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SEASONAL VARIATION OF PHYTOPLANKTON DURING THE YEAR 2024 AT SAN JUAN RESERVOIR IN ECUADOR

Dalton Michel Guarnizo Crespo[1*], Mayra Magali Cuenca Zambrano[2], Mario Fleitas Días[3] and William Jamil Santos Sánchez[4]

[1]Universidad Estatal de Milagro, Ecuador, Email: dguarnizoc@unemi.edu.ec Orcid ID: https://orcid.org/0000-0002-8086-7645
[2]Universidad Estatal Península de Santa Elena, Ecuador, Email: mcuenca@upse.edu.ec Orcid ID: https://orcid.org/0000-0003-0373-1645
[3]Instituto Superior Universitario Compu Sur, Quito, Ecuador Orcid ID: https://orcid.org/0000-0002-7180-9363
[4]Universidad Estatal Península de Santa Elena, Ecuador, Orcid ID: https://orcid.org/0000-0002-7180-9363

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Corresponding Author: Dalton Michel Guarnizo Crespo (dguarnizoc@unemi.edu.ec)

ABSTRACT

The study analyzes the seasonal variation of phytoplankton in the San Juan reservoir throughout 2024. A quantitative approach was employed, entailing the systematic sampling of the species of algae present in different seasons. The diversity and abundance of species were evaluated, as well as their relationship with key environmental variables. The results indicate substantial variation patterns, which are influenced by factors such as temperature, nutrient availability, and solar radiation. The San Juan reservoir exhibits a high diversity of Aulacoseira granulata phytoplankton represents 34.2%, Gynodinium sp. 13% and Chlorella vulgaris 11.6% of the total; Microcystis aeruginosa increased by 15% in summer. In summary, the phytoplankton of the San Juan Reservoir demonstrates seasonal variability, primarily in response to fluctuations in temperature and nutrient levels. These fluctuations have been identified as factors that influence the abundance and distribution of algae. Given the observed increase in cyanobacteria and eutrophication, continuous monitoring is imperative to ensure water quality is maintained.

KEYWORDS: Phytoplankton, Seasonal Variation, Aquatic Ecology, Water Quality.

1. INTRODUCTION

Phytoplankton represents an indispensable constituent of aquatic ecosystems (Sayeswara & Ashashree, 2022). Classified as a constituent of the base of the food chain, it plays an active role in regulating fundamental physicochemical processes (Jahan, 2023). Consequently, the dynamics of phytoplankton are influenced by environmental factors and anthropogenic activities thamodify its function in reservoirs (Hajikhalil, 2023).

In light of the global call to action to address the actual threats contributing to the deterioration of biodiversity (Piczak *et al.*, 2023), research into water quality continues to increase, particularly in studies targeting phytoplankton in assessment procedures (Stoyneva *et al.*, 2023).

This concept facilitates comprehension of the substantial variability to which phytoplankton is exposed within these ecosystems, thereby enhancing the discernment of the water quality in their habitat and the impact to be achieved in relation to the formulation of efficacious strategies for the conservation of aquatic ecosystems in diverse regions.

Conversely, global research on phytoplankton in freshwater ecosystems has gained increasing importance, as evidenced by the fact that 63% of studies in the twenty-first century have focused on this topic (Bautista-Regil *et al.*, 2023; Varmlandia & Hadisusanto, 2023; Stockenreiter, 2025).

Analyses have been conducted to identify ecological and technological trends, exploring their relationship with the sustainable use of resources and their potential in biotechnological applications (Overlingė *et al.*, 2023). This comprehensive approach enables not only sustainable use but also conservation in the face of emerging environmental threats (Lobus & Kulikovskiy, 2023).

In addition, it is acknowledged that phytoplankton abundance exhibits considerable seasonal fluctuations, which are predominantly dictated by alterations in environmental factors, including changes in nutrient availability and dissolved oxygen concentration (Ye *et al.*, 2023). Consequently, their response to environmental variations can be considered as a pertinent ecological indicator (Hui *et al.*, 2024). Indeed, there have been studies that demonstrate the influence of phosphorus and nitrogen as determining factors in the structure of the phytoplankton community. These studies highlight the importance of continuous monitoring in order to understand their impact on the dynamics of aquatic ecosystems (Huang *et al.*, 2023).

In relation to their ecological importance, phytoplankton not only sustains aquatic biodiversity (Hossain *et al.*, 2024) but also participates in the formation of biological products and nutrient cycling within reservoirs (Hajikhalil, 2023; Happe *et al.*, 2025).

Moreover, its function in the regulation of carbon is pivotal to the maintenance of ecological stability (Wang *et al.*, 2023). However, the impact of pollutants can significantly disrupt this equilibrium, resulting in adverse environmental consequences, including the disruption of food webs and the compromise of water quality.

It has been demonstrated that the evaluation of water quality, encompassing not only physicochemical indices of water but also an analysis of phytoplankton diversity, has been an effective method for monitoring freshwater ecosystems (Hui *et al.*, 2024).

Recent research has demonstrated that the stability of the phytoplankton community is influenced by a variety of factors. The presence of phytoplankton in excess has been shown to reduce oxygen levels, release toxins, increase eutrophication, turbidity and limit photosynthesis, all of which can lead to a deterioration in water quality (Akinyemi *et al.*, 2022; Li *et al.*, 2024). This has significant implications for the use of water bodies for consumption, recreation and wildlife presence. The research highlights the necessity for the implementation of environmental management strategies that focus on preserving the functionality of reservoirs and ensuring their long-term sustainability.

1.1. Study Area

The San Juan Reservoir is in the coastal region of Ecuador, in proximity to the El Empalme canton in the province of Guayas. It is fed by the San Juan River, which is part of the hydrographic basin of the Daule River. The reservoir is situated at an approximate altitude of 100 meters above sea level. It fulfills fundamental functions in the region, including serving as a water supply for agricultural irrigation, human consumption, and flood control. The reservoir has an approximate surface area of 280 hectares and a maximum depth of 24 meters.

The climate of the reservoir area is classified as tropical monsoon, with an average annual temperature of 26.3°C. The temperature range typically extends from 20.7°C to 31°C. A mean temperature of 3°C indicates that April is the warmest month, and rainfall is markedly seasonal, with an annual average of 1,025 mm, concentrated between February and April, reaching its maximum peak in March with 250 mm. During dry months, such as August and September, rainfall drops significantly, with records below 3 mm. This climatic variability makes the San Juan reservoir an essential component in the management of the region's water resources, guaranteeing water supply in critical times.

The construction of the dam has had a profound impact on the region, with a focus on promoting sustainable agricultural development and fostering the growth of surrounding rural communities. This area is distinguished by its notable agricultural activity, and the strategic location of the dam has led to its emergence as a pivotal ecosystem for local biodiversity. The hydrometeorological factors, including seasonal rainfall, temperature, and variations in river flow, exert a significant influence on the ecosystem.

The primary characteristics of this reservoir include the influence of climatic and anthropogenic factors on its phytoplankton dynamics, which necessitates a comprehensive analysis of its seasonal variations. Variations in temperature, nutrient availability, and human activity can impact the composition and abundance of species, thereby affecting water quality and aquatic biodiversity.

The high prevalence of phytoplankton in the San Juan Reservoir has led to a number of issues, including a decline in water quality, alterations in oxygen availability, an increase in odors, and effects on other aquatic species. These events of uncontrolled proliferation have led to the formation of harmful algal blooms, which have had a significant impact on activities such as fishing and tourism in the region.

The subject matter is of interest from a scientific perspective, as there is a paucity of research on this topic in Ecuador. The necessity to quantify the seasonal variation of phytoplankton in the San Juan reservoir is therefore justified, as is the identification of the species present, the ecological patterns, and their impact on water quality. Through the quantitative data provided, the objective is to implement sustainable management strategies.

Furthermore, the study will contribute to the existing body of knowledge regarding the ecological dynamics of the region's reservoirs. It will provide critical information for the management and preservation of these aquatic ecosystems. The objective of the research is to analyze the seasonal variation of phytoplankton in the San Juan reservoir during the year 2024. The study will evaluate changes in its dynamics by considering environmental and anthropogenic factors.

2. METHODOLOGY

From a methodological perspective, the research adopted a quantitative approach with an observational and descriptive design (Kittur, 2023). This approach enabled the analysis of the seasonal variability of phytoplankton in the San Juan Reservoir during the year 2024. The research team employed systematic sampling techniques and physicochemical analysis based on the Manual of Phycological Methods.

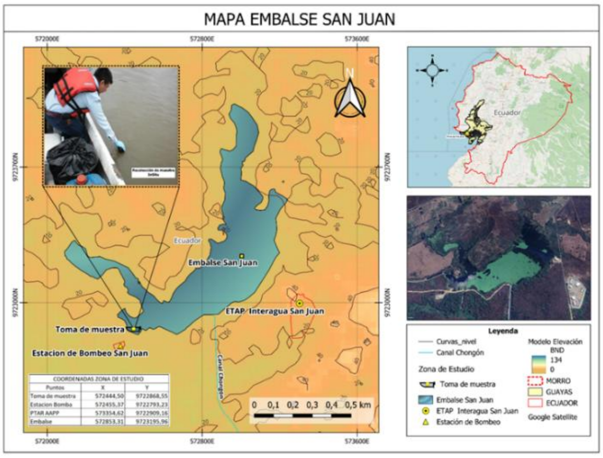


Figure 1: Sampling Site.
Source: Https://Download.Qgis.Org

2.1. Sample Collection

Sampling was conducted monthly at various strategic locations throughout the reservoir. The objective of this sampling protocol was to ensure the spatial representativeness of the data. Standardized protocols were implemented to prevent contamination and maintain the natural concentration of organisms. The quantitative analysis of phytoplankton was conducted using

Niskin-type hydrological bottles to collect samples that were then preserved with Lugol's solution.

In the context of qualitative analysis, cylindrical conical nets with a mesh span of 55 µm were used, employing vertical drags from 50 to 0 meters within the water column, in conjunction with surface drags of five minutes at an approximate speed of 2 knots. The samples were preserved using a 4% formaldehyde solution and subsequently neutralized with sodium tetraborate.

2.2. Sample Analysis

The counting was carried out using the Utermöhl method (Semina 1978), which is the most accepted method for phytoplankton quantification because it works with a certain volume and a standardized sedimentation time, which minimizes estimation biases for samples with variable densities of organisms (Villafañe and Reid 1995), in which sedimentation chambers with a capacity of 10 cc and an inverted microscope are used. The abundance was calculated considering the sedimented volume and the number of visual fields counted, obtaining the results in cell l-1.

To estimate the weighting of abundances, the following classification scale proposed by Avaria (1965) was used (Table 1).

Table 1: Cell Counting Scale: Cell Biomass Expressed in Cell/L:

Ranges	Productivity
$> 3 \times 10^3$ cells/L	Very abundant
$1 \times 10^3 - 3 \times 10^3$ cells/L	Abundant
$5 \times 10^2 - 9.99 \times 10^2$ cells/L	Moderate
$1 \times 10^0 - 4.99 \times 10^2$ cells/L	Scarce

The taxonomic identification of the species was carried out by means of optical and electron microscopy techniques. The quantification of phytoplankton biomass was carried out by determining chlorophyll-a using spectrophotometry. This ensured accuracy in the identification and quantification of the phytoplankton communities present in the aquatic ecosystem.

As part of the qualitative analysis, the species were quantified using the Semina drip method described in UNESCO (1978), and the results were expressed in cel.m-3 (Table 2). The classification scale proposed by Avaria (1965) was used to ascertain the weighting of abundances (Table 3).

Table 2: Species Classification Scale Expressed in Cel/M3.

Ranges	**Productivity**
$> 3 \times 10^6$ cells/m³	Very abundant
$1 \times 10^6 - 3 \times 10^6$ cells/m³	Abundant
$5 \times 10^5 - 9.99 \times 10^5$ cells/m³	Moderate
$1 \times 10^3 - 4.99 \times 10^5$ cells/m³	Scarce

The final data analysis was carried out using descriptive statistical methods, allowing for the characterization of the seasonal variability of phytoplankton in the San Juan reservoir. A variety of statistical analyses were employed to characterize the abundance and diversity of species over the course of the year. These analyses included measures of central tendency and dispersion, as well as graphical and tabular representations. These visual aids were used to illustrate the temporal fluctuations in the composition of the phytoplankton community and its relationship with environmental conditions.

In a similar way, the relative frequencies were analyzed to ascertain the dominant taxonomic groups in each season, which facilitated the observation of trends based on variables such as temperature, pH, dissolved oxygen, and nutrient concentration. The information obtained was systematically organized using specialized software, which facilitated the generation of a clear representation of the seasonal patterns of phytoplankton. This representation yielded pertinent information regarding their ecological dynamics within the reservoir.

3. RESULTS

The primary classifications of algae encompass cyanobacteria, chlorophytes, euglenophytes, dinoflagellates, and diatoms. These algae are distinguished by their heterogeneity in photosynthetic pigments, reserve substances, and cellular structures. They possess a variety of chlorophylls and specific accessory pigments, which enable adaptation to diverse environments. Some species possess a rigid or semi-rigid cell wall, while others are characterized by its absence, reflecting their extensive evolutionary adaptation within aquatic ecosystems and their ecological significance.

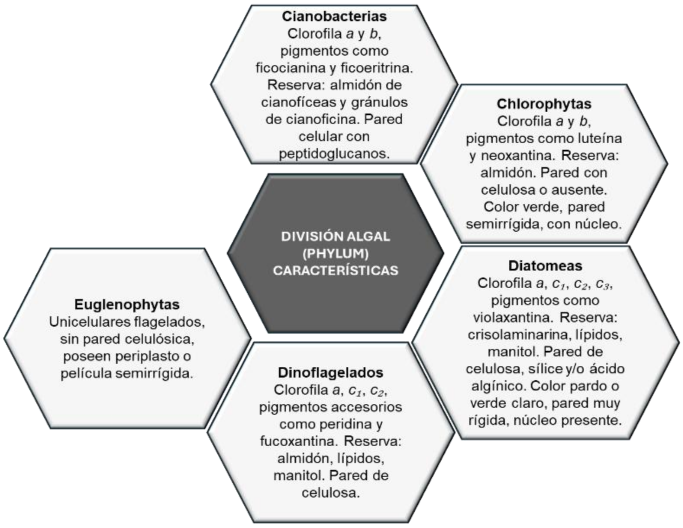


Figure 2: Characteristics of Algal Divisions (Phylum) In the San Juan Reservoir.

Some species of algae, including but not limited to cyanobacteria and dinoflagellates, have the potential to adversely impact water quality through the formation of deleterious blooms. These expansive blooms have been observed to consume oxygen, release toxins that are detrimental to aquatic fauna, and contaminate water sources used by humans.

Cyanobacteria are known to produce microcystins, which are hepatotoxic compounds. Meanwhile, certain dinoflagellates generate red tides that alter marine ecosystems. The result of these blooms is a deterioration of environmental health, an effect that is further compounded by the subsequent impact on biodiversity and the limitation of water usage for consumption, recreation, and agricultural activities.

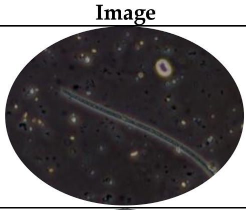
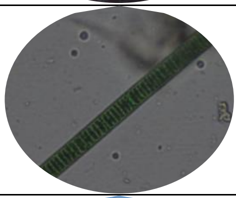
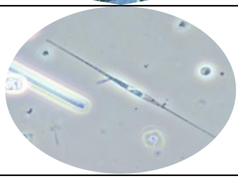
The data obtained reveal a substantial seasonal fluctuation in the composition of phytoplankton (Table 3). During the summer months, an augmentation in the biomass of cyanobacteria was documented, whereas in winter, diatoms were predominant. Environmental factors, specifically temperature and nutrient levels, exhibited a direct correlation with species distribution.

Table 3: Abundance Of Species in the San Juan Reservoir.

Algal Division (Phylum)	Species	Total Abundance
Cyanobacteria	*Pseudanabaena limnetica*	307,721
	Tenuis oscillatory	184,584
	Cortian oscillatory	134,596
	Anabaena sp.	
Chlorophytes	*Chlorella vulgaris*	1,267,930
	Closterium acutum	117,177
	Closterium acerosum	83,334
Euglenophytas	*Euglena acus*	293,310
	Euglena sp	35,354
	Euglena polymorpha	22,858
Dinoflagellates	*Gynodinium sp.*	1,415,306
	Peridinium sp	3,472
Diatoms	*Aulacoseira granulata*	3,722,354
	Nitzschia longissima	757,963
	Pleurosigma angulatum	202,375.472

The water mirror of the reservoir exhibits a noteworthy diversity of phytoplankton species, including several cyanobacteria, chlorophytes, euglenophytes, dinoflagellates, and diatoms. Among the cyanobacteria, *Pseudanabaena limnetica* (307,721 individuals) and *Oscillatoria tenuis* (184,584 individuals) are predominant, with a significant abundance in the reservoir waters (Table 4). These species are distinguished by their capacity to flourish in nutrient-rich environments and their ability to withstand diverse ecological conditions. The presence of *Oscillatoria cortiana* and *Anabaena sp*. is indicative of the tendency of cyanobacteria to proliferate in eutrophicated waters, suggesting a high level of nutrients in the water.

Tables 4: Characterization And Image of Species in the San Juan Reservoir.

Species	Image	Characteristics
Pseudanabaena limnetica		Filamentous cyanobacteria without heterocysts, common in eutrophic waters; forms thin colonies; It can fix atmospheric nitrogen under specific conditions.
Tenuis oscillatory		Filamentous cyanobacteria that move by gliding; tolerant to low oxygen concentrations; It grows in nutrient-rich environments.
Anabaena sp.		Filamentous cyanobacteria with heterocysts (nitrogen-fixing cells); it forms chains; It can produce toxins under certain conditions.
Nitzschia longissima		Elongated diatom with bilateral symmetry; it lives in benthic and planktonic environments; resistant to organic pollution; It is associated with silica-rich waters.

In the case of chlorophytes, *Chlorella vulgaris* is the most abundant species, with 1,267,930 individuals. This green alga adapts well to conditions of high light and nutrients, indicating the high productivity of the reservoir. The presence of other species, such as *Closterium acutum* and *Closterium acerosum*, has also been observed in smaller numbers. These species contribute to the diversity of this group within the aquatic ecosystem.

Among the euglenophytes, *Euglena acus*, with 293,310 individuals, is noteworthy for its capacity to flourish in waters, exhibiting fluctuations in the concentration of oxygen and nutrients, which may be indicative of seasonal variations or alterations in the quality of the water in the reservoir.

Dinoflagellates, including *Gynodinium* sp. (1,415,306 individuals), play a significant role in aquatic ecosystems. Their presence indicates favorable conditions for proliferation, such as suitable temperatures and nutrients. Conversely, diatoms, particularly *Aulacoseira granulata*, with a population of 3,722,354 individuals, predominate in colder, more oxygenated aquatic ecosystems. This observation suggests that the reservoir provides an optimal environment for the proliferation of these silicified algae.

The following section presents a quantitative and percentage analysis of the seasonal variation of the main phytoplankton species in the reservoir, considering the four quarters of the year.

The most prevalent species in absolute terms was *Microcystis aeruginosa*, with a peak of 435 individuals in the third quarter, representing a 15% increase compared to the first quarter (378) and 6.9% more compared to the second quarter (407). However, in the fourth quarter, its abundance decreased to 399, which is equivalent to a reduction of 8.3% compared to the previous quarter. This fluctuation underscores their proclivity for the warm and stable conditions characteristic of the third quarter, which is typified by the summer season (Table 5).

Table 5: Main Species by Quarter in the San Juan Reservoir.

Algal Division (Phylum)	Species	Quarter			
		1st	2nd	3rd	4th
Cyanophyta	*Microcystis aeruginosa*	378	407	435	399
Chlorophyta	*Chlorella vulgaris*	285	313	352	245
Cyanophyta	*Slimy oscillatory*	279	275	300	226
Cyanophyta	*Anabaena spiroides*	220	235	272	172
Euglenophyta	*Euglena viridis*	188	210	240	148

Conversely, *Chlorella vulgaris* exhibited a marked increase in growth, progressing from 285 in the first quarter to 352 in the third, signifying a 23.5% growth compared to the initial stages of the year. However, in the fourth quarter, its abundance decreased to 245, which indicates a 30.4% decrease compared to the annual peak. This phenomenon is indicative of a pronounced seasonality, which is believed to be associated with the availability of light and nutrients.

In the case of *Oscillatoria limosa*, the abundance exhibited an increase from 279 in the first quarter to 300 in the third, representing a 7.5% rise. However, a decline of 24.7% was observed in the fourth quarter, with the abundance dropping to 226. This decline is consistent with the general trend of decline in algal biomass during the cold months.

Anabaena spiroides also exhibited a peak in the third quarter, with 272 individuals, representing a 23.6% increase from the first quarter. However, its population decreased by 36.7% in the fourth quarter (172), confirming its sensitivity to seasonal conditions.

A 27.6% increase in *Euglena viridis* was observed from the first quarter (188) to its maximum of 240 in the third. Nonetheless, a decline was observed in the fourth quarter, with the value decreasing to 148, representing a 38.3% reduction. This decline is the most substantial percentage reduction observed among all species that were analyzed.

4. DISCUSSION

The results of phytoplankton monitoring indicate that the reservoir is classified as a eutrophic ecosystem, distinguished by a substantial proliferation of microalgae, particularly cyanobacteria, and pronounced seasonal fluctuations in biomass. This assertion is substantiated by analytical records that demonstrate the presence of inorganic nutrients, such as nitrite and nitrate, which function as the primary catalysts of algal proliferation. The elevated primary productivity observed, in conjunction with diminished water transparency and periodic pH increases, is congruent with the characteristic patterns of a chronic nutrient-loading system (Li *et al*., 2022).

The study revealed that the proliferation of cyanobacteria, including Microcystis aeruginosa, *Oscillatoria limosa,* and *Anabaena spiroides*, occurred predominantly during the second and third quarters of the year. This coincided with periods of optimal environmental conditions, characterized by elevated temperatures, substantial solar radiation, and stability in the water column. These conditions not only favor photosynthesis but also allow the accumulation of surface biomass. Cyanobacterial growth was especially significant in the third quarter, where the maximum abundance values were reached for all recorded species (Otero et al., 2023).

A salient aspect of the ecological behavior of cyanobacteria pertains to the coincidence of their growth with minimal carbon dioxide levels dissolved in water. This observation signifies that these microorganisms exhibit remarkable efficiency in absorbing and utilizing CO_2, even under conditions of limited availability. Cyanobacteria have evolved specialized biochemical mechanisms that enable them to capture inorganic carbon in the form of bicarbonate (HCO_3^-). These mechanisms subsequently transform the bicarbonate into carbon dioxide (CO_2) for incorporation through photosynthesis (Pilkaitytė *et al*., 2021).

Furthermore, this phytoplankton species exhibits a high degree of tolerance and adaptation to alkaline environments, as evidenced by the high pH values recorded during periods of peak biomass in the reservoir. This elevated pH is not solely a consequence of the vigorous photosynthetic process; it also selectively favors cyanobacteria due to their metabolic capacity to transform bicarbonate and carbonate ions into carbon dioxide, thereby conferring a competitive advantage over other algal groups that demonstrate less tolerance for alkalinity (Rosales *et al*., 2022).

The species *Chlorella vulgaris* (Chlorophyta), although it also exhibited significant abundance values, demonstrated a reduced persistence towards the conclusion of the year. This finding suggests a diminished capacity to adapt to extreme pH conditions and competition for nutrients against cyanobacteria. Conversely, *Euglena viridis* (Euglenophyta) exhibited a notable presence during the warmer months, a phenomenon that may be attributed to its mixotrophic characteristics. These characteristics enable it to transition between photosynthesis and the absorption of organic matter, a strategy that confers a competitive advantage in dynamic environments characterized by fluctuations in nutrients (Zhang *et al*., 2023).

The results of the study indicate that the structure of phytoplankton in this ecosystem is strongly influenced by physicochemical factors, including nutrient concentration, pH, and the availability of dissolved inorganic carbon. Cyanobacteria dominate in terms of biomass and exhibit remarkable ecological plasticity, capable of sustaining their proliferation in conditions that limit other algae. This pattern underscores the necessity for continuous monitoring of water quality. Excessive growth of cyanobacteria can precipitate advanced eutrophication processes, resulting in deterioration of water quality and potential risks to human health and aquatic ecosystems (Zhang *et al*., 2023).

The findings of Nguyen & Huynh (2023) underscore the intricate dynamics underlying the relationship between surface water quality and the composition of planktonic communities in tropical environments, such as that of An Giang, Vietnam. The use of the water quality index (WQI) in conjunction with the Shannon-Wiener diversity index facilitated the discernment of substantial variations in water quality, predominantly influenced by the presence of organic matter, total suspended solids, and pathogenic microorganisms. This resulted in a categorization of water conditions ranging from poor to good.

This heterogeneity is indicative of the contemporary environmental challenges faced by numerous watersheds in intensive agricultural regions, where nutrient inputs and organic residues exhibit a high degree of persistence (Zhou *et al*., 2021). From an ecological perspective, the results demonstrated that phytoplankton communities were dominated by species characteristic of eutrophic systems, such as *Melosira granulata, Pediastrum duplex*, and *Anabaena sp*., while in the zooplankton, rotifers and copepods, organism's sensitive to environmental variability, predominated.

Canonical correspondence analysis (CCA) and the similarity percentage analysis (SIMPER) were instrumental in establishing a correlation between the distinct composition of plankton and parameters such as temperature, pH, ammonium, orthophosphates, and coliforms. These analyses underscored the potential of these species as biological indicators. Recent studies have reinforced the utility of these species as bioindicators in bodies of water experiencing anthropogenic influence, particularly in tropical regions characterized by intricate hydrological cycles (Cheng *et al*., 2022; Su *et al*., 2023).

However, a critical aspect highlighted by Nguyen & Huynh (2023) is the limitation of diversity indices in fully reflecting water quality. Despite their extensive use in ecological assessments, these indices may not adequately capture the effects of specific pollutants or abrupt changes in trophic structure.

In this regard, it is imperative to integrate conventional methodologies with multivariate statistical tools and molecular approaches, which provide a more comprehensive perspective on the ecological status of water bodies (Liu *et al*., 2021). The findings indicate the necessity for adaptive and sensitive monitoring approaches that incorporate bioindicators and physicochemical variables to enhance the management of water resources.

5. CONCLUSIONS

The study corroborates the existence of substantial seasonal variations in the composition of phytoplankton in the San Juan reservoir. The information obtained is essential for the management of water quality and the conservation of the aquatic ecosystem. It is recommended that long-term monitoring and evaluation of mitigation measures be continued to prevent the proliferation of potentially harmful species.

The findings indicate that the seasonal cycle exerts a direct influence on the composition of phytoplankton in the San Juan reservoir. The population dynamics of species are determined by factors such as thermal stratification in summer and greater nutrient availability in winter. A comparison of the present study with those conducted in previous years reveals a tendency for an increase in cyanobacteria during the warm months, a phenomenon that could be attributed to eutrophication processes.

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Informed Consent: The study was carried out in accordance with the guidelines of the Declaration of Helsinki for compliance with the ethical, methodological, and legal aspects of this study, as well as the informed consent for the processing of personal data.

Data Availability: The data supporting the findings of this study are available from the corresponding author, upon reasonable request.

Conflict of Interest Statement: The authors declare that there are no financial, personal, or institutional conflicts of interest that may have inappropriately influenced the conduct of this research, the analysis and interpretation of the data, or the writing and publication of the results. This study was developed independently, with full transparency and under ethical criteria.

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