The Water Quality Assessment and Biodiversity of Phytoplankton in Phayao Lake, Phayao Province, Thailand

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The goals of this evaluation of Phayao Lake were to evaluate the physical, chemical, and biological water quality, to determine the phytoplankton biodiversity, and to examine the relationship between biodiversity and water quality. Seven stations gathered samples for six months, from September 2020 to February 2021. Twice a month, samples were collected from each location. The results identified eight divisions, fifty-nine genera, and eighty-nine species. The most prevalent division of phytoplankton was Chlorophyta (45%), composed of 40 species. *Coelomoron* sp. was the most dominant species, with 732 ± 252 individuals L-1. The ranges for the Shannon – Wiener index, the evenness index, the richness index, and the index of similarity were 0.210 to 3.101, 0.151 to 0.985, 0.481 to 6.487, and 40.00 to 76.11, respectively. Based on the relationship between water quality variables and phytoplankton and utilizing statistical data analyzed using canonical correspondence analysis, phytoplankton was categorized into seven types, each of which was linked to an increase in dissolved oxygen levels. Although community-use water was classed as having medium to low nutrient levels, the average water quality in terms of dissolved oxygen (DO), biological oxygen demand (BOD), conductivity, nitrate concentrations, and phosphorus was classified as having medium to high nutrient levels. Because aquatic organisms use the area surrounding Phayao Lake as a nursery and breeding site, it has been. It will continue to be an important source of food for the community. Aquatic animals use the area surrounding Phayao Lake as a nursery and breeding ground; hence, this area is and will continue to be an important food source for the local community. Long-term monitoring determines the annual phytoplankton succession and identifies the progression of anomalous events, as recommended by the policy recommendations.

Key words: Phayao Lake; biological water quality; AARL-PP score; aquatic animals; nutrient sources.

1. INTRODUCTION

The largest freshwater lake in Northern Thailand, Phayao Lake, is located in the Mueang Phayao District of Phayao Province. As a living entity, algae are vital to aquatic ecosystems due to their ability to produce oxygen and their position as the principal producer in aquatic food chains. Microscopic marine algae, phytoplankton, are microorganisms that are moved by wind and waves. Distinct species require different conditions for growth in freshwater, brackish water, and saltwater (Cetinić et al., 2006; Saifullah et al., 2019; Wu et al., 2020). Moreover, temperature, wind, and light intensity significantly impact the water conditions of Phayao Lake during each season (Han et al., 2021).

Consequently, there are statistically significant variations in phytoplankton levels depending on the season and lake region ($P<0.05$). Cyanobacteria are the predominant phytoplankton at all sampling sites of Phayao Lake during both the wet and cold seasons (Penny et al., 2005). According to the same study, cyanobacteria have the highest growth rate at water temperatures above 25 degrees Celsius. Cyanobacteria can have a variety of detrimental effects on the local community; *Microcystis aeruginosa*, for instance, can produce poisons that are harmful to humans and aquatic animals, whereas *Anabaena* sp. and *Oscillatoria* sp. can produce odorous soil. Due to cyanobacteria pollution in raw water during the rainy season, tap water preparation in the Phayao Lake region must be handled with caution (Catherine et al., 2016; Mooij et al., 2009; Penny et al., 2005). Previous research confirms the relationship between phytoplankton and water quality because various phytoplankton grows in water with varying attributes (Ding et al., 2022; Ding et al., 2021). Some phytoplankton can only grow in high-quality water, while others can grow in high-quality water and wastewater. Others can grow in high-quality water and wastewater (Back et al., 2021; Liu et al., 2015).

The spread of phytoplankton is determined by the concentration of nutrients in the water. These nutrients may originate from municipal wastewater or agricultural and industrial sectors. When water is rich in nutrients, phytoplankton grows swiftly and scatter quickly. Certain phytoplankton can create hazardous poisons for aquatic species and people who utilize the water (Agnihotri et al., 2021; Tsuchiya et al., 2017). Thus, phytoplankton can measure water quality (Back et al., 2021; Ding et al., 2021). The innovative aspects of this study include the Phayao lake and lake biodiversity in northern Thailand. These investigations also reveal that Phayao Lake experiences dynamic changes in its physical and biological parameters and is an appropriate water source for water quality and phytoplankton biodiversity research. Because the lake is a substantial source of income for the neighboring community, it is especially vital to monitor changes in its characteristics. The purpose of this study is to examine and evaluate the water quality associated with specific physical and biological aspects to determine the phytoplankton biodiversity and to observe the association between the biodiversity and the water quality, as well as the relationship between them, of Phayao Lake at its highest water level (September to February). In addition, phytoplankton biodiversity, water quality, and interaction were analyzed. This study's findings will aid in the planning, monitoring, and managing of Phayao Lake's water sources to ensure the lake's long-term viability. Seasonal differences in phytoplankton biodiversity and physiochemical properties were observed.

2. MATERIALS AND METHODS

2.1 Research Sites

Around Phayao Lake, phytoplankton, large algae, and water were collected from several areas. Water samples were analysed, and phytoplankton specimens were identified in the laboratories of the University of Phayao's School of Energy and Environment and the School of Science. The seven Phayao Lake sample stations were determined as follows:

2.2 Collection of Water Samples and Phytoplankton Technique

Samples were obtained roughly 30 cm below the water's surface. They were gathered twice every site, once per month, from September 2020 to February 2121, for six months. At each sample location, two 1.5 L bottles of water were collected to determine the dissolved oxygen level of the water and the oxygen needed by microbes to break down organic waste. The map of seven sampling station in Phayao lake (Fig 1).

Phayao Lake's outflow is located at Station 1 in the port area of the Inland Fisheries Research and Development Centre in District 1. It is impacted by human activities, such as fishing and sewage from cities. Its geographic coordinates are N 19.15917793 E 99.91010808.

The location of Station 2 is the Wat Tilok Aram Pier. This station acts as a tourist attraction and is located near the city. This region is impacted by human activity, such as wastewater contamination and tourism garbage. Its coordinates are N 19.16271169 E 99.9002685.

Station 3 is located at the Naga Monument. It is the station closest to the city and a popular tourist destination. The area is impacted by human activities, including municipal effluent, pollution, and garbage from tourism. It is located at N 19.16877668 E 99.89525411 latitude, longitude.

Station 4 is situated behind the Phayao Hospital. The water is murky with floating vegetation, and several plants are near the coast. This region is impacted by human activity, including fishing and hospital discharge. It is positioned at N 19.18913522 E 99.87584040.

Chao Pho Khun Det Shrine hosts Station 5. It is the inlet region of Phayao Lake, which contains both floating and shoreline vegetation. The surface of the lake is murky. The area is impacted by human activity, including fishing and farming. It is located at N 19.20416675 E 99.86861911 latitude, longitude.

The location of Station 6 is the former Ban Thung Kiew dock. The water is very transparent, with greenery along the coast and abundant floating vegetation. Human activities (including fishing and farming) impact this region. It is positioned at N 19.1571868 E 99.86130707.

Station 7 is located at the archaeological site of Ban Rong Hai. This area contains coastal and floating vegetation and is adjacent to fishing and farming regions. The sampling area is surrounded by numerous stores and is a tourist attraction. This region is impacted by human activity, such as fishing and wastewater storage. It is positioned at N 19.14891541 E 99.88689771. 20 liters of water were filtered with a phytoplankton mesh filter of 10 microns. The samples were then preserved with a solution of Lugol's iodine. At each location, two 750 mL bottles of water were collected to measure the amounts of total nitrogen and phosphorus.

Figure 1: Map of Seven Sampling Stations in Payao Lake

2.3 Physical and Chemical Quality Studies

2.3.1 Physical Studies

During the investigation there are four physical factors were determined to determine their influence on phytoplankton growth;

1) A standard 30-cm Secchi disk was used to measure the depth of light.

2) A multi-parameter (Hanna HI 98194) was used to measure water temperature and conductivity.

3) Air temperature was determined with a thermometer.

4) Turbidity was quantified with a turbidity meter.

2.3.2 Chemical studies; The study of phytoplankton photosynthesis (PP) on dissolved oxygen (DO) dynamics was evaluated in a red sea bream (*Pagrus major*) aquaculture site. (Yoshikawa et al., 2007)

1) Dissolved oxygen was analyzed by using the Azide modification technique.

2) The oxygen amounts used by microorganisms to decompose organic matter or Biochemical Oxygen Demand were determined using the Azide modification technique.

3) A multi-parameter meter was used to measure pH values.

4) A phosphorus analysis was conducted using the ascorbic acid technique.

5) Total Kjeldahl nitrogen (TKN) was determined using the Kjeldahl method (Kang et al., 2022).

6) Ammonia amounts were quantified by titration.

7) Nitrate contents were determined by using the Brucine method.

8) Nitrate amounts were measured by the colorimetric method.

2.4 Taxonomic Classification and Identification of Phytoplankton Species

➢ The morphology of phytoplankton was observed under a light microscope with 400x magnification, and verification was carried out with taxonomic documents or type-identification textbooks for classifying genus, such as the book *Freshwater Algae in Thailand* (Nukazawa et al., 2011).

The total number of plankton on one slide (20 µL) was counted using the whole count method, and images were taken of each plankton found under the light microscope.

The calculation for the number of phytoplankton found per 1,000 mL of water is as follows: initial volume (volume of the slide), initial concentration (cells volume of slide), Volume Factor (concentrated amount + amount decanted), concentration Factor (which volume factor/concentrated amount), and final concentration in cells/liter (Cells counted /slide volume) x (1/concentration factor) x (1,000/L)

2.5 Water Quality Assessment by AARL-PP Score Method and Management of Water Quality By Type And Quantity of Dominant Phytoplankton According to AARL-PP Score (Estifanos et al., 2022; Kumsiri et al., 2021)

Phytoplankton was collected from seven locations using a 10 m phytoplankton mesh filter, with the amount of water collected varying according to phytoplankton abundance. From there, phytoplankton species were identified. In cases where species could not be identified, the three to five most prevalent genera were enumerated, and their scores were recorded. As the monitoring scores indicated the water quality, the results of each genus were averaged to determine the overall scores. The average results were compared to assess water quality and nutrient levels.

2.6 The Correlation of All Variables Was Analyzed Using a Statistical Program for Environmental Research (Multivariate Statistical Package, MVSP) *(Shahrokhi et al., 2021).*

2.6.1 Analysis

Based on a shared dataset, the percentages of phytoplankton taxa were estimated. The diversity of the species assemblage was quantified by the Shannon–Wiener index (H'), richness was evaluated by Margalef's index (D), and evenness was determined by Pielou's index (J) using the Sorensen similarity index (species diversity and richness) 704 samples from 44 sampling locations along the Yellow River were studied to determine the biogeographic, environmental, and anthropogenic influences on phytoplankton community composition (Ding et al., 2022).

3. RESULTS AND DISCUSSION

3.1 Percentages of Phytoplankton Species Found in Phayao Lake

The phytoplankton population of Phayao Lake was comprised of eight divisions, 59 genera, and 89 species, as determined by a study of the phytoplankton found there. In the percentages of phytoplankton species in each division discovered, Chlorophyta (45%, 40 species) was the most abundant division followed by Euglenophyta (17%, 15 species), Bacillariophyta (14%, 12 species), Cyanophyta (12%, 11 species), Pyrrophyta (5%, 4 species), Chrysophyta (3%, 3 species), Cryptophyta (3%, 3 species), and Xanthophyta (1%, 1 species) (Fig.2).

According to the data, evenness indices for the phytoplankton collected from seven locations in Phayao Lake ranged from 0.563 to 0.985. In September 2020, the most evenness was observed at Station 4, with a value of 0.985. In contrast, the lowest observed evenness index was 0.151 at Station 7 in December 2020. (Table 1).

Evenness indices of phytoplankton ranged from 0.563 to 0.985, indicating that the phytoplankton in Phayao Lake are extremely uniformly distributed as the value approaches 1. Most of the seven stations' evenness indices were relatively similar throughout the research, showing that the phytoplankton distribution did not vary significantly from month to month. In agreement with (Catherine et al., 2016), who studied the phytoplankton distribution and water quality in coastal aquaculture areas of Bandon Bay in Surat Thani Province in 2016, these results show that summer and winter had similar phytoplankton indexes; thus, the phytoplankton distribution did not vary with the seasons (Jasprica et al., 2022). Moreover, fluctuations in thermocline depth influence the vertical distribution discrepancies between phytoplankton and zooplankton. Warming impairs phytoplankton regulation by lowering resource-consumer interactions that overlap (Wang et al., 2020).

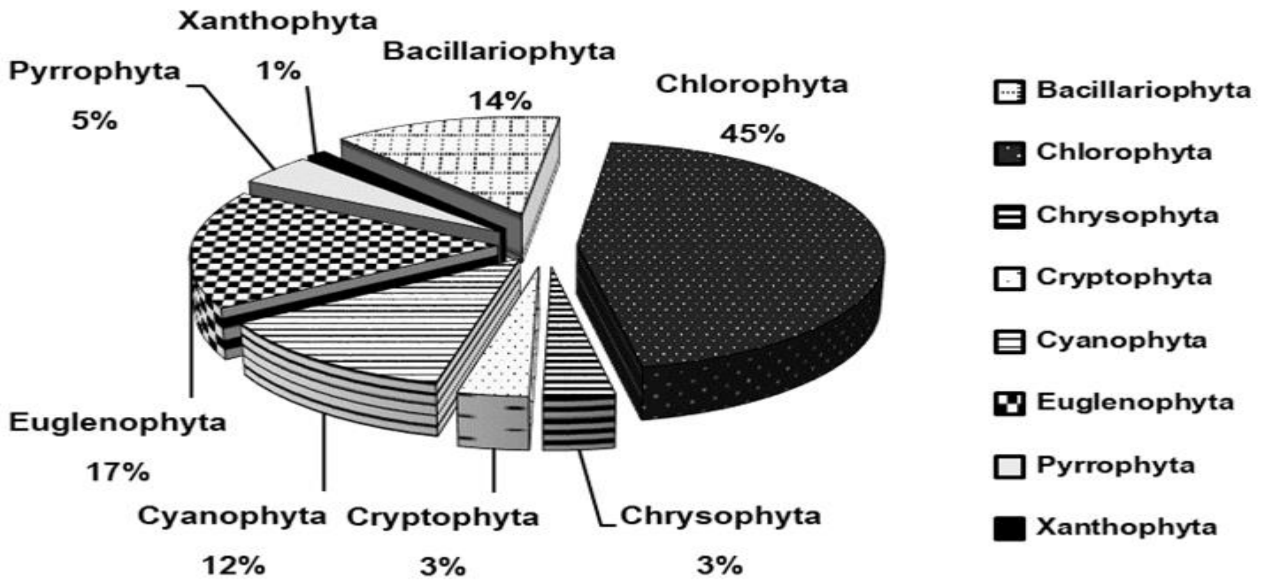

Figure 2: Percentages of Phytoplankton Species in Each Division Discovered in Phayao Lake from September 2020 to February 2021

Table 1 The Evenness Indexes of Phytoplankton Discovered in Phayao Lake from September 2020 to February 2021

Month	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
September	0.868	0.792	0.841	0.985	0.881	0.241	0.912
October	0.699	0.776	0.856	0.863	0.901	0.807	0.954
November	0.773	0.865	0.770	0.680	0.805	0.739	0.806
December	0.804	0.942	0.804	0.899	0.662	0.881	0.151
January	0.780	0.646	0.626	0.891	0.895	0.704	0.563
February	0.859	0.830	0.761	0.838	0.813	0.852	0.800

3.2 Richness Index

Regarding the richness index recorded in Phayao Lake within the relevant time frame, the results indicated a range of 0.481-6.487. In January 2021, the station with the greatest phytoplankton richness index in Phayao Lake was Station 5, with a richness index of 6.487%. In contrast, the station with the lowest phytoplankton richness index in October 2020 was 7. (Table 2).

Table 2 The Richness Index of Phytoplankton Discovered in Phayao Lake from September 2020 to February 2021

Month	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
September	4.864	6.439	3.631	0.932	4.519	1.243	2.118
October	3.961	4.777	4.233	2.236	1.454	2.280	0.481
November	2.642	2.038	4.345	1.516	4.315	1.447	1.626
December	4.111	1.668	2.574	3.083	4.262	1.737	0.624
January	6.210	4.062	4.829	2.826	6.487	2.190	2.711
February	5.204	4.655	4.611	1.204	4.343	1.165	2.260

The observed richness indices throughout this investigation ranged from 0.48 to 6.487. Station 1 in January 2021, Station 2 in September 2020, and Station 5 in January 2021 had the most dissimilar richness indices. The highest phytoplankton richness indices were 6.210, 6.439, and 6.487, showing that there are numerous phytoplankton species in Phayao Lake. In January 2012, the study assessed phytoplankton biodiversity in seagrass regions on Ko Yao Yai in Phang-nga Province and found richness indices ranging from 2.51 to 4. The prediction accuracy of lake-scale and catchment-scale factors for local species richness was comparable (R2 = 0.458 and 0.424, respectively). Seasonal temperature fluctuations and nutrition availability considerably alter regional species diversity (Catherine et al., 2016).

3.3 Shannon-Wiener Index

Shannon-Wiener indices for the phytoplankton biodiversity study conducted at seven locations ranged from 0.210 to 3.101. In January 2021, the highest Shannon-Wiener index was recorded at Station 5, with a value of 3.101. In contrast, Station 7 in December 2020 exhibited the lowest Shannon-Wiener index of 0.210. (Table 3).

Table 3 The Shannon-Wiener's Index of Phytoplankton Discovered in Phayao Lake from September 2020 to February 2021

Month	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
September	2.682	2.768	2.383	1.364	2.638	0.265	2.101
October	2.093	2.432	2.563	1.986	1.755	2.070	0.662
November	2.041	1.798	2.268	1.494	2.451	1.537	1.676
December	2.278	1.516	1.852	2.306	1.914	1.418	0.210
January	2.794	2.027	2.086	2.215	3.101	1.690	1.523
February	2.798	2.654	2.387	1.631	2.476	1.527	1.989

The range of observed Shannon-Wiener indices from 0.210 to 3.101 is consistent with Roschat et al. (2018). From April 2013 to September 2014, these researchers examined the water quality and phytoplankton biodiversity at Rasi Salai Dam in Si Sa Ket Province, discovering Shannon-Wiener indices of 2.534, 2.997, and 3.404 for the summer, rainy, and winter seasons, respectively. In other words, the Shannon-Wiener index was highest during the winter, followed by the wet season and summer. The Shannon-Wiener indexes were high throughout this investigation, ranging from 1.36 to 3.101. Nevertheless, among the seven locations, the indexes observed at Station 7 in October 2020 and December 2020 were the lowest. At these two times, Station 7's Shannon-Wiener indices were 0.210 and 0.662, which corresponded with the evenness and richness indexes found at the time. The evenness indexes for all locations ranged from 0.563 to 0.985, indicating that each phytoplankton species was spread extremely consistently. However, the distribution of phytoplankton was less even at Station 7 in December 2020, with an evenness index of 0.151.

Additionally, the phytoplankton richness indices in the present study ranged from 1.165 to 6.487%. Nevertheless, the richness indices of Station 7 in October 2020 and December 2020, which were 0.481 and 0.624, show that the phytoplankton biodiversity of Station 7 at those times was lower than that of other stations or months. The observed trend in the Shannon-Wiener index, the evenness index, and the richness index of Station 7 in October 2020 and December 2020 was attributable to the abundance of Dinobryon sp., measured at 25 ± 18 and 1492 ± 605 Individual L-1. There were fewer phytoplankton species at this location than at other stations. Therefore, Station 7's Shannon-Wiener index, evenness index, and richness index were lower than those of other stations at the time. Lipnicki et al. (2017) examined the water quality and phytoplankton diversity of Phayao Lake in 2017 and observed Shannon-Weiner Diversity Indexes ranging from 0.372 to 2.765; this implies a small increase in phytoplankton biodiversity in Phayao Lake. A study of phytoplankton populations along a tropical mangrove estuary in Sarawak, Malaysia, revealed a greater value during the dry season (Saifullah et al., 2019).

3.4 Similarity Index

In a similarity examination of the phytoplankton found at seven stations in Phayao Lake, the index of similarity between Station 1 and Station 3 was the greatest, at 76.11%. On the other side, the collection points with the lowest similarity indexes were: 1) Station 1 and Station 6 and 2) Station 2 and Station 6, both at 40%. The average similarity index of phytoplankton biodiversity across seven locations was 57.22 percent (Table 4).

Table 4: Similarity Index (Percent) of Phytoplankton in Phayao Lake from September 2020 to February 2021

Station	1	2	3	4	5	6	7
1				•	•		
2	75.44				•		
3	76.11	75.73			•		
4	50.00	46.34	46.91		•	•	•
5	68.33	67.27	62.39	54.55		•	•
6	40.00	40.00	45.95	67.92	51.85		•
7	48.89	45.00	48.10	62.07	58.14	70.59	

(black) 75 - 100 percent similarity; • 50 – 74.9 percent similarity; (blank) < 50 percent similarity

The current study evaluated phytoplankton diversity in Phayao Lake, Phayao Province, from September 2020 to February 2021. The phytoplankton community comprises eight divisions, fifty-nine genera, and eighty-nine species. The division Chlorophyta was the most numerous phytoplankton in this study, accounting for 45 percent or 40 species. According to (Cetinić et al., 2006), the division of Chlorophyta of green algae grows differently depending on the availability of nutrients and light. Chlorophyta as the dominating phytoplankton division implies a high nutrient content, consistent with the water quality assessment and the amount of dominant phytoplankton as measured by the AARL-PP Score technique (Kumsiri et al., 2021). In another investigation, algal beads were utilized for tilapia cultivation water quality management (Chen, 2001). The assemblage and variety of phytoplankton are extremely susceptible to climate change, and many species are employed as water quality indicators (Murugesan et al., 2021). In this study, the nutrient concentrations in Phayao Lake were graded as medium to high, and the water quality was marginally substandard. Due to the high nutritional content of Phayao Lake, green algae flourished rapidly and became the largest species in the division of Chlorophyta. Lipnicki et al. (2017) researched phytoplankton biodiversity in Phayao Lake from April to September 2020. Chlorophyta was the main division of phytoplankton. In addition, an evaluation of the water quality using the AARL-PP Score method revealed moderate nutrient levels and water quality.

In contrast to division Chlorophyta, division *Cyanophyta* contained a significantly smaller number of cyanobacteria species (Ding et al., 2022). However, the *Cyanophyta* division had the highest density proportion, at 28%. The present investigation discovered that division *Cyanophyta* may develop rapidly in neutral or slightly alkaline water and can endure unfavorable environmental circumstances. These algae cannot thrive in water with a pH between 4 and 5. (Cho et al., 2021; Schiel et al., 2019).

3.5 Physical and Chemical Water Quality Assessments Using the AARL-PC Score Technique

In the present study, the physical and chemical water quality of Phayao Lake was determined by measuring DO, BOD, conductivity, nitrate levels, ammonia, and phosphorus levels over six months. The results reveal that the average water quality of Phayao Lake can be classified as moderate. However, the nutrient levels ranged from moderate to high and may be classified as meso-eutrophic. At Station 2, the average water quality and nutrient concentrations were determined to be mesotrophic or moderate. In contrast, the water quality at Stations 1, 3, 4, 5, 6, and 7 was moderate to somewhat bad, and the nutrient concentrations were moderate to high or meso-eutrophic.

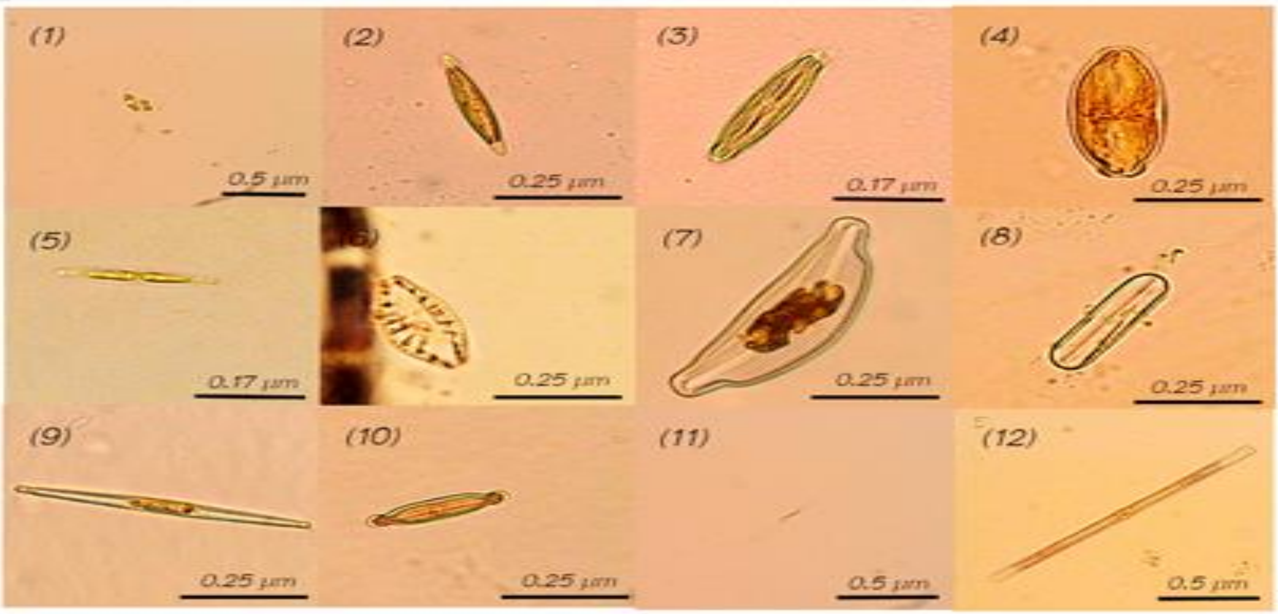

Figure 3. Examples of phytoplankton in Phayao Lake in the Division of Bacillariophyta from September 2020 to February 2021, e.g., *Achnanthidium minutissimum* (Kützing) Czarnecki (1), *Achnanthidium* sp. (2), *Amphora* sp. (3), *Brachysira* sp. (4), *Cymbella* sp.1 (5), *Cymbella* sp. 2 (6), *Diploneis* sp. (7), *Fragilaria* sp.1 (8), *Neidium* sp. (9), *Rizosolenia* sp. (10), *Synedra ulna* (Nitzsch) Ehrenberg (11), *Acanthoceras zachariasii* (12)

4. CONCLUSIONS

From the study of phytoplankton diversity in Kwan Phayao: From September 2020 to February 2021, all seven stations discovered phytoplankton belonging to eight divisions, 59 genera, and 89 species, with the Chlorophyta division having the biggest proportion of phytoplankton species (45%), forty species. Demonstrate that green algae in the division Chlorophyta develop differently depending on the availability of nutrients and the light source in the water. Examples of phytoplankton in Phayao Lake in the Division of Bacillariophyta from September 2020 to February 2021, e.g., *Achnanthidium minutissimum* (Kützing) Czarnecki (1), *Achnanthidium* sp. (2), *Amphora* sp. (3*)*, *Brachysira* sp. (4), *Cymbella* sp.1 (5), *Cymbella* sp. 2 (6), *Diploneis* sp. (7), *Fragilaria* sp.1 (8), *Neidium* sp. (9), *Rizosolenia* sp. (10), *Synedra ulna* (Nitzsch) Ehrenberg (11), *Acanthoceras zachariasii* (12) (Fig.3). Chlorophyta is a group of phytoplankton whose genus mostly indicates the quality of the accessible water. High nutrient content was consistent with the AARL-PP score method's water quality assessment by type and number of dominating phytoplankton. Kwan Phayao was found to have average water quality, with a medium to high nutrient level and poor to moderate water quality. In the study, the water temperature exceeded 25 degrees Celsius, the optimal growth temperature for blue-green algae.

5. THE SUGGESTIONS FOR FURTHER STUDY

In the global water pollution industry, the difficulties of addressing climate change have intensified. Participation by academics and researchers in community processes to make advice and conduct workshops is permissible. Additionally, the system is dynamic due to the future hazards connected with climate change. To develop such adaptation, it is necessary to evaluate risk management and resiliency in the context of fisheries and climate change. To achieve water management, it would be possible to identify the right methods for each social-ecological subsystem. Government officials and scholars should develop learning approaches and utilize them to coach individuals. Traditional knowledge and risk management practices that have been passed down over many generations, when paired with current understanding and technology, can be used to manage water systems in the face of climate change. The private sector can use social media to support water management. Finally, youth organizations and clubs should advocate for water management.

6. CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

7. ACKNOWLEDGMENTS

The University of Phayao partially supported this research. We thank the Department of Biology, the School of Science, and the University of Phayao for laboratory access.

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