

Distribution Dynamics of Vegetative Cells and Cyst of *Ceratium hirundinella* in Two Reservoirs, Turkey

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Keywords

Ceratium hirundinella,
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Abstract: The seasonal variation and vertical and horizontal distributions of *Ceratium hirundinella* (O.F.Müller) Dujardin and occurrence of its cyst form in Erfelek and Dodurga Reservoirs (Sinop, Turkey) were studied between August 2010 and July 2011. Our results showed that cyst form was observed with vegetative cells in phytoplankton. *Ceratium hirundinella* was recorded in high numbers in autumn/winter periods in these reservoirs. Winter conditions did not affect presence/absence of the species, but influenced the cell densities. Vegetative cells were observed mostly in lacustrine and transition zones, horizontally in two reservoirs and also cyst form was recorded in Erfelek Reservoir but not found in Dodurga Reservoir vertically. Dissolved oxygen had positive correlation with vegetative cells and also pH, conductivity and redox potential were important factors for vegetative cells and cyst occurrence.

Ceratium hirundinella Kist ve Vejetatif Hücrelerinin İki Baraj Gölünde Dağılım Dinamikleri, Türkiye

Anahtar Kelimeler

Ceratium hirundinella,
Kist,
Dağılım,
Fizikokimyasal özellikler,
Baraj gölü

Özet: *Ceratium hirundinella* (O.F.Müller) Dujardin vejetatif hücreleri ve kistlerinin mevsimsel değişimleri ile vertikal ve horizontal dağılımları Ağustos 2010 ve Temmuz 2011 tarihleri arasında Erfelek ve Dodurga Baraj Gölleri'nde (Sinop, Türkiye) çalışılmıştır. Sonuçlar fitoplanktonda kist formunun vejetatif hücreler ile birlikte bulunduğunu göstermiştir. *Ceratium hirundinella* sonbahar/kış dönemlerinde yüksek sayılarda kaydedilmiştir. Kış şartlarının türün varlığı/yokluğu üzerine etki etmediği, ancak hücre yoğunluğunu etkilediği gözlenmiştir. Her iki baraj gölünde de horizontal olarak vejetatif hücreler çoğunlukla lakustrin ve geçiş zonlarında gözlenmiş, vertikal olarak ise kist formu Erfelek Baraj Gölü'nde kaydedilmiş ancak Dodurga Baraj Gölü'nde tespit edilmemiştir. Çözünmüş oksijenin vejetatif hücrelerle pozitif yönde korelasyon gösterdiği, pH, iletkenlik ve redoks potansiyelinin ise vejetatif hücreler ve kist oluşumu için önemli faktörler olduğu tespit edilmiştir.

1. Introduction

Dinoflagellates are mostly biflagellate unicellular algae, although some are without flagella and are attached. They are present in the surface waters of lakes and ponds at certain times of the year. In freshwater environments, dinoflagellates are represented with about 220 species and they are typically large-celled organisms such as *Ceratium*, *Peridinium* and *Peridiniopsis* [1]. *Ceratium hirundinella* (O.F.Müller) Dujardin is characteristically found during late summer in water bodies and slow-growing phytoplankton [2].

Ceratium spp. are represented by low carbon, mixing, poor stratification, light, summer epilimnia in eutrophic lakes, according to the functional classification of Reynolds et al. [3] and it avoids anoxic hypolimnia [4].

Resting stages are present within all freshwater phytoplankton groups and their functions: survival during unfavorable environmental conditions, bloom initiation (as seeding), dispersal, reproduction, genetic variation [5, 6]. Observations of cyst formation in natural conditions have been rare that this is probably due to its quick occurrence and

sinking to the bottom of the lake. In deeper lakes, the chance of obtaining such cells in plankton samples is relatively high [7]. According to past studies on cyst formation in *C. hirundinella* displayed that two main factors (internal maturation processes and water temperature) determining the germination time although environmental factors such as anoxia and darkness can suppress germination [8].

Although *C. hirundinella* is a common species in freshwater phytoplankton, studies on cyst form in a natural environment and laboratory are very few [4, 8-13]. The aims of this study were to describe seasonal variation and vertical and horizontal distributions of *C. hirundinella* and its cyst, and to determine influential environmental factors on the presence of the cyst.

2. Material and Method

Erfelek (41°53' N and 34°55' E) and Dodurga Reservoirs (41°52' N and 34°97' E) are located in Sinop, Turkey (Figure 1). Erfelek Reservoir was established on Karasu Stream for irrigation and drinking water supply. It was constructed in the year 2006 beginning from 1995. The active storage volume is about 22.630×10^6 m³, with a depth of 67 m [14]. The other one, Dodurga Reservoir was established on the Keçili Creek in the year 2010 (beginning from 1994) for irrigation and drinking water purposes. The volume of the reservoir is 0.500 hm³ with a depth of 51 m and has an irrigated area of 720 hectares [15]. The trophic structure of the Dodurga and Erfelek Reservoirs varies from oligotroph to mesotroph [16, 17].

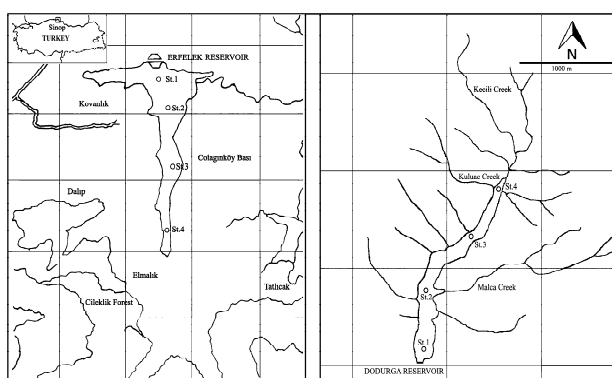


Figure 1. The geographical location of reservoirs and sampling stations.

Four stations were selected from the reservoirs. Surface samples were collected monthly, from four stations, horizontally. Depth samples were taken from station 1, the deepest part of the reservoir, from every 1 meters to 10 meters in Erfelek Reservoir and with 2 meter intervals until reaching 10 m in Dodurga Reservoir, in the period between August 2010 and July 2011.

Conductivity (Con), pH, temperature (T) and redox potential (ORP) were measured with the portable

digital HACH LANGE, HQ40D model, sampling equipment and water transparency (WT) was measured with a Secchi disc. Dissolved oxygen (DO), total hardness (TH), silica (Si), phosphorus (Phos) and organic matter (OM) analyses were made according to the standard methods [18]. These analyses were completed at all stations in Erfelek Reservoir and at surface stations in Dodurga Reservoir.

Water samples were taken by Hydro-Bios Nansen bottle (2L). Species identification and counts were made according to Utermohl method [19] using Micros Austria MCXI600 model inverted microscope and Leica DM500 light microscope. The counting results were evaluated according to Anonymous [18]. *Ceratium hirundinella* and cyst form were identified according to John et al. [20]. Spearman rank correlation analyses were run at SPSS (V.21, 2012) statistical programme. The Spearman rank correlation coefficient was computed for vegetative cells, cyst form and physicochemical parameters (by using the annual averages) of surface and depth samples of both reservoirs.

3. Results

The maximum, minimum, mean values and standard deviation of measured physicochemical variables were presented for Erfelek Reservoir [16] in Table 1 and Dodurga Reservoir in Table 2 [17].

Table 1. The minimum, maximum, mean values and standard deviation of measured physicochemical parameters in Erfelek Reservoir [16].

	Surface Samples				Depth Samples			
	Min.	Max.	Mean	S. D.	Min.	Max.	Mean	S. D.
T (°C)	7	29	17	6	7	29	16	6
DO (mg/L)	7	12	10	1	4	12	10	1
Con (µS/cm)	243	386	340	31	236	378	341	34
ORP (mV)	96	400	200	69	102	351	200	65
pH	8	9	8	0	8	9	8	0
Si (mg/L)	2	11	4	2	0	11	4	2
Nitrite (mg/L)	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00
Nitrate (mg/L)	0.05	0.27	0.13	0.05	0.00	0.19	0.12	0.03
TH (°FS)	88	320	201	36	0	280	197	29
Phos (mg/L)	0	5	1	1	0	23	1	2
OM (mg/L)	0	15	9	3	0	18	9	3
WT (cm)	30	555	188	109	-	-	-	-

Table 2. The minimum, maximum, mean values and standard deviation of measured physicochemical parameters in Dodurga Reservoir [17].

	Surface Samples				Depth Samples			
	Min.	Max.	Mean	S. D.	Min.	Max.	Mean	S. D.
T (°C)	9	27	17	6	10	27	16	5
DO (mg/L)	7	12	9	1	4	11	9	2
Con (µS/cm)	313	386	354	15	340	392	367	13
ORP (mV)	95	273	177	56	73	252	176	54
pH	8	9	8	0	8	9	8	0
Si (mg/L)	2	10	4	2	-	-	-	-
Nitrite (mg/L)	0.02	0.47	0.17	0.08	-	-	-	-
TH (°FS)	16	27	20	2	-	-	-	-
Phos (mg/L)	0	1	0	0	-	-	-	-
OM (mg/L)	8	17	11	3	-	-	-	-
WT (cm)	30	330	133	73	-	-	-	-

During the study period, the minimum and maximum water temperature values were measured as 7-29 °C in surface and depth samples in Erfelek Reservoir. In addition, the water temperature value was changed between 9-27 °C in surface samples and 10-27 °C in depth samples in Dodurga Reservoir. The minimum

and maximum dissolved oxygen values were measured as 7-12 mg/L in surface samples and 4-12 mg/L in depth samples in Erfelek Reservoir. The dissolved oxygen value was measured as 7-12 mg/L in surface samples and 4-11 mg/L in depth samples in Dodurga Reservoir. The mean electrical conductivity value was found 340 $\mu\text{S}/\text{cm}$ in surface samples and 341 $\mu\text{S}/\text{cm}$ in depth samples in Erfelek Reservoir. However, it was measured as 354 $\mu\text{S}/\text{cm}$ in surface samples and 367 $\mu\text{S}/\text{cm}$ in depth samples in Dodurga Reservoir. The ORP values were determined between 96-400 mV in surface water and between 102-351 mV in depths in Erfelek Reservoir. It was changed between 95-273 mV in surface water and between 73-252 mV in depths in Dodurga Reservoir. The mean pH values were measured as 8 in both surface and depth water in reservoirs. The mean amounts of silica were measured as 4 mg/L in both reservoirs. The total hardness values were found between 88-320 $^{\circ}\text{FS}$ in surface water and between 0-280 $^{\circ}\text{FS}$ in depth samples in Erfelek Reservoir. These values were measured as 16-27 $^{\circ}\text{FS}$ in surface samples in Dodurga Reservoir. The mean amount of organic matter was measured as 9 mg/L surface and depth samples in Erfelek Reservoir and 11 mg/L in surface samples in Dodurga Reservoir. The Secchi disc depth was changed between 30-555 cm in Erfelek Reservoir and 30-330 cm in Dodurga Reservoir throughout the study period.

Seasonal variation of *C. hirundinella* and its cyst in Erfelek and Dodurga Reservoirs were given in Figure 2. The distribution of them (by averaging) according to the stations were given in Figure 3. *Ceratium hirundinella* was not observed in the spring months, at the end of summer and the beginning of winter in Dodurga Reservoir. It reached the highest cell densities in September with 33000 org/mL. However, cyst form was observed only in September during this study. The vegetative cell frequencies changed between 8 and 33% when cyst form changed from 0 to 8% in Dodurga Reservoir. *Ceratium hirundinella* was recorded in all months in Erfelek Reservoir. However, cyst form was observed in the autumn months, December and July. Vegetative cells reached to 59786 and 30857 org/mL in July and September, respectively. Cyst form was the highest number in September, when the number of vegetative cells and cyst forms increased. In contrast, the vegetative cell frequencies changed from 58 to 100% when cyst form changed from 8 to 25% in Erfelek Reservoir.

Both cyst forms and vegetative cells were frequently observed in lacustrine and transition zones of Dodurga and Erfelek Reservoirs. However, vegetative cells decreased through the depth (but increased at about 10 meter of depth). Unlike vegetative cells, cyst form was not observed in deeper parts of Dodurga Reservoir. The amount of both decreased in station 4 which selected from fluvial zone. In depth, cyst and vegetative cells numbers increased, especially at 9 meter depth.

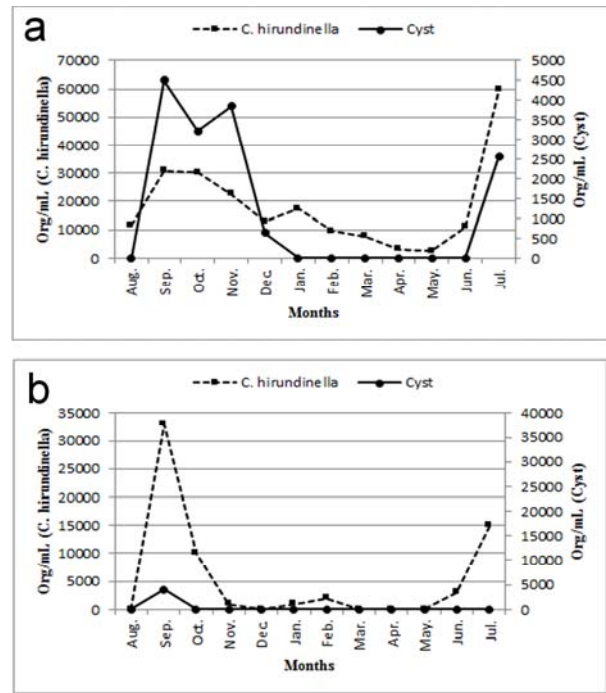


Figure 2. Seasonal variation of *C. hirundinella* and cyst form in reservoirs (a: Erfelek Reservoir, b: Dodurga Reservoir).

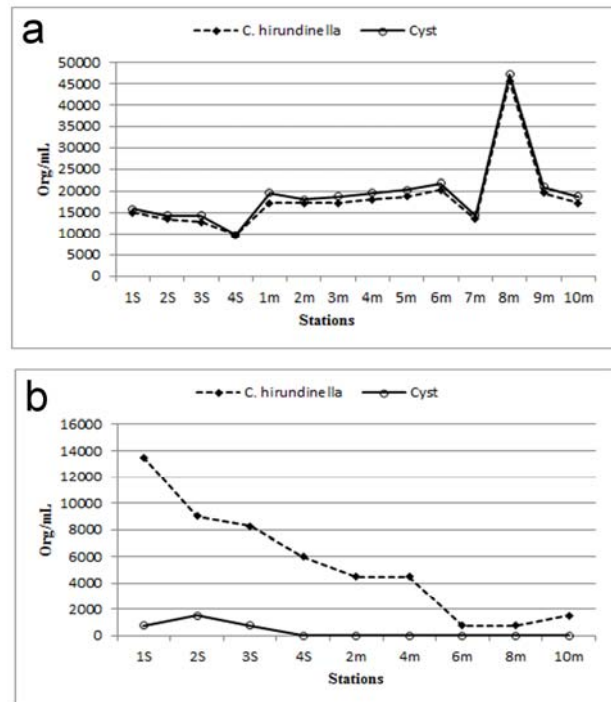


Figure 3. The distribution of *C. hirundinella* and cyst form in reservoirs (a: Erfelek Reservoir, b: Dodurga Reservoir).

The Spearman correlation coefficient was computed between vegetative cells (Ch), cyst form (cyst) and physicochemical parameters of surface and depth samples both reservoirs (Tables 3-6). *Ceratium hirundinella* was negatively correlated ($r=-0.430$) with dissolved oxygen and positively correlated with cyst form ($r=0.432$) in the surface samples of Dodurga Reservoir. In depth samples, a negative correlation was occurred between *C. hirundinella* and dissolved oxygen and redox potential, as well.

Table 3. Spearman rank correlation coefficient for Erfelek Reservoir in surface samples (**p < 0.01; *p < 0.05 level, N=48).

	Ch	Cyst	T	DO	Con	ORP	pH	Si	Nitrite	Nitrate	TH	Phos	OM	WT
Ch	1													
Cyst	0,434**	1												
T	0,161	-0,022	1											
DO	-0,265	-0,073	-0,897**	1										
Con	-0,306*	-0,09	-0,363*	0,554**	1									
ORP	-0,239	0,005	-0,685**	0,477**	0,021	1								
pH	-0,392**	-0,289*	0,113	0,084	0,093	-0,163	1							
Si	0,252	0,079	-0,142	0,249	0,255	-0,194	0,219	1						
Nitrite	-0,404**	-0,234	0,067	0,005	-0,046	-0,06	0,311*	-0,259	1					
Nitrate	-0,238	-0,014	-0,519**	0,408**	0,296*	0,664**	0,129	0,042	0,161	1				
TH	0,096	0,322*	-0,147	0,058	0,141	0,19	-0,085	-0,029	-0,01	0,252	1			
Phos	-0,045	-0,076	-0,356*	0,343*	0,383**	0,049	-0,04	0,419**	-0,193	0,109	-0,03	1		
OM	0,034	0,289*	-0,392**	0,192	0,182	0,338*	-0,371**	-0,204	0,041	0,214	0,451**	0,101	1	
WT	0,19	0	0,494**	-0,580**	-0,291*	-0,186	-0,443**	-0,356*	-0,344*	-0,295*	-0,268	-0,144	-0,033	1

However, in Erfelek Reservoir, a negative correlation was found between the species and conductivity ($r=-0.306$) and pH ($r=-0.392$), when positive correlation was found between the species and cyst form ($r=0.434$). Cyst form was negatively correlated with pH ($r=-0.289$) and positively correlated with total hardness and organic matter ($r=-0.322$, $r=0.289$, respectively). In depth, *C. hirundinella*, cyst form and temperature were positively correlated while *C. hirundinella*, dissolved oxygen, conductivity, oxidation-reduction potential, pH and phosphorus were negatively correlated. Cyst form, temperature and organic matter were positively correlated while cyst form, dissolved oxygen, conductivity, pH and phosphorus were negatively correlated.

4. Discussion and Conclusion

Ceratium hirundinella was dominant in oligotrophic waters, according to Naumann [21] and it was also present in both oligotrophic and eutrophic waters and widespread in the world [22]. This situation was explained with linked to the aeroplankton or dispersion mechanisms such as waterfowl [13]. Members of *Ceratium* are widespread in Turkey. *Ceratium* spp. were found in Yedikır Reservoir (Amasya), Lakes Balık and Uzun, Hasan Uğurlu, Suat Uğurlu and Derbent Reservoirs (Samsun), Erfelek Reservoir (Sinop), Lakes Abant, Yeniçağa and Gököy (Bolu) in Black Sea Region; Lake Sapanca (Kocaeli), Çaygören Reservoir (Balıkesir) in Marmara Region; Lakes Eğirdir and Beyşehir (Isparta) in the Mediterranean Region; Tercan Reservoir (Erzincan), Kuzgun Reservoir (Kars), Lake Tortum, Demirdöven Reservoir, pond 23 Temmuz (Erzurum), Orduzu Reservoir (Malatya) in Eastern Anatolia Region; Lakes Gölcük, Karagöl (İzmir), Lake Karamık, Topçam and Kemer Reservoirs (Aydın) in Aegean Region; Çubuk-I, Asartepe, Bayındır and Çamlıdere Reservoirs, Karagöl, Lake Mogan (Ankara), Hirfanlı Reservoir (Kırşehir), Lake Hafik (Sivas), Altınapa Reservoir (Konya), pond Mamuca, west pond Sakaryabaşı (Eskişehir) in Central Anatolia Region; Karakaya and Devegeçidi Reservoirs (Diyarbakır), Lower Euphrates Wetlands in Southeastern Anatolia Region [23]. Besides the seasonal distribution, variations in total cell length, width of cingulum and length of the different horns, and presence or absence of the fourth horn of *Ceratium hirundinella* in two

reservoirs (Kralkızı and Dicle Reservoirs) on the Tigris River (Turkey) were studied (Varol, 2016).

Martínez and Castillo [12] stated that *C. hirundinella* inhibited in winter conditions at northern, north-temperate systems, while temperature and light would allow their development at southern north temperate latitudes. Permanent and autumn/winter populations of *C. hirundinella* have also been reported in several Spanish reservoirs [12], however, in a study on subtropical lake, the presence of winter-spring populations were observed [24]. Winter populations of *Ceratium hirundinella* are relatively frequent in southern north-temperate systems [12]. In the study about the vegetatif form of *C. hirundinella* in our country (Kralkızı and Dicle Reservoirs), it was present during all seasons in the reservoirs. It showed the highest densities in the autumn and winter seasons in the Kralkızı Reservoir. *C. hirundinella* density did not show significant spatial variations in the Dicle Reservoir. Although the mean numbers of cells were higher in summer and autumn, there were no statistically significant differences among the seasons in the Dicle Reservoir (Varol, 2016). In comparison with current study, *C. hirundinella* did not observe from the spring months to December in Dodurga Reservoir when it was found throughout in Erfelek Reservoir. The species was recorded in high numbers in autumn/winter period in our country. Winter conditions did not affect presence/absence of *C. hirundinella* but autumn population densities were higher than winter.

It has been stated that cyst formation occurs at the end of a bloom [11]. Rengefors and Anderson [8] already mentioned that resting stage formation signifies the end of the population in the pelagic zone. Cyst formation of *Ceratium* occurred in September in Lake Erken and germinated during April and May because of the 4.5 month-long dormancy period despite temperatures allowing for germination. The cysts were mature in January and February but remained quiescent because of the low water temperatures (2-3 °C) [25]. However, in the Río the water column at the same time as the density of adult cells diminished abruptly [13]. Our findings are parallel to the findings of Mac Donagh et al. [13] but they are not in accordance with the findings of Rengefors [25]. In the Kralkızı Reservoir, no cysts of

Table 4. Spearman rank correlation coefficient for Erfelek Reservoir in depth samples (**p < 0.01; *p < 0.05 level, N=120).

	Ch	Cyst	T	DO	Con	ORP	pH	Si	Nitrite	Nitrate	TH	Phos	OM
Ch	1												
Cyst	0,485**	1											
T	0,236**	0,233*	1										
DO	-0,389**	-0,277**	-0,912**	1									
Con	-0,595**	-0,304**	-0,274**	0,375**	1								
ORP	0,017	-0,122	-0,709**	0,554**	-0,064	1							
pH	-0,372**	-0,193*	0,07	0,166	0,059	-0,181*	1						
Si	-0,087	0,068	0,153	-0,075	0,309**	-0,316**	0,02	1					
Nitrite	-0,175	-0,08	0,103	0,014	-0,047	-0,138	0,387**	-0,182*	1				
Nitrate	-0,171	-0,219*	-0,508**	0,408**	0,148	0,802**	-0,003	-0,015	-0,168	1			
TH	-0,027	0,176	-0,241**	0,133	0,172	0,209*	-0,012	-0,039	-0,044	0,211*	1		
Phos	-0,240**	-0,193*	-0,210*	0,236**	0,347**	-0,221*	0,126	0,465**	-0,16	-0,156	-0,079	1	
OM	0,154	0,288**	-0,196*	0,149	0,013	0,313**	-0,047	-0,035	-0,015	0,340**	0,532**	-0,316**	1

Table 5. Spearman rank correlation coefficient for Dodurga Reservoir in surface samples (**p < 0.01; *p < 0.05 level, N=24).

	Ch	Cyst	T	DO	Con	ORP	pH	WT	Si	Nitrate	TH	Phos	OM
Ch	1												
Cyst	0,432*	1											
T	0,156	-0,075	1										
DO	-0,430*	-0,105	-0,318	1									
Con	-0,34	-0,106	-0,494*	-0,127	1								
ORP	-0,27	-0,226	-0,714**	0,075	0,576**	1							
pH	-0,093	-0,121	0,495*	0,436*	-0,563**	-0,319	1						
WT	0,268	0,107	-0,024	-0,661**	0,401	0,197	-0,556**	1					
Si	0,144	0,256	-0,251	-0,051	0,069	0,076	-0,088	0,065	1				
Nitrate	0,228	0,015	-0,069	0,365	-0,606**	0,052	0,507*	-0,596**	0,05	1			
TH	0,397	-0,015	-0,251	-0,223	-0,138	0,258	-0,297	0,17	-0,078	0,255	1		
Phos	0,13	0,076	0,416*	0,005	-0,36	-0,039	0,546**	-0,133	-0,093	0,27	0,139	1	
OM	0,292	0,121	-0,201	-0,242	0,058	0,410*	-0,108	0,19	0,289	0,146	0,311	0,540**	1

C. hirundinella were observed. However, cysts of *C. hirundinella* were rarely observed in November and December in the Dicle Reservoir (Varol, 2016). In our study, *C. hirundinella* was not observed in the spring months, August and December, when the cyst form was observed only in September through the year in Dodurga Reservoir. However, *C. hirundinella* was recorded in all months while the cyst form was observed in the autumn months, in December and July in Erfelek Reservoir. Generally cyst form was observed when vegetative cell numbers were increasing. Mac Donagh et al. [13] explained this situation in this way that proliferation of cysts could not be related to unfavourable environmental conditions.

Low oxygen levels had a negative effect on germination of *Ceratium* cysts [8] and anoxia had an adverse effect for *Ceratium* development [12, 26]. In lakes with serious anoxia due to eutrophication, dinoflagellates may be lacking because of suppressed cyst germination. Because of these conditions, anoxia processes such as resuspension will be important to some species and in deep lakes [8]. *Ceratium hirundinella* and dissolved oxygen were negatively correlated in Dodurga Reservoir in surface and depth samples. *Ceratium hirundinella* and cyst form had negative correlation with dissolved oxygen in Erfelek Reservoir in depth samples. These results in natural environment supported laboratory results of Rengefors and Anderson [8].

Table 6. Spearman rank correlation coefficient for Dodurga Reservoir in depth samples (**p < 0.01; * p < 0.05 level, N=60).

	Ch	T	DO	Con	ORP	pH
Ch	1					
T	0,048	1				
DO	-0,259*	-0,280*	1			
Con	-0,104	-0,233	-0,103	1		
ORP	-0,294*	-0,742**	0,255*	0,146	1	
pH	0,027	0,147	0,537**	-0,411**	-0,108	1

Ceratium had a wide temperature range for excitement (from 6 to at least 21 °C). The minimum temperature for *C. hirundinella* excitement and the appearance of vegetative cells were reported to be 4 °C [8]. This species was present during all seasons between 10 °C and 26 °C and caused blooms when temperatures were higher than 18 °C and pH ranging was between 8.5 and 8.9 in Río Tercero Reservoir [13]. In our study, the temperature changed between 9 (January) and 27 (July) °C in Dodurga Reservoir and changed between 7 (February) and 29 (August) °C in Erfelek Reservoir. There was no correlation between temperature, cysts or vegetative cells in Dodurga Reservoir. *Ceratium hirundinella* and cyst form had a positive correlation with temperature in depth samples in Erfelek Reservoir.

Dinoflagellates can have two or three generations in circumstances of low phosphorus concentration due to their capacity for luxury phosphorus consumption when sufficient nutrients are available. In Río Tercero

Reservoir, the appearance of this alga was associated with low concentrations of total phosphorus [13]. *Ceratium hirundinella* and cyst form had negative correlation with phosphorus in depth samples in Erfelek Reservoir.

The positive relationship between *C. hirundinella* and high ionic content of waters was shown [12, 27]. However, *C. hirundinella* populations were also found in low ionic waters of the English lakes [10]. *Ceratium hirundinella* and redox potential were negatively correlated in Dodurga Reservoir in depth samples. *Ceratium hirundinella*, conductivity, pH were negatively correlated while cyst form and pH were positively correlated in surface samples in Erfelek Reservoir. *Ceratium hirundinella* had a negative correlation with conductivity, redox potential and pH while cyst form had a negative correlation with conductivity and pH in depth samples.

These reservoirs are generally similar in terms of some of the characters, but the phytoplankton variety, abundance and succession were different each other [16,17]. The differences between two reservoirs may be related to the reasons mentioned above, water withdrawal for drinking and irrigation from the reservoirs at different times and irregular water level fluctuations or the diversity of sources that feed them.

Consequently, in our study, *C. hirundinella* was recorded in high numbers in the autumn/winter period in two reservoirs that are located in northern north-temperate systems. It appears that seasonal variation of vegetative cells of *C. hirundinella* was similar with the other reservoirs located in temperate zones. Vegetative cells and cyst were observed in lacustrine and transition zones, but they were less in fluvial zones in reservoirs. Winter conditions did not affect presence/absence of *C. hirundinella* but affected cell densities. Generally cyst form was observed when vegetative cell numbers were increasing. Dissolved oxygen had positive correlation with vegetative cells and also pH, conductivity and oxidation-reduction potential were important factors for vegetative cells and cysts occurrence.

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