Mollusks: How are they arranged in the rocky intertidal zone?

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ABSTRACT. Mollusks occupy different kinds of environments, including the intertidal zone. The present study investigated the spatial distribution of mollusks on beach rocks of the intertidal zone of Pacheco Beach in the state of Ceará, Brazil. Sampling occurred from August 2006 to September 2007. Across two transects, six samples of 0.25 m^2 were collected monthly in gaps of 30 m (0 m, 30 m, 60 m, 90 m, 120 m and 150 m). The mollusks were counted in field, and samples of sediment and algae were taken for further analysis. A total of 74,515 individuals were found and classified into 67 species, 52 genera and 39 families. Gastropods were predominant, corresponding to 73.1% of the species, followed by bivalves (22.4%) and chitons (4.5%). *Caecum ryssotitum* de Folin, 1867 was the most abundant taxon, representing 68.8% of total specimen findings. In general, species were mostly found in Middle Littoral zone (samples 60 m and 90 m), suggesting that the greater number of microenvironments available in this area may contribute to establishment and survival.

KEYWORDS. Beach rocks, malacofauna, Middle Littoral zone.

RESUMO. Moluscos: Como estão distribuídos na zona entremarés rochosa? Moluscos ocupam diferentes tipos de ambientes, incluindo a zona entremarés. O presente estudo buscou investigar a distribuição espacial de moluscos em recifes de arenito situados na zona entremarés da Praia Pacheco, no estado do Ceará, Brasil. Sobre dois transectos, foram coletadas mensalmente seis amostras de 0,25 m^2 em cada um, em intervalos de 30 m (0 m, 30 m, 60 m, 90 m, 120 m e 150 m) no período de agosto de 2006 a setembro de 2007. Os moluscos foram contabilizados em campo, e porções de sedimento e algas foram armazenadas para posterior triagem e análise em laboratório. Foram encontrados 74.515 indivíduos, classificados em 67 espécies, 52 gêneros e 39 famílias. Gastrópodes foram predominantes, correspondendo a 73,1% das espécies, seguidos por bivalves (22,4%) e chitons (4,5%). *Caecum ryssotitum* de Folin, 1867 foi o táxon mais abundante, representando 68,8% do número total de organismos. De um modo geral, a zona com maior predominância de espécies foi o Mesolitoral Médio (amostras 60 m e 90 m), sugerindo que o maior número de microambientes disponíveis nesta área pode contribuir para o estabelecimento e sobrevivência de moluscos.

PALAVRAS-CHAVE. Recifes de arenito, malacofauna, Mesolitoral Médio.

Many different aspects can be analyzed within the structure of a biological community, including species composition, trophic relations (Menge & Lubchenco, 1981), abundance and species distribution in time and space (Oigman-Pszczol *et al*., 2004). One of the basic, but fundamental, elements is the "species richness", meaning the number of species that live in a given area. Even the simplest biological communities contain significant numbers of taxa, which may change over time in response to disturbances or some intrinsic dynamic processes (Ricklefs, 2003). In addition to qualitative data, quantitative data as absolute and relative abundance are also relevant in ecological studies. For example, it is possible to analyze the existence of dominance patterns between groups by considering the number of organisms (Underwood *et al*., 2000; Ricklefs, 2003).

Another tool that can contribute to a better understanding of how organisms interact with each other, and with the environment in which they live, is an analysis of their spatial arrangement (Underwood & Chapman, 1996; Arruda & Amaral, 2003). Underwood & Chapman (1996), analyzing spatial distribution of invertebrates using distinct scales, found significant differences of abundance at scales of centimeters and 1-2 meters in the intertidal zone.

From all the marine environments, epifauna seems to be more diversified in the intertidal zone, where the availability of microhabitats is high and where are offered milder microclimatic conditions supporting a large number of species (Soares-Gomes & Figueiredo, 2002), including invertebrates. Considering the peculiarity of this area and the biological diversity of Mollusca, this study investigated which mollusk species live on beach rocks and how some species are spatially arranged in the intertidal zone of a tropical beach, in the state of Ceará, northeastern Brazil.

MATERIAL AND METHODS

Pacheco Beach (3°41'11.66"S, 38°37'58.78"W), located along the west coast of state of Ceará, at 16.5 km from the city of Fortaleza, and is characterized predominantly by the occurrence of beach rocks (Fig. 1). The climate is Semi-Arid Tropical, with temperatures between 26 and 28°C, and the rainy season is from January to May, with average rainfall of 1,243.2 mm (IPECE, 2010).

Sampling occurred from August 2006 through September 2007, during periods of low tide. Two transects were established in the intertidal zone, each one with six sample sites. Actual samples were taken within a square border of 50 cm x 50 cm, at intervals of 30 m (0 m, 30 m, 60 m, 90 m, 120 m, 150 m), totaling twelve samples per month.

Mollusks found inside each square were counted, with some identified in the field and others taken to the laboratory; only living organisms were considered. Furthermore, pebbles collected at the

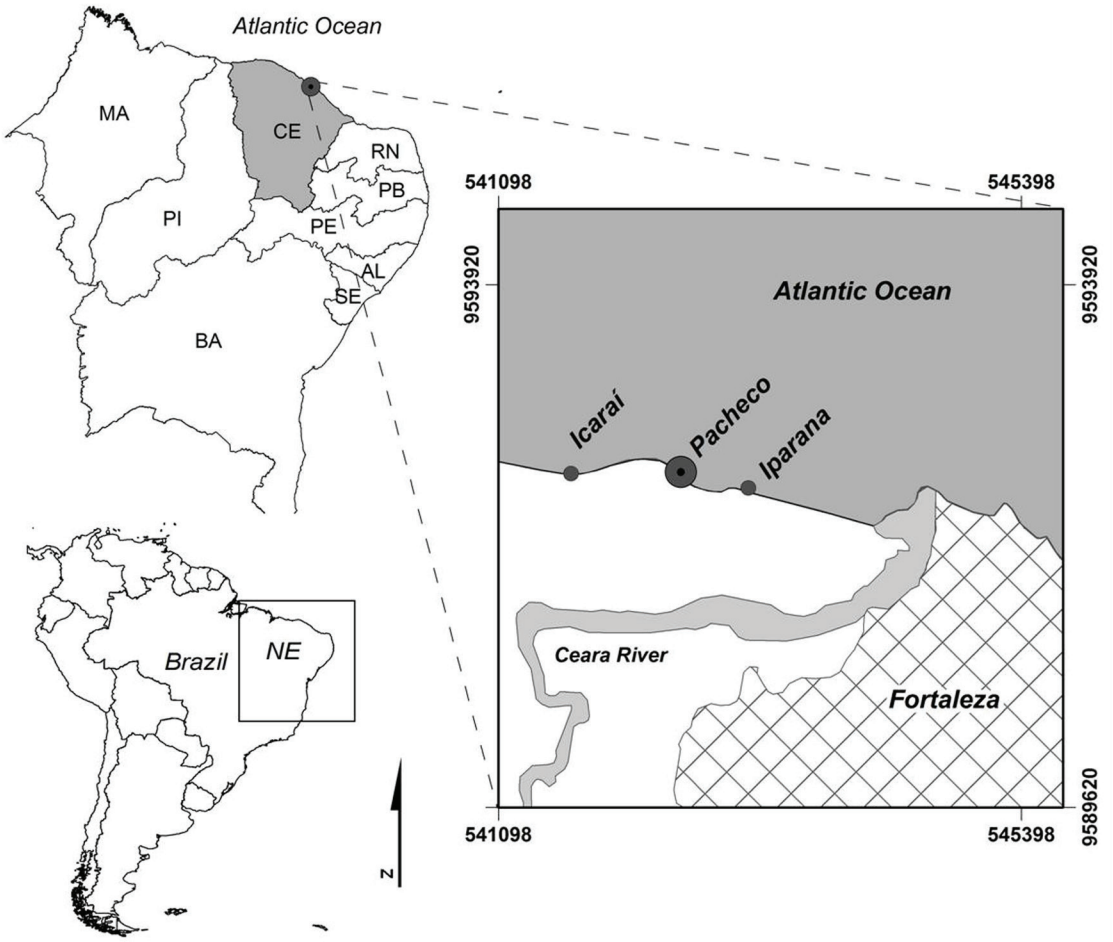


Fig. 1. Location map of the study area, Pacheco Beach, state of Ceará, northeastern Brazil.

sites were shaken within a plastic bag filled with water, with the material in the bag finally being sieved in a 0.5 mm mesh and stored. Salinity was measured with a refractometer, and precipitation data were obtained afterward from Fundação Cearense de Meteorologia e Recursos Hídricos - FUNCEME.

In the laboratory, after the screening with stereoscopic microscope, mollusks were counted, identified and stored in 70% ethanol. Specimens were deposited in the Malacological Collection Prof. Henry Ramos Matthews, at Instituto de Ciências do Mar (Labomar), Fortaleza, Ceará. Finally, to evaluate the similarity between the six samples sites (0 to 150 m), the Bray-Curtis Similarity (Log X +1) and the Cluster dendrogram were used with the quantitative data (abundance).

RESULTS

Qualitative and quantitative data. The malacofauna was constituted by 67 species, classified in Gastropoda, Bivalvia and Polyplacophora, distributed across 39 families (Tab. I). Gastropods were dominant, representing 73.1% of the species, while bivalves and chitons were equivalent to 22.4% and 4.5% respectively.

In total 74,515 organisms were counted, with 38,229 coming from Transect 1 and 36,286 from Transect 2. The most abundant species was *Caecum ryssotitum* de Folin, 1867, representing 68.8% of the total number of organisms, followed by *Eulithidium affine* (C. B. Adams, 1850) at 6.6% and *Caecum brasilicum* de Folin, 1874 at 5.1%.

Out of all collected mollusks, eight species showed relative abundance between 3.5% and 1%, while the 56 remaining species accounted for 4.5% of all specimens (Fig. 2). Twenty four species showed reduced abundance (between 2 and 10 individuals), while seven species were represented by only one individual.

Characterization of samples sites. Considering the varying environmental aspects of the rocky area where the sampling locations were established, the intertidal zone was divided for the study into three subzones: Upper Littoral (0 m to 30 m), Middle Littoral (60 m and 90 m) and Lower Littoral (120 m and 150 m). The Upper Littoral is the high-tide zone, where rocks with exposed surface could be seen, and there was no evidence of seaweeds. Large and smooth pebbles were observed inside the tide pools formed during low tide.

In the Middle Littoral, or middle-tide zone, samples of 60 m and 90 m had pebbles of variable sizes,

Tab. I. Mollusks recorded in beach rocks of Pacheco Beach, state of Ceará, northeastern Brazil, from August 2006 to September 2007.

CLASS	FAMILY	SPECIES
Gastropoda	Aeolidiidae	*Spurilla neapolitana* (delle Chiaje, 1841)
	Aplysiidae	*Aplysia dactylomela* Rang, 1828
		Aplysia fasciata Poiret, 1789
		Aplysia sp.
	Buccinidae	*Engina turbinella* (Kiener, 1836)
		Pisania pusio (Linnaeus, 1758)
	Caecidae	*Caecum brasilicum* de Folin, 1874
		Caecum multicostatum de Folin, 1867
		Caecum ryssotitum de Folin, 1867
		Caecum sp.
	Calyptraeidae	*Crepidula* sp.
	Cerithiidae	*Bittiolum varium* (Pfeiffer, 1840)
		Cerithium atratum (Born, 1778)
	Cerithiopsidae	*Seila adamsii* (H. C. Lea, 1845)
	Columbellidae	*Anachis catenata* (G. B. Sowerby, 1844)
		Anachis obesa (C. B. Adams, 1845)
		Astyris lunata (Say, 1826)
		Columbella mercatoria (Linnaeus, 1758)
		Mitrella dichroa (G. B. Sowerby I, 1844)
	Epitoniidae	*Epitonium* sp.
	Eulimidae	*Eulima arcuata* C. B. Adams, 1850
		Eulima sp.
	Fasciolariidae	*Aurantilaria aurantiaca* (Lamarck, 1816)
		Leucozonia nassa (Gmelin, 1791)
	Fissurellidae	*Fissurella rosea* (Gmelin, 1791)
	Haminoeidae	*Haminoea* **cf.** *antillarum* (d'Orbigny, 1841)
	Lottiidae	*Lottia subrugosa* (d'Orbigny, 1846)
	Littorinidae	*Echnolittorina ziczac* (Gmelin, 1791)
		Littoraria flava (King & Broderip, 1832)
	Marginellidae	*Volvarina* sp.
	Muricidae	*Aspella morchi* Radwin & D'Attilio, 1976
		Favartia alveata (Kiener, 1842)
		Morula nodulosa (C. B. Adams, 1845)
		Stramonita haemastoma (Linnaeus, 1767)
	Neritidae	*Neritina virginea* (Linnaeus, 1758)
	Phasianellidae	*Eulithidium affine* (C. B. Adams, 1850)
	Pyramidellidae	*Boonea jadisi* (Olsson & McGinty, 1958)
		Folinella robertsoni (Altena,1975)
		Odostomia laevigata (d'Orbigny, 1841)
		Odostomia unidentata (Montagu, 1803)
		Turbonilla abrupta Bush, 1899
		Turbonilla sp.
	Rissoidae	*Schwartziella catesbyana* (d'Orbigny, 1842)
	Siphonariidae	*Siphonaria pectinata* (Linnaeus, 1758)
	Triphoridae	*Marshallora nigrocincta* (C. B. Adams, 1839)
	Trochidae	*Tegula viridula* (Gmelin, 1791)
	Turbinidae	*Lothopoma phoebium* (Roding, 1798)
	Turridae	*Mangelia* sp.
		Pilsbryspira leucocyma (Dall, 1884)
Bivalvia	Arcidae	*Arca imbricata* Bruguière, 1789
	Cardiidae	*Dallocardia muricata* (Linnaeus, 1758)
	Corbulidae	*Corbula aequivalvis* Philippi, 1836
	Lucinidae	*Codakia* sp.
	Lyonsiidae	*Lyonsia hyalina* (Conrad, 1841)
	Myidae	*Sphenia fragilis* (H. & A. Adams, 1854)
	Mytilidae	*Brachidontes exustus* (Linnaeus, 1758)
		Musculus lateralis (Say, 1822)
		Mytilidae sp.
	Noetiidae	*Arcopsis adamsi* (Dall, 1886)
	Pectinidae	*Leptopecten* sp.
	Pteriidae	*Isognomon bicolor* (C. B. Adams,1845)
		Pinctada imbricata Roding, 1798
	Semelidae	*Semele bellastriata* (Conrad, 1837)
		Semele proficua (Pulteney, 1799)
Polyplacophora	Callistoplacidae	*Ischnoplax pectinata* (G. B. Sowerby II, 1840)
	Ischnochitonidae	*Ischnochiton striolatus* (Gray, 1828)
	Polyplacophora sp.	

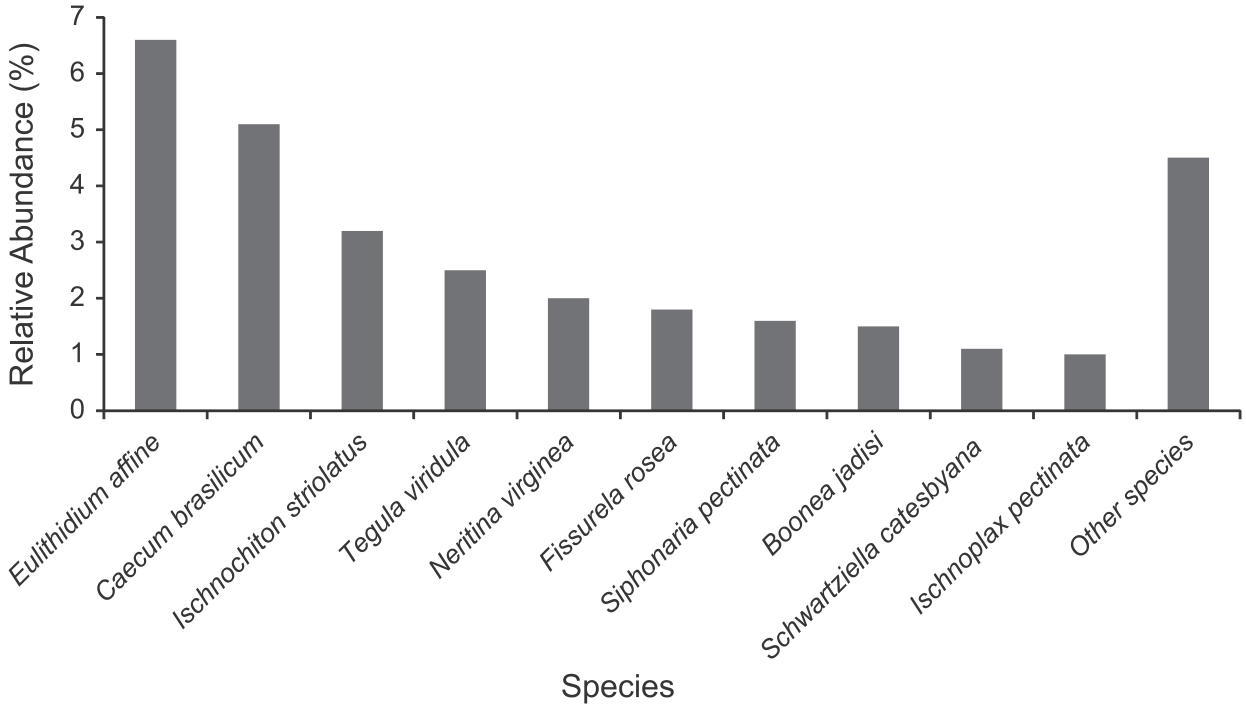


Fig. 2. Species found at Pacheco Beach, state of Ceará, northeastern Brazil, with relative abundance higher than 1% (*Caecum ryssotitum* was excluded).

sediments and different species of green and red algae. The Lower Littoral, or low-tide zone, was characterized by green and red algae, including coralline algae, which occurred exclusively within this area. The pebbles from sample 150 m were mainly of reduced size and covered by calcareous algae. The 120 m sample was partially or totally submerged, depending on the tide, while the 150 m sample was always submerged, with the water column oscillating from 20 to 30 cm.

Of the three subzones, the greatest species richness occurred in the Middle Littoral, including the 120 m sample of the lower littoral zone (Fig. 3). These three samples (60 m, 90 m and 120 m) were considered intermediate in the intertidal zone. The Bray-Curtis test showed higher similarity between samples 60 m and 90 m (88.6%), and samples 120 m and 150 m (80.6%), as illustrated by the cluster dendrogram (Fig. 4).

Spatial distribution of the most abundant species. With the exception of *Neritina virginea* (Linnaeus, 1758), the most abundant species occurred along the entire transect (0 -150 m). Although less abundant, some species also occurred in all subzones, as the gastropods *Bittiolum varium* (Pfeiffer, 1840), *Cerithium atratum* (Born, 1778), *Turbonilla* sp., and the bivalves *Isognomon bicolor* (C. B. Adams, 1845) and *Sphenia fragilis* (H. & A. Adams, 1854).

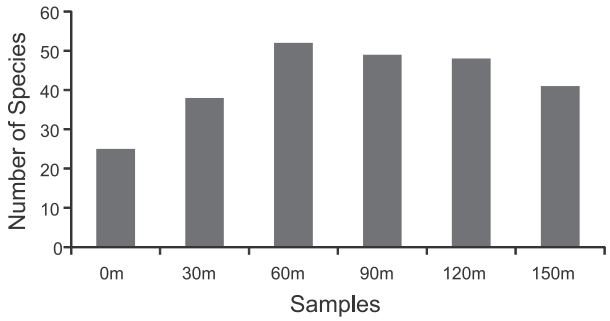


Fig. 3. Number of species found at the six sampling sites at intertidal zone of Pacheco Beach, state of Ceará, northeastern Brazil.

Species of the genus *Caecum* Fleming, 1813 were arranged similarly, being predominant in intermediate samples; however, *Caecum ryssotitum* de Folin, 1867 was more numerous in samples from 60 m and 90 m (Fig. 5), as was *Schwartziella catesbyana* (d'Orbigny, 1842), while *Caecum brasilicum* de Folin, 1874 was predominant in the 90 m sample (Fig. 6). The distribution pattern of *Boonea jadisi* (Olsson & McGinty, 1958) (Fig. 7) and *Tegula viridula* (Gmelin, 1791) (Fig. 8) indicated an increase in abundance from the Upper to Middle Littoral, reducing in the Lower Littoral.

Fissurella rosea (Gmelin, 1791) (Fig. 9) and *Eulithidium affine* (C. B. Adams, 1850) (Fig. 10) were more abundant in the Middle and Lower Littoral, mainly in the 60 m sample. Although *Siphonaria pectinata* (Linnaeus, 1758) (Fig. 11) occurred mostly in the same site (60 m), this mollusk was concentrated in the Upper Littoral, with a few individuals being found in the samples 120 m (six specimens) and 150 m (three specimens). *Neritina virginea* (Fig. 12) was more abundant in the 30 m and 60 m samples, with no record in the Lower Littoral, in contrast to chitons, which occupied mainly the 120 m sample in the Lower Littoral (Figs 13, 14).

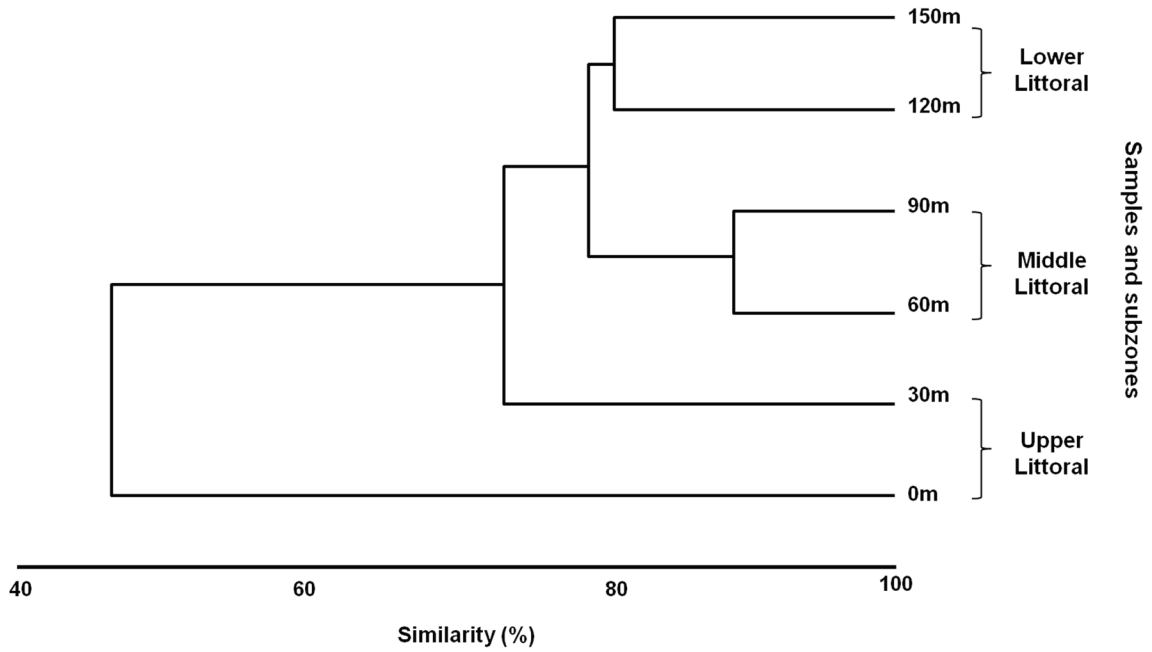


Fig. 4. Cluster Dendogram of the similarity between samples based on abundance, Pacheco Beach, state of Ceará, northeastern Brazil.

DISCUSSION

The mobility of mollusks can lead to changes in their spatial arrangement over time; however, such changes are on a small scale, considering that these organisms move only a few centimeters or meters per day (Underwood & Chapman, 1996). This study indicated that different species have different distribution patterns throughout the intertidal zone, depending on the biological aspects of each species. The possible limiting factors are resistance to desiccation and high temperatures during the low-tide periods (Wolcott, 1973).

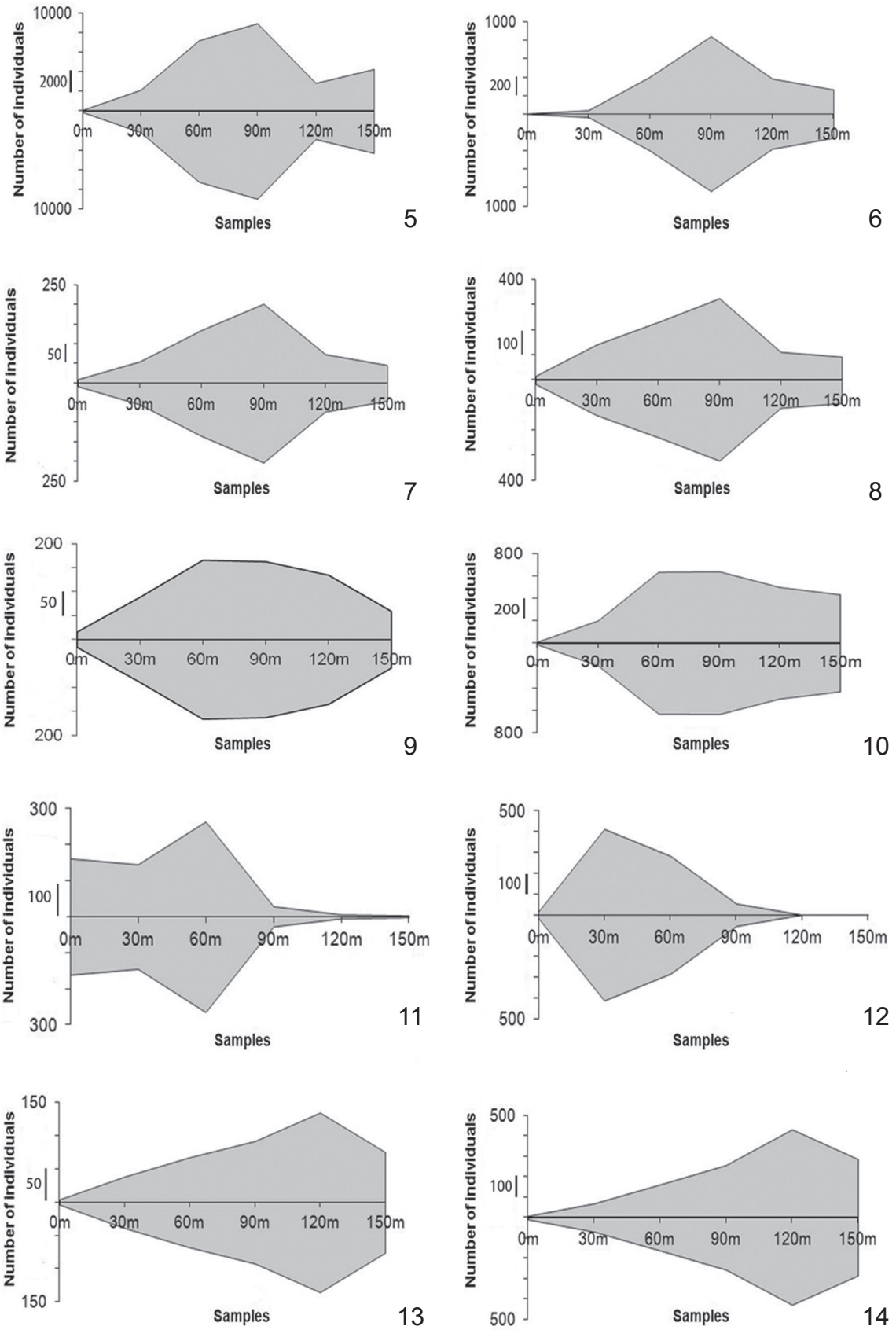
The similarity found among the six sampling sites confirms that spatially nearby areas are more similar to each other (Underwood & Chapman, 1996). Therefore, samples of the same subzone tend to have similar environmental characteristics, which might influence the richness and the abundance of mollusks in that subzone.

Species such as *Neritina virginea* that occur predominantly in the Upper Littoral are exposed for longer periods to terrestrial conditions, once this subzone is the first area to be exposed and the last to be submerged after the flood tide. Past research has shown that organisms living in the upper zones of a rocky shore have higher lethal temperatures, increased tolerance to dehydration, and greater resistance to osmotic stress (Wolcott, 1973). The gastropod *N. virginea* is common in estuaries, and is resistant to wide variations in salinity (Barroso & Matthews-Cascon, 2009).

The Middle Littoral, the zone with greater species richness, can be characterized as an environmentally more diverse area, with a greater formation of tidal pools, and agglomeration of algae and pebbles. Easily accessible at low tide, these components act as microcosms of marine life, offering milder conditions and favoring the survival of several mollusks (Matthews-Cascon *et al*., 2006), including *Caecum ryssotitum*. This microgastropod has dimensions of 1-5 mm (Rios, 1994), has herbivorous and detritivorous habit, and is the prey of crustaceans and other gastropods, participating actively in the food web (Mello & Maestrati, 1986). The significant number of organisms found in the study area suggests that the environmental conditions contribute to the mollusks survival and reproductive success, particularly in the middle-tide zone.

Mollusks that live mainly in the Lower Littoral zone remain exposed for a shorter period of time. This zone is characterized as a transition area, especially the 150 m sample, where the infralittoral region begins and the impact of waves is already strong. Hydrodynamism is one of the main challenges for mollusks that occupy this location, such as the chitons. In general, Polyplacophora are able to attach to rocky substrates by pressing their broad foot. These animals tend to remain in a restricted area, moving only over partially submerged or wet surfaces (Hyman, 1967), which corresponds with the spatial distribution pattern observed.

Finally, mollusks showed different spatial arrangements throughout the rocky intertidal zone evaluated in this study, possibly due to a combination of morphological, physiological and behavioral factors. The predominance of species in the Middle Littoral suggests that the environmental components available in this intermediate zone favor the formation of microhabitats that contribute to the establishment and survival of several species of marine invertebrates, such as mollusks.



Figs 5-14. Distribution pattern of mollusks over transects in the intertidal zone of Pacheco Beach, state of Ceará, northeastern Brazil: 5, *Caecum ryssotitum* de Folin, 1867; 6, *Caecum brasilicum* de Folin, 1874; 7, *Boonea jadisi* (Olsson & McGinty, 1958); 8, *Tegula viridula* (Gmelin, 1791); 9, *Fissurella rosea* (Gmelin, 1791); 10, *Eulithidium affine* (C. B. Adams, 1850); 11, *Siphonaria pectinata* (Linnaeus, 1758); 12, *Neritina virginea* (Linnaeus, 1758); 13, *Ischnoplax pectinata* (G. B. Sowerby II, 1840); 14, *Ichnochiton striolatus* (Gray, 1828).

Acknowledgments. The authors wish to thank the Laboratório de Invertebrados Marinhos of Universidade Federal of Ceará, the Programa de Educação Tutorial -PET, and wish a special thank to Mr. Walter Perkins Jr. and Mr. Frank Rabey for all the indispensable support given.

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Received 28 July 2012. Accepted 27 June 2013. ISSN 0073-4721
Article available at: www.scielo.br/isz