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A Holocene bat fauna from the Eifel Mountains, Germany

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Abstract. The analysis of a Pleistocene-Holocene faunal assemblage from a cave sediment in the Eifel Mountains (Western Germany) yielded cranial remains of 2,632 bats (MNI). Seventeen species are represented, most of which occur in the region today. More than 88% are *Myotis bechsteinii*, *M. nattereri*, and *M. mystacinus*. The cranial dimensions of *M. bechsteinii* are larger than in extant populations and approach those of *M. b. intermedius* Rybář, 1978. A comparison with AMS dated samples from the Holocene of Poland (Stanik & Woloszyn 2011) suggests the age of this bat assemblage to be approximately 6000 BP, corresponding to the onset of the Neolithic culture in Central Europe.

Cave fauna, Holocene, *Myotis bechsteinii*, size variation, Chiroptera

Introduction

Accumulations of bones in caves are a valuable source of information on the past occurrence of bats and other small vertebrates. Suitable cave sites, however, are not common and found mostly in mountain areas with a higher density of karstic fissures and other natural caves. Larger Holocene bat assemblages from such cave sites have been described from Austria (Bauer 1987, Rabeder 1973), Czech Republic, Germany, Hungary, Slovakia (Schaefer 1973, 1974, Horáček 1976, Obuch 1995), France (Mein 1975), Poland (Woloszyn 1970, Piksa & Woloszyn 2001) and Spain (Sevilla 1987).

Data on Holocene bat faunas from Germany are still scarce, and almost absent from the Eifel Mts., a mid-elevation mountain range in W Germany (Hutterer & Koenigswald 1993). Here we document, for the first time, a new fossil site from this region with a rich vertebrate fauna dominated by bats. The aim of this study is to describe this bat assemblage and to discuss the possible age of the deposit.

Material and Methods

The osteological material used for this report is deposited in collections of the Zoologisches Forschungsmuseum Alexander Koenig in Bonn (= ZFMK). It was collected by members of the "Höhlen und Karstforschungsgruppe Nordrhein" (Laumanns 1996) in a karstic cave called "Höhle am Kalkwerk" (= cave at limestone quarry, further referred to as: Eifel cave) from May to July 1985. The cave was discovered by W. Geucke in 1984. It is located in the Eifel Mountains in western Germany near Nettersheim-Roderath (50° 30' N, 06° 43' E), at 450 m a.s.l. The cave opens with a 0.5 m wide entrance into 27 m of karstic fissures. About 3.7 m below the surface, a 15 cm thick layer of soil enriched with bones was found and partly excavated. A larger amount of cave sediment was screen-washed, sorted and tentatively identified in the laboratory of Jochen Niethammer (1935–1998) at the Zoological Institute Bonn in 1985. Another 6 kg of cave sediments were screen-washed in the Museum Koenig in 2002, and all specimens were then sorted, counted and identified. Counts were expressed by the minimum number of individuals (= MNI). The identification of fragments was performed by comparison with extant skulls in the ZFMK collections, and by identification keys such as Jenrich et al. (2012).

The bones of *Myotis bechsteinii* were used for preliminary dating of the fossil assemblage. Based on the results of Rybář (1976) and Stanik & Woloszyn (2011), several cranial measurements were taken and compared with data taken from the literature. Due to the fragmented condition of the material we focused on dental characters, resulting in the following dimensions used for comparison: (1) Crown length of P4 to M3, (2) Crown length of M1 to M3, (3) Crown length of p4 to m3, (4) Crown length of m1 to m3, (5) Height of mandible at p4, (6) Height of mandible at m3, (7) Upper toothrow length (crown length), (8) Lower toothrow length (crown length), (9) Coronoid height, (10) Interorbital width, and (11) Total palatal length. Measurements were taken with a Wild Heerbrugg M5 binocular (object lens 12×) and an attached tenfold measuring eyepiece.

Results

General fauna

Surface findings on the cave floor and screening of the sediment yielded remains of 41 species of vertebrates: 5 soricomorphs, 17 bats, 12 rodents, 2 lagomorphs, 2 artiodactyls, 1 horse, and 2 carnivores. In addition, remains of birds, amphibians, reptiles, and gastropods were found. A more detailed documentation of the complete fauna will be published elsewhere.

Single bones of the reindeer, *Rangifer tarandus* (Linnaeus, 1758), steppe pika, *Ochotona pusilla* (Pallas, 1769), and Lemming (*Dicrostonyx* sp.) demonstrate that some of the fragments were deposited as early as in the Pleistocene. However, the bulk of the small mammal fauna from the cave sediment originated from more recent and climatically more favourable periods, as shown by the presence of dormice [*Eliomys quercinus* (Linnaeus, 1766), *Glis glis* (Linnaeus, 1766)], shrews (*Crocidura* sp.), and bats.

Chiroptera

We identified 5090 cranial elements (mandibles and maxillaries) of bats, representing 17 species and a minimum number of specimens of 2,632 (Table 1). The Bechstein's bat *Myotis bechsteinii* (Kuhl, 1817) is the most numerous species in the thanatocenosis with 57.6% (MNI), followed by the Natterer's bat *M. nattereri* (Kuhl, 1817) (18.3%), and whiskered bat *M. mystacinus* (Kuhl,

Table 1. List of species and numbers of bats identified in the bone assemblage

species	mandible left	mandible right	maxilla	MNI	MNI %
Barbastella barbastellus	3	10	1	10	0.38
Eptesicus nilssonii	2	2	0	2	0.08
Eptesicus serotinus	0	1	0	1	0.04
Myotis bechsteinii	1516	980	348	1516	57.60
Myotis brandtii	34	38	3	38	1.44
Myotis dasycneme	13	13	1	13	0.49
Myotis daubentonii	108	91	37	108	4.10
Myotis emarginatus	14	9	13	14	0.53
Myotis myotis	3	4	2	4	0.15
Myotis mystacinus	332	298	32	332	12.61
Myotis nattereri	335	482	240	482	18.31
Nyctalus leisleri	1	0	0	1	0.04
Plecotus auritus	3	4	97	97	3.69
Plecotus austriacus	0	0	3	3	0.11
Pipistrellus nathusii	2	6	2	6	0.23
Pipistrellus cf. *pipistrellus*	1	4	0	4	0.15
Rhinolophus hipposideros	1	1	0	1	0.05
total	2368	1943	779	2632	100.00

Table 2. Selected cranial and dental measurements of *Myotis bechsteinii* fragments from the Eifel cave

dimension	N	mean	range	SD
crown length of P4–M3	181	4.87	4.42–5.08	0.11
crown length of M1–M3	181	3.95	3.50–4.17	0.10
crown length of p4–m3	252	5.30	5.30–5.58	0.12
crown length of m1–m3	253	4.36	4.08–4.67	0.11
height of mandible at p4	253	1.46	1.17–1.67	0.08
height of mandible at m3	253	1.56	1.25–1.75	0.08
upper toothrow length (crown length)	6	8.40	8.00–8.58	0.21
lower toothrow length (crown length)	56	8.71	8.25–9.08	0.16
coronoid height	37	4.03	3.75–4.17	0.12
interorbital width	11	4.23	4.08–4.33	0.08
total palatal length	1	8.58	–	–

1817) (12.6%). The frequency of the remaining 15 species is less than 4%, in many cases less than 1%. The serotine *Eptesicus serotinus* (Schreber, 1774), lesser noctule *Nyctalus leisleri* (Kuhl, 1817), and lesser horseshoe bat *Rhinolophus hipposideros* (Borkhausen, 1797) are represented by a single specimen only (Table 1).

Age estimation of Myotis bechsteinii

A total of 1484 single values of 11 different dimensions were taken (Table 2). Most results were obtained for mandibular characters. The skulls (except one) were strongly fragmented and allowed only few measurements. These were compared with available data in the literature (Rybář 1976, Stanik & Woloszyn 2011).

The mean value of crown length of P4 to M3 of the Eifel cave population is comparable to that of *M. b. intermedius* (4.87 mm vs. 4.85 mm), as published by Rybář (1976). Crown length of M1 to M3 (3.95 mm vs. 3.95 mm), p4 to m3 (5.30 mm vs. 5.30 mm) and m1 to m3 (4.36 mm

Table 3. Comparison of skull and tooth measurements (means and range, in mm) of undated and dated Holocene populations of *Myotis bechsteinii*

dimension	*M. bechsteinii* (Eifel, this study)	*M. b. intermedius* (Rybář 1976)	*M. bechsteinii* (Stanik & Woloszyn 2011)
crown length of P4–M3	4.87 (4.42–5.08)	4.85 (4.70–5.10)	–
crown length of M1–M3	3.95 (3.50–4.17)	3.95 (3.80–4.10)	–
crown length of p4–m3	5.30 (5.00–5.58)	5.30 (5.15–5.45)	–
crown length of m1–m3	4.36 (4.08–4.67)	4.40 (4.25–4.45)	–
height of mandible at p4	1.46 (1.17–1.67)	–	1.46 (1.35–1.55): 5990 BP
height of mandible at m3	1.56 (1.25–1.75)	–	1.58 (1.43–1.78): 6725 BP
upper toothrow length (crown length)	8.40 (8.00–8.58)	–	–
lower toothrow length (crown length)	8.71 (8.25–9.08)	–	–
coronoid height	4.03 (3.75–4.17)	–	4.01 (3.80–4.34): 3905 BP
			4.01 (3.42–4.34): 5225 BP
			4.04 (3.78–4.17): 5990 BP
			4.00 (3.73–4.25): 6725 BP
interorbital width	4.23 (4.08–4.33)	4.35 (4.15–4.60)	–
total palatal length	8.58	–	8.52 (7.68–8.99): 4925 BP
			8.89 (7.98–9.92): 5990 BP

vs. 4.40 mm) also agree well with the Holocene *M. b. intermedius*. Extant *M. b. bechsteinii* have smaller measurements. Values of the interorbital constriction are intermediate between *M. b. bechsteinii* and *M. b. intermedius*. For the height of mandible at p4 and m3, coronoid height, and total palatal length, we used the data of Stanik & Woloszyn (2011) for comparison. They studied Bechstein's bats from 17 thanatocenoses dated by the ^{14}C AMS method (Accelerator Mass Spectrometry Radiocarbon Dating) and plotted the values of different dimensions against a time scale. The height of mandible at p4 correlates well with one of their samples dated 5990 BP (1.46 mm vs. 1.46 mm). For the height of mandible at m3 the best fit is 6725 BP (1.56 vs. 1.58). Our measurements for the height of the coronoid process (mean = 4.03 mm) do not provide clear results, however. The latter value would suggest an age of 3905 BP, but values for 5225 BP, 5990 BP, and 6725 BP are also close (Table 3). The single value for total palatal length (8.58 mm) seems to favour the age of 4925 BP (mean = 8.52 mm), but also fits within the range given for 5990 BP (7.98–9.92 mm, mean = 8.89 mm). Upper and lower toothrow lengths give no comparable results because the literature only provides data for alveolar length, not crown lengths. A combination of all available data sets (Table 3) suggests the age of the *Myotis bechsteinii* bones from the Eifel cave to fall between 5000 and 7000 years BP.

Discussion

Remains of seventeen species of bats were found in the sediment package from the Eifel cave. All bones have a similarly light-brown stain and seem to belong to the same fauna of the Holocene age. By contrast, bones of the Pleistocene species (pika, reindeer) are clearly distinguished by their blackish colour.

The seventeen species (Table 1) represent a large portion of the extant bat fauna of the Rhineland area (Roer 1993), which includes the Eifel Mountains. Most of the species hibernate in the area and therefore depend on the presence of rocks, caves, and fissures. Wissing & König (1996) recorded eighteen species of bats which hibernate in the adjacent Rhineland-Palatinate, and Kiefer et al. (1996) counted fifteen species in the nearby district of Koblenz. If the two long-distance migrants, the common noctule *Nyctalus leisleri* (Kuhl, 1817) and the Nathusius' bat *Pipistrellus nathusii* (Keyserling et Blasius, 1839), which leave the region for winter (Hutterer et al. 2005), are subtracted from the Eifel cave species list, fifteen species are left, all of which used the cave at a time. Woloszyn (1970) suggested that most of the Holocene remains originated from bat mortality during hibernation. This may have been the case in the Eifel cave and may partly explain the high abundance of *Myotis bechsteinii*, *M. nattereri*, *M. mystacinus*, and the Daubenton's bat *M. daubentonii* (Kuhl, 1817). However, one cannot exclude owl pellets as an additional source of small mammal bones, particularly for rodents and shrews.

The large size of the cranial fragments of *Myotis bechsteinii* suggests a Holocene age of the entire bat thanatocenosis. An application of the data of Stanik & Woloszyn (2011) indicates that the Eifel cave association dates back to approximately 6000 yrs BP. This would shift the origin of this fauna into the climatic optimum of the Holocene (Woloszyn 1970), or according to Obuch (1994), into the "forest optimum", a time where the impact of humans on the forest was low. The high proportion of forest bats (*Myotis bechsteinii*, *M. daubentonii*, *M. mystacinus*, *M. nattereri*) would support this view. The larger size of some bats was probably due to not yet fully understood micro-evolutionary effects. Ochman & Woloszyn (2001) noted similar size changes in *Myotis nattereri* from the Holocene of Poland. The onset of the Neolithic culture in Central Europe introduced agriculture and domestic animal husbandry into undisturbed forest areas and thus modified the landscape, including bat habitats.

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