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Carbon content of some freshwater rotifers

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Abstract

Carbon content of rotifers from 14 species (*Keratella cochlearis, K. c. tecta, K. c. hispida, K. ticinensis, K. quadrata, Polyarthra remata, P. vulgaris, P. major, P. euryptera, Synchaeta sp., S. stylata, S. pectinata, Trichocerca capucina, Asplanchna priodonta*) was determined with the high temperature combustion method of Salonen (1979). Rotifers for the carbon analysis were collected from different fresh water bodies in Russia (Lake Ladoga) and Finland (lakes Pohjalampi, Varaslampi, and two small ponds in Lammi). Average individual carbon mass of rotifers varied between 0.0064 and 0.058 μg in *Keratella* spp., 0.012 and 0.051 μg in *Polyarthra* spp., 0.020 and 0.133 μg in *Synchaeta* spp., 0.162 and 0.555 μg in *A. priodonta*. The carbon level in the studied rotifer species differed 100-fold ranging from 0.31% WW in *A. priodonta* to 31.5% WW in *K. c. tecta*. Body length/carbon mass and body volume/carbon mass regressions were established for the studied rotifers.

Introduction

Rotifers form the essencial structural and functional component of pelagic communities in different freshwater habitats. In rivers and estuaries, rotifers can be responsible for 95% of total zooplankton biomass (Telesh, 1995). Even in the pelagic areas of large lakes, such as the great North-American lakes Huron, Erie, Ontario and Superior, rotifers contribute 14–20% to the total averaged for June–September zooplankton biomass; in Lake St. Clair in August 1984, 30% of zooplankton biomass were formed by rotifers (Sprules & Munawar, 1991). In some northern areas of Lake Ladoga (Russia) rotifers form 85% of zooplankton biomass during certain periods (Telesh, 1998).

Adequate comparison of the relative importance of different structural components of any community or ecosystem is possible only on the basis of common units of the chosen parameter, for example biomass. At present biomass of aquatic organisms is generally expressed as dry weight (Botrell et al., 1976; Dumont et al., 1975) or carbon mass (Duncan et al., 1985; Latja & Salonen, 1978; McCauley, 1984; Rahkola et al., 1998; Salonen et al., 1976; Vasama & Kankaala, 1990), and still often is expressed as wet weight (Balushkina & Winberg, 1979). Until recently, carbon analysis of rotifers has been limited due to the small size of these animals, which prevented wide application of the method.

This study presents the results of carbon content measurements in 14 common species of planktonic rotifers from a number of fresh water bodies of different types in Russia and Finland. The aim of the study was to express numerically general relationships between carbon content and length/volume/wet weight of rotifers, for a more reliable determination of rotifer biomass and adequate evaluation of their role in the trophic webs within pelagic communities.

Materials and methods

Carbon content was measured in rotifers from 14 species collected in the freshwater habitats of different types: Lake Ladoga in Russia (the largest European lake, surface area 17 891 km^2), and four small lakes and ponds in Finland (lake Pohjalampi, area 0.61 km^2; lake Varaslampi, area 0.03 km^2; reference pond in Lammi, area 160 m^2; and small natural pond in Lammi, area 25 m^2). The following rotifer species were analysed: *Keratella cochlearis* (Gosse), *K. c. tecta* (Gosse), *K. c. hispida* (Lauterborn), *K. ticinensis*

(Callerio), *K. quadrata* (Müller), *Polyarthra euryptera* Wierzejski, *P. major* Burkhardt, *P. remata* Skorikov, *P. vulgaris* Carlin, *Synchaeta* sp., *S. stylata* Wierzejski, *S. pectinata* Ehrenberg, *Trichocerca (s. str.) capucina* (Wierzejski & Zacharias), and *Asplanchna priodonta* Gosse.

Samples for the carbon analysis were collected in August 1995 (Lake Ladoga), May through August 1996 (lake Pohjalampi), June 1996 (lake Varaslampi) and May 1996 (ponds in Lammi). Samples were taken with the plankton net (mesh size 50 μm), preserved in 4% formaldehyde and frozen at -18°C. This method provides superior presevation for the purpose of carbon analysis for most zooplankton species (Salonen & Sarvala, 1980).

Before carbon content measurement, zooplankton samples were thawed, 300–500 individuals of each rotifer species were picked from the sample and briefly rinsed five times in small volumes of distilled water in Petri dishes. The samples were kept at about 5°C until processing on the same day. Prior to carbon analysis, length and width of 20 individuals of each rotifer species were measured and average values were calculated. Body volumes of rotifers were calculated according to the standard formulae (Ruttner-Kolisko, 1977) on the basis of mean linear dimentions and converted to wet weights assuming that 10^6 μm^3 equals 1 μg wet weight (Botrell et al., 1976).

Carbon mass of rotifers was determined with the high temperature combustion method of Salonen (1979, 1981). Rotifers were transferred into the combustion tube (+950°C) of the Universal Carbon Analyser with a Pasteur pipette in drops of a standard volume of distilled water, either one by one (*Asplanchna, Trichocerca*), or in groups of three to five (*Polyarthra, Synchaeta, K. quadrata*) or 10 animals (*Keratella*). Carbon content of the standard volume of the same water was determined in each measurement and substracted from the carbon weight of the animals (Latja & Salonen, 1979). In total, the number of rotifers analysed for the carbon content varied between 14–47 (*Asplanchna*) and 320 (*Synchaeta*). Carbon level was calculated as percent of wet weight for each rotifer species. The length/carbon mass and body volume/carbon mass relationships for rotifers were discribed by a power function: $Y{=}aX^b$ separately for the genera *Keratella* (five species), *Polyarthra* (four species) and *Synchaeta* (three species). For *S. stylata* it was possible to perform a series of eight sets of the length–width measurements, therefore the regressions for the three species from the genus *Synchaeta* are based on 10 pairs of mean carbon/length and carbon/volume values. General regressions for 13 rotifer species are based on the species means of carbon content and body size. The statistical tests were performed using the SPSS program.

Results

The body length of the studied rotifer species varied 10-fold (0.07–0.675 mm), and body volumes were within the range of 0.018–84.5 $\times 10^6$ μm^3 (Table 1). The organic carbon content exposed a 200-fold difference for the 14 measured rotifer species ranging between 0.0036 and 0.685 μg (Table 1). Difference between the measured carbon mass and means for each species did not exceed 30%, averaging at 20%. The measured variation in carbon mass was lowest in *K. cochlearis*, *P. remata* and *P. vulgaris* from lake Pohjalampi, due to low variation in the individual body sizes of these rotifers (Table 1). The highest variation in the carbon content was registered in *S. pectinata* from the small pond in Lammi, and was most probably caused by the naturally high variation in the size of these rotifers. *A. priodonta* was sampled almost simultaneously in two lakes, Pohjalampi and Varaslampi, and the similar-sized animals from two lakes differed considerably in carbon content (Table 1).

Carbon content was positively correlated with rotifer length and body volume. (Tables 2 and 3, Figure 1). The coefficients of determination (r^2) were high (0.75–0.96) in all cases except for the relationship between the body length and carbon content of *Synchaeta* spp. (Table 2).

Carbon level in the studied rotifer species varied 100-fold ranging between 0.31% WW in *A. priodonta* and 31.5% WW in *K. c. tecta*. Standard deviations of the results obtained for each rotifer species varied between 12 and 34% of the mean. However, the carbon level values were rather stable when congeneric species were compared: 19.8–24.0% WW in *Keratella* of the *cochlearis* type, 6.8–10.3% WW in *Synchaeta*, 2.6–3.7% WW in *Polyarthra* (Table 1). Exceptionally, the carbon level of *A. priodonta* of the similar size (51.7 and 56.2 μg) from two lakes exposed a three-fold difference (0.31 and 0.99% WW, respectively).

Carbon level was inversely related with wet weight in rotifers smaller than 2 μg WW (Figure 2A), but

Table 1. Body length (L, mm), body volume ($V \times 10^6$ μm^3), carbon content (C, μg) and mean carbon level (% of wet weight and standard deviation, SD) of rotifers

Species of rotifers	Sampling sight	Date of sampling	Body length (L, mm), mean and range	Body volume ($V \times 10^6$ μm^3), mean and range	Carbon (C, μg) mean and range	Carbon level %WW	Carbon level SD	Number of measure-ments	Number of rotifers analysed
Keratella cochlearis tecta	Lake Pohjalampi	22.07.1996	0.079 (0.070–0.090)	0.027 (0.018–0.042)	0.0064 (0.0036–0.0085)	23.8	7.8	4	130
Keratella cochlearis	Lake Pohjalampi	14.05.1996	0.115 (0.110–0.120)	0.096 (0.091–0.100)	0.022 (0.019–0.027)	23.3	3.1	8	245
Keratella cochlearis hispida	Lake Pohjalampi	05.08.1996	0.098 (0.095–0.100)	0.064 (0.039–0.095)	0.015 (0.013–0.018)	24.0	3.1	6	139
Keratella ticinensis	Natural pond in Lammi	11.05.1996	0.120 (0.115–0.125)	0.085 (0.063–0.104)	0.017 (0.0098–0.022)	19.8	4.8	6	265
Keratella quadrata	Lake Varaslampi	07.06.1996	0.150 (0.140–0.180)	0.755 (0.604–1.283)	0.058 (0.045–0.075)	7.7	1.1	11	225
Polyarthra remata	Lake Pohjalampi	22.07.1996	0.101 (0.095–0.110)	0.304 (0.240–0.373)	0.012 (0.011–0.012)	3.7	0.1	2	60
Polyarthra vulgaris	Lake Pohjalampi	22.07.1996	0.128 (0.120–0.135)	0.559 (0.484–0.689)	0.018 (0.015–0.021)	3.2	0.4	4	68
Polyarthra euryptera	Lake Pohjalampi	22.07.1996	0.185 (0.160–0.200)	1.780 (1.147–2.240)	0.064 (0.052–0.080)	3.6	0.6	9	40
Polyarthra major	Lake Ladoga	09.08.1995	0.191 (0.180–0.215)	1.980 (1.630–2.783)	0.051 (0.041–0.064)	2.6	0.4	5	75
Synchaeta sp.	Lake Pohjalampi	05.08.1996	0.118 (0.100–0.155)	0.254 (0.188–0.326)	0.020 (0.012–0.027)	7.7	2.4	3	56
Synchaeta stylata	Reference pond in Lammi	11.05.1996	0.138 (0.105–0.180)	0.404 (0.140–1.239)	0.042 (0.030–0.057)	10.3	1.5	8	295
Synchaeta pectinata	Natural pond in Lammi	11.05.1996	0.213 (0.180–0.275)	1.956 (1.053–2.860)	0.133 (0.093–0.189)	6.8	1.6	9	320
Trichocerca capucina	Lake Pohjalampi	22.07.1996	0.268 (0.240–0.290)	1.251 (1.011–1.662)	0.057 (0.043–0.076)	4.6	0.7	8	54
Asplanchna priodonta	Lake Pohjalampi	11.06.1996	0.550 (0.500–0.600)	51.7 (43.9–57.9)	0.162 (0.047–0.224)	0.39	0.08	30	30
			0.637 (0.625–0.650)	70.3 (63.2–84.5)	0.328 (0.207–0.492)			47	47
Asplanchna priodonta	Lake Varaslampi	07.06.1996	0.450 (0.400–0.550)	15.3 (10.5–21.1)	0.063 (0.018–0.109)	0.71	0.24	14	14
			0.590 (0.575–0.600)	42.8 (35.0–50.0)	0.312 (0.148–0.448)			34	34
			0.675	56.2	0.555 (0.450–0.685)			17	17

Table 2. Carbon/length relationship for rotifers

Rotifers	L (mm) range	a±S.E.	b±S.E.	n	r^2
Keratella	0.070–0.180	0.351±0.066	0.290±0.047	5	0.93
Polyarthra	0.095–0.215	0.547±0.102	0.373±0.052	4	0.96
Synchaeta	0.110–0.275	0.200±0.041	0.119±0.063	10	0.31
Rotifers (13 species)	0.070–0.275	0.509±0.101	0.367±0.054	13	0.81

Range of length measurements (L, mm), intercept (a), the slope (b), number of observations (n) and coefficient of determination (r^2) are presented for the power function: $C = a\ L^b$.

Table 3. Carbon/body volume relationship for rotifers

Rotifers	$V \times 10^6$, μm^3 range	a±S.E.	b±S.E.	n	r^2
Keratella	0.018–1.283	42.76±33.47	1.512±0.193	5	0.95
Polyarthra	0.240–2.783	45.12±22.87	1.112±0.140	4	0.97
Synchaeta	0.188–2.860	2.466±0.947	0.570±0.116	10	0.75
Rotifers (13 species)	0.018–2.860	62.57±58.29	1.455±0.256	13	0.75

Range of body volume measurements ($V \times 10^6$ μm^3), intercept (a), the slope (b), number of observations (n) and coefficient of determination (r^2) are presented for the power function: $C = a\ V^b$.

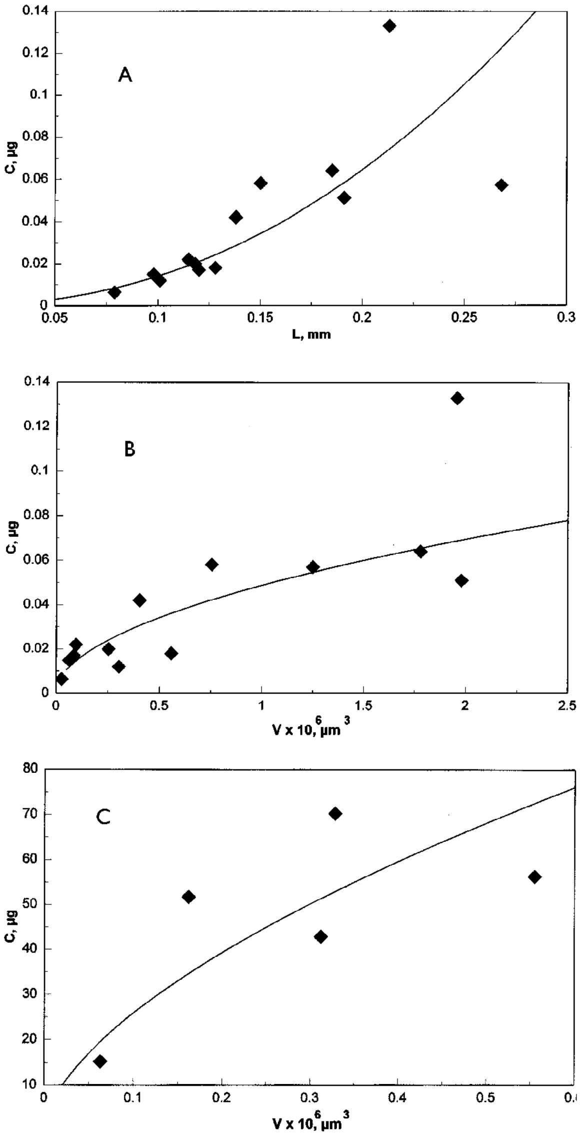

Figure 1. Relationships (A) between body length (L, mm) and carbon mass (C, μg), and (B) between body volume (V x 10^6, μm^3) and carbon mass (C, μg) for the studied rotifer species, excluding *A. priodonta*; (C) body volume (V x 10^6 , μm^3) versus carbon mass (C, μg) for *A. priodonta*.

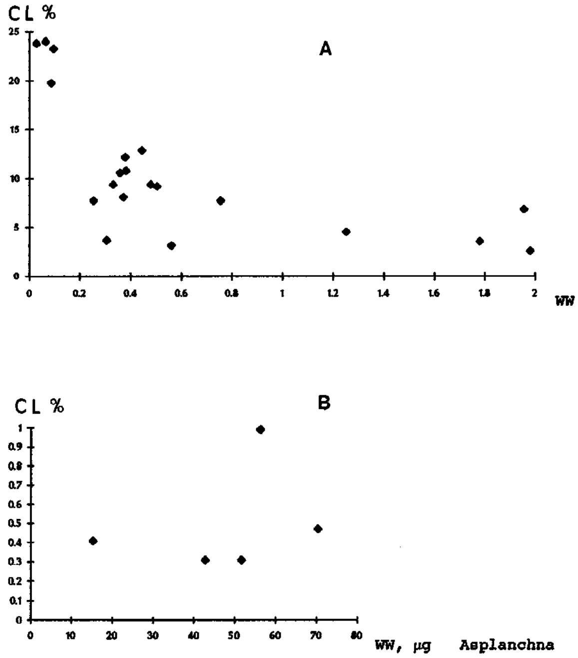

Figure 2. Relationship between wet weight (WW, μg) and carbon level (CL,%WW) for rotifers from the genera *Keratella, Polyarthra, Synchaeta* and *Trichocerca* (A), and for *A. priodonta* (B).

showed no correlation for *Asplanchna* of 10–80 μg WW (Figure 2B).

Discussion

Variation in weight estimates of aquatic organisms can depend on changing environmental conditions, types of water bodies, species-specific seasonal changes in body composition of the animals, as well as on methods of sampling and weight determination (Botrell et al., 1976; Duncan et al., 1985; Dumont et al., 1975; Guisande et al., 1991; Hessen & Lyche, 1991; Latja & Salonen, 1978; Rahkola et al., 1998; Sterner & Hessen, 1994). In rotifers, seasonal variation in body mass was demonstrated for *Kellicottia longispina* from Lake Pääjarvi when the rotifers carbon mass in November (0.030 μg C) was two times as high as in June (0.015 μg C, Latja & Salonen, 1978). However, population of *K. cochlearis* from the same lake demonstrated no seasonal variation of carbon content (Latja & Salonen, 1978).

In our study, most species of rotifers exhibited low intraspecific variation in carbon mass (Table 1), except for *S. pectinata* from the small pond in Lammi, Southern Finland, where a two-fold variation in carbon content probably reflected a natural size variation within the population. The low coefficient of determination for the carbon/length regression for *Synchaeta* (Table 2) is most probably due to the fact that rotifers were contracted in various degrees.

The measured individual carbon weights of *K. cochlearis, P. vulgaris* and *A. priodonta* are in accordance with those reported in literature, closest to values determined using the same method (Table 4). The most

Table 4. Comparison of the observed carbon weights of rotifers (C, μg) to those calculated from volumes (V), wet weights (WW) and dry weights (DW) presented in literature

Rotifer species	C, μg	Original unit	Source
Keratella cochlearis	0.004	V	Naulapaa, 1966
	0.005	V	Aasa, 1970
	0.055	DW	Dumont et al., 1975
	0.019	DW	Shindler & Noven, 1971
	0.024	C	Latja & Salonen, 1978
	0.019–0.027	C	This study
Polyarthra vulgaris	0.019	V	Naulapaa, 1966
	0.100	V	Aasa, 1970
	0.014–0.046	WW	Bottrell et al., 1976
	0.033	C	Latja & Salonen, 1978
	0.015–0.021	C	This study
Asplanchna priodonta	12.5	V	Naulapaa, 1966
	2.15	V	Aasa, 1970
	0.245–0.260	DW	Dumont et al., 1975
	0.300	DW	Narita & Mori, 1975
	0.11	DW	Makarewich & Likens, 1979
	0.22	DW	Bottrell et al., 1976
	0.115–0.504	C	Latja & Salonen, 1978
	0.15–0.66	C	Salonen & Latja, 1988
	0.018–0.685	C	This study

variable data were obtained for *A. priodonta* collected on almost the same date from two lakes in Eastern Finland (Table 1). Extreme values of carbon content of *A. priodonta* from Lake Pohjalampi varied 10-fold, in Lake Varaslampi this variation was over 40-fold. As a result, our data present a broader range of individual carbon mass values for *A. priodonta* than known from the literature. However, the maximal values of individual carbon mass of *A. priodonta* measured in our study (0.685 μg C) corresponded to the published data (Salonen & Latja, 1988).

The carbon level of rotifers estimated in our study was lowest in *A. priodonta*: it was always below 1% WW, with a mean of 0.55% WW. The same exceptionally low carbon levels (0.8% WW) for the contracted *A. priodonta* were reported by Latja & Salonen (1978). Even lower carbon level (0.2% WW) was reported by Salonen & Latja (1988) for the living animals of *A. priodonta*. These authors demonstrated an inverse relationship between carbon level and wet weight of two species, *A. priodonta* and *A. herricki*, ranging in size between 6 and 910 μg WW. In our study, wet weight of *A. priodonta* varied between 10 and 85 μg, and no trends of size dependance of carbon level were observed within these limits. Carbon level of *Asplanchna* of similar body volumes differed significantly (three-fold) thus demonstrating large differences between the populations of *Asplanchna* and/or the specific environmental conditions in the lakes.

Carbon level of other studied rotifer species tended to be inversely correlated with wet weight (Figure 2A) reaching maximal value of 31.5% WW in *K. c. tecta*. Variation in carbon level within the genera *Keratella*, *Polyarthra* and *Synchaeta* was low (Table 1). However, carbon level of *Keratella* spp. and *Synchaeta* spp. was significantly higher, and that of *Polyarthra* spp. was lower than the 5% value, or outside the limits of 5-10% proposed by Latja & Salonen (1978) to convert rotifers wet weight to carbon mass. Our data on carbon content and carbon level of 14 common planktonic species of rotifers as well as the proposed general regressions linking the measured body length and volume reflecting wet weight of rotifers with their carbon mass could serve for more unbiased estimation of rotifer biomass and carbon flow through pelagic communities.

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