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Zooplankton of Two Drinking Water Reservoirs in Central Anatolia: Composition and Seasonal Cycle*

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Abstract: Comparative studies were performed on the zooplankton composition and some physical and chemical properties of the Kurtboğazı and Çamlıdere reservoirs. Zooplankton abundance, conductivity, organic matter, hardness and orthophosphate concentrations were lower and Secchi depth was higher in Çamlıdere than in Kurtboğazı ($P < 0.01$). Rotifera species such as *Polyarthra dolichoptera*, *Keratella quadrata*, *Asplanchna priodonta* and *Ascomorpha saltans* showed peaks, particularly in spring, summer and late summer. *Diaphanosoma lacustris*, *Bosmina longirostris* and *Ceriodaphnia quadrangula* of Cladocera species increased in late summer whereas *Bosmina longirostris* and *Daphnia* spp. were prominent in spring. The cyclopoid copepod *Cyclops vicinus* was dominant in Kurtboğazı and calanoid *Acanthodiaptomus denticornis* in Çamlıdere.

Key Words: Zooplankton, composition, trophic state, reservoir

İç Anadolu'da İki İçme Suyu Baraj Gölünün Zooplanktonu: Kompozisyon ve Mevsimsel Döngü

Özet: Bu çalışmada Kurtboğazı ve Çamlıdere baraj göllerinin zooplankton kompozisyonu, bazı fiziksel ve kimyasal özellikleri karşılaştırmalı olarak incelenmiştir. Çamlıdere baraj gölünde, zooplankton bolluğu, iletkenlik, organik madde, sertlik ve ortofosfat derişimleri Kurtboğazı'na göre daha düşük ve Secchi derinliği daha yüksektir ($P < 0,01$). *Polyarthra dolichoptera*, *Keratella quadrata*, *Asplanchna priodonta* ve *Ascomorpha saltans* gibi Rotifera türleri özellikle bahar, yaz ve yaz sonunda pikler göstermişlerdir. Cladocera türlerinden *Diaphanosoma lacustris*, *Bosmina longirostris* ve *Ceriodaphnia quadrangula* yaz sonunda artarken, *Bosmina longirostris* ve *Daphnia* spp. bahar aylarında hakimdir. Cyclopoid copepod *Cyclops vicinus* Kurtboğazı'nda, calanoid *Acanthodiaptomus denticornis* ise Çamlıdere'de baskındır.

Anahtar Sözcükler: Zooplankton, kompozisyon, besin düzeyi, baraj gölü

Introduction

The Kurtboğazı and Çamlıdere reservoirs are the main source of drinking water for the capital, Ankara. In recent years, the accumulation of algae on the sand filters of the drinking water treatment plant has led to some problems. The management and prevention of such situations require not only a general knowledge about the problems but also detailed limnological investigations of the reservoirs. The phytoplankton biomass of Kurtboğazı reservoir was investigated between 1976 and 1977 (Aykulu and Obalı, 1981), and the State Hydraulics Works (DSİ) conducted some limnological studies (DSİ, 1981). The seasonal changes in phytoplankton biomass and chlorophyll *a* were investigated in the Çamlıdere and Kurtboğazı reservoirs (Demir and Atay, 1999). The aims of this study were to investigate the composition and seasonal succession of zooplankton and to characterise the limnological properties of the Kurtboğazı and Çamlıdere reservoirs.

Materials and Methods

Kurtboğazı reservoir is situated 56 km west of Ankara in Central Anatolia, while Çamlıdere reservoir is situated 60 km north-west of Ankara. Kurtboğazı has an elongate longitudinal morphometry, while Çamlıdere has a dentritic one (Figure 1). Some hydrological details of the reservoirs have been described (DSİ, 1996) (Table 1).

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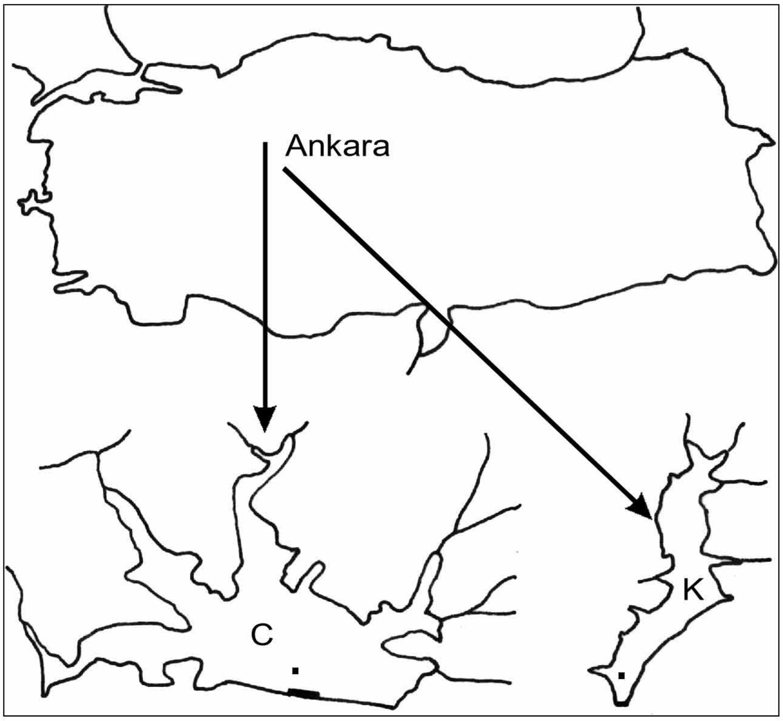

Figure 1. Location of Kurtboğazı (K) and Çamlıdere (C) reservoirs. (■); sampling point.

Fishing has been forbidden by the Ankara Health Commission in drinking water reservoirs.

The Kurtboğazı and Çamlıdere reservoirs were sampled monthly from June 1995 to May 1996. The deepest points near each dam were selected as sampling stations. Zooplankton and water samples were collected from 0, 1, 2, 3, 5, 8, 12, 20 and 30 m depths with a Ruttner sampler (Figure 1). Plankton samples were also taken by a 55 µm plankton net for qualitative analysis.

Zooplankton samples were preserved in 4% formaldehyde solution; 1, 2 or 3 l of water samples were filtered by a 30 µm mesh net and enumerated in a counting chamber (Wetzel and Likens, 1991). The common taxonomic literature was used for identifying the zooplankton (Kiefer and Fryer, 1978; Koste, 1978; Negrea, 1983). Water temperature (Ruttner sampler thermometer), Secchi depth (20 cm disc), dissolved oxygen (YSI Oxygenmeter), pH (pH meter) and conductivity (corrected to 25 °C) were measured. Organic matter, bicarbonate alkalinity, hardness, nitrate-N, nitrite-N, ammonia-N and total phosphorus were determined in the reservoir samples (methods in APHA, 1975).

Statistical analyses were performed using the Minitab and Mstat programs for Windows.

Table 1. Basic characteristics of the reservoirs (DSİ, 1996).

	Kurtboğazı	Çamlıdere
Beginning of the operation	1967	1985
Total volume (hm^3)	101	1226
Total area of the lakes (km^2)	5.5	32
Normal water level (m)	961	995
Height of the dam (m)	54	106
Raw water supply (hm^3/y)	67	150

Results

Surface water temperatures ranged between summer maxima of 24-26 °C and winter minima of 4 °C in both reservoirs (Table 2). Surface water temperatures increased in spring, thermal stratification occurred in May and mixing periods began in October (Figure 2). The

Table 2. Annual range and mean values (±SE) of physico-chemical parameters and zooplankton abundance of reservoirs, with significant results of F-test (* and ** indicate significant difference at p levels of <0.05 and 0.01, resp.).

Parameters	Kurtboğazı	Çamlıdere	F
Temperature (°C)	11.74 ± 0.57 (4 - 24)	12.17 ± 0.60 (4 - 26)	0.28
pH	8.18 ± 0.03 (7.59 - 9.19)	8.11 ± 0.03 (7.69 - 8.67)	2.27
Conductance (µS/cm)	199.02 ± 0.55 (187.3 - 212.0)	153.34 ± 0.70 137.3 - 166.0)	2650**
Dissolved oxygen (mg/l)	8.44 ± 0.10 (4.5 - 10.1)	8.64 ± 0.10 (6.3 - 10.2)	1.87
Secchi depth (m)	1.56 ± 0.08 (0.8 - 2.5)	2.20 ± 0.16 (1.0 - 4.0)	13.78**
Zooplankton abundance (no/l)	161.4 ± 12.1 (4 - 793)	73.8 ± 6.7 (1 - 288)	53.05**
Organic matter (mg/l)	5.72 ± 0.51 (1.6 - 12.6)	3.24 ± 0.39 (0.6 - 8.6)	14.57**
Bicarbonate alkalinity (mg$CaCO_3$/l)	154.3 ± 12.2 (100 - 360)	117.9 ± 9.2 (40 - 280)	5.67**
Hardness (FH°)	11.9 ± 0.45 (9.0 - 18.1)	8.5 ± 0.41 (5.6 - 13.9)	31.49**
PO_4-P (µg/l)	9.96 ± 0.36 (1.05 - 24.7)	8.57 ± 0.32 (2.0 - 21.41)	8.41**
TP (µg/l)	40.78 ± 2.08 (9.76 - 155.24)	40.13 ± 1.77 (9.52 - 128.57)	0.06
NO_2-N (mg/l)	0.026 ± 0.001 (0 - 0.082)	0.024 ± 0.001 (0 - 0.10)	2.24
NO_3-N (mg/l)	0.17 ± 0.009 (0 - 0.731)	0.21 ± 0.002 (0.03 - 1.51)	3.25
NH_3-N(mg/l)	0.034 ± 0.001 (0.013 - 0.091)	0.031 ± 0.001 (0.01 - 0.083)	1.84

vertical temperature changes showed strong thermal stratification in the period of summer stagnation.

Values for pH ranged between 7.6 and 9.2 in Kurtboğazı and between 7.7 and 8.7 in Çamlıdere. Dissolved oxygen ranged between 7.3 and 10.2 mg/l in surface waters. It decreased in August and September at 30 m to 4.5 and 6.3 mg/l in the hypolimnia of Kurtboğazı and Çamlıdere, respectively. No anoxic layers were found (Figure 2). The lake's surface can freeze in winter but during this study ice formation was seen only at the edges. Conductivity was higher in Kurtboğazı and ranged between 187 and 212 µS/cm, while the corresponding values were 137 and 166 µS/cm in Çamlıdere. Secchi depth ranged between 2.5 and 0.8 m in Kurtboğazı, and 4 and 1 m in Çamlıdere. The lowest values were measured in April for Kurtboğazı and in December for Çamlıdere, after heavy rain. Mean Secchi depth was lower while conductivity, organic matter, alkalinity, hardness

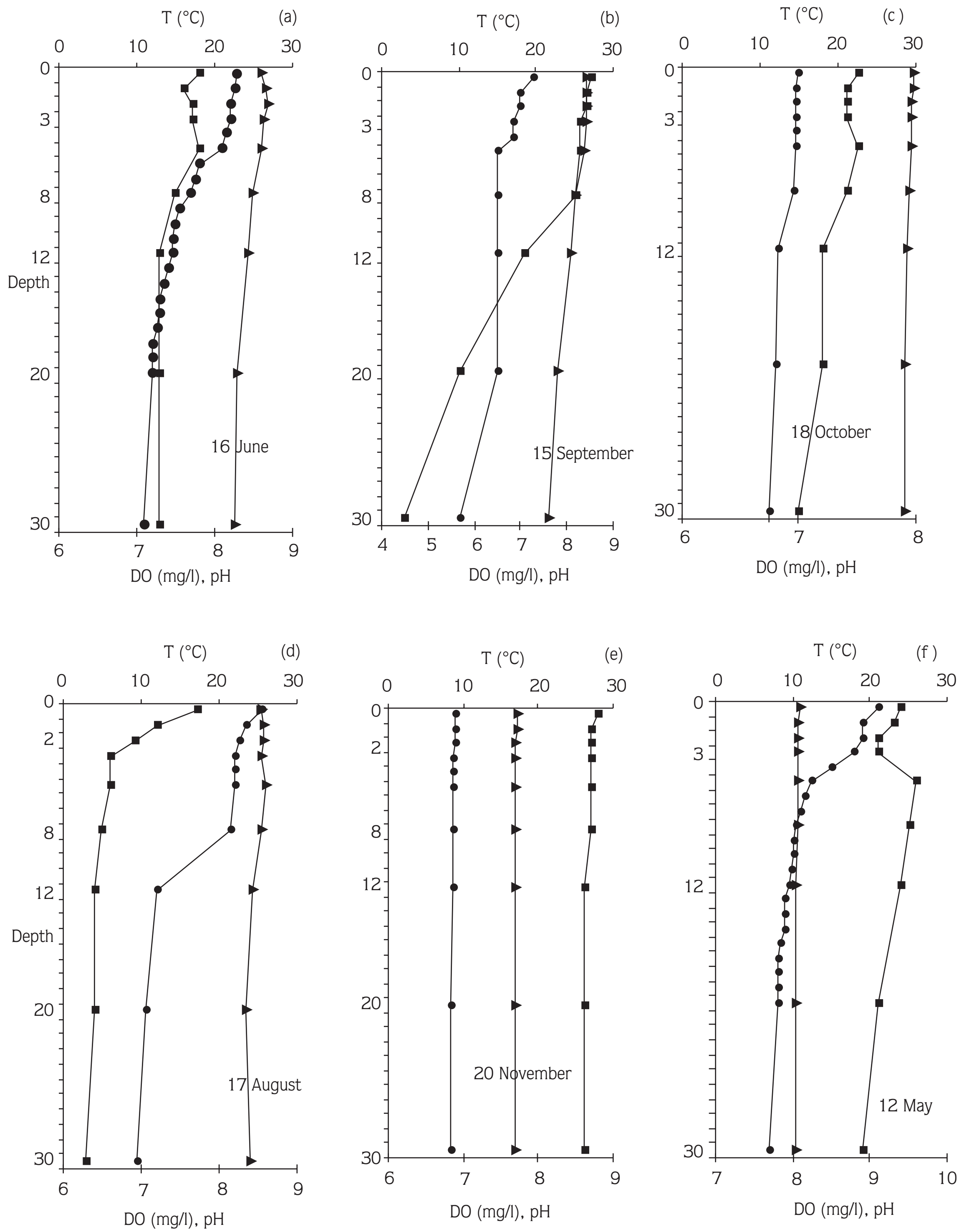

Figure 2. Vertical variation in temperature (●), dissolved oxygen (■) and pH (▲) for some sampling dates in the reservoirs. a, b, c; from Kurtboğazı, d, e, f; from Çamlıdere.

and orthophosphate were higher in Kurtboğazı than in Çamlıdere ($P < 0.01$) (Table 2).

In the study period, 27 and 24 zooplankton taxa were identified in Kurtboğazı and Çamlıdere, respectively (Table 3). The dominant rotifers in Kurtboğazı were *Asplanchna priodonta* and *Polyarthra dolichoptera* (June and July), *Keratella quadrata* and *Polyarthra* spp. (August), *Keratella* spp. and *Asplanchna priodonta* (September). Rotifers comprised 69% and 65% of total zooplankton numbers because of the increase in *Polyarthra* spp., *Asplanchna priodonta* and *Ascomorpha saltans* in February and March and decreased due to an increase in copepods in April and cladocerans in May (Figure 3).

Polyarthra dolichoptera and *Hexarthra fennica* increased in June and *Ascomorpha saltans* and *Asplanchna priodonta* in September and October in Çamlıdere. The ratio of rotifers showed a second peak in the mixing period in October. Rotifers started to increase in February with *Keratella* spp., *Asplanchna priodonta* and *Polyarthra dolichoptera* and comprised 48% of the total zooplankton.

Of the Cladocerans, *Daphnia pulex* increased in June, *Ceriodaphnia quadrangula* in July and *Diaphanosoma lacustris* in August. The highest number was found in September at the end of the thermal stratification period. The abundance decreased in winter and peaked with *Daphnia* spp. and *Bosmina longirostris* in May in both reservoirs again.

Table 3. The occurrence of zooplankton in Kurtboğazı and Çamlıdere reservoirs.

		Kurtboğazı	Çamlıdere
	Ascomorpha saltans Bartsch	X	X
	Asplanchna priodonta Gosse	X	X
	Brachionus angularis Gosse	X	
	B. calyciflorus Pallas	X	
	Brachionus sp.		X
	Conochilus unicornis (Rousselet)	X	X
	Filinia longiseta (Ehr.)	X	X
	F. terminalis (Plate)		X
	Hexarthra fennica (Levander)		X
R O T I F E R A	*Hexarthra* sp.	X	
	Keratella cochlearis (Gosse)	X	X
	K. quadrata (O.F.M.)	X	X
	Lecane luna (O.F.M.)		X
	Lepadella sp.	X	X
	Notholca squamula (O.F.M.)		X
	Platyias quadricornis (Ehr.)	X	
	Polyarthra dolicoptera Idelson	X	X
	P. vulgaris Carlin	X	X
	Testudinella patina (Hermann)	X	
	Trichocerca cylindrica (Imhof)	X	
	Trichotria tetractis (Ehr.)		X
	Bosmina longirostris (O.F.M.)	X	X
	Ceriodaphnia quadrangula (O.F.M.)	X	X
	Chydorus sphaericus (O.F.M.)	X	X
C L A D O C E R A	*Daphnia cucullata* Sars	X	X
	D. longispina (O.F.M.)	X	
	D. pulex Leydig	X	X
	Diaphanosoma lacustris Korinek	X	X
	Calanoida		
	Acanthodiaptomus denticornis (Wierzejski)	X	X
C O P E P O D A	Cyclopoida		
	Acanthocyclops robustus (Sars)	X	X
	Cyclops vicinus Uljanin	X	X
	Diacyclops bicuspidatus (Claus)	X	
	Harpacticoida	X	

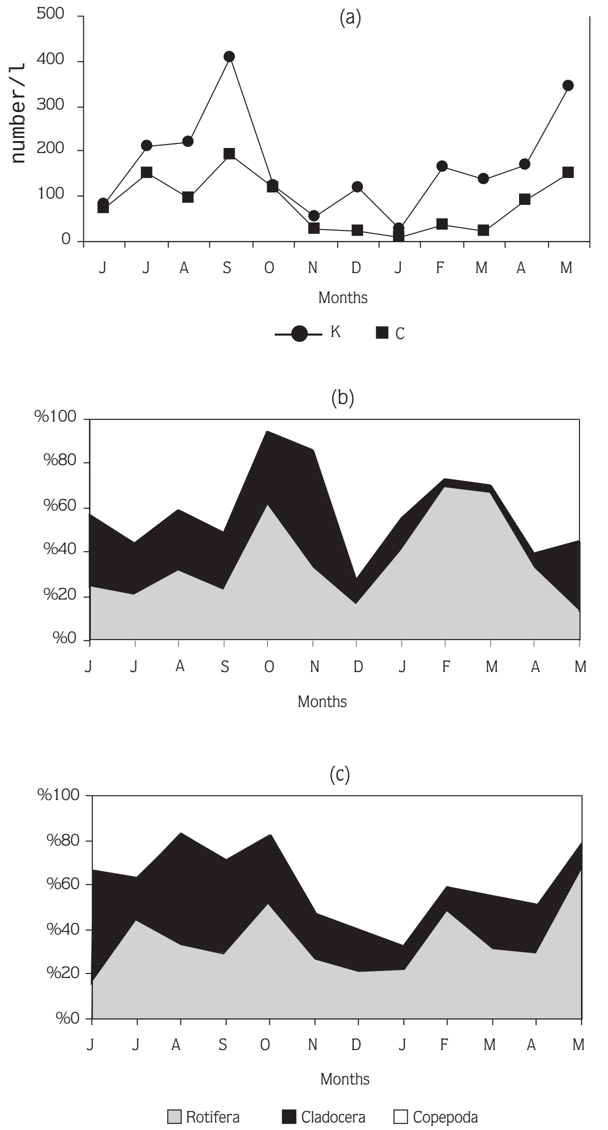

Figure 3. a, Mean values of zooplankton abundance in Kurtboğazı (K) and Çamlıdere (C) reservoirs. b, Seasonal variation in zooplankton composition in Kurtboğazı. c, Seasonal variation in zooplankton composition in Çamlıdere.

In Kurtboğazı the calanoid copepod *Acanthodiaptomus denticornis* showed an increase in June; apart from this the cyclopoid copepod *Cyclops vicinus* was dominant throughout the year. This was followed by *Acanthocyclops robustus* and *Diacyclops bicuspidatus*. Copepods composed more than 50% of the total zooplankton numbers in June, September, December, April and May. However, in Çamlıdere, calanoid copepods were dominant and cyclopoid numbers were higher in October, January, February, March and April.

Annual mean zooplankton numbers in Kurtboğazı were more than double those in Çamlıdere (Table 2). The highest numbers were recorded in September, 793 and 288 ind/l at 3 m depths in Kurtboğazı and Çamlıdere, respectively (Tables 4 and 5). After the mixing period in October, zooplankton abundance decreased throughout the water column.

Discussion

This study was conducted to determine the zooplankton composition in 2 drinking water reservoirs throughout the year. These reservoirs are a good drinking water supply, but eutrophication appeared to be gradually increasing due to the increase in blue-green algae (Demir and Atay, 1999).

According to the surface water quality parameters for drinking water (TSE, 1997), the reservoirs were classified as A1 with respect to water temperature, pH, conductivity, phosphorus and nitrate-N concentration and as A2 with respect to ammonia-N concentration. Alkalinity in the reservoirs was below the level of unwanted taste in water (Chow-Fraser and Trew, 1990).

Çamlıdere was evaluated as less productive with lower zooplankton abundance and higher Secchi depth than Kurtboğazı. The phytoplankton abundance and chlorophyll *a* values were also lower in Çamlıdere than in Kurtboğazı (Bakan Demir, 1997). Çamlıdere was constructed later than Kurtboğazı. The trophic state classification of reservoirs is problematic due to the often short water retention time, limited light transmission, and uncertain relationship between primary production and nutrients. Secchi depth may not be used for the evaluation of trophic state because light transmission can be prevented by abiotic suspended matter. When total phosphorus is used, reservoirs can remain in a more eutrophic class because of phosphorus not being transferred to the plankton due to the high turbidity and flow (Soballe and Bachman, 1984; Lind et al., 1993; Mallin et al., 1994). Trophic state classification may be used if the classification depends on the same parameter (Lind et al., 1993).

Polyarthra, Keratella, Asplanchna, Filinia and *Ascomorpha* were the dominant rotifers in both

Table 4. Monthly vertical variation of zooplankton abundance (number/l) (mean ± SE) in Kurtboğazı reservoir.

	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
0 m	65 ± 5	286 ± 23	91 ± 10	529 ± 25	143 ± 10	39 ± 5	117 ± 8	19 ± 4	64 ± 9	191 ± 13	221 ± 21	363 ± 18
1 m	106 ± 16	337 ± 14	349 ± 22	446 ± 27	123 ± 7	59 ± 6	120 ± 11	35 ± 5	160 ± 12	156 ± 12	252 ± 13	475 ± 17
2 m	131 ± 14	411 ± 22	392 ± 23	515 ± 38	189 ± 8	68 ± 5	159 ± 14	34 ± 5	214 ± 14	149 ± 15	264 ± 13	368 ± 20
3 m	120 ± 11	290 ± 14	333 ± 34	793 ± 39	159 ± 15	51 ± 4	120 ± 7	47 ± 5	171 ± 8	134 ± 14	295 ± 17	495 ± 22
5 m	94 ± 9	268 ± 12	233 ± 15	411 ± 20	116 ± 11	52 ± 7	148 ± 5	25 ± 6	211 ± 10	145 ± 10	211 ± 21	486 ± 15
8 m	75 ± 6	147 ± 21	216 ± 10	420 ± 27	136 ± 10	55 ± 4	138 ± 8	20 ± 4	160 ± 7	160 ± 17	97 ± 14	420 ± 27
12 m	80 ± 5	96 ± 10	253 ± 24	455 ± 18	84 ± 7	70 ± 8	149 ± 7	22 ± 5	236 ± 11	103 ± 10	98 ± 9	178 ± 12
20 m	67 ± 8	66 ± 7	113 ± 12	104 ± 18	93 ± 8	53 ± 5	108 ± 10	14 ± 2	139 ± 5	93 ± 7	83 ± 5	164 ± 16
30 m	25 ± 5	4 ± 1	8 ± 4	19 ± 2	66 ± 5	32 ± 4	7 ± 3	13 ± 3	124 ± 15	102 ± 11	23 ± 5	132 ± 18

Table 5. Monthly vertical variation of zooplankton abundance (number/l) (mean ± SE) in Çamlıdere reservoir.

May	J	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
0 m	97 ± 10	254 ± 11	23 ± 4	106 ± 5	32 ± 4	12 ± 2	15 ± 3	10 ± 2	1 ± 0	37 ± 2	9 ± 5	77 ± 5
1 m	68 ± 7	217 ± 8	127 ± 5	273 ± 9	158 ± 8	29 ± 6	34 ± 5	13 ± 1	42 ± 5	29 ± 4	165 ± 10	169 ± 9
2 m	125 ± 11	268 ± 17	218 ± 8	251 ± 8	163 ± 9	40 ± 6	40 ± 7	10 ± 4	54 ± 4	43 ± 8	138 ± 9	261 ± 7
3 m	134 ± 12	244 ± 10	231 ± 9	288 ± 7	192 ± 12	23 ± 5	41 ± 6	7 ± 3	46 ± 8	26 ± 10	143 ± 10	144 ± 10
5 m	159 ± 9	170 ± 11	162 ± 5	204 ± 5	165 ± 9	37 ± 7	38 ± 5	5 ± 2	39 ± 9	28 ± 11	110 ± 9	167 ± 11
8 m	43 ± 5	149 ± 10	87 ± 5	119 ± 8	111 ± 10	36 ± 8	25 ± 5	8 ± 2	73 ± 3	11 ± 5	144 ± 7	143 ± 12
12 m	22 ± 4	40 ± 5	17 ± 6	214 ± 9	181 ± 11	39 ± 7	14 ± 3	10 ± 2	36 ± 4	19 ± 6	68 ± 5	171 ± 9
20 m	22 ± 3	15 ± 2	16 ± 8	257 ± 4	63 ± 7	24 ± 4	8 ± 2	6 ± 1	35 ± 3	7 ± 1	61 ± 7	137 ± 4
30 m	6 ± 1	8 ± 1	6 ± 2	20 ± 3	6 ± 1	21 ± 2	5 ± 1	4 ± 1	20 ± 4	5 ± 1	7 ± 2	111 ± 10

reservoirs. Rotifers increased in September, February and March in Kurtboğazı and during May in Çamlıdere. *Keratella*, *Asplanchna* and *Polyarthra* were reported as eurythermal organisms frequently found in lakes, and peaks were observed 3-5 times a year (Herzig, 1987). *Polyarthra* was found throughout the year in Keban reservoir (Akbay, 1993). The cyclopoid copepod *Cyclops vicinus* was dominant in Kurtboğazı, and the calanoid *Acanthodiaptomus denticornis* in Çamlıdere. It was reported that calanoid copepods were predominant in oligomesotrophic lakes (Maier, 1996). Eutrophication increased the dominancy of cyclopoid copepods. *Cyclops vicinus* was a winter plankter but formed summer populations in lakes containing high amounts of organic matter. From the Cladocera, there was an increase in *Daphnia* in June, in *Ceriodaphnia* in July, and in *Diaphanosoma* in August, while rotifers decreased. Cladocerans have been reported to generally increase in late spring and summer (Dokulil et al., 1990), with a possible interrelationship between rotifers and cladocerans as predators and competitors (Herzig, 1987). Fishing is not allowed in drinking water reservoirs and the effects of selective feeding of fish must be considered in further studies.

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References

Akbay, N. 1993. Keban Baraj Gölünün Ova Kısmında Fito-Zooplanktonun Horizontal ve Vertikal Dağılımı. Yük. Lis. Tezi, Fırat Üniversitesi, Elazığ, 70 s.

APHA, 1975. Standard Methods for the Examination of Water and Wastewater. 14th ed. American Public Health Association, Washington D.C.

Aykulu, G. and Obalı, O. 1981. Phytoplankton biomass in the Kurtboğazı dam lake. Comm. de la Fac. Sci. d'Ank. 24: 29-45.

Bakan Demir, N. 1997. Ankara'ya Su Sağlayan Kurtboğazı ve Çamlıdere Baraj Gölleri ile İvedik Su Arıtım Tesisi'nde Plankton Kompozisyonunun Karşılaştırmalı Olarak İncelenmesi. Doktora Tezi. Ankara Üniversitesi, Ankara, 112 s.

Chow-Fraser, P. and Trew, D.O. 1990. A Compendium of Limnological Data for 23 Lakes in the Beaver River Watershed. Alberta Environ., Edmonton.

Demir, N. and Atay, D. 1999. Kurtboğazı ve Çamlıdere Baraj Göllerinin Fitoplanktonu. X. Ulusal Su Ürünleri Sempozyumu, Cilt II, Adana, pp. 577-587.

Dokulil, M., Herzig, A. and Jagsch, A. 1990. Trophic relationships in the pelagic zone of Mondsee, Austria. Hydrobiologia, 191: 199-212.

DSİ. 1981. Kurtboğazı Baraj Gölü Limnolojik ve Hidrobiyolojik Özelliklerinin Tesbiti (1979-1981). DSİ, Ankara.

DSİ. 1996. Türkiye'deki Barajlar ve Hidroelektrik Santraller. DSİ, Ankara.

Herzig, A. 1987. The analysis of planktonic rotifer populations: A plea for long-term investigations. Hydrobiologia, 147: 163-180.

Kiefer, F. and Fryer, G. 1978. Das Zooplankton des Binnengewasser. 2. Teil. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Koste, W. 1978. Rotatoria, Die Radiertiere Mitteleuropas. 2 Bande. Gebrüder Borntraeger, Berlin.

Lind, O.T., Terrell, T.T. and Kimmel, B.G. 1993. Problems in reservoir trophic-state classification and implications for reservoir management. In: Comparative Reservoir Limnology and Water Quality Management (Eds. M. Straskaba, J.G. Tundisi and A. Duncan), Kluwer, The Netherlands, pp. 57-67.

Maier, G. 1996. Copepod communities in lakes of varying trophic degree. Arch. Hydrobiol. 136: 455-465.

Mallin, M.A., Stone, K.L. and Pamperl, M.A. 1994. Phytoplankton community assessments of seven Southeast U.S. cooling reservoirs. Water Research, 28: 665-673.

Negrea, S. 1983. Fauna Republicii Socialiste Romania, Crustacea Cladocera. Vol. 4, Editura Academiei Republicii Socialiste Romania Press, Bucureşti.

Soballe, D.M. and Bachman, R.W. 1984. Influence of reservoir transit on riverine algal transport and abundance. Can. J. Fish. Aquat. Sci. 41: 1803-1813.

TSE. 1997. Sular-İçme ve Kullanma Suları. Türk Standardları Ens., Yay. No. 266, Ankara.

Wetzel, R.G. and Likens, G.E. 1991. Limnological Analysis. 2nd ed. Springer Verlag, New York.