MONITORING AND ANALYSIS OF THE SEASONAL VARIABILITY OF THE EPIFAUNA OF THE PHYLUM MOLLUSCA ASSOCIATED WITH THE PHYTAL OF THE TIDAL POOLS OF THE SANDSTONE REEF OF PIEDADE BEACH (PE)

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ABSTRACT

The malacofauna associated with the phytal ecosystem of the coastal reef of Piedade beach, Jaboatão dos Guararapes, PE, was studied. The phytal is a biocenosis with its own characteristics and the algae is the substrate that serves as a home, shelter and/or food for the associated fauna. Tide pools were selected at three collection points on the coastal reef that were sampled every two months during the period from August 2022 to June 2023. The collections carried out in October 2022, December 2022 and February 2023 were considered dry period; the collections carried out in August 2022, April 2023 and June 2023 of the rainy season. In the laboratory, the fronds were washed, filtered in a sieve with a 500 µm mesh mesh, the retained animals were fixed with 5% saline formaldehyde, later identified and quantified under a stereoscopic microscope. The environmental parameters water temperature, air temperature and relative humidity showed little variation between the dry and rainy periods. The wind speed had values with significant variation, with a maximum of 21.95 m/s in October 2022 and a minimum of 1.6 m/s in February and April 2023. Rainfall values varied significantly between the months of the dry season and those of the rainy season, with a maximum value of 481.95mm in June 2023 and a minimum of 42.6mm in December. A total of 3038 individuals were collected, totaling 38 species collected, representing 21 families of Gastropoda. It was considered a typical species in the study area: Eulithidium affine because it had a higher frequency of occurrence.

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Regarding seasonality, there was equity between the two seasons; The dry period presented species richness, with 31 species recorded. The rainy season presented the richness of species, with the occurrence of 29 species. It was concluded that there is no significant seasonal variation in the occurrence of species considered constant, with occurrence of E. affine throughout the year and other species considered constant. The low diversity, when compared to previous studies in the area, indicates a trend of impact on biocenosis.

Keywords: Phytal. Malacofauna. Coastal Reefs.

INTRODUCTION

The phytal is a habitat of the marine environment that serves as a home, shelter and food for the fauna and flora related to it (MASUNARI, 1981). The term 'fital' - from the Greek *phyton*, plant, was proposed to designate a division of the marine environment, such as the pelagic and the benthic environment, based on the fact that plant growths condition a fauna of its own, constant and independent of the substrate (FRIEDRICH, 1964). Vieira *et al*. (2018), states that macroalgae from the intertidal region are among the most abundant and diverse secondary substrates on rocky beaches.

Three-dimensional complexity can create microhabitats that protect epifaunal organisms from predators, wave action, and desiccation; as well as retain sediments, which can favor deposit-feeding species.

Epifauna is the fauna formed by groups of benthic animals, as in the case of mollusks. These species are adaptable and can even survive on other animal, plant as well as rocky or sedimentary substrate surfaces that are present in the sediment either in lakes or in the sea (VERAS, 2011).

The study of the population biology of mollusks has been growing in recent decades, given the ecological and economic importance of the group, especially bivalves. Mollusks, because they are in many cases relatively large and have most of the internal space of their shells filled with meat, contribute a large part of the biomass of the places where they live. This fact led mollusks to become targets for consumption, as food, by other mollusks, by other animals, vertebrates or invertebrates and, of course, by man (AMARAL *et al*., 2011).

In Brazil, research on mollusk populations focuses on four main themes, being (1) those of interest for the cultivation of edible species, (2) those that focus on the impact of fishing/extraction on these resources, (3) those that seek to understand the beach environment and its dynamics, and (4) those that focus on the impact of pollution on these organisms (AMARAL *et al*., 2011).

Urban coastal areas are under constant environmental impact, whether due to liquid or solid waste, tourist activity, trampling, urbanization, etc. One of the serious environmental problems of coastal areas is that resulting from oil spills, which has been well documented on rocky beaches (CLARK *et al*., 1992), which have a great faunal diversity, considered the greatest in the intertidal environment (COUTINHO, 1995), being of paramount importance in the ecological niches of several species of marine invertebrates and in the productivity of the coastal zone.

In terms of the consequences for the biodiversity of the beaches, the greatest is the impact resulting from urbanization: buildings, paving, sidewalks, beach fattening and other urban interventions, due to the absence of past data that can be compared with the situation verified after the intervention, the consequences will only be evaluated when the situation becomes irreversible or difficult to mitigate.

Piedade beach is considered an area subject to environmental impacts, the most recent of which are the oil spill that affected the coast of Pernambuco in 2019 and the construction of the pavement on the supra coast, between 2021 and 2022, which caused important disturbances such as earthworks and the inclusion of exogenous terrigenous material to the area, for the grounding of the beach strip on the supra coast.

The studies carried out in Piedade by LABMAR are focused on the reef area, aiming, for example, to monitor the bleaching of the coral *Siderastrea stellata*, and the variability and zonation of benthic organisms that resulted in a panel of the biodiversity of the area. Despite its importance for the metropolitan region of Recife, few studies have been carried out in the reef area of Piedade, many carried out at LABMAR; in addition to several TCC's, communications in congresses and Scientific Initiation projects, we can mention the articles: Guimarães and Luz *et al*. (2011); Guimaraens *et al*. (2011); Guimaraens and Macedo *et al*. (2012); Guimaraens *et al*. (2015); Guimaraens and Souza (2018).

Since reef areas are of high importance with regard to ecosystem services, there is a need to develop studies regarding the environmental impacts on the biodiversity of the coastal region of Pernambuco, as this is a factor that can harm the health of the reefs. In addition, due to easy access by the population, this area of the reef presents degradation of physical space and trampling during low tide. Thus, an evaluative study regarding the relationship between environmental parameters and mollusk biodiversity on the reef is necessary to ascertain which factors are responsible for the monthly variation of biodiversity, as well as the diversity of species that occur on Piedade beach (PE).

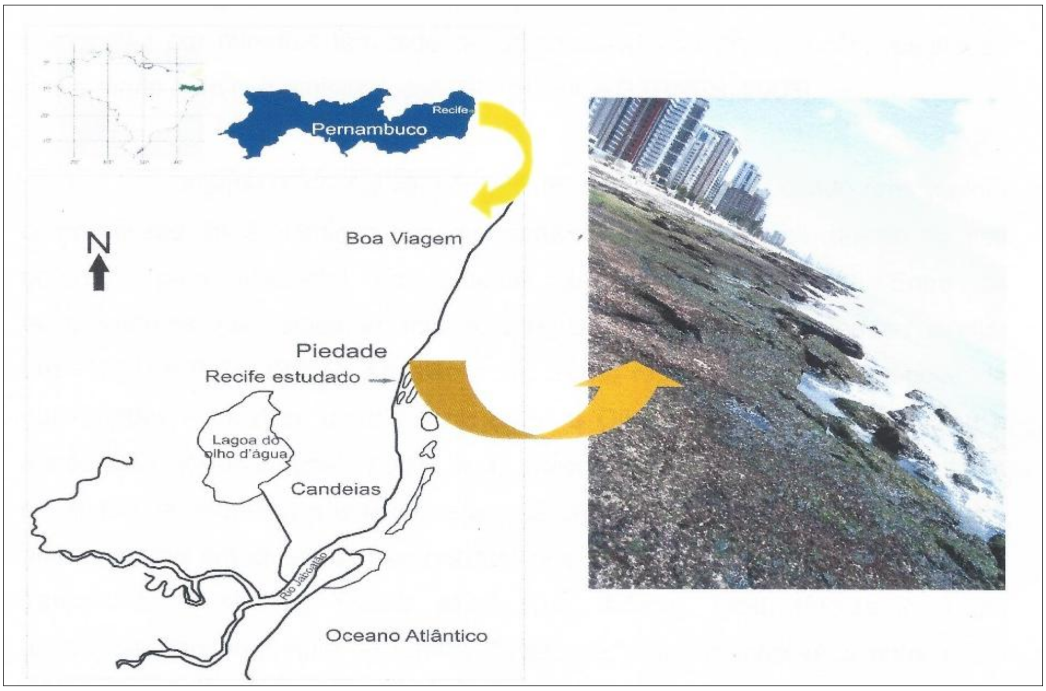
METHODOLOGY

The study was carried out at Piedade Beach, Jaboatão dos Guararapes, PE, in a reef area composed of limestone sandstone with tidal pools that shelter macroalgae and malacofauna. Three collection stations were defined, sampled between October 2022 and June 2023, in dry and rainy periods, during low tide. Environmental parameters such as salinity, temperature, humidity and winds were recorded, and biodiversity was documented with underwater photographs. In the laboratory, the fronds were washed to remove the epifauna, with the mollusks fixed in 70% alcohol, identified and counted under a microscope. The density of the organisms was calculated based on the volume of the fronds, and indices of diversity, dominance and evenness were determined using specific software. The species were classified according to frequency of occurrence and density, characterizing the ecological composition of the area.

2.1 DESCRIPTION OF THE AREA

Piedade Beach, in Jaboatão dos Guararapes (PE), is located in the south of the metropolitan region of Recife, between the parallels 08º09'17" and 08º11'19" south latitude, with 5.6 km of extension (Figure 1), hot and humid Atlantic tropical climate (As', in the Köppen system) and average temperature of 26 °C. It has two well-defined seasons: dry, from September to February, with precipitation below 100 mm, and rainy, from March to August, above 100 mm. The coastal strip includes beaches of quartz-limestone sediments and sandstone reefs that outcrop at low tide, forming basins and tide pools, where macroalgae and associated malacofauna predominate. The reefs oblique to the coast act as natural dikes, configuring habitat for benthic organisms such as *Brachidontes*, *Cirripedia* and macroalgae, distributed in horizontal strips.

Figure 1 – Map of the area of Praia de Piedade, municipality of Jaboatão dos Guararapes (PE) emphasizing the reef area studied.

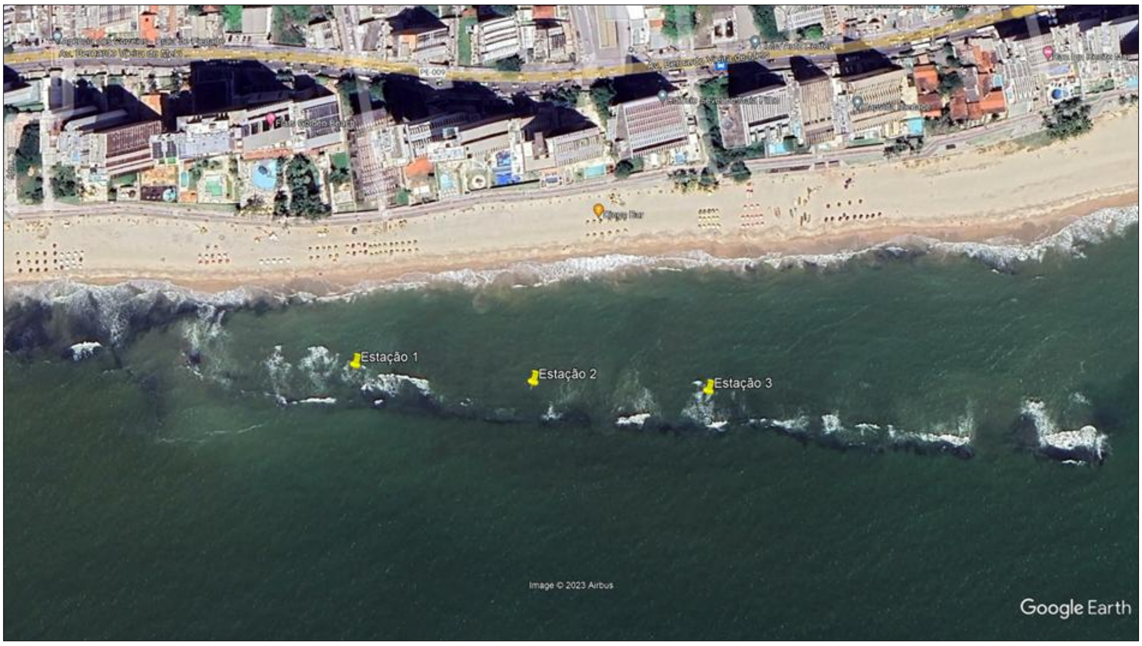


Source: Adapted from Souza and Cocentino (2004).

FIELD METHODOLOGY

The tidal pools on the upper surface of the reef, with an average depth of 30 cm, were sampled at three stations (E1, E2 and E3) located on the coastal reef of Piedade, between October 2022 and June 2023 (Figure 2), covering dry and rainy periods. The collections, carried out during daytime low tide, included underwater photographic records and environmental measurements, such as salinity, water temperature, wind direction and speed, luminosity, air temperature and humidity, using equipment such as refractometer and THAL-300. Rainfall data were obtained from APAC. The sampling used squares of 25 cm x 25 cm for delimitation, scraping of fronds with appressoria and fixation in 4% saline formaldehyde, following protocols by Jacobucci and Leite (2002), Silva (2018) and Vieira *et al*. (2018).

Figure 2 – Location of the three collection points in the reef area at Piedade Beach (PE)



Source: Google Earth (2023).

LABORATORY METHODOLOGY

At the Marine Biology Laboratory (ICB/UPE), each frond was washed separately in buckets with fresh water and stirred to detach the epifauna, filtered in 500 µm sieves and fixed in 70% alcohol. Screening was performed under a stereoscopic microscope, separating and storing the malacofauna in 70% alcohol, while other organisms were preserved and deposited in the laboratory. Empty shells or shells occupied by paguros were discarded. The mollusk species were photographed to compose a future illustrated catalog. The volume of the algae samples was determined by the displacement of water in a test tube, allowing the density of the organisms to be calculated in relation to the volume of the fronds collected.

STATISTICAL ANALYSIS

The Shannon-Wiener diversity index (H'), Simpson dominance index (1-D) and Equitability index (J) were calculated for the collection seasons and months using the

ECOLOGIA software. The frequency of occurrence, species abundance and density in frond volumes (individuals per ml³) were also analyzed using Excel®. The frequency of occurrence classified the species as constant (F ≥ 50%), common (50% > F ≥ 10%) or rare (F < 10%). Density was standardized as the number of organisms per 1000 ml of seaweed volume. Specific diversity, assessed by the Shannon index (H), was interpreted in four categories, from very low (H < 1.0) to high (H > 3.0). Equitability, on the other hand, indicated uniformity in the distribution of individuals, with values higher than 0.5 considered equitable, increasing diversity when close to 1.

RESULTS

ENVIRONMENTAL PARAMETERS

The following environmental parameters were recorded: determination of the salinity content of the water by the refractometer method, water temperature with a digital thermometer of the skewer type and wind speed and direction, luminosity, air temperature and relative humidity with a portable instrument THAL-300, manufactured by Instrutherm (SP). It is observed that the values of the abiotic factors recorded in the tidal pools, due to the small scale of surface area and depth, are conditioned to events such as precipitation and insolation that affect the reef area during the low tide period (Table 1).

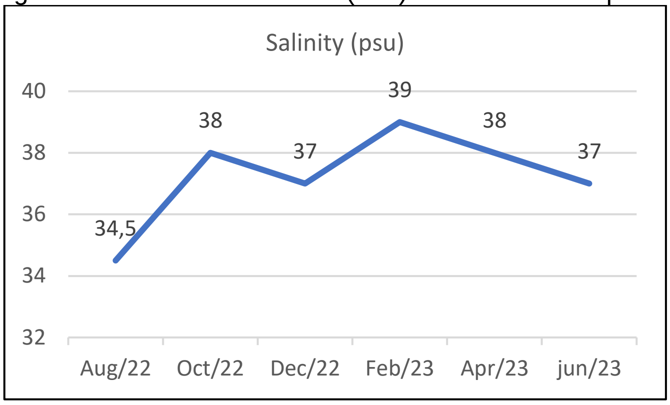
Table 1 - Hydrological and meteorological parameters of Piedade beach (PE) during the collection period.

Month	Rainfall (MM)	Water Salinity (PSU)	Water Temperature (°C)	Air Temperature (°C)	Air Humidity (%)	Air Velocity (M/S)
August/2022	184,85	**34,5**	28,5	30,5	70,3	11,6
October/2022	52,55	38,0	29,5	31,0	70,5	**21,95**
December/2022	**42,6**	37,0	31,0	34,0	**65,4**	18,2
February/2023	234,4	**39,0**	29,0	**38,8**	67,6	**1,6**
April/2023	253,7	38,0	**31,5**	29,5	75,8	**1,6**
June/2023	**481,95**	37,0	**28,0**	**25,9**	**83,8**	7,13

Rainfall (mm)

Rainfall indices varied considerably, according to the Pernambuco Water and Climate Agency (APAC), during the collection period. The month of June/2023 was the one that recorded the highest precipitation index (with total precipitation estimated at 481.95 mm) and October/2022 the lowest index, with 52.55 mm total (Table 1; Figure 3).

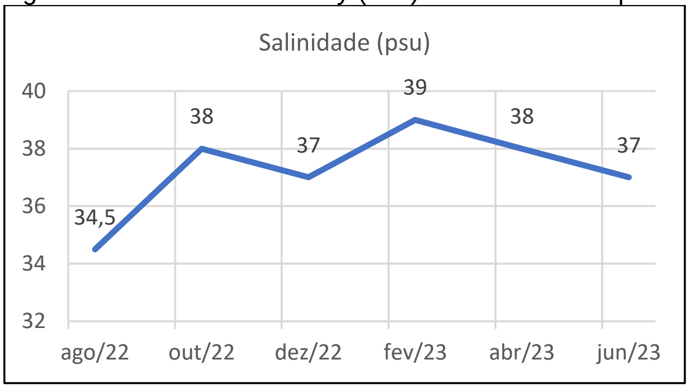
Figure 3 – Variation in rainfall (mm) in the collection period



Source: Apac

Water Salinity (PSU)

Figure 4 – Variation in salinity (mm) in the collection period



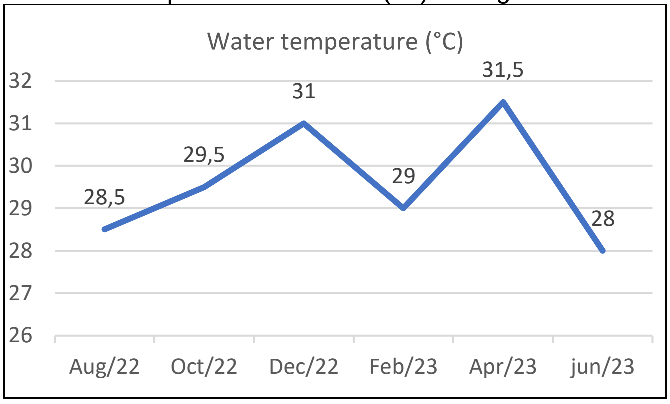
Source: The authors.

The average salinity of the water in the tidal pools was 37.2 psu; with a minimum value of 34.5 psu and a maximum of 39 psu, in the months of August/2022 and February/2023, respectively (Table 1; Figure 4).

Water Temperature (°C)

Analyzing in the general context, the water temperature in the tidal pools was quite uniform during the period studied, with an average water temperature of 29.5 °C, with a minimum of 28 °C in June 2023 and a maximum of 31.5 °C in April 2023 (Table 1; Figure 5).

Figure 5 – Water temperature variation (°C) during the collection period

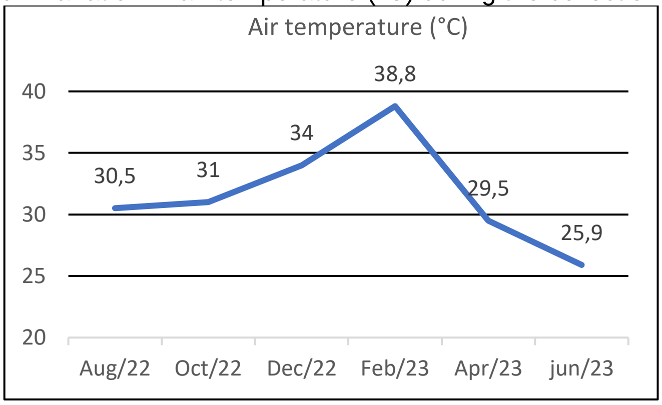


Source: The authors.

Air Temperature (°C)

The air temperature, measured at the time of collection, presented an average of 31.62 °C. The highest temperature recorded was during the dry season in February 2023 (38.8 °C) and the lowest during the rainy season in June 2023 (25.9 °C) (Table 1; Figure 6).

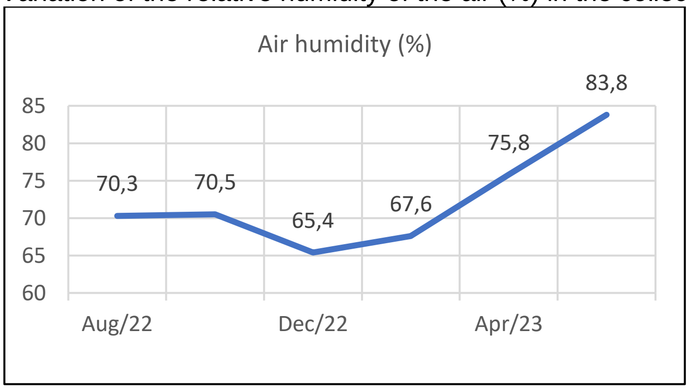
Figure 6 - Variation in air temperature (°C) during the collection period.



Source: The authors.

Relative humidity (Ura)

Figure 7 – Variation of the relative humidity of the air (%) in the collection period.



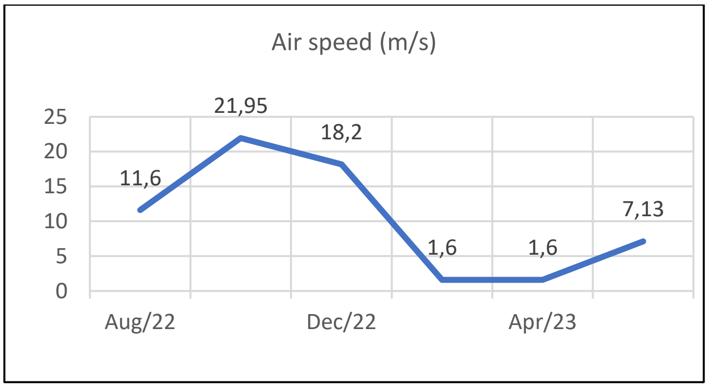
Source: The authors.

The values recorded for IVR at the time of collection showed significant variations between the dry and rainy seasons. The highest IVR was recorded in June 2023 (83.8) and the lowest in December 2022 (65.4) (Table 1; Figure 7).

Air velocity (m/s)

The recorded values of air velocity at the time of collection did not show significant variations between the dry and rainy seasons. The highest speed was recorded in October/22 (21.95 m/s) and the lowest in February and April/2023 (1.6 m/s) (Table 1; figure 8).

Figure 8 - Variation in air velocity (m/s) in the collection period.



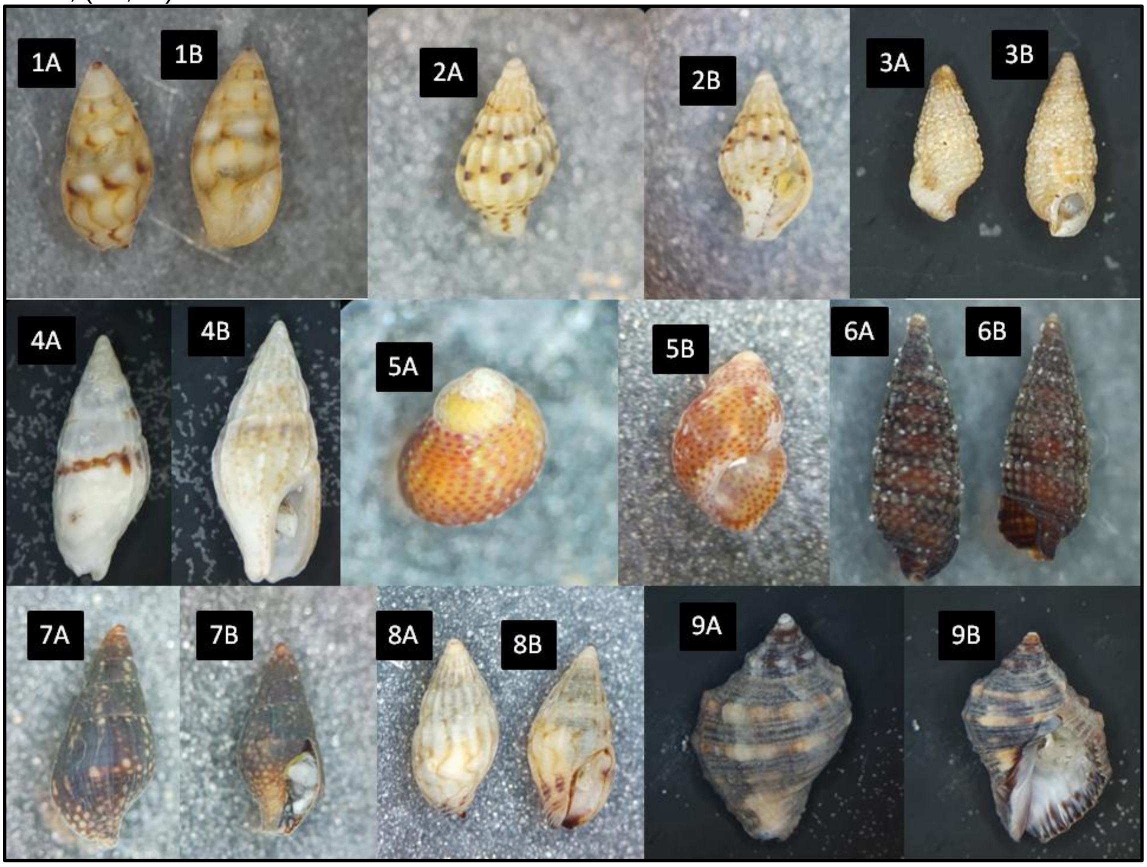
Source: The authors.

Faunal composition

A total of 3038 individuals of the class Gastropoda (1997 and 1041 in the dry season and rainy season respectively) were collected in three seasons associated with macroalgae in the tidal pools of the coastal sandstone reefs. These individuals belong to 21 families, 28 genera and 38 species (Table 2).

The families with the highest number of species were *Columbellidae* (07 species), meaning 18.42% of the total species; *Cerithiidae* (04 species) meaning 10.42% of the total and *Muricidae* and *Triphoridae* with three species, each meaning 7.89% of the total species. On the other hand, the families least represented in the samples were *Fissurellidae* and *Phasianellidae* (02 species each) and the others with one species each: *Pyramidellidae*, *Calliostomatidae*, *Littorinidae*, *Pisaniidae*, *Epitoniidae*, *Scaliolidae*, *Haminoeidae*, *Terebridae*, *Mitrellidae*, *Olividae*, *Fasciolariidae*, *Mangelidae*, *Zebinidae*, *Naticidae* (Figure 9).

Figure 9 - Some of the species of Gastropoda found in the macroalgae studied at Piedade beach (PE): (1A,1B) *Anachis lunata*; (2A,2B) *Anachis lyrata*; (3A, 3B) *Bittiolum varium*; (4A,4B) *Costoanachis sertuliarum*; (5A,5B) *Eulithidium affine*; (6A,6B) *Marshallora nigrocincta*; (7A,7B) *Mitrella ocellata*; (8A,8B) *Obese Parvanachis*; (9A,9B) *Stramonita rustica*



Source: The authors.

Table 2 – Taxonomic list of Gastropoda species associated with macroalgae studied at Piedade Beach (PE).

Family	Species
Calliostomatidae	*Calliostoma adspersum*
Cerithiidae	*Bittiolum varium* *Cerithium atratum* *Cerithium lividulum* *Cerithium vulgatum*
Columbellidae	*Anachis isabellei* *Anachis lyrata* *Astyris lunata* *Columbella mercatoria* *Costoanachis catenata* *Costoanachis sertulariarum* *Obese Parvanachis*
Epitoniidae	*Epitonium novangliae*
Fasciolariidae	*Pustulatirus virginensis*
Fissurellidae	*Fissurella clenchi* *Fissurella rosea*
Haminoeidae	*Haminoea petitii*
Littorinidae	*Echinolittorina lineolata*

Mangeliidae	*Pyrgocythara cinctella*
Mitrella ocellata	*Mitrella ocellata*
Muricidae	*Acanthinucella spirata* *Stramonite haemastoma* *Stramonita rustica*
Naticidae	*Stigmaulax cayennensis*
Olividae	*Olivella minutes*
Phasianellidae	*Eulithidium affine* *Eulithidium bellum*
Pisaniidae	*Engina turbinella*
Pyramidellidae	*Boonea jadisi*
Scaliolidae	*Finella dubia*
Tegulidae	*Agathistoma fasciatum* *Agathistoma hotessierianum* *Agathistoma viridulum*
Terebridae	*Hastula cinerea*
Triphoridae	*Marshallora nigrocincta* *Tryphora oreda* *Triphora pulchella*
Zebinidae	*Schwartziella catesbyana*

The most abundant group identified was *Phasianellidae*, with a total of 1402 individuals, representing 42.35% of the total collected, being almost exclusively composed of *Eulithidium affine* (N=1401). The second most abundant group was *Columbellidae* (N=952, 28.77%), dominated by *Parvanachis obesa* (N=796). Thirdly, the *Mitrellidae* (N=340, 10.27%) were represented exclusively by *Mitrella ocellata*.

Seasonal Analysis

The seasonal variation of abundance showed a greater number of individuals in the dry season (N=1997) distributed in 30 species, while the rainy season presented N=1041 individuals of 27 species. There was no significant variation in the relative abundance of the dominant species between the dry and rainy periods, with *Eulithidium affine*, *Parvanachis obesa* and *Mitrella ocellata* being the most representative in both (Table 3).

Table 3 – Taxonomic list of Gastropoda species associated with macroalgae studied at Piedade Beach (PE) and their occurrence in the dry and rainy seasons.

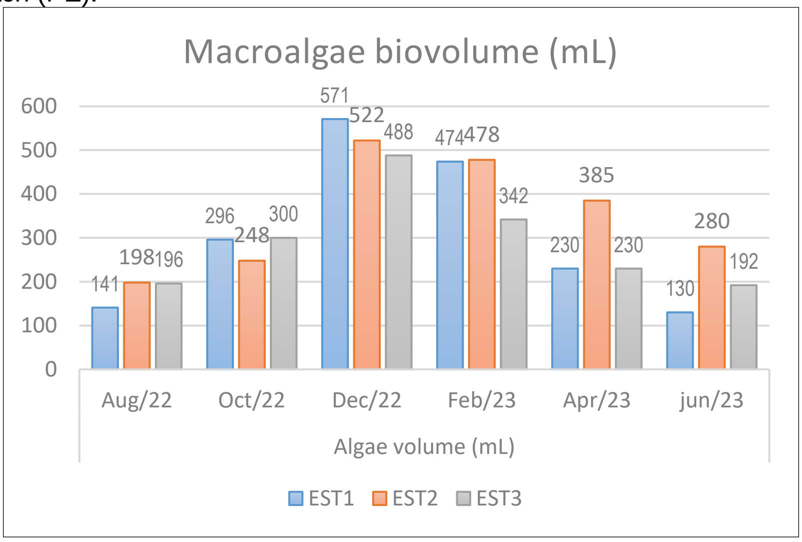
Species	Quantitative of Individuals	
	Dry Period	Rainy Season
Acanthinucella spirata	0	3
Agathistoma fasciatum	2	4
Agathistoma hotessierianum	1	0
Agathistoma viridulum	5	5
Anachis isabellei	9	0
Anachis lyrata	40	13
Astyris lunata	17	23
Bittiolum varium	17	62
Boonea jadisi	1	0
Calliostoma adspersum	18	0
Cerithium atratum	5	1
Cerithium lividulum	1	0
Cerithium vulgatum	10	6
Columbella mercatoria	0	2
Costoanachis catenata	27	5
Costoanachis sertulariarum	12	8
Echinolittorina lineolata	1	0
Engina turbinella	0	3
Epitonium novangliae	5	0
Eulithidium affine	1075	326
Eulithidium bellum	1	0
Finella dubia	0	1
Fissurella clenchi	0	1
Fissurella rosea	5	9
Haminoea petitii	0	1
Hastula cinerea	1	0
Marshallora nigrocincta	1	26
Mitrella ocellata	136	204
Olivella minutes	66	16
Obese Parvanachis	498	298
Pustulatirus virginensis	1	1
Pyrgocythara cinctella	3	0
Schwartziella catesbyana	10	12
Stigmaulax cayennensis	2	1
Stramonite haemastoma	1	0
Stramonita rustica	26	4
Tryphora oreda	0	1
Triphora pulchella	0	5

Biovolume of macroalgae

In the tidal pools, a miscellany of macroalgae were collected for fauna analysis, and all the algae in the area delimited by the square were scraped from the substrate, including its appressoria. The predominance of *Sargassum C. Agarh* (Phaeophyta division) stands out in the samples, a genus that is characterized by growing on beach rocks, in places not exposed to strong wave beatings, such as the infralittoral and tidal pools located on the reef area. The presence of epiphytic algae such as *Hypnea musciformis* (Rhodophyta) was also found, which contribute to the increase in the complexity of the algae-substrate (BELL *et al*., 1984; HALL; BELL, 1988; MILK; TURRA, 2003). Such an increase in structural complexity can affect the richness and diversity of the epifauna in the same way, diversifying the availability of microhabitats and food items to associated organisms.

The average volume of material collected was 308.38 mL, with a minimum of 178 mL in August 2023 and a maximum of 527 mL in February 2023. In station 1, the largest volume (571 mL) was collected in December 2022 and the smallest (130 mL) in June 2023. In station 2, the highest volume (522 mL) was in December 2022 and the lowest (198 mL) in August 2022. In station 3, the highest volume (488 mL) was in December 2022 and the lowest (192 mL) in June 2023. In general, it was verified that the dry period, with greater insolation in the reef area, presented the highest volumes of macroalgae in the tidal pools, when compared to the rainy season (Figure 10; Table 3).

Figure 10 – Monthly biovolume of the miscellany of macroalgae collected at stations 1, 2 and 3 in the tidal pools of Piedade beach (PE).



Seasonal density of organisms in macroalgae

Considering the seasonal seasons, the total density in each sample month was estimated (Figure 11). The dry period had the highest density value in February/23 (991.25 $^{ind.mL-1}$) and the lowest value in December/22 (208.72 $^{ind.mL-1)}$ (as well as the highest macroalgae biovolume values, 1144 mL and 1581 mL respectively) (Figure 11; Table 4).

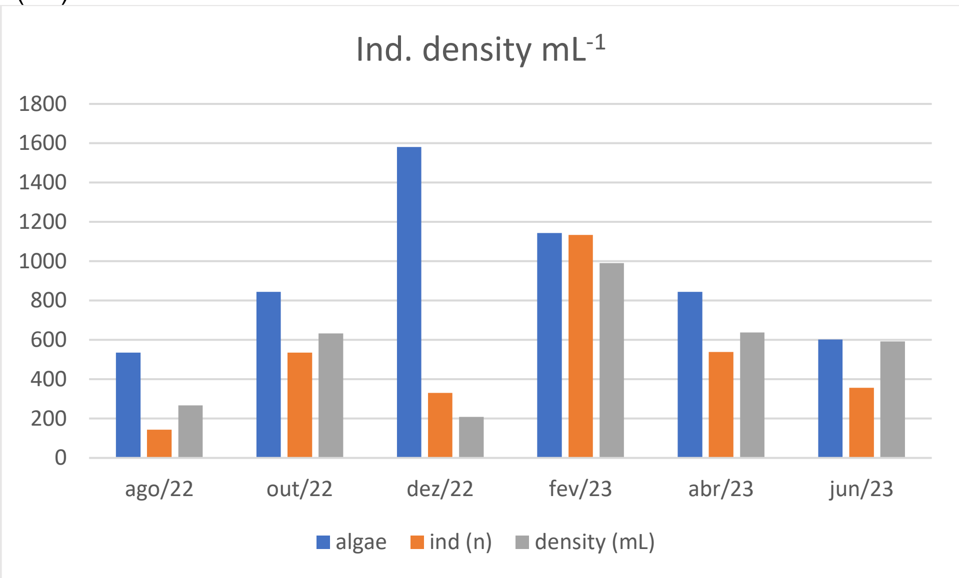
Lima (2013), studying the phytal of *Sargassum spp* in Pontal do Cupe (PE), also found that the density of Gastropoda individuals was lower in the rainy season compared to the dry season.

Table 4 – Biovolume of macroalgae in the months of collection and the corresponding density of individuals of the Phylum Mollusca.

	Algae	IND (N)	Density (mL)
Aug/22	535	143,00	267,28
Oct/22	844	535	633,88
Dec/22	1581	330	208,72

Feb/23	1144	1134	991,25
Apr/23	845	539	637,86
Jun/23	602	357	593,02

Figure 11 – Monthly density of organisms in the miscellany of macroalgae collected in the tidal pools of Piedade beach (PE).



Frequency of occurrence and biocenotic classification

Of the 38 species of Gastropoda identified, three were classified as constant in the macroalgae studied, as they occurred in more than 50% of the samples collected (F ≥ 50%); 13 species were classified as common (50% > F ≥ 10%) and 23 species were classified as rare (F < 10%).

Of the species classified as constant, *Eulithidium affine* stands out (F= 98.15%). The predominance of *E. affine* in the study area confirmed results obtained in previous studies of the Gastropoda malacofauna aiming at the end of the intertidal zone in Piedade, such as Braga (1983) and Ressurreição (1985).

Table 5 - Frequency of occurrence and biocenotic classification of species collected in tidal pools, in the dry season, of Piedade beach (PE).

Species	Oct/22	Dec/22	Feb/23	Total	Occurrences	Frequency	Classification
Acanthinucella spirata	0	0	0	0	0	0,00%	ABSENT
Agathistoma fasciatum	2	0	0	2	2	7,41%	RARE
Agathistoma hotessierianum	0	1	0	1	1	3,70%	RARE
Agathistoma viridulum	1	0	4	5	4	14,81%	COMMON
Anachis isabellei	4	0	5	9	4	14,81%	COMMON
Anachis lyrata	8	1	31	40	7	25,93%	COMMON
Astyris lunata	3	12	2	17	9	33,33%	COMMON
Bittiolum varium	4	0	13	17	8	29,63%	COMMON
Boonea jadisi	1	0	0	1	1	3,70%	RARE
Calliostoma adspersum	0	6	12	18	8	29,63%	COMMON
Cerithium atratum	1	0	4	5	2	7,41%	RARE
Cerithium lividulum	0	0	1	1	1	3,70%	RARE
Cerithium vulgatum	2	6	2	10	4	14,81%	COMMON

Columbella mercatoria	0	0	0	0	0	0,00%	ABSENT
Costoanachis catenata	2	15	10	27	9	33,33%	COMMON
Costoanachis sertulariarum	4	2	6	12	8	29,63%	COMMON
Echinolittorina lineolata	0	0	1	1	1	3,70%	RARE
Engina turbinella	0	0	0	0	0	0,00%	ABSENT
Epitonium novangliae	0	2	3	5	3	11,11%	COMMON
Eulithidium affine	456	179	440	1075	26	96,30%	CONSTANT
Eulithidium bellum	0	0	1	1	1	3,70%	RARE
Finella dubia	0	0	0	0	0	0,00%	ABSENT
Fissurella clenchi	0	0	0	0	0	0,00%	ABSENT
Fissurella rosea	3	1	1	5	4	14,81%	COMMON
Haminoea petitii	0	0	0	0	0	0,00%	ABSENT
Hastula cinerea	0	0	1	1	1	3,70%	RARE
Marshallora nigrocincta	0	0	1	1	1	3,70%	RARE
Mitrella ocellata	22	35	79	136	21	77,78%	CONSTANT
Olivella minutes	9	0	57	66	3	11,11%	COMMON
Obese Parvanachis	5	52	441	498	18	66,67%	COMMON
Pustulatirus virginensis	1	0	0	1	1	3,70%	RARE
Pyrgocythara cinctella	2	0	1	3	2	7,41%	RARE
Schwartziella catesbyana	4	2	4	10	6	22,22%	COMMON
Stigmaulax cayennensis	0	2	0	2	2	7,41%	RARE
Stramonite haemastoma	1	0	0	1	1	3,70%	RARE
Stramonita rustica	0	12	14	26	8	29,63%	COMMON
Tryphora oreda	0	0	0	0	0	0,00%	ABSENT
Triphora pulchella	0	0	0	0	0	0,00%	ABSENT

Table 6 – Frequency of occurrence of Gastropoda species associated with macroalgae, in the rainy season, at Praia de Piedade (PE).

Species	**Aug/22**	**Apr/23**	**Jun/23**	**Total**	**Occurrences**	**Frequency**	**Classification**
Acanthinucella spirata	0	3	0	3	1	3,70%	RARE
Agathistoma fasciatum	4	0	0	4	1	3,70%	RARE
Agathistoma hotessierianum	0	0	0	0	0	0,00%	ABSENT
Agathistoma viridulum	0	4	1	5	4	14,81%	COMMON
Anachis isabellei	0	0	0	0	0	0,00%	ABSENT
Anachis lyrata	1	0	12	13	6	22,22%	COMMON
Astyris lunata	0	5	18	23	4	14,81%	COMMON
Bittiolum varium	2	44	16	62	15	55,56%	COMMON
Boonea jadisi	0	0	0	0	0	0,00%	ABSENT
Calliostoma adspersum	0	0	0	0	0	0,00%	ABSENT
Cerithium atratum	1	0	0	1	1	3,70%	RARE
Cerithium lividulum	0	0	0	0	0	0,00%	ABSENT
Cerithium vulgatum	0	4	2	6	5	18,52%	COMMON
Columbella mercatoria	0	2	0	2	2	7,41%	RARE
Costoanachis catenata	0	4	1	5	4	14,81%	COMMON
Costoanachis sertulariarum	0	1	7	8	5	18,52%	COMMON
Echinolittorina lineolata	0	0	0	0	0	0,00%	ABSENT
Engina turbinella	0	3	0	3	2	7,41%	RARE
Epitonium novangliae	0	0	0	0	0	0,00%	ABSENT
Eulithidium affine	85	156	85	326	27	100,00%	CONSTANT
Eulithidium bellum	0	0	0	0	0	0,00%	ABSENT
Finella dubia	1	0	0	1	1	3,70%	RARE
Fissurella clenchi	0	0	1	1	1	3,70%	RARE
Fissurella rosea	0	4	5	9	5	18,52%	COMMON
Haminoea petitii	1	0	0	1	1	3,70%	RARE
Hastula cinerea	0	0	0	0	0	0,00%	ABSENT
Marshallora nigrocincta	1	17	8	26	11	40,74%	COMMON
Mitrella ocellata	25	89	90	204	26	96,30%	CONSTANT
Olivella minutes	0	15	1	16	6	22,22%	COMMON

Obese Parvanachis	13	181	104	298	22	81,48%	CONSTANT
Pustulatirus virginensis	0	0	1	1	1	3,70%	RARE
Pyrgocythara cinctella	0	0	0	0	0	0,00%	ABSENT
Schwartziella catesbyana	7	3	2	12	4	14,81%	COMMON
Stigmaulax cayennensis	1	0	0	1	1	3,70%	RARE
Stramonite haemastoma	0	0	0	0	0	0,00%	ABSENT
Stramonita rustica	0	1	3	4	4	14,81%	COMMON
Tryphora oreda	1	0	0	1	1	3,70%	RARE
Triphora pulchella	0	5	0	5	1	3,70%	RARE

Species, diversity and fairness

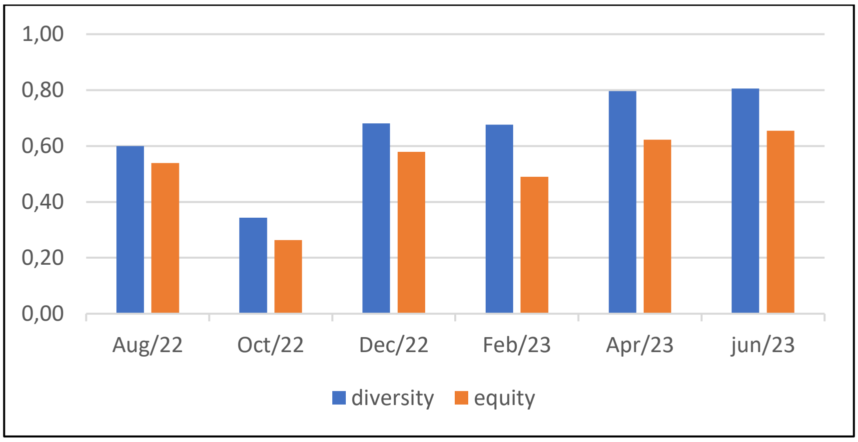
There was seasonal variation in the number of species, with a minimum of 13 in August/22 (rainy season) and a maximum of 26 in February/23 (dry season). On the other hand, when we compared the months of the rainy season and the dry period in general, we obtained a Jaccard coefficient of 0.5; representing 70.9% similarity.

The diversity of species in the study period was considered very low, when we analyzed the monthly indexes, being less than 1 bit.ind-1 in all months; ranging from a minimum of 0.343 in October/22 to a maximum of 0.806 in June/23. Diversity increases when the equitivity index presents values close to 1, that is, when the individuals present are evenly distributed among the occurring species. In the area studied, in October/22, there was a predominance in quantity of individuals of *E. affine* (456) in relation to the other species, with Shannon equitivity of 0.264; while in June/23, there was an equitable distribution of individuals among the most abundant species: *E. affine* (85), *M. nigrocincta* (90) and *O. minuta* (104), with equity of 0.655 (Table 7; Figure 12).

Table 6 – Diversity (bits.ind^{-1}) and Gastropoda Equitativity associated with algae in Piedade (PE).

	Aug/22	Oct/22	Dec/22	Feb/23	Apr/23	Jun/23
Diversity	0,60	**0,34**	0,68	0,68	0,80	**0,81**
Equestrian	0,54	0,26	0,58	0,49	0,62	0,66

Figure 12 – Diversity (bits.ind^{-1}) and Gastropoda Riding associated with algae in Piedade (PE) in the months of collection.



DISCUSSION

The analysis of the seasonal variation of the Gastropoda community in the sandstone reef of Piedade (PE) revealed patterns that corroborate previous studies carried out in the same region. Among the species analyzed, *Eulithidium affine* was consistently the most abundant, showing wide spatial distribution and significant resistance to anthropogenic actions, as highlighted by Guimaraens (2015). This author also related the abundance of the species to macroalgae biomass, salinity and temperature, with a higher incidence during the dry season. Similar results were observed in the present study, in which the dry period presented a higher number of individuals and species richness compared to the rainy season.

Silva (2008) also identified a reduction in the diversity and number of individuals in the rainy season, highlighting that 70% of the fauna recorded was composed of mollusks. Structuring factors, such as rainfall, temperature and the use of macroalgae as a secondary substrate and food resource, were pointed out as determinants for the dynamics of benthic communities. These factors were also observed in the present study, especially in the context of seasonality, which directly impacts environmental conditions and resource availability.

The temporal variation described by Luz *et al*. (2008) reinforces the predominance of *E. affine* in both the dry and rainy seasons, although with greater abundance in the former. This pattern reflects the resilience of the species in relation to variable environmental conditions, especially when associated with macroalgae. Studies such as those by Cutrim (1990) and Ribeiro (2004) have confirmed the reduction in diversity during the rainy season, highlighting the sensitivity of benthic communities to seasonal climate change.

In addition, factors such as eutrophication and anthropogenic impacts, such as trampling on reef areas, also play an important role in structuring these communities. Amaral (2009) observed that the post-disturbance growth of chlorophyceous algae is related to nutrient enrichment and human actions. However, unlike the present study, Amaral identified a near absence of pheophycea, while Souza and Cocentino (2004) indicated that these algae are typical of tropical and subtropical regions. This discrepancy can be attributed to factors such as local differences in environmental conditions and the degree of human impact.

Another relevant aspect for the composition of the benthic community is the interaction between algae and invertebrates, as described by Costa (2007). This author highlighted the intra- and interspecific competition, mainly involving encrusting bivalves and gastropods such as *Fissurellidae* and Littorinidae, which can also influence the distribution and abundance of species in the Piedade reef.

Finally, the monitoring carried out by Andrade (2022) reinforced the representativeness of *Eulithidium affine* as a typical species in the study area, being found in both seasonal seasons. Andrade also identified equitativeness between the seasons and a slight variation in species richness between the dry and rainy periods, a pattern that was also observed in the present study. In the dry season, 13 species were recorded, while in the rainy season there were 12 species.

In general, the results of this study reiterate the importance of seasonal environmental conditions, as well as biotic and abiotic interactions, in the structuring of benthic communities associated with macroalgae of the Piedade reef. These factors, added to the resilience of species such as *E. affine*, highlight the ecological complexity and the importance of conserving these environments in the face of increasing anthropogenic pressures.

CONCLUSION

It is concluded that there is no significant seasonal variation in the occurrence of species considered constant, with occurrence of *E. affine* throughout the year and other species considered constant. The low diversity, when compared to previous studies in the area, indicates a trend of impact on biocenosis.

In addition, it is important to mention that there was a significant record of three species: *E. affine, M. ocellata, P. obesa,* thus characterizing the predominance of the families *Phasianellidae*, *Mitridae* and *Columbellidae* in the present study. The gastropods *E. affine* are mostly benthic, corroborating the frequency of this taxon associated with algae. Regarding the *Mitridae*, they are found in a variety of marine environments, from sea level to great ocean depths.

Thus, this reduction in diversity verified in this study may be due to the oil spill on the coast of Pernambuco, revealing the trend of impact on the biological community, but no residues were found in the algae and in the animals analyzed.

Other impact factors such as the urbanization process, the trampling of the reef area that has intensified, can result in less algae coverage, consequently in the reduction of the substrate available for phytal organisms, verifying in the area that the fronds, although abundant, have a small size, with a predominance of algae covering the substrate.

In exposed regions, it was expected to find macrobenthic communities with little complexity, with low richness, density and diversity, as a response to the high environmental rigidity that hinders the settlement of larvae and the survival of juveniles and adults. However, Begon *et al*., (1990) mention that hydrodynamics, by removing individuals from the most abundant species, can prevent them from becoming dominant, contributing to the increase in the diversity of mobile organisms, confirming the results found in this work, where there was no variation in diversity between tide pools (exposed and protected) on reefs. Therefore, hydrodynamics modifies the structure of the algae, however, it can benefit the associated fauna. When disturbance in the environment is not rare or frequent, the diversity of species tends to increase (DIAL; ROUGHGARDEN, 1998). Norderhaug *et al*. (2014), state that the effect of hydrodynamics on fauna depends on the structure that the algae provides, such as microhabitats for the protection of animals.

The high abundance of mollusks is probably due to the feeding habit of this group, as most are scrapers and feed on the periphyton that covers the algae (PEREIRA *et al*., 2010). Mollusks can cause gaps or completely remove macroalgae from places, most of them are algae considered fleshy, this happens if grazing is intense (chitons and gastropods), depending on the interaction, they can play several roles that determine the structure of the macroalgae assemblage (SCHEIBLING, 1994).

Therefore, the continuity of monitoring is necessary to assess the environmental impact on the malacofauna associated with the Piedade phytal, Jaboatão dos Guararapes (PE).

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