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Distribution, diversity, and abundance of bivalves (pelecypoda) in the mangrove swamp of Chame bay, Panama Oeste province, Panama

Distribución, diversidad, y abundancia de bivalvos (pelecypoda) en los manglares de la bahía de Chame, provincia de Panamá Oeste, Panamá

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ABSTRACT: The mangrove ecosystem is vital both locally and globally, hosting a remarkable variety of flora and fauna, including animals, plants, mollusks, and birds. This makes it one of the five most productive ecological zones worldwide. Given Panama's extensive coastlines that provide ideal conditions for mangrove growth, it serves as an excellent site for studying the biodiversity of bivalve species associated with this habitat. Recognizing the significance of this ecosystem, a comprehensive study was conducted to gather information on the diversity and abundance of mollusks (Pelecypoda) at two sites within the mangrove of Chame Bay, located in the province of Panama Oeste. Two sampling sections were designated as Section A (Punta Chame) and Section B (El Líbano). At each site, individuals were collected using random sampling from three quadrants, with three adult mangrove trees selected for this purpose. Specimens were gathered from the sediment surrounding the mangrove, as well as from the roots and trunk, during low tide from July to December 2016. The collected specimens were preserved for identification in the laboratory at the Malacology Museum of the University of Panama (MUMAUP) and subsequently processed for inclusion in the National Reference Collection housed at this facility. The data revealed low species richness at both sites, with El Líbano demonstrating less diversity compared to Punta Chame, which had a higher abundance of organisms.

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A total of six genera and seven bivalve species were identified across three mangrove species: Rhizophora mangle (red mangrove), *Laguncularia racemosa* (white mangrove), *Pelliciera rhizophorae* (pinuelo mangrove), and *Avicennia germinans* (black mangrove). Notably, the bivalve species most consumed by residents were *Anadara tuberculosa* and *Mytella guyanensis*, with *A. tuberculosa* being the most overexploited due to consumption. A diversity analysis for the Chame district indicated that the Pelecypoda class exhibited an H' index of 1.509 in Punta Chame, with a dominance value (D') of 0.2797 and equity (J') of 0.7754. In contrast, the Líbano sector showed an H' index of 0.9507, with equity and dominance values of J' = 0.685 and D' = 0.5078, respectively. The observed low population levels and limited diversity of these species in the mangroves of the Chame district can be largely attributed to anthropogenic activities such as mangrove deforestation for charcoal production, excessive extraction by external settlers for commercial purposes, pollution, and the establishment of shrimp farms.

KEYWORDS: Libano; Chame; mangrove; biodiversity; consumption; population.

RESUMEN: El ecosistema de manglares es vital tanto a nivel local como mundial, albergando una notable variedad de flora y fauna, incluyendo animales, plantas, moluscos y aves. Esto la convierte en una de las cinco zonas ecológicas más productivas del mundo. Dadas las extensas costas de Panamá que brindan condiciones ideales para el crecimiento de los manglares, sirve como un excelente sitio para estudiar la biodiversidad de especies de bivalvos asociadas con este hábitat.

Reconociendo la importancia de este ecosistema, se realizó un estudio integral para recopilar información sobre la diversidad y abundancia de moluscos (Pelecypoda) en dos sitios dentro del manglar de Bahía Chame, ubicado en la provincia de Panamá Oeste. Dos secciones de muestreo fueron designadas como Sección A (Punta Chame) y Sección B (El Líbano). En cada sitio, los individuos se recolectaron mediante muestreo aleatorio de tres cuadrantes, con tres árboles de mangle adultos seleccionados para este propósito. Los especímenes se recolectaron del sedimento que rodea el manglar, así como de las raíces y el tronco, durante la marea baja de julio a diciembre de 2016. Los especímenes recolectados se conservaron para su identificación en el laboratorio del Museo de Malacología de la Universidad de Panamá (MUMAUP) y posteriormente se procesaron para su inclusión en la Colección Nacional de Referencia ubicada en esta instalación. Los datos revelaron una baja riqueza de especies en ambos sitios, con El Líbano demostrando menor diversidad en comparación con Punta Chame, que tuvo una mayor abundancia de organismos. Se identificaron un total de seis géneros y siete especies de bivalvos en tres especies de manglar: *Rhizophora mangle* (mangle rojo), *Laguncularia racemosa* (mangle blanco), *Pelliciera rhizophorae* (mangle de pinuelo) y *Avicennia germinans* (mangle negro). Cabe destacar que las especies de bivalvos más consumidas por los residentes fueron *Anadara tuberculosa* y *Mytella guyanensis*, siendo *A. tuberculosa* la más sobreexplotada debido al consumo. Un análisis de diversidad para el distrito de Chame indicó que la clase Pelecypoda exhibió un índice H' de 1.509 en Punta Chame, con un valor de dominancia (D') de 0.2797 y equidad (J') de 0.7754. En contraste, el sector Líbano mostró un índice H' de 0,9507, con valores de equidad y dominancia de J' = 0,685 y D' = 0,5078, respectivamente. Los bajos niveles poblacionales observados y la limitada diversidad de estas especies en los manglares del distrito de Chame pueden atribuirse en gran medida a actividades antropogénicas como la deforestación de manglares para la producción de carbón vegetal, la extracción excesiva por parte de colonos externos con fines comerciales, la contaminación y el establecimiento de granjas camaroneras.

PALABRAS CLAVE: Líbano; Chame; mangle; biodiversidad; consumo; población.

INTRODUCTION

The mangrove ecosystem is characterized by a complex array of tree and shrub species that have evolved to thrive in the intertidal zones of tropical and subtropical coastlines globally. These species have developed a tolerance to waterlogged soils and high salinity conditions (Pomareda & Zanella, 2006). This highly productive and intricate ecosystem contributes significant nutrients to coastal marine waters, benefiting seagrasses and various commercially important species (Gaxiola, 2011). Mangroves are typically found along coastlines, estuaries, coastal lagoons, wetlands, and river mouths. Their ecological significance lies in the roles that their organisms play in maintaining coastal balance and protection, providing spawning and feeding grounds for species ranging from fish to crustaceans, while also offering refuge to crabs, mollusks, and nesting areas for shorebirds. Economically, mangroves are valued for their role as habitats for fish species, bark tannins, and wood used in various artisanal and commercial applications (Olguín *et al*., 2007).

The richness of larger mollusks (malacofauna) associated with mangrove ecosystems significantly influences their biocenotic diversity. Abiotic factors such as salinity (Flores, 1973), temperature, seasonality, and soil composition regulate (Newell, 1958) patterns that determine species distribution, density, and adaptability in varying environments. Biotic factors like predation, competition, and food availability limit distribution (Connell *et al*., 1961; Haven, 1971), in addition to interactions with other factors such as exposure and distance from the shore (Franz, 1976). Invertebrate communities within mangrove ecosystems display variations in species density and abundance by zone, throughout the ecosystem, and across seasons (Jiménez, 1994), often leading to dominance by a few species that are highly adaptable to environmental changes. This differs from sandy beach communities where factors such as larval recruitment (specifically for mollusks, not juvenile fish), nutrient availability, and environmental conditions—including desiccation and thermal variation—can have markedly different impacts (Pfaff & Nel, 2019). However, abundance and diversity may also be influenced by habitat fragmentation or pollution (Cárdenas-Calle & Mair, 2014).

Mollusk populations associated with mangrove substrates generally comprise species that reside in the sediment as ectofauna and various Pelecypoda groups, buried up to 30 cm deep, representing the endofauna of the mangrove. All these organisms are marine-affiliated but must also endure temporary aerial conditions during low tides and the general variations associated with tidal changes (Flores, 1973).

Globally, numerous studies have been conducted on various aspects of mangrove faunal ecology, including research on the distribution, zonation, ratio, abundance, density, and diversity of Mollusca (Pelecypoda and Gastropoda) alongside population fluctuations over time/season, as well as their associations with substrate types and vegetation (Emmen & Tejada, 1984). Previous research focused on mollusks associated with mangroves has primarily emphasized the Pelecypoda group due to its economic significance and as a food source. Reports indicate 48 species of pelecypods from collections along African coasts, with additional studies in the west coast of the Americas identifying 11 species, and 10 species noted along the southeast coast of North America, plus 37 species in the Caribbean and northeast South America (Morton, 1983).

Organisms inhabiting submerged root regions exhibit impressive adaptation mechanisms, with a dominance of epizoic, epigenic, and delicate species; some hold significant commercial value, such as the oyster *Crassostrea rhizophorae* (Guilding, 1828) (Lalana & Perez, 1985). This extensive root system supports many animal groups throughout their life cycles, including fish, shrimp, crabs, and mollusks (Rützler & Feller, 1988). Consequently, the current study aims to estimate the occurrence, diversity, and abundance of the Bivalvia class within the Mollusca phylum, and to elucidate community structure based on the most significant species within the mangroves of the Chame district. This study will provide new insights into this taxon for a site with limited biological information, which may also highlight areas affected by wastewater pollution.

MATERIAL AND METHODS

Study Site: Although Panama boasts 2,800 km of coastline divided into 39% Caribbean and 61% Pacific regions, high diversity is observed due to habitat heterogeneity with a mix of biotopes (estuaries, rocky areas, mangroves, sandy beaches, and muddy zones), partially or fully situated on coastal lands originating from marine areas. Primarily, the Pacific coast hosts substantial numbers and volumes of benthic organisms (I.G.N.T.G., 2007).

Main Account: The Chame wetland comprises mangroves and muddy plains occupying the low area of the Chame River basin from its mouth to Monte Oscuro Abajo. The Chame mangroves are entirely flat, attached to a mountain chain like Cerro Campana or Punta Chame, located six kilometers from the Atlantic coast of Nicaragua (Fig. 1). The most representative data support the characterization of the floristic and environmental aspects of a dense mangrove forest extending approximately 59,576 km², covering close to 39,000 km² of muddy plains at the Chame River mouth, with an average temperature of 27.4°C and annual rainfall varying between 1,200 to 2,000 mm (Flores *et al*., 2010). Chame is a district in the province of Panama Oeste, Panama, covering an area of 352.93 km² (136.16 square miles). The district consists of 11 corregimientos, including El Líbano (Latitude: 8°39'35" N and Longitude: 79°49'45" W) and Punta Chame (Latitude: 8°39'45" N, Longitude: 79°52'51" W) (Panamanglar, 2013), which represent the quadrants where the research was conducted.

Punta Chame: This part of the Chame mangrove is situated within the internal area of the mangrove; the substrate comprises sandy mud. Rhizophora mangle is the dominant species, followed by *Laguncularia racemosa* and *Pelliciera rhizophorae* (Fig. 2a).

Líbano: This extensive mangrove area exhibits a high presence of red mangrove (Rhizophora mangle), alongside black mangrove (*Avicennia germinans*). Water access for this site is through channels, and the substrate consists of mud (Fig. 2a). Right along the inner edge of the mangrove, with a sandy-muddy substrate, R. mangle is the dominant species, with *L. racemosa* and *P. rhizophorae* also present (Fig. 2b).

Figura 1.
Map of the sampling site, El Libano and Punta Chame, Chame district, West Panama, Panama

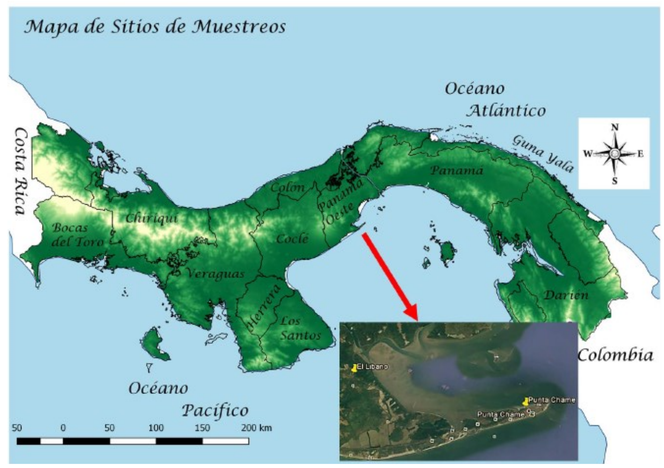
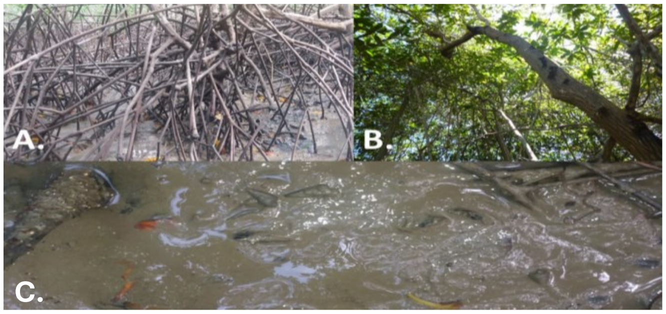


Figura 2a.
A Punta Chame sector, site where the samplings were carried out; sand-mud substrate. 2b: B Lebanon sector, sampling site with muddy substrate.

Field Methodology: Two sections were established in the field: Section A (Punta Chame) and Section B (El Líbano); each consisting of three quadrants of 100 m², spaced 200 meters apart. Field outings were conducted during low tide over six months, twice a month. The dates and times for collection outings were determined using tide prediction tables for the Pacific of Panama. Three adult mangroves were randomly sampled within the quadrants, collecting specimens from the mud surrounding the mangrove, as well as from the roots and trunk. Plastic bags were labeled with the section, date, and substrate type (trunk, root, or mud) for collecting biological materials. Only one living representative was taken from each sample, with all individuals found within the quadrant counted (Fig. 3).

Figura 3.
Substrates where the samples were taken (A. root; B. trunk; C. mud).



Laboratory Procedure: The collected material was deposited in the Malacology Museum of the University of Panama (MUMAUP) for identification. Prior to identification, the soft bodies of the specimens were separated from the shells and then dried in an oven. Identification was based on the morphological characteristics of the shell, including the aperture, siphonal canal, and, for some gastropods, additional information such as folds or teeth on the inner lip; types of teeth and muscle scars in Pelecypoda. Taxonomic identification was assigned using "Seashells of Tropical West America" (Keen, 1971) for Gastropoda and Pelecypoda, and "Bivalve Seashells of Tropical West America" (Coan & Valentich-Scott, 2012) exclusively for Pelecypoda. Taxonomic updates were cross validated against the World Register of Marine Species (WoRMS, 2025).

Statistical Analysis: Data processed during the research were tabulated using Excel. The statistical analysis utilized in this study employed the Past 3.0 software along with mathematical calculations such as the Shannon-Wiener Diversity Index (H’), Dominance (D’), and Equitability (J’).

Commercial Mollusk Survey: To better understand the species utilized in our studied locations, a survey was conducted with 40 individuals regarding consumption and extraction of shellfish. Questions addressed frequency of consumption, most consumed species by residents, product origin, and perceptions of population declines.

RESULTS

A total of 303 individuals were recorded across six families and seven species in six genera; the genus with the highest number of species was *Polymesoda* Rafinesque 1820, represented by two species. The highest counts obtained through genotypic technology were *Leukoma asperrima* (G.B. Sowerby I, 1835) (135 organisms; 44.55%), while *Isognomon recognitus* (Mabille, 1895) was represented by a single specimen (0.33%) (Fig. 4 and Table 1). Among the substrates, roots (one individual) and mud (302 individuals) were the only habitats where specimens were found, totaling 303 individuals. In the roots, only *I. recognitus* (0.33% of total) was present in the root substrate (Table 2); *L. asperrima* was the most representative species within the mud, comprising 135 individuals (44.55%) (Table 2). The Pelecypoda class exhibited an H' index of 1.509, while data based on Dominance (D') revealed a higher value within the class Pelecypoda (Table 4).

Punta Chame (Sector A): Two families were accumulated in this site, located at the inner edge of a mangrove with sandy-muddy substrate (303 individuals from two orders, six families, six genera, and seven species). The genus with the highest number of species was *Polymesoda* represented by two species, with *L. asperrima* being the most common, totaling 135 individuals (44.55%). Conversely, *I. recognitus* had one specimen and constituted 0.33% of the total species (Table 1). The pelecypods were confined to the root substrate (one individual) and the mud (302 individuals), totaling 303 individuals. Within the root substrate, only one individual of *I. recognitus* was found (0.33% of total); *L. asperrima* was the most representative species in the mud with 135 individuals (44.55%) (Table 2). The Pelecypoda class exhibited a diversity index of H’=1.509, with a dominance value (D’) of 0.2797 and equity of J’=0.7754 (Table 4).

Table 1.
Number of individuals and species of the Class Pelecypoda found in the study.

Species	Locality	
	Punta chame (Sandy- muddy)	**Líbano (Muddy)**
Mytella guyanensis (Lamarck,1819)	35	2
Anadara tuberculosa (Sowerbey,1833)	30	11
Isognomon recognitus (Mabille,1895)	1	0
Polymesoda inflata (Philippi, 1851)	13	0
Polymesoda notabilis (Deshaye,1855)	20	0
Leukoma asperrima (G. B. Sowerby I, 1835)	135	1
Panamicorbula ventricosa (A. Adams & Reeve, 1850)	69	2
Total Individuals	**303**	**16**

Table 2.
Identified mollusk species in Punta Chame by substrate type.

Species	RAÍZ	FANGO
Mytella guyanensis (Lamarck,1819)	0	35
Anadara tuberculosa (Sowerbey,1833)	0	30
Isognomon recognitus (Mabille,1895)	1	0
Polymesoda inflata (Philippi, 1851)	0	13
Polymesoda notabilis (Deshaye,1855)	0	20
Leukoma asperrima (G. B. Sowerby I, 1835)	0	135
Panamicorbula ventricosa (A. Adams & Reeve, 1850)	0	69
Total Individuals	**1**	**302**

Table 3.
Species of molluscs identified in Lebanon according to the type of substrate.

Species	FANGO
Mytella guyanensis (Lamarck,1819)	2
Anadara tuberculosa (Sowerbey,1833)	11
Leukoma asperrima (G. B. Sowerby I, 1835)	1
Panamicorbula ventricosa (A. Adams & Reeve, 1850)	2
Total Individuals	**16**

Table 4.
Diversity index of the class Pelecypoda for the different sampling sites.

Sitios	Riqueza (S)	Individuos	Shannon- Wiener (H’) (bels)	Dominance (D’) (bels)	Equidad (J’) (bels)
Punta Chame	7	303	1.509	0.2797	0.7754
El Líbano	4	16	0.9507	0.5078	0.6858

Líbano (Sector B): The fact that this mangrove ecosystem is located at the outer edge refers in this case to the association of bivalves with the mangrove or the muddy substrate. A clear vertical capture of samples from trunk, root, and mud showed that only 16 marines Bivalvia (Pelecypoda) were present within four species belonging to four genera and families. The dominant genus was *Anadara* Gray, 1847, with *Anadara tuberculosa* G.B. Sowerby I, 1833 being the most representative species (Fig. 5), comprising 11 specimens and constituting 0.23% (Table 1 and 3). The corresponding diversity index for the Pelecypoda class was H'=0.9507, with equity J'=0.685 and dominance D'=0.5078 (Table 4).

Figura 4.
Chame Bay Pelecypods: A. Mytella guyanensis. B. Anadara tuberculosa, C. Polymesoda notabilis, D. Leukoma aspérrima, E. Polymesoda inflata, F. Panamicorbula ventricosa.

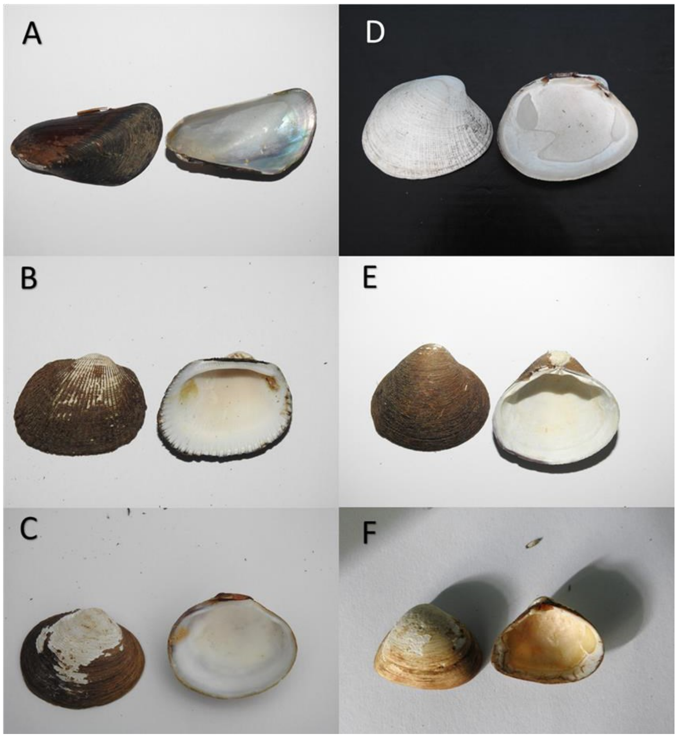


Figura 5.
Anadara tuberculosa (Sowerby, 1833) la especie más consumida y la más sobreexplotada de la Bahía de Chame, Chame, Provincia de Panamá Oeste.

DISCUSSION

Seven species of Pelecypoda, six genera, and six families were observed, totaling 319 individuals. Previous studies in the Pacific of Panama, particularly in Veraguas, have documented collections conducted by Hertlein in Bahía Honda (Strong & Hertlein, 1939) using drags and manual collection by local divers studying coral reefs. In Aguadulce, Tejera and Avilés (1975-1976) identified 35 species of pelecypods; Diéguez and Avilés (1981) recorded 83 species of commercially important pelecypods in the mangrove area of Bahía de Chame; Gonzáles (1983) reported 35 pelecypods in the Pacific coast (in the districts of Zona and Las Palmas); Morao (1983) noted 22 species in the northeastern coast of Venezuela between January and March of 1983; Avilés (1984) documented 45 pelecypods; Emmen & Tejada (1950) studied the distribution, abundance, and diversity of Pelecypoda in a mangrove in Aguadulce, finding 12 species of pelecypods; Lalana & Perez (1985) collected 14 species in the mangroves of Laguna and 23 species for the mangroves of the Caribbean cays of Cuba; Flores & Morales (2001) reported 89 species of bivalves from the sands of Santa Catalina and in their study on the diversity and abundance of pelecypods, Fairchild & López (2010) identified a total of 52 species of Bivalvia.

Comparisons between studies in Brazil and other regions indicated that this class is less diverse and abundant in mangroves, a situation like our findings, supported by Frith *et al*. (1976), who discovered that Pelecypoda distribution was rare in mangroves with salinity fluctuations due to tides, while occurrence within mangroves was higher under relatively stable saline conditions. While the number of pelecypods recorded in our study is low, this outcome may be explained by the proximity of the sampling sites to estuaries with significant salinity variations. Most organisms exhibit general behaviors that restrict their activities to favorable habitats (Meadows & Campbell in Spight, 1977), making habitat selection a crucial factor influencing distribution patterns. The quality and quantity of species are contingent upon tidal range, wave intensity, and substrate type (Vegas, 1971); species that avoid wave impacts and desiccation stress by burying themselves in sand or mud are found in sandy and muddy substrates. Conversely, although sand is more frequently disturbed, species deposited in these areas are less exposed and less likely to be moved (Rodríguez, 1967); consequently, we observed a higher number of individuals in the mud.

Species diversities (H') in our two study areas were as follows: Punta Chame H'= 1.835 and El Líbano H'= 1.596. Both indices are notably low, confirming that Punta Chame is more diverse than El Líbano, as indirectly demonstrated by the higher number of individuals seen in the physical data. This is evident in the dominance values, with D'= 0.2035 for Punta Chame, while El Líbano had a slightly higher value D'= 0.2543, indicating communities where species are numerically superior to others. Punta Chame (J' = 0.6777) is comparable to some countries regarding equity value, while El Líbano (J' = 0.6422) appears low for that group. Both sites exhibited low diversity; however, Punta Chame (H'=1.835) showed slightly greater diversity than El Líbano (H'=1.596). Punta Chame is situated at the inner edge of the mangrove, closer to the beach, whereas El Líbano lies at the outer edge of these forests, nearer to continental or human-populated areas.

The results of the dominance and equity indices suggest a homogeneous distribution; both sites display an equitable distribution of species, although the physical data imply marked dominance, aligning with Margalef (1995), who indicated that in a community where one species numerically dominates another, community diversity is low. The low diversity values are associated with significant sedimentation in El Líbano and pollution generated by human activities; hence, our records are considerably lower than those documented by other authors throughout the Panamanian Pacific, such as in studies conducted in Bahía de Chame (Diéguez & Avilés, 1981) and in Líbano (Fairchild & López, 2010). Specifically, Ortega *et al*. (1986) noted that communities differ in species diversity in relation to substrate type, dehydration risks, predation, and food availability. Mollusk diversity, as stated by Jackson (1972), is influenced by environmental factors such as turbidity, temperature, water pH, salinity, and grain size.

The mollusk species collected by us and consumed by the local population include *A. tuberculosa*, known as black shell, a significant source of protein and economic resource among coastal inhabitants, typically consumed in ceviche, rice dishes, among other recipes (Tejera *et al*., 2016). We found it to be the most exploited species in the area and along the Pacific coast; *M. guyanensis* is frequently harvested, adhering to roots and forming part of the human diet. Its soft flesh is nutritionally valuable as a protein source, ranking second internationally in species consumed after sardines (Tejera *et al*., 2016); *L. asperrima*, the white clam, is edible and used in cocktails, ceviches, and rice dishes (Tejera *et al*., 2016); *P. ventricosa* is consumed in Bahía de Chame, although many residents are unaware, as they are sold in mixed "clam" bags (Tejera *et al*., 2016); species such as *P. inflata* and *P. notabilis* are also consumed in small quantities. The genus *Polymesoda*, native to the Americas, is the most exploited fishery resource in countries like Colombia and Venezuela, and it is classified as "vulnerable" on the list of threatened species in the Colombian Caribbean (INVEMAR, 2002). The deforestation of mangroves for charcoal production, excessive shrimp extraction by external individuals for sale, pollution, and its impact from shrimp farm development are likely responsible in varying proportions (Macintosh, 1988 and Macintosh & Ashton, 2002).; also, in this document); all of this has led to reductions in available stocks for artisanal fishers in this area. The mollusk species most consumed by residents, in order, are: *A. tuberculosa*, *M. guyanensis*, *L. asperrima*, *P. ventricosa*, *P. inflata*, and *P. notabilis*; in this regard, the data gathered from the survey and other studies suggest that no other species harvested by the inhabitants of Punta Chame Bay (and likely along the Pacific coast of Panama) has been subjected to greater fishing pressure than *A. tuberculosa* (Nagabhushanam & Dhamne, 1977).

CONCLUSION

The observed low population levels and limited diversity of these species in the mangroves of the Chame district can be largely attributed to anthropogenic activities such as mangrove deforestation for charcoal production, excessive extraction by external settlers for commercial purposes, pollution, and the establishment of shrimp farms.

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