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Gastropod's and Bivalves from the rocky shore of la restingue, Montijo, Veraguas, Panama.

Gasteropodos y Bivalvos del litoral rocoso de la restingue, Montijo, Veraguas, Panamá.

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Abstract

Mollusk populations and their trophic level were analyzed at three stations with different degrees of exposure to waves (exposed area and protected area) on the rocky coast of La Restingue, Cerro Hoya National Park, Gulf of Montijo, Veraguas province. Biological material was collected manually, and specimens were preserved in jars with 70% alcohol. They were determined, counted and recorded in the National Reference Collection of the Malacology Museum of the University of Panama (MUAMUP) in the laboratory. The total abundance of species and specific evidence were determined and through a bibliographic review each species was assigned its trophic category, classifying them as: herbivores, filter feeders, suspension feeders, carnivores, scavengers, herbivore-filter feeders, herbivore-detritivores, and carnivore-herbivores. A total of 290 individuals were obtained; represented by seventy-seven species corresponding to the classes Gastropoda (64) and Bivalvia (13); contained in thirty-eight families. Herbivores were the dominant group (36.36%), followed by carnivores (35.06%), filter feeders (16.88%), suspension feeders (2.60%), scavengers (2.60%), herbivore-filter feeders (2.60%), carnivore-herbivore (2.60%) and herbivore-detritivore (1.30%). Herbivorous species, filter feeders and herbivore-filter feeders (54.54%) dominated in the protected area, while in the exposed area, they were carnivores and herbivores. The constant species in two of the three stations during the study period was the herbivore Littorina aspera Philippi, 1846. It can be deduced that the distribution of mollusks and the different trophic groups may be controlled by morphological adaptations, as well as the level of exposure to waves and substrate composition.

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Keywords: mollusks, rocky, herbivorous, filter-feeding, carnivorous.

Resumen

Se analizó las poblaciones de moluscos y su nivel trófico en tres estaciones, con diferentes grados de exposición al oleaje (área expuesta y área protegida), en el litoral rocoso de La Restingue, Parque Nacional Cerro Hoya, golfo de Montijo, provincia de Veraguas. La recolección del material biológico se realizó de forma manual y los especímenes fueron preservados en frascos con alcohol al 70%. En el laboratorio fueron determinados, contados y registrados en la Colección Nacional de Referencia del Museo de malacología de la universidad de Panamá (MUAMUP). Se determinó la abundancia total de especies, constancia específica y por medio de una revisión bibliográfica se le asignó a cada especie su categoría trófica, clasificándolos en: herbívoros, filtradores, suspensivoros, carnívoros, carroñeras, herbívoros-filtradores, herbívoros-detritívoros y carnívoras-herbívoras. Se obtuvo un total de 290 individuos; representado por 77 especies correspondientes a las clases Gastropoda (64) y Bivalvia (13); contenidas en 38 familias. Los herbívoras fueron el grupo dominante (36.36%), seguido por carnívoras (35.06 %), filtradoras (16.88%), suspensivora (2.60%), carroñeras (2.60%), herbívoras-filtradoras (2.60%), carnívoras-herbívoras (2.60%) y herbívora-detritívora (1.30%). Las especies herbívoras, las filtradoras y herbívoras-filtradoras (54.54%), dominaron en el área protegida, mientras que, en el área expuesta, fueron las carnívoras y herbívoras. La especie constante en dos de las tres estaciones durante el período de estudio fue la herbívora *Littorina aspera* Philippi, 1846. Pudiendo deducir que la distribución de los moluscos y los diferentes grupos tróficos, pueden estar controlados por adaptaciones morfológicas, así como el nivel de exposición al oleaje y composición del sustrato.

Palabras claves: moluscos, rocoso, herbívoros, filtradores, carnívoros.

Introduction

On rocky shores, there is a wide variety of incidental factors, such as physicochemical factors (wave exposure, temperature, desiccation, salinity, oxygen, light, and surface fixation), biological factors (competition, predation, and recruitment), and tidal interactions. The spatial and temporal variation of these factors determines the characteristics, distribution, and behavior of existing populations (Doty, 1957; Denley and Underwood, 1979; Garrity and Levings, 1981).

Some factors influencing the distribution of organisms on intertidal rocky substrates appear to follow Connell's (1961) classic model, in which the upper limit is determined by physical variables (temperature and desiccation) and the lower limit by biological interactions such as competition and predation. Other authors, Stephenson and Stephenson (1949) and Lewis (1972), point out that different degrees of wave exposure, different temperature regimes, and different types of rocky substrates influence the trophic structure of these environments. In this regard,

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Olabarría *et al*. (2001) indicate that the factors that control the distribution of trophic groups determine community structure; at the same time, the distribution and abundance of functional groups are correlated with the physical factors of the environment.

According to Livore *et al*. (2021), in rocky ecosystems, biodiversity studies are considered key tools for identifying changes in communities that help inform decisions for the protection of this coastline, providing an appropriate response to address potential coastal threats.

For Tait (1970), rocks in the tidal zone provide residence for numerous species; A wide variety of forms usually exist among the rocky bottom population due to the irregularities of the rock surfaces. Supported especially by browsing and scraping specimens, the rocky coast's erosive shape allows for almost no detritus accumulation, although the surviving mollusks in this area are primarily sessile organisms, which are slow-moving herbivorous and carnivorous gastropods and filter-feeding bivalves. However, feeding is an important aspect of the activities of organisms living in this type of habitat (Fernández and Jiménez, 2006).

On rocky shores, their biodiversity is represented by populations of highly adapted organisms that sustain and survive on vertical surfaces, withstand prolonged periods of desiccation, endure sharp changes in salinity and temperature, and are resilient to strong waves (López-Victoria *et al*., 2004; Fernández and Jiménez, 2006; Garay-Tinoco, 2010). These natural stress factors favor these ecosystems, contributing to the highly varied biocenosis, a consequence of these forced changes, due to certain spatial-scale demographic parameters such as species richness, abundance, and distribution, which vary depending on the availability of trophic resources and habitats (Tlig-Zouari *et al*., 2010; Jaleel *et al*., 2022).

Based on Mille *et al*. (1993); Williams (1994); Margalef (1995); In the rocky zone, the malacological fauna constitutes a very stable community due to the composition of the substrate. Colonization and the arrangement of mollusks in this habitat are determined by morphological adaptations that allow them to withstand environmental conditions. For Odum (1984), knowledge of the functional groups of marine benthic associations gives us an idea of how and to what extent the dominant energy in the ecosystem is utilized by mollusks and provides indirect information on the physical characteristics of the environment.

According to Margalef (1986), the fauna of rocky coasts varies greatly from one location to another, even if they are close together. Food alternatives are limited: either they filter the water or capture small planktonic animals, or they attack other members of the same community.

There are some studies on the important role of predation on rocky shores and their trophic structure (Paine, 1974 and 1976; Menge *et al*., 1985 and 1986; Ojeda and Dearborn, 1991; Williams, 1994).

There is little information on the trophic levels of mollusk communities in our country, so the objective of this work was to learn about the structure of a mollusk community and its trophic level in an area exposed and another protected from the waves in La Restingue, in the Cerro Hoya National Park, Veraguas, Panama.

Materials and methods

Sampling site: The study was conducted on the La Restringe coast, located within the Cerro Hoya National Park grounds; at the southwestern end of the Azuero peninsula, comprising the Hoya and Tres Cerros hills in the Montijo district, Veraguas province, and the Tonosí district, Los Santos province (Figure 1).

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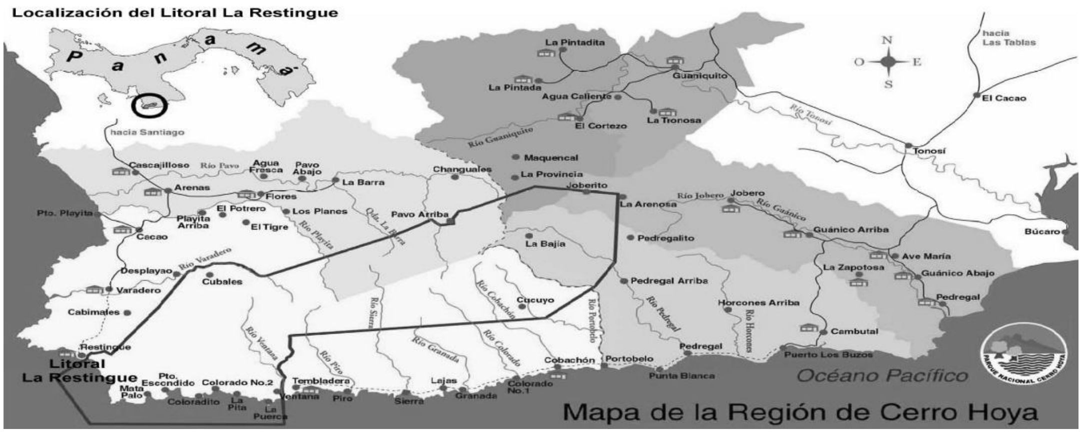
Figure 1

Location of the La Restingue coastline, Cerro Hoya National Park, between the provinces of Veraguas and Los Santos, in the district of Tonosí.



Fuente: Photo courtesy of Mi Ambiente.

This is a rocky-sandy coastal ecosystem with some white sandy beaches of approximately 2 km. long, including a small mangrove swamp. The beach is characterized by a rocky-sandy and rocky sediment with areas of bare rocks that mark the transition between land and sea. In addition, there are the mouths of the Restinge and Ventana rivers, with reefs, keys and an island of 1/2 km. in diameter in front of the beach. The continental shelf reaches up to one hundred meters deep. This coastal ecosystem has shrub vegetation among which are native cotton, squash and some types of palms such as *Bactris major* (uvito), Cocos nucifera (coconut); as well as trees such as *Licania platypus* (sapote) and *Cavanillesia platanifolia* (cuipo).

The forest type is the very humid premontane forest (bmh-PM). The vegetation of the very humid tropical forest life zone (bmh-T) has a similar appearance to the previous ones. This confirms that, at least from the point of view of its structure, the forests of Azuero suffer more from the conditions of the relief and the altitudinal levels than from the ecological conditions of the life zone to which they belong. On the less rugged relief we find, in the dominant stratum, Miguelario, Espavé, Sigua, Aguacatillo, Ratón, Níspero, Berba, Corotu, Sandé, Quira, Chutra, Zapote, Caoba, María; and in the dominated stratum, Alfajía, Alcarreto, Guabo, Ajo, Canaludo, Lechoso, Cortéz, Sahumerio.

The climate of the park and its surrounding area is within the humid tropical climate region, and is influenced by its geographical position, its proximity to the sea and its relief. Precipitation in the study area is of the convective and orographic type. Mountain barriers cause a rise in humid air, increasing cloudiness and precipitation. Precipitation is called orographic rain because it is caused by the collision of the dominant winds loaded with humidity with the mountains or the relief. The high temperatures of the sea also favor the warming and evaporation of water. As the air loaded with humidity, coming from the Pacific Ocean, moves inland, the air masses meet the mountains located in the upper part of the basins, causing orographic precipitation that reaches values of up to 4200 mm/a. The spatial variation of the temperature depends on the elevation. In the study area the average annual temperature ranges between 20ºC and 28ºC.

Study method: The collection was conducted over a six-month period from morning to afternoon when the tide began to go out until it rose again. Three perpendicular stations were established along the coastline, each 10 m long, following the methodology proposed by Jones (1980), cited by Contreras *et al*. (1991), taking as starting and ending points the position of organisms that indicate the environment. A total of three stations were established along the transect, locating station one in the supralittoral zone, station two in the mediolittoral zone, and station three in the sublittoral or completely submerged zone.

The samples were taken by scraping the entire surface of the rocks with a spatula and collecting the material present above and below manually. The collected organisms were then preserved in 70% and identified with the aid of specialized literature (Keen, 1971) to the lowest possible taxonomic rank.

According to the descriptions of Hughes (1986), Greenway (1995), Pontier & Lamy (1998) and Olabarría *et al*. (2001), each species was assigned a trophic category, classifying them as herbivores, filter feeders, carnivores, scavengers, suspension feeders, herbivore-filter feeders, herbivore-detritivores and carnivore-herbivore.

Results

Community structure: A total of 290 organisms were obtained in the three stations, represented by 77 species (28 herbivores, 27 carnivores, 13 filter feeders, two scavengers, two suspensivore, two herbivore-filter feeders, two carnivore-herbivore and one herbivore-detritivore), of which 64 belong to the Gastropoda class and 13 to Bivalvia, contained in 38 families (Table 1, 2 and 3). The most representative species were the herbivore *Nerita funiculata* Menke, 1850 and the carnivore *Plicopurpura columellaris* (Lamarck, 1816) followed by *Siphonaria gigas* G.B. Sowerby I, 1825 (Table 1) in terms of the total number of individuals.

The most abundant class was Gastropoda, with a total of 247 individuals, distributed in thirty-two families, forty-five genera, sixty-four species; in the Bivalvia class, forty-three individuals were collected, distributed in seven families, ten genera and thirteen species (Table 1 and 2).

Trophic categories: Regarding the composition of the trophic categories for the whole community, herbivores were the category with the highest frequency with twenty-eight followed by carnivores with twenty-seven species, respectively. In the others, thirteen filter feeders were collected, two species were placed in the herbivore-filter feeder category, two scavengers, two suspension feeders, two carnivore-herbivore and one herbivore-detritivore.

For the Gasteropoda class, the herbivorous species dominated: *Nerita funiculata*, N. scabricosta Lamarck, 1822, *Purpura pansa*, *Fissurella longifisa* Sowerby, 1862, *Tegula pellisserpentis* (W. Wood, 1828), *Opeatostoma pseudodon* (Burrow, 1815) and *Titanostrombus galeatus* (Swainson, 1823); While the species *Pinctada mazatlanica* (Hanley, 1856), *Ostrea conchaphila* P. P. Carpenter, 1857, *Chama echinata* Broderip, 1835, *Donax assimilis* Hanley, 1845 and *Leukoma grata* (Say, 1831) were the most abundant filter feeders for the class Bivalvia.

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Table 1

Families, species and trophic categories of rocky coast mollusks at station one (supralittoral floor)

Families	species	Trophic category	Total
Donacidae	*Donax assimilis*	Filter	3
Neritidae	*Nerita scabricosta*	Herbivore	10
	N. funiculata	Herbivore	22
	Teodozus luteofaciatus	Herbivore	7
Littorinidae	*Littorina aspera*	Herbivore	3
Cypraidae	*Cypraea cervinetta*	Herbivore	6
	C. robertsi	Herbivore	6
Cassididae	*Casis centiquadrata*	Carnivorous	1
Muricidae	*Plicopurpura columellaris*	Carnivorous	20
	Thais biserialis	Carnivorous	1
	Acanthina brevidentata	Carnivorous	1
	Cymia tecta	Carnivorous	1
Buccinidae	*Solenosteira mendozana*	Carnivorous	1
Olividae	*Olivella anazora*	Carnivorous	2
	O. morrisoni	Carnivorous	1
Mitridae	*Mitra lens*	Carnivorous	1
	M. tristis	Carnivorous	1
Terebridae	*Terebra panamensis*	Carnivorous	4
	Hastula luctuosa	Carnivorous	7
Bullidae	*Bulla rufolabris*	Carnivorous-Herbivorous	2
	B. punctulata	Carnivorous-Herbivorous	3
Siphonaridae	*Siphonaria gigas*	Herbivore	14

Table 2

Families, species and trophic categories of rocky coast mollusks at station two (mesolittoral floor).

Families	species	Trophic category	Total
Arcidae	*Anadara similis*	Filter	1
	Barbatia gradata	Filter	3
	B. rostae	Filter	1
	B. reeveana	Filter	2
Pteriidae	*Pinctada mazatlanica*	Filter	10
Ostreidae	*Ostrea conchaphila*	Filter	5
	O. iridescens	Filter	1
Crassatellidae	*Crassinella adamsi*	Filter	1

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Chamidae	*Chama echinata*	Filter	6
Veneridae	*Megapitaria aurantioca*	Filter	2
	Leukoma grata	Filter	7
	Tivela planulata	Filter	1
Fissurellidae	*Fissurella longifisa*	Herbivore	10
Acmaeidae	*Scurria stipulata*	Herbivore	4
	Collisella acetapex	Herbivore	6
Trochidae	*Tegula pelisserpentes*	Herbivore	10
	T. panamensis	Herbivore	4
	T. verrucosa	Herbivore	2
Turbinidae	*Astrea bushii*	Herbivore	4
	Turbo fluctuosos	Herbivore	1
Architectonicidae	*Architectonica nobilis*	Carnivorous	1
Littorinidae	*Littorina aspera*	Herbivore	4
	L. fasciata	Herbivore	1
Vermetidae	*Tripsycha tulipa*	Suspensivore	1
	Macrophragma petaloconchus	Suspensivore	1
Cerithidae	*Cerithium adustum*	Herbivore	1
	C. menkei	Herbivore	5
	C. uncinatum	Herbivore	2
Potamididae	*Cerithidea valida*	Herbivore	1
Ranellidae	*Cymatium vestitum*	Herbivore	2
Hipponicidae	*Hipponix grayanis*	Herbivore	5
Columbellidae	*Columbella sonsonatensis*	Herbivore	4
	C. labiosa	Herbivore	1
Nassaridae	*Nassarius corpulentus*	Scavengers	5
	N. angulicosta	Scavengers	1
Fasciolaridae	*Fasciolaria princeps*	Carnivorous	4
	Latirus centrifugus	Carnivorous	3
	L. tumens	Carnivorous	2
	Opeatostoma pseudodon	Carnivorous	10
Muricidae	*Muricanthus princeps*	Carnivorous	2
	Hexaplex erythrostomus	Carnivorous	2
	Murexiella keenae	Carnivorous	1

Table 3

Families, species and trophic categories of rocky coast mollusks at station three (sublittoral floor).

Families	species	Trophic category	Total
Turritellidae	*Turritella banksi*	Herbivore	1
	T. rubescens	Herbivore	1
	Vermetus fewkesi	Herbivore	1
Strombidae	*Titanostrombus galeatus*	Herbivore-Detritivore	10
Calyptraidae	*Crucibulum umbrela*	Herbivore-filter feeder	1
	Calyptraea mamillaris	Herbivore-filter feeder	1
Melongenidae	*Melongena patula*	Carnivorous	2
Conidae	*Conus gladiator*	Carnivorous	5
	C. fergunsoni	Carnivorous	2
	C. patricius	Carnivorous	3
	C. purpurascens	Carnivorous	4
	C. nux	Carnivorous	1
	C. dalli	Carnivorous	1

Regarding the degree of exposure to waves, in the protected locations a large quantity of algae and a greater number of herbivorous individuals were observed, represented mostly by the genera *Nerita*, *Fissurella*, *Tegula*, *Cerithium* and *Siphonaria*, while in the high energy areas (strong waves) the filter feeders of the genera *Pinctada*, *Ostrea*, *Chama*, *Donax* and *Protothaca* were more abundant; and the carnivores *Conus* and *Opeatostoma*.

Discussion

One of the richest ecosystems is rocky coastlines, because they are very practical natural laboratories to study ecological aspects, such as vertical distribution and biodiversity (Satyam and Thiruchitrambalam, 2018).

Gastropods had the most species, a result that agrees with what was described by Souza *et al*. (2020) for this type of ecosystem in tropical regions, which confirms the adaptability of the group for this type of coastline; this is well documented by Marval (1986), Jiménez et al. (2004) and Fernández-Malavé and Jiménez-Prieto (2007), in works carried out on rocky coastlines of Venezuela. For their part, Mille-Pagaza *et al*. (1994) add that this class of mollusks dominate in this ecosystem, due to their physiological and ethological adaptations that are favored by strong waves, they also avoid desiccation and solar radiation, with heat shock proteins, modifications in mitochondrial respiration and cardiac function, also behavioral adaptations such as aggregation, retraction of the foot into the shell or orientation of the shell and habitat selection, among others (Somero, 2002; Chapperon and Seuront, 2011; Miller and Denny, 2011).

In the analysis of mollusc populations, it was observed that the majority of species and individuals were obtained in the locations most protected from the waves (supralittoral and mesolitoral), and the fewest in the locations most exposed to the waves (sublittoral); these observations indicate that the characteristics of the substrate, consisting of small rocks, boulders and gravel; the low swell influenced by the incident wind, and the reduced tidal range in these shallow, calm waters, make it possible for a large number of species and organisms that have adapted to these coastal environments to establish themselves; positively influencing these indices, unlike the exposed locations where strong waves and the substrate formed by large rough rocks, with cracks and steep slopes affect, will not allow a greater abundance of species, but only the presence of the species most resistant to these exposed locations; according to Connell's model (1961), this distribution of mollusk populations is influenced by some factors that cause the distribution of organisms in the intertidal rocky substrates, in which the organisms found at the upper limit are located there by physical variables such as temperature and desiccation, while those found at the bottom by competition and predation, which are biological interactions.

The variability in the number of species in the three study locations is related to exposure to waves, which according to Lewis (1972) is the most influential factor in the presence and distribution of species on rocky coasts; in addition, Sevillano-Romero *et al*. (2022) indicate that in protected areas the number of species found is generally greater, because a limiting factor for some mollusks is the action of waves.

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The study shows that the trophic structure of the mollusk community seems to be defined based on the physical and environmental characteristics of each location; in this case, herbivores such as Nerita funiculata and N. scabricosta dominated the areas exposed to waves and strong incident winds, which makes it possible for the turgor event to be more noticeable in this area and, consequently, there is an enrichment of the water masses, which allows a greater contribution of organic matter and greater abundance of phytoplankton (Fukuoka, 1966; Rueda, 2000); this condition is used directly by filter-feeding organisms and indirectly by other organisms such as carnivores, which was the second most abundant group in these areas, through trophic networks; although for Dayton (1975) and Jiménez *et al*. (2004), this distribution of mollusks in trophic levels is controlled by the level of exposure to waves, the composition of the substrate, morphological adaptations and the morphological adaptations of each organism.

On the contrary, herbivores dominated in protected areas, possibly due to the less severe environmental conditions and the large amount of algae present in these locations, which is in agreement with the results observed by Olabarría *et al*. (2001) who observed that in the rocky coast of the Eastern Tropical Pacific, herbivores and algae dominated in locations protected from waves, indicating that the structure of rocky substrate communities is determined by complex interactions between biotic and abiotic factors.

Dayton (1975) and Menge and Sutherland (1976) indicate that biotic effects can be complex, ranging from grazing effects, carnivore/prey interactions and competition for space. The distribution of mollusks and the different trophic groups can be controlled by morphological adaptations, as well as the level of exposure to waves and the composition of the substrate (Dayton, 1975, Jiménez *et al*., 2004). Additionally, significant changes in the biomass and number of species of intertidal macroalgae are closely related to variations in the richness and abundance of mollusks when climatic periods are considered (Ojeda, 2012); furthermore,

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Beukema (1992) indicates that these climatic factors are very important in the variation of the structure of the benthos.

The complexity is associated with the increase of trophic groups where carnivores, filter feeders, suspension feeders and scavengers play a significant role (Bianchi and Morri 1985, Gambi and Giangrande 1985). Olabarría *et al*. (2001) indicate that the trophic complexity and spatial heterogeneity of the associations depend on the life history of each species.

Conclusion

The complexity of the trophic groups was greater in sites exposed to waves (mesolittoral and sublittoral), where herbivores, filter feeders and carnivores dominated, decreasing in the more protected sites (supralittoral), where carnivores and herbivores were more abundant. Regarding the trophic structure of the community, it´s defined by the degrees of exposure to waves, however, the absence of similar studies makes it difficult to make more precise qualitative and quantitative comparisons.

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