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Original Research Article

Phytoplankton Community, Functional Classification and Trophic State Indices of Yedikır Dam Lake (Amasya)*

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ABSTRACT

Functional classification, Trophic Status and composition of phytoplankton in Yedikır Dam Lake were studied between October 2004 and April 2006. Although Chlorophyta and Bacillariophyta were dominant in respect to species numbers, Cyanophyta and Chlorophyta type phytoplankton were registered in terms of population density in Yedikır Dam Lake. According to an average chlorophyll *a* concentration of 16 µg L^{-1}, Dam Lake belongs to the eutrophic level of the trophic scale. A total of 126 phytoplankton species were identified in the study period, belonging to 18 functional groups. The seasonal succession of dominant functional groups followed this sequence of coda: B (*Cyclotella*), F (*Kirchneriella*), J (*Crucigenia*), H1 (*Anabaena*, *Aphanizomenon*), L_O (*Merismopedia*), and W2 (*Trachelomonas*). Trophic state indices derived from chlorophyll *a* and transparency, were close together, but both were above the phosphorous index. Values of trophic state indices rank the Yedikır Dam Lake as being eutrophic. According to the some functional groups and indices the phytoplankton biomass in Dam Lake is probably limited by low phosphorus, low light and low nutrients.

Key Words: Yedikır Dam Lake, Phytoplankton, Functional group, Trophic state, Composition

Yedikır Baraj Gölü Fitoplanktonu'nun Kompozisyonu, Fonksiyonel Sınıflandırılması ve Trofik Yapısı

ÖZET

Yedikır Baraj Gölü fitoplanktonu'nun kompozisyonu, fonksiyonel sınıflandırılması ve trofik yapısı Kasım 2004–Nisan 2006 tarihleri arasında incelenmiştir. Baraj gölünde tür sayısı bakımından Chlorophyta ve Bacillariophyta üyeleri yoğun iken, tür yoğunluğu bakımından Cyanophyta ve Chlorophyta tipi fitoplanktona rastlanmıştır. 16 µg L^{-1} olan ortalama klorofil konsantrasyonuna göre baraj gölünün trofik derecesi ötrofik düzeyi göstermektedir. Çalışma alanımızda 18 farklı fonksiyonel gruba ait toplam 126 fitoplankton türü tespit edilmiştir. Mevsimsel artışa bağlı dominant fonksiyonel grupların kodon sıralanışı şu şekildedir: B (*Cyclotella*), F (*Kirchneriella*), J (*Crucigenia*), H1 (*Anabaena*, *Aphanizomenon*), L_O (*Merismopedia*), and W2 (*Trachelomonas*). Klorofil a ve seki diski derinliği bağlı gölün trofik yapı indis değerleri birbirine yakın olup toplam fosfat indis değerinden yüksek olmuştur. Trofik yapı indis değerlerine göre Yedikır Baraj Gölü ötrofik kategoridedir. Gerek bazı fonksiyonel gruplar gerekse indis değerlerine göre göl suyundaki ışığın, besinlerin ve fosfatın azlığı baraj gölündeki fitoplankton yapısını sınırlamaktadır.

Anahtar Kelimeler: Yedikır Baraj Gölü, Fitoplankton, Fonksiyonel grup, Trofik yapı, Kompozisyon

INTRODUCTION

The growth of phytoplankton in reservoirs is regulated by various physical and chemical factors (Komárková and Hejzlar 1996; Naselli-Flores and Barone 2000). Although the growth and biomass of phytoplankton in reservoirs and lakes are controlled by similar parameters, Wetzel (1990) and Komárková and Hejzlar (1996) have reported marked differences between these two types of aquatic ecosystems. In particular, factors including precipitation, evaporation, flow rate, stratification, irregular water use (including summer drawdown), concentrations of suspended solids, and flora and fauna diversity may influence the growth of phytoplankton as well as steady state assemblages.

In order to more precisely describe the periodicity of phytoplankton assemblages in different kinds of water bodies, Reynolds (1984) described a number of species groups consisting of species that tend to have similar seasonal sequences. This approach was further evolved in to a comprehensive list of phytoplankton

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functional associations or functional groups (Reynolds et al. 2002; Reynolds 2006). Then the application of functional classification, description of the typical misplacements and modification of the original habitat templates and species allocations were discussed by Padisák et al. (2009) by searching 67 articles closely related to the application of functional approach to phytoplankton. In this review, it is defined that this approach proved to be more useful for ecological purposes than the previously applied taxonomic grouping (Kruk et al. 2002; Salmoso and Padisák 2007; Padisák et al. 2009).

Functional groups consist of species with similar morphology and environmental requirements, but they do not necessarily belong to the same phylogenetic group. In contrast to long species lists or usage of dominant taxonomical groups, functional groups make it much easier to examine and compare the seasonal changes in various lake types and to evaluate the responses to environmental conditions and changes (Weithoff et al. 2001; Kruk et al. 2002; Naselli-Flores et al. 2003). The alphanumeric ascriptions help define the characteristics of the respondent phytoplankton but do not improve on dynamic resolution. Although there are many studies based on phytoplankton seasonality and ecology, little is known about the phytoplankton as regards functional approach. These groups have been investigated by several authors in lakes (Nixdorf et al. 2003; Romo and Villena 2005; Çelik and Ongun 2008; Soylu and Gönülol 2010), rivers (Devercelli and O'Farrell 2013), and reservoirs (Albay and Akçaalan 2003; Crossetti and Bicudo 2005; Borges et al. 2008).

The objectives of this study were to determine the trophic status and functional groups of Yedikır Dam Lake according to phytoplankton data. The spatial and temporal variation in chlorophyll *a*, phosphorus, and water transparencies were measured in order to estimate the trophic state index for Yedikır Dam Lake. Besides, we tried to estimate whether a significant relationship existed between levels of selected water quality parameters and chlorophyll *a* concentration, and to develop a predictive equation for estimating when water quality conditions were conducive to high chlorophyll *a* levels. The ability to eventually identify significant parameters and predict algal blooms with the use of chlorophyll *a* equations could be an important water quality management tool.

MATERIALS AND METHODS

Study site

Yedikır Dam Lake is situated in the Middle Black Sea region of Turkey (latitude: 40° 46' 48" N; longitude: 35˚ 33' 36'' E). It was built on Tersakan Stream, a tributary of Ladik Lake and pours their water to Yeşilırmak river. The Lake is 7-10 km away from Suluova and Merzifon town in Amasya city. Morphometrically, the dam lake has a surface area of 5.93 km^2, a drainage area of 7403 hectare and a volume of 6.30 hm^3 (Anonymous 2004). The structure of the bottom is thick, with a brown colour. Nevertheless, salt is widespread in the soil and the bottom deposits are extensively salty. The three sites sampled are shown on Figure 1. St. 1 is located near the Northeast edge of the Lake. The lake sediment of this station is covered with mud. St. 2 is located at the centre of the lake. St. 3 is located in the Northwest of the lake. The lake sediment is sandy (Figure 1).

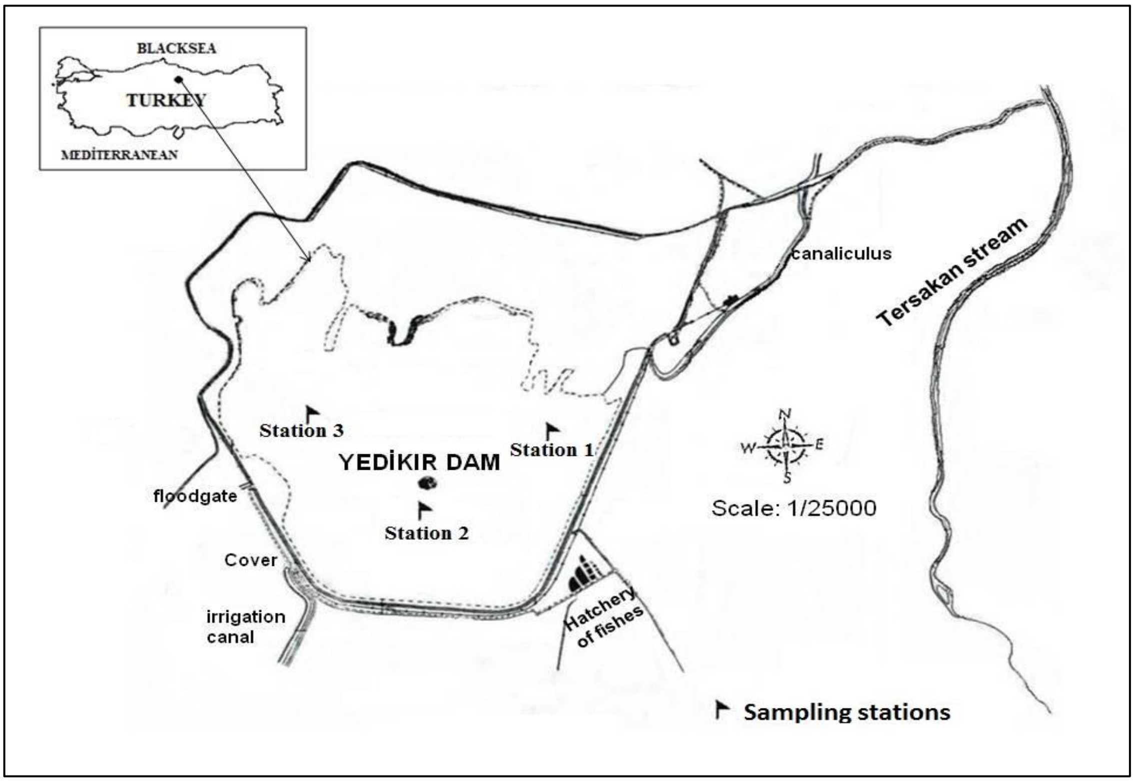

Figure 1. Map of the studied area and sampling stations.

Methods

Samples were collected monthly with 2-litre capacity Hydro-Bios water sampler from surface and depth (2 m) to determine the density of the algae from October 2004 and April 2006 at three stations. Phytoplankton determinations were carried out on subsamples preserved in acetic Lugol's solution; a constant volume of 10 ml was sedimented in the counting chambers. Algal cells were counted on a Prior inverted microscope at 400 x magnification, following Lund et al. (1958). At least 200 individuals were counted. In the evaluations, the average of three countings from each stations was used. The remaining part of the water sample was filtered using Whatman GF/A fibre filter paper to identify the algae except Bacillariophyta, were identified in permanent slides under oil immersion at 1000 x magnification which had been prepared according to Round (1953). Taxonomic identifications were performed following John et al. (2003), Krammer and Lange-Bertalot (1991a, b; 1999a, b).

Euphotic depth was measured by Secchi disks of 20 cm in diameter. Chl-*a* concentration was determined by the acetone extraction method using a spectrophotometer (Strickland and Parsons 1972). TP was determined by standard methods (APHA 1995). The trophic state index (TSI) of Carlson (1977) was used for algal biomass as the basis for trophic state classification.

The functional groups of phytoplankton were classified according to the ecological concept of adaptive strategist (Grime 1979; Reynolds 1988; Olrik 1994) and the trait-separated functional groups (Reynolds et al. 2002; Padisak et al. 2009). In this classification system according to Reynolds et al. (2002) phytoplankton species are grouped into 33 functional groups nominated by alphanumeric codes and based on their survival strategies, tolerances and sensitivities.

RESULTS

A total of 126 planktonic algae were found: 50 Chlorophyta, 47 Bacillariophyta, 13 Cyanophyta, 8 Euglenophyta, , 5 Dinophyta, 1 Xantophyta, 1 Chrysophyta and 1 Cryptophyta.

Cyanophyta and Chlorophyta type phytoplankton were registered in Yedikır Dam Lake. *Crucigenia fenestrata ve Kirchneriella lunaris* from Chlorophyta division were found to be dominant and subdominant in some months one by one. *Aphanizomenon flos-aquae* from Cyanophyta reached its the highest level contributing 82 % of total organism numbers in September 2005 at St. 1.

The total species diversity was similar at surface and at 2 m in Dam Lake. Whereas at surface mostly members of Chlorophyta and Cyanopyta were found to be dominat, while at a depth of 2 m members of Euglenophyta and Dinophyta were dominant.

The functional groups represented by the algae encountered in Yedikır Dam Lake were B, C, D, N, N_A, P, MP, T_B, X1,Y, E, F, J, H1, L_O, L_M, W1 and W2 (Table 1). In the classification of trait-separated phytoplankton groups, some characteristics of the H1, F and J Reynolds associations describe the Dam Lake assemblages, but they do not strictly match with them. The H1 assemblage (*Aphanizomenon flos-aquae*), which constituted a great part of the phytoplankton density, was mostly found in eutrophic, both stratified and shallow lakes with low nitrogen content and tolerant to low nitrojen and low C conditions. The members of F group function best in clear water and are otherwise tolerant of deep mixing, have a strong representation among mesotrophic lakes. F assemblage, which can develop in clear epilimnia, is tolerant to low nutrients, high turbidity includes *Kirchneriella* spp. This species is especially recorded in summer months in the Dam Lake. J assemblage is sensitive to settling into low light and includes *Crucigenia* spp.

Table 1. Trait-separated functional groups of phytoplankton in Yedikır Dam Lake

Group	Habitat	Typical Representatives	Tolerances	Sensitivities
B	Vertically mixed, mesothrophic small medium lakes	*Cyclotella ocelleta*	Light deficiency	pH rise, Si depletion stratification
C	mixed, eutrophic small medium lakes	*Cyclotella meneghiana Aulacoseria distans*	light and C deficiency	Si depletion, Stratification
D	Shallow, enriched turbid waters, including rivers	*Nitzschia spp. Fragilaria ulna*	Flushing	Nutrient depletion
N	Mesotrophic epilimnia	*Cosmarium depressum C. pseudopyramidatum, C. sphalerostichum*	Nutrient deficiency	Stratification, pH rise
N_A	oligo-mesotrophic, atelomictic environments	*Staurastrum spp.*	—	at lower latitudes with species sensitive to destratification.
P	Eutrophic epilimnia	*Aulacoseira granulata Closterium parvulum*	Mild light and C deficiency	Stratification, Si depletion
MP	frequently stirred up inorganically turbid shallow lakes	*Oscillatoria spp.*	—	—
T_B	highly lotic environments	*Gomphonema* spp. *Melosira varians Achnanthes* spp.	—	—
X1	Shallow mixed layers in enriched conditions	*Monoraphidium* spp. *Ankistrodesmus spp.*	stratification	Nutrient depletion
Y	Usually, small, enriched lakes	*Cryptomonas ovata*	Low light	phagothrophs
E	Usually small, ligotrophic, base poor lakes or heterothrophic ponds	*Dinobyron sociale* var. *americanum*	Low nutrients	CO_2 deficiency
F	Clear epilimnia	*Botryococcus braunii, Oocystis elliptica Oocystis parva Kirchneriella lunaris Kirchneriella obesa*	Low nutrients, High turbidity	CO_2 deficiency
J	Shallow, mixed, highly enriched systems (lakes ponds and rivers)	*Coelastrum microporum Pediastrum* spp. *Scenedesmus* spp. *Crucigenia* spp.	—	Settling into low light
H1	Eutrophic, both stratified and shallow lakes with low nitrogen content	*Anabaena spiroides Aphanizomenon flos-aquae, Anabaenopsis elenkinii,*	Low nitrogen, low C	Mixing, low light, low phosphorus
L_O	Summer epilimnia in mesotrophic lakes	*Peridinium* spp. *Merismopedia* spp. *Gymnodinium helveticum,*	Segregated nutrients	Prolonged or deep mixing
L_M	Summer epilimnia in eutrophic lakes	*Ceratium hirundinella Microcystis aeruginosa*	Highly low C	Mixing, poor stratification
W1	Small organic ponds	*Phacus crenulata, Peridinium* spp.	High BOD	Grazing
W2	Shallow mesotrophic lakes	*Trachelomonas* spp.	—	—

Three variables, chlorophyll pigments, Secchi depth, and total phosphorus, independently estimate algal biomass. A major strength of TSI is that the interrelationships between variables can be used to identify certain conditions in the lake or reservoir that are related to the factors that limit algal biomass or affect the measured variables. When all three variables are measured, it is possible that different index values will be obtained, and such situations were noted for Yedikır Dam Lake (Table 2).

Table 2. Trophic state indices for Yedikır Dam Lake derived from Secchi depth, total phosphorus and chlorophyll *a*.

Months	TSI (Secchi)	TSI (Chl)	TSI (TP)
November 2004	60	55	58
December	57	53	59
January 2005	56	52	63
February	54	41	65
March	67	59	76
April	63	57	39
May	66	61	34
June	77	63	34
July	80	67	36
August	77	64	34
September	67	61	46
October	73	58	52
November	70	58	56
December	63	54	63
January2006	61	52	70
February	57	49	68
March	60	46	60
April	64	57	46
Average	***65***	***56***	***53***

The deviations of the total phosphorus or the Secchi depth index from the chlorophyll index can be used to identify errors in collection or analysis, or real deviations from the 'standard' expected values (Carlson 1981). Some possible interpretations of deviations of the index values are given in Table 3.

Table 3. Relationship between TSI variables and interpretations of deviations of the index values (updated from Carlson 1983)

Relationship Between TSI Variables	Conditions
TSI(Chl)= TSI(TP) = TSI(SD)	Algae dominate light attenuation; TN/TP ~ 33:1
TSI(Chl) > TSI(SD)	Large particulates, such as *Aphanizomenon* flakes, dominate
TSI(TP)= TSI(SD) > TSI(Chl)	Non-algal particulates or color dominate light attenuation
TSI(SD) = TSI(Chl) > TSI(TP)	Phosphorus limits algal biomass (TN/TP >33:1)
TSI(TP) > TSI(Chl) = TSI(SD)	Algae dominate light attenuation, but some factor such as nitrogen limitation, zooplankton grazing or toxics limit algal biomass

In Yedikır Dam Lake, the chlorophyll and transparency indices were close together, but both were above the phosphorus index in 2005 summer, spring and autumn months. Whereas in 2005 winter months the average TSI scores based on Secchi depth were closer to TSI scores derived from chlorophyll, in comparison with TSI scores based on total phosphorus. Average TSI values based on chlorophyll *a* concentration, Secchi depth and total phosphorus during the investigated year indicate conditions of eutrophy in Yedikır Dam Lake.

DISCUSSION

Although Chlorophyta and Bacillariophyta were dominant in respect to species numbers, Cyanophyta and Chlorophyta type phytoplankton were registered in terms of population density in Yedikır Dam Lake. *Crucigenia fenestrata* and *Kirchneriella lunaris* species from Chlorophyta division and *Aphanizomenon flos-aquae* from Cyanophyta were found to be dominant and subdominant organisms in certain months alternately.

Quantitatively, the most important taxonomic groups were: Chlorophyta (in term of number of species present and in term of abundance of those species)**,** and Cyanophyta. *Crucigenia fenestrata and Kirchneriella lunaris* are typical perennial species of Dam Lake. Chlorophyta dominated the phytoplankton community during summer, with a peak in July. Chlorophyta developed mainly from early spring to late summer and attained their peak in abundance in June and July. Cyanophyta dominated the phytoplankton community during autumn with a peak in September, although Chlorophyta remained abundant during the entire autumn period. The autumn peak of Cyanophyta was sustained by the fact that they possess efficient mechanisms for nutrient uptake at low concentrations. Cyanophyta were found to be prominent in Bulgaria (Stoyneva 2003) and in Hungary (Padisák and Reynolds 1998), which are in the same climatic zone with Turkey. Cyanophytes were also the most numerous in Sanabria Lake (Spain) (Hoyos and Comin 1999) and Ladik Lake (Maraşlıoğlu et al. 2005). Cyanophyta dominance, and sometimes bloom formation are among the most visible symptoms of accelerated eutrophication of lakes and reservoirs (Moss et al. 1997). The dominance of Nostocales during autumn in the Dam Lake was a result of the anthropogenic that first reason was sewage moved by Tersakan stream and second reason was phosphorus or nitrate moved at some times by rain to study area induced eutrophication process.

Nowadays, the phytoplankton functional groups approach comprises more than 45 assemblages that are identified by alphanumerical codes according to their sensitivities and tolerances (Reynolds, 2006; Padisák et al. 2009). In Yedikır Dam Lake 18 functional groups (B, C, D, N, N_A, P, MP, T_B, X1,Y, E, F, J, H1, L_O, L_M, W1 and W2) were identified. In the classification of trait-separated phytoplankton groups (Reynolds et al. 2002) some charactersitics of the H1, F and J Reynolds associations describe the Dam Lake assemblages, but they don’t strictly match with them. H1 group (*Aphanizomenon flos-aquae*) was also seen in Hungarian lake (Hajnal and Padisák 2008), in Chinese oligotrophic deep and shallow lakes (Zang et al. 2007) and Greek waterbodies (Vardaka et al. 2005). Additionally, this species found are placed separately in groups SN, H1 and LM in Bulgarian wetlands (Stoyneva 2003). As in Bulgarian wetlands, SN and H1 functional groups, which are tolerant to mixing and poor light conditions, were found dominant in Kastoria Lake, Greece. J is the common group of Ladik Lake (Maraşlıoğlu et al. 2005), shallow lakes of the Kızılırmak Delta (Maraşlıoğlu et al. 2011), shallow hypertrophic Manyas Lake (Çelik and Ongun 2008) and Ömerli Reservoir (Albay and Akçaalan 2003). In the classification of trait-separated phytoplankton groups (Reynolds et al. 2002) some characteristics of B (*Cyclotella ocellata*), C (*Aulacoseria distans*), H1 (*Anabaena spiroides*, *Aphanizomenon flos-aquae*) and W_2 (*Trachelomonas* spp.) Reynolds associations describe the Ladik Lake assemblages (Maraşlıoğlu et al. 2005). Finally, the functional group approach constitutes a useful tool for understanding the phytoplankton community in every system; but it is necessary to check whether the grouping of species reflected the autoecological features of organisms (Padisák et al. 2009).

Using all three variables for the calculation of a trophic state index for Yedikır Dam Lake: chlorophyll *a*, Secchi depth and total phosphorus, differences between TSI values derived from different variables were observed. In Dam Lake, chlorophyll and transparency indices were close together, but both were above the phosphorus index. According to Carlson (1983), this might suggest that the algal biomass in Dam Lake are probably limited by phosphorus.

According to observed high values of TSI and some important functional groups, one can conclude that Yedikır Dam Lake is on eutrophic level, but this study showed that indices of diversity based on phytoplankton are weak indicators of trophic status, which was also supported by numerous literature data.

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