



Water Quality Assessment and Algae Diversity in the Seven Brackish Lakes North of Benghazi, Libya

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ABSTRACT

The present study investigates the relationship between water quality parameters and microalgae diversity in a brackish lake ecosystem. Water samples were collected across four seasons, from October 2022 to July 2023, from the surface of six sites distributed throughout the seven northern lakes of Benghazi. Water quality parameters—including electrical conductivity, pH, temperature, alkalinity, and nutrient concentrations—were analyzed. Microalgae were identified, counted, and their abundance estimated using the Utermöhl method. Microalgae diversity was assessed using Shannon, Simpson, species richness, and evenness indices. A total of 33 species belonging to 27 genera and five divisions were recorded. The most diverse group was Chlorophyta (49%), followed by Cyanophyta (21%), Bacillariophyta (12%), Euglenophyta (9%), and Dinophyta (9%). The highest species diversity, according to the Shannon–Weaver index, was observed in winter, while the lowest occurred in summer. The Simpson index was highest in autumn and lowest in summer. Principal Component Analysis (PCA) extracted two components from 14 environmental variables after Varimax rotation, explaining 46.47% of the total variance. Canonical Correspondence Analysis (CCA) identified two factors—F1 (41.35%) and F2 (17.77%)—which together accounted for 59.11% of the total data variance, with eigenvalues of 0.48 and 0.44, respectively. These results illustrate the relationship between microalgae species and environmental variables. Overall, the findings provide a foundation for developing sustainable conservation strategies to preserve the biodiversity of brackish lakes.

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INTRODUCTION

Microalgae are vital primary producers in aquatic ecosystems, contributing to nutrient cycling, carbon fixation, and supporting food webs (Rao *et al.*, 2024; Bhardwaj *et al.*, 2024). Their diversity and sensitivity to environmental changes make them effective bioindicators of ecosystem health (Martínez-Burgos *et al.*, 2024). They respond rapidly to shifts in water quality factors such as nutrients, salinity, and light (Adams *et al.*, 2020), making their study essential for ecological assessment and early detection of environmental stress (Nava *et al.*, 2021).

Brackish lakes, shaped by fluctuating salinity from seawater and freshwater mixing, create dynamic habitats that support specialized microalgal communities (Mrozińska *et al.*, 2021). Salinity in these ecosystems can range from 0.5 to 32 ppt (Sandrin *et al.*, 2009). Due to their sensitivity, microalgae serve as effective indicators for assessing ecological health and human impacts, such as nutrient pollution and climate-driven salinity shifts (Bhateria & Jain, 2016; Yan *et al.*, 2024). Brackish water ecosystems play crucial roles in maintaining biodiversity, regulating nutrient cycles, and providing ecosystem services that benefit both human populations

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and wildlife. Water quality in these lakes is influenced by land use, hydrological connectivity, and seasonal variation, with nutrient imbalances potentially leading to eutrophication or limiting biological productivity (Omar *et al.*, 2016; Muduli & Acharya, 2024). Despite the ecological significance of brackish ecosystems, microalgal diversity and its relationship with water quality in these environments remain underexplored compared to freshwater and marine systems. The seven brackish lakes located north of Benghazi have previously been investigated for heavy metal pollution (unpublished master's thesis), yet no study has integrated both microalgal diversity and water quality assessment in these lakes. This research aims to fill that gap by analyzing microalgal diversity and evaluating how water quality parameters influence the composition and abundance of microalgal communities through Canonical Correspondence Analysis (CCA) and Principal Component Analysis (PCA) (Shetty & Gulimane, 2023).

The specific objectives of this study are: 1- To evaluate the species diversity and composition of microalgal communities across different seasons and sites within the seven lakes north of Benghazi. 2- To assess the physico-chemical water quality parameters seasonally and spatially, and determine their correlation with microalgal diversity. 3- To identify whether variations in water quality influence the presence of specific microalgal taxa, including bloom-forming or potentially harmful species.

MATERIAL AND METHODS

Description of the Study Area

The Seven Northern Lakes of Benghazi form a vast, flat expanse located along the northern boundary at the eastern entrance of the city. These interconnected water bodies merge into a single, continuous lake without visible internal divisions. The total surface area of the lakes is approximately 1.203 km², with a shoreline length of about 9.86 km, as measured using the Offline Maps mobile application (Figure 1). These lakes are artificial, commonly referred to as the “Seven Lakes of the El-Thama Region,” and were originally constructed in the 1980s by an Italian company as part of the Benghazi North Lakes Project for recreational purposes. Over time, however, the site has been repurposed as a municipal landfill, receiving a wide variety of waste materials, including abandoned vehicles, oil, and other hazardous substances.

Samples Collection and analysis

Water samples collection was performed at seasonally base in October 2022, January, Aprile and July 2023, from distributed six sites. Total of 18 water samples were taken in clean and dry 500 ml bottles from the surface layer of the lakes. Triplicate sampling for water were done for microalgae identification and counting, nutrient analysis and water alkalinity measurements from the surface of the lakes (0.5 m depth) and from about 2m from the edge at autumn, winter, spring and summer. Sites and time of sampling (around 10 to 11 a.m.) were fixed every season (Eli, 2023).

Physico – chemical parameters measurements

Physical water quality parameters like pH, Electric conductivity and water temperature were measured directly by Instruments (HANNA instruments, model HI 98129) in the field. For measurement water lake nutrient's; water samples were transported to laboratory and analysed by the standard methods (Clesceri *et al.*, 1998; APHA, 2023). Ammonia (NH₃) and Ammonium (NH₄) concentration measured by indophenol (salicylate) method, Nitrate (NO₃) concentration measured by cadmium reduction method, Arthrphosphate (PO₄) concentration measured by ascorbic acid reduction method. Surface water alkalinity were measured in laboratory of Al-Arab Medical University, Faculty of Pharmacy, by titration of 100 ml of sample with 0.02 N sulphuric acid using few drops of mixed reagent (methyl red and bromocresol) as an indicator

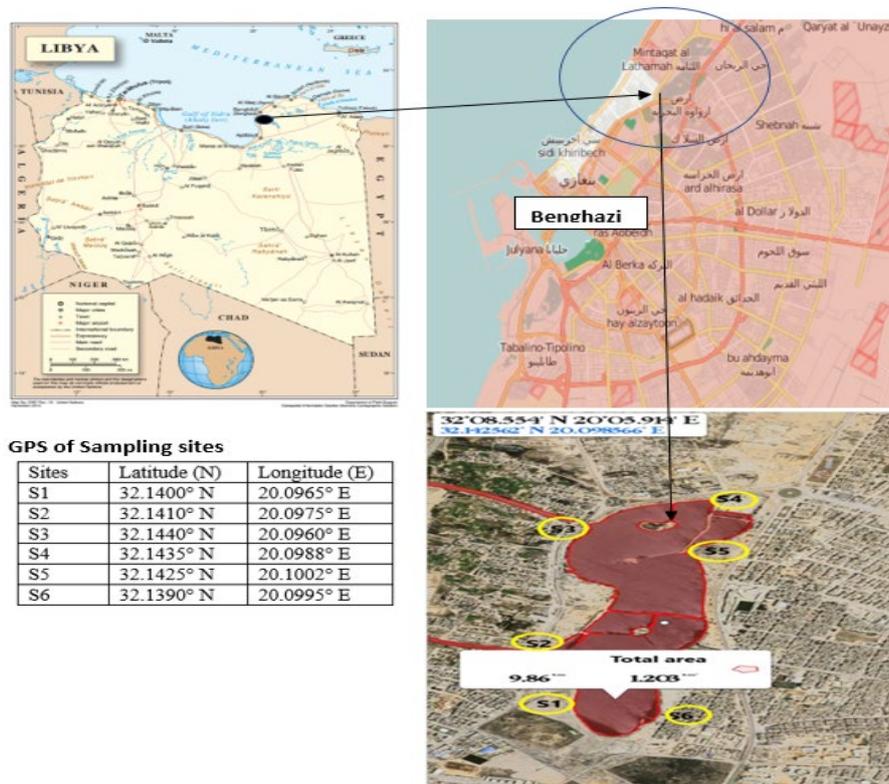


Fig. 1. The study area and sampling sites.

(Kim & Sansalone, 2008; Wilson, 2010).

Algae identification and enumeration

The abundance of algae was estimated by the Utermöhl method (Utermöhl, 1958). The samples were fixed by adding 10 ml of 4% formalin solution (Kumar, 2012). The samples were left undisturbed to allow microalgae to settle down for at least 48h (Edler and Elbrächter, 2010). Then 400 ml were moved gradually from surface of the bottle, then 1 drop from the remaining 100 ml were placed into Haemocytometer counting chamber (three times from each sample). Microalgae were counted and identified at species level according to a key of freshwater algae (Bellinger and Sigeo, 2010; Scholz & Liebezeit, 2012) and algae base web site (Guiry, 2024). Microalgae cell density calculated by the next equation (Edler & Elbrächter, 2010).

$$\text{Number of microalgae cells/ml} = \frac{\text{(Number of cells counted in large squares)}}{4} \times 10,000$$

Algal diversity calculations

Microalgae diversity was calculated by Shannon-Wiener Index (H'), Simpson index (D), Pielou's Evenness Index (J') and Species richness as the next formulas:

Shannon-Weaver index (Shannon & Weaver, 1949): $H' = -\sum p_i \ln(p_i)$

Where: p_i means the proportion of the species (n) microalgae in total individuals (N).

Simpson's index: $1 - \sum (p_i^2)$

Evenness: $H' / \ln(S)$

Where H' is the Shannon index value, S is the total number of species.

Species richness: $\ln(S)$ (Margalef, 1958).

Table 1. Mean \pm SD of Seasonally data for Physico-chemical parameters in lakes. (n = 72). The level of significance [P-Value] was set at $P < 0.05$

Parameters	Sampling seasons				P value
	Autumn	Winter	Spring	Summer	
pH	8.32 \pm 0.51	8.35 \pm 0.49	7.72 \pm 0.41	6.75 \pm 0.03	0.00
Electric Conductivity (μ s/cm)	13958.3 \pm 2608.84	11925.0 \pm 1148.72	9308.7 \pm 1814.97	16558.3 \pm 2438.36.	0.00
Water Temperature($^{\circ}$ C)	23.6 \pm 1.58	16.8 \pm 2.25	19.4 \pm 1.51	29.3 \pm 1.00	0.00
Total Alkalinity mg (CaCO ₃)/ L	130.0 \pm 60.3	106.6 \pm 58.8	106.7 \pm 27.3	73.33 \pm 20.1	0.22
Amonia (NH ₃) mg/L	0.47 \pm 0.28	0.26 \pm 0.13	0.36 \pm 0.20	4.10 \pm 0.51	0.00
Amonium (NH ₄) mg/L	0.50 \pm 0.30	0.26 \pm 0.14	0.39 \pm 0.21	4.44 \pm 0.90	0.00
Nitrate (NO ₃) mg/L	16.5 \pm 14.1	17.9 \pm 14.9	18.0 \pm 14.9	8.91 \pm 4.52	0.15
Phosphates (PO ₄) mg/L	1.15 \pm 0.92	1.66 \pm 1.10	1.46 \pm 0.88	1.40 \pm 0.38	0.37

Statistical analysis

One-way ANOVA statistical analysis from SPSS (version 28 software), was used to indicate the significant of variance in physical-chemical environmental parameters, species number and microalgae cell density among different sampling periods and sites. Diversity indices (Simpson diversity index, Shannon diversity index (H), Species Evenness and species richness index (S')) were calculated using Excel software. Principal component analysis (PCA) was analyzed using Statistical Software for Excel (XLstat) software Version 2024. PCA is a variable reduction technique, it is designed to reduce the original variables into new, uncorrelated variables or axes, called the principal components which are linear combinations of the original variables. Canonical Correspondence Analysis (CCA) was conducted by (XLstat) software version 2024 also to detect species distribution related to physical environmental parameters and different seasons and sampling sites conditions.

RESULTS AND DISCUSSION

Physicochemical characteristics of the seven lakes, north of Benghazi

The seven lakes that located in El-thama region North of Benghazi showed biological and limnological differences among the different seasons and sites. Water lake characters impacted principally by seasonality, consequently, biological process of microalgae have changed during different seasons. A summary of seasonally results were recorded for physico-chemical parameters in the seven lakes, north of Benghazi have been presented in Tables (1). Variations in all the physical and chemical characteristics of water in the lakes at a particular season and site during sampling periods revealed some of significant impacts of different seasons on the lakes system.

Water quality can be indicated using microalgae due to their rapid response to environmental changes. This is supported by numerous studies in aquatic ecology such as O'Neill & Rowan, (2022); Martínez-Burgos *et al.*, (2024). Algae, particularly phytoplankton and periphyton, have been widely used as bioindicators because they are sensitive to changes in nutrient levels, pH, temperature, and the presence of pollutants in aquatic ecosystems (Kashyap *et al.*, 2024; Stenerson, 2025).

Microalgae growth rates are highly sensitive to temperature, with each species having an optimal temperature range. In brackish lakes, where salinity is moderate, temperature fluctuations can significantly affect metabolic rates and photosynthesis. Warmer temperatures may favor cyanobacteria, which can outcompete other microalgae in warm, nutrient-poor conditions. In warmer conditions, some brackish lakes may experience an increase in harmful algal blooms,

particularly from toxin-producing species like *Microcystis*. These blooms can have negative ecological and human health impacts.

The pH of brackish water lakes is generally neutral to slightly alkaline, influenced by carbonate buffering systems. It can fluctuate due to biological processes such as photosynthesis (which raises pH) and respiration (which lowers pH). Typical range of pH in brackish water is 7.0 to 8.5. Lower pH (6.5–7.0) may occur in areas with high organic matter or acidic freshwater inflows. Higher pH (>8.5) may occur in eutrophic systems with high photosynthetic activity. There are many factors influencing pH such as the carbonate system (CO_2 , HCO_3^- , CO_3^{2-}) that buffers pH in brackish water. In addition, algal blooms can elevate pH during the day due to CO_2 uptake, and acidic runoff or pollution can lower pH. Electrical conductivity reflects the ionic concentration in water and is directly influenced by salinity in brackish systems. Conductivity is affected by seasonal changes such as evaporation and rainfall that can increase or dilute salinity and ionic concentrations. Also is affected by anthropogenic inputs like agricultural runoff can also raise EC levels. Conductivity in brackish water lakes is typically intermediate between freshwater and seawater. Typical range of EC in brackish water is between 1,500 to 15,000 $\mu\text{S}/\text{cm}$, in freshwater typically the $\text{EC} < 1,500 \mu\text{S}/\text{cm}$ while in seawater the EC is more than 50,000 $\mu\text{S}/\text{cm}$. in the current study the EC ranged from 6782 to 18990 $\mu\text{S}/\text{cm}$.

Alkalinity measures the buffering capacity of water, primarily the presence of bicarbonates (HCO_3^-), carbonates (CO_3^{2-}), and hydroxides (OH^-). In brackish water lakes, alkalinity values are influenced by the mixing of freshwater and seawater and the local geology. Its typical range in brackish water lakes is between 100 to 400 mg/L as CaCO_3 , while in the highly buffered systems such as carbonate-rich regions the range is up to 500 mg/L as CaCO_3 . In the current study the range is from 40 to 240 mg (CaCO_3)/L which indicate to brackish status of the lakes.

The accurate values for nitrate NO_3^- , ammonium NH_4^+ , ammonia NH_3 , and phosphate concentrations in a brackish water lake can vary significantly based on geographical location, seasonality, human activities and natural biological processes. The NO_3^- -N in groundwater and surface waters results from the oxidation of ammonia, which occurs as a result of the decomposition of proteins contained in vegetable and animal wastes, and nitrate fertilizers used in agricultural areas. It is very rare in uncontaminated waters (Masaba, 2020). Nitrate levels in brackish water typically range between 0.01 mg/L to 5 mg/L. Higher values may indicate anthropogenic pollution, such as agricultural runoff or sewage discharge. Samara, *et al.*, (2023) stated that the range of nitrate concentrations for unpolluted brackish lakes is between 0.01–0.5 mg/L, while for polluted brackish lakes the range is between 1–5 mg/L or higher. So, the results of NO_3^- concentrations in the current study which ranged (1.36 to 54.0 mg/L) indicate to pollution conditions of the seven lakes.

Ammonia NH_3 levels are often reported together with ammonium since they are in equilibrium, depending on pH and temperature. Ammonia concentrations in brackish water are generally low due to its toxic nature and rapid uptake by aquatic organisms. In natural conditions the range of ammonia is from less than 0.01 to 0.1 mg/L, while in polluted waters the concentration of ammonia is up to 1 mg/L. in current study the ammonia concentration ranged from 0.08 to 18.2 mg/L which also indicated to pollution conditions in the seven lakes specially during summer. Ammonium concentrations in natural brackish water systems generally range between 0.05 mg/L and 1.5 mg/L. The lower end (0.05–0.2 mg/L) is typical for pristine, low-nutrient systems, while higher values (up to 1.5 mg/L or more) are found in nutrient-enriched or hypoxic conditions. In eutrophic brackish lakes, ammonium concentrations can exceed 2–5 mg/L due to organic matter decomposition and nutrient runoff from agriculture and wastewater discharges. In surface layers, ammonium levels tend to remain lower due to nitrification (conversion to nitrate) and uptake by phytoplankton. The brackish nature of these lakes means that salinity can affect the solubility and toxicity of ammonium. Higher salinity levels generally reduce the proportion of un-ionized ammonia (NH_3), which is more toxic to

aquatic organisms. Both temperature and pH can influence the equilibrium between ammonium and un-ionized ammonia, with higher temperatures and pH levels increasing the toxicity of ammonia. Microbial processes, such as nitrification, can rapidly convert ammonium to other nitrogen forms, affecting overall concentrations in the water column. Alprol, *et al.*, (2021) found that ammonium concentrations in the brackish lake ranged from 0.013 to 4.45 mg/L, with agricultural runoff contributing to elevated levels.

Phosphates in brackish water lakes are critical for primary productivity but can lead to eutrophication if in excess. Its typical ranges are from 0.01 mg/L to 0.5 mg/L, with higher values often linked to anthropogenic inputs like fertilizers and sewage. Its range in unpolluted systems is from 0.01 to 0.1 mg/L, while in eutrophic systems the range is from 0.2 to 0.5 mg/L or higher. In the current study the PO₄ range was from 0.82 to 2.84 mg/L which confirm the pollution status of the seven lakes.

Microalgae species Composition in the seven lakes, North of Benghazi

During the four seasons from October 2022 to July 2023, 33 species following to 27 genera and 5 divisions were recorded from seven lakes north of Benghazi and presented in Table (2). The most diverse group was Chlorophyta (49%), followed by Cyanobacteria (21%), Bacillariophyta (12%), Euglenophyta (9%) and Dinophyta (9%) as well as presented in Figure (2).

Three species only were dominant during all seasons; *Microcystis aeruginosa*, *Microcystis wesenbergii* and *Stigonema ocellatum* from Cyanobacteria and formed (9%) of the dominance. Out of the identified microalgae species, 16 were classified as subdominant, accounting for 48% of the total. Among these, members of the phyla Chlorophyta, Cyanobacteria, Bacillariophyta, and Euglenophyta contributed 18%, 9%, 6%, and 3% respectively. Additionally, 12 species were frequently observed, while 2 species were considered rare in occurrence. Seasonal and spatial variations were evident in microalgae cell counts, measured using a hemocytometer chamber. The highest recorded cell density was 3,210,000 cells/ml during the summer at site 4, whereas the lowest was 1,040,000 cells/ml during the winter at site 3. On average, the cell density values across the seasons were as follows: autumn – 1,452,875 cells/ml, winter – 1,286,666.7 cells/ml, spring – 2,305,833.3 cells/ml, and summer – 2,422,500 cells/ml. Microalgae species composition was clearly influenced seasonally and spatially during the study period. Chlorophytes were the most microalgae group encountered both in terms of abundance and frequency occurrence. Chlorophytes was also dominant in many lakes and water resources in Libya. Ben-Mahmoud *et al.*, (2015) explored the seasonal dynamics of microalgae in Lake Umm Al-Maa, highlighting the dominance of chlorophytes during nutrient-rich periods. El-Sherbini *et al.*, (2004) conducted a study on freshwater algae in the Wadi Kaam reservoir and identified chlorophytes as the dominant group, particularly during the warmer months due to increased nutrient influx. Chlorophytes can live in wide range of nutrients and physical environments (Wehr & van Vuuren, 2024).

Cyanobacteria inhabit environments with diverse trophic states. Cyanobacteria which formed 21% in the current study have wide distribution in eutrophic lakes. They used as a critical indicator for water quality because of their toxicity and their probable risk to human health (Chorus and Welker, 2021). Growth of cyanobacteria increased with increasing temperature and organic contents in water bodies. This may explain why *Microcystis aeruginosa*, *Microcystis wesenbergii*, *Oscillatoria limosa*, *Calothrix confervicola*, *Chroococcus limneticus* and *Stigonema ocellatum* were dominant in the seven lakes during all seasons. El Herry *et al.*, (2008) found that *Microcystis* sp. and *Oscillatoria* sp. occurred on all the types of lakes. *Microcystis* sp. is the most dominant genus of cyanobacteria even in oligotrophic lakes (Tekanova *et al.*, 2024).

Bacillariophytes, are a significant component of microalgae in brackish lakes. Diatoms have long been used as powerful and reliable environmental indicators (Pouličková *et al.*, 2017). There are only four species of Bacillariophyta found in the seven lakes. Pennate diatoms

Table 2. List of microalgae species categorized from the study area. R= rare occurrence (<1000 cells/ml), F= frequent occurrence (1000-9999 cells/ml), S = subdominant (10000-99999 cells/ml), D= dominant (>100000 cells/ml). (-) means not found (Naqquiddin et al., 2014; Omar et al., 2016).

	Microalgae species	Autumn	Winter	Spring	Summer	
Chlorophyta	<i>Chlamydomonas reinhardtii</i> P.A.Dangeard	S	S	S	S	
	<i>Chlorella vulgaris</i> Beijerinck	F	F	F	-	
	<i>Coelastrum microporum</i> Nägeli	R	R	R	S	
	<i>Dictyochloropsis splendida</i> Geitler	-	S	F	F	
	<i>Golenkinia radiata</i> Chodat	-	F	F	R	
	<i>Monoraphidium minutum</i> (Nägeli) Komárková-Legnerová	F	R	F	F	
	<i>Oedogonium cardiacum</i> Wittrock ex Hirn	S	S	S	S	
	<i>Oocystis borgei</i> J.W.Snow	-	-	-	F	
	<i>Pandorina morum</i> (O.F.Müller) Bory	S	S	S	S	
	<i>Scenedesmus bijugus</i> (Turpin) Lagerheim	R	R	-	-	
	<i>Scenedesmus quadricauda</i> (Turpin) Brébisson	F	-	-	-	
	<i>Stichococcus bacillaris</i> Nägeli	F	-	F	F	
	<i>Stigeoclonium tenue</i> (C.Agardh) Kützing	F	F	F	F	
	<i>Ulothrix aequalis</i> Kützing	-	S	-	S	
	<i>Ulothrix zonata</i> (F.Weber & Mohr) Kützing	S	S	S	S	
Cyanobacteria	<i>Zygnema cruciatum</i> (Vaucher) C.Agardh	S	S	S	S	
	<i>Calothrix confervicola</i> C.Agardh ex Bornet & Flahault	S	-	S	F	
	<i>Chroococcus limneticus</i> Lemmermann	-	-	S	S	
	<i>Microcystis aeruginosa</i> (Kützing) Kützing	D	D	D	D	
	<i>Microcystis wesenbergii</i> (Komárek) Komárek ex Komárek	D	D	-	D	
	<i>Oscillatoria limosa</i> C.Agardh ex Gomont	S	S	-	-	
	<i>Oscillatoria curviceps</i> Vaucher ex Gomont	-	-	S	-	
	<i>Stigonema ocellatum</i> Thuret ex Bornet & Flahault	S	S	D	S	
	Bacillariophyta	<i>Cyclotella meneghiniana</i> Kützing	F	S	S	S
		<i>Gyrosigma acuminatum</i> (Kützing) Rabenhorst	-	F	-	-
<i>Navicula subtilissima</i> Cleve		F	F	S	F	
<i>Nitzschia palea</i> (Kützing) W.Smith		F	R	-	F	
Euglenophyta	<i>Euglena viridis</i> (O.F.Müller) Ehrenberg	F	S	F	S	
	<i>Euglena gracilis</i> G.A.Klebs	F	F	F	F	
	<i>Euglena mutabilis</i> F.Schmitz	F	F	F	F	
Dinophyta	<i>Dinophysis acuminata</i> Claparède & Lachmann	F	F	R	F	
	<i>Peridinium umbonatum</i> F.Stein	F	F	F	F	
	<i>Prorocentrum micans</i> Ehrenberg	R	F	F	-	

were more frequent than centric diatoms in the current study. Additionally, diatoms are highly sensitive to environmental conditions change. Studies have shown that specific genera, such as *Navicula*, *Nitzschia*, and *Cyclotella*, are commonly found in these environments. *Cyclotella meneghiniana* in the current study was subdominant during winter, spring and summer and this species known as pollutant tolerance diatom.

Dinophyta were represented by 3 species in the current study. They are found both in freshwaters and marine systems. It was expressed that these dinoflagellates are presented from oligotrophic to eutrophic waters in a wide range and *Prorocentrum micans* was recorded as euryhaline species and tolerated salinity changes (Yerli *et al.*, 2012). Dinoflagellates were found

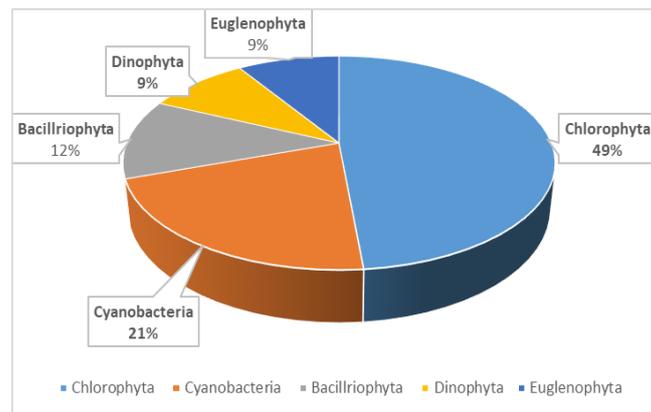


Fig. 2. Microalgae composition in the study area.

Table 3. Mean \pm SD of microalgae species diversity indices in the seven lakes, (n= 72).

	Autumn	Winter	Spring	Summer
Shanon-weaver index	0.97 \pm 0.26	1.00 \pm 0.29	0.94 \pm 0.25	0.92 \pm 0.42
Simpson index	0.51 \pm 0.14	0.44 \pm 0.16	0.42 \pm 0.11	0.41 \pm 0.19
Species number	9.00 \pm 0.82	11.0 \pm 3.20	10 .0 \pm 2.00	10.0 \pm 1.30
Species richness	2.23 \pm 0.09	2.32 \pm 0.29	2.25 \pm 0.21	2.33 \pm 0.12
Evenness	0.40 \pm 0.19	0.41 \pm 0.09	0.44 \pm 0.14	0.44 \pm 0.12

frequently during all seasons except to *Prorocentrum micans* since its quantity and abundance dropped when the water temperature increased during summer. This species is considered to be harmful algae because of they cause excessive blooms under appropriate conditions and cause red-tides (Yilmaz *et al.*, 2018).

Euglenophyta was represented in the current study by 3 species. It was stated that species of *Euglena* genus are found commonly in shallow mesotrophic and polluted lakes (Shevchenko *et al.*, 2020). Euglenophyta species in general, preferred more organic ecosystems conditions and they indicate to the trophic states of lakes (Lanza *et al.*, 2024). These algae are capable of utilizing both inorganic nutrients and organic matter, allowing them to thrive in nutrient-rich environments. Euglenophytes are particularly notable for their ability to adapt to varying salinity levels. Many species can tolerate brackish conditions. This adaptability allows them to colonize brackish lakes where salinity fluctuates due to tidal influences or freshwater inflow) Patiño *et al.*, 2023). The presence and abundance of specific euglenophyte species can serve as indicators of water quality and ecological health. Certain species are more tolerant to pollution and nutrient loading, making them useful for monitoring environmental changes.

Microalgae diversity Indices

Microalgae diversity Indices of the seven lakes were presented in Table (3). The highest species diversity in term of Shannon Weaver index was observed in winter, while the lowest was in summer. Simpson index was higher in Autumn, and lower in summer. The micro algae species evenness values were not much varied, but they were high in spring and summer. The maintenance and decline of species diversity are pivotal concerns in the field of ecology. The loss of biodiversity as a result of human activities represents a significant scientific concern. Recent experiments have underscored the importance of this topic by establishing a link between ecosystem function and diversity (Reisoglu & Aydin, 2023). The species diversity indices in

the current study were not much fluctuated seasonally instead of number of individuals which decreased during winter because of dilution factor and flooding due to heavy rains. Number of individuals was high while species diversity was low during because certain species were only dominating. The low values of species number with increasing in individual number is indicator to high water pollution (Omar *et al.*, 2016; Wu *et al.*, 2017; Alteerah *et al.*, 2022). The Shannon-Weaver Index (H') remains the most frequently employed index due to its minimal sensitivity to sample size and its utility in discerning the pollution and trophic status of aquatic ecosystems (Kumar & Thomas, 2019). The H' value is subject to change in response to alterations in ecological factors that affect diversity through changes in evenness, without affecting species richness. The Simpson index is a dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few representatives will not affect the diversity. In the Simpson diversity index, a value of 0 indicates a lower diversity, whereas a value of 1 indicates a higher diversity (Turkmen & Kazanci, 2010).

In the current study, all study sites and season exhibited values approaching 1, indicative of optimal diversity and richness. The general values for the Shannon index ranged between 1.5 and 3.5. Values below 1 indicate pollution and degradation of the water body (Chakraborty *et al.*, 2023), whereas values above the limit value indicate a healthy and stable ecosystem (Shetty & Gulimane, 2023). Renuka *et al.*, (2014) stated from their study that the lowest Shannon-Weaver index (0.56) and Simpson's diversity index (0.375) were recorded in the month of December, and this is well supported by the data on the higher pollution load. The Species evenness index values fell between 0 and 1, where a value nearing to 1 indicates the even distribution of species or low fluctuations. In the current study Site 3 during autumn and summer (0.66 & 0.77) respectively, and Site 4 (0.66) during winter showed even distribution of the species compared to other sites. The concept of evenness has been identified as a significant factor influencing the stability of ecosystem functioning. It has been observed to demonstrate a more rapid response to anthropogenic stressors or environmental constraints than species richness (Hillebrand *et al.*, 2008). For instance, warming can diminish evenness by intensifying the prevalence of particular species in both terrestrial and aquatic ecosystems (Rilov *et al.*, 2024). Communities with greater evenness which means more equal relative abundance of species. Conversely, when evenness is low that means the community is dominance by one or a few species (Mancuso *et al.*, 2023).

A significant environmental concern at temperate latitudes is the potential shift in microalgae species composition towards dominance by cyanobacteria species that are capable of forming noxious blooms. These organisms are responsible for a number of water quality issues in lakes and reservoirs, including the release of compounds that affect taste and odor, the production of toxins, and the overproduction of biomass that clogs water filters, disrupts zooplankton feeding, and causes oxygen depletion. In a warming climate, bloom-forming cyanobacteria are likely to be favored by several mechanisms (Mackay *et al.*, 2009).

Principal component analysis (PCA)

Principal component analysis biplot in Figure (3) indicates larger differences in environmental variables between the four seasons and the different sites. Two components were extracted by PCA from 14 original environmental variables. Principle components (PCs) extraction was based on the highest percentage of variance after Varimax rotation. They explain 46.47% of total variance. After varimax rotation, PC1 was defined by (Shannon index, Simpson index and Evenness) and explained (23.42%) of variance, PC2 was defined by (Alkalinity, pH, Temperature, Ammonia NH_3 , Amonium NH_4 , Nitrate NO_3) and explained (23.04%) of variance.

The application of multivariate analysis was sufficient to examine the alterations in microalgae communities and their associated physico-chemical parameters. The (PCA) parameters as statistical variables in this study demonstrated the influence of environmental and physico-chemical parameters in determining the quality of water. PC1 accounted for 23.42% of the

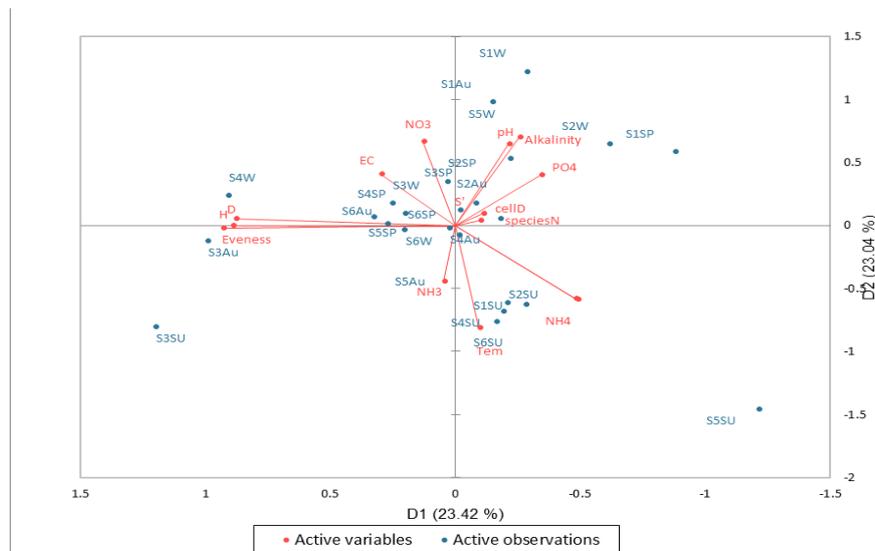


Fig. 3. Ordination diagram of principal component analysis (PCA) with the limnological variables registered from the seven lakes. Abbreviations: seasons and sites (S1Au to S6Au, S1W to S6W, S1SP to S6SP, S1SU to S6SU) mean sampling sites during Autumn, winter, spring, summer respectively. Environmental variables (T, pH, EC, Alkalinity, NH₄, NH₃, PO₄, NO₃), biological variables (H: Shannon index, D: Simpson index, Evenness, species number, S: species richness, cellID: Cell density).

variance and exhibited strong positive loadings on Shannon index, Simpson index and Evenness, which may be attributed to the influence of environmental variables on these parameters. The variance of 23.04 % of PC2 variables, which included Alkalinity, pH, temperature, NH₃, NH₄, NO₃ was expected to be due to the involvement of anthropogenic activities.

Canonical correspondence analysis (CCA)

Canonical Correspondence Analysis (CCA) was used to determine the relationships between microalgae species and physicochemical environmental variables. In the biplot (Figure 4), the two axes (F1 and F2) represent the primary gradients of variability in the dataset. F1 (41.35%) and F2 (17.77%) together explain 59.11% of the total variance in the data with eigenvalues of 0.48 and 0.44 respectively. F1 explains more variation than F2, making it the dominant gradient. Orange squares (□): represent species, green dots (●): represent sites, red text: represent environmental variables. Points that are closer together are more similar in terms of their relationships. The direction and length of environmental variable vectors (red text) indicate their influence and correlation with species and sites. Longer distances from (0,0) point indicate stronger environmental gradients. The positions of microalgae species along the ordination axis represent their respective optima along the environmental gradient.

The pH, NH₄, PO₄, Alkalinity, and NO₃ appear to be major factors influencing species distribution. Sites and species situated near the origin (0,0) are less influenced by these environmental variables. Species near pH are likely associated with higher pH levels. Species near NH₄ and PO₄ are associated with higher ammonium and phosphate concentrations. Sites and species clustering in the same region of the plot indicate a strong association. Such as, the site 4 in spring (S4SP) is closely associated with NH₃ and pH. The site 2 in Autumn (S2Au) and the site 2 in summer (S2SU) are associated with Alkalinity. While the isolated points such as *Scenedesmus bijugus* indicate to this unique species is not strongly influenced by the measured environmental variables. The site 6 in spring (S6SP) is closer to *Nitzschia palea* and *Pandorina morum*, suggesting these species are influenced by nitrate (NO₃) concentrations and are found at related sites. *Ulothrix aequalis* and *Coelastrum microporum* are far from most variables, suggesting that they are less influenced by the environmental factors measured.

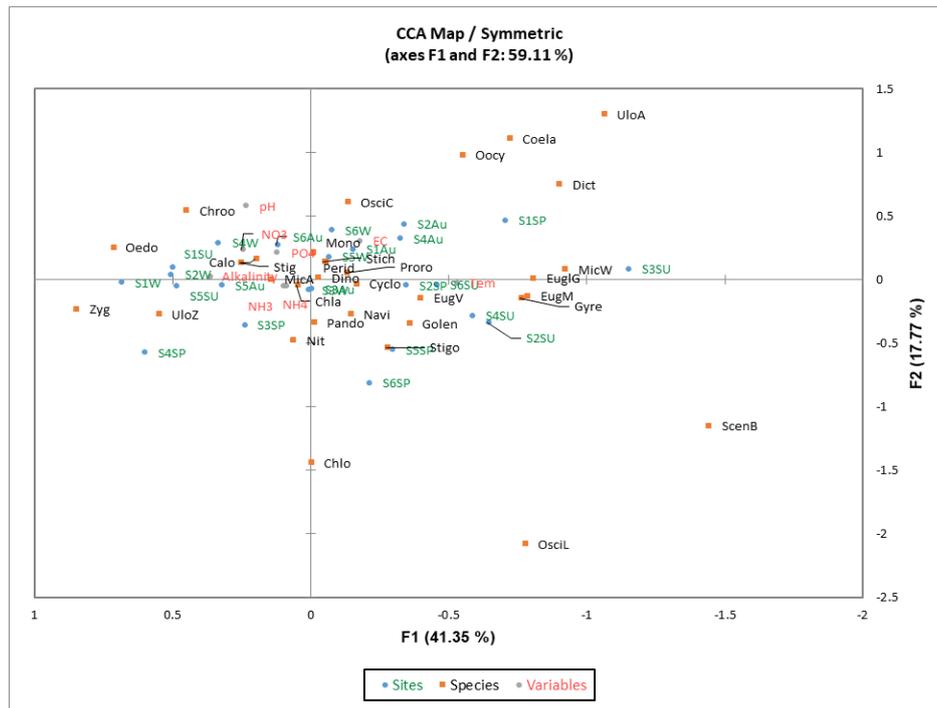


Fig. 4. CCA biplot showing the relationship between the seasonal and spatial microalgal composition and environmental parameters. Abbreviations: seasons and sites (S1Au to S6Au, S1W to S6W, S1SP to S6SP, S1SU to S6SU) mean sampling sites during Autumn, winter, spring, summer respectively. Environmental variables (T, pH, EC, Alkalinity, NH₄, NH₃, PO₄, NO₃). Chla: *Chlamydomonas reinhardtii*; Chlo: *Chlorella vulgaris*; Coela: *Coelastrum microporum*; Dict: *Dictyochloropsis splendida*; Golen: *Golenkinia radiata*; Mono: *Monoraphidium minutum*; Oedo: *Oedogonium cardiacum*; Oocy: *Oocystis borgei*; Pando: *Pandorina morum*; ScenB: *Scenedesmus bijugus*; ScenQ: *Scenedesmus quadricauda*; Stich: *Stichococcus bacillaris*; Stigo: *Stigeoclonium tenue*; UloA: *Ulothrix aequalis*; UloZ: *Ulothrix zonata*; Zyg: *Zygnema cruciatum*; Calo: *Calothrix confervicola*; Chroo: *Chroococcus limneticus*; MicA: *Microcystis aeruginosa*; MicW: *Microcystis wesenbergii*; OsciL: *Oscillatoria limosa*; OsciC: *Oscillatoria curviceps*; Stig: *Stigonema ocellatum*; Cyclo: *Cyclotella meneghiniana*; Gyre: *Gyrosigma acuminatum*; Navi: *Navicula subtilissima*; Nit: *Nitzschia palea*; EugV: *Euglena viridis*; EuglG: *Euglena gracilis*; EugM: *Euglena mutabilis*; Dino: *Dinophysis acuminata*; Perid: *Peridinium umbonatum*; Proro: *Prorocentrum micans*.

From the CCA biplot, microalgae species such as *Chlamydomonas reinhardtii*, *Pandorina morum*, *Monoraphidium minutum*, *Stichococcus bacillaris* from Chlorophyta, and *Microcystis aeruginosa*, *Stigonema ocellatum* from cyanobacteria, and *Dinophysis acuminata*, *Peridinium umbonatum*, *Prorocentrum micans* from Dinophyta were close to (0,0) point which means their occurrence did not affect by the fluctuations of environmental variables. The CCA analysis showed that the growth of Chlorophytes and Cyanophytes were positively correlated with the parameters of nitrate NO₃, PO₄, NH₄, NH₃, Alkalinity, and pH. Therefore, it can be assumed that the appearance of most of Chlorophytes and Cyanophytes is associated with high concentrations of these variables. These findings align with those of Gardner *et al.* (2011), who demonstrated that an increase in nitrate concentration results in elevated pH and enhanced photosynthetic activity in Chlorophytes and Cyanophytes. Additionally, Sari *et al.*, (2019) also confirmed that nitrate plays an important role for the growth of plankton, especially for Cyanophytes. Bacillariophyceae was in the middle of the line except *Gyrosigma acuminatum* which was far from the (0,0). This indicates that the appearance of the Bacillariophytes is associated with all environmental parameters with moderate concentrations. Although *Chlorella vulgaris* was frequent in three seasons (autumn, winter, spring), it is not appeared during summer at all. Singh and Singh (2015) reported that optimum range of temperature for *Chlorella vulgaris* is 25–30 °C this may explain why it's not found during summer and appeared so far from (0,0) point. Species *Dictyochloropsis splendida*, *Coelastrum microporum*, *Coelastrum microporum*,

Oocystis borgei from Chlorophyta were very close together and far from (0,0) point that mean that their distributions were affect by the environmental variables.

CONCLUSION

In conclusion, the assessment of water quality and algae diversity in the brackish lake has revealed the complex interplay between environmental factors and biological communities. Brackish lakes, characterized by their unique salinity gradients, serve as dynamic ecosystems where water quality parameters such as salinity, nutrient levels, pH, and dissolved oxygen significantly influence the composition and diversity of algae. The study demonstrates that variations in these parameters can promote shifts in algal populations, including an increase in opportunistic species and, in some cases, harmful algal blooms (HABs) such as *Microcystis aeruginosa* and *Microcystis wesenbergii*, which can pose risks to the ecological balance and water usability. The study also highlights that nutrient enrichment, often driven by anthropogenic activities such as agricultural runoff and urban discharge, can lead to eutrophication, threatening the lake's biodiversity and ecological stability. To ensure the sustainability of brackish lake ecosystems, it is crucial to implement targeted management strategies, including the regulation of nutrient input, habitat restoration, and continuous water quality monitoring. Future research should focus on understanding the long-term impacts of climate change and salinity fluctuation on algal communities in brackish environments. By adopting an integrated approach that combines water quality management with conservation efforts, the ecological integrity and biodiversity of brackish lakes can be preserved, supporting both their ecological and socio-economic value.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

REFERENCES

- Adams, J. B., Taljaard, S., Van Niekerk, L., & Lemley, D. A. (2020). Nutrient enrichment as a threat to the ecological resilience and health of South African microtidal estuaries. *African Journal of Aquatic Science*, 45(1-2); 23-40.
- Alprol, A. E., Heneash, A. M., Soliman, A. M., Ashour, M., Alsanie, W. F., Gaber, A., & Mansour, A. T. (2021). Assessment of water quality, eutrophication, and zooplankton community in Lake Burullus, Egypt. *Diversity*, 13(6), 268.
- Alteerah M. A., Matuogog N., Mohamed A., ELhariri Kh. S. 2022. Algae composition and diversity in Benghazi Lake, Libya. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 16(11); 3-8.
- APHA, AWWA, WEF (2023). *Standard Methods for the Examination of Water and Wastewater*, 23rd

Edition

- Ben-Mahmoud, A., & El-Khattabi, A. (2015). "Seasonal dynamics of freshwater phytoplankton in Lake Umm Al-Maa, Libya." *African Journal of Aquatic Science*, 40(1); 123-134.
- Bhardwaj, A., Singh, P., Gupta, N., Bhattacharjee, S., Srivastava, A., Parida, A., & Mishra, A. K. (2024). Cyanobacteria: a key player in nutrient cycling. In *Cyanobacteria* (pp. 579-596). Academic Press.
- Bhateria, R., & Jain, D. (2016). Water quality assessment of lake water: a review. *Sustainable water resources management*, 2; 161-173.
- Chakraborty, S. K., Sanyal, P., & Ray, R. (2023). Bio-monitoring and Bio-remediation of the Ecological Changes in Wetlands: Case Studies from East Kolkata Wetlands. In *Wetlands Ecology: Ecological Biological Uniqueness of a Ramsar Site (East Kolkata Wetlands, India)* (pp. 583-648). Cham: Springer International Publishing.
- Chorus, I., & Welker, M. (2021). Toxic cyanobacteria in water: a guide to their public health consequences, monitoring and management (p. 858), Taylor & Francis.
- Clesceri, L. S., Greenberg, A. E., & Eaton, A. D. (1998). *Standard Methods for the Examination of Water and Wastewater*, 20th ed
- Edler, L., & Elbrächter, M. (2010). The Utermöhl method for quantitative phytoplankton analysis. *Microscopic and molecular methods for quantitative phytoplankton analysis*, p.110.
- El Herry, S., Fathalli, A., Rejeb, A. J. B., & Bouaïcha, N. (2008). Seasonal occurrence and toxicity of *Microcystis* spp. and *Oscillatoria tenuis* in the Lebna Dam, Tunisia. *Water Research*, 42(4-5); 1263-1273.
- Eli, A. H. (2023). *Morphometric and Physico-Chemical Characterization of the Weija Reservoir: Implications for Water Resource Management at the Catchment Scale* (Doctoral dissertation, University of Ghana).
- El-Sherbini, A., & Abou El-Sherbini, K. (2004). "Phytoplankton community structure in the Wadi Kaam Reservoir, Libya." *Environmental Monitoring and Assessment*, 97(1-3); 231-242.
- Gardner, R., Peters, P., Peyton, B., & Cooksey, K. E. (2011). Medium pH and nitrate concentration effects on accumulation of triacylglycerol in two members of the chlorophyta. *Journal of Applied Phycology*, 23; 1005-1016.
- Guiry, M. D. (2024). How many species of algae are there? A reprise. Four kingdoms, 14 phyla, 63 classes and still growing. *Journal of Phycology*, 60(2); 214-228.
- Hillebrand, H., Bennett, D. M., & Cadotte, M. W. (2008). Consequences of dominance: a review of evenness effects on local and regional ecosystem processes. *Ecology*, 89(6); 1510-1520.
- Kashyap, N. K., Hait, M., & Bhardwaj, A. K. (2024). Planktons as a sustainable biomonitoring tool of aquatic ecosystem. In *Biomonitoring of Pollutants in the Global South* (pp. 275-319). Singapore: Springer Nature Singapore.
- Kim, J. Y., & Sansalone, J. J. (2008). Zeta potential of clay-size particles in urban rainfall-runoff during hydrologic transport. *Journal of hydrology*, 356; 163-173.
- Lanza, W. G., Hernández, V. C., Achá, D., & Lazzaro, X. (2024). Responses of phytoplankton and periphyton community structure to an anthropic eutrophication gradient in tropical high-altitude Lake Titicaca. *Journal of Great Lakes Research*, 50(2); 102294.
- MacKay, M. D., Neale, P. J., Arp, C. D., De Senerpont Domis, L. N., Fang, X., Gal, G., & Stokes, S. L. (2009). Modeling lakes and reservoirs in the climate system. *Limnology and Oceanography*, 54(6); 2315-2329.
- Mancuso, F. P., Giommi, C., Mangano, M. C., Airoldi, L., Helmuth, B., & Sarà, G. (2023). Evenness, biodiversity, and ecosystem function of intertidal communities along the Italian coasts: experimental short-term response to ambient and extreme air temperatures. *Science of the Total Environment*, 858; 160037.
- Margalef, R. (1958). Trophic Typology Versus Biotic Typology, as Exemplified In The Regional Limnology of Northern Spain.
- Martínez-Burgos, W. J., Pozzan, R., de Carvalho, J. C., Cavali, M., Mariano, A. B., Vargas, J. V., ... & Soccol, C. R. (2024). The Role of Microalgae as Bioindicators of Aquatic Contamination. In *Algae as a Natural Solution for Challenges in Water-Food-Energy Nexus: Toward Carbon Neutrality* (pp. 323-347). Singapore: Springer Nature Singapore.
- Masaba, J. L. (2020). *Physicochemical Water Quality and Macroinvertebrate Occurrence in Sasala Stream Receiving Wastewater Discharge from Earthen Fishpond Farmin Kakamega County, Kenya* (Doctoral dissertation).

- Mrozińska, N., Glińska-Lewczuk, K., & Obolewski, K. (2021). Salinity as a key factor on the benthic fauna diversity in the coastal lakes. *Animals*, 11(11); 3039.
- Muduli, P. R., & Acharya, P. (2024). Monitoring of Water Quality of Asia's Largest Brackish Water System, Chilika Lagoon. In *Aquatic Ecosystems Monitoring* (pp. 65-87). CRC Press.
- Nava, V., & Leoni, B. (2021). A critical review of interactions between microplastics, microalgae and aquatic ecosystem function. *Water research*, 188; 116476.
- Omar, M. A., Azmai, M. N. A., Omar, H., & Ismail, A. (2016). Water quality, primary productivity and carbon capture potential of microalgae in two urban manmade lakes, Selangor, Malaysia. *Advances in Environmental Biology*, 10(3); 10-22.
- Omar, M. A., Naqqiuddin, M. A., Shohaimi, S., Omar, H., & Ismail, A. (2016). Phytoplankton diversity in relation to different weather conditions in two urban made lakes. *Sustainability, Agri, Food and Environmental Research*, 4(1); 1-21.
- O'Neill, E. A., & Rowan, N. J. (2022). Microalgae as a natural ecological bioindicator for the simple real-time monitoring of aquaculture wastewater quality including provision for assessing impact of extremes in climate variance—a comparative case study from the Republic of Ireland. *Science of the Total Environment*, 802; 149800.
- Patiño, R., Christensen, V. G., Graham, J. L., Rogosch, J. S., & Rosen, B. H. (2023). Toxic algae in inland waters of the conterminous United States—A review and synthesis. *Water*, 15(15); 2808.
- Pouličková, A., Letáková, M., Hašler, P., Cox, E., & Duchoslav, M. (2017). Species complexes within epiphytic diatoms and their relevance for the bioindication of trophic status. *Science of The Total Environment*, 599; 820-833.
- Rao, P. S., Periyasamy, C., Kumar, K. S., & Rao, A. S. (2024). A Role of Algae in an Aquatic Ecosystem. In *Algal Biotechnology* (pp. 3-15). CRC Press.
- Reisoglu, Ş., & Aydin, S. (2023). Microalgae as a Promising Candidate for Mitigating Climate Change and Biodiversity Loss. *Intech Open*.
- Renuka, N., Sood, A., Prasanna, R., & Ahluwalia, A. S. (2014). Influence of seasonal variation in water quality on the microalgal diversity of sewage wastewater. *South African Journal of Botany*, 90; 137-145.
- Rilov, G., Canning-Clode, J., & Guy-Haim, T. (2024). Ecological impacts of invasive ecosystem engineers: A global perspective across terrestrial and aquatic systems. *Functional Ecology*, 38(1); 37-51.
- Samara, F., Knuteson, S. L., Abdulateef, T. A., Yaghmour, F., Whittington-Jones, B., Al Abdalla, S. M., ... & Ahmed, N. (2023). Assessment and management of the water quality and heavy-metal pollution of a protected hypersaline wetland in the United Arab Emirates. *Water*, 15(9), 1766.
- Sandrin, T. R., Dowd, S. E., Herman, D. C., & Maier, R. M. (2009). Aquatic environments. In *Environmental microbiology* (pp. 103-122). Academic Press.
- Sari, L. A., Pursetyo, K. T., Arsad, S., Masithah, E. D., Setiawan, E., & Affandi, M. (2019). The Effect of Nutrient Abundance on Distribution of Cyanobacteria and Chlorophyll-a in Sedati Water, Siooarjo. *Ecology, Environment and Conservation*, 38; 538-543.
- Scholz, B., & Liebezeit, G. (2012). Screening for biological activities and toxicological effects of 63 phytoplankton species isolated from freshwater, marine and brackish water habitats. *Harmful Algae*, 20, 58-70.
- Shannon, C. E., & Weaver, W. (1949). The mathematical theory of information.
- Shetty, K., & Gulimane, K. (2023). Application of microalgal diversity in assessing the water quality of freshwater ponds. *Environmental Monitoring and Assessment*, 195(5), 595.
- Shevchenko, T., Klochenko, P., & Nezbrytska, I. (2020). Response of phytoplankton to heavy pollution of water bodies. *Oceanological and Hydrobiological Studies*, 49(3); 267-280.
- Singh, S., & Singh, P. (2015). Effect of temperature and light on the growth of algae species: a review. *Renewable and Sustainable Energy Reviews*, 50; 431-444.
- Stenerson, S. D. (2025). Periphyton communities as bioindicators of environmental changes in lotic ecosystems. (Doctoral dissertation, Department of Biological Sciences University of Alberta).
- Tekanova, E., Sidelev, S., Kalinkina, N., Chernova, E., Barinova, S., Sharov, A., & Smirnova, V. (2024). Toxicogenic Cyanobacteria and Microcystins in a Large Northern Oligotrophic Lake Onego, Russia. *Toxins*, 16(11); 457.
- Utermöhl, H. (1958). Toward the improvement of the quantitative phytoplankton method. *Mitteilungen-Internationale Vereinigung für Limnologie*, 9; 1-38.

- Wehr, J., & van Vuuren, S. J. (2024). Algae and Cyanobacteria Communities. In Wetzel's Limnology (pp. 463-510). Academic Press.
- Wu, N., Dong, X., Liu, Y., Wang, C., Baattrup-Pedersen, A., & Riis, T. (2017). Using river microalgae as indicators for freshwater biomonitoring: Review of published research and future directions. *Ecological Indicators*, 81; 124-131.
- Yan, Z., Kamanmalek, S., Alamdari, N., & Nikoo, M. R. (2024). Comprehensive insights into harmful algal blooms: a review of chemical, physical, biological, and climatological influencers with predictive modeling approaches. *Journal of Environmental Engineering*, 150(4), 03124002.
- Yerli, S.V.; Kivrak, E.; Gürbüz, H.; Manav, E.; Mangıt, F.; Türkecan, O. 2012. Phytoplankton community, nutrients and chlorophyll a in Lake Mogan (Turkey); with comparison between current and old data. *Turk. J. Fish. Aquat. Sci.* 12; 95–104.
- Yilmaz, N., Yardimci, C. H., Elhag, M., & Dumitrache, C. A. (2018). Phytoplankton composition and water quality of Kamil Abduş Lagoon (Tuzla Lake), Istanbul-Turkey. *Water*, 10(5); 603.