International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 26 No. 4 Jul. 2019, pp. 992-1003

http://www.ijias.issr-journals.org/

Taxonomic diversity and structure of Macroinvertebrates in two small marginal lagoons of the South-eastern of Côte d'Ivoire

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ABSTRACT: The study was conducted to assess the spatial and seasonal variations of macroinvertebrates into two small marginal lagoons in the South-eastern of Côte d'Ivoire. Macroinvertebrates were obtained monthly using a hand net, a van veen grab and an artificial trap from September 2015 to August 2016. Physical and chemical parameters were quantified using standard methods of analysis. Analysis of the physical and chemical parameters in both lagoons showed significant seasonal variation, except for pH, nitrite and ammonium. We identified 145 and 105 macroinvertebrate species composed of aquatic Insects, Achaeta, Gastropoda, Crustacea and Arachnida respectively in Ono and Hébé lagoons. Megaloptera, Amphipoda and Basommatophora were only found in Ono lagoon whereas Lepidoptera was only present in Hébé lagoon. The highest values were found in dry season (127 taxa) and rainy season (126 taxa) in Ono lagoon whereas in Hébé lagoon, the highest values were found in dry season (93 taxa). The Shannon diversity index and evenness values of 3.72-4.25 and 0.84-0.91 respectively in both lagoons indicate that the macroinvertebrate stands are relatively diversified and balanced. However, the increase of anthropogenic disturbances on these lagoons constituted a real threat of the macroinvertebrates at long term.

KEYWORDS: Diversity indices, macroinvertebrates, rarefied richness, seasons, lagoon, Côte d'Ivoire.

1 INTRODUCTION

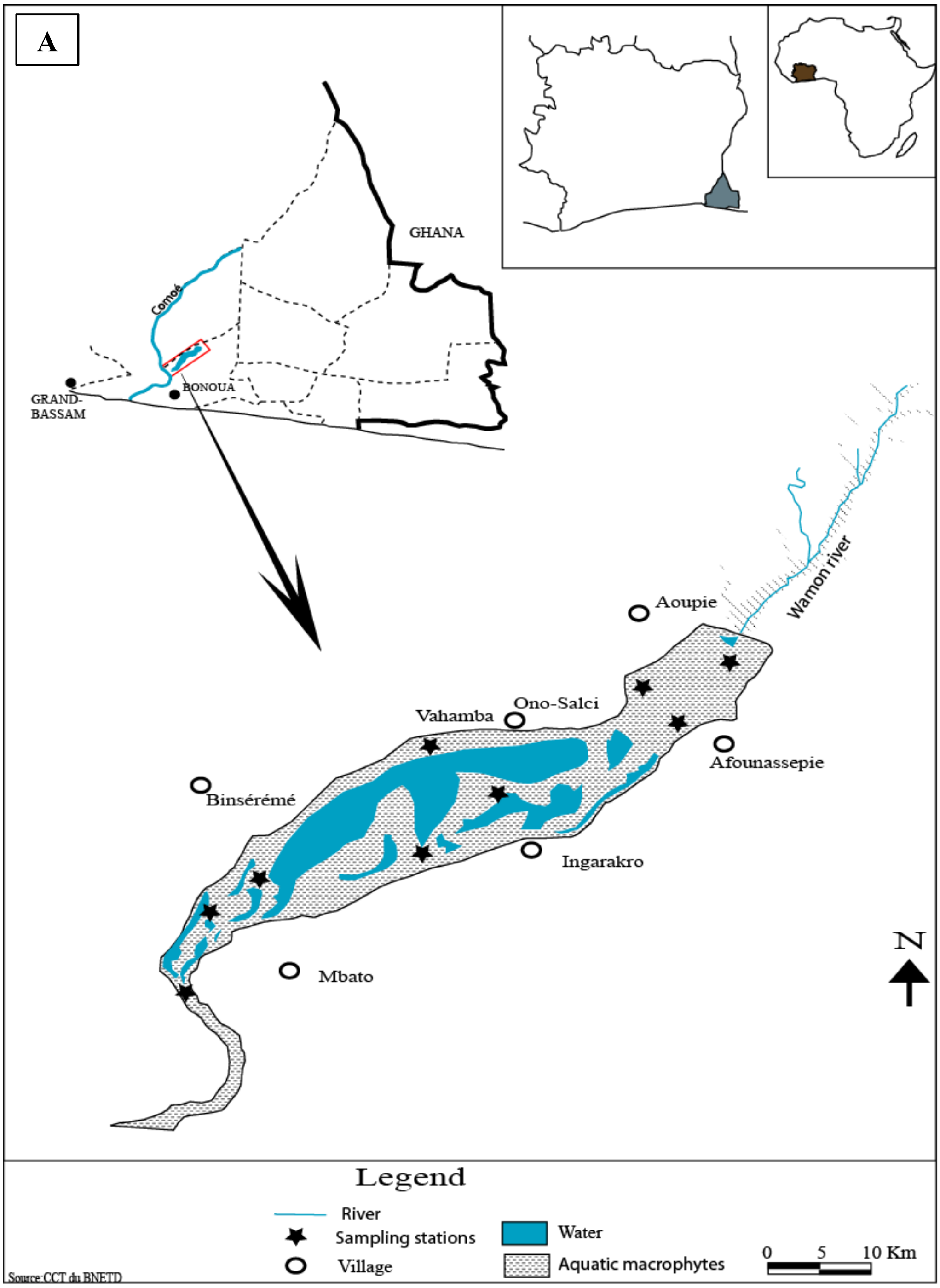
Aquatic habitats are of fundamental importance as they support essential resources, provide essential ecosystem services and contribute significantly to global biodiversity. The development of human society since the late 19th century led to high levels of pollution in aquatic ecosystems due to agricultural, urban and industrial discharges [1], [2] which in turn affected the quality of surface waters. According to [3], these discharges affect the lives of aquatic biota. Faced to these pollution issues, there is a need to protect aquatic ecosystems and consequently monitoring the effects of anthropogenic pressure on aquatic ecosystems [4]. Benthic macroinvertebrates are recognized to be a useful bio-indicator in understanding the ecological health of an aquatic ecosystem, rather than using chemical and microbiological data, which at least give short-term fluctuations [5], [6]. They are considered important because they reflect the cumulative effects of the present and past conditions. In addition, they have low mobility (i.e. are sedentary or sessile or nearly) and life cycles of several weeks and or years. So, their abundance, community structure and ecological function have long been used to characterize water quality in freshwater ecosystems.

For better management of aquatic ecosystems, biological monitoring of their ecological status is necessary because biological indicators have great power of integration of information. It has the advantage of measuring the ability of the ecosystem to maintain its functional equilibrium [7], [8]. In West Africa, there are few studies on macroinvertebrate communities and their ecology [9], [10]. In Côte d'Ivoire, previous works on macroinvertebrate ecology were mainly carried out by [11] and [12] in freshwater bodies. No study on macroinvertebrate community was done in small marginal lagoons. The aim of this study is to describe the composition and the diversity of benthic macroinvertebrates in Ono and Hébé lagoons.

2 Materials and methods

2.1 Study site

Ono lagoon (5°22'22"N and 3°33'53"W) and Hébé lagoon (5°12'14" N and 3°33'15" W) are two small lagoons of the Southeast of Côte d'Ivoire (Figure 1). Their surfaces are respectively 400 ha and 244 ha. Because Ono lagoon is invaded by several floating macrophytes, the exploitable surface is 162 ha. In Hébé lagoon, only the banks are occupied by mangrove and rare floating macrophytes. These lagoons, permanently connected to the Comoé river have an equatorial climate, including two rainy seasons (April-July and October-November) and two dry seasons (December-March and August-September). The permanent linkage with the Comoé river produces typical freshwater characteristics of these lagoons. Agriculture, trade, fishing and domestic wastes are the main anthropogenic activities affecting the functioning of these lagoons.



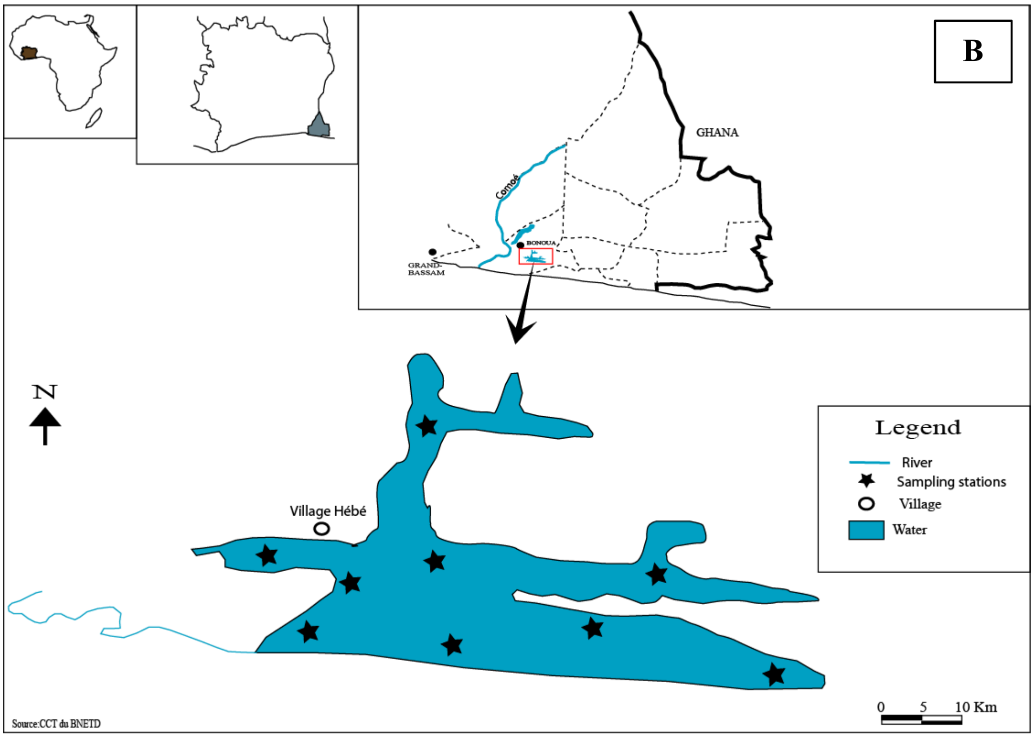


Fig. 1. Map of the Ono (A) and Hébé (B) lagoons showing the macroinvertebrates sampling sites

2.2 ENVIRONMENTAL PARAMETERS SAMPLING AND ANALYSIS METHODS

The parameters such as transparency, depth, pH, total dissolved solids, conductivity and dissolved oxygen were recorded in situ. Water samples were taken, stored in polyethylene bottles (500 mL) and kept at a temperature below 4°C for further determination of ammonium-nitrogen ($NH4^+$; mg/L), nitrate ($NO3^-$; mg/L), nitrite ($NO2^-$; mg/L) and phosphate ($PO43^-$ mg/L). The samples were filtered through Whatman GF/C fibreglass filters and concentrations were determined using a spectrophotometer Model HACH DR 6000.

2.3 BENTHIC MACROINVERTEBRATES SAMPLING

The macroinvertebrates were monthly sampled from September 2015 to August 2016 in the upstream, the middle and the downstream of each lagoon. The macroinvertebrates were collected using a van veen grab of 0.10 m² internal area, a triangular hand net (32 x 32 x 32 cm, 250 µm mesh, 50 cm length) and an artificial trap (basket) of 0.12 m². Samples obtained were carefully washed through a set of sieves of mesh size 0.2 mm in the water of lagoons and the retained materiel was bottled and preserved in a 10% formaldehyde solution in a plastic container for further analysis. At laboratory, preserved samples were washed to remove formaldehyde solution and then screened through a 500 µm mesh size to collect all macroinvertebrates on white plates. They were then fixed in a 70% alcohol solution for identification. Large macroinvertebrates were sorted by the naked eye while smaller fauna was sorted under a binocular loupe. All animals were then sorted out into different taxonomic groups, counted and identified up to lowest possible taxon under binocular loupe according to the keys of [13], [14] and [15].

2.4 DATA ANALYSIS

The macroinvertebrate assemblage composition was evaluated for each lagoon using number of taxa (S), total number of individuals, and relative abundance of each taxon. The Shannon-Wiener index (H'), Evenness index (E) and frequency of occurrence (%F) were used to characterize the diversity of species in a community following these equations:

$$H' = -\sum_{i=1}^{s} P_i \log_2 P_i$$

where P_i = number of individuals of the taxon/total number of individuals of the sample and log2 = the 2-base logarithm.

$$E = \frac{H'}{\log_2(S)}$$

where H' = Shannon-Wiener diversity index and S = total number of taxa.

$$\%F = \frac{F_i}{F_t} \times 100$$

Where F_i = frequency of individuals of taxon i and F_t = total frequency of individuals of the sample.

2.5 STATISTICAL ANALYSIS

The Shapiro-Wilk normality test for homoscedasticity were applied to the data, to determine whether the assumptions of the parametric and nonparametric analyses for the environmental variables (T°C, pH, DO, TDS, Transparency, $NH4^+$, $NO3^-$ and $NO2^-$), abundance, species richness, diversity and evenness were satisfied. All physicochemical parameters were tested by one-way analyses of variance, followed by Tukey multiple comparison tests for significant differences among lagoons and seasons. All diversity indices and rarefied richness were tested by the Kruskal-Wallis test and the Mann-Whitney U test for significant differences among lagoons and seasons. All Analyses were conducted using the software package STATISTICA version 7.1.

3 RESULTS

3.1 ENVIRONMENTAL VARIABLES

Table 1 discloses the summary of the mean values of the various physical and chemical parameters monitored at the different selected sampled stations during seasons. The mean for abiotic parameters showed significant seasonal variation ($p < 0.05$), except for pH, nitrite and ammonium. In Ono lagoon, the mean values of conductivity, TDS and depth where higher in flood season whilst transparency and nitrites where lower in flood season. In Hebe lagoon, the conductivity, TDS and depth where higher in flood season while transparency, nitrite were lower. When comparing the values between the two lagoons, the temperature, dissolved oxygen, conductivity and TDS were significantly highest ($p < 0.05$) in Hébé lagoon in all seasons. High values of transparency and nitrate were recorded in Ono lagoon while low values were observed in Hébé lagoon. Water of these lagoons was slightly acidic during dry and flood seasons and neutral in rainy season.

Table 1. The mean for environmental variables in the seasons on Ono and Hebe lagoons. Rs =Rainy Season, Ds =Dry Season, Fs =Flood season. Means with different letters (a, b, c) show a significant difference into each lagoon; means with different numbers (1, 2, 3) show a significant difference between lagoons p <0.05

	Ono lagoon			Hébé lagoon		
Parameters	**Ds**	**Rs**	**Fs**	**Ds**	**Rs**	**Fs**
Temperature (°C)	27.16^{a1}±1.58	26.98^{a1}±1.65	27.60^{a1}±1.49	29.74^{a2}±1.48	29.78^{a2}±1.36	30.82^{a2}±1.85
dissolved Oxygen (mg/L)	1.86^{a1}±1.38	2.44^{a1}±1.40	3.25^{a1}±3.22	6.18^{2}±1.22	5.90^{2}±1.13	6.88^{2}±1.37
pH	5.92^{a1}±0.76	7.02^{b1}±0.46	6.11^{a1}±0.44	6.38^{a1}±0.85	7.25^{b1}±0.91	6.34^{a1}±0.51
Conductivity (µS/cm)	18.83^{a1}±6.81	15.19^{a1}±4.58	21.60^{b1}±2.25	39.60^{b2}±15.25	25.97^{a2}±24.79	44.44^{b2}±31.79
Dissolved solids (TDS) (mg/L)	9.50^{b1}±3.64	7.49^{a1}±2.34	10.83^{b1}±1.07	19.63^{b2}±7.02	12.60^{a2}±12.22	23.10^{b2}±15.63
Transparency (m)	1.95^{b2}±0.40	1.33^{a2}±0.41	0.89^{a2} ±0.05	0.84^{b1}±0.12	0.60^{a1}±0.11	0.51^{a1}±0.18
depth (m)	2.30^{a2}±0.18	2.53^{b2}±0.08	2.75^{b1}±0.21	1.72^{a1}±0.49	2.05^{b1}±0.54	2.33^{b1}±0.80
Nitrites (mg/L)	0.30^{b1}±0.56	0.17^{a1}±0.29	0.02^{a1}±0.03	0.20^{b1}±0.56	0.10^{a1}±0.18	0.01^{a1}±0.00
Nitrate (mg/L)	2.94^{a2}±1.09	3.71^{a2}±1.44	2.29^{a2}±0.89	1.95^{a1}±1.11	1.90^{a1}±1.25	0.95^{a1}±0.43
Ammonium (mg/l)	0.07^{a1}±0.08	0.08^{a1}±0.04	0.10^{a1}±0.06	0.06^{a1}±0.06	0.07^{a1}±0.05	0.06^{a1}±0.05
Phosphorus (mg/L)	0.44^{a2}±0.32	0.49^{a2}±0.20	0.53^{a2}±0.83	0.28^{a1}±0.25	0.16^{a1}±0.20	0.27^{a1}±0.18

3.2 FAUNAL COMPOSITION AND SEASONAL PATTERN

A total of 17,228 macroinvertebrates of which 12,175 and 5,053 individuals were respectively collected in Ono and Hébé lagoons (Table 2). In Ono lagoon, 145 macroinvertebrate species divided into 47 families and 17 orders were collected whereas 105 taxa belonging to 35 families and 15 orders were obtained in Hébé lagoon. The Figure 2 showed the abundance of macroinvertebrates in Ono and Hébé lagoons. In Ono lagoon, the highest values were found in dry season (127 taxa) and rainy season (126 taxa) whereas the lowest values was recorded in flood season (86 taxa). In Hébé lagoon, the highest values were found in dry season (93 taxa), followed by rainy season (77 taxa) and flood season (59 taxa). Samples of the two lagoons were dominated by insects namely Heteroptera, Diptera, Coleoptera and Odonata in all season with Heteroptera and Coleoptera being respectively the most abundant and diverse groups. Megaloptera, Amphipoda and Basommatophora were only found in Ono lagoon while Lepidoptera was only present in Hébé lagoon.

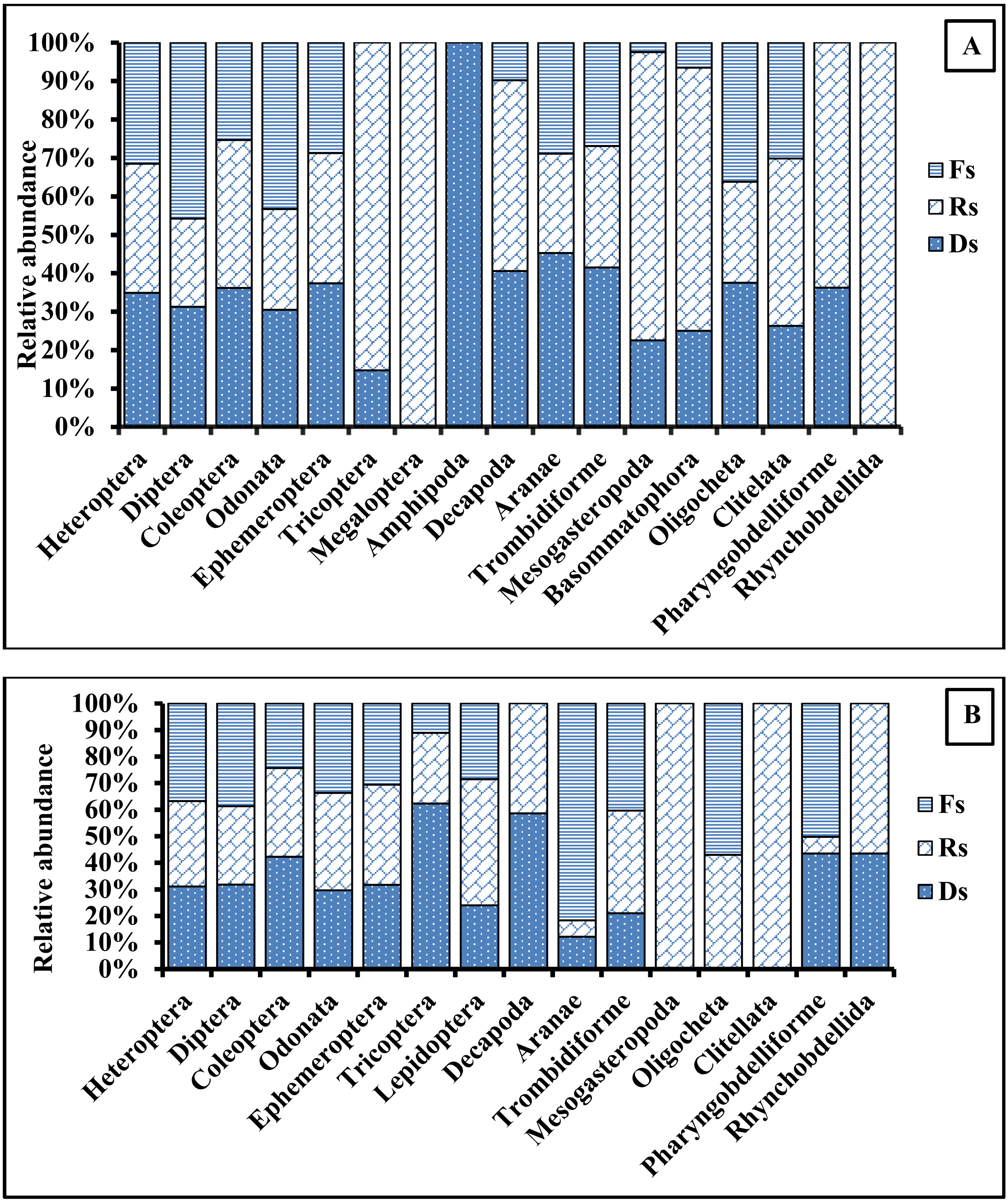


Fig. 2. Seasonal relative abundance of orders in Ono (A) and Hebe (B) lagoons

Table 2. List of macroinvertebrates found at two sampling lagoons (Ono and Hebe). +++: Very frequent. ++: Frequent. and +: Sporadic

Families	Taxa	Ono lagoon			Hébé lagoon		
		Abund.	Occurr.	Cl. of occurrence	Abund.	Occurr.	Cl. of occurrence
Heteroptera							
Belostomatidae	*Diplonychus annulatus*	+++	100	Constant	+++	75	Constant
	Diplonychus stappersi	+++	100	Constant	+++	83.33	Constant
	Diplonychus rusticus	+++	91.67	Constant	+	16.67	Accidental
	Diplonychus sp.	+++	100	Constant	+++	50	Constant
Naucoridae	*Naucoris cimicoides*	+++	100	Constant	+++	100	Constant
Hydrometridae	*Hydrometra stagnorum*	+++	83.33	Constant	+	16.67	Accidental
Notonectidae	*Anisops sardea*	+++	91.67	Constant	+++	91.67	Constant
	Notonecta glauca	+++	83.33	Constant	+	8.33	Accidental
Gerridae	*Eurymetra* sp.	+++	100	Constant	+++	100	Constant
	Rhagadotarsus hutchinsoni	++	33.33	Accessory	+++	50	Constant
	Limnogonus chopardi	+++	91.67	Constant	+++	83.33	Constant
Corixidae	*Micronecta scutellaris*	+++	100	Constant	+	8.33	Accidental
	Micronecta scholtizi	+++	91.67	Constant	+	8.33	Accidental
	Stenocorixa protrusa	+	16.67	Accidental			
Veliidae	*Corixini* sp.	++	33.33	Accessory			
	Velia affinix	++	33.33	Accessory			
	Rhagodovelia sp.	++	33.33	Accessory	+	8.33	Accidental
Mesovellidae	*Mesovelia vittigera*	+++	58.33	Constant	+++	75	Constant
	Mesovelia pigmaea	+	8.33	Accidental			
Nepidae	*Ranatra linearis*	+++	75	Constant	++	25	Accessory
	Ranatra parvipes	+++	83.33	Constant	+++	58.33	Constant
	Laccotrepes ater	+++	58.33	Constant	+	16.67	Accidental
Diptera							
Chironomidae	*Chironomus imicola*	+++	100	Constant	+++	100	Constant
	Chironomus sp.	+	8.33	Accidental			
	Stenochironomus sp.	++	41.67	Accessory	+++	58.33	Constant
	Stictochironomus sp.	++	41.67	Accessory	+++	66.67	Constant
	Cryptochironomus sp.	+++	66.67	Constant	+++	83.33	Constant
	Polypedilum sp.	+++	66.67	Constant			
	Nilodarum sp.	+++	83.33	Constant	++	41.67	Accessory
	Ablabesmyia dusoleili	+++	75	Constant	+++	50	Constant
	Ablabesmyia sp.	+	8.33	Accidental	++	25	Accessory
	Procladius sp.	+++	91.67	Constant	+++	75	Constant
	Tanytarsus sp.	+++	91.67	Constant	+++	75	Constant
	Tanypus fuscus	+	8.33	Accidental			
	Cricotopus sp.	+++	91.67	Constant	+++	100	Constant
Tabanidae	*Tabanus* sp.	++	41.67	Accessory			
Ceratopogonidae	*Bezzia* sp.	+	16.67	Accidental			
	Stratiomydae sp.	+	8.33	Accidental			
Culicidae	*Culex quinquefaciatus*	+++	100	Constant	+++	91.67	Constant
Syrphidae	*Eristales tenax*	++	33.33	Accessory			
Tipulidae	*Limonia tipulipes*	+	8.33	Accidental			
	Tipula sp.	++	25	Accessory			
Coleoptera							
Hydrophilidae	*Amphiops* sp.	+++	100	Constant	+++	83.33	Constant
	Hydrochara sp.	+++	91.67	Constant	+++	66.67	Constant
	Hydrochara flavipes	+	8.33	Accidental			
	Hydrochara richsecheri	++	41.67	Accessory			
	Hydrochara caraboides	+++	75	Constant			
	Hydrobiinae sp.	+++	91.67	Constant	+++	50	Constant
	Enochrus sp.	+++	75	Constant	++	41.67	Accessory

	Enochrus testaceus	++	25	Accessory	+	8.33	Accidental
	Hydrochus elongatus				++	33.33	Accessory
	Anacaena globulus	+++	100	Constant	++	25	Accessory
	Berosus signaticollis				+	8.33	Accidental
Dyticidae	*Dyticus* sp.	+	8.33	Accidental			
	Ilybi sp.	+++	50	Constant	+	8.33	Accidental
	Rhantus exsoletus	++	25	Accessory	++	33.33	Accessory
	Bidessu sp.	+	16.67	Accidental			
	Hydrobuis sp.	+++	66.67	Constant	+	16.67	Accidental
	Hydrovatus sp.	+	8.33	Accidental	+	8.33	Accidental
	Porhydrus lineatus	+++	66.67	Constant	+	8.33	Accidental
	Lacccophilus sp	+++	91.67	Constant	+++	100	Constant
	Laccophilus vermiculosus	+++	58.33	Constant	+++	100	Constant
	Laccophilus evanescens	+	16.67	Accidental	++	41.67	Accessory
	Laccophilus oblongus	+	16.67	Accidental	+	8.33	Accidental
	Agabetes sp.	+++	83.33	Constant			
	Agabus bifarius	++	41.67	Accessory	+	16.67	Accidental
	Agabus melanarius	+++	75	Constant	+	16.67	Accidental
	Agabus guttatus	+++	50	Constant			
	Agabus uliginosus				+	16.67	Accidental
	Hydrocanthus micans	+++	91.67	Constant	+++	50	Constant
	Hydrocoptus simplex	+++	91.67	Constant	+++	66.67	Constant
	Cybister fimbriolatus	+++	58.33	Constant	+	8.33	Accidental
	Cybister tripunctatus	+	16.67	Accidental			
	Cymbiodyta marginella	++	25	Accessory			
	Hydaticus ussheri	+	8.33	Accidental			
	Hydaticus piceus	++	33.33	Accessory			
	Hydaticus vitticollis	+	8.33	Accidental			
	Canthydrus xanthinus	+++	83.33	Constant	++	33.33	Accessory
	Heterhydrus senegalenlensis	+++	58.33	Constant	+	16.67	Accidental
	Hyphydrus sp.				+	8.33	Accidental
	Orectogyrus alluaudi				++	25	Accessory
Helodidae	*Elodes* sp.	+	16.67	Accidental	+	8.33	Accidental
	Elodes pal	+++	50	Constant			
Chysomelidae	*Oreina geminata*	++	25	Accessory			
	Pseudotetramerous tarsus	++	33.33	Accessory			
Curculionidae	*Pseudobargous* sp.	+++	66.67	Constant			
	Bargous sp.	+++	83.33	Constant	++	41.67	Accessory
Elmidae	*Limnius* sp.	+++	50	Constant	++	25	Accessory
	Elmis sp.	+++	58.33	Constant			
	Leptelmis seydeli	+++	83.33	Constant			
	Cyphon coarctatus	+++	75	Constant			
	Hydraena sp.	++	41.67	Accessory			
Odonata							
Libellulidae	*Libellula* sp.	+++	100	Constant	+++	100	Constant
	Palpopleura lucia lucia	+++	100	Constant	+++	100	Constant
	Crocothemis erytraea	+++	83.33	Constant	+++	75	Constant
	Leucorrhinia sp.	+++	66.67	Constant	++	41.67	Accessory
	Orthethrum caffrum	+++	50	Constant	+	16.67	Accidental
	Sympetrum sp.	+++	75	Constant	++	25	Accessory
	Somatochlora sp.	+++	83.33	Constant	+++	66.67	Constant
	Zygonychidium gracile	++	41.67	Accessory			
	Brachythemis leucosticta	++	41.67	Accessory	++	25	Accessory
	Brachinopyga strachani	++	33.33	Accessory	+	8.33	Accidental
Corduliidae	*Cordulia aenea*	+++	83.33	Constant	+++	66.67	Constant
	Epitheca bimaculata	+++	75	Constant	+	8.33	Accidental

	Oxygastra curtisii	+++	100	Constant	+++	66.67	Constant
	Phyllomacromia sp.	++	33.33	Accessory	+	8.33	Accidental
	Macromia sp.	+++	58.33	Constant	++	33.33	Accessory
	Macromia picta	+++	58.33	Constant	++	33.33	Accessory
Aeshnidae	*Aeshnia affinis*	+++	50	Constant			
Cordulegasteridae	*Cordulegastere* sp.	+	16.67	Accidental	+	8.33	Accidental
Coenagrionidae	*Pseudagrion* sp.	+++	91.67	Constant	+++	100	Constant
	Pseudagrion Wellani	+++	100	Constant	++	41.67	Accessory
	Ceriagrion tenelum	+++	100	Constant	+++	100	Constant
	Eurymetra sp.				+++	100	Constant
Ephemeroptera							
Baetidae	*Cloeon smaeleni*	+++	100	Constant	+++	100	Constant
	Cloeon bellum	+++	50	Constant	++	41.67	Accessory
	Cloeon gambiae	+++	75	Constant	+++	91.67	Constant
	Cloeon perkinsi	+++	58.33	Constant	+++	91.67	Constant
Leptophlebiidae	*Traulus* sp.				+	8.33	Accidental
Polymitarcyidae	*Povulla adusta*				+	16.67	Accidental
Tricoptera							
Ecnomidae	*Ecnomus* sp.				+	8.33	Accidental
Philopotamidae	*Chimarra petri*				+++	83.33	Constant
Hydroptilidae	*Hydroptila* sp.	++	33.33	Accessory			
Lepidoptera							
Crambidae	*Cataclysta lemnata*				++	33.33	Accessory
	Elophila obliteralis				+++	58.33	Constant
Megaloptera							
Corydalidae	*Corydalus* sp.	+	16.67	Accidental			
Amphipoda							
Gammaridae	*Gammarus* sp.	+	16.67	Accidental			
Decapoda							
Atydae	*Caridina* sp.	+	16.67	Accidental	+++	50	Constant
	Caridina africana	++	25	Accessory	+++	50	Constant
	Caridina niloticus	++	25	Accessory	+	8.33	Accidental
Crangonidae	*Crangon cranagon*	+++	83.33	Constant	+++	58.33	Constant
Penaidae	*Penaeus notialis*	++	33.33	Accessory			
	Parapenaeus longirostris	+++	100	Constant	++	41.67	Accessory
Aranae							
Tetragnatidae	*Tetragnatha* sp.	++	41.67	Accessory	++	41.67	Accessory
Pissauridae	*Thalassius massajae*	+++	83.33	Constant	+	8.33	Accidental
	Thalassius rossi	+	8.33	Accidental	+	8.33	Accidental
	Thalassius margaritatus	++	41.67	Accessory	++	25	Accessory
Trombidiformes							
Hydrachnidae	*Hydrachna globosa*	+++	83.33	Constant	+++	75	Constant
	Hydrachna sp.	+	8.33	Accidental	+++	66.67	Constant
Mésogasteropoda							
Ampullariidae	*Pila globosa*	+++	91.67	Constant			
Physcidae	*Aplexa hypnorum*	+++	50	Constant			
	Lanistes ovum	+++	50	Constant			
Hydrobiidae	*Potamopyrgus antipodarum*	+++	50	Constant	+	8.33	Accidental
Basommatophora							
Planorbidae	*Bulinus africana*	+	16.67	Accidental			
	bulinus truncatus	++	33,33	Accessory			
	Planorborus corneus	++	25	Accessory			
	Planorbis planorbis	+++	58.33	Constant			
	Gyraulus sp.	+++	50	Constant			
	Gyraulus costulatus	+++	50	Constant			
	Turbonula interrupta	+++	58.33	Constant			

Lymnaeidae	*Lymnaea natalensis*	++	41.67	Accessory			
Oligochaeta							
Oligochetes	*Oligochètes* sp.	+++	100	Constant	+	16.67	Accidental
Tubificidae	*Tubifex tubifex*	+++	100	Constant			
Clitellata							
Haplotaxidae	*Haplotaxis gordioides*	+++	83.33	Constant			
Lumbricidae	*Lumbricus rubellus*	++	41.67	Accessory	+	8.33	Accidental
Pharyngobdelliforme							
Herpodelidae	*Herpodella* sp.	+++	50	Constant	+++	58.33	Constant
Rhynchobdellida							
Glossiphoniidae	*Glossiphonia heteroclita*	+	16.67	Accidental	+++	66.67	Constant

3.3 FREQUENCY OF OCCURRENCE

Table 2 shows the percentages of very frequent, frequent and sporadic taxa in both lagoons. In Ono lagoon, we recorded 87 very frequent taxa (F ≥ 50%), 32 frequent taxa (25% ≤ F < 50%) and 26 sporadic taxa (F < 25%) whereas 48 very frequent taxa (F ≥ 50%), 23 frequent taxa (25% ≤ F < 50%), and 34 sporadic taxa (F < 25%) were found in Hébé lagoon. In Ono and Hébé lagoons, Coleoptera (26 and 07 species respectively), Heteroptera (16 and 11 species), Odonata (16 and 9 species) and Diptera (09 species each) dominated respectively by Dytiscidae, Belostomatidae, Libellulidae and Chironomidae were very frequently found in capture. In Ono lagoon, 08, 04, 05 and 05 species belonging to respectively Coleoptera, Heteroptera, Diptera and Odonata were frequent whereas frequent taxa were composed of 09 species of Coleoptera, 01 species of Heteroptera, 02 species of Diptera and 06 species of Odonata were frequent in Hébé lagoon. Sporadic taxa consisted of 10 species of Coleoptera, 02 species of Heteroptera, 01 species of Odonata and 06 species of Diptera in Ono lagoon and 14 species of Coleoptera, 06 species of Heteroptera and 05 species of Odonata in Hébé lagoon.

3.4 DIVERSITY INDICES AND RAREFIED RICHNESS

A Kruskal-Wallis test revealed no significant difference (p > 0.05) among diversity indices and rarefied richness between seasons (Table 3). In general, values were slightly higher in Ono lagoon (H’ = 4.25, E = 0.49 and S = 141.58) compared to that of Hébé lagoon (H’ = 3.91, E = 0.47 and S = 105) in all seasons. Concerning seasons, Shannon index was found to be higher in rainy (H’ = 4.30) and dry (H’ = 4.12) seasons and lower in flood season (H’ = 3.79) in Ono lagoon. In contrast, values were higher in dry season (H’ = 3.88) following by rainy season (H’ = 3.74) and flood season (H’ = 3.72) in Hébé lagoon. The Shannon-Weaver index was greater than 2 in all samples. High values of Evenness were obtained during rainy season (E = 0.85) in Ono lagoon and during flood season (E = 0.91) in Hébé lagoon. The rarefied richness was also higher in rainy season (S = 105.91) followed by dry season (S = 101.34) flood season (S = 79.31) in Ono lagoon. In contrast, the rarefied richness was higher in dry season (S = 79.39) followed by rainy season (S = 70.40) and flood season (S = 59) in the Hébé lagoon.

Table 3. Diversity indices and rarefied richness of macroinvertebrates in Ono and Hébé lagoons.

	Lagoon Ono				Lagoon Hébé			
	Ds	Rs	Fs	Annual	Ds	Rs	Fs	Annual
Taxa	127	126	86	145	93	77	59	105
Abundance	5654	5085	1436	12175	2653	1742	658	5053
Shannon diversity (H')	4.12	4.30	3.79	4.25	3.88	3.74	3.72	3.91
Evenness index (E)	0.85	0.88	0.85	0.85	0.86	0.86	0.91	0.84
Rarefied richness (S)	101.34	105.91	79.31	141.58	79.37	70.40	59	105

4 DISCUSSION

Analysis of the physical and chemical parameters in both lagoons showed significant seasonal variation, except for pH, nitrite and ammonium. The temperature range obtained in this study shows that the water remains relatively hot. This range is close to those observed in most Ivorian hydrosystems [9], [16]. The highest values of temperature in Hébé lagoon during all seasons is related to the exposure of this lagoon to direct solar radiation due to the absence of macrophytes on the exploitable surface. According to [17], surface water temperature is influenced by solar radiation intensity, evaporation, freshwater influx and cooling. Dissolved oxygen mean values were very low in Ono lagoon compared to Hébé lagoon, attesting that plant cover and root density influence strongly oxygen concentration. The reference [18] noted that the dense mats of macrophytes reduced water circulation and light penetration in water bodies and influenced dissolved oxygen concentrations. On the other hand, the lowest values of oxygen levels may be due to the removal of free oxygen through respiration by macrophytes bacteria and animals as indicated by [19]. Waters of both lagoons have a pH slightly acidic in dry and flood seasons and close to the neutral in rainy season. The pH was lower than the values of Grand-Lahou lagoon [20] and close to Banco river [9]. This acidity comes mainly from plant organic matter decomposition, with production of CO2 in the first layers of the soil [21], [22]. Acidic pH increases the risk of presence of metals and gas in a more toxic form because of runoff water during the flood season which brought materials in lagoon or from the re-suspension of sedimented materials. The low conductivity observed in Ono lagoon during all seasons can be due to the presence of saprophyte stands that act on the medium by slowing down current velocities, trapping sediments, releasing nutrients and creating new habitat as reported by [23]. Conductivity, TDS and depth were higher in flood seasons and lower in dry season for both lagoons. Nitrogenous materials (ammonium, phosphate, nitrate and nitrite) recorded in Ono lagoon were higher, which can explain problems of eutrophication (proliferation of numerous macrophytes) observed in this lagoon. The contamination of surface waters by total phosphorus can be induced by leaching of cropland containing phosphate fertilizers and some pesticides. Indeed, the Ono lagoon watershed closes several industrial plantations (rubber, palm oil, pineapple) that require the use of fertilizers and pesticides over large areas.

There is no realistic estimate of macroinvertebrates fauna in small lagoons of Côte d'Ivoire till now. Results of the present study showed that the main groups of macroinvertebrates were mostly aquatic insect larvae (Heteroptera, Coleoptera, Odonata, Ephemeroptera, Tricoptera, Lepidoptera, Megaloptera), Achaeta (Oligochaeta, Clitellata, Pharyngobdelliforme and Rhynchobdellida), Gastropoda (Mesogasteropoda and Basommatophora), Crustacea (Amphipoda and Decapoda) and Arachnida (Aranae and Trombidiformes). This result is relatively similar to those reported by previous studies in other water bodies of Côte d'Ivoire [24], [25], [9], Bénin [26] and Burkina Faso [27]. However, differences remain either in the taxa number or the dominant group between these results and those of the current study. Indeed, the number of taxa in our study was highest (Ono lagoon = 145 taxa and Hébé lagoon = 105 taxa) than that of earlier studies. The abundance was also highest during the dry season in Ono lagoon (127 taxa) and Hebe lagoon (93 taxa) and lowest during flood season in Ono lagoon (86 taxa) and Hebe lagoon (59 taxa). These differences could be explained by the difference between the sampling period, methods used and environments nature (the types of habitats sampled). On the other hand, the abundance of both lagoons was dominated by insects namely Heteroptera, Diptera, Coleoptera and Odonata in all season with Heteroptera and Coleoptera being respectively the most abundant and diverse groups. This finding is similar to the observation made by [28] in a municipal river from North Central Nigeria. The dominance of these Orders in term of richness was noted by [25] and [29]. In addition, Megaloptera, Amphipoda and Basommatophora were only found in Ono lagoon while Lepidoptera was only present in Hébé lagoon. Dytiscidae (25 and 19 species), Chironomidae (13 and 10 species), Hydrophilidae (10 and 09 species), Libellulidae (09 and 08 species) and are in order, the most abundant families repectively in Ono and Hébé lagoons during the sampling period. However, the diversity of Hébé lagoon appears to be less rich compared to Ono lagoon. The high number of macroinvertebrates in Ono lagoon could be due to the fact that this lagoon is invaded by numerous macrophytes. The reference [30] reported that the floating macrophytes of Ono lagoon supported a rich community of benthic and epiphytic macroinvertebrates. According to [31], these habitats are used by macroinvertebrates as food resource, shelter against predators and for reproduction

Values of diversity indices and rarefied richness were not significantly different between lagoons but relatively higher values were obtained in Ono lagoon than in Hébé lagoon in all seasons, except for evenness. The Shannon diversity index showed significant spatial variation from a minimum of 3.91 (Hébé lagoon) to a maximum of 4.25 (Ono lagoon), suggesting that Ono lagoon was able to sustain a richer associated community. The Shannon diversity index and evenness values of 3.72-4.25 and 0.84-0.91 respectively in both lagoons indicate that the macroinvertebrate stands are relatively diversified and balanced. According to [32], in exceptionally diverse environments, the Shannon diversity index does not exceed 4.5. In addition, according to [33], when equitability is closed to 1, the stand is balanced and stable. In view of the evenness values, the studied lagoons showed a relative heterogeneity. Relatively to seasons, the rainy and dry seasons sustained a richer associated macroinvertebrates community than flood season. According to [34], increased flow during the flood season usually leads to a reduction in macroinvertebrate diversity in tropical streams because of effects of wash off from the surrounding catchment and the dislodgement of taxa with no adhesive features. The rarefied richness did not vary significantly among lagoons and seasons. The rarefied richness shows that in absence of any bias in samples, dry and rainy seasons were rich in number of species for both lagoons. In Grand-Lahou lagoon, [35] showed that high values this index were recorded during the rainy season. According to [36] taxonomic wealth is related to the stability of the environment.

5 CONCLUSION

This study carried out on macroinvertebrates in Ono and Hébé lagoons is the first kind. Its showed that Ono and Hébé lagoons were characterized by a spatial and temporal change of physicochemical parameters. These parameters are dependent on periodic hydro-climatic variations and human activities. It has contributed to identify 145 and 105 macroinvertebrate species composed of aquatic Insects, Achaeta, Gastropoda, Crustacea and Arachnida respectively in Ono and Hébé lagoons. It is also revealed that these lagoons are able to sustain a richer associated and diverse community. However, the increase of anthropogenic disturbances on these lagoons constituted a real threat of the macroinvertebrates at long term.

ACKNOWLEDGMENTS

The authors are most grateful to Dr Wadja Mathieu Egnankou of SOS Forest and Mr. Jean Assi of the National Floristic Centre for their useful help in macrophyte identification. We are especially thankful to Drs. Oi Edia Edia and Kouadio Kouakou Norbert for their useful help in macroinvertebrates identification.

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