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Geographical variation of thermoregulation in wild populations of *Mus musculus* and *Mus spretus*

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Thermoregulation was studied in the house mice *Mus musculus* (Linnaeus, 1758) from Warsaw region (Dziekanów Leśny) and from Sofia (Kostinbrod) and in *Mus spretus* (Lataste, 1883) from southern France (Montpellier). The thermoregulation curves obtained in these three groups of mice were significantly different. The lowest values of metabolism rates in thermoneutral zone, assumed to approximate BMR values fell in range from 30° to 33°C. The body temperature in mice subjected to 5°C to 30°C range of temperatures remained fairly similar. The lowest intensity of thermoregulation, expressed in % per °C, was observed in *Mus spretus* while the lowest insulation index was found in *Mus musculus* from Dziekanów. The results indicate certain adaptations in metabolism rate of the rodent species studied, relevant to the conditions in the habitats where rodents live.

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Introduction

The house mouse is an ubiquitous species which forms many subspecies by crossing synanthropic forms with the original wild ones. Under favourable climatic conditions, the house mouse may return to the wild, away from human settlements (particularly on islands where predators are lacking) (Pucek 1984).

In Central Europe, two synanthropic subspecies of the house mouse occur. In the western part of the range *M. musculus domesticus* Rutty, 1772 is found whereas in Eastern Europe, up to Scandinavia to the north, and Elbe river to the west – *M. musculus musculus* Linnaeus, 1758. The latter is less associated with human settlements and moves easily into natural locations. The two subspecies form hybrids in the border zone of their ranges (Pucek 1984).

The mice of *Mus musculus musculus* from Poland and Bulgaria were obtained from similar habitats (cultivated fields close to human settlements), although still different in respect to climatic conditions *e.g.* average annual air temperature. In Poland it was lower (7.7°C) than in Bulgaria (9.7°C).

Mus spretus (Lataste, 1883) is distributed throughout Portugal and Mediterranean region (Spain, southern France, northern Africa) (Orsini *et al.* 1982). In southern

France *Mus spretus* occurs in dry warm locations (average annual temperature 14.7°C) close to salt lakes and unwatered vineyards.

The information about physiological parameters is available mainly for laboratory strains of *Mus musculus* (Bratke and Górecki 1968, Górecki and Krzanowska 1970, 1971). The data on wild populations of *M. musculus* are patchy (Pearson 1947, Mokriyevich 1966, Bashenina 1977).

The aim of this study was to determine basic physiological parameters (metabolism rate and thermoregulation) in wild representatives of genus *Mus* and to find if there is any geographical variation between animals living in natural habitats under remarkably different climatic conditions.

Material and methods

The study of thermoregulation and basal metabolism rate was carried out in two species of *Mus*: *Mus musculus musculus* and *Mus spretus*. The animals used in measurements were collected in three locations in Europe shown on the map (Fig. 1): *Mus spretus* (11 individuals) collected on cultivated fields near Montpellier (southern France) in October 1988. *Mus musculus* were captured near Warsaw, central Poland (Dziekanów Leśny locality) (13 individuals) and in Sofia region (near Kostinbrod locality) (20 individuals) – both in summer 1989. Captured mice were kept in laboratory under natural light regime, with fresh water and food (cereal grain, carrot, apple) provided *ad libitum*.

The measurements of metabolism rate and thermoregulation were made in a closed-system Kalabukhov-Skvortsov's respirometer (Górecki 1975). The mice were put into little metal cages ($4 \times 4 \times 7$ cm) that restricted their locomotor activity. The cages were then placed in glass chambers of 0.5 to 1 litre capacity immersed in water bath with temperature regulated to the nearest 0.2°C. The measurements were conducted in −5, 0, 5, 20, 30, 32, and 33°C ambient temperatures. Each experimental run lasting 20 minutes was

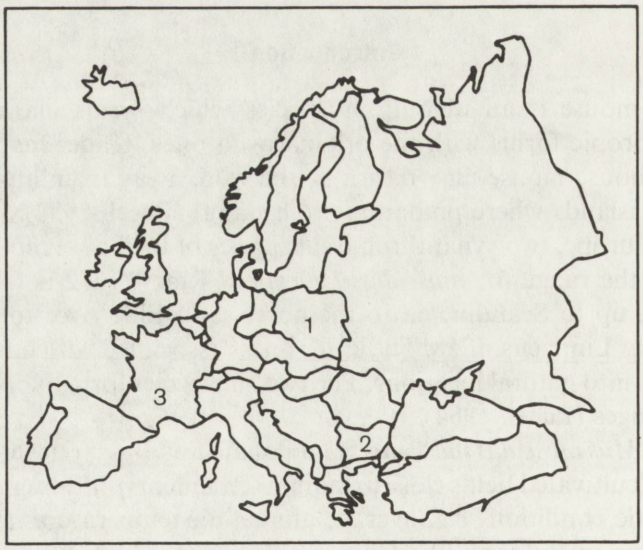

Fig. 1. Trapping sites of mice: 1 — *Mus musculus* – Dziekanów Leśny (Poland), 2 — *Mus musculus* – Kostinbrod (Bulgaria), 3 — *Mus spretus* – Montpellier (France).

preceded by acclimatization period in corresponding temperature. After the run, rectal temperature was measured in each animal at depth of about 1 cm by a thermistor thermometer (TL 2000) with accuracy to the nearest 0.1°C.

All the experiments were completed at the break of September and October between 9 a.m. and 15 p.m. to avoid any effects of season and of daily metabolism cycle.

Statistical analysis used averages, SD, SE, and the regression coefficients. The comparisons were assessed by Student test (T-TEST), one factor variation analysis (ANOVA1), and covariance analysis (ANCOVA).

Results

The body weight in mice used in experiments differed significantly. The lowest body weights were noted in *M. musculus* from Dziekanów (average 13.2 g± 2.9 SD), the highest – in *M. spretus* (21.8 g±1.8 SD) while average body weights in *Mus musculus* from Kostinbrod was 18.6 g±3.0 SD ($p<0.01$ and $p<0.05$).

The lowest value of metabolism rate in thermoneutral zone was assumed to approximate the basal metabolism rate (BMR). In *M. musculus* from Dziekanów such value was obtained at 32°C [4.95 cm^3 $O_2/(g \times h) \pm 1.07$ SD], in those from Kostinbrod at 30°C [2.64 cm^3 $O_2/(g \times h) \pm 0.63$ SD], and in *M. spretus* in 32 and 33°C [2.84 cm^3 $O_2/(g \times h) \pm 0.73$ and 0.67 SD] (Fig. 2).

The intensity of thermoregulation was calculated in % per °C. It was lowest in *M. spretus* (4.0% per °C) while the values for two groups of *M. musculus* were 6.3 and 7.2% per °C (Dziekanów, Kostinbrod).

The parameters of regression equations of thermoregulation are given in Table 1. The slope coefficients for the range of ambients used in this study differed statistically significantly from each other. The "a" coefficients in these equations differed between two groups of *M. musculus* and between *M. spretus* and *M. musculus* from Dziekanów.

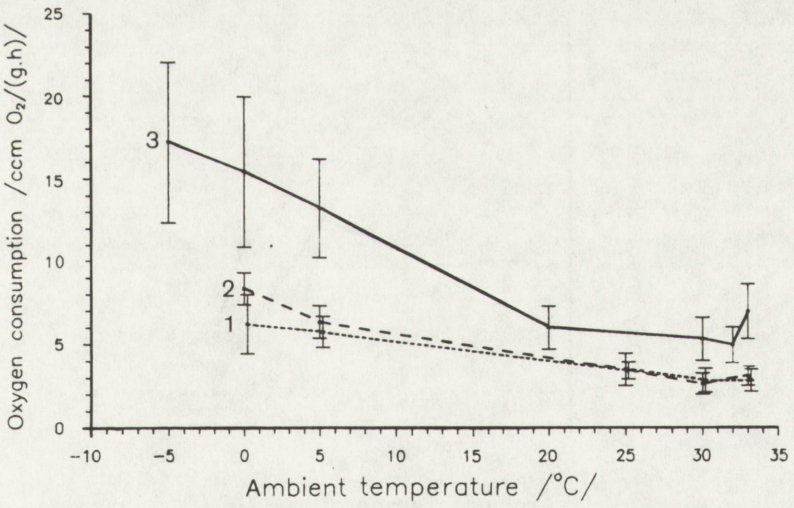

Fig. 2. Thermoregulation curves for: 1 — *Mus spretus*, 2 — *Mus musculus* from Kostinbrod, 3 — *Mus musculus* form Dziekanów Leśny.

Table 1. Regressions of matabolic rate [cm^3 $O_2/(g \times h)$] on ambient temperature (°C).

Group	n	Intercept	Slope	r^2	Regression S E	Slope S E
M. musculus (Dziekanów L.)	6	15.06	−0.344	0.96	2.48	7.01E−02
M. musculus (Kostinbrod)	4	7.84	−0.176	0.97	0.79	3.12E−02
M. spretus	4	6.28	−0.114	0.999	8.75E−02	3.43E−03

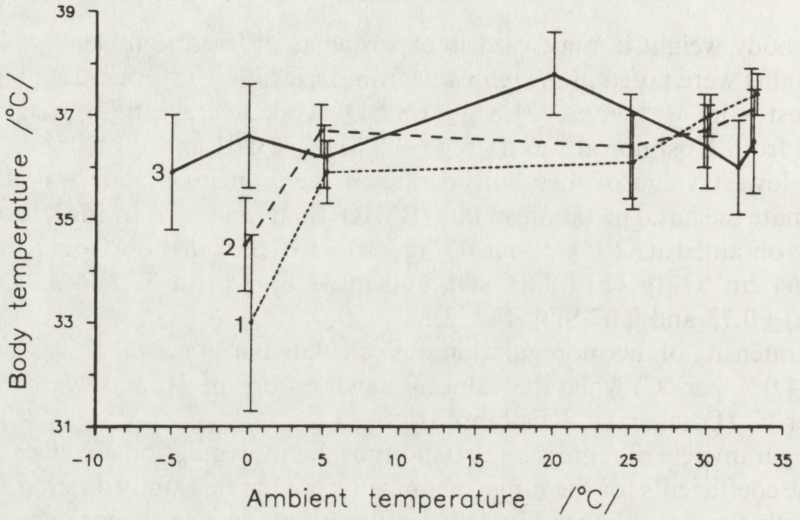

Fig. 3. Changes in rectal body temperatures at various ambients. Denotations as in Fig. 2.

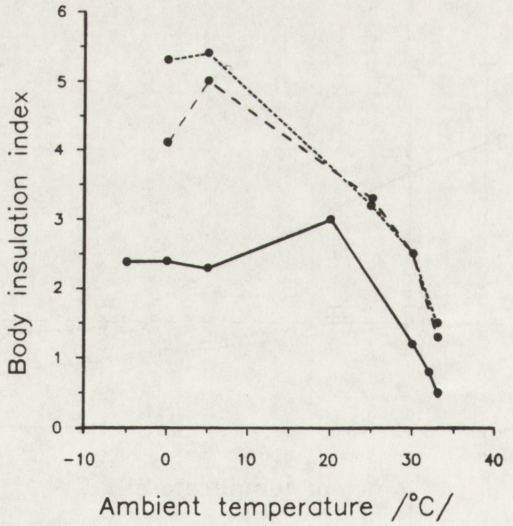

Fig. 4. Body insulation index. Denotations as in Fig. 2.

The body temperatures determined in mice under 5 to 30°C temperature range did not differed significantly. In *M. musculus* from Kostinbrod and in *M. spretus*, the body temperatures drop remarkably at 0°C, while in *M. musculus* from Dziekanów there was only a slight decrease, even at −5°C (Fig. 3). In all groups, the series of measurements taken at higher temperatures showed slight elevation of body temperature.

The insulation indexes were calculated according to formula suggested by Hart and Heroux (1955) (Fig. 4). The lowest values were found in *M. musculus* from Dziekanów. In the remaining groups, these values were similar, with the only differences occurring at 0°C.

Discussion

The insulation index is related to the habitat in which rodents live. Among *Mus* species studied, *M. spretus* occurs in the warmest situations. Although *M. musculus* from Dziekanów inhabits the area of more severe climate than that of Kostinbrod, the individuals from Dziekanów were statistically significantly smaller which, in turn, implied distinctly higher metabolism rate per unit of body weight. Since the insulation index was calculated on the basis of metabolism rate, the differences were obscured.

A metabolic adaptation phenomenon is suggested by the fact that similar values for near basal metabolic rate occur in *M. spretus* at 30 and 33°C. In both groups of *M. musculus* the metabolism rate at 33°C is markedly higher (by about 30%). According to Kondrashkin and Kuznecova (1959) and Benedict and Lee (1936) this temperature approaches the lethal temperature which, according to these authors, stands at 35°C. The metabolic adaptation is also indicated (by a drop in body temperature at lowest ambients applied. In *M. spretus* the body temperature drops to 33°C ($p<0.001$), in *M. musculus* from Kostinbrod – to 34.5°C ($p<0.001$) while in smaller *M. musculus* from Dziekanów the decrease was not statistically significant.

The range of basal metabolism values determined in this study [from 2.6 to 4.9 cm^3 $O_2/(g \times h)$] is slightly higher than those reported by Pearson (1947) and Mokriyevich (1966) and overlaps that obtained by Górecki and Krzanowska (1970, 1971) in laboratory strains of mice.

Laboratory mice, studied by Styrna *et al.* (1975) and by Górecki and Krzanowska (1971), of average body weight similar to mice from Kostinbrod, had distinctly higher intensity of thermoregulation. Laboratory mice studied by Górecki and Krzanowska (1971) whose body weight range was almost identical with that of *M. musculus* from Dziekanów had very similar shape of thermoregulation (although the range of experimental temperatures used was limited to 10−30°C).

In temperatures decreasing from 30 to 5°C, the mice from all three groups practically managed to maintain stable body temperature, while Górecki and Kania (1985) found that laboratory mice of much higher body weights (about 30 g) already showed decrease in their body temperature at 10°C.

The rectal temperature in *M. musculus* from Dziekanów determined at 20°C

ambient temperature was higher by about 1°C from relevant body temperatures in other groups. This fact is rather difficult to explain, perhaps it is associated with different "thermal experience" of these animals (which had perhaps more opportunities to spent some time within buildings in Dziekanów region which is densely built-up).

The thermoregulation curve, determined by Mokriyevich (1966) in wild *Mus musculus* from Volga region, showed lower values than those found in this study for any *Mus*. The intensity of thermoregulation calculated by this author in a slightly different manner for a 10–30°C range lower than that calculated in this paper for both groups of *M. musculus*, and remains very similar to that found in *M. spretus*.

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