

Light Microscopy Analysis of Algal Diversity and Abundance in the Freshwater Ecosystem of Lake Sebu, South Cotabato

Naila M. Giomna
South East Asian Institute of Technology, Inc.
suwaibnailah@gmail.com

Charmel Fretz R. Collamar
South East Asian Institute of Technology, Inc.
collamarcharmel@gmail.com

Mar Gerwin L. Bade
South East Asian Institute of Technology, Inc.
margerwinbade@gmail.com

Reyna Joy Pavia
South East Asian Institute of Technology, Inc.
paviareynajoy09@gmail.com

Jayffer Ivan P. Bayona
South East Asian Institute of Technology, Inc.
jayffer2@gmail.com

Jade Zaldimer L. Sambog
South East Asian Institute of Technology, Inc.
jadezaldimer@gmail.com

Aprille Joy F. Segunla
South East Asian Institute of Technology, Inc.
segunlaaprillejoy@gmail.com

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ABSTRACT

This study aimed to identify and classify algae, determine their abundance and distribution, and provide baseline data for ecological monitoring. Using a descriptive research design and light microscopy, samples were collected from four stations Falls 1, Falls 2, Lake Sebu (East), and Lake Sebu (West). Results revealed that green algae were the most dominant group, followed by filamentous green algae and diatoms. The computed indices, the Shannon ($H = 0.89$), Evenness ($E = 0.66$), and Dominance ($D = 0.50$) indicate moderate diversity and balanced distribution. These findings suggest that Lake Sebu supports a mesotrophic freshwater ecosystem,

characterized by moderate nutrient levels and ecological stability. Overall, the study provides essential baseline data for understanding algal composition, assessing water quality and supporting the sustainable management and conservation of Lake Sebu's freshwater resources. It is recommended that future studies include seasonal sampling, consult a statistician and secure an accessible laboratory in the area to ensure timely observation, improved accuracy, and long-term monitoring of Lake Sebu's algal diversity and ecological health.

Keywords: *Algae, Freshwater, Lake Sebu, Biodiversity, Abundance, Diversity Indices*

INTRODUCTION

Background of the Study

Freshwater ecosystem is more than just a scenic landscape. It is among the most critical habitats on Earth, which provides food, water, and ecological services that sustain humans, animals, and countless ecosystems. Freshwater habitats such as lakes, rivers, streams, wetlands and aquifers are home to an incredible proportion of the world's biodiversity (Briceño, 2021). These systems regulate nutrient cycles, supports fisheries, and serve as sources of drinking water and irrigation. However, freshwater ecosystems are vulnerable to ecological disturbances caused by pollution, eutrophication, and climate change. Maintaining its balance requires careful study of the organisms that live or thrive within them, especially the microorganisms that silently influence ecological health.

Among these microorganisms are algae. Algae are diverse and large groups of simple, photosynthetic, unicellular and multicellular organisms (Khalil et al., 2021). Algae are major source of food for aquatic organism and play an important role in aquatic food chain or food web (Galloway et al., 2012). It releases oxygen through photosynthesis, acts as a food source for invertebrates and fish, and contributes to nutrient cycling. Aside from being a primary producer, they are also reliable bioindicators. Algae have emerged as invaluable bioindicators for monitoring aquatic pollution due to their sensitivity to environmental changes and rapid response (Ahmed, 2025). That means that the shifts in algal composition and abundance often reflect the changes in nutrient level, pollution, and other ecological stress. Thus, monitoring algal diversity and abundance is not only valuable for understanding ecosystem function but also for detecting early signs of ecological imbalance. In the Philippines, freshwater lakes are valuable for biodiversity and communities. One such lake is Lake Sebu, located in South Cotabato. Lakes play a crucial role in supporting ecosystems worldwide, serving as vital freshwater sources that sustain life and biodiversity (Technology, 2025). In Lake Sebu, it is both a cultural treasure and an ecological resource, supporting aquaculture, agriculture, and tourism. It is also a home to indigenous communities that depend on its resources. Despite its ecological potential, Lake Sebu faces environmental threats such as intensive fish cage farming, poor waste management, uncontrolled tourism, pollution, and climate-related vulnerabilities, which affects algal populations. Yet, scientific studies documenting the algal diversity and abundance in Lake Sebu remain limited.

This lack of information poses challenges for Lake Sebu's management and conservation. Understanding which algal groups are present, and in what abundance, can provide valuable insights into the ecological health of Lake Sebu. Algae's presence and abundance are vital for the biodiversity and productivity of marine and freshwater habitats. For instance, the proliferation of certain algal species may indicate nutrient enrichment, while the presence of diverse algal communities often signals balanced ecological conditions. Without baseline data on algal diversity, the local authorities and communities may struggle to detect early warning signs of ecological stress. While Lake Sebu has been studied in terms of its ecology, socio-economic value, and tourism, little attention has been given to its algal communities. At present, there is no baseline data on the diversity and abundance of algae in Lake Sebu, assess their relative abundance, and describe how these patterns reflect the ecological state of the freshwater ecosystems.

This study aims to fill this gap by conducting a light microscopy analysis of algal diversity and abundance in selected freshwater sites within Lake Sebu, South Cotabato. The findings will not only provide baseline data for ecological monitoring but also contribute to a sustainable management of Lake Sebu resources. Furthermore, this study is significant for fisheries management, biodiversity conservation, and environmental education of Lake Sebu. This offers insights that may guide local decision-makers and inspire further research on freshwater ecosystem in Lake Sebu.

1.2 Objectives of the Study

- To identify and classify the different algal diversity present in the freshwater ecosystem of Lake Sebu using Light Microscopy
- To determine the abundance and distribution of algae in selected sampling sites within Lake Sebu
- To provide baseline data that can support Lake Sebu's ecological management, biodiversity conservation, and future ecological research.

REVIEW OF RELATED LITERATURE

Algal Roles and Classification

Algae are a diverse group of photosynthetic organisms that primarily live in aquatic habitats (Helmenstine, 2025). Algae utilize photosynthesis, and they function as primary producers in diverse aquatic ecosystems (Astronot, 2025). They perform oxygenic photosynthesis, which converts carbon dioxide into organic compounds that support wide range of living organisms. Although algae and plants share the ability to perform photosynthesis, algae lack the true roots, stems, leaves, and vascular tissue found in plants (Helmenstine, 2025). Algae appear as unicellular or multicellular, microscopic or macroscopic, free-floating or attached to substrate, and occur in variety of aquatic environments. Given this diversity in form and habitat, algae are commonly classified in microalgae and macroalgae, where each group exhibits distinct ecological roles and contributions to aquatic ecosystems.

An important classification distinction between the algae is between microalgae and macroalgae. The algae are chlorophyll-containing primitive plants, both prokaryotic and eukaryotic, with wide range starting from unicellular to multicellular organizations (T, 2016). Microalgae are unicellular algal species that may either live singly or in colonies (Biology Online, 2024). These are generally microscopic found in suspended water columns, this includes eukaryotic algae and prokaryotic cyanobacteria. Macroalgae are large, multicellular algae that form a whole plant (Team, 2021). These are usually often attached to substrates and visible to the naked eye such as green algae, brown algae, and red algae, though in freshwater contexts macroalgae are fewer and often filamentous types. As for microalgae such as phytoplankton, periphyton, biofilms, and sometimes larger filamentous algae also appear in freshwater ecosystem not just in marine. The ecological diversity of algae underlies its multiple roles in ecosystem.

Algae occupy the foundational level in the trophic structure of freshwater ecosystem, acting as primary producers. Through photosynthesis, they convert inorganic carbon (CO₂), light, and nutrients into organic matter, which supports higher trophic levels. This process contributes significantly to the oxygen content of the Earth's atmosphere but also acts as a carbon sink, mitigating the impacts of CO₂ (Biobide, 2024). Without algae, the base of the food web would collapse. Additionally, algae are the key to nutrient cycling, involving not only carbon but also nitrogen, phosphorus, and trace elements. Certain algae can fix nitrogen like cyanobacteria. The organism possesses various attributes that directly or indirectly not only improve nitrogen (N), phosphorus (P), potassium (K), iron (Fe), and other mineral content in the soils but facilitate plants to make better use of such minerals in plant growth promotion for enhanced crop production (Kumar et al., 2014). Their growth and decay mediate storage and recycling of elements, influencing nutrient availability, water chemistry, and ecosystem productivity.

Algae contribute significantly to oxygen production. It is estimated that there are more than 1 million species of algae that are all capable of producing oxygen (Pomelo, 2025). Its role in producing oxygen is central to aquatic life. It normally produces much more oxygen in the daylight than they consume during the night, but some situations reduce the amount of oxygen a bloom produces without reducing its nighttime oxygen consumption (Freshwater-Aquaculture, 2019). This duality poses both positive and potentially harmful ecological consequences. Additionally, algae occupy key roles in food webs. Algae are the foundation of the marine ecosystem, providing food and energy to a diverse range of aquatic organisms, including fish, marine mammals, and sea turtles (Howard, 2023). Decline in algal productivity can reduce food availability and will impact the higher trophic organism.

Bioindicators are living organisms such as plants, planktons, animals, and microbes, which are utilized to screen the health of the natural ecosystem in the environment (Johnson, 2022). Algae are widely used as bioindicators because of their sensitivity to changes in environmental conditions like plankton and benthic algae. Planktons that react quickly to changes in their environment have proven to be particularly valuable, and the identification of certain indicator species has become increasingly common in the process of determining the quality of the water (Chandel et al., 2023). In addition to plankton, benthic algae, specifically diatoms, have also proven to be useful in ecological assessment. Beyond its scientific indication, algae as bioindicators have practical advantages such as rapid reproduction, typically respond quickly to environmental stressors.

Patterns and Drivers of Freshwater Algal Diversity

Freshwater algal diversity is a critical component of aquatic ecosystems, contributing to primary productivity and ecological balance. Global assessments have shown variations in algal composition due to environmental, climatic, and anthropogenic factors. Freshwater algal diversity plays a crucial role in the ecological balance and productivity of aquatic ecosystems. Globally, researchers have investigated how environmental, climatic, and anthropogenic factors influence algal species composition and richness across lakes and rivers. Sherwood et al. (2014) conducted a biodiversity survey across freshwater habitats in Hawaii and emphasized the significance of biogeographic trends. Their study highlighted that island freshwater systems often exhibit high

endemism, particularly in macroalgal species. This research provides insights into conservation priorities and the need for more localized biodiversity assessments in tropical regions.

Similarly, Anderson et al. (2019) proposed the creation of a Global Harmful Algal Bloom Observing System (G-HABOS), which integrates regional datasets into a global monitoring framework. The study emphasized the value of consistent observations to track harmful algal bloom (HAB) trends, diversity, and associated ecological risks. Such integration enables scientists to detect global shifts in algal community structure, especially in the context of climate change. In a broad-scale analysis of China's lakes, Wang et al. (2023) examined patterns of algal blooms across two decades. The study revealed that algal bloom frequency and intensity have increased significantly due to eutrophication and warming trends. These findings demonstrate how climate change and nutrient enrichment synergistically impact freshwater algal diversity and dynamics at national and global scales.

In Asia, freshwater ecosystems are experiencing significant ecological changes due to urbanization, nutrient runoff, and seasonal weather fluctuations. Various regional studies have focused on assessing algal composition and its relationship with local environmental factors. According to Jia et al. (2022) analyzed phytoplankton communities in five distinct lakes in China, ranging from oligotrophic to eutrophic conditions. The results showed clear spatial variation in algal taxa, particularly between high-altitude and lowland lakes. The study emphasized that water temperature, nutrient levels, and human activity strongly influence phytoplankton composition.

In the Philippines, Reyes et al. (2024) examined phytoplankton distribution in Lake Taal, a tropical caldera lake. They found that phytoplankton communities are strongly influenced by seasonal monsoons, with cyanobacteria dominating during warmer months and diatoms more prevalent in the cooler season. The study underlined the need for continuous monitoring to manage algal blooms and protect aquatic biodiversity. Islam et al. (2021) studied high-altitude lakes in the Kashmir Himalayas and found that diatoms were dominant in cold, oligotrophic conditions. This study provided a baseline for future monitoring of climate-induced ecological changes in mountain lake systems. Similarly, Lestari et al. (2025) documented freshwater microalgae in the black-water ecosystems of Kalimantan, Indonesia. Their results showed that acidic conditions and low light availability shaped unique algal communities dominated by green algae and euglenoids. The abundance and distribution of algal populations are influenced by multiple environmental factors, most notably nutrient concentrations, temperature, and pollution.

Environmental Drivers of Algal Population Dynamics

Nutrient availability, particularly nitrogen and phosphorus, is one of the primary drivers of algal population dynamics. Excessive nutrient input from agricultural runoff, wastewater discharge, and other anthropogenic sources can lead to eutrophication, which promotes rapid algal growth or harmful algal blooms (HABs) (Brenckman et al., 2025). In a controlled experimental study, Lüring et al. (2018) demonstrated that nutrient enrichment alone could significantly increase the chlorophyll-a content and biomass of both cyanobacteria and green algae. However, the effect was found to be even more pronounced when elevated temperature was combined with nutrient pulses, indicating a synergistic interaction.

Temperature not only influences metabolic rates in algal cells but also affects species competition and seasonal succession. Wang et al. (2022) observed that increasing temperature could accelerate the growth rate of *Chlorella* sp., particularly when combined with other stressors such as heavy metals. Moreover, climate change and global warming have been implicated in the expansion of HABs, with warmer waters creating more favorable conditions for cyanobacteria dominance (Lüring et al., 2018). Brenckman et al. (2025) also highlight that temperature increases can intensify nutrient uptake and enhance photosynthetic efficiency in algae, further exacerbating bloom events under eutrophic conditions

Pollution, particularly heavy metals and industrial waste, can have complex effects on algal communities. While some pollutants are toxic and inhibit algal growth, others may act synergistically with nutrients and temperature to promote blooms. Wang et al. (2022) found that the presence of heavy metals such as cadmium and lead, when combined with rising temperatures, led to an unexpected increase in *Chlorella* sp. biomass, suggesting an adaptive or stress-induced proliferative response. Furthermore, Sun et al. (2023) reported that pollution alters the community composition of algae, favoring more tolerant species and reducing biodiversity, which may lead to ecological imbalance. Furthermore, seasonal variation plays a crucial role in shaping the structure, productivity, and physiology of algal communities across marine and freshwater ecosystems. These changes are largely driven by fluctuations in environmental conditions such as temperature, light intensity, salinity, and nutrient availability. Understanding how algal populations respond to these seasonal factors is essential for predicting bloom dynamics, evaluating ecosystem health, and informing aquatic resource management.

Marine phytoplankton communities demonstrate well-documented patterns of seasonal succession, particularly in temperate and polar regions. Van Leeuwe et al. (2020) conducted a long-term study on the seasonal dynamics of phytoplankton in Antarctic coastal waters and concluded that phytoplankton phenology is tightly linked to environmental factors such as light availability, sea ice cover, and nutrient dynamics. Their research revealed that spring and summer blooms were driven by increased sunlight and reduced ice cover, leading to shifts in dominant phytoplankton taxa, especially diatoms. These findings emphasize the sensitivity of polar phytoplankton communities to seasonal and climatic variations (van Leeuwe et al., 2020).

Similarly, Wang et al. (2022) examined seasonal variation in the coastal Yellow Sea, a temperate marine ecosystem, and identified temperature, light, and nutrient availability as primary factors influencing phytoplankton abundance and composition. Their results showed that diatoms typically dominate in the spring due to higher nutrient concentrations, while dinoflagellates become more prevalent in the summer under stratified, nutrient-depleted conditions. This seasonal alternation of species illustrates how phytoplankton communities are structured by environmental drivers that vary cyclically throughout the year (Wang et al., 2022).

In freshwater ecosystems, algal populations are also subject to pronounced seasonal dynamics, often influenced by monsoonal rainfall, stratification, and external nutrient inputs. Pokhrel et al. (2021) studied algal diversity in Jagadishpur Reservoir in Nepal and found that algal composition varied markedly between the pre-monsoon, monsoon, and post-monsoon periods. Chlorophytes and cyanobacteria dominated during the warmer months, while diatoms became more prevalent during the cooler, post-monsoon season. These shifts were closely associated with

changes in water temperature, nutrient availability, and turbidity caused by runoff and stratification. The study highlights how freshwater algal communities respond to both climate and hydrological factors that fluctuate seasonally (Pokhrel et al., 2021).

Macroalgae, such as *Ulva* species, also exhibit clear seasonal growth responses. Jansen et al. (2022) conducted an outdoor cultivation experiment to assess seasonal variations in the growth, biochemical composition, and nutrient uptake of *Ulva* spp. The results demonstrated that biomass production and nutrient uptake were highest during the spring and summer months, likely due to increased sunlight and warmer temperatures. Conversely, growth rates declined significantly in the winter. These seasonal patterns are critical for optimizing seaweed cultivation systems and understanding macroalgal productivity in natural habitats (Jansen et al., 2022).

Beyond species composition and growth rates, seasonal changes also elicit physiological adaptations in algal cells, particularly in extreme environments. Young et al. (2020) reviewed the adaptive strategies of high-latitude marine microalgae to extreme seasonal changes in temperature, photoperiod, and nutrient regimes. Key adaptations include the production of photoprotective pigments, modulation of carbon uptake mechanisms, and adjustments in metabolic pathways to optimize survival during prolonged darkness or low-light winter conditions. These physiological responses allow polar microalgae to maintain viability and resume rapid growth when conditions become favorable in spring and summer (Young et al., 2020).

Light Microscopy in Algal Studies

Light microscopy has long been a cornerstone in the study of algal biology, providing researchers with a fundamental tool for identifying and classifying various algal species. This technique employs visible light and optical lenses to magnify specimens, allowing for detailed examination of cellular structures and morphology. The importance of light microscopy in identifying algae cannot be overstated, as it offers a direct and immediate way to observe these organisms in their natural state, facilitating both educational and research purposes.

One of the primary advantages of light microscopy is its accessibility and cost-effectiveness. Most educational and research institutions are equipped with light microscopes, making this technique widely available for scientists and students alike. Additionally, light microscopy allows for real-time observation, enabling researchers to note the dynamic behaviors and interactions of algal cells within their environments. This immediacy of observation is invaluable for studies in ecology, physiology, and taxonomy, where understanding the nuances of algal life is crucial.

However, despite its many benefits, light microscopy does have limitations, especially when compared to more advanced molecular methods. While it can effectively reveal morphological characteristics, it may fall short in providing definitive species identification, particularly for closely related taxa that exhibit minimal morphological differences. Molecular techniques such as DNA sequencing offer higher resolution in terms of genetic information and can identify species that are indistinguishable under a microscope. Thus, while light microscopy

remains an essential tool in algal research, it is often complemented by molecular approaches to achieve a more comprehensive understanding of algal diversity and taxonomy.

According to Takahashi et al. (2014), in their study of *Cyanophora paradoxa*, they emphasize the intricate surface features of cyanophytes algae, which are revealed through ultra-high resolution imaging techniques. This complements Chan et al. (2018), where the morphological adaptations of mixotrophic nanoflagellates are examined under varying light conditions, demonstrating how light microscopy can effectively highlight these differences. Similarly, Arora and Sahoo (2015) discuss various microscopy methods, including light microscopy, essential for the characterization of algal species. Together, these studies illustrate the critical role of light microscopy in elucidating the structural diversity and ecological roles of different algal groups, whether they are chrysophytes, cyanophytes, or mixotrophic flagellates. Additionally, research by Chan et al. (2018) highlights how ingestion rates of mixotrophic nanoflagellates are influenced by light availability, reinforcing the interplay between environmental factors and algal morphology. This is further supported by Andersen et al. (2024), where physiological responses of various algal species to light conditions are examined, showing the significance of light microscopy in assessing algal health and productivity.

The study by Takahashi et al. (2014) reveals that the microstructural nuances of *Cyanophora paradoxa* can inform us about its ecological strategies and adaptations, indicating that detailed imaging can unveil the relationship between structure and function. This synthesis of findings across studies emphasizes the value of light microscopy not just as a tool for identification but as a means of understanding the complex dynamics of algal communities, their adaptations to light, and their roles in nutrient cycling within aquatic ecosystems. Furthermore, the integration of findings from these studies highlights the importance of a multidisciplinary approach to algal research. The morphological insights gained through light microscopy, as discussed by Arora and Sahoo (2015), are similar with physiological assessments from Chan et al. (2018) to create a holistic view of algal responses to environmental changes. This synergy allows researchers to better predict how different algal groups, such as chrysophytes and cyanophytes, will respond to varying light conditions, which is crucial for understanding their roles in aquatic food webs and biogeochemical cycles.

The findings by Takahashi et al. (2014) regarding the unique surface ornamentations of *Cyanophora paradoxa* illustrate the structural diversity within the Glaucophyta and suggest potential adaptive strategies for optimizing photosynthesis under varying light conditions. This aligns with Chan et al. (2018), which indicates that the morphological traits of mixotrophic flagellates can enhance their feeding efficiency in response to fluctuating nutrient and light availability. The integration of advanced imaging techniques, as discussed by Arora and Sahoo (2015), further enhances the study of algal cytoskeletons and their role in cellular processes. By employing light microscopy alongside electron microscopy, researchers can obtain complementary data that enriches our understanding of the dynamic nature of algal cells. This holistic approach is essential for unraveling the complexities of algal interactions within their ecosystems and their contributions to broader ecological processes.

Algal Diversity and Abundance

Algae serve as fundamental components of aquatic ecosystems, playing essential roles in nutrient cycling, oxygen production, and as primary producers in food webs. Despite their ecological significance, comprehensive studies on algal diversity and abundance remain limited, particularly in underrepresented geographical regions and across lesser-studied algal taxa. Adhiambo, Mensah, and Acheampong (2023) conducted a global review on phytoplankton ecology and highlighted the geographical disparities in research efforts. They observed that many regions in Africa, Asia, and South America are underrepresented in phytoplankton and algal research, leading to insufficient data on species diversity and ecological responses to environmental stressors such as climate change and nutrient enrichment. Similarly, Gu et al. (2024) employed environmental DNA (eDNA) metabarcoding to examine littoral algal communities and found that numerous algal species remain undetected or unreported, particularly in coastal zones. They attributed this gap to limited morphological expertise and the lack of standardized molecular reference databases. The study emphasized the need for integrated taxonomic approaches, including DNA-based tools, to accurately assess algal biodiversity and community structure.

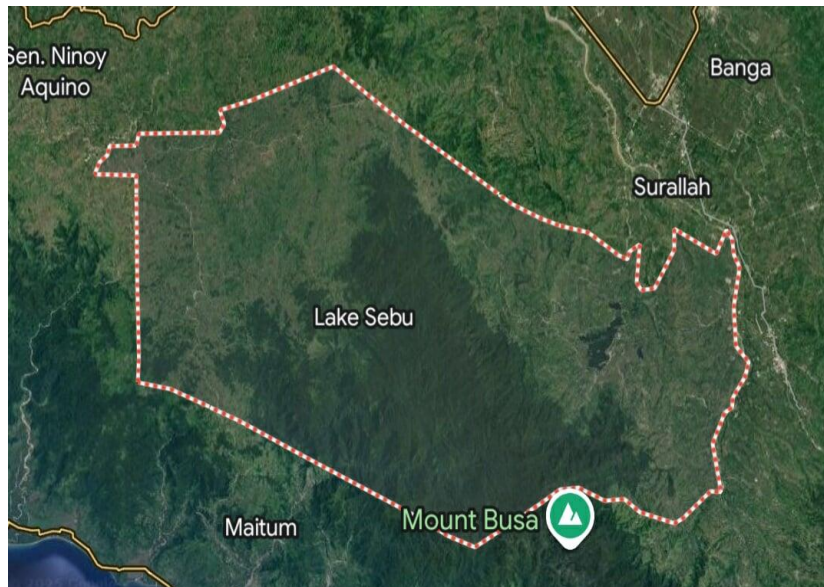
In a regional context, a study of algal assemblages in the Okavango Delta (MDPI, 2023) reported a lack of baseline data on both taxonomic and functional diversity of microalgae. Although some research has been conducted on diatoms, the authors noted that other algal groups are rarely studied, and there is limited understanding of their ecological functions along hydrological gradients. Furthermore, a perspective article from the *Journal of Phycology* discussed the broader need to integrate molecular, ecological, and educational approaches in phycological research. It stressed that the absence of curated genetic reference libraries for algae poses a major limitation to identifying species and estimating their abundance (Wiley Online Library, 2023). This systemic issue constrains efforts to monitor biodiversity and ecosystem responses accurately.

METHODOLOGY

Research Design

This study used a descriptive research design to document the diversity of algal communities in Lake Sebu, South Cotabato using light microscopy. A descriptive approach will be appropriate since the study aimed to establish baseline data on the comparison of algae without manipulating natural conditions. The use of light microscopy served as the primary tool for identifying algal groups and estimating their abundance.

Research Locale



The study was conducted in Lake Sebu, South Cotabato, a freshwater lake recognized for its ecological, cultural, and economic importance. The Sampling sites comprised four stations: Falls 1 (Hikong Alu), Falls 2 (Hikong Bente), Lake Sebu (East), Lake Sebu (West). These sites represented varied habitats including open lake water, areas near aquaculture fish cages, and flowing waterfalls streams. It is selected to capture potential variations in algal composition due to natural conditions and human activity. The coordinates of Lake Sebu are 6.2252, 124.7105 (6° 14' North, 124° 43' East) with an average elevation of about 720.9 meters (2,365.1 feet) above sea level.

Sampling Materials

The following materials were prepared for sample collection, preservation, and laboratory analysis during the study. The materials utilized included ziplock bags (6.5 × 5.875 inches), which served as the initial containers for collecting water samples from each sampling site, and ziplock bags (10.9 × 11 inches) as the final containers for secure storage. Rubber bands and tape were employed to seal the bags and prevent leakage, while a permanent marker was used to label each sample with the site name, date, and time of collection. An ice box containing ice was used to maintain low temperatures during transport, thereby preserving algal integrity and minimizing biological activity prior to laboratory analysis.

In the laboratory, the materials used included glass slides, cover slips, pipettes, a light microscope, and a cellphone for capturing images of algal specimens. These materials were essential for the microscopic observation and documentation of algal samples collected from the field.

Sampling Technique

The study employed a stratified random sampling technique to evaluate the algal diversity and abundance in Lake Sebu. The lake was divided into four distinct strata based on specific sampling locations: Falls 1, Falls 2, Lake Sebu East, and Lake Sebu West. These sampling sites were strategically selected to represent varying ecological conditions within the lake, including differences in water flow, depth, and the degree of human activity in the surrounding areas.

From each stratum, three surface water samples were randomly collected to ensure adequate representation and minimize sampling bias. Prior to collecting, the containers were rinsed three times with water present at the sampling site to reduce contamination and ensure sample accuracy. Water samples were initially collected using ziplock bags (6.5 × 5.875 inches), which served as the primary containers, and were subsequently transferred to larger ziplock bags (10.9 × 11 inches) for secure storage. Each sample was properly labeled with the site name, date, and time of collection using a permanent marker. The bags were then sealed using rubber bands and tape to ensure complete closure and to prevent any leakage during handling and transport.

Immediately after collection, the samples were placed in an ice box containing ice to maintain low temperatures, thereby preserving algal integrity and minimizing biological activity during transport. Upon arrival at the laboratory, all samples were stored in a refrigerator until further microscopic examination and analysis were conducted.

Sample Preparation

In the laboratory, water samples were gently mixed to evenly distribute algal cells. A portion of each sample was pipetted onto clean glass slides, covered with cover slips, and examined under a light microscope. Observations focused on identifying and documenting algal species and their structural features. Representative algal specimens were photographed using a cellphone to aid in identification and record-keeping.

Morphological Analysis

The identification of algae will be based on their external morphological characteristics as observed under the light microscope. Key features such as shape, pigmentation, arrangement of colonies, presence of flagella, and other distinguishing structures were carefully examined. Standard taxonomic references and identification keys will be used to classify algae up to the genus level whenever possible. For unidentified species, detailed descriptions and photographic documentation will be prepared to support future verification.

Microscopy

Microscopic examinations will be conducted using a compound light microscope at varying magnifications (10×, 40×, and 100× oil immersion when necessary). Prepared slides will

be systematically scanned from left to right and top to bottom to ensure representative coverage of each sample. Algae will be identified based on morphological features such as cell shape, size, pigmentation, and colony structure, using standard taxonomic keys and reference guides. For quantitative analysis, cell counts will be performed with a hemocytometer, allowing the estimation of algal abundance per milliliter of water. Representative organisms will be photographed using a microscope-mounted camera to document structural features and support accurate identification.

Statistical Treatment

The data gathered from the microscopic examination of algal samples were analyzed using descriptive statistics and ecological diversity indices to determine the diversity and abundance of algae in each sampling station. A diversity index is a quantitative measure that reflects how many different types (such as species) there are in a dataset (a community) (Libretext, 2024). The mean algal counts from ten random microscopic fields of view were computed to represent the average abundance of each algal type per sample. Also, the algal counts from each sampling site will be organized into tables, and the relative abundance of each algal group was calculated as a percentage of the total algal population. This simple percent composition allowed for easy comparison of the distribution of different algal groups across sampling sites and highlighted which groups will be dominant, common, or rare.

The Shannon Diversity Index (sometimes called the Shannon-Wiener Index) is a way to measure the diversity of species in a community (Bobbitt, 2022). $H = -\sum p_i \times \ln(p_i)$ was used to measure the overall diversity of algal communities based on species richness and relative abundance, while Evenness Index (E) assessed the uniformity of distribution among algal types. The term “evenness” simply refers to how similar the abundances of different species are in the community (Bobbitt, 2022). $E = H/\ln S$ was used to solve the Evenness. The Simpson’s Dominance Index (D) was also calculated using $D = \sum n_i(n_i - 1) / (N(N - 1))$ to determine the extent to which one or a few algal groups dominated the ecosystem. It is calculated as $1 - D$, the higher the value for this index, the higher the diversity of species (Bobbitt, 2021). It means that high diversity results to low dominance and vice versa. These indices, derived from the relative abundance of each algal group, provided quantitative measures of community structure that were used to interpret the ecological balance, productivity, and stability of the freshwater ecosystems in Lake Sebu. Additionally, this approach is particularly suitable for a descriptive study, providing baseline data for future ecological monitoring.

Ethical Considerations

This study will be carried out with consideration for both environmental and cultural values of Lake Sebu. Water sampling will be limited to small volumes and performed carefully to avoid disturbing aquatic life. No harmful substances will be introduced into the lake during collection or analysis. Coordination with local authorities will be observed prior to fieldwork, acknowledging the importance of the lake to surrounding communities, especially indigenous groups. Academic

integrity will be strictly maintained by ensuring accurate data collection and honest reporting of results.

RESULT AND DISCUSSION

This chapter presents the results of the microscopic analysis of algal diversity and abundance in four sampling stations within the freshwater ecosystems of Lake Sebu, South Cotabato. The data include mean counts, relative abundance, and computed diversity indices for each algal type observed under the light microscope. Interpretations are provided for every table to describe the community structure, dominance, and ecological implications at each station.

Falls 1 (Hikong Alu)

Sample 1

Table 1.1 Mean Abundance of Algal Type in Falls 1 Sample 1

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	18.00	90.00%	1.80	Dominant
Filamentous Green Algae	2.00	10.00%	0.20	Moderate
Blue-Green Algae	0.00	0.00	0.00	None
Yellow-Green Algae	0.00	0.00	0.00	None
Brown Algae	0.00	0.00	0.00	None
Red Algae	0.00	0.00	0.00	None
Diatoms	0.00	0.00	0.00	None
Total	20.00	100.00%	2.00	

The results showed that green algae dominated the community in Falls 1 Sample 1, comprising about 90% of the total observed algal population. The minimal presence of filamentous green algae at 10% and absence of other algal groups indicate low algal diversity within this site. Such dominance of green algae may suggest that the environmental conditions in this part of Lake Sebu favor chlorophytic growth. According to Khalil et al. (2021) and Galloway et al. (2012), members of Chlorophyta are widely dominant in freshwater environments under stable and well-illuminated waters due to their efficient photosynthetic adaptation and rapid reproduction rates. In addition, the absence of both diatoms and cyanobacteria may also imply limited nutrient enrichment, as these often dominate in eutrophic or disturbed habitats (Lürding et al., 2018; Pokhrel et al., 2021). Thus, the algal assemblage observed in this site was reflective of an environment of relatively low nutrient variability and stable water conditions, characteristic of less disturbed freshwater systems.

Table 1.2 Diversity Indices of Algal Types in Falls 1 Sample 1

Index	Result	Interpretation
Shannon - Diversity (H)	0.33	Low Diversity
Evenness (E)	0.47	Uneven Distribution
Simpson Diversity (Dominance, D)	0.19	Low Diversity = High Dominance

Shannon $H' = 0.33$, Evenness $E = 0.47$, and Simpson $D = 0.19$ indicate a low-diversity, highly dominated algal community. The dominance expressed by one group, namely green algae, is in concordance with the low Shannon value, while the low evenness shows an unbalanced distribution among the other taxa. Brenckman et al. (2025) refer to such reduced diversity as symptomatic of an ecosystem influenced by a narrow range of ecological drivers, like constant light intensity and low nutrient fluctuation. These kinds of conditions generally favor opportunistic, fast-growing species able to thrive in similar habitats (Reyes et al., 2024). The algal structure in Falls 1 Sample 1 indicates an ecologically stable but taxonomically simplified community and may reflect early successional conditions.

Table 1.3. Mean Abundance of Algal Type in Falls 1 Sample 2

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	38.00	82.61%	3.80	Dominant
Filamentous Green Algae	2.00	4.35%	0.20	Rare
Blue-Green Algae	0.00	0.00	0.00	None
Yellow-Green Algae	0.00	0.00	0.00	None
Brown Algae	2.00	4.35%	0.20	Rare
Red Algae	0.00	0.00	0.00	None
Diatoms	4.00	8.69%	0.40	Moderate
Total	46.00	100.00%	4.60	

Green algae kept dominating in Sample 2, at 82.61%, while diatoms and brown algae appeared in small proportions. Diatoms' reappearance already signals a slight improvement in diversity compared to Sample 1. The occurrence of brown algae, even though rare, may indicate subtle heterogeneity in the environment, probably because of variable light penetration or substrate availability. The continued dominance of Chlorophyta agrees with Biobide (2024), who recorded that green algae commonly dominate in freshwater habitats where there is just enough light with minimal turbidity. Thus, going from one group's dominance to the composition containing all these

groups can be taken to mean that Falls 1 might have microhabitat variations that allow more algal taxa to coexist.

Table 1.4. Diversity Indices of Algal Types in Falls 1 Sample 2

Index	Result	Interpretation
Shannon Diversity (H)	0.64	Low Diversity
Evenness (E)	0.46	Uneven Distribution
Simpsons Diversity (Dominance, D)	0.31	Low Diversity = High Dominance

The diversity indices $H' = 0.64$, $E = 0.46$, $D = 0.31$ indicate a slight increase in diversity but the continued dominance of Chlorophyta. According to Anderson et al. (2019) and Wang et al. (2023), algal diversity often increases with minor nutrient enrichment or habitat heterogeneity. The presence of diatoms supports this, as it usually proliferates under conditions of intermediate nutrient levels and well-oxygenated waters. While the relatively low evenness does suggest the continued dominance of a few taxa, the increased Shannon and Simpson values indicate a transitional algal community that may be responding to small-scale environmental shifts.

Table 1.5. Mean Abundance of Algal Type in Falls 1 Sample 3

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	20.00	38.46%	2.00	Dominant
Filamentous Green Algae	13.00	25.00%	1.30	Common
Blue-Green Algae	3.00	5.77%	0.30	Moderate
Yellow-Green Algae	1.00	1.92%	0.10	Rare
Brown Algae	1.00	1.92%	0.10	Rare
Red Algae	1.00	1.923%	0.10	Rare
Diatoms	13.00	25.00%	1.30	Common
Total	52.00	100.00%	5.20	

Sample 3 showed a marked increase in algal diversity, with green algae dominating at 38.46%, but accompanied by filamentous green algae, diatoms, and minor representatives of other groups. The occurrence of Cyanophyta, or blue-green algae, and Xanthophyta, or yellow-green algae, indicates nutrient variability and possibly organic enrichment, with Lüring et al. (2018) finding that cyanobacteria tend to become active under slightly eutrophic conditions. Similarly, the higher abundance of diatoms agrees with Pokhrel et al. (2021), who found that the population of diatoms increases under optimum levels of nutrients and light. The combination of multiple algae from several groups indicates a more complex and productive algal community that may result from improved environmental balance and microhabitat diversity in Falls 1 Sample 3.

Table 1.6. Diversity Indices of Algal Types in Falls 1 Sample 3

Index	Result	Interpretation
Shannon Diversity (H)	1.45	High Diversity
Evenness (E)	0.75	Uneven Distribution
Simpsons Diversity (Dominance, D)	0.74	High Diversity= Low Dominance

The obtained Shannon Diversity Index ($H' = 1.45$) and Simpson's Index ($D = 0.74$) indicate high diversity with low dominance, which means that the algal community is rich and well balanced ecologically. The Evenness value of $E = 0.75$ indicates that algal groups are more evenly distributed. These results indicate a process from a previous homogeneous ecosystem to a more heterogeneous one, perhaps due to improved light conditions, or a moderate influx of nutrients, or an increase in water flow conditions favorable for coexistence among the taxa studied (Reyes et al., 2024; Jia et al., 2022). This pattern supports Wang et al. (2022), who pointed out that freshwater algal communities exhibit increased biodiversity under stable but moderately productive conditions. Hence, Falls 1 Sample 3 denotes ecological maturity and further assures resilience in the algal composition.

Table 1.7. Summary of Mean Abundance, Relative Abundance, and Dominance Status of Algal Types in Falls 1, Lake Sebu, South Cotabato

Algal Type	Sample 1	Sample 2	Sample 3	Mean	% Relative Abundance	Remarks
Green Algae	1.80	3.80	2.00	2.53	64.38%	Dominant

Filamentous Green Algae	0.20	0.20	1.30	0.57	14.50%	Common
Blue-Green Algae	0.00	0.00	0.30	00.1	2.544%	Rare
Yellow-Green Algae	0.00	0.00	0.01	0.03	0.763%	Rare
Brown Algae	0.00	0.20	0.10	0.10	2.54%	Rare
Red Algae	0.00	0.00	0.10	0.03	0.763%	Rare
Diatoms	0.00	0.40	1.30	0.57	14.50%	Common
TOTAL	2.00	4.60	5.20	3.93	100.00%	

The overall summary data across all three samples confirm that green algae are the dominant algal group in the Falls 1 sample, with a leading percentage of 64.38%, while filamentous green algae and diatoms represent secondary contributors. Dominance of Chlorophyta indicates stable, moderately productive freshwater conditions, reflecting mesotrophic conditions characterized by nutrient inputs favoring steady algal growth without bloom conditions (Adhiambo et al., 2023; Brenckman et al., 2025). The Falls 1 station had a moderately diverse algal assemblage dominated by photosynthetically active green algae, indicating good water quality, stable oxygen production, and limited pollution-characteristics typical of a freshwater system with minimal disturbance.

4.2 Falls 2 (Hikong Bente)

Table 2.1 Mean Abundance of Algal Type in Falls 2 Sample 1

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	21.00	67.74%	2.10	Dominant
Filamentous Green Algae	6.00	19.35%	0.60	Moderate
Blue-Green Algae	0.00	0.00	0.00	None
Yellow-Green Algae	0.00	0.00	0.00	None

Brown Algae	0.00	0.00	0.00	None
Red Algae	1.00	3.23%	0.10	Rare
Diatoms	3.00	9.68%	0.30	Moderate
Total	32.00	100.00%	3.10	

Dominant algal composition revealed green algae (67.74%) to be the most dominant algal group in Falls 2 Sample 1, followed by filamentous green algae (19.35%) and diatoms at 9.68%, while red algae occurred in trace amounts. This composition indicates a moderately diverse algal community dominated by Chlorophyta, suggesting optimal environmental conditions such as light availability and nutrient concentrations that favor photosynthetic taxa. Indeed, studies have widely reported that green algae usually dominate freshwater systems in tropical lakes characterized by relatively stable nutrient input. Reyes et al. (2024) and Jia et al. (2022) reported evidence of this. The low abundance of red algae could be related to their habitat preference for low light environments. The overall algal composition indicated that it generally favorable water quality and moderate ecological productivity.

Table 2.2. Diversity Indices of Algal Types in Falls 2 Sample 1

Index	Result	Interpretation
Shannon Diversity (H)	0.92	Low Diversity
Evenness (E)	0.66	Uneven Distribution
Simpsons Diversity (Dominance, D)	0.51	Low Diversity= High Dominance

The calculated diversity indices of Shannon $H' = 0.92$, Evenness $E = 0.66$, and Simpson $D = 0.51$ indicate a low-moderate diversity level with partial dominance by green algae. The relatively high evenness value indicates that algal groups are somewhat balanced but still skewed toward chlorophytic dominance. Brenckman et al. (2025) indicated that such a pattern is typical in freshwater ecosystems when nutrient levels are sufficient to support multiple taxa but not excessive enough to trigger algal blooms. Co-occurrence of green algae and diatoms suggests a mesotrophic environment characterized by balanced nutrient conditions and stable productivity. This corroborates the findings of Wang et al. (2023) regarding nutrient composition within aquatic ecosystems.

Table 2.3. Mean Abundance of Algal Type in Falls 2 Sample 2

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	16.00	48.48%	1.60	Dominant
Filamentous Green Algae	10.00	30.30%	1.00	Dominant
Blue-Green Algae	0.00	0.00	0.00	None
Yellow-Green Algae	0.00	0.00	0.00	None
Brown Algae	0.00	0.00	0.00	None
Red Algae	0.00	0.00	0.00	None
Diatoms	7.00	21.21%	0.70	Common
Total	33.00	100.00%	3.30	

In Falls 2 Sample 2, green algae (48.48%) and filamentous green algae (30.30%) were dominant, followed by diatoms (21.21%). This relatively balanced composition represents an increase in community heterogeneity compared to Sample 1. The dominance of filamentous green algae could be related to good light penetration and a stable substrate that allows the attachment and growth of filamentous green algae (Khalil et al., 2021). The noticeable abundance of diatoms could indicate better water circulation and availability of silica, factors which maintain diatom productivity (Pokhrel et al., 2021).

Table 2.4. Diversity Indices of Algal Types in Falls 2 Sample 2

Index	Result	Interpretation
Shannon Diversity (H)	1.04	High Diversity
Evenness (E)	0.95	Uneven Distribution
Simpsons Diversity (Dominance, D)	0.65	High Diversity= Low Dominance

The diversity indices of Shannon Diversity Index ($H' = 1.04$), Evenness ($E = 0.95$), and Simpson's Index ($D = 0.65$) indicated a high level of diversity with well-proportioned algal taxa. The evenness value stands at 0.95, indicating that no algal group highly predominates the community. This implies an ecosystem with stable hydrological conditions and nutrient inputs able to support various algal growth, as stated by Wang et al. (2022). In any case, Brenckman et al. (2025) argue that such diversity is typical in mesotrophic lakes with periodic nutrient replenishment and consistent light exposure.

Table 2.5. Mean Abundance of Algal Type in Falls 2 Sample 3

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	31.00	63.27%	3.10	Dominant
Filamentous Green Algae	11.00	22.45%	1.10	Common
Blue-Green Algae	0.00	0.00	0.00	None
Yellow-Green Algae	0.00	0.00	0.00	None
Brown Algae	0.00	0.00	0.00	None
Red Algae	0.00	0.00	0.00	None
Diatoms	7.00	14.26%	0.70	Common
Total	49.00	100.00%	4.90	

Sample 3 results show that green algae (63.27%) continued to dominate, with filamentous green algae adding 22.45% and diatoms 14.26% to the community structure. The consistency in sample results indicates stability in the algal composition, with minor variations likely due to local environmental variability. Diatoms and filamentous forms indicate a combination of planktonic and benthic microhabitats. According to González et al. (2022), such mixed communities can be favored under seasonal or microspatial variations in light and nutrient availability. The repeated predominance of green algae speaks to their high adaptability under stable freshwater conditions, while the supporting dominance of diatoms reflects the maintained ecological balance and good water quality in the Falls 2 station.

Table 2.6. Diversity Indices of Algal Types in Falls 2 Sample 2

Index	Result	Interpretation
Shannon Diversity (H)	0.90	Low Diversity
Evenness (E)	0.82	Uneven Distribution
Simpsons Diversity (Dominance, D)	0.54	Low Diversity= High Dominance

The indices, Shannon $H' = 0.90$, Evenness $E = 0.82$, and Simpson $D = 0.54$, indicated a moderately diverse algal assemblage with low dominance. In comparison with the previous samples, these values reflect sustained biodiversity and a reasonably even distribution of the taxa. The high value for evenness aligns with Wang et al. (2022), who attributed such evenness to hydrological consistency and efficient mixing of nutrients. While green algae are dominant, the relatively high Shannon and Simpson indices signify that several taxa contribute toward ecosystem productivity, aligning with the findings of Pokhrel et al. (2021), who portrayed similar diversity trends in tropical freshwater reservoirs. Thus, Falls 2 Sample 3 retains a balanced and resilient algal community, suggestive of ecological stability.

Table 2.7. Summary of Mean Abundance, Relative Abundance, and Dominance Status of Algal Types in Falls 2, Lake Sebu, South Cotabato

Algal Type	Sample 1	Sample 2	Sample 3	Mean	% Relative Abundance	Remarks
Green Algae	2.10	1.60	3.10	2.27	60.21%	Dominant
Filamentous Green Algae	0.60	1.00	1.10	0.90	23.87%	Common
Blue-Green Algae	0.00	0.00	0.00	0.00	0.00%	Not Present
Yellow-Green Algae	0.00	0.00	0.00	0.00	0.00%	Not Present
Brown Algae	0.00	0.00	0.00	0.00	0.00%	Not Present

Red Algae	0.10	0.00	0.00	0.03	0.80%	Rare
Diatoms	0.30	0.70	0.70	0.57	15.12%	Moderate
TOTAL	3.10	3.30	4.90	3.77	100.00%	

The data from Falls 2 show that green algae are dominant, with a relative abundance of 60.21%, followed by filamentous green algae at 23.87%, and diatoms at 15.12%. Such tripartite composition indicates a moderate diversity and ecological balance where photosynthetic taxa maintain high primary production without any marked dominance by one group. Stable proportions between Chlorophyta and Bacillariophyta are characteristic of mesotrophic systems, as suggested by Adhiambo et al. (2023), which have a moderate nutrient input and support both suspended and attached algae. Other taxa, such as red algae, are hardly represented, which also suggests good water quality that is relatively free from pollution stress (Ahmed, 2025). Thus, Falls 2 is a moderately productive freshwater site with active algal populations contributing to oxygen production and nutrient cycling, which is essential for the overall ecological balance within the lake.

4.3 Lake Sebu (East)

Table 3.1. Mean Abundance of Algae Observed in Lake Sebu (East) Sample 1

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	29.00	82.86%	2.90	Dominant
Filamentous Green Algae	4.00	11.42%	0.40	Moderate
Blue-Green Algae	0.00	0.00	0.00	None
Yellow-Green Algae	1.00	2.86	0.10	Rare
Brown Algae	0.00	0.00	0.00	None
Red Algae	0.00	0.00	0.00	None
Diatoms	1.00	2.86%	0.10	Rare
Total	35.00	100.00%	3.50	

The results of Lake Sebu East Sample 1 reflect the dominance of green algae (Chlorophyta), which comprised 82.86% of the total algal population, followed by filamentous green algae at 11.42%, while yellow-green and diatoms were in minor proportions of 2.86% each. In such conditions, the predominance of Chlorophyta implies good environmental conditions for photosynthetic growth, presumably due to high light and average nutrient availability. Biobide (2024) and Galloway et al. (2012) reported that green algae dominate freshwater systems with stable light penetration and balanced nutrient levels, and they serve as indicators of mesotrophic status. The minor representation of diatoms implies enough silica and oxygen levels, thus further establishing the notion of a productive but reasonably well-oxygenated environment. This pattern agrees with Reyes et al. (2024), where green algae dominated in Lake Taal under tropical, well-illuminated freshwater conditions.

Table 3.2. Diversity Indices of Algal Types in Lake Sebu (East) Sample 1

Index	Result	Interpretation
Shannon Diversity (H)	0.61	Low Diversity
Evenness (E)	0.44	Uneven Distribution
Simpsons Diversity (Dominance, D)	0.31	Low Diversity = High Dominance

Shannon Index: $H' = 0.61$; Evenness: $E = 0.44$; Simpson's Index: $D = 0.31$, indicating low algal diversity with high dominance of green algae. The relatively lower evenness value indicates that the community structure of algae is not well balanced and dominated by one or a few ecologically dominant taxa. Such dominance often corresponds to a lack of environmental variability, whereby one type of algae outcompetes others (Brenckman et al., 2025). These values subsequently describe Lake Sebu East Sample 1 as a freshwater habitat of low diversity but ecologically stable.

Table 3.3. Mean Abundance of Algae Observed in Lake Sebu (East) Sample 2

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	19.00	59.375%	1.70	Dominant
Filamentous Green Algae	12.00	37.50%	1.20	Dominant
Blue-	0.00	0.00	0.00	None

Green Algae				
Yellow-Green Algae	0.00	0.00	0.00	None
Brown Algae	0.00	0.00	0.00	None
Red Algae	0.00	0.00	0.00	None
Diatoms	1.00	3.125%	0.10	Rare
Total	32.00	100.00%	3.00	

In Sample 2, green algae were dominant at 59.38%, as were filamentous green algae at 37.50%, while diatoms appeared at low proportions of 3.13%. This indicates the co-dominance of both greens and filamentous greens, pointing toward an increased structural complexity in the algal community. The high abundance of filamentous forms testifies to a higher substrate stability and good, consistent water clarity due to the need for attachment surfaces by such forms and significant light availability for photosynthesis (Khalil et al., 2021). Further, dominance maintained by Chlorophyta speaks to environmental stability, while the presence of diatoms speaks to moderate nutrient enrichment and balanced water chemistry (Wang et al., 2023). Therefore, it is mesotrophic, supporting moderate productivity without excessive eutrophication.

Table 3.4. Diversity Indices of Algal Types in Lake Sebu (East) Sample 2

Index	Result	Interpretation
Shannon Diversity (H)	0.80	Low Diversity
Evenness (E)	0.73	Uneven Distribution
Simpsons Diversity (Dominance, D)	0.52	Low Diversity= High Dominance

The calculated indices. $H' = 0.80$, $E = 0.73$, $D = 0.52$, show slightly higher diversity and more even distribution of taxa than Sample 1. The high evenness represented by $E = 0.73$ indicates better balance among algal groups and suggests environmental conditions may be becoming more heterogeneous. As Jia et al. (2022) mentioned, fluctuations in water flow or local nutrient gradients in a catchment have the potential to facilitate coexistence within a single aquatic environment. In addition, according to the increase in Shannon and Simpson indices, ecological balance and maintained water quality are comparatively guaranteed. This pattern is typical in tropical freshwater areas where consistent, yet moderate conditions have shaped the algal assemblage.

Table 3.5. Mean Abundance of Algae Observed in Lake Sebu (East) Sample 3

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	38.00	71.70%	3.80	Dominant
Filamentous Green Algae	8.00	15.09%	0.80	Common
Blue-Green Algae	0.00	0.00	0.00	None
Yellow-Green Algae	1.00	1.89%	0.10	Rare
Brown Algae	2.00	3.77%	0.20	Rare
Red Algae	0.00	0.00	0.00	None
Diatoms	4.00	7.55%	0.40	Rare
Total	53.00	100.00%	5.30	

Sample 3 results indicated that green algae dominance continued with 71.70%, and the next was filamentous green algae with 15.09%, followed by diatoms at 7.55% and yellow-green and brown algae in small proportions. This composition reflects a marked increase in algal diversity from earlier samples. Lüring et al. (2018) observe that such nutrient conditions-identified as moderate-are likely to support balanced algal growth with no harmful algal blooms. Thus, the Lake Sebu (East) Sample 3 community represents a stable, moderately diverse, and ecologically balanced assemblage.

Table 3.6 Diversity Indices of Algal Types in Lake Sebu (East) Sample 3

Index	Result	Interpretation
Shannon Diversity (H)	0.92	Low Diversity
Evenness (E)	0.57	Uneven Distribution

Simpsons Diversity (Dominance, D)	0.46	Low Diversity = High Dominance
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The diversity indices of $H' = 0.92$; $E = 0.57$; $D = 0.46$ reveal moderate diversity and unequal distribution of the taxa. The low evenness is indicative of continuant dominance by green algae, but a higher Shannon value reflects increased taxonomic richness compared to the previously analyzed samples. This supports Brenckman et al. (2025), who have stated that a moderate nutrient enrichment and stable water temperature favor diversity through the avoidance of strong dominance. The improved Simpson's Index has also suggested reduced pressure for dominance; therefore, the environmental conditions were favorable for sustaining multiple algal groups. Thus, Sample 3 represented a mesotrophic state in balanced productivity and biodiversity in agreement with the ecological traits of Lake Sebu.

Table 3.7. Summary of Mean Abundance, Relative Abundance, and Dominance Status of Algal Types in Lake Sebu (East), Lake Sebu, South Cotabato

Algal Type	Sample 1	Sample 2	Sample 3	Mean	% Relative Abundance	Remarks
Green Algae	2.90	1.70	3.80	2.80	71.06%	Dominant
Filamentous Green Algae	0.40	1.20	0.80	0.80	20.30%	Common
Blue-Green Algae	0.00	0.00	0.00	0.00	0.00%	Not Present
Yellow-Green Algae	0.10	0.00	0.10	0.07	1.78%	Rare
Brown Algae	0.00	0.00	0.20	0.07	1.78%	Rare
Red Algae	0.00	0.00	0.00	0.00	0.00%	Not Present
Diatoms	0.10	0.10	0.40	0.20	5.08%	Moderate
TOTAL	3.50	3.00	5.20	3.94	100.00%	

The summarized results indicate that green algae were dominant (71.06%), followed by filamentous green algae (20.30%) and diatoms (5.08%). The predominance of Chlorophyta among all the samples indicates their ecological adaptability to freshwater environments, most especially

under conditions with moderate light and nutrient availability (Biobide, 2024; Galloway et al., 2012). The lower count of diatoms compared with Falls 2 may reflect minor differences in substrate or water turbulence, which affect the distribution of silica-based taxa (Wang et al., 2022). Lake Sebu East maintains a mesotrophic ecosystem that is moderately productive, wherein algal populations remain stable and diverse without evidence of nutrient imbalance or pollution. This is further supported by the consistent presence of filamentous forms, indicating stable hydrological conditions favorable for algal colonization and growth.

4.4 Lake Sebu (West)

Table 4.1 Mean Abundance of Algae Observed in Lake Sebu (West) Sample 1

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	25.00	55.56%	2.50	Dominant
Filamentous Green Algae	18.00	40.00%	1.80	Dominant
Blue-Green Algae	0.00	0.00	0.00	None
Yellow-Green Algae	0.00	0.00	0.00	None
Brown Algae	1.00	2.22%	0.10	Rare
Red Algae	0.00	0.00	0.00	None
Diatoms	1.00	2.22%	0.10	Rare
Total	45.00	100.00%	4.50	

In Lake Sebu (West) Sample 1, green algae and filamentous green algae dominated at 55.56% and 40%, respectively, while brown algae and diatoms each contributed 2.22%. This composition indicates a relatively diverse algal community dominated by chlorophytic species. The strong presence of filamentous green algae suggests the site has stable substrate and good light penetration, promoting attached algal growth (Khalil et al., 2021). Diatoms and brown algae had minor occurrences, indicating sufficient oxygenation and nutrient availability without eutrophic stress (Wang et al., 2022). This dominance pattern represents a mesotrophic environment where nutrient and light conditions are optimal to maintain balanced algal productivity.

Table 4.2 Diversity Indices of Algal Types in Lake Sebu (East) Sample 1

Index	Result	Interpretation
Shannon Diversity (H)	0.86	Low Diversity
Evenness (E)	0.62	Uneven Distribution
Simpsons Diversity (Dominance, D)	0.54	Low Diversity= High Dominance

Shannon Index ($H' = 0.86$), Evenness ($E = 0.62$), and Simpson's Index ($D = 0.54$) also indicated low to moderate diversity with slight dominance brought about by the green algae. The value of evenness is moderate, which would mean that there are many taxa that take part in overall productivity but their distribution is not equal. Reyes et al. (2024) consider such a diversity pattern normal in freshwater systems with continued nutrient inflow and stable hydrology. The balance between planktonic-green algae and benthic-filamentous forms reflects healthy ecosystem functioning and has been found by Brenckman et al. (2025) to mostly accompany stable ecological equilibria. Thus, Lake Sebu (West) Sample 1 can be summarized as being moderately diverse and environmentally stable.

Table 4.3 Mean Abundance of Algae Observed in Lake Sebu (West) Sample 2

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	16.00	59.26%	1.60	Dominant
Filamentous Green Algae	7.00	25.93%	0.70	Common
Blue-Green Algae	0.00	0.00	0.00	None
Yellow-Green Algae	1.00	3.70%	0.10	Rare
Brown Algae	2.00	7.41%	0.20	Moderate
Red Algae	0.00	0.00	0.00	None
Diatoms	1.00	3.70%	0.10	Rare
Total	27.00	100.00%	2.70	

Sample 2 was dominated by green algae (59.26%) and filamentous green algae (25.93%), although there were minor elements of brown algae (7.41%), diatoms (3.70%), and yellow-green algae (3.70%). Higher percentages of brown algae may indicate variable light or nutrient conditions due to localized organic matter accumulations (Lürling et al., 2018). Dominance by green algae and the presence of several minor taxa indicate that this station supports ecologically diverse and productive algal communities' representative of a stable, mesotrophic freshwater environment.

Table 4.4 Diversity Indices of Algal Types in Lake Sebu (East) Sample 2

Index	Result	Interpretation
Shannon Diversity (H)	1.10	High Diversity
Evenness (E)	0.68	Uneven Distribution
Simpsons Diversity (Dominance, D)	0.60	High Diversity= Low Dominance

The computed indices give evidence of a highly diverse and well-balanced algal community: $H' = 1.10$, $E = 0.68$, $D = 0.60$. A Shannon value greater than 1.0 indicates substantial species richness, while a moderate evenness score shows that the taxa are not too heavily dominated by one group. Wang et al. (2022) recorded similar diversity in moderately nutrient-enriched tropical lakes where consistent light availability allows coexistence among green algae, diatoms, and brown algae. Simpson's Index also denotes low dominance structure, which reflects good ecological balance. Based on the findings, Sample 2 represents an optimal habitat for diverse algal assemblages in Lake Sebu (West).

Table 4.5 Mean Abundance of Algae Observed in Lake Sebu (West) Sample 3

Algal Type	Total Count (10 FOVs)	% Relative Abundance	Mean	Remarks
Green Algae	23.00	58.97%	2.30	Dominant
Filamentous Green Algae	8.00	20.51%	0.80	Common
Blue-Green Algae	0.00	0.00	0.00	None

Yellow-Green Algae	1.00	2.56%	0.00	Rare
Brown Algae	4.00	10.26%	0.40	Moderate
Red Algae	1.00	2.56%	0.10	Moderate
Diatoms	2.00	5.12%	0.20	Moderate
Total	39.00	100.00%	3.80	

Sample 3 is dominated by green algae (58.97%), followed by filamentous green algae (20.51%), brown algae (10.26%), and smaller proportions of diatoms, red algae, and yellow-green algae. This composition is the most diverse among all the assemblages from Lake Sebu (West). The strong presence of red algae points to stable, clear-water conditions, as Rhodophyta are generally adapted for low turbidity conditions (Adhiambo et al., 2023). Generally, the community structure in Sample 3 describes a robust algal community that can support multiple taxa under favorable physical and chemical conditions.

Table 4.6 Diversity Indices of Algal Types in Lake Sebu (West) Sample 3

Index	Result	Interpretation
Shannon Diversity (H)	1.12	High Diversity
Evenness (E)	0.70	Uneven Distribution
Simpsons Diversity (Dominance, D)	0.61	High Diversity= Low Dominance

Diversity indices indicated high diversity and a low dominance of algae within the community, with $H' = 1.12$, $E = 0.70$, and $D = 0.61$, respectively. High Shannon and Simpson values are indicative of robust biodiversity, while evenness at 0.70 denotes a fair dispersal among the various taxa. Such values fit balanced mesotrophic ecosystems wherein light, nutrient, and hydrological conditions have maintained diverse species interactions (Wang et al., 2023; Pokhrel et al., 2021). According to Brenckman et al. (2025), high diversity coupled with low dominance most likely indicates ecological stability and resistance to disturbance. Thus, Lake Sebu (West) Sample 3 represents the characteristics of a mature and ecologically healthy algal community.

Table 4.7. Summary of Mean Abundance, Relative Abundance, and Dominance Status of Algal Types in Lake Sebu (West), Lake Sebu, South Cotabato.

Algal Type	Sample 1	Sample 2	Sample 3	Mean	% Relative Abundance	Remarks
Green Algae	2.50	1.60	2.30	2.13	62.46%	Dominant
Filamentous Green Algae	1.80	0.70	0.80	0.86	25.22%	Common
Blue-Green Algae	0.00	0.00	0.00	0.00	0.00%	Not Present
Yellow-Green Algae	0.00	0.10	0.00	0.03	0.88%	Rare
Brown Algae	0.10	0.20	0.40	0.23	6.74%	Moderate
Red Algae	0.00	0.00	0.10	0.03	0.88%	Rare
Diatoms	0.10	0.10	0.20	0.13	3.81%	Rare
TOTAL	4.50	2.70	3.80	3.41	100.00%	

The summarized data show that green algae (62.46%) remained the dominant group across all samples, followed by filamentous green algae (25.22%) and brown algae (6.74%). Diatoms and other minor taxa were also present but in smaller proportions. This distribution highlights moderate diversity and high ecological stability, where no single group completely monopolizes the community. The co-dominance of diatoms and filamentous Chlorophyta indicates balanced light and nutrient regimes supporting both free-floating and attached algal growth (Khalil et al., 2021; Biobide, 2024). The presence of brown algae and diatoms suggests adequate oxygenation and water transparency, hallmarks of a healthy mesotrophic lake (Wang et al., 2022; Reyes et al., 2024). Hence, Lake Sebu (West) can be characterized as a biologically rich and stable freshwater habitat with sustained primary productivity.

Algal Diversity Indices per Station

Table 5.1 Diversity Indices of Lake Sebu, South Cotabato

Station	Shannon Diversity (H)	Evenness (E)	Dominance (D)
Falls 1	0.81	0.56	0.41

Falls 2	0.95	0.81	0.56
Lake Sebu (East)	0.78	0.58	0.43
Lake Sebu (West)	1.03	0.67	0.58
Total	0.89	0.66	0.50

The calculated diversity indices for the four sampling stations show that Lake Sebu is moderately diverse in algae and that ecological balance prevails. Shannon Diversity (H') ranged from 0.78 to 1.03, showing that all study sites had moderate species richness. Lake Sebu (West) recorded the highest diversity ($H' = 1.03$), which indicated a more complex and stable algal assemblage, while the lowest value was recorded for Lake Sebu (East) with $H' = 0.78$, indicating higher dominance by a few taxa. Shannon index values within these ranges characterize freshwater systems that are mesotrophic and have balanced productivity with oxygen availability, according to Wang et al. (2022) and Pokhrel et al. (2021).

Evenness values range from 0.56 to 0.81, indicating that the algal distribution among species is moderately even. The highest evenness at Falls 2 ($E = 0.81$) reveals a well-represented algal composition, whereas lower evenness indicates selective dominance of green algae over other groups in Falls 1 and Lake East. The Simpson's Dominance Index (D) values (0.41–0.58) are supportive of a similar, balanced algal composition, with no single species exclusively dominating the ecosystem. Brenckman et al. (2025) note that moderate dominance reflects environmental stability and nutrient equilibrium typical of minimal anthropogenic pressure on a lake ecosystem. Overall, these results reflect a mesotrophic lake system with sustained biodiversity and healthy algal functioning.

Table 5.2 Overall Result of Diversity Indices of Lake Sebu, South Cotabato

Index	Lake Sebu Result	Interpretation
Shannon Diversity (H)	0.89	Moderate Diversity
Evenness (E)	0.66	Moderate Balanced
Dominance (D)	0.50	Moderate Dominance

The overall diversity indices of Lake Sebu, specifically Shannon ($H' = 0.89$), Evenness ($E = 0.66$), and Dominance ($D = 0.50$), demonstrate that the algal community is moderately diverse, balanced, and ecologically stable. These indices altogether establish a prevailing balance between the diversity and dominance of the algal assemblage across all sites, typical of a mesotrophic freshwater ecosystem (Reyes et al., 2024; Wang et al., 2023).

The dominance of the green algae, Chlorophyta, across sites indicates their adaptation to the prevailing light and nutrient conditions, serving as a primary producer that sustains energy flow within the trophic levels (Galloway et al., 2012; Biobide, 2024). The presence of diatoms, Bacillariophyta, on the other hand, reflects stable oxygen levels and silica availability, therefore confirming good water quality. Such a diversity pattern is typical for tropical lakes that maintain an intermediate nutrient input from natural and anthropogenic sources without proceeding to eutrophication (Lüring et al., 2018). Therefore, overall, the lake's indices demonstrate a resilient and ecologically balanced algal community, which is essential for sustaining biodiversity and water quality in Lake Sebu

Table 5.3 Overall Result of Mean Algal Count of Lake Sebu, South Cotabato




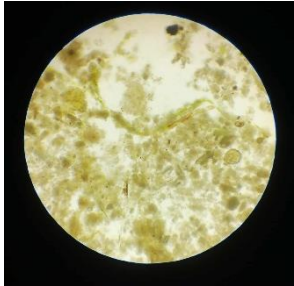
Station	Mean Algal Count
Falls 1 (Hikong Alu)	3.93
Falls 2 (Hikong Bente)	3.77
Lake (East)	3.90
Lake (West)	3.67



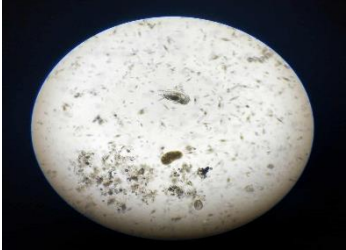
The mean algal count ranged from 3.67 to 3.93 individuals per field of view across stations, showing that the algal abundance did not vary much over Lake Sebu. The higher counts at Falls 1 (3.93) and Lake East (3.90) perhaps are a result of enhanced light exposure and nutrient inflow from surrounding land areas to support photosynthetic activity and proliferation of algae (Reyes et al., 2024). Conversely, marginally lower densities were noted in Lake West (3.67) and Falls 2 (3.77), possibly due to water movement or reduced sediment deposition that limits algal settlement.

Such minor variations in abundance reflect spatial ecological equilibrium where algal growth is regulated by natural nutrient cycling and hydrological stability. According to Jia et al. (2022), consistent algal counts across sampling sites indicate nutrient distribution in balance and minimal environmental stress. The findings validate that the algal populations of Lake Sebu are ecologically stable, moderately productive, and evenly distributed in accordance with its mesotrophic character.

Taxonomic Table

Table 5.4. Identified Algal Types Observed through Light Microscopy in the Freshwater Ecosystem of Lake Sebu, South Cotabato

Algal Type	Species	Picture
Green Algae	<i>Chlorophyta spp.</i>	
Filamentous Green Algae	<i>Chlorophyta spp.</i> (Filamentous forms)	
Blue-Green Algae	<i>Cyanophyta spp.</i>	
Yellow- Green Algae	<i>Xanthophyta spp.</i>	

Brown Algae	<i>Phaeophyta spp.</i>	
Red Algae	<i>Rhodophyta spp.</i>	
Diatoms	<i>Bacillariophyta spp.</i>	

Microscopic analysis confirmed the presence of seven major algal groups: green algae (*Chlorophyta spp.*), filamentous green algae (*Chlorophyta spp.*, filamentous forms), blue-green algae (*Cyanophyta spp.*), yellow-green algae (*Xanthophyta spp.*), brown algae (*Phaeophyta spp.*), red algae (*Rhodophyta spp.*), and diatoms (*Bacillariophyta spp.*). The predominance of green algae across stations reflects their ecological plasticity and adaptability in freshwater habitats with moderate light and nutrient levels (Khalil et al., 2021). Co-occurrence of diatoms and filamentous forms suggests that the waters are oxygen-rich and silica-bearing, reflecting stable trophic conditions (Wang et al., 2022; Pokhrel et al., 2021).

On the other hand, this irregular occurrence of cyanobacteria and red algae may point to variations in the microhabitats, possibly due to water flow or substrate type. The phyla of confirms identified in Lake Sebu confirm its good ecological condition, where various algal groups are represented and play roles in primary production, nutrient cycling, and oxygen production. According to Adhiambo et al. (2023), such composition-level diversity serves as an indicator of a well-functioning freshwater ecosystem that can support biodiversity and ecological resilience.

Summary

The present study aimed to evaluate algal composition, abundance, and diversity indices at four sampling sites (Falls 1, Falls 2, Lake Sebu (East), and Lake Sebu (West)) to determine the ecological status of the lake. The most dominant algal group in the three stations was green algae (Chlorophyta), followed by filamentous green algae and diatoms (Bacillariophyta). This suggested that the physicochemical conditions of Lake Sebu, particularly light penetration, moderate nutrient levels, and stable hydrology, were highly favorable for chlorophytic growth. Diversity indices, including the Shannon-Wiener Index (H'), Simpson's Index (D), and Evenness (E), consistently showed moderate diversity and balanced species distribution, characteristic of mesotrophic ecosystems.

Among all the stations, Lake Sebu (West) had the highest diversity and evenness values, while Falls 1 had the lowest, indicating a localized variation in environmental stability and nutrient availability. The consistent occurrence of diatoms across sites confirmed the good quality and oxygenation of the water, while the minimal presence of cyanobacteria indicated the absence of eutrophication or any pollution stress. Overall, the results suggest that Lake Sebu have a moderately diverse, ecologically stable, and mesotrophic freshwater environment where the algal community plays an important role in primary productivity and the ecological balance of the lake.

Conclusion

Algal diversity and community composition were demonstrated in the present study to be an accurate biological reflection of the lake's ecological condition. The algal assemblages of all the sampling stations (Falls 1, Falls 2, Lake Sebu East, and Lake Sebu West) were consistently dominated by green algae, Chlorophyta, followed by filamentous green algae and diatoms of the division Bacillariophyta. This dominance pattern reflected a mesotrophic ecological state of Lake Sebu, characterized by stable productivity, adequate nutrient availability, and balanced oxygenation, as indicated by the moderate Shannon and Simpson diversity indices.

The presence of diatoms in almost all sampling sites shows that the lake water still maintains good oxygenation and quality because these taxa are bioindicators of well-preserved and balanced freshwater systems. It may also be observed that there was a limited occurrence of cyanobacteria or blue-green algae, which would have indicated eutrophication or organic pollution leading to algal blooms. This pattern of diversity indicates that the freshwater environment is resilient and stable, with the potential for sustaining its biological productivity over time. Of all the different sampling sites, the highest value for diversity and evenness was found in Lake Sebu (West), indicative of optimal environmental balance with substrate stability, whereas the diversity index was lower at Falls 1, suggesting localized nutrient limitation or stronger current effects. Such differences put additional emphasis on the role of microhabitat variability-light availability, water flow, and nutrient distribution-in algal growth and community structure.

Collectively, these findings affirm that algal diversity is a good ecological indicator of water quality and productivity in tropical freshwater systems. The dominance of Chlorophyta and the persistent occurrence of diatoms justify the deduction that Lake Sebu remains in a healthy,

moderately productive, ecologically balanced freshwater state, with stable conditions that support biodiversity and primary productivity important to the overall ecological functioning of the lake.

Recommendation

Based on the findings and challenges encountered during the study, several recommendations are proposed to improve the accuracy, reliability, and efficiency of future research on algal diversity and abundance in Lake Sebu and similar freshwater ecosystems. First, it is recommended that researchers secure accessible laboratory facilities to allow immediate microscopic observation of collected samples. Timely examination prevents morphological changes in algae that may occur due to storage delays. Second, future studies should use Lugol's iodine solution or other suitable preservatives to maintain the color, structure, and visibility of algal cells, especially when immediate analysis is not possible. Third, it is essential to provide adequate laboratory materials and functional equipment, such as microscopes, slides, cover slips, and sampling containers, to ensure accuracy and consistency during microscopic observation.

Fourth, researchers should be allotted sufficient time to conduct multiple observations and repetitions, allowing a more representative and reliable dataset for statistical analysis. Fifth, it is recommended to collect samples under different weather conditions or seasons to assess how varying environmental factors influence algal diversity, abundance, and distribution patterns. Sixth, future researchers are encouraged to consult a statistician or data analyst to apply inferential statistical tests, such as correlation or analysis of variance (ANOVA), to provide deeper validation and stronger quantitative support for the results. Seventh, it is also advised that regular ecological monitoring of Lake Sebu be conducted to track potential changes in algal diversity and nutrient levels, helping detect early signs of eutrophication or ecosystem imbalance.

Lastly, collaboration among academic institutions, local government units, and environmental agencies should be promoted to enhance research capacity, improve access to laboratory resources, and strengthen biodiversity management initiatives in the area. This integrated approach would provide a more comprehensive understanding of the ecological health and productivity of Lake Sebu.

REFERENCES

- Admin. (2025, July 12). Bioindicators Nature's Early Warning System – Green Metric. <https://greenmetric.uma.ac.id/2025/07/12/bioindicators-natures-early-warning-system/>
- Ahmed, S. (2025). Algae as bioindicators of aquatic pollution. Randolph. https://www.academia.edu/142975950/Algae_as_Bioindicators_of_Aquatic_Pollution
- Arora, M., & Sahoo, D. (2015). Concepts and techniques for the study of algae. In Cellular origin and life in extreme habitats (pp. 519–553). https://doi.org/10.1007/978-94-017-7321-8_21
- Astronot. (2025, March 22). Photosynthesis in Algae: Fueling Aquatic life. Scienceinsider.blog. <https://scienceinsider.blog/photosynthesis-algae-aquatic-life/>
- Biobide. (2024, June 11). Algae: Understanding its role in the ecosystem. Biobide. <https://biobide.com/what-is-algae-and-uses>
- Biology Online. (2024b, January 25). Microalgae Definition and Examples - Biology Online Dictionary. Biology Articles, Tutorials & Dictionary Online. <https://www.biologyonline.com/dictionary/microalgae>
- Briceño, G., V. (2021, December 2). Fresh water | What is it, characteristics, types, how it is produced, uses, sources. Euston96. <https://www.euston96.com/en/fresh-water/>
- Freshwater-Aquaculture. (2019, August 26). If algae produce oxygen in a pond, how can having too many algae cause oxygen depletion? – Freshwater Aquaculture. <https://freshwater-aquaculture.extension.org/if-algae-produce-oxygen-in-a-pond-how-can-having-too-much-algae-cause-an-oxygen-depletion/>
- Bobbitt, Z. (2021, March 29). Simpson's Diversity Index: Definition & Examples. Statology. <https://www.statology.org/simpsons-diversity-index/>
- Bobbitt, Z. (2022, April 20). Shannon Diversity Index: Definition & example. Statology. <https://www.statology.org/shannon-diversity-index/>
- Helmenstine, A. (2025, August 13). Algae - Definition, Examples, Characteristics. Science Notes and Projects. <https://sciencenotes.org/algae-definition-examples-characteristics/>
- Howard, D. (2023, October 20). How does algae contribute to the ocean food webs? – TravelAsker. TravelAsker. <https://travelasker.com/how-does-algae-contribute-to-the-ocean-food-webs/>
- Johnson, A. (2022, September 8). What are biological indicators? Temporary. <https://scienceoxygen.com/what-are-biological-indicators/>

- Kiprop, J. (2018, September 28). What is the ecological importance of algae? WorldAtlas. <https://www.worldatlas.com/articles/what-is-the-ecological-importance-of-algae.html>
- Pomelo. (2025, July 30). Do algae produce oxygen? | Atlas Scientific. Atlas Scientific. <https://atlas-scientific.com/blog/does-algae-produce-oxygen/>
- Team, M. (2021, February 26). What are macroalgae and how are they useful? - My reef. My Reef. <https://myreef.aquariumdepot.com/what-are-macroalgae-and-how-are-they-useful/>
- Technology, L. (2025, July 7). Importance of lakes in ecosystems: vital freshwater source. Life TechnologyTM. <https://www.lifetechnology.com/blogs/life-technology-science-news/importance-of-lakes-in-ecosystems-vital-freshwater-source>
- T, N. (2016, August 24). Algae: Definition, Characteristics and Structure (With Diagram). Biology Discussion. <https://www.biologydiscussion.com/algae/algae-definition-characteristics-and-structure-with-diagram/46727>
- Young, J. N., Anderson, R., Martiny, A. C., & Morel, F. M. (2020). Physiological adaptations of high-latitude marine microalgae to environmental change. *New Phytologist*, 226(2), 366–372. <https://doi.org/10.1111/nph.16648>
- Adhiambo, R., Mensah, P. K., & Acheampong, E. (2023). Widespread geographical disparities in phytoplankton ecology research in the face of climate change: A review. *Water*, 15(24), 4288. <https://doi.org/10.3390/w15244288>
- Anderson, C. R., Berdalet, E., Kudela, R. M., Cusack, C. K., Silke, J., O'Rourke, E., Dugan, D., McCammon, M., Newton, J. A., Moore, S. K., Paige, K., Ruberg, S., Morrison, J. R., Kirkpatrick, B., Hubbard, K., Morell, J. (2019). Scaling up from regional case studies to a global harmful algal bloom observing system. *Frontiers in Marine Science*, 6, 250. <https://doi.org/10.3389/fmars.2019.00250>
- Brenckman, C., Jayalakshamma, A. P., Pennock, C., Ashraf, M., & Borgaonkar, H. (2025). A review of harmful algal blooms: Causes, effects, monitoring, and prevention methods. *Water*, 17(13), 1980. <https://doi.org/10.3390/w17131980>
- Carey, R. O., Hochmuth, G. J., Martinez, C. J., Boyer, T. H., Dukes, M. D., & Toor, G. S. (2021). A review of water quality responses to air temperature and precipitation changes 2: Nutrients, algal blooms, sediment, pathogens. *Environmental Science & Technology*, 55(1), 12–30. <https://doi.org/10.1021/acs.est.0c02470>
- Chan, Y., Chiang, K., Ku, Y., & Gong, G. (2018). Abiotic and biotic factors affecting the ingestion rates of mixotrophic nanoflagellates (Haptophyta). *Microbial Ecology*, 77(3), 607–615. <https://doi.org/10.1007/s00248-018-1249-2>

- Chekanov, K. A., & Solovchenko, A. E. (2015). Possibilities and limitations of non-destructive monitoring of the unicellular green microalgae (Chlorophyta) in the course of balanced growth. *Russian Journal of Plant Physiology*, 62(2), 270–278. <https://doi.org/10.1134/s1021443715010033>
- Chandel, P., Mahajan, D., Thakur, K., Kumar, R., Kumar, S., Brar, B., Sharma, D., & Sharma, A. K. (2023). A review on plankton as a bioindicator: A promising tool for monitoring water quality. *World Water Policy*, 10(1), 213–232. <https://doi.org/10.1002/wwp2.12137>
- Galloway, A. W. E., Britton-Simmons, K. H., Duggins, D. O., Gabrielson, P. W., & Brett, M. T. (2012). Fatty acid signatures differentiate marine macrophytes at ordinal and family ranks. *Journal of Phycology*, 48(4), 956–965. <https://doi.org/10.1111/j.1529-8817.2012.01173.x>
- Gu, X., Cao, Z., Zhao, L., Seswita-Zilda, D., Zhang, Q., Fu, L., & Li, J. (2024). Application of environmental DNA metabarcoding to differentiate algal communities by littoral zonation and detect unreported algal species. *Phycology*, 4(4), 605–620. <https://doi.org/10.3390/phyco4040033>
- Harun, R., Singh, M., Forde, G. M., & Danquah, M. K. (2013). Biochemical composition of algae influenced by environmental conditions: A review. *Energies*, 6(9), 4607–4638. <https://doi.org/10.3390/en6094607>
- Islam, S. T., Dar, S. A., Sofi, M. S., Bhat, S. U., Sabha, I., Hamid, A., Jehangir, A., Bhat, A. A. (2021). Limnochemistry and plankton diversity in some high-altitude lakes of Kashmir Himalaya. *Frontiers in Environmental Science*, 9, 681965. <https://doi.org/10.3389/fenvs.2021.681965>
- Jacobs, P., Serre-Fredj, L., Koeman, R. P. T., Van Den Oever, A., Peck, M. A., & Philippart, C. J. M. (2024). Impacts of counting protocols for light microscopy on estimates of biodiversity and algal density of phytoplankton. *Limnology and Oceanography Methods*. <https://doi.org/10.1002/lom3.10651>
- Jansen, H. M., Bernard, M. S., Marit, Ingrid, & van. (2022). Seasonal variation in productivity, chemical composition and nutrient uptake of *Ulva* spp. (Chlorophyta) strains. *Journal of Applied Phycology*, 34(3), 1649–1660. <https://doi.org/10.1007/s10811-022-02708-z>
- Jia, J., Chen, Q., Ren, H., Lu, R., He, H., & Gu, P. (2022). Phytoplankton Composition and Their Related Factors in Five Different Lakes in China: Implications for Lake Management. 19(5), 3135–3135. <https://doi.org/10.3390/ijerph19053135>
- Kawai, H., & Motomura, T. (2024). Structural colour in the brown algal genus *Sporochnus* (Sporochnales, Phaeophyceae). *European Journal of Phycology*, 59(3), 271–278. <https://doi.org/10.1080/09670262.2024.2340020>

- Khalil, S., Mahnashi, M. H., Hussain, M., Zafar, N., Waqar-Un-Nisa, N., Khan, F. S., Afzal, U., Shah, G. M., Niazi, U. M., Awais, M., & Irfan, M. (2021). Exploration and determination of algal role as bioindicator to evaluate water quality – Probing freshwater algae. *Saudi Journal of Biological Sciences*, 28(10), 5728–5737. <https://doi.org/10.1016/j.sjbs.2021.06.004>
- Kumar, M., Singh, D. P., Prabha, R., & Sharma, A. K. (2014). Role of cyanobacteria in nutrient cycle and use efficiency in the soil. In *Springer eBooks* (pp. 163–171). https://doi.org/10.1007/978-81-322-2169-2_10
- Lestari, N., Kusuma, L., Yuliana, N., & Noerdjito, D. R. (2025). Biodiversity and distribution of freshwater microalgae from the black-water ecosystem of Rungan River, Central Kalimantan, Indonesia. *Biodiversitas*, 26(3), 4218–4227. <https://doi.org/10.13057/biodiv/d260315>
- Libretexts. (2024, October 28). 22.2: Diversity indices. *Biology LibreTexts*. https://bio.libretexts.org/Courses/Gettysburg_College/01%3A_Ecology_for_All/22%3A_Biodiversity/22.02%3A_Diversity_Indices
- Lürling, M., Mendes e Mello, M., van Oosterhout, F., & de Senerpont Domis, L. N. (2018). Response of natural cyanobacteria and algae assemblages to a nutrient pulse and elevated temperature. *Frontiers in Microbiology*, 9, 1851. <https://doi.org/10.3389/fmicb.2018.01851>
- MDPI. (2023). Assemblage patterns of microalgae along the upstream to downstream gradient of the Okavango Delta: Abundance, taxonomic diversity, and functional diversity. *Water*, 15(15), 2692. <https://doi.org/10.3390/w15152692>
- Pokhrel, P., Ghimire, L., & Rai, S. (2021). Seasonal variation of algal diversity with reference to water quality in Jagadishpur Reservoir, Nepal. *Water*, 13(21), 3003. <https://doi.org/10.3390/w13213003>
- Remias, D., Jost, S., Boenigk, J., Wastian, J., & Lütz, C. (2013). Hydrurus-related golden algae (Chrysophyceae) cause yellow snow in polar summer snowfields. *Phycological Research*, 61(4), 277–285. <https://doi.org/10.1111/pre.12025>
- Reyes, J. P., Bicaldo, P. G., & Tamayo, A. R. (2024). Spatiotemporal variability of phytoplankton communities in the euphotic layers of a tropical caldera lake (Lake Taal, Batangas, Philippines). *Biodiversitas*, 26(6), 3302–3314. <https://doi.org/10.13057/biodiv/d260635>
- Sherwood, A. R., Carlile, A. L., Neumann, J. M., Kociolek, J. P., Johansen, J. R., Lowe, R. L., Conklin, K. Y., Presting, G. G. (2014). The Hawaiian freshwater algae biodiversity survey (2009-2014): systematic and biogeographic trends with an emphasis on the macroalgae. *BMC Ecology*, 14(1). <https://doi.org/10.1186/s12898-014-0028-2>

- Takahashi, T., Sato, M., Toyooka, K., & Nozaki, H. (2014). Surface ornamentation of *Cyanophora paradoxa* (Cyanophorales, Glaucophyta) cells as revealed by ultra-high resolution field emission scanning electron microscopy. *CYTOLOGIA*, 79(1), 119–123. <https://doi.org/10.1508/cytologia.79.119>
- Van Leeuwe, M. A., Tedesco, L., Arrigo, K. R., Assmy, P., Campbell, K., Meiners, K. M., ... & Stefels, J. (2020). Annual patterns in phytoplankton phenology in Antarctic coastal waters explained by environmental drivers. *Limnology and Oceanography*, 65(9), 2125–2142. <https://doi.org/10.1002/lno.11477>
- Wang, Q., Gao, Y., Song, X., Wang, Z., & Zhang, X. (2022). Exploring the key factors affecting the seasonal variation of phytoplankton in the coastal Yellow Sea. *Frontiers in Marine Science*, 9, 1076975. <https://doi.org/10.3389/fmars.2022.1076975>
- Wang, W., Li, Z., & Huang, C. (2022). Heavy metals exacerbate the effect of temperature on the growth of *Chlorella* sp.: Implications on algal blooms and management. *Processes*, 10(12), 2638. <https://doi.org/10.3390/pr10122638>
- Wang, Y., Feng, L., Hou, X. (2023). Algal blooms in lakes in China over the past two decades: Patterns, trends, and drivers. *Water Resources Research*, 59(10), e2022WR033340. <https://doi.org/10.1029/2022WR033340>
- Watanabe, S., & Lewis, L. A. (2017). Phylogenetic interpretation of light and electron microscopic features of selected members of the phylogroup *Moewusinia* (Chlorophyceae), with new generic taxonomy. *Phycologia*, 56(3), 329–353. <https://doi.org/10.2216/16-64.1>
- Wiley Online Library. (2023). The importance of integrating phycological research, teaching, outreach, and engagement in a changing world. *Journal of Phycology*. <https://doi.org/10.1111/jpy.13507>