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RESEARCH ARTICLE

Use of different indices to assess the ecological status of lake systems in the eastern mediterranean river basin

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Abstract – The objective of this research was to assess the ecological status of lentic systems in the Eastern Mediterranean River basin (Türkiye) using some biotic (Q index, PT-BV, MedPTI, TDIL, and PTI) and abiotic (WQI, WQImin-nw, TSI, TLI, and Kna) indices. Phytoplankton species such as *Peridinium cinctum*, *Ceratium hirundinella*, and *Gyrosigma balticum* were the species that contributed the most to the algal biovolume of lake systems with different ecological statuses in the basin. According to the results, it was seen that CCA coordination, which analyzed the relationship structures between dominant phytoplankton taxa and environmental water quality parameters, explained the variation sufficiently. As pointed out in the CCA analysis, conductivity and ammonium were the main environmental parameters influencing algal assemblages at sampling sites in the basin ($p < 0.01$). Strong correlations were observed between TSI and TLI (correlation coefficient: 0.99), and TDIL showed significant correlation only with the Q index ($p < 0.01$). TSI, TLI and WQI, abiotic indices, indicated significant correlations with most environmental parameters ($p < 0.01$), while PTI, a biotic index, had weak correlations with most environmental parameters ($p > 0.05$). Among the indices used in this study, it seems that diatom-based TDIL and physicochemical-based WQI appear to be the most suitable indices for assessing the ecological status of lentic systems in the Mediterranean region. Accordingly, it can be deduced that coupling biotic and abiotic indices is more accurate in determining the water quality of lentic systems.

Keywords: Biotic assessment / Abiotic assesment / Phytoplankton / Diatoms / River Basin

1 Introduction

Phytoplankton are tiny floating algae that are sensitive to nutrient levels and can cause problems like algal blooms, and an imbalance in water ecosystems if there are too many nutrients. Excess nutrients can create eutrophication, a process characterised by increased plant growth, problematic algal blooms and undesirable disturbance of the balance of organisms present in the water (EEA, 2018). The Water Framework Directive (WFD) (EC, 2000) requires achieving good status in all water bodies, and phytoplankton is an important biological quality element that must be monitored for the ecological status assessment in lakes and reservoirs according to the WFD. Diatoms are a major component of the phytobenthos in lotic and lentic systems (Bennion *et al.*, 2014) and should also be monitored in WFD assessments (EC, 2000).

The phytoplankton quality element should be assessed in terms of composition, biovolume, and abundance for the ecological status assessment. Composition indices especially use total phosphorus as a proxy in PTI (Phytoplankton Trophic Index) (Phillips *et al.*, 2013) and MedPTI (Mediterranean Phytoplankton Trophic Index) (Marchetto *et al.*, 2009). The PTI index derived from 20 European countries is widely used in European lakes (Molina-Navarro *et al.*, 2014; Carvalho *et al.*, 2013; Lyche-Solheim *et al.*, 2013). The MedPTI index is also a useful tool to verify the impact of eutrophication in Mediterranean basin. Many researches in Europe have employed the MedPTI index (Vadrucci *et al.*, 2017; Molina-Navarro *et al.*, 2014). The assemblage index (Q index) based on phytoplankton functional groups, developed by Padisák *et al.* (2006) was used to assess the ecological status of lakes. The Q index has a strong theoretical foundation and can be utilized to assess ecological status across different regions. It has been extensively employed in studies of European lakes, as demonstrated by Pasztaleniec and Poniewozik (2010) and Poniewozik and Lenard (2022). In recent years, a large number of monitoring activities have been carried out in Türkiye, and phytoplankton biovolume (PT-BV) with cyanobacteria biovolume (CY-BV) indices were developed (DGWM, 2020). The ecological status of deep and shallow lakes was classified

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according to total and cyanobacteria biovolume. Many European phytoplankton indices have been studied in Turkish lakes (Demir *et al.*, 2014; Sevindik *et al.*, 2017; Çelekli *et al.*, 2018, Çelekli *et al.*, 2020). The Phytobenthos quality element should also be evaluated in the littoral regions of lakes. The Trophic Diatom Index for Lakes (Stenger-Kovacs *et al.*, 2007) was developed as a trophic diatom index on the basis of diatom species' optimum and tolerance charecteristics along the total phosphorus gradient in Hungary.

In addition to using biological indices, researchers also investigated water quality using environmental factors. Some trophic indices, such as Carlson (1977), Walker (1982), and Burns *et al.* (1999), use eutrophication-related parameters like total phosphorus, total nitrogen, chlorophyll a, and transparency. Other water quality indices, such as Ramakrishnaiah *et al.* (2009) and Wu *et al.* (2021), incorporate additional parameters such as pH, electrical conductivity, dissolved oxygen, total dissolved solids, calcium, magnesium, chloride, sulfate, nitrate, ammonium, biological oxygen demand, chemical oxygen demand, total hardness, bicarbonate, iron, manganese, fluorides, sulphur, mercury, zinc, and cadmium. The Carlson trophic index is frequently utilized to assess lakes in Europe and Turkey (Jarosiewicz *et al.*, 2011; Kutlu *et al.*, 2017; Jekatierynczuk-Rudczyk *et al.*, 2014). Water quality evaluations with environmental parameters can be done more quickly and simply according to biotic indices.

The Eastern Mediterranean River basin is found in the south of Türkiye and flows its waters into the Mediterranean Sea. While the point sources of pollution in the Eastern Mediterranean basin are urban and industrial wastewater, agriculture and livestock activities are among the diffuse sources (DGWM, 2013). In a study carried out in the basin, Alp *et al.* (2016) determined the water quality and trophic status of Akgöl as a mesotrophic structure. Koyuncu and Çevik (2014) indicated that the Berdan Dam in the basin belong to the mesotrophic class according to phytoplankton composition. In this study, we aimed (1) to check the correlations between environmental water quality parameters (pH, water temperature, dissolved oxygen, conductivity, ammonium-nitrogen, nitrite, nitrate, sulfate, suspended solids, biochemical oxygen demand, chemical oxygen demand, total organic carbon, total nitrogen, total phosphorus), phytoplankton species, biotic (Q index, PT-BV, MedPTI, TDIL, and PTI) and abiotic (WQI, WQImin-nw, TSI, TLI, and Kna) indices. (2) According to correlations, we tried to evaluate the ecological status of lentic systems in the Eastern Mediterranean River basin (Türkiye).

2 Materials and methods

2.1 Study area

The Eastern Mediterranean River basin is one of 25 basins in Türkiye, and with an area of 2.18×10^4 km^2. The basin is located within the geographical co-ordinates 36°00′−37°28′N and 32°06′−35°09′E (DGWM, 2016). The basin area includes the water collection areas of the rivers between the Sedir River in the west and the Tarsus River in the south of Türkiye, and covers the area that discharges the water of the Göksu River (Bayer-Altin and Altin, 2021). Phytoplankton and diatoms were sampled twice (autumn and spring) a year during 2020 and 2021 in each lake. The eighteen monitoring stations covering 7 lakes were carefully selected to represent the Eastern Mediterranean River basin. The lakes considered in the study area were illustrated in Figure 1, and features of the lakes were given in Table 1.

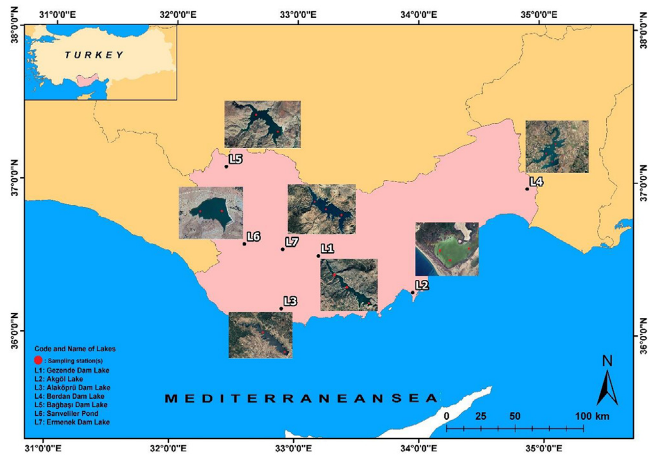

Fig. 1. Location map of the study area in the Eastern Mediterranean River basin.

2.2 Sampling and field analysis

Water temperature (Temp), pH, dissolved oxygen (DO), and conductivity (EC) were measured in situ with electronic field probes (YSI, model Pro Plus). Water samples were collected and then transported to the laboratory in cool boxes and analyzed according to standard methods (APHA, 2012) within 24 h. The concentrations of ammonium-nitrogen (NH_4^+-N), nitrite (NO_2-N), nitrate (NO_3-N), sulfate (SO_4), total nitrogen (TN), and total phosphorus (TP) were quantified. Suspended solids (SS), biological oxygen demand (BOD_5), chemical oxygen demand (COD), and total organic carbon (TOC) were also determined. All described parameters were obtained seasonally (autumn 2020 and spring 2021) from seven lakes (L1-L7) whose coordinates and monitoring station numbers are given in Table 1.

2.3 Laboratory analysis

The phytoplankton samples were collected with a Hydrobios water sampler, and a plankton net with a pore diameter of 50 μm was also used for collecting samples of phytoplankton. Diatom samples were obtained in the littoral zone of the lakes, near the stations that were selected for phytoplankton sampling. Epiphytic diatoms were preferred, however, if macrophytes such as *Typha* or *Phragmites* were absent, epilithic diatoms were sampled. All the samples (phytoplankton and diatoms) were fixed by an acetic Lugol solution (Sournia, 1978). The diatom samples were cleaned with hydrochloric acid and hot hydrogen peroxide (EC, 2014), and permanent slides were mounted with Naphrax.

Phytoplankton were enumerated from a 10 ml sub-sample after settling for 24 h in an Utermöhl style counting chamber. The phytoplankton counts were made in the inverted microscope from the entire chamber following the Utermöhl methodology (Utermöhl, 1958), and the diatom frustules were

Table 1. Sampling sites of the Eastern Mediterrenian River basin.

Code and name of lakes (sites)		Coordinate of lakes		Surface Area (ha)	Typologies*	Monitoring station
		N	E			
L1	Gezende Dam Lake	36° 32′ 00.14″	33° 11′ 10.81″	397	R3D2A2J1	3
L2	Akgöl Lake	36° 17′ 49.52″	33° 57′ 10.48″	820	R1D1A2J1	3
L3	Alaköprü Dam Lake	36° 11′ 20.23″	32° 53′ 07.38″	140	R1D2A1J2	2
L4	Berdan Dam Lake	36° 58′ 16.63″	34° 53′ 12.09″	670	R1D2A2J1	3
L5	Bağbaşı Dam Lake	37° 6′ 43.48″	32° 25′ 28.82″	180	R2D2A1J1	2
L6	Sarıveriler Pond	36° 45′ 55.52″	32° 34′ 32.51″	80	R3D2A1J1	2
L7	Ermenek Dam Lake	36° 35′ 22.51″	32° 52′ 07.15″	5874	R3D2A2J1	3

* Has shown altitude (R), lake depth (D), lake size (A), and geology (J) (DGWM, 2015).

counted and identified by permanent slides using a light microscope (630× and/or 1000× magnification). The total biovolume of the phytoplankton samples was estimated using biovolume estimation techniques (Hillebrand *et al.*, 1999; Sun and Liu, 2003) and calculated using the corresponding geometrical forms. The taxa identification for phytoplankton and diatom, the most common taxonomic literature was applied (Krammer and Lange Bertalot, 1991a; 1991b; 1999a; 1999b; Cox, 1996; Komarek *et al.*, 1998; Komarek and Anagnostidis, 1999; Baker and Fabbro, 2002; John *et al.*, 2003; Krammer, 2003; Komárek and Anagnostidis, 2005; Joosten, 2006; Hofmann *et al.*, 2011; Park, 2012; Komárek, 2013; Taşkın *et al.*, 2019). Taxa and author names were identified following standardized databases (Guiry and Guiry, 2022). At least 400 cells were counted for all of the samples (phytoplankton and diatoms).

2.4 Phytoplankton indices and calculate of ecological quality

The ecological quality of the Eastern Mediterranean River basin was assessed using five biotic and five abiotic indices. These indices were calculated to determine the ecological quality of the lakes. Among the biotic indices, the Assemblage Index (Q), Mediterranean Phytoplankton Trophic Index (MedPTI), Phytoplankton Biovolume Index (PT-BV) and Phytoplankton Trophic Index (PTI) were calculated using phytoplankton biovolume, while the relative abundance of diatom species was taken into account in calculating the Trophic Diatom Index for Lakes (TDIL) values. In the Assemblage Index (Q), the phytoplankton species into functional groups representing more than 5% of total biovolume were selected, and the index was estimated by Reynolds *et al.* (2002) and Padisák *et al.* (2006). The Mediterranean Phytoplankton Trophic Index (MedPTI) was calculated as trophic values (v) and indicator values (i) by Marchetto *et al.* (2009). The Trophic Diatom Index for Lakes (TDIL) was calculated applying the equation modified by Zelinka & Marvan, (1961) in the Omnidia v6.0 software (Stenger-Kovacs *et al.*, 2007). The Phytoplankton Biovolume Index (PT-BV) was evaluated according to total biovolume in deep and shallow lakes (DGWM, 2020). The Phytoplankton Trophic Index (PTI) was calculated according to the optimum value of the taxon in the sample (Phillips *et al.*, 2013). Trophic State Index (TSI), Trophic Level Index (TLI), Water Quality Index minimum (WQImin-nw), Water Quality Index (WQI), and Light Attenuation Coefficient (Kna) indices were calculated by environmental water quality parameters as abiotic indices. The trophic condition of the study area was determined using Carlson's Trophic State Index (TSI), and Trophic Level Index (TLI) values (Carlson, 1977; Burns *et al.*, 1999). In addition to trophic assessments, the water quality status of the sampling stations were assessed by Kükrer and Mutlu (2019) and Wu *et al.* (2021) using Water Quality Index (WQI) and Water Quality Index minimum (WQImin-nw) methods, to more objectively evaluate the water quality status of the study areas and compare them with biotic indices. Also, the computation of the light attenuation coefficient (Kna) was used by Walker (1982) and Nayek *et al.* (2018) to assess the underwater light availability in the study.

2.5 Statical analysis

Prior to conducting statistical analysis, the datasets containing information on environmental parameters and indices were evaluated for normality and homogeneity through the Kolmogorov-Smirnov test. Non-parametric tests were then used for all mathematical-statistical procedures, as recommended by Nejumal *et al.* (2021). To measure the correlation between the environmental parameters and indices (both biotic and abiotic), the Spearman correlation matrix was utilized and analyzed with the SPSS v18.0 statistical software designed for Windows (SPSS for Windows, 2008).

Principal component analysis (PCA) was utilized to identify the fourteen water quality parameters that showed significance in the data set. Outliers in relation to these parameters were also identified through the use of PCA. To investigate patterns in phytoplankton assemblages, detrended correspondence analysis (DCA) was employed. The gradient lengths obtained through DCA were used to confirm that unimodal response models were the best method for examining species responses to environmental parameters. Due to the gradient length of axis 1 in DCA analysis being longer than 4, the relationship between environmental parameters and phytoplankton assemblages was determined by Canonical Correspondence Analysis (CCA) using the Canoco v5.0 software (Smilauer, 2012). A Model of the logarithmic transform "Log($X+1$)" for the decrease in skewness was applied for the environmental parameters (except for pH). The CCA analysis was tested in the Monte Carlo simulation

(499 unrestricted permutations, $p < 0.05$) to clarify the significance of the environmental parameters on phytoplankton data (Leps and Smilauer, 2003; Ter Braak CJF, Šmilauer, P. 2012).

3 Results

3.1 Hydrographic parameters

Among the seven monitoring lakes, the highest values of most environmental water quality parameters (temp, pH, EC, SS, COD, BOD_5, TN and TP) were measured in Akgöl Lake (AL2) which is a shallow lake, while the lowest values for temp, EC and SS were mostly recorded in Sarıveliler Pond (SL6). The lowest dissolved oxygen value (5.97 $mg\,L^{-1}$) was recorded in Akgöl Lake (AL2) during autumn sampling, while Berdan Dam Lake (SL4) had the highest value (9.2 $mg\,L^{-1}$) in spring season. The lentic systems in the Eastern Mediterranean River had slightly alkaline waters. The highest mean pH value (8.6) was recorded in station AL2 (Akgöl Lake), and Gezende Dam Lake (AL1) showed the lowest pH level (7.3). Relatively low values of total organic carbon (TOC) were measured in Gezende Dam Lake (AL1), Berdan Dam Lake (AL4, SL4), Ermenek Dam Lake (AL7), and Akgöl Lake (SL2) as the following: 3.9, 3.7, 3.8, 3.7 and 3.9 $mg\,L^{-1}$, respectively. The highest mean TOC value (16.5 $mg\,L^{-1}$) was recorded in Bağbaşı Dam Lake (AL5). The water temperature showed similar spatio temporal patterns to the EC gradient in the lakes surveyed.

Sampling sites in the Eastern Mediterranean system had a mostly low nutrient gradient except Akgöl station (AL2). The highest mean TP was found in Akgöl Lake (AL2) with 0.14 $mg\,L^{-1}$, whereas the lowest value (0.0045 $mg\,L^{-1}$) was determined in Alaköprü Dam Lake (AL3), Bağbaşı Dam Lake (AL5), and Sarıveliler Pond (AL6). Station SL6 had also the lowest TN (0.09 $mg\,L^{-1}$), temp (5.5 °C), EC (192 $\mu S\,cm^{-1}$), and SS (8.9 $mg\,L^{-1}$) values. Alaköprü Dam Lake (AL3) consisted of the highest mean NH_4^+-N with 0.083 $mg\,L^{-1}$. Mainly, low values of dissolved oxygen and high values of chemical oxygen demand and total nitrogen were found in the sampling sites of the Eastern Mediterranean system during autumn sampling period.

3.2 Phytoplankton dynamics

In the Eastern Mediterranean River basin, a total of 90 phytoplankton taxa from eight major taxonomic categories were found. Out of these, 32 taxa were selected for analysis because they constituted more than 1% of the total biovolume and were observed at least three times. The names, codes, and life-forms of these 32 taxa are presented in Table 2. While 46 phytoplankton species were only reported once at the monitoring stations, 44 species were observed more than once in the phytoplankton of the lake systems. During the study, *Pantocsekiella ocellata*, *Dinobryon divergens*, *Fragilaria tenera* var. *nanana*, and *Cryptomonas ovata* were frequently found. Miozoa and Bacillariophyta members were the main contributors to the biovolume in the Eastern Mediterranean River basin, mainly represented by *Peridinium cinctum*, *Ceratium hirundinella*, and *Gyrosigma balticum* respectively. While both divisions contributed equally to the total biovolume of the basin in the autumn season, it was seen that the Miozoa members came in to prominence due to individual dominance in the spring season. The total biovolume in the spring period was lower than in the autumn, with the exception of the L1 and L3 sampling sites. Miozoa members contributed equally to the total biovolume of the basin in both sampling periods (autumn and spring seasons). On the other hand, Bacillariophyta was the dominant division of the basin in the autumn period, but it did not maintain this dominance in the spring and its biovolume decreased considerably. While the biovolume distributions of both dominant groups of phytoplankton at the sampling sites in the spring season were balanced, it differed between the lakes in the autumn season. In the autumn season, the phytoplankton biovolume was dominated by diatoms (40.4%), and the greatest contribution to the biovolume came from *G. balticum* species, which peaked at the Akgöl Lake (AL2). In seven monitoring lakes of the river basin, Miozoa and Euglenozoa members contributed subdominantly to the phytoplankton biovolume in the autumn season (31.9% and 16.2%, respectively). However, dinoflagellates were important contributors to biovolume (64.4%) in the spring season, and *Peridinium cinctum* and *Peridiniopsis kulczynskii* from Miozoa peaked in Berdan Dam Lake (SL4). In the phytoplankton of the basin, diatoms had the highest number of species (34 taxa), although they did not contribute as much to the biovolume of the lakes as dinoflagellates, which had only 5 taxa.

3.3 Statistical observations

The Spearman correlation coefficient (SCC) was used to reveal the relationships between parameters and indices in Table 3. The Kolmogorov-Smirnov test showed that all parameters were not normally distributed ($p < 0.05$) except the pH and DO ($p > 0.05$). Results of the Spearman correlation analysis revealed that abiotic indices (especially, TSI, TLI, and WQI) have more significant correlations with most indices and parameters than biotic indices (Tab. 3). For instance, WQI, an abiotic index, showed significantly positive correlations with PT-BV, TDIL, TSI, and TLI indices ($p < 0.01$), while this abiotic index correlated negatively with MedPTI and WQImin-nw ($p < 0.01$). Among indices, very strong associations were seen between TSI with TLI, and WQI with WQImin-nw ($r > 0.8$). According to the Spearman correlation between environmental parameters and abiotic indices (Tab. 3), electrical conductivity (EC) and dissolved oxygen (DO) parameters correlated with all abiotic indices, while some water quality parameters such as chemical oxygen demand (COD), temperature (temp), and total nitrogen (TN) showed a relation with most abiotic indices except Kna ($p < 0.01$). However, ammonium (NH_4^+) and total organic carbon (TOC) parameters had no association with any abiotic indices (correlation coefficients: ±0.0 to ±0.2). Among the aforementioned parameters, DO, COD and TN showed the best relationship with all indices, and the correlation strengths of the three parameters with the indices were at moderate association (correlation coefficients: ±0.4 to ±0.6). It was observed that there was a positive correlation between WQI and some environmental parameters

Table 2. List of the 32 taxa with names, codes and life-forms.

Phylum	Class	Order	Taxa	Life-Form	Codes
		Achnanthales	*Cocconeis placentula* var. *euglypta* (Ehrenberg) Cleve		Cplae
		Bacillariales	*Nitzschia sigmoidea* (Nitzsch) W.Smith		Nsig
		Fragilariales	*Fragilaria tenera* var. *nanana* (Lange-Bertalot) Lange-Bertalot & S.Ulrich		Ftenn
		Licmophorales	*Ulnaria ulna* (Nitzsch) Compère		Uuln
			Gyrosigma acuminatum (Kützing) Rabenhorst		Gacu
Bacillariophyta	Bacillariophyceae	Naviculales	*Gyrosigma attenuatum* (Kützing) Rabenhorst	Phy, Epl, Epp	Gatt
			Gyrosigma balticum (Ehrenberg) Rabenhorst		Gbal
		Rhabdonematales	*Diatoma vulgaris* Bory		Dvul
		Surirellales	*Surirella librile* (Ehrenberg) Ehrenberg		Slib
		Thalassiophysales	*Amphora commutata* Grunow		Acom
	Mediophyceae	Stephanodiscales	*Pantocsekiella ocellata* (Pantocsek) K.T.Kiss& Ács		Pocel
	Chlorophyceae	Sphaeropleales	*Monactinus simplex* (Meyen) Corda		Msim
	Klebsormidiophyceae	Klebsormidiales	*Elakatothrix gelatinosa* Wille		Egel
Charophyta	Trebouxiophyceae	Chlorellales	*Oocystis lacustris* Chodat		Olac
	Zygnematophyceae	Desmidiales	*Staurastrum gracile* Ralfs ex Ralfs		Sgra
Cryptophyta	Cryptophyceae	Cryptomonadales	*Cryptomonas ovata* Ehrenberg		Cova
		Oscillatoriales	*Oscillatoria limosa* C.Agardh ex Gomont		Olim
Cyanobacteria	Cyanophyceae	Synechococcales	*Drouetiella lurida* (Gomont) Mai, J.R.Johansen& Pietrasiak		Dluri
			Leptolyngbya tenuis (Gomont) Anagnostidis & Komárek		Lten
			Euglena granulata (G.A.Klebs) F.Schmitz		Egra
			Euglenaformis proxima (P.A.Dangeard) M.S.Bennett & Triemer		Epro
			Euglena repulsans J.Schiller	Phy	Erep
			Euglena velata G.A.Klebs		Evel
Euglenozoa	Euglenophyceae	Euglenida	*Lepocinclis acus* (O.F.Müller) B.Marin & Melkonian		Lacu
			Lepocinclis oxyuris (Schmarda) B.Marin& Melkonian		Loxy
			Trachelomonas hispida (Perty) F.Stein		This
			Trachelomonas superba Svirenko		Tsup
		Gonyaulacales	*Ceratium hirundinella* (O.F.Müller) Dujardin		Chiru
			Peridinium cinctum (O.F.Müller) Ehrenberg		Pcinc
Miozoa	Dinophyceae	Peridiniales	*Peridiniopsis kulczynskii* (Wołoszyńska) Bourrelly		Pkul
			Peridiniopsis quadridens (F.Stein) Bourrelly		Pquad
Ochrophyta	Chrysophyceae	Chromulinales	*Dinobryon divergens* O.E.Imhof		Ddiv

*It was shown as Phy: Phytoplankton, Epl: Epilithic, Epp: Epiphytic.

Table 3. Spearman rank correlation between indices and environmental parameters ($N = 87$). The meanings of the coefficients in the table is as follows: very weak or no association (±0.0 to ±0.2), weak association (±0.2 to ±0.4), moderate association (±0.4 to ±0.6), strong association (±0.6 to ±0.8), very strong association (±0.8 to ±1.0).

		Correlation Coefficients									
		Biotic indices					Abiotic indices				
		Q Index	**PT-BV**	**MedPTI**	**TDIL**	**PTI**	**TSI**	**TLI**	**WQImin-nw**	**WQI**	**Kna**
Environmental parameters	**Temp**	0.006	0.348**	-0.201	0.157	0.060	0.335**	0.318**	-0.193	0.302**	0.138
	pH	-0.223*	-0.155	-0.244*	0.143	0.142	0.482**	0.492**	-0.098	0.166	0.019
	EC	0.284**	0.260*	0.024	0.026	0.167	0.322**	0.322**	-0.127	0.425**	0.449**
	SS	0.161	0.413**	-0.233*	-0.188	-0.134	-0.053	-0.045	-0.181	0.205	0.175
	DO	0.383**	-0.113	0.430**	-0.499**	-0.307**	-0.695**	-0.671**	0.431**	-0.365**	-0.251*
	TOC	-0.161	-0.191	-0.133	-0.143	-0.158	0.025	0.004	-0.286**	-0.029	-0.082
	COD	-0.374**	0.252*	-0.348**	0.651**	0.181	0.662**	0.674**	-0.543**	0.651**	0.085
	BOD_5	0.011	0.145	0.055	-0.159	0.183	0.136	0.152	-0.094	0.157	0.096
	SO_4	0.186	0.269*	0.156	-0.013	0.092	0.026	0.025	-0.031	0.230*	0.432**
	NO_2	-0.135	0.048	-0.394**	0.185	-0.190	0.395**	0.426**	-0.514**	0.537**	0.075
	NO_3	0.261*	0.143	-0.184	-0.503**	-0.137	-0.056	-0.080	-0.324**	0.028	0.158
	NH_4^+	-0.421**	0.009	-0.208	0.427**	0.079	-0.008	-0.032	-0.136	0.067	-0.002
	TN	-0.365**	0.312**	-0.345**	0.635**	0.037	0.559**	0.553**	-0.502**	0.603**	0.067
	TP	0.088	0.072	-0.009	0.033	0.004	0.258*	0.265*	-0.185	0.237*	0.225*
Biotic	**Q Index**	**1.000**	0.217*	0.140	-0.578**	-0.089	-0.306**	-0.311**	0.037	-0.086	0.026
	PT-BV		**1.000**	-0.484**	0.205	-0.041	-0.069	-0.062	-0.437**	0.396**	0.058
	MedPTI			**1.000**	-0.351**	-0.077	-0.067	-0.103	0.525**	-0.377**	0.313**
	TDIL				**1.000**	0.335**	0.450**	0.450**	-0.199	0.346**	0.082
	PTI					**1.000**	0.367**	0.351**	0.115	-0.056	0.346**
Abiotic	**TSI**						**1.000**	0.990**	-0.439**	0.533**	0.516**
	TLI							**1.000**	-0.465**	0.594**	0.432**
	WQImin-nw								**1.000**	-0.832**	0.008
	WQI									**1.000**	-0.022
	Kna										**1.000**

*Correlation is significant at the 0.05 level (two-tailed), **Correlation is significant at the 0.01 level (two-tailed)

(temp, EC, COD, TN), however, this abiotic index had a negative correlation with DO parameter ($p < 0.01$). TSI and TLI had significant positive correlations with temp, pH, EC, COD, and TN parameters, while negatively interacting with DO. Kna, non-algal light attenuation, was negatively correlated with DO ($p < 0.05$) and positively correlated with EC, SO_4 ($p < 0.01$) and TP ($p < 0.05$). The correlation between environmental parameters and biotic indices are shown in Table 3. DO, COD and TN parameters indicated significant positive and negative correlations with most biotic indices ($p < 0.01$). Among the biotic indices, TDIL index showed the significant correlations with parameters ($p < 0.01$), while PTI index did not have significant associations with water quality parameters ($p > 0.05$). Although Q index, MedPTI, and TDIL biotic indices correlated negatively with most environmental parameters, PT-BV index correlated positively with parameters such as temp, EC, SS, SO_4, COD, TN, COD and TN parameters indicated a strong correlation with TDIL ($r > 0.6$), while temp, EC, SS, TOC, SO_4, BOD_5, COD, and TP parameters displayed very weak association with this biotic index ($r < 0.2$).

The Principal Component Analysis (PCA) was used to reveal the relationships between environmental parameters (arrow) and sampling sites (circle) in Figure 2. The first two PCA axes accounted for 95.4% of the total variability as explained in the PCA plot pattern. The PCA ordination showed a good relationship between lakes and environmental parameters as reflected by the high lake-environment correlation coefficient associated with each axis. L3 and L5 sampling sites (lakes) were grouped closely and were associated with high total organic carbon and ammonium concentrations. L7 was associated with high dissolved oxygen concentrations. L2 sampling site was linked to high SS, EC, TP, temp and BOD_5 values as also demonstrated by the significant correlations between them in the biplot ordination. Furthermore, a positive relationship detected between L4 and high concentrations of some parameters (SO_4, NO_3, TN), and these parameters were opposed to the L3 and L5 sampling sites in the PCA ordination (Fig. 2).

For the whole sampling set of lake systems, the eigenvalues of the first two CCA axes ($\lambda_1 = 0.729$, 27.8% of variance explained and $\lambda_2 = 0.505$, 47.1% of variance explained) were both significant ($p < 0.05$; Monte Carlo permutation test, 499 random permutations), and they explained 91.6% of the total variation (2.62) in the species data. The species-parameter correlations for CCA axis 1 (0.99) and 2 (0.96) were high, indicating a relatively strong relationship between phytoplankton assemblages and environmental parameters. Of the phytoplankton taxa, 32 species with a biovolume greater than 1% were used in multivariate statistical analysis (CCA).

After a forward selection 14 environmental water quality parameters formed the best set of parameters that explained a statistically significant amount of the total variation in the phytoplankton communities (Fig. 3). A comprehensive overview of Canonical Correspondence Analysis, electrical conductivity (EC), suspended solids (SS), total phosphorus (TP), biological oxygen demand (BOD_5), nitrite (NO_2-N), ammonium (NH_4^+-N), and total nitrogen (TN) were the environmental parameters that accounted for significant portions of the total variance in phytoplankton species composition ($p < 0.05$). EC, TP, SS, BOD_5 parameters (explaining 23.8, 23.7, 22.5 and 19.7% of the total variance in

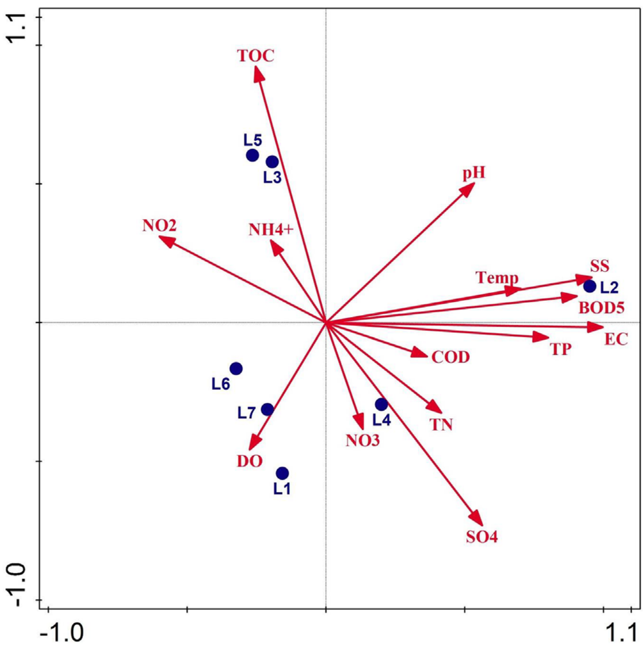

Fig. 2. PCA diagram of sampling sites (circle) and environmental parameters (arrow) relationships. Water temperature (Temp), electrical conductivity (EC), suspended solids (SS), ammonium (NH_4^+), nitrite (NO_2), nitrate (NO_3), total nitrogen (TN), sulfate (SO_4), total phosphorus (TP), dissolved oxygen (DO), biological oxygen demand (BOD_5), chemical oxygen demand (COD), total organic carbon (TOC), and potential hydrogen (pH). The full names and abbreviation codes of the lakes are given in Table 1.

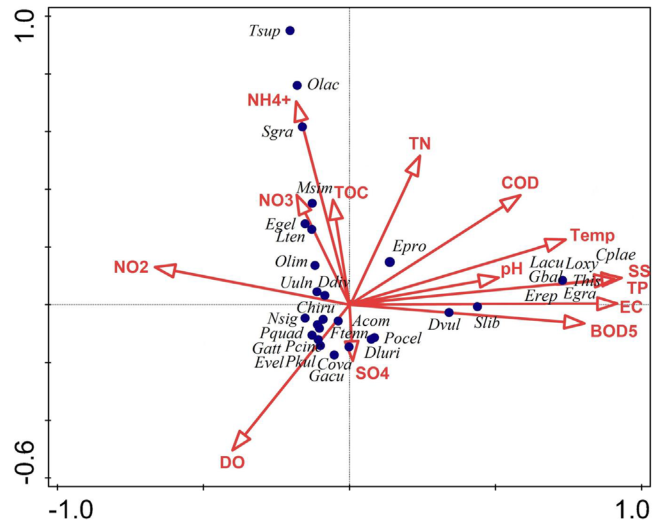

Fig. 3. CCA diagram of species (circle) and environmental parameters (arrow) relationships. Water temperature (Temp), electrical conductivity (EC), suspended solids (SS), ammonium (NH_4^+), nitrite (NO_2), nitrate (NO_3), total nitrogen (TN), sulfate (SO_4), total phosphorus (TP), dissolved oxygen (DO), biological oxygen demand (BOD_5), chemical oxygen demand (COD), total organic carbon (TOC), and potential of hydrogen (pH). The full names abbreviation codes of 32 taxa are given in Table 2.

the phytoplankton assemblages, respectively) showed high positive correlations with the first CCA axis and negative correlations with NO_2-N (explaining 15.2% of the variance). The second CCA axis indicated a positive correlation with ammonium (NH_4^+-N) (explaining 15.6% of the variance). As seen in the CCA ordination diagram, pollution-tolerant species such as *Cocconeis placentula* var. *euglypta*, *Gyrosigma balticum*, *Euglena repulsans*, *E. granulata*, *Lepocinclis oxyuris*, *L. acus*, and *Trachelomonas hispida* taxa were located on the positive side of axis 1 associating especially with SS, EC, temp, and TP parameters. Another phytoplankton species situated on the upper right side of the biplot was the pollution-tolerant *Euglenaformis proxima* species, which displayed a positive correlation with TN. However, pollution-sensitive organisms (*e.g.*, *Fragilaria tenera* var. *nanana*, *Gyrosigma attenuatum*, *Pantocsekiella ocellata*, *Peridinium cinctum*, *Peridiniopsis kulczynskii, P. quadridens*) and facultative species (*Nitzschia sigmoidea*, *Euglena velata*, *Ceratium hirundinella*, *Cryptomonas ovata*, *Gyrosigma acuminatum*) were located on the lower negative side of axis 1 associating with DO. *Oocystis lacustris* and *Staurastrum gracile* species exhibited a close relationship with ammonium (NH_4^+-N) on vertical axis. Nitrite (NO_2-N), another nitrogenous nutrient, displayed association with facultative *Ulnaria ulna* and *Dinobryon divergens* species on the upper left side of the plot.

3.4 Ecological status of the lakes

Table 4 presents the bioassessment results of the sampling sites based on different biotic and abiotic indices. These indices, developed in various regions, indicated different ecological statuses for the Eastern Mediterranean Lake Systems, ranging from high to poor conditions. Among the abiotic indices, WQImin-nw displayed the largest variation in ecological status between lakes and seasons. On the other hand, MedPTI could not distinguish the ecological status of the stations and seasons, except for AL2, but it indicated a high ecological status for all stations.

The ecological results of TSI and TLI indices for all stations were exactly similar. Q index, TDIL, PTI, WQI, and Kna indices made a small distinction in the environmental conditions of the sampling sites. Deterioration of AL2 station was represented by several indices, which indicated a poor ecological status based on PT-BV, PTI, TSI, TLI, WQI, WQImin-nw and Kna; MedPTI indicated a bad ecological status. However, results of Q index and TDIL indicated that AL2 station had a high and moderate environmental condition, respectively. Q index, MedPTI, TSI, and TLI indices showed mainly similar behavior to differentiate the environmental conditions of the sampling sites in the Eastern Mediterranean River basin. Results of these indices indicated that AL1, AL3, AL4, AL5, AL6, AL7, SL1, SL2, SL3, SL4, SL5, SL6, and SL7 sampling sites were mostly in high ecological status. However, WQI and Kna from abiotic indices and TDIL from biotic indices indicated that most lake systems had good ecological conditions, which is a subclassification of high quality (Tab. 4).

Table 4. Ecological status of the seven sites (lakes) according to various biotic and abiotic indices. The meaning of different colors used in the table is as follows: blue – high quality, green – good quality, yellow – moderate quality, orange – poor quality, red – bad quality.

		Indices Score / Water Quality									
		Biotic indices					Abiotic indices				
		Q Index	PT-BV	MedPTI	TDIL	PTI	TSI	TLI	$WQI_{min\text{-}nw}$	WQI	Kna
Autumn 2020	AL1	3.3	2.1	3.3	3.2	0.7	26.5	1.9	73.3	68.8	1.0
	AL2	4.2	9.3	1.7	2.6	1.1	52.2	4.1	43.3	266.6	10.0
	AL3	2.7	2.1	2.1	3.2	0.3	24.6	1.7	53.3	80.9	0.3
	AL4	4.2	5.3	3.1	3.0	0.4	32.8	2.4	46.7	103.5	0.6
	AL5	4.1	1.9	3.2	2.9	0.02	25.0	1.8	53.3	82.8	0.2
	AL6	2.7	3.3	3.3	2.9	0.8	38.4	2.8	53.3	81.0	10.0
	AL7	3.9	2.1	3.3	3.22	0.3	26.4	1.9	56.7	88.7	0.2
Spring 2021	SL1	4.1	3.5	3.2	3.4	0.1	19.0	1.2	53.3	83.5	0.3
	SL2	2.1	0.2	3.4	2.8	0.1	48.2	3.8	50	215.7	10.0
	SL3	3.5	3.1	3.1	3.1	0.1	17.2	1.1	70	65.5	0.2
	SL4	4.6	2.8	3.3	3.1	0.2	16.7	1	73.3	66.7	0.4
	SL5	4.3	1.2	3.4	3.4	0.5	25.0	1.7	70	65.0	0.9
	SL6	3.7	0.5	3.4	3.1	0.8	32.5	2.3	73.3	61.5	10.0
	SL7	4.1	1.3	3.1	3.4	0.5	24.3	1.7	70	80.0	0.2

4 Discussion

The study identified key indices that most accurately reflect the ecological status of the lakes based on environmental variables and phytoplankton communities. Indices highlighted the significant effect of phytoplankton communities and physico-chemical variables on lake systems. Phytoplankton community structure and parameters in this study closely followed the observed changes in pollution levels as a result of changes in the lake systems. The index results indicated that the highly polluted sampling site, specifically Akgöl Lake, showed notable differences in phytoplankton communities compared to the less polluted sampling sites within the basin. The algal communities were primarily affected by inorganic dissolved solids (as conductivity) and nutrient concentration (amonium) in the lakes resulting from agricultural runoff and climatic environment. Specifically, conductivity had a greater impact on shallow lake (as Akgöl Lake), while ammonium played a more significant role in other lakes located in distal areas. The prominence of EC in Akgöl Lake suggests that the mineral content and salinity of the water play a significant role in determining its water quality. Conversely, the importance of ammonium in the other oligo-mesotrophic lakes suggests that nitrogen compounds, specifically in the form of ammonium, is a crucial factor in assessing their water quality. Oligo-mesotrophic lakes typically have lower nutrient levels and are less productive compared to meso-eutrophic lakes.

Based on PCA analysis, EC, SS, BOD_5, temp, DO, TOC, TP, SO_4, NH_4^+, NO_3, and TN parameters exhibited a positive relationship with each other and played a significant role in shaping the water quality characteristics of the lakes ($p < 0.05$). Their strong influence on the principal components suggests that changes in these parameters are likely to reflect variations in overall water quality. However, certain parameters such as pH, NO_2, and COD had a lesser influence on the principal components or showed an inverse relationship with the other variables in the analysis. This implies that these parameters may not play a major role in determining the overall water quality in the lakes studied. The ecological status of the seven lakes in the Eastern Mediterranean River basin was stratified into two types on the basis of some environmental variables that have a strong influence on lake's algal community and productivity. Meso-eutrophic status falls into the first type, characterized by Akgöl Lake is primarily responsible for its low water quality classification, causing an increase in more pollution-tolerant species in this water body. The second type, oligo-mesotrophic structure, was characterized by eight other lakes in the basin. Unlike the first type, these lakes have lower levels of nutrients and are considered to have better water quality. Regarding the specific sampling sites within the lake basin, the PCA results indicated that the L2 sampling site exhibited the closest relationship with the water quality parameters (EC, SS, BOD_5, temperature, and TP) among the seven lakes. This suggests that these environmental parameters measured at L2 were characteristic of that specific lake and can be considered representative of its water quality. These findings align with previous studies conducted by Ersanlı (2001), Pereira *et al.* (2005), Soylu (2006), Alp *et al.* (2016), Mangadze *et al.* (2017) and Balasubramaniam *et al.* (2018), which have demonstrated the influence of the above-mentioned parameters on algal abundance and distribution. However, TP and PO_4-P parameters were found to be effective on the abundance and distribution of algae in shallow lakes with low conductivity such as Küçük Akgöl Lake (Ongun-Sevindik *et al.*, 2023) and Ladik Lake (Maraşlıoğlu *et al.*, 2005). Furthermore, the PCA analysis showed that the L1 and

L6 sampling sites did not directly correlate with any environmental parameter in the ordination, unlike other lakes in the basin. This suggests that the water quality parameters measured at L1 and L6 may be influenced by different underlying factors not captured in the study. It is possible that other variables or local conditions, not considered in the analysis, are driving the variations in water quality at those particular sites.

Gyrosigma balticum is a pollution-tolerant species that has contributed significantly to the total biovolume in a study. The presence of undamaged *G. balticum* cells in water samples from Akgöl lake with high salinity indicated that this species is typically found in estuarine environments characterized by high conductivity levels. Its abundance and contribution to the total biovolume indicate its ecological significance in polluted aquatic ecosystems. The observation aligns with previous research studies (Bere and Tundisi, 2011; Sahu *et al.*, 2012; Pednekar *et al.*, 2014; Balasubramaniam *et al.*, 2018), which demonstrated a correlation between high conductivity levels and increased diatom diversity. Additionally, *G. balticum* exhibited a peak biovolume during autumn sampling in Akgöl Lake, coinciding with high suspended solids levels, and similar patterns have been observed in other study from different location (Pereira *et al.*, 2005). The similarity of these findings with the study conducted in Olinda-PE (Brazil), reinforces the notion that *G. balticum*'s response to environmental stressors, such as high suspended solids, is consistent across different locations. The presence of this diatom species in significant quantities during periods of high suspended solids may indicate the species' ability to adapt and thrive in these stressed environments. The higher total phosphorus concentration observed during the *G. balticum* bloom in autumn supports the notion that phosphorus availability influenced the growth and abundance of this diatom species. The lower phosphorus concentration during spring, when *G. balticum* was absent, indicates that the absence of this species may be attributed to the limited phosphorus availability during that period. This result align with the finding reported by Pereira *et al.* (2005), emphasizing the importance of phosphorus in the dynamics of *G. balticum*. The overlapping finding from different study suggest a consistent pattern and reinforce the significance of phosphorus as a limiting factor in the growth and proliferation of this species.

The data provided by CCA analysis suggest that there is a negative correlation between *P. cinctum*, a freshwater dinoflagellate, and ammonium levels ($p < 0.05$). This finding is in agreement with previous studies conducted by Sanz-Luque *et al.* (2015), Öterler (2018), and Darki and Krakhmalnyi (2019), which also reported that low nitrogen levels stimulate the growth of *P. cinctum* cells. The predominance of *P. cinctum* in lightly polluted freshwater ecosystems, as observed in studies by Starmach (1974), Padisak (1985), Grigorszky *et al.* (2006) and Öterler (2018), further supports its association with such environments. It is considered an indicator species associated with low trophic levels, as indicated by Reynolds *et al.* (2002) and Darki and Krakhmalnyi (2019). Furthermore, *P. cinctum* species has a widespread distribution in waters with low-organic compounds, particularly in the Eastern Mediterranean basin with an oligo-mesotropic character, as exemplified by the Berdan Dam Lake.

The Spearman's correlation analysis revealed that the abiotic indices showed more significant correlations both with each other and with environmental parameters than with biotic indices. The similarity of some environmental parameters used in the calculation of abiotic indices such as TSI and TLI, and also WQI and WQImin-nw caused a strong correlation between these indices. The biotic indices generally didn't show significant relationships with each other. The strongest correlation among biotic indices was found between Q index and TDIL ($r = -0.578$, $p < 0.01$). Although both indices are used for shallow lakes, the fact that the TDIL is diatom-based and the Q index is phytoplankton-based makes the negative correlation between the two indices meaningful. The fact that most of the lakes in the study basin are not shallow lakes has caused this contrast correlation for Q index which was specially developed for Hungarian shallow lakes was found more convenient in Hungarian lakes such as Lake Balaton (Bolla et al., 2010) than other European lakes such as Great Lake in Albania (Vidaković *et al.*, 2020) and French Atlantic lakes (Cellamare *et al.*, 2012). Therefore, the TDIL from biotic indices seems to be a promising tool for ecological status evaluation of lakes in the Eastern Mediterranean system.

Based on the Spearman's correlation results between the indices and the environmental variables, it was found that TSI, TLI and WQI abiotic measurements showed strong positive correlations with parameters such as temp, EC, DO, COD, NO_2, TN, and TP. Similarly, high positive correlation ($R^2 = 0.78$) was observed between WQI and DO in Siling Reservoir (Hashmi *et al.*, 2016). Additionally, the level of DO variability was strongly correlated with TSI ($p < 0.05$) in six lakes located in five different districts in urban Hanoi (Viet *et al.*, 2016). Among the biotic indices, the strong correlations oberved between the TDIL and parameters such as COD and TN suggest that the diatom communities assessed by the TDIL index are particularly responsive to variations in COD-induced organic pollution and TN-induced nutrient enrichment in aquatic environments ($r > 0.6$, $p < 0.01$). However, it is worth noting that most of the Hungarian lakes classified as being in bad or poor status according to the TDIL index are characterized as shallow, saline lakes with naturally high TP content and high conductivity (Stenger-Kovács *et al.*, 2007). It is important to consider these limitations and contextual factors when applying biotic indices like the TDIL index. Considering the above information, it can be concluded that various oxidizable pollutants (such as COD) and nutrients (such as TN and TP) have a significant influence on the indicator diatom communities used in the calculation of the TDIL index. The pollution tolerance index, another biotic index commonly used in lakes, classified all lakes in a lower class (mesotrophic) compared to other indices that indicated good to excellent water quality in the Eastern Mediterranean basin. The negative correlation observed between PTI and DO levels in L2 sampling site implies that when the dissolved oxygen level in a lake is low, it indicates poorer water quality, which is associated with a high PTI value. On the other hand, in other lakes within the Eastern Mediterranean systems where oxygen levels are higher, the water quality conditions are better, and this is associated with relatively lower PTI values. The studies by Çelekli *et al.* (2018) and Çelekli and Özpınar (2021) also support the existence of this negative relationship between PTI and DO levels. Additionally, it was found that the correlation between the PTI and TP was very weak ($r = 0.004$, $p > 0.05$) due to the low average TP value in the studied lake systems ($0.03\ mg\ L^{-1}$). Accordingly, when TP levels are low in a lake, the PTI index may not adequately differentiate between different ecological statuses or effectively reflect water quality variations. The PTI index, which has been found to be strongly correlated with TP in previous studies conducted in European freshwater bodies (Philips *et al.*, 2013; Çelekli *et al.*, 2018; Çelekli and Özpınar (2021)), may not provide sufficient discrimination among ecological statuses or accurately reflect water quality conditions in systems with low TP loads like our study area. For this reason, PTI is well suited for environments with higher TP levels and more pronounced eutrophication pressures.

Differences in species diversity and environmental parameters between sampling sites reflected on all indices except PTI. Most of these indices captured and integrated the effects of species diversity and various environmental conditions on the overall ecological status of the lakes. Otherwise, the PTI, which specifically focuses on phosphorus concentrations, was not be as sensitive to variations in species diversity and certain environmental parameters. Based on the average values and monthly changes of all indices values during the studied period, it was found that the diatom-based TDIL and the physicochemical-based WQI indices were more representative indices of the ecological status of lakes in the Eastern Mediterranean system. Both indices classified the ecological status of the majority of the sampling sites in the basin as good quality, except for one site (L2). These indices provided a holistic view of ecosystem health, taking into account both biological and physicochemical aspects of water quality.

Assessing the ecological status of lentic ecosystems requires the development of integrated approaches that consider the complex relationships between bio-indicator assemblages and ecological factors. Since the application of the European WFD (EC, 2000), the biological assessment of surface water quality has been a more important issue to accomplish environmental sustainability. The evaluation results of the sampling sites indicated that the indices developed from biotic-based and abiotic-based different parameters have different scores resulting in different ecological status from high to bad condition in the Eastern Mediterranean River systems. In the ecological evaluation of the sampling sites, PTI from biotic and WQImin-nw from abiotic reflect partially low ecological status, while MedPTI from biotic and TSI, TLI from abiotic have high ecological status. Biotic indices such as Q index, PT-BV, MedPTI, and TDIL mostly showed similar behavior in the bioassessment of ecological conditions of sampling sites in the Eastern Mediterranean basin. Similar findings for TDIL and Q indices were also detected in two shallow Mediterranean lakes (Taşkısığı Lake and Little Akgöl Lake) in Sakarya river bed (Sevindik *et al.*, 2017; Ongun-Sevindik *et al.*, 2023). The PTI index, on the other hand, differed partially from other biotic indices and showed moderate conditions in the basin due to having the different tolerance/sensitivity values of phytoplankton species. The all indices exposed that the water quality of the lentic systems in the Eastern Mediterranean region was better during spring and Akgöl was a shallow lake with the lowest ecological status among the seven lakes in the Eastern Mediterranean River basin. Some phytoplankton species and environmental parameters used in the calculation of biotic and abiotic indices played a significant role on the improving the ecological status in the lakes during spring season. The assessment using some biotic and abiotic indices gave compatible results for determining the ecological status of lake systems in in the Eastern Mediterranean River basin.

5 Conclusion

The present study pointed out that certain phytoplankton species and environmental parameters used in the calculation of biotic and abiotic indices have a significant impact on improving the water quality of the lakes, particularly during the spring season. The evaluation results of the sampling sites in the Eastern Mediterranean River systems indicated that the available indices developed from biotic-based and abiotic-based parameters, leading to different ecological status classifications. These classifications can range from a high ecological condition to a bad ecological condition, indicating variations in water quality among the different sampling sites. The results for all available indices consistently indicated that the distal sites (L1, L3, L4, L5, L6, and L7) have a high ecological status. This suggested that these sites generally exhibit better water quality and are considered to be in good ecological condition compared to the other sampling site (L2). According to the present study, it appears that the diatom-based TDIL and the physicochemical-based WQI could be more suitable indices for assessing the ecological status of lentic systems in the Mediterranean region. Both indices provided a more comprehensive approach to water quality assessment of lakes in the basin.

The results of the present study revealed that electrical conductivity (EC) was identified as the main environmental water quality parameter in the meso-eutrophic Akgöl Lake, whereas in the six oligo-mesotrophic lakes, nitrogen-based ammonium (NH_4^+) was found to be a more successful parameter in assessing water quality. However, it is important to note that the statistical analysis findings of the study support the notion that no single environmental parameter has a limiting effect on species diversity and algal biovolume. This means that the ecological status of the lakes is determined by multiple interacting factors, both biotic and abiotic. While EC and NH_4^+ may be key indicators in assessing water quality in the seven lakes of the basin, other parameters and biotic factors also play significant roles in determining the ecological status of the lakes.

Consequently, it would be more accurate to use biotic indices based on diatom or phytoplankton and abiotic indices based on physicochemical parameters together in determining the ecological status of lentic systems. Thus, by integrating abiotic data with biological assessments, a more comphrehensive understanding of water quality and ecosystem health can be obtained. This integration allows for a multidimensional assessment that considers the interactions and feedbacks between the biological and environmental components of the ecosystem.

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