PHYTOPLANKTON COMMUNITY DYNAMICS RELATED TO CERTAIN PHYSICAL AND CHEMICAL VARIABLES IN ARDIÇTEPE RESERVOIR (BALIKESIR, TURKEY)

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Ardıçtepe Reservoir (Balıkesir, Turkey) was sampled seasonally at three stations between October 2018 and August 2019 to **determine** the phytoplankton community dynamics in relation to water temperature, speciffic conductance (SC), total dissolved solids (TDS), pH, oxidation-reduction potential (ORP) and Secchi disk depth. A total of 43 phytoplankton species were identified, 27 from Bacillariophyta, 4 from Charophyta, 6 from Chlorophyta, 5 from Cyanobacteria and 1 from Euglenozoa. Bacillariophyta made 76% total number of species, Cyanobacteria 11%, Chlorophyta 6%, Charophyta 4% and Euglenozoa 3%. *Aulacoseria granulata, Aulacoseira granulata var. angustissima, Cyclotella meneghiniana* and *Ulnaria ulna* from Bacillariophyta and *Anabaena circinalis* from Cyanobacteria dominanted phytoplankton during the study.
The CCA explained 90.8% of the cumulative variance in the relationships of dominant species-environment. The CCA also showed that water temperature, TDS, ORP and pH had significant effects on the phytoplankton community of Ardıçtepe Reservoir (Monte Carlo test, $p<0.05$).

Keywords: Ardıçtepe Reservoir, Bacillariophyta, CCA, phytoplankton.

INTRODUCTION

Phytoplankton is critical in the functioning of aquatic ecosystems since it provides food for all other organisms in the upper level of food webs (Feuchtmayr *et al.*, 2012). The spatio-temporal distribution of phytoplankton and its relationships with the physical and chemical variables can give insights into understanding factors responsible for its dynamics (Elliott, 2012).

The seasonal dynamics of phytoplankton community provides further understanding of ecological interactions in aquatic ecosystems. Thus, the seasonal dynamics of phytoplankton have been investigated worldwide (Mishra *et al.*, 2019; Nikolenko and Fedonenko, 2021).

In temperate region, phytoplankton community dynamics are driven mostly by variations of physical and chemical variables that vary with the different periods of the year (Borics *et al.*, 2011). For a clear understanding of the processes affecting phytoplankton dynamics, it is important to study the linkage between changes in environmental variables and phytoplankton abundance and community composition (George *et al.*, 2004).

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Multivariate statistical techniques have been proved to be useful for understanding the interactions between the environmental factors and phytoplankton community dynamics in aquatic ecosystems (Kruk *et al*., 2002). In this study, the seasonal and spatial dynamics of phytoplankton community were studied in relation to certain environmental variables in Ardıçtepe Reservoir, Balıkesir, Turkey, using Canonical Correspondence Analysis (CCA) (Braak and and Verdonschot, 2002).

MATERIALS AND METHODS

Study Area

Ardıçtepe Reservoir is located at 39° 30' 73" N-027° 21' 73" E in the Ivrinde province of Balıkesir, Turkey (Fig. 1). It was constructed on the Kocaçay (Madra) Stream in 2015 by the General Directorate of State Hydraulic Works for the purpose of irrigation. It has a 4.5 km^2 area and a *Maximum depth of* 39 m.

Three sampling stations were set. The first station was set where the Kocaçay Stream enters the reservoir (the riverine zone), the second station is the transition zone where the stream loses its influence to a large extent and the third station is at the deepest part of the reservoir (the lacustrine zone) near the dam.

Water temperature, specific conductance (SC), total dissolved solids (TDS), pH and oxidation-reduction potential (ORP) were measured in situ using a YSI multi-probe. Water transparency was measured using a Secchi disk.

For phytoplankton, integrated water samples were taken at three stations using a Kemmerer water sampler. In the field, phytoplankton samples were fixed with Lugol’s solution and poured in 250 ml dark bottles. In the laboratory, the samples were first shaken, then placed into 50 ml graduated tubes to settle for 24 hours, then the upper 45 ml of water were aspirated and the remaining 5 ml were placed into a small bottle for microscopic analysis.

Enumeration and identification of phytoplankton were performed using Palmer-Maloney counting cell on an Olympus compound microscope equipped with a phase-contrast attachment and water immersion lenses (40X and 60X magnifications). Phytoplankton species were identified according to Caspers and Nicklisch (1984), Komárek *et al*. (1982), Bourrelly (1968), Krammer and Lange-Bertalot (1999), Komarek and Anagnostidis (2008), Anagnostidis and Komarek (1988), Round *et al*. (1990), Sims (1996) and John *et al*. (2011).

The Canonical Correspondence Analysis was performed to assess the relationships between the abundance of the dominant phytoplankton species and environmental variables using CANOCO (v.4.5) software (Braak and and Verdonschot, 2002). Prior to the application of CCA, Detrended Correspondence Analysis (DCCA) was run on data and the gradient lengths for the first two axes was greater than 4, justifying the use of unimodal models. The Monte Carlo permutation test with the forward selection was used to test which variables had significant effects on the dynamics of dominant phytoplankton species (ter Braak and Verdonschot, 2002).

An analysis of variance (ANOVA) test was used to test the significance of differences in physical and chemical variables between the stations and seasons. Prior to statistical analysis data were log transformed to satisfy normality assumption. Statistical analysis was performed using SPSS software (SPSS, 2001).

RESULTS

There were no significant differences in pH, specific conductance (µscm^{-1}), oxidation reduction potential (mV), Secchi disk depth (m) and total dissolved solids (mgl^{-1}) between the statoins and seasons (F=0.15, p>0.05), but water temperature differed significantly between the seasons (F=3.04, p<0.05). The maximum, minimum, the mean and standard deviation of the measured physical and chemical variables are given in Table 1.

A total of 43 phytoplankton species were identified, 27 from Bacillariophyta , 6 from Chlorophyta, 4 from Charophyta, 5 from Cyanobacteria and 1 from Euglenozoa (Table 2). Bacillariophyta made 76% total number of species, Cyanobacteria 11%, Chlorophyta 6%, Charophyta 4% and Euglenozoa 3%. *Aulacoseria granulata, Aulacoseira granulata var. angustissima, Cyclotella meneghiniana* and *Ulnaria ulna* from Bacillariophyta and *Anabaena circinalis* from Cyanobacteria were dominanted phytoplankton during the study.

In fall 2018, 26 species were identified *A. circinalis*, *C. meneghiniana* and *A. granülata* dominated phytoplankton. In winter 2018, 15 phytoplankton species were identified, *C. meneghiniana* and *A. granulata var. angustissima* were the dominant species. In Spring 2019, 19 species were identified, *C. meneghiniana* and *U. ulna* dominated phytoplankton. In summer 2019, 29 phytoplankton species were identified, *A. granulata var. angustissima* and *C. meneghiniana* were the dominant species.

The first axis of CCA had an eigenvalue of 0.014 and second had 0.005. The first two axes explained 55.6% of the cumulative percentage variance in dominant species and environment relationships (Table 3). CCA showed that *A. granulata var. angustissima* and *A. circinalis* were related to pH and ORP, *U. ulna* to SC and *C. meneghiniana* to water temperature and TDS. *A. granulata* was not associated with any measured physical or chemical variables (Fig. 2).

DISCUSSION

In Ardıçtepe Reservoir, Bacillariophyta dominanted phytoplankton, making 76% of the total number of species during the study. Diatoms were most abundant at the first station where the Kocaçay Stream enters the reservoir. The inflow of the feeding stream causes turbulence at this station, promoting fast-growing taxa, such as diatoms and disadvantaging organisms that require stable water columns, such as colonial cyanobacteria (Stockwell *et al*., 2020). Hansen and Visser (2019) state that diatoms are competitive at high turbulence and dim light. Thus, they are favored by turbulence, as it reduces the sinking rate.

A. granulata, A. granulata var. angustissima, C. meneghiniana and *U. ulna* from Bacillariophyta and *A. circinalis* from cyanobacteria were dominant species during the study.

Sallow depths and high ORP have positive and high-water temperature have negative effects on the growth rate of *A. granulate* and *A. granulata var. angustissima* (Raupp *et al.*, 2009*;* Wei *et al.*, 2023). The first station is shallow and turbulent, providing sufficient *oxygen (*high ORP). This may have led the high abundance of these species. The other two dominant diatoms, *C. meneghiniana* and *U. ulna,* are typical cosmopolitan, widely distributed in the inland waters of all continents (Klimaszyk *et al*., 2022).

CCA showed that TDS was closely related to the dominant diatom, *C. meneghiniana. This species is* commonly collected in Turkish lakes (Koçer *et al*., 2012) and it is considered to be tolerant to mixing and its distribution is controlled by turbulent currents (Crossetti and Bicudo, 2008). In Ardıçtepe Reservoir, this species waste abundant at the first station (the riverine zone) which is usually turbulent due to the stream inflow.

CCA showed that *A. circinalis* was closely related to pH and ORP. This species was dominant in summer at the third station (at the deepst part of the reservoir). *A. circinalis* is linked to stable water column and high water temperatures (Philips *et al*., 1997). In summer, Ardıçtepe Reservoir stratifies at deep sections, providing stable environment for cyanobacterial growth.

In summary, the phytoplankton community of Ardıçtepe Reservoir was dominated by diatoms and they were most abundant in the riverine zone of the reservoir. The phytoplankton community dynamics in the reservoir were mostly controlled by turbulence caused by the inflow of feeding stream.

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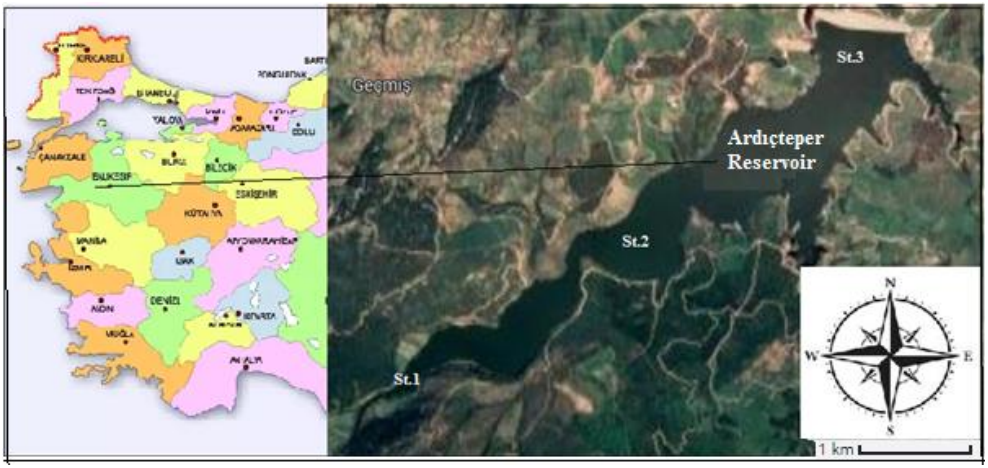

Figure 1. The map of Ardıçtepe Reservoir and the locations of sampling stations

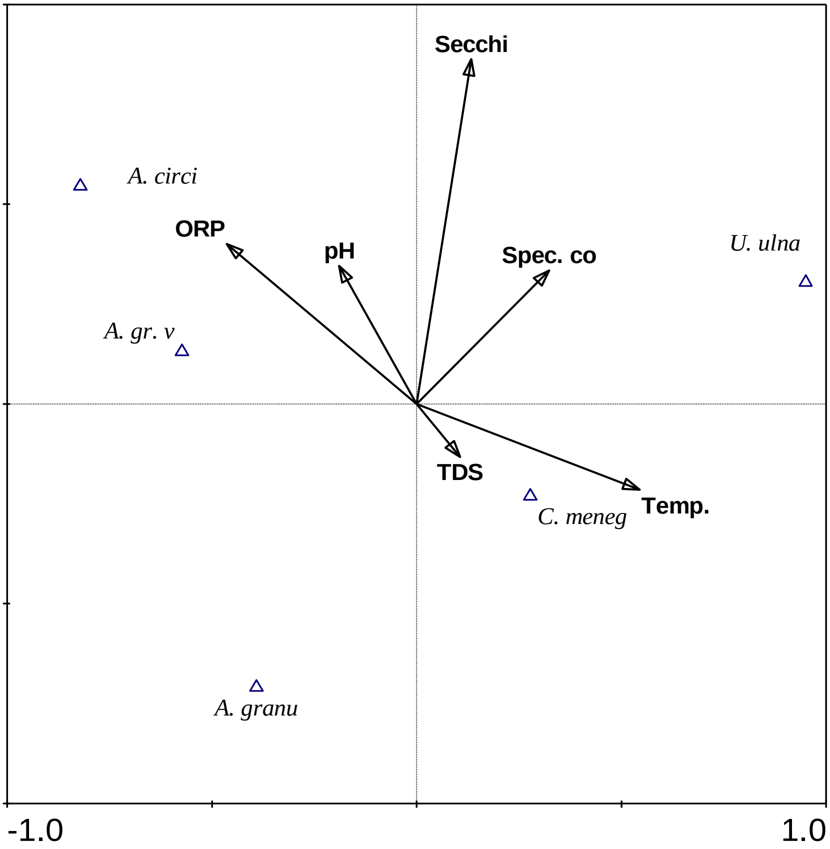

Figure 2. The Canonical Correspondence Analysis (CCA) diagram, showing the relationships between the measured environmental variables and the dominant phytoplankton species; Abbreviations: *A. granu*: *Aulacoseria granulata*; *A. gr. v*: *Aulacoseira granulata var. angustissima*; *C. men*: *Cyclotella meneghiniana* and U. *ulna*: *Ulnaria ulna*.

Table 1
The maximum, minimum, the mean and standard deviation of the measured physical and chemical variables in Ardıçtepe Reservoir

Variable	Maximum	Minimum	Mean	Std. Dev.
Temperature (ºC)	26.2	7	13.3	6.8
pH	11	9.5	9.35	0.47
Oxidation Reduction Potential (mV)	450	300	370.5	110
Specific conductance (µscm^{-1})	409	211	295.5	66.9
Secchi disk Depth (m)	2.2	1	1.54	0.45
Total dissolve solids (mgl^{-1})	484	302	444	113

Table 2
List of phytoplankton species in Ardıçtepe Reservoir

Bacillariophyta
Aulacoseira granulata (Ehrenberg) Simonsen 1979
Aulacoseria granulata var. angustissima (O. F. Müller) Simonsen
Aulacoseira italica (Ehrenberg) Simonsen 1979
Cocconeis placentula Ehrenberg 1838
Cyclotella meneghiniana Kützing 1844
Cymatopleura solea (Brébisson) W.Smith 1851
Cymbella lanceolata (C.Agardh) Kirchner 1878
Cymbella tumida (Brébisson) Van Heurck 1880
Diatoma elongatum (Lyngbye) C.A. Agardh, 1824
Diatoma vulgaris Bory 1824
Fragilaria crotonensis Kitton 1869
Gomphonema vibrio Ehrenberg 1843
Gyrosigma acuminatum (Kützing) Rabenhorst 1853
Hantzschia amphioxys (Ehrenberg) Grunow 1880
Melosira lineata (Dillwyn) C.Agardh 1824
Melosira varians C.Agardh 1827
Navicula cryptocephala Kützing 1844
Navicula decussis Østrup 1910
Navicula gracilis Ehrenberg 1832
Navicula salinarum Grunow in Cleve & Grunow 1880
Nitzschia acicularis (Kützing)W.Smith
Pinnularia borealis Ehrenberg 1843
Pinnularia viridis (Nitzsch) Ehrenberg 1843
Rhoicosphenia curvata (Kützing)Grunow 1860
Tetracyclus rupestris (Braun) Grunow 1881
Ulnaria acus Kützing 1844
Ulnaria ulna (Nitzsch) Ehrenberg 1832
Chlorophyta
Chlamydomonas umbonata Pascher 1927
Chlorella vulgaris Beijerinck [Beijerinck] 1890
Coelastrum microporum Nägeli in A.Braun 1855
Oocystis naegelii A.Braun 1855
Pediastrum boryanum (Turpin) Meneghini 1840
Scenedesmus armatus (Chodat) Chodat 1913
Charophyta
Closterium parvulum Nägeli 1849
Cosmarium contractum O.Kirchner 1878

Cosmarium punctulatum Brébisson 1856
Cosmarium quinarium P.Lundell 1871
Cyanobacteria
Anabaena circinalis Rabenhorst ex Bornet & Flahault 1886
Chroococcus minutus (Kützing) Nägeli 1849
Gloeocapsa magma (Brébisson) Kützing, 1847
Oscillatoria limosa C.Agardh ex Gomont 1892
Oscillatoria splendida Greville ex Gomont 1892
Euglenozoa
Trachelomonas volvocina Ehrenberg 1838

Table 3

Summary statistics for canonical correspondence analysis (CCA)

Axes	1	2	3	4	Total inertia
Eigenvalues	0.014	0.005	0.004	0.002	0.035
Species-environment correlations	0.77	0.62	0.55	0.7	
Cum. perc. var. spec. data	32.2	32.2	38.2	42	
Cum. perc. var. spec.-envir. relation	55.6	76.5	85.2	90.8	
Sum of all eigenvalues					0.024