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Changes in Structure and Composition of Two Communities of Rocky Shores Molluscs Exposed to Different Human Impact in Playa Jibacoa, Cuba

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Abstract

Rocky shore molluscs are highly relevant in keeping shore's dynamics and ecological balance of beaches. The knowledge regarding species distribution patterns is important in understanding how environmental and anthropogenic factors may influence the structure of these communities. This study aimed to explore changes in structure and composition of littoral molluscs in two sites of Playa Jibacoa, Cuba with different human use. Forty-four species of littoral molluscs were identified. The supralittoral zones exhibited the lowest diversity whereas the interlittoral and sublittoral the highest. These findings point the latter as the most vulnerable zones to human perturbation. Species were more abundant and evenly distributed in the site with less human activity. This effect showed a seasonal pattern since in both sites these variables were more affected in the summer probably because of an increased attendance of tourists to the beach. Species were mostly associated with the type of substrate and the stratum than to any other variable. Significant changes in diversity were observed between seasons with a decrease in summer.

Keywords: Marine molluscs; Rocky shore; Diversity; Ecology; Evenness; Human impact

Introduction

The ecology of intertidal rocky shore communities has been a topic of interest for decades worldwide Underwood [1]. The knowledge regarding the patterns of species distribution is important in understanding how environmental and anthropogenic factors may influence the structure of these communities [2,3]. Rocky shores can be found at the margins of the oceans throughout the world and are the most common littoral habitats on open wave-exposed coasts [3]. These ecosystems are greatly diverse as to which molluscs are the most abundant and important groups [1,4]. Mollusc communities occurring in rocky shores and coral reefs play key roles in the trophic chains and nutrients recirculation [5]. Also, several species act as ecological regulators and are identified as bio-indicators of disturbances by Baqueiro [6]. Human accessibility to rocky shore habitats has made them susceptible to a variety of human disturbances [3]. In this way, disturbances in these ecosystems can alter the fragile balance of mollusc communities and indirectly affect the dynamics of beaches [7].

Cuba is considered a 'Hot Spot' of mollusc's diversity including 1770 marine species [8]. Many malacological investigations have been carried out in Cuba regarding the taxonomy of this group [9-11]. However, ecological studies on Cuban marine molluscs are comparatively scarcer regarding species interactions with environmental factors and only a few of them deal with the conservation status of some species [12].

Sandy beaches (usually sandwiched between rocky shore segments) constitute one of the most used marine-coastal landscapes in Cuba. In the northeast, Playa Jibacoa is actually one of the most visited beaches with diverse recreational activities which include music festivals. In this study we examine the potential impact of direct human activity upon a mollusc community through the changes of some ecological patterns. These results may help to redirect actions towards minimizing actual damages occurring in these habitats.

Materials and Methods

Description of the studied locality

The study was carried out in Playa Jibacoa (70 km northeast of Havana) in the two nearby beach sites Hurrutinier and Tibaracon, which share similar topographic features but differed on the public use criteria (Figure 1). Both sites are formed of 300 m of exposed rocky shores interrupted with a sandy patch of about 200 m. A coral reef fringe of 5 meters deep surrounds both sites at 150 m off shore. Vegetation is mainly xeromorphic where succulents are abundant above the high tide mark and *Coccoloba uvifera* dominating the upper line of the shore. On the wet zones algae are dominant alternating with bare rocks of variable ruggedness that serves as refuge to a number of invertebrates. However, Tibaracon receives more tourist influence during summer time due to its double function of beach and hosting of music festivals. In contrast, Hurrutinier is less visited probably because this site lacks accessibility to other sources of recreation.

Methodology and study design

Considering that mollusc communities and environmental factors vary in accordance to differences in the zonation of the littoral, the rocky shore was divided into three strata. Each stratum was classified as follow for the purposes of these study: (1) Sublittoral was considered from the bottom to the lowest tide mark; (2) Interlittoral corresponded

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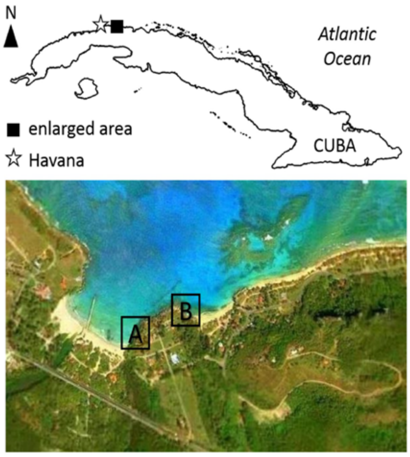

Figure 1: Studied sites at Jibacoa Beach. A=Tibaracon, B=Hurrutinier.

to the fringe from the lowest to the highest tide marks; and (3) Supralittoral was considered from the highest tide mark to the limit of landward vegetation. All strata were approximately 1.5–2 m wide along the studied coastline and were sampled in summer (July–August) and winter (January–February). Linear transects (10 m × 1 m) parallel to the shore line were randomly placed each time the sites were visited and used as the sampling unit. Ten transects were sampled in each stratum of both sites (30 transects per site). Individuals were counted *in situ* considering only those visible along transect keeping a constant effort to avoid bias. Identification of species was carried out also *in situ* using specific guides of Caribbean seashells [13,14] and species names were updated according to Espinosa et al.[8].

Variables and data analysis

Species' relative abundance in both individually and in overall number of transects were obtained for each stratum. Ecological variables (substratum type (e.g.: wrinkled, medium wrinkled and smooth), vegetation/algal cover, diversity and evenness indexes) were associated with the species abundance using a canonical correspondence analysis [15]. Rank/abundance curves [16] were used to explore the structure of mollusc communities. Diversity indexes Simpson [17] and Shannon and Weaver [18] were correlated between them and with the abundance of the dominant species to explore the effects over the whole community diversity. Ecological calculations were done using Biodiversity Pro v.2 [19] and Ecological Methodology software [20]. Statistical analyses were carried out in Statistica 8.0 [21] and MVSP 3.12h [22] software packages. Differences were always considered statistically significant at values of $P<0.05$.

Results

Species composition

Forty-four species of marine molluscs belonging to 33 genera and 18 families were identified in Playa Jibacoa. Most species were gastropods, while bivalves were represented by six species and only three polyplacophores were observed. Families with the greatest number of species observed were Littorinidae, Neritidae, Columbellidae and Turbinidae.

Tibaracon displayed overall slightly more species than Hurrutinier (36 and 33 species respectively). However, both sites decreased the species richness in the summer from 29 to 23 in Hurrutinier and 30 to 21 in Tibaracon. Interestingly, the latter showed a more marked decrease in species composition. This apparent descend in richness was accompanied by a swapping of several species that were only observed in winter. In summer only 10 species were absent and 4 different new records appeared (*Brachidontes exustus*, *Thais rustica*, *Tegula excavata* and *Turbo castanea*). In Tibaracon the species replacement was slightly higher, 15 of the 30 species occurring in winter were absent in summer and 6 new species appeared (*Thais deltoidea*, *Nodilittorina mespillum*, *Columbella mercatoria*, *Diodora arcuata*, *T. castanea* and *Astralium phoebium*).

Diversity patterns

The Overall results of species diversity and dominance are seen in the rank/abundance curves (Figure 2). Supralittoral stratum always rendered the lowest species richness values with a higher dominance of one or two species. Here, species like *Echinolittorina ziczac* and *Cenchritis muricatus* were the most common and virtually prevented the settlement of other species. In fact, *E. ziczac* was observed forming compact clusters of about 100 individuals in both sheltered and open rock. Interlittoral and sublittoral strata on the contrary, harboured higher species richness. No apparent dominance among species was found to occur in these two sections of the littoral rocky shore. However, it is interesting to note that species composition suffered a replacement in families with more representatives from the Littorinidae in upper section to the Neritidae, Fissurellidae and Chitonidae (Polyplacophora) in the lower sections. Nerites varied their abundances considerably and an exchange of abundance ranks was especially observed in *Nerita tessellata* over *Nerita versicolor* in summer and reversely in winter. Nevertheless, both species suffered a marked decrease in their abundances in summer.

Comparisons between seasons evidenced higher values of diversity at Hurrutinier (less human pressure site) than in Tibaracon for 2 of 3 stratums with the exception being the sublittoral, where species diversity was always found to be higher at Tibaracon. Here, although richness was found slightly lower, species were more evenly distributed than in the interlittoral section (Figure 2). The sublittoral was commonly dominated by the limpets *Lottia leucopleura* in winter and only at Hurrutinier and *Fissurella nodosa* in summer at both locations.

The dominant species in the interlittoral was *B. exustus* and *N. tessellata* in winter, and *E. ziczac* (both locations) and *Chiton tuberculatus* at Tibaracon in summer. In winter there was no clear overall dominance among species whereas in summer this dominance was higher especially in Tibaracon. Most bivalve species were found in the sublittoral stratum in winter.

In general, both sites displayed higher diversity in winter than in summer regarding both species richness and evenness (Figure 2). The mean values of Simpson index showed significant differences between the supralittoral zone and the two other studied zones (inter and sublittoral) ($P=0.0023$, ANOVA results). However, no statistical difference regarding diversity between the interlittoral zone and the sublittoral zone was observed ($P=0.098$).

The diversity indexes [17,18] were correlated for each site and season showing a high positive association in Hurrutinier and Tibaracon. The correlation between the Simpson index and each particular stratum's dominant species in each season showed relevant results especially for *E. ziczac* (Table 1). The relative abundance of this species was strongly and positive correlated with the Simpson index in the supralittoral zone in both sites on winter while it was negatively

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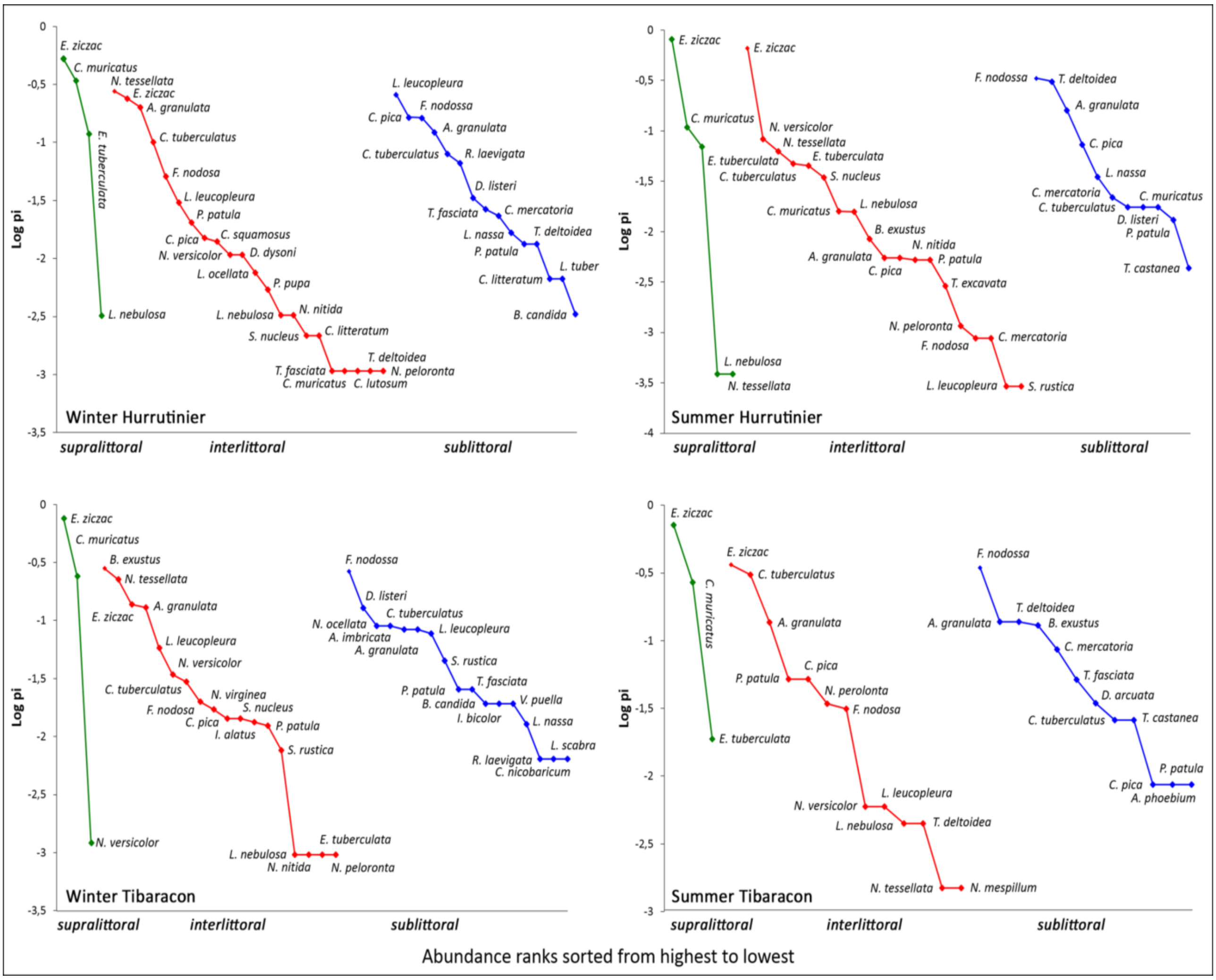

Figure 2: Rank/Abundance curves of each studied site for each stratum.

Season	Hurrutinier		Tibaracon	
	H' - D		H' - D	
	r	P	r	P
Winter	0.983	0.0001	0.981	0.0001
Summer	0.972	0.0001	0.983	0.0001

Table 1: Spearman´s correlation coefficient (r) between Shannon-Weaver (H) and Simpson (D) diversity indexes for each site and season.

correlated in summer only in Hurrutinier (Table 2).

Species-environment associations

The main association between the species abundances and the ecological factors by a canonical correspondence analysis showed a correlation species-environment equals 0.85 (Figure 3A). There is a clear pattern of community structuring in the littoral mollusc community regarding each studied strata in both sites. Although some species were found occurring in two different strata (interlittoral and sublittoral) a strong differentiation was attained in terms of abundances. However, species inhabiting well above the high tide mark in the supralittoral stratum (e.g.: *C. murictus*, *E. tuberculata* and *E. ziczac*) were rarely observed elsewhere. Only in Tibaracon (Figure 3B), a slight mixture of species abundances arose between interlittoral and sublittoral strata. In any case, most species were representative of a particular area at any time. Supralittoral species were always associated with wrinkled substratum. It should be noted that flat substratum was highly associated to sublittoral species in Tibaracon while no apparent relation was observed in Hurrutinier. Although summer and winter seasons did not show the strongest of relationships with most species, there did seem to be a particular association of the latter

Zone	Hurrutinier					
	DS	Winter		DS	Summer	
		r	P		r	P
Supralittoral	*E. ziczac*	0.740	0.014	*E. ziczac*	0.227	0.528
Interlittoral	*N. tessellata*	0.421	0.222	*E. ziczac*	-0.833	0.003
Sublittoral	*L. leucopleura*	-0.056	0.877	*F. nodosa*	-0.042	0.907
Zone	**Tibaracon**					
	DS	Winter		DS	Summer	
		r	P		r	P
Supralittoral	*E. ziczac*	0.738	0.015	*E. ziczac*	0.509	0.132
Interlittoral	*B. exustus*	0.112	0.758	*E. ziczac*	0.097	0.789
Sublittoral	*F. nodosa*	-0.336	0.343	*F. nodosa*	0.346	0.326

Table 2: Spearman´s correlation coefficient (r) between Simpson diversity index and the dominant species abundances (DS) for each zone, site and season.

with interlittoral species in both sites. Other variables like ecological indexes exhibited interesting patterns. Diversity and evenness had their maximum values at both interlittoral Hurrutinier and sublittoral Tibaracon. The highest number of families and species where found in these two strata. Contrary, supralittoral species were negatively related with diversity and species richness was consequently lower here (Figures 2 and 3).

Discussion

Species composition

Marine mollusc species observed in Playa Jibacoa coincided with the typical species described for the rocky shore ecosystems [7] in other regions of Cuba. The proportion of mollusc classes is also in accordance with the information recorded in other studies carried out in littoral ecosystems [11]. The colonization and disposition of the molluscs in the rocky shores are probably related with morphological and behavioural adaptations that allow them to resist the environment conditions [23]. Families observed in the supralittoral (Littoriniidae) and interlittoral (Neritidae, Chitonidae) zones have been described as typical in other regions [11,24]. Some species previously reported in other studied sites in Cuba as very abundant like *Turbo castanea*, *Lithopoma tuber*, *Astralium phoebium* and *Lima scabra* in the sublittoral zones [25] were however, considered rare in this study.

Diversity and ecological association patterns

In this study we observed a tendency toward two patterns related to the diversity changes between sites and seasons. Species distribution

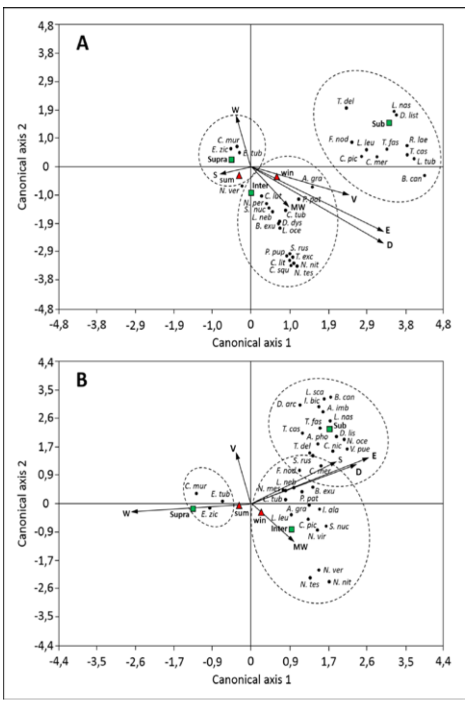

Figure 3: Scatter plot of the canonical correspondence analysis carried out at Tibaracon (A) and Hurrutinier (B) (vectors represent ecological variables measured: W: wrinkled substratum, MW: medium wrinkled substratum, S: smooth substratum, V=vegetation cover, E: evenness, D: diversity; squares represent each stratum: Supralittoral, Interlittoral and Sublittoral); triangles represent seasons: winter and summer; black circles represent species; and elipses indicate species/stratum representations).

in rank/abundance curves at sites subjected to pollution or stress are characterized by geometric series instead of log-normal distribution where only a few species are dominants and the rest practically rare [16]. The patterns observed in the rank/abundance curves in the supralittoral zone could be related to a major exposure of this zone to a harsher environment and/or greater human activity. The scarce diversity in this stratum could be influenced significantly for this effect, especially in summer when there is a marked increase of tourists that go to these beaches. Some studies discuss about the negative impact of human activities in the supralittoral zone related with the collection or handling of charismatic species with key ecological roles in the ecosystem [26,27]. This would be a likely explanation if we take into account the anthropic impact on rocky shores communities. However, it should be important to emphasize the effect that other abiotic factors (wave exposure, temperature, desiccation and salinity) could have over the community structure.

The natural environmental conditions in the supralittoral zone become extreme with a marked increase in the salinity in the supralittoral tide-pools because of the water evaporation and the increase of substratum and air temperature [28]. In this way, species occurring in this habitat must endure the physical stress of the temperature, salinity fluctuations and the mechanical action of waves [29]. This could explain why only a few species are able to colonize this habitat. Despite the limiting factors of this habitat, *C. muricatus* and *E. ziczac* had their highest abundance values probably by a combination of morphological, physiological and behavioral adaptations.

The interlittoral zone is one of the rocky shore environments with higher species richness than other stratum due to diverse factors (e.g. the substratum features and small spatial scale variations of environmental conditions) that converged in this particular zone and give place to complex assemblages of species [30]. In fact, it may be considered like the ecotone between the supralittoral and sublittoral communities, which contributes to the major diversity seen in this zone. The interlittoral zone was the most diverse in Hurrutinier as this zone displayed the highest species richness in both sites. It is possible that species occurring in the supralittoral are forced to migrate to lower areas to scape some anthropogenic pressures (e.g. trampling, handling and collect of charismatic species) [26].

Many authors have stated that physical conditions in the sublittoral zone are not as extreme as in the supralittoral zone neither so variable like in the interlittoral zone and in fact, some abiotic factors (temperature and salinity) attain stable values [31]. This might constitute an advantage for some species because they are not subjected to the strong environmental pressures. However, the microhabitats available may decrease compared to the interlittoral zone. Highest diversity in the sublittoral zone at Hurrutinier may not only be a direct effect of community structure but due to an indirect effect of a lesser diversity in the other strata that are perhaps more perturbed. Rank/abundance curves showed tendencies to an increase of the diversity in winter because of a higher species richness and evenness which was more evident in Hurrutinier than Tibaracon. The positive correlation of Shannon and Simpson indexes points to diversity fluctuations at both sites are likely dependent on changes in both rare and dominant species [16].

The observed correlation of the Simpson index and dominant species in each zone and season may have its explanation in the structure and species composition. The interlittoral zone was characterized by a higher species richness and evenness, so an increase of any species that is not followed by the others could have a negative effect in the diversity and community structure [32]. However, in the supralittoral zone, where the species richness is very low, the contributions of any species with high important values of abundances may contribute to increase the total diversity of this zone.

Substrate roughness is considered a factor of great importance when examining mollusc's densities [33]. This rough substrate provides more humid and shaded areas in which snails can escape to reduce thermal and desiccation stress [34], more crevices that serve as refuges from predators, and/or greater surface area or more attractive surfaces for recruitment [33]. On the other hand, the lack of association of any species with the smooth substrate could be explained by the scarce refuge it offers and the exposure to predators or might mean the inability to get a strong hold onto substrate. Some authors, however, point that this type of substrate offers some advantage to the species occurring in the interlittoral zone giving a major surface area for fixing [35]. However, our results show that most species were mainly found in wrinkled or slightly wrinkled substrates, especially inside cavities in the sublittoral zone.

Rocky shores are and have been affected by pollution, species extraction, trampling, exotic species introduction and human modifications [3]. This work these factors were not directly measured, it is highly possible that this locality is subjected to several of them. In both sites in winter there is higher species richness. Some studies point to an increase of diversity especially after intermediate levels of trampling [36]. This pattern follows the hypothesis proposed for Connell [37] which predicted that intermediate levels of disturbance foster higher levels of diversity through three main factors: (1) interfere with the competitive exclusion process; (2) change the community structure; and (3) favor new stages in the succession. These processes allow the colonization of rare or absent species in well-established communities and also increase the diversity due to an increase in the species richness. In Cuba only a few studies consider the impact that tourists provokes to the rocky shores which in the north region of Havana is associated to many coastal camping sites. However, the results presented here may lead us to think that unmeasured human impact in other sites might be actually an impact in mollusc diversity and serve as an example of what might be happening in other non-studied groups susceptible to human perturbation.

Conclusion

The results obtained in this study show different diversity patterns associated with location in intertidal zone. The diversity could be an indicator of the ecosystem health and in this case any change in this factor can be attributable to negative or positive changes in the community. The studied locality attained showed two patterns of diversity related with the season and a possibly with different human use in each studied site. Tibaracon, which was apparently the less conserved probably because a higher human exploitation, had a seasonal component of diversity loss. On the other hand, the more influential ecological factors on species distribution were the type of substrate combined with zonation in intertidal zone. This variable may have a direct effect in colonization and settlement of populations. The effect of dominant species that regulate the distribution of others is actually shaping the structure of the community and may render most populations more susceptible to the potential harm of human activity.

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