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Skull Variability of Mustela putorius Linnaeus, 1758

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Buchalczyk T. & Ruprecht A. L., 1977: Skull variability of *Mustela putorius* Linnaeus, 1758. Acta theriol., 22, 5: 87—120 [With 9 Tables, 10 Figs. & Plates I—III].

Examination was made of the degree of differentiation — both from the age and population aspect — of dimensions and proportions and also the correlation structures in 596 skulls of the common polecat, *Mustela putorius* Linnaeus, 1758, from Poland. Two local populations were distinguished — the Białowieża and Rzeszów populations, which exhibit certain differences in respect of the relations examined in uniform sex and age groups. The skull of the common polecat is distinguished by very marked sex dimorphism of size, proportions, rate of growth and obliteration of sutures. The processes taking place in the polecat's skull are characterized by continuous changes lasting throughout the animal's life. Some skull dimensions of *M. putorius*, in particular zygomatic breadth (*ZyB*) and ectoorbital breadth (*EctB*), and also mondible weight (*MdWt*) are distinguished by continuous growth, unlike braincase capacity (*BcC*), which diminishes with age. Commutability of periods of isometric and allometric growth was distinct in the correlation structures of the skull dimensions of males.

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1. INTRODUCTION

The common polecat, a species widespread in the Paleoarctic and characterized by considerable variation, has formed the subject of many studies, including craniological studies, relating to comparative taxonomic problems (Hensel, 1881; Rempe, 1970), problems connected with age variations (Paramonov, 1937; Széky, 1963; Röttcher, 1965; Habermehl & Röttcher, 1967) and age structure of populations (Stubbe, 1969).

There have, however, been no studies of this type on more numerous material from Poland which permit comparisons of species characteristics based on the correlation structure of dimensions of different types of mammal skulls, similar to those by Caboń-Raczyńska (1964) and Ruprecht (1972 and 1974). This study is therefore aimed at making the most possible comprehensive analysis of variations, chiefly craniometrical, in the common polecat, *Mustela putorius* Linnaeus, 1758 from Poland.

2. MATERIAL AND METHODS

2.1. Criteria for Age Classes

Cranial material of *M. putorius* was divided into 5 age classes separately for the two sexes, on the basis of the following criteria: (1) time of death, (2) degree of obliteration of sutures (*sutura: internasalis* (*harmonia*), *nasomaxillaris, nasofrontalis, maxillofrontalis, petrobasialis, vomeropalatina,* and *synchondrosis sphenooccipitalis*), (3) general appearance of skull bones (*e.g.* surfaces of the frontal bones and parietal bones, spongiose or smooth, more or less massive, *crista sagittalis* absent or present, usually more distinct in males), (4) state of preservation of the teeth (change in the dention, natural degree of tooth wear excluding cases of secondary injuries, usually easy to distinguish, *e.g.* «wear» in a trap)[1], (5) dimensions of baculum.

2.2. Age Classes (Plates I—III)

1. Infants. Polecats killed from July to August, usually with milk teeth or directly after the change to permanent teeth, all skull sutures loose and bone surface spongiose. *Crista sagittalis* is usually absent in females, but may be in the initial stage of formation in males. Age approximately 3 to 4 months.

2. Juveniles. Animals killed from September to December, with permanent teeth, only slightly worn. Visible traces of persistence of the following sutures: *s. nasomaxillaris, nasofrontalis, maxillofrontalis* and *synchondrosis sphenoocci-*

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[1] In situation when the date on which the animal was killed and other features failed to define this beyond doubt the »degree of denudation of the canine teeth« was used as a supplementary and good criterion for defining age groups. With increasing age there is progressive »pushing up« of teeth from the alveoli, combined with exposure of part of the root. In individuals in the higher age classes this process may be greatly advanced and consequently useful for defining relative age, particularly in skulls of females.

pitalis. Crista sagittalis forming. Surfaces of skull bones rough to the touch. Age approximately 5 to 8 months.

3. Subadults. Animals killed from January to April. Traces of *synchondrosis sphenooccipitalis* frequently still present, surface of skull bones only slightly rough, *crista sagittalis* in the final phase of formation — junction between *cristae frontales* marking the beginning of *crista sagittalis* and usually located below the line of the postorbital breadth. Baculum has a narrow base. Age approximately 9 to 11 months.

4. Adults. Animals from 1—2 years old, usually killed from spring to winter of the second calendar year of life and also up to the spring of the third calendar year. Surfaces of skull bones smooth to the touch. *Crista sagittalis* formed — point of transection of *cristae frontales* situated above the line of the postorbital breadth. Baculum has a wide base.

5. Old adults. Polecats killed at similar times of the year as animals in the preceding class. The surfaces of the skull bones are, however, smooth (even slippery to the touch and shiny) with traces of muscular attachments (*e.g.* additional depressions, cristae and nodular formations). *Crista sagittalis* high, though situated similarly to that in the preceding group. Wear visible on all tooth crowns, some teeth may be missing and the alveoli closed. Baculum has a wide base and markedly rough surface. Age two years or more.

Table 1

Skull material of *M. putorius* arranged according to sex, age and population.

Age class	1		2		3		4		5		Total
Sex	M	F	M	F	M	F	M	F	M	F	
West Pomeranian Lake District	3	2	20	9	40	20	6	8	4	8	120
Białowieża Primeval Forest	7	5	34	14	26	14	16	9	1	3	129
Central Poland Lowlands, W	—	—	5	6	15	5	5	10	1	2	49
Central Poland Lowlands, E	1	—	7	6	15	8	5	3	1	1	47
Małopolska Upland	—	—	3	2	8	6	6	4	2	1	32
Rzeszów environs	5	4	36	24	41	15	25	12	10	6	178
Other regions	—	1	7	2	13	9	3	2	1	3	41
Total	16	12	112	63	158	77	66	48	20	24	596

W — west part, E — east part

2.3. Division into Population Groups

Skulls of 596 common polecats (372 males and 224 females) come from: Mammals Research Institute, Polish Academy of Sciences (MRI PAS); the private collection of A.L. Ruprecht (ALR); Institute of Systematics and Experimental Zoology PAS, at Kraków (ISEZ PAS); Zoological Institute of the B. Bierut University at Wrocław (ZIWU) and Institute of Zoology PAS, at Warszawa (IZ PAS). Six population groups were distinguished, allowing for the age division accepted for this study. Certain groups (*e.g.* Białowieża Primeval Forest and the Rzeszów region) consist of populations of a decidedly local character, while others were formed by integration into one group of smaller skull samples obtained from larger areas physiographically similar. They are: 1. West Pomeranian Lake District, 2. Białowieża Primeval Forest, 3. West part of Central Poland Lowlands, 4. East part of Central Poland Lowlands, 5. Małopolska Upland, 6. Rzeszów region. The other skulls (24:17), were impossible to combine with any of the other 6 population groups and were treated together as simply skulls from Poland and used for certain calculations (Table 1).

2.4. Dimensions and Quotient Indices

Fourteen of linear measurements were made on each of the skulls (Fig. 1) using a vernier caliper with accuracy to 0.1 mm. Their definitions and symbols are as follows:

1. Condylobasal length (*CbL*),
2. Profile length (*PL*),
3. Zygomatic breadth (*ZyB*),
4. Ectoorbital breadth (*EctB*),
5. Interorbital constriction (*IC*),
6. Postorbital breadth (*PB*),
7. Mastoid breadth (*MB*),

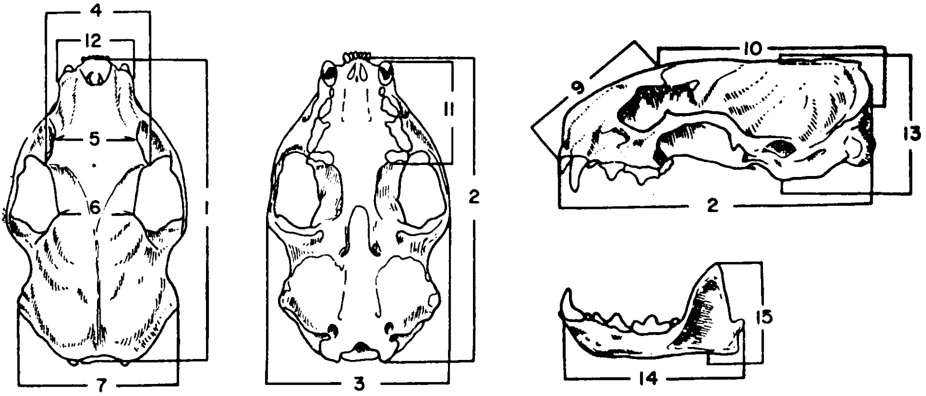

Fig. 1. Method for making skull measurements of *M. putorius*.
1 — Condylobasal length (*CbL*), 2 — Profile length (*PL*), 3 — Zygomatic breadth (*ZyB*), 4 — Ectoorbital breadth (*EctB*), 5 — Interorbital constriction (*IC*), 6 — Postorbital breadth (*PB*), 7 — Mastoid breadth (*MB*), 9 — Viscerocranium length (*VcL*), 10 — Braincase length (*BcL*), 11 — Maxillary tooth-row length (*MxTRL*), 12 — Rostrum breadth (*RB*), 13 — Braincase height (*BcH*), 14 — Mandible length (*MdL*), 15 — Height of *ramus mandibulae* (*HRM*).

8. Braincase capacity in millilitre using fine shot ⌀ 1.5 mm measured in a graduated cylinder to 0.1 ml (*BcC*),
9. Viscerocranium length (*VcL*), (=Sagekt-P),
10. Braincase length (*BcL*) — (=Sagekt-O, after Wyrost & Kucharczyk, 1967),
11. Maxillary tooth-row length (*MxTRL*),
12. Rostrum breadth on C^1—C^1 (*RB*),
13. Braincase height per bullae (*BcH*),
14. Mandible length, measured from the anterior margin of alveolus I_1 to the end of *proc. articularis mandibulae* (*MdL*),
15. Height of *ramus mandibulae* (*HRM*),

16. Mandible weight in grams with accuracy to 0.01 g (*MdWt*).

The following quotient indices were calculated:

1. Viscerocranium length × 100 : Condylobasal length,
2. Braincase length × 100 : Condylobasal length,
3. Zygomatic breadth × 100 : Condylobasal length,
4. Postorbital breadth × 100 : Ectoorbital breadth,
5. $\sqrt[3]{\text{Braincase capacity}}$ × 100 : Condylobasal length (after Heráň, 1973),
6. Mandible weight × 100 : Braincase capacity,
7. Mandible weight × 100 : Mandible length (after Heptner & Morozova-Turova, 1951 — modification),
8. Braincase height × 100 : Mandible weight (after Rossolimo, 1958),
9 Postorbital breadth : Interorbital constriction (after Röttcher, 1965).

Standard body measurements: body length (*L*), tail length (*C*), hind foot (*P*), ear (*A*) and body weight (*Pd*) were made on part of the specimens. The following three measurements were made on the baculum: *os penis* length (*OPL*), height of base (*BH*) and weight of baculum (*BWt*).

2.5. Mathematical Methods

Calculation was made of average values ($\bar{x}$), standard deviations (SD) and coefficients of variation (C.v.) for skull measurements, quotient indices based on them and dimensions of the body and baculum.

Comparison of the average values obtained were made by analysis of variation. The importance of the effect exerted by the animals' origin on skull dimensions and proportions was examined by the Snedecor F test, with $P_{0.05}$ and $P_{0.01}$.

Comparative methods were also used in relation to the correlation matrix, reflecting the degree of correlation of 16 craniometric characters and forming the given correlation structure. The correlation coefficient (r) was calculated by methods in general use. Significance of differences between correlation matrices was calculated, testing the homogeneity of the »average correlation matrix« for both population and age groups, and checking it by chi-square statistics. Considering the amount of material used, calculation was made of 6 correlation matrices for males only from two populations: Białowieża Primeval Forest and the Rzeszów region, in age groups 2, 3 and 4. In addition, in order to obtain a general description of changes with age taking place in the skull in both males and females, correlation matrices were calculated for 5 age groups for all material. The calculations were made at the Computer Centre of the Polish Academy of Sciences in Warszawa on the »Odra 1305« computer. Correlation matrices and all the other statistical calculations are held in the Mammals Research Institute of the Polish Academy of Sciences at Białowieża.

3. RESULTS

3.1. Sex Dimorphism

Differentiation in the size of both body and skull dimensions is so great in the common polecat that no statistical methods were employed for checking the extent of such differentiation. Individuals of both sexes were treated separately. The size of both body and skull differs in both sexes of *M. putorius* from the very youngest age classes (Plates I—III).

Table 2
Morphological characteristics of *M. putorius* from Polish territory from the age aspect.

Age class	1		2		3		4		5	
	$\bar{x} \pm$ SD	C.v.	$\bar{x} \pm$ SD	C.v.	$\bar{x} \pm$ SD	C.v.	$\bar{x} \pm$ SD	C.v.	$\bar{x} \pm$ SD	C.v.
MALES										
Skull measurements	n=16		n=112		n=158		n=66		n=20	
1. CbL	58.27 ± 4.17	7.1	66.21 ± 2.69	4.0	65.72 ± 2.66	4.0	67.21 ± 2.41	3.5	69.05 ± 2.24	3.2
2. PL	59.32 ± 3.56	6.0	66.67 ± 2.83	4.2	66.03 ± 2.79	4.2	67.45 ± 2.70	4.0	69.51 ± 2.25	3.2
3. ZyB	35.09 ± 2.30	6.5	39.23 ± 1.78	4.5	39.95 ± 2.00	5.0	41.94 ± 2.13	5.0	43.64 ± 1.59	3.6
4. EctB	18.50 ± 1.24	6.7	21.33 ± 1.37	6.4	21.76 ± 1.20	5.5	23.52 ± 1.39	5.9	24.37 ± 1.40	5.7
5. IC	15.33 ± 0.91	5.9	17.28 ± 0.98	5.6	17.57 ± 0.93	5.3	18.53 ± 0.95	5.1	18.59 ± 0.86	4.5
6. PB	16.52 ± 0.97	5.8	16.24 ± 0.84	5.2	16.29 ± 0.80	4.9	16.44 ± 0.90	5.5	16.37 ± 1.02	6.2
7. MB	32.28 ± 2.10	6.5	36.57 ± 3.29	9.0	36.41 ± 1.73	4.7	37.36 ± 2.04	5.4	38.26 ± 2.06	5.3
8. BcC	9.49 ± 0.93	9.8	9.73 ± 0.76	7.8	9.34 ± 0.69	7.4	9.25 ± 0.83	3.9	9.20 ± 0.63	6.9
9. VcL	25.73 ± 1.85	7.2	28.11 ± 1.26	4.5	27.85 ± 1.25	4.4	28.66 ± 1.13	3.9	29.35 ± 1.19	4.0
10. BcL	40.41 ± 2.56	6.3	45.33 ± 1.99	4.4	45.08 ± 1.93	4.2	45.92 ± 1.98	4.3	47.51 ± 1.65	3.4
11. MxTRL	18.22 ± 1.04	5.7	19.25 ± 0.76	3.9	19.21 ± 0.74	3.8	19.53 ± 0.70	3.6	19.95 ± 0.62	3.1
12. RB	14.73 ± 0.85	5.8	16.48 ± 0.80	4.9	16.53 ± 0.84	5.0	17.18 ± 0.79	4.6	17.84 ± 0.57	3.2
13. BcH	23.32 ± 0.81	3.5	24.53 ± 0.85	3.4	24.59 ± 0.86	3.5	25.19 ± 0.95	3.7	26.30 ± 0.80	3.0
14. MdL	36.50 ± 2.37	6.5	40.81 ± 1.86	4.5	40.71 ± 1.88	4.6	41.94 ± 1.75	4.1	43.38 ± 1.61	3.7
15. HRM	17.26 ± 1.48	8.5	20.00 ± 1.27	6.3	19.89 ± 1.17	5.9	20.44 ± 1.16	5.7	21.65 ± 1.02	4.7
16. MdWt	2.08 ± 0.56	26.8	3.73 ± 0.57	15.3	3.97 ± 0.58	14.6	4.50 ± 0.63	13.9	5.10 ± 0.52	10.1
Quotient indices										
1. 9 x 100 : 1	44.19 ± 1.88	4.2	42.46 ± 1.01	2.4	42.38 ± 0.90	2.1	42.64 ± 0.97	2.2	42.50 ± 1.29	3.0
2. 10 x 100 : 1	69.41 ± 1.50	2.1	68.46 ± 1.25	1.8	68.60 ± 1.33	1.9	68.31 ± 1.30	1.9	68.81 ± 1.26	1.8
3. 3 x 100 : 1	60.30 ± 2.76	4.5	59.26 ± 1.51	2.5	60.79 ± 2.04	3.3	62.41 ± 2.22	3.5	63.21 ± 1.53	3.0
4. 6 x 100 : 4	89.40 ± 3.71	4.1	76.31 ± 4.55	5.9	74.98 ± 3.82	5.0	70.03 ± 3.80	5.4	67.33 ± 4.66	6.9
5. $\sqrt[3]{8}$ x 100 : 1	3.64 ± 0.19	5.4	3.22 ± 0.11	3.5	3.20 ± 0.10	3.2	3.12 ± 0.09	2.9	3.03 ± 0.09	3.0
6. 16 x 100 : 8	21.93 ± 5.00	22.8	38.46 ± 5.52	14.3	42.47 ± 5.30	12.5	48.78 ± 6.06	12.4	55.58 ± 5.50	9.9
7. 16 x 100 : 14	5.65 ± 1.13	20.1	9.12 ± 1.06	11.6	9.71 ± 1.06	10.9	10.71 ± 1.17	10.9	11.75 ± 0.89	7.4
8. 13 x 100 : 16	1189.35 ± 315.35	26.5	670.42 ± 97.36	14.5	630.67 ± 79.99	12.6	568.10 ± 71.43	12.5	519.66 ± 49.95	9.6
9. 6 : 5	1.07 ± 0.06	5.9	0.94 ± 0.05	5.7	0.92 ± 0.04	5.1	0.88 ± 0.04	4.9	0.86 ± 0.05	6.6
Body measurements	n=4-6		n=17-30		n=11-28		n=8-17		n=2-3	
1. Body length	299.00 ± 23.95	8.0	388.76 ± 25.92	6.6	387.50 ± 23.17	5.9	399.00 ± 25.89	6.4	398.33 ± 2.88	0.7
2. Tail length	103.26 ± 6.70	6.4	136.65 ± 15.39	11.2	133.27 ± 11.85	8.8	125.50 ± 22.02	17.5	143.00 ± 18.08	12.6
3. Hind foot	52.21 ± 2.91	5.5	58.78 ± 3.68	6.2	56.25 ± 2.99	5.3	57.06 ± 4.00	7.0	61.50 ± 2.12	3.4
4. Ear	23.23 ± 3.00	12.9	24.72 ± 2.70	10.9	24.41 ± 2.42	9.9	25.22 ± 3.44	13.6	24.00 ± 0.00	0.0
5. Body weight	427.85 ± 58.14	13.5	840.15 ± 193.15	22.9	869.97 ± 120.68	13.8	1204.12 ± 328.80	27.3	- -	-
Baculum measurements	n=4		n=33		n=34		n=16		n=3	
1. Os penis length	27.02 ± 2.46	9.1	35.40 ± 3.05	8.6	38.43 ± 2.56	6.6	40.75 ± 1.35	3.3	42.96 ± 0.23	0.5
2. Height of base	2.90 ± 0.34	11.9	3.16 ± 0.64	20.3	4.68 ± 1.25	26.7	6.16 ± 0.85	13.8	6.03 ± 0.58	9.7
3. Os penis weight	0.06 ± 0.01	29.4	0.15 ± 0.04	31.0	0,27 ± 0.09	33.5	0.45 ± 0.07	16.6	0.50 ± 0.07	14.4

Table 2, continued.

	FEMALES									
Skull measurements	n=12		n=63		n=77		n=48		n=24	
1. CbL	52.76 ± 3.90	7.3	57.85 ± 2.08	3.5	58.06 ± 1.88	3.2	59.01 ± 1.84	3.1	58.42 ± 1.69	2.8
2. PL	53.36 ± 3.55	6.6	57.73 ± 2.33	4.0	57.94 ± 1.96	3.3	58.92 ± 1.77	3.0	58.39 ± 1.71	2.9
3. ZyB	30.90 ± 2.00	6.4	33.25 ± 1.29	3.8	33.43 ± 1.20	3.6	34.17 ± 1.07	3.1	34.49 ± 1.14	3.3
4. EctB	15.92 ± 1.30	8.1	18.13 ± 0.96	5.3	18.31 ± 1.03	5.6	19.08 ± 1.00	5.2	20.36 ± 1.10	5.4
5. IC	13.25 ± 1.05	7.9	14.80 ± 0.79	5.3	14.73 ± 0.67	4.5	15.19 ± 0.70	4.6	15.47 ± 0.59	3.8
6. PB	14.76 ± 0.96	6.5	15.00 ± 0.72	4.8	14.86 ± 0.80	5.3	14.61 ± 0.93	6.3	14.66 ± 0.73	5.0
7. MB	28.26 ± 1.75	6.2	30.56 ± 1.55	5.0	30.88 ± 1.16	3.7	31.55 ± 1.24	3.9	31.48 ± 0.94	3.0
8. BcC	7.79 ± 0.93	11.9	7.65 ± 0.70	9.2	7.27 ± 0.58	7.9	7.09 ± 0.53	7.4	6.92 ± 0.38	5.5
9. VoL	22.99 ± 1.50	6.5	24.11 ± 1.12	4.6	24.29 ± 0.90	3.7	24.87 ± 0.89	3.6	24.87 ± 0.79	3.1
10. BoL	36.71 ± 2.39	6.5	39.84 ± 1.66	4.1	39.81 ± 1.49	3.7	40.62 ± 1.41	3.4	40.07 ± 1.05	2.6
11. MxTRL	16.24 ± 0.89	5.5	17.12 ± 0.67	3.9	17.10 ± 0.67	3.9	17.29 ± 0.55	3.2	17.31 ± 0.58	3.3
12. RB	12.35 ± 0.96	7.7	13.42 ± 0.60	4.4	13.50 ± 0.60	4.4	13.83 ± 0.57	4.1	13.80 ± 0.58	4.2
13. BcH	21.99 ± 0.63	2.8	22.08 ± 0.69	3.1	21.72 ± 0.74	3.4	21.73 ± 0.80	3.6	21.57 ± 0.83	3.8
14. MdL	31.80 ± 2.13	6.7	34.53 ± 1.53	4.4	34.72 ± 1.30	3.7	35.44 ± 1.24	3.5	35.37 ± 1.21	3.4
15. HRM	14.97 ± 1.33	8.9	16.27 ± 0.92	5.6	16.08 ± 0.82	5.1	16.47 ± 0.86	5.2	16.52 ± 0.74	4.4
16. MdWt	1.33 ± 0.46	34.8	2.16 ± 0.34	15.8	2.18 ± 0.29	13.3	2.38 ± 0.28	11.9	2.47 ± 0.29	11.7
Quotient indices										
1. 9 x 100 : 1	43.62 ± 1.52	3.5	41.67 ± 1.07	2.5	41.84 ± 0.82	1.9	42.15 ± 1.08	2.5	42.58 ± 0.83	1.9
2. 10 x 100 : 1	69.63 ± 1.25	1.7	68.86 ± 1.42	2.0	68.57 ± 1.29	1.8	68.84 ± 1.16	1.6	68.61 ± 1.33	1.9
3. 3 x 100 : 1	58.63 ± 1.62	2.7	57.48 ± 1.32	2.2	57.60 ± 1.54	2.6	57.92 ± 1.50	2.5	59.05 ± 1.81	3.0
4. 6 x 100 : 4	93.01 ± 6.26	6.7	82.83 ± 3.78	4.5	81.29 ± 4.27	5.2	76.68 ± 5.09	6.6	72.20 ± 4.99	6.9
5. $\sqrt[3]{8}$ x 100 : 1	3.76 ± 0.18	4.9	3.40 ± 0.12	3.5	3.33 ± 0.10	3.2	3.25 ± 0.11	3.4	3.26 ± 0.08	2.4
6. 16 x 100 : 8	17.00 ± 5.21	30.6	28.46 ± 4.56	16.0	30.10 ± 3.55	11.8	33.66 ± 4.09	12.1	35.72 ± 3.68	10.3
7. 16 x 100 : 14	4.13 ± 1.19	28.9	6.25 ± 0.74	11.9	6.28 ± 0.65	10.3	6.70 ± 0.62	9.3	6.98 ± 0.68	9.7
8. 13 x 100 : 16	1840.75 ± 668.47	36.3	1040.37 ± 146.95	14.1	1008.17 ± 118.58	11.7	923.13 ± 98.68	10.6	882.24 ± 95.97	10.8
9. 6 : 5	1.11 ± 0.05	4.6	1.01 ± 0.05	5.2	1.00 ± 0.04	4.7	0.96 ± 0.06	6.1	0.94 ± 0.05	5.2
Body measurements	n=5-7		n=6-13		n=4-18		n=5-11		n=2-3	
1. Body length	279.28 ± 41.61	14.8	326.46 ± 22.82	6.9	346.66 ± 17.49	5.0	344.81 ± 20.66	5.9	357.33 ± 6.42	1.7
2. Tail length	89.57 ± 22.27	24.8	117.40 ± 11.20	9.5	121.05 ± 7.44	6.1	124.27 ± 6.75	5.4	125.33 ± 2.51	2.0
3. Hind foot	46.42 ± 4.07	8.7	48.30 ± 2.45	5.0	50.07 ± 1.81	3.6	49.75 ± 3.32	6.6	49.00 ± 1.73	3.5
4. Ear	19.02 ± 2.37	12.4	21.00 ± 1.76	8.3	22.42 ± 1.15	5.1	21.75 ± 2.25	10.3	21.00 ± 1.41	6.7
5. Body weight	273.80 ± 102.38	37.3	434.11 ± 89.28	20.5	516.62 ± 21.70	4.2	586.48 ± 154.86	26.4	- -	-

The greatest differences in body dimensions can be seen in length and weight, which are particularly marked in age class 4, where the average weight of females is half that of males. Average body length of males in age class 4 is more than 15% greater than the average body length of females and correspondingly in group 5 more than 11% (Table 2).

In relation to skull dimensions, however, it is possible to distinguish certain features clearly differentiating the two sexes and also expressing sex dimorphism to a slighter degree. The first group includes such significant dimensions as: *CbL, ZyB, EctB, MB, BcC* (Fig. 2), *RB* and *MdWt*, and the second *PB*, the average value of which for females from age class 1 and in males from age class 5 differs by only 1.6 mm.

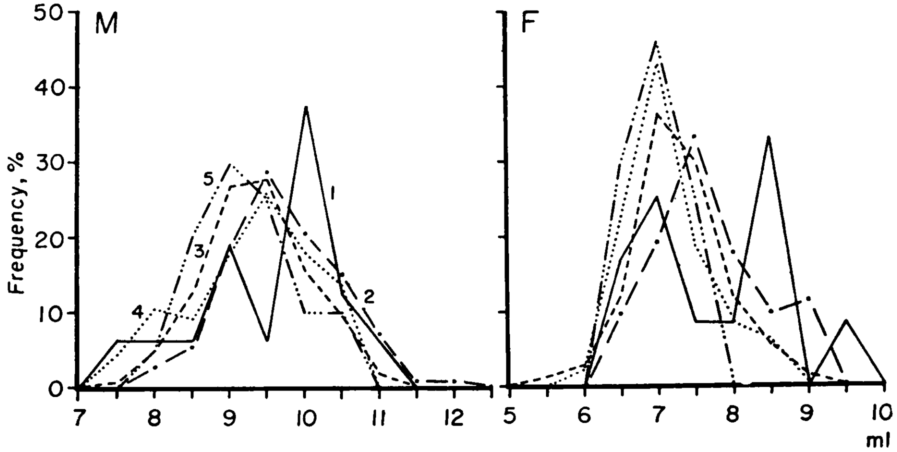

Fig. 2. Variations in braincase capacity (*BcC*) of M. putorius from the sex and age aspect. 1—5 age classes.

Dimorphism is also visible in the case of *CbL* and *PL* — two length dimensions which might appear to be almost of equal value and which determine the shape of the skull profile. In males *PL* is always greater than *CbL* in all age classes, whereas in females, with the exception of age class 1, the reverse applies—condylobasal length is greater than profile length (Table 2).

Sex dimorphism is evident in the generally higher values of the coefficient of variation (C.v.) characteristic of the majority of male skull measurements throughout all age classes. An exception to this is formed by age classes 1 and 5 for females, in which higher C.v. values occur in the case of *MdWt*. Generally higher values of the coefficient of variation for these characters occur in males (Table 2).

3.2. Population Differentiation

3.2.1. Differences in Absolute Values of Measurements and Indices

Certain differences, which can be connected with the place of the animals' origin, did not become evident until the higher age classes. Together with age the rank of such differences — in the sense of their statistical significance — generally increases.

In males significant differences are found as from age class 2 (4 out of 33 examined); there are 9 significant differences in class 3, but only 2 in class 4. In class 5 the number of differences again rises to eight. In general the Białowieża and Central Poland Lowlands groups are distinguished by the smallest average values for the characters examined, which significantly affect skull size. Conversely the Małopolska Upland and Rzeszów region populations are characterized in the majority of cases by the greatest dimensions.

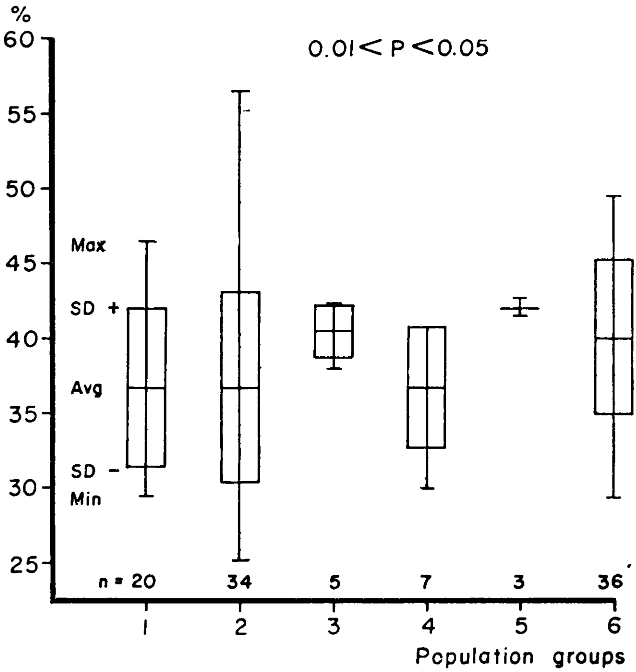

Fig. 3. Population variations in index $MdWt \times 100 : BcC$ in males of *M. putorius* in age class 2.

Population groups: 1 — West Pomeranian Lake District, 2 — Białowieża Primeval Forest, 3 — West part of Central Poland Lowlands, 4 — East part of Central Poland Lowlands, 5 — Małopolska Upland, 6 — Rzeszów environs.

In differentiation of skull proportions in age class 2 the lowland males from the west of Poland are distinguished by a narrower skull at the zygomatic arches, and in the Białowieża population the mandible weight (*MdWt*) formed the smallest percentage of *BcC* — Fig. 3 (which is also repeated in age class 3). In other words, Białowieża polecats have relatively low *MdWt* but large *BcC* ($0.01<P<0.05$). Polecats from southeast Poland, on the other hand, are characterized by maximum values of these indices. Lowland polecats in age class 3 are characterized by, *inter alia*: shortest *BcL*, narrowest *ZyB*, smallest *MdWt* — both in relation to *BcH* and to *MdL*, unlike the animals from southeast Poland

Table 3

Population differences in skull dimensions, in indices and body dimensions and *os penis* size in *M. putorius* from Polish territory ($P_{0.05}$*; $P_{0.01}$**).

	Males					Females				
Age class	1	2	3	4	5	1	2	3	4	5
No. of compared populations	3	6	6	6	3	2	6	2	6	4
Skull measurements										
CbL	—	—	—	—	*	**	—	—	—	—
PL	—	—	—	—	*	**	—	—	—	—
ZyB	—	—	—	—	—	**	—	—	—	*
EctB	—	—	—	—	*	—	**	—	**	—
IC	—	—	—	—	—	—	**	—	—	—
PB	—	—	—	—	—	—	**	—	*	—
MB	—	—	—	—	—	—	*	—	—	—
BcC	—	—	—	—	—	*	*	—	—	—
VcL	—	—	—	—	—	—	**	—	—	—
BcL	—	—	—	—	—	—	**	—	—	*
MxTRL	—	—	—	—	—	—	**	—	—	**
RB	—	—	—	—	—	—	**	—	—	—
BcH	—	—	—	—	—	—	**	—	—	—
MdL	—	—	—	—	*	—	**	—	—	—
HRM	—	—	—	—	—	—	**	—	—	—
MdWt	—	—	*	—	—	—	**	—	—	**
Quotient indices										
VcL×100:*CbL*	—	—	—	*	—	—	—	—	—	—
BcL×100:*CbL*	—	—	**	*	—	—	—	—	—	—
ZyB×100:*CbL*	—	*	*	—	—	—	—	—	—	—
PB×100:*EctB*	—	—	—	—	—	—	—	—	*	—
$\sqrt[3]{BcC}$×100:*CbL*	—	—	—	—	**	—	**	—	—	—
MdWt×100:*BcC*	—	*	**	—	**	—	**	—	—	*
MdWt×100:*MdL*	—	—	**	—	—	—	*	—	—	*
BcH×100:*MdWt*	—	—	*	—	*	—	*	—	—	**
PB:*IC*	—	—	—	—	—	—	—	—	—	—
Body measurements										
Body length	—	—	—	—	—	—	—	—	—	—
Tail length	—	*	*	—	—	—	—	**	—	—
Hind foot	—	—	*	—	—	—	—	—	—	—
Ear	—	—	—	—	—	—	—	—	—	—
Body weight	—	—	—	—	—	—	—	—	—	—
Os penis measurements										
Os penis length	—	—	—	—	—					
Height of base	—	*	—	—	—					
Os penis weight	—	—	*	—	—					

($0.01<P<0.05$, and also $P<0.01$). Similarly in the age class 4 lowland animals are distinguished by the shortest *VcL* and *BcL* — in relation to *CbL* — as distinct from the other population groups ($0.01<P<0.05$). In age class 5 certain differences in skull proportions (only in the three population groups examined) were also accompanied by differences in five absolute values, of which only *MdWt* is the component of one of the indices. These differences were found within three indices in animals from Małopolska and Rzeszów regions ($P<0.01$ and $0.01<P<0.05$ — Table 3).

In females, on the other hand, differences between population groups appeared in age class 2 as much as 20 out of the 30 examined, then not until class 4 (three differences) and class 5, where the number of differences again rose to 7.

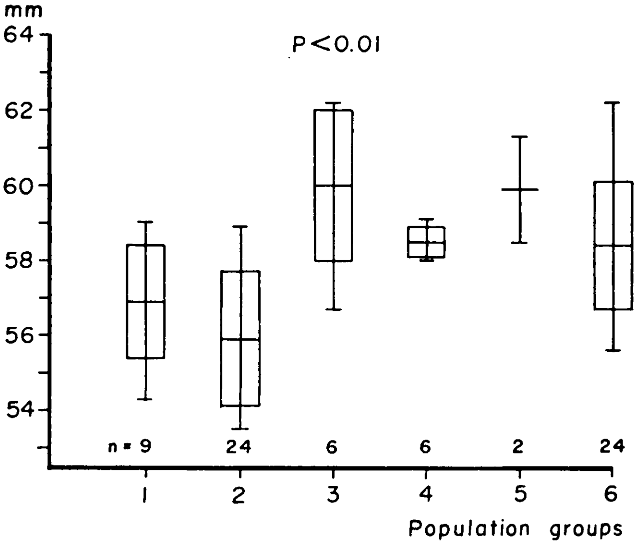

Fig. 4. Population variations in condylobasal length of the skull in females of *M. putorius* in age class 2. Population groups as for Fig. 3.

In females from age class 2 the statistically significant population differences found in all average values of 16 measurements (14 significant differences with $P<0.01$) are remarkable — Table 3, *e.g.* *CbL* — Fig. 4. Considering differences in skull proportions, however, females from Białowieża are characterized by relative large *BcC* and *BcH* in relation to *CbL* and *MdWt* — unlike the females from southeast Poland. These regularities also apply to the other two indices in this age class, in which *MdWt* for the Białowieża population is lowest, in relation both to *BcC* and to *MdL*. In age class 4 females from lowland areas are characterized by narrow *EctB*, whereas the group from the Małopolska region is distinguished by the least postorbital breadth (*PB*), that is, somewhat similar to those in the skull of *Mustela eversmanni* Lesson, 1827. This is also confirmed in the index *PB* : *IC* (Table 2).

In age class 5 polecats from the Rzeszów population are characterized by generally greater dimensions. In the light of differences in indices the relations are similar to those in age class 2 ($0.01<P<0.05$ and $P<0.01$).

The distribution of frequency of *CbL* in three age classes (2, 3 and 4) in males from the two most numerous population groups (Białowieża and Rzeszów region) point on the one hand to the factual existence of population differences, and on the other to their successive increase as the animals grow older (Fig. 5). The presence of large male skulls is remarkable (class *CbL* — 72 mm; extreme values for common polecat skulls for Poland) as from age class 2 in the Rzeszów population, and in age class 4 they occur in 6% of both population groups. In age class 5 of the Rzeszów population giant form constitute about 1/3 of the material (4 out of 11).

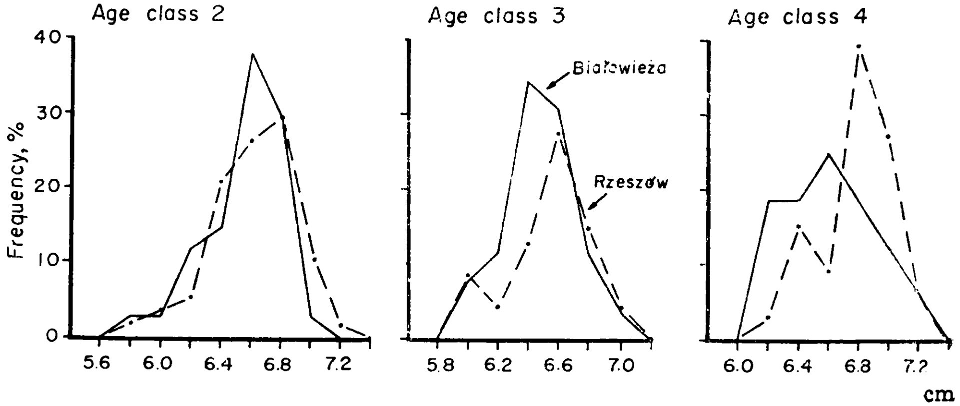

Fig. 5. Populations differentiation in *CbL* values in males of *M. putorius* in age classes 2, 3 and 4.

3.2.2. Differences in Correlation Structures of Skull Dimensions

Males in age classes 2, 3 and 4 only in the Białowieża and Rzeszów populations, for which a sufficiently large amount of material was available were examined. The effect of sex dimorphism on correlation structures was therefore eliminated. Population differences were analysed in correlation matrices at the level of $r \geqslant 0.8$, which we accept as the highest consistent with the methods and the terminology used (Terentjev, 1960).

Independent pleiads (triangles — counterparts of characters no connected by secants) are formed in the case of age class 2 of the Białowieża population by five characters: *PB*, *BcC*, *MxTRL*, *RB* and *BcH*, and in the Rzeszów population by four characters: *PB*, *MB*, *BcC* and *BcH*. Characters highly dependent in the Białowieża population form a large pleiad consisting of 9 components; a separate small pleiad is formed further by: *EctB* and *IC*. In the case of the Rzeszów population the strongly developed pleiad of dependent characters consists of 12 components, closely connected with the remainder and including *EctB* and *IC* also (Fig. 6).

In age class 3 the Białowieża population is characterized by the presence of five independent pleiads relating to: *ZyB*, *PB*, *BcC*, *RB* and *BcH*, whereas there are only three of these pleiads in the Rzeszów population (*IC*, *PB* and *BcC*). In the case of the dependent pleiad in the Rzeszów population the maximum number of connections in the form of correlations between its components is remarkable (Fig. 6).

Age class 4 in the Białowieża population is characterized by the presence of only two independent pleiads (*EctB* and *PB*), and the pleiad of characters highly dependent on each other is strongly developed and links its different components fairly evenly. In the Rzeszów population, conversely, the number of independent pleiads relates to five characters (*ZyB*, *PB*, *MB*, *BcC* and *BcH*). Two dependent pleiads occur — a large one covering 9 components, connected most closely around the characters: *PL*, *CbL*, *MdWt*, *HRM*, *MdL* and *RB* and also a small one connecting two characters only (*EctB* and *IC*) — as in age group 2 of the Białowieża population (Fig. 6).

Population differences in correlation structures were also confirmed by the existence of a ceratin number of statistically significant differences. The maximum number of differences in the degree of reciprocal correlations with the other characters is found in mastoid breadth (*MB*), for which significantly differing connections were not observed only in its correlation with *BcC*, *BcL* and *BcH*. It is a striking fact that all these three characters are braincase dimensions correlated to a great degree with *MB* (Table 4).

3.3. General Craniological Description of M. putorius from Poland

3.3.1. Obliteration of Sutures

In order to define the degree of suitability of the obliteration of skull sutures for determining the relative age of *M. putorius*, this process was examined in all the skulls available. A different degree of suture obliteration was found depending on the animals' sex and the regio of the skull examined. The following regularities were observed: in males

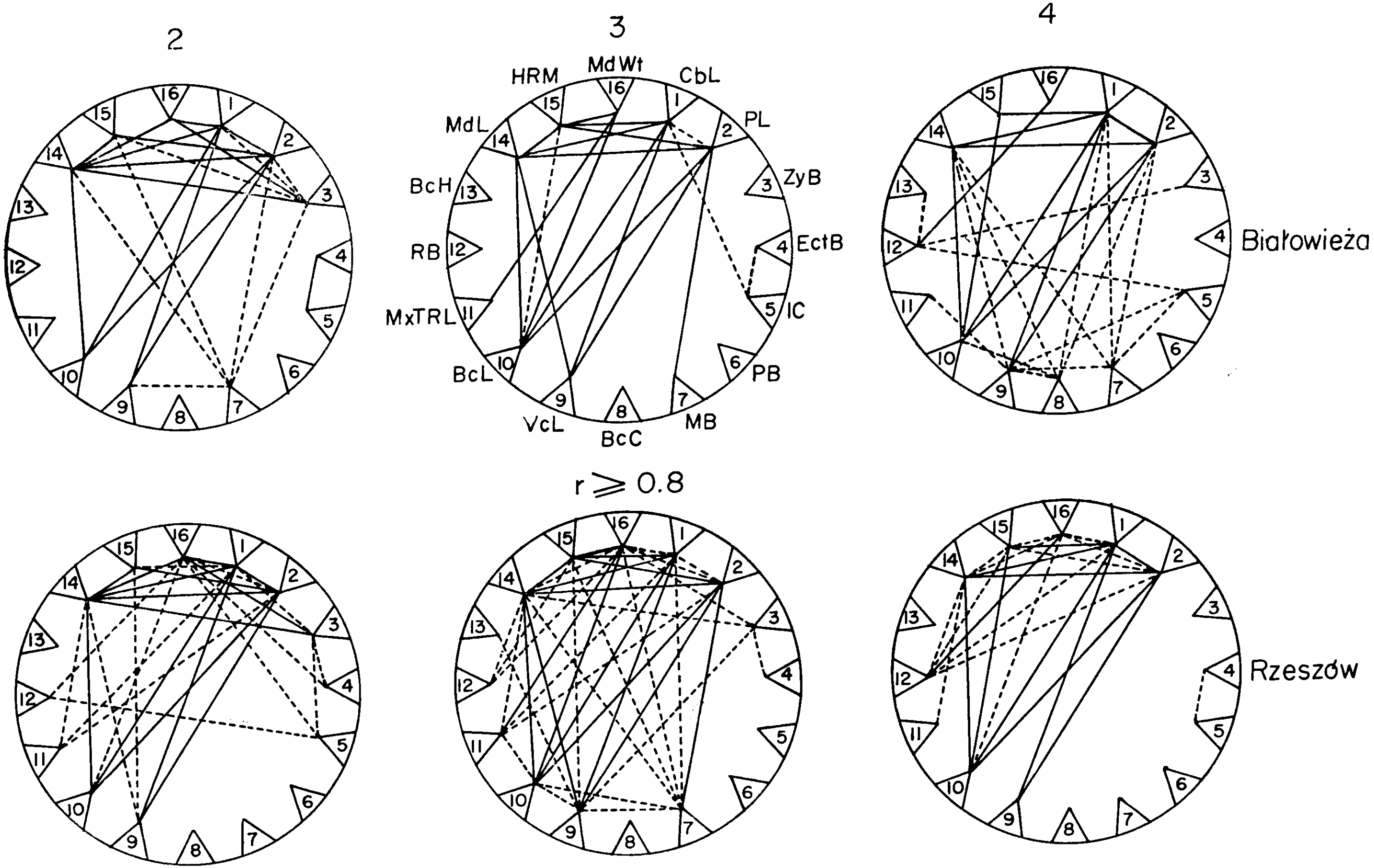

Fig. 6. Population differences in correlation matrices of skull dimensions in males of *M. putorius* from the age aspect using Terentjev's method. The thick line marks the secants corresponding to joint connections of characters in the populations compared.

from 5—8 months old (class 2) — *sutura internasalis* (*harmonia*) is loose in 33⁰/₀, and ossified in 15⁰/₀; *s. nasomaxillaris* — loose in 15⁰/₀ and ossified in 33⁰/₀; *s. maxillofrontalis* and *s. vomeropalatina* are losse in 11⁰/₀ and ossified in 77 and 81⁰/₀; *synchondrosis sphenooccipitalis* — loose in 7⁰/₀ only, and ossified in 79⁰/₀. At the age of 9—11 months (males — class 3) the percentage of completely ossified sutures has greatly increased — *e.g.* for *s. internasalis* by twice as much (34⁰/₀), for *s. nasomaxillaris* (60⁰/₀)

Table 4

Population differences in correlation matrices of 16 skull dimensions of male individuals of *M. putorius* from the age aspect.

$P=0.05$ (+); $P=0.01$ (++). Differences have been given proved to be statistically significant by testing the homogeneity of matrices of average coefficients of correlation of the various populations in groups 2—4 using the chi-square test.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
						‡2	+2									**1 Condylobasal length**
						‡2	+2									**2 Profile length**
						‡2										**3 Zygomatic breadth**
						‡2										**4 Ectoorbital breadth**
						‡2									+2	**5 Interorbital constriction**
																6 Postorbital breadth
+4	+4				+4			‡2		+2	‡2		‡2	‡2	‡2	**7 Mastoid breadth**
									+2						+2	**8 Braincase capacity**
				+4		+4										**9 Viscerocranium length**
																10 Braincase length
	+3					+3		+3								**11 Maxillary tooth-row length**
																12 Rostrum breadth
															+2	**13 Braincase height**
																14 Mandible length
																15 Height of *ramus mandibulae*
							+3									**16 Mandible weight**

and in the case of *synchondrosis sphenooccipitalis* there is no loose connection but its complete ossification has occurred in 88⁰/₀. From the age of 1—2 years — class 4, entry into the period of sexual maturity 80—100⁰/₀ of the sutures examined have completely ossified. The sutures: *s. petrotemporalis* and *petrobasialis* exhibit different nature of obliteration, since even in age class 5 (*i.e.* animals over 2 years old) they are loose in 88⁰/₀ of the cases. The process of suture obliteration in females begins before 3 months (class 1) and generally occurs more intensively in all animals (Table 5).

Table 5

Legibility of cranial sutures of *M. putorius* in percentages from the sex and age aspects.

Age groups	1			2			3			4			5		
Degree of legibility	+	±	—	+	±	—	+	±	—	+	±	—	+	±	—
							MALES								
Sutura internasalis	100	—	—	33	52	15	12	54	34	2	15	83	—	6	94
Sutura nasomaxillaris	100	—	—	15	39	45	3	37	60	2	14	85	—	12	88
Sutura maxillofrontalis	100	—	—	11	11	77	1	—	99	2	—	98	—	—	100
Sutura petrotemporalis	100	—	—	99	1	—	100	—	—	98	2	—	88	12	—
Sutura petrobasialis	100	—	—	98	1	1	100	—	—	100	—	—	88	12	—
Sutura vomeropalatina	100	—	—	11	7	81	2	2	96	—	—	100	—	—	100
Synchondrosis sphenooccipitalis	100	—	—	7	14	79	—	12	88	—	—	100	—	—	100
							FEMALES								
Sutura internasalis	88	12	—	26	48	26	7	62	31	—	40	60	5	25	70
Sutura nasomaxillaris	88	12	—	10	40	50	—	32	68	—	28	72	—	20	80
Sutura maxillofrontalis	88	12	—	2	5	93	—	—	100	—	—	100	—	—	100
Sutura petrotemporalis	100	—	—	95	5	—	97	3	—	98	2	—	85	12	—
Sutura petrobasialis	100	—	—	98	2	—	100	—	—	100	—	—	95	5	—
Sutura vomeropalatina	88	6	6	5	10	84	—	4	96	—	2	98	—	—	100
Synchondrosis sphenooccipitalis	100	—	—	—	—	100	—	—	100	7	—	93	—	—	—

3.3.2. Age Variation in Coefficient of Variation

Among the 16 skull measurements analyzed for males *MdWt* has the highest coefficient of variation, and C.v. of all values of measurements decreases with age, reaching a minimum in age class 5. In female skulls a similar relations are observed, C.v. for *MdWt* — 34.8% (Table 2). Three indices (6, 7 and 8), distinguished by the highest degree of variation, despite a similar tendency to decrease usual for all their values of C.v.

Table 6

Increases in percentages of skull dimensions and indices and dimensions of body and baculum of *M. putorius* from Polish territory from the age and sex aspects. Average values for age class 1 were taken as 100%.

Increase in age class	Males				Females			
	2	3	4	5	2	3	4	5
Skull measurements								
CbL	13.6	12.8	15.3	18.5	9.6	10.0	11.8	10.7
PL	12.4	11.3	13.7	17.2	8.2	8.6	10.4	9.4
ZyB	11.8	13.8	19.5	24.4	7.6	8,2	10.6	11.6
EctB	15.3	17.6	27.1	31.7	13.9	15.0	19.8	27.9
IC	12.7	14.6	20.9	23.6	11.7	11.2	14.6	16.8
PB	−1.7	−1.4	−0.5	−0.9	1.6	0.7	−1.0	−0.7
MB	13.3	12.8	15.7	18.5	8.1	9.3	11.6	11.4
BcC	2.5	−1.6	−2.5	−3.1	−1.8	−6.7	−9.0	−11.2
VcL	9.2	8.2	11.4	14.1	4.9	5.6	8.2	8.2
BcL	12.2	11.6	13.6	17.6	8.5	8.4	10.6	9.2
MxTRL	5.6	5.4	7.2	9.5	5.4	5.3	6.5	6.6
RB	11.9	12.2	16.6	21.1	8.7	9.3	12.0	11.7
BcH	5.2	5.4	8.0	12.8	0.4	−1.2	−1.2	−1.9
MdL	11.8	11.5	14.9	18.8	8.6	9.2	11.4	11.2
HRM	15.9	15.2	18.4	25.4	8.7	7.4	10.0	10.3
MdWt	79.3	90.9	116.3	145.2	62.4	63.9	78.9	85.7
Quotient indices								
VcL×100:*CbL*	−3.9	−4.1	−3.5	−3.9	−4.5	−4.1	−3.4	−2.4
BcL×100:*CbL*	−1.4	−1.2	−1.6	−0.9	−1.1	−1.5	−1.1	−1.5
ZyB×100:*CbL*	−1.7	0.8	3.5	4.8	−2.0	−1.8	−1.2	0.7
PB×100:*EctB*	−14.6	−16.1	−21.7	−24.7	−11.0	−12.6	−17.6	−22.4
$\sqrt[3]{BcC}\times 100:CbL$	−11.5	−12.1	−14.3	−16.8	−9.6	−11.4	−13.6	−13.3
MdWt×100:*BcC*	75.4	93.7	122.4	153.4	67.4	77.0	98.0	110.1
MdWt×100:*MdL*	61.4	71.8	89.6	108.0	51.3	52.0	62.2	69.0
BcH×100:*MdWt*	−43.5	−46.9	−52.2	−56.2	−43.5	−45.2	−49.9	−52.1
PB:*IC*	−12.2	−14.8	−17.8	−19.6	−9.0	−9.9	−13.5	−15.3
Body measurements								
Body length	30.0	29.6	33.4	33.2	16.9	24.1	23.5	27.9
Tail length	32.3	29.0	21.5	38.5	31.1	35.2	38.7	39.9
Hind foot	12.6	7.7	9.3	17.8	4.0	7.9	7.2	5.6
Ear	6.0	5.1	8.6	3.3	10.4	17.9	14.4	10.4
Body weight	96.4	102.9	281.4	—	57.4	88.7	114.2	—
Os penis measurements								
Os penis length	31.0	42.2	50.8	59.0				
Height of base	9.0	61.4	112.4	108.0				
Os penis weight	130.8	315.4	538.5	669.2				

with age, are remarkable among skull indices for both sexes. A particularly high C.v., *MdWt* is involved as a component of all three of the indices, accounting for their great degree of variation. Weight measurements are also characterized by considerable variation relative to both body and baculum dimensions of males, as well as for body measurements of females (Table 2).

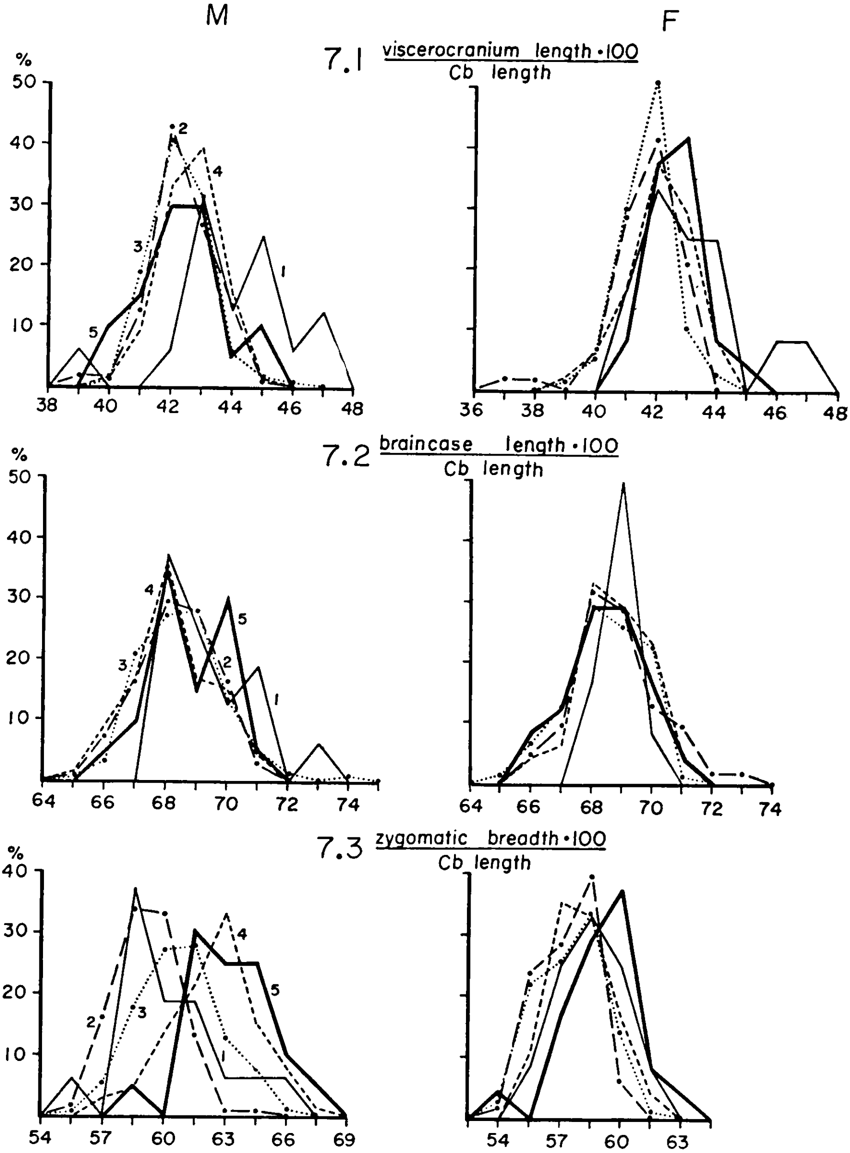

Fig. 7. Age variation in skull quotient indices in both sexes of *M. putorius*. Age classes 1—5.

3.3.3. Differences in Values of Absolute Measurements and in Indices

Calculated percentage increases in skull dimensions and also in the indices based on them indicate the continuity of the changes taking place,

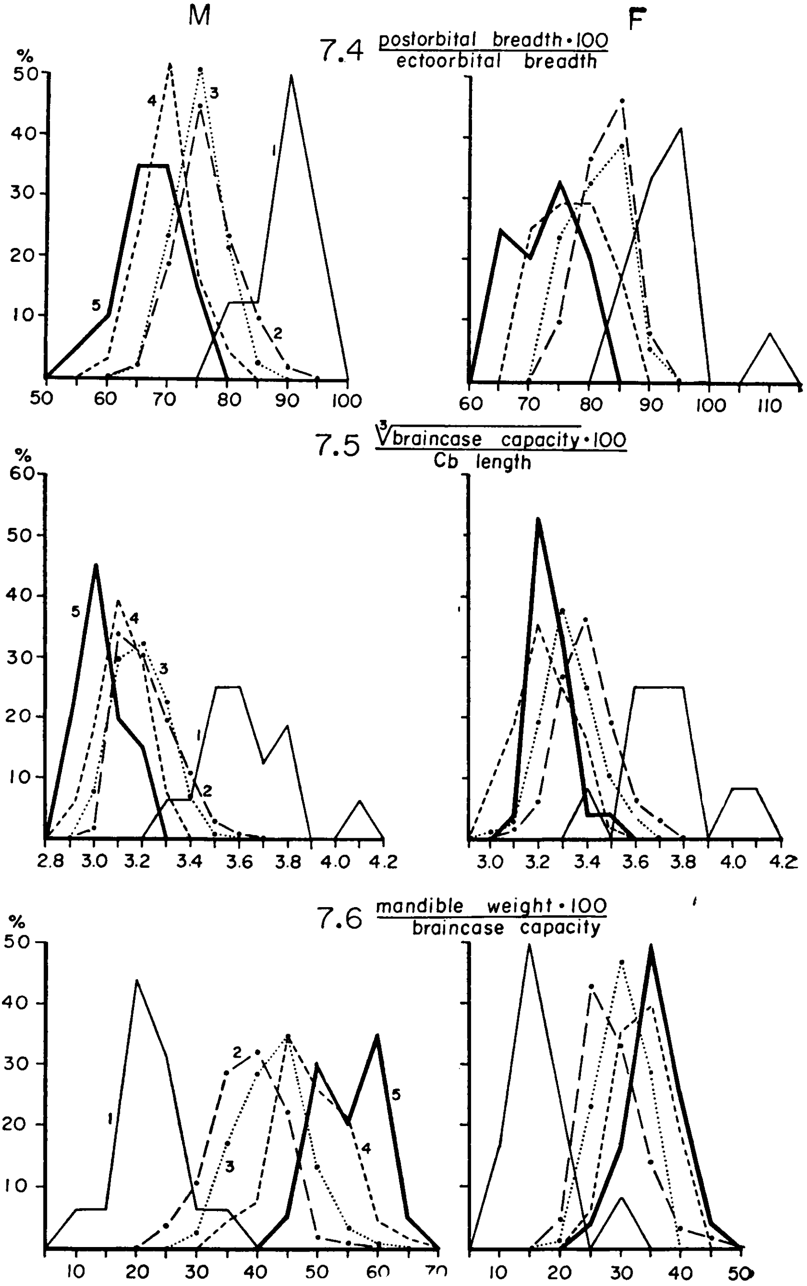

Fig. 7, continued.

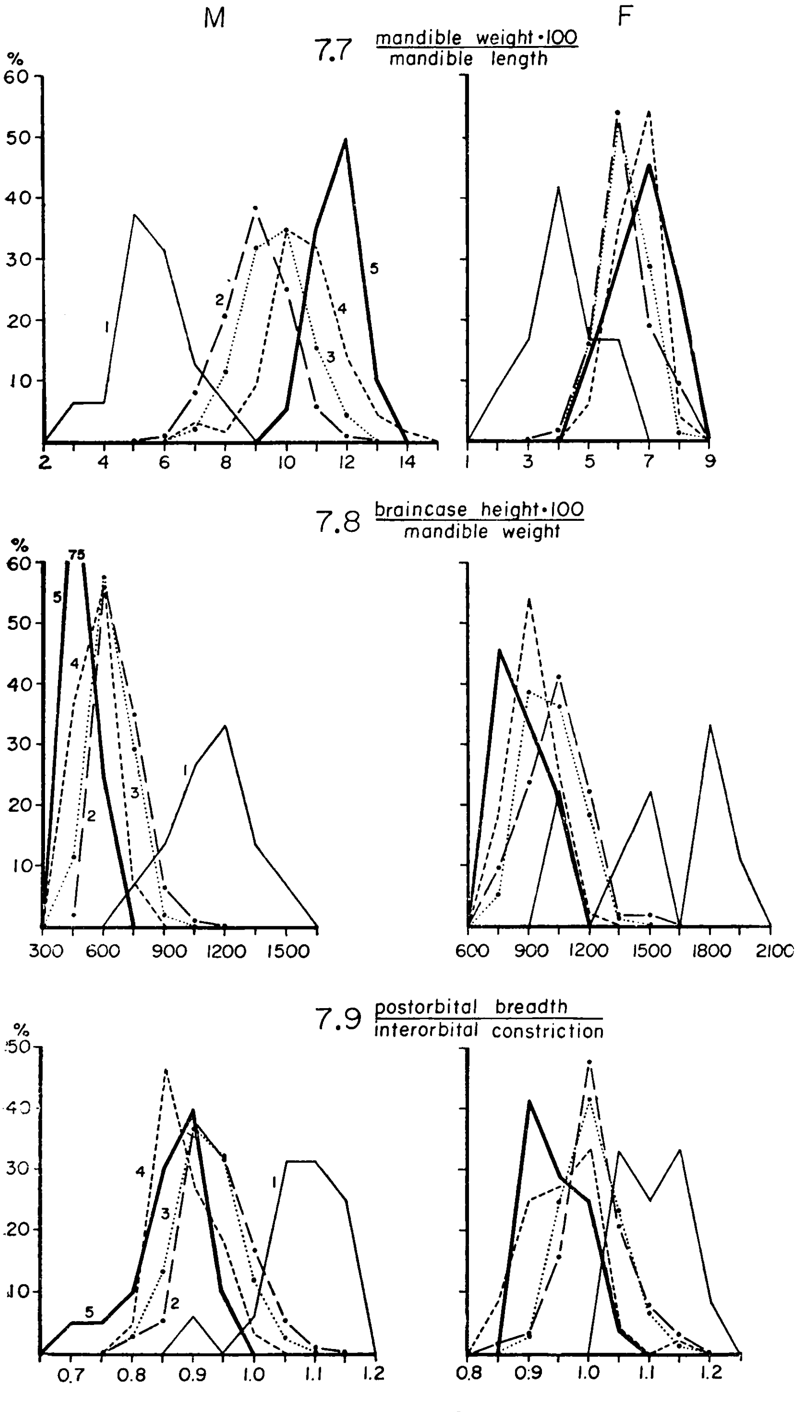

Fig. 7, continued.

usually of a progressive type. Clearly the larger skull dimensions of males have higher percentage increases with age. The greatest age changes in both sexes are observed in *MdWt* (which simultaneously exhibits the greatest variability cf. section 3.3.2.) and also certain measurements of the facial part of the skull: *ZyB* (particularly in males), *EctB*, *RB*, *MdL* and *HRM*. Relatively slight changes are, however, characteristic of the dimensions of the braincase (except for *MB*), while *BcC* exhibits an actual successive decline in average value with age, especially in females, loss of 11.2⁰/₀ (Fig. 2). Similarly it is possible to distinguish among skull indices groups changing to a slight, (indices 1—3) or considerable degree with age (4—9), which points to the continuous process of changes in proportions (Table 6, Fig. 7).

Weight, of all body measurements, is characterized by the greatest increase.

In view of the importance attributed to the baculum in determination of relative age in *Carnivora*, particular attention has been paid to age increases in the dimensions of the *os penis*. In the common polecat sixfold increase in weight (*BWt*), a twelvefold increase in *BH* and an almost doubling in *OPL* are observed (Table 8).

Most of these dimension characteristics of the skull, indices, body measurements and baculum are distinguished by either less ($0.05 > P > 0.01$) or more ($P < 0.01$) marked differences throughout all the age classes (Table 7).

3.3.4. Changes in Correlation Structures with Age

With advancing age the peak of the curve corresponding to intrapleiad connections shifts toward minimal values (terminology after Terentjev, 1960), and consequently the number of *r* coefficients corresponding to mixed connections and interpleiad connections increases, as can be seen particularly clearly in age classes 4 and 5.

Analysis of the highest level of characters correlation presented diagramatically within the area forming the basis of the correlation cylinder shows between which characters the correlation connections disappear, and which persist throughout all age classes (Fig. 8).

In both sexes we observed decrease with age in the capacity of the pleiad concentrating highly interdependent characters. This occurs by reduction in the number of connections of the given character (shown in diagram form by a secant) with the others, consequently resulting in characters dropping from the pleiad and forming of »independent« pleiads. There is some degree of alternation connected with age especially in males due to the more synchronous, isometric growth of the skull and with allometric growth, involving as a consequence changes in proportions. While in age class 1 the number of reciprocal connections between skull dimensions is maximal, it decreases in class 2, to increase again in age class 3, remaining minimal in age classes 4 and 5. The

Table 7

Comparison of statistically significant differences on the level $P=0.05$ (*) and $P=0.01$ (**), obtained using reciprocal comparison of arithmetical means for five age groups (separately for both sexes of *M. putorius*) by means of variance analysis.

Comparison	Males				Females			
of age class	1 to 2	2 to 3	3 to 4	4 to 5	1 to 2	2 to 3	3 to 4	4 to 5
Skull measurements								
CbL	**	—	**	**	**	—	**	—
PL	**	—	**	**	**	—	**	—
ZyB	**	**	**	**	**	—	**	—
EctB	**	**	**	*	**	—	**	**
IC	**	*	**	—	**	—	**	—
PB	—	—	—	—	—	—	—	—
MB	**	—	**	—	**	—	**	—
BcC	—	**	—	—	—	**	—	—
VcL	**	—	**	*	**	—	**	—
BcL	**	—	**	**	**	—	**	—
MxTRL	**	—	**	*	**	—	—	—
RB	**	—	**	**	**	—	**	—
BcH	**	—	**	**	—	**	—	—
MdL	**	—	**	**	**	—	**	—
HRM	**	—	**	**	**	—	*	—
MdWt	**	**	**	**	**	—	**	—
Quotient indices								
$VcL\times 100:CbL$	**	**	—	—	**	—	—	—
$BcL\times 100:CbL$	**	—	—	—	—	—	—	—
$ZyB\times 100:CbL$	*	**	**	—	**	—	—	**
$PB\times 100:EctB$	**	**	**	*	**	*	**	**
$\sqrt[3]{BcC}\times 100:CbL$	**	—	**	**	**	**	**	—
$MdWt\times 100:BcC$	**	**	**	**	**	*	**	*
$MdWt\times 100:MdL$	**	**	**	**	**	—	**	—
$BcH\times 100:MdWt$	**	**	**	**	**	—	**	—
$PB:IC$	**	*	**	—	**	—	**	—
Body measurements								
Body length	**	—	—	—	**	*	—	—
Tail	**	—	—	—	**	—	—	—
Hind foot	**	*	—	—	—	—	—	—
Ear	—	—	—	—	—	*	—	—
Body weight	**	—	**	—	*	—	—	—
Os penis measurements								
Os penis length	**	**	**	*				
Height of base	—	**	**	—				
Os penis weight	**	**	**	—				

following are always components a dependent pleiad: *ZyB*, *PL*, *CbL*, *MdWt*, *HRM*, *MdL* and *BcL* (Fig. 8). In females, conversely, the number of connections between components of a dependent pleiad is subject, from class 1, to even and gradual reduction (Fig. 8).

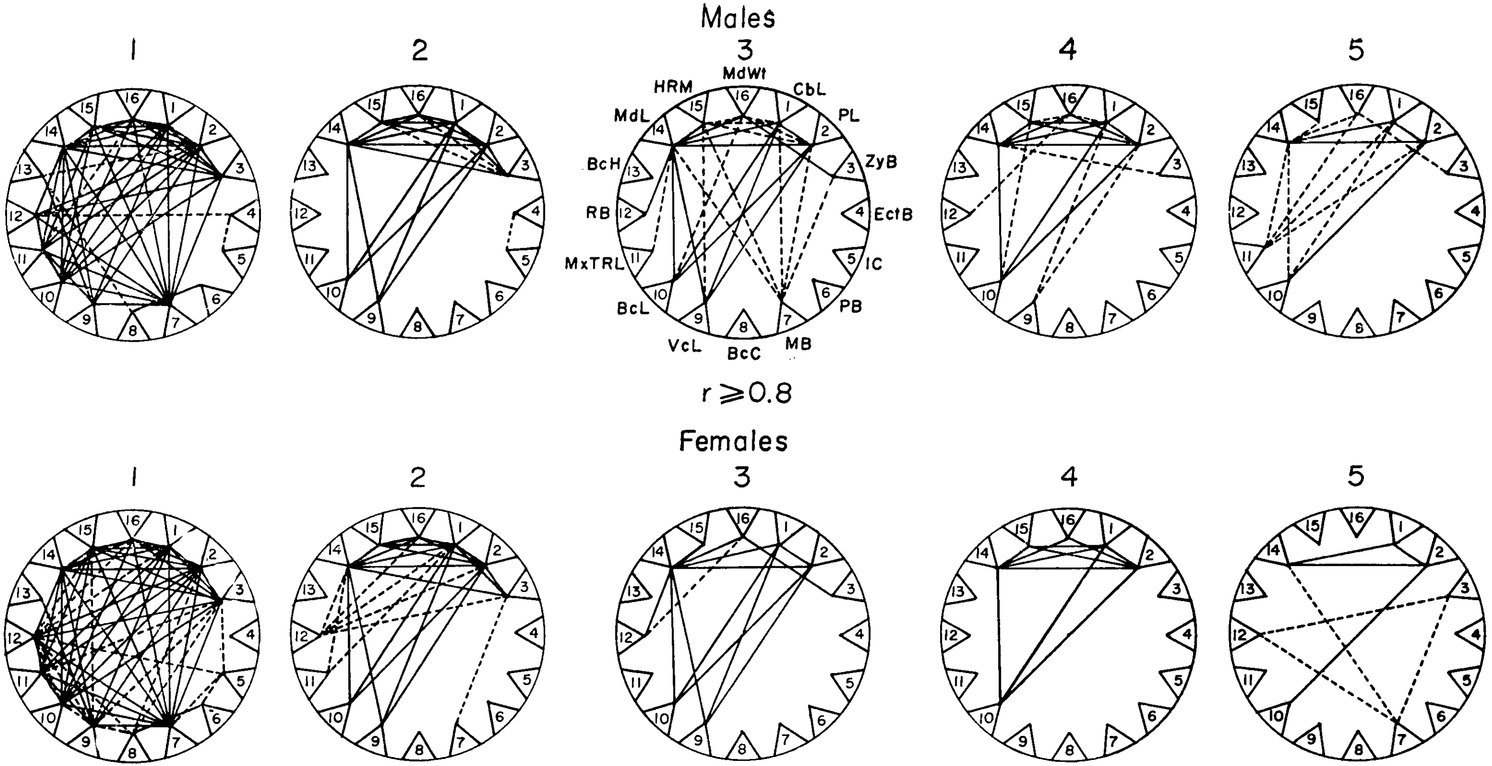

Fig. 8. Age differences in correlation matrices for 16 skull dimensions of *M. putorius* from the sex aspect.

The maximum level of interrelation of characters ($r \geqslant 0.8$) has been taken into account in accordance with Terentjev's method. Secants corresponding to joint connections of characters in males and females are indicated by a thick line.

Age differences in the correlation matrices were also confirmed by the existence of several statistically significant differences, but relating to different pairs of characters, in both sexes (Table 8).

3.3.5. Dwarf and Giant Forms of *M. putorius*

Several specimens markedly differing in dimensions were found in the polecat skull series. While the large forms were considered as admissible in the calculations used (they did not significantly differ from average for the given age group and sex, Table 9), the two dwarfs were excluded on account of their considerable deviation from the average ($P<0.01$ for both, and $P<0.001$ for one). As these specimens are somewhat unusual, a short morphological description is given for them. All extreme specimens were caught under natural conditions, and the skull of the smallest male came from an animal shot in the pheasantry of the arboretum at Przelewice (Table 9).

Table 8

Age differences in correlation matrices of 16 skull dimensions of *M. putorius*. $P=0.05$ (+); $P=0.01$ (++). Differences have been given proved to be statistically significant by testing the homogeneity of matrices of average coefficients of correlation for different age groups (jointly for all populations) using the chi-square test.

MALES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Condylobasal length							++									
2 Profile length							++									
3 Zygomatic breadth	+	+		+			++									
4 Ectoorbital breadth					++		++									
5 Interorbital constriction							++									
6 Postorbital breadth		+														
7 Mastoid breadth								++	++	++	++	++	++	++	++	++
8 Braincase capacity																
9 Viscerocranium length						++		++								
10 Braincase length							+									+
11 Maxillary tooth-row length	+	+	+				+	+								
12 Rostrum breadth									+							
13 Braincase height	+	++							+							
14 Mandible length			+								+					
15 Height of *ramus mandibuae*	+	+	+	+			++			++				+		
16 Mandible weight																

FEMALES

The dwarfs occur in both sexes, irrespective of the animal's place of origin, while giant forms were more often encountered, particularly among males, in the Rzeszów population (Fig. 5).

The smallest male polecats have smaller skulls than those of the largest females, but even so their skulls retain the male configuration. This is particularly evident in the frontal region (*EctB*), rostrum breadth (*RB*) and general massiveness of the skull bones. By braincase capacity (*BcC*) they cannot, however, be distinguished from average females. On the other hand, giant female forms exceed dwarf males with respect

Table 9

Extreme forms of skulls of *M. putorius* from Polish territory.

Sex & age	F, 4	F, 2	M, 4	M, 2	M, 5
CbL	53.7	62.2	56.6	72.9	72.6
ZyB	32.8	35.1	34.4	43.0	45.4
BcC	6.9	9.2	7.0	12.2	10.3
MdWt	2.06	2.87	2.62	4.90	5.65
Relation to avg. *CbL*, %	−9.0	+7.5	−15.8	+10.1	+5.1
Difference	$0.001 < < P < 0.05$	$0.02 < < P < 0.05$	$0.001 > P$	$0.01 < < P < 0.05$	$P > 0.05$
Date of capture, locality	July 3, 1966 Białowieża	Nov. 16, 1910 Wrocław	May 26, 1962 Przelewice	Nov. 21, 1911 Lubań Śląski	May 22, 1968 Rzeszów
Owner	MRI PAS	ZIWU	MRI PAS	ZIWU	ISEZ PAS
No. coll.	52294	37	27998	47	4144/68

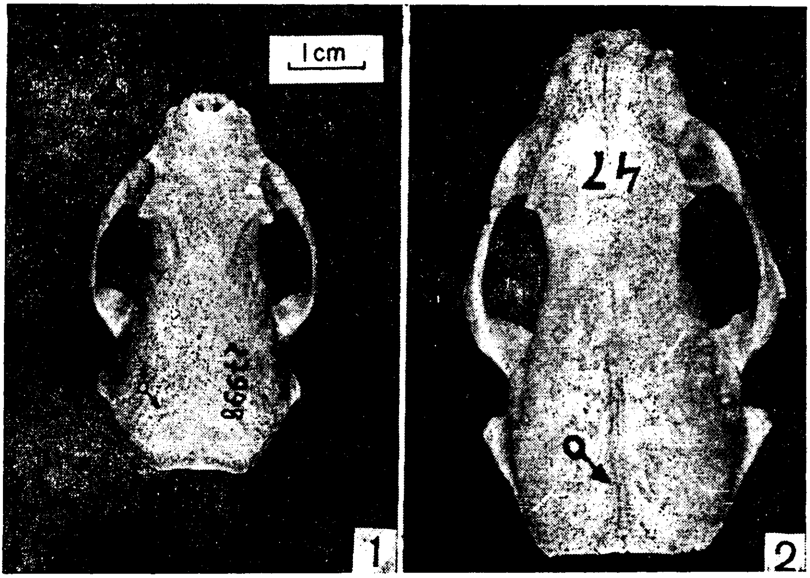

Fig. 9. Extreme forms of skulls of *M. putorius*. 1 — dwarf no. coll. 27998 from Przelewice, 2 — giant no. coll. 47 from Lubań Śląski.

to *BcC* sometimes by 2 cm^3 (about 25%), which in the case of a polecat skull is a high value. Zygomatic breadth (*ZyB*) of giant females was, however, only a slightly greater than in dwarf males (Table 9, Fig. 9).

It must be emphasised that male skulls usually differ from the average value for a given class more than those of females (Table 9).

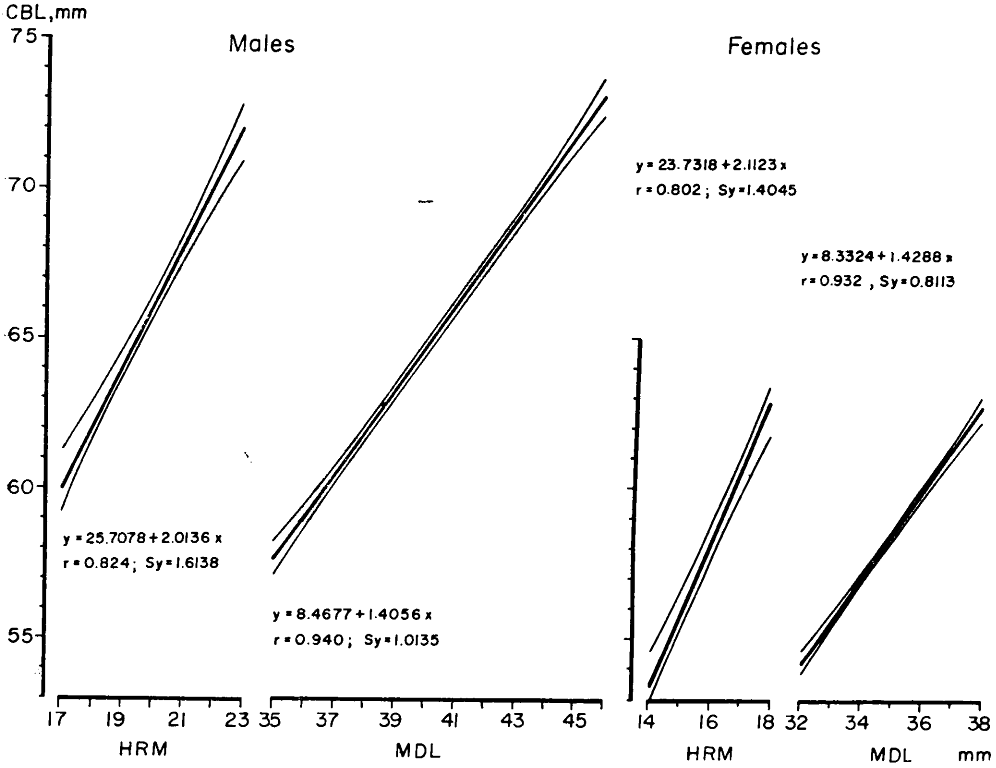

Fig. 10. Relations (*CbL* and *MdL*) and (*CbL* and *HRM*) in both sexes of *M. putorius.*

Giant forms of common polecats are also encountered among the oldest animals (cf. Rzeszów population; Fig. 5). Their skulls are usually massive and bear strongly developed *cristae sagittalis* and *lambdoidea.*

3.3.6. Dimensions of the Mandible and Skull Size in *M. putorius*

As we had a large amount of contemporary polecat skulls we considered it useful to trace the relations between skull length and dimensions of the mandible.

Because of the high correlation of *CbL* with *MdL* and *HRM*, which varies only slightly through all age classes, four regression equations were calculated for these relations — separately for the sexes. As shown by regression equations the correlations: *CbL* with *MdL* and *CbL* with *HRM* make it possible to obtain a relatively accurate reconstruction of condylobasal length of skull confirmed by confidence intervals (Fig. 10).

This »reconstruction« was undertaken because the common polecat mandible is commonly undamaged in fossil material. Consequently it is usually possible to reconstruct on this basis the condylobasal length of skulls of fossil forms. This methodology may find practical application in studies of micro-evolutionary processes in *M. putorius* over the Quaternary period.

4. DISCUSSION

The division of skull material of *M. putorius* into five age classes on the basis of morphological criteria fully met our requirements. It permitted us to distinguish polecats 1 and 2 years old from the remainder of the material, and enabled us to trace age changes in the skull at relatively late periods of ontogenesis. Thus we concur with Stubbe (1969), who used this kind of age division in his studies of the age structure of a *M. putorius* population, considering it as sufficient in ecological studies. It must also be emphasised that there are few skulls of polecats over 2 years old in the material and therefore no good purpose was served by distinguishing additional age classes among them. Our introduction of five age classes only thus minimizes the possibility of erroneous classification of a given individual. In addition the 5 age classes correspond well with the actual developmental periods in *M. putorius* skulls (cf. Paramonov, 1937).

Despite the fact that according to Heptner *et al.*, (1967) the skull of the common polecat probably does not reach its final dimensions until the third year of its life, we show that age changes in at least certain regions of the skull in *M. putorius* are of a continuous character. Thus, for example, the following skull measurements: *EctB*, *ZyB*, *BcC* and *MdWt*, undergo successive age changes even though they are accompanied by complete obliteration of skull sutures. Zygomatic breadth, ectoorbital breadth and mandible weight increase continuously, while braincase capacity decreases. This disagrees to some extent with the data given by Paramonov (1937), who considers that the polecat skull does not alter in dimensions once the obliteration of cranial sutures is complete. Certain dimensions examined, although distinguished by small percentage increases with age (*e.g.* *CbL* and *PL*), also exhibited statistically significant differences in their average values in all age classes.

During analysis of the age division of skulls of *M. putorius* we searched for new, additional auxiliary criteria in the form of quotient indices. Some of them would appear to come up to our expectations, for instance the absence, or minimal interrelation, of their ranges of variation — in the case of extreme age classes — were found in indices based on the components *BcC* and *MdWt*. Owing to the application in the indices of a parameter which, on the one hand, varied very little with age, and on the other varied greatly, it became possible to obtain successful results in separating at least the extreme age classes (cf. Fig. 5.7; 7.6 and 7.7). It is, incidentally interesting that the index successfully applied by Rossolimo (1958), aged coypu skulls as well as house sparrows and muskrats (Ruprecht, 1968 and 1974), but was less applicable to the common polecat. In it, considerable overlapping of extreme age classes occurred (Fig. 7.8).

The index based on the quotient of postorbital breadth (*PB*) and interorbital constriction (*IC*) (Röttcher, 1965 and Habermehl & Röttcher, 1967) merits special analysis. In both these methodical publications it is only the average values of this index which are given together with the age in days of the polecat attributed to them, with complete lack of diagrams of its variations in age classes. The need therefore became obvious to check the real diagnostic value of this index. The average values calculated by us and their statistically significant differences in age classes, based on abundant material, fully confirm the usefulness of the index examined. Curves of the distribution of its frequency in classes of variation almost entirely separate the extreme age groups (Fig. 7.9).

Differences in *M. putorius* and *M. eversmanni* are connected with postorbital breadth (*PB*). Thus with reduction in this breadth with age in both species the effect of this character on age estimates and its taxonomic value become cumulative (Buchalczyk & Ruprecht, 1975).

Our results fully confirm sex dimorphism in the common polecat, both with respect to skull dimensions, its proportions and rate of growth and with the concomitant obliteration of cranial sutures. The fact that differences are found in the composition of food consumed by males and females of the same species (Rzebik-Kowalska, 1972) is also evidence of the extent of sex dimorphism in *M. putorius*.

Although the material presented — on account of the small amount in samples from different population groups — was not very suitable for tracing ontogenetic changes in the skull of *M. putorius*, certain relations were revealed which may have the character of general regularities. While at an early age (class 2) population differences in skull proportions related mainly to indices based on values of linear measurements, at a greater age (classes 3 and 5) the participation of indices based on capacity and weight parameters became plain. A similar increase in the degree of differences with age also took place in *Ondatra zibethica* (Linnaeus, 1766) (Ruprecht, 1974).

The differences between Polish populations of *M. putorius* from the Białowieża Primeval Forest and the Rzeszów region were confirmed by a number of statistically significant differences within the structures examined. The results are therefore similar to the differences found in correlation structures, observed in the case of 8 species of voles of the genus *Microtus* (Kanep, 1967), two species of hedgehogs of the genus *Erinaceus* (Ruprecht, 1972) and also 4 Central European populations of muskrats (Ruprecht, 1974).

In the light of our results the correlation structures of skull dimensions may be of significance both in examination of micro-evolutionary processess (population differences) and of ontogenetic changes.

In skull ontogenesis, correlation structures may, in our opinion, play the part of very sensitive indicators of the changes taking place in the skull. We realize, however, that the correlation structure may be labile, *i.e.* subject to the influence of various additional factors — and thus the application of groups as uniform as possible with respect to sex and age — may importantly eliminate undesirable influences. Observations of certain regularities in the age changes in correlation structures which are accompanied by alternation of periods of more (isometric growth) or less (allometric growth) synchronous growth of the skull — occurring both in the case of *M. putorius, Lepus europaeus* Pallas, 1778 (Caboń-Raczyńska, 1964), *Clethrionomys glareolus* (Schreber, 1780) (Gerasimov, 1969) and also *O. zibethica* (Ruprecht, 1974) — shows that this is one of the more promising growth study methods. The occurrence of certain differences in correlation structures depending on the sex of *M. putorius* is, in our opinion, an additional proof of the existence of subtle manifestations of sex dimorphism which were also observed by Gerasimov (1969) in the bank vole.

We emphasize that in *M. putorius* cranial measurements the special analysis of variation coefficients and the high C.v. values in age class 1, can be explained by a certain lack of homogeneity in this class (Yablokov, 1966). This may be connected with the extended birth period of polecats being subject to some extension in time (Habermehl & Röttcher, 1967; Stubbe, 1969). A general tendency to decrease in C.v. value together with age is proper both to *M. putorius* and *O. zibethica* (Ruprecht, 1974) and is therefore to some degree a regularity characterizing ontogenetic changes in the skulls of these mammals.

During measurements of a large series of skulls of *M. putorius* we encountered extreme forms in respect of size belonging to representatives of both sexes. Both dwarf and giant specimens are found among polecats, to which fact Hensel (1881) drew attention earlier. In our case these specimens differed to a statistically significant degree from their corresponding average values in sex and age groups. Similar size variants of the skull, also known to occur in mink (Pohle, 1970) are more frequently encountered in polecats (Heptner *et al.*, 1967). In the opinion of Russian authors the existence of giant forms in polecats can be explained on the one hand by manifestations of heterosis in possible hybrids of *M. putorius* and mink, and also by an excess of food[2].

Shubin & Shubin (1975) take a different attitude to this case, since they assume that the considerable dimensions of males of the small forms of *Mustelidae* occur in areas with pessimal conditions which, in their opinion, may occur on the fringe of the given species' range. This is accompanied by increased ecological divergence, *i.e.* differences in ways of obtaining food by males and females differing in size. For instance the giant forms of *M. eversmanni* occur in the Ukraine and in the steppe zone of Kazakhstan, as compared with the rest of the range of this species.

It is worth recalling here that giant forms of the common polecat in Poland were more often encountered in the Rzeszów region, which may indicate the existence of a peculiar local gene pool. This would appear to refute in part the statement by Heptner *et al.* (1967) concerning the absence of geographical variation in the skull dimensions of *M. putorius.*

It must be emphasised that specimens of *Neomys anomalus* Cabrera, 1907, from the Rzeszów region (Bieszczady Mts) were also distinguished, in comparison with other Polish populations of this species, by maximum mandible measurements (Ruprecht, 1971). In a similar way skull dimensions of European hedgehogs from foothill populations were found to have the largest measurements (Ruprecht, 1972). This probably points to the specific character of these local populations of mammals.

The phenomenon of dwarf forms is known to occur in other species of mammals and may not infrequently cause taxonomic difficulties (Kubik, 1951; Ruprecht, 1971). In such cases the small skull dimensions of certain individuals of *Sorex araneus* Linnaeus, 1758, are explained by food factors and their role in early ontogenesis (Ku-

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[2] Giant forms, the so-called »velikany« of the steppe polecat — in the dialect of the steppe dwellers of the Upper Irtysh area also given the name »mogilščiki«, are supposed, according to popular legend, to live in cemeteries and feed on corpses (Zverev, 1931, after Heptner *et al.*, 1967).

bik, 1951). It is difficult to deny that this hypothesis may to some degree be correct, in view of the fact that both shrews and mustelids are animals characterized by rapid postnatal development. Any serious lack of food in early youth may therefore lead to far-reaching changes, resulting in dwarfs. A similar conclusions has been obtained by Dryden & Ross (1971).

In the ligth of our results, the common polecat appears a species exhibiting a wide spectrum of variation, such variations being expressed particularly in sex dimorphism, individual variation and population variation. A comprehensive description of this kind of morphological variations in the skull of a representative of the genus *Mustela*, compared with analogous data on other taxa would appear to warrant more extensive monographic study.

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ZMIENNOŚĆ MORFOLOGICZNA CZASZKI *MUSTELA PUTORIUS* LINNAEUS, 1758

Streszczenie

Na kolekcjach czaszek tchórza zwyczajnego, *M. putorius* pochodzących z 6 krajowych grup populacyjnych (n=596; 372:224; Tabela 1) zbadano wpływ dymorfizmu

płciowego i miejsca pochodzenia zwierząt na wymiary i proporcje czaszki (Fig. 1—5, 7; Tabela 2). Badano także związki korelacyjne wymiarów czaszki w aspekcie wiekowym i populacyjnym (Fig. 6 i 8 oraz Tabela 4 i 7—9).

Czaszka tchórza zwyczajnego charakteryzuje się znacznym zróżnicowaniem wymiarów, związanym z dymorfizmem płciowym (Tablice I—III), a także proporcji (Fig. 7) oraz tempa wzrostu (Tabela 6) i związanej z nim obliteracji szwów czaszkowych (Tabela 5).

Tchórze zwyczajne pochodzące z dwóch krajowych populacji lokalnych — Puszczy Białowieskiej i Rzeszowszczyzny — różnią się wymiarami i wynikającymi stąd odmiennymi proporcjami czaszki w odpowiadających sobie grupach płci i wieku. Stwierdzono także istnienie między nimi pewnych odrębności w strukturach korelacyjnych. Liczba różnic populacyjnych rośnie wraz z wiekiem zwierząt (Fig. 3, 5 oraz Tabela 3 i 4).

Najintensywniejszy wzrost większości wymiarów czaszki *M. putorius* zachodzi w pierwszym i drugim kalendarzowym roku ich życia. Tym niemniej pewne wymiary czaszki, a w szczególności: szerokość jarzmowa oraz czołowa, a także ciężar żuchwy odznaczają się wzrostem ciągłym, natomiast pojemność puszki mózgowej maleje z wiekiem (Fig. 2 i Tabela 6).

Zróżnicowane tempo wzrostu wymiarów czaszki tchórza zwyczajnego znajduje swe odzwierciedlenie w zmianach współczynnika zmienności (Tabela 2) oraz w strukturach korelacyjnych, odpowiadających grupom wieku (Fig. 8 oraz Tabela 8). Szczególnie u samców w 1 i 3 klasie wieku obserwujemy znacznie wyższe współzależności wymiarowe cech niż w klasach 2, 4 oraz 5. Świadczy to o przemienności okresów bardziej synchronicznego wzrostu czaszki i pewnej jej stabilizacji. Synchroniczny wzrost czaszki odpowiadałby wzrostowi izometrycznemu, natomiast okresy stabilizacji odznaczałyby się wzrostem allometrycznym, pociągającym za sobą zmiany w proporcjach.

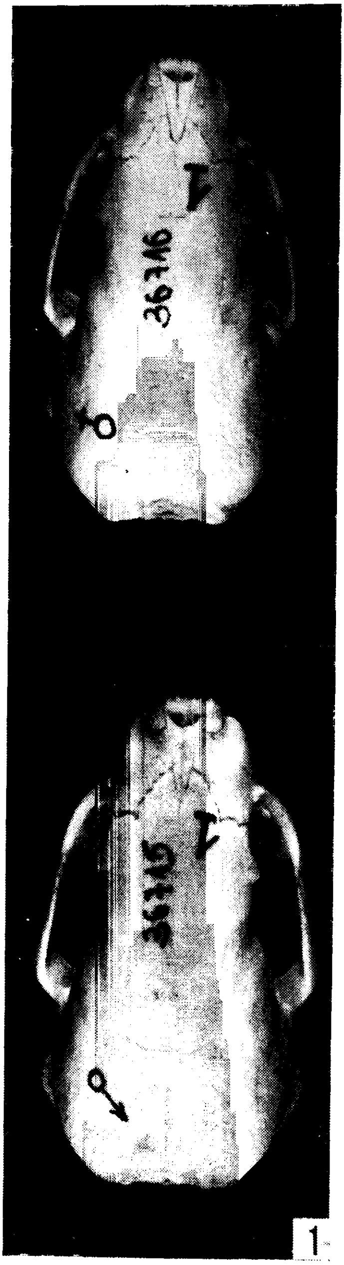
W materiale natrafiono na okazy czaszek form ekstremalnych pod względem wielkości, istotnie różniące się tak jeśli chodzi o rozmiary minimalne jak i maksymalne w porównaniu z odpowiadającymi im grupami wieku i płci (Fig. 9 i Tabela 9).

Wysoka korelacja długości kondylobazalnej czaszki z długością żuchwy i wysokością *ramus mandibulae*, nie zmieniająca się zbytnio poprzez wszystkie klasy wieku, skłoniła nas do obliczenia czterech równań regresji dla tych zależności — osobno dla samców i samic. Równania regresji dla powyższych zależności umożliwiają uzyskanie względnie dokładnego odtworzenia długości kondylobazalnej czaszki na podstawie wymiarów żuchwy (Fig. 10). Metoda powyższa może znaleźć praktyczne zastosowanie w badaniach paleontologicznych.

EXPLANATIONS OF PLATES I—III

Size and shape of the skull of the common polecat in different age classes. Skulls of females and males are shown.

Plate I.
Age class 1.
Plate II.
Age classes 2 and 3.
Plate III.
Age classes 4 and 5.



1

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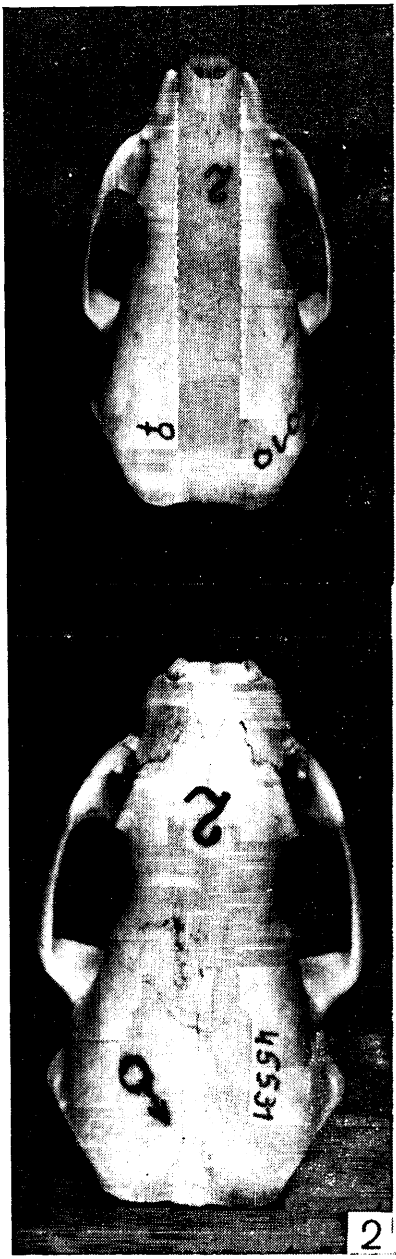

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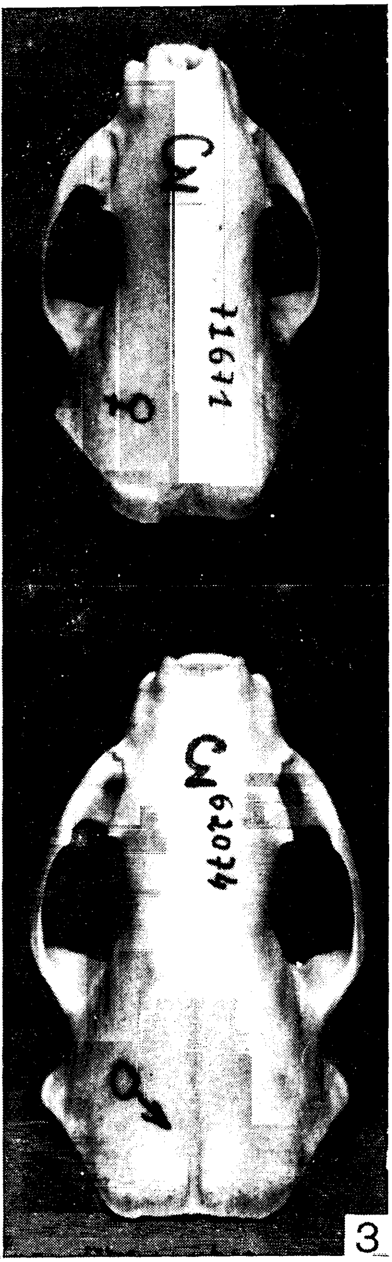

3

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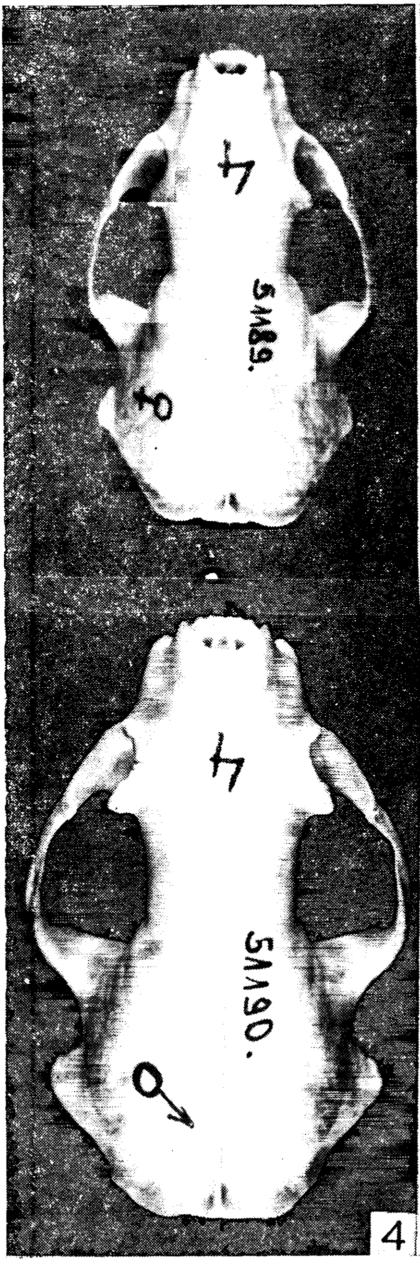

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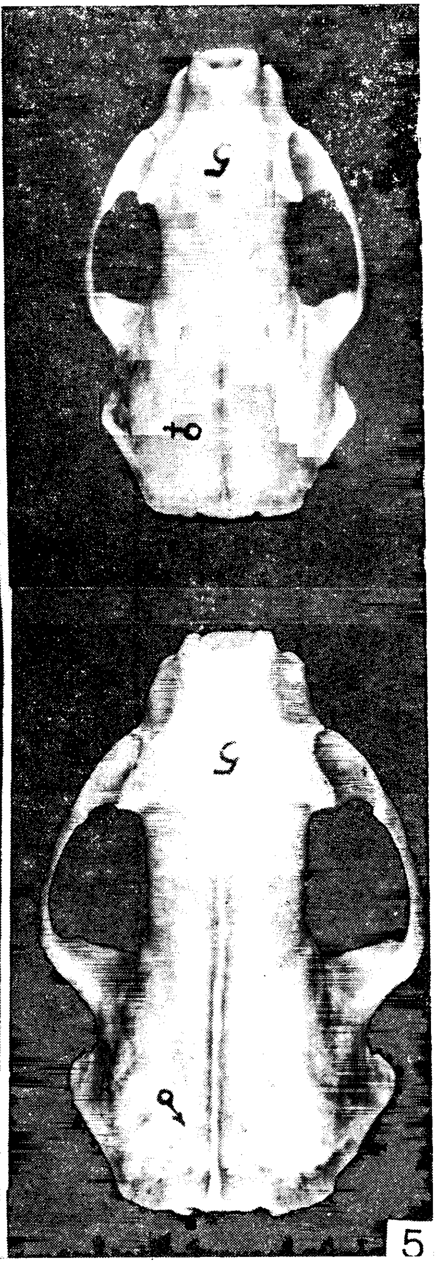

5

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