

Sexual Dimorphism and Sex-Ratio of Cave Bears from Križna jama (Slovenia)

by

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Zusammenfassung

Nicht nur an den Caninen sondern an fast allen Skelettelementen, die mit einer gewissen Häufigkeit überliefert worden sind, ist ein sexing möglich. Es ergab sich allgemein eine deutliche Dominanz der männlichen Tiere. Es hat sich gezeigt, dass die Möglichkeit der geschlechtsbedingten Clusterbildung vom Sexualdimorphismus-Index (sdi) abhängig ist. Im Vergleich zu anderen Höhlenbärenfaunen werden eventuelle Korrelationen zwischen Sexualdimorphismus, Sexratio, Höhenlage der Fundstellen und taxonomischer Zugehörigkeit diskutiert.

Schlüsselwörter: Sexing, sex-dimorphism-index, Dominanz der Männchen, Križna jama, Slowenien

Summary

Despite former assumptions that sexing is only possible with canines, it appears that nearly every skeletal element is usable for sexing, if only the number is big enough. In Križna jama there is a clearly visible dominance of male individuals. The possibility of sex-related clustering is depending on the sex-dimorphism-index (sdi). Possible correlations between sex-dimorphism, sex ratio, altitude of the site and taxonomic attribution are discussed by means of comparison with other cave bear faunas.

Keywords: Sexing, sex-dimorphism-index, dominance of males, Križna jama, Slovenia

Izvleček

Ne le podočniki (kanini), temveč skoraj vsi deli okostja, če so ohranjeni v večjem številu, so uporabni za ločevanje spolov. V Križni jami je opazna močna prevlada moških osebkov. Možnost razvrščanja v skupine (klastri), je odvisna od indeksov spolnega dimorfizma. Na podlagi primerjave podatkov iz različnih najdišč jamskega medveda, bomo razpravljali o možnih povezavah med spolnim dimorfizmom, razmerjem spolov, nadmorsko višino najdišča in taksonomsko pripadnostjo.

Ključne besede: razmerje spolov, indeks spolnega dimorfizma, prevlada samcev, Križna jama, Slovenija

1. Introduction

The sexing of cave bears faunas is based on the actualistic approach. It is assumed that – in analogy to the extant brown bear – the male cave bears were bigger than their female counterparts. This difference of sexes in respect of size is big enough, i.e. the biggest females are still smaller than the smallest males, so that there will form clusters when these data is used in a metric distribution, but only if there is sufficient material. The resulting clusters are interpreted as males and females. This theory is only true with the following two restrictions:

1. As it is based on the actualistic assumption, which can be found in the extant brown bear, it is only true for populations and not for the whole species because, for instance, female Grizzly bears (*Ursus arctos horribilis*) are bigger than males of the European brown bear (*Ursus arctos arctos*). When dealing with a fossil assemblage it must be reassured that the fossil remains belong to only one species and a defined evolutionary level.

2. This hypothesis is not true for all skeletal remains to the same extent. It was KURTÉN (1955) who found out that it is nearly impossible to sex a population of bears based on molars, whereas the best results (separation of two clusters) are obtained with canines. Kurtén assumed

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that the canines of cave bears were used as (show-)weapons during the rutting season.

In the following it will be investigated which skeletal elements allow for sexing and thus for an estimation of sex ratio and whether there is a difference of sexual dimorphism in teeth and bone. For this analysis only those skeletal elements with a number above 20 will be used. Two indices will be calculated to resolve this question: Firstly, the sex-index (RABEDER, 2001) will be used instead of the sex-ratio to avoid undefined results like, for instance, if there were only females it would lead to a sex-ratio equalling ∞ . Secondly, the sex dimorphism index (BARYSHNIKOV et al., 2003) will be used as an indicator for the divergence of sex-specific means.

Sex-index: Amount of females in percent of the total amount of a specific skeletal element.

Sex dimorphism-index: Mean of the male cluster divided by the mean of the female cluster times 100.

In mathematical expressions, with f – number of females, m – number of males, x_f – mean of female values and x_m – mean of male values, it reads like:

$$\text{Sex-index} = \frac{f \times 100}{f + m}$$

$$\text{Sex-ratio} = \frac{f}{m}$$

$$\text{Sex dimorphism-index} = \frac{x_m \times 100}{x_f}$$

2. Material

Most of the material dealt with herein originates from the excavation campaign carried out in 2001. The smaller part, but the majority of the metapodial bones, is from the excavations carried out in 1878 and 1879 under the direction of Ferdinand von Hochstetter, see HOCHSTETTER (1881).

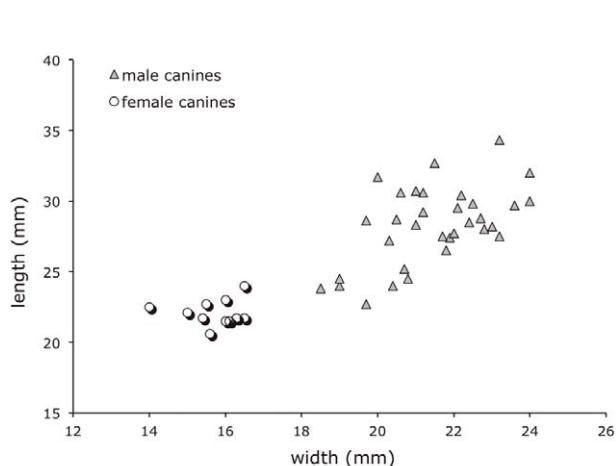


Figure 1: Scatter-plot of the canines from Križna jama (Slovenia).

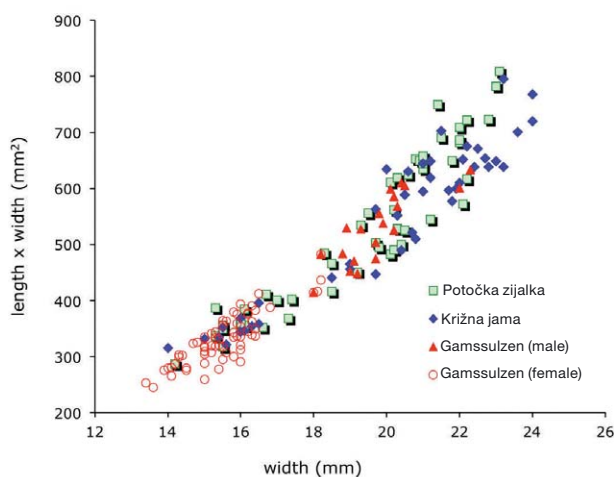


Figure 2: Sexing of cave bear canines from three different sites bearing remains from *Ursus ingressus*.

3. Sexing Based on Teeth and Metapodial Bones

3.1. Canines (Canini inferiores et superiores)

With the canines from Križna jama, a simple scatter-plot of crown width versus crown length results in two clearly separated clusters (see Fig. 1), which very likely represent the ratio of sexes. It must be noted that the crown-width proved to be a better factor for separating sexes than the crown-length. There were only 11 female canines opposed to 34 male canines, which leads to a sex-index equalling 24.44 and a sex-ratio of 0.32. The cave bear association from Križna jama was – at least in Kittl's Bärenhöhle – dominated by males, only a quarter of measurable canines were supposed to be female. A comparison with the canines from Potočka zijalka (Slovenia, see PACHER

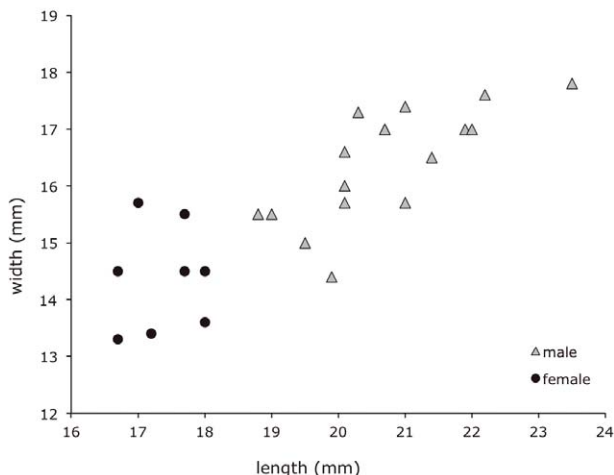


Figure 3: Sexing of the third upper incisors from Križna jama (Slovenia).

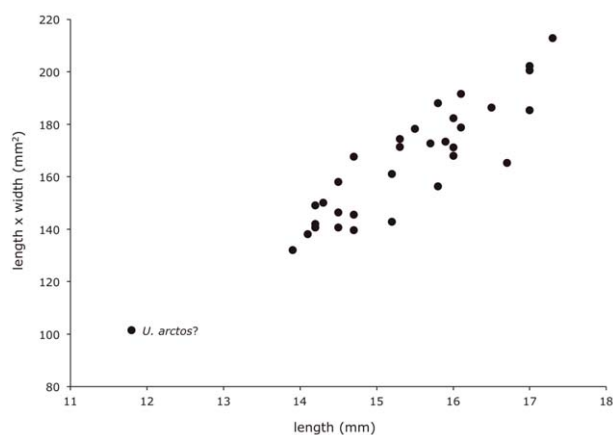


Figure 4: Scatter diagram of the lower fourth premolars from Križna jama.

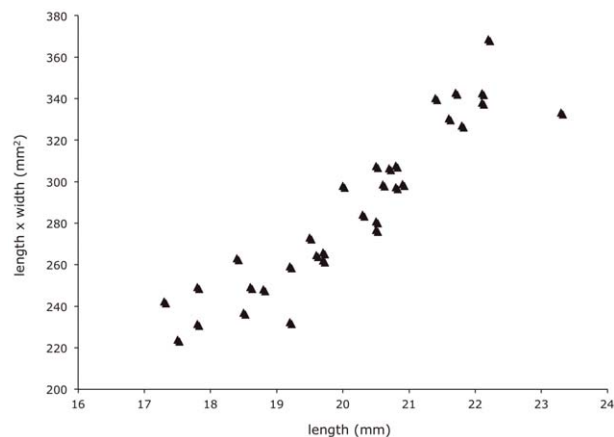


Figure 5: Scatter diagram of the upper fourth premolars from Križna jama.

et al., 2004) showed a convincing similarity between size distributions from these two cave bear sites, with only one difference: the separation of the clusters is more clear in Križna jama. A better separation can be achieved by applying the relation width to product length times width; unless this brings an improvement, some of the canines sexual attribution still remains enigmatic. Despite this fact, in Potočka zijalka there is a clear dominance of males too.

Opposed to the cave bear fauna from Gamssulzen cave (Upper Austria, see RABEDER, 1995), the reversed relation of sexes is striking: this fauna is clearly dominated by females. A comparison of the three aforementioned faunas enables us to do a better estimation of the real sex ratio in the Potočka fauna, see Tab. 1 and Fig. 2.

3.2. Third upper Incisor (I³)

Despite the fact that there are only 25 third upper incisors in the material from Križna jama, a clear separation can

be achieved when being put into a scatter-plot of length versus width. The sex-index equals 32.0 and the sex-ratio is 0.47 and is thus significantly higher than in canines. This result must not be overestimated, as the number of teeth is comparably low, see Fig. 3.

3.3. Premolars

Neither length nor width of the fourth premolars is suitable for a sexing. It is simply impossible to discover two clusters in the scatter-plots, which could represent the sex ratio. One of the fourth premolars is obviously out of the usual range because it is smaller, which could imply that it is from a brown bear, see Figs. 4+5.

3.4. Molars (Molares)

Based on common sense one would expect that molars are not suitable for sexing. Nevertheless it was interesting for

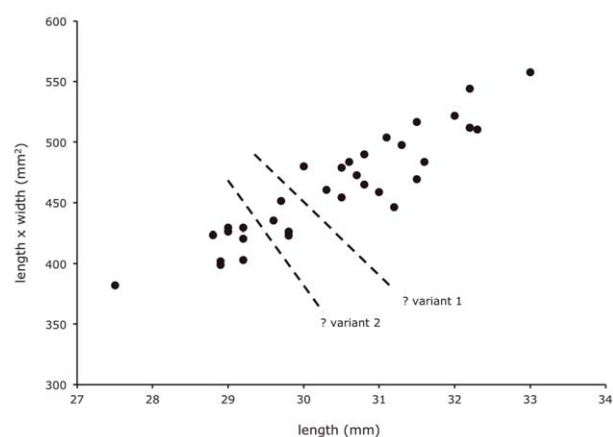


Figure 6: Scatter diagram of the lower first molars from Križna jama.

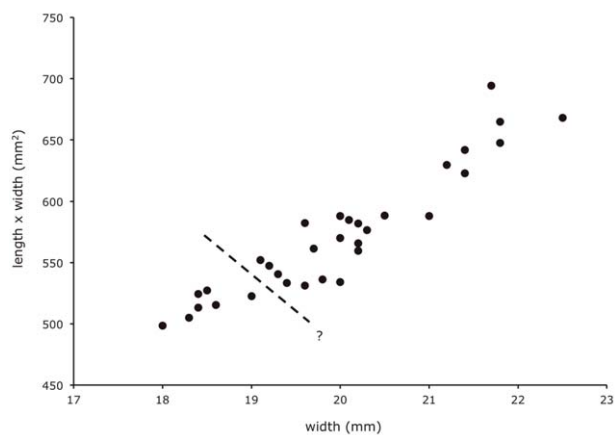


Figure 7: Scatter diagram of the upper first molars from Križna jama.

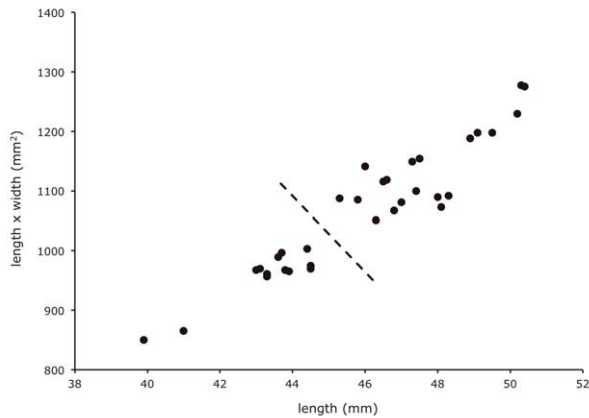


Figure 8: Sexing of the second upper molars from Křižna jama for means of comparison with the distribution from the Gamssulzen M^2 .

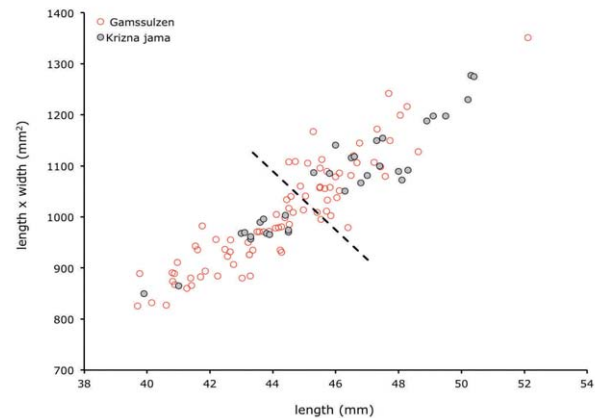


Figure 9: Sexing of the second upper molars from Křižna jama superimposed on the distribution from Gamssulzen cave.

us to test whether the pattern of distribution (sex index of about 25 %), which was found in the canines, will also be reproducible with molars or not.

3.4.1. First Upper Molars (M^1)

The distribution area of the upper first molars splits into three groups; the group with the smallest values is supposed to be female whereas the two others are supposedly male. The calculated sex index is approximately 22 %, which comes quite close to the value calculated from canines, see Fig. 7.

3.4.2. First Lower Molars (M_1)

The lower first molars show the same pattern of distribution as their upper counterparts, i.e. a splitting into three groups. There is also a very small tooth too, which appears to be from a brown bear. In the diagrams below there are two possibilities for the separation of the females: the first variant, with 13 females and a sex index of 37.14 % is the

more likely one, the second variant has only nine females and thus a sex index of 25.71 %. This is backed up by a comparison with the $m1$ -distribution from Gamssulzen

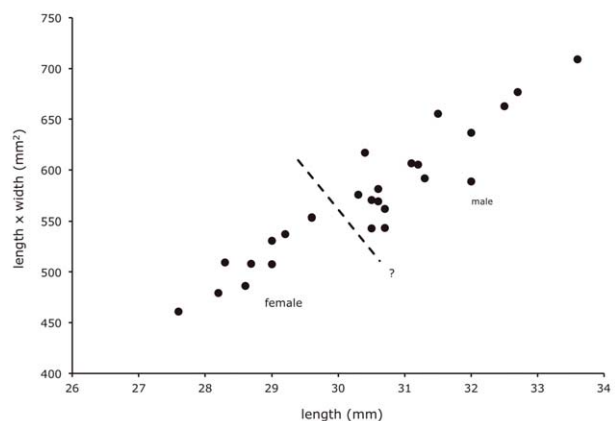


Figure 10: Sexing of the second lower molars from Křižna jama.

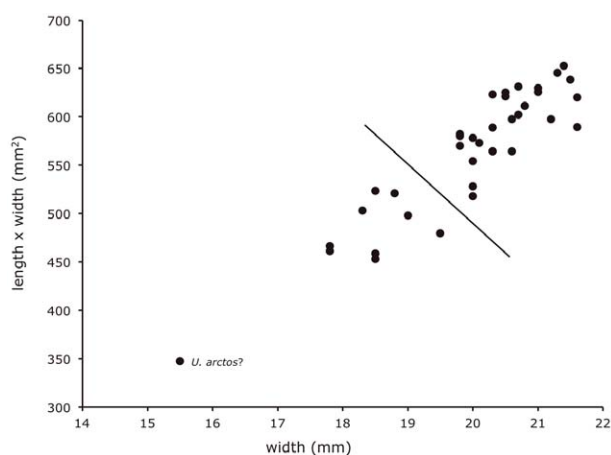


Figure 11: Sexing of the lower M_3 from Křižna jama.

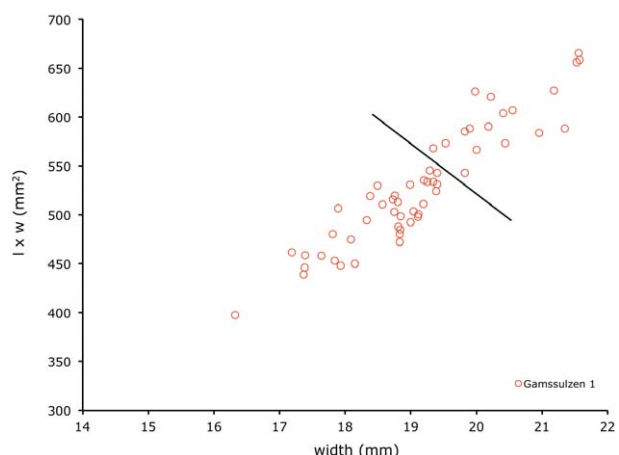


Figure 12: Sexing of the M_3 from Gamssulzen cave.

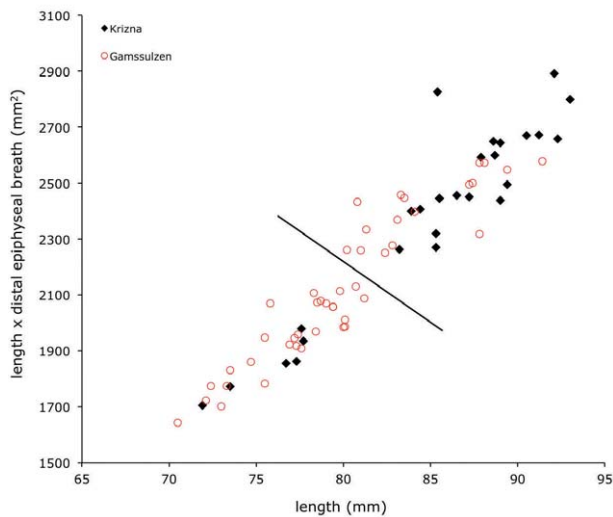


Figure 13: Sexing based on the third metacarpal bones from Krizna jama in comparison with the material from Gamssulzen cave.

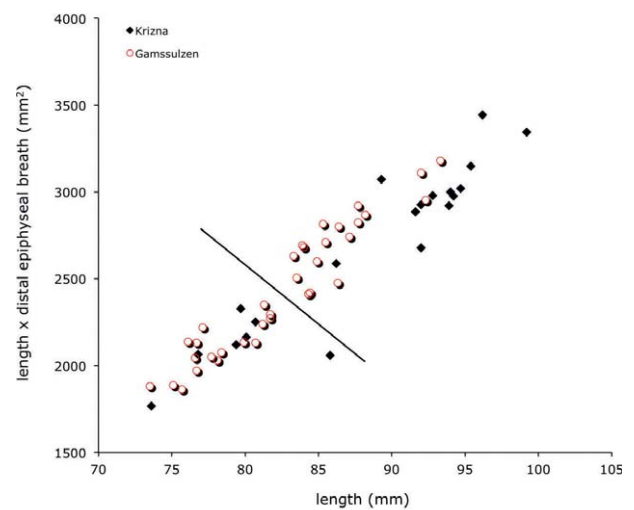


Figure 14: Sexing based on the fifth metacarpal bones from Krizna jama in comparison with the material from Gamssulzen cave.

cave. Also the negative outlier, which has a length of only 27.5 mm, is within the distribution area of the m1 from Gamssulzen cave, see Fig. 6.

3.4.3. Second Upper Molars (M^2)

It was astonishing to see that the distribution area splits into two clearly separated groups, which seem to represent males and females. There are two significantly smaller teeth, which cannot be attributed to *Ursus arctos*, but – instead of this – belong to *U. ingressus* as shown by a comparison with the M^2 -distribution from Gamssulzen cave. The sex index of the second upper molars from Krizna jama equals 39 % and thus supersedes the value calculated from the canines by far. For better illustration see Figs. 8+9.

3.4.4. Second Lower Molars (M_2)

Also the second lower molars seem to offer the possibility of sexing. The two appearing clusters could probably refer to males and females. The resulting sex index of 32 % is lower than that from the second upper molars, but is still higher than that from the canines, see Fig. 10.

3.4.5. Third Lower Molars (M_3)

In a scatter-plot, the values obtained from the third lower molars are segregating into two clearly separated groups, which show a dominance of males. The resulting sex index equals 25 % and is thus congruent with the value from the canines. The distribution area of the third lower molars from Gamssulzen cave shows two clearly separated groups

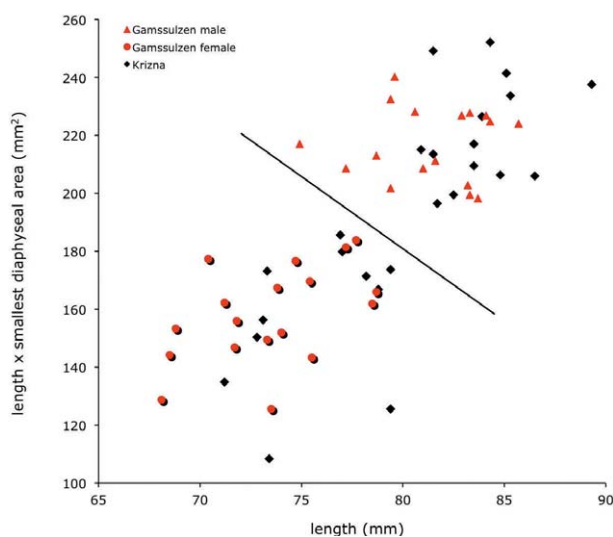


Figure 15: Sexing by means of the third metatarsal bones from Krizna jama in comparison to those from Gamssulzen cave.

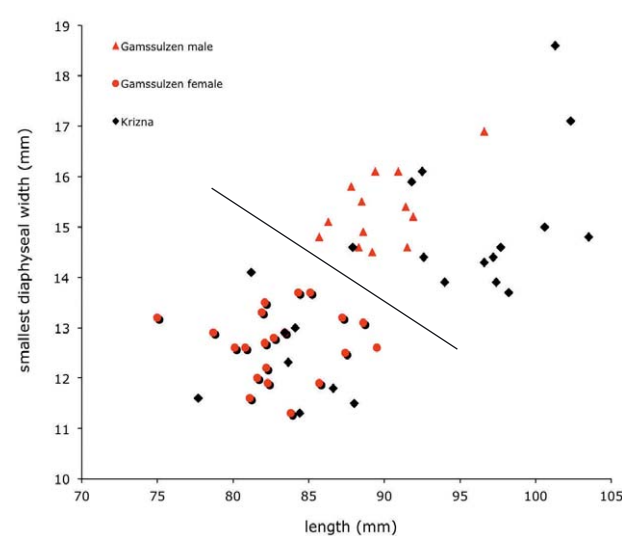


Figure 16: Sexing by means of the fifth metatarsal bones from Krizna jama in comparison to those from Gamssulzen cave.

Križna jama	Female	Male	n	Sex index	Sex dimorphism index		Sexing is
Element					Length	Width	
canini	11	33	44	25.00	129.88	135.75	distinct
I ³	7	18	25	28.00	114.91	117.14	distinct
P ⁴	—	—	32	—	—	—	not possible
P ₄	—	—	33	—	—	—	not possible
M ¹	7	25	32	21.88	103.07	110.53	doubtful
M ₁	13	22	35	37.14	106.84	106.70	doubtful
M ²	11	20	31	35.48	109.21	106.88	distinct
M ₂	8	17	25	32.00	109.13	109.17	distinct
M ₃	9	27	36	25.00	110.44	111.12	distinct
Mc3	6	21	27	22.22	115.86	118.52	distinct
Mc5	7	13	20	35.00	117.31	121.86	distinct
Mt3	9	15	24	37.50	111.58	117.46	distinct
Mt5	7	15	22	31.82	115.30	121.10	distinct

Table 1: Sex index and sex dimorphism index based on the analysis of teeth and metapodial bones from Križna jama.

with a dominance of the females (sex index = 75 %). In this distribution the length has greater influence than the width, see Figs. 11+12.

3.5. Metapodial Bones

In the material from Križna jama, there are only four metapodial elements which are sufficiently numerous to allow for a sexing: Mc3, Mc5, mt3 and mt5.

3.5.1. Metacarpals 3 and 5 (ossa metacarpalia III + V)

In a scatter diagram, the value pairs of the 3rd and 5th metacarpal bones are forming two clusters, which can be

interpreted as males and females – based on a comparison with the material from Gamssulzen cave. The sex index calculated from the 3rd metacarpal bones equals 22.2 % and comes close to the value obtained from the canines (25 %), despite the comparably low number of specimens. On the other hand, the sex index of the 5th metacarpal bones is much higher, see Fig. 13+14.

3.5.2. Metatarsals 3 and 5 (ossa metatarsalia III + V)

The third metatarsal bones are clearly separating and form thus two distinct groups. During a proof with the material from Gamssulzen cave it showed up that a clear separation was only possible with a scatter plot of length versus volume; i.e. length x diaphyseal area. The resulting sex index

Gamssulzen	Female	Male	n	Sex index	Sex dimorphism index		Sexing is
Element					Length	Width	
canini	61	22	83	73.49	127.81	125.13	distinct
I ³	35	15	50	70.00	112.74	126.57	distinct
P ⁴	—	—	124	—	—	—	not possible
P ₄	61	23	84	72.62	112.05	115.75	distinct
M ¹	63	30	93	67.74	108.34	107.57	doubtful
M ₁	—	—	76	—	no grouping		not possible
M ²	—	—	87	—	—	—	not possible
M ₂	—	—	151	—	—	—	not possible
M ₃	42	14	56	75.00	111.82	121.83	distinct
Mc3	28	17	45	62.22	108.28	113.49	doubtful
Mc5	20	20	40	50.00	111.25	117.58	distinct
Mt3	18	17	35	51.43	110.69	115.19	distinct
Mt5	21	12	33	63.64	107.71	113.80	distinct

Table 2: Sex index and sex dimorphism index based on the analysis of teeth and metapodial bones from Gamssulzen cave.

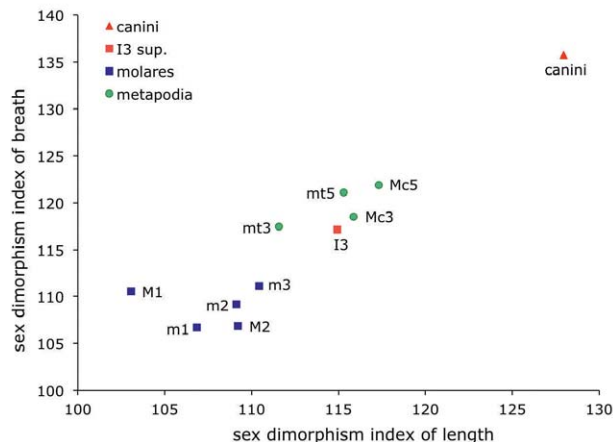


Figure 17: Sex dimorphism index of frequent skeletal elements (n > 20) from Križna jama.

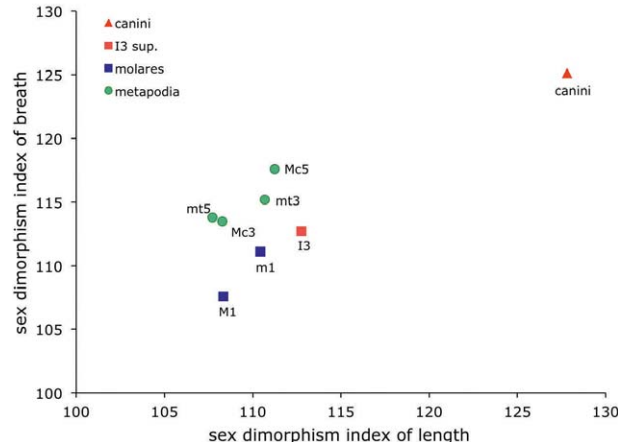


Figure 18: Sex dimorphism index of frequent skeletal elements (n > 20) from Gamssulzen cave.

equals 42.86 % and is thus by far higher than in any other skeletal element. Sexing by means of the fifth metatarsal bones is even easier than with the third metatarsals as they separate when being put into a scatter diagram of length versus diaphyseal width. From this results a sex index of 31.8 %, which comes closer to the value obtained from canines than that of the third metatarsals. The numerous big sized and slender metapodial bones from Križna jama are eye-catching, see Figs. 15+16.

4. Sex Index

4.1 Comparison of the Various Skeletal Elements

From the analysis of those skeletal elements with a number of n > 20 it can be deduced that a sexing is not equally reliable but strongly depends on the skeletal ele-

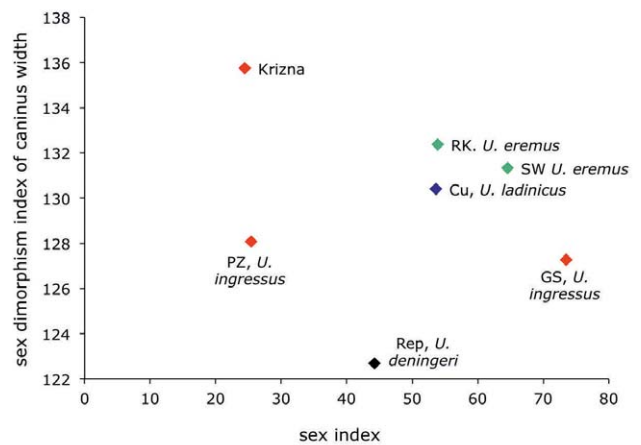


Figure 19: Sex-dimorphism of canines from different cave bear faunas and species.

ment in use. As the distributions show more or less clear separations for canines, incisors and even for metapodial bones, which can be interpreted as males and females, it

Cave	Canini		n	Sex-Index	Altitude	Means: female		Means: male		Sex dimorphism index		Species
	Female	Male				Length	Width	Length	Width	Length	Width	
Brieglersberg	22	7	29	75.86	1960	19.9	14.9	25.2	20.3	126.79	136.26	<i>ladinicus</i>
Conturines	52	45	97	53.61	2800	19.9	14.8	24.4	19.3	122.27	130.40	<i>ladinicus</i>
Gamssulzen	61	22	83	73.49	130	20.4	15.4	25.2	19.6	123.53	127.27	<i>ingressus</i>
Križna jama	11	34	45	24.44	670	22.1	15.7	28.7	21.3	129.88	135.75	<i>ingressus</i>
Potočka zijalka	16	47	63	25.40	1650	16.0	22.4	20.9	28.7	130.75	128.08	<i>ingressus</i>
Ramesch	82	72	154	53.25	1960	20.5	13.9	26.2	18.4	125.86	129.23	<i>eremus</i>
Schwabenreith	51	28	79	64.56	960	21.0	15.0	27.9	19.7	132.86	131.33	<i>eremus</i>
Repolust	23	29	52	44.23	525	18.5	14.1	23.3	17.3	125.95	122.70	<i>deningeri</i>

Table 3: Sex index and sex dimorphism index of canines along with the altitude of the sites.

is much more difficult or even impossible with molars. The assumption that this is correlated with sexual dimorphism is demonstrated in Figures 17 and 18. The sex related differences in size are expressed by means of the sex dimorphism index (sdi), refer to chapter 1. Introduction. The comparison with the indices obtained from the Gamssulzen material shows on one hand that there are striking differences in the possibility for sexing between the different bear faunas, and, on the other hand that there are also astonishing congruencies. This can be illustrated by the sexing of the third upper incisors and the third lower molars, which show identical sex indices.

Opposed to this, the results obtained from other teeth show strongly diverging distributions: either sexing is reliable, as in the second upper and lower molars from Križna jama and in the P_4 from Gamssulzen cave, or it is dubious as, for instance, in the first upper molars from both sites, or it is simply impossible as this is the case for the P^4 and M^2 and the M_1 and M_2 from Gamssulzen fauna and the upper and lower P_4 from Križna jama. On the other hand, sexing based on metapodial bones seems to be possible in most of the cases, but the sex index shows deviations from up to 25 % from the value obtained from canines. **Due to this fact, it should be avoided to calculate the sex ratio based on metapodial bones only!**

5. Sex Dimorphism Index

The sex dimorphism index can be calculated from every skeletal element that allows for sexing and thus for a calculation of the sex index. From Table 1 and 2 as well as from Figure 17 it is evident, that various skeletal elements show various results.

As already known and thus supposed, the canines show the by far biggest sex-related differences in size. The metapodial bones and the third upper incisors form a group of intermediate usability, whereas the molars have the smallest differences in size. This is at least true for the faunal remains from Križna jama and Gamssulzen cave, see Table 3.

Comparison with Alpine Cave Bear Faunas

In comparison with other alpine cave bear faunas it shows up that the sex dimorphism index of canines is neither correlated with the taxonomic attribution nor with the altitude of the bear site, but it is correlated with the sex index. The bears from Križna jama have unusual big sized canines, a feature which makes them unique amongst other bear faunas. This is especially true for the width

of the canines when measured at the base of the crown, showing a mean that is more than 35 % above the mean of the female canines.

6. Conclusions

- The cave bear fauna from Križna jama is dominated by males: only a quarter of the thanatocoenosis was female. The domination of males is also visible in the distribution from other skeletal elements, even if the sex-index values strongly vary.
- Sexing based solely on metapodial bones or molars could easily produce wrong results.
- Sex dimorphism index shows the best results with canines and the worst with molars; metapodial bones and incisors are in between.
- The possibility of correct sexing increases with sex dimorphism index and is thus best with canines and worst with molars.
- Sex index and sex dimorphism index show no obvious correlation.
- It is very likely that the sex dimorphism index is neither correlated with the altitude of the site nor with the taxonomic attribution of the bears.

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