International Journal of Fisheries and Aquatic Studies

E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 76.37
(GIF) Impact Factor: 0.549
IJFAS 2023; 11(4): 113-122

www.fisheriesjournal.com
Received: 20-06-2023
Accepted: 23-07-2023

Gougloin Touamin Hugues Esmel
Doctoral Student, Department of Environment and Aquatic Biology Laboratory (LEBA), UFR-Sciences et Gestion de l' Environnement (SGE), Universite Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02, Ivory Coast, Côte d'Ivoire

Dietoa Yehe Mathieu
Senior Lecturers, Department of Laboratory of Environment and Aquatic Biology (LEBA), UFR-Sciences et Gestion de l' Environnement (SGE), Universite Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02, Ivory Coast, Côte d'Ivoire

Tah Leonard
Research Officers, Centre de Recherches Océanologiques (CRO), Abidjan 02, Ivory Coast, Côte d'Ivoire

Corresponding Author:
Gougloin Touamin Hugues Esmel
Doctoral Student, Department of Environment and Aquatic Biology Laboratory (LEBA), UFR-Sciences et Gestion de l' Environnement (SGE), Universite Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02, Ivory Coast, Côte d'Ivoire

Diversity and taxonomic structure of aquatic macroinvertebrates in a fluvio-lacustrine system in south-west Côte d'Ivoire: The case of the Soubré hydroelectric dam lake

Gougloin Touamin Hugues Esmel, Dietoa Yehe Mathieu and Tah Leonard

DOI: https://doi.org/10.22271/fish.2023.v11.i4b.2832

Abstract
The macroinvertebrate inventory was carried out using samples taken at 6 stations distributed along the longitudinal profile of the Soubré lake and the downstream part of the Sassandra river. Sampling was carried out monthly from July 2019 to February 2020. A total of 20581 macroinvertebrate individuals belonging to 117 taxa (genera and species), 60 families, 17 orders and 6 classes were recorded. The macrofauna was largely dominated by molluscs, which accounted for 55.69% of the total richness of the macrofauna collected. Insects accounted for 40.26% of the total abundance of organisms collected. Annelids and crustaceans were the poorest groups in the population. Coleoptera was the most abundant order in terms of numbers of individuals, and Thiaridae was the most abundant family. Individuals from the Malacostracan faunal group represented 2.68% of the total population collected in the aquatic environments of the fluvio-lacustrine environment. This Malacostracan population was only sampled in the river environment, i.e. at the Tiémé (TIE, upstream from the dam), Pont (PON) and Karmel (KAR, downstream from the dam) stations. Arachnids (0.61%), bivalves (0.57%) and annelids (0.29%) appear to be present only anecdotally or even absent from other sites. In terms of the qualitative abundance of macroinvertebrates, there were 96 taxa belonging to the Insect class, representing 82.05% of the total diversity of the fluvio-lacustrine environment sampled. However, Gastropods had 12 taxa collected. The sampling stations located in the fluvial environment recorded high taxonomic diversity: Tiémé (73 taxa), Pont (68 taxa) and Karmel (62 taxa), in contrast to the sampling sites in the lacustrine environment, which recorded the lowest taxonomic richness. The Shannon diversity indices (H') vary spatially, with averages of H'=3.71 for the TIE site and H'=2.85 for the KPE station. Pollution-sensitive species such as Chironomidae, Thiaridae and Viviparidae were predominantly abundant. A taxonomic dissimilarity was observed between the lake and river stations. The fluvial-lacustrine zone has a greater diversity of aquatic macroinvertebrates than the Taabo lakes. Anthropogenic activities are the main factors influencing macroinvertebrate diversity in this ecosystem. This study opens up a scientific question on different aspects of research on the taxonomy, ecology and functional structure of aquatic invertebrates in this ecosystem for further study in this field.

Keywords: Lake, Soubré, macroinvertebrates, Sassandra river, dam

1. Introduction

For a long time, water management was based on sectoral objectives focused on specific uses of the physical resource: supplying water to cities, producing electricity, agriculture, etc. More often than not, the ecological or social implications were marginalised or even ignored. More often than not, the ecological or social implications were marginalised or even ignored [1]. The construction of hydroelectric dams has a negative effect on the organisms that colonise this environment [2]. To this end, the dammed rivers are divided into three ecologically distinct sections: upstream, the lake zone and downstream. These structures modify the hydrological conditions downstream, transform the lotic habitat into a lentic habitat at the level of the reservoir and isolate the upstream part of the river [3]. They disrupt ecological conditions both upstream and downstream of the reservoir. This modification of the river environment is thought to have an impact on the diversity of aquatic macroinvertebrates [4]. Macroinvertebrates play an important role in lake food webs.

Côte d'Ivoire has four major rivers (Comoé, Bandama, Cavally and Sassandra) and around ten small coastal basins that drain from north to south and east to west [5]. A number of hydroelectric or agricultural dams have been built on these different watercourses to meet electricity and other needs. These dams have an impact on aquatic ecosystems, as they create reservoirs in the watercourses. From an energy and climate point of view (zero CO2 emissions), dams are therefore positive. In fact, every dam, whether hydroelectric or not, constitutes an obstacle to the circulation of biological species and sediments (sand, silt, etc.). The organisms living in these aquatic environments can be affected to a greater or lesser extent by this degradation. They recycle detrital organic matter [6] and serve as food for many fish and birds [7]. They can also be exploited directly by humans (e.g. Malacostracans) [8]. As a result, monitoring the integrity of these aquatic ecosystems is now largely based on measurements of the biological communities in place, particularly macroinvertebrates [9-10]. Macroinvertebrates, which are widely distributed in different water strata, are characterised by their differential pollutant sensitivity, a feature used in bioindication of aquatic ecosystems [11]. In Côte d'Ivoire, several studies have focused on the structural and temporal organisation of macroinvertebrates in lake environments. These include the work of Sankaré (1991) [12] on macroinvertebrates associated with aquatic vegetation in Lake Ayamé II and the Comoé river in the south-east of the country, and that of Kouamé (2014) [13] on the Taabo dam lake. Diomandé *et al.* (2013) [14] and Kra *et al*. (2018) [15] conducted research on Lake Kodjoboué. Finally, Djoman *et al*. (2020) [16] worked on Lake Taabo (Bandaman Basin). The creation of the hydroelectric dam lake in this area has led to a modification of the normal course of the river, and could therefore have considerable biological and ecological impacts. Previously, no studies had been carried out on aquatic organisms in these environments, which is the main reason for our research work. Our study was carried out between July 2019 and February 2020. The research question of the present study is whether agricultural or anthropogenic activities have an impact on the biodiversity and spatio-temporal distribution of macroinvertebrates that are attached to bodies of water in the fluvio-lacustrine zone.

Materials and Methods

Sampling sites

Criteria such as accessibility, occupation of the surrounding perimeter and the ecological particularity established on the basis of the habitat type of the site were taken into account to define the various sampling stations for macrofauna. These stations were defined following a survey carried out in the fluvio-lacustrine zone of the Soubré dam in June 2019. A total of six sampling stations (Tiémé, Amaragui, Gnamandji, Kpéhiri, Pont and Karmel) were selected (Figure 1).

Tiémé (TIE) is a station located upstream in the fluvial section of the Sassandra River (Figure 14). The substrate is heterogeneous, but dominated by sand with silt in some places (localised clogging). The current is fast and the banks slope between 45 and 85°. The canopy is high (75-95%).

Amaragui (AMA), is the station located in the upstream zone of the lake with geographical coordinates of 05°48'20"N and 06°43'09"W. It is an intermediate environment between the lake and the fluvial part of the Sassandra. The substrate at this station is made up of sand and clay. This area is covered by rubber and cocoa plantations.

Gnamandji (GNA), is located in the median zone of the lake in geographical position 05°46'57"N and 06°36'08"W. The station's substrate consists of clay and sand. The station is located near a village that bears its name. It has a landing stage for collecting fisheries data. e. The body of water is covered in places by aquatic vegetation.

Kpéhiri (KPE), is located in the lower reaches of the lake in a flood plain with a sandy bed in geographical position: 05°46'82"N and 06°38'74"W. The banks are made up of sandy-clay materials with a gentle slope that is steep in places. The bed of this part of the lake has a sandy bottom. The vegetation consists of very degraded forest, cocoa and rubber plantations and yam fields.

Pont (PON) is one of the downstream stations in the fluvial section of the Sassandra (Figure 18). It is located in the town of Soubré. The substrate is sand. The plant cover is essentially composed of Poaceae (Echinochloa pyramidalis). The slope of this station is not very steep.

Karmel (KAR) is a station located near the town of Soubré, upstream from the Pont station. At Karmel, man-made activities such as washing, rice growing and cocoa farming are practised in the surrounding area. Part of the riverbank is forested. The slopes of the banks are steep. The substrate at this station consists mainly of mud and clay (Figure 1).

Fig 1: Location map of the sampling area in the Soubré dam lake (Ivory Coast) Tiémé = TIE; Amaragui = AMA; Gnamandji = GNA; Kpéhiri = KPE; Pont = PON; Karmel = KAR

Sampling of macroinvertebrates

Biological data were collected monthly from July 2019 to February 2020 at the various stations. The biological material was taken from the bottom (benthos) and the bank. A 30 cm square opening net was used to collect organisms on the bank, more precisely in the grass beds at each station. Sampling was carried out by dredging the bottom with a drag net, moving back and forth over a distance of around three metres for four to five minutes. The Van Veen grab was then used to collect macroinvertebrates from the sediment [17-18]. At each station, 12 grab samples (corresponding to a surface area of 0.1125 m²) were taken [17].

The substrate from each material thus obtained was tipped onto a rectangular sieve (50 cm x 40 cm) with a mesh size of 1 mm, on which the sediment samples were rinsed several times with water in order to reduce the quantity of substrate taken. The resulting rejects were placed in a jar, fixed with 5% formaldehyde and transferred to the laboratory. In the laboratory, after sorting, the recovered organisms were observed using an Olympus SZ 30 binocular magnifier. The macroinvertebrate individuals collected were identified and, in most cases, counted down to genus or species using the identification keys of Dejoux *et al.* (1981) [19]; De Moor *et al.* (2003) [20]; Tachet *et al.* (2003) [21].

Data analysis

The aquatic macroinvertebrate data were analysed using methods with simple and multivariate variables. Indices such as Shannon-Weaver diversity, Pielou equitability and taxon occurrence were also calculated at each station.

Percentage of species occurrence

The percentage of occurrence provides information on the habitat preferences of a given species. According to Hyslop (1980), it is the number of times the species appears in the samples. It is calculated as follows

$F= Fi*100/Ft$

Where

Fi = number of samples containing species i; Ft = total number of samples obtained. Depending on the value of F, three groups of species are distinguished: constant species ($F \geq 50\%$); accessory species ($25\% \leq F < 50\%$); accidental species ($F < 25\%$).

Shannon diversity index H'

Shannon diversity is the degree of complexity of a stand. It is expressed by an index that incorporates both the richness of the stand and the specific abundances. It is used to express the structure of the population and to characterise the equilibrium of the population in an ecosystem. The Shannon index is calculated as follows: $H' = - \Sigma Pi \; Log2 \; Pi$ or $Pi= Ni / N$. Ni = Number of species i, N = Total number of the stand and Log 2 = logarithm to the base of 2.

Equitability index (E)

The equitability or Pielou index expresses the distribution of individuals between species in the same environment. The regularity index varies between 0 and 1. If E tends towards 1, the population is in equilibrium and the distribution of individuals between species is fair. Conversely, equitability tending towards zero characterises an unbalanced population [22]. For this study, Pielou equitability was calculated using index data. RStudio software was used to calculate the Pielou index (J) using the following formula: $E = H'/H' max$ or $H' max = Log2 \; S$ (H' = Shannon-Weaver index. S = Specific richness).

Statistical Method

The spatial variability of taxonomic richness, abundance and diversity indices was assessed using the Kruskal-Wallis test with a threshold of 5% using R software. The t-test performed with XLSTAT v2018 software (Microsoft Office Excel) was used to compare the means, Shannon indices and benthic macroinvertebrate density, and to calculate the probabilities that the communities in the different samples, taken in pairs, are identical. XLSTAT v2018 software (Microsoft Office Excel) was used to construct the hierarchical classification dendrogram for discriminating between the various sampling stations in the reservoir. The Euclidean distance is used as the assembly distance.

Results

Composition of aquatic macroinvertebrates in the Soubré dam lake: A total of 20581 individuals divided into six classes of macroinvertebrates were collected: Insects, Gastropods, Annelids, Bivalves, Arachnids and Malacostracans. The population is dominated by. The population is dominated by Gastropods with 55.69% of the total number of individuals, followed by Insects with 40.26% (Fig. 2).

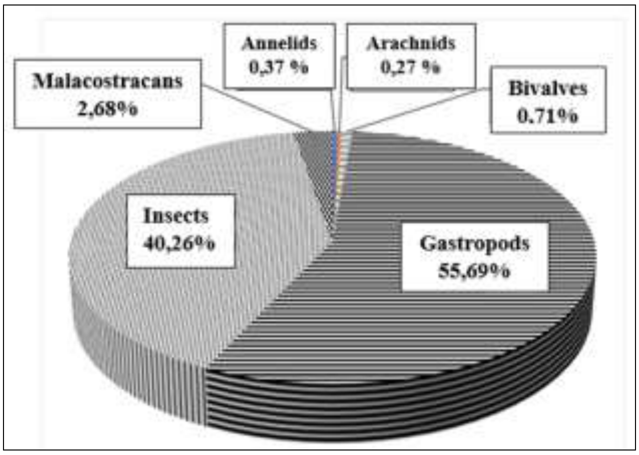

Fig 2: Proportions of taxa collected at the Soubré dam lake

At the various sampling stations, the macroinvertebrates collected were divided into six (6) classes, 17 orders, 60 families and 117 taxa (Table I). The Insect class is the most diverse, with eight (8) orders, 44 families and 95 taxa, followed by the Gastropod class, with 03 orders, eight (8) families and 12 taxa. They are followed by the Bivalves and Malacostracans with three (3) taxa each. Next comes the class of Annelids with two (2) families comprising two (2) taxa. The class Peanuts is the least represented with only one family.

Table I shows the orders of aquatic macroinvertebrates in the study area. The abundance of orders of aquatic organisms is dominated by individuals of the Mesogastropoda class of Gastropoda in the sampling environments. They are followed by the order Basommatophores at stations located in lacustrine environments (AMA, GNA and KPE). On the other hand, in river environments, two orders of insects (Hemiptera and Odonata) came seconde at the TIE and KAR stations for

Hemiptera and at the PON station for Odonata. Annelid Haplotaxida were not collected at the TIE and PON sites. The maximum abundance of this order was observed at station KPE, one of the lake's stations. The orders Lepidoptera and Plecoptera were only sampled in fluvial environments during this study. The orders Malacostraca were present only at the TIE and PON stations. In the Bivalve class, the Venoroides order was abundant at the AMA station, located in the lacustrine environment upstream of the Soubré hydroelectric dam.

The taxonomic composition of macroinvertebrates in the fluvio-lacustrine zone of the Soubré hydroelectric dam is presented in Table II.

Table 1: Preponderance of orders of aquatic macroinvertebrates in the fluvio-lacustrine zone of the Soubré hydroelectric dam

Macro invertebrates	TIE	AMA	GNA	KPE	PON	KAR
Annelids	0	16	5	38	18	0
Haplotaxidas	0	16	5	38	18	0
Arachnids	9	20	7	6	6	8
Araneids	9	20	7	6	6	8
Bivalves	25	49	18	20	15	19
Myids	15	33	18	20	0	19
Venoroids	10	16	0	0	15	0
Gastropods	722	3041	2756	2904	777	1263
Basommatophores	163	796	582	612	145	168
Littorinimorphs	24	0	73	91	0	0
Mesogasteropods	535	2245	2101	2201	632	1095
Insects	1542	1447	1544	1053	1210	1491
Coleoptera	182	132	100	29	57	102
Diptera	107	482	550	498	242	313
Ephemeroptera	247	78	125	55	158	249
Hemiptera	395	244	234	195	228	352
Lepidoptera	47	0	0	0	2	0
Odonates	334	397	364	173	339	297
Plecoptera	75	0	0	0	55	0
Trichoptera	155	114	171	103	129	178
Malacostracans	514	0	0	0	0	38
Amphipods	276	0	0	0	0	0
Decapods	238	0	0	0	0	38

				Sampling stations in the study environment					
Classes	Orders	Families	*Taxa*	TIE	AMA	GNA	KPE	PON	KAR
Annelids	Haplotaxidas	Alluroididae	*Alluroides tanganyikae*	-	+	-	-	-	-
		Lumbricidae	*Helobdella* sp.	-	+	+	++	+	-
Malacostracans	Amphipods	Gammaridae	*Gammarus pulex*	+++	-	-	-	-	
	Decapoda	Desmocarididae	*Desmocaris trispinosa*	+++	-	-	-	-	-
		Palaemonidae	*Macrobrachium dux*	+	-	-	-	-	+
Arachnids	Araneids	Thomisidae	*Misumena* sp.	+	++	+	+	+	+
Bivalves	Myidae	Corbuliidae	*Corbula gibba*	+	-	+	+	-	-
			Corbula trigona	+	+++	+	+	-	+
	Venoroids	Sphaeriidae	*Pissiduim punetifera*	++	+	-	-	++	-
Gastropods	Basommatophores	Lymnaeidae	*Lymnaea natalensis*	+	++	++	+	-	-
		Physidae	*Physa marmorata*	+	+++	++	+++	+	+
		Planorbidae	*Afrogorus* sp.	-	+	-	++	+	+
			Biomphalaria pfeifferi	-	+	+	++	+	+
			Bulinus globosus	-	+	-	-	-	-
			Indoplanorbis exustus	+++	+++	+++	+++	+++	+++
	Littorinimorphs	Hydrobiidae	*Hydrobia gabonensis*	+	-	+	+	-	-
	Mesogasteropoda	Ampullariidae	*Lanites varicus*	+++	+++	+++	+++	+++	+++
		Bithyniidae	*Gabbiella africana*	-	+++	+++	++	++	++
		Thiaridae	*Melanoides tuberculata*	+++	+++	+++	+++	+++	+++
			Potadoma liricincta	-	-	-	-	-	+
Gastropods	Mesogasteropoda	Viviparidae	*Viviparus* sp.	+++	+++	+++	+++	+++	+++
Insects	Coleoptera Diptera	Dytiscidae	*Dytiscus marginalis*	-	-	++	-	+	-
			Hydrocoptus simplex	+	-	-	-	+	-
			Laccophilus vermiculosus	+	+	-	-	-	-
			Neptostermus sp.	+	-	-	-	-	-
			Yola elegantula	-	-	-	-	+	+
		Elmidae	*Elmis* sp.	+	++	+	+	+	+
		Gyrinidae	*Aulonogyrus* sp.	+	-	-	-	-	-
			Dineutus Aereus	-	-	+	-	-	-
			Orectogyus sp.	+++	+++	-	-	+	+
		Hydrophilidae	*Enochrus* sp.	+	++	+	+	+	+

			Hydrobius sp.	+	-	-	-	-	+
			Laccobius sp.	+	-	-	-	-	-
		Athericidae	*Atherix* sp.	-	+	-	-	+	+
		Ceratopogonidae	*Cerotopogon* sp.	-	-	-	-	+	+
		Chaoboridae	*Chaoborus* sp.	+	+	+	+	-	+
		Chironomidae	*Chironomus formosipennsi*	-	+	+	+	+	+
			Chironomus imicola	+	+	+++	++	+++	+
			Chironomus sp.	-	+	+	+	-	+
			Cricotopus sp.	-	-	-	+	-	-
			Nilodorum brevipalpis	+	-	++	+	-	+
			Orthocladiinae	-	+	-	+	-	-
Insects	Diptera	Chironomidae	*Polypedilum fuscipenne*	-	-	+	+	+	+
			Procladius sp.	-	+	+	+	-	-
			Tanypus fuscus	-	++	-	+	+	-
		Culicidae	*Aedes* sp.	-	++	-	+	-	-
			Anopheles sp.	+	++	++	++	+	+
			Culex sp.	+	+++	++	+++	+	+++
		Muscidae	*Musca* sp.	-	-	+	-	-	-
		Simuliidae	*Simulium damnosum*	-	+	++	+	-	-
		Syriphidae	*Eristalis* sp.	-	-	-	-	+	-
		Tipulidae	*Tipula* sp.	-	+	+	+	-	-
	Ephemeroptera	Baetidae	*Afrobaetodes* sp.	+	-	-	-	-	+
			Cloeon dentatus	-	+	++	-	+	+
		Baetidae	*Procloeon sylvicolo*	+	-	+	+	+	-
			Pseudocloeon bertrandi	+	-	-	-	-	+
		Caenidae	*Caenis* sp.	++	-	-	-	+	++
		Heptageniidae	*Afronurus* sp.	++	-	-	-	+	+
			Notonurus sp.	+	-	-	-	+	-
		Leptophlebiidae	*Adenophlebia* sp.	+	-	-	-	+	++
			Choroterpes sp.	+	+	-	-	+	+
			Thraulus sp.	+	-	-	-	+	-
		Oligoneuriidae	*Elassoneuria* sp.	+	+	-	-	-	+
			Oligoneuria sp.	-	-	-	-	+	+
Insects	Hemiptera	Tricorythidae	*Tricorythus* sp.	+	+	+	+	+	+
		Belostomatidae	*Diplonychus* sp.	+	++	+	+	-	-
			Limnogeton fieberi	+	++	+++	+	+	++
		Corixidae	*Micronecta scutelloris*	+++	+	-	+	+	-
			Stenocorixa protusa	+	-	-	+	-	-
		Gerridae	*Gerris* sp.	+	-	+	-	+	+
			Limnogonus chapardi	-	-	-	-	+	+
		Hydrometridae	*Hydrometra* sp.	+	-	-	+	-	+
		Mesoveliidae	*Mesovelia vittigera*	+	-	+	+	-	-
		Naucoridae	*Laccocoris* sp.	+	-	-	-	+	-
			Naucoris sp.	+	+	-	-	-	-
		Nepidae	*Laccotrephes ater*	+	-	-	-	-	-
		Notonectidae	*Anisops sardae*	++	+	+	+	-	+
		Pleidae	*Plea pullula*	+	-	-		+	+
			Plea sp.	+	-	-	-	-	-
		Psychomydae	*Paduniella* sp.	+	-	-	-	+	-
		Ranatridae	*Ranatra* sp.	+	-	-	-	++	++
		Veliidae	*Microvelia* sp.	+	-	+	+	+	+
			Rhagovelia reitteri	+	+	-	+	++	+++
	Lepidoptera	Crambidae	*Eoophila* sp.	+	-	-	-	+	-
	Odonates	Calopterygidae	*Phaon iridipennis*	-	+	+	-	+	+
			Sapho bicolor	+	-	-	-	-	-
Insects	Odonates	Chlorocyphydae	*Chlorocypha* sp.	-	-	-	-	+	+
		Coenagrionidae	*Coenagrion* sp.	+++	+	+++	+	++	++
			Pseudogrion wellani	+	+	-	-	+	+
		Corduliidae	*Cordulia* sp.	-	+	+	-	+	-
			Oxygastra curtisii	-	-	-	-	+	+
		Gomphidae	*Ictionogomphus* sp.	-	++	+	-	+	-
			Microgomphus sp.	-	-	-	+	++	-
			Paragomphus hageni	+	+	+	+	+	+
			Phyllogomphus aethiops	+	+	+	+	+	-
		Libellulidae	*Bradinopyga strachani*	+	-	-	-	-	-
			Chalcostephia flavifrons	-	-	-	-	-	+++
			Libella sp.	++	-	-	-	+	+
			Libellula sp.	+	++	+	+	+	+

			Olpoogastra sp.	-	+	-	-	-	-
			Pantala plavescens	-	-	+	+	+	-
			Urothemis sp.	+	+	-	+	-	-
			Zygonix sp.	-	+	++	-	-	-
			Zygonix torrida	+	+	+	+	+	++
		Macromiidae	*Macromia* sp.	+	-	-	-	+	+
	Plecoptera	Perlidae	*Neoperla spio*	++	-	-	-	+	-
	Trichoptera	Ecnomidae	*Ecnomus* sp.	++	++	++	+	+	++
		Hydropsychidae	*Amphipsyche* sp.	-	-	+	+	-	-
Insects	Trichoptera	Hydropsychidae	*Hydropsyche* sp.	-	-	-	-	+	+
			Macrostemum capense	+	+	-	-	-	-
			Polymorphanisus sp.	-	-	-	+	-	-
		Hydroptilidae	*Afritrichia* sp.	-	+	-	-	-	-
			Hydroptila sp.	-	+	-	+	++	-
		Leptoceridae	*Ceraclea* sp.	-	-	-	-	+	+
			Leptocerus sp.	+	+	+++	++	-	+
			Oecetis sp.	++	-	-	-	+	+

Frequency of occurrence

Table III shows the frequency of occurrence of the taxa collected at all the stations. Collections. This table shows four (4) frequent taxa: *Viviparus* sp., *Melanoides tuberculata*, *Lanites varicus* and *Indoplanorbis exustus*, (Gastropods). At the TIE station, we recorded nine (9) taxa (*Gammarus pulex*, *Desmocaris trispinosa*, *Coenagrion* sp., *Micronecta scutelloris*, *Orectogyus* sp., *Viviparus* sp., *Lanites varicus*, *Indoplanorbis exustus* and *Melanoides tuberculata*) which were constant, i.e. 12.33%, and eight (8) taxa (*Oecetis* sp., *Ecnomus* sp., *Neoperla spio*, *Libella* sp., *Anisops sardae*, *Afronurus* sp., *Caenis* sp., and *Pissiduim punetifera*) accessory, i.e. 10.96% of the number of taxa collected in this environment. As for the AMA station, nine (9) taxa *(Culex* sp., *Orectogyus* sp., *Viviparus* sp., *Melanoides tuberculata*, *Gabbiella africana*, *Lanites varicus*, *Indoplanorbis exustus*, *Physa marmorata* and *Corbula gibba*) were constant in the samples and 12 taxa (*Ecnomus* sp., *Libellula* sp., *Ictionogomphus* sp., *Limnogeton fieberi*, *Diplonychus* sp., *Anopheles* sp., *Aedes* sp., *Tanypus fuscus*, *Enochrus* sp., *Elmis* sp., *Lymnaea natalensis* and *Misumena* sp.) were accessory. At station GNA, analysis of the results shows that nine (9) taxa (*Leptocerus* sp., *Coenagrion* sp., *Limnogeton fieberi*, *Chironomus imicola*, *Viviparus* sp., *Melanoides tuberculata*, *Gabbiella africana*, *Lanites varicus* and *Indoplanorbis exustus*) or 17.64% are frequent. At station KPE, six (6) taxa (*Physa marmorata*, *Indoplanorbis exustus*, *Viviparus* sp., *Lanites varicus*, *Melanoides tuberculata* and *Culex* sp.) were constant in the samples, i.e. 10.91%. In addition, samples from the PON station recorded five (5) taxa (*Indoplanorbis exustus*, *Lanites varicus*, *Melanoides tuberculata*, *Viviparus* sp. and *Chironomus imicola*) constant at 07.36%. At station KAR, we recorded seven (7) constant taxa *(Indoplanorbis exustus*, *Lanites varicus*, *Melanoides tuberculata*, *Viviparus* sp., *Culex* sp., *Rhagovelia* sp. and *Chalcostephia flavifrons*). Analysis of the occurrences shows that at station GNA we obtained the highest proportion of constant taxa (15.68%) and accessory taxa (21.56%). However, the highest proportion of accidental taxa was noted at the PON site.

Table 3: Frequency of occurrence of taxa in the Soubré hydroelectric dam lake

	Sampling stations					
Frequency of occurrence (%)	**TIE**	**AMA**	**GNA**	**KPE**	**PON**	**KAR**
Taxonomic richness	73	58	51	55	68	62
Constant	12,33	15,51	17,64	10,91	07,36	11,29
Accessories	10,96	20,69	19,60	12,72	10,29	12,90
Accidental	76,71	63,79	62,76	76,37	82,35	75,81

Taxonomic distribution of aquatic macroinvertebrates in the Soubré dam lake

The diversity index and abundance of taxa obtained at the various sampling stations are shown in Table IV. The AMA station recorded the highest abundance (4573 ind.) of the six sampling stations. It was followed by the GNA and KPE sites with 4330 and 4021 individuals respectively. The lowest quantitative richness was observed at the TIE, PON and KAR stations. Station TIE recorded the highest taxon richness (73 taxa), followed by station PON with 68 taxa. Then the KAR station with 62 taxa. The lake sites had the lowest taxon richness, with 51 taxa collected at station GNA, 55 taxa at station KPE and 58 taxa at station AMA. The highest Shannon indices (H) were obtained at the TIE site (3.71), while the lowest index was observed at the KPE site (2.85). With regard to the equitability of Pielou (J), the highest values were observed at the TIE sampling point (0.86), while the KPE site (0.71) also had the lowest Pielou (J) value. Analysis of the indices (Taxonomic Richness, Shannon_H and Equitability of Piélou J) subjected to the Kruskal-Wallis test revealed no significant difference between the stations ($p > 0.05$).

Table 4: Spatial variations in taxonomic richness, relative abundance, Shannon_H Index and Equitability of organisms collected during the study

	Sampling stations					
Index	**TIE**	**AMA**	**GNA**	**KPE**	**PON**	**KAR**
Abundance	2812	4573	4330	4021	2026	2019
Taxonomic Richness	73	58	51	55	68	62
Shannon index H	3,71	3,05	3,06	2,85	3,50	3,43
Equitability J	0,86	0,75	0,78	0,71	0,84	0,83

Hierarchical classification of dissimilarity of stations in the fluvio-lacustrine zone of the Soubré dam according to the species of aquatic macroinvertebrates collected

An ascending hierarchical classification analysis of the various sampling stations was carried out on the basis of the abundance of macroinvertebrate species (Figure 4). The dissimilarity dendrogram obtained allows us to consider two main groups of stations. Group I comprises the TIE station. Group II comprises the other stations. This second group can be subdivided into two sub-groups: the PON and KAR stations on the one hand, and the AMA, GNA and KPE stations on the other.

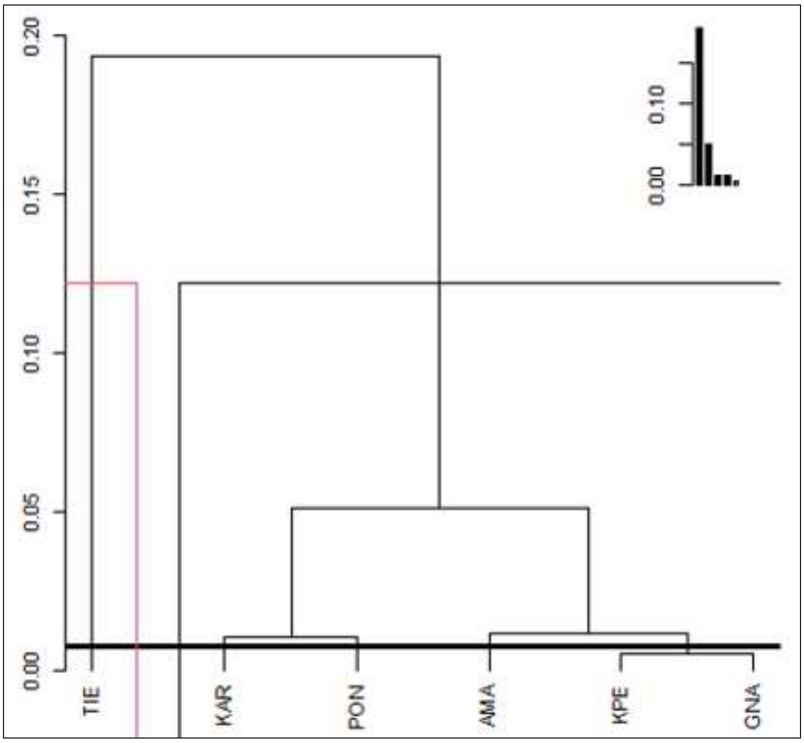

Fig 4: Hierarchical classification of sampling stations based on the similarity of assemblages of aquatic macroinvertebrate families.

Correlation analysis of the spatial distribution of macroinvertebrate orders

A Principal Correspondence Analysis (PCA) was carried out between the different sampling stations and the abundance of macroinvertebrate orders (Figure 5). Axis I expresses 55.1% of the information, while axis II expresses 17.8%. The first two axes represent 69.8% of the total variability. Analysis of the graph shows that the order of Plecoptera, Ephemeroptera, Hemiptera, Trichoptera and Amphipoda are correlated with the TIE, KAR and PON stations. Stations AMA, GNA and KPE are correlated with Diptera, Mesogasteroptera and Basommatophtera.

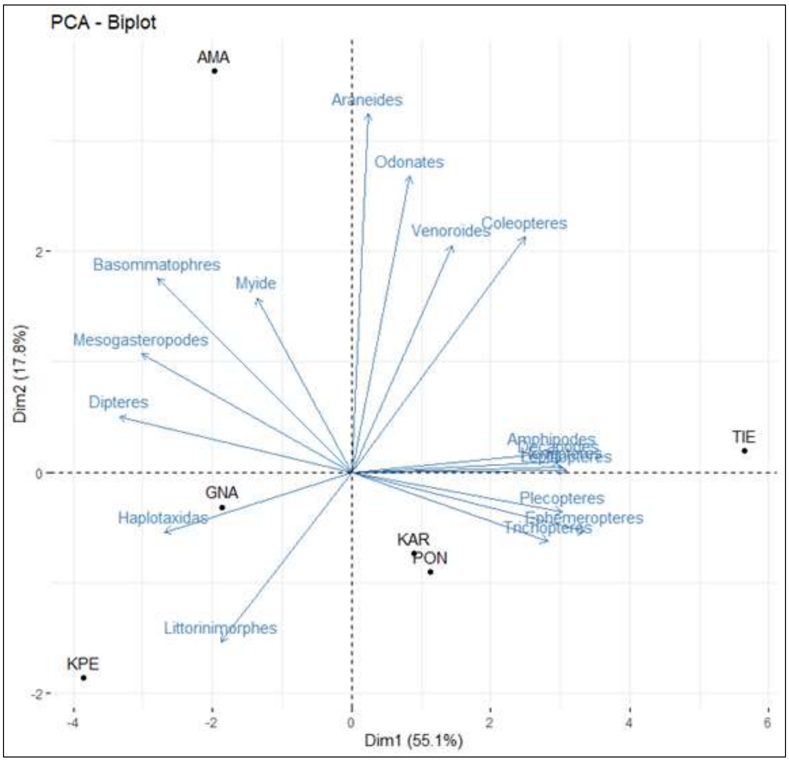

Fig 5: Correlation of the spatial distribution of macroinvertebrate orders

Discussion

The study of the benthic macrofauna of the fluvio-lacustrine zone of the Soubré hydroelectric dam recorded 20581 individuals. The number of individuals observed is significantly higher than that collected in Lake Taabo [23] and in the Aghien lagoon in Côte d'Ivoire [17]. On the other hand, it is lower and very far from the number obtained by Sanogo *et al.* (2014) [24] in three bodies of water in the Volta basin in Burkina-Faso. Indeed, the results show that the study environment has a large number of macroinvertebrates dominated by the Gastropoda class, which represents 55.69% of the faunal groups in the fluvio-lacustrine zone of the Soubré hydroelectric dam. In second place comes the class of Insects with 4485 individuals, or 29.31%. The results of this study do not corroborate those of: Allouko *et al*. (2018) [25]; Kra *et al* (2018) [15]; Camara (2013) [26] and Edia (2008) [27] who found in their samples the abundance of individuals of the Insect class compared to the other classes of aquatic macroinvertebrates. The Insect class is made up of 08 orders. The orders Diptera (2192), Odonata (1904) and Hemiptera (1648) have a very high abundance compared to the other orders of insects sampled in the fluvio-lacustrine zone of the Soubré hydroelectric dam, more specifically in the lacustrine environment. Our results are contrary to those of Sanogo *et al*. (2014) [24] whose work in the Volta basin in Burkina Faso noted that the macroinvertebrate community largely dominated by the Insect class. It could be that the water at stations located near built-up areas is highly mineralised and loaded with organic matter. Stress in these environments could be at the root of the reduction in the composition of the benthic community. Thus, a disturbed watercourse can create unfavourable conditions for certain organisms (polluosensitive), leaving room for other, more tolerant organisms (polluoresistant) [28]. Given that the dam zone is constantly subject to several anthropogenic activities such as daily fishing, field work and gold panning, this could explain the development of polluo-resistant organisms (Chironomidae, Thiaridae, Culicidae, Physidae, Ampullariidae, Viviparidae). This also results in a low presence of polluo-sensitive taxa, with organisms from the Plecoptera, Ephemeroptera, etc. being less abundant in the environments studied.

The macroinvertebrate communities collected in the Soubré dam area are fairly diverse, with 117 taxa divided into 17 orders, 60 families, 06 classes and 03 phyla: Arthropods, Annelids and Molluscs. On the one hand, this high taxonomic richness could reflect the existence of better environmental conditions in these aquatic environments, especially in the fluvial stations. The organisation of the specific composition of macroinvertebrates in the aquatic environments of the study sites is close to that of African freshwater [17-18-23-27-29-30]. The high abundance of aquatic macroinvertebrates observed in these studies could be linked to the performance of the equipment and the sampling techniques used. In fact, during this study, in addition to sampling the benthos with the bank grab, several sampling points were defined radially on each site of the lake and two points in the fluvial environment to collect abundant aquatic macroinvertebrates in the waters of the fluvio-lacustrine zone of the Soubré hydroelectric dam. These assertions confirm the remarks made by Yapo *et al.* (2017) [31], Allouko (2018) [17] and Kressou (2020) [18], who also used the same conventional tools for sampling. However, according to Gnohossou (2006) [32], artificial substrates are more effective than conventional sampling tools (Troubleau net and Van Veen bucket). Compared with the results of other studies in Ivorian freshwater, our data are more diverse than the results of the work of Kouamé *et al.* (2011) [33], who obtained 40 families of macroinvertebrates in the lacustrine environment of the Taabo hydroelectric dam, sampling only macrophytes, and Yapo *et al*. (2012) [34], who collected 45 families of macroinvertebrates in fishponds in the south of Côte d'Ivoire. Abbou *et al.* (2014) [35] collected 52 families and 80 taxa in the Sebou basin in Morocco. Similarly, Kra *et al*. (2018) [15] inventoried 04 classes subdivided into 74 taxa in the Comoé river basin (Côte d'Ivoire). However, this composition of aquatic macroinvertebrates seems to be similar to those found by de Edia (2008) [27] who obtained 119 taxa for 62 families in the Soumié, Eholié, Ehania and Noé coastal rivers (south-east, Côte d'Ivoire). Our results also corroborate those of Camara *et al.* (2012) [36] who identified 62 families divided into 119 taxa in the Banco forest (south, Côte d'Ivoire) and those of Djene *et al.* (2019) [37] who obtained 132 taxa in the Aghien lagoon (south-east, Côte d'Ivoire). The taxonomic richness of the macroinvertebrate community is dominated by the Insect class, which accounts for 96 of the 117 taxa collected (82.05%). The Gastropod class came second with 12 taxa, i.e. 10.25% of the taxonomic richness of the Soubré dam zone. The difference in taxonomic richness observed in our study is due to the sampling methodology adopted.

These results seem to confirm other studies in which Odonata, Hemiptera and Diptera dominate the taxonomic richness of freshwater lagoons [26-38]. The specific abundance of Odonata, Diptera and Gastropoda at the stations studied could explain the high level of organic pollution in this environment. On the other hand, there was a total absence of Plecoptera and Lepidoptera at stations located in lacustrine environments, which could be explained by the fact that these orders are composed of invertebrates that are polluted and sensitive to environments affected by any disturbance [39]. With regard to the spatial distribution of the taxa collected in the study environments, the stations in the natural environment (TIE, PON and KAR) recorded the highest numbers of taxonomic richness. These results indicate that changes in habitat determine the structure of the macroinvertebrate population. In fact, no station is perfectly identical to another in the two aquatic environments. Also, at the stations (AMA, TIE and GNA) in the lacustrine part, the number of taxa is low but the density of species, which are mainly euryhaline, is very high, which is in line with the results of Tudorancea *et al*. (1989) [40] in Ethiopian lakes. According to these same authors, the minimum density of macroinvertebrates is observed during the flood period and the maximum during low water, which is confirmed by our results. Moreover, according to Yapi *et al.* (1994) [41], macroinvertebrate eggs are laid during the rainy season, followed by hatching and development of the larval stage during the dry season.

The highest Shannon-Weaver index values were recorded at the TIE fluvial environment sites (3.71), followed by the PON site (3.50) and the KAR (3.43), while the lowest index was noted in the lacustrine environment at the KPE station (2.85). On a monthly basis, this index was high in August at the TIE station and low at KAR and. As for the Piélou equitability index, the river stations had the highest values, unlike the lake sites. These results indicate that 03 families, namely Viviparidae (*Viviparus* sp.), Ampullariidae (*Lanites varicus*) and Thiaridae (*Melanoides tuberculata*), are the most important species colonising the sediment at the study sites.

These results therefore indicate that organisms of the class Gastropoda are the only taxa collected on a very regular basis at the 06 sites considered. Indeed, Merritt & Cummins (1996) [43] have indicated that the variation in environmental conditions under which Gastropoda individuals are found is more extensive than that of other groups of aquatic macroinvertebrates. These organisms therefore have a wide range of resilience and morphological, physiological and behavioural adaptations. Furthermore, at the 03 stations (AMA, GNA and KPE) located in the lake environment, there was also a high occurrence of 03 families, namely the Chironomidae (*Chironomus imicola*), the Culicidae (*Culex* sp.) and the Planorbidae (*Indoplanorbis exustus*). At the riverine stations (TIE, PON and KAR), in addition to the 04 taxa that are very common at all the sampling sites in the study area, 02 families of insects were recorded, namely the Libellulidae (*Zygonix torrida*) and the Veliidae (*Rhagovelia reitteri*).

The dissimilarity dendrogram remains of interest for our study, which is aimed at the biological evaluation of the Soubré lake and river ecosystem after impoundment. Its analysis reveals that the use of taxon density shows the impact of the dam on the distribution of aquatic macroinvertebrates. This taxonomic level is classically used in calculations of the biological quality index of watercourses at European level [43].

Conclusion

The work undertaken as part of this project enabled us to carry out an inventory of macroinvertebrates in the Soubré hydroelectric dam area on the Sassandra River in Côte d'Ivoire. The macroinvertebrate community collected in the study area is fairly diverse, dominated by arthropods, which account for 89.74% of the taxa collected, followed by molluscs (10.25%). The dam has an impact on the distribution of macroinvertebrates.

References

1. Lévêque C. Conséquences des barrages sur l'environnement. Colloques de l'Académie d'Agriculture de France, n° 1. Colloque du 19 mai. c2005. p. 12.
2. Horeau V, Cerdan P, Champeau A. La mise en eau du barrage hydroélectrique de Petit-Saut (Guyane): ses conséquences sur les peuplements d'invertébrés aquatiques et sur la nourriture des poissons. Hdroécol. Appl. 1997;9(1/2):213-240.
3. Scope. Man-made lakes as modified ecosystems. ICSU-SCOPE, Paris; c1972. p. 76.
4. Moisan J, Pelletier L. Guide de Surveillance Biologique Basée sur les Macroinvertébrés Benthiques d'Eau Douce du Québec-Cours d'Eau Peu Profonds à Substrat Grossier. Direction du Suivi de l'Etat de l'Environnement, Ministère du Développement Durable, de l'Environnement et des Parcs: Québec; c2008.
5. Girard G, Sircoulon J, Touchebeuf P. Aperçu sur les régimes hydrologiques de la Côte d'Ivoire. Office de la recherche scientifique et technique outre-mer. Centre d'Adiopodoumé; c1970. p. 91.
6. James MR, Hawes I, Weatherhead M. Effects of settled sediments on grazer-périphyton-macrophyte interactions in the littoral zone of a large oligotrophic lake. Freshwater Biology. 2000;44:311-326.
7. Warwick R, Ashman C, Brown A, Clarke K, Dowell B, Hart B. Inter-annual changes in the biodiversity and community structure of the macrobenthos in Tees Bay and the Tees estuary, UK, associated with local and regional environmental events. Marine Ecology Progress Series. 2002;234:1-13.
8. Covich A, Ewel C, Hall O, Giller G, Merritt M, Goedkoop W. Ecosystem services provided by freshwater benthos. In: Sustaining biodiversity and ecosystem services in soils and sediments. Wall D. H., (Ed.), Washington, DC: Island Press; c2004, 45-72.
9. Resh V, Jackson J. Rapid assessment approaches to biomonitoring using benthic macroinvertebrates. In: Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, London, UK: c1993. p. 195-223.
10. Ysebaert T, Meire P, Herman P, Verbeek H. Macrobenthic species response surfaces along estuarine gradients: Prediction by logistic regression. Marine Ecology Progress. 2002;22:79-95.
11. Woodcock T, Huryn A. The response of macroinvertebrates production to a pollution gradient in a headwater stream. Freshwater Biology. 2007;52:177-196.
12. Sankaré Y. Etude comparative de la macrofaune associée aux racines de *Pistia stratiotes* L. (Araceae) du lac de barrage d'Ayamé II et du fleuve Comoé (Côte d'Ivoire). Journal Ivoirien d'Océanologie et Limnologie. 1991;1(2):131-138.
13. Kouamé KM. Diversité, structure et réponse fonctionnelle des macroinvertébrés à l'invasion du lac de Taabo (Côte d'Ivoire) par la jacinthe d'eau, Eichhornia crassipes (Mart.) SolmsLaubach, 1883. Thèse de doctorat, Université d'Abobo-Adjamé, Côté d'Ivoire; c2014. p. 201.
14. Diomandé D, Kpai N, Kouadio N, Da Costa S, Gourène G. Spatial distribution and structure of benthic macroinvertebrates in an artificial reservoir: Taabo Lake (Côte d'Ivoire). International Journal of Fisheries and Aquatic Studies. 2013;7(4):1503-1514.
15. Kra M, Camara A, Edia E, Konan M, Dramane D, Ouattara A. Qualitative analysis of aquatic macroinvertebrates in lower Comoé river (Côte d'Ivoire). International Journal of Fisheries and Aquatic Studies. 2018;6(2):472-481.
16. Djoman Y, Camara I, Doumbia L, Kouadio KN, Allassane O. Taxonomic Diversity and Structure of Benthic Macroinvertebrates of Taabo Lake (Basin of Bandama; Ivory Coast). Journal of Environmental Science Studies. 2020;3(1):1-15.
17. Allouko JR. Diversité des communautés de macroinvertébrés et contribution à l'évaluation de la qualité des eaux de la lagune Aghien (Sud-est, Côte d'Ivoire). Thèse de Doctorat, Université Jean Lorougnon Guede, Daloa, Côte d'Ivoire; c2018. p. 154.
18. Kressou A. Diversité, structure des communautés de macroinvertébrés aquatiques et état d'intégrité écologique des milieux aquatiques de la Réserve de Faune et de Flore du Haut-Bandama (Centre-nord, Côte d'Ivoire). Thèse de Doctorat, Université Jean Lorougnon Guede, Daloa, Côte d'Ivoire; c2020. p. 166.
19. Dejoux C, Elouard MJ, Forge P, Malsin J. Iconographic catalog of aquatic insects of Côte d'Ivoire. Rapport Orstom, Bouaké, Côte d'Ivoire; c1981. p. 172.
20. De Moor IJ, Day AJ, De Moor CF. Guide to the Freshwater Invertebrates of Southern Africa. Volume 8: Insecta II: Hemiptera Megaloptera, Neuroptera Trichoptera and Lepidoptera. Report N° TT 214/03

WRC, South Africa, Pretoria; c2003.

21. Tachet H, Bournaud M, Richoux P, UsseglioPolatera P. Invertébrés d'eau douce, systématique, biologie, écologie. Cnrs (Eds), Paris; c2006. p. 587.
22. Barbault R. Ecologie des populations et des peuplements (Structure, dynamique et évolution). Ed. Masson, Paris; c1981. p. 200.
23. Kouamé M. Diversité, structure et réponse fonctionnelle des macroinvertébrés à l'invasion du lac de Taabo (Côte d'Ivoire) par la jacinthe d'eau, Eichhornia crassipes (Mart.) SolmsLaubach, 1883. Thèse de doctorat, Université d'AboboAdjamé, Côté d'Ivoire; c2014. p. 201.
24. Sanogo S, Kabre J, Cecchi P. Inventaire et distribution spatio-temporelle des macroinvertébrés bioindicateurs de trois plans d'eau du bassin de la Volta au Burkina Faso). International Journal of Fisheries and Aquatic Studies. 2014;8(3):1005-1029.
25. Allouko JR, Bony KY, Edia OE, Konan KF. Composition, Distribution and Abundance of Macroinvertebrates in Aghien lagoon (Ivory Coast; West Africa). International Journal of Innovative Research in Science, Engineering and Technology, 2018;5(6):10104-10111.
26. Camara IA. Composition, structure et déterminisme des macroinvertébrés de la rivière: Banco (Parc National du Banco, Côte d'Ivoire). Thèse de Doctorat, Université Nangui Abrogoua, AboboAdjamé, Côte d'Ivoire; c2013. p. 151.
27. Edia OE. Diversité taxonomique et structure des peuplements de l'entomofaune des Rivières côtières Soumié, Eholié, Ehania, Noé (Sud-est, Côte d'Ivoire). Thèse de Doctorat, Université d'AboboAdjamé, Abidjan, Côte d'Ivoire; c2008. p. 171.
28. Farouch A, Berrahou A, El Halouani H. Impact d'un effluent urbain de la ville de Taourirt sur la structure des communautés de macroinvertébrés de l'oued Za (Maroc oriental). Revue des Sciences de l'Eau. 2011;24(2):87-101. DOI:10.7202/1006104ar.
29. Ramade F. Elément d'écologie: Ecologie fondamentale. Dunos, (éd.), Paris. 2003;2:190.
30. Ben Moussa A, Chahlaoui A, Rour E, Chahboune M,. Diversité taxonomique et structure de la macrofaune benthique des eaux superficielles de l'oued khoumane. Moulay idriss Zerhoun, Maroc. Journal of Materials and Environmental Science. 2014;1:183198.
31. Yapo M, Aste B, Kouassi P. Inventaire des insectes aquatiques des étangs de piscicoles au sud de la Côte d'Ivoire. Journal of Applied Biosciences. 2012;58:4208-4222.
32. Gnohossou PM. La faune benthique d'une lagune ouest africaine (le lac Nokoue au Benin), diversité, abondance, variations temporelles et spatiales, place dans la chaine trophique. Thèse de Doctorat de l'Institut National Polytechnique de Toulouse, Toulouse, France; c2006. p. 188.
33. Kouamé M, Diétoa M, Edia E, Da Costa S, Ouattara A, Gourène G. Macroinvertebrate communities associated with macrophyte habitats in a tropical manmade lake (Lake Taabo, Côte d'Ivoire). Knowledge and Management of Aquatic Ecosystems. 2011;20(1):1-12.
34. Yapo M, Aste B, Kouassi P. Inventaire des insectes aquatiques des étangs de piscicoles au sud de la Côte d'Ivoire. Journal of Applied Biosciences. 2012;58:4208-4222.
35. Abbou F, Fahde A. Structure et diversité taxonomique des peuplements de macroinvertébrés benthiques du réseau hydrographique du bassin du Sebou (Maroc). International Journal of Fisheries and Aquatic Studies. 2014;11(4):1785-1806.
36. Camara AI, Diomandé D, Bony YK, Ouattara A, Franquet E, Gourène G, *et al*. Diversity assessment of benthic macroinvertebrate communities in Banco National Park (Banco Stream, Côte d'Ivoire). African Journal of Ecology. 2012;50:205-217.
37. Djene K, Bony Y, Allouko R, Kamagate Y, Konan F. Aquatic Macroinvertebrates diversity and assessment of urban water quality with the use of EPTC index in Daloa (Côte d'Ivoire; West Africa). Journal of Biodiversity and Environmental Sciences. 2019;14(4):1-7.
38. Houelome A, Adandedjan D, Chikou A, Toko I, Koudenoukpo C, Bonou C, *et al*. Inventaire et caractéristiques faunistiques des macroinvertébrés de la rivière Alibori dans le bassin cotonnier du Bénin. International Journal of Innovation and Applied Studies 2017;21:433-448. ISSN 2028-9324
39. Tachet H, Bournaud M, Richoux P, UsseglioPolatera P. Invertébrés d'eau douce, systématique, biologie, écologie. Cnrs (Eds), Paris; c2006. p. 587.
40. Tudorancea C, Baxter RM, Fernando CH. A comparative limnological study of zoobenthic associations in lakes of the Ethiopian Rift Valley. Archiv fur Hydrobiologie Suppl. 1989;83:121-174.
41. Yapi Y, N'goran K, Salia D, Cunin P, Bellec C. Population dynamics of *Indoplanorbis exustus* (Deshayes, 1834) (Gastropoda: Planorbidae), an exotic freshwater snail recently discovered at Yamoussoukro (Ivory Coast). Journal of Molluscan Studies. 1994;60:83-95.
42. Merritt R, Cummins K. An introduction to the aquatic insects of North America. 3rd edition. *Kendall/Hunt Publishing Company*, Dubuque, IA, USA; c1996. p. 862.
43. AFNOR. Qualité Ecologique des Milieux Aquatiques. Qualité de l'Eau. Prélèvement des Macroinvertébrés Aquatiques en Rivières Peu Profondes. Association Française de Normalisation, Norme expérimentale T 90-Paris; c2009. p. 333.