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Original Research Article

Assessing the Diversity and Abundance of Plankton Communities in River-Fed Earthen Fish Ponds in Relation to Productivity in Niger Delta (Ekpan Community), Nigeria

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ABSTRACT
Fish health and productivity in the Niger Delta's tropical aquaculture rely on good water quality, with river-fed ponds playing a key role in local fish production due to their nutrient-rich waters. This study evaluated seasonal variations in plankton communities in six river-fed earthen fish ponds in Ekpan Fishing Community, Niger Delta, Nigeria, from June to November. Phytoplankton diversity indicated primary productivity and nutrient status, with Cyanophyceae, Bacillariophyceae, Chlorophyceae, and Zygnemataceae as dominant families. Anabaena (450) and Oscillatoria (419) were the most abundant in June. Diatom Craticula (409) and green alga Coelastrum (319) also showed notable densities. High Cyanophyceae abundance suggests possible eutrophication, while Bacillariophyceae and Chlorophyceae levels reflect relatively balanced water conditions. Zooplankton also followed seasonal trends, with Rotifera and Copepoda dominating. Keratella spp. and Synchaeta spp. peaked at 244 and 214 individuals in October and November, respectively. Copepods such as Cyclops spp. (208 in September), Eucyclops spp. (230 in October), and Mesocyclops spp. (187 in November) were prominent, indicating stable conditions favourable for zooplankton and fish. Overall, the ponds exhibited nutrient-rich conditions that support plankton growth but pose a risk of eutrophication if not properly managed. The study recommends pond management strategies, including aeration, controlled feeding, and regular water exchange to maintain water quality and ecological balance. These findings offer valuable insights into the ecological dynamics of aquaculture ponds and inform sustainable fish farming practices in the Niger Delta.

INTRODUCTION

Nigeria is a coastal nation with an 853 km long coastline, a continental shelf that is around 256,000 km square, and an Exclusive Economic Zone (EEZ) that is 210,900 km square and 46,000 km square. Within these areas, Nigeria has exclusive rights to fish and other natural resources. Nigeria has an abundance of inland waterways at its disposal (Adagha, 2017). These consist of ponds, streams, rivers, floodplains, lakes, and man-made and natural lakes. The species composition and diversity of aquatic life found in these bodies of water are influenced by the habitat's physical location as well as its water quality, claims Adagha (2017).

River-fed earthen fish ponds are among the aquatic ecosystems found in the Niger Delta, one of the most biodiverse and ecologically significant areas on earth. In communities like Ekpan, these ponds are essential for artisanal fishing and aquaculture, which support local food security and livelihoods (Lazarus *et al*., 2018). The physico-chemical traits and plankton diversity that support these ecosystems are still poorly understood, despite the significance of these ponds. Promoting sustainable aquaculture methods and maintaining the wellbeing of the aquatic ecosystems in the area depends on an understanding of these factors: ecological significance and sustainable aquaculture, plankton diversity as an indicator of aquatic health, assessment of physico-chemical parameters in relation to plankton, addressing local aquaculture challenges, contribution to regional environmental management and filling gaps in existing literature (Olaifa *et al.*, 2022; Awhefeada *et al* 2024). This study is to assess the diversity and abundance of plankton communities in River-Fed Earthen Fish Ponds in relation to productivity in Niger Delta (Ekpan Community), Nigeria

MATERIALS AND METHODS

Study area

The study was conducted at the Teaching and Research Farm of the Department of Fisheries and Aquaculture, Delta State University, Abraka, which is located between latitudes 5°45' and 5°.50' North and longitude 6°.00' and 6.15' East.

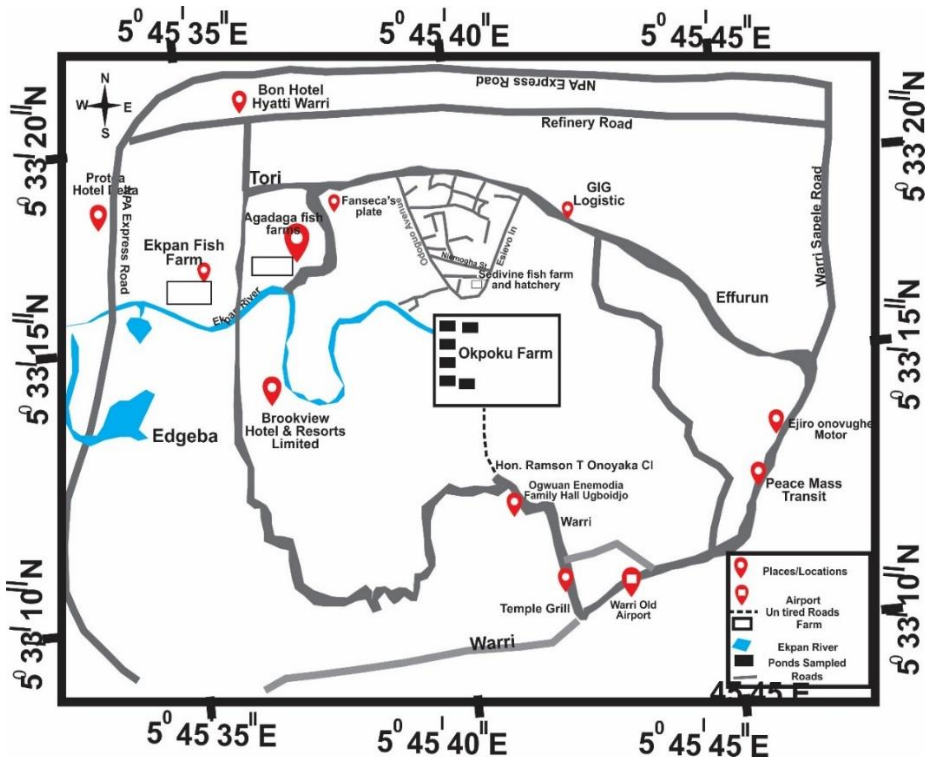

Figure 1: Map of the Niger Delta indicating the sample locations (Source: Researcher)

Sampling Location

The sampling location was Okpoku Fish Farm, Okwuisoko, located within Latitude $5^{0}33'$N and Longitude $5^{0}45'$E. Okpoku Fish Farms is part of the Ekpan fishing community in Uwvie Local Government Area of Delta State, where the farm is located. Its terrain is sloppy and prone to erosion. Out of the fish ponds in Okpoku fish farm, six (6) earthen fish ponds were used for the study. Each pond has an average depth of about 1.2m to 2m and the pond is fed with water from the Ekpan River. (Fig 1 above). It is a perennial freshwater ecosystem, and its water volume decreases during the dry season.


Plate 1: Earthen Pond 1


Plate 2: Earthen Pond 2


Plate3: Earthen Pond 3


Plate 4: Earthen Pond 4


Plate 5: Earthen Pond 5


Plate 6: Earthen Pond 6

Duration of Study

This study was conducted over 6 months, from June to November 2024, to determine plankton diversity and assess the water quality of river-fed earthen fish ponds in the Ekpan community.

Collection of Samples

Samples were collected from six (6) earthen fish ponds in Okpoku fish farm in Ekpan community with different bottles for phytoplankton, zooplankton and water quality parameter measurement.

Plankton Collection

Plankton was collected using the appropriate mesh size (10–20 μm for phytoplankton and 50–100 μm for zooplankton) of net from each of the six ponds. The net was deep into the water surface, and the towing rope was used to tow the net along the surface of the water and the plankton were collected at the cod end (Collection bottle) attached to the net (APHA,2023). The water samples were filtered through a plankton net of 55μm and concentrated up to 100ml (APHA,2017). The concentrated plankton samples were preserved immediately with the help of 5% buffered formalin in the field before being taken to the laboratory for identification and analysis. The samples were observed under the microscope, and planktons were identified using standard keys (Edward, 1990; Edward, 2010; Awhefeada *et al.*, 2024).

Plankton Abundance

The value for the highest occurring plankton (zoo and phytoplankton) was taken and recorded from each of the pond. The water quality parameters were collected and determined at the Department of Chemistry, Delta State University, Abraka

The number of plankton were counted using

Number of plankton/ml = (T x 1000) ÷ (NA x V) (1)

where: T = total number of algae counted, N= number of grids counted, A= area of grid in mm^2

1000 = area of counting chamber in mm^2, V= volume of concentrate in ml/vol. of the sample (Nwabueze, 2015)

Plankton Indices

Species richness and diversity were calculated using Margalef's,

Shannon-Weiner and Evenness indices were determined using the following standard formulae (Shannon-Weiner, 1963):

Margalef's Index (d) = $\frac{S-1}{\ln N}$ (2)

Where S = Total number of species, N = Total number of individuals, In () = Natural logarithm ($\log_e$)

Shannon-Weiner Diversity Index (H)

$$= \frac{N \, log \, N - \sum_{i-1}^{S} n_i \, log \, n_i}{N} \quad (3)$$

Where, H = Shannon-Weiner Index of diversity, n_i = Total number of individuals of a species, N = Total number of individuals of all species

$$\text{Evenness (E)} = \frac{H}{H_{max}} = \frac{H}{H \log S} \quad (4)$$

Where, H = Shannon-Weiner Diversity Index, H_{max} = Maximum diversity

Simpson Dominance index(D) H

$$= \sum_{i=1}^{S} n_i(n_i - 1) \Big/ N(N-1) \quad (5)$$

Where, n_i = number of individuals of species, N = total number of individuals

Person Correlation Matrix (r)

$$rXY = \frac{\sum(Xi - \bar{X})(Yi - \bar{Y})}{\sqrt{\sum(Xi - \bar{X})^2 \sum(Yi - \bar{Y})^2}} \quad (6)$$

Where X_i, Y_i are the data values

X, Y are the means of X and Y

rXY ranges from -1 to +1

Data Analysis
The data obtained was subjected to descriptive statistics, while the treatment mean comparison was conducted using Analysis of Variance (ANOVA). Test for significant differences at P<0.05 level was separated using the Duncan's Multiple Range Test (DMRT). Statistical packages SPSS 26.0 and Microsoft Excel were used. Correlation matrix was used to determine the relationship between seasonality and plankton abundance. Shannon-Wiener Index (H'), Margalef's Index (d), Evenness (E), and Simpson's Index (1−D) were used to determine species biodiversity and species richness.

RESULTS AND DISCUSSION
The values of plankton abundance obtained in this study are shown in table 1

Table 1: Abundance of phytoplankton in ponds for the month of June

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Zygnemataceae	*Spirogyra*	15	17	21	10	12	26	101
	Zygnema	60	45	52	68	60	51	336
Bacillariophyceae	*Craticula*	70	65	71	59	63	81	409
	Navicula	10	12	8	13	17	12	72
	Amphipleura	08	13	14	10	09	14	68
Cyanophyceae	*Oscillatoria*	63	71	68	73	80	64	419
	Anabaena	80	74	76	78	79	63	450
Chlorophyceae	*Coelastrum*	50	56	61	52	49	51	319
	Total	356	353	371	363	369	362	2,174

Table 2: Abundance of phytoplankton in ponds for the month of July

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Zygnemataceae	*Spirogyra*	10	13	20	16	14	12	85
	Zygnema	51	52	48	42	50	47	290
Bacillariophyceae	*Craticula*	60	52	57	61	51	56	337
	Navicula	08	09	10	07	12	17	63
	Amphipleura	10	05	07	09	11	09	51
Cyanophyceae	*Oscillatoria*	42	47	51	40	40	38	258
	Anabaena	50	52	49	52	53	60	316
Chlorophyceae	*Coelastrum*	32	37	50	41	34	32	226
	Total	263	292	267	268	265	271	1,626

Table 3: Abundance of phytoplankton in ponds for the month of August

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Zygnemataceae	*Spirogyra*	10	08	10	12	11	09	60
	Zygnema	30	32	34	40	37	39	212
Bacillariophyceae	*Craticula*	31	32	40	38	42	37	220
	Navicula	05	07	08	10	09	07	46
	Amphipleura	10	11	08	12	09	11	61
Cyanophyceae	*Oscillatoria*	28	32	31	27	35	37	190
	Anabaena	40	42	38	43	37	43	243
Chlorophyceae	*Coelastrum*	24	24	23	26	27	21	145
	Total	178	188	192	316	207	204	1,177

Table 4: Abundance of phytoplankton in ponds for the month of September

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Zygnemataceae	*Spirogyra*	20	10	13	12	12	20	87
	Zygnema	30	32	28	34	37	31	192
Bacillariophyceae	*Craticula*	40	37	32	42	35	47	233
	Navicula	08	10	09	12	11	05	55
	Amphipleura	10	12	11	13	14	17	77
Cyanophyceae	*Oscillatoria*	31	32	32	29	34	37	195
	Anabaena	37	34	32	40	36	32	211
Chlorophyceae	*Coelastrum*	30	32	28	34	32	40	196
	Total	206	199	185	216	211	229	1,246

Table 5: Abundance of phytoplankton in Ponds for the Month of October

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Zygnemataceae	*Spirogyra*	30	17	16	10	18	24	115
	Zygnema	41	37	10	38	41	51	218
Bacilliariophyceae	*Craticula*	43	39	18	51	38	54	243
	Navicula	10	11	18	14	08	17	78
	Amphipleura	05	17	16	17	17	20	92
Cyanophyceae	*Oscillatoria*	38	34	31	38	37	42	220
	Anabaena	50	30	34	47	43	38	242
Chlorophyceae	*Coelastrum*	33	37	29	28	38	51	219
	Pandorina	10	12	14	08	21	18	83
	Total	260	234	186	251	261	315	1,507

Table 6: Abundance of phytoplankton in Ponds for the month of November

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Zygnemataceae	*Spirogyra spp*	34	16	14	21	19	31	135
	Zygnema spp	47	34	21	46	45	49	242
Bacilliariophyceae	*Craticula spp*	48	42	22	54	41	56	263
	Navicula spp	12	08	21	15	12	17	85
	Amphileura spp	11	19	18	21	20	24	113
Cyanophyceae	*Oscillatoria spp*	41	38	28	32	79	51	269
	Anabaena	53	34	32	43	48	41	251
Chlorophyceae	*Coelastrum spp*	41	32	32	31	42	53	231
	Pandorina spp	13	14	18	12	31	24	112
	Total	300	237	206	275	337	346	1,701

Table 7: Abundance of zooplankton in Ponds for the month of June

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Rotifera	*Keratella spp*	15	12	20	10	13	20	90
	Synchaeta spp	30	45	52	24	39	47	237
Copepoda	*Cyclops spp*	26	44	16	50	34	20	190
	Eucyclops spp	22	48	16	33	15	29	163
	Mesocyclops spp	26	12	10	35	17	20	120
	Total	119	161	114	152	118	136	800

Table 8: Abundance of zooplankton in ponds for month of July

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Rotifera	*Keratella spp*	10	14	08	24	11	18	85
	Synchaeta spp	20	32	16	22	29	13	132
Copepoda	*Cyclops spp*	16	34	22	37	19	17	145
	Eucyclops spp	13	25	48	10	16	26	138
	Mesocyclops spp	20	55	37	34	12	44	202
	Total	79	160	131	127	87	118	702

Table 9: Abundance of zooplankton in ponds for the month of August

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Rotifera	*Keratella spp*	10	20	23	30	14	12	109
	Synchaeta spp	08	12	17	19	23	13	87
Copepoda	*Cyclops spp*	11	19	22	07	10	09	78
	Eucyclops spp	05	07	13	19	16	20	80
	Mesocyclops spp	28	10	12	15	23	25	113
	Total	62	68	87	90	86	79	467

Table 10: Abundance of zooplankton in ponds for the month of September

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Rotifer	*Keratella*	10	12	14	08	23	29	96
	Synchaeta	24	06	17	38	37	28	150
Copepoda	*Cyclops*	48	42	21	20	45	32	208
	Eucyclops	13	14	31	42	28	41	169
	Mesocyclops	05	25	10	12	21	18	91
	Total	100	99	93	120	154	148	714

Table 11: Abundance of zooplankton in ponds for the month of October

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Rotifera	Keratella	30	37	42	45	50	40	244
	Synchaeta	25	23	20	44	17	34	163
Copepoda	*Cyclops*	18	16	37	47	42	26	186
	Eucyclops	27	32	42	29	48	52	230
	Mesocyclops	31	15	18	27	29	30	150
	Total	131	123	159	192	186	182	973

Table 12: Abundance of zooplankton in ponds for the month of November

Group	Species	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Total
Rotifer	*Keratella*	16	22	25	32	33	37	132
	Synchaeta	26	34	37	40	38	39	214
Copepoda	*Cyclops*	35	24	16	17	21	29	142
	Eucyclops	48	37	35	27	28	52	227
	Mesocyclops	20	23	37	46	18	43	187
	Total	145	140	150	162	138	200	935

Table 13: Correlation matrix table for planktons

	Spirogyra	Zygnemia_spp	Craticula_spp	Anlacosetra_spp	Niiviciila_spp	Amphipleura_spp	Oscillatone_spp	Coelastrum_spp	Pandorina_spp
Spirogyra	1	.178	.226	.127	.200	.302	.195	.501**	.492**
Zygnemia_spp		1	.737**	.867**	.068	-.190	.716**	.651**	-.118
Craticula_spp			1	.789**	.068	-.324	.741**	.672**	-.254
Anlacosetra_spp				1	.062	-.166	.766**	.726**	-.283
Niiviciila_spp					1	.397*	.164	.241	.445**
Amphipleura_spp						1	-.016	.158	.723**
Oscillatone_spp							1	.795**	.062
Coelastrum_spp								1	.127
Pandorina_spp									1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

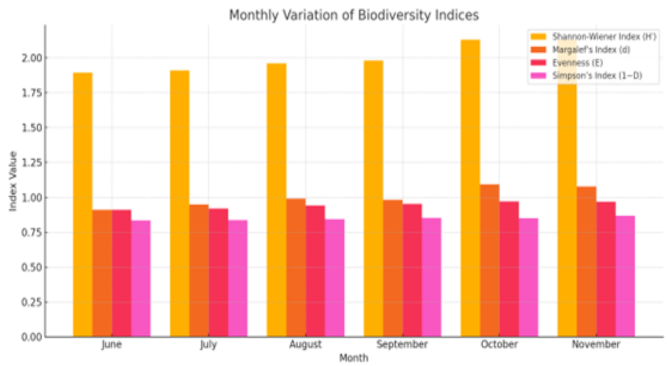

Figure 2: biodiversity indices by month across the six ponds for Phytoplankton

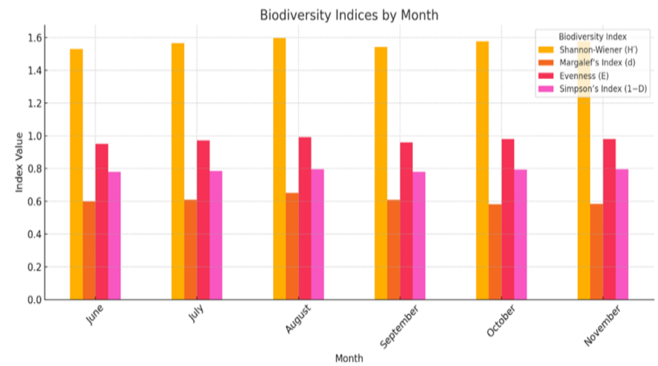

Figure 3: Biodiversity indices by month across the six ponds for Zooplankton

Discussion

Plankton Analysis

Table 1 shows the abundance of phytoplankton in the study ponds. In aquatic environments, phytoplankton composition is a vital indicator of primary productivity, nutrient levels and water quality. The *Cyanophyceae, Bacillariophyceae, Chlorophyceae*, and *Zygnemataceae* families dominate the phytoplankton abundance in the six ponds during June (Adeogun *et al.* 2018; Awhefeada *et al.*, 2024). The two most prevalent species in the ponds (table 1 above) are *Anabaena* (450 individuals) and *Oscillatoria* (419 individuals). In eutrophic environments, especially during warm months, *Cyanophyceae* predominate (50–55%), according to studies conducted by Ogbuagu and Ayoade (2012) in fish ponds in Nigeria. Similarly, high densities of *Anabaena* and *Oscillatoria* were found in nutrient-rich waters. Blue-green algae's great prevalence points to eutrophication, which could be caused by organic matter, fish waste, and feed runoff. *Anabaena,* a nitrogen-fixing genus, thrives in environments with low nitrate levels but can develop blooms, leading to oxygen depletion and hazardous circumstances for fish (Weizhen et al. 2022). Diatoms like *Craticula* are bioindicators of stable environmental conditions, but a lower density of *Navicula* suggests possible shifts in water pH or conductivity, as it thrives in more alkaline waters Kadiri (2006) found similar dominance of *Craticula* and *Navicula* in freshwater ponds, indicating good water circulation and moderate nutrient levels. *Craticula* (409 individuals) is highly abundant, while *Navicula* (72) and *Amphipleura* (68) occur in lower numbers. *Coelastrum* of 319 individuals represents the dominant green algal species. Adekanmi *et al.*, (2020) observed high *Coelastrum* abundance in clean, well-oxygenated fish ponds. However, high densities (>500 cells/mL) can indicate organic pollution, leading to oxygen depletion. The moderate presence of *Chlorophyceae* suggests a balanced ecosystem with sufficient dissolved oxygen, as green algae support zooplankton growth, which is essential for fish diets. The high density of *Zygnema* may indicate mild pollution, as this species can withstand moderate organic waste, while the abundance of *Spirogyra* suggests good water quality but possible filamentous algal blooms, which can clog fish gills and lower dissolved oxygen levels if excessive. *Zygnema* (336 individuals) is significantly more abundant than *Spirogyra* (101 individuals). Nkwoji *et al.,* (2010) found similar patterns in stagnant, nutrient-enriched waters, where *Zygnemataceae* dominated due to their ability to thrive in moderate to high organic loads. The dominance of *cyanophyceae* (blue-green algae) indicates eutrophication, or high nutrient levels, and the possibility of hazardous algal blooms (HABs). The presence of *Bacillariophyceae* (Diatoms) indicates average water quality; however, a decrease in *Navicula* may be a symptom of conductivity and pH changes. The balance of *chlorophyceae* (green algae) indicates adequate oxygenation, which supports robust zooplankton populations. The prevalence of *Zygnemataceae* suggests some organic pollution, but not to a dangerous degree. According to these results, the pond ecosystem is nutrient-rich, and if nutrient inputs are not managed, eutrophication may occur. Aeration, occasional water exchange, and controlled feeding are some of the management techniques that will be required to keep the phytoplankton balance in a healthy state for the best possible fish output.

Plankton abundance and composition

From table 1-12, based on the availability and abundance of phytoplankton and zooplankton in the ponds, the following information was taken: *Chlorophyceae* (*Spirogyra, Zygnema*) were the most common species in this survey; in July, *Zygnema spp*. peaked at 290 individuals. This is consistent with the results of Ogbuagu *et al.* (2011), who found that the Chlorophyceae were the most prevalent group in fish ponds in Lagos, suggesting that the environment was conducive to the growth of green algae.

Significant populations of *Cyanophyceae* (*Anabaena spp*. and *Oscillatoria spp*.) have been observed, which is consistent with research by Sultana *et al*. (2021), who discovered comparable dominance in fish ponds that are rich in nutrients. The presence of Bacillariophyceae (Craticula, Navicula) in the ponds is consistent with findings by Davies *et al*. (2009), who noted that *Nitzschia* and *Navicula* are markers of different environmental conditions.

Zooplankton abundance and composition

Ebesi *et al.,* (2022), found that *Keratella, Synchaeta (Rotifera)* and *Cyclops, Eucyclops*, and *Mesocyclops (Copepoda*) are the main zooplankton groups in fish pond ecosystems. These findings are consistent with their findings.

Variations in Observations

The variations in observations of phytoplankton abundance are consistent with research by Ogamba (2017); Nwabueze (2015), which discovered that dissolved oxygen, total dissolved solids, and fertilizer inputs cause phytoplankton populations to differ. The results align with earlier research, bolstering the knowledge that nutrient availability and variations in water quality parameters have an impact on phytoplankton and zooplankton dynamics in ponds.

Biodiversity indices of Phytoplankton

The bar chart (Fig 2) visually represents the variation in biodiversity across six months using four indices: Shannon-Wiener Index (H'), Margalef's Index (d), Evenness (E), and Simpson's Index (1−D). There is a consistent increase in H' from June (1.893) to October (2.128), after which it stabilizes in November (2.1278). A higher Shannon-Wiener value indicates greater species diversity and evenness in species abundance. The upward trend suggests a progressively more diverse ecosystem across the months. This aligns with Magurran (2021), who emphasized that higher H' values signify complex and resilient communities. Margalef's Index increases from 0.910 in June to a peak of 1.093 in October, followed by a slight dip to 1.0759 in November. This trend indicates a growing number of species in relation to the total individuals, suggesting increased species richness. According to Khan *et al*. (2023), Margalef's Index is sensitive to richness, and a rise suggests improved environmental conditions or colonization by new species. Evenness starts at 0.910 in June and improves to 0.969 in October, slightly decreasing to 0.9684 in November. High and consistent evenness across months indicates a balanced distribution of individuals among species, showing no single species dominates the community. Begum *et al.* (2022) highlighted the ecological stability implied by high evenness values, suggesting efficient resource partitioning. The index gradually increases from 0.835 in June to 0.8674 in November. A higher value means a lower probability that two randomly selected individuals belong to the same species. Thus, diversity is improving. Morris *et al.* (2014) confirmed that Simpson's Index is a reliable measure of both richness and evenness, and rising values indicate enhanced biodiversity. Modern interpretations of Simpson's Index highlight its role in indicating both dominance and vulnerability to disturbances (Zhao *et al*., 2020; Awhefeada *et al.,* 2024).

Biodiversity indices of Zooplanktons

The bar chart (Fig 3) illustrates the variation in biodiversity indices Shannon-Wiener (H'), Margalef Index (d), Evenness (E), and Simpson's Index (1−D) from June to November. The values indicate that August demonstrates peak biodiversity across all indices.

Shannon-Wiener (H' = 1.5963) and Simpson's Index (1−D = 0.7953) suggest the highest diversity and lowest dominance in August. Evenness (E = 0.9919) in August indicates that individuals were almost perfectly evenly distributed among species. Margalef's Index (d = 0.6498) also peaks in August, reflecting slightly greater species richness compared to other months.

The high evenness and diversity values imply that August offered optimal ecological conditions, likely related to seasonal stability, nutrient availability, or minimal disturbance. This aligns with recent studies emphasizing the role of seasonal phenology and environmental buffering in driving community diversity peaks (García-Palacios *et al.,* 2023; Hillebrand *et al*., 2020).

CONCLUSION

The study found that river-fed earthen fish ponds in Ekpan have nutrient-rich waters that support aquaculture and diverse plankton, which are vital for fish productivity. However, seasonal changes and rising nutrient levels pose eutrophication risks. Specific plankton species indicate water quality, highlighting the need for regular monitoring and proactive management to sustain fish production and ecological balance in these aquaculture systems.

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