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Craniometric Variation of Apodemus agrarius (Pallas, 1771) in Urban Green Areas

Michał D. SIKORSKI

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Comperative analysis was made of variations in four skull measurements of the field mouse *Apodemus agrarius* (Pallas, 1771) inhabiting urban green areas in Warsaw characterized by different degrees of urbanization. Differences were found in size, skull proportions and rate of increase in dimensions. Skull dimensions and their growth rate are greatest in mice from city centre habitats and decrease with increasing distance from the city centre. Mice from Młociny Wood have short and flattened skulls, while the skulls of individuals from Łazienki Park and Bielany Grove are longer and narrower, and mice from the Orthodox Cemetery have long, narrow and markedly arched skulls. It was considered that the cause of these differences lies in the different character of the habitats and in particular in the different food in these habitats, and also the isolation of populations inhabiting the different areas.

[Mammals Res. Inst., Polish Acad. Sci., 17-230 Białowieża, Poland]

1. INTRODUCTION

The field mouse is an inhabitant of the majority of urban green areas in Warsaw (Babińska-Werka *et al.*, 1979). These areas are situated in zones characterized by different degrees of urbanization, ranging from the only slightly urbanized suburban zone to the city centre. Studies on the ecology of field mice living in these areas revealed the increasing domination of this species in the rodent community, and also significant differences in the structure, dynamics and certain intrapopulation processes. These differences increase together with increase in the degree to which the habitat occupied is urbanized (Andrzejewski *et al.*, 1978). The field mouse, as one of the few non-synanthropic species of *Rodentia*, enters into towns and cities and adapts itself to the specific conditions it there encounters. The processes connected with this phenomenon have been given the term synurbization (Andrzejewski *et al.*, 1978; Gliwicz, 1980).

The differences shown in the study by Andrzejewski *et al.* (1978) in the body weight of individuals from different habitats suggest that populations of field mice may be characterized by different growth rate and may be morphologically differentiated. The best way of establishing morphological changes would be to find differences in skull dimensions. Analysis has consequently been made in this paper of variations in four craniometric features, making it possible to obtain a better knowledge of the changes which these rodent populations undergo when they occupy new urban areas.

2. STUDY AREA, MATERIAL AND METHODS

The studies were made in four urban green areas in Warsaw. Trapping was carried out from 1975—1977 in Łazienki Park jointly with the Botanic Gardens (ŁP), in 1977 in the Orthodox Cemetery (OC) and from 1975—1976 in Bielany Grove and Młociny Wood. Trapping took place twice a year, in spring from May-June and in autumn from September-October, using live-traps set out in lines.

The following four linear measurements were made on field mouse skulls picked clean by insects (*Dermestes lardarius*): condylobasal length, length of mandible (on right half), maximum braincase breadth and braincase height *inter bullae*. Measurements were made with a nonius, with accuracy to 0.1 mm. The braincase breadth × 100/condylobasal length index was calculated on the basis of the values obtained by the measurements on a total of 678 skulls (Table 1).

Table 1

Number of individuals on which craniometric measurements were made.

Age class	Generation	Łazienki Park	Orthodox Cemetery	Bielany Grove	Młociny Wood
I	spring	62	19	24	8
	autumn	25	2	51	17
II	spring	44	18	34	42
	autumn	30	23	32	42
III	spring	18	9	19	28
	autumn	18	—	12	12
IV	spring	8	3	6	7
	autumn	17	10	18	20
Total		222	84	796	176

Material from each study area was divided into four age classes according to the animals' absolute age in months, determined by means of the dry eye lens weight. Class I included individuals up to 2 months, class II from 3—4 months, class III from 5—6 months, class IV over 7 months old. As it was expected that there would be differences in growth rate, samples were segregated into two seasonal generations: the spring generation, consisting of individuals born in spring and early summer, and the autumn generation, individuals born at the end of summer and in autumn.

3. RESULTS

3.1. Condylobasal Length

Curves of frequency distributions for the measurement values are symmetrical in all the study areas. The narrowest distribution was found in MW, where 85.8% of all individuals come within a range from 20.5—23.4 mm, and the widest for ŁP, where 68.9% of the individuals come within this range. The distribution mean for MW comes within the range from 21.5—22.4 mm, and for the other areas within the range from 22.5—23.4 mm (Fig. 1).

The average values for the Cb measurement for individuals of the spring generation are similar in all areas for age class I. In consecutive age classes individuals from MW have distinctly lower mean values. Individuals of the autumn generation have shorter skulls in the corresponding age classes, but the average values for this measurement are more balanced for the various areas. As in the spring generation, lowest mean values were found in MW (Table 2).

Increases in Cb in age class IV on an average for both generations expressed in percentages in relation to values from age class I, are as follows: ŁP — 12.1%, OC — 13.7%, BG — 11.0%, MW — 8.0%.

3.2. Length of Mandible

Frequency distributions are analogical with Cb distributions. The peak of the curve for MW is also shifted in the direction of lower values and comes within the range from 13.0—13.4 mm, and for the other areas within the range from 13.5—13.9 mm (Fig. 1).

Greater differences for average values between individuals from the various areas were found for the spring generation. In both generations individuals from MW have the shortest mandibles (Table 2). In age class IV increases in mandible length are: ŁP — 10.0%, OC — 11.6%, BG — 8.6%, MW — 9.2%.

3.3. Brain-case Breadth

Curves for frequency distribution are symmetrical for all the areas. Their peaks come within the range from 10.3—10.5 mm. Differences can be seen in the width of distribution and here too the narrowest distribution was found in MW and widest in ŁP (Fig. 1).

In age class I average dimensions for the spring generation are more similar in all the study areas. There is distinct differentiation in consecutive age classes. The narrowest skulls are found in mice from OC and are increasingly broad in the following order — MW, BG and ŁP. In the autumn generation the narrowest skulls are found for individuals from OC, while average values are very similar for the remaining areas, although the order found for the spring generation is not maintained in all age classes (Table 2).

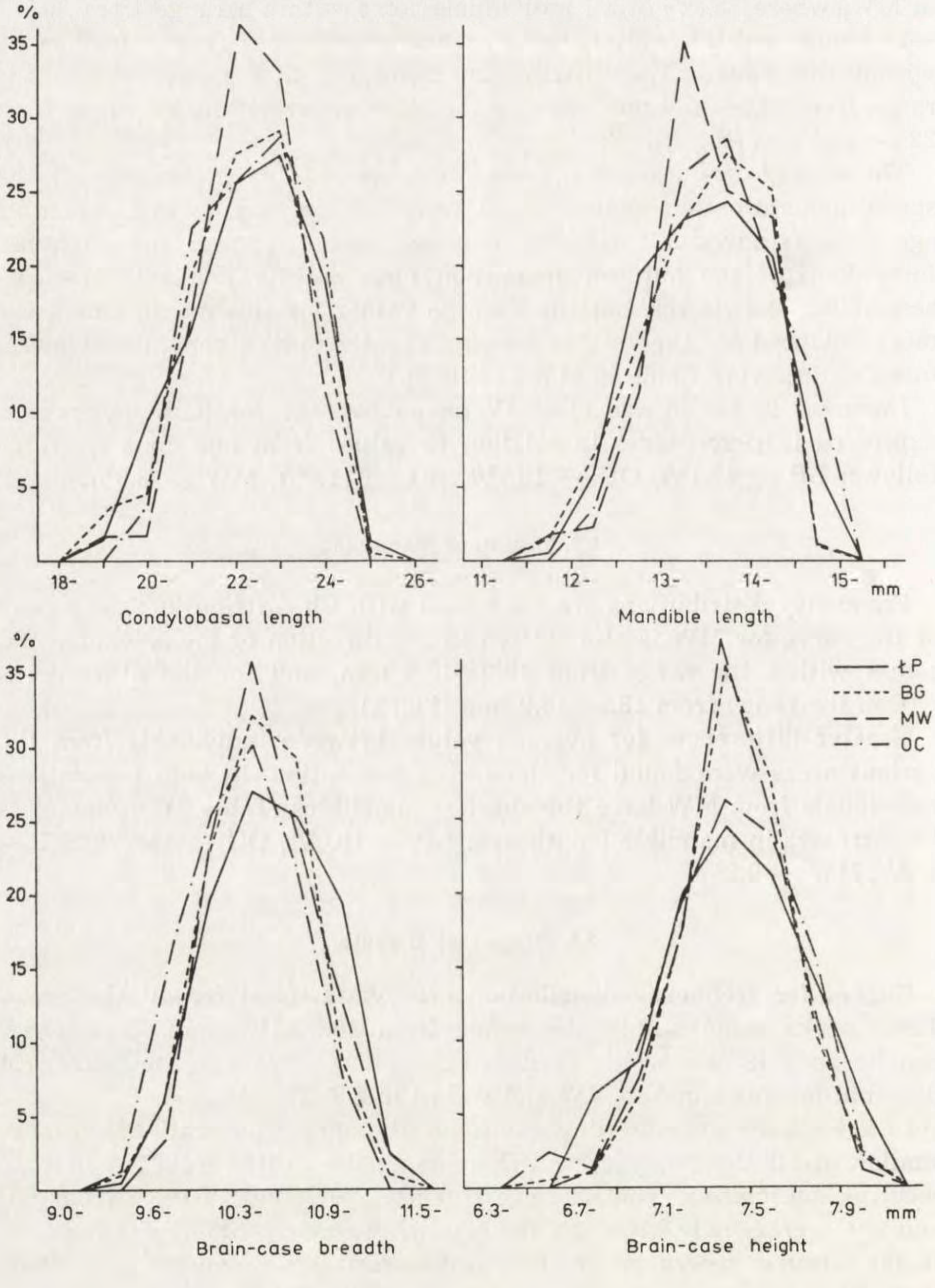

Fig. 1. Frequency distribution for skull measurements in percentages. ŁP — Łazienki Park, OC — Orthodox Cemetery, BG — Bielany Grove, MW — Młociny Wood.

Table 2

Variations in skull measurements of *Apodemus agrarius* in age classes, separately for each study area and seasonal generation.
Statistically significant differences between seasonal generations have been indicated by an asterisk (Student *t* test.). * $p<0.05$ ** $p<0.001$.

Study area	Age class	Spring generation Min.-Max.	Mean	S.D.	C.V.	Autumn generation Min.-Max.	Mean	S.D.	C.V.
					Condylo-basal length				
ŁP	I	18.8—23.9	21.57	1.19	5.57	19.4—22.8	20.87	0.84	4.02
	II	21.4—24.3	22.91**	0.68	2.97	21.0—22.9	21.96**	0.45	2.05
	III	22.1—24.4	23.51	0.65	2.76	22.5—24.7	23.40	0.57	2.44
	IV	22.1—25.0	23.88	0.96	4.02	22.9—24.4	23.48	0.54	2.30
OC	I	19.6—23.2	21.65	1.01	4.67	20.1—20.5	20.30	—	—
	II	20.8—24.0	22.51*	0.96	4.28	20.5—23.4	21.84*	0.92	4.21
	III	22.3—24.3	23.06	0.73	3.17	— —	—	—	—
	IV	23.5—24.3	23.87	—	—	23.1—24.2	23.77	0.35	1.47
BG	I	20.2—22.9	21.64**	0.67	3.10	19.0—22.5	20.86**	0.85	4.07
	II	21.4—24.2	22.79**	0.69	3.03	21.0—23.6	21.98**	0.69	3.14
	III	22.4—24.2	23.35	0.47	2.01	22.6—24.1	23.04	0.42	1.82
	IV	23.2—25.0	23.85*	0.66	2.77	22.3—24.0	23.33*	0.45	1.93
MW	I	19.7—22.4	21.36	0.90	4.21	18.4—22.4	21.61	1.07	4.95
	II	19.6—23.7	22.18*	0.78	3.52	20.7—22.9	21.75*	0.48	2.21
	III	21.4—24.4	22.92	0.65	2.84	22.2—23.6	22.80	0.45	1.97
	IV	21.1—24.0	23.11	1.06	4.59	22.7—24.0	23.29	0.41	1.76
					Mandible length				
ŁP	I	11.7—14.6	13.02*	0.59	4.53	12.0—13.9	12.70*	0.46	3.62
	II	13.0—14.5	13.70**	0.39	2.85	12.8—14.0	13.28**	0.33	2.48
	III	12.9—14.5	14.02	0.41	2.92	13.3—14.7	14.03	0.35	2.49
	IV	13.4—14.8	14.23	0.46	3.23	13.6—14.7	14.07	0.34	2.42
OC	I	12.4—14.4	13.37	0.57	4.26	12.3—12.5	12.40	—	—
	II	12.0—14.4	13.52*	0.57	4.22	12.5—14.3	13.35*	0.50	3.75
	III	12.9—14.4	13.68	0.46	3.36	— —	—	—	—
	IV	13.8—14.5	14.27	—	—	13.4—14.9	14.43	0.44	3.05
BG	I	12.3—13.8	13.08*	0.48	3.67	11.7—13.8	12.80*	0.47	3.67
	II	12.7—14.4	13.77*	0.40	2.90	12.4—14.4	13.43*	0.42	3.13
	III	13.3—15.0	14.08*	0.38	2.70	13.4—14.2	13.78*	0.25	1.81
	IV	13.5—14.4	14.05	0.36	2.56	13.4—14.7	14.06	0.32	2.28
MW	I	12.5—13.9	12.94	0.47	3.63	11.4—13.8	12.57	0.62	4.93
	II	12.4—14.3	13.45*	0.45	3.35	12.7—14.0	13.26*	0.28	2.11
	III	13.0—14.5	13.81	0.43	3.11	13.2—14.1	13.73	0.27	1.97
	IV	12.9—14.7	13.86	0.54	3.90	13.3—14.4	13.99	0.36	2.57
					Brain-case breadth				
ŁP	I	9.5—11.3	10.34*	0.38	3.68	9.6—10.9	10.15*	0.27	2.66
	II	9.8—11.2	10.65**	0.31	2.91	9.7—10.8	10.35**	0.24	2.32
	III	10.2—11.2	10.81	0.28	2.59	10.2—11.2	10.83	0.25	2.31
	IV	10.6—11.3	10.96*	0.21	1.92	10.3—11.1	10.74*	0.22	2.05
OC	I	9.3—10.9	10.34	0.35	3.38	9.9— 9.9	9.90	—	—
	II	10.0—11.0	10.39*	0.32	3.08	9.5—10.7	10.06*	0.29	2.88
	III	9.8—11.0	10.42	0.43	4.13	— —	—	—	—
	IV	10.5—10.8	10.63	—	—	10.3—11.1	10.68	0.25	2.34
BG	I	9.9—10.9	10.37*	0.23	2.22	9.4—10.8	10.15*	0.29	2.86
	II	10.1—11.0	10.54*	0.25	2.37	10.0—10.9	10.39*	0.27	2.60
	III	10.2—11.0	10.71	0.16	1.49	9.9—10.9	10.55	0.27	2.56
	IV	10.7—11.3	10.88	0.23	2.11	10.0—11.2	10.71	0.30	2.80

MW	I	9.6—11.3	10.39	0.48	4.62	9.7—10.8	10.21	0.30	2.94
	II	9.7—11.0	10.46 *	0.29	2.77	9.9—11.0	10.30 *	0.23	2.23
	III	10.2—11.2	10.61	0.25	2.36	10.3—10.9	10.60	0.22	2.08
	IV	10.2—11.2	10.70	0.37	3.46	10.4—11.2	10.79	0.20	1.85
		Brain-case height (*inter bullae*)							
ŁP	I	6.7— 7.8	7.24	0.30	4.14	6.8— 7.6	7.11	0.21	2.95
	II	6.9— 8.0	7.45 *	0.25	3.36	7.0— 7.7	7.32 *	0.18	2.46
	III	7.1— 8.0	7.55	0.23	3.05	7.0— 8.0	7.56	0.27	3.57
	IV	7.5— 8.0	7.89 *	0.19	2.41	7.1— 7.9	7.54 *	0.25	3.32
OC	I	6.5— 7.8	7.31	0.28	3.83	6.8— 6.9	6.85	—	—
	II	7.0— 8.0	7.48 *	0.31	4.14	6.6— 7.6	7.23 *	0.24	3.32
	III	7.2— 7.8	7.52	0.21	2.79	— —	—	—	—
	IV	7.6— 7.8	7.73	—	—	7.2— 7.8	7.51	0.17	2.26
BG	I	7.0— 7.7	7.37 *	0.16	2.17	6.5— 7.7	7.24 *	0.22	3.04
	II	7.0— 7.9	7.47	0.19	2.54	7.0— 7.8	7.38	0.19	2.57
	III	7.1— 7.8	7.48	0.20	2.67	7.0— 7.9	7.38	0.36	4.88
	IV	7.4— 7.9	7.62	0.17	2.23	7.1— 7.9	7.47	0.24	3.21
MW	I	7.0— 7.5	7.30	0.19	2.60	6.8— 7.7	7.19	0.25	3.48
	II	6.7— 7.9	7.38	0.23	3.12	6.9— 7.7	7.32	0.17	2.32
	III	7.0— 7.8	7.45	0.17	2.28	7.0— 7.7	7.35	0.18	2.45
	IV	7.3— 7.8	7.56	0.22	3.04	7.1— 7.9	7.49	0.21	2.80
		Coefficient brain-case breadth × 100/condylo-basal length							
ŁP	I	44.59—52.00	48.44	1.72	3.55	45.95—51.79	48.67	1.40	2.88
	II	44.68—48.65	46.61 *	0.96	2.06	45.13—49.53	47.15 *	1.02	2.16
	III	43.44—47.64	46.01	1.02	2.22	44.13—48.26	46.31	1.29	2.79
	IV	44.04—47.96	45.96	1.32	2.87	43.75—47.62	45.75	1.04	2.27
OC	I	45.65—50.00	47.78	1.42	2.97	48.29—49.25	48.77	—	—
	II	43.72—49.04	46.22	1.61	3.48	44.05—48.11	46.10	1.31	2.84
	III	43.95—45.96	45.20	0.65	1.44	— —	—	—	—
	IV	43.44—45.96	44.51	—	—	43.75—45.87	44.89	0.81	1.80
BG	I	44.98—50.50	47.94 *	1.21	2.52	46.76—51.79	48.69 *	1.34	2.75
	II	43.93—48.87	46.28 **	1.16	2.51	44.92—49.32	47.34 **	0.96	2.03
	III	44.40—48.00	45.86	0.91	1.98	43.98—48.02	45.79	1.27	2.77
	IV	44.00—46.65	45.65	0.93	2.04	42.55—47.53	45.92	1.18	2.57
MW	I	47.22—50.73	48.63 *	1.30	2.67	47.89—55.08	49.64 *	2.00	4.03
	II	44.73—50.00	47.21	1.31	2.77	44.98—50.69	47.37	1.32	2.79
	III	43.03—50.00	46.32	1.45	3.13	45.61—47.60	46.49	0.58	1.25
	IV	45.11—48.34	46.32	1.05	2.27	45.00—47.66	46.33	0.79	1.71

Maximum increases in brain-case breadth jointly for the two generations are: ŁP — 5.9%, OC — 5.3%, BG — 5.2%, MW — 4.3%.

3.4. Brain-case Height Inter Bullae

Curves for frequency distribution for MW and BG have a far narrower range of variation than those in ŁP and OC. The peaks of all curves come within the range of values from 7.3—7.4 mm (Fig. 1).

The mean values of this measurement can be divided into two groups, the first including MW and BG in the younger age classes, and having slightly higher average values. In consecutive age classes mean values increase slowly in comparison with the mean values for OC and ŁP, which increase far more rapidly and attain greater values in age class IV.

Similar relations between mean values were found in the autumn generation, although mean values of dimensions in age class IV individuals from ŁP and OC are not so distinctly greater than the values for the two other study areas (Table 2).

Percentage increases in age class IV are as follows: ŁP — 7.5%, OC — 7.7%, BG — 3.3%, MW — 3.9%.

3.5. Skull Proportions

Mean values of the index: brain-case breadth×100/condylobasal length illustrating the skull breadth and length ratio are as follows: lowest in individuals from OC and then in turn increasing in individuals from BG, ŁP and MW. There are slight divergences from this order in the autumn generation (Table 2).

As a result of the more intensive increase in condylobasal length the proportions of the skull also alter as the individuals grow. Young individuals have broad and short skulls, and as the skull grows it becomes elongated and more slender.

4. DISCUSSION

Morphological differentiation of individuals belonging to different seasonal generations has been found in many species of rodents, including the field mouse (Haitlinger, 1962; Adamczewska-Andrzejewska, 1973). Generation differentiation is due to the far more rapid growth rate in individuals born in spring. The results presented also confirm differentiation in field mice occupying urban green areas in Warsaw.

The range of differences in mean values of skull dimensions between individuals of the spring and autumn generations decreases as the individuals grow. The skull dimensions of young individuals of the spring generation distinctly exceed those of individuals of the autumn generation, but as growth proceeds these differences become smaller. It is only the brain-case height which remains lower in the autumn generation in old individuals also. Analogical changes were found in skull proportions. Young mice of the spring generation have longer and narrower skulls than representatives of the autumn generation, but these proportions become balanced in old individuals (Table 2).

When mean values for craniometric measurements were compared for the field mouse populations it was found for three of the study areas that the smallest skulls are found in individuals from Młociny Wood and the largest from Łazienki Park. Condylobasal length and mandible length in individuals from Bielany Grove are very similar to these dimensions in individuals from Łazienki Park, and brain-case heigth to

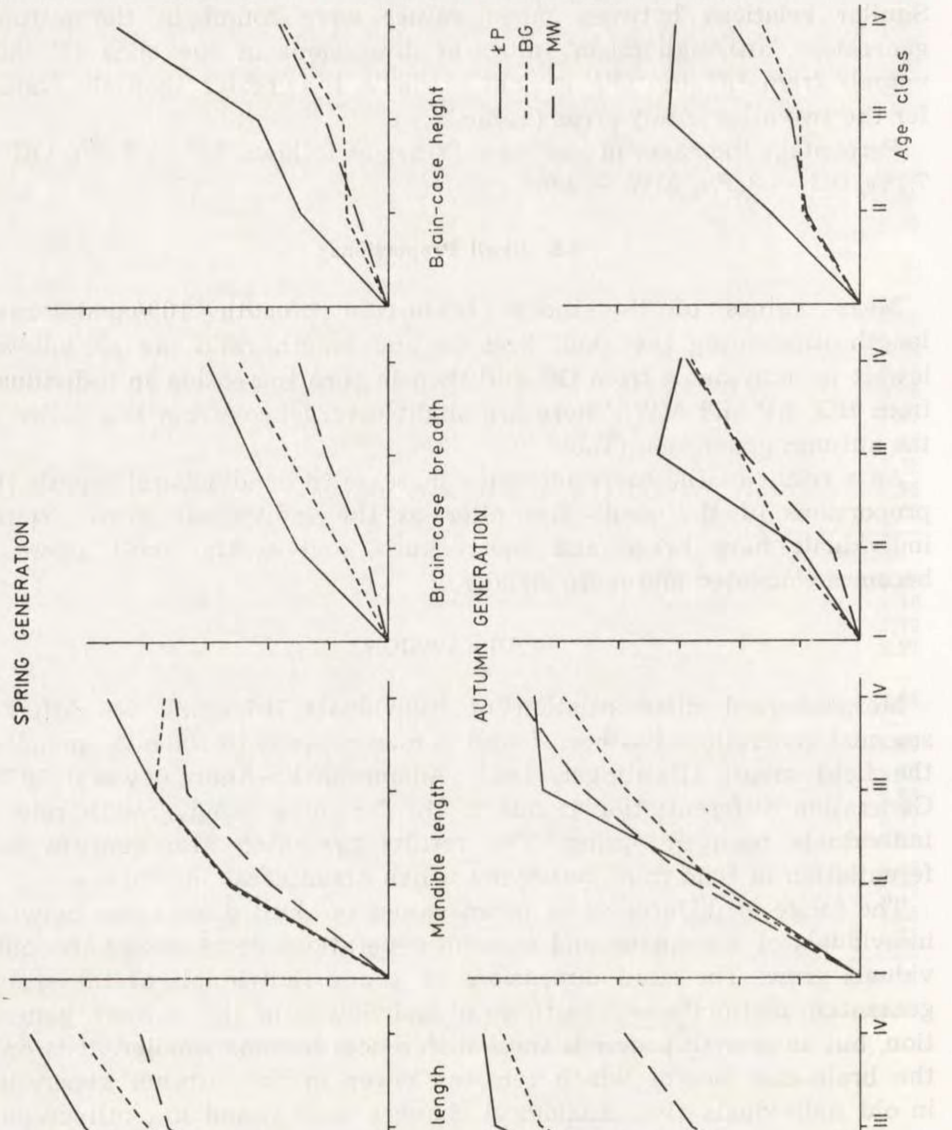

Fig. 2. Percentage increase in mean values of skull measurements in successive age classes. ŁP — Łazienki Park, OC — Orthodox Cemetery, BG — Bielany Grove, MW — Młociny Wood.

that of individuals from Młociny Wood. Skulls of mice from the Orthodox Cemetery have dimensions similar to those of skulls from Łazienki Park, with the exception of brain-case breadth, which is distinctly smaller in animals from this area. As the result of these differences, and also on the basis of the value for the skull breadth to length coefficient, it is possible to define differences in skull proportions. Field mice from Młociny Wood have short, flattened skulls. The skulls of individuals

Table 3

List of statistically significant differences between mean values for skull measurements for all pairs of study areas (Student *t* test). 1 — Condylobasal length, 2 — Mandible length, 3 — Brain-case breadth, 4 — Brain-case height (*inter bullae*), 5 — Coefficient: brain-case breadth ×100/Condylobasal length. Roman numerals show age classes. — differences not statistically significant; + statistically significant differences $p<0.05$; ++ statistically significant differences $p<0.001$.

Areas compared		Spring generation				Autumn generation			
		I	II	III	IV	I	II	III	IV
ŁP — OC	1	—	—	—			—		—
	2	+	—	—			—		+
	3	—	+	++			++		—
	4	—	—	—			—		—
	5	—	—	+			+		+
ŁP — BG	1	—	—	—	—	—	—	—	—
	2	—	—	—	—	—	—	+	—
	3	—	—	—	—	—	—	+	—
	4	+	—	—	+	+	—	—	—
	5	—	—	—	—	—	—	—	—
ŁP — MW	1	—	++	+	—	—	—	+	—
	2	—	+	+	—	—	—	+	—
	3	—	+	+	—	—	—	+	—
	4	—	—	—	+	—	—	+	—
	5	—	+	—	—	—	—	—	—
OC — BG	1	—	—	—			—		++
	2	—	—	+			—		+
	3	—	—	+			++		—
	4	—	—	—			+		—
	5	—	—	—			++		+
OC — MW	1	—	—	—			—		+
	2	—	—	—			—		+
	3	—	—	—			++		—
	4	—	—	—			—		—
	5	—	+	+			++		++
BG — MW	1	—	++	+	—	—	—	—	—
	2	—	+	+	—	—	+	—	—
	3	—	—	—	—	—	—	—	—
	4	—	—	—	—	—	—	—	—
	5	—	+	—	—	+	—	—	—

from Łazienki Park and Bielany Grove are longer and narrower, but differ as to height. Mice from the Orthodox Cemetery, on the other hand, have long, narrow and well-arched skulls. The growth rate for skull measurements in the populations occupying tree of the study areas (curve for the Orthodox Cemetery population has not been given as data were incomplete) alter in accordance with the urbanization gradient. It is lowest in the population from Młociny Wood and increases in turn in Bielany Grove and Łazienki Park. These differences are far more distinct in the spring than in autumn generation (Fig. 2).

Differences in growth rate and the skull size attained in the age classes compared (not statistically significant in all cases, but distinct and occurring in all measurements — Table 3) for field mice occupying urban areas may be due to the differences in their food. Populations from city centre areas consume higher-calorie food than those in suburban areas (Babińska-Werka, 1981). In addition the greatest increases in all parameters measured in the population living in Łazienki Park may be due to greater consumption of animal food (Babińska-Werka & Garbarczyk, 1981).

Thus the craniometric differences between field mice populations living in urban green areas in Warsaw, in agreement with the degree of urbanization of these areas, can be interpreted as due to the differences in habitat conditions and in particular to food differences, and not to differences in the individuals' length of life, since all comparisons were made in corresponding age classes. Differences in skull proportions between populations from two city centre habitats, i.e. Łazienki Park and the Orthodox Cemetery, may also have a genetic basis caused by isolation. The isolation of the Orthodox Cemetery population was established during studies on density (Goszczyński, 1979). In order to clarify this question it would be necessary to carry out further studies on marked individuals and also undertake genetic studies.

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Michał D. SIKORSKI

ZMIENNOŚĆ KRANIOMETRYCZNA *APODEMUS AGRARIUS* (PALLAS, 1771) NA TERENACH ZIELENI MIEJSKIEJ

Streszczenie

Badania kraniometryczne przeprowadzono na myszy polnej odławianej na terenach zieleni miejskiej Warszawy, w Parku Łazienki, Cmentarzu Prawosławnym, Lasku Bielańskim i w Lesie Młocińskim. Na czaszkach dokonano czterech pomiarów liniowych: długości kondylobazalnej, długości żuchwy, maksymalnej szerokości puszki mózgowej i wysokości puszki mózgowej.

Stwierdzono zróżnicowanie morfologiczne między osobnikami należącymi do generacji wiosennej i jesiennej (Tabela 2). Ustalono, że największe czaszki mają myszy z Łazienek a najmniejsze z Młocin. Stwierdzono różnice w stosunku szerokości do długości czaszki mierzone wskaźnikiem (szerokość puszki mózgowej ×100/długość kondylobazalną). Czaszki myszy polnych z Młocin są krótkie i spłaszczone z Łazienek i Bielan dłuższe i węższe a z Cmentarza Prawosławnego jeszcze węższe i dobrze wysklepione (Tabela 2, 3). Populacja zasiedlająca Park Łazienki wykazuje najwyższe tempo przyrostu wymiarów czaszki (Fig. 2). W dyskusji omówiono przyczyny zróżnicowań kraniometrycznych między badanymi populacjami.