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, specific 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 dominated 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 km² 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 stations 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 dominated phytoplankton during the study.

In fall 2018, 26 species were identified. A. circinalis, C. meneghiniana and A. granulata 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 Arıçtepe Reservoir, Bacillariophyta dominated 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 deepest 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.

REFERENCES


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. gr.: 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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<tr>
<td>Temperature (°C)</td>
<td>26.2</td>
<td>7</td>
<td>13.3</td>
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<td>pH</td>
<td>11</td>
<td>9.5</td>
<td>9.35</td>
<td>0.47</td>
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<tr>
<td>Oxidation Reduction Potential (mV)</td>
<td>450</td>
<td>300</td>
<td>370.5</td>
<td>110</td>
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<tr>
<td>Specific conductance (µscm⁻¹)</td>
<td>409</td>
<td>211</td>
<td>295.5</td>
<td>66.9</td>
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<td>Secchi disk Depth (m)</td>
<td>2.2</td>
<td>1</td>
<td>1.54</td>
<td>0.45</td>
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<tr>
<td>Total dissolve solids (mgl⁻¹)</td>
<td>484</td>
<td>302</td>
<td>444</td>
<td>113</td>
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</table>

Table 2
List of phytoplankton species in Ardıçtepe Reservoir

**Bacillariophyta**
- *Alacoseira granulata* (Ehrenberg) Simonsen 1979
- *Alacoseira granulata var. angustissima* (O. F. Müller) Simonsen
- *Alacoseira 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
- *Diatomella 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
- *Rhizosphenia 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 naegeli* 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 splendidida* Greville ex Gomont 1892

**Euglenozoa**

*Trachelomonas volvocina* Ehrenberg 1838

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