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Diversity and abundance of aquatic insects in three lentic ecosystems of the Bongouanou Department (Cote d'Ivoire)

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Abstract

This study aimed to assess the biodiversity of aquatic insects in three lacustrine ecosystems subjected to different levels of anthropogenic pressure in the department of Bongouanou (Côte d'Ivoire). The study was conducted in Lakes Sokotè and Kaby, located in urban areas, and Lake Ehuikro, located in a peri-urban area. Data were collected monthly from May 2017 to April 2018. Benthic aquatic insects were sampled using a Van Veen grab, while insects associated with aquatic macrophytes were collected using a hand net. Out of a total of 55 taxa recorded, Lake Ehuikro was the most diverse with 39 taxa, whereas Lakes Kaby and Sokotè harbored 32 and 23 taxa, respectively. At the family level, Baetidae dominated the assemblage in Lake Ehuikro, accounting for 29.77% of the total abundance. In Lakes Sokotè and Kaby, Chironomidae were the most abundant, with proportions of 86.43% and 33.41%, respectively. The ecological quality of the three water bodies was assessed based on the tolerance/intolerance of insects to water pollution using their relative abundance. Tolerant individuals dominated the assemblage in Lake Sokotè (94.67%), indicating very poor water quality. Lake Kaby was characterized by a predominance of intermediate insects (48.90%) with a considerable proportion of tolerant insects (40.46%), suggesting poor water quality. In contrast, Lake Ehuikro was mainly populated by intermediate (54.34%) and intolerant insects (29.77%), indicating good water quality. This study highlights variations in aquatic insect diversity according to the environmental characteristics of these three ecosystems. The results provide a baseline for improved management of these water bodies.

Keywords: Assemblage, organisms, tolerance, lakes, Cote d'Ivoire

Introduction

Freshwater ecosystems are highly productive environments that support high biological diversity and provide numerous services to humanity (Kaboré *et al*., 2023) [1]. It should be noted that their conservation is essential not only for biodiversity but also for the well-being of human populations that depend on the services they provide. Unfortunately, in developing countries, aquatic ecosystems constitute the main support for anthropogenic activities and are therefore increasingly subjected to various forms of pressure. Indeed, agricultural practices involving the excessive use of inputs, as well as livestock farming with animal waste discharged into water bodies, represent additional nutrient inputs that lead to the degradation of water quality (Sanogo *et al*., 2014; Kaboré *et al*., 2018) [2, 3].

In addition, mining, industrial, and urban discharges, which have increased over recent decades, further exacerbate pressures on aquatic ecosystems, particularly in urban areas (Kaboré *et al*., 2018) [3]. These anthropogenic pressures are highly detrimental to aquatic biodiversity in general and to aquatic insects in particular. According to Dunbar *et al*. (2010) [4], insects play an important role in the functioning of aquatic ecosystems. Aquatic insects are excellent indicators of habitat quality, which is why they are widely used as bioindicators of water quality (Varandas *et al*., 2010) [5].

Beyond this role, aquatic insects constitute an important link in aquatic food webs, serving as a food source for many invertebrates and several fish species. In the field of public health, insects cause numerous nuisances to humans, mainly due to the presence of hematophagous species such as mosquitoes, blackflies, and Tabanidae (Tachet, 2003) [6].

In Côte d'Ivoire, several studies on aquatic insects have been conducted. Most of these studies have focused on running waters, hydroelectric reservoir lakes, or fish farming ponds (Yapo *et al*., 2017) [7]. In contrast, knowledge of the entomological fauna of small lacustrine ecosystems remains limited. This is the case for Sokotè, Kaby, and Ehuikro lakes in the Bongouanou Department, eastern Côte d'Ivoire. Studying this fauna will help establish a reference database for future studies.

Materials and Methods

Study Area

The study was conducted in three lentic ecosystems in the Bongouanou Department (eastern Côte d'Ivoire): Sokotè and Kaby lakes, located within the urban area, and Ehuikro Lake, situated on the outskirts of Bongouanou.

Sokotè Lake is an artificial and sacred lake (15,000 m²) mainly supplied by groundwater and rainfall runoff. It receives domestic wastewater and household solid waste. Two sampling stations were established: Sokotè 1 (6°39′10.10″ N, 4°12′26.40″ W) and Sokotè 2 (6°39′07.50″ N, 4°12′23.20″ W).

Kaby Lake is an artificial reservoir (35,000 m²) located downstream of Sokotè Lake and originally created to supply drinking water. It is fed by groundwater and surface runoff and is influenced by agricultural activities, solid waste

disposal, roadworks, and wastewater inputs. Two sampling stations were selected: Kaby 1 (6°38′52.80″ N, 4°11′58.60″ W) and Kaby 2 (6°38′49.20″ N, 4°11′59.90″ W).

Ehuikro Lake is connected to the Yakpo River and Kaby Lake. Its surroundings are dominated by market gardening, poultry and pig farming, and rubber plantations. Three sampling stations were defined: Ehuikro 1 (6°38′34.00″ N, 4°09′54.60″ W), Ehuikro 2 (6°38′31.20″ N, 4°10′27.40″ W), and Ehuikro 3 (6°38′23.20″ N, 4°10′01.30″ W) (Figure 1).

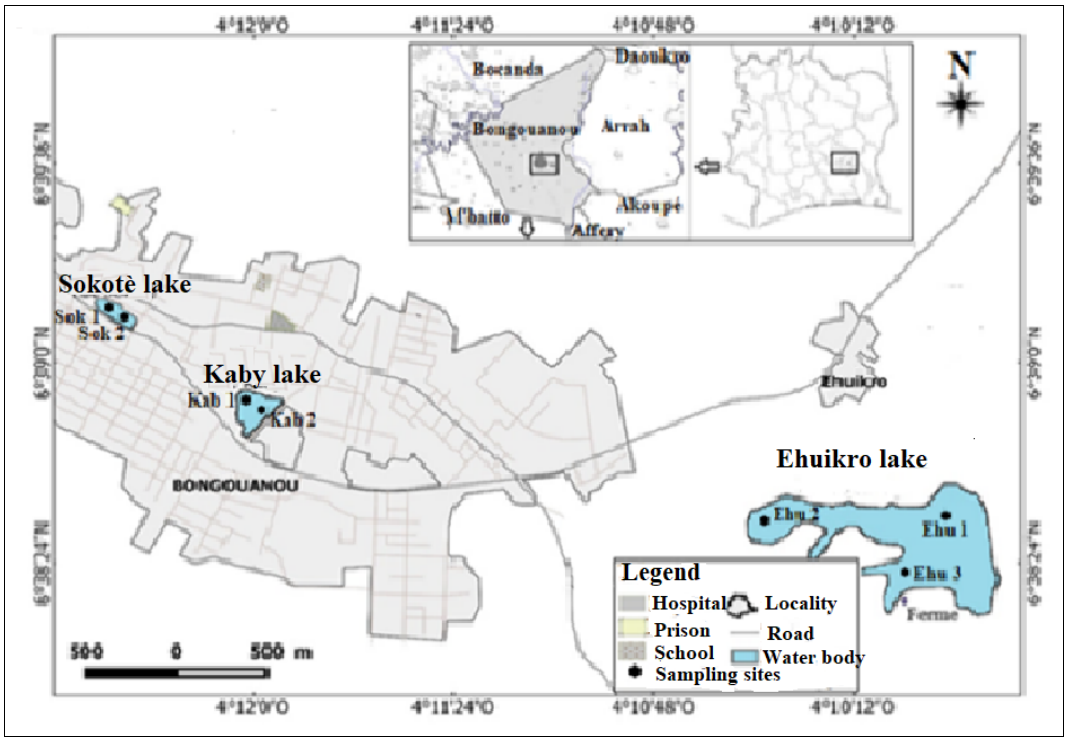

Fig 1: Location of Sokotè, Kaby, and Ehuikro lakes and benthic macroinvertebrate sampling sites in the Bongouanou Department (Côte d'Ivoire), May 2017-April 2018

Aquatic Insect Sampling

Aquatic insects were sampled monthly from May 2017 to April 2018 in the three lakes. Benthic insects inhabiting the sediment were collected using a Van Veen grab, while insects associated with submerged macrophytes were sampled using a hand net. Additional microhabitats, such as submerged dead wood, were also explored. Collected specimens were placed in labeled vials and preserved in 5% formaldehyde.

In the laboratory, specimens were examined under a stereomicroscope and identified to genus or species level using identification keys by Déjoux *et al*. (1981) [8], Diomandé *et al*. (2000) [9] and Tachet *et al*. (2010) [10].

Data Analysis

Taxonomic richness was determined for each lake. The data were analyzed using the relative abundance of individuals (N = Ni/Nt × 100), where *Ni* is the number of individuals of a given taxonomic group (taxon, family, or order) and *Nt* is the total number of individuals recorded in a given ecosystem.

The Shannon diversity index (H′) and Pielou's evenness index (E) were calculated for the aquatic insect communities of Sokotè, Kaby, and Ehuikro lakes based on numerical taxon abundance. All indices were computed using the software PAST. These analyses were performed according to the formulas presented below.

$H' = -\Sigma ((Ni/N) \times \ln (Ni/N))$.

Where**:** Pi is the relative abundance of taxon *i* in the sample (Pi = ni/ N); S is the total number of taxa; N is the total number of individuals; and ni is the number of individuals belonging to each taxon.

$E = H'/Hmax = H'/Log2\ S$

Where**:** H′ is the Shannon species diversity index, and S is taxonomic richness.

The chi-square (χ^2) test was used to compare Shannon diversity and evenness between the three lakes on a pairwise basis. This test was performed using Statistica 7.1 software.

Results

Taxonomic Richness and Composition

A total of 55 aquatic insect taxa were recorded across the three lakes. These taxa belong to six orders and 29 families. Ehuikro Lake exhibited the highest taxonomic richness with 39 taxa, followed by Kaby Lake with 32 taxa and Sokotè Lake with 23 taxa (Table I).

Analysis of order-level abundance showed that Diptera were the most dominant group in Sokotè Lake, accounting for 96.1% of the total relative abundance. Similarly, Diptera dominated the assemblage in Kaby Lake, representing 50.28% of the total abundance. In contrast, Ephemeroptera were the most abundant order in Ehuikro Lake, with a relative abundance of 29.77% (Figure 2).

Table I: Taxonomic richness and sensitivity of aquatic insects in the three lakes studied (Bongouanou Department, Côte d'Ivoire)

Lakes						
Orders	Families	Taxa	Sokotè	Kaby	Ehuikro	Tolerance
Coleoptera	Chrysomelidae	*Pyrralta* sp.	+			Intermediate
	Dryopidae	*Dryops* sp.		+		Intermediate
		Pomatinus sp.		+		Intermediate
	Dytiscidae	*Dytiscus* sp.		+		Intermediate
		Hydrovatus sp.			+	Intermediate
		Laccophilus luctuosus	+	+	+	Intermediate
		Laccophilus sp.	+	+	+	Intermediate
	Hydrophilidae	*Amphiops* sp.		+	+	Intermediate
		Coelostoma sp.			+	Intermediate
		Helochares sp.	+	+	+	Intermediate
		Hydrobius sp.			+	Intermediate
		Laccobius sp.	+	+	+	Intermediate
	Noteridae	*Noterus* sp.		+	+	Intermediate
Diptera	Ceratopogonidae	*Bezzia* sp.			+	Intermediate
		Ceratopogon sp.	+			Intermediate
	Chaoboridae	*Chaoborus* sp.			+	Intermediate
	Chironomidae	*Chironomus formosipennis*	+	+	+	Tolerant
		Corynoneura sp.			+	Tolerant
		Nilodorum fractilobus	+	+	+	Tolerant
		Polypedilum sp.	+	+	+	Tolerant

+ = Presence

Continuation of Table I

Lakes						
Orders	Families	Taxa	Sokotè	Kaby	Ehuikro	Tolerance
	Culicidae	*Culex* sp.	+	+	+	Tolerant
	Ephydridae	*Hydrellia* sp.	+	+		Intermediate
	Limoniidae	*Hexatoma* sp.	+			Intermediate
	Psychodidae	*Clogmia albipunctata*		+		Tolerant
		Psychoda sp.		+		Tolerant
	Scatophagidae	*Acanthocnema glaucescens*		+		Intermediate
		Acanthocnema sp.		+		Intermediate
	Sciomyzidae	*Sciomyza* sp.		+		Intermediate
	Stratiomyidae	*Hermetia illucens*		+		Intermediate
		Odontomyia sp.	+	+	+	Intermediate
Diptera	Syrphidae	*Eristalis* sp.	+	+	+	Tolerant
Ephemeroptera	Baetidae	*Baetis* sp.	+	+	+	Intolerant
Heteroptera	Belostomatidae	*Belostoma* sp.		+	+	Intermediate
		Diplonychus sp.	+	+	+	Intermediate
	Corixidae	*Micronecta scutellaris*		+	+	Intermediate
	Gerridae	*Gerris* sp.			+	Intermediate
	Mesoveliidae	*Mesovelia* sp.			+	Intermediate
	Naucoridae	*Macrocoris flavicolis*			+	Intermediate
		Naucoris sp.			+	Intermediate
	Népidae	*Nepa rubra*		+		Intermediate
		Ranatra linearis	+	+	+	Intermédiaire
	Notonectidae	*Anisops* sp.	+	+	+	Intermediate
	Pleidae	*Plea* sp.		+	+	Intermediate
Lepidoptera	Crambidae	*Elophila* sp.		+		Intermediate
		Parapoynx sp.			+	Intermediate
Odonata	Coenagrionidae	*Ischnura* sp.	+	+	+	Intermediate
		Pseudagrion punctum	+		+	Intermediate
		Coeriagrion tenellum			+	Intermediate
	Corduliidae	*Epitheca bimaculata*	+		+	Intermediate
		Somatochlora sp.	+		+	Intermediate
		Somatochlora flavomaculata	+			Intermediate
		Cordulia aenea			+	Intermediate
		Oxygastra curtisii			+	Intermediate
	Libellulidae	*Brachythemis leucosticta*			+	Intermediate
		Orthetrum sp.			+	Intermediate
6	29	55	23	32	39	

+ = Presence

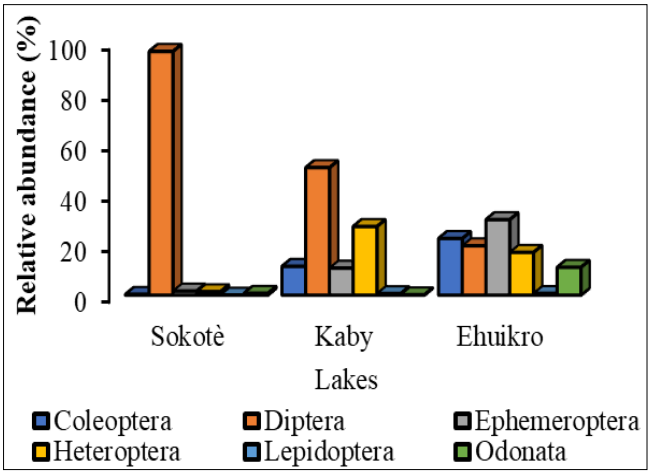

Fig 2: Relative abundance of aquatic insect orders in the three studied lakes

He relative abundance of insect families and taxa considered in this study included only those representing at least 5% of the total abundance in a given lake. At the family level, Chironomidae were the most abundant in Sokotè and Kaby lakes, with relative abundances of 86.43% and 33.41%, respectively. In contrast, Baetidae dominated the assemblage in Ehuikro Lake, accounting for 29.77% of the total abundance (Figure 3).

At the taxon level, *Chironomus formosipennis* dominated the assemblage in Sokotè Lake, representing 72.08% of the total abundance. In Kaby Lake, *Polypedilum* sp**.** was the most abundant taxon, accounting for 18.50% of the total individuals. In Ehuikro Lake, *Baetis* sp**.** was the most dominant taxon, with a relative abundance of 29.77% (Figure 4).

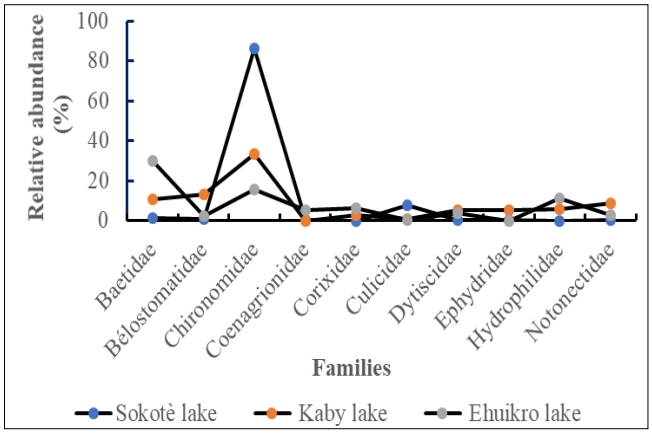

Fig 3: Relative abundance of aquatic insect families in the three studied lakes

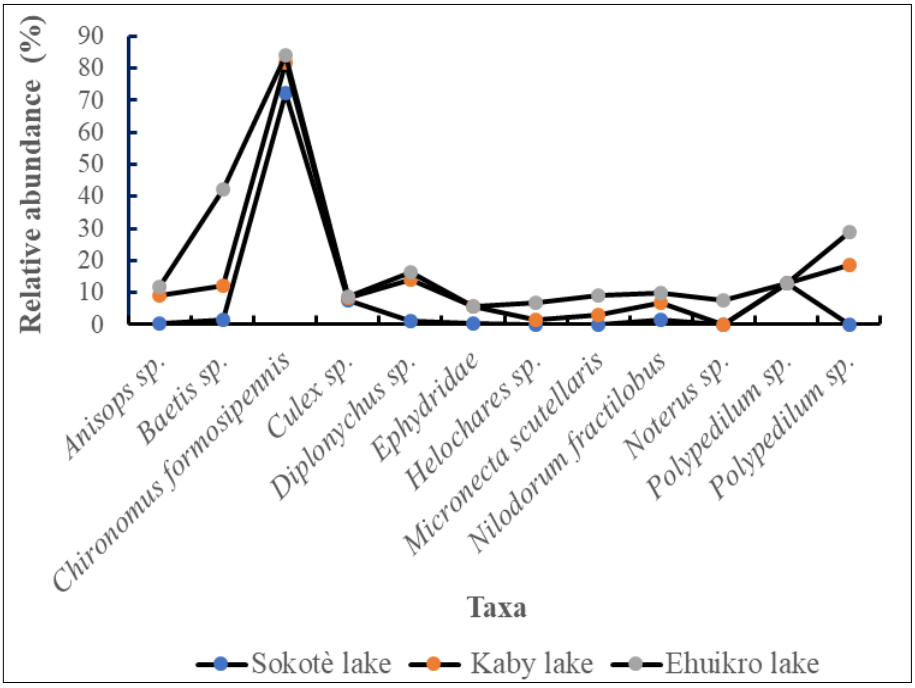

Fig 4: Relative abundance of aquatic insect taxa in the three studied lakes

The values of the Shannon diversity index (H′) and Pielou's evenness (E) in the different lakes are presented in Table II. The chi-square test showed that the Shannon diversity index was significantly higher in Kaby Lake than in Sokotè Lake ($p < 0.05$).

Table 2: Shannon diversity and evenness indices in the three studied lakes

Lakes			
Diversity indices	Sokotè	Kaby	Ehuikro
Shannon (H)	1,02 a	2,67 b	2,78 b
Pielou's evenness (E)	0,34 a	0,75 b	0,78 b

Values sharing the same letter (a or b) between two lakes do not differ significantly (chi-square test, $p > 0.05$).

In addition, this index was significantly higher in Ehuikro Lake than in Sokotè Lake ($p < 0.05$). Regarding evenness (E), values were significantly higher in Kaby Lake than in Sokotè Lake ($p < 0.05$), and also significantly higher in Ehuikro Lake than in Kaby Lake ($p < 0.05$).

Ecological Quality of the Lakes

The ecological quality of the lakes was assessed based on the proportion of aquatic insect individuals according to their tolerance or intolerance. Analysis of the aquatic entomofauna showed that tolerant organisms predominated

in Sokotè Lake (94.67%), indicating very poor water quality. In Kaby Lake, intermediate organisms dominated the assemblage (48.90%), with a substantial proportion of tolerant organisms (40.46%), suggesting poor water quality. In contrast, Ehuikro Lake was characterized by a predominance of intermediate organisms (54.34%) and a relatively high proportion of intolerant organisms (29.77%), indicating good water quality (Figure 5).

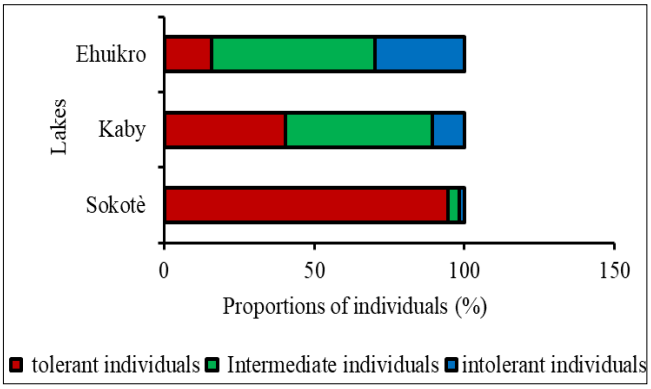

Fig 5: Relative abundance of aquatic insects by pollution tolerance in the three studied lakes

Discussion

Ehuikro Lake showed the highest taxonomic richness (39 taxa) compared to Kaby (32 taxa) and Sokotè (23 taxa). This pattern can be attributed to its larger surface area and greater habitat heterogeneity, which favor higher biodiversity (*Vannote et al*., 1980; Hugueny, 1990) [11, 12]. Moreover, lower anthropogenic pressure likely contributes to this higher richness, as ecosystems subjected to limited human disturbance generally support more diverse communities (Aazami *et al*., 2015) [13]. Located about 1 km from Bongouanou, Ehuikro Lake is relatively stable and less impacted by human activities.

Sokotè and Kaby lakes were dominated by Diptera, particularly Chironomidae, whose high abundances (86.43% and 33.41%, respectively) indicate poor water quality. Chironomidae are well known for their high tolerance to pollution and organic enrichment (Moisan, 2013; Camargo *et al*., 2004) [14, 15], often reflecting strong anthropogenic impacts (Carvalho *et al*., 2006) [16]. In contrast, Ehuikro Lake was dominated by Ephemeroptera, mainly Baetidae (29.77%), which are widely recognized as indicators of good ecological conditions (Moisan and Pelletier, 2008) [17].

Community structure analysis further supported these patterns. Ehuikro Lake exhibited the highest Shannon diversity (H′ = 2.78) and evenness (E = 0.78), indicating a well-balanced and stable ecosystem. Conversely, Sokotè Lake showed low diversity (H′ = 1.02) and evenness (E = 0.34), reflecting ecological disturbance. This degradation is likely related to intense anthropogenic pressure, including domestic wastewater, solid waste inputs, and effluents from nearby urban infrastructures.

Finally, the dominance of intolerant taxa in Ehuikro Lake confirms its good ecological quality, whereas Sokotè and Kaby lakes, characterized by a high proportion of tolerant organisms, exhibit degraded environmental conditions. According to Gooré Bi (2009) [18], ecosystems with high richness and abundant intolerant taxa are indicative of healthy aquatic environments.

Conclusion

A total of 55 aquatic insect taxa (six orders, 29 families) were recorded in the three lakes. Sokotè and Kaby lakes were dominated by tolerant taxa (*Chironomus formosipennis* and *Polypedilum* sp.), indicating anthropogenic disturbance, whereas Ehuikro Lake was dominated by *Baetis* sp. with a notable presence of intolerant taxa, reflecting better ecological quality. This study demonstrates the relevance of using tolerance-based metrics to assess the ecological status of lacustrine ecosystems.

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