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Biometrical Analysis of Postcranial Elements of Fossil Ursids from Einhornhöhle, Germany

Zusammenfassung:

Ziel der in einem Poster präsentierten Untersuchung an Stylopodium, Zygopodium und Metapodium von *Ursus deningeri* und *Ursus spelaeus* ist die Benennung weiterer arttypischer Merkmale, mit denen die beiden Spezies gegeneinander abgegrenzt werden können. Ein weiteres Ziel besteht darin, das Fundmaterial aus der Einhornhöhle/BRD einer der beiden Arten zuzuordnen. Wie sich hier zeigt, liegt das Datenmaterial Einhornhöhle im Überschneidungsbereich zwischen *Ursus deningeri* und *Ursus spelaeus*.

Abstract:

A detailed study, which has been carried out on long bones and metapodia of *Ursus deningeri* and *Ursus spelaeus,* will be presented in this poster. One aim of this project is to make a distinction between these two species using further clear distinctive marks. A further aim is to classify the finds of fossil ursids from Einhornhöhle/FRG as belonging to one of the two species. It will be demonstrated that the material from Einhornhöhle shows characteristics of both species, which implies an intermediate state between *Ursus deningeri* and *Ursus spelaeus*.

Résumé:

Le but de cette étude des stylopodium, zygopodium et métapodium d'*Ursus deningeri* et d'*Ursus spelaeus* est l'identification de caractéristiques discriminatoires supplémentaires permettant de différentier clairement les deux espèces. Un autre but est d'attribuer le matériel en provenance de la Grotte de la Licorne (Einhornhöhle, Allemagne) à l'une des deux espèces. Il s'est avéré que les mensurations du matériel de la Grotte de la Licorne se situent dans la zone de recoupement entre *Ursus deningeri* et *Ursus spelaeus*.

Key words: long bones, metapodia, *Ursus deningeri*, *Ursus spelaeus*, Einhornhöhle/FRG

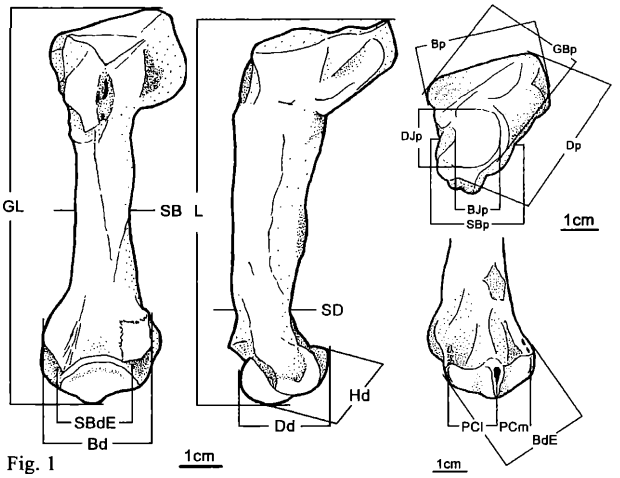

Fig. 1

Fig. 1: Metacarpalia I (Mc I), 15 measurements, GL (greatest length), SB (smallest breadth of diaphysis), SD (depth of diaphysis), GBp (greatest breadth proximal), SBp (smallest breadth of proximal epiphysis), Dp (depth proximal i.e. thickness of epiphysis), Bd (greatest breadth distal), Dd (greatest depth of distal epiphysis), SBdE (smallest breadth of epicondyls), BdE (greatest breadth of distal epiphysis), Hd (distal height from middle of epiphysis to highest point of joint), BJp (greatest breadth of proximal joint facet), DJp (greatest depth of proximal joint facet), PCm (position of distal joint facet, distance between joint facet and medial margin), PCl (position of distal joint facet, distance between joint facet and lateral margin). All measurements were taken from: DUERST (1926), VON DEN DRIESCH (1976) and GRANDAL D'ANGLADE (1993).

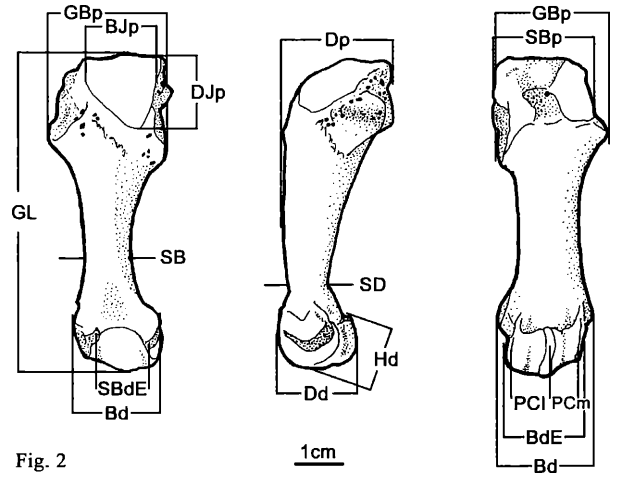

Fig. 2

Fig. 2: Metatarsalia V (Mt V), 15 measurements, same as Mc I.

Introduction

At present it is assumed that the evolution of cave bears took the course from *Ursus deningeri* to *Ursus spelaeus*. One aim of this detailed study on long bones and metapodia is to make a distinction between these two species. Therefore, 249 measurements (DUERST 1926; VON DEN DRIESCH 1976; GRANDAL D'ANGLADE 1993) on 16 different skeletal elements (humerus, ulna, radius, metacarpals I-V, femur, tibia, fibula, metatarsals I-V; Fig. 1, Fig. 2) of 2890 specimens of exclusively adult individuals have been selected for this study. The samples originated from the sites (Fig. 3): Deutsch-Altenburg/Lower Austria (DA), Hundsheim/Lower Austria (HH) and Repolusthöhle/ Styria (RH) in Austria; Goyet/ Condroz/Ardennes (Goy) in Belgium; Château/Saône-et-Loire (CHA) in France; Einhornhöhle/ Scharzfeld/Harz (EHH), Erpfingen/ Swabian Alb (Erpf), Mosbach-Sande close to Wiesbaden (MS) and Zoolithenhöhle/Franconian Alb (ZHSp) in Germany; Bacton/Norfolk (Bac), Banwell Bone Cave/Somerset (Ban) and Westbury-sub-Mendip/ Somerset (WSM) in the United Kingdom. The data sets have been statistically analysed using univariate and multivariate tests like the *t*-test and Welch-*t*-test, and discriminant analysis in the programs SPSS and SAS in order to divide the two groups significantly. The second aim of this study is to classify the finds of fossil ursids from the Einhornhöhle (EHH) as belonging to one of the two species. The project was financially supported by the German Society of Research (DFG).

A Brief History of Einhornhöhle

The most EHH bear bone finds stemmed from old excavations of the years 1881 to 1907. This material was declared by RODE (1935) to belong to the sub-species *Ursus spelaeus* var. *hercynica*, whereas SCHÜTT (1968) classified this material as belonging to the species *Ursus deningeri*. Further excavations followed between 1985 and 1988. NIELBOCK (1987) classified his finds as belonging to the species *Ursus spelaeus*. Datings of bone samples did not lead to any reliable results (ROSENDAHL et al. 2005). Alone a charcoal sample from the Jacob-Friesen-Gang in the Einhornhöhle pointed to an age of the underlying bone layers as being older than 42,500 years.

Statistical Analysis: *t*-Test Results

The aim of the *t*-test (also the Welch-*t*-test in some cases) on 2980 specimens was to track down differences between the fossil bear species *Ursus deningeri* and *Ursus spelaeus*. Requirements were met by forty-two variables, whose values followed an approximately Gaussian distribution in both groups. The EHH finds were left out of these tests for the time being. Significant differences were detected in the case of 36 of the 42 variables. (Table 1. Abbreviations cf. Fig. 1, Fig. 2).

Statistical Analysis: Discriminant Analysis Results

From altogether 602 EHH finds, 272 were classified as *deningeri (Ud)* and 236 as *spelaeus (Us)*, specimen by specimen, using discriminant analysis. Ninety-four specimens could not be classified. Out of 38 significant results

Fig. 3: Map with abbreviations for selected fossil sites; *Ursus deningeri* (black), *Ursus spelaeus* (red), classification case (blue).

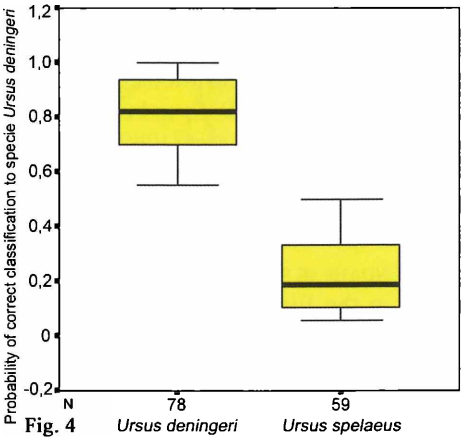

Fig. 4: Probability of correct classification to species *Ursus deningeri*. Skeletal element Mc I, variables GL, SB, SD, GBp, Bd, SBdE.

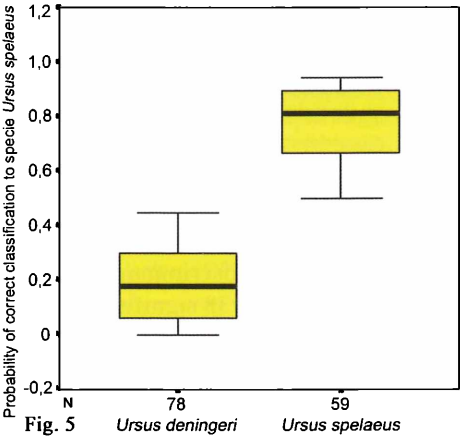

Fig. 5: Probability of correct classification to species *Ursus spelaeus*. Skeletal element Mc I, variables GL, SB, SD, GBp, Bd, SBdE.

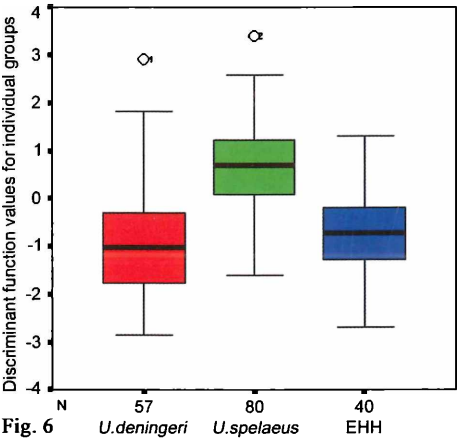

Fig. 6: Discriminant function values for individual groups, *Ursus deningeri*, *Ursus spelaeus* and the EHH collection, depicted as box plots. Skeletal element Mc I, variables GL, SB, SD, GBp, Bd, SBdE.

in all, only 19 of high quality are cited in the Table 2. The EHH finds were in 11 cases assigned to *Ursus deningeri (Ud)* and in 7 cases to *Ursus spelaeus (Us)* (italicized numbers). Only in one case could EHH material not be explicitly classified (ranged right). With all 38 results the ratio actually came to 25 *Ud* : 12 *Us* : 1 indeterminate case (Fig. 4, Fig. 5 and Fig. 6 show the probability of correct classification to one or other of the species on the basis of an example).

Conclusions

The results showed that the breadth and thickness of the diaphysis, in the limb bones, was for the most part significantly different i.e. the skeleton of the typical cave bear *Ursus spelaeus* appeared to be bulkier, than that of *Ursus deningeri*. The weight-bearing elements were reinforced, in particular the front extremities. At present one proceeds on the assumption that bear evolution went from a tree dwelling ancestor to *Ursus etruscus* to *Ursus deningeri*, and on to the purely ground dwelling *Ursus spelaeus*, roaming over long distances, which used its front paws to dig for food, e. g. roots (Thenius 1945). Also in keeping with this adaptation to 'economic locomotion' are the dental findings, from which it can be seen that

Ursus spelaeus was almost exclusively herbivorous, as opposed to the omnivorous species *Ursus arctos* and *Ursus deningeri*, and it attained bigger bodily proportions.

EHH data in this investigation show the EHH finds to lie in an intermediate area between the two species, with predominant indications favouring membership of the species *Ursus deningeri*. There now ensue the following interpretation possibilities: Either this bear group was at a stage of development of high evolutionary level in the case of *deningeri* membership. This version speaks for a high geological age of the finds. The geological age though is not yet conclusively settled. Or the finds indicate an endemic living form with original 'old' characteristics, which coexisted contemporaneous with *Ursus spelaeus*. On the other hand the coherences expounded here still also allow of the interpretation, that it could be a question of a low evolutionary level in the case of *spelaeus* membership.

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Species	N	mean value	sd	bone / variable	test	teststatistics	df	*p*-value in SPSS	raw *p*-value in SAS	adjusted *p*-value, Bonferroni	adjusted *p*-value, Holm
U. deningeri	41	34.4034	3.8308	Ulna / ltroch	*t*	-9.225	104	0.000	0.000000	0.000000	0.000000
U. spelaeus	65	41.2137	3.61856								
U. deningeri	50	15.687	1.6237	Mc I / Dd	*t*	-6.771	113	0.000	0.000000	0.000000	0.000000
U. spelaeus	65	17.5595	1.34091								
U. deningeri	47	7.856	0.9609	Mc I / PCm	*t*	-7.772	93	0.000	0.000000	0.000000	0.000000
U. spelaeus	48	9.334	0.8928								
U. deningeri	65	16.6931	1.85673	Mc II / SBp	*t*	-7.848	150	0.000	0.000000	0.000000	0.000000
U. spelaeus	87	18.9857	1.72399								
U. deningeri	34	9.3532	0.96931	Mc III / PCm	*t*	-8.069	81	0.000	0.000000	0.000000	0.000000
U. spelaeus	49	10.9355	0.81027								
U. deningeri	57	9.126	1.05506	Mc IV / PCm	*t*	-10.391	112	0.000	0.000000	0.000000	0.000000
U. spelaeus	57	10.9714	0.82748								
U. deningeri	48	10.0825	1.10413	Mc V / PCm	*t*	-9.548	98	0.000	0.000000	0.000000	0.000000
U. spelaeus	52	12.265	1.17577								
U. deningeri	36	44.04	4.89836	Tibia / BDd	*t*	-6.725	112	0.000	0.000000	0.000000	0.000000
U. spelaeus	78	50.7033	4.926								
U. deningeri	41	17.0927	2.25295	Mt I / DJp	*t*	-6.864	89	0.000	0.000000	0.000000	0.000000
U. spelaeus	50	20.0176	1.81309								
U. deningeri	49	18.8245	2.15236	Mt II / Bd	*t*	-6.924	136	0.000	0.000000	0.000000	0.000000
U. spelaeus	89	21.1825	1.77142								
U. deningeri	24	15.5663	1.79731	Mt V / SBdE	*t*	-6.635	96	0.000	0.000000	0.000000	0.000000
U. spelaeus	74	17.8915	1.38158								
U. deningeri	14	341.132	14.529	Humerus / GL	Welch-*t*	-6.959	44.547	0.000	0.000000	0.000000	0.000000
U. spelaeus	35	384.88	29.247								
U. deningeri	45	9.246	0.96034	Mc II / PCm	Welch-*t*	-8.240	82.262	0.000	0.000000	0.000000	0.000000
U. spelaeus	57	10.6867	0.75769								
U. deningeri	25	24.4152	2.57307	Femur / Dp	Welch-*t*	-8.774	52.120	0.000	0.000000	0.000000	0.000000
U. spelaeus	60	30.0677	3.00177								
U. deningeri	29	7.7938	0.87635	Mt III / PCl	*t*	-6.034	77	0.000	0.000000	0.000000	0.000001
U. spelaeus	50	8.8522	0.66973								
U. deningeri	17	58.5712	4.73891	Femur / HCl	*t*	-6.030	60	0.000	0.000000	0.000000	0.000002
U. spelaeus	45	67.3187	5.2196								
U. deningeri	53	10.5532	1.57019	Mt II / BJp	*t*	-5.707	130	0.000	0.000000	0.000000	0.000002
U. spelaeus	79	12.0023	1.3282								
U. deningeri	31	36.339	3.1577	Humerus / SB	Welch-*t*	-5.877	81.343	0.000	0.000000	0.000000	0.000002
U. spelaeus	57	41.2386	4.6125								
U. deningeri	18	10.41	1.139	Mt V / PCl	*t*	-5.683	61	0.000	0.000000	0.00001	0.000008
U. spelaeus	45	12.04	0.98								
U. deningeri	40	23.3503	3.04179	Mt III / DJp	*t*	-5.286	89	0.000	0.000001	0.00003	0.000016
U. spelaeus	51	26.3698	2.40958								
U. deningeri	52	14.1325	1.64834	Mt I / Dd	Welch-*t*	-5.262	89.848	0.000	0.000001	0.00004	0.000016
U. spelaeus	52	15.5869	1.12069								
U. deningeri	48	18.4	1.601	Mc II / Dd	*t*	-5.022	108	0.000	0.000002	0.00008	0.000033
U. spelaeus	62	19.81	1.352								
U. deningeri	41	6.999	0.8691	Mt I / PCl	*t*	-5.083	80	0.000	0.000002	0.00009	0.000036
U. spelaeus	41	7.869	0.6688								
U. deningeri	38	8.2376	0.86124	Mt II / PCm	*t*	-4.966	88	0.000	0.000003	0.00012	0.000047
U. spelaeus	52	9.0923	0.76431								

U. deningeri	27	37.5289	4.578	Femur / BColl	*t*	-4.921	80	0.000	0.000005	0.00017	0.000059
U. spelaeus	55	42.0502	3.,54374								
U. deningeri	42	7.6624	0.98626	Mt I / PCm	Welch-*t*	-4.777	68.347	0.000	0.000010	0.00036	0.000118
U. spelaeus	34	8.5332	0.58507								
U. deningeri	46	15.0839	1.82337	Mt I / BdE	Welch-*t*	-4.596	78.428	0.000	0.000016	0.00060	0.000178
U. spelaeus	38	16.6108	1.20279								
U. deningeri	47	79.41	8.22384	Mt IV / GL	Welch-*t*	-4.233	73.616	0.000	0.000066	0.00243	0.000657
U. spelaeus	81	85.1923	5.88024								
U. deningeri	21	27.4895	3.3374	Femur / Col	*t*	-4.204	71	0.000	0.000075	0.00279	0.000677
U. spelaeus	52	31.569	3.90447								
U. deningeri	43	22.0156	2.60166	Mt IV / DJp	*t*	-4.122	91	0.000	0.000083	0.00306	0.000677
U. spelaeus	50	24.2802	2.67509								
U. deningeri	22	21.1518	3.16086	Femur / Pfov	*t*	-4.097	59	0.000	0.000129	0.00479	0.000906
U. spelaeus	39	24.1672	2.51141								
U. deningeri	40	24.4212	3.39127	Mt V / GBp	Welch-*t*	-3.777	56.798	0.000	0.000382	0.01414	0.002293
U. spelaeus	69	26.6622	2.10824								
U. deningeri	57	9.7065	1.16386	Mt II / SD	*t*	-3.502	149	0.001	0.000610	0.02256	0.003048
U. spelaeus	94	10.3366	1.01208								
U. deningeri	43	12.534	1.42048	Mt I / BJp	*t*	-2.435	79	0.017	0.017146	0.63440	0.068584
U. spelaeus	38	13.2713	1.2879								
U. deningeri	53	12.4896	1.52618	Mc I / BJp	*t*	-2.332	104	0.022	0.021628	0.80024	0.068584
U. spelaeus	53	13.1515	1.39305								
U. deningeri	64	9.3148	1.01049	Mc I / SD	*t*	-2.235	150	0.027	0.026895	0.99512	0.068584
U. spelaeus	88	9.6624	0.8972								

Tab. 1: Table with Results of *t*-test, Welch-*t*-test, respectively.

Tab. 2:
Table with list of classification results of finds from Einhornhöhle, Harz/FRG (EHH). Out of 38 significant results in all, only of high quality are cited in this table.

Species	N	bone / variables	results of the probability of correct classification in %	classification of EHH to	
				Ud	*Us*
U. deningeri	46	Mt V / SB, SD, SBdE	92,7		
U. spelaeus	83				
EHH	43			*16*	*23*
U. deningeri	64	Ulna / BPcii, DPanc	91,5		
U. spelaeus	80				
EHH	33			7	3
U. deningeri	75	Mc I / SD, BdE	85,6		
U. spelaeus	90				
EHH	42			20	8
U. deningeri	70	Mt IV / GBp, PCm	85,4		
U. spelaeus	94				
EHH	41			14	9
U. deningeri	80	Mc V / GL, SB, SD, GBp, Bp, BJp, Dp, Bd, Hd, SBdE	85,0		
U. spelaeus	97				
EHH	34			*10*	*23*
U. deningeri	70	Mc II / GL, SB, SD, GBp, Bd, SBdE	84,7		
U. spelaeus	97				
EHH	43			25	15
U. deningeri	70	Mc IV / GL, SB, SD, GBp, SBp, Dp_II, BJp, Bd, SBdE	82,9		
U. spelaeus	94				
EHH	41			*14*	*18*
U. deningeri	49	Radius / D, DColl, Bd	82,9		
U. spelaeus	83				
EHH	26			4	1
U. deningeri	75	Mc I / GL, SB, SD, GBp, Bd, SBdE	81,8		
U. spelaeus	90				
EHH	42			26	14
U. deningeri	80	Mc V / GL, SB, SD	80,7		
U. spelaeus	97				
EHH	34			*9*	*24*
U. deningeri	47	Tibia / SB, SD, BDd, Bd, Dd, BJd, DJd	79,8		
U. spelaeus	87				
EHH	39			*10*	*20*
U. deningeri	70	Mt IV / GL, SB, SD, Bd, SBdE	79,3		
U. spelaeus	94				
EHH	41			*7*	*34*
U. deningeri	69	Mc III / SB, SD, Bd	79,1		
U. spelaeus	97				
EHH	42			28	7
U. deningeri	65	Mt II / Dd, PCm	78,6		
U. spelaeus	96				
EHH	36			15	4
U. deningeri	65	Mt II / SBp, DJp	76,9		
U. spelaeus	96				
EHH	36			15	1
U. deningeri	38	Humerus / SB, BT, MT, LT, Bd, HO, BCse	75,0		
U. spelaeus	63				
EHH	25			14	3
U. deningeri	38	Humerus / SB, BT, MT, LT, Bd	75,0		
U. spelaeus	63				
EHH	25			15	2
U. deningeri	80	Mt III / GL, SB, SD, GBp, SBp, Dp, BJp, DJp, Bd, Dd, Hd, BdE, SBdE	74,7		
U. spelaeus	104				
EHH	64			20	20
U. deningeri	64	Ulna / B, D, GDO, DPanc, BpPcor, OPcor, BPcor, BPcii, Bd, Dd, Bpsty, Dpsty	74,3		
U. spelaeus	80				
EHH	33			*3*	*7*