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Dynamic of Mangrove Associated Molluscs in Anthropized Areas of the Cameroon Coastline

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Abstract

Due to unabated anthropogenic exploitations, mangrove forests globally are constantly under pressure and degradation, which may result in the reduction of ecosystem functioning and biodiversity. Molluscan fauna, which is one of the main macroinvertebrates that play a major ecological role in nutrient dynamics in mangroves, are sensitive to the changes in their habitat. This survey aims to assess the impact of anthropogenic activities on the diversity of molluscs' communities in the mangrove forest. Anthropogenic disturbances within 20 sampling sites were valued at six mangrove stands and patched scoring the degree of influence according to vegetation, structure, waste and trampling. Molluscs were caught by hand and counted within 1 × 1 m^2 plots placed at three points distant of 50 m established using a straight line transect of 100 m. Upon the 20 sites investigated, five were slightly disturbed, eight moderately disturbed and seven sites were highly disturbed. The mean abundance of molluscs decreased from slightly disturbed areas (172.25 ± 73.09 Ind·m^{-2}) to highly disturbed areas (100.57 ± 62.84 Ind·m^{-2}). Highly disturbed areas have shown lower species richness (R = 1.09 ± 0.15) and diversity (H' = 2.30 ± 0.31). Human activities in the mangrove forest could particularly have effects on the diversity of molluscs, however, feature potential conservation measures have to be in harmony with the needs of the local population.

Keywords

Anthropogenic Disturbance Index, Human Activities, Level of Degradation, Mollusc Diversity

1. Introduction

Anthropogenic activities are widely recognized as a driver of environmental impact due to the significant pressure they are recognized to generate. Almost all global mangrove losses that have occurred in the recent past decades are a result of anthropogenic pressures and anthropogenic edges. These losses are also evident in mangrove forests as this ecosystem is most at risk due to deforestation and reclamation [1] [2]. These anthropogenic pressures are mainly made necessary by the rapid coastal population growth [3]. Nowadays, although many studies have focused on mapping and quantifying mangrove loss, there are few comprehensive assessments on the impacts of mangrove degradation [4]. This, because mangrove habitats are regions of remarkable biological productivity [5] that provide food, breeding grounds and nursery sites for a variety of terrestrial and marine organisms [6].

Mollusca is represented by predators, herbivores, detritivores or filter feeders in the mangrove food web [7] and it is an important animal phylum, which inhabits the mangrove environment [8] [9]. Molluscs play a significant role in terms of providing food sources to aquatic animals, migratory birds, and humans. They form a key link in the food chain and have a high socioeconomic value for coastal fisheries [10]. Thus, molluscs are identified as an important biological indicator because molluscan diversity helps to assess the effect of environmental impacts on benthic ecosystem functioning [11]. Since they have the ability to assess water quality and ecological risk assessments, the mollusc population is greatly affected by changes in their habitat [12] [13]. In mangroves, molluscs can reach astonishingly high biomass and they occupy very different levels of the ecosystem food web. While gastropods contribute to entrap primary production within the system, both grazing fallen leaves and consuming mud (mainly composed by mangrove litter), bivalves are efficient filter feeders, able to capture suspended particles of various origins [7].

Mangrove associated molluscs diversity in Cameroon include 42 species [8]. Many authors have contributed to the knowledge of their taxonomy, diversity and distribution [8] [14] [15] [16]. However, in view of anthropogenic activities increasing on mangroves in Cameroon, these data are scarce and should be completed. A key question is how these faunistic communities behave in different anthropized habitats? This survey aims to assess the impact of anthropogenic activities on the diversity of molluscs' communities in the mangrove forest of Cameroon.

2. Materials and Methods

2.1. Study Area

Twenty sites located in the Cameroon coastline were chosen according to mangrove scope in six localities, the importance of human activities in ecosystem and variability of the stands (**Figure 1**). The sites were distributed as follows: two sites in Limbe, three in Tiko, seven in Douala, three sites in Mouanko, three sites

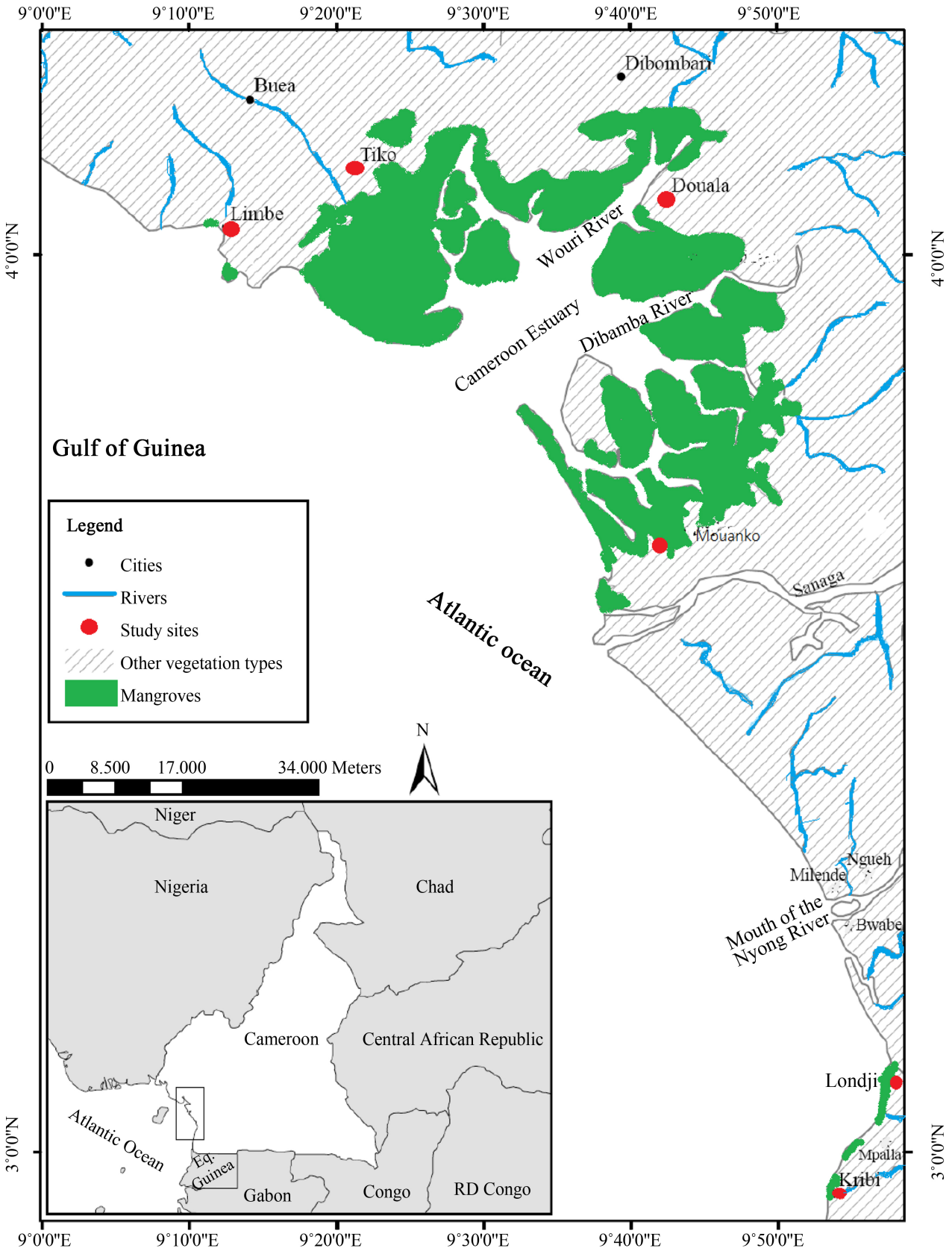

Figure 1. Localisation of study areas (adapted from [23]).

in Kribi and Two in Londji (Table 1). Human activities within the mangrove habitats are the excessive harvest of mangrove trees for firewood, charcoal, clearing of mangrove areas for agricultural purposes coupled with the rapid urbanization of the adjacent towns and pollution [1] [17] [18] [19], which have led to a gradual degeneration of these ecosystems.

Two types of climate dominated the study area. In the northern and central parts, climate belongs to a particular equatorial regime called Cameroonian regime, characterized by a long rainy season (March-November) and a short dry season (December-February) with an annual average temperature of about 26.7˚C [17]. Climate in the southern region is of a typical equatorial regime with four seasons (two rainy seasons and two dry seasons well individualized), marked by high and stable temperatures of about 28.7˚C. Heavy annual rainfalls are observed from more than 5000 mm in Limbe area and decreased to about 3000 mm in Kribi area. The tidal regime along the coastline reaches 3 m in the Cameroon Estuary, 1.2 m in the mouth of Nyong and 1.5 m in Kribi [20].

These three coastal regions are also distinguishable in terms of mangrove area (small patches in the South and large units in the Cameroon estuary and Rio del Rey estuary which gathered a great part of mangroves in Cameroon) and anthropogenic pressure [21]. Soils are gray or black muds, of silty, sandy or clay texture, and deriving from fluvial sediments [22]. The flora has consisted of seven

Table 1. Coordinates of different sampling sites.

Localities	Sites	North latitude	East longitude
Limbe	Down beach	04˚00'40.64"	09˚10'21.67"
	Mabeta	04˚00'10.42"	09˚12'25.74"
Tiko	Avion beach	04˚00'52.92"	09˚23'02.65"
	Apollo beach	04˚00'56.35"	09˚23'43.58"
	Mbomè	04˚00'07.14"	09˚17'33.79"
Douala	Bois des singes	03˚57'48.56"	09˚45'53.81"
	Bonamouang	04˚05'03.90"	09˚42'57.64"
	Bonamoussadi	04˚06'10.23"	09˚43'49.10"
	Bonendallè	04˚07'21.46"	09˚39'09.14"
	Essenguè	04˚01'07.62"	09˚40'16.84"
	Pont du wouri	04˚04'18.36"	09˚42'17.08"
	Village	04˚04'11.58"	09˚50'50.14"
Mouanko	Mbiako	03˚14'25.44"	09˚34'73.29"
	Yoyo I	03˚50'18.02"	10˚03'45.37"
	Yoyo II	03˚39'56.98"	09˚38'39.43"
Londji	Londji I	03˚04'27.36"	09˚58'46.82"
	Londji II	03˚05'03.81"	09˚58'32.64"
Kribi	Mpalla	03˚00'33.99"	09˚57'09.00"
	Mpolongwe	03˚01'49.27"	09˚57'50.90"
	Nziou	02˚59'09.82"	09˚57'28.96"

indigenous or true mangrove species (*Acrostichum aureum* L., *Avicennia germinans* (L.) Stearn, *Conocarpus erectus* L., *Laguncularia racemosa* (L.) Gaertn. F, *Rhizophora harrisonii* Leechman, *R. mangle* L. and *R. racemosa* GFW Meyer) with the last species being the most dominant [1]. These species live in association with several others considered like associates. The faunal component includes vertebrates, such as birds, reptiles and fish, and a wide range of invertebrates, mainly crabs and molluscs which constitute the bulk of benthic diversity [8] [16] [22] [23].

2.2. Assessment of Mangrove Damage

To estimate degradation, human activities that occurred in mangrove in different sites were noticed. Anthropogenic disturbance within each site, associated with transect line, were valued and patch scoring the degree of degradation according to four (04) categorical variables:

- Vegetation (V): Evidence of logging on mangrove species and presence of invasive species.
- Trampling (T): The presence of human footprints.
- Waste (W): The presence of solid wastes on the forest floor and entangled on the roots.
- Structure (St): The evidence of human modifications of mangrove hydrology and/or topography.

According to the local situation, each variable was scored from 0 to 5 where:

- 0 = absence of damage;
- 1 = very little damages;
- 2 = little damages;
- 3 = average damages;
- 4 = high damages;
- 5 = very high damages.

The score of each categorical variable was combined and summarized into Anthropogenic Disturbance Index (ADI). According to [24], values for each variable were average each local/site context and summarized as follows: V + T + W + St = ADI. Therefore, the ADI ranged from 0 to 20 which characterizes the mangrove degradation level. Three mangrove degradation levels (low, medium or moderate and high) were recognized, considering the value of ADI in any site:

- $0 < ADI < 6$ equivalent to low degradation;
- $7 < ADI < 12$ equivalent to moderate degradation;
- $ADI > 12$ equivalent to high degradation.

2.3. Molluscs Sampling

Molluscs were caught by hand and counted within 1×1 m^2 plots placed at three zones established using a straight line transect of 100 m perpendicular to the water shoreline in the mangrove vegetated area as mentioned by [25]. Arboreal

species were also harvested by hand from roots and stems of mangrove trees [26]. To quantify abundance of molluscs, the transect is carefully looked through to search specimens that were not collected in the plots. Given the variability of each site, the distance between two transects was about 100 m. Individuals were sorted out by eye, identified, when possible, in the field and counted. Fully unidentified collected molluscs were washed and preserved in 70% alcohol then were taken to laboratory for further identification using available data [14] [15] [16] and molluscs database (https://www.molluscabase.org/) websites.

2.4. Data Analysis

Depending on the presence/absence of each species and the number of its individuals in the different sites, the following annotations have been retained:

- − (absent) = no individual of the species was found;
- + (low recorded) = species is present and its number of individuals is less than or equal to 5;
- ++ (medium recorded) = species is present and its number of individuals is between 6 and 50;
- +++ (high recorded) = species is present and its number of individuals is greater than 50.

The occurrence of the sample species was calculated as following [27]:

$$F = \frac{Pi}{P} \times 100$$

where F represent the frequency of occurrence (%), Pi and P are the sample sites where species i is present and the total number of sites surveyed respectively.

The result obtained were used to qualified the species as rare (0 - 15%), occasional (15% - 25%), common (25% - 50%), constant (50% - 75%) or ubiquitous (75% - 100%) [28].

The abundance and species richness (Margalef index) of different sites and relative density of each species were assessed, likewise, diversity index of Shannon-Weaver (H') and the evenness index of Pielou (J') of each site were calculated using PAST v 3.05" software. ADI, mean and standard deviation of data were assessed using Microsoft Office Excel 2019.

3. Results

3.1. Mangrove Degradation Level

Between different categorical variables choose to assess degradation, vegetation was highly affected in Apollo beach, Mbomè, Bois des Singes, Essenguè, Pont du Wouri, Village, Mpalla and Nziou. Trampling was well marked in down beach, Bois des Singes, Bonendalè, Essenguè, Village and Nziou. Concerning dumping of wastes in mangrove ecosystems, Bois des Singes was the most affected. The mangrove structure was highly altered at Pont du Wouri and Appolo Beach sites (**Table 2**).

Table 2. Degradation level assessment and parameter structure of different sites: V = vegetation; T = trampling; W = waste; St = structure; ADI = Anthropogenic Disturbance Index; N = number of individuals; S = number of species; P = number of plots; A = Abundance (ind·m^{-2}); H' = Shannon-Weaver index; R = Margalef index; J' = Pielou evenness.

Localities		Limbe		Tiko			Douala							Mouanko			Londji		Kribi		
Sites		Down Beach	Mabeta	Apollo Beach	Avion Beach	Mbomè	Bois des Singes	Bonamouang	Bonamoussadi	Bonendalè	Essenguè	Pont du Wouri	Village	Mbiako	Yoyo I	Yoyo II	Londji I	Londji II	Mpalla	Mpolongwe	Nziou
Variables	V	3	3	4	2	4	4	2	2	3	4	4	4	2	1	2	2	3	4	2	4
	T	4	3	3	1	3	4	3	3	4	4	3	4	1	2	1	1	2	3	3	4
	W	3	2	2	3	3	4	3	2	3	3	3	3	1	2	1	0	1	1	2	3
	St	2	3	4	2	2	3	2	2	3	2	4	3	0	0	0	0	1	2	1	2
ADI		**12**	**11**	**13**	**8**	**12**	**15**	**10**	**9**	**13**	**13**	**14**	**14**	**4**	**5**	**4**	**3**	**7**	**10**	**8**	**13**
Degradation level		**Moderate**	**Moderate**	**High**	**Moderate**	**Moderate**	**High**	**Moderate**	**Moderate**	**High**	**High**	**High**	**High**	**Low**	**Low**	**Low**	**Low**	**Moderate**	**Moderate**	**Moderate**	**High**
Parameters	N	1248	624	813	579	958	2103	6460	5181	1008	1291	196	1681	5127	3639	8343	790	1229	795	1445	576
	S	12	7	9	10	8	11	15	12	9	9	6	7	15	10	18	5	8	7	9	8
	P	15	6	12	15	9	15	27	18	12	6	9	15	27	18	36	12	18	15	21	9
	A	83	104	67	39	106	140	239	288	84	215	22	112	189	202	232	66	68	53	69	64
	H'	3.25	2.19	2.84	2.61	2.49	2.12	3.02	3.13	1.84	2.38	2.02	2.33	3.16	2.37	2.83	2.07	2.49	2.52	2.11	2.57
	R	1.54	0.93	1.19	1.41	1.02	1.31	1.59	1.29	1.16	1.12	0.94	0.81	1.64	1.09	1.88	0.59	0.98	0.89	1.09	1.10
	J'	0.91	0.78	0.89	0.79	0.83	0.61	0.77	0.87	0.58	0.75	0.78	0.83	0.81	0.71	0.68	0.89	0.83	0.89	0.67	0.85

An assessment of the mangrove degradation, based on the scores of the variables affected by human activities is given in Figure 2 below. Among the 20 sites sampled, depending on the damage caused by human activities, the anthropogenic disturbance index (ADI) was higher in the Bois des Singes site (15) and lower in Londji I (3). This index permitted to distinguish four (04) slightly degraded sites (Mbiako, Londji I, Yoyo I and Yoyo II), nine (09) moderately degraded (Down beach, Londji II, Mabeta, Avion beach, Mbomè, Bonamouang, Bonamoussadi, Mpalla and Mpolongwe) and seven (07) highly degraded (Apollo beach, Bois des Singes, Bonendalè, Essenguè, Pont du Wouri, Village and Nziou).

3.2. Molluscan Community Structure

A total of 34 species of molluscs were collected during this study. They comprised two classes: Bivalvia (4 species) and Gastropoda (30 species). The list of different species collected is shown in Table 3. *Pachymelania fusca* showed higher occurrence percentage (100%) found to be high recorded in the different assemblages, while most species with low occurrence percentage (5%) showed

Table 3. Presence of molluscs at different sites: Dob = Down Beach; Mab = Mabeta; Avb = Avion beach; Apb = Apollo beach; Mbo = Mbome, Bos = Bois des Singes; Bng = Bonamouang; Bdi = Bonamoussadi; Blè = Bonendalè; Ess = Essenguè; Pow = Pont du Wouri; Vil = Village; Mbi = Mbiako; YoI = Yoyo I; YoII = Yoyo II; LoI = Londji I; LoII = Londji II; Mpa = Mpalla; Mpo = Mpolongwe; Nzi = Nziou. (–) Absent; (+) Recorded; (++) Medium recorded; (+++) High recorded.

Species	Limbe		Tiko						Douala				Mouanko			Londji		Kribi		
	Dob	Mab	Avb	Apb	Mbo	Bos	Bng	Bdi	Blè	Ess	Pow	Vil	Mbi	YoI	YoII	LoI	LoII	Mpa	Mpo	Nzi
Crassostrea gasar	++	-	++	++	+++	-	-	-	-	-	-	-	-	-	-	-	+++	+++	-	-
Cyrenoida rosea	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Egeria radiata	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Iphegenia rostrata	-	+	-	-	-	-	+	+	-	-	-	-	-	+	+	-	-	-	-	-
Aachatina achatina	-	-	-	-	-	+	+	-	+	+	+	-	-	+	-	-	-	-	-	-
Littorina angulifera	++	-	++	++	+	-	-	-	-	-	-	-	+	+	+	-	+	-	-	-
Littorina sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	++
Melanopsis sp.	-	-	-	-	-	+	+	-	-	-	-	-	++	-	+	-	-	-	-	-
Murex sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	+	-
Neritilia rubida	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Neritina andansoniania	-	-	-	-	-	-	+	-	+	-	-	-	-	-	+	-	-	-	-	-
Neritina glabrata	+	+	-	+	+	+	+	+	++	++	-	-	-	-	-	-	-	-	-	-
Neritina lineolata	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Neritina senegalensis	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	++
UD1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
UD2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
UD3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
UD4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Pachymelania aurita	++	+++	-	-	-	+++	++	++	+++	++	+++	+++	++	++	++	-	-	-	-	-
Pachymelania Byronensis	+	-	++	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Pachymelania fusca	+++	+++	+++	++	+++	++	+++	+++	++	+++	++	+++	+++	+++	+++	+++	++	++	+++	+++
Pachymelania granifera	+	-	-	-	-	+	-	++	-	-	-	-	++	-	+	+	-	-	+	+
Pachymelania mutans	++	-	-	-	-	-	-	++	-	+	-	-	++	-	++	+++	+	-	+	+
Pachymelania sp.	++	-	+	+	-	-	++	++	-	-	-	-	-	-	-	-	-	+	-	-
Pachymelania quadriseriata	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	+++
Potadoma liricincta	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-
Tympanotonus fuscatus	++	+++	+++	++	+++	+++	+++	++	-	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+
Tympanotonus radula	++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	++	++	+++	+++	+++	+++	+++	-
Thais callifera	-	-	+	-	+	-	-	-	-	-	-	-	+	+++	++	-	+	-	-	-
Theodoxus niloticus	-	-	++	++	-	+	+	-	+	+	-	++	+	+	+	-	+	-	+	-
Theodoxus sp.	-	-	-	-	-	+	-	+	-	-	-	-	-	-	+	-	-	-	-	-
Melanopsis pergracilis	-	-	-	-	-	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-
Melanoides tuberculata	-	-	-	-	-	+	-	+	+	-	+	+	+	-	-	-	-	-	-	-
UD5	-	-	-	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-

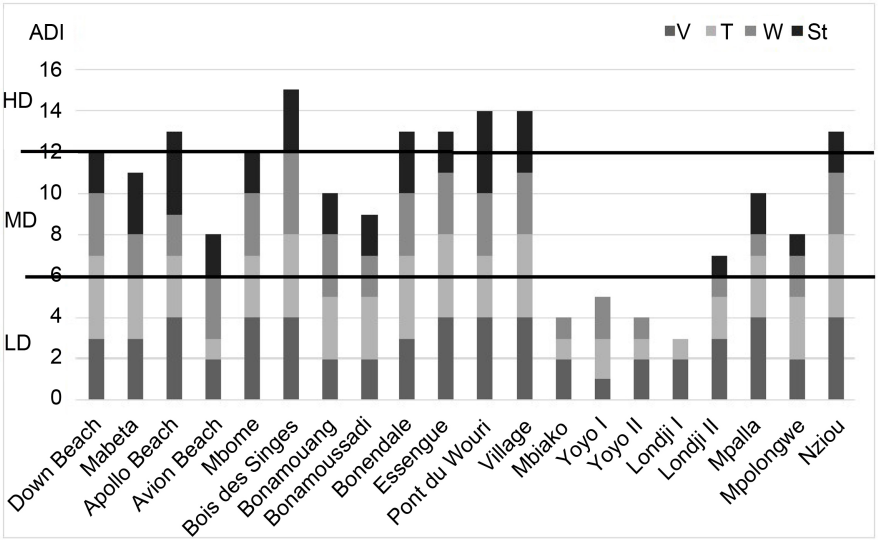

Figure 2. Degradation level of different sites: ADI = Anthropogenic Disturbance Index; LD = Low degradation; MD = Moderate degradation; HD = High degradation.

low numbers of individuals in the sites where they were presents. However, *Potadoma liricincta* is medium recorded in Bonamouang although with a low percentage of occurrence. The bivalve *Crassostrea gasar* is medium recorded or high recorded in the sites where it was collected (medium recorded at Down beach; Apollo beach and Avion beach; high recorded at Mbomè, Londji II and Mpalla.

Figure 3 shows distribution of occurrence among these species. Six species are rare (*Cyrenoida rosea*, *Potadoma liricincta*, UD1, UD2, UD3 and UD4), fourteen species are uncommon or occasionals (*Egeria radiata*, *Iphegenia rostrata*, *Littorina* sp., *Melanopsis* sp., *Murex* sp., *Neritilia rubida*, *Neritina adansoniana*, *N. lineolata*, *N. senegalensis*, *Pachymelania byronensis*, *P. quadriseriata*, *Theodoxus* sp., *Melanopsis pergracilis* and UD5), nine species are commons (*Crassostrea gasar*, *Achatina achatina*, *Littorina angulifera*, *Neritina glabrata*, *Pachymelania granifera*, *P. mutans*, *Pachymelania* sp., *Thais callifera* and *Melanoides tuberculata*), two are constants (*Pachymelania aurita* and *Theodoxux niloticus*) and three species are ubiquitous (*Pachymelania fusca*, *Tympanotonus fuscatus* and *Tympanotonus radula*).

3.3. Effect of Mangrove Degradation

Following classification of mangrove based on anthropogenic disturbance index (ADI), abundance of molluscs, species richness and diversity index given are the means of cumulative sample values in different sampling sites. Globally, slightly differences were observed in abundance of molluscs, species richness and Shannon-Weaver index among degradation levels of mangrove stands (**Figure 4**). The abundance of molluscs and species richness were higher (respectively D = 172.25 ± 73.09 Ind·m^2 and R = 1.29 ± 0.56) in areas with a low degradation level. Areas with high degradation level presented low values of abundance (D =

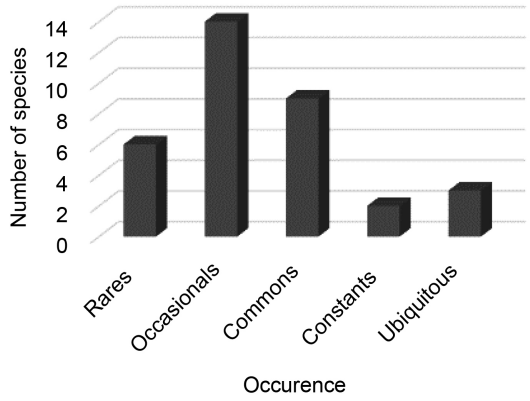

Figure 3. Occurrence of molluscs collected.

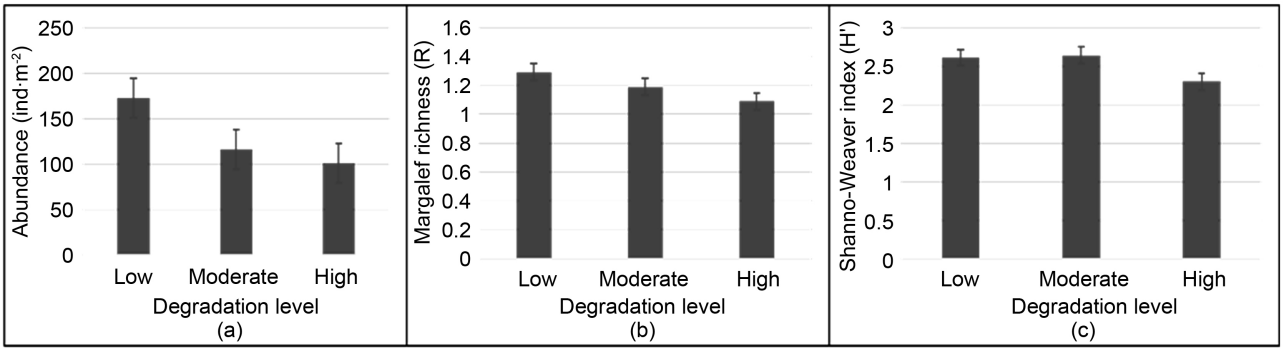

Figure 4. Variation of molluscan communities according to mangrove degradation level: (a) Abundance; (b) Margalef richness index; (c) Shannon-Weaver diversity index.

100.57 ± 62.84 Ind·m^{-2}), of species richness (R = 1.09 ± 0.15) and of Shannon-Weaver index (H' = 2.30 ± 0.31). The high value of mean Shannon-Weaver diversity index was found in moderate degradation level (H' = 2.64 ± 0.40).

4. Discussion

The observations made in the various study areas have shown that all the mangrove stands were disturbed, but at different levels. Human activities have a massive impact on mangrove forests, especially their deforestation [29]. These impacts can significantly transform forests by triggering negative effects on the entire ecosystem assembly resulting in reduced biodiversity and functionality [30]. Among the anthropogenic activities identified, logging is the main cause of partial or complete deforestation of large spaces of mangroves, thus promoting rampant urbanization in coastal regions [1]. Observations made in this work have shown that vegetation is the most affected variable, thus presenting, in major sites, scores greater or equal to 3. In non-peri-urban mangroves (Londji and Mouanko), fishing is always the main activity. For local residents, fish smoking is well developed, and as a result, the wood of red mangroves (*Rhizophora* spp.) is highly prized for drying fish because of its high resin content and its ability to burn at fresh [31]. However, the level of disturbance is low in non-peri-urban mangroves (low degradation in the sites of Londji I, Londji II, Mbiako, Yoyo and

Yoyo II) in comparison with peri-urban mangroves.

The consequences of urban development vary according to region and so far, remain only roughly predictable [32]. However, with regard to the impacts of urbanization on habitats and living organisms, as well as the urbanization factors responsible for these effects, certain trends emerge from the literature. Human footprints such as the construction of houses and infrastructure are observed in most of the peri-urban mangroves of Douala, Limbe and Kribi. The realization of development projects, in particular the construction of Wouri second bridge and the anarchic urbanization, which pushes the populations to occupy the mangrove areas, are all disturbances of human origin [1]. These activities are responsible for severe impacts in these ecosystems: Changing or completely degrading the physical structure of the mangrove, and affecting the abundance and distribution of benthic macrofauna and therefore molluscs as reported by [33].

Anthropogenic stress is the response of a biological entity, or any individual, population, or community, to anthropogenic disturbance. This stress at one level of the organization can also have an impact on another level. Since it is difficult to detect the effects of anthropogenic stress at the individual level, they are very often sought at the level of populations or communities [34]. The specific impacts of anthropogenic activities on the diversity and abundance of molluscs could vary depending on the low, medium or high level of human disturbance, the geographical location, the presence of pollutants in the sediments, the dynamics of nutrients and the extent of spatial modifications [13] [35]. This work has shown that the abundance, specific richness and diversity of molluscs were affected by human activities that have taken place in the mangroves. These results are in conformity with the work of many authors who have shown that habitat degradation and fragmentation are typically associated with a loss of species diversity, richness and evenness [25] [36] [37]. The high molluscan diversity in mangroves is mainly due to availability of a diverse range of microhabitats [10]. The distribution and diversity of molluscs depend on several physico-chemical factors, but the underlying factor is the habitat wherein they thrive [11]. [38] suggested that the impacts generated by human activities would be changes in the dynamics of tidal flooding and, therefore, the distribution of leaves in the substrate resulting in a decrease in mollusc abundance in affected areas. [39] also concluded that an extreme impact could greatly reduce abundance of molluscs due to the change in the level of flooding, tide and through the availability of organic matter in the sediment. However, in accordance with these authors, mollusc abundance may be altered by human impacts causing fragmentation in the system because intra and interspecific interactions would be affected. However, in this work, the highest diversity was found in moderately degraded areas. These results have suggested that when the environment is not too affected by human activities, a good number of functions are still performed because human impacts participated also to the normal evolution of an ecosystem. If the mangrove is not too degraded, new conditions (e.g. presence of debris from human activities that can serve as habitats for benthic macrofauna) are created favour-

ing the establishment of other species [4]. Small-scale changes in mangrove structure can affect the diversity and abundance of benthic organisms in these habitats [10] [13].

5. Conclusion

Mangrove forests in Cameroon are suffered from habitat destruction and fragmentation. This is shown in this study by the method used to assess the anthropogenic disturbance index which has permitted to discriminate the twenty sampling sites in seven highly degraded, nine moderately degraded and four slightly degraded. This situation may result in a severe reduction in mangrove biodiversity and disturbance ecosystem functioning. The present work has reported that abundance, species richness and diversity index of molluscs are lower in highly degraded mangroves when compared with slightly and moderate degraded areas. These results provided indicators for mangrove features under the anthrone classification and reflected the importance of habitats for the conservation of sensitive biocenoses as macrobenthos and highlighted the need for further understanding the effects of anthropogenic stressors on mangrove ecosystems. Human activities on the mangrove forest could particularly have effects on the diversity of molluscs, however, to mitigate the above impacts to a great extent, feature potential conservation measures have to be in harmony with the needs of the local population.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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