Spatio-Temporal Distribution and Abundance of Plankton in Relation to Physico-Chemical Parameters of Kafin Gana Dam, Jigawa State

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Abstract
The study determined the seasonal and spatial variation in the species distribution and abundance of phytoplankton and zooplankton in Kafin Gana Dam, Jigawa State. Sampling was conducted from March to August 2024, covering the dry and rainy seasons. Plankton were collected using planktonic net of 55µm mesh size by hauling horizontally for five meters. The collected samples were preserved in 4% formalin and transported to laboratory for counting and identification. One-way analysis of variance (ANOVA) was used to compare seasonal variations and Pearson's correlation was applied to determine the relationships between various parameters. Results indicated significant seasonal and spatial variations in plankton abundance, driven by changes in temperature, pH, turbidity, and dissolved oxygen. A total of 834 phytoplanktons from four phyla namely. Chlorophycaea, Bacilliorophycaea, Euglenophycaea and Cyanophycaea were encountered in the study. Zooplankton consisting a total of 230 species belonging to three major taxonomic groups namely Cladoceran, Copepoda and Rotifera were identified. The dry season variables were more favourable to plankton survival. Site B consistently supported the highest plankton abundance, while site A had the lowest overall count. The findings highlight the critical need for sustainable dam management, periodic water quality monitoring, and pollution control measures to ensure the dam's ecological balance and utility.

Keywords: *Plankton, Spatial abundance, Temporal variation, Physico-chemical parameters, Kafin Gana Dam.*

Introduction

Plankton, derived from the Greek word planktos meaning "wanderer," are microscopic organisms that drift with water currents and play critical roles in aquatic ecosystems (Fathibi, 2021; Chakaborty, 2023). As primary producers, phytoplankton form the foundation of aquatic food webs, converting solar energy into biomass that supports higher trophic levels, including zooplankton, fish, and other aquatic organisms (Wang et al 2024). Zooplankton, on the other hand, act as primary consumers, feeding on phytoplankton and transferring energy to secondary and tertiary consumers in the food chain. Together, phytoplankton and zooplankton are essential for nutrient cycling, ecosystem functioning, and sustaining biodiversity (Bakhtiyar 2020; Botterell 2023).

The distribution and abundance of plankton are influenced by various environmental factors, including physico-chemical parameters and the presence of heavy metals (Benmatouk 2024). These factors can cause significant spatial and temporal variations in plankton communities, which, in turn, impact the productivity and health of aquatic ecosystems.

Globally, water bodies face increasing pressure from anthropogenic activities, including agriculture, urbanization, and industrialization (Ogidi, and Akpan, 2022; Mishra 2023). These activities contribute to pollution and eutrophication, which alter the water quality and disrupt the natural balance of aquatic ecosystems (Bashir *et al* 2020).

In Nigeria, while several studies have focused on plankton ecology in large water bodies such as lakes and rivers, smaller reservoirs and dams, which are vital for local communities, have received limited attention (Anyanwu et al 2021). These smaller water bodies, like Kafin Gana Dam in Jigawa State, Nigeria, are essential for irrigation, fishing, and domestic water supply, but they remain vulnerable to pollution and ecological degradation.

Kafin Gana Dam, situated in the Sudan savanna ecological zone, is a critical water resource for nearby communities. The dam's water quality is influenced by runoff from agricultural fields, domestic waste, and other human activities, making it an important case study for understanding the dynamics of plankton abundance in relation to environmental factors. Despite its ecological and economic significance, little is known about the spatial and temporal variations of plankton in this dam, particularly in relation to physico-chemical parameters and heavy metal concentrations.

MATERIALS AND METHODS

Study Area

Kafin Gana Dam is located in Birnin Kudu, Jigawa State, Nigeria, between Latitudes 11°20′N and 11°39′N and Longitudes 9°10′E and 9°40′E. It covers a surface area of 121 ha and lies within the Sudan savanna ecological zone. The dam was constructed primarily for irrigation, with fishing and water supply as secondary uses.

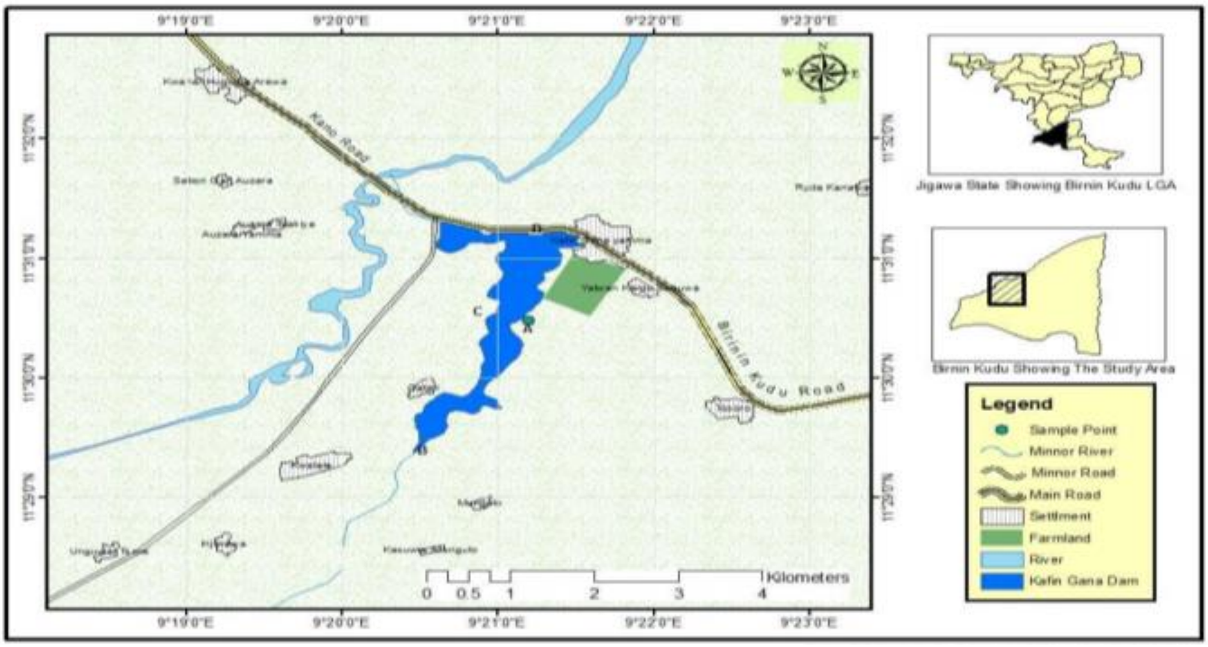

Figure 1: Map showing Kafin Gana Dam in Birnin kudu LGA Jigawa State

Sampling stations

Four sampling sites were chosen for the purpose of this study, designated as A, B, C, and D based on the ecological setting of the sampling area. Site '**A**' being located at the southern part of the dam, happened to be shallow and characterized with irrigational activities during dry season and human activities. As such, vegetation might be considered being subjected to chemicals input. Whereas site **'B'** contains less human activities apart from fishing, site '**C**' provides avenue for water entrance in to the dam and that site **'D**' is dominated with human activities including but not limited to washing and bathing.

Sampling techniques

Monthly sampling was carried out from March to August 2024 towards the end of every month between 9:00 am to 12:30 pm every sampling day, encompassing both the dry and rainy seasons.

Data Collection

Temperature was measured in situ using a calibrated thermometer or a multiparameter probe to ensure immediate and accurate readings. pH was determined using a pH meter, calibrated with standard buffer solutions (pH 4.0, 7.0, and 10.0) before measurement. Dissolved Oxygen (DO) were measured using the Winkler titration method, which involves chemical fixation of oxygen followed by titration to determine concentration. Turbidity was assessed using a turbidimeter, where water samples are analyzed for light scattering caused by suspended particles. Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were measured with portable conductivity meters, correlating electrical conductance with ion concentrations.

Plankton Sampling

Phytoplankton and zooplankton were collected using a 55 µm plankton net. The collected samples were preserved in 4% formalin and transported to the Federal university Dutse, Fishery and aquaculture laboratory for counting and identified to the genus level using standard taxonomic keys.

Data Analysis

Descriptive and inferential statistics, including one way ANOVA and Pearson correlation, were used to assess spatial and temporal variations and their relationships with environmental parameters. All statistical analyses were conducted in SPSS v.25, with significance set at $p < 0.05$.

RESULTS

Physico-chemical Parameters

Temperature: Ranged from 25°C (rainy season) to 32°C (dry season). The highest temperature value is within the normal range for optimal growth of phytoplankton. This is in accordance with the statement (Sarker 2020, Sheehan 2020), that in general the optimal temperature for the development of plankton is 20.00 – 30.00 °C. Water temperature influences the metabolic rates of aquatic organisms and the solubility of gases like oxygen (Boyd, 2020; Verberk 2020, Tari 2024). Water temperature is an important factor in biotic and abiotic processes; affecting the amount of dissolved matter, organic/inorganic pollutants, nutrients, micro bacterial concentrations, and the behavior of organisms in the aquatic environment (Emeka *et al.;* 2021, Okeke *et al* 2022). According to (Diana *et al*.; 2021), generally phytoplankton can develop well at the temperatures of 20–30°C and can affect the distribution, composition and phytoplankton abundance in the waters.

pH: Neutral to slightly alkaline (6.8–8.3), with higher values in the rainy season. The recorded pH (6.52–7.55) complies with both WHO/NESREA standards acceptable range of 6.5–8.5, suggesting the water is neither too acidic nor too alkaline for most uses. Aquatic organisms are extreme sensitivity to pH levels below 5; death could occur at such low pH values (Emeka *et al.;* 2021). A pH range near neutral (6.5–7.5) is ideal for most aquatic life, suggesting the water is suitable for sustaining ecosystems (Abdel-Satar 2024).

The TDS values (79.2–96.0 mg/L) are significantly below the WHO permissible limit of 500 mg/L (recommended for drinking water), indicating excellent water quality in terms of dissolved solids. TDS affects water clarity and habitat suitability (Mishra, 2023). Values here indicate relatively clean water.

Dissolved oxygen (DO): Higher at the inflow zone during the rainy season (6.2 mg/L). Dissolved oxygen (DO) has been described as one of the major parameters used in the evaluation of water quality and the level is necessary to support aquatic biodiversity. (Emeka *et al.;* 2021) reported that dissolved oxygen is essential to support aquatic life and good fish production at levels >5 mg/L.

The standard limit (5 NTU) was exceeded by some values recorded in all the stations attributable to the cumulative effect of receding flood and anthropogenic activities. This increase is likely due to sediment inflow during the rainy season. This could be due to run-off from the catchment area during rainfalls which carry debris, pollutants and sediment into the waterways. Elevated turbidity may affect light penetration and photosynthesis in aquatic systems (Boyd, 2022).

Nitrate (NO3$^-$) (mg/L) Nitrate levels increase significantly across months, peaking in August at 3.36 mg/L (P=0.021). This rise could result from agricultural runoff or natural decomposition. The nitrate values (1.07–3.36 mg/L) are well within the permissible limit, indicating no significant pollution from agricultural or organic sources.

Table 1: PHYSICOCHEMICAL PARAMETERS OF WATER IN KAFIN GANA DAM

	MONTHS						
PAR.	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG.**	**P-Val.**
TEMP.(°C)	30.75±0.95^{a}	30.50±0.57^{ab}	30.25±0.50^{b}	29.25±0.25^{bb}	28.0±0.40^{c}	26.0±0.40^{d}	0.001
pH	7.55±0.36^{a}	7.10±0.04^{ab}	6.52±0.04^{d}	6.60±0.04^{c}	7.10±0.04^{ab}	7.07±0.07^{b}	0.002
T.D.S.(mg/L)	79.2±4.34^{d}	91.50±4.97^{ab}	96.00±3.67^{a}	91.00±0.91^{b}	88.00±0.40^{c}	88.25±0.62^{bb}	0.031
E.C.(µS/cm)	94.25±2.01^{ab}	96.50±0.50^{a}	87.50±1.89^{bb}	81.50±2.21^{bb}	79.00±1.29^{c}	47.50±4.78^{d}	0.001
D.O.(mg/L)	5.45±0.12^{d}	6.65±0.33^{c}	7.10±0.90^{b}	6.7±0.64^{bb}	7.75±0.44^{ab}	8.22±0.12^{a}	0.020
Turb.(NUT)	14.33±0.07^{d}	14.4±0.14c	14.99±0.06^{bb}	16.26±0.13^{b}	24.15±13^{ab}	25.67±023^{a}	0.001
C(mg/L)	21.20±2.29^{b}	48.03±7.70^{ab}	60.83±4.58^{a}	15.89±0.52^{bb}	12.70±0.66^{d}	15.50±0.40^{c}	0.001
Mg (mg/L)	0.7.±0.25^{bb}	4.92±3.09^{ab}	0.57±0.15^{c}	0.41±0.18^{d}	1.62±1.27^{b}	5.05±0.08^{a}	0.104
Na (mg/L)	4.69±0.21^{c}	5.11±0.32^{bb}	5.12±0.16^{b}	4.64±0.23^{d}	5.63±0.73^{a}	5.14±0.11^{ab}	0.445
K (mg/L)	9.38±0.33^{a}	6.74±2.11^{b}	3.54±0.18^{c}	5.55±0.80^{bb}	5.36±1.05^{d}	8.19±099^{ab}	0.001
NO_3^-(mg/L)	1.07±0.03^{d}	2.01±0.98^{b}	1.65±0.15^{c}	2.01±0.34^{b}	2.92±0.17^{ab}	3.36±0.16^{a}	0.021

abcd: Means on the same row having different superscripts are significantly different = significant at P<0.05; and NS = not significant at P>0.05, ±SEM=Standard Error of means Temp. is Temperature, TDS is Total Dissolved Solids, E.C. is Electrical Conductivity, D.O. is Dissolved Oxygen, Turb. is Turbidity, C is Calcium, Mg is Magnesium, Na is Sodium, K is Potassium, NO3$^-$ is Nitrate

Spatial abundance of plankton

Station **B** had the highest percentage abundance for all the phytoplankton groups (Figure 4.14). Station B (28.18%) had the highest percentage abundance of all the phytoplankton, while Station A (22.6%) had the lowest value (Table 2). The total percentage abundance of phytoplankton at Station **B** was significantly higher than the other stations.

Table 2: Spatial abundance of phytoplankton according to Station

FAMILY	SPECIE	SITE A	SITE B	SITE C	SITE D	TOTAL	%
Chlorophycaea	Chlamydomonas	16	31	17	20	84	10.1
	Closterium	9	3	8	6	26	3.1
	Spirogyra	24	11	21	24	80	9.6
	Volvox	13	21	10	13	57	6.8
	Oocystis	11	8	11	6	36	4.3
	Casmerium	6	6	5	11	28	3.4
	Eastrum	5	10	1	5	21	2.5
	Total	84	90	73	85	332	39.8
Cyanphycaea	Anabaena	10	17	13	16	56	6.7
	Microsystis	7	13	7	4	31	3.7
	Oscillatoria	12	11	11	8	42	5.0
	Athrospira	2	5	4	6	17	2.0
	Total	**31**	**46**	**35**	**34**	**146**	**17.5**

All the groups had highest abundance of Zooplankton in Station **B**. Rotifera (8.98%) and Cladocera (10.40%), had their lowest percentage abundance at Station **C** while Copepoda (10.01%) had lowest abundance in Station **A**. Station **A** had the lowest abundance of total zooplankton (Table 3)

Table 3: Spatial abundance of zooplanktons according to Station

FAMILY	SPECIE	SITE A	SITE B	SITE C	D	TOTAL	%
Chladocera	Naupli	---	6	3	5	14	6.1
	Moina	6	10	5	5	26	11.3
	Bosmina	6	1	4	5	16	7.0
	Diaphanosona	5	10	3	3	21	9.1
	Total	17	27	15	18	77	33.5
Copepoda	Copepodite	2	7	5	5	18	8.3
	Cyclopodite	---	4	2	6	12	5.2
	Calanoid	5	5	4	4	18	7.8
	Total	7	16	11	15	49	21.3
Rotifera	Cylindrical	4	9	6	6	25	10.9
	Filina	3	5	5	7	20	8.7
	Lecane	7	8	4	4	23	10
	Karatella	2	6	4	6	18	7.9
	Trichocera	8	5	3	1	16	7.6
	Total	**24**	**33**	**23**	**24**	**104**	45.2
TOTAL	**Grand Total**	**47**	**76**	**50**	**57**	**230**	**100**

4.1.4.2 Temporal Abundance of Plankton

Higher seasonal abundance of the total phytoplankton was recorded in the dry season (56.35%) than rainy season (43.65%). The higher percentage of temporal abundance in the dry season for Chlorophyceae, Euglenophyceae, Bacillariophyceae and Cyanophyceae were (21.6%), (10.0%), (14.7%) and (9.7%) while their lower percentage of temporal abundance in rainy season were (17.7%), (7.0%) (11.4%) and (8.0%) respectively.

The highest monthly abundance for Bacillariophyceae, 61 was recorded in March, 2024 and the lowest, 28 was recorded in August, 2024. The highest temporal abundance of Chlorophyceae 63 was in March, 2024, while the lowest 44 was in August, 2024. Monthly abundance of Cyanophyceae was highest (29 each) in March and June, 2024 and the lowest 44 in August, 2024. Euglenophyceae had higher monthly temporal abundance in the March 31 and lowest (15) was in July.

Table 4: Spatial abundance of planktons according to Station

FAMILY	SPECIE	SITE A	SITE B	SITE C	D	TOTAL	%
Phtoplankton							
Euglenophycaea	Euglena	16	27	18	20	81	9.7
	Phacus	8	14	12	14	48	5.8
	Stormbonas	3	3	2	4	12	1.4
	Total	27	44	32	38	141	16.9
Chlorophycaea	Chlamydomonas	16	31	17	20	84	10.1
	Closterium	9	3	8	6	26	3.1
	Spirogyra	24	11	21	24	80	9.6
	Volvox	13	21	10	13	57	6.8
	Oocystis	11	8	11	6	36	4.3
	Casmerium	6	6	5	11	28	3.4
	Eastrum	5	10	1	5	21	2.5
	Total	84	90	73	85	332	39.8
Cyanphycaea	Anabaena	10	17	13	16	56	6.7
	Microsystis	7	13	7	4	31	3.7
	Oscillatoria	12	11	11	8	42	5.0
	Athrospira	2	5	4	6	17	2.0
	Total	31	46	35	34	146	17.5
Bacillariophycaea	Crycotella	9	15	16	14	54	6.5
	Pinularia	7	8	11	8	34	4.0
	Aulascosera	9	16	10	8	43	5.1
	Naviculla	9	10	12	14	45	5.4
	Gyrogsima	5	1	2	1	9	1.1
	Cynatoplaura	---	3	3	---	6	0.7
	Asterionella	8	7	2	7	24	2.9
	Total	47	60	56	52	215	25.7
	Grand Total	**189**	**240**	**196**	**209**	**834**	**100**

Higher seasonal abundance of Zooplankon was recorded in the dry. A total abundance of 145 (63.1%) of zooplankton was recorded in the dry season, while a total of 85 (36.9%) was recorded in the rainy season (Table 4).

Rotifera had the highest abundance 22 (9.6%) in May, 2024, while the lowest 9 (3.9%) was recorded in August, 2024 (Figure 4.20). Cladocera had the highest abundance 18 (7.8%) in March, 2024, while the lowest 7 (3.0) was in August, 2024. The highest abundance 11 (4.8% each) of Copepoda was recorded in March, April and May 2024, while the lowest value 4 (1.7%) was in August. The high abundance of plankton during the dry season agrees with Adamu *et al.;* (2021) in Dangana lake Lapai, Niger State, Obiuto *et al.;* (2024) in Abia, Niger Delta, Tusayi *et al.;* (2020) in Dadin Kowa dam, Gombe State, Suleiman *et al.;* (2021) in Ajiwa reservoir Katsina, Emeka *et al.;* (2021) in Eme river, Ummahia and Bamaiyi *et al.;* (2021) in ABU Zaria. On contrary, the finding is not in tandem with the findings of Hameed *et al.*, (2019) in Southwestern Nigeria, Akinyemi *et al.;* (2022) in Eko-Nde reserviour Osun, and Adedeji (2020) of OPA Reservoir, Ile Ife, Nigeria. The dry season supported a higher overall plankton abundance, likely due to factors such as stable water levels, reduced turbidity, and higher nutrient availability. These conditions provide a conducive environment for both phytoplankton and zooplankton growth. The dry season's stable conditions favor increased plankton abundance, contributing to higher productivity and trophic interactions. In contrast, the rainy season recorded lower plankton abundance. The low abundance of planktons observed during the wet season could best be attributed to further dilution of essential growth nutrients in the area (Adamu *et al.;* 2021).

Table 5: Spatial abundance of planktons according to Station

FAMILY	**SPECIE**	**SITE A**	**SITE B**	**SITE C**	**D**	**TOTAL**	**%**
Chladocera	Naupli	---	6	3	5	14	6.1
	Moina	6	10	5	5	26	11.3
	Bosmina	6	1	4	5	16	7.0
	Diaphanosona	5	10	3	3	21	9.1
	Total	17	27	15	18	77	33.5
Copepoda	Copepodite	2	7	5	5	18	8.3
	Cyclopodite	---	4	2	6	12	5.2
	Calanoid	5	5	4	4	18	7.8
	Total	7	16	11	15	49	21.3
Rotifera	Cylindrical	4	9	6	6	25	10.9
	Filina	3	5	5	7	20	8.7
	Lecane	7	8	4	4	23	10
	Karatella	2	6	4	6	18	7.9
	Trichocera	8	5	3	1	16	7.6
	Total	**24**	**33**	**23**	**24**	**104**	45.2
TOTAL	**Grand Total**	**47**	**76**	**50**	**57**	**230**	**100**

Table 4: Correlation matrix of Relationship between plankton, physicochemical parameter

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	
A	1																					
B	0.032	1																				
C	-0.017	-0.891	1																			
D	0.962	0.088	-0.35	1																		
E	-0.855	-0.359	0.471	-0.788	1																	
F	-0.953	0.095	-0.065	-0.853	0.844	1																
G	0.581	-0.39	0.611	0.486	-0.165	-0.602	1															
H	-0.448	0.262	0.081	-0.429	0.453	0.387	0.027	1														
I	-0.426	0.004	0.267	-0.242	0.695	0.626	0.024	0.315	1													
J	-0.126	0.855	-0.854	-0.172	-0.33	0.094	-0.487	0.362	-0.355	1												
K	-0.933	-0.094	0.204	-0.83	0.931	0.929	-0.438	0.578	0.634	-0.041	1											
L	-0.047	-0.265	0.591	-0.146	0.347	-0.048	0.726	0.638	0.231	-0.194	0.174	1										
M	-0.542	-0.76	0.76	-0.508	0.749	0.416	-0.023	0.256	0.271	-0.571	0.66	0.282	1									
N	0.615	0.562	-0.565	0.497	-0.757	-0.561	0.277	-0.254	-0.403	0.467	-0.762	-0.024	-0.936	1								
O	-0.817	-0.434	0.423	-0.715	0.935	0.838	-0.329	0.156	0.657	-0.443	0.871	0.035	0.759	-0.824	1							
P	0.816	0.121	-0.191	0.729	-0.896	-0.904	0.277	-0.235	-0.792	0.234	-0.83	-0.124	-0.431	0.503	-0.889	1						
Q	0.75	0.361	-0.22	0.764	-0.757	-0.745	0.289	0.109	-0.422	0.307	-0.622	0.017	-0.452	0.425	-0.826	0.861	1					
R	0.884	0.021	-0.126	0.847	-0.897	-0.915	0.265	-0.442	-0.685	0.03	-0.862	-0.28	-0.398	0.426	-0.801	0.954	0.812	1				
S	0.527	0.58	-0.781	0.442	-0.857	-4.498	-0.168	-0.48	-0.636	0.581	-0.745	-0.521	-0.88	0.843	-0.773	0.6	0.411	0.57	1			
T	0.97	0.228	-0.192	0.911	-0.902	-0.921	0.541	-0.36	-0.453	0.079	-0.946	-0.02	-0.705	0.775	-0.911	0.815	-0.779	0.833	0.652	1		
U	0.956	0.1	0.014	0.918	-0.748	-0.873	0.711	-0.319	-0.232	-0.131	-0.865	0.143	-0.597	0.688	-0.779	0.668	0.684	0.717	0.453	0.959	1	
v	0.972	-0.049	0.079	0.895	-0.778	-0.938	0.716	-441	-0.383	-0.197	-0.926	0.106	-0.526	0.6863	-0.778	0.727	0.629	0.778	0.479	0.954	0.974	1

Conclusion

The study found a diverse and abundant plankton community comprising phytoplankton and zooplanktons, are vital to aquatic food chains and serve as bioindicators of water quality. Seasonal variation significantly influenced plankton distribution and abundance in the dam. The dry season variables were more favorable to plankton survival, while Plankton species abundance were highest in area of no anthropogenic activity and areas of poor water quality showed reduced plankton abundance. Spatially, regions with favorable physicochemical conditions supported higher plankton abundance, emphasizing the importance of habitat variability in shaping community structure. These results underscore the dam's ecological importance as a habitat for primary producers and consumers, contributing to its food web stability and ecosystem productivity.

Recommendations

1. Implement stringent regulations to control agricultural runoff and industrial effluents.
2. Promote community awareness programs on the impacts of water pollution.
3. Establish a long-term water quality monitoring framework to track changes and guide policy decisions.

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