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Phytoplankton diversity as bio-indicator of water quality in Caranan River, Pasacao, Camarines Sur

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Abstract

This study assessed phytoplankton diversity as a bio-indicator of water quality in the Caranan River, Pasacao, Camarines Sur. Specifically, it aimed to: (1) identify phytoplankton species at surface and sub-surface layers; (2) determine the river's physico-chemical characteristics using physical parameters (color, odor, turbidity, salinity, temperature, total dissolved solids (TDS), total suspended solids (TSS)) and chemical parameters (biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, nitrate (NO_3^-), phosphate (PO_4^{3-})); (3) assess phytoplankton diversity in surface and sub-surface layers; and (4) determine the significance of phytoplankton diversity in evaluating water quality. Water samples and phytoplankton were collected from three stations along the river. A total of 774 individual phytoplankton belonging to Dinoflagellates, Diatoms, Cyanobacteria, and Chlorophytes were identified. Diatoms were the most abundant group, with Pseudo-nitzchia species the most abundant across all stations. Physico-chemical analysis revealed that most parameters, such as water temperature (25.11 °C average) and pH (8.32), were within standard limits, while nitrate (NO_3^-, 25.9 ppm) and phosphate (PO_4^{3-}, 4.62 ppm) concentrations exceeded permissible levels. Dissolved oxygen (DO) levels were above the minimum standard, and total suspended solids (TSS) and biochemical oxygen demand (BOD) were below the limits. Results indicated that phytoplankton diversity reflected water quality conditions, where high nutrient concentrations favored opportunistic species, potentially signaling early eutrophication. This study concluded that Caranan River's water quality was moderately impacted by nutrient enrichment, and phytoplankton diversity served as an effective bio-indicator for environmental monitoring.

Future studies were recommended to include seasonal variations, more sampling stations, and additional bio-indicator organisms for comprehensive water quality assessment.

Keywords: phytoplankton, species diversity, water quality, bio-indicator, Caranan River

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1. Introduction

Freshwater ecosystems such as rivers and lakes are vital to maintaining environmental balance and supporting human well-being. These water bodies provide clean water for communities, sustain biodiversity, and support livelihoods through activities like agriculture and fisheries (Delos Reyes et al., 2020). Healthy freshwater systems are essential not only for supplying drinking water and food but also for regulating climate, preventing floods, and maintaining the balance of natural ecosystems. When these water bodies are polluted or degraded, both the environment and local communities suffer. An important part of these ecosystems is phytoplankton, tiny photosynthetic organisms that float in the water and help produce oxygen and sustain aquatic food chains (NASA Earth Science Division, 2021). Because phytoplankton respond quickly to changes in environmental conditions, they are commonly used as bioindicators to assess water quality and ecosystem health (Cruz et al., 2021). Shifts in the abundance and composition of phytoplankton communities often reflect early signs of water quality issues even before more obvious symptoms appear. Their populations can be influenced by factors such as nutrient levels, pH, temperature, and the presence of pollutants (Cruz et al., 2021). Monitoring the structure of these communities is an effective way to detect ecological imbalance and pollution in freshwater systems (APHA, 2017). For this reason, environmental researchers increasingly rely on phytoplankton as a cost-efficient and practical tool in water quality assessment (Nguyen et al., 2020).

Freshwater ecosystems in tropical regions, such as the Philippines, are highly susceptible to ecological changes due to seasonal rainfall, population growth, and land use. The discharge of domestic waste and fertilizers into rivers can lead to nutrient over-enrichment, resulting in eutrophication. This process causes algal blooms and decreases oxygen levels in the water, which can negatively impact aquatic life and potentially human health (Reyes et al., 2021). According to the major study of Villanueva and Dela Cruz (2024), Toxic algal blooms are on the rise in various freshwater areas in the Philippines, illustrating the impact of human activities on water quality. Recent research has demonstrated that phytoplankton can serve as early indicators of water pollution, often before visible changes are detectable. A study by Torres et al. (2023) highlighted that specific algae species in Leyte rivers can signal the levels of organic pollution by using Palmer's Pollution Index. Similarly, Martinez et al., (2024) discovered that in lakes within Batangas, phytoplankton diversity and abundance vary with changes in water temperature and dissolved oxygen. These findings highlight how useful phytoplankton are as indicators of environmental health.

In the Philippines, freshwater ecosystems face mounting challenges due to pollution, climate change, and unsustainable land use. A study by Salonga et al., (2022) recorded approximately 45 genera of phytoplankton in Philippine freshwater bodies, including diatoms, dinoflagellates, and blue-green algae. One pressing concern is the rise in algal blooms caused by excessive nutrients from human waste and agricultural runoff. Locally, Lake Buhi in Camarines Sur has reported issues like overfishing, high E. coli counts, and frequent algal blooms, stressing the need for better freshwater management (Beltran, 2023). Moreover, integrating phytoplankton analysis with physicochemical parameters such as pH, turbidity, temperature, and dissolved oxygen can provide a more complete picture of water quality. Ramos and Villanueva (2024) emphasized that combining biological and chemical assessments allows researchers to better understand pollution sources and ecosystem responses. This approach can also help communities like those living near the Caranan River to create informed conservation strategies that protect their water resources and livelihoods.

The study focused on the Caranan River in Pasacao, Camarines Sur, examining the impact of pollution on phytoplankton diversity. It aimed to enhance understanding of phytoplankton diversity and use phytoplankton as a bio-indicator for diagnosing freshwater pollution in the river, given their sensitivity to environmental changes.

(Domingo et al., 2019). By identifying the types and concentrations of phytoplankton, this research aimed to evaluate the water quality in the Caranan River and provide scientific data for local decision-making. Understanding phytoplankton diversity is not only about identifying microscopic organisms but also about interpreting how these tiny life forms respond to changes in their environment. Their presence, abundance, or sudden disappearance tells a story about the river's health. As Zhang, Y., et al., (2020) pointed out, monitoring these organisms gave researchers a clearer "voice" of the ecosystem revealing whether it was healthy, stressed, or deteriorating. Therefore, studying the phytoplankton community in the Caranan River was crucial for maintaining a sustainable and balanced freshwater environment for the people of Pasacao.

This research supports two key United Nations Sustainable Development Goals: Goal 6, which promotes clean water and sanitation, and Goal 14, which focuses on protecting life below water (United Nations, 2022). It also upholds national environmental policies like the Philippine Clean Water Act of 2004 (R.A. 9275), which addresses water pollution from various sources, and the Philippine Fisheries Code of 1998 (R.A. 8550), which ensures the protection and sustainable use of aquatic resources (Arellano Law Foundation, 2024). By using phytoplankton as bioindicators, this study contributes valuable data that will support local conservation efforts and guide better environmental policies and water resource management in the region.

Statement of the Problem - The Caranan River in Pasacao, Camarines Sur is vital for the local community water supply, agriculture, and fishing, but it is suffering from pollution, particularly harmful algal blooms that adversely affect aquatic life by diminishing oxygen levels. Despite the importance of phytoplankton as indicators of water quality, there is a lack of research on the rivers ecosystem to inform conservation practices. This study aims to identify prevalent phytoplankton species, assess the river physicochemical traits, examine phytoplankton diversity, analyze the relationship between these characteristics, and propose recommendations for improving water quality..

Objective of the study - This study aimed to determine the phytoplankton community as a bio-indicator of water quality in the Caranan River in Pasacao Camarines Sur. It is in this context to:

- Identified the different species of Phytoplankton at surface and sub-surface layer.
- Determined the physicochemical characteristics of Caranan River using A. Physical parameters such as; Color, Odor, Turbidity, Salinity, water temperature, total dissolved solid (TDS) and total suspended solid (TSS), B. Chemical parameters such as; biochemical oxygen demand (BOD), dissolved oxygen (DO), hydrogen Ion concentration (pH), nitrate, and phosphate.
- Assessed the diversity of Phytoplankton species in the surface and sub-surface layer of the Caranan river, Pasacao.
- Determined the significance of phytoplankton diversity in the water quality of Caranan River, Pasacao.

Significance of study - This research primarily benefits the residents of Caranan, Pasacao, Camarines Sur, particularly the barangay officials. Relevant groups, including the Department of Environment and Natural Resources (DENR), Bureau of Fisheries and Aquatic Resources (BFAR), Local Government Unit (LGU), barangay officials, and researchers, can utilize the study's findings in various ways. The DENR can use the results to monitor pollution and improve environmental policies. BFAR can understand water quality's impact on aquatic life essential for food and local employment. The LGU can identify pollution sources, enhance water quality plans, and prepare for climate change consequences. Barrio officials can better protect the river's health to support community needs. Researchers gain valuable knowledge about phytoplankton and encourage enhanced monitoring for environmental management.

Scope and limitation - The research investigated phytoplankton diversity in the Caranan River, Pasacao, Camarines Sur, to use as bioindicators of water quality. Sampling occurred at three sites along the river, analyzing both surface and subsurface layers. The study identified phytoplankton species and assessed population densities through field and laboratory methods. Additionally, various physico-chemical parameters were measured to evaluate water quality. Despite acknowledged challenges like seasonal variations and sample collection issues, the research seeks to enhance understanding of the connection between phytoplankton diversity and river health.

Theoretical Framework - The study explores how phytoplankton can indicate water quality changes in the Caranan River, which is vital for the Pasacao community for farming and fishing. It examines the impact of human activities like agriculture and waste disposal on the river's health using theories linking phytoplankton and water quality (NASA Earth Science Division, 2021). The Bioindicator Theory, developed by Ruth Patrick in the mid-20th century, suggests that living organisms can reflect environmental health, particularly in aquatic ecosystems, by responding to pollution and climate changes. Sensitive species indicate stress through their decline, whereas tolerant species can increase. The Freshwater Ecosystem Theory by G. Evelyn Hutchinson further expands on this by highlighting that freshwater environments like rivers and lakes are dynamic systems influenced by factors such as light, nutrients, and temperature, affecting the communities they host, including sensitive phytoplankton. Changes in these organisms provide insights into water quality and ecosystem health. The Eutrophication Theory, proposed by G. Evelyn Hutchinson in the 1950s, examines how increased nutrient levels, especially nitrogen and phosphorus, in freshwater ecosystems boost phytoplankton and algae growth. While this can enhance productivity initially, excessive nutrients lead to light reduction and low oxygen levels, harming aquatic life and degrading water quality, thereby highlighting phytoplankton as crucial indicators of water health.

Conceptual framework - The study assessed the phytoplankton diversity and water quality of the Caranan River through composite sampling at three stations. Researchers used the Shannon-Wiener and Simpson diversity indices to evaluate phytoplankton species and their abundance, while also examining the river's physicochemical characteristics to establish a baseline understanding of its overall health.

2. Methodology

This section discussed the research methodology used in the study, which comprises the study area, research design, research method, sampling design, data collection procedure, and statistical treatment.In text citations

Area of the study - The study focused on the Caranan River in Pasacao, Camarines Sur, which is approximately 6.6 km long and supports local lifestyles through fishing, bathing, agriculture, and recreation. As a crucial freshwater resource that runs through rural and semi-urban areas, the river has faced environmental challenges due to factors like population growth, agricultural runoff, and improper waste disposal. Various organizations, including local governments and the Department of Environment and Natural Resources (DENR), are actively working together to evaluate the river's ecological status and implement conservation efforts, positioning it as a priority area for community environmental management.

Research Design - This study employs a Descriptive-Quantitative Research Approach to assess the phytoplankton community and water quality in the Caranan River. The descriptive aspect involves analyzing the physicochemical properties of the water, such as color, odor, temperature, turbidity, salinity, pH, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), nitrate, and phosphate concentrations. This information provides a comprehensive overview of the river environmental conditions and their suitability for aquatic life. The quantitative part focuses on evaluating phytoplankton diversity by collecting water samples from different depths, which are then microscopically analyzed to determine the abundance of various species. This data is subject to statistical analysis to calculate diversity indices that reflect the richness and evenness of phytoplankton species. By integrating both descriptive and quantitative methods, the research aims to present a detailed understanding of the river ecosystem.

Research Method - The research method used is species identification and Composite sampling. Plankton Net Sampling was used for the sample collection, and the Phytoplankton Identification Guide by the Department of Marine Resources, a field guide for phytoplankton used for the identification of phytoplankton species. In computing the species diversity, the Simpson Diversity Index and Shannon-Weiner Index were used (Ege

University, 2022). Samples for physicochemical collection are typically stored in an ice-filled fridge to prevent degradation, and it is crucial that they are transported to the laboratory within eight hours of collection to maintain their integrity. This practice is supported by research indicating that refrigeration is an effective method for preserving the chemical and cellular characteristics of samples (Ribeiro et al., 2015).

Sampling design - Sampling stations along the Caranan River were set up by partitioning the river into three stations, taking into consideration the guidelines from the Manual on Ambient Water Quality Monitoring (2008). This guide gave precise sampling methods and procedures for determining sampling stations.

Establishment of sampling station - The study examined the Caranan River in Sarimao, Pasacao, Camarines Sur, by establishing three sampling stations at upstream, midstream, and downstream locations. Each station featured a 100-meter stretch of the river representative of its conditions, with each sample minimized road or bridge influences by ensuring at least 100 meters of upstream distance. Three replicates of the designated reach were created at each sampling station at one-hundred-meter intervals.

Data gathering procedure - The researchers conducted a study on the Caranan River in Pasacao, Camarines Sur, coordinating with local authorities to obtain necessary permissions. Water samples were collected from upstream, midstream, and downstream locations using clean bottles and marked for easy identification. Sample preservation was prioritized to ensure accuracy during subsequent laboratory analyses, which required monitoring various physical and chemical parameters. Key assessments included turbidity, salinity, pH, dissolved oxygen, and several nutrient concentrations, all of which contributed to a comprehensive understanding of the river overall water quality. Essential metrics, like Total Suspended Solids (TSS) and Nitrate levels, were tested based on recognized standards and consulted analytical procedures to yield reliable findings.

Identification of Phytoplankton - A compound microscope with magnifications of 4x, 10x, and 40x was used for the study, and phytoplankton species were identified using a camera. The identification was conducted by employing a Phytoplankton Identification Guide by DMR. The direct counting method is a widely utilized technique across various fields for obtaining accurate numerical data from observations. This method involves counting entities directly from samples, which can enhance measurement precision and reliability (Erkmen, 2022).

Statistical Treatment and Data Analysis - The researchers quantified the phytoplankton community by counting the organisms in each sample. The calculations used for this analysis followed the procedures for quantitative phytoplankton assessment described by Hillebrand et al. (2019). The researcher discusses various ecological indices used in assessing biodiversity within a community. Relative abundance refers to the commonality or rarity of a species compared to others in a specific area, calculated by determining the proportion of each species in a sample. The Shannon-Wiener Diversity Index (H’) measures biodiversity based on species richness and population evenness, specifically for phytoplankton. The Equitability Index (E) indicates how evenly individuals are distributed among different species, reflecting community balance, while the Dominance Index (D) highlights the prominence of the most common species in the community. Lastly, Pearson Correlation analysis was conducted using Past 4.03 software to explore the impact of water quality factors like pH and dissolved oxygen on phytoplankton communities in the Caranan River, illustrating the ecological relationships influencing the river and aquatic life.

3. Results and Discussion

In this section, the results and discussion of the data gathered were elaborated. This included the identified phytoplankton species, physicochemical characteristics, relative abundance by sensitivity tolerance, diversity index, dominance index, equitability index, and Pearson correlation.

3.1 Identified Phytoplankton Species in the Surface and Sub-surface area of Caranan River

The study conducted on the Caranan River identified a total of nineteen species of phytoplankton, categorized into four groups: Dinoflagellates, Cyanobacteria, Diatoms, and Chlorophytes. Among these, Diatoms, particularly Pseudo-nitzschia (large type), were the most prevalent, with 387 individuals collected from various stations along the river. The dominance of certain phytoplankton species is attributed to environmental conditions like nutrient availability, water temperature, and light penetration, which support diverse species growth. Pseudo-nitzschia (large) likely flourishes in areas with higher nutrient concentrations, especially nitrogen and phosphorus, contributing to its prevalence in the river (Bargu et al., 2016).

Table 1
Identified Phytoplankton in Surface and Sub-surface of Caranan River

The Identified Phytoplankton in Caranan River						
Taxonomical Classification	**Surface/ Subsurface**	**Phytoplankton Species**	**STATIONS**			**Total No. of Individuals (ai)**
			S1	S2	S3	
Dinoflagellates	Surface	D.norvegica	3	-	-	3
	Surface	Kerenia mikimotoi	1	-	-	1
	Surface	Dinophysis acuminata	2	3	-	5
	Surface	Scrippsiella trochoidea	-	-	1	1
	Surface	Acuminata	1	-	-	1
Diatoms	Surface	Pseudo-nitzchia (S)	48	68	75	191
	Sub-surface	Pseudo-nitzchia (S)	19	28	42	89
	Surface	Pseudo-nitzchiz (L)	49	87	72	208
	Sub-surface	Pseudo-nitzchiz (L)	35	87	57	179
	Surface	Gyrasigma	2	-	2	4
	Surface	Pleurosigma	11	3	5	19
	Sub-surface	Pleurosigma	8	3	2	13
	Surface	Navicula	6	-	-	6
	Surface	Fragilaria	3	-	-	3
	Surface	Thalassiosira	1	-	-	1
	Surface	Consinodicus	-	5	-	5
	Surface	Rhilosolena	-	-	2	2
	Surface	Ditylum	-	-	2	2
	Surface	Synedra sp.		1		1
Cyanobacteria	Surface	Woronichia naegellana	-	-	2	2
	Surface	Cylindrospermopsis	-	3	-	3
Chlorophyte	Surface	Bryozan	10	10	2	22
	Sub-surface	Bryozan	8	3	2	13
	Total		207	301	266	774

The findings, supported by the studies of Reed et al., (2016) and Mallin (2023), state that the growth and reproduction of diatoms are greatly affected by nutrient-rich conditions, especially those rich in nitrogen (N) and phosphorus (P). Such nutrients tend to arise from agricultural runoff and wastewater discharge, which results in eutrophic conditions in rivers. Diatoms are an indicator of such eutrophication since they prefer to grow under high levels of nutrients, which may lead to algal blooms and ecological imbalance.

Other species found at the sampling sites were Pseudo-nitzschia (small), with a total of 280 individuals recorded across the three sampling stations. Bryozoan (Class Chlorophyta) was the third most dominant phytoplankton in the Caranan River, with a total of 35 individuals. Pleurosigma, which belongs to the class Diatoms, also had a total of 35 individuals. For Navicula, only six (6) individuals were recorded, all of which were found in Station 1, while Stations 2 and 3 showed no presence at all. Dinophysis acuminata and Coscinodiscus were two phytoplankton species recorded in the Caranan River with a total of five (5) individuals. Gyrosigma was a small diatom found in the Caranan River, with a total of four (4) individuals. D. norvegica, Fragilaria, and Cylindrospermopsis were three phytoplankton species recorded with a total of three (3) individuals. Rhizosolenia, Ditylum, and Woronichinia naegeliana were three phytoplankton species with two (2) individuals recorded. The least dominant species of phytoplankton in the Caranan River were Karenia mikimotoi, Scrippsiella trochoidea, Dinophysis acuminata, Thalassiosira, and Synedra, each of which was represented by only one (1) individual; this showed that they were rare and survived only in areas where conditions briefly suited them.

Color. The results showed that all sampling sites recorded a clear color. Any difference in color between the stations could have been due to the location of the stations. The clear appearance of the water in the Caranan River was attributed to the low concentrations of TSS and TDS. According to the United States Geological Survey (USGS, 2016), elevated Total Suspended Solids (TSS) reduce water transparency, causing the water to appear turbid, while high Total Dissolved Solids (TDS) can alter the color of the water when dissolved organic compounds are present. Such reductions in light penetration can negatively affect phytoplankton communities that depend on sufficient sunlight for photosynthesis and growth. In addition, according to Davies-Colley and Smith (2015), clearer water allows deeper penetration of sunlight, supporting primary production. However, they also note that extremely clear but nutrient-poor waters may limit the organic resources required by some phytoplankton for survival.

Table 2
The physico-chemical characteristics of Caranan River

Physico-chemical Characteristics of Caranan River (Class C River)						
Water Parameters	**Stations**			**Average**	**Standard Water Parameters Range (DAO 2016-08) (DAO-2021-19)**	**Remarks**
	I	II	III			
Color	2 TCU	3 TCU	2 TCU	2.33 TCU	≤ 5 TCU	Within the standard
Turbidity(m)	1.91m	2.87m	1.61m	2.13m	≥ 1.0 m	Within the standard
Salinity (ppt)	10 ppt	0.5 ppt	0.012 ppt	5.0 ppt	0.5 - 30 ppt	Within the standard
Temperature (C°)	25°C	25.33°C	25°C	25.11°C	25 - 31	Within the standard
Total Dissolved Solids (ppm)	2.76	2.68	2.57	2.67	≤ 500 ppm	Below standard
Total Suspended Solids (mg/L	24.7	27.3	34.0	28.66	80	Below standard
Biochemical Oxygen Demand (mg/L)	6.3	6.6	6.0	6.3	7.00	Below standard
Dissolved Oxygen (mg/L)	7.3	7.57	7.43	7.43	5.00	Above standard
Hydrogen Ion Concentration (pH)	8.01	7.93	9.02	8.32	6.5 - 9.0	Within the standard
Nitrate (ppm)	29.40	25.20	23.10	25.9	7.00	Above standard
Phosphate (ppm)	3.91	3.19	6.77	4.62	0.025	Above standard

Odor. The results showed that Station 1 had a salty air odor. This smell in rivers near the coast usually occurs because of ocean water and tides. When more salt from the ocean enters the river, it can change the types of plants and animals that live there and might reduce fish catch (Smith et al., 2021). This salty water also makes it harder to use the water for drinking or farming. This can then affect food supply and people's health (Johnson & Lee, 2023). Both Stations 2 and 3 recorded an earthy seaweed odor. According to Luo et al., (2022) The earthy "seaweed" odor in river water, particularly in midstream and downstream areas, is primarily attributed to the presence of geosmin and other odorous compounds produced by microorganisms such as cyanobacteria and actinomycetes. These compounds are often released during algal blooms, which were more prevalent in nutrient-rich waters where plankton thrive. The presence of plankton in midstream and downstream river sections creates an environment conducive to algal blooms, which are significant sources of geosmin (Luo et al., 2022).

Turbidity. The results showed that the Caranan River had an average light penetration of 2.13 meters, which indicated a specific level of turbidity. This depth was significant as it reflected the relationship between turbidity and light availability. According to the USGS (2018), turbidity is the measure of a liquid's relative transparency. When light penetrates through a body of water, the amount of light scattered by the suspended materials in the water is determined. High intensity of scattered light indicates higher turbidity. Conversely, Mann et al., (2017) state that the source of turbidity can be a result 27 of clay and silt particles from erosion, runoff, and re-suspended bottom sediments. Smith et al., (2018) highlight that limited light penetration restricts the growth of submerged vegetation, leading to altered habitat availability.

Salinity. The results showed that the average salinity across the three stations was 5.0 ppt. This average indicated a salinity gradient which had several ecological and hydrological consequences. This salinity level implied that the downstream regions had faced greater salinity under the influence of tides and saltwater intrusion into freshwater areas. In contrast, the upstream regions might have been affected more by the input of freshwater. According to Liu et al., a salinity of 5.0 ppt can influence dissolved oxygen levels and nutrient availability, potentially leading to eutrophication in affected areas.

Temperature. The results showed that the average water temperature of the Caranan River was 25.11°C. Specifically, the temperature recorded at Station 1 was 25.0°C, Station 2 was 25.33°C, and Station 3 was 25.0°C. These readings were within the standard range for freshwater (25–31°C) as stated in DENR Administrative Orders No. 2016-08 and 2021-19. This meant that the water temperature in the river was acceptable and met the standard limit for good water quality. Temperature is one of the most important factors affecting water quality because it influences how gases dissolve and how aquatic organisms' function. When the water temperature remains within a suitable range, it supports the metabolism, growth, and movement of fish, plankton, and other aquatic life (USGS, 2018). Johnson et al. (2017) state that most tropical freshwater species thrive within the 25–31°C range, which helps their enzymes and body processes work normally. Although the temperature in the Caranan River was a bit lower than this range, it still supported the life and activities of aquatic organisms. The slightly cooler temperature observed may have been caused by environmental factors such as shade from trees, water movement, and the time of day when samples were collected. Overall, the temperature condition was favorable for aquatic life.

Total Dissolved Solids (TDS). The results showed that the total dissolved solids (TDS) concentration in the Caranan River, Pasacao, Camarines Sur, ranged from 2.57 ppm to 2.76 ppm, with an average of 2.67 ppm. The highest TDS value was recorded at Station 1 (2.76 ppm), followed by Station 2 (2.68 ppm), while the lowest was observed at Station 3 (2.57 ppm). The slightly higher TDS level at Station 1 may have been because it was closer to residential areas, where household activities and runoff could have carried small amounts of organic and inorganic materials into the river. These materials might have included minerals, salts, and waste particles that dissolved in the water (Olsen & Hawkins, 2017). Meanwhile, the lower TDS level at Station 3 suggested that this area received less waste or runoff since it was farther from homes and other human activities. In general, the TDS levels in all three stations were very low, showing that the Caranan River still had good water quality during the study. Low TDS means that there are only small amounts of dissolved substances in the water, which is a good sign for the health of the river ecosystem. According to the Department of Environment and Natural Resources (DENR) Administrative Orders No. 2016-08 and 2021-19, freshwater with TDS levels below 500 ppm is considered safe and acceptable. This meant that the recorded values in the Caranan River were well within the safe range. High TDS levels can harm aquatic organisms such as phytoplankton by reducing their number and diversity (Olsen & Hawkins, 2017). Since the TDS values in the Caranan River were low, they were unlikely to have had a negative effect on the phytoplankton and other aquatic life during the study period.

Total Suspended Solids (TSS). Total Suspended Solids (TSS) in the Caranan River revealed varying concentrations across the three sampling stations. Station 3 recorded the highest TSS level at 34.0 mg/L, followed by Station 2 with 27.3 mg/L, while Station 1 showed the lowest concentration at 24.7 mg/L. The computed overall TSS value for the river was 28.66 mg/L. The higher TSS concentration observed at Station 3 could be attributed to increased human activities and the presence of possible sources of sediment and particulate matter in the surrounding area. Stations located near residential zones, agricultural land, or areas with soil disturbance typically show elevated TSS levels due to surface runoff, erosion, and waste discharge. In contrast, the slightly lower TSS levels at Stations 1 and 2 suggested fewer disturbance sources or better vegetation cover that helped stabilize soil and reduced sediment input into the river. Human activities such as land conversion, improper waste disposal, and surface runoff are major contributors to changes in TSS levels in aquatic systems Xue and Ma (2017). This supported the likely influence of nearby anthropogenic activities on the TSS concentration observed in the Caranan River, especially at Station 3.

According to the article by Morata and Caligan (2019), freshwater bodies typically allow a certain level of suspended solids as long as they do not impair water usage or harm aquatic life. The TSS values recorded in all three stations fell within acceptable freshwater ranges, indicating that the river was still capable of supporting aquatic organisms. TSS levels are also closely linked to dissolved oxygen (DO). High TSS can reduce DO by increasing water temperature through light absorption and by promoting microbial decomposition that consumes oxygen. This meant that, in this study, TSS and DO were inversely proportional. Overall, the TSS concentrations measured in the three stations of the Caranan River indicated manageable levels of suspended solids, with Station 3 showing a noticeable increase likely influenced by nearby human activities. These results emphasized the importance of monitoring land use and controlling surface runoff to maintain healthy water quality conditions.

Biochemical Oxygen Demand (BOD). The Biochemical Oxygen Demand (BOD) levels measured in the three stations of the Caranan River showed relatively similar concentrations, with Station 2 recording the highest value at 6.6 mg/L, followed by Station 1 with 6.3 mg/L, and Station 3 with the lowest value at 6.0 mg/L. Although the differences were minimal, the pattern suggested a slight increase in organic pollution load in the mid-portion of the river where Station 2 was located. According to the DENR Water Quality Guidelines (DAO 2016-08), the recommended BOD limit for Class C freshwater bodies is at most 7 mg/L. This indicated that the BOD concentrations in all stations of the Caranan River remained within the acceptable freshwater standard. However, their proximity to the upper limit suggested the influence of moderate organic pollution in certain sites. The slightly elevated BOD values may have been attributed to anthropogenic activities near the river, particularly domestic wastewater discharge, surface runoff, and organic matter entering the river from surrounding communities. Stations near residential areas were more susceptible to wastewater inflow, which increased microbial activity and thus raised the BOD concentration.

Furthermore, Station 1 and Station 2 were areas observed to be frequently exposed to human activities such as washing, small-scale disposal, and agricultural runoff. These conditions contributed organic matter that microorganisms decomposed, which elevated the BOD levels. According to the article by Junaidi and Venoreza (2021), despite these BOD readings, the river’s Dissolved Oxygen (DO) might still have remained sufficiently high due to the fast-flowing water in portions of the Caranan River, especially during the dry season when turbulence enhanced oxygen mixing. Studies have shown that rivers with high flow velocity can sustain elevated DO levels even when BOD is moderately high because oxygen is replenished quickly. Although the current BOD levels did not exceed the allowable limit, continued increases posed risks to aquatic organisms, particularly macroinvertebrates known for their sensitivity to oxygen depletion. Sustained monitoring was therefore essential to ensure that the river maintained its capacity to support aquatic life and did not experience further organic pollution.

Dissolved Oxygen. The results showed that the average dissolved oxygen (DO) level in the Caranan River was 7.43 mg/L, based on readings of 7.30 mg/L at Station 1, 7.57 mg/L at Station 2, and 7.43 mg/L at Station 3. According to the Department of Environment and Natural Resources (DENR) under DAO 2016-08 and DAO 2021-19, the standard level of DO for Class C waters is at least 5.0 mg/L. The fact that the recorded levels exceeded the Department of Environment and Natural Resources (DENR) standard of 5.0 mg/L for Class C waters indicated a healthy aquatic environment, as higher DO levels are associated with better water quality and support diverse aquatic life. This was supported by a Philippine study where higher DO levels were linked with healthier aquatic communities and good river conditions (Gonzales et al., 2020). While the Caranan River’s DO levels were satisfactory, it was essential to monitor potential pollution sources that could affect water quality in the future. Dissolved oxygen is very important for aquatic life because it allows fish and other organisms to breathe and survive. When DO levels are high, more species can live and grow in the water, which helps maintain a healthy and balanced ecosystem (Ali et al., 2022). On the other hand, if oxygen levels become too low, it can cause stress or even death to some aquatic organisms (Senn et al., 2016). According to the Environmental Studies Institute (2024), water with enough oxygen can also help break down wastes and organic materials through natural aerobic processes, improving water quality and preventing the growth of harmful bacteria. Overall, the recorded DO levels in the Caranan River indicated that the water was still capable of supporting aquatic life, although continuous monitoring was needed to ensure stable and healthy oxygen levels.

Hydrogen Ion Concentration (pH). The pH results of the Caranan River in Pasacao, Camarines Sur showed that the water was slightly alkaline, with an average pH of 8.32. Among the three sampling stations, the highest pH was recorded at Station 3 (9.02), followed by Station 1 (8.01), and the lowest was at Station 2 (7.93). According to the Department of Environment and Natural Resources (DENR) Administrative Orders 2016-08 and 2021-19, the standard pH range for Class C freshwater is 6.5 to 9.0. This meant that the pH levels of the river were within the acceptable range and passed the standard for water quality. The slightly alkaline condition of the river suggested that the water was basic but still safe for most aquatic life. This could have been due to natural factors, such as minerals and rocks in the riverbed, that made the water less acidic. It could also indicate that there was less pollution coming from household or industrial waste, which often makes water more acidic. According to Anh (2023), waste materials that flow from households and drainage systems can lower the pH of water due to the chemicals they contain. A slightly basic condition is generally not harmful, but it can influence which species are able to live in the river. Some macroinvertebrates and phytoplankton prefer slightly alkaline water, while others may find it hard to survive if alkalinity becomes too high (Department of the Environment, Tourism, Science and Innovation, 2023). The Environmental Literacy Council (2025) also explained that a pH level slightly above neutral is usually not dangerous. However, if alkalinity is caused by pollution from industries or agricultural runoff, it can reduce dissolved oxygen and affect sensitive aquatic organisms. Overall, the Caranan River's pH values showed that the water quality was still good and suitable for freshwater species, following the standards set by the DENR.

Phosphate. The data showed that phosphate levels were highest at Station I, measuring 29.40, followed by Station II at 23.10, while Station III had the lowest level at 20.25. According to freshwater phosphate standards, which recommend a maximum of 0.025 mg/L, the phosphate levels in the study area exceeded the acceptable limits (DAO 2021-19). It reviews how anthropogenic phosphorus (e.g., from fertilizer runoff) alters aquatic plant communities, changing competitive balances and thereby affecting the whole ecosystem. This demonstrates that phosphate pollution not only stimulates algal growth but also degrades habitats, influencing macroinvertebrate communities and overall biodiversity (Liu et al., 2025). High phosphate concentrations can contribute to eutrophication, resulting in reduced oxygen levels, algal blooms, and changes to habitat conditions. These changes negatively affect macroinvertebrates by making the environment less suitable, thereby influencing their abundance and overall diversity. The US Environmental Protection Agency (2024) notes that excessive phosphorus can promote overgrowth of algae, decrease dissolved oxygen, produce harmful algal toxins, block sunlight needed by aquatic plants and organisms, and degrade habitat conditions for benthic macroinvertebrates and other aquatic life. Consequently, only macroinvertebrates with high tolerance are likely to survive and adapt under these conditions.

Nitrate. The findings revealed that nitrate concentration was highest at Station I (29.40 mg/L), followed by Station II (25.20 mg/L), while the lowest level was observed at Station III (23.10 mg/L); the average concentration was 25.9 mg/L. The elevated nitrate levels might have been attributed to human-related activities, which was likely considering the locations of the sampling sites. At Station I, human activities also contributed significantly. Runoff from farms, sewage, and nearby urban areas can release extra nitrates into the river. Overuse of fertilizers, leaking septic systems, and poor waste management further increase nitrate input. Because nitrate dissolves easily, it can move quickly through the soil—especially in disturbed areas—and eventually reach rivers (Dalu et al., 2020). High nitrate concentrations can strongly affect freshwater phytoplankton. Elevated nitrate stimulates rapid growth of opportunistic algae, which can reduce overall diversity and shift community composition toward bloom-forming species (Rahav et al., 2020). Such nutrient enrichment can destabilize the ecosystem by promoting oxygen depletion when blooms collapse and by altering the food web (Hao et al., 2024). Given the nitrate levels observed in this study (23–29 mg/L), these effects could have threatened phytoplankton diversity and weakened the overall health of the river ecosystem.

3.2 Diversity of Phytoplankton Species in the surface and subsurface layers of Caranan River.

Table 3 showed the total values of the Diversity Index (H'), Equitability Index (E), and Dominance Index (D) of the Caranan River. The Diversity Index measurements in the Caranan River indicate moderate species diversity, with values ranging from 1.75 at Station 1 to 0.84 at Station 3. This reflects a balanced ecosystem, conducive to resilience against environmental changes like pollution. The Equitability Index reveals that Battery Station 1 has a more even species distribution (0.55), while Station 2 shows a stark imbalance (0.09). The Dominance Index shows higher dominance at Station 1 (0.72) due to fewer abundant flowering species, hinting at possibly favorable environmental conditions conducive to those particular forms of phytoplankton. In contrast, Stations 2 and 3 display lower dominance and variability, suggesting broader support for diverse species owing to balanced environmental factors. Overall, the findings suggest that the environmental conditions significantly influence the diversity dynamics among the phytoplankton community in the Caranan River.

Table 3
Diversity Index (H), Equitability Index (E), and Dominance Index (D) of Caranan River

CARANAN RIVER					
PARAMETER	**S1**	**S2**	**S3**	**Average**	**Level of Parameters**
Diversity Index (H)	1.75	1.07	0.84	1.22	High Diversity
Equitability Index (E)	0.55	0.46	0.54	1.55	High Equitability
Dominance Index (D)	0.72	0.62	0.57	1.91	High Dominance

Table 4 showed the relative distribution of phytoplankton species in the Caranan River, revealing that the most prevalent species, Pseudo-nitzschia (L), comprised 50% of the phytoplankton population, indicating its dominance. This type of diatom thrives particularly well under favorable environmental conditions such as abundant nutrients, light, and suitable water temperatures. While it appeared across all sampling stations, the presence of other less common phytoplankton species, including Karenia mikimotoi and Scrippsiella trochoidea, was quite low, at only 0.12% each. These rarer species displayed lower tolerances to environmental changes, affecting their growth and distribution. Despite its scarcity, they contribute to the ecosystem by participating in primary production and nutrient cycling, consequently highlighting their role in maintaining ecological balance in the river.

Table 4
Relative Abundance (RA %) of Phytoplankton species in Caranan River

Relative Abundance of Phytoplankton in Caranan River		
Class	**Phytoplankton Species**	**RA (%)**
Dinoflagellates	norvegica	0.38
	Kerenia mikimotoi	0.12
	Dinophysis acuminata	0.64
	Scrippsiella trochoidea	0.12
Diatoms	Acuminata	0.12
	Pseudo-nitzchia (S)	36.17
	Pseudo-nitzchiz (L)	50
	Gyrasigma	0.51
	Pleurosigma	4.13
	Navicula	0.77
	Fragilaria	0.38
	Thalassiosira	0.12
	Consinodicus	0.64
	Rhilosolena	0.25
	Ditylum	0.25
	Synedra sp.	0.12
Cyanobacteria	Woronichia naegellana	0.25
	Cylindrospermopsis	0.38
Chlorophyte	Bryozan	4.52

3.3 Correlation between the Physico-chemical Characteristics and level of Phytoplankton biodiversity in Caranan River

A strong relationship was observed between phytoplankton composition, abundance, diversity, and the physico-chemical characteristics of the Caranan River. The dominance of nutrient-tolerant species and moderate diversity levels indicated that the river was moderately affected by nutrient pollution.

3.4 Recommendations to maintain good water quality in Caranan River, Pasacao, Camarines Sur.

To maintain and protect the water quality of the Caranan River, it is essential to implement strict waste management practices. Solid waste and untreated wastewater must not be disposed of in the river, and domestic sewage should be properly treated before being released. Promoting eco-friendly agricultural practices is also important to reduce runoff, leveraging organic fertilizers as alternatives to chemical ones that contribute to pollution. Controlling nutrient inputs from fertilizers and sewage is crucial in preventing environmental issues like algal blooms. Enhancing community awareness through educational campaigns and encouraging participation in activities such as clean-up drives and tree planting are key for long-term conservation efforts aimed at preserving the river's ecological health.

4. Summary, findings, conclusion and recommendation

Summary and Findings - This study examined the diversity of phytoplankton in the Caranan River, focusing on its potential as an indicator of water quality. Researchers identified nineteen phytoplankton species and analyzed the river's physico-chemical characteristics at upstream, midstream, and downstream locations. They found that while many water quality parameters met the standards for Class C freshwater, nitrate and phosphate levels were high, pointing to nutrient enrichment likely due to agricultural and domestic influences. The phytoplankton diversity was moderately high, especially upstream, with diatoms being the most abundant group. Observations indicated a strong link between water quality and phytoplankton variations, highlighting ongoing nutrient pollution issues. Recommended actions for improving water quality included adequate waste management and community engagement in river preservation efforts.

Conclusion - The study found that the tolerance of phytoplankton to environmental conditions significantly influences their abundance, distribution, and community structure in the Caranan River. Phytoplankton diversity in the river was moderate, with diatoms, particularly Pseudo-nitzschia species, being the most dominant, suggesting moderate nutrient pollution and signs of early eutrophication. Key factors affecting phytoplankton distribution included nutrient concentrations, dissolved oxygen, pH, and temperature, with elevated nitrate and phosphate levels impacting their growth. The research indicated that human activities, such as agricultural runoff and wastewater discharge, enriched the river's nutrients, thus altering the ecosystem's balance. The study emphasized that phytoplankton serve as effective indicators of water quality and stressed the importance of ongoing monitoring and management efforts to prevent further degradation of the river.

Recommendation - Based on the Findings of the study, the researchers recommended the following:

- Implement Best Management Practices for Agriculture. Collaborate with local farmers to adopt sustainable agricultural practices, including precise organic fertilizer application techniques and buffer strips along waterways. These measures can significantly reduce the runoff of nitrates and phosphates from agricultural lands into the river.
- Establish Community Awareness Programs. Develop educational campaigns targeting residents and stakeholders about the impacts of nitrate and phosphate pollution.
- Conduct a regular water quality monitoring program for the Caranan River to ensure the continuous assessment of nitrate and phosphate levels for the river's health.

Implication for school Education - This study offers a local foundation for environmental education by focusing on Phytoplankton Diversity as Bio-indicator of Water quality in Caranan River, Pasacao, Camarines sur. The findings can be integrated into science curricula to help student to grasp the impact of Phytoplankton diversity on water quality and ecosystem health, fostering a deeper understanding of local environmental issues and promoting ecological literacy among students. This can encourage them to become more engaged in environmental conservation efforts within their community.

Implications for Students - For students, this study links academic theory with environmental responsibility. It helps them understand phytoplankton diversity as a water quality bioindicator, showing how changes in these organisms reflect ecosystem health. It also develops while skills in field research, species identification, ecological monitoring and encourages care for local aquatic environments.

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