, with Strip 1 located in the strip of sand parallel to the waterline, at the lowest level of the syzygy tide; Track 3 in the furthest portion, situated on the lowest tidal line of quadrature; and Track 2, located between tracks 1 and 3 (Figure 2). In these strips, five profiles perpendicular to the coastline were established (profile A; profile B; profile C; profile D and profile E), each profile with 3 points, totaling 15 collection points (Figure 2). The points were georeferenced with a Garmin GPS.

At each collection point, a 1 m² square was used and the organisms were obtained with the aid of shovels. Morphometry was

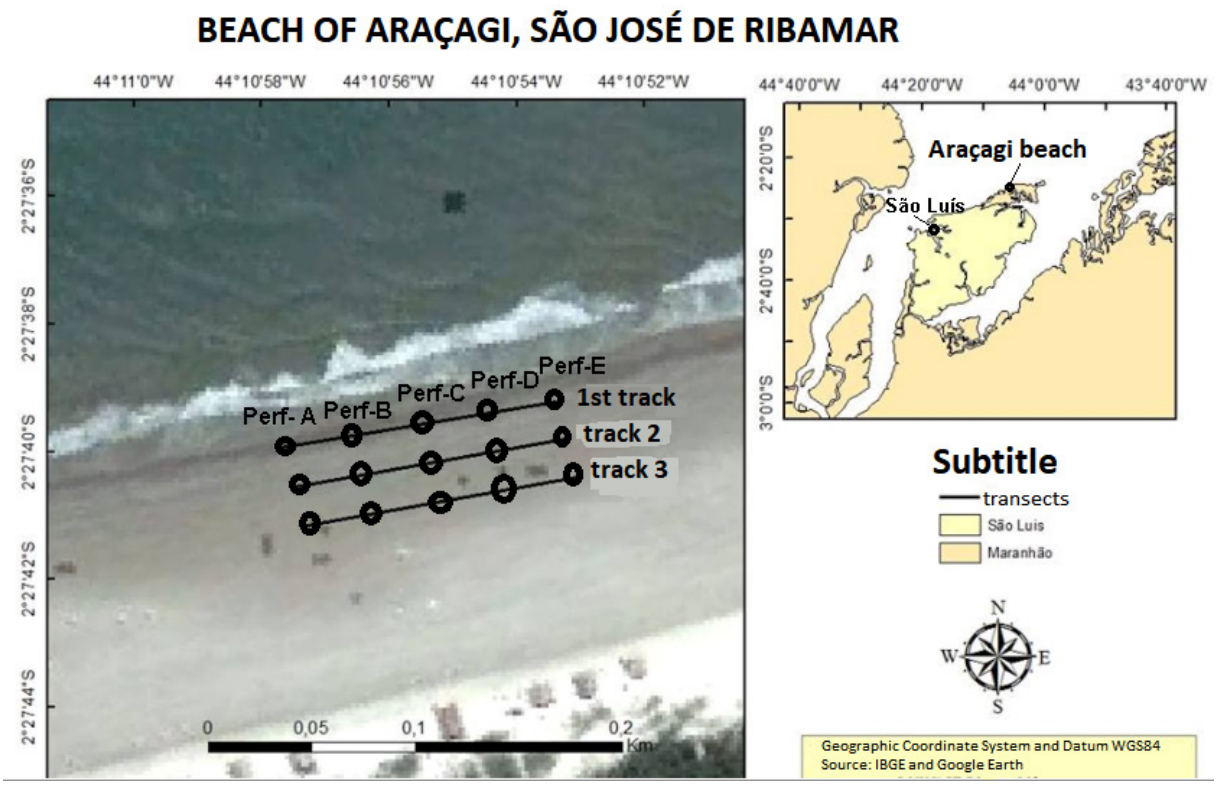

Figure 2: Tracks, profiles and collection points on Araçagi beach, São José de Ribamar.

Source: the authors, from IBGE and Google Earth.

measured directly in the field, with a caliper, for each individual removed from the sediment. In addition to morphometry, the number of live individuals at each collection point and other observations were carried out, handling the animals with care and returning them to the environment soon after the analysis. All measurements were calculated along with other information regarding the environmental conditions of each collection. The species M. quinquiesperforata has five lunulas on the upper surface of the disc: two arranged parallel and three lower, where the central lunula is the largest of all, a typical characteristic of the species (BORZONE, 1992; TAVARES, 1996; RIBEIRO-COSTAE and ROCHA, 2002).

The morphometric variables considered were length and width of the body, and the length and width of the smallest lunula, according to RUPERT and BARNES (1996). For endoskeleton measurements (full body) width was considered (horizontal diameter) and the length (vertical diameter) being the size of the skeleton given by the formula in BORZONE, 1992: (0,5 x [length + width])

The different sizes found were divided into 4 classes, establishing an interval of 1.148 cm for each class, considering juveniles up to 4.196 cm in endoskeleton size and adults from 4.196 cm, based on the work of PRAZERES (2008).

The collections were carried out in the rainy season (FEITOSA, 1989), between December 2010 and January 2013 (Dec./10, Mar./11, Apr./11, May./11, Mar./12 and Jan./12 13), during syzygy tides, with a maximum height of 0.80 m and a minimum height of -0.40 m according to the DHN Tide Table (2013). The salinity of the collection

points was obtained in the field with a Quimis ® refractometer or analyzed in the laboratory when it was not possible to be analyzed during the collection. The sediment was analyzed for granulometry, moisture content and organic matter in all collections. For granulometric analysis, the samples were sieved, according to Folk and Ward (1957), and the SYSGRAN program was used, following the textural classification of Shepard (1964). For the moisture content of the sediment and the organic matter content, the samples were analyzed according to Brower and Zar (1977), with drying in an oven at 60º and subsequent calcination in a "muffle" oven at 550º, for twenty-four hours. The data referring to rainfall were taken from the BDMEP – Meteorological Database for Teaching and Research. From these data, the Accumulated Rainfall (PP) of the 30 days preceding each collection was calculated.

The data referring to the population of beach cookies were analyzed such as abundance and density of individuals, body measurements (morphometry), and relationships with abiotic factors such as salinity, rainfall, granulometry, through correlation matrix, similarity analysis, principal components, canonical correspondence analysis, correlation analyses, ANOVA tests, Tukey. For the application of tests and statistical analysis, the programs PAST and PRIMER were used (HAMMIR, *et. al.,* 2003)

RESULTS AND DISCUSSION

Within the rainy period analyzed (December to May) in the four years of study, the rainfall varied so that two periods were configured: a period with less rainfall, ranging between 0.80 mm and 238.1 mm, in which the rainfall average was 85.03 mm, and another period with intense rainfall, ranging from 430.9 mm to 621.7 mm, in which the average rainfall was 503.33 mm. The values recorded for rainfall were:, Dec.16.20mm; jan. 0.80mm; sea. 238.1; Mar.457.40 mm; Apr. 430.90 mm; May 621.70 mm These variations significantly influenced the abundance, density and size of *M. quinquiesperforata* in this study and the relationship with salinity. The collections of March, April and May presented the lowest values for salinity, with the lowest record of 27 for the month of May, and April presented 29.5. The highest values of salinity were recorded in the months of December and January, with the highest record of 48 for the month of January, and the month of December presented the value of 41. In all the collections carried out at Araçagi beach, the fine sand was predominant in 83.5% of the grains (76 samples) and very fine sand completed 16.45% of the grains (15 samples). The size of the sand grains ranged from 3.18 to 2.63, all being moderately selected. The fine sand is one of the main features of Araçagi beach (MOCHEL et al., 1997; CUTRIM, 1987; MOREIRA and RODRIGUES, 1992) and the preferred habitat of the species. *M. quinquiesperforata* (TAVARES e BORZONE, 1998). The results for water moisture in the sediments ranged from 19.32% to 21.78% and for the organic matter content ranged from 0.82% to 0.97%. in all collections. Organic matter was not very variable during the research. They also showed no significant differences. The distribution of animals in different tidal ranges was analyzed. Range 1, closer to the sea line, had a total of 172 individuals, range 2, with the largest number of animals, totaling 189 individuals, and range 3, with a total of 122 individuals. No significant differences were found that could establish patterns in the distribution of animals between different heights, profiles and tidal ranges, in agreement with studies by Maia and Cavalcante (2005). indicating that all were in the lower mesolittoral.

Diniz et al. (2021) analyzed the population of M. *quinquiesperforata* on different beaches on the Island of Maranhão and found that Praia do Araçagi has the highest abundances of this species because it is a less impacted place with high hydrodynamics. In the present study, the relationship between the abundance of individuals and salinity was significant (Tukey p= 0.5218) and the correlation matrix with the salinity data and the abundance of individuals shows that the abundance of the species grows as the salinity increases (Figure 3).

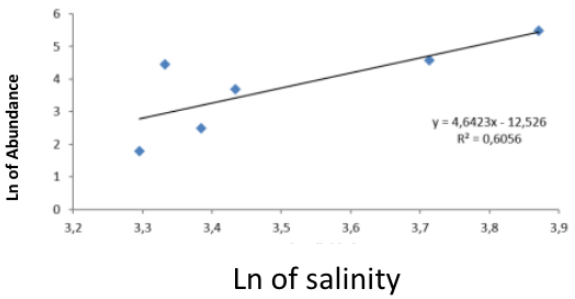

Figure 3 Correlation matrix between salinity and abundance of beach biscuit individuals *Mellita quinquiesperforata* at *Praia do Araçagi, Maranhão.*

In the rainy season, three collections were organized in the period of more intense rains (March, April, and May), and three collections in the period of less precipitation (December and January). In the period of lower precipitation (average rainfall of 85.03 mm) 425 animals were found, representing an average abundance of 141.16 individuals, about 88% of the sample. In the period of intense rains (average rainfall of 503.33 mm) 58 animals were found, which represents an average abundance of 19.33 individuals, about 12% of the sample (Figure 4).

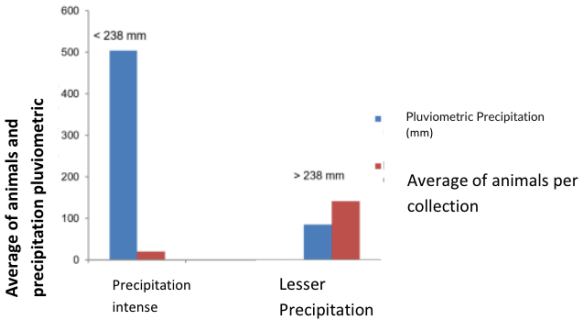

Figure 4 Relationship between Mean abundance of beach wafer individuals *Mellita quinquiesperforata* and the average rainfall in the rainy season: intense precipitation (Mar, Apr., May), less precipitation (December and January.) on Araçagi beach, Maranhão.

The wettest months (periods of intense precipitation), which presented the least abundance of *M. quinquiesperforata* (months of april and may) showed a greater tendency to similarity, showing that the abundance of individuals in these months was similar to each other, except in March, which appeared more similar to the period with less rainfall. This fact can be explained by the possible occurrence of the reproductive season of individuals who discharge their female gametes usually at the beginning of the rainy season (TAVARES and BORZONE, 1998; DIAS, 2008) (Figure 5).

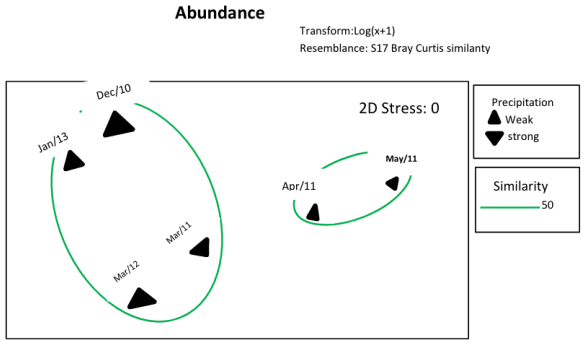

Figure 5. Similarity between the abundance of *Mellita quinquiesperforata* and different periods of rainfall in all collections, on Araçagi beach, Maranhão. Strong: period of more intense rains; Weak: period of lower rainfall.

The results of the principal component analysis (PCA) corroborate the other analyzes performed in this study. Figure 6 shows that granulometry, humidity and tidal height do not influence the abundance of *M. quinquiesperforata*. On the other hand, it is observed that salinity is related to abundance so that the lower the salinity, the smaller the number of individuals, and vice versa (Figure 6).

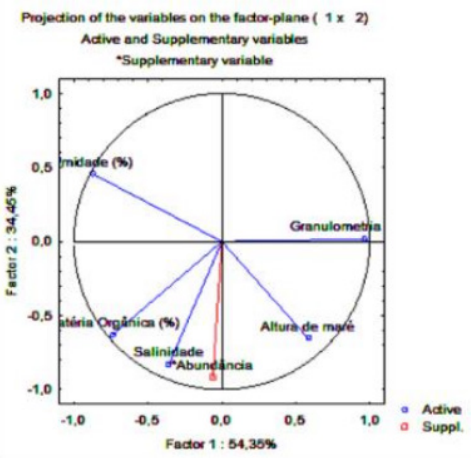

Figure 6: Principal Component Analysis between the abundance of *Mellita quinquiesperforata* and the environmental variables salinity, granulometry, water humidity, organic matter and tidal height.

The total average density of individuals from *M. quinquiesperforata* obtained in all collections was 5.366 ind./m². The highest average density was 16.20 ind./m² and occurred in January, with the lowest rainfall of 0.80 mm. The lowest average density was 0.40 ind./m² and occurred in May with the highest rainfall, of 621.7 mm, and, in the same year, the month of April also stands out, with an average density of 0.80 ind./m² and rainfall of 430.9 mm. In relation to the variation of density in terms of rainfall (intense and low), a higher ratio of animals was observed in the rainy season, totaling 425 individuals, while in the period of lower rainfall only 58 individuals were found (Figure 7).

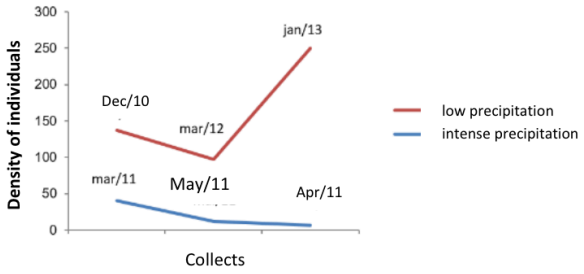

Figure 7. Relationship between individuals of *Mellita quinquiesperforata* in different rainfall in the rainy season at Araçagi beach, Maranhão.

Considering the average density of *M. quinquiesperforata* with the variation of salinity, the highest average densities were found in the highest salinities, while the lowest densities occurred in the lowest salinities The highest average density of individuals, 16.2 ind./m², was recorded in the highest salinity of the water (48), in January, and the month of December also stands out, with an average density of 6.46 ind./m² and water salinity of 41. The lowest average density, of 0.4 ind./m², occurred in the salinity of 27, in May, and the month of April also stands out, with an average density of 0.8 ind./m² and water salinity of 29.5. In studies in Ceará, Martins (2003) also found periodic variations in the density of *M. quinquiesperforata that could be attributed to environmental variations, such as rain, which directly interfered with the salinity of marine waters.*

The results for measurements of endoskeleton width and length and smallest lunula width and length. They are shown in Table 2. The variations found for the lunula measurements were not significant, therefore, the age of the organisms was inferred based on the diameter (width) of the endoskeleton (Table 2).

The width of the endoskeleton was greater than its length in all animals collected, in agreement with other authors (BORZONE,

Body Size (cm)	dec/10	mar/11	apr./11	May /11	mar/12	jan./13
Body width	5,0 - 2,0	5,9 - 3,0	5,4 - 2,0	5,4 - 2,7	6,7 - 3,2	5,4 - 1,9
Body Length	4,6 - 1,9	4,9 - 2,8	4,7 - 1,8	4,6 - 2,5	5,7 - 2,9	4,7 - 1,8
Lunula width	0,3 - 0,1	0,3 - 0,1	0,2 - 0,1	0,3 - 0,2	0,3 - 0,2	0,2 - 0,1
lunula length	0,7 - 0,1	0,9 - 0,4	0,8 - 0,1	0,9 - 0,4	1,2 - 0,6	1,2 - 0,2

Table 2: Variations in measurements of the size of the endoskeleton and the smallest lunula of individuals of *Mellita quinquiesperforata* analyzed at Araçagi beach, Maranhão.

1992; DIAS, 2008). The division into size classes was based on the largest and smallest amplitudes of endoskeletons (LANE and LAWRENCE, 1980). Based on this size difference, in the present study, four size classes were elaborated with an interval of 1.148 cm between them. Thus, the results for the size classes, indicative of the age/development of the animals, in ascending order were: 1st Class - young individuals (1.90 – 3.048); 2nd class - juvenile individuals (3,048 – 4,196); 3rd class young-adult individuals (4,196 – 5,344); 4th class – adult individuals (5,344 – 6,492).

Considering the total of 483 analyzed individuals, class 1, represented by young individuals, presented 14.29% of the total samples, class 2, of juveniles, made up 52.38% of the samples, class 3, of young-adults, showed 31.68% and class 4, adult individuals, showed 1.66% of the analyzed samples.

It was observed the influence of the rainy season on the distribution of the size classes of the individuals of *M. quinquiesperforata*. The result for the period of lower precipitation, including the 1st and 2nd classes together, which represent the young and juvenile individuals, represented 72% of the total number of animals analyzed. However, in the period of intense precipitation, these two size classes, together, added up to 27.58% (Figures 8 and 9).

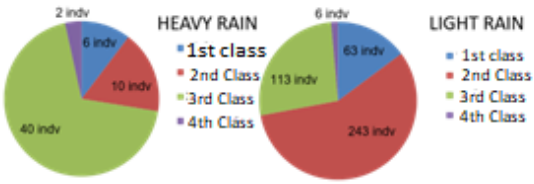

Figure 8: Abundance of beach cookie size classes in the Light Rain period (Dec.to Jan.: 0.8 mm to 238.01 mm) and Heavy Rain (Mar. to May: 430.9 mm to 621.7 mm)

In the rainy season, in the collections carried out in the period in which the precipitation was lower, the accumulated average was 85.03 mm, the size distribution was: 1st class - young individuals 14.82%; 2nd class - juvenile individuals 57.17%; 3rd class - young-adult individuals 26.58%; 4th class adult individuals 1.41% (Figure 9). In the collections carried out in the period of intense precipitation, accumulated average of 503.33 mm, the majority, 68.96%, fell into the 3rd class of young-adult individuals and only 10.34% in class 1 of young individuals. The other sizes found were: 2nd class juvenile individuals 17.24%, and 4th class adult individuals, 3.44%. (Figure 9).

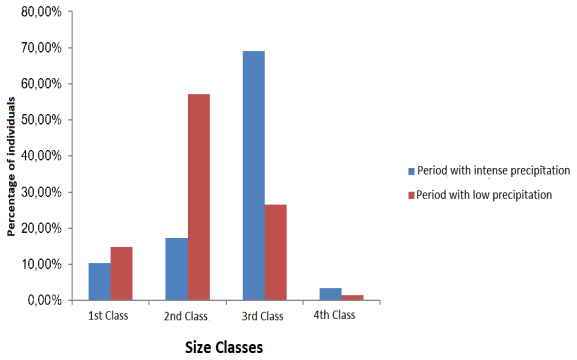

Figure 9: Percentages of individual size classes in relation to rainfall periods at Araçagi beach, Maranhão.

Some authors have shown that, during the rainy season, populations of *M. quinquiesperforata* developed a recess of reproductive activity (DIAS, 2008 TAVARES and BORZONE, 1998). Tavares and Borzone (1998) found that this species spawns between February and March on beaches along the southern coast of Brazil, coinciding with the end of the period of lighter rainfall on Araçagi beach, in Maranhão. Furthermore, these authors point out that *M. quinquiesperforata* presents an annual reprodutive cycle, with high mortality rates.

The result for the Canonical Correspondence Analysis (ACC) showed that salinity influences the size classes 1 and 2, therefore the young and juvenile individuals, while the rainfall influences the size class 3, young-adult individuals. The ACC did not show a relationship between adult individuals of size class 4 and the analyzed variables of salinity and rainfall (Figure 10). According to Meril and Hobson (1970) the distribution by age group in *Dendraster excentricus occurs* with more abundant juveniles near the coast, moving to the bottom with age, which would explain the class of adults less related to factors that affect more exposed organisms. Borzone (1992;1993) found recruitment (pups and juveniles) of *M. quinquiesperforata* on a Rio Grande beach extending to points further away from the waterline, this fact leaves them more exposed to variations in rainfall and salinity.

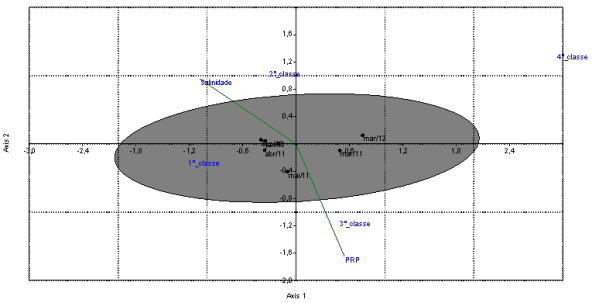

Figure 10. Results for Canonical Correspondence Analysis Relationship between the environmental variables salinity and rainfall with the different size classes and abundance of individuals.

In addition to natural stressors such as excessive rainfall and reduced salinity on the beach cookies at Praia do Araçagi, there is also vehicle traffic on the sand, causing compaction and a decrease in sediment permeability. Studies carried out by Button et al, 2019, on the compaction and permeability of sediments at depths of 0 to 45 cm in Praia do Araçagi Beach showed that compartments located in the slatted area subjected to vehicle traffic were approximately 6 times more compacted than areas without traffic, and the permeability in Praia do Araçagi decreased in the area where the passage of vehicles was greater.

CONCLUSION

The influence of rainfall on the abundance and average density of *M. quinquiesperforata,* so that in the period of more intense rains the abundance and the average density of individuals were significantly lower than in the period of low rainfall. The size of individuals also showed significant variation between periods of heavy and low rainfall, with most young individuals being found in the period when it rained less. No significant

differences were found that could establish patterns in the distribution of animals between different heights and tidal ranges, between profiles and between collection points, indicating that all were found in the mid-littoral, in the same facies of fine sandy sediments, moderately selected. The rains indicated to be a determining factor for the structure of the population of *M. quinquiesperforata*.

THANKS

To CNPq/PIBIC for the granting of a research grant, to DEOLI/UFMA for the support in the infrastructure, to the Geological Studies Laboratory-LEOG for the support in the granulometric analysis, to the team of the Mangrove Laboratory-LAMA/ CERMANGUE for the support in the field activities and in laboratory analysis.

REFERENCES

BORZONE, C. A. Spatial distribution and growth of *Mellita quinquiesperforata* (Leske, 1778) on a sandy beach of Southern Brazil. **Neritica,** v. 7, n. 1-2, p. 87-100, 1992/93.

BORZONE, C. A. Spatial distribution and growth of *Mellita quinquiesperforata* (Leske, 1778) on a sandy beach of southern Brazil.***Nerítica,*** *7*: 87-100, 1993

BOTÃO, J.C., FRANCO, B.J., PEREIRA, D.M, LEITE, J.S.S. ALBUQUERQUE,S.S, MELO,T.S. PEREIRA,V.V, e LIMA,L.G. Compactação de praias arenosas: efeitos de espigões costeiros e tráfego de veículos, Ilha do Maranhão- Brasil. *In*: **Gerenciamento costeiro e gerenciamento portuário 2**. (Org.F.R.Mochel). Cap. 1, v. 2, p.1-12, Ponta Grossa, PR: Atena Editora, 2019.

BROWER, J. E.; ZAR, J. H. Field and laboratory methods for general ecology.WN. C Brown Company Publishers, Iowa, 194p. 1977.

BROWN, A.C.& MCLACHLAN, A. Ecology of Sandy Shores.Elsevier, Amsterdam, Holland, 1990.

BDMEP. **Banco de Dados Meteorológicos para Ensino e Pesquisa,** 1961. Disponível em: http://www.inmet.gov.br/projetos/rede/pesquisa/. Acesso em: 05 jun. 2014.

BRUSCA, R.C.; BRUSCA, G.J. **Invertebrados**. 2ed. Editora Guanabara Koogan, 2006. 1098p.

CORREIA, M. D.; SOVIERZOSKI, H. H. Ecossistemas marinhos: recifes, praias e manguezais / Mônica Dorigo Correia, Hilda Helena Sovierzoski. – Maceió: EDUFAL, 2005.55p: il. – (Conversando sobre ciências em Alagoas).

CUTRIM, M. V. J. Algas Marinhas bentônicas e aspectos ambientais – Praia do Araçagi, município do Paço do Lumiar. Monografia de conclusão do curso de Ciências Biológicas da Universidade Federal do Maranhão.

DHN. Diretoria de Hidrologia e Navegação da Marinha do Brasil, 1946. Disponível em: https://www1.mar.mil.br/dhn/?q=node/79. Acesso em: outubro de 2022.

DIAS, I.C.C.M Biologia populacional de *Mellita quinquiesperforata* Leske (1778) (ECHINODERMATA: CLYPEASTEROIDA: MELLITIDAE) na praia da Taíba, Ceará, Brasil. Dissertação Mestrado) - Universidade Federal do Ceará, Instituto de Ciências do Mar, Fortaleza, 2008

DINIZ A.L.C; FURTADO J.A., FRANÇA, A.P.; BEZERRA, N.P.C.; FIGUEIREDO, M.B. Distribuição populacional de Mellita quinquiesperforata (Echnodermata:ehinoidea) em diferentes praias do Litoral Maranhense, Brasil. Ciência e Tecnologia do Pescado: Uma Análise Pluralista - Volume 2. Cap.6, 87-98, 2021

FEITOSA, A.C., 1989. Evolução Morfogenética do Litoral Norte da Ilha do Maranhão. Rio Claro, UNESP: 210p.Dissertação de Mestrado.

FOLK. & WARD, W.C. 1957. Brazos River Bar: Study and significance of grain size parameters. **Journal Sedimentary Petrology,** 27(1):03-26.

HAMMIR, O.; HARPER, D. A. T. & RYAN, P. D. Past.Paleontological Statistics SoftwarecPackege for Education and Data Analysis.Paleontologia Electronica 4(1):9p. 2003.

INMET (Instituto Nacional de Meteorologia). Disponivel em <http://www.inmet.gov.br/portal/>. Acesso em outubro de 2022.

IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

LANE, J.E.M.; LAWRENCE, J.M. Seasonal variation in body growth, density and distribution of a population of sand dollars, *Mellita quinquiesperforata* (Leske). Bull. Mar. Sci.,v. 30, n.4, p.871-882, 1980.

LAITANO, K. S., GONÇALVES, C. & RESGALLA C. JR. Viabilidade do Uso da Bolacha-do-mar *Mellita quinquiesperforata* como organismo Teste J. Braz. Soc. Ecotoxicol., v. 3, n. 1, 2008, 9-14

MARTINS, I. X. 2003. Fauna cearense de substrato inconsolidado. Projeto de Convervação e Utilização Sustentável da Diversidade Biológica Brasileira. Fortaleza. Disponível em: http://.sbpcnet.org.br/livro/57ra/programas/CONF_SIMP/textos/inesmartins.htm. Acesso 13 julho, 2014.

MCLACHLAN, A. Sandy beach ecology – a review.In. Sandy beaches as ecossistems. Mclachlan, A. e Erasmus, T. (eds.) Pot Elizabeth South Africa: The Hague, Dr. W. Junk Publ. p. 321 – 380. 1983.

MOCHEL F.R 1997. Mangroves on São Luís Island, Maranhão Brazil. In: KJERFVE B, LACERDA LD & DIOP EHS (Ed.). Mangrove ecosystem studies in Latin America and Africa; UNESCO, Paris, 145-154.

NIMER, E. **Climatologia do Brasil**. 2. ED. Rio de Janeiro: Fundação IBGE, 421p. 1989.

PRAZERES, F. N. Aspectos Bioecológicos da população de *Mellita quinquiesperforata* (LESKE, 1778) na praia do Araçagi, São José de Ribamar. MA/Fabiana do Nascimento Prazeres. – São Luís, 2008. 61f.

PERRY, T. O.; LARSEN, K. **Guide to shelf invertebrates, Golf of Mexico**. Didponível em: http://www.gsmfc.org/seamap/picture_guide/Echinoderms/mellita%20quiquiesperforata.pdf. Acesso em: 07 dez, 2014.

RIBEIRO-COSTA, C.S., ROCHA, R.M. **Invertebrados:** manual de aulas práticas. Ribeirão Preto: Holos, 2002.

ROSELLON-DRUKER, J.; STOKESBURY, K.D.E. Quantification of echinoderms (Echinodermata) on Georges Bank, and the potential influence of marine protected areas on these populations. **Invertebrate Biology**. 2019;138:e12243.

SALDANHA, L. Fauna Submarina Atlântica. Portugal Continental, Açores e Madeira. 4.ª Edição. Publicações Europa-América, Lda. Portugal. 2003.

TAVARES, Y. A. Ecologia Populacional de *Mellita quinquiesperforata* Leske, 1778 (Echinodermata: Echinoidea: Clyperasteroida) em diferentes praias do litoral do Paraná, Brasil. 1996. 95 f.

TAVARES, Y. A. G. & BORZONE, C. A., 1998, General features ofpopulation dynamics of the sand dollar *Mellita quinquiesperforata* (Leske, 1778) in southern Brazilian sandy beaches. In: Mooi & Telford(eds.), **Echinoderms**: San Francisco. Balkema, Rotterdam, pp. 837-842

SALSMAN, G. G.; TOLBERT, H. W. Observations on the Sand Dollar, *Mellita quinquiesperforata.***Limnology and Oceanography**, v.10, p. 553-560. 1965.

SHEPARD, R. N. The analysis of proximities: Multidimensional scaling with na unknown distance function. **Psychometrika,** 27:125-139, 1964.

WEIHE, S C., GRAY, I. E. Observations on the biology of the sand dollar *Mellita quinquiesperforata.***J. Elisha. Mitchell Sei. Soc.,** v. 84, p. 315-327, 1968.