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Craniometrical sex determination of wild cat *Felis silvestris* in Bulgaria

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Analyses were made of 118 skull measurements of adult wild cats *Felis silvestris* Schreber, 1777 from Bulgaria, taken on 24 males, 20 females, and 10 animals whose sex was not known in advance. Group (cluster) analysis of cases, factor analysis, and stepvise discriminant analysis were adapted. The cluster analysis of cases indicated a high level of sex mixture (up to 40%), which suggested the importance of the outliers in the data. Six keys to sexual dimorphism, of very high statistical significance were produced, through the stepvise discriminant analysis. They included from 9 down to 1 variables each, which provided from 100% down to 93.8% of correct sex classification of wild cat skulls.

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Introduction

Sexual dimorphism of the cranial features of wild cat *Felis silvestris* Schreber, 1777 was noted by French *et al.* (1988). Arrighi and Salotti (1988) found for wild cats from Corse a male bigger than a female. Petrov *et al.* (1990) noted significant differences between males and females for a population of wild cats from Bulgaria for most of 121 skull measurements. This forms a basis to apply discriminant analysis for obtaining keys to the sexual dimorphism in wild cat. Similar approach was used for *Martes foina* and *M. martes* by Gerasimov (1985). Principal component analysis (PCA) could be applied in order to determine the main sources of the morphometric differences between sexes. Both discriminant analysis (although without providing keys to classify new individuals) and PCA were applied to study sexual dimorphism in two populations of domestic cats (Wetzel *et al.* 1982, Petrov *et al.* 1992).

The aim of this study was to analyse the sexual dimorphism in skulls of wild cats in Bulgaria, using the above mentioned methods.

Material and methods

For the study was used 24 males and 20 females of adult wild cats, *Felis silvestris* Schreber, 1777, from Bulgaria. Additional 10 individuals of unknown sex were used for some verifications. The material examined is kept at the National Museum of Natural History, Sofia, at the Forest Research Institute, and in some private collections.

All the material used was collected as "wild cat", and additionally, was verified by means of the Schauenberg's index (Schauenberg 1969). The values of the index were 2.46, SD = 0.134 for males and 2.45, SD = 0.129 for females.

The age of wild cats was determined by analysing annual growth layers in dentine of lower canines. The teeth were decalcified in 6.5% HNO_3 solution, cross-sectioned to 10 µm. Four slides were obtained for each specimen: one of them was kept unstained while each one of the other three were then stained with either of Ehrlich's, or Mayer's, or Delafield's hematoxylin. Annual growth layers were observed and counted under a microscope. The wild cats used were from 1+ to 7 years old.

Results from PCA by French *et al.* (1988) showed that increasing the number of variables used increased to a greater extent the distance between sexes for old wild cats (from 3.2 to 7.1) than for recent and modern ones (from 2.6 to 5.7). Thus, a wide set of measures to be applied for studies of sexual dimorphism in wild cat could be recommended.

The list of all 118 skull measurements and their determinations used are given in the Appendix 1. Variables were denoted further in the text as V1, V2, etc. The scheme of measurements was the same as in Petrov *et al.* (1990), except V10, V53, and V81. All measurements, except the *neurocranium* capacity (V56), were taken by a vernier caliper, with an approximation of 0.1 mm. The brain volume (V56) was measured using lead balls of 1.5 mm diameter. All measurements were taken by the same person. Locations of measurement points on wild cat skull are shown in Appendix 1.

The multivariate methods applied could be specified as follows: cluster analysis of cases based on Euclidean distances (without standardization of data prior to the analysis), principal component analysis (PCA) based on correlation matrices (with standardization of the variables used), and stepwise discriminant analysis with a choice of F-to-enter value of 4.0 (see Forsythe's remark in Dixon 1981, pp. 698 – 699).

The statistical analysis was performed using BMDP software (Dixon 1981): BMDPKM for cluster analysis of cases, BMDP4M for PCA analysis, BMDP7M for stepwise discriminant analysis, and BMDPAM was applied for a preliminary testing of the assumptions of the above mentioned multivariate methods.

Results

The arithmetical means, and standard deviations of 118 skull measurements of wild cat from Bulgaria are listed in an Appendix 2. Multivariate analyses were utilized in order to distinguish between sexes on the basis of the whole complex of variables, and not on single variables, as it was in all univariate analyses (Petrov *et al.* 1990).

Cluster analysis of cases was applied on the whole data matrix not giving *a priori* any information about sex. Although the two groups (clusters) were formed predominantly by individuals of the same sex (Table 1), it should be noted that about 40% of the males belonged to the "female" cluster. Thus, despite of the large number of highly significant differences that were previously found between the means of 121 dimensions for the two sexes (Petrov *et al.* 1990), outliers in the data seem to be important in the morphometrical characteristics of the wild cat

Table 1. Percentages of individuals of *Felis silvestris* forming two clusters based on cranial or mandibular measurements.

Sex	Cranial measurements		Mandibular measurements	
	Cluster I	Cluster II	Cluster I	Cluster II
Males	62.5%	37.5%	59.0%	41.0%
Females	5.0%	95.0%	19.0%	81.0%

in Bulgaria. Therefore, finding working discriminant keys to the sexual dimorphism in this species is a priority task.

Principal component analysis with standardization and varimax rotations, based on correlation matrices was applied. The results for the first two principal components (called futrher PC1 and PC2) based on both absolute and relative cranial measures showed that PC1 explains 42.7% of the total variance in the data space, while PC2 – only 9.9% . Both principal components could strongly be related to sex (see Fig. 1a). The first PC was related mainly to 43 absolute and 13 relative variables, predominantly lengths, while PC2 was explained by the brain volume (V56) and it's indices, the sizes of P^4, and three cranial widths. It is worth mentioning that specimens deviating from their groups on Fig. 1a are practically

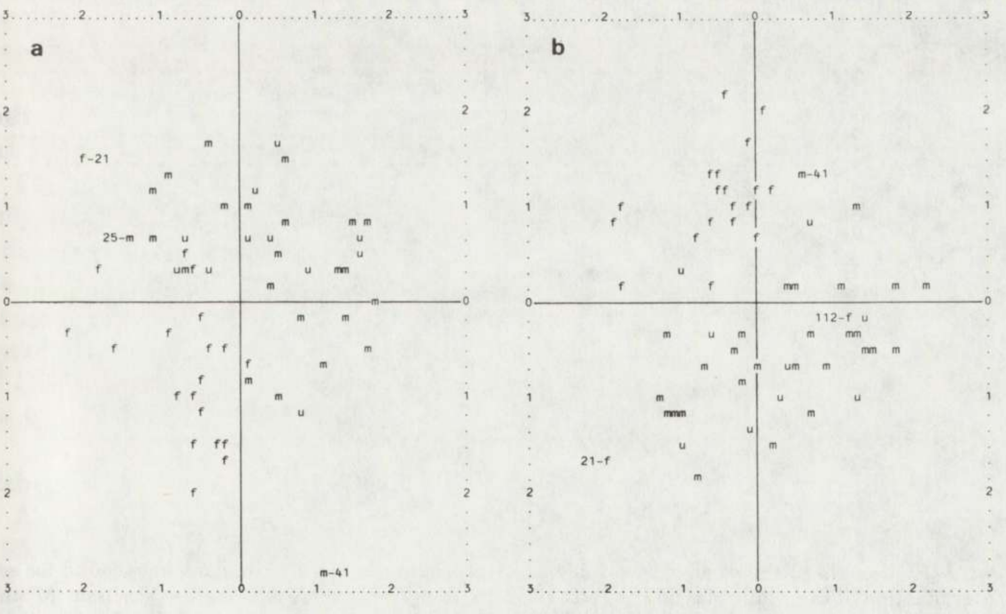

Fig. 1. Individual values of specimens of *Felis silvestris* from Bulgaria for the PC1 and PC2, based both on absolute and relative cranial measurements (a), and mandibular measurements (b). Factor scores is along the abscissa (factor 1) and the ordinate (factor 2). Males are denoted by 'm', females by 'f', and specimens of unknown sexes by 'u'. Numbers of highly deviating individuals are also given.

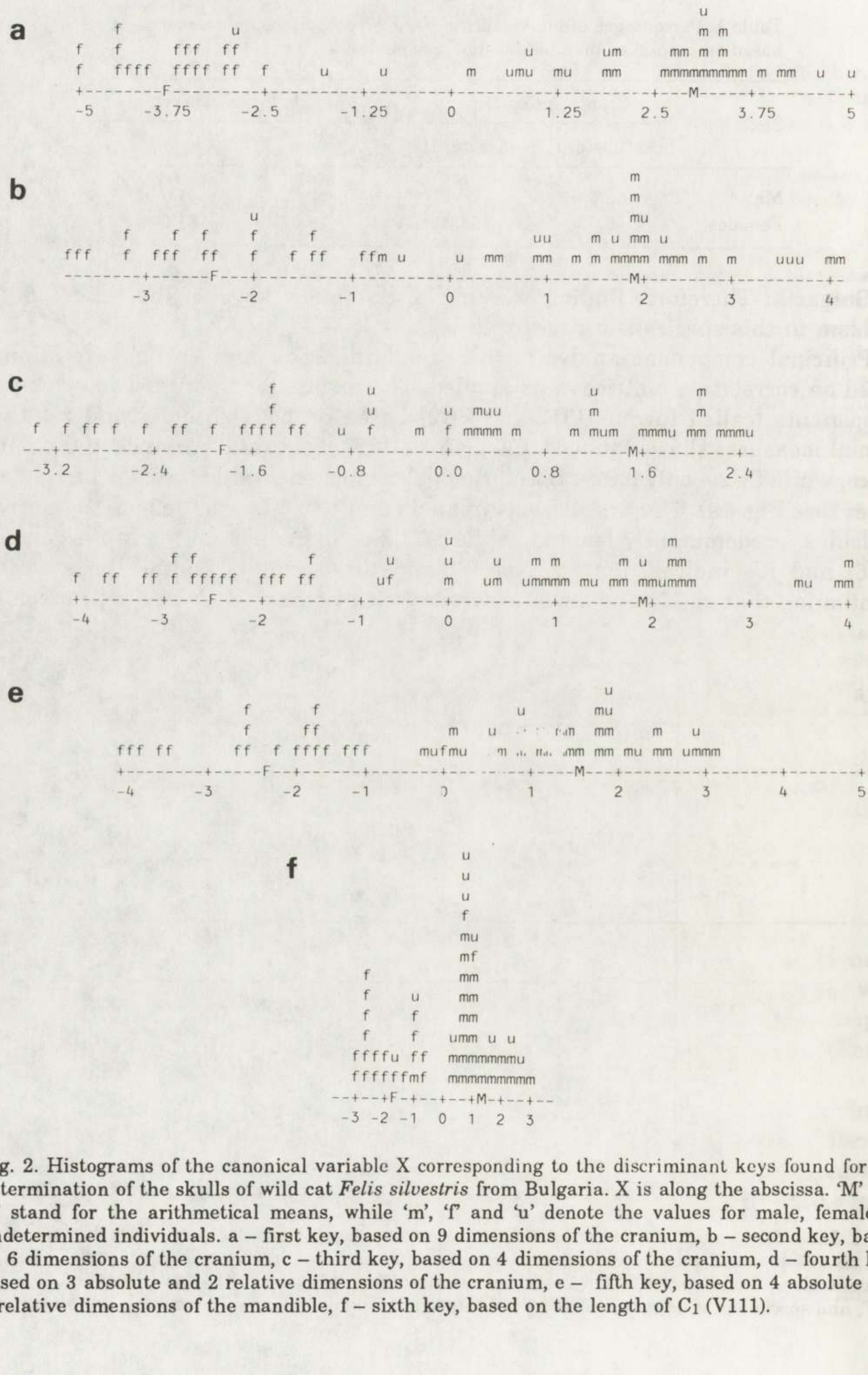

Fig. 2. Histograms of the canonical variable X corresponding to the discriminant keys found for sex determination of the skulls of wild cat *Felis silvestris* from Bulgaria. X is along the abscissa. 'M' and 'F' stand for the arithmetical means, while 'm', 'f' and 'u' denote the values for male, female or undetermined individuals. a – first key, based on 9 dimensions of the cranium, b – second key, based on 6 dimensions of the cranium, c – third key, based on 4 dimensions of the cranium, d – fourth key, based on 3 absolute and 2 relative dimensions of the cranium, e – fifth key, based on 4 absolute and 2 relative dimensions of the mandible, f – sixth key, based on the length of C_1 (V111).

the same specimens which were wrongly classified through some discriminant keys, based on the crania (numbers 21, 25, and 41), which confirms the explanation of both components by sex.

The PC1 obtained on the basis of both absolute and relative sizes of mandibles explains 49.3%, and the PC2 – 18.7% of the total variance in the data space. Both principal components could too much be related to sex (see Fig. 1b). PC1 was more related to common lengths and then to widths, heights, or their indices, while the PC2 – only to teeth sizes and their indices. Once again the same specimens which were wrongly classified through the discriminant keys based on mandible measures (numbers 21, 41, and 112; Fig. 1b), deviated from their groups, which confirms the explanation of both PC's by sex. The results of the PCA demonstrated the sexual dimorphism being the main source of variability in the craniometrical data for the wild cat from Bulgaria.

By means of stepwise discriminant analysis, several classification functions were found. The first key provided a 100% correct classification and was based on 9 dimensions of each skull: the greatest diameter of the orbit (V14), the distance between *processus zygomaticus* and *crista sagittalis externa posterior* (V15), the greatest mastoid breadth (V35), the frontal breadth (V41), the least distance between the *meata acustica externa* (V42), the least distance between the auditory bulla (V43), height of the *foramen magnum* (V57), the distance between *foramina incisiva* (V61) and the least diameter of C^1 (V79). In terms of a standardized (by the pooled within-group variances) canonical variable x, the key was as follows:

$$x = -0.8904 \times V14 + 0.8389 \times V15 + 1.3689 \times V35 - 0.601 \times V41 - 0.4641 \times V42 -0.7711 \times V43 + 0.836 \times V57 + 1.2921 \times V61 + 2.41518 \times V79 - 53.23661$$

with the means of 3.04677 and –3.65612 for males and females, respectively, (Fig. 2a).

The second discriminant key presented, provided a 97.7% correct classification (only the male No 25. was determined wrongly as a female) and it was based on 6 dimensions of each skull: the cranial breadth behind cheek-bone arcks (V33), the distance between *proc. zygomaticus* and *os zygomaticum* (V40), the *prot. occipitalis* height (V52), the distance between *os incisivum anterior* and *os frontale posterior* (V66), the height of nasal opening (V69), and the greatest diameter of C^1 (V78). In terms of a standardized canonical variable x, the key was as follows:

$$x = 0.66418 \times V33 + 0.34561 \times V40 + 0.44966 \times V52 - 0.21997 \times V66 + 0.62691 \times V69 + 2.303 \times V78 - 39.38011$$

with means of 1.92698 for males and –2.31237 for females (Fig. 2b).

A third discriminant key was produced, basing only on 4 variables. It provided a 95.5% correct classification, since a male, No. 41 and a female, No. 21 were in the intersection zone of the two "normal" curves (Fig. 2c), being somewhat closer to the center of the opposite group. Nevertheless, the key is useful for its simplicity, since it involves only the distance between the hind edges of *osa palatina* (V32), the length of the auditory bulla (V45), the height of C^1 (V80), and the breadth of P^4 (V88). The third key was as follows:

$x = -0.31303 \times V32 + 0.55335 \times V45 + 0.81814 \times V80 + 1.91179 \times V88 - 23.33241$ with means of 1.53228 for males and −1.83874 for females (Fig. 2c).

In attempt to improve the discrimination between sexes, 32 relative indices were constructed by dividing some variables describing widths, heights or teeth sizes by other ones, mainly skull lengths. On the basis of both absolute and relative sizes a fourth key was obtained, providing a 100% correct classification. It involves the condylobasal length (V2), the distance between *processus zygomaticus* and *crista sagittalis externa posterior* (V15), the least breadth of the supraorbital processes (V31), the cranial breadth behind cheek-bone arcks (V33), the palatal breadth measured between alveoli C^1 (V38), the distance between *foramina incisiva* (V61), and the least diameter of C^1 (V79). The fourth discriminant key was as follows:

$$x = 0.45036 \times V15 + 0.73329 \times V33 - 1.26831 \times V38 + 96.31937 \times V61/V2 + 60.89773 \times V79/V31 - 48.19314$$

with means of 1.97845 for males and −2.37413 for females (Fig. 2d).

As sometimes in practice only mandibles and not entire skulls are available, discriminant keys based on 32 mandible measurements, and on 17 indices formed out of them, were also produced. Thus, the fifth key provided a 95.8% correct classification (the male No. 35 and the female No. 112 were closer to the center of the opposite group). It is based on 8 mandible sizes: the mandibular length (V90), the mandibular length (V92), the total length of the mandibular teeth row (V96), the height of *corpus mandibulae* (V102), the mandibular breadth after C_1 (V105), the distance between *processus coronoidei* (V107), the greatest gauge of *corpus mandibulae* (V120), and the total length of C_1 (V121). The fifth (mandibular) key was as follows:

$$x = -0.80739 \times V102 + 0.80112 \times V105 + 1.53886 \times V120 + 0.7158 \times V121 + 23.42722 \times V90/V92 + 15.34642 \times V96/V107 - 61.32274$$

with means of 1.64593 for males and −2.11619 for females (Fig. 2e).

A very simple sixth key based only on one measurement, namely the greatest diameter of C_1 (V111), was found. It provided a 93.8% correct classification (a male, No. 41 and two females: No. 21, and No. 112 were attached to the opposite sex, Fig. 2f). The key is as follows:

$$x = 3.3661 \times V111 - 16.0521$$

with means of 1.27709 for males and −1.64198 for females (Fig. 2f).

The six keys above show a very high statistical significance ($p < 0.0005$).

Discussion

Univariate statistics for all the variables used here were presented, together with the results of a t-test between the corresponding values for male and female wild cats (Petrov *et al.* 1990). Univariate analysis showed the means for males being significantly higher than the corresponding values for females in most of the measurements taken. However, the results from cluster analysis of cases in this study showed the importance of the outliers in the data, also demonstrated for some other *Carnivora* species (Buchalczyk and Ruprecht 1977, Reig 1989).

Both cluster analysis and principal component analysis showed sexual differences appearing as the main sources of variability. Sexual dimorphism was related both with dimensions (i.e. absolute sizes) and shapes (relative sizes) of skulls. Among the first ones, more important were lengths, followed by widths, heights, and teeth sizes while among the latter ones – the indices formed by dividing widths to lengths, or brain volumes to lengths differentiate sexes better than those that heights participate in. Similar results with respect of the importance of lengths, widths, heights, as well as their indices, were also obtained for the mandibles. Studies of other species of *Carnivora* have shown size to be more important in terms of sexual dimorphism for stone marten *Martes foina* (De Marinis *et al.* 1990), and shape – for otter *Lutra lutra* and European badger *Meles meles* (Wiig 1986).

An important practical advantage of the stepwise discriminant analysis is that it provides keys involving only few dimensions (from 1 to 9 in our case). However, neither the factors responsible for the variability in the data-set could be determined, nor the significance for the sexual dimorphism of all the dimensions used in the analysis, could be estimated. For these purposes a principal component analysis based both on absolute and relative sizes, was performed.

The results of the stepwise discriminant analysis show highly significant differentiation between sexes, and also permit specimens of unknown sex to be classified.

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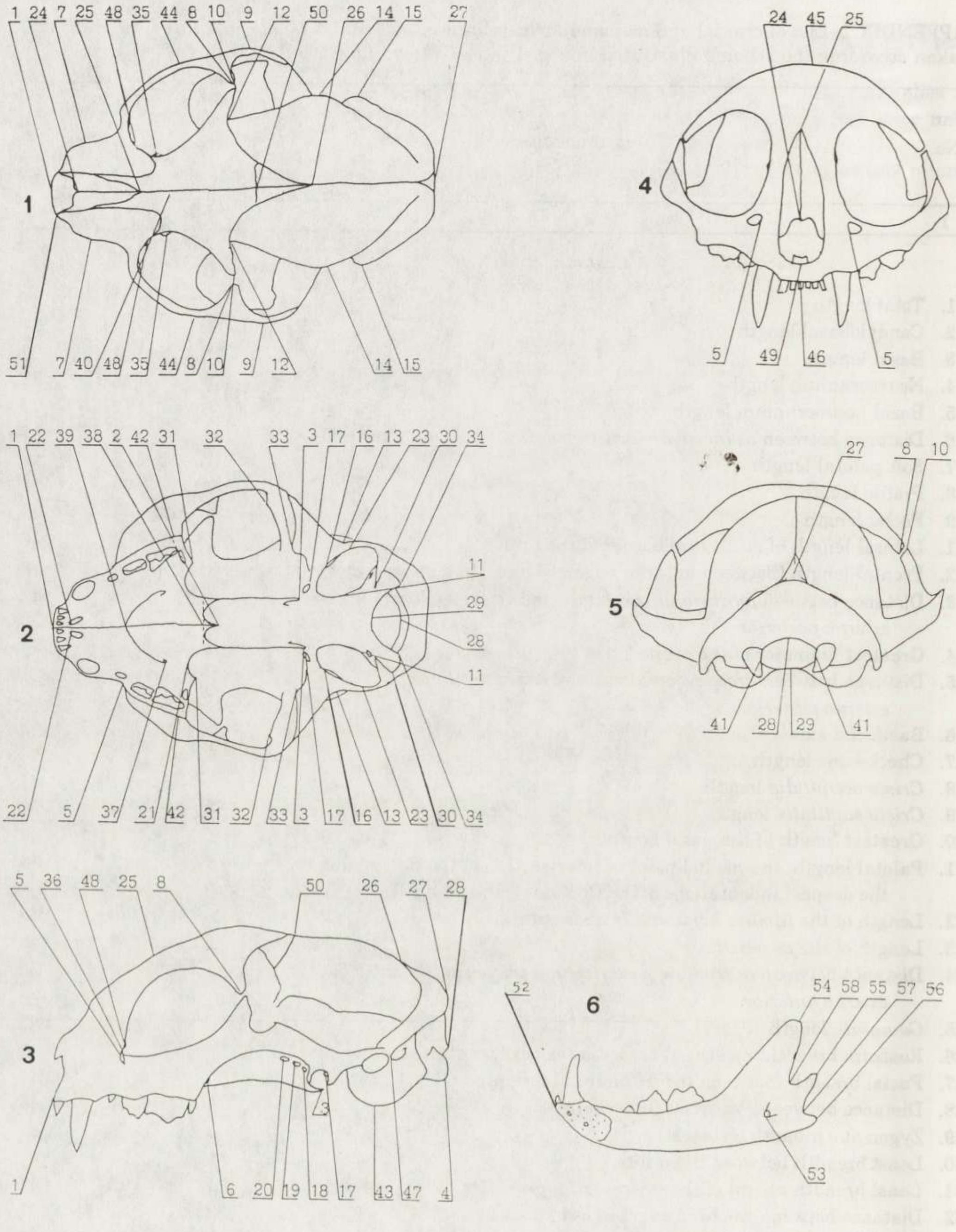
APPENDIX 1. List of cranial and mandibular measurements of wild cat *Felis silvestris* from Bulgaria, taken according the scheme illustrated in Fig. 1 (after Petrov *et al.* 1990).

Var. No.	Measurements	Fig. No.	Measurement points	
			from	to
1	2	3	4	5
	Cranium			
1.	Total length	3	1	27
2.	Condylobasal length	2	1	34
3.	Basal length	2	1	29
4.	Neurocranium length	3	25	28
5.	Basal neurocranium length	2	2	29
6.	Distance between *os incisivum anterior* and *os palatinum posterior*	2	1	2
7.	Soft palatal length	2	2	3
8.	Profile length	3	1	28
9.	Facial length	1	1	25
11.	Lateral length of snout oral border of the orbit	3	1	36
12.	Frontal length (between anterior edge alveolus I^1 and *proc. zygomaticus*)	3	1	8
13.	Distance between *foramen infraorbitale* and *crista sagittalis externa posterior*	3	5	27
14.	Greatest diameter of the orbit			
15.	Distance between *proc. zygomaticus* and *crista sagittalis externa posterior*	1	8	27
16.	Basifacial axis	3	1	3
17.	Check-bone length	2	5	13
18.	*Crista occipitalis* length	3	27	47
19.	*Crista sagittalis* length	1	26	27
20.	Greatest length of the nasal bone	1	51	25
21.	Palatal length: the medial point of inter-section of the line joining the deepest indentations of the Choanae – Prosthion	2	1	38
22.	Length of the *lamina horizontalis ossis palatini*	2	38	39
23.	Length of the *os maxillare*	1	1	40
24.	Distance between *os frontale posterior* and *crista sagittalis externa anterior*	1	50	26
25.	*Os nasale* length	1	24	25
26.	Rostrum breadth: measured across outer borders at the canine alveoli	1	7	7
27.	Facial breadth (between the infraorbital foramina – least distance)	4	5	5
28.	Distance between eye-orbits (external)	1	44	44
29.	Zygomatic breadth (greatest)	1	9	9
30.	Least breadth between the orbits	1	35	35
31.	Least breadth aboral of the *supraorbital processes*	1	12	12
32.	Distance between the hind edges of *osa palatina*	2	31	31
33.	Cranial breadth behind cheek-bone arcks	2	13	13
34.	Greatest breadth of braincase	1	14	14
35.	Greatest mastoid breadth	1	15	15
36.	Distance between upper-jaw joints (external)	2	32	32



Appendix 1. Figs 1 – 6. Scheme of the wild cats' *Felis silvestris* skull showing the location of measuring points (after Petrov *et al.* 1990).
1 – dorsal view, 2 – ventral view, 3 – lateral view, 4 – frontal view,
5 – posterior view of the skull, 6 – lateral lingual view of the mandible.

APPENDIX 1 – continued.

1	2	3	4	5
37.	Distance between upper-jaw joints (internal)	2	33	33
38.	Palatal breadth: measured between alveoli C^1 (internal)		not shown	
39.	Greatest palatal breadth: measured across the borders of the alveoli M^1 (internal)	2	42	42
40.	Distance between *processus zygomaticus* and *os zygomaticum*	1	8	10
41.	Frontal breadth	1	8	8
42.	Distance between the *meata acustica externa* (least)	2	16	16
43.	Least distance between the auditory bullae	2	11	11
44.	Breadth measured across the outer borders at the auditory bullae	2	23	23
45.	Length of the auditory bulla: from the most aborolateral points to the most oromedial point		not shown	
46.	Least diameter of the auditory bulla: from the middle of the opening of the external acoustic meatus up to the most medial protrusion of the bulla on the opposite side of the bulla			
47.	Breadth of *processus pterygoideus*		not shown	
48.	Greatest breadth of the occipital condyles	2	30	30
49.	Facial height: measured through the hind end of *os nasale*	4	25	h
50.	Greatest height of the cranium	4	45	h
51.	Cranial height: measured through the auditory bulla	3	26	43
52.	Height of the *protuberantia occipitalis*	5	27	28
54.	Height of *os incisivum* at *alveoli incisiva*	4	46	49
55.	Rear height	3	26	4
56.	Neurocranium capacity		not shown	
57.	Height of the *foramen magnum*	5	28	29
58.	Breadth of the *foramen magnum*	5	41	41
59.	Greatest diameter of the *meatus acusticus externus*		not shown	
60.	Least diameter of the *meatus acusticus externus*		not shown	
61.	Distance between *foramina incisiva*	2	22	22
62.	Distance between *foramen ovale* and *foramen rotundum*	3	17	18
63.	Distance between *foramen ovale* and *fissa orbitalis*	3	17	19
64.	Distance between *foramen ovale* and *foramen opticum*	3	17	20
65.	Distance between *foramina ovalia*	2	17	17
66.	Distance between *os incisivum anterior* and *os frontale posterior*	1	1	50
67.	Least diameter of the orbit		not shown	
68.	Breadth of the nasal opening: measured between *osa incisiva*		not shown	
69.	Height of the nasal opening: measured between *os incisivum*	4	24	49
	and *os nasale*	1	48	48
70.	Distance between lacrimal ducts (*canalis lacrimalis*)			
71.	Distance between *os incisivum anterior* and *crista sagittalis externa anterior*	1	1	26
72.	Distance between *os nasale posterior* and *crista sagittalis externa posterior*	1	25	27
73.	Distance between *foramen sphenopalatinum* and *canalis lacrimalis*	3	6	48
74.	Distance from the arch of *os palatinum* to *canalis palatinus*	2	21	37

APPENDIX 1 – continued.

1	2	3	4	5
75.	Length of maxilar teeth row from the fore end of alveolus I^1 to the hind end of alveolus M^1		not shown	
76.	Length of incisive teeth row		not shown	
77.	Distance between alveolus I^3 and alveolus C^1		not shown	
78.	Greatest diameter of C^1: measured near to the alveolus		not shown	
79.	Least diameter of C^1: measured near the alveolus		not shown	
80.	Height of the C^1: measured above the alveolus		not shown	
82.	Distance between posterior edge of alveolus C^1 and anterior edge of alveolus P^3		not shown	
83.	Length of the cheektooth row: measured on the buccal side	2	P^2	M^1
84.	Teeth row length: measured between posterior edge of alveolus C^1 and posterior edge of alveola M^1	2	C^1	M^1
85.	Length of the premolar row: measured along the alveoli on the buccal side	2	P^2	P^4
86.	Length of premolar row on P^3 and P^4	2	P3	P^4
87.	Length of P^4: measured on the buccal side		not shown	
88.	Breadth of P^4		not shown	
89.	Distance between the tips of C^1		not shown	
	Mandible			
90.	Length of the mandible: measured between anterior edge of alveolus I_1 and *processus coronoideus posterior*	6	52	54
91.	Length of the mandible: measured between anterior edge of alveolus I_1 and the middle of *processus condyloideus*	6	52	55
92.	Length of the mandible: measured between anterior edge of alveolus I_1 and *processus angularis posterior*	6	52	56
93.	Length of *processus condyloideus*		not shown	
94.	Distance between *processus condyloidei*		not shown	
95.	Height of the *ramus mandibulae*	6	54	55
96.	Total length of the mandible teeth row	6	I_1	M_1
97.	Distance between anterior edge of alveolus I_1 and *incisura mandibulare*	6	52	58
98.	Distance from anterior edge of alveolus I_1 to the angle between *processus condyloideus* and *processus angularis*	6	52	57
99.	Distance between posterior egde of alveolus C_1 to *processus coronoideus*	6	C_1	54
100.	Distance between posterior egde of alveolus C_1 and the angle between *processus condyloideus* and *processus angularis*	6	C_1	57
101.	Distance between posterior egde of alveolus C_1 and *processus angularis*	6	C_1	56
102.	Height of *corpus mandibulae* measured in the point between P_3 and P_4		not shown	
103.	Height of *corpus mandibulae* measured behind M_1		not shown	
104.	Total height of *corpus mandibulae*	6	54	56
105	Mandibular breadth after C_1		not shown	
106.	Distance between the middles of alveolus C_1 (internal)		not shown	
107.	Distance between *processus coronoidei*		not shown	
108.	Distance between *processus angularies*		not shown	

APPENDIX 1 – concluded.

1	2	3	4	5
109.	Distance between anterior edge of alveolus I_1 to *foramen mandibulare*	6	52	53
110.	Distance between *foramen mandibulare* and *processus angularis*	6	53	56
111.	Greatest diameter of C_1 measured near to the alveolus		not shown	
112.	Distance from posterior edge of C_1 to posterior edge of M_1	6	C_1	M_1
113.	Length of cheektooth row: measured between anterior edge of P_3 posterior edge of M_1	6	P_3	M_1
114.	Length of premolar row	6	P_3	P_4
115.	Length of M_1		not shown	
116.	Greatest breadth of M_1		not shown	
117.	Distance between the tips of C_1		not shown	
118.	Breadth of C_1 measured near alveolus		not shown	
119.	Height of C_1 measured above the alveolus		not shown	
120.	Greatest gauge of *corpus mandibulae*		not shown	
121.	Total length of the C_1		not shown	

APPENDIX 2. Arithmetic means and standard deviations of 118 craniometrical measurements of wild cat *Felis silvestris* from Bulgaria (numeration and description of the measurements after Petrov *et al.* 1990, except V10, V53, V81).

V	Males				Females				t
	$\bar{x}$	SD	min	max	$\bar{x}$	SD	min	max	
1	2	3	4	5	6	7	8	9	10
	Cranium								
1	98.86	4.84	89.1	105.3	91.85	3.42	84.4	97.3	5.44
2	91.04	4.11	83.5	96.4	84.95	3.04	78.6	89.5	5.49
3	83.88	4.28	72.3	89.0	78.28	2.74	71.4	82.5	5.05
4	74.75	3.12	67.8	78.4	70.57	2.66	65.0	74.0	4.73
5	44.34	2.36	40.2	48.0	41.19	2.02	37.3	44.7	4.70
6	39.79	2.14	35.5	43.7	36.99	1.31	34.4	38.9	5.08
7	18.70	1.50	16.5	21.3	17.91	1.42	15.0	20.1	1.78
8	93.70	4.27	85.3	99.3	87.83	3.10	81.2	92.6	5.12
9	38.22	2.18	34.0	42.5	35.72	1.63	33.4	39.7	4.23
11	26.66	1.52	24.1	28.8	24.66	1.19	22.0	26.4	4.78
12	55.31	2.82	50.0	58.8	52.41	2.26	48.1	55.5	3.71
13	81.38	3.86	73.0	87.3	75.74	2.67	70.0	80.1	5.52
14	28.66	1.39	26.1	30.5	27.87	0.99	26.0	29.4	2.13
15	60.63	3.20	54.7	66.0	56.09	2.37	50.9	59.4	5.25
16	57.20	3.01	52.2	62.4	53.76	2.11	49.4	56.1	4.30
17	52.64	2.65	46.0	56.2	49.08	2.20	45.1	51.8	4.77
18	35.58	1.73	32.9	38.1	33.14	1.05	31.0	34.7	5.50
19	19.13	6.51	8.0	34.0	13.73	2.73	8.0	17.5	3.46
20	27.57	1.73	24.9	30.7	25.98	1.52	23.4	29.5	3.21
21	38.07	1.94	34.3	41.0	35.32	1.28	32.7	37.1	5.43
22	16.34	1.08	14.4	17.8	14.79	0.96	12.3	16.5	5.01
23	36.02	1.86	31.7	39.1	33.12	1.41	30.8	35.5	5.73
24	27.43	4.32	18.1	37.0	28.62	1.71	25.5	31.7	− 1.16
25	23.72	2.17	20.3	28.9	22.22	1.41	19.4	25.6	2.66
26	25.28	1.53	22.1	27.9	23.32	0.94	21.8	24.7	4.99
27	27.74	1.83	24.9	31.2	25.97	1.22	23.6	27.7	3.69
28	62.30	3.42	57.6	68.7	59.92	2.44	54.3	63.4	2.61
29	70.46	4.90	62.2	79.2	65.22	3.23	58.2	70.3	4.09
30	19.20	1.44	17.2	23.1	18.14	1.07	16.0	19.8	2.72
31	33.76	1.79	30.0	37.2	34.03	1.21	32.0	36.7	0.57
32	30.68	2.14	27.1	36.0	29.60	1.91	25.5	32.4	1.75
33	42.07	1.28	39.5	44.4	39.73	0.80	38.3	41.0	7.09
34	46.43	1.12	43.3	48.8	45.34	1.04	43.2	47.8	3.32
35	44.26	1.59	40.7	46.5	41.37	0.61	40.1	42.6	7.66
36	57.25	3.16	52.5	63.4	53.12	1.85	49.0	56.2	5.15
37	34.47	1.66	32.0	37.9	32.35	1.16	30.5	34.0	4.81
38	14.28	1.19	12.0	16.2	13.71	1.00	11.5	15.1	1.70
39	35.58	1.54	32.9	38.5	34.14	1.31	32.0	36.0	3.30
40	2.74	1.93	0.0	5.9	2.64	1.91	0.0	6.9	0.19
41	51.10	4.02	44.0	57.6	49.57	2.95	43.1	54.5	1.41

APPENDIX 2 – continued.

1	2	3	4	5	6	7	8	9	10
42	32.97	1.93	29.3	36.3	30.83	0.98	28.7	32.8	4.49
43	9.82	0.67	8.9	11.7	9.31	0.68	8.1	10.5	2.50
44	38.37	1.50	35.5	40.9	36.38	1.22	34.7	39.0	4.76
45	21.47	1.30	19.5	24.0	19.85	0.72	18.0	21.5	4.95
46	13.64	0.62	12.1	14.6	12.85	0.48	11.9	13.6	4.65
47	13.82	0.81	12.5	15.4	13.43	0.77	12.1	15.3	1.63
48	24.30	0.85	22.6	26.0	23.34	0.69	21.8	24.5	4.06
49	28.81	1.44	26.2	31.3	27.29	1.32	25.0	29.7	3.62
50	38.59	1.09	36.9	40.8	36.96	1.05	35.3	3.89	5.02
51	41.10	2.45	34.4	43.9	37.98	1.31	34.2	39.7	5.11
52	15.85	1.18	13.5	18.0	14.52	0.99	12.3	16.7	4.00
54	5.32	0.65	4.0	6.6	4.64	0.48	4.0	5.8	3.93
55	37.22	4.43	29.0	44.7	33.62	1.95	29.3	37.5	3.37
56	40.25	2.45	35.0	44.5	37.64	2.33	34.0	42.6	3.60
57	12.79	0.95	11.1	14.9	12.68	0.75	11.3	14.5	0.42
58	14.99	0.65	13.8	16.6	14.93	0.48	14.0	15.6	0.32
59	6.95	0.32	6.0	7.4	6.96	0.27	6.6	7.6	− 0.10
60	4.38	0.20	4.0	4.7	4.28	0.17	4.0	4.6	1.55
61	2.30	0.41	1.3	3.5	2.01	0.44	1.4	2.8	2.26
62	3.38	0.68	2.2	4.9	3.10	0.50	2.6	4.3	1.53
63	6.21	0.65	5.0	7.7	5.95	0.45	5.0	6.6	1.57
64	11.18	1.05	9.6	13.5	10.67	0.65	9.2	12.0	1.85
65	20.85	1.17	17.8	22.3	20.14	0.67	19.1	21.4	2.40
66	68.15	3.75	58.0	73.0	64.74	2.16	60.9	68.5	3.60
67	24.78	1.10	23.0	27.0	24.03	0.91	22.3	25.3	2.28
68	11.99	0.88	10.5	13.9	10.75	0.85	8.8	11.8	4.76
69	10.69	0.90	8.6	12.0	9.97	0.54	8.8	11.0	3.13
70	24.94	2.18	21.5	29.0	23.16	1.42	20.2	25.4	3.14
71	88.12	2.84	83.5	93.4	84.68	2.54	80.0	90.2	4.20
72	74.87	3.50	67.1	80.0	69.86	2.94	64.4	73.2	5.08
73	13.48	0.87	11.7	14.9	12.28	0.55	11.0	73.2	5.08
74	7.90	1.09	6.4	10.7	7.74	0.76	6.6	9.6	0.59
75	39.13	1.60	36.0	41.4	37.08	0.94	35.0	38.5	5.04
76	9.93	0.54	9.1	11.0	9.59	0.48	9.0	10.9	2.12
77	3.92	0.73	2.5	5.1	3.72	0.51	2.5	4.7	1.01
78	5.90	0.53	4.7	7.2	4.89	0.27	4.5	5.4	7.66
79	4.25	0.32	3.5	4.8	3.62	0.20	3.3	4.0	7.64
80	14.27	1.36	11.5	17.2	11.73	0.83	9.6	13.6	7.22
82	6.38	0.92	5.0	8.7	6.00	0.92	4.3	7.4	1.36
83	23.10	0.95	21.4	24.8	21.93	0.87	20.5	24.3	4.19
84	25.39	1.09	23.1	27.3	24.50	0.97	22.5	26.5	2.85
85	22.40	0.66	21.0	23.7	21.28	0.75	20.0	22.7	5.27
86	18.72	0.60	17.4	20.0	18.10	0.59	17.0	19.0	3.44
87	11.45	0.44	10.7	12.7	10.99	0.57	10.1	12.2	2.95
88	5.72	0.34	5.0	6.4	5.30	0.22	4.9	5.6	4.75
89	17.61	1.62	13.7	21.0	16.25	1.08	14.8	18.6	3.18

APPENDIX 2 – concluded.

1	2	3	4	5	6	7	8	9	10
		Mandible							
90	65.92	3.97	59.40	72.3	62.18	3.62	56.0	70.4	3.36
91	63.24	3.58	57.0	68.5	59.58	3.02	53.4	66.8	3.76
92	64.56	4.55	56.5	71.7	60.68	3.59	53.1	69.5	3.21
93	14.43	1.73	11.3	17.5	13.56	1.42	11.0	16.6	1.87
94	32.86	2.07	28.2	36.4	30.81	2.99	26.3	36.3	2.81
95	16.57	1.96	13.2	20.8	14.56	1.55	11.4	18.6	3.85
96	36.61	1.40	33.7	39.0	34.66	1.22	32.3	37.9	5.06
97	59.30	3.42	53.0	64.5	55.77	2.86	49.9	63.0	3.80
98	61.89	3.56	54.6	68.0	58.15	3.10	51.8	66.5	3.92
99	58.04	3.77	51.5	64.2	54.77	3.43	49.0	62.9	3.10
100	53.72	3.57	46.2	59.5	50.91	3.02	44.5	58.1	2.89
101	56.51	4.29	48.7	63.5	53.59	3.39	46.5	61.5	2.55
102	10.80	0.99	9.0	12.4	9.98	0.90	8.5	11.9	2.96
103	11.86	0.72	10.5	13.1	10.89	0.91	9.4	12.7	4.38
104	28.16	2.87	23.5	34.0	25.79	2.20	22.0	31.7	3.13
105	12.85	0.75	11.7	15.0	11.70	0.58	11.0	13.1	5.80
106	5.79	0.54	5.0	6.8	6.05	0.63	4.5	7.2	– 1.55
107	50.49	3.53	44.4	55.5	49.44	4.15	41.2	56.7	0.95
108	43.32	4.40	37.0	52.3	41.41	4.03	35.5	50.0	1.56
109	48.67	2.58	43.0	52.6	45.61	2.34	41.0	51.9	4.24
110	15.71	2.92	12.0	24.3	15.02	1.49	12.4	18.2	0.99
111	5.15	0.25	4.5	5.7	4.28	0.35	3.9	5.1	10.05
112	28.45	1.02	26.1	30.0	27.49	1.60	25.5	29.9	3.03
113	21.85	0.94	18.3	23.0	21.10	0.73	19.5	22.6	3.01
114	13.76	0.49	13.0	14.7	13.12	0.50	11.8	13.9	4.45
115	8.84	0.43	7.7	9.5	8.35	0.37	7.7	9.0	4.24
116	3.58	0.22	3.2	4.1	3.53	0.26	3.0	4.2	0.58
117	16.87	1.23	14.6	20.0	15.59	0.78	14.0	17.3	4.16
118	3.81	0.27	3.2	4.3	3.21	0.29	2.8	3.9	5.79
119	12.44	1.60	9.9	16.9	10.78	0.99	9.0	13.3	5.17
120	5.97	0.56	5.0	7.3	5.28	0.16	5.0	5.6	5.46
121	23.99	1.05	22.0	26.3	21.02	2.23	16.7	24.3	6.12