JPII 14 (2) (2025) 229-240

Jurnal Pendidikan IPA Indonesia

https://journal.unnes.ac.id/journals/jpii

SPATIAL IMPACT OF NITROGEN FERTILIZER RESIDUE ON THE BIOTIC ENVIRONMENT OF RICE FIELD IRRIGATION CHANNELS

S.Wantasen*[1], J. N. Luntungan[1], R. Koneri[2], S. Tumbelaka[1], J. Joseph[3], J. V. Jermias[1]

[1]Faculty of Agriculture, Universitas Sam Ratulangi, Indonesia,
Universitas Sam Ratulangi, Indonesia
[2]Department of Biology, Faculty of Mathematics and Natural Sciences,
Universitas Sam Ratulangi, Indonesia
[3]Faculty of Plantation and Agrotechnology,
Universiti Teknologi MARA UiTM Sabah Branch, Kota Kinabalu Campus, Malaysia

DOI: 10.15294/jpii.v14i2.22577

Accepted: March 20th, 2025. Approved: June 29th, 2025. Published: June 30th 2025

ABSTRACT

This study aims to analyze the spatial distribution of the impact of nitrogen residue and diversification on the diversity of aquatic biota, contributing to the management of aquatic ecosystems as a vital source of life. Water quality sampling was conducted using grab sampling, with water quality parameters measured, including total nitrogen (TN), ammonia (NH_3), nitrate (NO_3^-), and nitrite (NO_2^-). TN analysis was carried out using the Total Kjeldahl Nitrogen (TKN), nitrate, and nitrite calculation methods. NH_3 was measured using the Flow Injection Analysis method, while NO_3^- was analyzed using the Cadmium Reduction Method, and NO_2^- with the colorimetric method. Plankton sampling was done by filtering 20 liters of water from the surface layer using a 2-liter bucket. The plankton species diversity index was calculated using the Shannon-Wiener Index method. The effect of environmental factors on nitrogen chemical fertilizer residues in each research location was analyzed using Principal Component Analysis (PCA). The results showed an increase in ammonia and nitrite residues, followed by a decrease in total nitrogen and nitrate concentrations. Seven classes and 22 plankton species were identified, consisting of 18 phytoplankton species and four zooplankton species. The dominant plankton came from *Cyanophyceae, Bacillariophyceae, and Chlorophyceae*. The highest plankton species diversity index was recorded in Irrigation IX and VII. Based on the study results, the plankton diversity at the research location falls within the moderate category. The primary environmental factors influencing the presence of plankton in irrigation channels are the concentration of nitrates and nitrogen in the water.

Keywords: impact; chemical fertilizer residue; biotic environment

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for more than half of the world's population, and its sustainable production is critical to global food security. Rice is one of the primary food sources consumed by nearly three billion people worldwide. Rice is also a food commodity that can meet 32% of calorie needs (Syarifah et al., 2025). Various efforts have been made to increase rice production as a staple food to keep pace with the growing population. With the increasingly narrowing of fertile land due to the conversion of agricultural land into residential and industrial areas, the selection of agricultural land on land that requires input so that plants can produce optimally (Erman et al., 2022)

The intensification of rice cultivation, particularly through the widespread use of nitrogen (N) chemical fertilizers, has played a pivotal role in increasing yields to meet growing food

*Correspondence Address
E-mail: swantasen09@gmail.com

demands. However, this intensification has also led to significant environmental challenges, including alterations to the biotic environment of rice field irrigation systems. The excessive and inefficient application of nitrogen fertilizers contributes not only to soil and water contamination, but also to biodiversity loss and the exacerbation of climate change through increased greenhouse gas (GHG) emissions (Hassan et al., 2022; Shaaban et al., 2022; Wang et al., 2024) The United Nations Sustainable Development Goals (SDGs) provide a framework for addressing these intertwined challenges. Specifically, SDG 2 (Zero Hunger) emphasizes the need for sustainable food production systems, while SDG 6 (Clean Water and Sanitation), SDG 13 (Climate Action), and SDG 15 (Life on Land) highlight the importance of protecting water resources, mitigating climate change, and preserving terrestrial ecosystems. Addressing the SDGs in research on the impact of nitrogen chemical fertilizer residue on the biotic environment of rice field irrigation is essential because this issue sits at the intersection of food security, environmental sustainability, and resource management (Purba et al., 2024)

The balance of fertilizer application in lowland rice cultivation plays a crucial role in determining the dynamics of nutrients in the soil and their impact on the surrounding environment. Macronutrients such as N and phosphorus (P) are essential components for the growth and production of rice plants. Plants absorb nitrogen fertilizers as nitrate (NO_3^-) and ammonium (NH_4^+). However, nitrate that plants do not absorb can leach and be carried into water bodies, including rivers, irrigation canals, lakes, and other bodies of water, potentially reducing water quality and disrupting the balance of aquatic ecosystems (Di et al., 2024; Liu et al., 2025). Deficiencies in these nutrients can inhibit plant growth and significantly reduce rice yields.

Nitrogen is the primary nutrient that plays a crucial role in plant growth and development, particularly as a significant component in synthesizing proteins and amino acids, which are essential for photosynthesis. Urea fertilizer, one of the most commonly used nitrogen sources in solid form, contains around 46% nitrogen. This nitrogen fertilizer is mainly absorbed in the form of nitrate and ammonium (Hassan et al., 2022; Wang et al., 2024)

The use of inorganic fertilizers based on nitrogen (N) and phosphorus (P) has a significant impact on aquatic ecosystems through the process of leaching and surface runoff. After being applied to the soil, this fertilizer will transform ammonium carbamate, where some of the nitrogen can evaporate into ammonia. Fertilizer waste that enters water bodies increases nutrient levels, which can trigger an imbalance in aquatic ecosystems, especially affecting the structure of phytoplankton communities. Nitrogen fertilizer application techniques have a significant impact on nitrogen loss to the environment through evaporation and leaching, ultimately reducing the amount of nitrogen plants can utilize (Bibi, 2016).

Nitrogen diversification, which can lead to increased aquatic biota diversity, such as nitrate that plants do not absorb, can accumulate in water bodies and cause increased nitrogen levels, further degrading water quality and disrupting the stability of aquatic ecosystems. In addition to nitrogen, phosphorus is an essential element for plant growth. Phosphorus in aquatic environments and sediments comes from various sources, including natural phosphorus deposits, industrial and domestic waste, agricultural activities, phosphate rock exploitation, and deforestation. Therefore, proper fertilizer management is essential to increase fertilizer use efficiency while reducing environmental negative impacts, such as water residue accumulation.

Water quality must meet the standards concerning the Implementation of Environmental Protection and Management, specifically in Appendix VI, which pertains to National Water Quality Standards Class I and Class II. Nutrient accumulation due to fertilizer application also contributes to changes in the community structure of aquatic organisms, including plankton (phytoplankton and zooplankton) (Haryadi et al., 2012; Zeng et al., 2025). Increased nutrient levels in waters can trigger changes in the composition and abundance of phytoplankton, which are naturally influenced by various environmental factors, such as light availability, temperature, and the N:P nutrient ratio (Anas et al., 2020; Kagan et al., 2024). Plankton abundance and diversity are greatly influenced by physicochemical factors of water, including sedimentation, water level fluctuations, nutrient availability, heavy metal contamination, temperature, pH, and dissolved oxygen levels (Odulate et al., 2017; Arimoro et al., 2018; Kumar et al., 2020; Ray et al., 2021). Phytoplankton and zooplankton also act as bioindicators that can be used to assess the water quality of a water body (Chandel et al., 2024; Yusuf, 2020)

Nutrient inputs such as nitrate and phosphate from agricultural activities can significantly impact plankton abundance (Sabar et al., 2024). Increased populations of certain plankton indicate high nutrient levels in the water, which, if exceeded, can lead to water quality degradation (Wadi et al., 2021). Plankton is used as a bioindicator because it has a short life cycle and a rapid response to changes in environmental conditions, making it a valuable parameter for evaluating water quality (Chandel et al., 2024). Additionally, phytoplankton play a crucial role in aquatic ecosystems by producing oxygen through photosynthesis and providing organic matter as a primary source of energy for other aquatic organisms (Maresi et al., 2015; Welde et al., 2024).

Research on plankton as a bioindicator of species diversity to evaluate water quality has been conducted in various countries, including Malaysia (Norlida et al., 2023) and Japan (Sazawa et al., 2023). These studies demonstrate that water quality is correlated with plankton abundance, making it crucial to analyze the impact of nitrogen and phosphate residues in irrigation canals on water quality and plankton diversity. Most studies conducted have focused on large-scale agricultural systems, while small-scale irrigation systems remain less explored. In Indonesia, these systems have unique water management practices that affect nitrogen dynamics differently (Putri et al., 2023). Therefore, this study aims to analyze the spatial distribution of nitrogen residues in irrigation canals and their impact on the biotic environment, particularly on plankton diversity.

METHODS

Samples were taken in rice fields in Tomohon City, North Sulawesi, Indonesia. The water quality sampling method was grab sampling, where samples were taken directly from the monitored water body. In addition, the composite sampling method was also applied, as described in Standard Methods for the Examination of Water and Wastewater (Hadi, 2015; APHA (American Public Health Association), 2005).

Table 1. Sampling Coordinate Point

Point	Latitude	Longitude
1	1°18'54.88"N	124°47'6.39"T
2	1°18'59.11"N	124°47'9.25"T
3	1°19'6.65"U	124°47'19.34"T
4	1°19'21.18"U	124°47'40.30"T
5	1°19'27.94"U	124°48'0.12"T
6	1°19'31.68"U	124°48'12.07"T
7	1°19'24.73"U	124°48'24.87"T
8	1°19'34.77"U	124°48'33.36"T
9	1°19'34.61"U	124°48'46.71"T

Water and plankton samples were collected from nine irrigation canals in the rice fields of Tomohon City. The water quality parameters measured included ammonia, nitrate, nitrite, and total nitrogen levels. Total nitrogen (TN) was analyzed using the Total Kjeldahl Nitrogen (TKN) method, as well as calculation methods for nitrate and nitrite. Ammonia (NH_3) was analyzed using the Flow Injection Analysis method, while nitrate (NO_3^-) was analyzed using the Cadmium Reduction Method, and nitrite (NO_2^-) was analyzed using the colorimetric method. Water quality measurements were conducted in situ, while further analysis was performed in the laboratory. Primary data were obtained through direct measurements at the irrigation canal outlet.

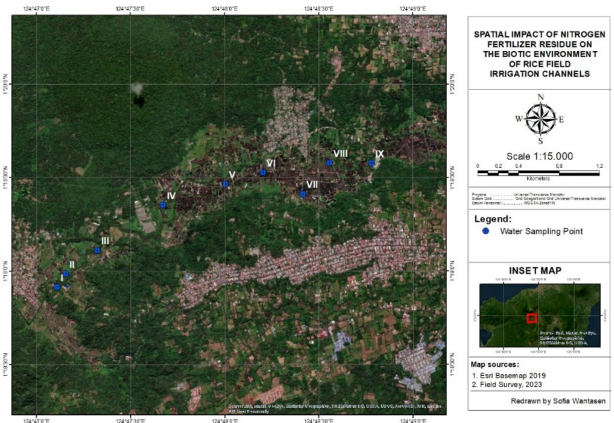

Figure 1. Irrigation Water Quality Sampling Location

Phytoplankton abundance was analyzed using the following formula: E = c × A/fa × V, where E is phytoplankton density (ind / ltr), c is the total individuals observed, A is phytoplankton concentrate volume, fa is phytoplankton sample volume, and V is sample volume (Nam et al., 2022). Phytoplankton and zooplankton abundance were analyzed using the APHA formula (APHA, 2023). The abundance and species richness of plankton at all study sites were tabulated using Microsoft Excel. Community structure was analyzed based on several attributes, including species abundance, species richness, Shannon-Wiener diversity index (H '= -Σpi ln pi), and Pielou's evenness index (J = H' / ln S), which were calculated for each observation station. Principal Component Analysis (PCA) was employed to examine the relationship between environmental factors (independent variables) and sampling locations (dependent variables). In addition, Analysis of Similarities (ANOSIM) and Non-Metric Multidimensional Scaling (NMDS) analyses were applied to interpret the relationship patterns between variables. All statistical analyses were performed using Paleontological Statistics Software (PAST 3.10) (Andriyani et al., 2020; Koneri et al., 2022)

RESULTS AND DISCUSSION

Fertilization is one strategy that can be used to improve environmental balance (Syarifah et al., 2025). Nitrogen (N) fertilization is a common agricultural practice that enhances plant growth and productivity. N input into cropping systems has increased rapidly over the past decades to meet the needs of food and biofuel production (Kagan et al., 2024). However, excessive and repeated N inputs increase nitrate leaching and reactive N gas production, adversely impacting the environment and human health (Fowler et al., 2013; Yang et al., 2019, 2023). The results showed that the concentrations of ammonia, nitrate, nitrite, and total nitrogen varied. However, according to Government Regulation Number 22 of 2021, Appendix VI, the concentrations met the quality standard requirements. The details are presented in Figures 2-5.

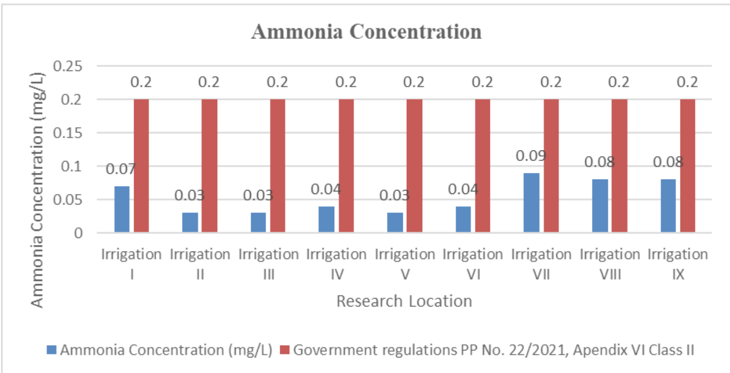

Figure 2. Ammonia Concentration in Rice Field Irrigation Canals

Irrigation II, III, and V show the lowest concentrations, each at 0.03 mg/L. These values suggest minimal ammonia pollution, possibly due to reduced fertilizer runoff or better water management in those locations. Irrigation VII records the highest ammonia level at 0.09 mg/L, followed by Irrigation VIII and IX at 0.08 mg/L. These values are still well within safe limits but indicate comparatively higher ammonia input, potentially due to more intensive farming or recent fertilization activities. The irrigation canals for the rice fields exhibit low ammonia concentrations, all of which are significantly below the regulatory threshold of 0.2 mg/L. These findings reflect a healthy water quality status with minimal risk from ammonia pollution across the surveyed areas. However, irrigation sites VII–IX, while still compliant, may warrant periodic monitoring to prevent potential future exceedances due to increased nutrient loading. The results show that the ammonia concentration meets the class II quality standard (Figure 2). The distribution of ammonia in irrigation canals ranges from 0.03 to 0.09 mg/L. According to Government Regulation No. 22 of 2021, Attachment VI, the quality standard for ammonia concentration is 0.2 mg/L. Therefore, the ammonia concentration data meet the quality standard.

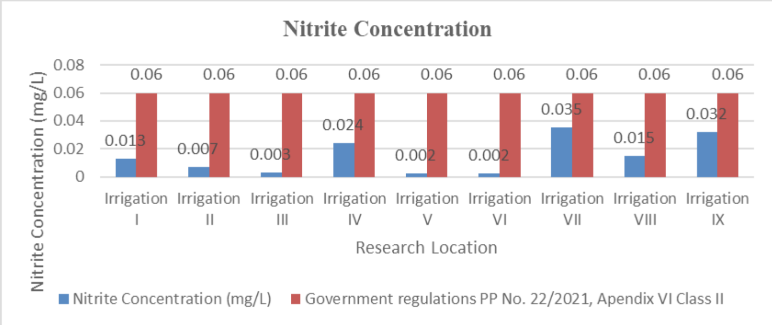

Figure 3. Nitrite Concentration in Rice Field Irrigation Canals

As depicted in Figure 3, all irrigation sites show nitrite concentrations significantly below the regulatory limit of 0.06 mg/L, indicating good water quality regarding nitrite pollution. The measured concentrations range from 0.002 mg/L (Irrigation V & VI) to 0.035 mg/L (Irrigation VII). Irrigation V and VI exhibit the lowest nitrite levels, each at 0.002 mg/L, suggesting minimal organic matter breakdown or contamination from agricultural sources. Irrigation VII shows the highest nitrite concentration at 0.035 mg/L, followed by Irrigation IX: 0.032 mg/L and Irrigation IV: 0.024 mg/L. These values are still well within the safe limit, but they may indicate higher microbial activity or recent fertilizer runoff in those areas. All values are within the government standard of 0.06 mg/L, meaning the nitrite content in the irrigation canals poses no immediate risk to aquatic ecosystems or agricultural use.

Irrigation VII and IX have the highest concentrations of both ammonia and nitrite, suggesting possible recent fertilizer application, organic waste input, incomplete nitrification, or higher microbial activity converting ammonia into nitrite. Irrigation II, III, V, and VI consistently show very low levels of both compounds, indicating minimal nitrogen input and a healthier water quality profile. Irrigation IV is interesting as ammonia is moderate (0.04 mg/L) but nitrite is relatively high (0.024 mg/L), which may reflect active nitrification processes or older ammonia inputs already being transformed. The test results showed that the nitrite concentration ranged from 0.002 mg/L to 0.035 mg/L, meeting the quality standards (Figure 3). The highest spatial distribution of nitrite concentration was observed at location 7 in the irrigation canal, during the active vegetative stage. According to Government Regulation No. 22 of 2021, Attachment VI, the quality standard for nitrite concentration is 0.2 milligrams per liter (mg/L). Therefore, the nitrite concentration data meet the quality standard.

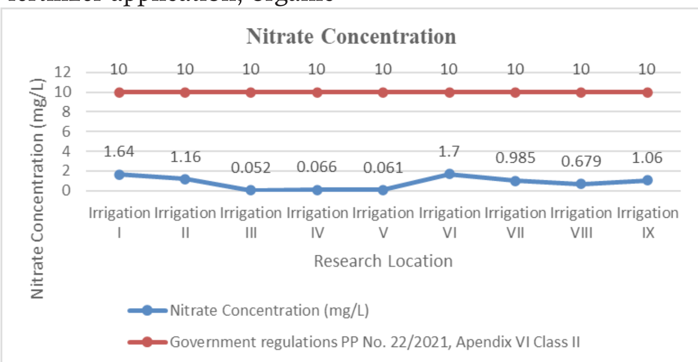

Figure 4. Nitrate Concentration in Rice Field Irrigation Canals

Figure 4 shows that the nitrate levels across all locations are well within safe limits, indicating a low risk of contamination or eutrophication. Irrigation VI shows the highest nitrate presence, possibly due to nearby agricultural runoff or fertilization, but it is still far below the 10 mg/L threshold. The very low values in Irrigation III–V (less than 0.07 mg/L) suggest either excellent natural filtration, minimal nitrogen input, or both. The overall trend shows a spike at Irrigation VI, followed by moderate values, which could indicate localized sources of nitrate input. The irrigation canal water is safe with respect to nitrate pollution. The concentrations observed do not pose environmental or health concerns under current conditions. Continued monitoring is advisable, especially at locations like Irrigation VI, where levels are relatively higher. The nitrate concentration ranged from 0.052 mg/L to 1.700 mg/L, meeting the quality standards. The vegetative and generative phases of rice plant growth influence the increase and decrease in nitrate concentration.

In Figure 5, the total nitrogen levels are consistently low, suggesting minimal nitrogen pollution across all irrigation canal locations. The highest level (2.9 mg/L in Irrigation VI) is still significantly lower than the legal threshold, indicating no immediate environmental concern regarding nitrogen contamination. The slight fluctuations across sites may be due to local land use, fertilizer runoff, or organic matter input; however, all are within safe limits. The irrigation canals are in good environmental health regarding nitrogen pollution, and the current management or usage practices are effective in keeping nitrogen levels under control.

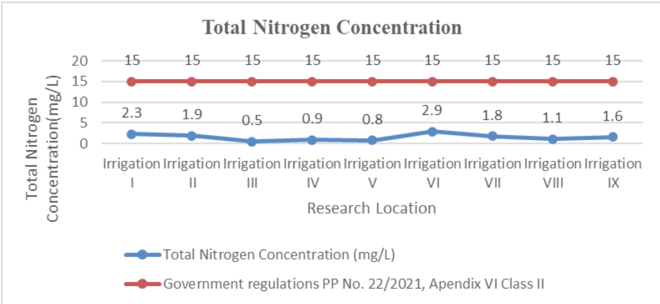

Figure 5. Total Nitrogen Concentration in Rice Field Irrigation Canals

Analysis of water quality parameters, including ammonia, nitrite, nitrate, and total nitrogen, during the active vegetative period revealed an increase in nitrate and total nitrogen concentrations, followed by a decrease in ammonia and nitrite levels. Aerobic conditions, ammonia volatilization, and nitrogen residues in the aquatic system contribute to environmental changes. This process involves the transformation of nitrogen into various nitrogen compounds, including nitrate, nitrite, and ammonia (Da Silva et al., 2020). Research in nine rice field irrigation canals identified seven classes and 22 plankton species, comprising 18 phytoplankton species and four zooplankton species. The most dominant phytoplankton species was *Melosira* sp. (*Bacillariophyceae* class) with an abundance of 7.14%, followed by *Staurastrum* sp. (*Chlorophyceae* class) at 6.44%, and *Anabaena* sp. (*Cyanophyceae* class) at 6.14%. Meanwhile, the species with the lowest abundance was *Tetrapedia* sp., which was only 2.87%. Among the zooplankton groups, the species with the highest abundance were *Lestes* sp. larvae (2.68%) and *Libellula* larvae (2.48%). The zooplankton with the lowest abundance was *Nauplius* sp., only 1.19% (Table 2).

Table 2. An Abundance of Plankton Taxa in Rice Field Irrigation Canals

No	Taxa/Class/Genus	Irrigation									∑	%
		I	II	III	IV	V	VI	VII	VIII	IX		
	Phytoplankton											
	Cyanophyceae											
1	*Anabaena* sp	6	8	4	4	7	5	9	11	8	62	6.14
2	*Coleosphaerium* sp	8	11	3	1	6	4	0	6	11	50	4.96
3	*Tetrapedia* sp	0	1	1	1	2	3	9	7	5	29	2.87
	Bacillariophyceae											
4	*Pinnularia* sp	5	3	1	9	3	6	8	5	3	43	4.26
5	*Gomphonema* sp	4	2	8	6	3	9	4	0	13	49	4.86
6	*Navicula* sp	10	6	6	2	7	0	9	4	5	49	4.86
7	*Synedra* sp	2	7	3	3	6	0	10	13	5	49	4.86
8	*Gyrosigma* sp	9	5	5	7	0	1	6	8	9	50	4.96
9	*Nitzchia* sp	8	0	9	5	7	10	3	7	2	51	5.05
10	*Cymbella* sp	8	10	3	4	9	6	5	11	0	56	5.55
11	*Surirella* sp	3	7	5	0	7	2	14	10	8	56	5.55
12	*Eunotia* sp	6	0	9	5	0	9	12	6	14	61	6.05
13	*Melosira* sp	9	6	11	8	10	2	8	11	7	72	7.14

	Cholorophyceae											
14	*Staurastrum* sp	0	5	5	12	8	13	7	2	13	65	6.44
15	*Pediastrum* sp	5	7	3	9	0	11	4	6	6	51	5.05
	Conjugatophyceae											
16	*Mougeotia* sp	2	5	1	1	4	9	3	5	9	39	3.87
	Fragilariophyceae											
	Tabellaria sp	5	9	3	10	6	8	1	0	3	45	4.46
17	Zygnemophyceae											
18	*Gonatozygon* sp	0	9	2	7	4	11	11	5	8	57	5.65
	Zooplankton											
	Insecta											
19	Larva *Libelulla* sp	4	6	2	4	1	1	2	1	4	25	2.48
20	Larva *Lestes* sp	5	3	3	1	0	2	4	3	6	27	2.68
	Crustacea											
21	*Cyclops* sp	2	4	1	1	2	0	1	0	0	11	1.09
22	*Nauplius* sp	2	0	0	1	3	1	1	1	3	12	1.19
	Total	103	114	88	101	95	113	131	122	142	1009	100.00

The highest number of species was found in Irrigation III, IV, and VII, with 21 species each. This finding suggests that the environmental conditions in the three irrigation canals are relatively stable, supporting plankton diversity. In contrast, the lowest number of species was recorded in Irrigation V, with 18 species (Figure 7a). This finding suggests that environmental factors, such as poor water quality or low nutrient availability, limit plankton diversity. The highest abundance of plankton was found in Irrigation IX, with 142 individuals, followed by Irrigation VII, with 132 individuals (Figure 7b). This number indicates that both irrigation canals have conditions that support the growth and reproduction of plankton.

In contrast, the lowest abundance of plankton was recorded in Irrigation III with 88 individuals. The calculation of the species diversity index revealed variations among irrigation canals. The highest diversity index was found in Irrigation IX, with a value of 2.87, followed by Irrigation VII, with a value of 2.84. Meanwhile, the lowest diversity index value was recorded in Irrigation VI at 2.71 (Figure 7c). Overall, the diversity index values at all research locations are classified as moderate. The species evenness index showed the highest values in Irrigation I, II, and IX, with a value of 0.96 each, while the lowest value was recorded in Irrigation IV, with 0.91 (Figure 7d).

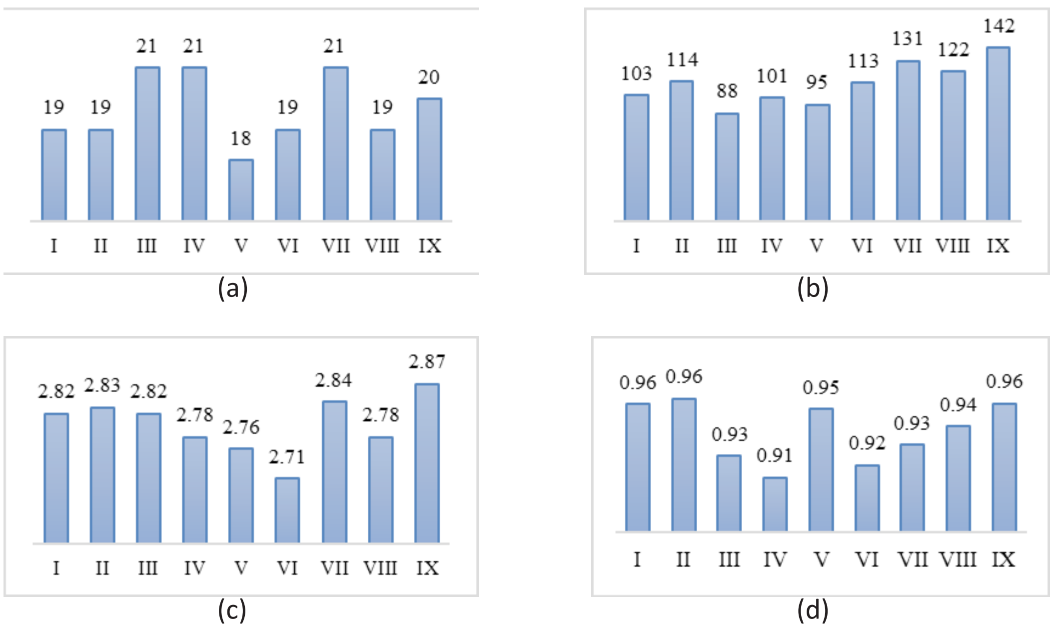

Figure 7. Number of Species (a), Abundance (b), Diversity Index (c), and Evenness of Plankton Taxa Species in Irrigation Canals of Rice Fields in Tomohon City, North Sulawesi

The influence of environmental factors on sampling locations was analyzed using Principal Component Analysis (PCA). The PCA ordination diagram indicates that the first axis (axis 1) accounts for approximately 97.27% of the variation in environmental characteristic data measured at each observation location. The analysis results indicate that environmental characteristics, including nitrate and nitrogen levels, have a significant impact on sampling locations. In contrast, environmental parameters such as nitrite and ammonia levels show a lower influence on the distribution of sampling locations. The PCA ordination of environmental factors at nine irrigation locations reveals that Irrigation 1 and 9 are predominantly affected by high nitrate levels (Figure 8). In contrast, Irrigation 6 is characterized by high nitrogen levels, which distinguish it from other locations.

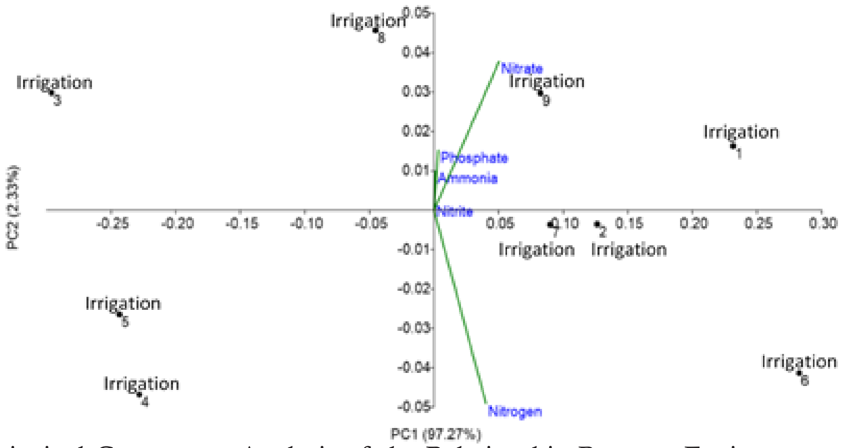

Figure 8. Principal Component Analysis of the Relationship Between Environmental Factors and Sampling Location

The results of this study indicate that the number of plankton species in rice field irrigation canals in Tomohon City is higher compared to Arfiati et al. (2024) in Rawa Klampok, Malang Regency, who only reported 13 plankton genera. However, the number of species found in this study was lower than the results reported by Nahiduzzaman et al. (2023), who identified 46 plankton genera, and Nizar et al. (2022), who identified 25 plankton species. The difference in the number of plankton species between these studies is greatly influenced by habitat conditions and sampling methods used. According to Titaley et al. (2021), the abundance and diversity of plankton at each location are highly dependent on the physical, chemical, and biological factors that shape the conditions of its habitat. These factors are influenced by the season and anthropogenic disturbances, such as settlements, agricultural activities, and industrial areas, which contribute to ecosystem productivity, including the abundance and diversity of plankton (Nugroho et al., 2020).

The study results showed that *Melosira* sp. (*Bacillariophyceae* class) and *Staurastrum* sp. (*Chlorophyceae* class) were the dominant species in all study locations. The dominance of the *Bacillariophyceae* class can be attributed to its ability to adapt to freshwater environmental conditions, and the availability of sufficient nutrients supports its survival. This group is one type of algae that is qualitatively abundant in various types of waters, especially rivers. According to Wantasen et al. (2022), Bacillariophyceae is a group of algae that is qualitatively and quantitatively abundant in various types of waters, both as plankton and periphyton. *Bacillariophyceae* is part of the cosmopolitan phytoplankton group, which exhibits high resistance to extreme conditions, is easily adaptable, and has a very high reproductive capacity. Nizar et al. (2022) stated that the plankton that generally dominate freshwater come from the diatom (*Bacillariophyceae*) and green algae (*Chlorophyceae*) groups. High adaptability and rapid reproduction rates make *Bacillariophyceae* the most manageable plankton group to grow in various aquatic environmental conditions (Xia et al., 2024). This group also has a wide distribution, covering marine waters, freshwater, and moist soil. *Bacillariophyceae* is also the primary food source for fish and shrimp larvae, thereby playing a crucial ecological role in the aquatic food chain. *Chlorophyceae* or green algae contain *chlorophyll* a and b and are often found in relatively calm waters. This phytoplankton has a high photosynthetic ability, so it is the primary producer in the aquatic ecosystem. Amini et al. (2024) also showed that *Chlorophyceae* is the most dominant phytoplankton group in various waters.

The diversity index (H') at all observation stations is 1–3, indicating that the irrigation waters of rice fields in Tomohon City are included in the moderate pollution category. According to Rukminasari (2018), an H' value of 1 indicates that the biota community is unstable, so that the water can be categorized as heavily polluted. Meanwhile, an H' value between 1 and 3 reflects the stability of the moderate biota community, so that the waters can be categorized as moderately polluted. If the H' value > 3, the biota community is considered stable, indicating that the waters are unpolluted. The higher the diversity index value, the more diverse the life in the waters, indicating that the ecosystem is in better condition. According to Chandel et al. (2024), plankton diversity can be used to indicate water quality because plankton is highly sensitive to changes in water conditions.

The evenness index determines the likelihood of a greater abundance of some types of biota over others, resulting in dominance. The evenness index in the study ranged from 0.91 to 0.96, which falls within the high evenness category (E > 0.6) (Palupi et al., 2024). According to Nam et al. (2022), the greater the evenness index in a community, the more nearly equal the number of individuals of each species is. Based on the evenness index data in this study, the habitat conditions appear to be stable. The smaller the evenness index value, or the closer it is to zero, the greater the uniformity of the phytoplankton population. An evenness index approaching zero tends to indicate an unstable community, meaning that the distribution of the number of individuals of each species is not uniform and is dominated by a particular species in the population.

Environmental characteristics, such as nitrates and nitrogen, significantly affect plankton diversity at the research location. Nitrate is the main form of nitrogen in water. Nitrate is the primary nutrient for plant growth. In Irrigations 1, 2, 6, 7, 8, and 9, the nitrate concentration ranges from 0.7 to 1.7 mg/L, and these irrigations also have the highest abundance of plankton compared to the other irrigations. Changes in land use in drainage basins and the introduction of pollutants into the water system can alter the balance of functional relationships within aquatic ecosystems, which can be indicated by the dominance of certain types of biota, such as blooming algae, disrupting the food chain system, and deteriorating water quality. Nitrate is the primary form of nitrogen in natural waters and serves as the primary nutrient for plant and algal growth. Nitrate is stable, very soluble in water, and abundant in water polluted by organic waste. Input from organic matter and runoff from domestic activities increases the concentration of nitrates in the water. Nitrate can also be obtained from agricultural activities during the rice planting season, which is attributed to the addition of NPK fertilizer (Kaswinarni et al., 2023; Xia et al., 2024).

According to Fachrul et al. (2021), nitrate concentrations exceeding 0.2 mg/L lead to eutrophication, or an increase in water fertility, resulting in excessive algae and aquatic plant growth. Oligotrophic waters generally have nitrate levels of 0–1 mg/L (Yeanny & Barus, 2019). Irrigation channels in Tomohon City, which are surrounded by rice and vegetable farms, receive runoff containing chemical fertilizers, which then affect nutrient levels in the water. High levels of nitrate and total nitrogen in water can increase the abundance of phytoplankton, including potentially toxic species (Nõges et al., 2023). According to Nur Aini and Safira (2023), nitrate is the primary nutrient for plankton and is highly soluble in water, making it stable when nitrogen compounds undergo complete oxidation in the water system. Plankton serve as a bioindicator, providing an overview of the quality status of water bodies, which can be used as a tool to assess water conditions (Asriansyah et al., 2021; Susilo & Tito, 2023; Thakur et al., 2013). Although the results indicate that plankton diversity remains in the moderate category, the study reveals that the irrigation ecosystem is under particular pressure due to nitrogen residues from fertilizers. However, this ecosystem still has resilience, as indicated by the presence of various plankton species. The aquatic ecosystem can be degraded if nitrogen input increases (Ujianti et al., 2019).

This study underlines the environmental feasibility of the rice field irrigation system in Tomohon City, characterized by controlled nitrogen residue levels and a diversified and thriving plankton community. Effective nitrogen fertilizer management can enhance ecosystem health, agricultural productivity, and the sustainability of agricultural resources, as well as the environmental quality and sustainability of production systems. The contribution of this study to the environmental field is to determine the impact of chemical fertilizer residues, particularly nitrogen, on aquatic ecosystems and assess water quality. The optimal use of best management practices, such as precision agriculture and buffer zones, to reduce nitrogen runoff can be explored in this study soon. Water-related agronomic techniques require efficient and sustainable water use in agriculture to increase crop yields while conserving water resources, which should be included in future strategies.

CONCLUSION

The concentration of total nitrogen and nitrate residues decreased, followed by an increase in ammonia and nitrite residues. The diversity of plankton found was classified as moderate, with the dominance of species from the *Bacillariophyceae* and *Chlorophyceae* classes. This indicates that the irrigation water system can still support plankton life, but also shows potential for ecological pressure to increase with increasing nitrogen accumulation. The findings of this study confirm that the use of nitrogen fertilizers in agricultural practices needs to be better managed to mitigate adverse impacts on the aquatic environment. Implementing sustainable agricultural strategies, such as fertilizer management tailored to plant needs, precision irrigation systems, and reducing nitrogen runoff through vegetative buffer zones, are crucial steps in maintaining the balance of the irrigation water ecosystem in rice fields.

ACKNOWLEDGMENTS

We would like to thank Universitas Sam Ratulangi, through the Institute for Research and Community Service, for providing research funding through SKIM RTUU_K1, which is funded by DIPA Funds (SP-DIPA-023.17.2.677519/2023), as of November 20, 2023.

REFERENCES

Anas, M., Liao, F., Verma, K. K., Sarwar, M. A., Mahmood, A., Chen, Z. L., Li, Q., Zeng, X. P., Liu, Y., & Li, Y. R. (2020). Fate of nitrogen in agriculture and environment: agronomic, eco-physiological and molecular approaches to improve nitrogen use efficiency. In *Biological Research* (Vol. 53, Issue 1). BioMed Central Ltd.

Andriyani, N., Mahdiana, A., Hilmi, E., & Kristian, S. (2020). The Correlation between Plankton Abundance and Water Quality in Donan River. *Omni-Akuatika*, *16*(3), 14.

APHA (American Public Health Association). (2005). Standard methods for the examination of water & wastewater. In *Standard methods for the examination of water* (21st ed.).

Arimoro, F. O., Olisa, H. E., Keke, U. N., Ayanwale, A. V., & Chukwuemeka, V. I. (2018). Exploring spatio-temporal patterns of plankton diversity and community structure as correlates of water quality in a tropical stream. *Acta Ecologica Sinica*, *38*(3), 216–223.

Asriansyah, A., Wildan, D. M., Pratiwi, N. T. M., Simanjuntak, C. P. H., Sulistiono, Hestirianoto, T., Shafrudin, D., & Nugroho, T. (2021). Study on phytoplankton diversity of Batang Toru River and its surrounding, North Sumatra, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *800*(1).

Bibi, S., Saifullah, Naeem, A., & Dahlawi, S. (2016). Environmental impacts of nitrogen use in agriculture, nitrate leaching and mitigation strategies. *Soil science: Agricultural and environmental prospectives*, 131-157.

Chandel, P., Mahajan, D., Thakur, K., Kumar, R., Kumar, S., Brar, B., Sharma, D., & Sharma, A. K. (2024). A review on plankton as a bioindicator: A promising tool for monitoring water quality. *World Water Policy*, *10*(1), 213-232.

Di, D., Wang, S., Chen, G., Wang, Q., Zhang, J., Niu, X., & Huang, D. (2024). NH4+-N and Low Ratios of NH4+-N/NO3−-N Promote the Remediation Efficiency of Salix linearistipularis in Cd- and Pb-Contaminated Soil. *Forests*, *15*(3), 419.

Erman, N., Ginting, S., Tufaila, M., Syaf, H., Zulfikar., Z. (2022). Analysis of the Distribution of N, P, and K Nutrients in Rice Fields in Ngkari-Ngkari Village, Bungi District, Baubau City. *Berkala Ilmu-Ilmu Pertanian-Journal of Agricultural Sciences*, *2022*(02), 98–103.

Fachrul, M. F., Rinanti, A., Hendrawan, D. I., Salsabil, M. A., & Alreekabi, N. K. (2021). Distribution of Nitrate, Phosphate and N/P Ratio in Maninjau Lake, West Sumatra, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *754*(1).

Fowler, D., Coyle, M., Skiba, U., Sutton, M. A., Cape, J. N., Reis, S., ... & Voss, M. (2013). The global nitrogen cycle in the twenty-first century. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *368*(1621), 20130164.

Hadi, A. (2015). Pengambilan sampel lingkungan. *Erlangga, Jakarta*.

Haryadi, J., & Hadiyanto, H. (2012). Korelasi Nutrien Terlarut Dengan Struktur Komunitas Plankton Di Tambak Mangrove Blanakan, Kab. Subang. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan (Journal of Natural Resources and Environmental Management)*, *2*(2), 73-73.

Hassan, A., Gulzar, S., & Nawchoo, I. A. (2022). Role of nitrogen in photosynthesis. In *Advances in Plant Nitrogen Metabolism* (pp. 86-95). CRC Press.

Kagan, K., Jonak, K., & Wolińska, A. (2024). The Impact of Reduced N Fertilization Rates According to the "Farm to Fork" Strategy on the Environment and Human Health. *Applied Sciences*, *14*(22), 10726.

Kaswinarni, F., Aristiyana, F. N., & M. Anas Dzakiy. (2023). *Water quality status based on phytoplankton bioindicator in Tayu River, Tayu Sub-district, Pati District, Central Java, Indonesia.* In *Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia* (Vol. 9, No. 2).

Koneri, R., Nangoy, M. J., Maabuat, P. V., Saroyo, & Wakhid. (2022). Diversity and composition of butterflies in three habitats around Rayow Waterfall, Minahasa District, North Sulawesi, Indonesia. *Biodiversitas*, *23*(2), 1091–1098.

Kumar, R., Kumari, R., Prasad, C., Tiwari, V., Singh, N., Mohapatra, S., Merugu, R., Namtak, S., & Deep, A. (2020). Phytoplankton diversity in relation to physicochemical attributes and water quality of Mandakini River, Garhwal Himalaya. *Environmental Monitoring and Assessment*, *192*(12), 1-23.

Liu, Y., Zhang, Y., Lv, H., Zhao, L., Wang, X., Yang, Z., ... & Gu, H. (2025). Research on the traceability and treatment of nitrate pollution in groundwater: a comprehensive review. *Environmental Geochemistry and Health*, *47*(4), 107.

Nahiduzzaman, M., Karim, E., Nisheeth, N. N., Bhadra, A., & Mahmud, Y. (2023). Temporal distribution of plankton and fish species at Mithamoin Haor: Abundance, composition, biomass and ecosystem based management approach. *Heliyon*, *9*(12).

Maresi, S. R. P., Priyanti, P., & Yunita, E. (2015). Fitoplankton sebagai bioindikator saprobitas perairan di Situ Bulakan Kota Tangerang. *Al-Kauniyah: Jurnal Biologi*, *8*(2), 113-122.

Nam, N. D. G., Giao, N. T., Nguyen, M. N., Downes, N. K., Ngan, N. V. C., Anh, L. H. H., & Trung, N. H. (2022). The Diversity of Phytoplankton in a Combined Rice-Shrimp Farming System in the Coastal Area of the Vietnamese Mekong Delta. *Water, 14*(3).

Nizar, M., Ardelia, V., & Rizki, A. (2022). Plankton Community Structure in Teloko Lake, Teloko Village, Kota Kayuagung Subdistrict, Ogan Komering Ilir Regency, South Sumatra. *Journal of Public Waters Fisheries*, *1*(April 2015), 1–12.

Nõges, T., McCarthy, M. J., Nõges, P., & Kumar, R. (2023). Nitrogen cycle and its effect on phytoplankton community structure. In *Role of Green Chemistry in Ecosystem Restoration to Achieve Environmental Sustainability*.

Norlida, M. H., Shahid, S. M., Jamaliah, J., Zamir, A. M., & Hasliana, K. (2023). Evaluation of irrigation water quality for paddy cultivation in Bachok, Kelantan. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1205, No. 1, p. 012014). IOP Publishing.

Nugroho, L. A., Piranti, A. S., & Sastranegara, M. H. (2020). Plankton Community and Water Quality during Maximum Tidal Range in Segara Anakan Cilacap. In *IOP Conference Series: Earth and Environmental Science* (Vol. 593, No. 1, p. 012020). IOP Publishing.

Nur Aini, A. I., & Safira, M. A. K. (2023). Identifikasi Keanekaragaman Plankton Sebagai Bioindikator Pencemaran Air di Sungai Brantas. *Environmental Pollution Journal* (Vol. 2, Issue 2).

Odulate, D. O., Omoniyi, I. T., Alegbeleye, W. O., George, F. A., & Dimowo, B. O. (2017). Water Quality in Relation to Plankton Abundance and Diversity in River Ogun, Abeokuta, Southwestern Nigeria. *International Journal of Environmental Health Engineering*, *6*(1), 3.

Purba, H. J., Azahari, D. H., Dani, F. Z. D. P., Alsyouf, I., Masmoudi, M., & Obaideen, K. (2024). Enhancing rice resilience and sustainability: A bibliometric analysis of innovations for food security and environmental conservation. *BIO Web of Conferences*, *119*.

Putri, A. D. R., Sartimbul, A., & Yuniarti, A. (2023). Plankton Community Composition and Water Quality in Gili Ketapang, Probolinggo Regency, East Java. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9290–9299.

Ray, J. G., Santhakumaran, P., & Kookal, S. (2021). Phytoplankton communities of eutrophic freshwater bodies (Kerala, India) in relation to the physicochemical water quality parameters. *Environment, Development and Sustainability*, *23*(1), 259-290.

Rukminasari, N. (2018). Struktur Komunitas Dan Kelimpahan Fitoplankton Di Pulau Kapoposang Kabupaten Pangkajene dan Kepulauan Provinsi Sulawesi Selatan. *Jurnal Pengelolaan Perairan*, *1*(1), 51-65.

Sabar, M., Samman, A., Abubakar, S., Sunarti, S., Rina, R., & Bahtiar, B. (2024). Nitrate, Phosphate, Silica and Phytoplankton Abundance in the Coastal Waters of Maitara Island, North Maluku. *Omni-Akuatika*, *20*(2), 71.

Sazawa, K., Komiyama, T., Tsuchida, T., Taguchi, R., Nakashima, F., Ohta, T., Nishio, M., Yamazaki, Y., & Kuramitz, H. (2023). Effects of paddy irrigation-drainage system on water quality and productivity of small rivers in the Himi region of Toyama, Central Japan. *Journal of Environmental Management*, *342*.

Shaaban, M., Hatano, R., Martínez-Espinosa, R. M., & Wu, Y. (2022). Editorial: Nitrogen in the Environment. In *Frontiers in Environmental Science* (Vol. 9). Frontiers Media S.A.

Susilo, E., & Tito, C. K. (2023). Phytoplankton responds to environmental variables in Bali Straits, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *1251*(1).

Syarifah, R. N. K., Purwanto, P., Sarjito, A., Hanifa, H., & Bayyinah, L. N. (2025). The interaction of nitrogen and potassium nutrients in increasing growth, yield, and quality of sweet corn products. *Kultivasi*, *24*(1).

Thakur, R. K., Jindal, R., Singh, U. B., & Ahluwalia, A. S. (2013). Plankton diversity and water quality assessment of three freshwater lakes of Mandi (Himachal Pradesh, India) with special reference to planktonic indicators. *Environmental Monitoring and Assessment*, *185*(10), 8355–8373.

Titaley, Y. M., Toha, A. H. A., & Tapilatu, R. F. (2021). Diversity and Abundance of Plankton in Mangrove Waters. *Musamus Fisheries and Marine Journal*, 128–143.

Ujianti, R. M. D., Anggoro, S., Bambang, A. N., Purwanti, F., & Androva, A. (2019). Environmental Study on Phytoplankton in Garang Watershed, Central Java, Indonesia and Its Water Quality. *IOP Conference Series: Earth and Environmental Science*, *246*(1).

Wadi, F., Yusup, D. S., & Suartini, N. M. (2021). Plankton Community Structure In Tamblingan Lake, Buleleng District, Bali. *Simbiosis*, *9*(2), 131.

Wang, Q., Li, S., Li, J., & Huang, D. (2024). The Utilization and Roles of Nitrogen in Plants. In *Forests* (Vol. 15, Issue 7). Multidisciplinary Digital Publishing Institute (MDPI).

Wantasen, S., Luntungan, J. N., & Koneri, R. (2022). Chlorine Concentration and Phytoplankton Diversity in the Streams Around Tondano Watershed, North Sulawesi, Indonesia. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 129–141.

Welde, G. T., Li, B., Hou, Y., Ayana, G. U., Zhou, L., Jia, R., & Zhu, J. (2024). Effect of Rice–Carp Coculture on Phytoplankton and Microzooplankton Community Composition in Paddy Water during Different Rice Growth Stages. *Water, 16*(19).

Xia, J., Hu, H., Gao, X., Kan, J., Gao, Y., & Li, J. (2024). Phytoplankton Diversity, Spatial Patterns, and Photosynthetic Characteristics Under Environmental Gradients and Anthropogenic Influence in the Pearl River Estuary. *Biology*, *13*(7), 550.

Yang, X., Jomaa, S., Büttner, O., & Rode, M. (2019). Autotrophic nitrate uptake in river networks: A modeling approach using continuous high-frequency data. *Water Research*, *157*, 258–268.

Yang, X., Tang, S., Ni, K., Shi, Y., Yi, X., Ma, Q., Cai, Y., Ma, L., & Ruan, J. (2023). Long-term nitrogen addition increases denitrification potential and functional gene abundance and changes denitrifying communities in acidic tea plantation soil. *Environmental Research*, *216*.

Yeanny, M. S., & Barus, T. A. (2019). Distribution of Nitrate, Phosphate, Dissolved Oxygen and Macrozoobenthos Density in Belawan River. *IOP Conference Series: Earth and Environmental Science*, *305*(1).

Yusuf, Z. H. (2020). Phytoplankton as bioindicators of water quality in nasarawa reservoir, Katsina State Nigeria. *Acta Limnologica Brasiliensia*, *32*.

Zeng, Z., Chen, F., Lao, Q., & Zhu, Q. (2025). Effects of Nutrients on the Phytoplankton Community Structure in Zhanjiang Bay. *Journal of Marine Science and Engineering*, *13*(7), 1202.