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Assessment of aquatic insect species composition, abundance and diversity within two dam lake in Korhogo: Koko and Natiokobadara (Northern Côte d'Ivoire)

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Abstract
A study had conducted to contribute to the knowledge of aquatic insects in two artificial lakes in the northern region of Côte d'Ivoire. Aquatic insect were collected monthly from January 2020 to March 2020 using a kick-net. Abiotic variables such as transparency, temperature, pH, dissolved oxygen and conductivity were measured in situ. Water samples were collected and conducted to the laboratory for inorganic nutrients analysis. A total of 6 orders, 23 families and 55 taxa have been recorded. The taxonomic richness of the aquatic insects was dominated by Heteroptera, Odonata, Coleoptera and Diptera. The richness and abundance were highest at the Natiokobadara 1 site. Shannon's index and evenness were higher at the Koko 3 site. A canonical correspondence analysis was used to visualize the influence of environmental parameters on the structure of aquatic insect community.

Keywords: Aquatic insects, diversity, Koko and Natiokobadara dam lake, Côte d'Ivoire

1. Introduction
In the 1970s, the state of Côte d'Ivoire built wetlands in the form of artificial lakes in the northern parts of the country. These artificial lakes were created for the purpose of supplying water and irrigating rice fields. Despite these important functions, these environments have long been neglected. Very little knowledge exists on the ecological function of these habitats, in particular at the level of the invertebrate community [1]. While these habitats could play an important role in the conservation of aquatic biodiversity, in particular aquatic insects. Aquatic insects are a group of arthropods that live or spend part of their life cycle in water bodies [2, 3]. They are of great importance for the aquatic habitat where they are found, therefore their presence in water bodies serves a variety of purposes: some serve as food for fish and other invertebrates [4], others act as vectors through which pathogens can be transmitted to humans and animals [5]. In addition, aquatic insects are very good indicators of water quality because they have different levels of tolerance to environmental disturbances [3]. Some are very vulnerable and susceptible to pollution, while others can live and thrive in disturbed and extremely polluted waters [6, 7]. In Côte d'Ivoire, insects living in stagnant water, in particular lakes, are little inventoried. The studies conducted in lake environment were those of Sankaré [8] and Kouamé *et al.* [9] which concerned the macroinvertebrates associated with aquatic vegetation in Ayamé II lake and in Taabo lake respectively. All these studies were carried out in the south-eastern and central part of the country. In the north of the Côte d'Ivoire, studies relating to aquatic insects in lake water bodies are non-existent, although this area abounds in several small agro-pastoral lakes. It therefore appears necessary to deepen our knowledge of the aquatic insect communities of lakeside water bodies in the north of Côte d'Ivoire. It is in this vein that this study was carried out in two dam lakes (Koko and Natiokobadara) in the city of Korhogo in order to contribute to the knowledge of aquatic insects that colonize these habitats.

2. Material and methods
2.1 Study area
This study was carried out in the town of Korhogo, in the Koko and Natiokobadara dam lakes

(Fig. 1) . Koko lake is located in the center west of the city. It lies between 09 ° 28'19.0 "N and 005 ° 30'50.4" W. As for the Natiokobadara lake, it is located in the north of the city, it extends between 09 ° 29'38.5 " N and 005 ° 37'13.6" W. Three sampling sites were chosen in each lake. The climate of the city of Korhogo is Sudanese, with two seasons: a dry season (December to May) and a rainy season (June to November). Average annual precipitation varies between 1,300 mm and 1,400 mm.

2.2 Data collection

Monthly sampling had done from January 2020 to March 2020. Physico-chemical parameters such as pH, temperature, conductivity, dissolved oxygen and transparency were measured between 8 a.m. and 10 a.m. before any entomological sampling. In addition, for the chemical parameters on each site, water samples were collected and conducted to the laboratory for nutrients analysis including phosphorus (PO_4^{3-}), nitrite (NO_2^-), nitrate (NO_3^-) and ammonium (NH_4^+). Aquatic insects from the vegetation covering the shores of the lake were sampled with a 400 µm mesh size kick- net. On each site, 6 net strokes were sampled. A net stroke consists of pulling the net over a distance of about 1 m. The initial net is followed by two round trips to the surface to capture dislodged organisms. Samples were collected in labeled pill boxes and fixed with 10% formalin. In the laboratory, the identification of the organisms was carried out under a binocular magnifying glass using keys from Déjoux *et al.* [10] and Suhling *et al.* [11].

2.3 Data analysis

For data processing, ecological descriptors such as abundance, species richness, Shannon-Weaver index, Evenness, Margalef index were used. The Sorensen similarity index was used to evaluate the similarity of aquatic insects communities between sites. Before performing comparison analyses, data normality was checked using Kolmogorov Smirnov test. The non parametric test of Kruskal-Wallis was performed to compare data between sampling sites concerning the biotic and environment data distribution follow non-normal distribution ($P<0.05$). Ecological parameters were calculated using the PAST 1.0 software while the test of Kruskal-Wallis was performed using Statistica 7.1 software. A canonical correspondence analysis allowed us to investigate the relationships between the physico-chemical parameters of water and aquatic insects taxa. The importance of this analysis was tested by the Monte Carlo test [12]. This analysis was performed using the CANOCO (Canonical Community Ordination) program for Windows version 5.0 [13].

3. Results

3.1 Environment variables

The spatial variations of the abiotic parameters recorded are presented in Table 1. The minimum concentrations of the three nitrogenous content, nitrate ($N0_3^-$), nitrite ($N0_2^-$) and ammonium (NH_4^+), were observed at Natiokobadara 2 and at Koko 2. The highest values of these parameters were recorded at Natiokobadara 1 and Natiokobadara 3. These concentrations ranged from 0.003 to 0.16 mg / L, from 1 to 1.33 mg / L and from 0.20 to 1.13 mg / L respectively for NO_3^-, NO_2^- and NH_4^+. Regarding phosphorus (PO_4^{3-}), the lowest concentration (0.70 mg / L) was recorded at Natiokobadara 3 while the highest value (1.13 mg / L) was noted at Natiokobadara 2. The temperature of the lakes oscillated between 22.26 ° C (Natiokobadara 1) and 29.60 ° C (Koko 3). The lowest value of dissolved oxygen is obtained at Koko 1 (3.36 mg / L) and the highest was observed at Natiokobadara 3 (4.66 mg / L). The pH varied from 6.91 (Koko 3) to 7.35 (Natiokobadara 1). The electrical conductivity was between 67.2 µS / cm (Natiokobadara 1) and 220.45 µS / cm (Natiokobadara 3). The values of water transparency ranged between 0.26 cm (Natiokobadara 1) and 0.56 cm (Koko 2). A significant difference between sites was observed with regard to water transparency (Kruskal-Wallis, $p = 0.002$) and dissolved oxygen (Kruskal-Wallis, $p = 0.002$).

3.2 Composition and abundance of aquatic insect

A total of 55 taxa, divided into 23 families and 6 orders (Table 2) were sampled. The settlement was qualitatively dominated by Heteroptera (17 taxa). These are followed by Odonata (13 taxa) and Coleoptera (12 taxa). In the Koko lake, aquatic insect was dominated by Heteroptera (33%), Diptera (33%) and Odonata (22%) (Fig. 2A), while in Natiokobadara, Heteroptera (36%), Coleoptera (22%) and Odonata (20%) were the most dominant (Fig. 2 B). In both lakes taxonomic richness was maximum at Natiokobadara 1 and minimum at Koko 2 (Table 2). A total of 1245 individuals including 944 individuals in Natiokobadara and 256 individuals in Koko were harvested. Heteroptera and Diptera were numerically the most important taxonomic groups. These orders accounted for 78.55% of the total abundance of aquatic insects collected. The family Notonectidae recorded the highest abundance. It is followed by Chrironomidae. *Anisops sardea* and *Chironomus imicola* were the most abundant species. Abundance was highest at Natiokobadara 1 and lowest at Koko 2 (Table 3). A significant difference in abundance between sites was observed (Krukal-Wallis, $p= 0.000$).

3.3 Diversity indices

Shannon-Weaver index values ranged from 1.93 (Natiokobadara 3) to 2.55 (Koko 3) (Table 3). Evenness was highest at Koko 3 (0.83) (Table III) and lowest at Natiokobadara 1 (0.57). Margalef index values oscillated between 3.18 (Koko 2) and 5.14 (Natiokobadara 1). The diversity indices do not show any significant difference between sites (Krukal-Wallis, $p>0.05$).

3.4 Sorensen similarity index

The Sorensen index was calculated to assess the similarity of insect communities between the different sites. Analysis of Table 4 indicates that the Sorensen similarity index values ranged from 18.7% to 81.4%. The values recorded between the sites of Koko lake ranged from 49.5% to 72.7%. That observed between the sites of Natiokobadara lake ranged from 71% to 81.4%. The indices calculated between Koko and Natiokobadara sites ranged from 18.7% to 50%.

3.5 Influence of abiotic factors on the distribution of aquatic insects

A canonical correspondence analysis was performed in order to relate the environmental parameters to the distribution of taxa. In this analysis, we used the main taxa. The main taxa considered are those whose abundance represented at least 0.8% of the total abundance of insects harvested. The total percentage of variance explained was 84.22% of which 62.53% was for the first axis and 21.69% for the second. These first two axes were therefore considered in the expression of the results. The Monte Carlo test allowed the selection of the environmental variables that most discriminated the distribution of aquatic insects. Fig. 3 clearly distinguishes Koko lake from Natiokobadara lake. In Koko, the sites were characterized by high transparency. These sites were colonized by species such as *Anisop sp*., *Eurymetra sp*., *Brachythemis laccustris*, *Nilodorum brevipalpis*, *Brachythemis leucostica* and *Cryptochironomus sp*. In Natiokobadara lake, two groups of organisms can be defined: group B and group C. Group B was composed of the following taxa : *Amphiops sp*., *Anisop sardea*, *Cloeon smaeleni*, Crambidae, *Dineutus sp*., *Diplonychus sp*., *Gerisella sp*. and *Laccotrephes ater*. These taxa prefer the site of Natiokobadara 1 (N1), characterized by a high nitrogen content. Group C was composed of *Chironomus imicola*, *Limnogonus chopardi*, *Micronecta sp*., *Pseudagrion massaicum* and *Ranatra linearis*. These organisms were recorded in Natiokobadara 2 (N2) and Natiokobadara 3 (N3). These sites were characterized by poorly transparent water.

4. Discussion

The insect orders that were identified during this study are part of the insect settlement living in the lakes and that have been reported by previous work [14, 15]. Dam lake are therefore ecosystems that contribute to the biodiversity of aquatic insect assemblages given the importance of the communities living in these biotopes. The entomofauna of the lakes prospected in this study was more diverse compared to that reported by Kouamé *et al.* [9] and Diomandé *et al.* [16] who recorded 43 and 29 taxa in Taabo lake respectively. The dominance of Heteroptera in terms of species has been noted in previous studies [14, 15, 17]. Among the different groups of insects collected, the families Libellulidae, Hydrophilidae and Chironomidae present the highest taxonomic richness in Odonata, Coleoptera and Diptera respectively. The dominance of Chironomidae within the Diptera group has also been reported by Diomandé *et al.* [18] (2009) and Yapo [17]. Furthermore, Tachet *et al.* [19] point out that in aquatic environments, Chironomidae are the most important family of Diptera. The main aquatic beetles were provided by the families Hydrophylidae and Dytiscidae, represented by the genera *Laccophilus*, *Cybister*, *Hydrocoptus*, *Amphiops* and *Enochrus*. The family Dytiscidae generally inhabits the leaves of clean freshwater bottom macrophytes and are predators in the wild. The family Hydrophylidae, in contrast, is generally found in shallow areas of wetlands where macrophytes are abundant, especially emergent macrophytes, and feeds primarily on detritus, algae and decaying plant matter [20]. The results showed that aquatic insects richness was highest in the sites of Natiokobadara lake. Indeed, the sites of Natiokobadara lake contain many macrophytes that probably serve as habitat and are favorable to many aquatic insects, compared to the sites of Koko lake [21]. The insect population of the different sites showed a significant similarity. The taxonomic composition of aquatic insects from the different sites within the same lake would therefore be similar. Furthermore, the distribution of taxa showed that 11 taxa were common to at least 4 of the 6 sites. They had a wider distribution. These taxa would be ecologically less demanding [17]. Shannon-Weaver index values reveal that Koko 1 and Koko 3 sites presented a well-diversified settlement where several taxa are well represented numerically. The insect diversity in aquatic ecosystems tends to increase with increasing nutrients and optimal environmental conditions favor their abundance in the habitat. The distribution of aquatic insects in a habitat is determined by the complex interaction between substrate, turbulence and food availability [14]. The recorded evenness values indicate that the settlement at Natiokobadara sites, Koko 1 and Koko 2 is slightly unbalanced while Koko 3 is in equilibrium [22]. This slight imbalance is thought to be due to the presence of a small number of very abundant taxa compared to the others. Indeed, a high abundance of the taxon *Anisops sardea* has been recorded at Natiokobadara 1, while *Chironomus imicola* was abundant at Natiokobadara 2 and Natiokobadara 3. Heteroptera and Diptera recorded the greatest abundance in both lakes. The abundance of Heteroptera and Diptera has been observed in previous studies [23, 24]. Notonectidae and Chironomidae were the most abundant families in the order of Heteroptera and Diptera respectively. The dominance of Chirinomidae was illustrated by Déjoux *et al.* [10] and Ogbeibu [25]. Di Giovani *et al.* [26] and Kouamé *et al.* [9] reported that Chironomidae are almost always numerically predominant in lotic and lentic environments because of their tolerance to extreme conditions. At the sites of Natiokobadara lake, *Anisops sardea* and *Chironumus imicola* were the most abundant. The predominance of *Anisops sardea* has been reported in previous studies [27, 28, 29]. According to Dejoux *et al.* [10], *A. sardea* is a taxon that proliferates preferentially in stagnant waters. In addition, the predominance of this taxon in our samples would be one of the causes of the low abundance of the other components of the community [17]. Indeed, this insect is a great predator of aquatic insect larvae [30].

Table 1: Environmental variables measured at each sampling sites of Koko and Natiokobadara Lake (North of Côte d'Ivoire). K1= Koko 1, K2=Koko 2 et K3=Koko 3: N1=Natiokobadara 1, N2=Natiokobadara 2 et N3=Natiokobadara 3.

Parameters	Sites					
	K1	K2	K3	N1	N2	N3
Temperature (°C)	26,95 ± 3,11	28,43 ± 3,13	29,60 ± 0,98	22,26 ± 3,39	25,46 ± 4,46	26,30 ± 4,65
pH	7,05 ±0,29	7,34 ± 0,42	6,91 ± 0,16	7,35 ± 0,38	6,95 ±0,08	7,23 ± 0,23
Conductivity (µS/cm)	166,06 ± 30,43	171,26 ± 29,39	169,73 ± 25,96	67,20 ± 35,12	198,30 ± 65,27	220,45 ± 27,01
Transparency (cm)	0,45 ± 0,08	0,56 ± 0,08	0,47 ± 0,04	0,26 ± 0,02	0,30 ± 0,01	0,29 ± 0,04
Dissolved oxygen (mg/L)	3,36 ± 0,36	3,77 ± 0,06	3,50 ± 0,07	4,49 ± 0,35	4,41 ± 0,42	4,66 ± 0,56
Nitrites (NO^{2-}) (mgL)	0,04 ± 0,05	0,01 ± 0,003	0,02 ± 0,02	0,16 ± 0,28	0,003± 0,005	0,06 ± 0,11
Nitrates (NO^{3-}) (mg/L)	1,00 ± 0,00	1,00 ± 0,00	1,00 ± 0,00	1,33 ± 0,57	1,00 ± 0,00	1,00 ± 0,00
Ammonium (NH_4^+) (mg/L)	0,30 ± 0,17	0,20 ± 0,00	0,25 ± 0,22	1,13 ± 1,61	0,46 ± 0,25	0,53 ± 0,35
Phosphorus (PO_4^{3+}) (mg/L)	0,76 ± 0,64	0,83 ± 0,57	0,83 ± 0,57	0,25 ± 0,22	1,13 ± 0,63	0,70 ± 0,70

Table 2: List of aquatic insect taxa collected in the different study sites. K1= Koko 1, K2=Koko 2 et K3=Koko 3: N1=Natiokobadara 1, N2=Natiokobadara 2 et N3=Natiokobadara 3. - : Absence of taxa; + : Presence of taxa

Orders	Families	Taxa	Sites					
			K_1	K_2	K_3	N_1	N_2	N_3
		Nepa cinerea	-	-	-	-	-	+
	Nepidae	*Laccotrephes ater*	-	+	-	+	+	+
		Ranatra linearis	-	-	+	+	+	+
		Anisops sp.	+	+	+	+	+	-
	Notonectidae	*Anisops sardea*	+	+	+	+	+	+
Heteroptera		*Enithares sp.*	-	-	-	+	+	
	Belostomatidae	*Limnogeton fieberi*	-	-	-	-	-	+
		Diplonychus sp.	+	+	+	+	+	+
		Gerisella sp.	-	+	+	+	+	+
	Gerridae	*Eurymetra sp.*	+	+	+	+	-	-
		Limnogonus chopardi	-	-	+	+	+	+
		Veliidae	-	-	-	-	+	-
	Veliidae	*Microvelia sp.*	-	-	+	-	-	-
	Mesoveliidae	*Mesovelia sp.*	-	-	-	-	+	-
	Corixidae	*Micronecta scutellaris*	-	-	-	-	-	+
		Micronecta sp.	-	-	-	+	+	+
	Naucoridae	*Naucoris cimicoides*	-	-	-	+	-	-
Ephemeroptera	Baetidae	*Pseudocentroptilum*	-	-	-	+	-	-
		Cloeon smaeleni	-	-	-	+	+	-
		Cloeon gambiae	-	+	-	+	-	+
	Libellulidae	*Bradinopyga strachani*	+		+	-	-	-
		Palpopleura jacunda	-	-	-	+	+	-
		Palpopleura lucia	-	-	-	+	-	+
		Brachythemis lacustris	+	+	+	-	-	
		Brachythemis Leucosticta	+	+	+	-	-	-
		Orthetrum sp.	+	-	-	+	+	+
		Parazyxomma flavicans	+		+	-		
		Crocothemis erythraea	-	-	-	-	+	-
	Aeshnidae	*Gynacantha manderica*	-	-	-	-	+	-
		Anax tristis	-	-	-	+	-	-
	Coenagrionidae	*Pseudagrion citricola*	-	-	-	+	-	-
		Pseudagrion massaicum	+	+	+	+	+	+
	Gomphidae	*Ictinogomphus sp.*	-	-	-	-	+	+

Table 2continued: List of aquatic insect taxa collected in the different study sites. K1= Koko 1, K2=Koko 2 et K3=Koko 3; N1=Natiokobadara 1, N2=Natiokobadara 2 et N3=Natiokobadara 3. - : Absence of taxa; + : Presence of taxa

			Sites					
Orders	Families	Taxa	K_1	K_2	K_3	N_1	N_2	N_3
Coleoptera	Dytiscidae	*Cybister tripunctatus*	-	-	-	+	+	-
		Hydrocoptus simplex	-	-	-	-	-	-
		Laccophilus sp.	-	-	-	+	-	+
	Hydrophilidae	*Enochrus sp.*	-	-	-	+	-	+
		Amphiops sp.	-	-	-	+	+	+
		Hydrobiinae	-	-	-	+	-	+
		Hydrophilidae sp.	-	-	-		+	
	Gyrinidae	*Dineutus sp.*	-	-	-	+	+	+
		Aulonogyrus sp.	-	-	-	+	-	-
	Spercheidae	*Spercheus sp.*	-	-	-	+	-	-
	Haliplidae	*Haliplus sp.*	-	+	+	-	-	-
	Curculionidae	Curculionidae	+	-	-	-	-	-
	Culicidae	*Culex fatigans*	-	+	-	+	-	-
		Chironomus imicola	+	-	+	+	+	+
		Ablaesmyia dusoleili	+	-	+	-	-	-
Diptera	Chironomidae	*Nilodorum brevipalpis*	+	+	+	-	+	-
		Nilodorum fractilobus	-	-	+	+	-	-
		Tanypus fuscus	+	-	+	-	-	-
		Clinotanypus Claripennis	-	-	+	-	-	-
		Cryptochironomus sp.	+	+	+	-	+	
	Tabanidae	*Tabanus sp.*	+	-	-	-	-	+
Lepidoptera	Crambidae	Crambidae	-	-	-	+	+	+
Total = 6	23	55	18	14	21	33	26	23

Table 3: Species richness, abundance, Shannon-Weaver index, Evenness and Margalef index of the different sites in Koko and Natiokobadara dam lake. K1= Koko 1, K2=Koko 2 et K3=Koko 3; N1=Natiokobadara 1, N2=Natiokobadara 2 et N3=Natiokobadara 3.

Parameters	Sites					
	K1	K2	K3	N1	N2	N3
Species richness	18	14	21	33	26	23
Abundance	88	59	109	502	276	211
Shannon-Weaver index	2.26	1.97	2.55	2.03	2.03	1.93
Evenness	0.78	0.74	0.84	0.58	0.62	062
Margalef index	3.79	3.18	4.26	5.14	4.44	4.11

Table 4: Values of Sorensen similarity index between the different sampling sites of the two lakes (Koko and Natiokobadara). K1= Koko 1, K2=Koko 2 et K3=Koko 3 : N1=Natiokobadara 1, N2=Natiokobadara 2 et N3=Natiokobadara 3.

SITES	K1	K2	K3	N1	N2	N3
K1		72 .7%	59.2%	25.6%	38.2%	44.8%
K2			49.5%	18.7%	29.3%	35.2%
K3				29.8%	43.2%	50%
N1					77.5%	81.4%
N2						71%
N3						

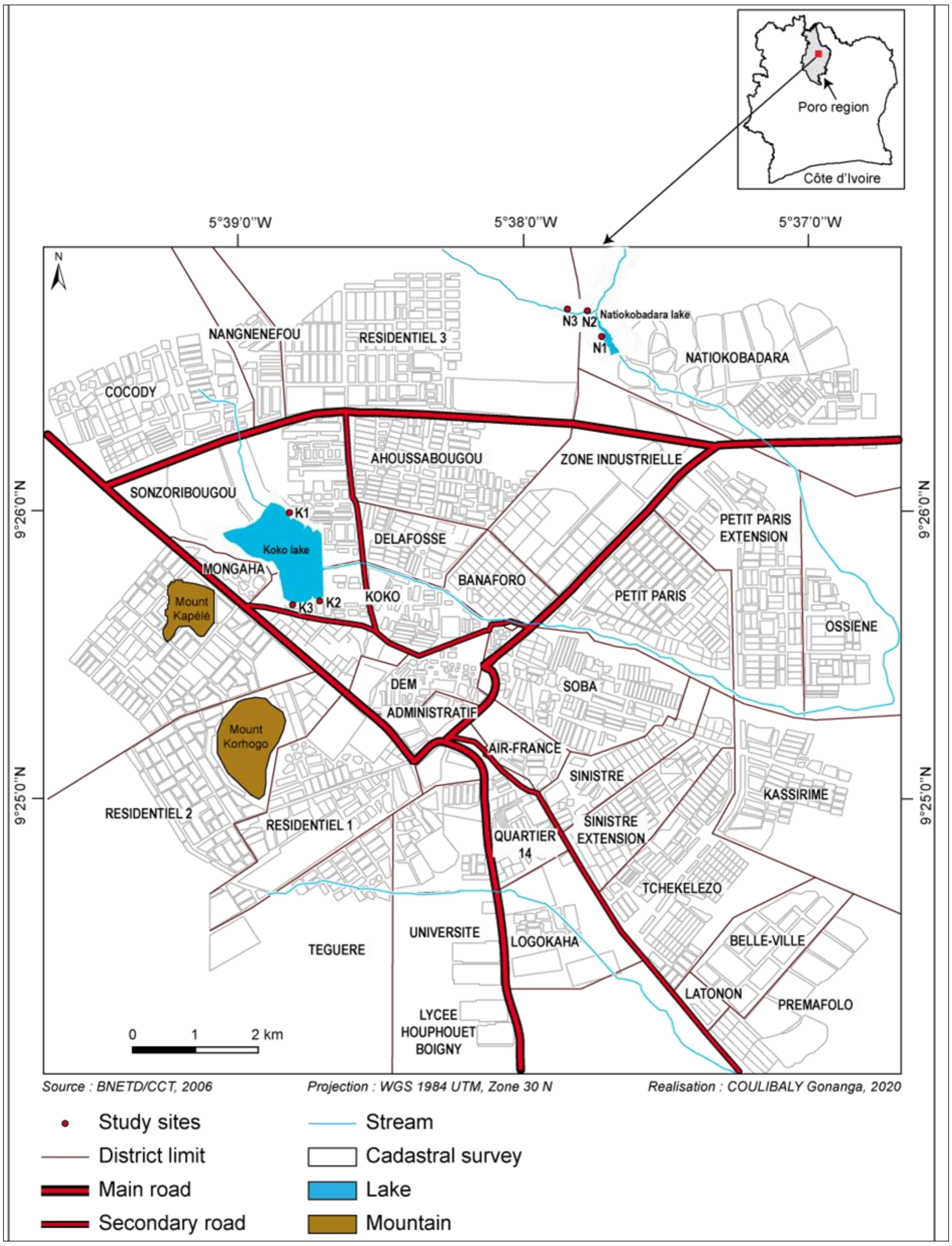

Fig 1: Location of the study area showing the different sampling sites of Koko and Natiokobadara dam lake (North of Côte d'Ivoire).

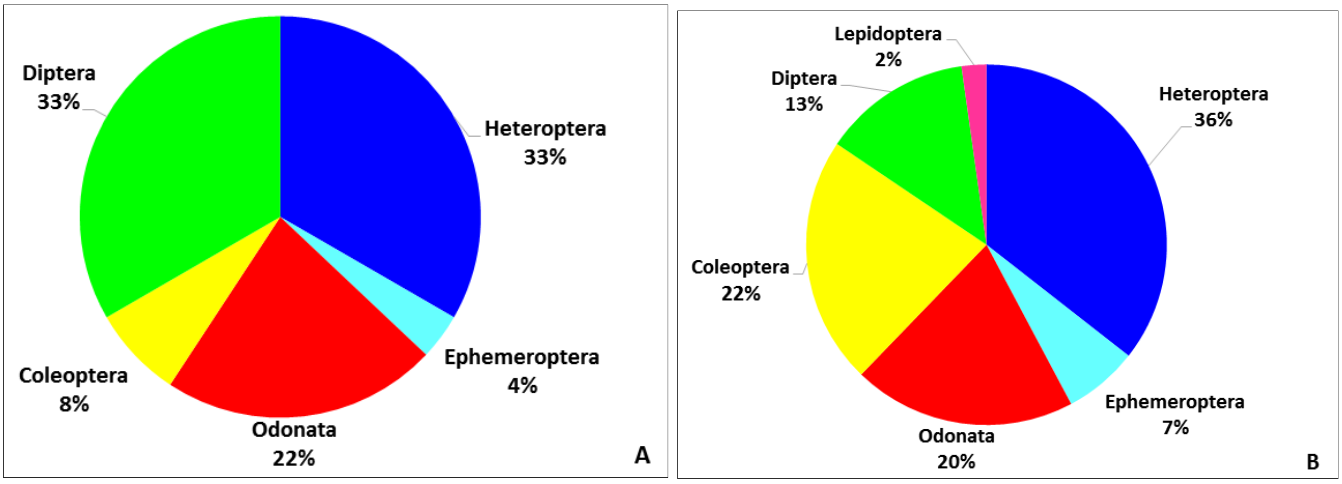

Fig 2: Composition of aquatic insect orders of the Koko (A) and Natiokobadara (B) dam lake.

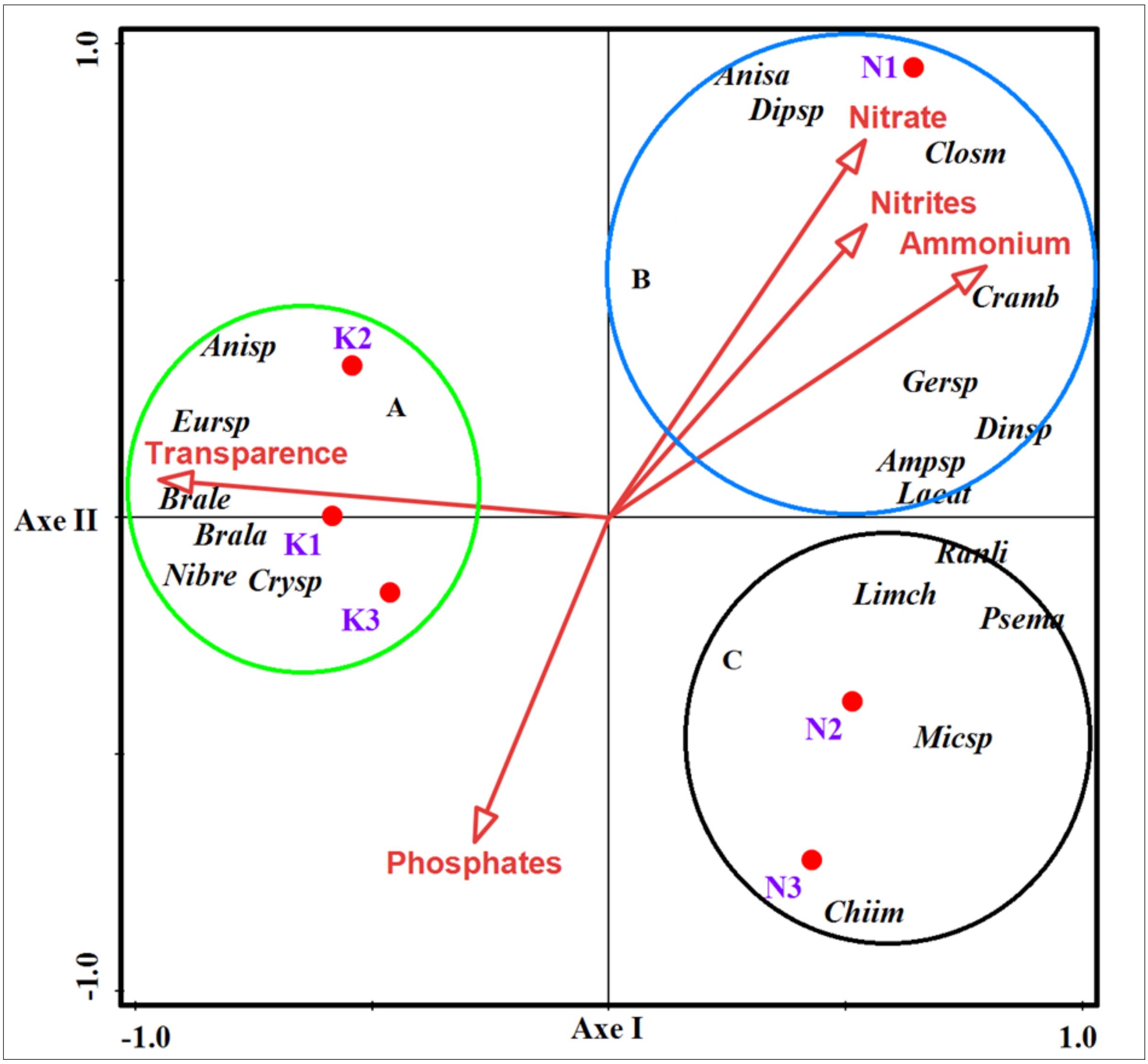

Fig 3: Canonical correspondence analysis of the environmental variables and the main taxa collected in the different study sites. K1= Koko 1, K2=Koko 2 et K3=Koko 3 :
N1=Natiokobadara 1, N2=Natiokobadara 2 et N3=Natiokobadara 3
Ampsp : *Amphiops* sp ; Anisa : *Anisops sardea* ; Anisp : *Anisops* sp ; Brala: *Brachythemis laccustris* ; Brale : *Brachythemis leucosticta* ; Chiim : *Chironomus imicola* ; Closm : *Cloeon smaeleni* ; Cramb : Crambidae ; Crysp : *Cryptochironomus* sp ; Dinsp : *Dineutus* sp ; Dipsp : *Diplonychus* sp ; Eursp : *Eurymetra* sp ; Gersp : *Gerisella* sp ; Lacat : *Laccotrephes ater* ; Limch : *Limnogonus chopardi* ; Micsp : *Micronecta* sp ; Nibre : *Nilodorum brevipalpis* ; Psema : *Pseudagrion massaicum* ; Ranli : *Ranatra linearis*.

5. Conclusion

The present study on aquatic insect composition at Koko and Natiokobadara lakes can be used as baseline data for the northern lake ecosystem. The study observed that the three sites of Natiokobadara recorded the highest richness and abundance compared to the sites of Koko lake. This might be due to the intense anthropogenic pressure at the Koko lake. Environmental variables such as nitrogen content and water transparency influenced aquatic insect distribution.

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