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# Spatial and Temporal Analysis of the Relationship between Phytoplankton Community Structure and Environmental Parameters of Yuvacık Reservoir

# Yuvacık Rezervuarı Fitoplankton Topluluk Yapısı ile Çevresel Parametreler Arasındaki İlişkinin Mekansal ve Zamansal Analizi

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**Abstract:** In the present study, in order to determine the local (sampling stations) and temporal (seasonal) distribution phytoplankton in the Yuvacık Reservoir sampling was carried out in four seasons from two stations: from the entrance area of the streams to the dam (Y2) and from the dam embankment front (Y1). A total of 52 taxa were identified in the phytoplankton composition, including 30 Heterokontophyta, 9 Chlorophyta, 1 Cryptista, 4 Cyanobacteria, 5 Dinoflagellata and 3 Euglenophyta. *Anabaena* sp.1, *Chlorella vulgaris*, *Fragilaria crotonensis*, *Prestauroneis crucicula*, *Melosira varians* and *Ulnaria ulna* were recorded as the dominant species according to relative abundance of total biovolume. Nitrate nitrogen ($NO_3$-N) values varied between stations, while sulfate ($SO_4$), temperature (T) and pH values differed across seasons. According to Canonical Correspondence Analysis (CCA); *Chlorella vulgaris* and *Melosira varians* were associated with $NO_3$-N and $SO_4$; while *Ulnaria ulna*, *Prestauroneis crucicula*, phytoplankton total biovolume (TBV), species richness (RICH), and species diversity (DIVERS) were correlated with temperature (T), nitrite nitrogen ($NO_2$-N) and silica (Si). Moreover, *Anabaena* sp. 1 and *Fragilaria crotonensis* were related with electrical conductivity (EC), ortho-phosphate ($PO_4$-P), total phosphorus (TP) and pH. In the Yuvacık Reservoir, when the riverine region (Y2) and the lacustrine region (Y1) compared, it was observed that the total biovolume, species number and diversity of phytoplankton were generally higher at station Y1 than station Y2.

**Keywords**
- Yuvacık Reservoir
- Environmental parameters
- Phytoplankton

**Özet:** Bu çalışmada Yuvacık Barajının fitoplankton yersel (örnekleme istasyonları) ve zamansal (mevsimsel) dağılımının belirlenmesi amacıyla baraja derelerin giriş bölgesinden (Y2) ve baraj set önünden (Y1) olmak üzere iki istasyondan 4 mevsim örneklenme yapılmıştır. Fitoplankton tür kompozisyonunda 30 Heterokontophyta, 9 Chlorophyta,1 Cryptista, 4 Cyanobacteria, 5 Dinoflagellata ve 3 Euglenophyta grubuna ait olmak üzere toplamda 52 takson tespit edilmiştir. Toplam biyohacimin nispi bolluğu açısından *Anabaena* sp.1, *Chlorella vulgaris*, *Fragilaria crotonensis*, *Prestauroneis crucicula*, *Melosira varians* ve *Ulnaria ulna* türleri dominant olmuştur. İstasyonlar arasında nitrat azotu ($NO_3$-N), mevsimler arasında ise sülfat ($SO_4$), sıcaklık (T) ve pH istatiksel olarak anlamlı bulunmuştur. Kanonik uyum analizi (CCA) sonuçlarına göre $NO_3$-N ve $SO_4$ ile *Chlorella vulgaris*, *Melosira varians*; sıcaklık (T), nitrit azotu ($NO_2$-N) ve silika (Si) ile *Ulnaria ulna* ve *Prestauroneis crucicula* türleri, fitoplankton toplam biyohacmi (TBV), tür sayısı (RICH) ve tür çeşitliliği (DIVERS) ilişkili bulunmuştur. Ayrıca elektriksel iletkenlik (EC), orto-fosfat ($PO_4$), toplam fosfor (TP) ve pH ile *Anabaena* sp 1 ve *Fragilaria crotonensis* türleri ilişkili bulunmuştur. Yuvacık Barajında, derelerin bağlantılı olduğu riverin bölgesi (Y2) ile durgun su kütlesinin bulunduğu lakustrin (Y1)

**Anahtar kelimeler**
- Yuvacık Rezervuar
- Çevresel parametreler
- Fitoplankton

bölgesi karşılaştırıldığında, fitoplankton toplam biyohacimi, tür sayısı ve çeşitliliğinin Y1 istasyonunda çoğunlukla Y2 istasyonuna göre daha fazla olduğu görülmüştür.

# 1. INTRODUCTION

Lakes and reservoirs constitute a significant portion of the Earth's freshwater. Lakes are unique ecosystems characterized by their distinct physical, chemical, and biological features. They can be fresh, salty, shallow, deep, permanent or temporary. The interactions between physical, chemical and biological processes in lake ecosystems differ quantitatively and qualitatively from those in other ecosystems (Bhateria and Jain, 2016). One of the most important types of lakes is the reservoir, which is built to collect streams within a specific area. Reservoirs are used for agriculture, drinking water, fish farming, flood control and energy production. Of all reservoirs, 48% are used for irrigation, 20% are energy production, and the remainder for urban and industrial water supply (Özyalın and Ustaoğlu, 2008; Kutlu et al. 2020). On the horizontal plane extending from the stream entrance to the reservoir embankment, the reservoirs are generally divided into three distinct regions based on their physical, chemical and biological differences. These three regions are known as riverine (stream region), transition (transition region) and lacustrine (lake region) (Geddes, 1984).

Pollution of water resources plays a crucial role in the degradation of these ecosystems, and to detect the pollution and ecological quality of freshwaters, chemical analyzes alone may not be sufficient. Bioindicators, on the other hand, are important for monitoring both environmental quality and the health of organisms living in ecosystems (Ozmen et al., 2008). Phytoplankton, along with benthic algae and macrophytes, are responsible for primary production in aquatic ecosystems. Planktonic algae are valuable indicators of water quality due to their short life cycle and rapid response to environmental changes and are used as biological quality elements in monitoring studies (European Union, 2000, Wu et al., 2014).

There are many phytoplankton studies conducted on reservoirs in Türkiye (Baykal and Açıkgöz, 2004; Sömek et al., 2005; Atıcı et. al. 2005; Taş and Gönülol, 2007; Atıcı and Çalışkan 2007; Özyalın and Ustaoğlu, 2008; Atıcı and Obalı, 2010; Sevindik, 2010; Akin et. al. 2011; Sevindik et al. 2011; Atıcı and Alaş, 2012; Ersanlı and Gönülol, 2014; Çelik and Sevindik, 2015; Ongun Sevindik et. al. 2022; Aksoy and Soylu, 2023). The species composition and community ecology of phytoplankton in Yuvacık Reservoir have not been studied before. As a result of quantitative estimates of the hydrological effects of climate change, Özdemir (2021) has stated that there would be a decrease in the flow rates of Kazandere, Kirazdere and Serindere streams which feed the Yuvacık Reservoir. Additionally, Kalıpcı et al. (2020) reported that the water quality of Yuvacık Reservoir was between Class I and Class II quality, and its trophic level was mesotrophic. This study aims to determine the spatial (sampling stations) and temporal (seasons) distribution of phytoplankton and to understand their relationship with environmental parameters in the riverine and the lacustrine regions of Yuvacık Reservoir.

# 2. MATERIAL and METHODS

## 2.1. Work area

Yuvacık Reservoir was established to supply drinking water to Kocaeli province and its surroundings. Its basin covers parts of Kocaeli, Sakarya and Bursa provinces, with an area of 257.86 $km^2$. The Kirazdere, Serindere and Kazandere streams along with their basins, contribute significantly to the reservoir (Figure 1). The largest sub-basin is Serindere with a recharge area of 120.53 $km^2$, followed by Kirazdere with 79.54 $km^2$, Kazandere with 23.10 $km^2$ and intermediate basins with 34.69 $km^2$. Additionally, many ground waters also feed the reservoir. Of the reservoir water, 0.41% is discharged and sent to Lake Sapanca, and 67% is purified and used as drinking water (Kalıpcı et al., 2020; Özdemir, 2021).

## 2.2. Sampling and Analysis of Phytoplankton

Water samples for phytoplankton were collected seasonally at a depth of 10 cm below the water surface between August 2022 and May 2023. Sampling stations were designated as the reservoir embankment area-Y1 (lacustrine region) and the streams inlet-Y2 (riverine region) (Table 1). Samples taken from each station were fixed with lugol and formaldehyde solution. In the laboratory, the samples were allowed to settle in a 50 mL graduated cylinder for 24 hours. After the settling period, the remaining 45 mL of water was discarded, and the 5 mL of the precipitated material at the bottom was transferred to small glass bottles for microscopic examination (Utermöhl, 1958). Phytoplankton species identified using an Olympus BX 51 microscope and counting was performed with Olympus IX81 inverted microscope using standard methods (Utermöhl 1958). The current names of phytoplankton species were verified according to Guiry and Guiry (2024). The biovolume of the cells were calculated from cell numbers and cell size measurements according to Wetzel and Likens (1991) and Sun and Liu (2003).

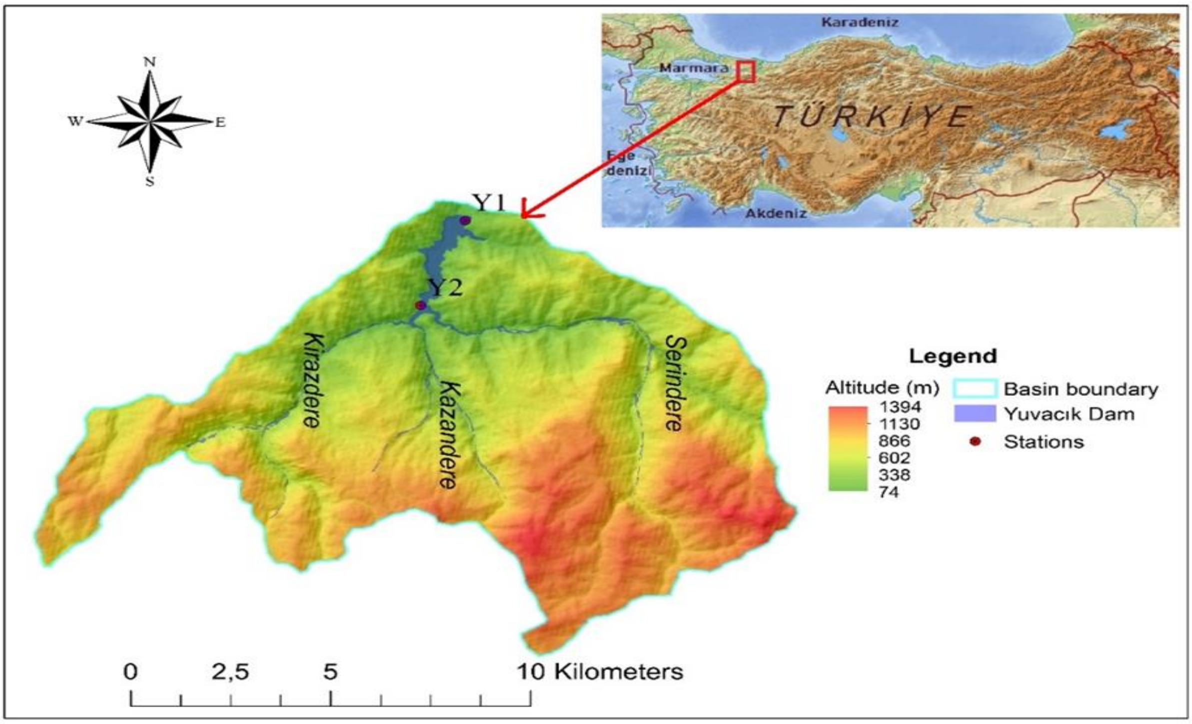


**Figure 1.** Map of the Yuvacık Reservoir and location of the sampling stations.

**Table 1.** Coordinates of the sampling stations in Yuvacık Reservoir.

| No | Position | Station Code | Coordinate | |
|---|---|---|---|---|
| | | | UTM Easting | UTM Northing |
| 1 | Yuvacık Reservoir (Lacustrine) | Y-1 | 29.970366 | 40.672875 |
| 2 | Yuvacık Reservoir (Riverine) | Y-2 | 29.958227 | 40.649050 |

**2.3. Sampling and Analysis of Environmental Parameters**

Sampling for physical and chemical variables was conducted alongside phytoplankton sampling. Electrical conductivity (EC), pH, dissolved oxygen (DO) and water temperature (T) were measured using a YSI multi-probe device at 10 cm below the water surface. For chemical analysis, water samples were collected from 10 cm below the water surface in 1000 mL polyethylene bottles and stored at +4 C° until analysis. Total phosphorus (TP), ortho-phosphate ($PO_4$-P), nitrite nitrogen ($NO_2$-N), nitrate nitrogen ($NO_3$-N), silica (Si) and sulfate ($SO_4$) were analyzed according to methods described by Strickland and Parsons (1972) and Technicon Industrial Methods (1977a, 1977b).

**2.4. Data analysis**

The species diversity index (H) was calculated according to Shannon and Weaver (1963). To detect differences among stations and seasons, (one-way ANOVA), t-test (two-sided, independent samples) or Mann-Whitney U-test (two-sided) were applied depending on the normality of data distribution using SPSS 20.0 software. Data were logarithmically transformed for Pearson correlation analysis. Pearson correlations between physicochemical parameters and phytoplankton biovolume, diversity and species richness were done using SPSS 20.0 software. ArcMap 10.0 and Google Earth Pro, both geographical information system programs, were used for map creation. Since the gradient length was found as 3.226 SD by Detrended Correspondence Analysis (DCA), Canonical Correspondence Analysis (CCA) was performed using CANOCO software (Ter Braak and Smilauer 2002). Phytoplankton species used in CCA were selected from those with a relative abundance higher than 10% (6 taxa) (Weilhoefer and Pan, 2006). The statistical significance of the determinants of environmental parameters was evaluated with 999 restricted Monte Carlo permutations. The relationship between six dominant species, phytoplankton biovolume, species richness, diversity and nine environmental parameters (T, pH, EC, $NO_3$-N, $NO_2$-N, TP, $PO_4$-P, Si, $SO_4$) was performed with CCA. Initially, CCA was performed on phytoplankton data with all environmental parameters. The results showed that 8 (T, pH, Si, $PO_4$-P, TP, $SO_4$, $NO_3$-N and $NO_2$-N) out of 10 environmental factors significantly contributed to phytoplankton biovolume, richness and diversity.

# 3. RESULTS

## 3.1. Environmental Parameters

The amount of $NO_3$-N was higher at station Y2 than at station Y1 in every season ($U$=0.00, $Z$=-2.309, $p$<0.05). The highest $NO_3$-N concentration was measured at station Y2 in winter (0.234 mg/L), while the lowest was measured at station Y1 in summer (0.007 mg/L) (Figure 2). $SO_4$, T and pH values were found statistically significant across seasons. There was a significant increase in $SO_4$ values in winter compared to spring and summer ($F$ = 14.89, $df$ = 3, $p$ < 0.05). T values varied significantly between seasons ($F$ = 161.27, $df$ = 3, $p$ < 0.05). Additionally, there was a significant increase in pH values in fall compared to spring and summer ($F$ = 21.69, $df$ = 3, $p$ < 0.05). The highest $NO_2$-N (fall, 0.015 mg $L^{-1}$), EC (fall, 699.00 µS $cm^{-1}$) and $PO_4$-P (fall, 0.068 mg $L^{-1}$) values were recorded at station Y1, while the highest Si (winter, 11.32 mg $L^{-1}$) and TP (spring, 0.405 mg $L^{-1}$) were recorded at station Y2 (Figure 2, 3). Pearson correlation results among environmental parameters are given in Table 2.

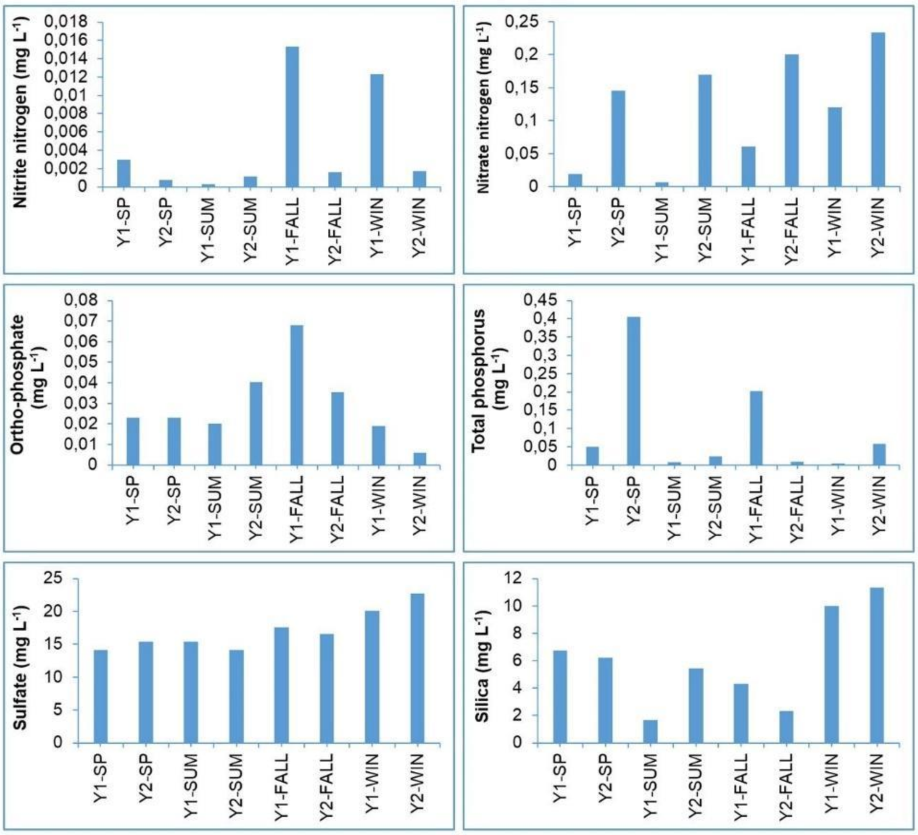


**Figure 2.** Seasonal distribution of some environmental parameters (nitrite nitrogen, nitrate nitrogen, ortho-phosphate, total phosphorus, sulfate, and silica) measured at two stations in Yuvacık Reservoir.

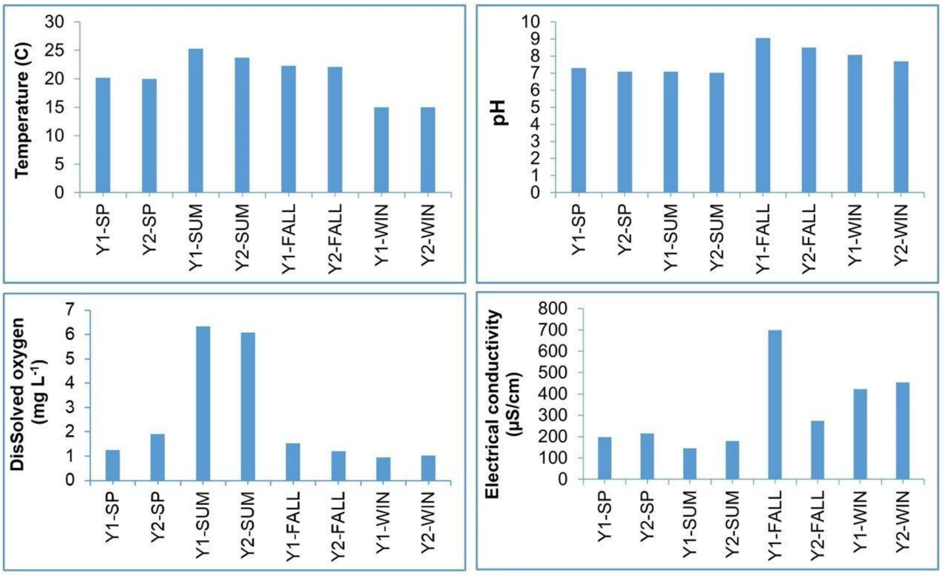


**Figure 3.** Seasonal distribution of some environmental parameters (temperature, pH, dissolved oxygen, and electrical conductivity) measured at two stations in Yuvacık Reservoir.

**Table 2.** Pearson correlation results among some environmental parameters and phytoplankton total biovolume (**TBV**), species richness (**RICH**) and Shannon diversity (**DIVERS**) (**$PO_4$-P**: orto-phosphate**; TP:** total phosphorus, **$NO_3$-N:** nitrate-nitrogen, **$NO_2$-N:** nitrite–nitrogen, **Si:** soluble silica, **$SO_4$:** sulfate, **EC:** electrical conductivity, **T:** water temperature).

| | **TBV** | **SHNN** | **RICH** | **$NO_2$-N** | **$NO_3$-N** | **TP** | **$PO_4$-P** | **Si** | **$SO_4$** | **T** | **EC** | **pH** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TBV | 1 | 0,681 | **0,720**$^{*}$ | 0,500 | -0,490 | -0,107 | 0,462 | -0,184 | -0,186 | 0,088 | 0,151 | 0,370 |
| SHNN | 0,681 | 1 | **0,852**$^{**}$ | 0,063 | -0,275 | -0,032 | 0,166 | -0,264 | 0,007 | 0,009 | 0,024 | 0,142 |
| RICH | **0,720**$^{*}$ | **0,852**$^{**}$ | 1 | 0,281 | -0,303 | 0,277 | -0,002 | 0,093 | 0,129 | -0,242 | 0,228 | 0,168 |
| $NO_2$-N | 0,500 | 0,063 | 0,281 | 1 | 0,250 | 0,073 | 0,279 | 0,471 | 0,419 | -0,449 | **0,822**$^{*}$ | **0,750**$^{*}$ |
| $NO_3$-N | -0,490 | -0,275 | -0,303 | 0,250 | 1 | 0,185 | -0,104 | 0,507 | 0,430 | -0,475 | 0,422 | 0,269 |
| TP | -0,107 | -0,032 | 0,277 | 0,073 | 0,185 | 1 | 0,132 | 0,281 | -0,094 | 0,029 | 0,247 | 0,014 |
| $PO_4$-P | 0,462 | 0,166 | -0,002 | 0,279 | -0,104 | 0,132 | 1 | -0,461 | -0,581 | 0,679 | 0,031 | 0,356 |
| Sİ | -0,184 | -0,264 | 0,093 | 0,471 | 0,507 | 0,281 | -0,461 | 1 | 0,492 | **-0,835**$^{**}$ | 0,425 | -0,038 |
| SUL | -0,186 | 0,007 | 0,129 | 0,419 | 0,430 | -0,094 | -0,581 | 0,492 | 1 | **-0,803**$^{*}$ | **0,742**$^{*}$ | 0,473 |
| T | 0,088 | 0,009 | -0,242 | -0,449 | -0,475 | 0,029 | 0,679 | **-0,835**$^{**}$ | **-0,803**$^{*}$ | 1 | -0,526 | -0,168 |
| EC | 0,151 | 0,024 | 0,228 | **0,822**$^{*}$ | 0,422 | 0,247 | 0,031 | 0,425 | **0,742**$^{*}$ | -0,526 | 1 | **0,838**$^{**}$ |
| pH | 0,370 | 0,142 | 0,168 | **0,750**$^{*}$ | 0,269 | 0,014 | 0,356 | -0,038 | 0,473 | -0,168 | **0,838**$^{**}$ | 1 |

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

## 3.2. Phytoplankton

A total of 52 taxa were identified in the phytoplankton of Yuvacık Reservoir, including 30 Heterokontophyta, 9 Chlorophyta, 1 Cryptista, 4 Cyanobacteria, 5 Dinoflagellata and 3 Euglenophyta (Table 3). *Anabaena* sp. 1, *Chlorella vulgaris* Beyerinck [Beijerinck], *Fragilaria crotonensis* Kitton, *Prestauroneis crucicula* (Smith) Genkal & Yarushina, *Melosira varians* C.Agardh and *Ulnaria ulna* (Nitzsch) Compère were recorded as the dominant taxa based on the relative abundance of the total biovolume (Figure 4).

Total biovolume (TBV) was higher at station Y1 than station Y2 in all seasons ($U$=0.00, $Z$=-2.309, $p$<0.05) (Figure 5). The highest TBV was recorded at station Y1 in winter (2.868 $mm^3$ $L^{-1}$), and the lowest was recorded in winter at station Y2 (0.033 $mm^3$ $L^{-1}$). The highest species richness (RICH) was recorded at station Y2 in spring (21), and lowest was recorded at station Y2 in summer (2). The highest Shannon diversity (DIVERS) was recorded at station Y2 in spring (2.131), and lowest was recorded at station Y2 in summer (0.367) (Figure 5). Based on the Pearson correlation results, DIVERS showed a significant positive correlation with TBV ($R$ = 0.72, $p$<0.05) and RICH ($R$ = 0.85, $p$<0.01) (Table 2).

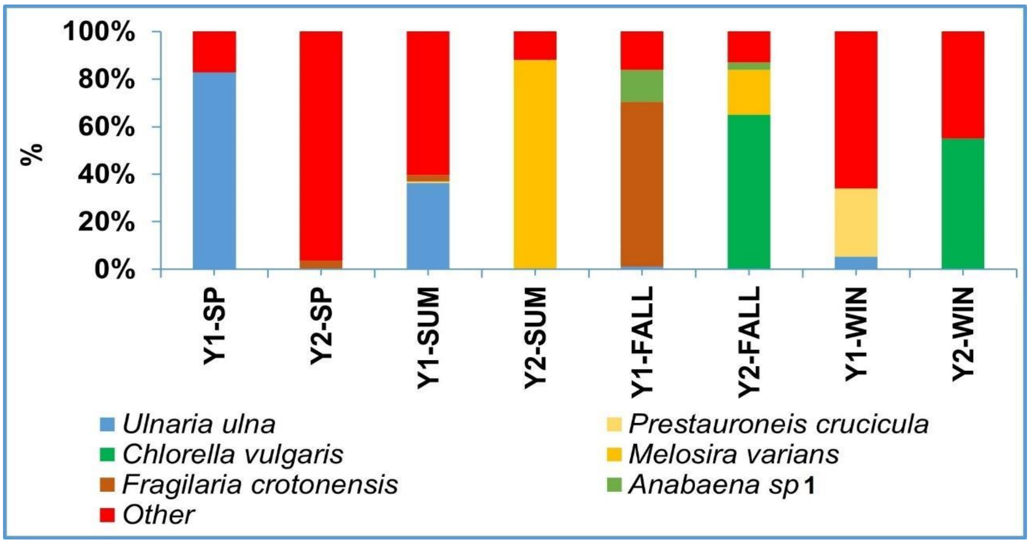


**Figure 4.** Seasonal distribution of dominant phytoplankton species in two stations of Yuvacık Reservoir.

**Table 3.** List of phytoplankton species identified in Yuvacık Reservoir between August 2022 and May 2023.

| **HETEROKONTOPHYTA** | **CHLOROPHYTA** |
|---|---|
| **Bacillariophytina** | **Chlorophytina** |
| *Amphora pediculus* (Kützing) Grunow | *Chlamydomonas elegans* West |
| *Asterionella formosa* Hassall | *Chlamydomonadopsis klinorostris* (Skuja) Fott |
| *Cocconeis pediculus* Ehrenberg | *Chlamydomonas* sp. |
| *Cyclotella affinis* Makarova & Genkal | *Chlorella* sp. 1 |

**Continuation of the Table 3.**

| **HETEROKONTOPHYTA** | **CHLOROPHYTA** |
|---|---|
| *Cymbella* sp. | *Chlorella* sp. 2 |
| *Diatoma ehrenbergii* Kützing | *Chlorella vulgaris* Beyerinck [Beijerinck] |
| *Encyonema caespitosum* Kützing | *Monoraphidium circinale* (Nygaard) Nygaard |
| *Fragilaria crotonensis* Kitton | *Coenochloris fottii* (Hindák) Tsarenko |
| *Gomphocymbellopsis ancyli* (Cleve) Krammer | *Papenfussiomonas cordata* (Pascher&Jahoda) Desikachary |
| *Gomphonema parvulum* (Kützing) Kützing | |
| *Gyrosigma acuminatum* (Kützing) Rabenhorst | **CRYPTISTA** |
| *Lindavia radiosa* (Grunow) De Toni & Forti | **Rollomonadia** |
| *Navicula* sp. 1 | *Chroomonas pochmannii* Huber-Pestalozzi |
| *Navicula* sp. 2 | |
| *Nitzschia acula* (Kützing) Hantzsch | **CYANOBACTERIA** |
| *Nitzschia costei* Tudesque, Rimet & Ector | *Dolichospermum* sp. |
| *Nitzschia dissipata* (Kützing) Rabenhorst | *Anabaena* sp. 1 |
| *Nitzschia umbonata* (Ehrenberg) Lange-Bertalot | *Anabaena* sp. 2 |
| *Prestauroneis crucicula* (Smith) Genkal & Yarushina | *Anabaena sphaerica* var. *attenuata* Bharadwaja |
| *Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot | |
| *Surirella librile* (Ehrenberg) Ehrenberg | **DINOFLAGELLATA** |
| *Tabularia fasciculata* (Agardh) Williams & Round | **Myzozoa** |
| *Tryblionella apiculata* Gregory | *Parvodinium centenniale* (Playfair) Carty |
| *Tryblionella calida* (Grunow) Mann | *Parvodinium lubieniense* (Woloszynska) Carty |

| | |
|---|---|
| *Ulnaria acus* (Kützing) Aboal | *Parvodinium cunningtonii* (Lemmermann) Pandeirada ve diğ. |
| *Ulnaria delicatissima* var. *angutissima* (Grunow) Aboal & Silva | *Peridinium willei* Huitfeldt-Kaas |
| *Ulnaria ulna* (Nitzsch) Compère | *Naiadinium polonicum* (Woloszynska) Carty |
| **Coscinodiscophytina** | |
| *Aulacoseira italica* (Ehrenberg) Simonsen | **EUGLENOPHYTA** |
| *Melosira varians* C.Agardh | **Euglenoida** |
| **Ochrophytina** | *Phacus* sp. |
| *Phacomonas pelagica* Lohmann | *Euglena chlamydophora* Mainx |
| | *Trachelomonas crebea* var. *brevicollaris* Prescott |

### 3.3. Relationships Between Phytoplankton and Environmental Parameters

The first two eigenvalues of the CCA axes are 0.92 and 0.15. While 81.40% of the cumulative percentage values of phytoplankton species (axis 1: 37.7%, axis 2: 43.7%) are explained by the first two CCA axes, the variance of the phytoplankton species-environment relationship is explained as 92.90% (Figure 6).

According to the CCA results, three regions were grouped on the axes. In the positive part of the first axis, summer, fall and winter seasons at station Y2 were associated with $SO_4$, $NO_3$-N, *Chlorella vulgaris* and *Melosira varians*. In the negative part of the first axis, RICH, DIVERS, TBV, $NO_2$-N, T and Si were associated with the spring, summer and winter seasons at station Y1 as well as *Ulnaria ulna* and *Prestauroneis crucicula*. In the positive part of the second axis, EC, $PO_4$, TP and pH were associated with the spring season at Y2 and the fall season at Y1, as well as *Anabaena* sp.1, and *Fragilaria crotonensis*.

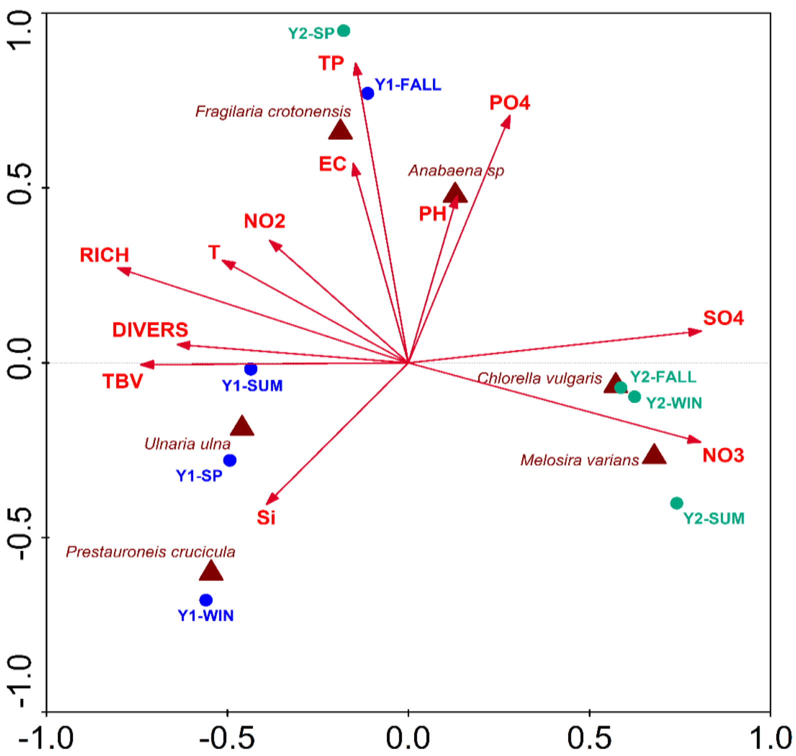


**Figure 5.** Ordination diagram of the canonical correspondence analysis (CCA) with the scores of dominant phytoplankton species, total biovolume (**TBV**), species richness (**RICH**), Shannon diversity (**DIVERS**) and environmental variables in different seasons and stations in Yuvacık Reservoir. Environmental variables: **T:** temperature, **$SO_4$:** sulfate, **TP:** total phosphorus, **$PO_4$**: orto-phosphate, **EC:** electrical conductivity, **$NO_3$:** nitrate-nitrogen, **$NO_2$:** nitrite–nitrogen, **Si:** soluble silica (**blue:** Y1, **light blue:** Y2, **SP:** spring, **SUM:** summer, **FALL:** fall, **WIN:** winter).

## 4. DISCUSSION

While reservoirs generally exhibit high electrical conductivity, alkaline pH, average temperature, varying dissolved oxygen concentrations (Ariyadej et al., 2004; Chellappa et al., 2008; Moura et al., 2021), seasonality and local differences can have impact on environmental factors (Moura et al., 2021). When the environmental parameters of Yuvacık Reservoir were examined, the highest temperature was recorded in summer and the lowest in winter, while there was a temperature difference in every season. In Yuvacık Reservoir, the highest temperature was recorded in summer and the lowest in winter, with noticeable temperature differences across seasons. The reservoir's water is characterized as alkaline based on pH values, a finding supported by Kalıpcı et al. (2020). Generally, the reservoir pH values are alkaline, which is crucial for maintaining biological and chemical balance (Şengül and Müezzinoğlu, 2008). The alkaline nature of Yuvacık Reservoir's water is thought to be influenced by surface water discharge (Kalıpcı et al., 2020). The fall discharge of surface waters is believed to contribute to the water's alkaline nature. Electrical conductivity (EC) is the potential of water to conduct electric current (Güler and Çobanoğlu, 1997). The geological structure and the precipitation level affect the EC (Temponeras et al., 2000). Although the EC values of Yuvacık Reservoir are recorded on average, precipitation, evaporation, temperature and water inputs play important roles in fluctuations in EC values. An increase in sulfate ion concentration is a symptom of chemical pollution. Sulfate concentration in natural waters typically ranges from 3 to 30 mg $L^{-1}$ (Giritlioğlu, 1975; Svobodá et al., 1993). Despite seasonal fluctuations, the highest $SO_4$ concentration at station Y2 in winter was 22.7 mg/L, which is consistent with natural water values. Depending on the geological structure, surface runoff during rainy periods may have been effective in the increase of sulfate values in winter (Kalıpcı et al., 2017). Ortho-phosphate values in water typically range from 0.05 to 0.30 mg/L, but higher values can increase primary production (Cirik and Cirik, 2005). In Yuvacık Reservoir, $PO_4$-P value was recorded as 0.41 mg $L^{-1}$ in spring at station Y2. Since agriculture, animal husbandry and other pollution activities are prohibited in the Yuvacık Reservoir basin (Anonymous, 2018), the increase of $PO_4$-P values at Y2 (riverine region) during spring when the precipitation increases, was likely due to allochthonous inputs with the effects of precipitation and erosion. Nitrogen can be found in freshwater in different forms such as nitrite ($NO_2^-$) and nitrate ($NO_3^-$) (Wetzel 1983). The amount of $NO_3$-N was higher at station Y2 than at station Y1 in every season. Conversely, $NO_2$-N levels were higher at both stations. It is thought that the high $NO_3$-N amount at Y2 station is due to stream inflows, while high $NO_2$-N in Y1 may result from anoxic sediments (Wetzel 1983). Total phosphorus (TP) is a key indicator of production capacity (Clark et al., 2010). The highest TP in Yuvacık Reservoir was recorded at Y2 station in spring, likely due to high precipitation and nutrient input from the stream. Silica levels in lakes can vary due to inputs, outputs and sediment accumulation (Schelske and Stoermer, 1971). Changes in Si values at Yıvacık Reservoir are probably related to precipitation, lake mixing and stream input or discharge.

According to CCA, *Anabaena* sp.1 was related to $PO_4$-P and pH. The increase in pH at station Y1 in fall seemed to have an impact on the biovolume of *Anabaena* sp.1. Changes in the pH of the environment can affect the nutrient uptake of algae, thereby influencing their growth and species composition (Meseck et al., 2007). While increased pH does not affect the internal pH of *Anabaena* species, inhibition of photosynthesis is unlikely (Kaplan, 1981). On the contrary, Chaudhary et al. (2013) stated that there was an increase in the photosynthetic activity of *Anabaena* species as the pH increased from 7.5 to 9.5. Therefore the higher pH at Y1 in fall likely to have positively affected the photosynthetic activity of *Anabaena* sp.1. This was one of the factors that enabled the *Anabaena* sp.1 to dominate the total biovolume in fall. Cyanobacteria can assimilate phosphate and convert it into soluble organic phosphorus forms, resulting in an increase in usable phosphorus. (Mandal et al., 1999; Yandigeri et. al., 2011). With this result, it can be said that during periods when *Anabaena* sp. 1 is dominant in the biovolume, the amount of usable phosphorus increases due to pH's contribution to photosynthetic activity. Additionally, some studies on Anabaena species have stated that the increase in photosynthesis rate is related to pH (Keenan, 1973; Tsygankov et. al. 1997; Chaudhary et. al. 2013; Kumar et. al. 2015). EC and TP were associated with *Fragilaria* *crotonensis*. It has been noted that *F. crotonensis* shows a positive correlation with EC, and that it prefers alkaline waters (Zebek, 2007). Additionally, the temperature range of 10.0°C to 25.0°C is suitable for the *F. crotonensis*, and a 1°C decrease in water temperature leads to an increase in its biomass (Zebek, 2007). In fall, the increase in EC and T values at Yuvacık Reservoir, combined with suitable temperatures may have influenced the dominance of *F. crotonensis* in terms of biovolume. *Prestauroneis crucicula* and *Ulnaria ulna* were associated with silica (Si). *Prestauroneis crucicula* was the dominant species in total biovolume at Y1 in winter. Da Rosa et al. (2023) reported that *P. crucicula* was common in the winter community in lagoon lakes. Zhang et al. (2019) reported an increase in the abundance of *U. ulna* with higher silica concentrations in drinking water reservoirs in spring. The dominance of *U. ulna* in the spring at Y1 was likely due to the increased Si level. *Melosira varians* and *Chlorella vulgaris* were associated with $NO_3$-N and $SO_4$. *Melosira varians* showed the highest growth rate with 0.24 cells day$^{-1}$ at 28 C° at 0.0020 mg L$^{-1}$ nitrate concentration. Rukminasari (2021) stated that high nitrate concentration and temperature increase the abundance of *Melosira* sp. Probably, appropriate temperature (23.7 C°) and high $NO_3$-N (0.169 mg L$^{-1}$) concentration likely contributed to the dominance of *M. varians* in the summer at Y2 station. *Chlorella vulgaris* can survive at high nitrate concentrations (Jeanfils et al., 1993; Choi and Lee, 2013) but its growth and biomass may be reduced (Jeanfils et al., 1993). Additionally, Passera and Ferrari (1975) found that *Chlorella vulgaris* has a positive relationship with $SO_4$. Therefore, high $NO_3$-N (0.20 mg L$^{-1}$) and $SO_4$ (22,74 mg/L) concentration likely contributed to the dominance of *C. vulgaris* biovolume in fall and winter at Y2 station. Additionally, *F. crotonensis,* one of the dominant indicator species in the reservoir, is characteristic for mesotrophic waters, *Melosira varians* is characteristic for eutrophic waters (Van Dam et al., 1994), while Anabaena species are characteristic for eutrophic waters (Nalewajko et al., 2001). Considering the dominance of species that are indicators of mesotrophic and eutrophic waters in terms of trophic level and the relationship of these species with environmental parameters such as ortho-phosphate, total phosphorus, nitrite nitrogen and nitrate nitrogen, and the water quality in previous studies, it can be said that the trophic level of the reservoir is between mesotrophic and eutrophic.

A relationship was observed between total biovolume (TBV), diversity (DIVERS) and richness (RICH) with temperature (T) and nitrite-nitrogen ($NO_2$-N). Raimbault (1986) stated that diatoms excrete nitrite-nitrogen into the environment at certain temperatures. Additionally, nitrifying bacteria contribute minimally to decomposing nitrate and converting it into nitrite (Lomas and Lipschultz, 2006). Therefore, the dominance of Heterokontophyta members (diatoms) in terms of biovolume, species richness, and diversity was one of the reasons for the increase in the amount of $NO_2$-N released into the environment. Furthermore, Canonical Correspondence Analysis (CCA) indicated that TBV, DIVERS and RICH showed a positive relationship with Y1 and a negative relationship with Y2, with these values generally being higher at Y1. Phytoplankton tend to grow better in stagnant water. In contrast, wave movements and current effects caused by streams at inlet points hinder the persistence of phytoplankton (Akgöz et al., 2000). As a result, although $NO_3$-N values were higher in Y2, the TBV, DIVERS and RICH values of phytoplankton were not high due to the turbulent environment and current effect.

In conclusion, there were spatial and temporal fluctuations in environmental parameters, as well as spatial and temporal differences in dominant species, TBV, DIVERS and RICH at Yuvacık Reservoir. Additionally, physico-chemical parameters and indicator species should be monitored for many years to control the water quality of Yuvacık Dam Lake.

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## CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## AUTHOR CONTRIBUTIONS

Uğur GÜZEL conducted the chemical analysis, identified and counted the phytoplankton, analyzed the data, and wrote the text. Tuğba ONGUN SEVİNDİK analyzed the data and revised the manuscript. Ayşe Gül

TEKBABA conducted the chemical analysis. Rabia POLŞAK, Layla EL DRAYHI and Zehra Nur AKDEMİR conducted the field sampling. All authors have read the article and contributed to the editing in the preparation of the final version.

## ETHICAL STATEMENTS

Local Ethics Committee Approval was not obtained because experimental animals were not used in this study.

## DATA AVAILABILITY STATEMENT

Data supporting the findings of the present study are available from the corresponding author upon reasonable request.

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