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Seasonal variation of mollusc's community living in a tropical lagoon (Aby lagoon, Côte d'Ivoire)

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Abstract

This paper aims to reveal the seasonal variation of mollusc's community living in Aby lagoon (Côte d'Ivoire) and abiotic variables affecting the spatial distribution of the settlement. The organisation of molluscs was recorded at thirteen (13) stations across the whole lagoon. The study was based on seasonal sampling (Long Rainy Season, Short Dry Season, Short Rainy Season and Long Dry Season) over a one year period. Each faunal sampling was coupled with *in situ* measurements of abiotic parameters and samples were also collected for granulometry analyses. A total of 20 species of mollusc belonging to 7 families (Neritidae, Thiaridae, Potamididae, Corbulidae, Donacidae, Ostreidae, Tellinidae) and 2 orders (Mesogastropoda, Eulamellibranchia) were collected. Families of Nereidae and Thiaridae with respectively 7 and 6 taxa corresponding to 35% and 30% of the species richness dominated qualitatively mollusc's communities in the lagoon. Four species included *Pachymelania aurita, P. fusca, Neritina glabrata* and *Corbula trigona* were more represented in sampling sites. Seasonal variations of abundance and diversity of molluscs were not significantly different in the lagoon. However, the temporal patterns indicated periodic changes ranging from high abundances and diversities of molluscs during the Long Rainy Season to impoverished ones in the Long Dry Season. The ordination technic used to perform a characterization of the lagoon based on the mollusc's distribution according to abiotic parameters suggested that sediment grain-size (especially mud, very fine sand, fine and coarse sand) and salinity were the most important variables explaining the mollusc's distribution in Aby lagoon.

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Introduction

Transitional waters such as lagoons may be considered as ecosystems that structurally and functionally link, continental and freshwater ecosystems along the coastline (Levin *et al*., 2001; Basset *et al*., 2012). Their existence along the interface between the sea and the land determines their abiotic environment which is characterised by complex spatial gradient in structural features and pronounced temporal variability (Little, 2000). In Côte d'Ivoire, such ecosystems are rather well represented. Indeed, three lagoons in communication with the Atlantic Ocean can be noticed. It is about the Ebrié lagoon (566km²) localised in the central part of the littoral frontage, the Aby lagoon (424km²) in the eastern part andthe Grand-Lahou lagoon (190km²) in the west (Kouadio *et al*., 2011; Seu-Anoï *et al*., 2018). Among them, the Aby lagoon is known for its high halieutic productivity and ecological value (Ecoutin *et al*., 1994; Seu-Anoï *et al*., 2014). It provides many ecosystem services (Fisheries) to surrounding populations. The watershed is occupied by large plantations and cities (Simmou *et al*., 2019). Despite its importance, the Aby lagoon is subjected to natural variations of the climatic conditions and of the increasing of anthropic disturbances such as overexploitation of aquatic resources, deforestation of the watershed and riverbanks (Kouadio *et al*., 2008; Koné *et al*., 2009, Simmou *et al*., 2019). Additionally, in this lagoon, the exchange and mixture of sea and freshwater from Bia and Tanoé rivers is irregular and the hydrography of the lagoon may show fluctuations daily, seasonally and over longer periods of time (Koné *et al*., 2009). Such situation could have an influence on the faunistic composition in general and particularly on the benthic macroinvertebrates (Agostinho *et al*., 2005). Among the benthic macroinvertebrates, molluscs constitute one of the largest phyla, in both numbers of living species and numbers of individuals (Gomes *et al*., 2004). According to Diaz and Puyana (1994), two classes of molluscs (Gastropoda and Bivalvia) are the best represented in benthic systemsand their species have been used to characterize benthic associations. This characterization could suggest means of sustainable exploitation and appropriate management of commercially exploited species (Colas *et al*., 2014), as well as providing important data for biodiversity evaluations. Despite the importance of this group in lagoon areas, mollusc's fauna is still insufficiently investigated in the Aby lagoon. Previous studies on this group in the lagoons of Côte d'Ivoire were out dated and only devoted to the Ebrié lagoons (Binder, 1968; Gomez, 1978). Thus, the present study fills the gaps and aims to appreciate the seasonal variation of mollusc's community living in the Aby lagoon and identify the abiotic parameters driving the structure and the functioning of the settlement.

Materials and methods

Study area

The study was conducted in the Aby lagoon of Côte d'Ivoire (Fig. 1.). This lagoon is located between 2°51' and 3°21' W and 5°05' and 5°22' Nin the far east of Côte d'Ivoire and forms a natural boundary with Ghana country. The lagoon is composed primarily of 3 small lagoons which are Aby, Ehy and Tendo. It covers an area of 424km² and stretches for 24.5km north to south and 56km east to west with a maximum width of 15.5km (Avit *et al*., 1996). The maximum depth is 17m in its broadest part. The lagoon is connected to the sea in its southern part by an artificial channel and receives freshwater primarily of Bia river in the North part and Tanoériver in the East. Bottom sediments in Aby lagoon are mostly composed by sand towards the banks and mud with high organic content and shell fragments in the central part of the basin (Sankaré *et al*., 1999).The vegetation around this lagoon is dominated by a mangrove forest (*Rhizophora racemosa*, *Avicennia germinans*, *Conocarpus erectus*), the palm tree (*Elaeis guineensis*) and coconut (*Cocos nucifera*) cultures (Kouadio *et al*., 2008). The climate is an equatorial type with an annual rainfall ranged between 1500 to 1800mm. It is characterized by two rainy seasons and two dry seasons (Durand and Skubich, 1982). The Long Rainy Season (LRS) extends from April to July, the Short Dry Season (SDS) from August to September, the Short Rainy Season (SRS) from October to early December and the Long Dry Season (LDS) from December to March.

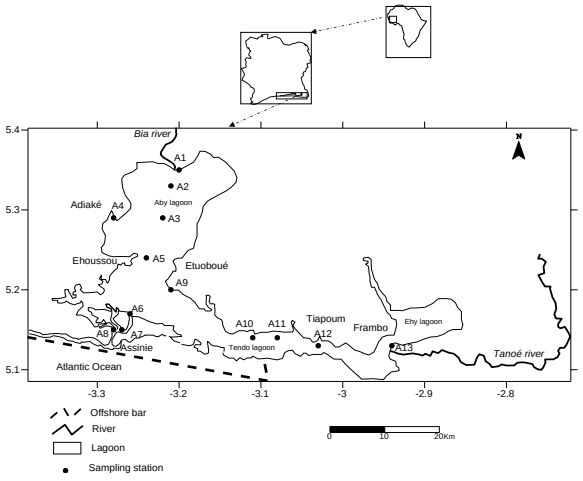

Fig. 1. Part of Côte d'Ivoire lagoon system showing Aby lagoon and sampling stations.

Sample collection

Sampling stations were selected by using criteria such as accessibility, water depth, sediment characteristics and in order to reflect the lagoon's different sedimentary and watershed habitats. Thus, thirteen (13) stations abbreviated A1 to A13 were sampled (Fig. 1.). The coordinates of the sampling stations were geo-referenced using a hand-held GPS. The sampling was undertaken seasonally during four cruises (June 2006, September 2006, November 2006 and March 2007). At each station and time, six samples were collected for mollusc analyses using a 0.05m² Van Veen grab. Each sample was sieved *in situ* through a 1 mm mesh. The material retained on the mesh was fixed in formaldehyde 10%. In the laboratory, the molluscs were sorted, identified at the lowest taxonomic level possible and counted.Species were identified using taxonomic guides and manuals such as Nicklès (1950); Tachet *et al.* (2003) and FAO (1992) as well as other publications.

Each faunal sampling was coupled with *in situ* measurements of abiotic parameters including water salinity, temperature, pH, dissolved oxygen, transparency and water depth. Salinity and temperature were measured by using a portable conductivity meter (WTW Cond-340) with a precision of ± 0.1 and 0.1°C, respectively. pH were measured with a pH-meter (WTW pH-330). Dissolved oxygen data were obtained by using a portable oxymeter (WTW OXI-340) while a Secchi disc was used for water transparency measures. At each station, sediment samples were also collected for granulometry analyses (AFNOR, 1996) using three sediment grain-size classes: mud (size ≤ 63µm), very fine sand (125µm > size > 63µm) and fine and coarse sand (size ≥ 125µm).

Data analysis

The structure of molluscs was studied through the species richness (S), the abundance (A), the Shannon-Weaver diversity index (H') and the Pielou evenness index (E). Shannon Weaver diversity index was used to assess taxa diversity of molluscs. Evenness was used to show the organisation of the structure, regardless of species richness. Molluscs assemblages were identified by an Ascending Hierarchical Classification (AHC, Weighted mean distances as a criterion of aggregation, Chi-square distance) method based on the abundance matrix. Data on abundances were square-root transformed to avoid over-domination of the analysis by the very abundant taxa and to allow taxa of intermediate and rarer abundances to contribute to the analysis. Before performing the comparison test, the normality of data was checked by Shapiro test. Significant differences in species richness, diversity indices and abundances were performed using Kruskal-Wallis test, a non parametric analysis of variance, followed by Rank multiple comparison tests (Zar, 1999). A significance level of $p < 0.05$ was considered. The analyses were carried out using the *vegan* package (Oksanen *et al.*, 2013) for the R 3.0.2 freeware (R Core Team, 2013).

A Redundancy analysis (RDA) was performed taking into account the abundance data of the molluscs as biotic variables and the abiotic parameters in order to determine the possible factors influencing the assemblages of the settlement in the Aby lagoon (ter Braak, 1986). Species data were log (X + 1) transformed to prior analysis (ter Braak and Smilauer, 2002). The statistical significance of the first four axes and of the sum of all constrained eigenvalue of the RDA model was tested using a Monte-Carlo permutation test (499 unrestricted permutations) (ter Braak and Verdonschot, 1995; ter

Braak and Smilauer, 1998). The results of this analysis were presented as ordination diagrams containing continuous explanatory variables plotted as vectors with points for sites and taxa. RDA was conducted using the CANOCO 4.5 software program.

Results

Taxonomic composition and abundance

A total of 20species of molluscs belonging to 7 families (Nereidae, Thiaridae, Potamididae, Corbulidae, Donacidae, Ostreidae, Tellinidae) and 2 orders (Mesogastropoda and Eulamellibranchia) were collected during this study (Table 1). Families of Nereidae and Thiaridae with respectively 7 and 6 taxa corresponding to 35% and 30% of the species richness dominate qualitatively mollusc's communities. Four species (4) appeared in more than 50% of the sampling stations. These groups comprised *Pachymelania aurita, P. fusca, Neritina glabrata* and *Corbula trigona*. Among these taxa, the last one (*Corbula trigona*) is common to all the stations. Additionally, high numbers of taxa were obtained in stations A4, A5 and A11. Species richness in these stations was comprised between 10 and 16 taxa.

Table 1. Taxonomic list of molluscs encountered in Aby lagoon during the study.

				Stations												
Order	Family	Taxon	Acronym	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
	Neritidae	*Neritina afra*	Nafr				+	+	+					+		
		Neritina andansoniana	Nand				+	+		+						
		Neritina cristata	Ncri				+	+	+							
		Neritina glabrata	Ngla				+	+	+	+			+		+	+
		Neritina kuramoensis	Nkur				+	+		+	+					
		Neritina oweniana	Nowe				+	+								
		Neritina rubricata	Nrub				+	+								
Mesogastropoda	Thiaridae	*Melanoides tuberculata*	Mtub		+			+	+							+
		Pachymelania aurita	Paur	+			+	+	+	+	+		+			+
		Pachymelania byronensis	Pbyr	+	+		+	+		+	+					
		Pachymelania fusca	Pfus				+	+	+	+	+			+		+
		Pachymelania fusca quadriseriata	Pfuq				+	+	+	+	+					
		Potadoma freethii	Pfre				+	+			+					
	Potamididae	*Tympanotomus fuscatus*	Tfus		+		+	+						+		+
		Tympanotomus fuscatus radula	Tfur					+	+							
	Corbulidae	*Corbula trigona*	Ctri	+	+	+	+	+	+	+	+	+	+	+	+	+
	Donacidae	*Iphigenia delesserti*	Idel				+			+	+					
Eulamellibranchia		*Iphigenia laevigata*	Ilae						+	+	+	+				
	Ostreidae	*Crassostrea gasar*	Cgas						+	+	+					
	Tellinidae	*Tellina ampullacea*	Tamp								+					
2	7	20		3	4	1	15	16	11	11	11	5	10	4	2	6

For numerical abundance, mollusc's assemblage was dominated by families of Thiaridae (Gastropods) and Corbulidae (bivalves) with respectively 326 and 249 individuals (Fig. 2.). The two families cumulated 67% of the abundance. On the over hand, family of Donacidae and Telinidae with 25 (3%) and 6 (1%) individuals respectively, either a total of 4% of the number were the less abundant in the Aby lagoon. Relatively to the species richness of molluscs, family of Neritidae with 7 taxa was most diversified while Corbulidae, Tellinidae and Ostreidae with one (1) specie each were less diversified.

Seasonal patterns of abundance and taxonomic richness

Seasonal pattern of abundance and species richness of molluscs in Aby lagoon were showed in fig. 3. Values of both biotic parameters were relatively high during Long Rainy Season and in Short Dry Season. Conversely low values were registered during Long Dry Season. Abundances varied from 11.83 to 25.91 individuals (Fig. 3A.). Concerning the species richness, values fluctuated between 1.91 and 5.41 taxa (Fig. 3B.). There were no significant differences of values of the two biotic parameters between seasons (Kruskal-wallis test, $p > 0.05$).

Seasonal variation of diversity and equitability

Seasonal variations of Shannon-Weaver and evenness indices of molluscs in Aby lagoon (Fig. 4.) were not significantly different (Kruskall-Wallis test, $p > 0.05$). However the values of theses parameters were relatively high in Long Rainy Season (LRS) and low in Long Dry

Season (LDS). Concerning Shannon-Weaver index, the values varied between 0.30 and 0.85 while evenness oscillated between 0.44 and 0.84.

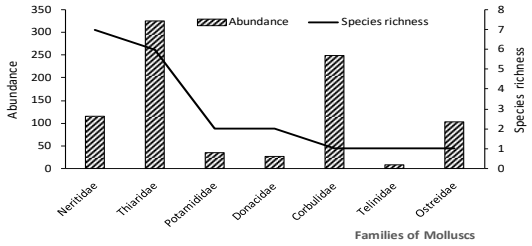

Fig. 2. Abundances and species richness in families of molluscs in the Aby lagoon.

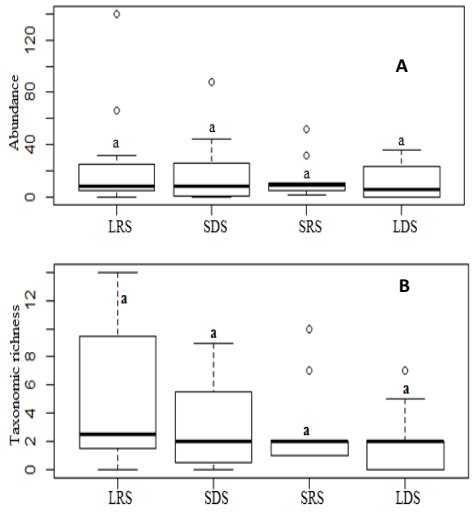

Fig. 3. Seasonal variation of Abundance and taxonomic richness of mollusc's community in Aby lagoon.

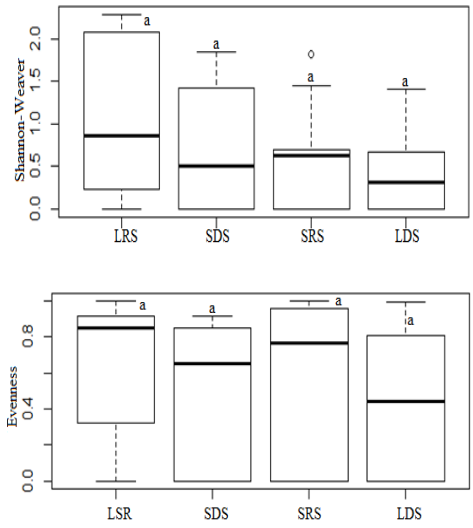

Fig. 4. Seasonal variation of Shannon-weaver diversity (H') and Evenness of mollusc's community in Aby lagoon.

Cluster identification

The cluster analysis indicated the existence of two (II) main classes of samples (Fig. 5.). First class (class I) included mainly samples from stations A4, A5, A6 closed to Adiaké city and Ehoussou village and stations A7 and A8 in the south of the lagoon. In these areas, the sediment was characterized by very fine sand and the lagoon is influenced by seawater throw the channel of Assinie. Additionally, the shoreline is fringed by mangrove forest. Two sub-groups can be distinguished in class II (IIA and IIB). In Class IIA, samples belonged exclusively to the stations found in the central part of the lagoon (A2, A3, A9 and A10). These stations were characterized by high deep and muddy substrate. Finally, in Class II B, stations were mostly located at the mouths of rivers in the lagoon in its northern and eastern (A1, A12 and A13) part. These stations were shallow and floating macrophytes such as *Eichhornia crassipes* and *Pistia stratiotes* were present and sediment characterized by fine and coarse sand.

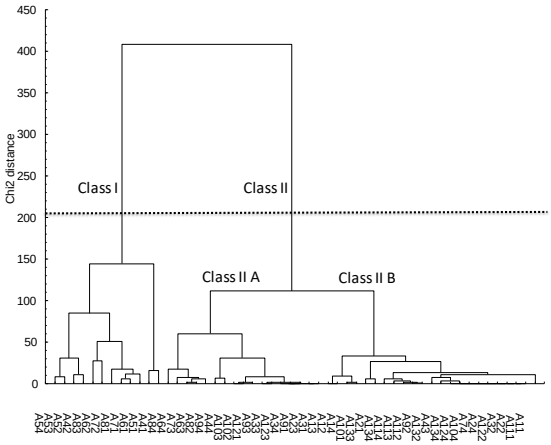

Fig. 5. Cluster analysis showing similarities between the sampling sites of mollusc communities in Aby lagoon. A1 to A13 = sampling stations; in index: 1 = LRS (Long Rainy Season); 2 = SDS (Short Dry Season); 3 = SRS (Short Rainy Season); 4 = LDS (Long Dry Season).

Correlation between molluscs and environmental variables

Mollusc's taxa and environmental parameters were evaluated according to Redundancy Analysis (RDA). In the RDA, a total of 55.6% of the variance were explained by the first and second axes chosen for the

interpretation of the analysis (Table 2). The first axis explained 37.3% against 18.3% for the second axis.

Table 2. Variances and cumulated variances expressed by the four first axes of the Redundancy Analysis.

Axes	1	2	3	4
Variances	0.373	0.183	0.132	0.060
Cumulated variances (%)	37.3	55.6	68.8	74.8

The environmental variables are shown as arrows, the lengths of which indicate the relative importance and the directions of which are obtained from the correlation of the variable to the axes (Fig. 6.). Sediment grain-size (especially mud, very fine sand, fine and coarse sand) and salinity were the most important variables explaining the mollusc's distribution in Aby lagoon. Conversely dissolved oxygen and temperature appeared to be the least important factor affecting the organisation of molluscs in the lagoon. The first ordination axis (Axis 1) reflected samples with a gradient related to percentage of very fine sand at the negative end of the axis and mud at the positive end. The second axis (Axis 2) was associated with salinity at the negative end while the positive end was related to percentage of fine and coarse sand.

Three groups of samples and molluscs species can be observed in the graph: (1) samples of stations A4, A5, A6 closed to the town of Adiaké and the village of Ehoussou and stations A7 and A8 in the south of the lagoon. This group is characterized by a very fine sand (VFS) and *Pachymelania aurita*, *P. byronensis, P. fusca, P. fusca quadriseriata, Tympanotomus fuscatus, T. fuscatus radula, Neritina afra, N. andansoniana, N. cristata, N. kuramoensis, N. rubricata*, *N. oweniana, N. glabrata, Potadoma freethii, Corbula trigona* and *Crassostrea gasar* were the taxa; (2) sample of station A1 near the entrance of Bia river to the lagoon with sediment characterized by fine and coarse sand (FCS) and low salinity in which *Melanoides tuberculata* is the main species; (3) samples of stations A11, A12 and A13 with sediment characterized by mud in which *Tellina ampullacea* and *Iphigenia laevigata* were the taxa.

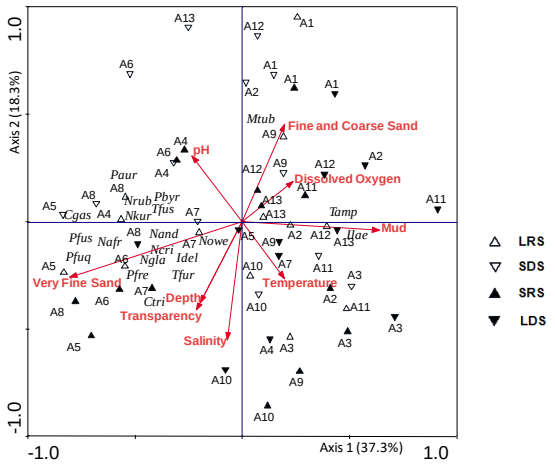

Fig. 6. Redundancy Analysis showing the 20 taxa of molluscs and the stations with respect to the environmental parameters, relative to axis I and II: A1 to A13 = sampling stations; LRS = Long Rainy Season; SDS = Short Dry Season; SRS = Short Rainy Season; LDS = Long Dry Season.

Discussion

This study is the first full inventory of mollusc's taxa in Aby lagoon. It also identifies the main environmental parameters explaining the spatial and the seasonal variations of the mollusc's community structure in the lagoon. The taxonomic list has contributed to identify 20 species of molluscs belonging to 7 families (Nereidae, Thiaridae, Potamididae, Corbulidae, Donacidae, Ostreidae, Tellinidae) and 2 orders (Mesogastropoda and Eulamellibranchia). This list is more or less similar to the traditional ones in the lagoons environment both in Côte d'Ivoire (Kouadio *et al.*, 2011, 2018) and elsewhere in other regions (Mistri *et al.*, 2002; Bazaïri *et al.*, 2003; Chaouti and Bayed, 2011). In terms of the number of species, when compared with other lagoons, obtained data revealed lower molluscs diversity (Palmer *et al.*, 2000; Bazairi *et al.*, 2005; Filippenko, 2011; Uwadiae, 2013). This fact could certainly be attributed to the small surface of the Aby lagoon in comparison with the open areas mentioned by the above authors.Additionally mollusc's assemblage in Aby lagoon was dominated by families of Thiaridae (Gastropods) and Corbulidae (bivalves) which are the same as found in other lagoons (Bachelet, 2000; Basset *et al.*, 2007; Filippenko, 2011; Kouadio *et al.*, 2018).

Spatial distribution revealed high numbers of species in stations A4 and A5. High diversities in these sites could be explained by high degree of habitat heterogeneity due to the presence of mangroves forests in these parts of the lagoon (Gilmore and Snedaker, 1993). Additionally, a large quantity of organic debris from agglomerations such as Adiaké, Ehoussou and Assiny could favour high diversity in these areas (Sousa, 1979a; 1979b). On the other hand, high depths and the substrate primarily characterized by mud could explain the low values of these biotic parameters observed in stations A3 and A12. Indeed, Chantraine (1980) and Métongo (1985) mentioned that water at the bottom of these study sites is not renewed and remains anoxic all the year and the mud is not favourable for the transfer of certain groups of molluscs to another site.

Seasonal variations of abundance and diversity of molluscs were not significantly different in the Aby lagoon. However, the distribution patterns over seasons indicated periodic changes ranging from high abundances and diversities of mollusc's community in the Aby laggon during the Long Rainy Season to impoverished ones in the Long Dry Season. The highest values of these biotic parameters (abundance and diversity) in Long Rainy Season could be attributed to many additional factors like hydrological and hydrochemical features of the water body as suggested by Filippenko (2011). Moreover, the intrusion of floating macrophytes such as *Eichhornia crassipes* and *Pistia stratiotes* and emergent plants (reed) from Bia and Tanoérivers respectively in Long Rainy Season could also induce the highest values of molluscs abundance and diversity. According to Chertoprud and Udalov (1996), emergent plants include more suitable local habitats for many molluscs specially the gastropods. In return, lowest values in the Long Dry Season could be due to the intense environmental stress, such as hypersalinity and temperature. According to Posey *et al.* (1998), such conditions probably affected the physiological responses of the molluscs, leading to a reduction in the number. Also, Hart and Fuller (1979) reported that many molluscs are living near their upper thermal limits and few degrees increase in temperature as it is the case in Long Dry Season in Aby lagoon may be fatal or result in the interruption of the normal maturation.

Results of the ordination technique used to perform a characterisation of the Aby lagoon based on the mollusc's distribution according to abiotic parameters suggested that sediment grain-size (especially mud, very fine sand, fine and coarse sand) and salinity were the most important variables explaining the mollusc's distribution in Aby lagoon. The importance of sediment characteristic and salinity in the distribution of molluscs is widely recognized (Rueda and Salas, 2003; Uwadiae, 2013). This assertion agrees with results of studies carried out in Côte d'Ivoire (Kouadio *et al.*, 2011; 2018) and in other parts of the world (Rempel *et al.*, 2000; Sousa *et al.*, 2006; Fujii, 2007; Morrissey *et al.*, 2013; Colas *et al.*, 2014; Arimoro *et al.*, 2015) where salinity gradient and sediment type strongly influenced the spatial distribution and diversity of mollusc's fauna. According to Culp *et al.* (1983), Hagberg and Tunberg (2000) and Rempel *et al.* (2000), the grain size of the bottom sediments is one of the most important parameters determining the composition of benthic communities.

Conclusion

This study on mollusc's community living in Aby lagoon is the first of the kind. It has contributed to identify 20 species of molluscs belonging to 7 families (Neritidae, Thiaridae, Potamididae, Corbulidae, Donacidae, Ostreidae, Tellinidae) and 2 orders (Mesogastropoda and Eulamellibranchia). Families of Neritidae and Thiaridae dominated qualitatively this biotic structure. Four species included *Pachymelania aurita, P. fusca, Neritina glabrata* and *Corbula trigona* were more represented in sampling sites. Overall, our data suggest that short term changes in the structure of mollusc's community are not obvious. However, long term monitoring should be initiated to better unravel the postulated effects of environmental factors on the composition of mollusc's community in the Aby lagoon.

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