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Dynamics of plankton communities and trophic state in Taabo Lake (Côte d'Ivoire)

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ABSTRACT

Objective: This study examined spatial and seasonal patterns in the biomass of plankton assemblages (phytoplankton and zooplankton) and evaluated the trophic state of Taabo Lake, in order to determine how plankton dynamics reflect and influence the lake's level of eutrophication.

Methodology and results: Spatial and seasonal variation of biomass of plankton assemblages and Trophics stats were investigated in Taabo lake from November 2017 to October 2018 (Côte d'Ivoire; West Africa). Field sampling was conducted every 45 days at five sites representing different levels of anthropogenic influence. Plankton samples were collected at five sites along a seven-kilometer transect using a 20 µm mesh plankton net. Both the Carlson Trophic State Index and the Zooplankton Trophic State Index were employed to determine the trophic condition of Taabo Lake. High nutrient concentrations (PT: 1.5 $mg \cdot L^{-1}$; NT: 0.5 $mg \cdot L^{-1}$) coincided with an elevated phytoplankton biomass (88 $mg \cdot L^{-1}$) during the rainy season, with Dinophyta contributing over 39% of the total phytoplankton density in October. In contrast, zooplankton biomass peaked during the dry season (3.4 $mg \cdot L^{-1}$), dominated by copepods (>60%), followed by rotifers (>30%). Carlson Index values exceeded 50 at all sites and sampling periods, indicating eutrophic conditions in Taabo Lake (TSI > 50). Likewise, median values of the zooplanktonic trophic index ranged between 55 and 65 across seasons and stations. Together, these results confirm that the waters of Taabo Lake consistently fall within the eutrophic state.

Conclusion and application of results: The persistent eutrophic state of Taabo Lake highlights the influence of nutrient enrichment, particularly during the rainy season. These results support the implementation of nutrient reduction strategies, improved wastewater management, and the use of plankton-based monitoring as effective tools for water quality assessment and sustainable lake management.

Keys words: plankton, eutrophic, Carlson Index, zooplanktonic trophic index, Biomass, Taabo lake, Côte d'Ivoire, Trophic state.

INTRODUCTION

Anthropogenic increases in nutrient inputs have caused severe degradation and water quality deterioration in lake ecosystems worldwide, posing significant health risks in regions that rely on lake water for drinking (Engdaw *et al*., 2025; Luan *et al*., 2025). In this context, tropical freshwater lakes represent particularly vulnerable environments, as their biological communities respond rapidly to environmental fluctuations and anthropogenic disturbances, including nutrient enrichment and hydrological variability (Dudgeon & Strayer, 2025). Among these communities, plankton encompassing phytoplankton as primary producers and zooplankton as key grazers constitute fundamental components of aquatic food webs (Dongoran & Nyompa, 2025; To *et al*., 2024). Variations in plankton diversity, composition, and biomass not only reflect ecological balance but also provide critical diagnostic signals of trophic state, nutrient availability, and ecosystem functioning (Dong *et al*., 2025; Miao *et al*., 2025). In many African reservoirs, shifts in hydrological regimes, watershed land-use changes, and nutrient inputs from human activities have resulted in accelerated eutrophication, altered primary productivity, and disruptions of biotic interaction (Nangho *et al*., 2019; Adon et al., 2021). Taabo Lake, located in Côte d'Ivoire, is a man-made lake supporting fisheries, agriculture, hydroelectric production, and local livelihoods. Yet, its ecological stability is increasingly threatened by runoff from agricultural zones, untreated domestic waste, and seasonal hydrological oscillations, which may modify nutrient loads and affect plankton dynamics (Kouassi *et al*., 2007; Aliko *et al*., 2010). Understanding the spatial heterogeneity of plankton distribution between pelagic and littoral zones as well as their seasonal variability across rainy and dry periods, is essential for assessing nutrient cycling, energy pathways, and ecosystem resilience. Moreover, evaluating trophic state through integrated biological and physicochemical indicators contributes to diagnosing the lake's current ecological status and anticipating potential eutrophication risks (Mamun, 2021; Karpowicz *et al*., 2025). The present study aims to characterize plankton communities in Taabo Lake, investigate their spatial and seasonal variations, and determine the trophic state of the lake. By providing updated ecological insights, this work intends to support long-term biomonitoring efforts and promote sustainable management strategies for freshwater resources in the region.

MATERIAL AND METHODS

Study area and sampling sites: Located in central Côte d'Ivoire (6°25'–6°56' N; 5°07'–5°33' W), Taabo Lake (Figure 1) covers an area of 69 km², has an average depth of 16 m (maximum depth 30 m), and exhibits a water residence time of approximately 49.2 days (Kouassi *et al*., 2007). The climate is characterized by four seasons (two rainy seasons and two dry seasons). The rainy seasons are represented by a long rainy season (LRS) from April to July and a short rainy season (SRS) from October to November. The two dry seasons are represented by a long dry season (LDS) from December to March and a short dry season (SDS) from August to September (Kouassi et al., 2013). The mean annual precipitation varies from 1100 to 1600 mm, and the mean annual air temperature ranges between 24.5 °C and 34 °C (Aliko *et al*., 2010). A year-long survey was carried out from November 2017 to October 2018 at five sampling sites distributed along a seven-kilometre transect in the open waters of the reservoir. Sampling site characteristics are summarized in Table 1. Samples were collected every 45 days.

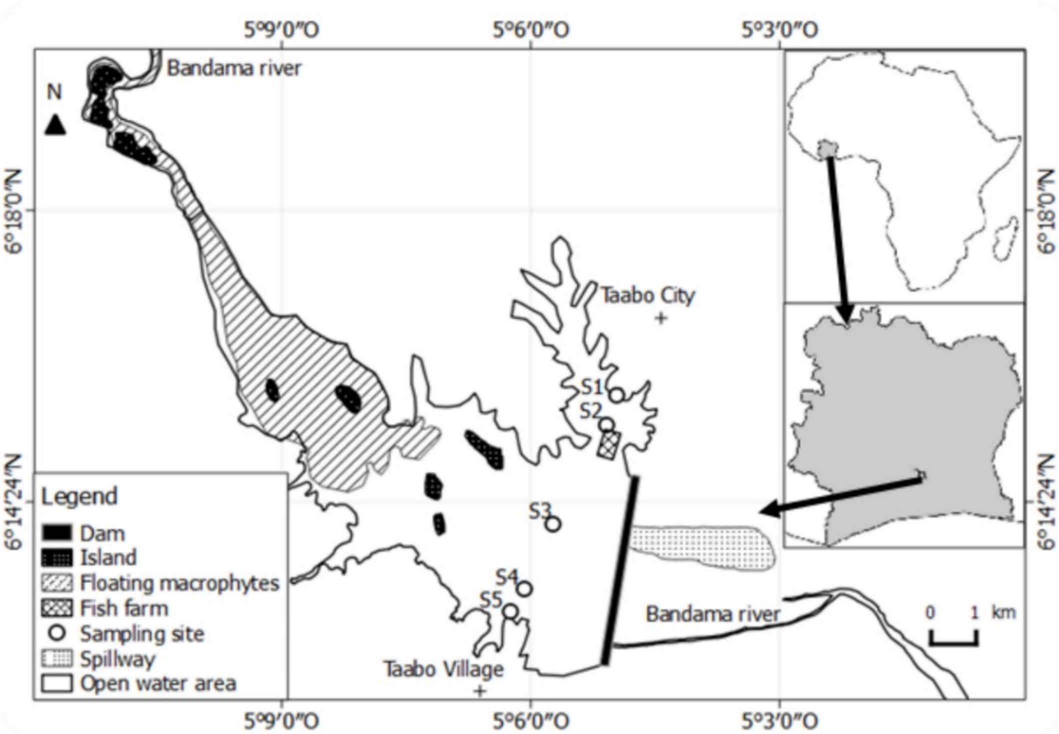

Figure 1: Map showing the location of sampling sites in Taabo lake (Côte d'Ivoire): S1-S5 = sampling sites

Table 1: Coordinates and characteristics of the sampling sites in Taabo lake (2017-2018, Côte d'Ivoire)

Sampling sites	Latitude (N)	Longitude (W)	Mean Depth (m)	Characteristics of the sampling sites
St1	06°15'46.6"	05°04'57.4"	2.8	Urban area of the reservoir, cattle farming on the bank, agriculture, bathing and washing activities
St2	06°15'42.5"	05°04'59.3	8	Fish farming operation into the reservoir
St3	06°15'06.3"	05°05'11.2"	19	Fishing area
St4	06°13'00.8"	05°06'13.7"	8.5	Fishing area
St5	06°12'59.2"	05°06'14.6"	3.2	Rural zone of the reservoir, fishing area, agriculture

Environmental variable: The environmental variables measured to characterize Taabo Lake included water transparency and nutrient concentrations (total nitrogen and total phosphorus). Water samples for the analysis of environmental variables were collected at two depths (0.5 and 1 m) at each sampling site using a Van Dorn bottle. Water transparency was measured with a 20-cm black-and-white Secchi disk. Nutrient concentrations were quantified using a HACH DR 2010 spectrophotometer. Total nitrogen (TN) and total phosphorus (TP) were determined following the standard NF EN ISO 10304-1 (2009).

Plankton sampling: Plankton were collected at each site in Taabo Lake using a single vertical haul from 1 m depth to the surface with a 20 µm mesh net (34 cm diameter, 108 cm length) and preserved in 5% formaldehyde.

Phytoplankton were identified to the lowest possible taxonomic level under a Zeiss microscope at 400× magnification using standard keys and manuals, with names verified in AlgaeBase (Guiry & Guiry, 2016). Cells were counted following Utermöhl (1958) with an inverted microscope (200×–400×) according to NF EN 15204 (2006). Biomass ($mg \cdot L^{-1}$) was calculated as species density × mean cell volume (Hillebrand *et al*., 1999; Sun & Liu, 2003), assuming $1\ mm^3 \cdot L^{-1} = 1\ mg \cdot L^{-1}$ (Wetzel & Likens, 2000). Chlorophyll *a* was quantified using a HACH DR 2010 spectrophotometer and its biomass was calculated using the Lorenzen (1967) method. Zooplankton were identified using standard keys. Abundance was determined from three 1.5 ml subsample counts in a 100 ml Sedgwick-Rafter chamber. Biomass (mg) was estimated from dry weight using length–weight relationships and filtered water volume (McCauley, 1984; Sun *et al*., 2010).

Trophic index: The Carlson Trophic State Index (TSI) was used to assess the trophic status of Lake Taabo, based on chlorophyll *a*, Secchi depth, and total phosphorus. The mean TSI values of these three variables provided the overall trophic state index (Carlson, 1980). Based on TSI values, lakes are classified as oligotrophic (low productivity), mesotrophic (moderate productivity), or eutrophic (high productivity). According to Carlson's Trophic state Index were TSI < 40: oligotrophic; 40 < TSI < 50: mesotrophic; TSI ≥ 50: eutrophic. The trophic status of Lake Taabo was also assessed using the zooplankton Trophic State Index (TSIzoo). According to Jekatierynczuk-Rudczyk *et al*. (2014), this index is calculated from the rotifer (TSI_ROT) and crustacean (TSI_CRU) indices established by Ejsmont-Karabin (2013) and Ejsmont-Karabin & Karabin (2013). The mean of TSI_ROT and TSI_CRU yields TSIzoo, which classifies the lake as follows: TSIzoo < 45: mesotrophic; 45 < TSIzoo < 55: meso-eutrophic; 55 < TSIzoo < 65: eutrophic; TSIzoo > 65: hypereutrophic.

Data analysis: Differences in nutrient concentrations, plankton biomasses, Carlson Trophic State Index, and zooplankton Trophic State Index among sites and season were assessed using the non-parametric Kruskal–Wallis test, followed by pairwise comparisons with the Mann–Whitney test. Data normality was verified using the Shapiro test ($p > 0.05$ for all sites). All analyses were performed in RStudio (R version 3.1.3; R Core Team, 2013) with a significance level set at $p < 0.05$. Owing to the very low spatial variability of total nitrogen and total phosphorus (Camara *et al*., 2022), as well as of phytoplankton and zooplankton biomass, the values were pooled to produce a single representative value for Taabo Lake.

RESULTS

Planktonic interactions in Taabo Lake : The annual variations in nutrients (TN and TP), phytoplankton biomass, and zooplankton biomass sampled in Lake Taabo from November 2017 to October 2018 are shown in Figure 2. Concerning nutrient availability, high total nitrogen (TN: $1.5\ mg \cdot L^{-1}$) and total phosphorus (TP: $0.5\ mg \cdot L^{-1}$) concentrations were recorded during the short rainy season (October). In contras the lowest TN ($0.3\ mg \cdot L^{-1}$) and TP ($0.12\ mg \cdot L^{-1}$) values were observed during the long dry season (LDS). Nutrient concentrations were significantly higher in rainy seasons than dry seasons (Mann-Whitney test; $p < 0.05$). Regarding variations in phytoplankton and zooplankton biomass, Maximum total phytoplankton biomass ($88\ mg \cdot L^{-1}$) was recorded during SRS. The minimum total biomass ($9\ mg \cdot L^{-1}$) was observed during the LDS. In terms of phytoplankton community structure, Dinophyta exhibited pronounced dominance (>39% of total biomass), constituting more than half of the phytoplankton recorded in

Taabo Lake in October. The total phytoplankton biomass was significantly lower during the LDS than in the other seasons (Mann–Whitney test; $p = 0.002$). The highest value (3.4 mg·L⁻¹) of total Zooplankton biomass was recorded in LDS, and the lowest value (0.74 mg·L⁻¹) biomass was noted in LRS. Copepods dominated the community (>60%), followed by rotifers (>30%). Zooplankton biomass was significantly higher (Mann-Whitney test; $p < 0.05$) in dry seasons than rainy seasons.

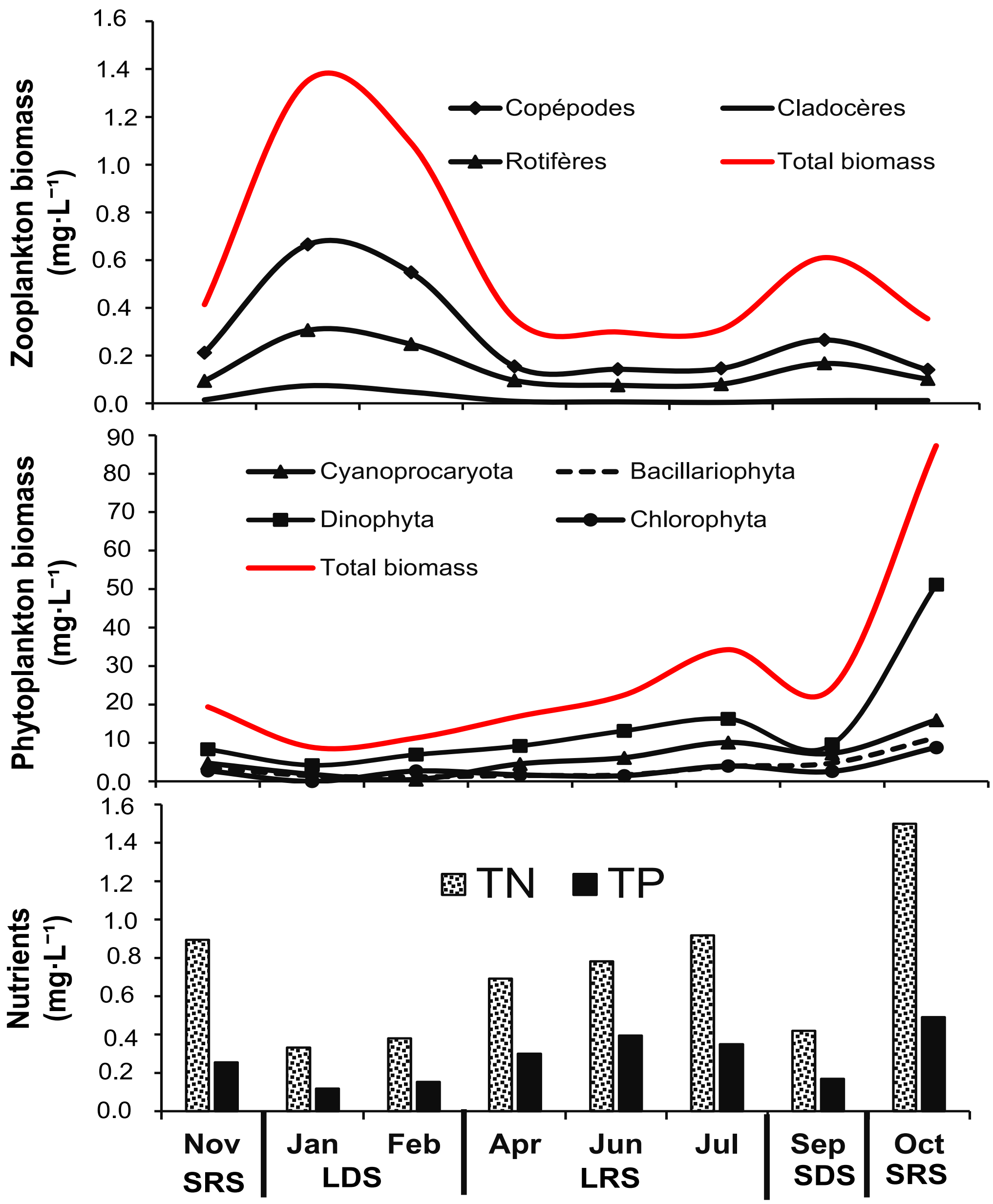

Figure 2 : Annual variations in nutrients (NT and PT), phytoplankton biomass, and zooplankton biomass sampled in Lake Taabo from November 2017 to October 2018: TN = Total Nitrogen; TP = Total Phosphorus; Jan=January; Feb= February, Apr= April, Jun= June, Jul= July, Sept= September, Oct= October, Nov= November; LDS = Long Dry Season ; LRS = Long Rainy Season , SDS = Short Dry Season ; SRS = Short Rainy Season

Trophic state in Taabo lake

Carlson Trophic State Index: Spatial and seasonal variation in the Carlson Trophic State Index (TSI) is shown in Figure 3. Maximal values were generally observed across all sites during the short rainy season, ranging from 77.81 at S4 to 87.41 at S2. In contrast, minimal values, ranging from 58.19 at S5 to 66.59 at S2, were recorded during the long dry season. However, no significant differences in TSI were detected among sites in Taabo Lake (Kruskal–Wallis test; $p > 0.05$). TSI values were significantly lower during the long dry season compared with the other seasons (Mann–Whitney test; $p = 0.001$).

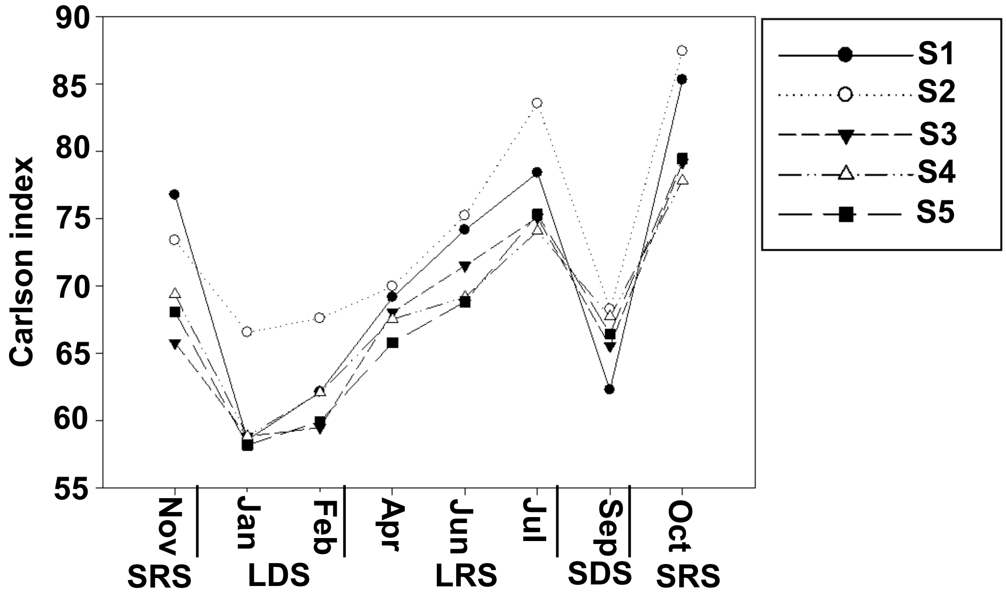

Figure 3 : Spatial and seasonal variations in Carlson's trophic index at different sampling sites (S1 - S5) on Lake Taabo from November 2017 to October 2018 (Côte d'Ivoire) : Jan=January; Feb= February, Apr= April, Jun= June, Jul= July, Sept= September, Oct= October, Nov= November; LDS = Long Dry Season ; LRS = Long Rainy Season , SDS = Short Dry Season ; SRS = Short Rainy Season;

Zooplankton Trophic State Index : Spatial and seasonal variation in the zooplankton trophic index (TSIzoo) is presented in Figure 4. TSIzoo values were higher during the short dry season (S4: 66.24) and lower during the short rainy season (S1: 52.87). The median values of the zooplanktonic trophic index recorded across sites and seasons ranged between 55 and 65. No significant differences were detected among S3, S4, and S5 (Mann–Whitney test; $p > 0.05$), while these stations differed significantly from S1 and S2 (Mann–Whitney test; $p = 0.05$). Zooplankton trophic index values were significantly higher during the dry seasons compared to the rainy seasons (Mann–Whitney test; $p = 0.006$).

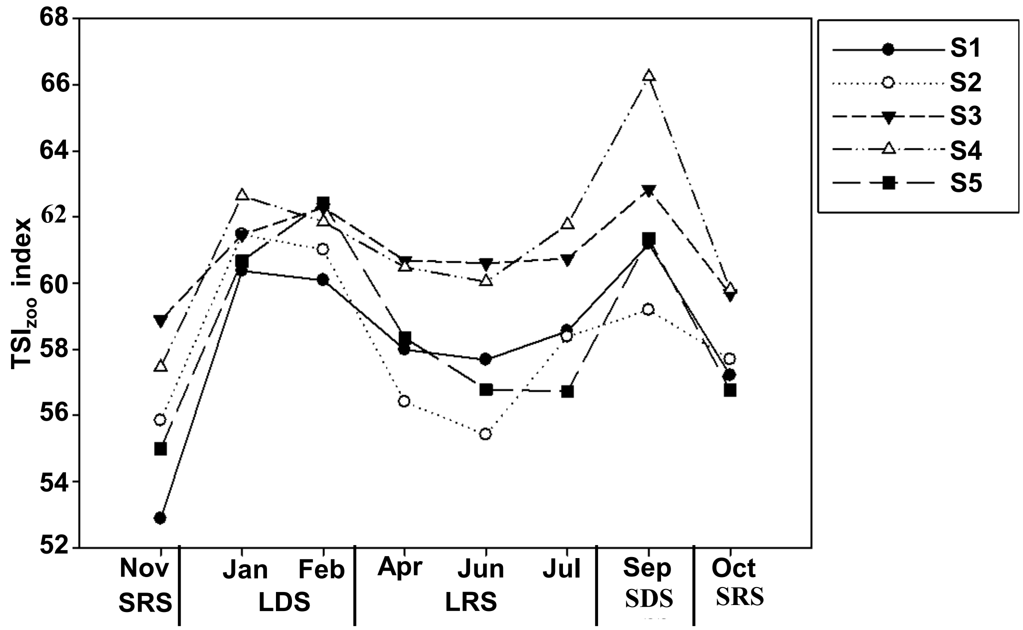

Figure 4 : Spatial and seasonal variations in the zooplankton trophic index (TSIzoo) at different sampling sites on Lake Taabo from November 2017 to October 2018 (Côte d'Ivoire): St1 - St5 = sampling sites; Jan=January; Feb= February, Apr= April, Jun= June, Jul= July, Sept= September, Oct= October, Nov= November; LDS = long dry season; LRS = long rainy season; SDS = short dry season; SRS = short rainy season

DISCUSSION

The planktonic food web of Taabo Lake exhibits a structure typical of eutrophic systems. The plankton community is characterised by a dominance of Dinophyta in the phytoplankton biomass and by the prevalence of small copepods (copepodites, *Thermocyclops* sp. and *Mesocyclops* sp.) in the zooplankton biomass, all of which are typical of turbid lakes subjected to strong predation pressure. According to Berthold *et al*. (2018) and Wang *et al*. (2022), planktonic food webs in eutrophic lakes are generally defined by the small size structure and specific composition of their communities. Carlson Index values exceeded 50 across all sites and sampling periods, indicating that the waters of Taabo Lake fall within the eutrophic category (TSI > 50). Moreover, the median values of the zooplanktonic trophic index recorded across sites and seasons ranged between 55 and 65. These values indicate that the waters of Taabo Lake are in a eutrophic state. Both the Carlson and zooplanktonic trophic indices corroborate the eutrophic condition previously reported by Anoh *et al*. (2018) and Kouassi *et al*. (2007). In this regard, land-use assessments by Anoh *et al*. (2018), as well as a Landsat image analysis conducted by Kouassi *et al*. (2007), revealed that Taabo Lake is affected by pronounced eutrophication, expressed through the continuous and progressive colonisation of the water surface by invasive aquatic plants. This eutrophic status results from numerous anthropogenic activities within the lake and its catchment, which have contributed to nutrient enrichment of the water. Our findings are consistent with those reported by Zhang *et al*. (2013) for Lake Diachi in China.

CONCLUSION AND APPLICATION OF RESULTS

This study demonstrates that Taabo Lake is consistently eutrophic, as evidenced by high plankton biomass and elevated Trophic State Index values across sites and seasons. The dominance of Dinophyta and copepod-rich zooplankton communities reflects strong nutrient enrichment, particularly during the rainy season, highlighting the influence of seasonal runoff and anthropogenic inputs. Based on these findings, several practical management actions are recommended. First, nutrient inputs should be reduced by promoting sustainable agricultural practices (e.g., controlled fertilizer use) and improving wastewater treatment in the watershed, especially during the rainy season when nutrient inflows are highest. Second, the establishment of vegetated buffer zones around the lake is essential to limit surface runoff and sediment transport. Third, regular monitoring programs integrating plankton biomass and trophic indices should be implemented as cost-effective bioindicators of water quality. Finally, raising awareness among local communities and strengthening environmental regulations will be crucial to ensure the sustainable management of the lake. These measures are necessary to prevent further eutrophication and avoid a shift toward hypereutrophic conditions, thereby preserving the ecological balance and long-term resilience of Taabo Lake.

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