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SEASONAL VARIATIONS IN THE LENGTH OF ZOOPLANKTON RELATED TO CERTAIN PHYSICOCHEMICAL VARIABLES IN TWO FRESHWATER RESERVOIRS

BY

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ABSTRACT

Seasonal variations in the body length of zooplankton were studied in relation to water temperature, nitrate (NO_3), soluble reactive phosphorus (SRP), total chlorophyll, Secchi disk depth, pH, conductivity, and oxidation-reduction potential (ORP) in a mesotrophic (Ikizcetepeler) and a eutrophic (Çaygören) reservoir from February 2007 to March 2008. During the study, the body lengths of a total of 7590 zooplankton specimens (1110 rotifers, 3270 cladocerans, and 3210 copepods) were measured. The length of the majority of the species was significantly smaller in summer than in winter, fall, and spring, including that of the most dominant species, *Asplanchna priodonta*, *Daphnia galeata*, *Daphnia longispina*, *Diaphanosoma brachyurum*, *Bosmina longirostris*, *Leptodora kindtii*, *Ceriodaphnia pulchella*, *Cyclops vicinus*, *Metacyclops gracilis*, and *Acanthocyclops robustus* ($F > 5$, $p < 0.05$). Correspondence analysis (CA) showed that the body length of the zooplankton studied was inversely related to water temperature, whereas it was positively related to ORP and pH. The results of our study suggest that, although nutrients (NO_3 and SRP) apparently have an effect on zooplankton body length only in the mesotrophic reservoir, temperature influences the body length in both the mesotrophic and the eutrophic reservoir.

RÉSUMÉ

Les variations saisonnières de la longueur du corps de différentes espèces du zooplancton ont été étudiées en fonction de la température, des nitrates (NO_3), du phosphore réactif soluble (SRP), de la chlorophylle totale, de la profondeur au disque de Secchi, du pH, de la conductivité, du potentiel d'oxydo-réduction (ORP), dans un réservoir mésotrophe (Ikizcetepeler) et dans un réservoir eutrophe (Çaygören) de février 2007 à mars 2008. Au cours de cette étude, les longueurs du corps d'un total de 7590 spécimens du zooplancton (1110 rotifères, 3270 cladocères, et 3210 copépodes) ont été mesurées. La longueur de la majorité des espèces était significativement inférieure en été par rapport

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à celles mesurées en hiver, à l'automne et au printemps, y compris celle des espèces dominantes, *Asplanchna priodonta*, *Daphnia galeata*, *Daphnia longispina*, *Diaphanosoma brachyurum*, *Bosmina longirostris*, *Leptodora kindtii*, *Ceriodaphnia pulchella*, *Cyclops vicinus*, *Metacyclops gracilis*, et *Acanthocyclops robustus* ($F > 5$, $p < 0{,}05$). L'analyse des correspondances (CA) a montré que la longueur du corps chez les espèces étudiées était inversement liée à la température de l'eau, alors qu'elle était positivement corrélée à l'ORP et au pH. Les résultats de notre étude suggèrent que, bien que les nutriments (NO_3 et SRP) aient apparemment un effet sur la longueur du corps des zooplanctontes seulement dans le réservoir mésotrophe, la température a une influence sur la longueur du corps, dans les deux réservoirs, mésotrophe et eutrophe.

INTRODUCTION

Variations in biotic and abiotic environmental factors influence the distribution, abundance, and body size of zooplankton (Liu et al., 2003). Biological processes such as migration, reproduction, predation, and competition shape the population dynamics of zooplankton communities. Likewise, these communities are affected by environmental variables such as water temperature, conductivity, pH, oxidation-reduction potential, and food supply (Dupuis & Hann, 2009).

Temperature has been recognized as the most important factor affecting rates of biological processes such as plankton growth, and filtering and assimilation rates (McLaren et al., 1989; Beisner et al., 1997; Güntzel et al., 2003). The importance of temperature in the population dynamics of zooplankton is also increasing, given the anticipated effects of global warming on aquatic systems (Dupuis & Hann, 2009). The majority of the species of the zooplankton are dependent upon a narrow range of temperature and high concentrations of food for successful reproduction and growth (Chen & Folt, 2002).

Although a number of environmental factors can influence growth, size, reproduction, and survival of zooplankton, water temperature as well as the quality and availability of food are considered to be critical (Vijverberg, 1989). Seasonal variation in zooplankton size has been reported under different climatic conditions (low, temperate, and high temperatures) and dietary regimes (Hopp et al., 1997; Rukert & Giani, 2008).

Environmental variables that are invoked to explain changes in zooplankton body size include temperature, food quality and availability, and size-selective predation (McLaren, 1963, 1965), but there seems to be little consensus about a single variable that could explain all cases. Differences between species' responses to environmental factors (i.e., temperature, pH, dissolved oxygen, phytoplankton concentration) are the result of differences in the species' requirements and strategies for withstanding environmental changes, while the effect of predation on the size of different species reflects both predator preferences and the prey's ability to avoid predation (Rykken et al., 2007).

The principal generalization concerning the size structure of zooplankton and the trophic state of a lake is, that oligotrophic lakes are often dominated by large calanoid copepods, versus eutrophic lakes by smaller cyclopoid copepods, rotifers, and cladocerans (McNaught, 1975). It has also been argued that oligotrophic environments may contain insufficient energy to support small bacterivorous ciliates and rotifers (Pace, 1982).

Whatever factor drives body size variation, differences between species and different developmental stages of the same species can be expected, as have been observed in various studies (McLaren, 1963, 1965; Warren et al., 1986). The body size of rotifers is primarily genetically determined, though it changes slightly under the influence of environmental factors like temperature, salinity, and food type (Yang & Chou, 2000).

We studied the seasonal length variations of zooplankton species in relation to water temperature, conductivity, pH, oxidation-reduction potential, Secchi disk depth, and concentrations of nitrate, phosphate (soluble reactive phosphorus, SRP), and chlorophyll *a* in the Ikizcetepeler and Çaygören reservoirs, Turkey.

We hypothesized that different levels of nutrients and water temperature have significant effects on the body length of zooplankton species in freshwater lakes. Correspondence Analysis (Ter Braak & Verdonschot, 1995; Yelland, 2010) was used to elucidate the seasonal length variations of zooplankton species in relation to the measured physicochemical parameters in the Ikizcetepeler and Çaygören reservoirs, in order to find out if different levels of these parameters have significant effects on the length of zooplankton in freshwater reservoirs with different trophic states.

MATERIAL AND METHODS

Ikizcetepeler Reservoir is a mesotrophic (Carlson, 1977; OECD, 1982; Rast & Holland, 1988; Matthews et al., 2002; Karadžić et al., 2010) man-made lake with an annual mean chlorophyll *a* concentration of 5.5 μg L^{-1} and Secchi disk depth of 1.75 m. Rast & Holland (1988) give the boundary values of chlorophyll *a* and a Secchi disk depth for the trophic classification of lakes. According to these values, Ikizcetepeler is a mesotrophic lake. The reservoir is located at 39°29′N 27°56′E, 15 kilometers southwest of Balıkesir, Turkey, and it lies at 175 m above sea level (fig. 1). The reservoir has a maximum depth of 25 m, a length of 6.34 km, and a surface area of 10 km^2. It is mainly fed by the Kile Stream. The maximum inflow ($5 \cdot 10^3$ m^3 s^{-1}) to the reservoir occurred in spring, and the minimum (25 m^3 s^{-1}) in the fall. The reservoir was built in 1992 and it is used for irrigation and providing drinking water (State Water Works, 2005).

Fig. 1. Map of the Ikizcetepeler and Çaygören reservoirs and the location of the sampling stations [courtesy Google Earth: © 2011 Google].

Çaygören Reservoir is a eutrophic (Carlson, 1977; OECD, 1982; Rast & Holland, 1988; Matthews et al., 2002; Karadžić et al., 2010) man-made lake with an annual mean chlorophyll *a* concentration of 16 μg L^{-1} and a Secchi disk depth of 1 m. According to the results of Karadžić et al. (2010) on the range of physical and chemical parameters for the trophic classification of reservoirs, the Çaygören Reservoir could be considered eutrophic. The reservoir is located at 38°51′N 27°86′E, 55 kilometers southeast of Balıkesir, Turkey and it lies at 273 m above sea level (fig. 1). It has a maximum depth of 28 m, a length of 4.6 km, and a surface area of 9 km^2. The reservoir is mainly fed by the Simav Stream. The maximum inflow ($87 \cdot 10^3$ m^3 s^{-1}) to the reservoir occurred in spring, and the minimum ($13 \cdot 10^2$ m^3 s^{-1}) in the fall. The reservoir was built in 1971 and it is used for irrigation and power generation (State Water Works, 2005).

Three sampling stations were set in each reservoir. The maximum depths of the first, second and third stations in Ikizcetepeler Reservoir were 10, 14, and 20 m, respectively. The maximum depths of the first, second, and third stations in Çaygören Reservoir were 12, 18, and 24 m, respectively. Sampling was started in February 2007 and ended in March 2008. Soluble reactive phosphorus (SRP) and nitrate (NO_3) concentrations were determined spectrophotometrically on filtered water (APHA, 1995). Measurements of water temperature, conductivity, pH, oxidation-reduction potential, and chlorophyll *a* were taken using a YSI water quality multi-probe.

Zooplankton was sampled with vertical net hauls using a 0.30 m diameter net with 60 μm mesh size at three stations in each reservoir. Vertical tows were carried out from the bottom to the surface. Samples were fixed and preserved with 4% formaldehyde in 500 mL plastic bottles immediately after collection. Zooplankton specimens were identified, counted, and measured under an inverted microscope. Counting was done in Petri dishes from 4 mL sub-samples.

In the laboratory, the male and female sexes (with and without egg sacks) were also sorted under an inverted microscope. The total body length of 30 adults of each species of Rotifera and Cladocera (Cladocera females only) and of 60 adults (30 males + 30 females) of each species of Copepoda species were measured monthly for each sample, with an ocular micrometer (100 subdivisions) at 10× magnification.

The following taxonomic keys were used for zooplankton identification: Stemberger (1979) and Koste (1978) for Rotifera; Borutsky (1964), Dussart (1969), and Kiefer & Fryer (1978) for Copepoda; Scourfield & Harding (1966), Negrea (1983), and Amoros (1984) for Cladocera. Species were identified and counted under an inverted microscope in the Plankton Laboratory of the Fisheries Faculty, Mustafa Kemal University, Iskenderun, Turkey.

The Detrended Correspondence Analysis (DCA) was used to detect the length of the environmental gradient. After DCA, Correspondence Analysis (CA) was applied to the data to determine the relationships between water temperature, conductivity, pH, oxidation-reduction potential, soluble reactive phosphorus, nitrate, chlorophyll *a*, and the body length of zooplankton using the CANOCO program (Ter Braak & Smilauer, 2002).

Pearson correlations between the body length of the dominant species and the population density of rotifers were also determined using the program SAS (SAS Institute, 2003). An analysis of variance (ANOVA) test was applied to the data for determining the statistical differences in chlorophyll *a* and nutrient concentrations among the sampling stations, and a t-test was used to determine the differences in body length of the zooplankton between seasons, using the SAS program. The data for each variable were allocated to four seasons (September, October, and November for fall; December, January, and February for winter; March, April, and May for spring; and June, July, and August for summer). The t-test procedure was run for each variable and each reservoir.

RESULTS

The mean and standard deviation of water temperature (°C), nitrate (NO_3; mg L^{-1}), soluble reactive phosphorus (SRP; mg L^{-1}), chlorophyll *a* (Chl.; μg L^{-1}), Secchi disk depth (cm), pH, conductivity (mS cm^{-1}), total dissolved solids (TDS; g L^{-1}) and oxidation-reduction potential (ORP; mV) in the Çaygören and Ikizcetepeler reservoirs, from February 2007 to March 2008, are given in table I.

During the study, a total of 7590 specimens (1110 rotifers, 3270 cladocerans, and 3210 copepods) were collected. The body size of *Asplanchna priodonta* Gosse, 1850, *Daphnia galeata* Sars, 1864, *Daphnia longispina* (O. F. Müller, 1776), *Diaphanosoma brachyurum* (Liévin, 1848), *Bosmina longirostris* (O. F. Müller, 1776), *Leptodora kindtii* (Focke, 1844), *Ceriodaphnia pulchella* Sars, 1862, *Cyclops vicinus* Uljanin, 1875, *Metacyclops gracilis* (Lilljeborg, 1853), and *Acanthocyclops robustus* (G. O. Sars, 1863) varied with the seasons. The summer specimens of these common species were significantly smaller than those of the winter samples ($t = 11$, $p < 0.01$), spring ($t = 5$, $p < 0.05$), and autumn ($t = 5.5$, $p < 0.05$). The seasonal variations in the lengths of these common zooplankters were significant ($F = 6.2$, $p < 0.05$; table II, fig. 2).

A. priodonta reached its maximum length in January and October. The maximum length of *D. galeata* was recorded in February. *D. longispina* reached its maximum length in March. The maximum length of *D. brachyurum* was measured in December. *B. longirostris* and *C. pulchella* reached their maximum lengths

TABLE I

The mean and standard deviation of water temperature (°C), nitrate (NO_3) (mg L^{-1}), phosphate (SRP) (mg L^{-1}), chlorophyll (μg L^{-1}), Secchi disk depth (cm), pH, conductivity (mS cm^{-1}), total dissolved solids (TDS) (g L^{-1}), and oxidation-reduction potential (ORP) (mV) in the Çaygören and Ikizcetepeler reservoirs from February 2007 to March 2008

	Secchi (cm)	Conduct. (mS cm^{-1})	TDS (g L^{-1})	pH	ORP (mV)	Temp. (°C)	Chl. (μg L^{-1})	NO_3 (mg L^{-1})	SRP (mg L^{-1})
Çaygören Reservoir									
F	85 ± 5.00	0.52 ± 0.05	0.34 ± 0.03	9.43 ± 0.24	43.11 ± 45.47	6.82 ± 0.43	25.66 ± 4.98	2.09 ± 0.18	0.06 ± 0.02
M	123 ± 7.64	0.52 ± 0.01	0.34 ± 0.001	9.55 ± 0.09	110.32 ± 10.12	8.57 ± 0.26	12.39 ± 7.38	1.79 ± 0.27	0.14 ± 0.07
A	112 ± 22.55	0.53 ± 0.01	0.34 ± 0.002	9.41 ± 0.07	98.04 ± 32.38	13.32 ± 1.42	5.02 ± 2.32	1.43 ± 0.35	0.15 ± 0.01
M	140 ± 57.66	0.53 ± 0.01	0.35 ± 0.006	9.44 ± 0.10	103.29 ± 16.34	17.61 ± 3.22	6.00 ± 3.80	2.29 ± 0.27	0.15 ± 0.01
J	108 ± 12.58	0.47 ± 0.03	0.34 ± 0.001	9.37 ± 0.24	86.93 ± 38.49	20.54 ± 4.45	4.77 ± 3.12	2.28 ± 0.39	0.18 ± 0.06
J	80 ± 10.00	0.47 ± 0.03	0.33 ± 0.004	9.41 ± 0.34	64.88 ± 37.37	22.45 ± 2.81	7.19 ± 4.36	2.28 ± 0.39	0.19 ± 0.12
A	90 ± 10.00	0.49 ± 0.04	0.35 ± 0.003	8.75 ± 0.42	69.37 ± 69.88	20.41 ± 5.25	15.07 ± 9.62	2.07 ± 0.19	0.28 ± 0.05
S	63 ± 5.77	0.51 ± 0.01	0.37 ± 0.002	9.41 ± 0.39	89.37 ± 38.71	19.27 ± 0.66	11.86 ± 9.45	2.31 ± 0.24	0.25 ± 0.09
O	53 ± 11.55	0.48 ± 0.01	0.37 ± 0.001	10.09 ± 0.12	103.39 ± 6.99	16.61 ± 0.09	16.02 ± 10.66	1.72 ± 0.41	0.29 ± 0.18
N	57 ± 10.41	0.46 ± 0.02	0.41 ± 0.02	9.19 ± 0.17	77.25 ± 17.73	10.79 ± 0.34	16.17 ± 9.55	1.50 ± 0.01	0.16 ± 0.02
D	58 ± 11.55	0.33 ± 0.01	0.33 ± 0.001	9.16 ± 0.15	156.22 ± 8.84	6.97 ± 0.42	2.72 ± 0.35	1.21 ± 0.18	0.34 ± 0.02
J	128 ± 7.64	0.33 ± 0.01	0.35 ± 0.001	10.17 ± 0.14	131.65 ± 18.37	5.20 ± 0.13	10.15 ± 4.29	1.61 ± 0.09	0.31 ± 0.01
F	167 ± 15.27	0.34 ± 0.01	0.36 ± 0.01	9.85 ± 0.57	135.40 ± 41.92	4.88 ± 0.37	6.41 ± 2.66	2.07 ± 0.18	0.26 ± 0.02
M	80 ± 43.59	0.36 ± 0.03	0.33 ± 0.03	10.42 ± 0.13	132.22 ± 12.36	9.83 ± 1.05	16.03 ± 8.42	2.00 ± 0.00	0.28 ± 0.02
Mean	96.07 ± 34.69	0.45 ± 0.08	0.35 ± 0.02	9.55 ± 0.44	100.10 ± 31.37	13.09 ± 6.27	11.11 ± 6.30	1.90 ± 0.36	0.22 ± 0.08

TABLE I
(Continued)

	Secchi (cm)	Conduct. (mS cm^{-1})	TDS (g L^{-1})	pH	ORP (mV)	Temp. (°C)	Chl. (μg L^{-1})	NO_3 (mg L^{-1})	SRP (mg L^{-1})
İkizcetepeler Reservoir									
F	100 ± 0.00	0.37 ± 0.01	0.25 ± 0.003	9.40 ± 0.13	183.68 ± 12.85	8.35 ± 0.08	7.35 ± 2.19	2.43 ± 0.19	0.14 ± 0.001
M	177 ± 5.77	0.37 ± 0.01	0.24 ± 0.002	9.08 ± 0.31	145.68 ± 29.94	9.85 ± 0.23	7.09 ± 2.53	1.86 ± 0.38	0.26 ± 0.06
A	337 ± 63.51	0.38 ± 0.00	0.25 ± 0.001	9.64 ± 0.10	105.71 ± 12.91	12.81 ± 1.22	1.51 ± 0.65	2.36 ± 0.48	0.15 ± 0.00
M	240 ± 40.00	0.38 ± 0.003	0.25 ± 0.002	9.45 ± 0.19	103.54 ± 20.83	18.24 ± 3.56	2.28 ± 0.98	2.64 ± 0.24	0.16 ± 0.04
J	167 ± 18.93	0.35 ± 0.03	0.24 ± 0.01	9.73 ± 0.22	94.13 ± 16.84	21.71 ± 5.26	3.03 ± 1.10	2.50 ± 0.01	0.33 ± 0.13
J	170 ± 26.46	0.36 ± 0.02	0.27 ± 0.003	9.55 ± 0.17	94.56 ± 10.55	22.84 ± 2.96	4.70 ± 3.69	2.50 ± 0.00	0.37 ± 0.09
A	85 ± 15.00	0.39 ± 0.001	0.25 ± 0.002	9.46 ± 0.19	99.61 ± 19.01	24.80 ± 0.46	10.20 ± 4.05	2.50 ± 0.01	0.31 ± 0.00
S	83 ± 5.77	0.35 ± 0.002	0.26 ± 0.002	9.65 ± 0.08	115.48 ± 7.79	19.70 ± 0.55	5.32 ± 0.71	2.00 ± 0.00	0.15 ± 0.00
O	140 ± 5.00	0.34 ± 0.001	0.26 ± 0.001	9.89 ± 0.13	118.49 ± 2.42	17.36 ± 0.11	2.03 ± 0.53	2.50 ± 0.01	0.17 ± 0.06
N	157 ± 5.77	0.30 ± 0.001	0.26 ± 0.002	9.51 ± 0.14	116.72 ± 15.86	11.97 ± 0.12	1.66 ± 0.99	1.50 ± 0.00	0.15 ± 0.00
D	105 ± 8.66	0.26 ± 0.002	0.25 ± 0.002	9.46 ± 0.17	144.17 ± 6.13	7.32 ± 0.17	2.81 ± 0.94	1.19 ± 0.09	0.31 ± 0.15
J	177 ± 5.77	0.25 ± 0.003	0.26 ± 0.002	9.77 ± 0.13	161.57 ± 5.24	5.56 ± 0.33	4.72 ± 2.16	2.00 ± 0.00	0.26 ± 0.02
F	167 ± 11.55	0.25 ± 0.001	0.26 ± 0.003	10.25 ± 0.11	125.29 ± 8.46	4.87 ± 0.47	3.91 ± 2.42	1.50 ± 0.00	0.25 ± 0.00
M	123 ± 2.88	0.29 ± 0.005	0.26 ± 0.001	10.09 ± 0.16	167.29 ± 8.62	10.48 ± 0.58	2.30 ± 0.53	1.00 ± 0.00	0.28 ± 0.03
Mean	159.05 ± 66.92	0.33 ± 0.05	0.25 ± 0.01	9.64 ± 0.30	126.85 ± 28.92	13.99 ± 6.69	4.21 ± 2.56	2.03 ± 0.55	0.24 ± 0.08

TABLE II

Seasonal variations in the length in the lenght of the common zooplankton species in the Çaygören and Ikizcetepeler reservoirs from February 2007 to March 2008. Spr., spring; Summ., summer; Wint., winter; Max., maximum; and Min., minimum

Species	Çaygören Reservoir			Ikizcetepeler Reservoir		
	Spr.-Summ.	Summ.-Wint.	Max.-Min.	Spr.-Summ.	Summ.-Wint.	Max.-Min.
Daphnia longispina (O. F. Müller, 1776)	0.39	0.20	0.21	0.34	0.09	0.27
Bosmina longirostris (O. F. Müller, 1776)	0.06	0.09	0.21	0.27	0.28	0.27
Ceriodaphnia pulchella Sars, 1862	–	–	–	0.22	0.45	0.44
Cyclops vicinus Uljanin, 1875	0.22	0.45	0.44	0.10	0.16	0.17
Acanthocyclops robustus (G. O. Sars, 1863)	0.02	0.90	0.10	0.08	0.09	0.17
Asplanchna priodonta Gosse, 1850	0.17	0.20	0.21	0.33	0.32	0.34
Moina micrura Kurz, 1874	0.12	0.11	0.13	0.01	0.01	0.03
Metacyclops gracilis (Lilljeborg, 1853)	0.10	0.11	0.12	–	–	–
Leptodora kindtii (Focke, 1844)	1.17	1.47	1.48	–	–	–
Daphnia galeata Sars, 1864	0.25	0.48	0.45	–	–	–
Diaphanosoma brachyurum (Liévin, 1848)	0.40	0.12	0.40	0.15	0.12	0.26

in February. The maximum length of *C. vicinus* was measured in February and March. Female *C. vicinus* reached their maximum length in March. The maximum length of *M. gracilis* was measured in February and in April. *L. kindtii*'s longest specimens were recorded in November. Female *A. robustus* reached their maximum length in April and November. The maximum length of the male *A. robustus* was measured in November and December (table III).

In the Çaygören reservoir, the first and second axes of CA explained 99.5% of the variance in the body length of zooplankton-environment relationships (Eigenvalues, 0.54 and 0.02, respectively). The third and fourth axes together explained 0.4% of the variance (Eigenvalues, 0.001 and 0.001). The length gradients detected by DCA were 2.43 for the first axis, 1.45 for the second axis, 1.07 for the third axis, and 0.18 for the fourth axis.

In the CCA diagram of Çaygören Reservoir, *A. priodonta*, *A. robustus*, *Moina micrura* Kurz, 1874, and *L. kindtii* occurred near the ORP vector. *D. galeata* and *M. gracilis* occurred near the Secchi disk vector. *D. longispina* and *B. longirostris* occurred near the pH and ORP vectors. *A. priodonta*, *A. robustus*, *M. micrura*, and *L. kindtii* occurred on the opposite side of the SRP, NO_3, and chlorophyll vectors. *M. gracilis*, *D. longispina*, and *B. longirostris* occurred on the opposite side of the water temperature vector (fig. 3).

In the Ikizcetepeler reservoir, the first and second axes of CCA explained 90.3% of the variance in body length of the zooplankton-environment relationships (Eigenvalues, 0.4 and 0.3, respectively). The third and fourth axes together explained 7% of the variance (Eigenvalues, 0.001 and 0.001). The length gradients

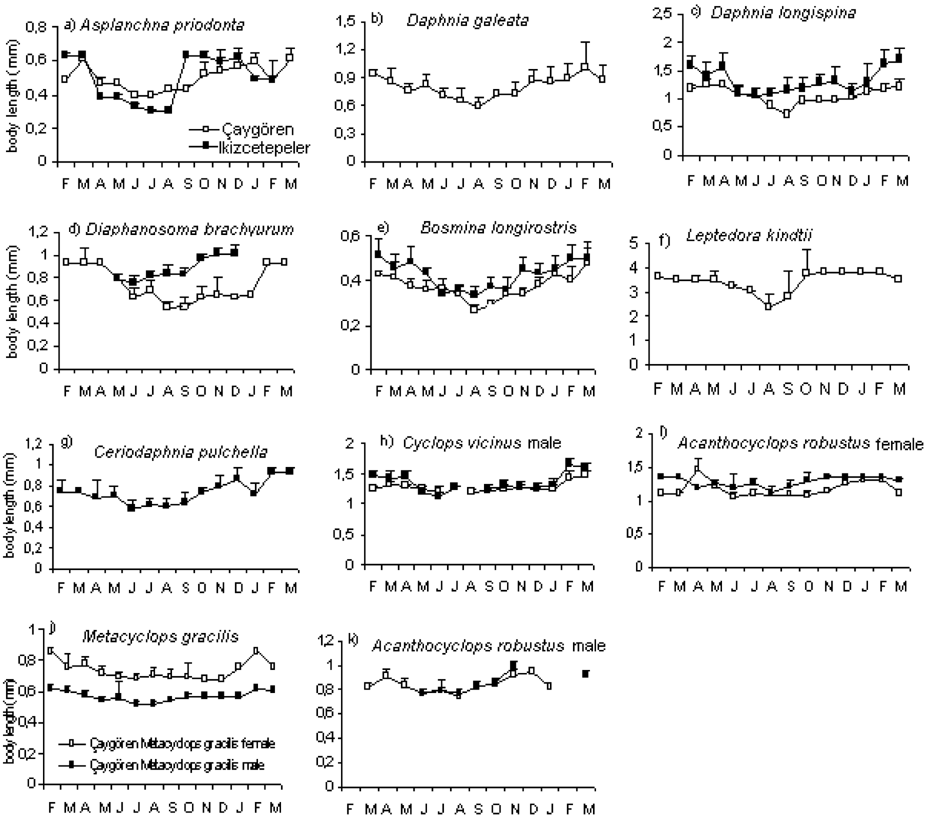

Fig. 2. Body length of the most abundant zooplankton species in the Çaygören and Ikizcetepeler reservoirs over a year cycle.

detected by DCA were 1.02 for the first axis, 1.02 for the second axis, 0.12 for the third axis, and 0.115 for the fourth axis.

In the CCA diagram of Ikizcetepeler Reservoir, *A. priodonta*, *A. robustus*, *D. brachyurum*, and *C. vicinus* occurred near the ORP vector. *M. gracilis* and *M. micrura* occurred near the SRP and Secchi disk vectors. *B. longirostris*, *C. pulchella*, and *D. longispina* occurred together near the pH vector. The majority of these species occurred on the opposite side of the water temperature and NO_3 vectors (fig. 4).

DISCUSSION

All zooplankton species showed larger body lengths during cold weather (winter), while having smaller lengths during summer (June, July, and August) in both reservoirs. The observed seasonal variations in body length of zooplankton

TABLE III

Maximum and minimum of the mean body length of the common zooplankton species in the Çaygören and Ikizceteler reservoirs; for full names of species see table II

		Maximum and minimum body length (mm) of zooplankton species in Çaygören Reservoir					Maximum and minimum body length (mm) of zooplankton species in Ikizcetepeler Reservoir				
		Max length	**Month**	**Min length**	**Month**	**Mean length**	**Max length**	**Month**	**Min length**	**Month**	**Mean length**
Rotifera											
A. priodonta (n = 253)		0.61	Mar.	0.43	Sep	0.53 ± 0.06	0.63	Feb.	0.29	Jul.	0.49 ± 0.13
Cladocera											
D. galeata (n = 165)		1.01	Feb.	0.59	Aug.	0.81 ± 0.12	–	–	–	–	–
D. longispina (n = 183)		1.26	Mar.	0.97	Nov.	1.13 ± 0.10	1.69	Mar.	1.05	Jun.	1.32 ± 0.22
D. brachyurum (n = 265)		0.93	Mar.	0.54	Aug.	0.67 ± 0.13	1.02	Dec.	0.75	Jun.	0.87 ± 0.11
M. micrura (n = 211)		0.59	Jan.	0.48	Aug.	0.55 ± 0.05	0.79	May.	0.74	Jul.	0.76 ± 0.02
B. longirostris (n = 321)		0.48	Mar.	0.27	Aug.	0.37 ± 0.06	0.52	Feb.	0.34	Aug.	0.43 ± 0.06
L. kindtii (n = 54)		3.82	Nov.	2.35	Aug.	3.22 ± 0.53	–	–	–	–	–
C. pulchella (n = 113)		–	–	–	–	–	0.93	Feb.	0.58	Jun.	0.73 ± 0.12
Copepoda											
C. vicinus (n = 131)	♂ (35)	1.43	Feb.	1.20	Jun.	1.28 ± 0.08	1.63	Feb.	1.20	May.	1.35 ± 0.15
	♀ (53)	1.85	Mar.	1.38	Aug.	1.62 ± 0.14	1.91	Mar.	1.46	Jun.	1.69 ± 0.16
A. robustus (n = 145)	♂ (82)	0.94	Dec.	0.74	Aug.	0.84 ± 0.07	1.00	Nov.	0.77	Aug.	0.85 ± 0.09
	♀ (65)	1.45	Apr.	1.05	Jun.	1.17 ± 0.13	1.34	Nov.	1.13	Aug.	1.24 ± 0.07
M. gracilis (n = 65)	♂ (71)	0.62	Feb.	0.51	Jul.	0.56 ± 0.04	–	–	–	–	–
	♀ (62)	0.78	Apr.	0.67	Nov.	0.72 ± 0.04	–	–	-	–	–

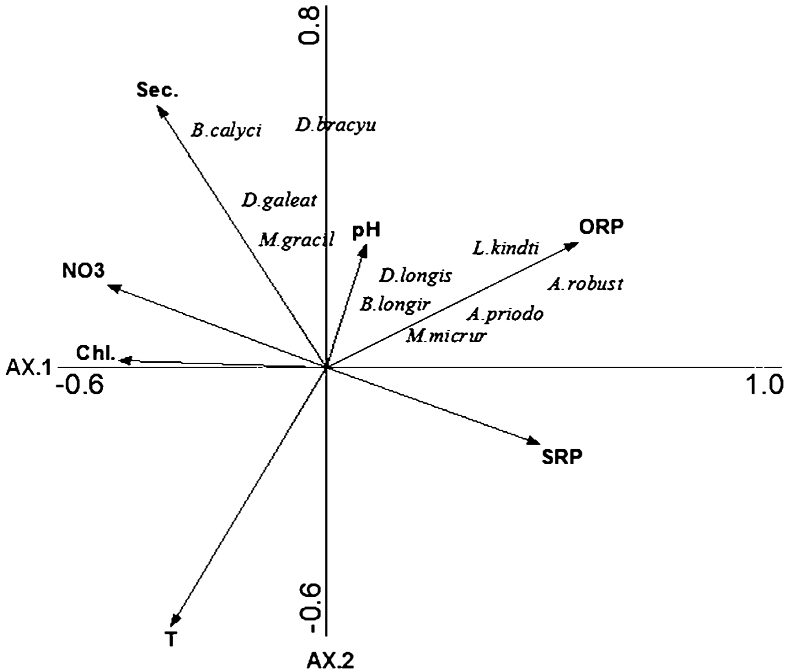

Fig. 3. Diagram of the Correspondence Analysis (CA) showing the relationships between the body size of the most common zooplankters and the physicochemical parameters in Çaygören Reservoir. For full scientific names of the species, see table II.

(Rotifera, Cladocera, and Copepoda) are typical for temperate, subtropical, and boreal waters (Kiefer & Fryer, 1978). The species showed a tendency towards a reduction of body length in summer, while showing an opposite trend in winter, spring, or autumn. This constitutes a clear effect of water temperature on the body size of zooplankton.

The CA results showed the effects of temperature on zooplankton body length clearly by placing most of the common zooplankton species opposite to the water temperature vector in both reservoirs. Vijverberg (1989) found that the body length of zooplankton was strongly related to water temperature, while culturing zooplankton in the laboratory. The results of this study conform to the results of Coker (1933) and McLaren (1963, 1965), suggesting that water temperature is the primary determinant of the body size of most species of zooplankton.

Nutrient concentrations have been found to be effective on the body size of zooplankton (Manca et al., 1994). In our study, CA showed that nutrients were positively correlated with the body length of the common zooplankton species in the mesotrophic Ikizcetepeler Reservoir, while they were inversely related to body length in the eutrophic Çaygören Reservoir.

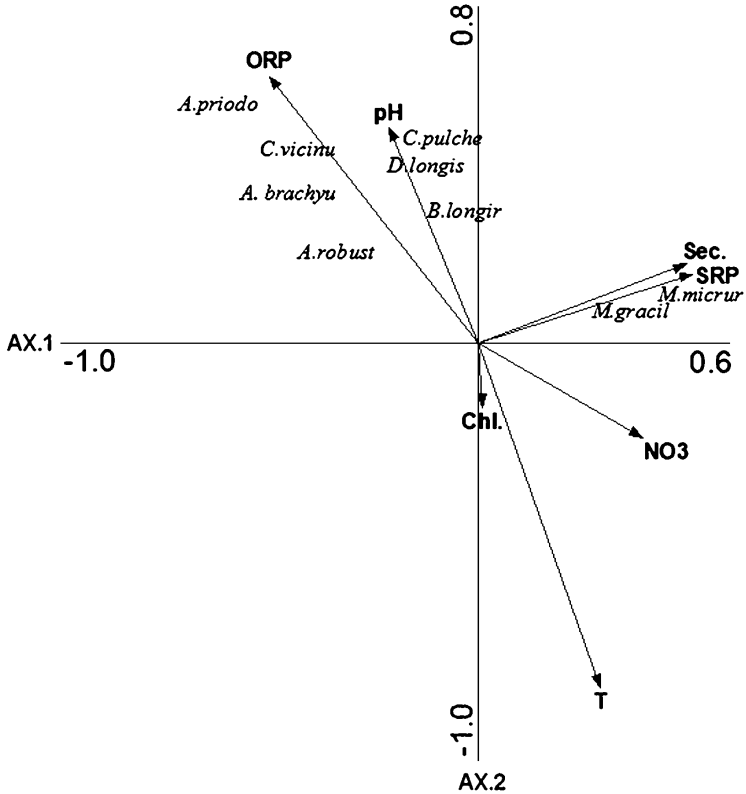

Fig. 4. Diagram of Correspondence Analysis (CA) showing the relationships between the body size of the most common zooplankters and the physicochemical parameters in Ikizcetepeler Reservoir. For full scientific names of the species, see table II.

Harman et al. (1995) found that 36% of the crustacean zooplankton of a mesotrophic lake was larger in total length (TL) compared to a range of 11-20% in three eutrophic lakes. Bays & Crisman (1983) found an increase in the percentage of microzooplankton relative to total zooplankton abundance with increasing trophic state of a lake in 35 Florida lakes. In our present study, we found significant relationships between the length of *A. robustus* and chlorophyll *a*, between the length of *M. gracilis* and conductivity, and between the length of *M. micrura* and nitrate in the mesotrophic Ikizcetepeler Reservoir, but not in the eutrophic Çaygören Reservoir.

In conclusion, the results of this study showed that water temperature and nutrient concentration were the most important environmental factors affecting the size variability of zooplankton species in both a eutrophic and a mesotrophic freshwater reservoir. Furthermore, the major nutrients NO_3 and SRP were positively related to zooplankton size in the mesotrophic reservoir, while they were negatively related to the body length of zooplankton in the eutrophic reservoir. It seems that, over a long time, zooplankton body size cannot be ascribed to only one factor, but to a network of factors in both mesotrophic and eutrophic freshwater bodies.

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