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Diversity of Bivalves (Pelecypoda) in the Mangroves of El Líbano, Province of Panama Oeste, Panama.

Diversidad de Bivalvos (Pelecypoda) en los Manglares de El Libano, Provincia de Panamá Oeste, Panamá.

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ABSTRACT:

A study of the malacological fauna was carried out with the purpose of identifying the species of bivalves, in four stations of the Bay of Chame, Province of Panama Oeste. Samplings were carried out monthly for 6 months (July to December 2009), in the sampling stations were from the mangrove area of El Líbano, Punta San Juanito, The Sajalices River Bank and The Black Bass; these were cataloged according to the granulometry of the sediment as muddy, sandy and sandy-muddy; additionally, for the mangrove area in Lebanon, root and mud substrates were considered. The organisms were obtained manually and immediately introduced into previously labeled plastic bags; Later, the bivalves were separated for identification up to the category of species. For the substrates studied (root and mud) in Lebanon, analyses of the Shannon-Wiener diversity indices, Simpson predominance and Equitativity were presented. A total of 961 individuals were collected, grouped into 28 genera belonging to the class Bivalvia; 52 species were identified; the most abundant were: *Leukoma asperrima* (212), *Iliochione subrugosa* (85) and *Dosinia dunkeri* (78), 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 The Sajalices River Bank and The Black Bass 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, bivalves, distribution, seasons, substrates.

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RESUMEN:
Se realizó un estudio de la fauna malacológica con el propósito de identificar las especies de bivalvos, en cuatro estaciones de la Bahía de Chame, Provincia de Panamá Oeste. Los muestreos se realizaron mensualmente durante 6 meses (julio a diciembre de 2009), en las estaciones de muestreo fueron de la zona de manglares dé El Líbano, Punta San Juanito, Banco del Río Sajalices y El Bajo 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 raíz y fango. Los organismos fueron obtenidos manualmente e introducidos inmediatamente en bolsas plásticas previamente etiquetados; posteriormente los bivalvos fueron separados para su identificación hasta la categoría de especies. Para los sustratos estudiados (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 961individuos, agrupados en 28 géneros pertenecientes a la clase Bivalvia; se identificaron 52 especies; las más abundantes fueron: *Leukoma asperrima* (212), *Iliochione subrugosa* (85) y *Dosinia dunkeri* (78), 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 Banco del Río Sajalices y El Bajo 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, bivalvos, distribución, estaciones, sustratos.

INTRODUCTION

Mangroves are ecosystems found in coastal areas, river mouths, lagoons, and estuaries, mainly in tropical and subtropical regions with flat, muddy soils (Lacerda *et al*., 2001). In Panama, these ecosystems cover approximately 5.6% of the country's forested area, which is equivalent to around 172,000 hectares. Most are located on the Pacific coast, with 166,318 hectares, while about 5,858 hectares are in the Caribbean Sea (Berdiales *et al*., 2009).

Within marine communities, mangroves are considered one of the most productive ecosystems in the tropics. They play a crucial role as subsystems in coastal estuaries, bays, and lagoons (Cintrón & Schaeffer-Novelli, 1983). From an ecological perspective, their relevance is notable because they constitute quiet areas with shallow bottoms and high productivity. This makes them ideal habitats for the sustainable management of various species; many of which require a firm substrate to fix, as is the case of bivalve molluscs that establish themselves in dense populations forming groups that create microhabitats conducive to the growth and protection of these organisms (Márquez & Jiménez, 2002).

The biological richness of a mangrove ecosystem is mainly influenced by the malacofaunal diversity present (Plaziat, 1984). The patterns that determine this distribution (Newell, 1958), as well as its density and environmental response (Petraits, 1982); they are regulated by physicochemical factors such as salinity (Flores, 1973), temperature, seasonality and soil composition. The energy from protein-rich biomass generated by the early fall and decomposition of leaves allows virtually all zoological groups to be represented in this medium. Likewise, biotic factors such as predation, competition and food availability influence biomass (Connell, 1961; Haven, 1971) limiting its distribution. Other elements correlated with this distribution include degrees of exposure (Field & McFarlane in Fran *et al*., 1976) and distance from the coast (Hughes & Thomas in Franz *et al*., 1976).

Molluscs are the second most numerous groups after arthropods both in number of species and in abundance, this group tends to colonize various habitats from oceanic environments to high mountains; however, they are particularly abundant in tropical coastal areas. Gastropods and bivalves represent 98% of the total population of molluscs inhabiting terrestrial freshwater environments, as well as marine environments. Other classes are strictly marine (Shanmugan & Vairamani, 1984).

Molluscs are key indicators of environmental change and are effectively involved in biofiltration processes, as well as water purification; they are also accessible sources of protein-rich food, sustaining significant fisheries and even allowing paleontological interpretations (Giam *et al*., .987, Hoi-Chaw *et al*., 1984).

In the mangrove environment there are mainly some bivalve groups that live buried up to a maximum depth of around 30 cm, thus constituting the endofauna associated with the mangrove. At a global level, numerous descriptive studies have been carried out on various aspects related to faunal ecology within the mangrove context, among them some approaches have specifically addressed the Malacological fauna including Pelecypoda and Gastropoda analyzing relative zonal distribution, abundance, density, dominance, diversity and annual population fluctuations; in addition, its association with specific types of vegetative substrate (Emmen & Tejada, 1984).

Most of the research is focused on mollusks associated with mangroves, which have been predominantly directed towards bivalves due to their economic importance in food, with more than 48 species of bivalves being reported on the African coasts; 11 on the American west coast, 10 for the southeastern North American and 37 for the Caribbean and northeast coast of South America (Morton, 1983). Romero-Murillo and Polania (2008) analyzed the early succession or Taxocenosis of a mangrove swamp that is Mollusca - Anélida - Crustacea in submerged roots *Rhizophora mangle* Linnaeus (red mangrove) using branches of this artificial substrate in San Andrés, Colombian Caribbean island; in 188 days 34,175 individuals were identified in 130 experimental units, annelids showed the highest proportion (77.1%); molluscs seemed to need longer periods to settle; revealing that geomorphological characteristics, presence or absence of freshwater currents, tides and rainfall, mainly and anthropic factors can influence the development of mollusc communities.

Various studies refer to the fauna associated with mangrove roots in different parts of the world, which we can cite; works such as Anónimo (1969), who classified the various biotopes within the mangrove community according to their dominant faunal and floristic components; Coomans (1969) studied some biological aspects of mangrove-associated molluscs in the West Indies; Lalana *et al*., (1985), Lalana (1986) and Lalana and Ortiz (1992) studied the fauna associated with mangroves in the coastal lagoons of Cuba; Castaing *et al*., (1980) made some observations on the ecology of mangroves on the Pacific coast of Costa Rica and their relationship with the distribution of *Polymesoda inflata* (R. A. Philippi, 1851); Victoria and Pérez 1979), Anónimo (1980), Reyes and Campos (1992 a, b) analyzed the macroinvertebrates colonizing the roots of *R. mangrove* in the Colombian Caribbean.

In the sister country Venezuela, research on mangrove areas is scarce, mentioning Rodríguez (1963) who studied estuarine communities in Lake Maracaibo; Flores (1968) described the ecological and economic importance of Venezuelan mangroves; Sutherland (1980) used asbestos sheets in substrate to study the dynamics of the epibenthic community in red mangrove roots in Buche Bay; Pannier (1983) characterized the main coastal areas of eastern Venezuela; Morao (1983) analyzed the faunal diversity of mollusks and crustaceans associated with roots in the Restinga Lagoon of the State of Nueva Esparta; Ordosgoitti (1985) studied the epifauna of the roots of *R. mangle* in Mochima Bay in the State of Sucre; in addition to a work carried out by Frith (1977) and Frith *et al*. (1976) who carried out studies of zonation and abundance of macrofauna in Thailand including Gastropod and Pelecypoda.

In Panama we can mention the works of Tejera and Avilés (1976) and Tejera *et al*. (1980) who presented a list of Gastropod and Pelecypoda of the coast in the district of Aguadulce, province of Coclé and in the province of Chiriquí respectively; works carried out in specific areas of the Pacific coast of Avilés: Panamanian malacological fauna Punta Paitilla (1981a); Molluscs from the district of San Carlos, in the province of Panama Oeste (1981b); Molluscs from Santa Catalina beach, in the province of Veraguas (1983a); Molluscs coastal waters of the township of La Ensenada and La Esmeralda and Isla del Rey in the Pearl Archipelago (1986b) and Bivalve taxonomic list (1991); Avilés and Tejera: Bivalve Gastropods Aguadulce (1975); Avilés *et al*.: Classification of molluscs (1981); Aguadulce Bivalve Inventory (1976); Bique Bay Mollusks, Arraiján District, West Panama Province (1983) and Pacific Biogeographic Distribution (1986); Diéguez: Ecophysiology of bivalve molluscs (1982); Zoogeographic categories: Panamanian Pacific Malacological Province (1986) and Contribution to the study of bivalve gastropods on the Pacific coast, Republic of Panama (1991); Emmen and Tejada: Study of the distribution, abundance and diversity of Pelecypoda and Gastropod a mangrove swamp in the district of Aguadulce (1984); Arrunategui: Macromollusks of the Chiriqui Lagoon and Adjacent Areas (1995); Rodríguez and González: Evaluation of the aspects of the biology of *Anadara tuberculosa* (Bivalvia: Arcidae) in the mangrove of La Diáfana, township of Mariato in the province of Veraguas (1995); Vásquez: Molluscs (Pelecypoda and Polyplacophora) from Achotines Bay, Pedasi District, in the Province of Los Santos (1995), Gil and Pérez: Malacological Inventory (Classes: Bivalvia, Gasterópoda Polyplacophora) in Leones Island, Veraguas Province (1996); Lombardo and Martínez: Abundance and distribution of molluscs (Pelecypoda Gasterópoda) on the Juan Hombrón beach, Antón district in the province of Coclé (1999).

The mangrove areas in Panama highlight their importance because they are among the dominant vegetation of the Panamanian coasts, with an estimated coverage of approximately 1,600 to 1,700 square kilometers, being the largest in Central America and the ratio between mangroves and continental territory is among the highest in the world (D'Croz & Kwiencinski, 1979). Although in our country there are local human localities on both the Caribbean and Pacific coasts, the subsistence of the mangrove swamp also depends on various causes that cause its forest loss (Guevara-Mancera *et al*., 1998, Ulloa-Delgado *et al*., 1998). Despite this, in Panama the malacological richness especially of bivalves stands out, Panama is home to a great diversity of bivalves, with recent studies reporting more than 100 species only in areas such as the Bay of Panama (108 species), and figures of more than 200 species in specific areas such as the Veragüense Pacific (Coiba National Park), although the total number for the country requires more exhaustive inventories, estimating hundreds of bivalve species, some such as the *Anadara tuberculosa* (Sowerby I, 1833) being very important culturally and economically (Avilés, 1991).

That is why our interest in knowing the true distribution of bivalve mollusks in a Pacific mangrove swamp, leads us to collect data, indicating the logical state of this mangrove, highlighting the status of its population, even due to the pressure derived from the great economic importance in the country, particularly from some fishermen who depend directly and indirectly on the malacological natural resources that are found.

This work is of vital contribution to a better knowledge of the populations of bivalves in the mangroves of the Panamanian Pacific, obtaining information that will provide criteria in the development of management plans in the integrated management of the mangrove ecosystems; seeking sustainability and the conservation of resources that ensure an orderly use and preservation of biodiversity in the face of the current inevitable trends of changes in the coastal zone, as a result of the landfills under construction of tourism projects that alter the physical appearance of the area, also affecting the ecology of the mangrove. How these environmental modifications impact animal behavior; knowledge of distribution, abundance and diversity through the identification of bivalve species of economic importance for human populations associated with the mangrove in El Líbano, Bahía Chame, Panama Oeste province; will help to stop the land removals that affect this area.

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 79º 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 8º 40' 38" N and 79º 45' 59" W; it has a meadow of *R. mangrove* less dense than the aforementioned town and whose coastline has rocky areas with sandy and muddy beaches. Sajalices River Bank: 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 8º 39' 00" N and 79º 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 & Kwiencinski, 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 m^2, an area that was divided into smaller units of one m^2; 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 bivalve 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 River Bank and The Black Bass, registering a total of 961 individuals distributed in 28 genera and 51 species of the class Bivalvia (see Table 1). Likewise, 27 species of bivalves 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 coasts of Panama, 31% of bivalve 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 present in the mangroves are comparable to the results obtained in previous research carried out by Strong and Hertlein (1939) on the Pacific coast of Veraguas, specifically in Bahía Honda (district of Soná), where they found 58 species of bivalves. Hertlein and Strong (1946-1950) reported 25 species collected at different points on the Veraguas coast. González (1983), who carried out a preliminary inventory of mollusks in the districts of Soná and Las Palmas, documented

35 bivalves; Avilés (1983a, 1984b) carried out a malacological inventory in Ensenada Santa Catalina (Soná district) with a total collection of 45 bivalves. Emmen and Tejada (1984) studied the distribution, abundance and diversity of Pelecypoda and Gastropods in a mangrove swamp in the Aguadulce District, reporting 12 species; Vásquez (1995) identified 24 species in Bahía Achotines in Pedasí; 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 58 Bivalves; San Martín *et al*. (1997) mentioned three species for the Coiba National Park; in addition, González and Cáceres (1999), after a more exhaustive search in Coiba, collected 206 species. González (1999) studied mollusks from the Restingue Coast (Montijo district), finding 11 bivalves; Lombardo and Martínez (1999) reported 56 species in Juan Hombrón, Antón; while Flores and Morales (2001) documented 89 species on Santa Catalina beach. When comparing these studies, it is concluded that, among the 167 species described for the mangroves of the Panamanian Pacific coast, only those mentioned above coincided with this study: that is, only 31%.

Evaluation according to sampling site:

El Libano

This mangrove is mainly composed of roots of the *R. mangle* stand, presenting clearly different characteristics from other substrates analyzed; a total of 21 specimens were collected grouped into five species belonging to the same number of genera. The most representative bivalves were of the genus *Anadara* J.E. Gray, 1847 with *Anadara tuberculosa* (Sowerby, 1833), reaching n=15 or 71.43% (Fig. 2), followed by *Zemysina subquadrata* (P.P. Carpenter, 1856) and *Mytella guyanensis* (Lamarck, 1819), both with n=2 or 9.52% 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 according to 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.

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 365 specimens were recorded, grouped into 18 species. The most abundant bivalves belong to the genus *Leukoma* Römer, 1857 which includes three predominant species: *Leukoma aspérrima* (G.B. Sowerby I., 1835) with n=128, 35.07%, *L. grata* (Say, 1831) with n=68, 18.63% (Fig. 1) and *L. histrionica* (G.B. Sowerby I., 1835) with n=61, 16.71%; they usually live between rocky or sandy beaches, as well as under stones within the estuarine substrate (Cruz and

Jiménez, 1994). Some others such as *A*. *tuberculous*, *Carditamera radiata* (G. B. Sowerby I, 1833), *Cyclinella producta* (P.P. Carpenter, 1856), *M*. *guyanensis*, *Lamelliconcha tortuosa* (Broderip, 1835) and *Elpidollina decumbens* (P.P. Carpenter, 1865) record only one individual each (Table 1). Most generally reside at low tides, adjacent to the forest, buried within small drainage channels into estuaries, which explains their sparse local population.

Figure 2.
Anadara tuberculosa (Sowerby, 1833) con voucher MUMAUP-MB-31816, Leukoma grata (Say,1831) con voucher MUMAUP-MB-18170.

Palacios *et al*. (1986) indicate that heterogeneous substrates allow greater interstitially, providing accessible oxygen as well as available food; Rodríguez (1972) mentions that organisms here depend only on phytoplankton by consuming it through siphons. The inhabiting organisms require adaptations to tidal movement and substrata instability. Rodríguez (1972) suggests that they could follow internal physiological rhythms adjusting when the tide rises/falls.

Sajalices River Bank

In this locality, a sandy substrate was observed with a total collection of up to 160 individuals classified within 31 species; *Felaniella sericata* (Reeve, 1850) with n=37, 23.12% was best represented, followed by *Dosinia dunkeri* (R.A. Philippi, 1844) with n=11, 6.87% (Fig. 3), *Lirophora mariae* (A.d' Orbigny, 1846), *Mulinia pallida* (Broderip & G.B. Sowerby I., 1829), *Saccostrea palmula* (P.P. Carpenter, 1857) and *Tellina subangulata* G.B. Sowerby II, 1869 (all with n = 10, 6.25%). The smallest populations corresponded to *Anadara nux* (G.B. Sowerby I., 1833), *Iliochione subrugosa* (W. Wood, 1828) (Fig. 3), *Leptopecten tumbezensis* (A.d' Orbigny, 1846), *Tumbeziconcha thracioides* (A. Adams & Reeve, 1850), *Lamelliconcha callicomata* (Dall, 1902); *Tagelus politus* (P.P. Carpenter, 1857); *Tagelus peruvianus* Pilsbry & Olsson, 1941; *Tagelus dombeii* (Lamarck, 1818) and *E*. *decumbens* with only one individual (see Table 1). This occurs because similar environments do not offer ideal conditions for growth/development since the previous ones are specifically adapted to soft outer seabed's, mangroves. In contrast, Lombardo and Martinez (1999) report 56 pelecypod species: Juan Hombrón, Antón, showing similarities in sandy substrate, however, according to Rodríguez (1972), the shells that inhabit this type of substrate are strong/thick, with robust musculature (adductor muscle, without palial line); adaptations that allow them to survive in this type of habitat equally.

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). In addition, 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 522 bivalve individuals grouped into 28 species were collected. The best representations corresponded to *L. asperrima* (n=75, 14.36%), *L. tortuosa* (n=73, 13.98%), *D. dunkeri* (n=64, 12.26%) and *Psammotreta dombei* (Hanley, 17844) with n=61, 11.68%); these species generally inhabit mud while *Anadara labiosa* (G.B. Sowerby I., 1833), *Argopecten ventricosus* (G.B. Sowerby II., 1842), *Cyclinellas subquadrata* (Hanley, 1845), *Isognomon recognitus* (Mabille, 1895), *Leptopecten tumbezensis* (A.d' Orbigny, 1846), M. pallida and *Polymesoda* sp. They were the least numerous (see Table 1); These species reside in mud on the outside of mangroves in estuarine areas, which is the reason for the low numbers found here. However, sandy/muddy substrates harbor those that evade the mechanical action of waves and drying effects by burying themselves in the ground. The sand tends to be unstable and the mud deposited here stabilizes the places protecting them (Rodríguez, 1967).

Mangrove ecosystem in the area of Lebanon

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). The common term mangrove recognizes a shrub-tree formation that occupies the coasts of low coasts, reaching its greatest vigor on the shores of coastal lagoons, bays and protected gulfs. It develops on flat and muddy soil, rich in mineral salts, brown in hue and very little aerated (Diéguez, 1993). This sludge limits the diversity and distribution of species, and even contributes to the disappearance of some of them.

Of the sampled stations, the El Líbano sector constitutes a mangrove ecosystem and its internal part, it was observed that mollusks can be associated with trees or muddy substrate, here 21 individuals were reported collected; the dominant genus was *Anadara* with 15 individuals, followed by the genera *Diplodonta*, *Mytella* and *Ostrea* with two individuals and finally the genera *Iliochione* and *Polymesoda* both with an individual. Between substrates 2 in root and 21 in the soil (muddy type) typical of the mangrove area. On the floor of this mangrove, characterized by its soft and dense consistency, facilitating the survival of five species of Bivalves; *A. tuberculosa* (n=15, 9.52%), *M. guyanensis* (n=2, 9.52%), *Crassostrea columbiensis* (Hanley, 1846) (n=2, 9.52%) and *Diplodonta suprema* (n=1, 9.52%), *I. subrugosa* (n=1, 4.76%) (Fig. 3) and *Polymesoda notabilis* (Deshayes, 1855) with n=1, 4.76% (Table 2). Sibaja and Villalobos (1986) point out that the preference for muddy substrates of many of the mangrove bivalves favors shell growth. While Sibaja (1988) indicates that bivalves in this habitat prefer environments with high sedimentation and a high index of suspended particles. Mangrove soil species must adapt to different physiological conditions such as tolerance to salinity change, influence of fresh water during the rainy season, the presence of a muddy sediment that creates new problems because it contains less dissolved oxygen, therefore, the need to secrete mucus through the gills to obtain food, due to the absence of a siphon Rodríguez (1972).

Figure 3.
Dosinia dunkeri (*R.A. Philippi,1844), Iliochione subrugosa (W. Wood, 1828), con voucher MUMAUP-MB-4698*.

Diversity of organisms

Through our statistical analysis, we noticed that the diversity of bivalve species identified in this mangrove area is lower compared to records made in other Pacific localities adjacent to Chame Bay.

For example, Playa Venado reported 37 species (Shasky, 1975), Bahía Bique had 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 & Lima, 1997); indicating that the difference observed between individuals during high versus low tides is related to specific tolerances to desiccation (Margalef, 1967). Each species has the necessary requirements to inhabit a given area, thus regulating its distribution under environmental parameters including temperature, salinity, and the characteristics of favorable sediments (Pérez-Farfante, 1971).

The soil diversity index was calculated using the Shannon-Wiener function, resulting in H' = 1.374 bits and an intermediate value for the root substrate with H' = 1.08 bits. When analyzing the diversity by type of substrate, it is observed that the soil biotope, which hosts the largest number of individuals, presents a greater diversity compared to other substrates evaluated in the mangrove zone of Lebanon (Table 3). Some researchers suggest that these results are common in other mangroves and depend on specific environmental conditions inherent in these ecosystems. Hernandez and Davis (1979) argue that the low diversity indices observed in our study are representative for certain mangrove habitats. Meadows and Campbell, cited by Spight (1977), mention that many organisms limit their activities to favorable habitats; thus, their distribution is conditioned by habitat selection and is likely to be restricted to specific coastal areas. Significant differences have been noted in the distribution of species between the different substrates within the same mangrove. Spight (1977) considers each mangrove as a complex association of habitats where both abundance and diversity vary according to the habitat.

The highest diversity indices were observed in Sajalices River Bank and The Black Bass with H' = 3.258 and H' = 3.021 respectively; while the lowest values corresponded to El Líbano (H' = 1.374) and San Juanito (H' = 2.58) see Table 3. The mangrove substrate in our studied area showed lower distribution and diversity, possibly due to the increase in sedimentation caused by organic waste and garbage accumulated daily in this area; backing us up, we cite Jackson (1972) who points out that Mollusca diversity is related to environmental variations such as temperature, turbidity, salinity and pH of the water. Dexter cited by Diéguez *et al*. (1995) mentions that significant differences between localities with respect to Mollusca distribution are attributable to structural water variations such as exposure to waves and floods together with biotic factors such as predation or food availability; while Paine, quoted by Bakus (1968), argues that such diversity is directly linked to how predators prevent monopolies on essential environmental requirements.

As has been evidenced so far, there is a variable biodiversity among the different types of substrates studied, frequently influenced by their specific composition, although also affected by various factors according to Caicedo (1984), such as type of substrate, amount of light received and influences caused by waves, in addition to the present degree of organic sedimentation, whether detritus or planktonic algae, essential for microphagous forms and local filter organisms; simultaneously, sedentary or wandering organisms potentially participate in abundance or population zonation on these molluscs depending on the particular type of substrate. According to Vegas (1971), determining factors include tidal amplitude together with wave intensity along with the type of material affect the specific quality as well as dispersion.

Research carried out by Newell, cited by Garrity (1984), indicates abiotic conditions that are less influential on organisms inhabiting three-dimensional habitats such as sand or mud compared to those present in other types of coasts; For this reason, bivalve infaunal organisms stand out, adapting efficiently to such environments, being common to find arcs, venerids, teminids, donacids, corbulids, among others. Ortega (1986) mentions how the community variety varies according to aspects related to the type of substrate exposed to risks of dehydration, predation and the time available to feed on plankton.

The Simpson Index (D')

It revealed high values corresponding to the localities of San Juanito, Sajalices River Bank and The Black Bass: D'=0.8859, D'=0.9396, D'=0.9354 respectively; where Lebanon presented D'=0 .654, this being the minimum obtained (Table 3). High values suggest the absence of a clear predominance of any species; where the good distribution of individuals occurs; on the other hand, a low D' observed in Lebanon indicates a certain dominance of some particular species present; explaining this, Margalef (1995) argues that if one community shows a numerically dominant species against another, then the diversities are low, as evidenced by the community of Lebanon.

Finally, the equal values range from J'=0.5208 to J'=0.851, with maximums corresponding to Sajalices River Bank and The Black Bass (J'=0.851, J'=0.7983 respectively); The minimum found are El Líbano and San Juanito with J'=0.5208 and J'=0.7146 respectively (Table 3). Equity or Equity (J); it measures how individuals are distributed among different species; These results show a distribution slightly above 50%. In general, the value obtained was low, which suggests the possible presence of some dominant species during the study. The data derived from previously mentioned predominance against fairness indices indicate homogeneous existence, distribution, individuals within communities found there, without marking defined dominance.

Table 1.
Distribution, diversity and abundance of mollusc species bivalve collected in Chame Bay, Province of Panama.

CLASS BIVALVIA					
Species / Locality	**El Líbano**	**San Juanito**	**Sajalices River Bank**	**The Black Bass**	**Total**
Anadara tuberculosa (Sowerby, 1833)	15	1	0	46	**62**
Anadara nux (Sowerby, 1833)	0	0	1	3	**4**
Anadara emarginata (Sowerby, 1833)	0	0	2	0	**2**
Anadara concinna (Sowerby, 1833)	0	0	2	0	**2**
Anadara labiosa (Sowerby, 1833)	0	0	0	1	**1**
Anadara grandis (Broderip & Sowerby, 1829)	0	2	0	14	**16**
Argopecten ventricosus (Sowerby, 1842)	0	18	0	1	**19**
Carditamera radiata (G. B. Sowerby I, 1833)	0	1	0	0	**1**
Carditamera affinis (G. B. Sowerby I, 1833)	0	1	0	0	**1**
Corbula nasuta (Sowerby, 1833)	0	0	2	16	**18**
Corbula inflata (C. B. Adams, 1852)	0	0	0	2	**2**
Crassostrea columbiensis (Hanley, 1846)	0	2	0	6	**8**
Cyclinella producta (P. P. Carpenter, 1856)	0	1	2	31	**34**
Cyclinella subquadrata (Hanley, 1845)	0	0	0	1	**1**
Donax gracilis (Hanley, 1845)	0	0	6	0	**6**
Donax navícula (Conrad, 1837)	0	0	3	0	**3**
Dosinia dunkeri (Philippi, 1844)	0	0	11	64	**75**
Elpidollina decumbens (P. P. Carpenter, 1865)	0	1	1	0	**2**
Ensis tropicalis (Hertlein & Strong, 1955)	0	0	2	0	**2**
Felaniella sericata (Reeve, 1850)	0	0	37	0	**37**
Florimetis asthenodon (Pilsbry & Lowe, 1932)	0	0	2	11	**13**
Iliochione subrugosa (W. Wood, 1828)	1	52	1	31	**85**
Iphigenia altior (Sowerby, 1832)	0	0	2	0	**2**
Isognomon recognitus (Mabille, 1895)	0	4	0	1	**5**
Lamelliconcha tortuosa (Broderip, 1835)	0	1	2	73	**76**
Lamelliconcha callicomata (Dall, 1902)	0	0	1	0	**1**
Leptopecten tumbezensis (Orbigny, 1846)	0	0	1	1	**2**
Leukoma asperrima (Sowerby, 1835)	0	128	9	75	**212**
Leukoma grata (Say, 1831)	0	68	4	0	**71**
Leukoma histrionica (Sowerby, 1835)	0	61	0	0	**61**
Lirophora mariae (A. d'Orbigny, 1846)	0	0	10	0	**10**
Mactra fonsecana (Hertleing & Strang, 1950)	0	0	9	3	**12**
Mexicardia procera (G. B. Sowerby I, 1833)	0	0	6	0	**6**
Mulinia pallida (Broderip & G. B. Sowerby I, 1829)	0	0	10	1	**11**
Mytella guyanensis (Lamarck, 1819)	2	1	0	0	**3**
Polymesoda sp. (Rafinesque, 1828)	0	0	0	1	**1**
Polymesoda notabilis (Deshayes, 1855)	1	0	0	0	**1**
Psammotreta dombei (Hanley, 1844)	0	3	7	61	**71**
Saccostrea palmula (Carpenter, 1857)	0	13	10	7	**30**
Sphenia fragilis (H. & A. Adams, 1854)	0	0	0	4	**4**
Striostrea iridencens (Hanley, 1854)	0	7	0	0	**7**
Tagelus politus (Carpenter, 1855)	0	0	1	0	**1**
Tagelus peruvianus (Pi1bry & OJsson, 1941)	0	0	1	0	**1**
Tagelus dombeii (Lamarck, 1818)	0	0	1	2	**3**
Tagelus affinis (C. B. Adams, 1852)	0	0	2	44	**46**
Tellina subangulata G. B. Sowerby II, 1869	0	0	10	0	**10**

Tellina prínceps (Hanley, 1844)	0	0	0	9	**9**
Tellina insculpta (Hanley, 1844)	0	0	0	2	**2**
Tellina reclusa (Dall, 1900)	0	0	0	4	**4**
Tumbeziconcha thracioides (A. Adams & Reeve, 1850)	0	0	1	7	**8**
Zemysina subquadrata (P. P. Carpenter, 1856)	2	0	0	0	**2**
Total	**21**	**365**	**160**	**522**	**961**
Species	**5**	**18**	**31**	**28**	**82**

Table 2.

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

Species	Root	Fango	Total individuals per species
Anadara tuberculosa	0	15	15
Iliochione subrugosa	0	1	1
Diplodonta suprema	0	2	2
Mytella guyanensis	0	2	2
Ostrea columbiensis	2	0	2
Polymesoda notabilis	0	1	1
Total Individuals	**2**	**21**	**23**
Total species	**1**	**5**	**6**

Table 3.

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

	El Líbano	Punta San Juanito	Sajalices River Bank	The Black Bass
Individuos	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 at Sampling Sites

Within the framework of this research, the collection of bivalves that have commercial importance was carried out, either for human consumption, as food for other species or for sale in local markets. In addition, shells are used as decorative elements and in the production of handicrafts. The most representative species included: *L. asperrima* (n=212, 22.026%), *I. subrugosus* (n=85, 8.84%), *D. dunkeri* (n=78, 8.12%), *Lamelliconcha tortuosa* (n=76, 7.91%), Leukoma grata (n=71, 7.39%) and *L. histrionica*, together with *A. tuberculosis* (n=61, 6.35%) (see Table 4). These species were collected in estuarine areas, mangroves and sandy-muddy bottoms. Carrying out malacological and biological studies on these commercial species is essential for proper conservation and management of the resource.

Several species of bivalves are essential as a source of protein and represent a considerable economic resource for coastal communities; therefore, they are intended for human consumption (Squires et al., 1975; Villalobos & Baéz, 1983). A study carried out by the Food and Agriculture Organization of the United Nations (FAO) in 1994 revealed that clams are the most important economic resource in Central America within the group of molluscs present in mangroves.

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

CLASS BIVALVIA			
Familia	**Species**	**Common name**	**Usefulness**
Arcidae	*Anadara tuberculosa*	Concha prieta / Black shell	1-2
	Anadara grandis	Casco de burro / Donkey's Foot / Cocaléca	1-2
	Anadara nux	Mule Leg	1-2
Pectinidae	*Argopecten ventricosus*	Conchuela	1-2
Carditidae	*Carditamera affinis*	Clam	2
Donacidae	*Donax gracilis*	Sand clam	2
	Donax navícula	Sand clam	2
Veneridae	*Dosinia dunkeri*	White clam	1-2
	Iliochione subrugosa	Wrinkled clam / Cachicho	1-2
	Lamelliconcha tortuosa	Clam	1-2
	Lamelliconcha callicomata	Clam	2
	Leukoma asperrima	Franciscan/ Mud clam / Cachicho	1-2
	Leukoma grata	White clam	1-2
	Leukoma histriónica	White clam	1-2
	Leukoma fuscolineata	White clam	1-2
	Lirophora mariae	Rusty clam	1-2
Mactridae	*Mactra fonsecana*	Craves miona	1-2
Cardiidae	*Mexicardia procera*	Cockle	1
Mytilidae	*Mytella guyanensis*	Mussel	1
	Mulinia pallida	Clam	1-2
Cyrenoididae	*Polymesoda sp.*	Miona	1-2
	Polymesoda notabilis	Miona	1-2
Ostridae	*Ostrea columbiensis*	Oyster	1
	Saccostrea palmula	Oyster	1
	Striostrea iridencens	Stone oyster	1
Solecurtidae	*Tagelus peruvianus*	Penknife/ Stone oyster	1-2
	Tagelus affinis	Mussel/ Penknife	1-2

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

The collection of molluscs, in particular the black shell (*A. tuberculosis*), is essential in the region studied, since a large part of the population depends on this activity. These molluscs are found in areas colonized by the mangrove of the genus *Rhizophora* and are exposed to periodic tidal flooding. Harvesting is carried out manually in the outer area of the mangrove swamp, between the roots of the mangrove, preferably at low tides and in shady places (Vergara, 1997). Due to its rapid recovery from intensive exploitation and its importance as a renewable resource, it has been the subject of numerous studies, which makes it a key resource within mangrove ecosystems on the Pacific coast. This species produces a large amount of biomass in a short time and is considered a significant form of conversion and energy transfer to the upper levels of the food chain in this ecosystem (Campos *et al*., 1990; Vega, 1994). For this reason, it is one of the most exploited organisms in the American Pacific, generating notable scientific interest (Vergara, 1997).

The demand for black shell has grown due to the overexploitation of other species associated with the mangrove (Von Prahl *et al*., 1990; FAO, 1994). According to Maturrell *et al*. (1992), *A. Tuberculosis* is an important product for export from Panama. In 1989, it ranked first among bivalve molluscs exported mainly to Guatemala and the United States. However, the impact that this capture has on natural populations is unknown. Local reports suggest that populations of *A. Tuberculosis* have been declining in both size and number in recent years. The collection is not organized or accompanied by adequate marketing; It is usually collected manually on beaches or during fishing activities. However, these mollusks are crucial to the local family economy because they provide food and income through the direct sale of their meat and shells. Its demand varies seasonally according to traditional customs (such as Easter) and climatic conditions (swells and storms) (Vergara, 1997).

"Recent degradation of mangrove habitats has led to a reduction in catches of species that inhabit aerial roots and intertidal mudbanks. Despite this, the total number of exploited species tends to increase; experiments are currently being carried out for artificial crops in various areas of the Central and South American coastal west in order to counteract the negative effects caused by overexploitation and pollution" (FAO, 1995).

CONCLUSIONS

The present study reveals that several localities are home to both rare and common species, showing greater abundance in certain areas probably due to more favorable conditions. The data obtained for different regions of the Panamanian Pacific can be attributed to physical and chemical characteristics present in Chame Bay. This bay offers a wide environmental range that gives rise to various habitats (sandy, sandy-muddy and rocky). In addition, it acts as a refuge for the juvenile growth of many species; however, comparing numbers between different studies can be complicated due to methodological variations, as well as differences in geographical areas and times considered for sampling; now, according to Tait (1970), the vital needs, both terrestrial and aquatic, are so dissimilar that each organism cannot adapt to any given coastal level; Thus, each stratum is inhabited by different faunal and floristic groups where each species presents greater abundance under specific optimal conditions.

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