Libyan Journal of Ecological & Environmental Sciences and Technology
(LJEEST)

LJEEST
ISSN: 2710-5237
www.srcest.org.ly/jou

DOI: https://doi.org/10.63359/ntqqjf58

Spatio-Temporal Distribution of Plankton in Waya Dam, Bauchi, Nigeria: An Ecological Assessment

Shamsudden Abdullahi*[1] Muhammad Nazir Abdulmalik[2] Stacey Jabeha Nzomo[3]

ARTICLE INFO

Vol. 8 No. 2 August, 2026

Pages (74- 79)

Article history:
Revised form 18 June 2026
Accepted 30 June 2026

Authors affiliation
1,3. School of Ecology and Environment Studies, Nalanda University, India
2. Department of Applied Biological Sciences, Federal Polytechnic Damaturu Yobe State, Nigeria.
Email IDs:
1.Shamsudden.sees23@nalandauniv.edu.in
2.Muhammadnazirabdulmalik@fedpodam.edu.ng
3. Staceyjabz@gmail.com

Keywords:
Temporal variation, plankton diversity, physiochemical parameters, freshwater ecology, Water Quality.

ABSTRACT

This study assessed the spatio-temporal distribution of plankton in Waya Dam, and examined its relationship with selected physiochemical characteristics of the reservoir. Samples were collected monthly from June to August (2021) using standard limnological procedures. Physiochemical parameters were analyzed using standard methods, while plankton samples were identified microscopically. Species diversity was evaluated using Shannon–Wiener and Simpson diversity indices.

The physiochemical parameters recorded during the study showed temporal variations, with mean temperature 26.0°C, DO 6.07mg/L, pH 6.9, E.C 0.11mS/cm, TDS 72.3 ppm, and turbidity 91 NTU. Most parameters were within recommended limits, although turbidity exceeded the WHO guideline value. A total of 89 plankton individuals belonging to 11 species and five major taxa were recorded. *Ochrophyta* was the dominant group, accounting for 54.55% of the species identified, while *Crucigenia* sp. (16.85%) and *Nitzschia longissima* (15.73%) were the most abundant species. Plankton abundance was highest in June (52 individuals) and lowest in July (17), indicating marked temporal variation in community structure. Species richness ranged from 9 to 11 species, while the Shannon–Wiener diversity index (H′), varied from 2.07 to 2.26 and Simpson's diversity index (D) from 0.86 to 0.89, indicating moderate diversity and low species dominance.

The findings suggest that Waya dam supports a moderately diverse and productive plankton community during the months of the study which was under generally favourable environmental conditions. During the study period, the dam exhibits characteristics of a relatively stable freshwater ecosystem capable of supporting aquatic life. However, the study was limited to only three months. Future research should include different seasons over long range of time. Continuous monitoring of physicochemical conditions and plankton communities is recommended to facilitate sustainable management and conservation of the dam.

التوزيع المكاني والزماني للعوالق في سد وايا، ولاية باوتشي، نيجيريا :تقييم بيئي

شمس الدين عبد الله[1]، محمد نذير عبد المالك[2]، ستايسي جابيها نزومو[3]

هدفت هذه الدراسة إلى تقييم التوزيع المكاني والزماني للعوالق في سد وايا، ودراسة علاقتها ببعض الخصائص الفيزيائية والكيميائية لمياه الخزان .جُمعت العينات شهريًا خلال الفترة من يونيو إلى أغسطس 2021باستخدام الطرق القياسية المعتمدة في علم البحيرات (Limnology).كما تم تحليل الخصائص الفيزيائية والكيميائية وفقًا للطرق القياسية، في حين جرى التعرف على عينات العوالق باستخدام الفحص المجهري .وتم تقييم التنوع الحيوي للعوالق باستخدام مؤشري شانون–وينر (Shannon–Wiener)وسيمبسون (Simpson)للتنوع.

أظهرت الخصائص الفيزيائية والكيميائية للمياه تباينًا زمنيًا خلال فترة الدراسة، حيث بلغ متوسط درجة الحرارة 26.0°م، والأكسجين الذائب 6.07ملغم/لتر، والأس الهيدروجيني 6.9 (pH)، والتوصيلية الكهربائية 0.11ملي سيمنز/سم، وإجمالي المواد الصلبة الذائبة 72.3جزءًا في المليون، بينما بلغت العكارة 91وحدة NTU. وكانت معظم هذه القيم ضمن الحدود الموصى بها، باستثناء العكارة التي تجاوزت القيمة الإرشادية الموصى بها من قبل منظمة الصحة العالمية.

تم تسجيل ما مجموعه **89 فردًا من العوالق** تنتمي إلى **11نوعًا** وخمس مجموعات تصنيفية رئيسية .وكانت شعبة ***Ochrophyta*** هي الأكثر سيادة، حيث مثلت **54.55٪** من الأنواع المسجلة، في حين كانت ***Crucigenia*** (16.85٪) و***Nitzschia longissima*** (15.73٪) أكثر الأنواع وفرة .وسُجلت أعلى كثافة للعوالق في شهر يونيو (52 فردًا)، بينما كانت أقل كثافة في شهر يوليو (17 فردًا)، مما يشير إلى وجود تباين زمني واضح في تركيب مجتمع العوالق . وتراوح الغنى النوعي بين **9و 11نوعًا**، بينما تراوح مؤشر شانون–وينر (H′) بين **2.07و2.26**، وتراوح مؤشر سيمبسون (D) بين **0.86و0.89**، مما يدل على وجود تنوع حيوي متوسط وانخفاض في سيادة الأنواع.

تشير نتائج الدراسة إلى أن سد وايا يدعم مجتمعًا عوالقيًا متوسط التنوع وعالي الإنتاجية خلال أشهر الدراسة، وذلك في ظل ظروف بيئية مواتية بصورة عامة .وخلال فترة الدراسة، أظهر السد خصائص نظام بيئي للمياه العذبة يتمتع بدرجة جيدة من الاستقرار، وقادر على دعم الحياة المائية .ومع ذلك، اقتصرت الدراسة على فترة زمنية بلغت ثلاثة أشهر فقط .لذا، توصي الدراسة بإجراء أبحاث مستقبلية تشمل مواسم مختلفة وتمتد على فترات زمنية أطول .كما يُوصى بالاستمرار في رصد الخصائص الفيزيائية والكيميائية للمياه ومجتمعات العوالق بصورة دورية، بما يسهم في الإدارة المستدامة والحفاظ على النظام البيئي لسد وايا.

INTRODUCTION

Phytoplankton are responsible for approximately half of global primary production and oxygen generation (Jahan, 2023). Moreover, they play a crucial role in driving biogeochemical cycles and nutrient recycling, not only within aquatic ecosystems but also across terrestrial environments. The health of aquatic ecosystems is a key indicator of the overall state of water bodies and their surrounding environments (Cao *et al*., 2021). phytoplankton can be also used as an indicator organism group for eutrophication control (Qu & Peng, 2025). They are distinguished from other aquatic organisms by their rapid growth rates, ease of identification, and relatively low research costs (Hu *et al*., 2025). The abundance, species composition, and diversity of phytoplankton communities are key indicators of the ecological health of aquatic systems. Assessing and understanding the health and quality of these ecosystems continues to be a major challenge in global research within this field. (Cao *et al*., 2021).

According to Naselli-Flores and Padisák (2022) phytoplankton also make significant contributions to climate regulation (regulating services), provide resources such as food, biofuels, pharmaceuticals, and genetic materials (provisioning services), and inspire art, craftsmanship, mythology, and scientific inquiry (cultural services), among many other functions. Consequently, phytoplankton can justifiably be regarded as fundamental engineers of the biosphere (Zhu *et al*., 2021).

Bampton, (2026) described dams as human-made structures constructed across rivers or streams to regulate and control water flow, forming reservoirs that serve multiple purposes, including flood mitigation, irrigation, potable water supply, and hydroelectric energy production. The construction of dams can alter water flow regimes, temperature patterns, and nutrient dynamics, thereby influencing phytoplankton communities and their ecological functions (Jahan, 2023; Bampton, (2026)). The condition of aquatic ecosystems, including phytoplankton populations, is closely connected to human health, as changes in these systems can affect water quality and, consequently public well-being (Naselli-Flores and Padisák, 2022). As a result, understanding the interactions between phytoplankton and dam-regulated environments is essential for effective water resource management and the maintenance of healthy aquatic ecosystems, ultimately supporting human health and sustainability. Therefore, this research was aimed to determine the diversity of planktons' species and how physiochemical parameters affects planktons over time at Waya Dam Ganjua LG, Bauchi state, Nigeria.

MATERIALS AND METHODS

STUDY AREA

Waya Dam is located in Ganjuwa Local Government Area of Bauchi State, Nigeria, approximately 25 km from Bauchi town (10°01′42″ N, 10°34′53″ E). The reservoir serves as a major source of potable water for domestic use, irrigation, and small-scale hydropower generation. It has a surface area of about 4.5 km² and a storage capacity of approximately 3,000,000 m³(UBRDA, 2026).

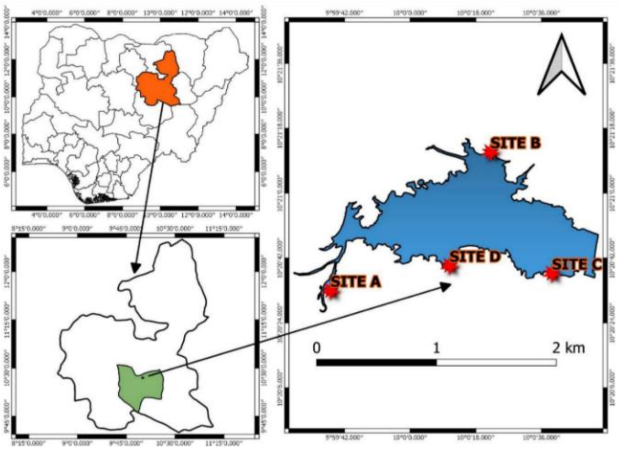

Figure 1: Location of Waya Dam, Ganjua Local Government, Bauchi State, Nigeria

COLLECTION OF WATER SAMPLE

Water samples were collected from four locations (Sites A, B, C, and D), as shown in Figures 1 and 2, during June, July, and August. Surface water temperature and pH were measured in situ using a HANNA pHep HI9810 meter. Other parameters, including dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), and turbidity, were analysed in the Civil Engineering Laboratory at Abubakar Tafawa Balewa University (ATBU), Bauchi, following standard procedures (APHA, 2012).

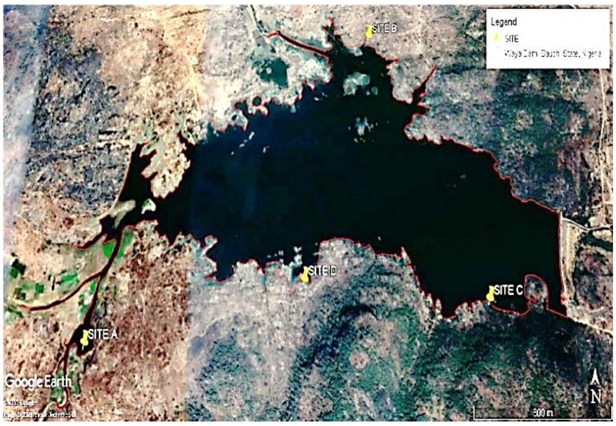

Figure 2: Satellite Map showing the Waya dam, Source: Google map data 2021

ANALYSIS OF PHYSIOCHEMICAL PARAMETERS

Physicochemical parameters of water were determined using standard methods. Temperature and pH were measured in situ using a portable HANNA pHep HI9810 meter, with pH calibrated using a pH 7 buffer solution prior to measurement. Dissolved oxygen (DO) was measured in the field using a calibrated HANNA HI 9831-5 oxygen meter. Water transparency and turbidity were determined using a HANNA turbidity/transparency meter, while electrical conductivity was analysed in the laboratory using a HANNA HI 9831-5 conductivity meter following sample collection. All measurements were taken after appropriate calibration, and values were recorded once stable readings were achieved.

ALGAL SAMPLES

The study was conducted between June and August 2021. Plankton samples (phytoplankton and zooplankton) were collected monthly between 09:00 and 10:00 h. Approximately 50-60L of surface water was collected and filtered through a plankton net with a 50 µm mesh size to concentrate planktonic organisms. The concentrated samples were transferred into labelled sample bottles and preserved immediately with formalin to achieve an approximate final concentration of 4% prior to laboratory analysis.

ANALYSIS OF ALGAL SAMPLES

a) IDENTIFICATION

Samples were allowed to settle for three days, after which the supernatant was carefully decanted. A drop of the settled sediment was placed on a clean, grease-free microscope slide and examined under a light microscope using appropriate objectives (×10, ×40, and ×100 where necessary). Identification was carried out following standard taxonomic procedures (Bellinger & Sigee, 2010; Stadtländer, 2012) and confirmed using relevant identification keys. Plankton were identified to species level where possible.

b) PLANKTON CELL COUNTS

Plankton enumeration was performed using a compound light microscope under varying magnifications depending on organism size. Larger planktonic forms were counted under low magnification, while smaller or more delicate taxa were examined under higher magnification. An oil immersion lens was used when necessary for very small algae. For samples with low plankton abundance, the entire counting chamber was examined to ensure accuracy. In cases of high density, representative subsamples (e.g., selected fields or diagonal transects of the chamber) were counted following the Utermöhl method to account for spatial distribution and ensure reliable estimates (Utermöhl, 1958; Nauwerck, 1963).

STATISTICAL ANALYSES

Diversity of plankton communities across the sampling months was assessed using the Shannon diversity index (H′) and Simpson diversity index (D). These indices were selected to provide complementary measures of species diversity, with Shannon index emphasizing species richness and evenness, while Simpson index gives greater weight to dominant species and overall community dominance structure. Physicochemical parameters were summarized using descriptive statistics (mean and standard deviation) to describe temporal variation across the study period. All statistical analyses were performed using Microsoft Excel for data organization and preliminary calculations, and R statistical software for diversity index computation and graphical visualization. Results were presented in tables and figures to illustrate spatial and temporal trends in plankton diversity and environmental variables.

The Shannon index was calculated as:

$$H' = -\Sigma (p_i \ln p_i)$$

Where p_i is the proportion of individuals of the *i*th species relative to the total number of individuals and H' represents Shanon index diversity.

The Simpson diversity index was computed as:

$$D = \Sigma ni(ni-1) / N(N-1)$$

Where **ni** is the number of individuals of each species, and **N** is the total number of individuals.

RESULTS AND DISCUSSION

Table (1): Composition and Distribution of Plankton in Waya Dam

The table below presents the composition, frequency, and percentage distribution of plankton species recorded between June and August. A total of 11 species belonging to 5 taxa were identified, with marked temporal variation in abundance. The highest total frequency was recorded in June 52(58%), followed by August 20 (23%), while July showed the lowest abundance 17(19%). Among the species, *Nitzschia longissima* and *Crucigenia* were the most dominant, contributing 14 (15.73%) and 15 (16.85%) individuals, respectively, whereas *Chaetophora* showed the least occurrence 1 (1.12%). These variations indicate shifts in plankton community structure across the sampling period.

Table (1): Composition and Distribution of Plankton in Waya dam

S/N	Plankton's		Frequency				Percentage (%)
	Division	Taxon	June	July	August	Total	
1	*Ochrophyta*	*Nitzchia longissima*	7	4	3	14	15.73
2	*Chlorophyta*	*Crucigenia* sp.	8	3	4	15	16.85
3	*Ochrophyta*	*Triceratium reticulatum*	5	1	2	8	8.99
4	*Ochrophyta*	*Eucampia zoodiacus*	4	1	3	8	8.99
5	*Bacillariopyta*	*Proboscia* sp.	7	2	2	11	12.36
6	*Dinoflagellata*	*Amphidinium* sp.	4	2	1	7	7.87
7	*Ochrophyta*	*Erataulina bergonii*	3	1	1	5	5.62
8	*Chlorophyta*	*Chaetophora* sp.	1	0	0	1	1.12
9	*Cyanophyta*	*Spirulina* sp.	5	2	1	8	8.99
10	*Ciliophora*	*Ciliates*	7	1	1	9	10.11
11	*Dinoflagellata*	*Noctiluca* sp.	1	0	2	3	3.37
	Total		**52**	**17**	**20**	**89**	**100**

The result of the study reveals that the plankton community of Waya Dam comprised of 11 species belonging to six major taxa (Table 1). *Ochrophyta* was the dominant taxon having 54.55% of the total species recorded, while *Crucigenia* (16.85%) and *Nitzschia longissima* (15.73%) were the most abundant species. The dominance of phytoplankton groups observed is consistent with findings from Nigerian freshwater ecosystems and research of Akindele & Olutona (2017) in Osun River (Nigeria) where phytoplankton consist of a major component of aquatic productivity. These findings also align with result of Adebayo *et al*. (2021), studies on Opa Reservoir in southwestern Nigeria reported a predominance of phytoplankton species, particularly *Bacillariophyta* and other algal groups, which were attributed to favourable environmental conditions and nutrient availability. *Bacillariophyta*, *Ochrophyta* and other algal groups have similarly been reported as the dominant groups in different countries and continents of the world (Tavernini *et al*., 2011; Wu *et al*., 2012; Peresin *et al*., 2014, and Akindele & Olutona, 2017).

A total of 89 plankton individuals were recorded with June accounting for the highest abundance (52 individuals), followed by August (20) and July (17). The higher abundance recorded in June might be due to favourable environmental conditions that promote primary productivity. Similar seasonal fluctuations have been reported by Suleiman *et al*. (2021) in Ajiwa Reservoir, Katsina State, where plankton assemblages vary by seasonal changes and variations in physiochemical parameters. This observation agrees with reports from Eko-Nde Reservoir, Osun State, where phytoplankton diversity was linked to water quality characteristics and ecosystem productivity (Akinyemi *et al*., 2022). The low occurrence of species such as *Chaetophora* (1.12%) and *Noctiluca* (3.37%) may indicate limited ecological tolerance or competition with more dominant species (Adebayo *et al*., 2021).

Table (2): Diversity of Plankton using Shannon–Wiener diversity index (H′) and Simpson's diversity index (D),

The diversity and structure of plankton communities in the study area were assessed using species richness (S), Shannon–Wiener diversity index (H′), Simpson's diversity index (D), and dominance (1−D). As shown in Table 2, June recorded the highest abundance (N = 52) and species richness (S = 11), with a Shannon diversity value of H′ = 2.26 and D = 0.89 and a relatively low dominance value (1−D = 0.11). In July, the lowest abundance (N = 17) and species richness (S = 9) were observed, alongside the lowest Shannon diversity (H′ = 2.07), D = 0.86; and comparatively higher dominance (1−D = 0.14). In general, the diversity index for all the months were found to be H′ = 2.2 indicating moderate plankton diversity in Waya Dam.

Table (2): Diversity of Plankton using Shannon–Wiener diversity index (H′) and Simpson's diversity index (D),

Month	N	S	H′	D	1−D
June	52	11	2.26	0.89	0.11
July	17	9	2.07	0.86	0.14
August	20	10	2.18	0.88	0.12

The diversity indices observed in Waya Dam suggested a moderately diverse and relatively stable plankton community for the duration of the study. June had the greatest abundance (N = 52), species richness (S = 11) and Shannon–Wiener diversity index value (H′ = 2.26), suggesting more suitable environmental conditions for plankton growth, less volume of water and a more heterogeneous community structure (Adesakin *et al*., 2017). On the contrary, July revealed the lowest abundance (N = 17), species richness S (= 9) and Shannon diversity H′ (= 2.07) highlighting a minor decrease in community complexity probably due to low temperature, low dissolved oxygen, high water volume in the Dam and low velocity. Simpson’s diversity index was high throughout the study (D = 0.86–0.89). The consistently high values of species diversity, in combination with low dominance values (0.11–0.14), indicate that no one species overwhelmingly dominated the plankton assemblage. With the mean Shannon diversity of H′ = 2.2 which indicates a moderate plankton diversity and more equitably balance community in Waya Dam; More similar patterns of diversity values ranging from 2 to 3 have also been reported for other Nigerian freshwater ecosystems such as lakes and rivers, which are generally associated with productive stable aquatic environments in moderate levels (Adebayo *et al*., 2021; Suleiman *et al*., 2021; & Akinyemi *et al*., 2022; Orie, 2017).

Table (3): Physiochemical Water Parameters

The physiochemical parameters of Waya Dam are presented in Table 3. Variations were observed among the parameters during the sampling period (June–August). Water temperature ranged from 23.5–27.3 °C, with a mean value of 26.0 °C. Electrical conductivity varied from 0.08–0.13 mS/cm, while pH ranged from 6.5–7.2, indicating near-neutral conditions throughout the study period. Total dissolved solids ranged from 55–100 ppm, with a mean value of 72.3 ppm. Turbidity showed considerable variation (17–89 NTU), likely due to increased surface runoff during the rainy season. Generally, higher physiochemical values were recorded in June compared to the other sampling months. Figure 3 shows the monthly variation of the physiochemical parameters from June to August.

Table (3): Physiochemical Parameters

Parameters	Months			Mean Value ± SD (n=3)	WHO Std
	June	July	August		
Temperature (°C)	27.3	27.2	23.5	26.0 ± 2.17	<30
E.C (mS/cm)	0.13	0.08	0.12	0.11 ± 0.03	1000
DO (mg/L)	6.1	5.3	6.8	6.07 ± 0.75	>4
TDS (ppm)	100	62	55	72.3 ± 24.21	<500
pH	7.2	7.0	6.5	6.9 ± 0.36	6-8
Turbidity (NTU)	17	167	89	91 ± 75.02	< 5

The moderate plankton diversity recorded in Waya Dam could be the result of favourable physiochemical factors and conditions at the time of this study. Water temperature, pH and dissolved oxygen were all within ranges considered acceptable for plankton development according to WHO which will sustain the diverse phytoplankton community observed within the reservoir (Yang *et al*., 2020; Gao, *et al*., 2019).

CONCLUSION AND FUTURE DIRECTIONS

The current study showed that Waya Dam harbours a relatively diverse and productive plankton community with 11 species in total divided into five major taxa. The most abundant taxonomic group was *Ochrophyta*, and the most abundant species were *Crucigenia* sp. and *Nitzschia longissima*. Moreover, the moderate Shannon diversity index (H′ = 2.07–2.26) and high Simpson diversity values (0.86–0.89) suggest that a stable plankton assemblage of low species dominance has developed. The physiochemical characteristics of the reservoir during the time of the study were within ranges determinant for aquatic life generally and probably promoted plankton diversity and abundance. Based on these findings it was concluded that Waya Dam is in a fairly good ecological state and has the potential to sustain aquatic productivity during rainy season.

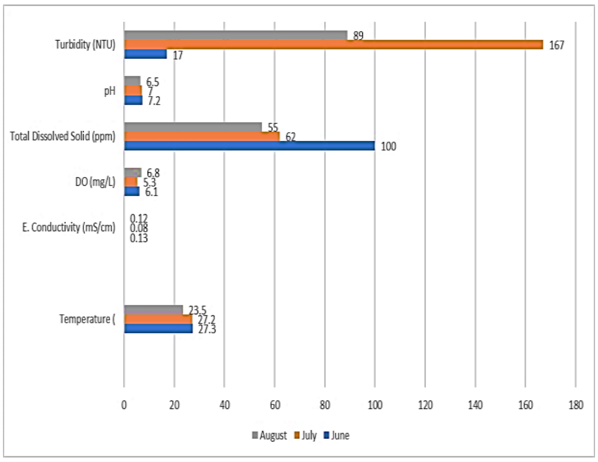

Figure 3: Physiochemical parameters of Waya Dam

However, the research was only limited to three months and one season. Future research should include different seasons (wet and dry season) and a very long period of research. Continuous monitoring of both biological and physicochemical parameters can facilitate detection of environmental changes that may result from and assistance in decision-making for reservoir management.

REFERENCES

Adebayo, A. T., Adewole, H. A., Akindele, E. O., & Olaleye, V. F. (2021). Planktonic flora and fauna of Opa Reservoir wetlands, Obafemi Awolowo University, Ile-Ife, Nigeria. *The Journal of Basic and Applied Zoology*, *82*(1). https://doi.org/10.1186/s41936-021-00237-8

Akindele, E. O., & Olutona, G. O. (2017). Water quality and biodiversity of potamoplankton in an African sacred grove and world heritage site. *Zoology and Ecology*, *27*(3–4), 292–303. https://doi.org/10.1080/21658005.2017.1357290

Akinyemi, S., Chia, M., Jimoh, M., Ibrahim Okpanachi, & Dolapo Oyeleke. (2022). An investigation of physicochemical parameters and phytoplankton community structure of eko-nde reservoir in Osun State, Nigeria. *FUDMA Journal of Sciences*, *6*(1), 44–53. https://doi.org/10.33003/fjs-2022-0601-823

Bampton, M. (2026). Dams and their reservoirs. *Encyclopedia of Earth Science*, 110–111. https://doi.org/10.1007/1-4020-4494-1_70

Cao, H., Han, L., Liu, Z., & Li, L. (2021). Monitoring and driving force analysis of spatial and temporal change of water area of Hongjiannao Lake from 1973 to 2019. *Ecological Informatics*, *61*, 101230. https://doi.org/10.1016/j.ecoinf.2021.101230

Gao, Y., & HU WG, Z. Y. (2019). Phytoplankton community and trophical status in Moguhu Reservoir. *Journal of Dalian Ocean University*, *34*(1), 126-132. https://doi.org/10.16535/j.cnki.dlhyxb.2019.01.018

Hu, T., Hu, C., Olena, B., Xie, C., Wei, J., Sun, J., Thomas, H., & Wang, C. (2025). Phytoplankton similarity indices as ecological metrics in a fragmented river system. *Hydrobiologia*, *853*(6), 1697–1712. https://doi.org/10.1007/s10750-025-06022-w

Jahan, S. (2023, July). *The Role of Phytoplanktons in the Environment and in Human Life, a Review*. ResearchGate; College of Science, University of Basrah. https://www.researchgate.net/publication/377163683_The_Role_of_Phytoplanktons_in_the_Environment_and_in_Human_Life_a_Review

Naselli-Flores, L., & Padisák, J. (2022). Ecosystem services provided by marine and freshwater phytoplankton. *Hydrobiologia*, *850*, 2691–2706. https://doi.org/10.1007/s10750-022-04795-y

Orie, E. G. (2017). Sustainable wetlands and biodiversity conservation: Nigeria's Lagos Lagoon in focus. In *Biodiversity* (pp. 11-35). Routledge India.

Peresin, D., Torgan, L. C., Schulz, U. H., & Crossetti, L. O. (2014). Structure of potamoplankton along a gradient of preservation of riparian vegetation in subtropical streams. *Anais Da Academia Brasileira de Ciencias*, *86*(2), 841–853. https://pubmed.ncbi.nlm.nih.gov/30514012/

Qu, J., & Peng, J. (2025). *Significance and Enlightenment of Implementing Water Ecological Assessment*. 100002–100002. https://doi.org/10.1016/j.wateco.2025.100002

Stadtländer, C. T. K.-H. . (2012). E. G. Bellinger, D. C. Sigee (2010). Freshwater Algae: Identification and Use as Bioindicators. *Journal of Applied Phycology*, *25*(4), 1265–1266. https://doi.org/10.1007/s10811-012-9926-x

Suleiman, U. F., Ibrahim, S., Isyaku, H. I., Nabila, T. I., Amir, A., Nadede, A. S., & Bello, L. (2021). effects of environmental parameters on plankton assemblage in Ajiwa reservoir, Katsina State, Nigeria. *FUDMA Journal of Sciences*, *5*(1), 118–125. https://doi.org/10.33003/fjs-2021-0501-684

Taiwo, A. A., Adebukola, A. A., Adedeji, I. A., & Yetunde, F. T. (2017). Effect of discharges from re-channeled rivers and municipal runoff on water quality of Opa reservoir, Ile-Ife, Southwest Nigeria. *African Journal of Environmental Science and Technology*, *11*(1), 56–70. https://doi.org/10.5897/ajest2016.2086

Tavernini, S., Pierobon, E., & Viaroli, P. (2011). Physical factors and dissolved reactive silica affect phytoplankton community structure and dynamics in a lowland eutrophic river (Po river, Italy). *Hydrobiologia*, *669*(1), 213–225. https://doi.org/10.1007/s10750-011-0688-2

UBRDA. (2026). *Upper Benue River Basin Development Authority*. Ubrbda.gov.ng. https://www.ubrbda.gov.ng/wayadam.php

Wu, N., Schmalz, B., & Fohrer, N. (2011). Development and testing of a phytoplankton index of biotic integrity (P-IBI) for a German lowland river. *Ecological Indicators*, *13*(1), 158–167. https://doi.org/10.1016/j.ecolind.2011.05.022

Yang, W., Yan, J., Wang, Y., Zhang, B.-T., & Wang, H. (2020). Seasonal variation of aquatic macrophytes and its relationship with environmental factors in Baiyangdian Lake, China. *Science of the Total Environment*, *708*, 135112. https://doi.org/10.1016/j.scitotenv.2019.135112

Zhu, H., Liu, X.-J., & Cheng, S. (2021). Phytoplankton community structure and water quality assessment in an ecological restoration area of Baiyangdian Lake, China. *International Journal of Environmental Science and Technology*, *18*(6), 1529–1536. https://doi.org/10.1007/s13762-020-02907-6