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Temporal Dynamics of Phytoplankton in Retention Pond as a Water Source for Striped Catfish (Pangasianodon hypophthalmus) Farming

Dinamika Temporal Fitoplankton pada Kolam Retensi sebagai Sumber Air untuk Budidaya Ikan Patin (Pangasianodon hypophthalmus)

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ABSTRACT

This comprehensive study investigates the temporal dynamics and ecological aspects of phytoplankton communities in water reservoirs utilized for Pangasius cultivation. Over a six-week observation period, 25 phytoplankton species, including Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae, and Cryptophyceae, were identified. Chlorophyceae displayed the highest species richness, emphasizing the dominance of this group, particularly Chlorella, which remained stable throughout weekly observations. Other taxa, such as Euglenophyceae, exhibited delayed increases in density. The study revealed two crucial groups in the water reservoir: the first, composed of Actinastrum sp., Closterium sp., Staurastrum sp. (Chlorophyceae), Navicula sp., Pleurosigma sp., Schroedaria sp., Surirella sp. (Bacillariophyceae), and the second, more diverse group consisting of Nitzschia sp. (Bacillariophyceae), Cryptomonas sp. (Cryptophyceae), Trachelomonas sp. (Euglenophyceae), Anabaena sp., Merismopedia sp., Phormidium sp. (Cyanophyceae), Ankistrodesmus sp., Chlorella sp., and Crucigenia sp. (Chlorophyceae). Chlorella was consistently present which was observed to interact with various species, fostering a balanced environment for growth and reproduction within its family and across others based on network analysis. Contradictory dynamics emerge in the initial weeks, where the highest species richness ($N = 19$ species) coincides with a high dominance index ($1/D = 0.54$). Conversely, the peak diversity index ($H' = 2.04$) occurs during the second observation, aligning with a comparable evenness index ($J = 0.89$). The saprobic index indicates a shift in pollution levels from β-mesosaprobic to α/β-mesosaprobic between the initial and final weeks of observation. Simultaneously, trophic-saprobic index alterations signify an environmental quality transition from polysaprobic to oligosaprobic. This presents contradictory trends, where, based on species richness, the environment is ecologically classified as polluted. However, considering the contribution of non-indicator groups in the formula, the pond conditions shift towards nutrient impoverishment, suggesting potential suitability for aquaculture practices.

Keywords: *α/β-mesosaprobic, Chlorella, Chlorophyceae, network analysis, oligosaprobic, reservoir*

ABSTRAK

Penelitian ini bertujuan untuk menyelidiki dinamika temporal dan aspek ekologi dari komunitas fitoplankton di waduk yang digunakan untuk budidaya Pangasius. Observasi dilakukan hingga enam minggu dan memperoleh sebanyak 25 spesies fitoplankton, diantaranya Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae, dan Cryptophyceae. Chlorophyceae menunjukkan kekayaan spesies tertinggi, menunjukkan adanya dominasi kelompok tersebut, terutama Chlorella, yang tetap stabil sepanjang pengamatan mingguan. Taksa lainnya, misalnya Euglenophyceae, menunjukkan nilai kepadatan yang menurun di akhir pengamatan. Studi ini mengungkapkan dua kelompok penting dalam waduk: Pertama, terdiri atas Actinastrum sp., Closterium sp., Staurastrum sp. (Chlorophyceae), Navicula sp., Pleurosigma sp., Schroedaria sp., Surirella sp. (Bacillariophyceae), Kedua, kelompok yang lebih beragam terdiri atas Nitzschia sp. (Bacillariophyceae), Cryptomonas sp. (Cryptophyceae), Trachelomonas sp. (Euglenophyceae), Anabaena sp., Merismopedia sp., Phormidium sp. (Cyanophyceae), Ankistrodesmus sp., Chlorella sp., dan Crucigenia sp. (Chlorophyceae). Chlorella secara konsisten hadir dan teramati berinteraksi dengan berbagai spesies, menciptakan lingkungan seimbang untuk pertumbuhan dan reproduksi di dalam familinya dan terlibat dengan kelompok lain berdasarkan analisis jaringan (network). Dinamika yang bersifat kontradiktif muncul pada minggu pertama, di mana kekayaan spesies tertinggi (N = 19 spesies) bersamaan dengan indeks dominasi tinggi (1/D = 0.54). Sebaliknya, puncak indeks keanekaragaman (H' = 2.04) terjadi selama observasi kedua, sejalan dengan indeks keseragaman yang sebanding (J = 0.89). Indeks saprobik menunjukkan pergeseran tingkat polusi dari β-mesosaprobik ke α/β-mesosaprobik antara minggu observasi awal dan akhir. Pada saat yang sama, perubahan indeks trofik-saprobik menandakan transisi kualitas lingkungan dari polysaprobik ke oligosaprobik. Ini menimbulkan tren yang kontradiktif, di mana, berdasarkan kekayaan spesies, lingkungan secara ekologis diklasifikasikan sebagai tercemar. Namun, jika mempertimbangkan kontribusi kelompok non-indikator dalam formula, kondisi kolam beralih ke kemiskinan nutrisi, menunjukkan potensi kecocokan untuk praktik akuakultur.

Kata kunci*: α/β-mesosaprobic, analisis jaringan, Chlorella, Chlorophyceae, oligosaprobik, kolam retensi*

INTRODUCTION

The striped catfish, commonly known as *patin* (Bahasa) or *Pangasius hypophthalmus* stands out as a native freshwater species in Indonesia, belonging to the catfish group extensively cultivated in aquaculture. Its considerable potential in the aquaculture sector arises from several key advantages, including ease of breeding, high adaptability, rapid growth, and substantial economic value as a favored consumable fish (Tran *et al.,* 2017). These attributes, coupled with the rising popularity of *patin*, have spurred the expansion and intensification of cultivation practices to meet the escalating demands of the market (Ramadhan *et al.,* 2016). The fundamental concept of *patin* farming is relatively straightforward, relying on the utilization of earthen ponds and the natural abundance of nutrients in the environment (Hasibuan *et al.,* 2023).

In the established *patin* farming concept, the inclusion of a retention pond serves as a crucial element for water storage, facilitating the supply and exchange of water to both cultivation and grow-out ponds (Nhut *et al.,* 2019; Phan *et al.,* 2009). In tropical regions, particularly within North Sumatra, the availability of numerous river waters becomes a valuable resource channeled through the extensive network of canals. Notably, the high tolerance of *patin* allows the utilization of seemingly less favorable or marginal areas, including those proximate to oil palm plantations, for pond farming. This strategic approach ensures optimal land use and underscores the adaptability of *patin* farming practices to diverse environmental conditions. The appeal of *Pangasius* farming extends beyond just suitable conditions, encompassing its recognized benefits and substantial demand in the market. *Pangasius*, characterized by rapid growth, supports high stocking density in cultured conditions, contributing to its swift adoption among fish farmers in the region. The farming system follows a controlled aquaculture approach, necessitating the meticulous management of water quality parameters to ensure optimal growth and health of the *Pangasius* population (Abedin *et al.,* 2017). The dynamic interplay between water quality and aquaculture practices underlines the importance of maintaining a harmonious environment for successful *Pangasius* farming. Phytoplankton, comprising a diverse microalgal community, plays a pivotal role in the intricate balance of aquatic ecosystems (Pal and Choudhury, 2014). In the context of *Pangasius* farming, the contribution of phytoplankton becomes particularly significant, whether through intentional strategies involving algae-based feed intensification or targeted control measures against potentially harmful species.

Recognizing the connection between phytoplankton dynamics and water quality, particularly concerning pollution levels, this study aimed to analyze the temporal patterns of phytoplankton abundance and identify prevalent species. The findings of this study will reveal the extent to which the dominance of specific phytoplankton influences dualistic outcomes, whether as a natural food source that supports the sustainability of *P. hypophthalmus* during cultivation or, conversely, hinders the fishes due to microalgal blooming.

METHODOLOGY

This research was conducted in September 2023 in an intensive giant catfish farming area located in Deli Serdang Regency, North Sumatra, Indonesia. The observation site was a large retention pond made of earthen ponds, covering an area of 400 m^2 (Figure 1). The water, serving as a reservoir, was discharged through a canal system into breeding ponds within the farm area. The physicochemical characteristics of the water during the study period included a temperature ranging from 29 to 30.2°C, pH levels from 7.1 to 7.4, and total dissolved solids ranging from 810 to 2000 ppm. The water source was derived from adjacent tributaries around the farm. The study utilized a causal ex-post facto design and a purposive sampling method for data collection. The ex-post facto causal design is a scientific approach based on empirical data obtained in the field without any external treatment. Samples were collected from the edge, middle, and central areas, taken once every two weeks until the third sampling or the sixth week. The water sampler was first disinfected using detergent/alcohol (70%) to eliminate adhering microorganisms. Samples were collected at each location at four different points and then combined into one. The samples were taken approximately 10 cm below the water surface using a 5 L bucket, filtered six times using a plankton net to obtain a total volume of 30 L. The filtered results were stored in sample bottles (100 mL each) and preserved with a few drops of Lugol's iodine (0.3 mL) as a preservative. The observation and identification of phytoplankton were conducted using an Olympus compound microscope model CX23 with an optical infinity system, binocular with observations ranging from 40 to 400 times magnification. The calculation of phytoplankton abundance (cells/m^3) was performed using a strip technique based on the APHA (2022) guidelines. Identification of phytoplankton was based on photographic images and confirmed through atlas and guide books. Graphical images were created using GraphPad Prism ver. 8.0. Ecological indices, including Shannon's diversity index, Simpson's dominance index, and Pielou's evenness index, were calculated using PAST ver. 4.04, while network analysis was constructed using appropriate software (Hammer and Harper, 2001). Saprobic and trophic-saprobic indices were calculated following the descriptions by Dresscher and Mark (1976) and Siregar et al. (2023).

Figure 1. Retention pond (A) used as water reservoir for *Pangasius* breeding and sampling sites for phytoplankton with distribution through canal system (B)

RESULTS AND DISCUSSION

Twenty-five phytoplankton species, comprising Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae, and Cryptophyceae, were identified through microscopical observations in the water reservoir over a period of 6 weeks, with a 2-week interval for each sampling (Figure 2).

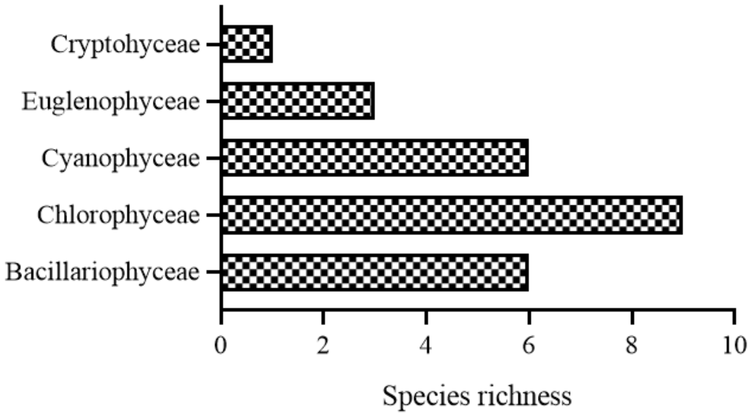

Figure 2. Number of species per phytoplankton families in water reservoir

The highest species richness was observed in the Chlorophyceae group (9 species), while the lowest was noted in the Cryptophyceae group (*Cryptomonas*). Borges *et al.* (2008) similarly reported the highest species richness in Chlorophyceae in reservoirs in Brazil. D'Alessandro et al. (2020) also reported that 40% of the obtained taxa were from Chlorophyceae in facultative and maturation ponds in Brazil. In general, the dominance of Chlorophyceae species was noted in the early stabilization ponds, indicative of a potential richness in organic matter. In a more recent study, Halder *et al.* (2019) documented 17 genera from Chlorophyceae out of 23 taxa highlighting their richness and important role in the community pond in West Bengal, India. hting their The phytoplankton community in aquaculture ponds depends on factors such as the water source used, whether the pond is open or closed, the observation season or time of day, and the influence of innate environmental factors or nutrient elements. In general, the dominance of Chlorophyceae species was noted in the early stabilization ponds, indicative of a potential richness in organic matter. The phytoplankton community in aquaculture ponds depends on factors such as the water source, whether the pond is open or closed system, seasonal variation or daily observation period (diurnal, nocturnal), and the influence of innate environmental conditions and nutrients (Alam *et al.,* 2001; Hassall, 2014; Jindal, 2005; Naselli-Flores *et al.,* 2000).

Further monitoring of the phytoplankton assemblage was conducted to show temporal patterns and distinctions among groups. Chlorophyceae and Cyanophyceae exhibited stable relative densities (>25%), while Bacillariophyceae showed a decline from 26% to 14% in final observation period (Figure 3).

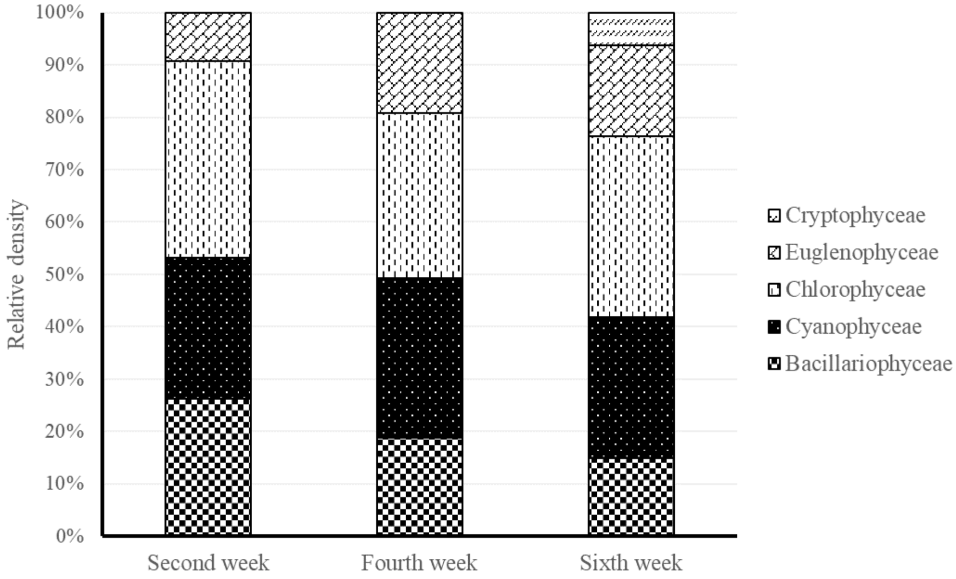

Figure 3. Temporal dynamics of phytoplankton density based on family grouping

A similar pattern was documented by Sipaúba-Tavares et al. (2011), who reported that both Chlorophyceae and Cyanophyceae maintained stable cell densities as long as nitrate was available in water. Conversely, Euglenophyceae demonstrated a delayed increase in density compared to other groups. Rahman *et al.* (2007) previously reported a higher density of euglenoids at a specific point, during which the density of other phytoplankton groups significantly influenced the environment, rendering it more acidic and nutrient-rich. Cryptophyceae was only observed in the late observation period, likely emerging after prior competition among planktonic organisms. However, this needs further confirmation, especially through experiments using axenic culture to observe growth responses in relation to other taxa. An experiment conducted by Mirth *et al.* (2019), examining the interaction between *Cryptomonas* and *Dinobryon* unveiled a size-related shift into smaller cell size when *Cryptomonas* underwent stress and competition during culture. This phenomenon could potentially account for the occurrence or absence of *Cryptomonas*, attributed to a very small individual load in the sample. Moreover, the timing of algal blooms in water bodies is complex and may vary depending on seasonal and environmental conditions. Further details regarding the structure and composition of phytoplankton during the observation period is presented in Figure 4.

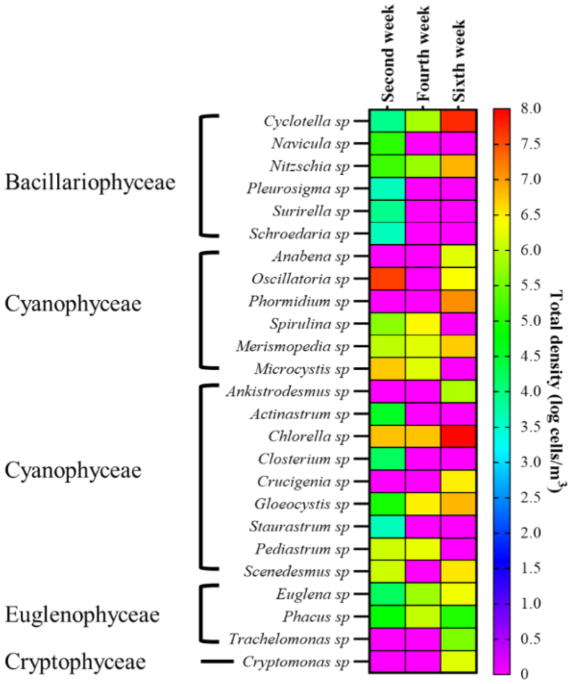

Figure 4. Heat map showing temporal dynamics of phytoplankton in water reservoir based on their total density and species composition

The rainbow scale depicts the correlation values, ranging from the lowest (purple-to-blue) to the highest (yellow-to-red) for each microalgal species. The highest total density in the initial observation was obtained from *Oscillatoria* sp., reaching log 7.61 cells/m^3 (Cyanophyceae), followed by *Chlorella* sp. (Chlorophyceae) with log 6.78 cells/m^3, while the lowest was recorded for *Staurastrum* sp. (Chlorophyceae). In the second observation or fourth week, a shift occurred, with Chlorella having the highest density at log 6.77 cells/m^3, and the lowest recorded for *Nitzschia* sp. at log 5.76 cells/m^3 (Bacillariophyceae). Next, the dominance of *Chlorella* sp. continued, reaching its peak in the final week with an abundance value of log 7.97 cells/m^3, and the lowest density observed in *Phacus* sp. at log 4.99 cells/m^3 (Euglenophyceae). Based on the results, it appears that the dominance of *Chlorella* is remarkably high in the reservoir, and the water source used may have had a high density of *Chlorella* from the outset. *Chlorella* spp. encompasses a category of single-celled microalgae extensively employed for its biomass in feed production and its capacity to release oxygen via photosynthesis (Ahmad *et al.*, 2020). The stability observed in *Chlorella* suggests a state of minimal fluctuations in biological parameters, as long as these parameters stay within permissible limits that do not hinder their growth and productivity (Wang *et al.*, 2022). Khanna *et al.* (2019) indicated that, even in ponds characterized by fertility and a nitrogen to phosphorus (N/P) ratio of 20:1, *Chlorella* spp. will flourish and persist in growth. Maintaining *Chlorella* density at optimal levels is likely to have no adverse impacts on higher organisms. Furthermore, the balance among nitrite, nitrate, ammonium, and phosphate parameters plays a pivotal role in determining the density of *Chlorella* spp. in water (Angela *et al.*, 2021). Moreover, the consistent presence of stable *Chlorella* in weekly observations shows its potential value when introduced to pangasius breeding. Ahmad *et al.* (2020) reported that *Chlorella* harbors a range of nutrients and associated compounds collectively referred to as Chlorella Growth Factor (CGF), a beneficial phytonutrient known to contribute to a gradual enhancement in fish performance. In a separate investigation, Azani *et al.* (2022) developed an effective feed for *Pangasius nasutus* larval breeding by formulating a functional feed

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composed of *Chlorella* and rice bran. Following the recommendations of Vu and Huynh (2020), enhancing the nutritional content of *Pangasius* larvae feed by incorporating not only indigenous microalgae but also mixing it with zooplankton can lead to improved growth performance and survival of *Pangasianodon hypopthalmus* larvae. Network analysis was conducted to investigate interactions and co-occurrences among phytoplankton taxa, considering Pearson's correlation values (*r*) with a 95% edge cutoff for simplified data visualization (Figure 5).

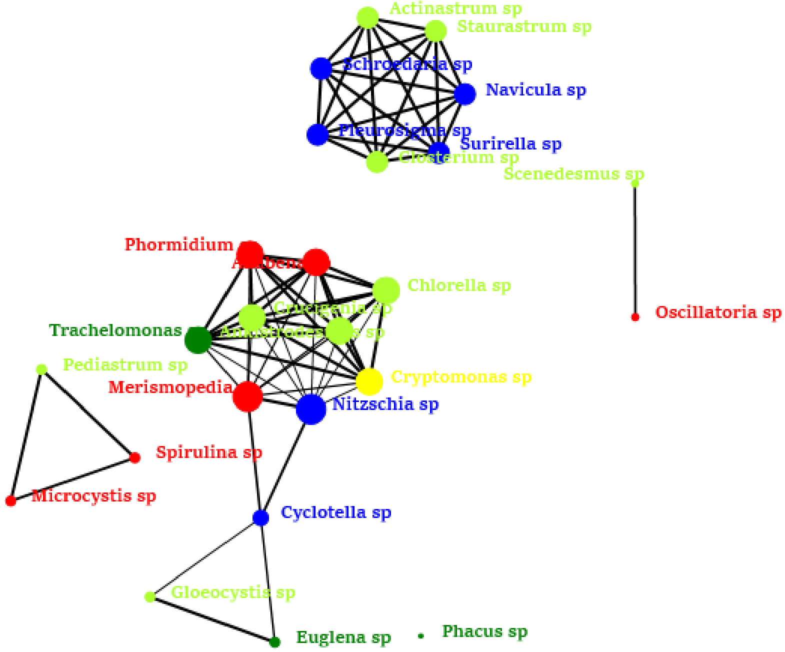

Figure 5. Network of phytoplankton co-occurrence across species in water reservoir based on Pearson's correlation values and Fruchterman-Reingold Algorithm. Nodes and species name in different colors represent specific family. Blue = Bacillariophyceae, Red = Cyanophyceae, Green = Chlorophyceae, Green-yellow = Euglenophyceae, Yellow = Cryptophyceae

The results revealed both uni-/multi-directional and interaction patterns within the phytoplankton community. Nodes represent the radius of a functional unit signifying the significance of interactions, while thicker edges indicate stronger correlation strength between connected nodes. The study identified two distinct groups, each playing a crucial role in the water reservoir under investigation. The first group comprised *Actinastrum, Closterium,* and *Staurastrum* (Chlorophyceae), *Navicula, Pleurosigma, Schroedaria,* and *Surirella* (Bacillariophyceae), while the second, more diverse group included *Nitzschia* (Bacillariophyceae), *Cryptomonas* (Cryptophyceae), *Trachelomonas* (Euglenophyceae), *Anabaena, Merismopedia*, and *Phormidium* (Cyanophyceae), as well as *Ankistrodesmus, Chlorella,* and *Crucigenia* (Chlorophyceae).

Consistent occurrences of *Chlorella* were noted to play a role in interacting with other species, maintaining a balance and favorable conditions for growth and reproduction, not only within its own family but also with other families. Furthermore, *Cryptomonas*, the less abundant species appearing at the end of the observation period, exhibited strong correlations with *Chlorella* to *Trachelomonas* in significant interactions. This may suggest contributions from other attributes facilitated by *Cryptomonas*, supporting its growth, or conversely, *Cryptomonas* playing a role in the existence of other interconnected species. Specific experiments are required to address this assumption. Concurrently, the temporal dynamics reflected in the fluctuation or consistency of the density of each species, along with the patterns of their interactions, indicate the potential occurrence of a successional gradient. This succession is relatively brief for some co-dominant species (Khemakhem *et al.,* 2010). The high adaptability of *Chlorella* also suggests that when this water source is eventually used for dense stock of *Pangasius*, there is a likelihood of *Chlorella* persisting due to its tolerance to CO_2 and increased photosynthetic rate (Turker *et al.*, 2003). Gilles *et al.* (2013) further proposed that, given their rapid growth potential and spontaneous development, *Chlorella* and rotifers appear to be ideal candidates for planktonic artificial ecosystems in brackish water.

An ecological analysis of the phytoplankton community reveals a consistent pattern of fluctuations that are similar between the number of taxa and dominance index, as well as between the diversity index and evenness index (Figure 6). Contradictory relationships are apparent in the initial weeks, where species richness is highest (N = 19 species), yet it results in a high dominance index as well ($1/D$ = 0.54). Meanwhile, the highest diversity index (H' = 2.04) is observed in the second observation, corresponding to a similar evenness index (J = 0.89).

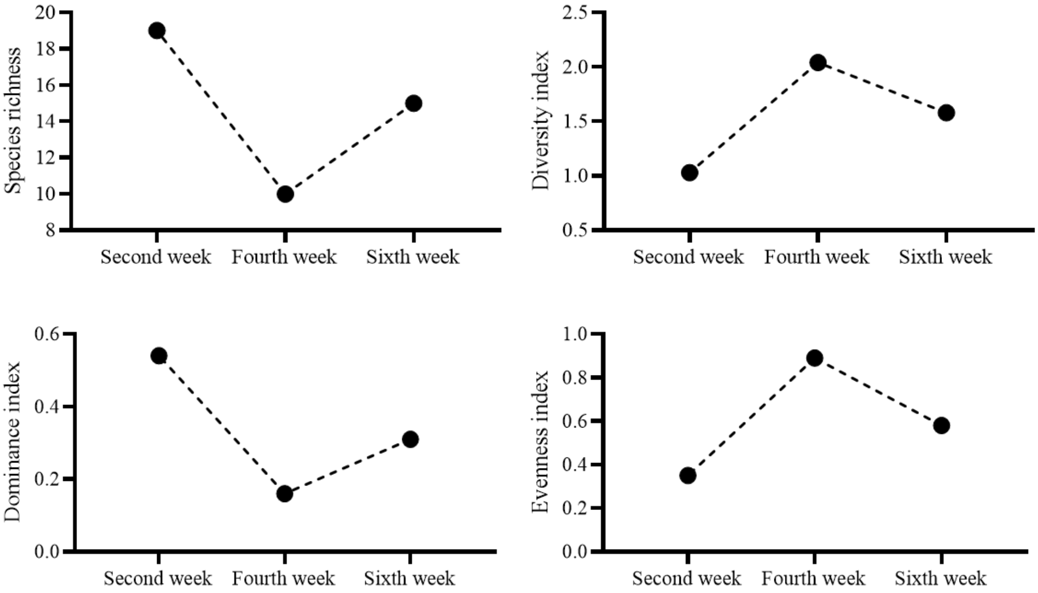

Figure 6. Temporal variation in community ecology of phytoplankton in water reservoir

The fluctuations observed in both taxa and dominance indices reveal a dynamic and responsive phytoplankton community, likely influenced by environmental dynamics and interspecific interactions. The initial weeks present a contradictory scenario, where high species richness aligns with a dominant species, suggesting the role of certain species on the community structure. The further increase in diversity and evenness indices indicates a shift towards a more balanced distribution of species, possibly driven by, again, changing environmental conditions or altered competition dynamics. These patterns hint at ongoing successional dynamics within the phytoplankton community as evidenced from network patterns previously. The diversity profile indicates that the phytoplankton diversity in the water reservoir ranged from low to moderate levels. Effendi *et al.* (2016) established that a diversity index value exceeding 1.0 falls into the category of a moderately stable community, whereas values below that threshold indicate instability and sensitivity to external conditions, as observed in their study in the Mahakam Delta. In a separate study, Basavaraja *et al.* (2013) identified a phytoplankton-rich community in the Anjanapura reservoir, characterized by diversity index values ranging between 1.60 and 1.88. Following the ecological characteristics, we assessed pollution level by measuring the saprobic and trophic-saprobic indices as presented in Figure 7.

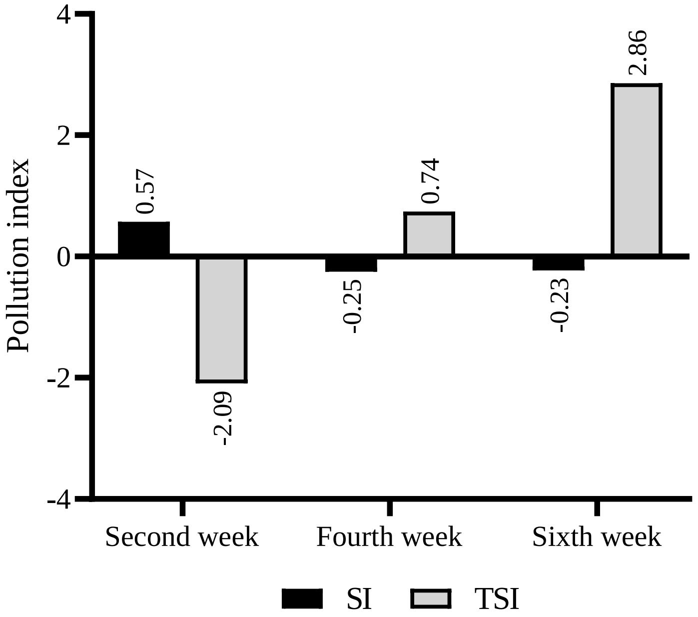

Figure 7. Temporal dynamics of pollution level based on saprobic index (SI) and trophic-saprobic index (TSI) of phytoplankton abundance in water reservoir.

Saprobic and trophic indices, derived from phytoplankton attributes, have been widely employed for assessing water quality in lentic systems (Maznah and Makhlough, 2015). According to Dresscher and Mark's (1976) classification values, the pollution levels ranged from β-mesosaprobic to α/β-mesosaprobic from the initial to the final week of observation for the saprobic index. Meanwhile, pollution levels based on the trophic-saprobic index indicated an environmental quality shift from polysaprobic to oligosaprobic. There seems to be contradictory trends, where considering species richness, the environment is ecologically classified as polluted. However, when taking into account the contribution of non-indicator groups in the formula, the pond conditions shift towards nutrient impoverishment, potentially suitable for aquaculture. The implications of saprobic index calculations only become significant if toxin-producing species are present, and even in small populations, they can impact other organisms (Stevenson, 2014). However, in this study, no species were identified as definitively non-harmful, despite the plankton identification being limited to the genus level. Further identification, especially for significant groups like Cyanophyceae and toxin load, is crucial to accurately assess the risk of water source usage and its dynamics under retention conditions (Rojas-Tirado *et al.,* 2018; Utkilen and Gjolme, 1992).

CONCLUSIONS

The monitoring results shed light on the temporal dynamics and ecological parameters of the phytoplankton community, revealing a dual impact on water trophic quality. One aspect of this impact is evident in the consistent high density of *Chlorella*, which serves as a natural food source throughout the observation period. However, a comprehensive perspective suggests that contributions from other phytoplankton groups also play a role in the observed pollution levels. Acknowledging the influence of *Chlorella* on the existence of other microalgal species, a potential approach could involve either eliminating Chlorella to mitigate the presence of interconnected species or investigating the experimental pond's capacity to sustain the life of test animals under elevated pollution levels.

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