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Biodiversity of the malacological fauna of some mangroves of the Cameroonian Littoral: Influence of abiotic factors

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Abstract
In order to contribute to the knowledge and conservation of the benthic macrofauna of the mangrove ecotones of Cameroon, a study was carried out in the mangrove swamps of the Cameroonian coast during the period from December 2019 to May 2020. The objective was to assess the mollusc biodiversity in relation to the abiotic factors of the environment. For this purpose, 14 sampling stations were selected. The Physico-chemical parameters of the waters were determined according to standard methods and the mollusc fauna was identified using the appropriate keys. Then, correlations were made. The results of the Physico-chemical analyses show that the mangrove waters studied are moderately oxygenated with high temperatures, are highly mineralized, have a slightly basic pH and high salinity. We also note high levels of Suspended Solids and highly turbid waters. Concerning the malacological fauna, 1644 specimens belonging to 02 classes 07 orders, 08 families, 12 genera and 15 species have been identified. The families of Thiaridae and Potamidididae were the most predominant, while the families of Lymnaeidae and Sphaeeriidae were the least represented. The species *Tympanotonus fuscatus* was the most regular over all study stations, followed by *Pachymelania fusca* and *Neritina glabrata*. Station S14 was the richest with 8 species while station S12 was the most diverse. The results of the statistical analyses show positive correlations between *Pinaxia coronata* species and salinity. Negative correlations were obtained between the species *Neritina glabrata* and salinity, conductivity and nitrates. On the other hand, there was a positive correlation between *Pinaxia coronata* species and oxidability.

Keywords: Mangrove, mollusc's, littoral, abiotic factors, Physico-chemistry

1. Introduction

With 2,749 km² of mangrove area along its coast (Envi-rep Cameroon, 2010) [1], Cameroon is one of the 18 countries with the largest mangroves in the world (WCMC, 1992) [2]. As a result, it has ratified several international agreements and has set up, both regionally and nationally, programs for the preservation of ecosystems and management of natural resources, including mangroves. Mangroves, which are tropical forests at the crossroads of freshwater and marine waters, are important because of carbon storage, as well as providing spawning grounds, protection against land encroachment and sewage treatment (Herteman, 2010) [3]. They represent a refuge and are home to several animals and fish species, among which mollusc's figure prominently (Nagelkerken *et al*., 2000) [4]. The latter play a major role in this ecosystem because of their role in energy transfer and the fact that they are located at almost all levels of the food webs (from filter feeders to predators) in the mangroves (Plaziat, 1984) [5]. Furthermore, the animals that contribute the most biomass to mangroves are shellfish, a collective term designating both bivalve and gastropod mollusc's (Keen, 1971) [6]. Despite these functions that mangroves offer, they are increasingly subject to strong anthropogenic pressures (fishing, logging, various types of pollution, etc.), to which are added the effects of climate change and coastal erosion (PANGIRE, 2009) [7]. The ever-increasing demographic pressure, coupled with difficult living conditions, push coastal populations to an abusive exploitation of mangrove areas, which leads to the loss of habitats. According to Sinsin *et al*. (2018) [8], the loss of habitats in mangroves is the first threat factor for mollusc fauna. This loss of habitat and various pressures lead to a degradation of water quality and consequently an imbalance in the distribution of the malacological fauna in the mangroves. In Cameroon, some works, notably those of Plaziat (1974 and 1984) [9], Ngo-Massou *et al*. (2012) [10] and Kotté-Mapoko *et al*. (2017) [11] have been carried out in the mangroves of Kribi, Tiko, Wouri River and Limbe. This work essentially focused on the inventory of the benthic macrofauna of these areas, without however dwelling on the quality of the water in which these organisms live. In order to propose methods and means for the protection and conservation of mollusc fauna in the mangroves of Cameroon, the present work aims at evaluating the malacological biodiversity of some mangroves of the Cameroonian coast in relation to the abiotic factors of the environment.

2. Materials and Methods

2.1 Study area

This study was carried out in two localities of the coastal strip of Cameroon, namely Mouanko and Manoka (Figure 1). These localities enjoy a tropical coastal climate with two seasons, a long rainy season from March to October characterized by abundant rainfall, and a short dry season from November to February (Suchel, 1972; Sighomnou, 2004) [12, 13]. The soils are ferralitic hydromorphic in nature with vegetation dominated by mangroves of the *Rhizophora* sp. type. (Din Ndongo, 2001) [14]. A total of 14 sampling stations were selected according to criteria such as water salinity and the presence of possible pollution sources.

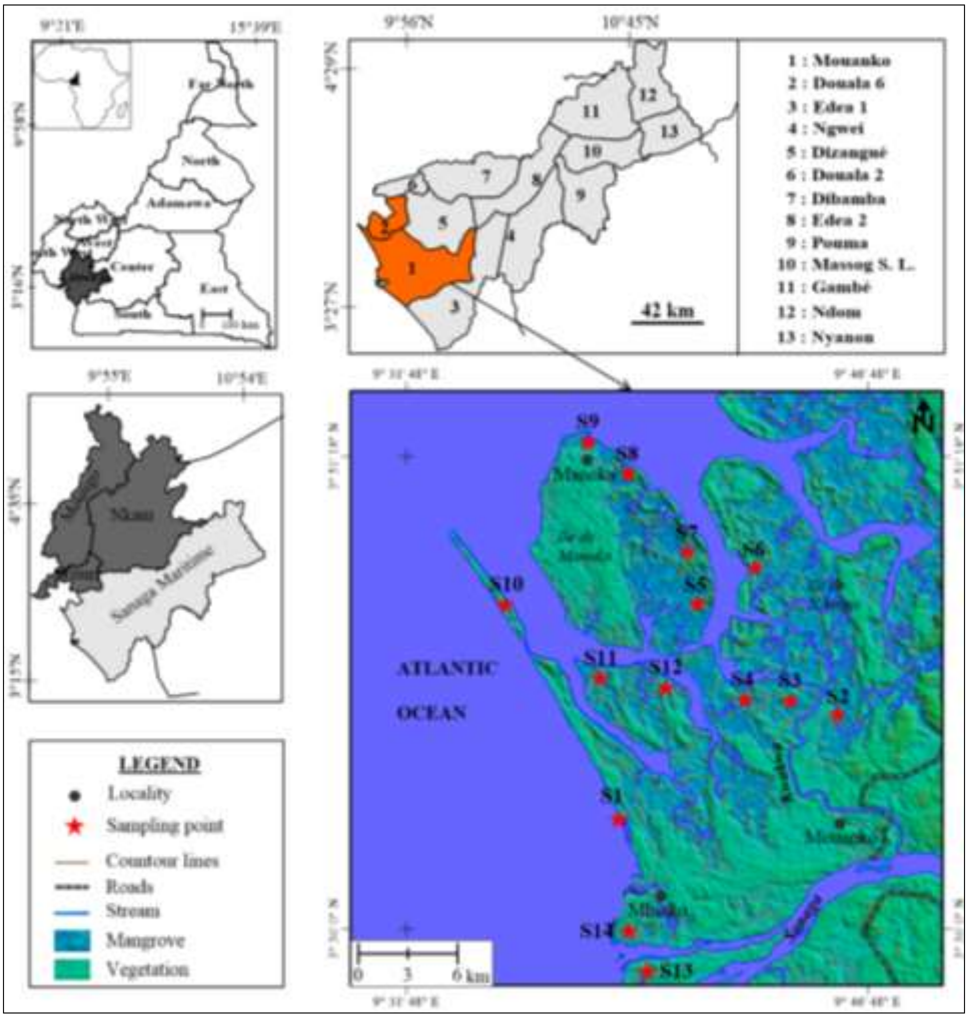


Fig 1: Geographical representation map of sampling stations

2.2 Sampling methods and measured parameters

Water and wildlife sampling was conducted over an area of 100 m^2, as described by Gemert (2019) [15] at high and low tide for six months (3 months in the dry season and 3 months in the rainy season) following a monthly sampling frequency. Water sampling and analysis of Physico-chemical parameters were done *in situ* and in the laboratory following the recommendations of APHA (1998) [16] and Rodier *et al.* (2009) [17]. Among the parameters measured were: temperature, suspended solids (TSS), turbidity, color, oxygen, conductivity, salinity, nitrogen forms, among others. These parameters were chosen because they provide information on the degree of mineralization of the water, the quantity of organic matter and the quality of the elements brought by the tides during periods of flooding of the mangroves. Molluscan shellfish collection was carried out over the entire defined area using the cloud net (Stark *et al*., 2001) [18] and by hand harvesting (Pokryszko and Cameron, 2005; Pokryszko *et al*., 2006) [19, 20]. Specimens were collected from both mud and mangrove roots. The collected specimens were then fixed with 95° alcohol. The identifications in the laboratory were made with the Wild M5 binocular magnifying glass using the keys and works of Brown (1994) [21] and Bouchet and Rocroi (2005; 2010) [22, 23].

2.3 Statistical analyses

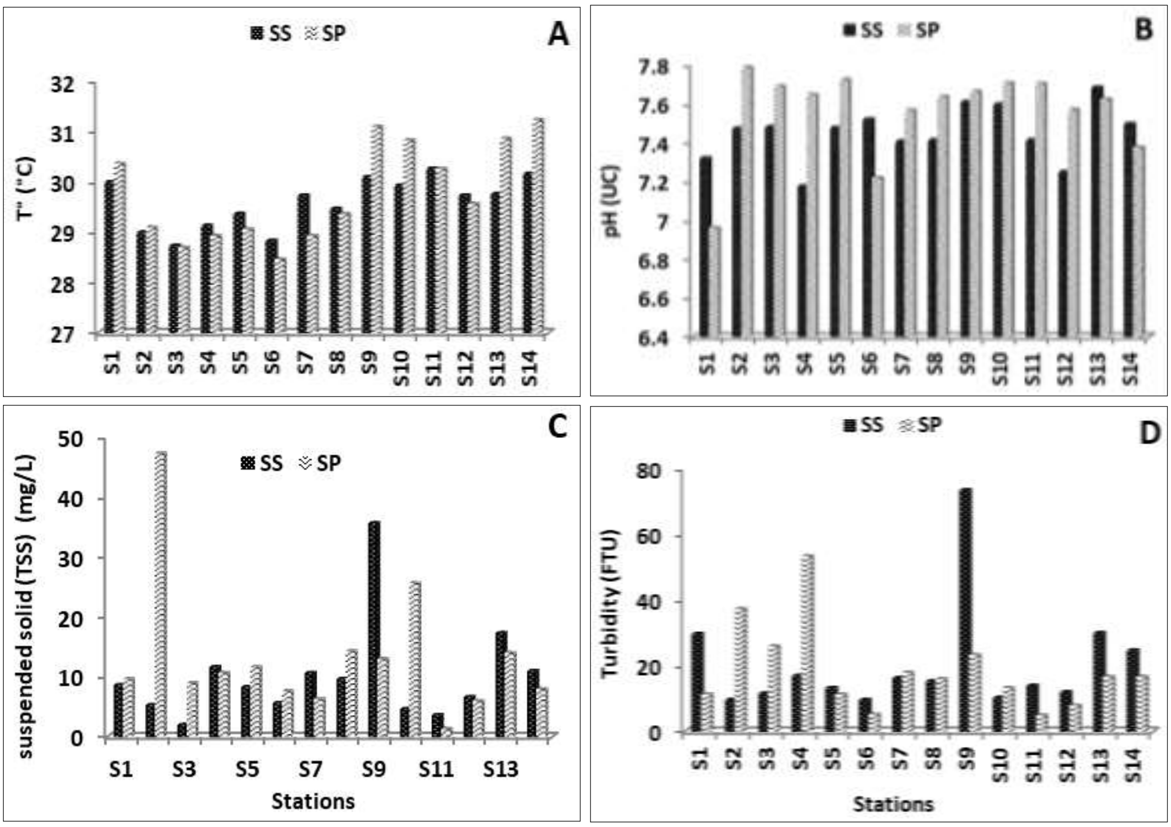
Kruskall-Wallis and Mann Whitney's H' tests allowed us to determine whether or not there were significant differences in the Physico-chemical variables between the stations. The Spearman r test allowed us to make correlations between

Physico-chemical and biological parameters. The frequencies of occurrence were calculated by the formula established by Dufrêne and Legendre (1997) [24]. These tests and calculations were performed using SPSS 20.0, Past, and Microsoft Excel spreadsheet software. The species richness (S), abundance (N), Piélou's equitability index (J) and Shannon and Weaver's diversity index (H') were determined from an index spreadsheet in Microsoft Excel. The Organic Pollution Index (OPI) was calculated using the classification table of Leclercq (2001) [25].

3. Results

3.1 Physico-chemical parameters of mangrove waters

Seasonal temperature values range from 28.4 °C to 31.23 °C, recorded in the rainy season in stations S6 and S14 respectively (Fig. 2A). The overall mean was 29.67 ± 0.76 °C. No significant difference was obtained between the seasonal mean temperature values (P = 0.8). Mann Whitney's U-test revealed significant differences between stations S2, S3, S9, S10 and S14 (*P* < 0.05). For pH, the minimum and maximum values (6.9 and 7.8 CU) were obtained also during the rainy season and in stations S1 and S2 respectively (Fig. 2B). The mean value was 7.5 CU. There were significant seasonal differences (P = 0.02) and no spatial differences (P = 0.5). Suspended solids (TSS) ranged from 1.33 mg/L to 47.33 mg/L in the wet season at stations S11 and S2 respectively (Fig. 2C) around a mean of 11.63 ± 9.87 mg/L. No significant difference was revealed (P > 0.05) between the study stations. Turbidity values ranged from 5 to 73.33 FTU, obtained respectively at station S11 in the wet season and S9 in the dry season (Fig. 2D). The overall mean was 19.60 ± 14.7 FTU. No significant differences were obtained, both spatially (P = 0.2) and temporally (P = 0.87).



SS = Dry season, SP = Rainy season

Fig 2: Spatial and temporal variation of temperature (A), pH (B), TSS (C) and turbidity (D)

Concerning the color, the values ranged from 14 to 412 Pt. Co respectively in stations S6 in the rainy season and S9 in the dry season (Fig. 3A) with an average of 116.46 ± 87.26 Pt. Co. However, no significant seasonal and temporal differences were observed (P > 0.05). Salinity values varied between 20.73 and 13696.67 mg/L in the wet season at stations S13 and S9, respectively, around a mean of 5962.2 ± 4478.2 mg/L (Fig. 3B). There is a significant difference between stations (P = 0.02). This difference is between stations located in the estuary (S5, S6, S7, S8 and S9) and those located at the level of rivers (S2, S3, S13 and S14) (P < 5%). The conductivity varied between 54.47 (S13) and 23300 (S9) µS/cm (Fig. 3C), during the rainy season, around an average of 10465.83 ± 7757.3 µS/cm. There are significant differences between stations S9 on the one hand and S2, S3, S4, S13, S14 on the other hand (P < 5%). The percentage values of dissolved oxygen saturation varied between 42 and 76% (Fig. 3D), respectively in stations S6 in the rainy season and S14 in the dry season with an average of 64.80 ± 7.94%. No significant différence was recorded in space and time. The highest nitrate value (15.36 mg/l) was obtained in the dry season at station S1, while the lowest value (3.4 mg/l) was obtained in the wet season at station S3 (Fig. 4A). The overall mean was 7.04 ± 2.56 mg/l. No significant difference in time and space was recorded (P > 0.05). Seasonal nitrite values fluctuated between 0.02 and 0.18 mg/l (Fig. 4B) during the rainy season in stations S13 and S7. These values fluctuated around 0.06 ± 0.03 mg/l. No significant difference was revealed (P > 0.05).

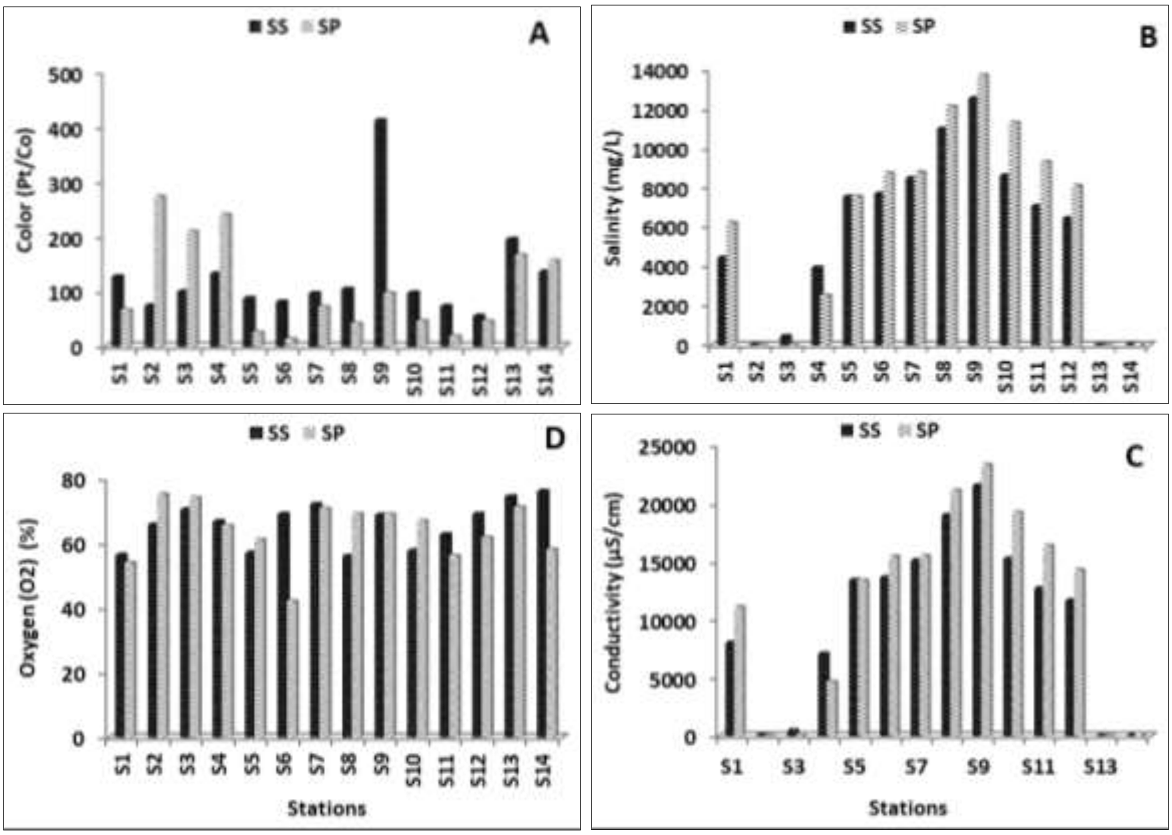


Fig 3: Spatial and temporal variation of color (A), salinity (B), conductivity (C) and O2 (D)

Seasonal orthophosphate values ranged from 0.01 mg/L at station S2 in the wet season to 0.063 mg/L at station S1 in the dry season, around a mean of 0.027 ± 0.01 mg/L (Fig. 4C). No significant difference was obtained between seasons and stations ($P > 0.05$). Analysis of oxidability results shows no significant seasonal differences between the values obtained ($P = 0.91$). However, the values obtained during the study period ranged from 0.72 mg/L (S8) in the wet season to 12.45 mg/L (S1) in the dry season, around an average of 4.5 ± 2.52 mg/L (Fig. 4D).

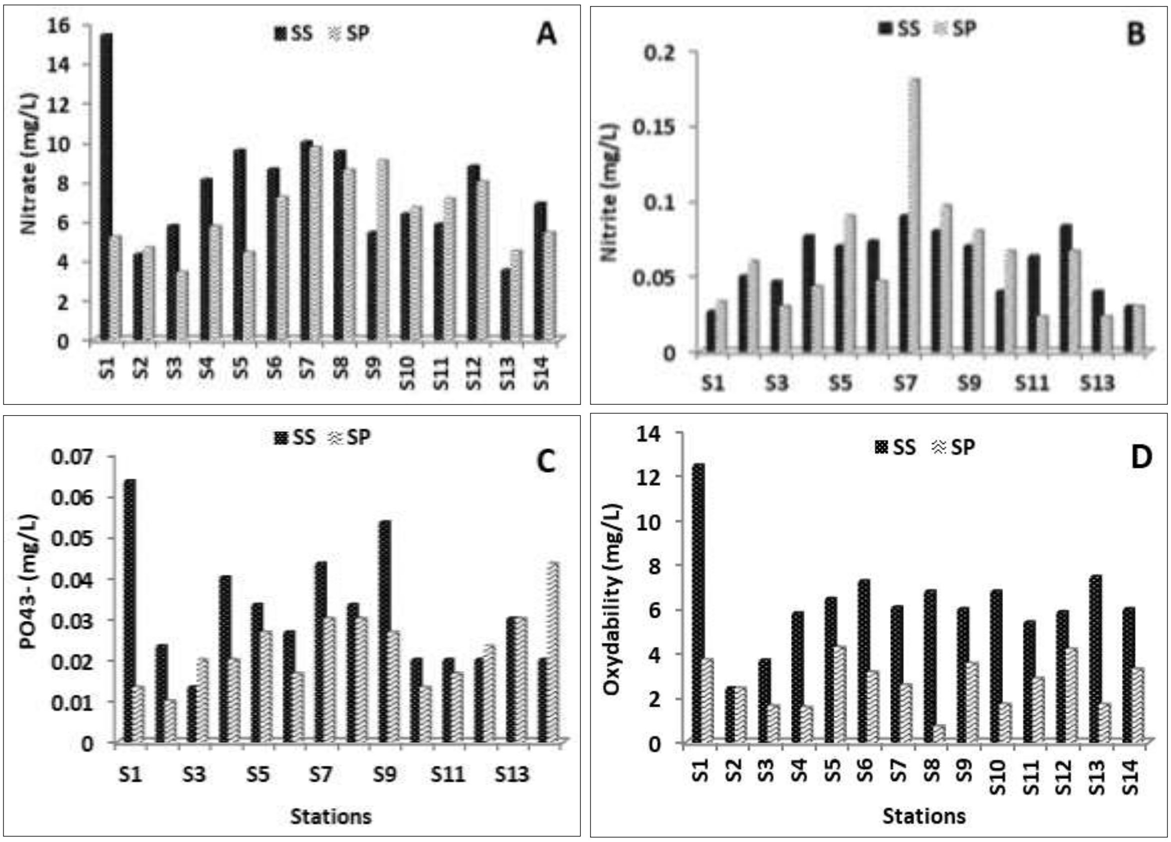
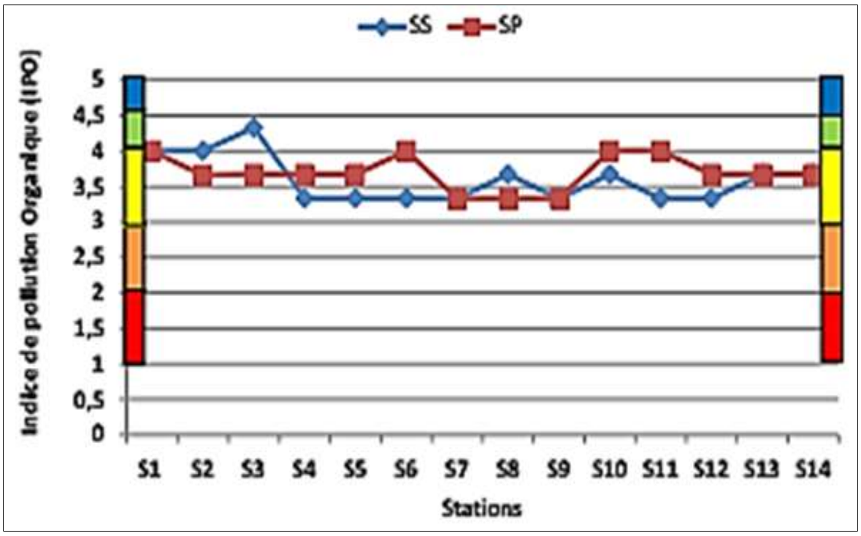


Fig 4: Spatial and temporal variation of nitrates (A), nitrites (B), PO43-(C) and oxidability (D)

3.2 Organic pollution index (OPI)

During this study the IPO ranged between 3.3 and 4.3 (Fig. 5). However, no significant differences were recorded in space (P = 0.37) and time (P = 0.29). The OPI values reveal moderate to low organic pollution, according to the classification grid of Leclercq (2001) [25].



SS = dry season; SP = rainy season; Color: red = very high pollution, orange = high pollution, yellow = moderate pollution, green = low pollution, blue = no pollution

Fig 5: Organic pollution index (OPI) of the studied stations

3.3 Malacological biodiversity

A total of 1644 mollusc specimens were identified during the study period. The taxonomic ranges are presented in Table 1. Stations S12 (H' = 2.18), S9 (H' = 1.98) and S11 (H' = 1.8) show the highest diversity. Station S1 was the richest (S = 8). However, the stand as a whole was dominated by a single species (J < 0.5). There was an equi-partition between stations S9 and S12 (J > 0.5). The highest abundance was 365 organisms, obtained at station S14 (Table 1).

Table 1: Malacological biodiversity harvested in the mangroves studied

Class	Orders	Families	Species	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	Total
Gaster-opoda	Caenoga-stropoda	Hemisinidae	*Pachymelania byronensis*	4	13	1	0	0	0	0	0	12	0	0	0	4	0	34
			Pachymelania fusca	8	0	89	1	0	0	0	0	34	0	0	0	49	241	422
			Pachymelania aurita	29	2	0	0	0	0	0	0	4	0	2	0	0	2	39
		Potamididae	*Tympanotonoss fuscatus*	241	8	9	54	3	0	11	11	53	0	0	8	7	72	477
	Neoga-stropoda	Muricidae	*Indothais blanfordi*	0	0	0	0	0	2	0	0	0	2	0	0	0	0	4
			Pinaxia coronata	0	0	0	3	37	46	16	23	34	25	24	8	0	0	216
	Cycloneritida	Neritidae	*Theodoxus niloticus*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
			Vitta rubricata	6	0	0	0	0	0	0	0	0	0	0	0	0	0	6
			Vitta glabrata	0	157	94	0	0	0	1	1	0	0	4	20	58	24	359
		Lymnaeidae	*galba* sp.	1	0	0	0	0	0	0	0	0	2	0	0	0	0	3
			Lymneae sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
	Littorini-morpha	Littorinidae	*Littoraria scabra*	0	0	0	0	3	0	0	0	0	0	4	4	19	23	53
Bivalve	Venerida	Cyrenidae	*Corbicula* sp.	3	0	3	2	0	0	0	0	0	0	12	1	0	0	21
	Sphaeriida	Sphaeriindae	*Pisidium* sp.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
			Sphaerium sp.	1	0	0	0	0	0	0	0	0	0	0	2	0	3	6
Total abundance (N)				293	180	197	60	43	48	28	37	137	29	46	44	137	365	
Specific richness (S)				8	4	6	4	3	2	3	4	5	3	5	7	5	6	
Diversity index of Shannon and Weaver (H’)				1,03	0,72	1,4	0,61	0,72	0,25	1,16	1,31	1,98	0,72	1,8	2,18	1,82	1,46	
Equi index of Piélou (J)				0,31	0,23	0,56	0,19	0,25	0,08	0,53	0,53	0,72	0,25	0,65	0,73	0,67	0,51	

The Thiaridae, Potamidididae and Neritidae families were the most abundant, representing 30.10%, 29.01% and 22.26% of the overall stand, respectively. In contrast, the families Lymnaeidae (0.14%), Sphaeeriidae (0.27%) and Corbiculidae (1.27%) were the least abundant (Figure 6A). At the specific level, three species represented more than half of the stand (Figure 6B): *T. fuscatus* (29.01%), *P. fusca* (25.67%) and *N. glabrata* (21.83%).

Calculation of the frequencies of occurrence of the different taxa allows the species to be classified into 4 categories (Dufrêne & Legendre, 1997) [24]: i) regular species (threshold 75 to < 100%): only one species concerned (*T. fuscatus*) present in 85.71% of the surveys, ii) constant species (threshold 50 to <75%): 5 species *P. fusca*, *N. glabrata*, *P. coronata*, *P. byronensis* and *L. scabra*. Their respective frequencies of occurrence are: 71.42%, 71.42%, 64.28%, 57.14% and 50%. (iii) 2 accessory species (threshold 25 to < 50%): *P. aurita* (42.85%) and *T. blanfordi* (28.57%) and (iv) 7 rare species (*N. rubricata*, *T. niloticus*, *Sphaerium* sp., *Stagnicola* sp., *Pisidium* sp., *Corbicula* sp. and *Lymneae* sp.) as their frequency of occurrence is less than 25%.

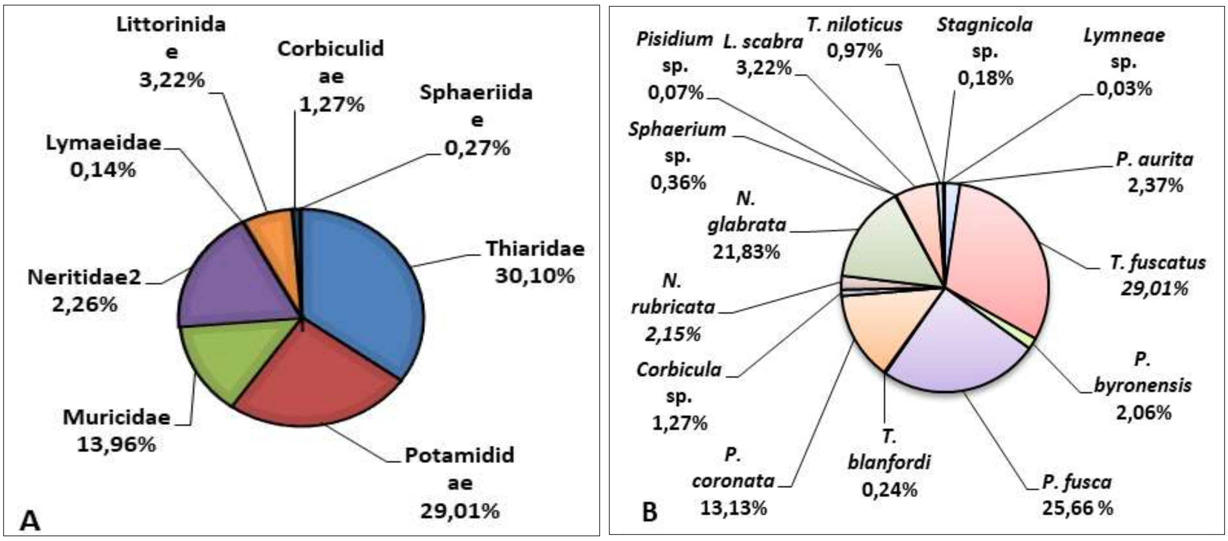


Fig 6: Distribution of the different families (A) and species (B) of the malacological fauna collected in mangroves during the sampling period

4. Discussion

4.1 Physico-chemical parameters

The high temperature values (mean = 29.67 ± 0.76 °C) obtained during the study period are similar to those of the ambient temperature (mean = 30.94 ± 2.77 °C). These high values would be related to the warm marine waters that arrive in the mangroves through the upwelling of the tides. According to Theuerkauff (2018) [26], mangrove waters have temperatures characteristic of coastal areas, which are high-temperature environments. The average pH obtained (7.5 ± 0.2 CU) reveals a slight basicity of the mangrove waters studied. This basicity could be due to alkaline ion inputs by sea water during high tide. Indeed, the pH of the marine environment is generally basic (varies between 7.5 and 8.4 UC) (Renaudin, 2001) [27]. Concerning suspended matter (TSS), the high values obtained in these mangroves come mostly from the foliage of the Rhizophora, which falls, decomposes and leaves debris in the water. This result is similar to that of Wolanski (1995) [28] who showed that vegetation in the mangrove contributes to increase the rate of TSS in the water. The high values of turbidity, especially in the dry season at Station S9 (73.33 FTU) are thought to be due to the tidal movement of the waters, which release suspended particles resulting in an increase in the turbidity of the waters. The salinity results led to subdivide the study stations into three zones: mangroves located in fresh water (S2, S3, S13 and S14: salinity < 1g/L), mangroves located in brackish water (S1, S4-S7, S10-S12: 1 ≤ salinity < 10g/L) and mangroves located in marine water (S8 and S9: salinity ≥ 10g/L) (Renaudin, 2001) [27]. This classification is a function of the distance from the ocean and the impact of the tides within the different study stations. The test of U Mann Whitney's revealed significant differences between the study stations (P = 0.018). Conductivity values within the Mouanko and Manoka mangroves showed a very high mean value (10465.83 ± 7757.3 µS/cm). These high values can be explained by two factors. On the one hand, at the level of stations S2, S3, S13, and S14 they could be linked to permanent and diffuse inputs of highly mineralized domestic, communal and industrial wastewater through the Sanaga and Kwa-Kwa rivers. Montgomery (1992) [29] points out those effluents from chemical industries are very often loaded with various mineral pollutants (sulphides, phosphates, silicates, metals, etc.). For all the other stations, this could be explained by mineralized water inputs following the flooding of the mangrove during high tides. The concentrations of chloride, sodium and potassium ions in the different study stations are high (averages: Cl^- = 72.62mg/L; K^+ = 19.26mg/L; Na^+ = 5.05mg/L). Moreover, these high conductivity values could also be due to the high mineralization activity of mangrove leaves by microorganisms. According to Koull and Halilat (2016) [30] the mineralization of organic matter leads to an increase in conductivity. Contrary to forest and peri-urban rivers which generally have oxygen saturation percentages above 75% (Tchakonte, 2016; Foto Menbohan *et al*., 2013) [31, 32], mangrove waters are generally poor in oxygen (Failler, 2010) [33]. The results obtained confirm this particularity of mangroves (mean = 64.80 ± 7.94%). These low values can be explained on the one hand by reduced photosynthetic activity due to the large canopy formed by mangrove branches, and on the other hand by the virtual absence of water mixing. The arrival of oxygen-poor water in the mangroves by the tide could also be at the origin of this low oxygenation (Villanueva, 2004) [34]. In spite of daily TSS inputs and endogenous pollution in the mangrove, very low average values of nitrogen forms are noted. According to Herteman (2010) [3], mangroves have strong bioremediation capacities. For orthophosphates, very low values (0.027 ± 0.01 mg/L) are recorded compared to relatively high values in urban rivers (Tchakonte, 2016) [31]. This reflects the low practice of agricultural activities and the use of detergents in the vicinity of the stations studied. Indeed, orthophosphates can be contributed by pesticides used in agricultural activities and by domestic detergents (Herteman, 2010) [3]. The high oxidability concentration (12.45 ± 2.52 mg/L) obtained at station S1 during the dry season would be due to the relatively high anthropogenic activity at this station. This is because the populations of the village of Yoyo have transformed it into a wood park station. There they store and split wood (decomposed mangrove roots). These activities would be at the origin of this organic pollution.

The moderate to low level of organic pollution revealed by the IPO can be explained by the bio-purifying nature of the mangrove. Indeed, mangroves play a role similar to that of planted filters vis-à-vis forms of nitrogen, orthophosphates, among others (Herteman, 2010) [3].

4.2 Malacological fauna

Among the mollusc species harvested, we note the dominance of *T. fuscatus* (29.01%), *P. fusca* (25.67%) and *N. glabrata*

(21.83%). This dominance is related not only to their tolerance to salinity variation, which is the determining factor of the distribution of molluscs in the mangrove (Villanueva, 2004) [34], but also to their diet and their capacity to resist the phenomena of flooding and exoneration of the mangroves. These results are similar to those of Kurhe *et al*. (2009) [35] and Kottè-Mapoko *et al*. (2017) [11] who also mentioned the predominance of *T. fuscatus*, *P. fusca* and *N. glabrata* species in the mangroves of Kribi, Tiko and Limbe (Cameroon). They are also in agreement with the work of Bouchet (1977) [36] carried out in the mangroves of Senegal, which revealed the predominance of the species *T. fuscatus*, *P. fusca* and *N. glabrata*. Of the 12 species of gastropods obtained, 10 belong to the prosobranch super family. They are all characterized by the presence of an operculum (Brown, 1994) [21]. This operculum is said to play a fairly important role in these organisms, insofar as it allows the organism to protect itself against exposure to the sun (at certain times of the day), against predators and even against perpetual variations in salinity (through tidal phenomena). Moreover, the low abundance of the lungs *Lymnea* sp. and *Stagnicola* sp. could be explained by their non-tolerance to high concentrations of dissolved salts, and also by the absence of a seal (Tachet *et al*., 2010) [37]. The prosobranchs are molluscs of marine origin while the lungs are of terrestrial and freshwater origin (Tachet *et al*., 2010) [37]. Regular and consistent species at the stations studied include: *T. fuscatus* and *P. fusca*, which are species tolerant of wide variations in salinity and feed on organic matter buried in the mud (Plaziat, 1984; Jamabo, 2010) [5,38]; *N. glabrata*, which is a species of very small diameter (8mm) in brackish to fresh water (hence its predominance in stations S2, S3, S11 - S14), generally living either fixed on tree trunks or in mud (Pilsbry and Bequaert, 1927) [39] and is a prey for fish; *P. coronata*, which is a predatory species of small bivalves living in highly mineralized and highly saline environments (Bouchet, 1977) [36]. The low representativeness of the bivalves (1.76%) could be due to sampling bias. Indeed, in mangroves, they generally live attached to the shells of *P. coronata* or to the roots of mangroves as support, which sometimes makes them invisible. The same observation was also made by Kotté-Mapoko (2017) [11] in the coastal zone of Kribi.

4.3 Influence of some abiotic factors on shellfish fauna

Several interactions between abiotic factors and molluscs in the mangroves studied were noted. In particular, it appears that the species *P. coronata* would flourish and develop better in a highly saline environment (r = 0.75; $p < 0.01$). This species could therefore be qualified as euryhaline. This justifies its abundance in stations S5 to S11 located in the Cameroon estuary. For the species *N. glabrata*, high salinity (r = - 0.56; $p < 0.01$), conductivity (r = - 0.56; $p < 0.01$) and high nitrate contents (r = - 0.39; $p < 0.05$) are not favorable to its development. However, high levels of organic matter in mangrove areas would be favorable to their development; this is reflected in the positive correlation obtained between oxidability and *N. glabrata*. (r = 0.38; $p < 0.05$). This justifies the abundance of this species in stations S2, S3 and S14, which are highly degraded mangroves, where an abundance of fallen raffia branches can be noted. The acidity of the mangrove waters would be favorable to the development and multiplication of the *P. aurita* species. This is revealed by Spearman's r correlation test (r = - 0.42; $p < 0.05$). Turbid water (r = 0.48; $p < 0.01$) and high levels of ammoniacal nitrogen (r = 0.39; $p < 0.05$) and TSS (r = 0.48; $p < 0.01$) are favorable for the development and growth of *P. byronensis*. This justifies their abundance in stations S1, S2 and S9 which are relatively degraded mangrove stations.

5. Conclusion

It emerges from this work that the mangrove waters studied shown high temperatures, a slightly basic pH, are poorly oxygenated and have low levels of nitrogenous elements. It should also be noted that these parameters in the mangroves of Mouanko and Manoka are a function of the type of environment, whether we are in fresh or brackish water. The predominant species are *T. fuscatus*, *P. fusca* and *N. glabrata*. Prosobranch molluscs were the most predominant in the mangroves studied. This predominance is due to the presence of an operculum in their anatomical structure and the halotolerant character of these species. It is noted that the main factor on which the distribution and composition of molluscs in the mangroves depend are salinity, flooding and exoneration movements of the mangroves and the different anthropogenic activities practiced in the surroundings.

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