Oxygen consumption in *Macrotrachela musculosa* and *Trichotria truncata* (Rotatoria) from the High Arctic

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Oxygen consumption by rotifers *Macrotrachela musculosa* and *Trichotria truncata* from Spitsbergen tundra (77°N) was measured using the method of Cartesian divers. The metabolic rate of *M. musculosa* was: 0.205 $10^{-3}mm^3$ O_2 per g 10^{-6} per hour at 2°C, 0.201 $10^{-6}mm^3$ at 6°C and 0.616 $10^{-3}mm^3$ O_2 per g 10^{-6} per hour at 10°C. The metabolic rate of *Trichotria truncata* at 6° was 0.103 $10^{-3}mm^3$ per g 10^{-6} per hour. The relation between body weight and oxygen consumption by *M. musculosa* at 2°C is expressed with the equation $R = 0.18W^{0.67}$, with R – oxygen consumption in $mm^3 10^{-3}$ per individual per hour and W – wet weight of an animal in g 10^{-6}.

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Terrestrial and freshwater poikilothermic organisms, which inhabit the polar regions, are adapted not only to low temperatures, but also to frequent and irregular temperature oscillations around 0°C during the vegetation period (Chambers 1966). The phenomenon of 'relative temperature independence' of metabolism sensu Duncan & Klekowski (1975) is an adaptation of the organism to this type of temperature regime. This phenomenon – independence of metabolism in ambient temperature range – has been observed for example for Antarctic Acarina (Block & Young 1978) and Arctic Tardigrada (Klekowski & Opaliński 1989).

The aim of this study is to investigate the effect of temperature (in its natural range of variability) on the metabolic rate of Rotatoria which live in the Spitsbergen tundra.

Material, methods and study area

The object of this study is a rotifer, *Macrotrachela musculosa* Milne 1886 (Bdelloidea: Philodinidrea). This animal is up to 0.4 mm long and lives in moss turf, soil and occasionally in flowing waters. It is a cosmopolitan species occurring on Spitsbergen and in North America, Asia, New Zealand and South Africa (Bartos 1959). On Spitsbergen, *M. musculosa* occurs in the interstitial water among mosses on wet moss meadows.

Trichotria truncata (Whitelegge 1889) (Monogononta: Trichotriidae) is the second of the studied rotifers. The body length of this animal reaches 0.4 mm and this species occurs in flowing waters, swamps and peat bogs. It is a cosmopolitan species found in Greenland, in the whole of Europe, North America, New Zealand and Oceania (Bartos 1959). On Spitsbergen, *T. truncata* occurs in the same habitats as *Macrotrachela musculosa*.

Rotifers were identified to the species level by Henryk Klimowicz (Institute of Environmental Planning, Warsaw) on the basis of live animals brought to Warsaw (*M. musculosa*) and formalin preparations (*T. truncata*).

Animals for these studies have been collected from the coastal moss tundra near the Hornsund fjord (Spitsbergen, 77°00′N, 15°00′E). In this region, the average temperatures range from 2.4 to 4.9°C in the summer months and from −4.9 to −11.9°C in the winter months (Pereyma 1983). The description of the natural environment of the Hornsund region was given by Klekowski & Opaliński (1986).

Measurements of oxygen consumption by rotifers were carried out at 2, 6 and 10°C. Measurements at 2°C were carried out in the period when interstitial water temperature in moss turf at about 0.5 cm depth was 0–5°C (from 3 June to 18

June 1980), at 6°C when interstitial water temperature was 4–7°C (from 20 June to 23 June 1980) and at 10°C in the period when interstitial water temperature was 5–8°C (29 June to 3 July 1980).

Tufts of moss of 25–100 cm^2 surface area together with interstitial water and animals living in it were collected from the tundra and placed in a thermostat at the temperature of measurement. Tufts with animals remained in the thermostat for 24 hours at 2°C and 6°C and 48 hours at 10°. Next, interstitial water was pressed from moss tufts and rotifers found in it were placed in Cartesian divers (one animal in each diver). Ampulla-type divers were used (Zeuthen 1953; Klekowski 1975).

After the oxygen consumption measurements had been completed, animals were taken out from the divers and their body length was measured. Plasticine models of the *M. musculosa* and *T. truncata* were made. The volume of animals was determined from plasticine models. The models were submerged in water to calculate the water volume pressed out (model's volume) and their length was measured. The animals' volume was calculated from so-called 'Coefficient of Filling', used in techniques

$$Kv = \frac{Vm}{(Lm)^3}$$

where Kv = coefficient of filling, i.e. measured volume of the subject to subject 'volume' as a third power of its length ratio, Vm = model's volume and Lm = model's length. To calculate the animal's volume, the formula

$$Va = Kv\,La^3 \quad \text{or} \quad Va = \frac{Vm\,La^3}{Lm^3}$$

$$\text{or} \quad Va = Vm\left(\frac{La}{Lm}\right)^3$$

can be used, where Va = animal's volume and La = animal's length.

In the calculations of an animal's wet body weight, its specific gravity was assumed as being equal to 1 gcm^{-3}. A detailed description of this method of calculating animal wet body weight was given by Klekowski & Tumanseva (1981).

This study was carried out at the Polish Polar Station, Hornsund, Spitsbergen.

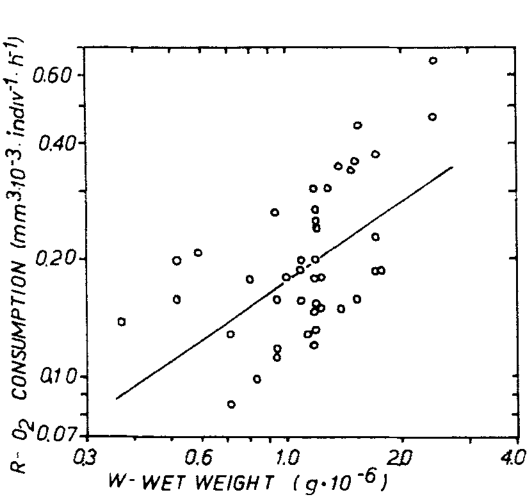

Fig. 1. Size dependence of oxygen consumption (R) and body wet weight (W) in *Macrotrachela musculosa* (Rotatoria) from Spitsbergen tundra at 2°C. $R = 0.18\,W^{0.67}$.

Results

The results of the measurements of wet body weight and oxygen consumption by *Macrotrachela musculosa* and *Trichotria truncata* are given in Table 1. In spite of similar length (about 0.4 mm), *T. truncata* was estimated to be almost 20 times heavier than *M. musculosa* as a consequence of different body shape in the two species. The body length to width ratio is 0.75 for *T. truncata* and 0.22 for *M. musculosa*.

The oxygen consumption at 6°C per individual is higher for *T. truncata* – the larger animal (2.29 and 0.33 $mm^3\,10^{-3}$ per individual per hour, respectively). The metabolic rate at 6°C is of course higher for the smaller animal, i.e. *M. musculosa* (0.201 and 0.103 $mm^3\,10^{-3}$ per g^{-6} per hour, respectively).

The metabolic rate of *M. musculosa* at 2 and 4°C was practically the same: 0.205 and 0.201 $mm^3\,10^{-3}$ per individual per hour, respectively (Table 1), but at 10°C, the increase was almost threefold. The temperature coefficient Q for the temperature range 4–6°C was 1.0, for the range 6–10°C as much as 16.4.

The relation between body weight of *M. musculosa* and oxygen consumption at 2°C was calculated. It is given by the equation $R = 0.18\,W^{0.67}$, where R = oxygen consumption in $mm^3\,10^{-3}$ per individual per hour and W = wet weight of an animal in $g\,10^{-6}$. The correlation coefficient for this relation is 0.541 at 45 degrees of freedom;

Table 1. Body weight and oxygen consumption in *Macrotrachela musculosa* and *Trichotria truncata* (Rotatoria) from Spitsbergen tundra. T – temperature of measurement, n – number of measurements. Mean values ± standard error.

Species	Date	T°C	n	Wet wt. g 10^{-6} per individual	Oxygen consumption mm^3 10^{-3} per individual per h.	Metabolic rate mm^3 10^{-3} O_2 per g 10^{-6} per h.
Macrotrachela musculosa	3 June–18 June	2	47	1.18 ± 0.07	0.222 ± 0.016	0.205 ± 0.015
	20 June–23 June	6	31	1.71 ± 0.06	0.331 ± 0.016	0.201 ± 0.010
	29 June–3 July	10	7	1.02 ± 0.05	0.610 ± 0.064	0.616 ± 0.066
Trichotria truncata	20 June–22 June	6	3	22.73 ± 0.86	2.29 ± 0.035	0.103 ± 0.013

the standard error of the regression coefficient is ±0.17.

Discussion

The literature dealing with the metabolic rate of Rotatoria is exceptionally scarce. Most studies refer to animals from laboratory culture (Belyatskaya 1959; Galkovskaya 1968; Pourriot & Deluzarches 1970; Pourriot 1973; Doohan 1973; Pilarska 1977). Rotatoria coming directly from the natural environment are objects of only a few studies (Winberg 1937; Krylova 1971; Galkovskaya & Winberg 1979). Moreover, in only a few cases individual animals have been measured (Belyatskaya 1959; Doohan 1973; Pilarska 1977); usually measurements were taken of whole communities (cultures) of Rotatoria. All the literature data refer to Rotatoria from the temperate zone.

As there are no data in literature on the metabolic rate of Rotatoria from polar regions, *M. musculosa* oxygen consumption could be compared only with data on laboratory-reared Rotatoria from the temperate zone, whose oxygen consumption was measured at 10°C (Fig. 2). As demonstrated in Fig. 2, the level of oxygen consumption by *M. musculosa* does not differ from that of other Rotatoria. It should be noted, however, that oxygen consumption of similar weight *Brachionus calyciflorus* from laboratory cultures was about one half of individuals from the natural environment (Table 2). Thus, an indirect conclusion can be drawn: the rate of metabolism of *M. musculosa* is rather low, as compared to other Rotatoria living in the natural environment.

The rate of metabolism of *M. musculosa* at 2 and 6°C is practically the same; a considerable increase is observed only at 10°C (Fig. 2). During the Spitsbergen spring and summer, the temperature of interstitial water in moss turf, where Rotatoria occur, ranges from 2 to 8°C, rarely exceeding 10°C. Therefore the plateau of the temperature dependence curve of *M. musculosa* metabolic rate should be considered as 'relative temperature independence' sensu Duncan & Klekowski (1975). Attaining such partial independence of the metabolic rate from small oscillations of environment temperature can be favourable for poikilothermic animals as far as their energy budget is concerned; in this manner energy is 'saved', which is necessary for the processes of enzyme activation and repression within the temperature changes. These processes (activation and repression), which are the adaptation mechanisms of the organism to the environmental temperature conditions, are energy-consuming

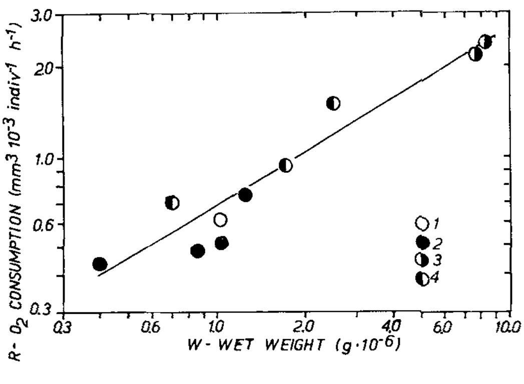

Fig. 2. The regression of oxygen consumption (P) against body wet weight (W) for some Rotatoria species at 10°C. $R = 0.67\,W^{0.60}$. 1 – *Macrotrachela musculosa*, present paper; 2 – *Keratella valga*, after Pourriot & Deluzarches (1970); 3 – *Rhinoglena frontalis*, after Pourriot & Deluzarches (1970); 4 – *Brachionus calyciflorus*, after Pourriot & Deluzarches (1970).

Table 2. Oxygen consumption in *Brachionus calyciflorus* (Rotatoria) at 20°C from natural environment and from laboratory culture.

Source of animals	Wet wt. g 10^{-6} per individual	Oxygen consumption mm^3 10^{-3} per individual per h.	Author
Natural environment	2.4	2.8	Galkovskaya & Winberg 1979
	2.4	3.6	Galkovskaya & Winberg 1979
	2.4	3.9	Galkovskaya & Winberg 1979
Mean	2.4	3.4	
Laboratory culture	2.6	2.2	Belyatskaya 1959
	2.0	1.2	Galkovskaya 1968
	2.8	1.5	Pourriot & Deluzarches 1970
	2.0	1.6	Pourriot & Deluzarches 1970
Mean	2.35	1.6	

and decreasing their dynamics can cut down the maintenance cost of the organism (Hochachka & Somero 1973).

The regression coefficient 'b' of the relation between oxygen consumption and body weight of *M. musculosa* at 2°C is 0.67 ± 0.17, and does not differ significantly from the 'b' stated by Galkovskaya (1968) for different species of Rotatoria (b = 0.721 ± 0.037) or by Hemmingsen (1960) for Metazoa (b = 0.751 ± 0.015; the t-values of the Student's t-test for comparing two regression coefficients (Volk 1969) are 0.075 and 0.045, respectively, with the boundary value $t_{0.05:40}$ = 2.021).

The relatively low values of regression coefficient 'b' obtained for *M. musculosa* and Rotatoria en bloc (0.60 – see Fig. 2) suggest that the metabolic rate of these animals is proportional to the surface and not to the weight of the body (Kleiber 1961). It is justifiable, since in Rotatoria the gas exchange takes place only through the body surface as a consequence of their small size.

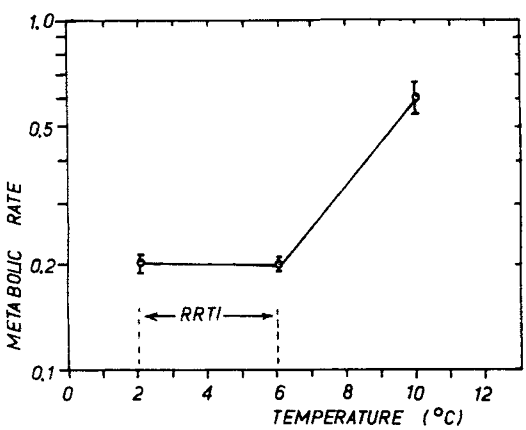

Fig. 3. Metabolic rate (mm^3 10^{-3} per g 10^{-6} per h.) versus temperature in *Macrotrachela musculosa* (Rotatoria) from Spitsbergen tundra. RRTI – range of relative temperature independence. Vertical lines – standard errors.

Summary

Wet body weight and oxygen consumption were measured in rotifiers *Macrotrachela musculosa* and *Trichotria truncata* living in interstitial waters in moss turfs on southern Spitsbergen (77°N) tundra. Oxygen consumption measurements have been carried out in Cartesian divers at 2, 6 and 10°C ambient temperatures, which correspond to the temperatures prevailing in the natural environment of this species in spring and summer on Spitsbergen. Oxygen consumption in *M. musculosa* at these temperatures is 0.222, 0.331 and 0.619 mm^{-3} 10^{-3} indiv. h^{-1}, respectively, which is rather low compared to that of other Rotatoria living in natural habitats. In the temperature range of 2–6°C, metabolism of *M. musculosa* was relatively independent of temperature. This is an adaptation of this species to life in such a temperature range. The dependence of oxygen consumption on the body weight of *M. musculosa* is given by the equation $R = 0.18\, W^{0.67}$, in which R = oxygen consumption in mm^3 10^{-3} $indiv.^{-1}$ h^{-1} and W = wet body weight in g^{-1}.

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