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Morphometric analysis of recent brown bears (*Ursus arctos* Linnaeus, 1758) from Republic of North Macedonia

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Abstract

The research on morphology and dimensions of the skulls of recent brown bear (Ursus arctos Linnaeus, 1758) showed the morphological and metric variability between intraspecific populations as well as the determination of sexual dimorphism. For the purpose of this study were analyzed 18 recent skulls from the territory of the Republic of North Macedonia and 1 recent skull of the territory of the Republic of Bulgaria. Up to date, published records indicated that the size of the bears from southern part of Europe were smaller, compared to the species of other parts of Europe. For this purpose, were analyzed the bones of the skull and was made the complete description of dentation. The sexual dimorphism according to the morphometry of ectoorbital bone and canines, were studied and confirmed too. Herein, is set the hypothesis concerning the cannines differences between male and female individuals too. Furthermore, was determined that the studded brown bear population belongs to the typical Ursus arctos. In future, the presented tables and forms will contribute to further studies to compare the skulls of bears from Republic of North Macedonia, the Balkans and beyond.

Key words: Skull morphometry, Holocene bears, sex dimorphism.

Introduction

This paper consists part of results obtained in the master thesis „Comparative morphometric characteristics of cave bear (*Ursus spelaeus* Rosenmüller, 1794) and brown bears (*Ursus arctos* Linnaeus, 1758) of Macedonia“. Herein, will point out only the results of metric analysis of recent bears which are in correlation with age and sex dimorphism. In general, Ursidae family represent a small group of 8 species that are classified according to arctoid characteristics and it is believed that their evolution began 15-20 million years ago (Thenius, 1959). Brown bears in south part of Europe origin from late Pleistocene (Spassov, 2003).

Concerning its species variability in the morphology of the skull and teeth makes it difficult to compare the description of the species, especially because of strong relationship between canines (Kurten, 1953). The great confusion in taxonomy of brown bear is mainly because of intraspecific differences such as color of the fur, form of the skull, form of the teeth and growth (Erdbrink, 1953). This refers to the Balkan species as well where Spassov (1990, 2003) and Spassov et al. (2015) proved that many brown bears have a “golden” coat color especially evident in females individual. It is also noted that some activities concerning non-native bear migration from different regions were evident in the past, where brown bears from different habitats/ regions were introduced in new habitats (Misumachi et al., 2020). Population of Balkan brown bears are fragmented, so the south line of bears is adapted on high mountains (Spassov, 2003) and morphologically and genetically differ from north-west European populations and are closer to its Mediterranean populations (Taberlet et Bouvet, 1994; Misumachi et al., 2020).

The study of the skull morphology and morphometry of the brown bear from Republic of North Macedonia and the Balkans in general are important because recent genetic studies, show that the southern European bear populations from the Apennine to the Balkan Peninsula area, differs from the population of more northern Europe (Misumachi et al., 2020). In this respect, the manuscript in question is of interest and provides some useful information, for example on sexual dimorphism, which vary in the different geographical groups of brown bear

(Baryshnikov et al. 2003). According to Baryshnikov et al. (2003) sexual dimorphism is not so expressed in canines at recent bears, raise the question to set the following hypothesis: if their width is greater than 14 mm, it belongs to a male, i.e. if it is less than 13 mm it is a female.

Bearing in mind all this features, the aim of this paper is to provide information about anatomical differences in the skull and teeth which is in connection with the sex dimorphism within *Ursus arctos* species from Republic of North Macedonia and other brown bears from Europe.

Material and methods

The research is based on the morphology and measurement of the separate bones of the skull and teeth of recent bears. Used measurement methods are according to: Couturier (1954) and Von Den Driesch (1976). The nomenclature of the elements of dentation are according to the methods of Dufour (1989) and Baryshnikov et al. (2003, 2007). Methods and principles in zoology as taxonomic procedure and steps in identification used in this study are according to the recommendations from Mayr et al. (1953). The taxonomy determination is according to Grey (1825 in Gromova, 1962). Measurement was done with a shaft with an accuracy of 0.02 mm, the results are rounded to 1 mm for values greater than 50 mm and a tenth of a millimeter for values less than 50 mm. The performed analysis are based on the research carried out on 18 brown bears *Ursus arctos* skulls originating from various localities of Republic of North Macedonia (stored at National Museum of Natural History – Skopje and Faculty of Forest Sciences - Skopje) and 1 found in a cave from Mountain Pirin – Bulgaria (stored at National Museum of Natural History – Sofia). Gained results are then compared with species of the genus *Ursus* found across Europe.

Results

The general features of the brown bear skulls, studied in this paper are listed in Tab. 1. Herein, the obtained morphological similarities relevant for this study are presented. The largest morphological differences occur in the third upper incisor, which is well developed at recent specimens. Greatest feature in the teeth derives from the upper third premolars present in all studied specimens in the form of a tooth or alveolus, which indicates their presence. Tab. 2 contains the metrical results of studied skulls. Furthermore, the analyzes of the obtained parameters (Tab. 2) are compared according to recommendations by Baryshnikov et al. (2003) and Couturier (1954) and further the main measured ratios are pointed out in the Figs.1,2.

Table 1. Main characteristics of *Ursus arctos.* Abbreviations: I^1, I^2, I^3 - upper incisors ce; $p^{1,2,3,4}$ - upper premolars; C - canines; M^1, M^2 - upper molars; I_1, I_2, I_3 - lower incisors; $P_{1,2,3,4}$ - lower premolars; M^1, M^2, M^3 - lower molars.

	Ursus arctos
skull	Completely developed
glabella	Absent
I^1	Mid developed
I^2	Mid developed
I^3	Caniniform
Upper C	Mid developed mesial furrow
$P^{1,2,3}$	present / primitivity
P^4	Paracon without ridges, placement of deuterocon posterior without accessory tubercles
M^1	4 tubercles, poorly developed parastyl and metastyl without accessory tubercles
M^2	4 tubercles without accessory tubercles, the posterior field is not grooved
Lower jaw	Obliquely placed coronoid outgrowth
I_1	Mesial worn out
I_2	Mesial worn out
I_3	Caniniform
Lower C	Poorly developed anterior and posterior boundary line of the surface
$P_{1,2,3}$	present / primitivity
P_4	Paraconid without secondary tubercles
M_1	Double lingual tubercles (metaconid and entoconid) without secondary tubercles central to the tooth
M_2	Double lingual tubercles (metaconid and entoconid) without secondary tubercles central to the tooth
M_3	Ovoid form with smooth surface
Cement	Absent

Table 2. Comparative cranial dimensions of brown bear (*Ursus arctos*) from Republic of North Macedonia. Used abbreviations: TD – Total length – incisive to sagittal crest; EC – ectoorbital width; KD – Condylobasal length – incisive to condyles occipitalis; BD – Basal length – incisive to foramen magnum; ZG – Zygomatic width.

***–Ursus arctos* (mm)**											
Specimen	**TD**	**KD**	**BD**	**ZG**	**EC**	**KD / TD**	**BD / TD**	**ZG / TD**	**EC / TD**	**ZG / EC**	♂ / ♀
Мк 1	284	268	250	152	76	0.94	0.88	0.535	0.267	0.5	♀
Мк 15	322	314	294	184	92.5	0.97	0.91	0.554	0.287	0.502	♀
Мк 17	315	301	287	166	90	0.95	0.91	0.526	0.285	0.542	♀
Мк 19	254	/	/	186	99	/	/	/	/	0.532	♀
Мк 21	308	299	281	178	88	0.97	0.91	0.577	0.285	0.494	♀
Мк 23	252	246	229	143	62	0.97	0.9	0.567	0.246	0.433	♀
Мк 27	253	235	223	137	75	0.92	0.88	0.541	0.296	0.547	♀
Мк 29	256	229	222	146	78	0.89	0.86	0.57	0.304	0.534	♀
Bg 35	321	303.5	286	188	92.5	0.94	0.89	0.585	0.288	0.492	♀
Мк 3	307	290	290	182	97.5	0.94	0.94	0.592	0.317	0.535	♂
Мк 5	290	278	262	167	91.5	0.95	0.9	0.575	0.315	0.547	♂
Мк 7	320	273	250	212	109	0.85	0.78	0.662	0.34	0.514	♂
Мк 9	332	330	308	206	114	0.99	0.92	0.62	0.343	0.553	♂
Мк 11	357	334	313	219	111	0.93	0.87	0.613	0.31	0.506	♂
Мк 13	296	280	258	187	111	0.94	0.87	0.631	0.357	0.587	♂
Мк 20	260	/	/	225	122	/	/	/	/	0.542	♂
Мк 25	302	267	263	175	97	0.88	0.87	0.579	0.321	0.554	♂
Мк 31	380	335	321	232	126	0.88	0.84	0.552	0.331	0.543	♂
Мк 33	357	321	301	210	128	0.89	0.84	0.588	0.358	0.609	♂
SD	39.1	36.4	32.5	28.2	20.4	/	/	/	/	/	/

According to the ratio of the width of the EC/TD (Tab. 2) for determining the sexual dimorphism as the maximum value is 0.304 mm with a ratio in the range of 0.25 - 0.30 mm for female individuals of the species *Ursus arctos* (Fig. 1a). The ectoorbital/total length ratio (Tab. 2) for determining sexual dimorphism has a maximum value of 0.358 mm with a range of 0.31 - 0.36 for male *Ursus arctos* (Fig. 1b). The ratio of zygomatic arches width/forehead width for female *Ursus arctos* has a range of 0.42 - 0.54 mm (Fig. 1c) with a maximum value of 0.547 mm. The ratio ZG/EC for male *Ursus arctos* has a range of 0.5 - 0.61 mm (Fig. 1d) with a maximum value of 0.609 mm.

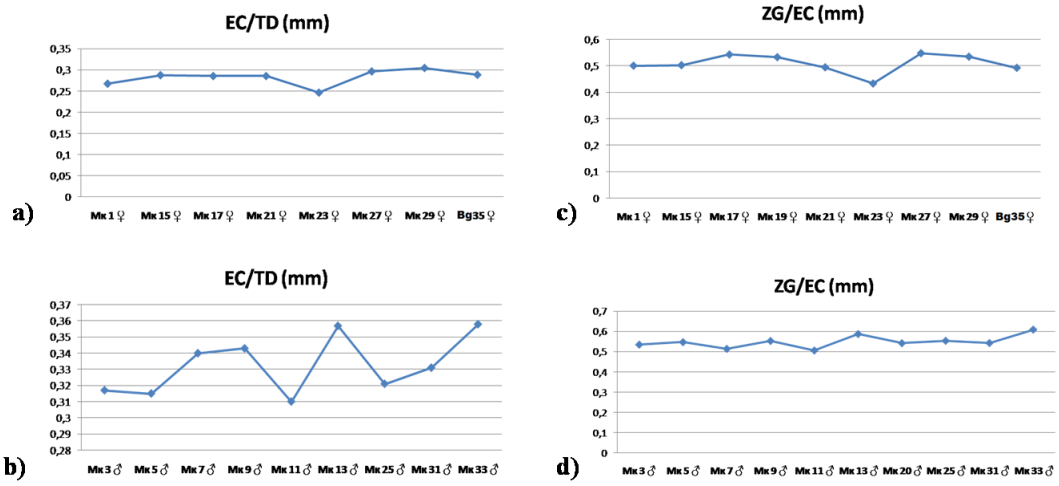

Figure 1. a) Correlation of ectoorbital width/total length (EC/TD) of female bears (*Ursus arctos*); b) Correlation ectoorbital width/total length (EC/TD) at male bears; c) Correlation width of zygomatic arch/ectoorbital width (ZG/EC) for female bears; d) Correlation zygomatic arch/ectoorbital width (ZG/EC) for male bears.

Table 3. Metrical results of mandibles of brown bear (*Ursus arctos*). Used abbreviations: RM – Length of lower jaw Incisive to proc. angularis; Hma/Hmb – Height of lower jaw - under P_4 and M_2; PMa – Length P_4 и M_3; DD – Diastema C - P_4; AC – Height of lower jaw - proc. angulare to proc. coronoideus; CPa - Length C – P_4; CM - Length C - M^2; CMa - Length C - M_3; MC – Distance between mandibular condyles; CCb – External width C - C.

***Ursus arctos* (mm)**													
Specimen	RM	H ma	Hm b	PMa	DD	AC	CP a	CM a	MC	CC b	AC / RM	AC / Hmb	♂ / ♀
Мк 2	205	36	33	77	16	78	62	123	129	35	0.38	0.423	♀
Мк 16	232	42	40	77	33	90	73	140	160	43	0.387	0.444	♀
Мк 18	224	39	35	86	19	89	69	141	144	43	0.397	0.393	♀
Мк 22	220	40	38	77	21	36	67	131	0	0	0.163	1.055	♀
Мк 24	187	33	31	71	17	80	51	115	123	37	0.427	0.387	♀
Мк 28	180	30	28	75	17	70	55	119	122	37	0.388	0.4	♀
Мк 30	190	36	33	79	19	74	58	126	126	42	0.389	0.445	♀
Bg 36	250	44	45	78,5	0	98	71	132	155	44	0.392	0.459	♀
Мк 26	208	37	35	69	25	87	67	129	142	39	0.418	0.402	♂
Мк 32	259	51	51	72	35	116	81	143	184	55	0.447	0.439	♂
Мк 34	244	45	46	71	35	102	75	138	175	42	0.418	0.451	♂
Мк 4	208	36	35	72	0	86	65	127	147	36	0.413	0.406	♂
Мк 6	207	41	41	70	26	86	66	128	134	37	0.415	0.476	♂
Мк 8	236	50	51	82	18	117	76	147	168	45	0.495	0.435	♂
Мк 10	245	49	51	82	22	115	79	146	169	47	0.469	0.443	♂
Мк 12	247	46	44	76	32	106	76	142	189	47	0.429	0.415	♂
SD	23.9	6.3	7.7	5.3	7.4	20	8.5	10	21.9	5.1	/	/	/

In Tab. 3, are presented the relevant measurements for comparative analyzes. The calculated ratio AC/RM (Tab. 3, Fig. 2) has a range of 0.38-0.5 abrupt drop of the curve in the lower jaw Mk 22 which is a result of present deformities in its development, which was obvious before measuring.

The calculated ratio AC/Hmb (Tab.3, Fig. 3) has a range of 0.4–0.55 mm. This sudden growth of the curve of the lower jaw Mk 22 is a result of present deformities in the development of the jaw. The lower jaw of the mandibulae Mk 32 (Tab. 3) has maximum values of all measured dimensions, i.e. deviates from other measurements for *Ursus arctos*. Sex dimorphism according to the ratios presented in Tab. 3 coincides with the one determined according to ratios in Tab. 2. Only the jaw Mk 24 has larger values.

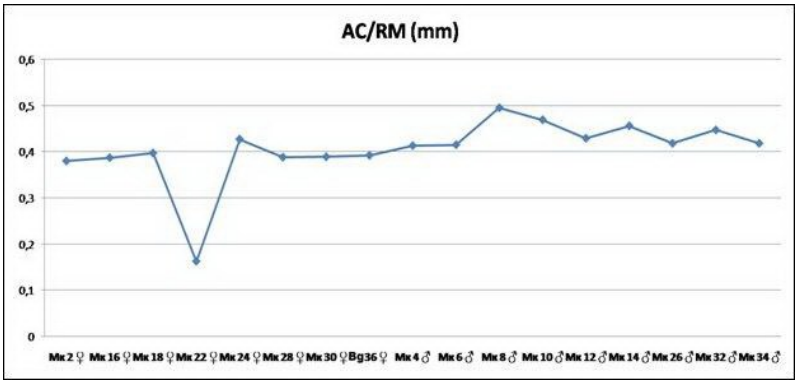

Figure 2. Correlation height of lower jaw - proc. angulare to proc. Coronoideus/length of lower jaw Incisive to proc. Angularis (AC/RM).

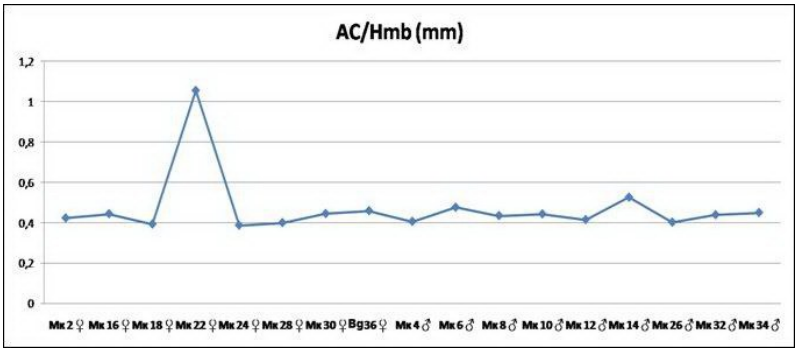

Figure 3. Correlation height of lower jaw - proc. angulare to proc. Coronoideus/height of lower jaw - under M_2 (AC/Hmb).

Table. 4: Metrical results of the teeth at brown bear (*Ursus arctos*). Used abbreviations: C sup. – upper canines; P^4 – fourth upper premolar; M^1 – first upper molar; M^2 – second upper molar; L – length; W - Width.

Specimen	*Ursus arctos* (mm)							
	C sup.		P^4		M^1		M^2	
	L	W	L	W	L	W	L	W
Мк 1	18.22	11.32	15.60	10.68	22.28	16.76	32.30	16.22
Мк 3	17.06	14.40	14.06	9.98	21.68	14.80	31.00	16.44
Мк 5	21.40	14.38	16.46	11.72	22.40	16.70	31.72	16.48
Мк 7	29.20	17.12	16.60	13.88	22.42	16.88	35.10	18.58
Мк 9	26.20	16.02	15.60	11.28	21.16	18.60	37.24	18.54
Мк 11	24.52	16,58	14.06	11.88	21.60	16.11	35.80	17.86
Мк 13	24.1	14.4	11.1	8.9	17.5	13.4	27.8	16.0
Мк 15	21.04	13.24	14.94	11.42	22.00	15.26	37.64	17.52
Мк 17	21.12	13.08	16.54	9.96	21.58	16.50	39.00	18.50
Мк 19	/	/	15.44	10.58	21.52	15.05	32.86	16.96
Мк 20	/	/	/	/	21.86	16.88	35.74	18.52
Мк 21	24.14	15.16	12.32	10.04	20.86	14.02	34.28	19.06
Мк 23	18.10	11.42	14.92	11.18	20.40	14.92	31.74	16.46
Мк 25	20.88	14.04	13.80	11.58	19.42	16.54	31.68	17.14
Мк 27	16.60	11.18	15.78	9.76	20.38	14.76	33.24	16.42
Мк 29	20.84	13.44	16.68	13.48	24.76	17.56	35.30	18.78
Мк 31	22.56	16.12	16.34	12.44	20.68	15.12	34.88	17.00
Мк 33	22.04	15.24	13.58	10.04	20.24	14.66	35.54	15.32
Bg35	19.54	12.48	15.08	12.44	22.32	12.62	21.68	10.18

The measurements present in Tab. 4, were used to test the settled hypothesis for male and female units according dimensions of upper canines. At the Tbls. 4 and 5 are listed measurements of upper and lower the teeth that will potentially allow to further set the taxonomic status of the researched species.

Table 5. Metrical results of teeth of brown bear (*Ursus arctos*). Used abbreviations: C inf. – lower canines; P^4 – fourth lower premolar; M^1 – first lower molar; M^2 – second lower molar; M^3 – third lower molar; L – length; W – Width.

Specimen	***Ursus arctos* (mm)**									
	C inf.		**P_4**		**M_1**		**M_2**		**M_3**	
	L	**W**	**L**	**W**	**L**	**W**	**L**	**W**	**L**	**W**
Мк 2	/	/	/	/	/	/	/	/	/	/
Мк 4	16.26	13.02	11.48	6.68	21.50	7.24	22.52	12.48	17.70	12.24
Мк 6	19.36	13.94	12.28	6.14	21.60	9.46	22.60	14.06	15.88	13.44
Мк 8	28.10	15.04	14.06	7.84	24.36	12.02	24.88	15.74	19.60	14.64
Мк 10	20.00	12.34	14.50	6.94	23.00	12.04	25.68	16.28	20.60	16.24
Мк 12	22.20	12.42	12.14	5.88	21.52	10.14	23/34	14.88	19.00	15.04
Мк 16	23.78	11.50	10.94	5.98	21.70	9.98	23.78	12.06	19.86	13.64
Мк 18	23.50	15.10	12.90	7.00	22.80	11.88	25.10	15.20	22.40	12.72
Мк 22	24.06	17.20	13.00	7.76	22.76	9.96	24.18	13.74	19.12	13.58
Мк 24	19.24	11.22	11.90	6.66	20.38	9.48	23.32	13.68	16.48	13.46
Мк 26	19.18	12.78	10.78	5.96	21.38	10.00	23.08	12.98	16.58	14.16
Мк 28	15.32	11.52	12.76	6.70	21.90	10.26	23.70	13.88	19.50	13.62
Мк 30	21.04	14.82	12.68	7.74	24.26	11.88	25.40	16.66	17.02	15.14
Мк 32	23.12	14.56	13.22	5.08	19.24	9.48	22.08	13.74	23.88	14.16
Мк 34	23.08	12.68	9.14	6.82	19.18	9.66	22.56	13.12	16.44	12.24
Bg 36	19.32	14.42	12.46	6.62	22.88	12.56	22.28	13.66	19.76	15.32

Table 6. Metrical results of skulls of brown bear (*Ursus arctos*). Used abbreviations: CC – Canine width; PA – Width of palatinum between M^2-M^2; PM – Length P^4-M^2; CP - Length C–P^4; CM - Length C-M^2; CCa - Internal width C-C; II – Length of incisive; FT/FV – Transversal and vertical width of foramen magnum; PP – Internal width P^4-P^4; OC - Distance of condyles occipitalis.

Ursus arctos **(mm)**											
Specimen	CC	PA	PM	CP	CM	CC a	II	FV	FT	PP	OC
Мк 1	56	39	69	57	111	31	37	20	34	38	63
Мк 3	62	42	62	60	111	36	36	/	/	40	/
Мк 5	61	41	67	61	113	34	33	18	28	40	66
Мк 7	77	44	73	71	127	44	/	/	/	48	/
Мк 9	72	49	74	70	129	42	43	26	35	49	70
Мк 11	71	50	69	67	124	42	43	27	31	45	66
Мk 13	66	39	56	51	102	39	38	23	28	42	61
Мк 15	62	44	73	67	127	39	41	25	31	45	64
Мк 17	68	44	77	63	127	34	40	22	31	41	69
Мк 19	/	49	69	/	/	/	/	/	/	47	/
Мк 20	/	/	/	/	/	/	/	26	34	/	71
Мк 21	63	42	74	64	119	36	40	19	33	41	61
Мк 23	57	37	64	51	105	33	37	18	30	34	58
Мк 25	63	41	65	61	115	37	37	28	31	40	/
Мк 27	57	37	68	51	105	35	36	19	31	33	60
Мк 29	67	42	74	55	114	35	36	/	/	33	/
Мк 31	77	53	81	73	126	43	45	23	30	47	67
Мк 33	72	48	74	57	123	42	39	22	33	46	67

Bg 35	69	43	71	61.5	122	40	41.5	21	31	43	65
SD	6.6	4.6	5.9	7.2	8.8	3.9	3.3	3.3	2.1	5	3.9

Table 7. Metrical results of skulls at brown bear (*Ursus arctos*). Used abbreviations: OO – Width of skull behind orbits; EC – Ectoorbital width; SP – Height between foramen magnum to sagittal crest; OT – Width between of bulla tympani; DN – Length of nasal bones; NN – Width of nasal bones.

***Ursus arctos* (mm)**										
Specimen	OO	EC	OO / EC	SP	OT	SP / OT	DN	NN	NN / DN	♂ / ♀
Мк 1	63	76	0.82	70	74	0.945	82	26	0.317	♀
Мк 15	71	92.5	0.76	83	136	0.61	80	31	0.387	♀
Мк 17	65	90	0.72	81	133	0.609	87	36	0.413	♀
Мк 19	69	99	0.69	80	130	0.615	/	/	/	♀
Мк 21	69	88	0.78	83	128	0.648	89	32	0.359	♀
Мк 23	65	62	1.04	66	110	0.6	65	29	0.446	♀
Мк 27	62	75	0.82	64	104	0.615	67	29	0.432	♀
Мк 29	70	78	0.89	84	115	0.73	71	22	0.309	♀
Bg 35	82	92.5	0.88	95	140	0.678	87	32	0.367	♀
Мк 3	72	97.5	0.73	71	132	0.537	84	32	0.38	♂
Мк 5	66	91.5	0.72	74	121	0.338	84	32	0.38	♂
Мк 7	71	109	0.65	100	131	0.496	55	38	0.69	♂
Мк 9	79	114	0.69	74	149	0.496	75	32	0.581	♂
Мк 11	73	111	0.65	96	170	0.564	91	36	0.395	♂
Мк 13	83	111	0.74	85	86	0.988	32	37	1.156	♂
Мк 20	68	122	0.55	106	165	0.642	/	/	/	♂
Мк 25	72	97	0.74	79	129	0.612	72	31	0,430	♂
Мк 31	84	126	0.66	100	181	0.552	99	41	0.414	♂
Мк 33	74	128	0.57	91	180	0.505	65	40	0.615	♂
SD	6.5	20.4	/	12.7	29.8	/	6.6	4.9	/	/

Table 8. Comparative metric analysis of *Ursus arctos* from Europe. Used abbreviations: TD – total length; KD - Condylobasal length; BD - Basal length; ZG – Zygomatic width; PA – Width of palatinum between M^2-M^2; OC - Distance of condyles occipitalis; EC – Ectoorbital width; CC – Canine width; RM – Length of lower jaw Incisive to proc. Angularis; AC – Height of lower jaw - proc. angulare to proc. coronoideus; Hma– Height of lower jaw - under P_4; CP - Length C–P^4; CPa - Length C–P_4; PM – Length P^4-M^2; PMa – Length P_4 и M_3; CM - Length C - M^2; CMa - Length C - M_3; OO – Width of skull behind orbits; PP – Internal width P^4-P^4; CCa - Internal width C-C; II – Length of incisive; FT/FV – Transversal and vertical width of foramen magnum; DN – Length of nasal bones; NN – Width of nasal bones; MC – Distance between mandibular condyles; CCb – External width C - C.

Specimen N°	**1**	**2**	**3**	**4**	**5**
Measure-ments (mm)	***Ursus arctos L.* From R. of N. Macedonia**	***Ursus arctos L.*, Couturier, (1954) - France**	***Ursus arctos L.*, Martino, (1939) - Serbia**	***Ursus arctos L.*, Heptner et al., (1967) - USSR**	***Ursus arctos* L., Ruskov and Markov (1974) - Bulgaria**
TD	252-380	141-351	/	311-455 m 275-397 f	277-350
KD	235-335	131-324	270	261-418 m 258-373 f	269-330
BD	222-321	119-304	/	/	252-310
ZG	143-232	87-217	179	175-277 m 147-217 f	166-214
PA	37-53	30-52			
OC	58-70	34-68			
EC	62-126	33-79			
CC	56-77	37-78			
RM	180-250	91-233	194		189-237
AC	36-117	/			
Hma	21-58	18-48			
CP	51-73	13-40			
CPa	51-81	14-39			
P^1 - M^2	72-101	81-95			
P_1- M_3	97-121	96-114			
PM	63-78	62-72			
PMa	67-86	69-82			
CM	105-129	96-120			
CMa	115-147	109-138			
OO	62-84	64-70			61-72
PP	33-49	31-51			
CCa	31-43	26-43			
FV	18-28	16-24			
FT	28-35	23-34			
NN	22-41	19-37	88		
MC	123-189	81-180			
II	33-45	23-46			
DN	55-100	35-91			66-85
CCb	36-55	25-45			

In Tabls. 6, 7 and 8 are presented measurements used for the comparative metric analysis of *Ursus arctos* from Republic of North Macedonia and Europe. Herein, is evident that the specimen number 4 has the largest dimensions, while specimen used in this study (specimen 1) has second larger dimensions and all the rest specimens 2, 3 and 5 has lower dimensions than our analyzed one.

Discussion

Morphologic features of the *Ursus arctos*

In the research itself, as part of the considered problem, the study of the morphology and dimensions of the teeth was imposed, which showed certain anatomical and phylogenetic characteristics of the species.

When analyzing the results of the skulls of the recent brown bear, we can conclude that a similar morphology has been recorded, especially in the wide-open zygomatic arcs and the presence of premolars as characteristics of the species *Ursus arctos* (Tab. 1). Presence of $P^{1,2,3}$ at examined skulls is a primitive feature, typical for the species. Baryshnikov et al. (2004) concluded that *U. arctos has* a number of archaic features which are closer to its ancestor. Deviations in the description, differences in the appearance and size of the skulls are related to sexual dimorphism, individual age and evolutionary development of bears indicate on clear heterogeneity in the skull size and cheek teeth dimensions (Baryshnikov et al., 2004a).

It is characteristic to amplify that there are dimensions that overlap in the examined specimens. From the measured values of the respective quantities and the calculated values for the standard deviation it can be concluded that it is small, but important to say that the measured values are close to the average value of the measurement (Tab. 2). Herein, it is evident that there are three skulls (Mk 23, Mk 27 and Mk 29) that make an outlier, i.e. significantly affect the calculations. As a conclusion about this skulls, we can say that they belong to younger individuals.

Sexual dimorphism of *Ursus arctos*

The sexual dimorphism is important from the aspect that its study can determine the sex of the studied individuals, which indicates a certain percentage or dominance within a population. The measured differences in the dimensions of certain skulls are result of the present sexual dimorphism in this family, so that the size values of a number of metric features are larger in the male individuals (Cregut et al., 2001). In the past and until last decade, determination of sexual dimorphism is based on external appearance such as development of ridges and measurements of the skull (Farkash et al., 2009). Also, the sexual dimorphism at examined units can be determinate according to development and metric size of the forehead (ectoorbital bone) (Spassov, pers. comm.). Obtained correlations (EC/TD and ZG/EC) enable the determination of sex with the studied recent individuals (Fig. 1).The growth of the curve is due to the fact that males have a higher ratio than females.

The results showed that out of the total 19 examined skulls, 10 belong to male, and 9 belong to female bears (Tbls. 2, 3). The finding of sexual dimorphism was also, confirmed by calculated ratios of the dimensions showed in Tab. 2. The ratios presented in graphs allow easier observation of the differences in dimensions between males and females of the species *Ursus arctos.*

Using the methods by Kurten (1955) and Baryshnikov et al. (2003, 2010) to determine sexual dimorphism at cave bears according to different dimensions of canines, the researched dimensions from the recent bears in the study for the upper canine enabled the establishment of the reported hypothesis for sex differentiation in the researched subjects.

When comparing the obtained results for determining the sexual dimorphism according to the dimensions of the canines in recent species, the following hypothesis was taken into consideration: if their width is greater than 14 mm, it belongs to a male, i.e. if it is less than 13 mm it is a female. The obtained results (Tab. 4) showed that 9 individuals were males and 8 females, which confirmed the hypothesis with 89% accuracy, since two skulls (Mk 19 and Mk 20) lack the front parts of the skull. For now, this statement will remain at the level of a hypothesis, since for its complete confirmation it is necessary to process at least 30 skulls.

Taxonomic status of researched species

This study also made it possible to determine the taxonomic status of the species, i.e. whether the bears living in the Republic of North Macedonia belongs to the typical *Ursus arctos arctos* and by what characteristics it differs from the other populations of brown bears living in Europe. According to Barishnikov (2007) and Mizumachi et al. (2020) brown bears from North West Europe and Balkan belong to typical *Ursus arctos arctos,* but the Balkan bears are very close to the South European population (especially to the Italian one) and differ from the bears from Central and North-

ern Europe. Mizumachi et al. (2020) amplify on the possibility that the Balkan Peninsula (Bulgaria) act as a corridor for coexisting of 2 clades.

For determining the examined species and whether belongs to the typical *Ursus arctos arctos*, was used the key of Gray (1825, in Gromova 1962), which is based on the morphology of the skull and the dimensions of the teeth. The expressed percentage of some findings is less than 100% due to small deviations in dimensions or the absence of the corresponding element in the units: (1) The profile of the skull is slightly concave, weakly expressed glabella which is 100% confirmed; (2) Nose opening is round with frame width and height 100% confirmed; (3) P^4 short without parastyl, confirmed with 90% accuracy; (4) M^1 is longer than its width confirmed with 100% accuracy; (5) M^2 is longer twice than its width confirmed with 90% accuracy; (6) The length of M^2 is less or not much less than $P^4 + M^1$ - the accuracy is 89%; (7) P_4 - the gable is narrow, its width not much more than half of the length - accuracy of 100%; (8) M_1 length almost similar to M_2 - 89% accuracy; (9) M_3 almost two times longer than P_4 - accuracy of 85%. The obtained results (Tbls. 1, 4, 5) for now confirm that the examined recent skulls belong to the typical *Ursus arctos arctos*. Metric results helped to determine the taxonomic status of the species and whether it belonged to the typical *Ursus arctos arctos*, using Gromova's (1962) determinant based on the morphology of the skull and the dimensions of the teeth.

Comparative results with other European studies of the recent bear (*Ursus arctos*)

When processing the results of the comparative analysis shown in Tabls. 6, 7 and 8 it can be concluded that the skulls from Republic of North Macedonia have larger dimensions compared to those from the Pyrenees (Couturier, 1954), and those researched from Martino (1939) from the Rugovski mountains and by Ruskov and Markov (1974) from Bulgaria. According to Heptner at al. (1967) bears in the territory of the former SSSR are the largest. On the other hand, differences can also be seen in proportions of the skulls at specimens which belong to Southern group of bears which in general are smaller than bears from former SSSR (Baryshnikov et al. 2004). From the results present in Tab. 8 it is noted that bears from territory of Republic of North Macedonia has decreased in skull size as indicated by Baryshnikov et al. (2004).

Conclusions

In summary, within this paper was concluded that male bears are with larger dimensions of the sculls in general. Observed sex dimorphism of the recent species was determined by the development of the ectorbital bone showed that out of a total of 19 examined skulls, 10 belong to male and 9 to female, respectively. The hypothesis for determining the sex dimorphism according to the dimensions of the canine teeth in recent bear has been confirmed with 89% accuracy, but due to insufficient number of researched units, the conclusion remains at the level of a hypothesis at the moment.

Determination of the taxonomic status of the recent brown bears compared with bears from North West Europe and Balkan belongs to typical *Ursus arctos arctos*. Being assumed that within the newest genetic studies from the territory of Bulgaria, act as a corridor were was confirmed that 2 bear clades coexist, we do not exclude the possibility that and in the territory of Republic of North Macedonia this could be a case. So, in further studies is highly recommend further research besides morphology features and the genetics too. The measured dimensions of bears in this research will make easier to see the differences in size, and that the geographical distribution and type of available food influence the development of *Ursus arctos*.

The analyzed material is relevant to study the morphological value of the skull features of *Ursus arctos* and to determine the metric variability, providing an opportunity to further compare the species of Ursidae family, amplifying on importance for certain findings from individual teeth morphology.

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