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Dry Weights of the Zooplankton of Lake Mikri Prespa (Macedonia, Greece)

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ABSTRACT. Length-weight regressions and dry weight estimates of the main crustaceans of Lake Mikri Prespa are presented. The calanoid copepod and most of the cladocerans were heavier during summer than in other seasons, while the rest of the crustaceans were heavier during spring. The mean calculated dry weights were : (a) 0.005 µg (*Keratella cochlearis*), 2.268 µg (*Asplanchna priodonta*), 0.033 µg (*Trichocerca capucina*), 0.024 µg (*Filinia longiseta*) for the predominant rotifer species ; and (b) 0.420 µg for the planktonic larvae of the molluscan *Dreissena polymorpha*.

KEY WORDS : *Dry weights, length-weight regressions, zooplankton, Greece*

INTRODUCTION

Dry weight data exist for several areas mainly in Europe and America (e.g. NAUWERK 1963 ; DUMONT et al., 1975; SCHINDLER & NOVEN 1971, LAWRENCE et al., 1987; MALLEY et al., 1989), while the length-weight relationships of freshwater zooplankton species from the same areas are reviewed by BOTTRELL et al. (1976) and McCAULEY (1984). Nevertheless, no data are available for the Balkan lakes, including for the calanoid copepod *Arctodiaptomus steindachneri,* an endemic species of the Western Balkan. On the other hand, many factors have been found to control the individual weight underlining the necessity to develop length-weight relationships specific to an area (RAHKOLA et al., 1998). Thus, the data presented herein will allow the estimation of the zooplanktonic biomass and production of the lakes in the surrounding area.

MATERIAL AND METHODS

Samples were collected monthly from June 1990 to October 1992 from Lake Mikri Prespa. A detailed description of the lake, the phytoplankton and zooplankton communities as well as the sampling procedure has been presented by TRYPHON et al. (1994) and MICHALOUDI et al. (1997).

Crustacean samples were preserved immediately in 4% formalin. Individuals were sorted from the samples and grouped according to species, sex, developmental stage (copepodites, nauplii), and size class (see Table 1) in the laboratory. Each group comprised 30-100 individuals. The individual length was measured (to the nearest 0.01 mm) and the animals were rinsed with distilled water, placed on pre-weighed and pre-dried (60° C for 48 h) aluminium boats, dried at 60° C for 48 h, cooled in a desiccator and weighed on a microbalance (10 µg precision). Ovigerous females were not selected. The developmental stages of copepods were not separated by species except for the copepodites of the calanoid *Arctodiaptomus steindachneri*. The above procedure was done for each season separately except for the groups of very low density (e.g. *Daphnia cucullata* of IV size class), for which individuals were sorted out from all the samples throughout the year. Length-weight regressions were performed using the linear form ln(W)=lna+bln(L), where L is body length in mm and W is body weight in µg dry weight.

For rotifers, the wet weight was calculated using the geometric formulae of RUTTNER-KOLISKO (1977), applied on live individuals. Wet weight was consequently transformed to dry weight assuming that dry weight is 10% of wet weight except for *Asplanchna* for which it was assumed to be 4% (DUMONT et al., 1975). The same method was applied for the dry weight calculation of the planktonic larvae of *Dreissena polymorpha* using the 10% factor to convert wet to dry weight (M. VRANOVSKY, pers. comm.). The biovolume estimates for *Dreissena* were based on the formula of the ellipsoid of revolution (RUTTNER-KOLISKO, 1977).

RESULTS

Weight data for the crustacean populations of Lake Mikri Prespa are shown in Table 1. The main filter feeders *Daphnia cucullata*, *Diaphanosoma* cf. *mongolianum*, *Ceriodaphnia pulchella* and *Arctodiaptomus steindachneri* were heavier during summer than in other seasons. *Bosmina longirostris*, *Mesocyclops leuckarti* and the calanoid copepodites were heavier during spring, while nauplii were heavier in the winter.

The length-weight regressions are shown in Table 2. The slopes of the length-weight regressions were all significantly ($p<0.01$) different from zero and ranged from 1.9 to 3.5.

For rotifers and the molluscan larvae of *Dreissena polymorpha* the dimensions (mean values) and calculated dry weights for each species are shown in Table 3.

TABLE 1

Dry weights (in µg) of the crustacean species of Lake Mikri Prespa. W=winter, Sp=spring, SU=summer, A=autumn. *Data refer to groups for which the number of individuals was not enough for seasonal weight determination, and which were sorted out from all samples throughout the year.

Species size class (µm)	W	SP	SU	A	all*
Daphnia cucullata Sars, 1862					
300-500	0.47	0.4	0.4	0.408	
501-700	0.606	0.909	2.75	1.886	
701-900	2.5	2.258	3.125	2.058	
901-1100					4.8
Diaphanosoma cf. *mongolianum* Ueno, 1938					
300-500			0.5	0.425	
501-700			0.82	0.43	
701-900			2	1.38	
901-1100				2.727	
males				0.57	
Bosmina longirostris (O.F. Müller, 1758)					
200-300	0.29	0.48		0.224	
301-400	0.78	1		0.886	
401-500	1.14	1.54			
Ceriodaphnia pulchella Sars, 1862					
200-300			0.309	0.156	
301-400			0.64	0.454	
401-500			0.816	0.816	
Leptodora kindtii (Focke, 1844)					13.33
Arctodiaptomus steindachneri (Richard, 1897)					
females	5	6	6.845	3.47	
males	3	4	3.66	2.325	
copepodites					
300-500	0.45	0.92	0.8	0.416	
501-700	1.304	1	1.13	0.8	
701-900	1.67	3.45	2	1	
901-1100	3.6	5.2	2.67	1.79	
Mesocyclops leuckarti (Claus, 1857)					
females		4.117	1.38	2	
males		1.034	1.33	1	
Cyclops vicinus Ulianine, 1875					
females	21.67	25.315			
males	10	9			
Macrocyclops albidus (Jurine, 1820)					
females	20				
males	5				
Eucyclops serrulatus (Fischer, 1851)					
females		7.5			
males		6.25			
cyclopoid copepodites					
300-500		0.4	0.2	0.196	
501-700	1.76	0.87	0.46	0.884	
701-900	1.272	2.33		2.72	
901-1100					4.29
nauplii					
200-300	0.303	0.202	0.235	0.119	
301-400	0.58	0.5	0.303	0.303	
401-500					1.35

DISCUSSION

The filter feeders *Daphnia cucullata*, *Diaphanosoma* cf. *mongolianum*, *Ceriodaphnia pulchella* and *Arctodiaptomus steindachneri* are the main components of the spring and summer crustacean community (MICHALOUDI et al., 1997). They increase in numbers after the nanoplankton peak and dominate throughout summer (MICHALOUDI et al., 1997) when their main food source is probably bacteria (GLIWICZ, 1969 ; SOMMER et al., 1986). At the same period they were also heavier (Table 1). This could be the result of the increased food availability as well as the increase of temperature that has a positive effect on their filtering rate (BURNS, 1969 ; MOURELATOS & LACROIX, 1990). Such a coincidence of maximum weight and abundance is also reported by VUILLE & MAURER (1991). On the other hand, *Bosmina longirostris* was heavier during spring although it reaches maximum abundance during autumn (MICHALOUDI et al., 1997). At this time the phytoplankton community is dominated by Cyanobacteria while during spring nanoplankton biomass is at its peak (TRYPHON et al., 1994). Moreover, it has been found that although temperature has no considerable effect on its filtration rates (BOGDAN & GILBERT, 1982 ; MOURELATOS & LACROIX, 1990), high concentration of inedible particles has a distinct negative effect (BOGDAN & GILBERT, 1982).

TABLE 2

Length-dry weight relationships of the planktonic crustaceans (all size classes included) in Lake Mikri Prespa ln(W)=lna+bln(L), R^2=coefficient of determination, p=probability of b being different from zero, S.E.=standard error of b. L in mm and W in µg.

Species	N		R^2	p	S.E.
D. cucullata	13	Ln(W)=1.586+2.963Ln(L)	0.797	0.0001	0.451
B. longirostris	8	Ln(W)=3.203+3.466Ln(L)	0.909	0.0002	0.448
C. pulchella	6	Ln(W)=1.807+2.517Ln(L)	0.836	0.0107	0.557
D. cf. *mongolianum*	7	Ln(W)=1.046+2.501Ln(L)	0.857	0.0028	0.458
A. steindachneri (1)	24	Ln(W)=1.111+2.121Ln(L)	0.796	0.0001	0.229
copepodites cyclopoida	11	Ln(W)=1.535+3.532Ln(L)	0.908	0.0001	0.376
Cyclopoida (1)	25	Ln(W)=1.205+2.685Ln(L)	0.902	0.0001	0.185
nauplii	9	Ln(W)=1.777+1.914Ln(L)	0.715	0.0041	0.457

1.Pooled data for adults and copepodites

The weights of *Bosmina longirostris*, *Mesocyclops leuckarti*, *Cyclops vicinus* and *Diaphanosoma* cf. *mongolianum* (Table 1) are in good agreement with those reported by BURGIS (1974) ; DUMONT et al. (1975) ; GOPHEN (1976) ; LAWRENCE et al. (1987) and VUILLE & MAURER (1991) for individuals of the same length. On the other hand *Ceriodaphnia pulchell*a is much lighter than *C. quandrangula* (DUMONT et al., 1975) probably because the first one is a pelagic and the second one a littoral species (VUILLE & MAURER, 1991). As for the non pelagic *Eucyclops serrulatus* and *Macrocyclops albidus,* they were found to be lighter though bigger than the individuals reported by DUMONT et al. (1975). Considering the altitude of Mikri Prespa (850 m asl) it is evident that the assumption of DUMONT et al. (1975), that non-pelagic species tend to be lighter at high altitudes, is true for the above species.

From the above it can be concluded that crustacean weight is controlled by geographical distribution, differ-

TABLE 3

Mean dimensions (in µm) and calculated dry weight (in µg) of the rotifers and *D. polymorpha* in Lake Mikri Prespa, n=number of individuals, S.E.=standard error.

		a=lenght		b=height		c=width		w=weight	
Species	**n**	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**
Asplanchna priodonta Gosse, 1850	145	653.55	16.06	397.50	13.12			2.268	0.1000
Brachionus angularis Gosse, 1850 [(1)]	30	102.08	0.81	92.29	1.11	52.29	1.18	0.026	0.0010
B. diversicornis (Daday, 1883)	99	262.50	6.18	157.19	5.39	85.13	5.01	0.188	0.0210
B. forficula Wierzejski, 1891	30	87.50	1.09	78.00	1.71	49.50	1.06	0.018	0.0010
Conochilus hippocrepis (Schrank, 1830)	30	301.50	9.08	72.50	1.74			0.043	0.0030
Filinia longiseta (Ehrenberg, 1834)	46	39.75	25.25	54.58	6.83			0.024	0.0100
Keratella cochlearis (Gosse, 1851)	359	118.46	3.53	55.02	1.07			0.005	0.0003
Polyarthra sp.	60	142.75	0.25	95.00	5.00	65.63	1.13	0.090	0.0300
Synchaeta pectinata Ehrenberg, 1832	60	294.75	6.25	205.50	1.50			0.343	0.0200
Trichocerca capucina Wierzejski & Zacharias, 1893	4	202.50	4.33	56.25	2.17			0.033	0.0020
T. cylindrica (Imhof, 1891)	33	284.88	5.13	64.38	4.38			0.012	0.0020
T. similis (Wierzejski, 1893)	142	148.39	3.71	46.55	1.74			0.017	0.0020
Dreissena polymorpha (Pallas, 1771)	240	185.88	6.47	206.88	8.28			0.420	0.0400

1. Measures on preserved specimens

ent habitat types, temperature and food availability and composition. Moreover, the trophic status of a lake may have an impact on the seasonal variations of the weights. This could be seen when comparing the results of the present study, where most crustaceans were heavier during summer, with the results from HAWKINS & EVANS (1979) at the oligotrophic Lake Michigan, where most crustaceans were heavier during winter and spring.

The slopes of the length-weight regressions were all significantly ($p<0.01$) different from zero and ranged from 1.9 to 3.5 (Table 2). The smallest b value was found for nauplii, which could be attributed to the fact that they tend to elongate faster than they grow in the other two dimensions (MALLEY et al., 1989). The values of lna and b found for the crustacean species in Lake Mikri Prespa (Table 2) generally fall within the range of values for other species of the world (DUMONT et al., 1975 ; MCCAULEY, 1984 ; LAWRENCE et al., 1987 ; MALLEY et al., 1989 ; VUILLE & MAURER, 1991).

As for rotifers, comparing the results from the present study with those from other lakes worldwide (Table 4) it is evident that rotifer volumes cover quite a wide range of values. Thus, it seems that rotifer biomass estimates must be calculated for each lake separately.

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TABLE 4

Volumes (μm^3 10^{-6}) of rotifer species from Lake Mikri Prespa and other lakes.

Species	Volume	Site	Country	Trophic Status	Source
Asplanchna priodonta	57.16	Lake Mikri Prespa	Greece	eutrophic	present study
	33.6	Lake Volvi	Greece	eutrophic	ZARFDJIAN 1989
	30-300	Lake Erken	Sweden	eutrophic	NAUWERK 1963
	200	Lake Windermere	England	eutrophic	RUTTNER-KOLISKO 1977
	44	Lake Suwa	Japan	eutrophic	BOTTRELL et al. 1976
	37.5	Lake Kinneret	Israel	eutrophic	GOPHEN 1973
	22.5	Lake Lucerne	Switzerland	mesotrophic	BURGI et al. 1985
	20	Danube river+ sidearms	Slovakia	mesotrophic	VRANOVSKY (pers.comm.)
	16	Lake Lunz	Austria	mesotrophic	RUTTNER-KOLISKO 1977
	13.12	ELA lakes	Canada	oligotrophic	MALLEY et al. 1989
Brachionus angularis	0.26	Lake Mikri Prespa	Greece	eutrophic	present study
	0.4	Lake Volvi	Greece	eutrophic	ZARFDJIAN 1989
	0.5	Lake Suwa	Japan	eutrophic	BOTTRELL et al. 1976
	0.1	Lake Kinneret	Israel	eutrophic	GOPHEN 1973
	0.28	Funada-ike pond	Japan	eutrophic	URABE 1992
	0.45-0.63	Lake Lough Neagh	Ireland	eutrophic	ANDREW & FITZISIMONS 1992
	0.4	Danube river+ sidearms	Slovakia	mesotrophic	VRANOVSKY (pers.comm.)
Brachionus diversicornis	1.88	Lake Mikri Prespa	Greece	eutrophic	present study
	2.9	Lake Volvi	Greece	eutrophic	ZARFDJIAN 1989
	1.5	Lake Suwa	Japan	eutrophic	BOTTRELL et al. 1976
	3	Danube river+ sidearms	Slovakia	mesotrophic	VRANOVSKY (pers.comm.)
Brachionus forficula	0.18	Lake Mikri Prespa	Greece	eutrophic	present study
	0.22	Funada-ike pond	Japan	eutrophic	URABE 1992
Conochilus hippocrepis	0.43	Lake Mikri Prespa	Greece	eutrophic	present study
	0.6	Lake Erken	Sweden	eutrophic	NAUWERK 1963
	0.15	Lake Suwa	Japan	eutrophic	BOTTRELL et al. 1976
Filinia longiseta	0.24	Lake Mikri Prepsa	Greece	eutrophic	present study
	1.5	Lake Suwa	Japan	eutrophic	BOTTRELL et al. 1976
	0.41	Funada-ike pond	Japan	eutrophic	URABE 1992
	0.17-0.24	Lake Lough Neagh	Ireland	eutrophic	ANDREW & FITZISIMONS 1992
	0.32	Lake Lucerne	Switzerland	mesotrophic	BURGI et al. 1985
	0.3	Danube river+ sidearms	Slovakia	mesotrophic	VRANOVSKY (pers.comm.)
	0.52	ELA lakes	Canada	oligotrophic	MALLEY et al. 1989

TABLE 4 (CONT.)

Volumes (µm^3 10^{-6}) of rotifer species from Lake Mikri Prespa and other lakes.

Species	Volume	Site	Country	Trophic Status	Source
Keratella	0.05	Lake Mikri Prespa	Greece	eutrophic	present study
cochlearis	0.05	Lake Volvi	Greece	eutrophic	ZARFDJIAN 1989
	0.05	Lake Erken	Sweden	eutrophic	NAUWERK 1963
	0.15	Lake Windermere	England	eutrophic	RUTTNER-KOLISKO 1977
	0.1	Lake Kinneret	Israel	eutrophic	GOPHEN 1973
	0.09	Funada-ike pond	Japan	eutrophic	URABE 1992
	0.046	Lake Lough Neagh	Ireland	eutrophic	ANDREW & FITZISIMONS 1992
	0.07	Lake Lanao	Philippine	eutrophic	LEWIS 1979
	0.11	Lake Lunz	Austria	mesotrophic	RUTTNER-KOLISKO 1977
	0.04	Lake Lucerne	Switzerland	mesotrophic	BURGI et al. 1985
	0.25	Danube river+ sidearms	Slovakia	mesotrophic	VRANOVSKY (pers.comm.)
	0.15	Lake Balaton	Hungary		RUTTNER-KOLISKO 1977
	0.15	ELA lakes	Canada	oligotrophic	MALLEY et al. 1989
	0.7	ELA lakes	Canada	oligotrophic	SCHINDLER & NOVEN 1971
Polyarthra	0.9	Lake Mikri Prespa	Greece	eutrophic	present study
spp.	1.1	Lake Volvi	Greece	eutrophic	ZARFDJIAN 1989
	0.55	Lake Erken	Sweden	eutrophic	NAUWERK 1963
	0.65	Lake Winderermere	England	eutrophic	RUTTNER-KOLISKO 1977
	2	Lake Suwa	Japan	eutrophic	BOTTRELL et al. 1976
	0.3	Lake Kinneret	Israel	eutrophic	GOPHEN 1973
	0.23	Funada-ike pond	Japan	eutrophic	URABE 1992
	0.3-0.54	Lake Lough Neagh	Ireland	eutrophic	ANDREW & FITZISIMONS 1992
	0.29	Lake Lanao	Philippine	eutrophic	LEWIS 1979
	0.3	Lake Valencia	Venezuela	eutrophic	SAUNDERS & LEWIS 1988
	0.4	Lake Lunz	Austria	mesotrophic	RUTTNER-KOLISKO 1977
	0.14	Lake Lucerne	Switzerland	mesotrophic	BURGI et al. 1985
	0.1-1	Danube river+ sidearms	Slovakia	mesotrophic	VRANOVSKY (pers.comm.)
	0.38	Lake Balaton	Hungary		RUTTNER-KOLISKO 1977
	0.5	ELA lakes	Canada	oligotrophic	MALLEY et al. 1989
	1.4	ELA lakes	Canada	oligotrophic	SCHINDLER & NOVEN 1971
Synchaeta	3.43	Lake Mikri Prespa	Greece	eutrophic	present study
pectinata	1.5	Lake Volvi	Greece	eutrophic	ZARFDJIAN 1989
	2	Lake Erken	Sweden	eutrophic	NAUWERK 1963
	4.5	Lake Kinneret	Israel	eutrophic	GOPHEN 1973
	0.65	Lake Lucerne	Switzerland	mesotrophic	BURGI et al. 1985
	1	Danube river+ sidearms	Slovakia	mesotrophic	VRANOVSKY (pers.comm.)
Trichocerca	0.33	Lake Mikri Prespa	Greece	eutrophic	present study
capucina	0.7	Lake Volvi	Greece	eutrophic	ZARFDJIAN 1989
	0.15	Lake Erken	Sweden	eutrophic	NAUWERK 1963
	1	Lake Kinneret	Israel	eutrophic	GOPHEN 1973
	0.11	Lake Lucerne	Switzerland	mesotrophic	BURGI et al. 1985
	0.2	Danube river+ sidearms	Slovakia	mesotrophic	VRANOVSKY (pers.comm.)
Trichocerca	0.12	Lake Mikri Prespa	Greece	eutrophic	present study
cylindrica	0.2	Danube river+ sidearms	Slovakia	mesotrophic	VRANOVSKY (pers.comm.)
	1	ELA lakes	Canada	oligotrophic	MALLEY et al. 1989
	0.1	ELA lakes	Canada	oligotrophic	SCHINDLER & NOVEN 1971
Trichocerca	0.17	Lake Mikri Prespa	Greece	eutrophic	present study
similis	0.3	Lake Volvi	Greece	eutrophic	ZARFDJIAN 1989
	0.15	Lake Erken	Sweden	eutrophic	NAUWERK 1963
	1	Lake Kinneret	Israel	eutrophic	GOPHEN 1973
	0.08	Lake Lucerne	Switzerland	mesotrophic	BURGI et al. 1985
	0.2	Danube river+ sidearms	Slovakia	mesotrophic	VRANOVSKY (pers.comm.)