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Research Article

ECOLOGICAL STATUS OF THREE SUB-SAHARAN DAM LAKES BASED ON MACROINVERTEBRATES COMMUNITY (COTE D'IVOIRE, WEST AFRICA)

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ABSTRACT

The government of Côte d'Ivoire had built numerous small dam lakes in the north of the country to irrigate crops. Today, these ecosystems are in a state of degradation. In order to provide the authorities with reliable data for decision-making on the conservation of these aquatic environments, a study was carried out to assess the ecological quality of three dam lakes in the Korhogo department. To this end, macroinvertebrate sampling was carried out from June 2023 to April 2024, using a 350 µm turban net and a Van veen grab (0.042m^2). The ecological status of the three lakes was assessed using the multimetric index of lake environments in Burkina Faso (IMLB). A total of 3 phyla, 4 classes, 11 orders, 38 families, 89 species and 4,548 individuals were sampled in all three dam lakes. The insect class was the most abundant, accounting for over 70% of individuals. The multi-metric index of lake environments in Burkina Faso (IMLB) was 50.41 at Nindjo, 53.45 at Koko and 76.61 at Nangakaha. These values indicate that the ecological quality of the first two lakes is average. Lake Nangakaha, on the other hand, is in good ecological condition. This study will lead to decisions in favor of the protection of Koko and Nindjo lakes, which are under heavy anthropic pressure.

Keywords: Dam lakes, Korhogo, Macroinvertebrates, Water quality.

INTRODUCTION

Nowadays, the various players in human society (scientists, politicians, citizens, etc.) can no longer ignore global ecological problems, as the means of disseminating information about them are developing so rapidly (Rambaud *et al*., 2008). As a result, some countries, individually or collectively, are setting up means of combating these problems. In the northern part of Côte d'Ivoire, for example, numerous small dams were built in the 1970s to combat the drought that gripped the West African region during this period (Aka-Koffi, 2003). These water resources play a key role in the development of a country's various economic sectors. These dams, which were originally intended for crop irrigation (Silué and Koudou, 2019) and livestock watering, have seen their uses diversify. However, in recent years, the waters of these dams in Côte d'Ivoire have come under threat from pollution problems of anthropogenic origin (urban discharges, industrial and agricultural activities, etc.) (McKinney, 2002). These activities tend to diminish the potential and quality of water resources. They also have a negative impact on the health of the population through certain diseases such as: diarrhea, cholera, typhoid fever, malaria, dengue fever, schistosomiasis, paratyphoid, etc. (Alhou, 2007), through water use (water catchment, bathing, etc.) and socio-economic development (Burton and Pitt, 2001).

These conditions call for an understanding of the ecological functioning of these aquatic environments (dams) and a diagnosis of their health, so that appropriate measures can be taken to use them more efficiently and rationally. Given the importance of these aquatic environments, their conservation and sustainable management requires water quality assessment and monitoring. These are generally based on a physico-chemical approach. Although important, this method has a

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number of shortcomings (Karr *et al.*, 1986; Ohio, 1987; Lévêque, 1997. Thus, water quality assessment and monitoring based on the use of biotic indices developed from living aquatic organisms such as fish, diatoms, algae and aquatic macroinvertebrates seems to be the best alternative (Edia, 2008; Camara, 2013). Among these organisms, aquatic macroinvertebrates are by far the most widely used as bioindicators for water quality assessment (Clarke *et al*., 2002). In Côte d'Ivoire, macroinvertebrates have been used to assess lake water quality (Tapé, 2020; Aimé, 2023; Konaté; 2023). In the north of the country, very little data on lake water quality is available (Aimé, 2023). To remedy this shortcoming, this study was initiated to assess the state of ecological integrity of three lakes in the Poro region (northern Côte d'Ivoire).

MATERIALS AND METHODS

Description of the Study Area

Sampling was carried out on three dam lakes (Koko, Nindjo and Nangakaha) in the Korhogo department in the northern Côte d'Ivoire (Figure 1). They are subject to heavy human pressure from activities such as crop cultivation (often using unregistered chemicals), fishing, urban, industrial and agricultural discharges and water abstraction. Lake Koko, located in the heart of the town, is used to supply drinking water. Since 1973, it has been in operation on behalf of the Côte d'Ivoire water distribution company (SODECI). Lake Nindjo is located near the town of Korhogo. With a surface area of 180 ha, it has been in operation since the 1970s. Lake Nangakaha. Unlike the other two dams, this one is located in the forest. It is bordered on one side by the CNRA classified forest and on the other by farmers' fields.

Data collection

Environmental variables such as electrical conductivity, pH and water temperature were measured using a HI12883 multi-parameter handheld digital display. Turbidity was measured with a HACH 2100P turbidimeter. Dissolved oxygen was measured using a DO-5519 portable digital oximeter. Samples were collected between 8 a.m. and 12 p.m. using a 350 µm hand net and a Van Veen grab (0.042m^2). A Secchi disk was used to measure water transparency. Sampling campaigns are carried out every two months from June 2023 to April 2024. Five samplings with the Van Veen grab sampler and three samplings with the hand net were carried out per site, with the aim of gathering as much diversity as possible (Yapo, 2013). Samples were rinsed in situ in containers; the remaining materials were preserved in pillboxes and then fixed in 5% formalin. These samples were taken to the laboratory.

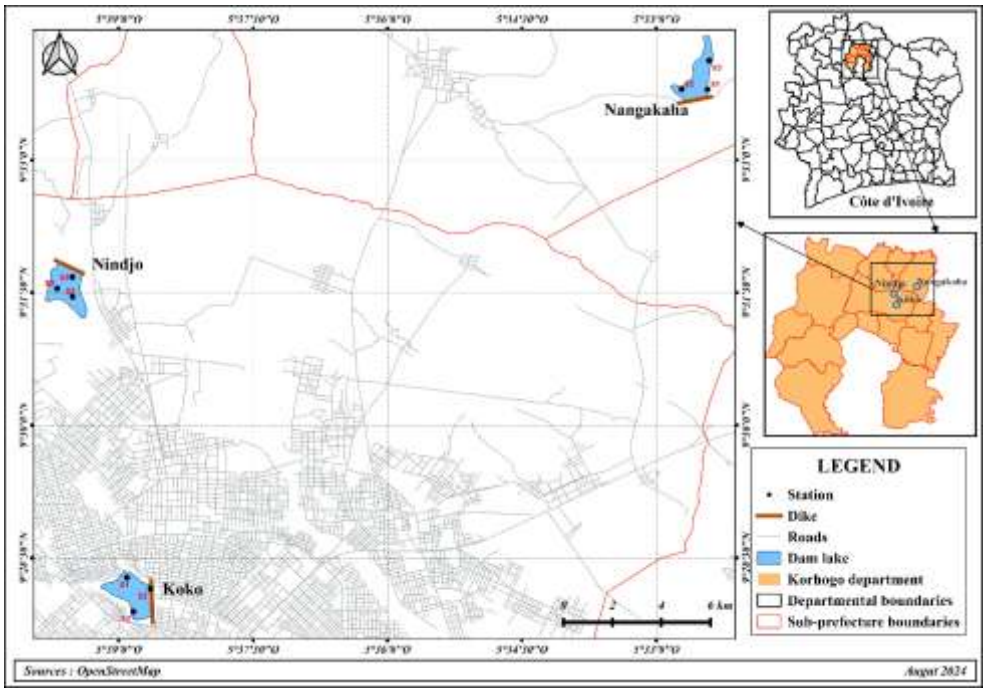

Figure 1. Location of study area

Sorting and identification

In the laboratory, to remove formalin, specimens from each site were rinsed thoroughly with tap water on a sieve. Specimens are sorted under a light source. Organisms sorted in this way were collected in pillboxes containing a 70% alcohol solution. Organisms were identified under a Euromex Stereoblue trinocular magnifier (X 40), down to the lowest possible level, using the keys of Déjoux *et al*. (1981), De Moor *et al.* (2003a; 2003b), Tachet *et al*. (2010) and Suhling *et al*. (2014).

Statistical data analysis

Environmental parameters were analyzed by determining means and standard deviations for each parameter. Macroinvertebrate abundance, taxonomic richness, Shannon-Wiener diversity ∑index (1) and Piélou equitability index (2) were used to assess macroinvertebrate community structure.

$$H' = -\sum \left(\frac{ni}{N}\right) Log2 \left(\frac{ni}{N}\right) \quad (1)$$

$$E = \frac{H'}{Log2(S)} \quad (2)$$

With ni the number of individuals of the taxa of rank i, N the total number of individuals and S the total number of taxa counted. The multimetric index of lake environments in Burkina (IMLB) (3) was used to assess the ecological status of the three lakes. It was calculated using the following equation.

IMLB= [4,4(#Taxa) + 1,79(%EOT) + 40,98 (H') – 1,01(%Chi) – 1,47(%2T. Abon) – 1,002(%N-ins) + 348,21] /6……..(3)

Taxa= total number of families; %EOT= percentage of Ephemeroptera, Odonata and Trichoptera families; H'=Shannon Index; %Chi= percentage of Chironomidae; %2T. Abon= percentage of the 2 most abundant taxa and N-ins= percentage of non-insects.The results of this index were interpreted according to the following scale (Table 1).

RESULTS AND DISCUSSION

The mean values and standard deviations of the physico-chemical variables measured during the various sampling campaigns are shown in Table 2. The pH values recorded in these lakes ranged from 6.85 (Nangakaha) to 7.59 (Koko). The highest value was recorded in Lake Koko. The basic appearance of this lake could be due to its geographical location. As well as being located in the heart of the city (Korhogo), from which it derives its name Koko, the basicity could be linked to the different geological bases on which these dams are built. Indeed, the northern dams are built on Birrimian and granitoid formations (Aimé., 2023). The activities carried out around the lake and the discharge of effluent of an alkaline nature may also be responsible for its slightly basic character (Sanogo *et al*., 2021). The mean temperature recorded in the lakes ranged from 28.78°C (Nangakaha) to 29.73°C (Koko). This range of variation indicates that the waters of the lakes surveyed are warm. Similar results were reported by Lemoalle (1999), who highlighted the fact that in inter-tropical Africa, average water temperatures in aquatic environments are high, most often in excess of 20°C. Similar results were obtained by Yapo *et al*. (2016) in the ponds of the Banco national park and Tapé (2020) in the urban lakes of Yamoussoukro. The different temperatures recorded oscillate within the range tolerated by warm-water aquatic species (Tapé, 2020). Dissolved oxygen levels are higher in Lake Nangakaha than in Lake Koko. The high oxygen content of Lake Nangakaha may be due to the fact that the dam is located in a rural area. Anthropogenic activities and human and industrial discharges are minimal or absent, and the lake's surrounding vegetation (forest) could be one of the reasons for the higher oxygen levels. Unlike the Nangakaha dam, the Koko dam is under heavy pressure from human activity. Lake Koko's central location makes it more accessible than the other two lakes. The market gardening practised all around this lake, with the abusive use of chemical fertilizers and pesticides, motorcycle waste oils and the discharge of waste water from domestic toilets could explain the low oxygen levels recorded in this lake. These assertions are correlated by Kaboré *et al*, (2023) who have observed these disturbances in urban streams such as Ouagadougou's reservoir n°2.The high TDS value and low transparency are observed in Lake Koko in contrast to Lakes Nindjo and Nangakaha. These parameters disrupt the biological quality of this water and have a negative impact on the development of aquatic organisms (Monney *et al*., 2016). These observations could be due to pollutants of various origins flowing into the lake through drainage channels, human activities such as market gardening, with the use of fertilizers and pesticides, laundry and animal grazing that contribute to increasing water turbidity (Houelome *et al*., 2016).

A total of 3 phyla, 4 classes, 11 orders, 38 families, 89 species and 4,548 individuals were sampled in all three dam lakes. Lake Koko recorded 2,050 individuals (45%), Lake Nangakaha 1,478 (33%) and Lake Nindjo 1,020 (22%) (Table 3).The order Diptera (43%) was the most abundant, followed by Gasteropoda (22%), Heteroptera (15%), Odonata (8%) and Littorinimorphae (8%). Other orders (4%) such as Coleoptera, Araneae, Ephemeroptera, Lepidoptera, Trichoptera and Arhynchobdellidae are relatively abundant (Figure 2). Unlike physico-chemical parameters, macroinvertebrates are true preservers of past and present ecological phenomena (Kaboré *et al*., 2016).The aquatic macroinvertebrate structure resulting from this study is characterized by a dominance of taxonomic richness and arthropod abundance. Such an aquatic macroinvertebrate structure is typical of African freshwaters (Durand and Lévêque, 1980). This is partly linked to the climate in our tropics, and partly to the state of health and activities practised in these environments. These results are corroborated by those obtained by Alhou *et al*. (2009) in Niger, Diomandé *et al*. (2009) in Côte d'Ivoire, Foto *et al*. (2010) and Tchakonté (2016) in Cameroon. They are in line with the results of KambTshijik *et al*. (2015). The abundance of arthropods (69 taxa out of 89)

over the other taxonomic groups and the dominance in terms of abundance of insects (65 taxa) confirm their ubiquitous nature and therefore ability to colonize different ecological niches (Tchakonté, 2016).

Shannon-Wiener index values range from 1.2 (Nindjo) to 2.11 (Nangakaha). Piélou equitability values range from 0.41 (Nindjo) to 0.64 (Nangakaha).

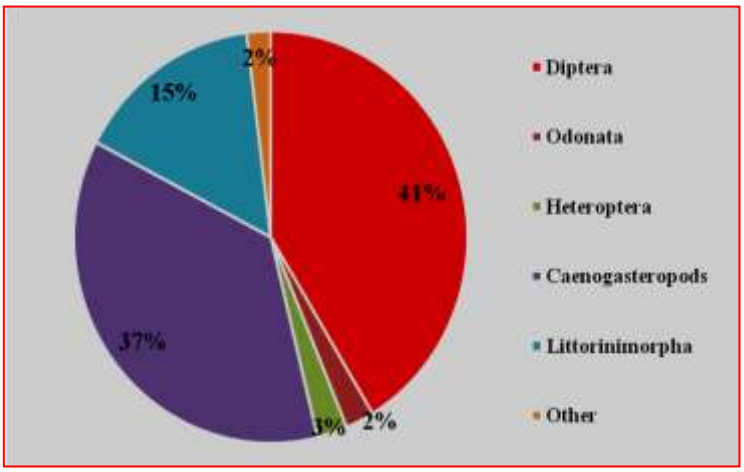

Figure 2. Abundance of macroinvertebrate orders in the three lakes.

Table 1. Ecological quality scale for lake environments (Bancé, 2022)

[0 - 24,31]	[24,32 – 48,63]	[48,64 – 72,95]	[72,96 – 80,84]	[80,85 - 100]
Very poor	**Poor**	**Medium**	**Good**	**Very good**

Table 2. Mean values of physico-chemical variables measured in the three lakes of the Korhogo department from June 2023 to April 2024.

Parameters	Koko	Nindjo	Nangakaha
pH	7,59 ± 0,83	7,15 ± 0,51	6,85 ± 0,71
T(°C)	29,73 ± 2,34	29,08 ± 3,03	28,78 ± 2,58
Conductivity (µS/cm)	150,04 ± 5,84	80,57 ± 0,03	40,02 ± 0,01
Dissolved oxygen (mg/L)	4,1 ± 1,39	6,94 ± 1,11	6,53 ± 1,72
Tubidity (NTU)	151,72 ± 45,89	105,13 ± 19,29	226,13 ± 119,71
Transparency (Cm)	49,89 ± 5,20	49 ± 7,01	44,22 ± 11,61
TDS (mg/L)	120,7 ± 3,36	40,5 ± 0,01	20,12 ± 0,005

Table 3. List and mean abundance values of macroinvertebrate orders collected in the three dam lakes of Korhogo department from June 2023 to April 2024.

Phyla	Classes	Orders	Koko	Nindjo	Nangakaha
		Diptera	121,14±593,26	104,28±500,63	74,14±352,85
		Odonata	12±7,07	22±26,87	54±1,41
Arthropods	**Insecta**	Ephemeroptera	2,66±1,41	2,66±4,24	29,33±24,74
		Trichoptera	0	0	6,66±3,53
		Heteroptera	8,5±3,53	28,16±104,65	67,16±272,24
		Coleoptera	1,75±1,41	1,75±2,12	7,75±19,09
		Lepidoptera	0	3±	0
	Arachnids	Araneae	8±11,31	3±2,82	1±1,41
Annelides	**Clitellata**	Arhynchobdellida	9±00	0	0
Molluscs	**Gastropods**	Caenogasteropods	168,75±17,68	2±0	45±63,64
		Littorinimorpha	105,33±176,06	0,33±0	6,33±3,53
Total=3	**4**	**11**	2050	1020	1478

The multi-metric index of lake environments in Burkina Faso (IMLB) shows a value of 50.41 at Nindjo, and 53.45 at Koko, revealing average ecological quality for these two lakes. Lake Nangakaha, on the other hand, has a value of 76.61, showing that this dam is in good condition, unlike the Koko and Nindjo dams. Lake Nangakaha recorded the highest equitability (>0.60). This indicates a good distribution of organisms in this lake. This good distribution could be due to the lake's good water quality. This quality was shown by the calculation of the multimetric index of lake environments in Burkina (IMLB), which indicates a value above 72.96 for Lake Nangakaha, while the values of this index for the other two lakes are below 72.95, indicating acceptable water quality. The good ecological quality of Lake Nangakaha may be due to its immediate environment. In fact, this lake is bordered by a forest on the one hand, and smaller-scale market garden crops on the other. This lake is located in a rural environment. The low IMLB values observed in Koko and Nindjo lakes may be due to their geographical location. Indeed, Lake Koko and Lake Nindjo are urban and peri-urban lakes respectively. The immediate environment of these two lakes is made up of market garden crops and housing in the case of Lac de Koko. When it rains, Lake Koko receives runoff and wastewater from the surrounding neighborhoods. Pesticides used in market gardening could be drained by runoff into both lakes. All this could contribute to the pollution of these two lakes.The activities carried out around these lakes, such as market gardening, use large quantities of inputs, and the lack of maintenance and monitoring of these dam lakes could be at the root of their average ecological quality. The area around these dam lakes is also subject to slash-and-burn cultivation, leading to the disappearance of certain plant species and macroinvertebrates. Urbanization, domestic sewage and waste from human activities are deteriorating the quality of watercourses. These actions affect ecosystems by fragmenting the different habitats of the organisms that live there (Talaga *et al*., 2017; Sanogo *et al*., 2021).

CONCLUSION

This study focused on the use of aquatic macroinvertebrates to determine the ecological quality of three dam lakes in the Korhogo department of northern Côte d'Ivoire. Sampling in these lakes yielded 4,548 individuals, divided into 3 phyla, 4 classes, 11 orders, 38 families and 89 species. Lake Koko recorded 2050 individuals, making it the most abundant, followed by Lake Nangakaha with 1478 individuals, and finally Lake Nindjo with 1020 individuals. According to the biotic index used, the Koko and Nindjo lakes were moderately polluted, unlike Lake Nangakaha, which is still in good condition. Pollution-sensitive taxa are more abundant in Lake Nangakaha than in the other two lakes (Koko and Nindjo). This study has shown that the population structure of aquatic macroinvertebrates provides information on the state of health of these aquatic ecosystems. In view of the ecological, economic and health benefits of these various dam lakes, it would be worthwhile taking measures to conserve and make more efficient use of these environments.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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