



Diversity of Gastropods (Gastropoda) in the Mangroves of El Libano, Province of Panama Oeste, Panama.

Diversidad de Gasterópodos (Gastropoda) en los Manglares de El Libano, Provincia de Panamá Oeste, Panamá.

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<https://doi.org/10.48204/j.mesoamericana.v28n1.a9672>

INFORMACIÓN SOBRE EL ARTÍCULO

Recibido: 15 de noviembre 2025 | Aceptado: 14 de enero 2026 |

DOI:

Como citar este documento: Córdoba González, Darío; Lopez, Susan and Fairchild Sánchez Nancy. 2026. Diversidad de Gasterópodos (Gastropoda) en los Manglares de El Libano, Provincia de Panamá Oeste, Panamá. *Mesoamericana* 28(1): 11-39.

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Contribución de los autor: El autor de este trabajo declaran haber participado en la realización de este proyecto de investigación en todas sus etapas, búsqueda de información y redacción del artículo.

Editor: Dr. Alonso Santos Murgas.

ABSTRACT

A study of the malacological fauna was carried out with the purpose of identifying the species of gastropods, in four stations of the Bay of Chame, Province of Panama Oeste. The samplings were carried out monthly for six months (July to December 2009), in the sampling stations were from the mangrove area of El Líbano, Punta San Juanito, Banco del Río Sajalices and El Banco Negro; these were cataloged according to the granulometry of the sediment as muddy, sandy and sandy-muddy; additionally, for the mangrove area in El Líbano, the trunks, root and mud substrates were considered. The organisms were obtained manually and immediately introduced into previously labeled plastic bags; Later the snails were separated for identification up to the category of species. For the substrates studied (trunk, root and mud) in Lebanon, analyses of the Shannon-Wiener diversity indices, Simpson predominance and Equitativity were presented. A total of 3322 individuals were collected distributed in 30 genera and 38 species; the most dominant were: *Cerithideopsis californica* (Haldeman, 1840) with n=1202,

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36.18%, *Littoraria varia* (G. B. Sowerby I, 1832) with n=644, 19.39%, and *Thaisella kiosquiformis* (Duclos, 1832) with n=542, 16.31%, the highest indices of diversity, abundance and homogeneous distribution were obtained in the mud substrate. In addition, El Líbano registered the highest abundance, however, it showed less diversity, compared to the other stations, with El San Juanito, Sajalices River Bank and The Black Bank being the stations with the highest diversity of species, which is related to the environmental characteristics of the area, such as currents and predominance of winds.

Keywords: abundance, Chame Bay, distribution, seasons, gastropods, substrates.

RESUMEN:

Se realizó un estudio de la fauna malacológica con el propósito de identificar las especies de gasterópodos, en cuatro estaciones de la Bahía de Chame, Provincia de Panamá Oeste. Los muestreos se realizaron mensualmente durante seis meses (julio a diciembre de 2009), en las estaciones de muestreo fueron de la zona de manglares de El Líbano, Punta San Juanito, Banco del Río Sajalices y El Banco Negro; estas fueron catalogadas según la granulometría del sedimento como fangosa, arenosa y areno-fangosa; adicionalmente, para la zona de manglares en El Líbano se consideraron los sustratos troncos, raíz y fango. Los organismos fueron obtenidos manualmente e introducidos inmediatamente en bolsas plásticas previamente etiquetados; posteriormente los caracoles fueron separados para su identificación hasta la categoría de especies. Para los sustratos estudiados (tronco, raíz y fango) en El Líbano se presentaron análisis de los índices de diversidad de Shannon - Wiener, Predominio de Simpson y Equitatividad. Se colectaron un total de 3322 individuos distribuidos en 30 géneros y 38 especies; las más dominantes fueron: *Cerithideopsis californica* (Haldeman, 1840) con n=1202, 36.18%, *Littoraria varia* (G. B. Sowerby I, 1832) con n=644, 19.39%, y *Thaisella kiosquiformis* (Duclos, 1832) con n=542, 16.31%, los mayores índices de diversidad, abundancia y con distribución homogénea se obtuvieron en el sustrato fango. Además, El Líbano registró la mayor abundancia, sin embargo, mostró menor diversidad, en comparación a las otras estaciones, siendo El San Juanito, Banco del Río Sajalices y El Banco Negro las estaciones con mayor diversidad de especies, lo cual está relacionado con las características ambientales de la zona, como corrientes y predominancia de los vientos.

PALABRAS CLAVES: abundancia, bahía de Chame, distribución, estaciones, gasterópodos, sustratos.

INTRODUCTION

Molluscs represent the second most numerous groups in terms of species and abundance, only

after arthropods. The number of species within the phylum Mollusca is estimated to range from 80,000



to 100,000. These organisms can adapt to various habitats, from oceanic environments to high mountainous regions, being especially abundant in coastal areas of tropical seas. Gastropods and bivalves make up 98% of the total mollusc population, inhabiting terrestrial, fresh, and marine ecosystems (Shanmugan & Vairamani, 1984).

In mangroves, the soil-associated mollusc fauna is predominantly composed of gastropods, which are the second most diverse animal class after insects. This is particularly true in tropical forests (Schilthuizen & Rutjes, 2001; Schilthuizen *et al.*, 2002). These snails live as ectofauna on specific substrates and have marine affinities. However, they can also tolerate brief periods out of the water during low tides and in intertidal conditions; notable examples include the families Littorinidae and Thaididae, which are commonly found in the aerial roots and trunks of mangroves (Flores, 1973).

The diet of gastropods includes living or decaying algae, as well as organic detritus and plant materials. Therefore, they play a crucial role in food webs (Houbriek, 1984; 1991; Plaziat, 1984; Kelaher *et al.*, 2007; Nagelkerken *et al.*, 2008). They are rich in protein and are considered a delicacy in several regions of Malaysia such as Sarawak (Hamli *et al.*, 2013). In places like Brunei, Thailand, and Indonesia, they are an integral part of the local diet (Nursalwa, 2016; Sri-Aroon *et al.*,

2004; Burgos, 2016). They can be classified according to their habitat as epifauna that lives on solid surfaces or trees that reside in vegetative areas. From a unique ecological perspective, these gastropods occupy extremely varied habitats, unlike other larger metazoans (Dayrat *et al.*, 2011; Webb, 2012). Cantera *et al.* (1983) documented the global presence of 277 species associated with mangroves.

Sea snails have multiple functions: they serve as environmental indicators, participate in biofiltration and water purification processes, as well as being accessible sources of protein-rich food. They also support significant fisheries and provide information for paleontological studies (Giam *et al.*, 1987; Hoi-Chaw *et al.*, 1984). In addition, they are a source of nutrition for various birds and positively influence aquatic food chains (Amarasinghe *et al.*, 2021; Moradi *et al.*, 2019). Snails provide valuable calcium to seabirds and reptiles during all their life stages. Its role is also essential for organic decomposition along with soil microbial regulation, contributing significantly to terrestrial nutritional cycles (Rinehart *et al.*, 2021; Shriver *et al.*, 2021; Wang *et al.*, 2023).

The habitats where these snails reside include saline or brackish waters, as well as estuaries and rocky intertidal zones among other sandy subtidal environments (Han *et al.*, 2024; Harzhauser *et al.*,



2023). They have a prominent role within the nutrient cycle within the mangrove ecosystem due to the high malacological diversity present there (Ernawati *et al.*, 2024; Ebadzadeh *et al.*, 2024). The predominant families observed include Neritidae, Muricidae, Nassariidae and Ellobiidae (Yadav *et al.*, 2019), while sandy beaches or coral reefs offer ideal refuges for them with common specimens such as *Oliva* sp. and *Conus* sp. (Rajendra & Sivaperuman, 2020; Sujarta *et al.*, 2022).

Mangroves extend along many coasts and are considered one of the most productive ecosystems globally (Berger *et al.*, 2008). For gastropods, this environment is essential since it provides areas conducive to reproduction, breeding, as well as safe food against natural predators (Vermeij, 1973; Plaziat, 1984; Reid, 1986; Plaziat *et al.*, 2001; Lozouet & Plaziat, 2008; Reid *et al.*, 2008; Reid *et al.*, 2010). The total area covered by mangroves has seen a considerable decrease from approximately 170,000 km² in 2001 to 150,000 km² in 2008 (Valiela *et al.*, 2001; Alongi, 2008).

Within the field of marine ecology, mangroves stand out among tropical ecosystems since they form key subsystems within estuaries, bays, lakes (Cintrón & Schaeffer-Novelli, 1983). Ecologically, they are of great relevance since they offer quiet areas with high productivity, being optimal

scenarios for diversified sustainable management, species many require firm substrates to be fixed; including molluscs, mainly snails; creating dense populations, forming groups, generating microhabitats, favoring growth and providing protection to a wide variety of organisms (Márquez & Jiménez, 2002). This environment represents an essential habitat that provides food, reproduction, and protection against predators (Wiraatmaja *et al.*, 2022; Islamy & Hasan, 2020). Mangroves are defined by their coastal location near mouths, rivers, lagoons, estuaries and muddy terrain; tropical and subtropical (Lacerda *et al.*, 2001). In Panama, they cover approximately 5.6% of the national forest cover or around 172,000 hectares and are mostly located on the Pacific coast (166,318 hectares) and 5,858 hectares of the Caribbean Sea (Berdiales *et al.*, 2009).

Biodiversity within a mangrove ecosystem is determined primarily by the richness of malacofauna (Plaziat, 1984), distribution patterns (Neweell, 1958), and density in response to the environment (Petraits, 1982); they are regulated by physicochemical parameters such as: salinity (Flores, 1973), temperature, seasonal changes and soil composition. Nutrients from the early fall or death of leaves determine the representation of zoological groups present here. Like predation, competition for food availability and biotic factors that affect biomass (Connell, 1961; Haven, 1971)



limit distribution. Other correlated factors are degrees of exposure (Field & McFarlane in Fran in Franz, 1976) and distance from the coast (Hughes & Thomas in Franz, 1976).

Globally, numerous descriptive studies have been carried out on various aspects of mangrove faunal ecology, some focusing on the fauna of Pelecypoda and Gastropoda molluscs; analyzing the distribution, zone of relative abundance, density, dominance, diversity, annual population fluctuations and the substrate-vegetation association (Emmen & Tejada, 1984).

Various works mention the fauna associated with mangrove roots in different parts of the world, an example we have in Anónimo (1969), who classified biotopes of the mangrove community according to dominant floristic faunal components. Coomans (1969) studied biological aspects of molluscs associated with mangroves in the West Indies. Inclán (1989) conducted research on epibiosis ecology in submerged roots of *Rhizophora mangle* Linnaeus in Ascension Bay, Mexico. Lalana *et al.* (1985), Lalana (1986) and Lalana and Ortiz (1992) investigated the fauna associated with mangroves in the coastal lagoons of Cuba. Castaing *et al.* (1980) conducted ecological observations on the Pacific coast of Costa Rica in relation to the distribution of *Geloina inflata* (Philippi, 1847) Victoria and Pérez (1979),

Anónimo (1880), Reyes and Campos (1992 a, b) analyzed macroinvertebrates colonizing the roots of *R. mangle* in the Colombian Caribbean.

In Panama, mangroves are essential, as they dominate coastal vegetation. The coverage of mangroves on the Panamanian coasts has been estimated between 1600-1700 square kilometers, being the highest in the Central American region, seeing the proportion between the mangrove and the continental territory; a world-renowned figure (D'Croz & Kwincinski, 1979). There are local human communities on both the Caribbean and Pacific coasts, living and depending on the resources of the mangrove swamp, where degradation occurs due to different causes, some causing a great loss of their forest areas (Guevara-Mancera *et al.*, 1998; Ulloa-Delgado *et al.*, 1998).

Research has been carried out in Panama with respect to the mollusc fauna, highlighting the works Tejera and Avilés (1976); Tejera *et al.* (1980) presenting the list Gasterópoda, Pelecypoda, Aguadulce district, Chiriquí province, respectively; but there are others carried out in specific areas of the Pacific coast such as Avilés: Panamanian malacological fauna Punta Paitilla (1981a); Molluscs San Carlos (1981b); Santa Catalina Veraguas (1983a); Molluscs from Santa Catalina beach, in the province of Veraguas (1983a); Molluscs coastal waters of the municipality of La



Ensenada and La Esmeralda and Isla del Rey in the Pearl Archipelago (1986b) and taxonomic list of bivalves (1991); Avilés and Tejera: bivalve gastropods Aguadulce (1975); Avilés et al.: Classification of molluscs (1981); Inventory of Freshwater Bivalves (1976); mollusks of Bique Bay, district of Arraiján, province of Western Panama (1983) and biogeographic distribution of the Pacific (1986); Diéguez (1982): Ecophysiology of Bivalve Molluscs: Zoogeographic Categories of the Panamanian Malacological Province (1986); Contribution to the study of gastropods and bivalves on the Pacific coast of the Republic of Panama, (1991). Emmen & Tejada (1984): Study of Distribution Abundance Diversity Pelecypoda Gastropod Mangrove Aguadulce District. Arrunategui (1995): Macromollusks of the Chiriquí Lagoon and adjacent areas. Vásquez (1995): Pelecypoda and Polyplacophora mollusks from Achotines Bay in Pedasi. Gil and Pérez (1996): Malacological inventory (classes: Bivalvia, Gasterópoda and Polyplacophora in Islas Leones de la provincia de Veraguas; Lombardo and Martínez (1999): Abundance and Distribution of molluscs (Pelecypoda Gasterópoda) Playa Juan Hombrón Antón Coclé province.

Panama shows extraordinary malacological richness, highlighting the existence of approximately 1222 known gastropods (Avilés,

1991). This has aroused interest in the area allowing data to be obtained reflect logical status (mangroves emphasizing importance mollusks given pressure some species given economic relevance country especially units directly depend indirectly on these natural resources.

This work is fundamental, contributing to a better understanding of populations, mollusks (gastropods), mangroves, Panamanian Pacific, obtaining necessary information, establish criteria, development, plans, management, integrated management (ecosystems), mangrove, oriented, sustainable use, conservation of resources, ensuring orderly management, preserving biodiversity, ecological functions. The latter becomes important if current trends persist in the face of inevitable changes, they will affect coastal area generated landfills, construction, tourism projects, altering the physical appearance of the area, its ecology. Environmental modifications impact animal behavior affecting distribution abundance diversity reasons identify species snail associated ecosystem; Lebanon adjacent areas Chame Bay Panama West Province, will determine distribution of mollusk species (mangrove) sites comparative sampling potentially shared localities evaluating those economically relevant bivalves employing human communities (mangrove mentioned above.)

MATERIAL AND METHODS

Description of the study area

The research was carried out specifically in four localities: the collection stations according to their locality were: El Líbano: located between 8° 39' 35" N and 79° 49' 45" W; it is characterized by a large mangrove area, where the presence of water is subject to daily intertidal changes. The vegetation is mainly composed of species. *R. mangle* and *Avicennia germinans* Linnaeus (white mangrove, black mangrove or black mangrove). Punta San Juanito: located between 8° 40' 38" N and 79° 45' 59" W; it has a meadow of *R. mangrove* less dense than the town and whose coastline has rocky areas with sandy and muddy beaches. Sajalices Riverbank: located between 8° 40' 39" N and 79° 45' 60" W; It is an estuarine area, made up of beaches that are exposed during periods of low tides. The Black Bass: located between 8° 39' 00" N and 79° 48' 48" W; Chame Bay area with muddy substrate belonging to the estuarine zone of the outer part of the mangrove (Fig. 1).

Figure 1.
Collection sites in Lebanon, adjacent areas, Chame Bay, West Panama Province.



In the study sites there are some human settlements dedicated mainly to artisanal fishing, shrimp farming, the extraction of mangroves as a source of forest products (firewood, sticks, wood and charcoal) and the extraction of molluscs mainly for trade and consumption. The substrate was qualitatively determined by tactile manipulation, resulting in heterogeneous organic matter where mud (clays and silts), sand and decomposing materials constitute its main elements (Cintrón & Schaeffer - Novelli, 1983).

Fieldwork

Malacological material was collected at random in areas established as sampling sites and included sandy and muddy coastlines (D'Croz & Kwincinski, 1979); or combinations thereof; for a period of six months (from July to December 2009) always during the day, mainly during the hours of low tide. To plan the dates and times of collection, the tide prediction tables for the Pacific of Panama (ACP, 2009) were used.

In the Mangrove Zone of Lebanon, the collections were made randomly in a transect of 375 meters, choosing a mangrove every 25 meters and following the mainland line to the vicinity of the beach to sample in each of them the substrates where we found associated molluscs: root and mud.



In total, 15 mangroves were sampled in four samplings (tours) to the study area.

In Lebanon and adjacent areas, a direct search for each organism was carried out in an area of approximately 10 m², an area that was divided into smaller units of one m²; the macroscopic bivalves found in the areas of San Juanito, Sajalices River Bank and The Black Bass were collected for subsequent transfer to the laboratory where they were identified and added to an inventory of the malacofauna of the area. All the samples obtained (specimens) were deposited in plastic bags and identified with a field label with the following data: date, location and substrate and then transferred to the laboratory for taxonomic identification.

Lab work

The individuals collected were identified by species using specialized taxonomic literature, particularly with works by Kenn (1971), Abbott (1974), Cruz and Jimenez (1994). In addition, the specimens were morphologically compared with existing in the national reference collection of the Museum of Malacology of the University of Panama (MUMAUP). The identified species were also photographed using a Samsung S860 camera of 8.1 megapixels. Finally, the most representative identified species were processed and labeled for their subsequent location in the MUMAUP, as a reference collection with their respective voucher.

Diversity analysis

Once the identification of the organisms was completed, we proceeded to count the total number of snails species and the number of individuals of each species to determine the diversity and abundance of the class present at each sampling station. The data were organized into tables to determine the relative abundance of each species in the different seasons, as well as the most abundant species in all seasons. The information obtained was processed using the Shannon-Wiener (H'), Evenness or Equity (J'), Species Richness (S), Simpson Index (D') and Jaccard Similarity (to determine the specific and total diversity), the distribution or frequency of individuals in each species, the predominance of species and the degree of similarity of the environments. The equations used and the definitions are described according to Odum (1972) and Krebs (1978); all analyses were performed using the free Paste program.

RESULTS AND DISCUSSION

Four localities located in Chame Bay were analyzed: El Líbano, San Juanito, Sajalices Riverbank and The Black Bass, registering a total of 3322 individuals distributed in 30 genera and 38 species of the class Gasterópoda (see Table 1). Likewise, 10 species of snails of commercial interest were identified throughout the mangrove area of Chame Bay, all previously documented by



Diéguez and Avilés (1981). Of the 167 species of mollusks recorded in mangrove areas for the Pacific coast of Panama, 22% of snail species correspond to habitats influenced by the mangrove ecosystem in this study, which highlights the relevance of the malacological fauna of this area.

The data on the species of snails present in this mangrove are comparable to the results obtained in previous research carried out by González (1983), who carried out a preliminary inventory of mollusks in the districts of Soná and Las Palmas, documented 63 gastropods; Avilés (1983a, 1984b) carried out a malacological inventory in Ensenada Santa Catalina (Soná district) with a total collection of 97 Gasterópoda. Emmen and Tejada (1984) studied the distribution, abundance and diversity of Pelecypoda and Gastropods in a mangrove swamp in the Aguadulce District, reporting 17 gastropods; Gil and Pérez (1996) carried out an inventory in various areas of the Gulf of Montijo such as Isla Leones and Tres Islas with a total of 100 gastropods; San Martín *et al.* (1997) mentioned 31 Gasterópoda for the Coiba National Park; in addition, González (1999) studied mollusks from the Restingue Coast (Montijo district), finding 60 gastropods.

Adding the three substrates, a total of 2700 individuals were collected (n=569, 21.15% trunks, n=661, 24.57% root and n=1460, 54.27% mud), the

best represented snails were *Cerithideopsis californica* (Haldeman, 1840) with n=1202, 44.68%, followed by *Littorina varia* (G. B. Sowerby I, 1832) with n=644, 23.94% (Fig. 2) and *Thaisella kiosquiformis* (Duclos, 1832) with n=542, 20.07%; the species with the lowest record of individuals were: *Cerithideopsis montagnei* (A. d'Orbigny, 1839) with n=38, 1.41% (Fig. 2) and *Littoraria aberrans* (R. A. Philippi, 1846) with n=3, 0.11% (see Table 2); according to Day *et al.* (1989), mangrove areas are characterized by a high rate of primary production which contributes to food for organisms that feed on the water and sediment column. The substrate of mangrove ecosystems gives organisms the facility to obtain a greater amount of nutrients; however, they must develop physiological adaptations to changes in salinity, temperature, high oxygen demand, and predation caused by other organisms (Yañez-Arancibia, 1986).

Evaluation according to sampling site:

El Libano

This mangrove is mainly composed of roots from the mangrove, presenting clearly different characteristics from other substrates analyzed. A total of 2504 individuals were recorded collected grouped into 8 species, the best represented gastropods were *C. californica* (n=1191, 47.56%), followed by *L. varia* (n=632, 25.24%) and *T. kiosquiformis* (n=533, 21.29%); the species with

the lowest individual records were: *C. montagnei* (n=38, 2.12%), *Littoraria zebra* (Donovan, 1825) and *L. aberrans* (n=3, 0.11%) see Table 1. These species inhabit this area due to their rich organic source; during high tides they can take advantage of plankton rich in microalgae necessary for their food (Emmen and Tejada 1984). Berry (1963) argues that this probably results from the specific dietary requirement related to their larval methods based on planktonic colonization.

Figure 2.

On the left is *Littorina varia* (G. B. Sowerby I, 1832) and on the right *Cerithideopsis montagnei* (A. d'Orbigny, 1839), specimens that rest in the reference collection of the Museum of Malacology of the University of Panama (MUMAUP).



San Juanito

This locality is characterized by its sandy-muddy soil; the resident species must burrow for possible threats by staying connected to the surface by siphons. A total of 576 specimens were recorded, grouped into 18 species. The most abundant snails belong to *Nerita funiculata* (Menke, 1851) with n=186, 32.29%, followed by the species *L. zebra* (n=164, 28.47%), *Phrontis luteostoma* (Broderip & G. B. Sowerby I, 1829) with n=70, 12.15%, and

Anachis rugosa (Sowerby, 1832) with n=60, 10.41% (see Table 1). These species are organisms belonging to the intertidal zone that react to a wide range of environmental variables that tend to restrict them to certain areas on the coasts (Meadow and Campbell in Spigth 1977). When making a comparison with the studies carried out on the Pacific coast of Veragua, we have that Gil and Pérez (1996) in Isla Leones, found 97 species, highlighting the *N. funiculata*. González (1999) found a total of 60 species of Gastropod on Restingue beach, of which *N. funiculata*. In addition to these studies, it is important to mention the study carried out by Pérez and Vásquez (2000) on Isla Coiba who found 235 species, the most dominant being *N. funiculata*. Flores and Morales (2001) in Santa Catalina, found 145 species of gastropods, the most abundant species being *N. funiculata*.

The species *Crepidula excavata* (Broderip, 1834), *Pilsbryspira albinodata* (Reeve, 1846) and *Vitta luteofasciata* (K. Miller, 1879) were found only one specimen for each; most reside generally adjacent to the forest buried within small drainage channels into estuaries and are collected at low tides; according to Cruz and Jiménez (1994) this is because these species are not found more frequently in these types of species. environments and substrates.



Sajalices River Bank

A sandy substrate was observed in this locality; the class Gastropoda here is represented by a total of 66 individuals of 14 species and 12 genera, where the species with the largest number was *N. unifasciata* (n=22, 33.33%), followed by *Calyptreaea conica* Broderip, 1834 (n=16, 22.22%), (see Table 1). These species are common on sandy beaches, or are found attached to other shells or solid objects. The species with the lowest record of individuals were: *Crepidula incurva* (Broderip, 1834), *Drillia* sp., *Phrontis complanata* (Powys, 1835), *Semicassis centiquadrata* (Valenciennes, 1832) and *Thaisella kiosquiformis* (Duclos, 1832) with n=1, 1.51%, which were mainly located in the external part of the forest or on the roots in the mangrove swamp (see Table 1). This type of environment is subject to alterations by the action of wind and waves, which does not provide a good anchor for the attachment of these species to the substrate, as reported by Tait (1970). This occurs because similar environments do not offer ideal conditions for growth/development since the previous ones are specifically adapted to soft outer seabeds, mangroves.

In addition, Mate *et al.* (1994) argue that substrates such as sand, sometimes in areas that absorb the impacts of strong waves, protect the coast, benefiting agile organisms, slow organisms that create small tunnels in order to survive (Rodríguez,

1972); also Mate *et al.* (1994) find that these species live and move between the grains of sand with vertically synchronized tides. Vegas (1971) mentions that wave actions, sun exposure, and drying act uniformly on sandy beaches. The establishment of life in this type of substrate depends essentially on the amplitudes of the tides, while indicating that the sands mitigate and the variations of abiotic factors such as salinity/temperature, all this influence the existence of organisms and their adaptations to this type of substrate.

The Black Bass

Characterized by being a muddy bank where 176 individuals of snails were collected grouped into 15 species and 14 genera. The best representations corresponded to *C. excavata* (n=50, 28.41%), *Rhinocoryne humboldti* (Valenciennes, 1832) with n=35, 19.89%, and *Phrontis luteostoma* (Broderip & G. B. Sowerby I, 1829) with n=24, 13.64%, were the best represented species. These species are typical on mudbanks and on sand, usually near the high tide line, and in sites where water runs off at low tide (Cruz and Jiménez, 1994). The species with the least abundance were *Crucibulum concameratum* Reeve, 1859, *Diodora alta* (C. B. Adams, 1852), *Granolaria salmo* (W. Wood, 1828), *Monoplex wiegmanni* (Anton, 1838) and *Natica unifasciata* (Lamarck, 1822) with n=1, 0.57% (see Table 1). Possibly their low number is

since some of the species are generally associated with the roots of the red mangrove.

Table 1.

Distribution, diversity and abundance of species of gastropod mollusks collected in Chame Bay, Province of Panama.

CLASS GASTEROPODA						
Species	Location	El Libano	San Juanito	Sajalices River Bank	Black Bass	Total
	<i>Anachis rugosa</i> (Sowerby, 1832)		0	60	0	0
<i>Calyptrea conica</i> Broderip, 1834		0	2	16	21	39
<i>Calyptrea mamillaris</i> Broderip, 1834		0	0	2	0	2
<i>Cerithideopsis montagnei</i> (A. d'Orbigny, 1839)		38	0	0	0	38
<i>Cerithideopsis californica</i> (Haldeman, 1840)		1191	0	0	11	1202
<i>Cerithium stercusmuscarum</i> (Valenciennes, 1833)		0	4	0	0	4
<i>Cosmioconcha modesta</i> (Powys, 1835)		0	33	0	6	39
<i>Cotonopsis turrata</i> (G. B. Sowerby I, 1832)		0	8	0	2	10
<i>Crepidula incurva</i> (Broderip, 1834)		0	0	1	0	1
<i>Crepidula excavata</i> (Broderip, 1834)		0	1	0	50	51
<i>Crucibulum concameratum</i> Reeve, 1859		0	0	0	1	1
<i>Crucibulum personatum</i> Keen, 1958		0	0	4	0	4
<i>Diodora alta</i> (C. B. Adams, 1852)		0	0	2	1	3
<i>Drillia sp.</i>		0	0	1	0	1
<i>Granolaria salmo</i> (W. Wood, 1828)		0	0	0	1	1
<i>Littoraria aberrans</i> (R. A. Philippi, 1846)		3	0	0	0	3
<i>Littoraria varia</i> (G. B. Sowerby I, 1832)		632	12	0	0	644
<i>Littoraria zebra</i> (Donovan, 1825)		3	164	0	0	167
<i>Marinula concinna</i> (C. B. Adams, 1852)		38	0	0	0	38
<i>Melampus carolianus</i> (R. P. Lesson, 1842)		66	0	0	0	66
<i>Monoplex wiegmanni</i> (Anton, 1838)		0	0	3	1	4
<i>Nassarius wilsoni</i> (C. B. Adams, 1852)		0	15	0	0	15
<i>Natica unifasciata</i> (Lamarck, 1822)		0	0	22	1	23
<i>Neoterebra glauca</i> (Hinds, 1844)		0	0	4	0	4
<i>Nerita funiculata</i> (Menke, 1851)		0	186	0	0	186
<i>Nerita scabricosta</i> (Lamarck, 1822)		0	4	0	0	4
<i>Notocochlis chemnitzii</i> (L. Pfeiffer, 1840)		0	2	3	0	5
<i>Olivella volutella</i> (Lamarck, 1811)		0	0	3	0	3
<i>Parvanachis nigricans</i> (G. B. Sowerby I, 1844)		0	5	0	0	5
<i>Phrontis complanata</i> (Powys, 1835)		0	11	1	3	4
<i>Phrontis luteostoma</i> (Broderip & G. B. Sowerby I, 1829)		0	70	0	24	94
<i>Pilsbryspira albinodata</i> (Reeve, 1846)		0	1	0	0	1
<i>Polinices uber</i> (Valenciennes, 1832)		0	0	2	3	5
<i>Prunum sapotilla</i> (Hinds, 1844)		0	0	0	16	16
<i>Rhinocoryne humboldti</i> (Valenciennes, 1832)		0	0	0	35	35

<i>Semicassis centiquadrata</i> (Valenciennes, 1832)	0	0	1	0	1
<i>Thaisella kiosquiformis</i> (Duclos, 1832)	533	8	1	0	542
<i>Vitta luteofasciata</i> (K. Miller, 1879)	0	1	0	0	1
Total	2504	576	66	176	3322
Species	8	18	15	15	56

Table 2.

Mollusc species identified in Lebanon, according to the type of substrate.

Species	Trunk	Root	Mud	Total individuals per species
<i>Cerithideopsis californica</i>	5	5	1,192	1202
<i>Cerithideopsis montagnei</i>	3	4	31	38
<i>Littoraria aberrans</i>	1	1	1	3
<i>Littoraria varia</i>	306	232	106	644
<i>Littoraria zebra</i>	103	61	3	167
<i>Marinula concinna</i>	0	0	38	38
<i>Melampus carolianus</i>	0	0	66	66
<i>Thaisella kiosquiformis</i>	151	368	23	542
Total Individuals	569	671	1460	2700
Total species	6	6	8	20

According to Tait (1970) the needs for life in the air and in the water are so different that each organism does not meet the sufficient conditions to live at any level of the coast. The different levels are therefore occupied by different groups of animals and plants; each species occurs more abundantly over a particular area where conditions are the most favorable for them; in addition, sandy and muddy substrates host species that escape the mechanical action of waves and the effects of desiccation; To escape this, they bury themselves in the ground. Sand is more unstable, while mud, which is deposited in more protected places, is more stable (Rodríguez, 1967).

According to Caicedo (1984) factors such as: the type of substrate, the influence of the amount of

light, the substrate itself that is determined by the action of the waves; the waves and the degree of organic sedimentation present, both of detritus and planktonic organisms, which constitute food for the microphagous forms and for the filter organisms of the area, at the same time the presence of sedentary and wandering organisms of different groups, which do not constitute an eminent danger to the filter organisms of the area; They may be involved in the abundance, distribution or zonation of the populations of these mollusk's in the different types of substrate.

Diversity Analysis

After identifying the organisms, we carry out a total count of gastropod species and the number of individuals per species to assess the diversity and



abundance of this class at each sampling station. The data were organized in tables, which allowed establishing the relative abundance of each species in the different seasons, as well as identifying the most prevalent species in all of them. The information collected was analyzed using the Shannon-Wiener (H'), Evenness or Equity (J'), Species Richness (S), Simpson Index (D') and the Jaccard Similarity Index, in order to determine both specific and general diversity, as well as the distribution or frequency of individuals by species, the predominance between them and the degree of similarity between environments. The formulas used and their definitions are described according to Odum (1972) and Krebs (1978); all analyses were performed using the free Paste software.

Through the statistical analysis carried out, we observed that the diversity of the bivalve species detected in this area of the mangrove is lower compared to records obtained in other places in the Pacific near the Bay of Chame. For example, Playa Venado reported 37 species (Shasky, 1975), Bahía Bique had a total of 121 species (Avilés *et al.*, 1983), Veracruz recorded 73 species (Avilés, 1986a), and San Carlos had more than 200 species (Diéguez, per. comm., 1997; cited in Acosta and Lima, 1997). This suggests that the variation observed between individuals during high and low tides is related to specific tolerances to desiccation (Margalef, 1967). Each species requires conditions

to establish itself in a given area, which regulates its distribution under environmental parameters such as temperature, salinity and favorable sedimentary characteristics (Pérez-Farfante, 1971).

The soil diversity index was determined using the Shannon-Wiener function, resulting in $H' = 1.374$ bits for the root substrate with an intermediate value $H' = 1.08$ bits. When evaluating the diversity according to substrate type, it was found that the soil biotope hosts a greater number of individuals and presents a higher diversity compared to other substrates analyzed within the El Líbano mangrove (Table 3). Some researchers have pointed out that these findings are common in other mangroves and depend significantly on specific environmental conditions present in these ecosystems. Hernández and Davis (1979) argue that the low rates observed are representative for certain mangrove habitats. Meadows and Campbell cited by Spight (1977) indicate that many organisms limit their activities to favorable habitats; therefore, their distribution is conditioned by habitat selection, which may restrict them to specific coastal areas. Significant differences in distribution have been observed between the various species according to substrates within the same mangrove. According to Spight (1977), each mangrove represents a complex habitation association where both abundance and diversity vary depending on the habitat.



The observed difference in the distribution between individuals during high versus low tides is linked to the maximum tolerable level of desiccation by each specific group (Margalef, 1967). Each species has essential requirements to survive in a specific area; its distribution then depends on factors such as environmental temperature, salinity and environmental properties together with sedimentary characteristics suitable for its development (Pérez-Farfante, 1971). In addition, it was noted that the 38 species identified were not consistent across three different localities.

The highest diversity indices corresponded to Sajalices River Bank and Black Bass with values $H' = 3.258$ and $H' = 3.021$ respectively; while Lebanon showed the lowest values $H' = 1.374$ and San Juanito $H' = 2.58$ as indicated in Table 3. The substrate present within the mangrove swamp reflected less variety, possibly due to the increase in sedimentation generated by organic waste accumulated daily; He also cites Jackson (1972), who mentions how Mollusca diversity is linked to environmental variations such as temperature, turbidity, salinity, pH and water. Dexter cited by Diéguez *et al.* (1995) highlights significant differences with respect to Mollusca distribution between localities attributable to structural water changes, including exposure to waves and floods, together with biotic factors such as predation or food availability; while Paine, cited by Bakus

(1968), warns about how this biodiversity is directly related to how predators prevent monopolies on essential resources.

As has been evidenced up to this point, there is a variable biodiversity between different types of substrates studied, frequently influenced by their specific composition, although also affected by various factors according to Caicedo (1984), such as substrate type, light received, influences, waves, in addition to the degree of organic sedimentation present, either detritus or planktonic algae, essential for microphages or local filter organisms; In addition, sedentary or wandering organisms can potentially affect the abundance of population zonation related to these molluscs depending on the particular type of substrate. According to Vegas (1971), determining factors include amplitude, tide, intensity, waves, material, affect specific quality, dispersion.

Research carried out by Newell cited Garrity (1984), indicates less influential abiotic conditions organisms inhabit three-dimensional habitats sand mud compared to those present other types coasts; therefore, bivalve infaunals stand out, adapting efficiently to environments, being common to find Nassaridae, Olividae and Terebridae among others. Ortega (1986) mentions community variety, varies related aspects, type of substrate, exposed, risks,



dehydration, predation, available time, feeding, plankton.

The Simpson(D') Index

It revealed high values corresponding to localities San Juanito, Sajalices River Bank and Black Bass: $D'=0.8859$, $D'=0.9396$, $D'=0.9354$ respectively; where Lebanon presented $D'=0.654$, this minimum being obtained (Table 3). High values suggest the absence of clear predominance of some species; good distribution occurs; in contrast to D' observed Lebanon indicates dominance some species present explaining this Margalef (1995) argues if community shows numerically dominant against

other diversities such evidence community Lebanon is low.

Finally, equal values range from $J'=0.5208$ to $J'=0.851$, with maximums corresponding to Banco Río Sajalices to Bajo Negro ($J'=0.851$ and $J'=0.7983$ respectively); minimums found El Líbano San Juanito with $J'=0.5208$ $J'=0.7146$ respectively (Table 3). Equity measures how individuals distribute different species, results show slight superiority over 50%. In general, low values suggest the possible presence of some dominant lesions during the study.

Table 3.
Species diversity indices for the different collection stations in Chame Bay.

	El Líbano	Punta San Juanito	Sajalices River Bank	Black Bass
Individuals	1481	799	225	689
Riqueza (S)	14	37	46	44
Sbannon - Wiener (H') (beis)	1.374	2.58	3.258	3.021
Simpson (D')	0.654	0.8859	0.9396	0.9354
Equidad (J')	0.5208	0.7146	0.851	0.7983

Commercial Relevance of Molluscs

In the current context, snails are of commercial importance, whether they are human consumption, food, other species, sale, local markets. In addition, shells are used decorative elements of artisanal production. 10 species of gastropods were collected, highlighting *T. kiosquiformis* (n=532, 6.35%) *N. funiculata* (n=186, 6.35%) best represented (see Tables 1 and 4). These collected estuarine areas, sandy-muddy bottoms. Various species snails'

fundamental source of protein represents considerable economic resource coastal communities, both intended for human consumption (Squires *et al.*, 1975; Villalobos & Baéz, 1983).

Recent degradation of mangrove habitats has led to reduced catches of species inhabiting aerial roots and intertidal mudbanks. Despite this, the total number of exploited tends to increase;



currently experiments artificial crops various areas west coast Central American South America seek to counteract negative effects caused by overexploitation pollution (FAO, 1995).

well as geographical and temporal differences in sampling. According to Tait (1970), the fundamental needs of both terrestrial and aquatic are so different that no organism is capable of adapting to any specific coastal level; therefore, each stratum is occupied by diverse faunal and floristic groups where each species shows greater abundance under particular optimal conditions.

Table 4.
Commercially important mollusc species found in Chame Bay.

CLASE BIVALVIA			
Family	Species	Common Name	Usefulness
Calypttraeidae	<i>Calypttraea mamillaris</i>	Snail Beanie	1
Cerithiidae	<i>Cerithium stercusmuscarum</i>	Snail	2
Fasciolaridae	<i>Granolaria salmo</i>	Snail / Comet	2
Cymatiidae	<i>Monoplex wiegmanni</i>	Snail	2
Neritidae	<i>Nerita scabricosta</i>	Cherelé / Chelelé / Burgao	1
	<i>Nerita funiculata</i>	Cherelé / Chelelé	1
Naticidae	<i>Notocochlis chemnitzii</i>	Burgao	1
	<i>Polinices uber</i>	Moon Snail	2
Cassidae	<i>Semicassis centiquadrata</i>	Snail	2
Muricidae	<i>Thaisella kiosquiformis</i>	Snail	2

*Meaning of numerical code: 1- meat for human consumption
2- Snails and shells used in handicrafts and as an ornamental piece

CONCLUSIONS

The present analysis indicates that several localities contain both rare and common species, with a higher concentration in certain areas, possibly due to more favorable conditions. Information collected from various areas of the Panamanian Pacific can be related to the physical and chemical characteristics of Chame Bay. This bay provides a wide environmental range that generates different types of habitats (sandy, sandy-muddy and rocky). In addition, it serves as a refuge for the juvenile development of numerous species; However, comparing data between different investigations can be complex due to variations in the methods used, as

ACKNOWLEDGMENTS

We want to thank from the bottom of our hearts, the staff of the Museum of Malacology of the University of Panama (MUMAUP) and the entire resident population of the mangrove town of El Líbano.

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