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Southernmost Postglacial Record of Pond Bat *Myotis dasycneme* (Boie, 1825) (Mammalia: Chiroptera) – Varteshka Cave, NW Bulgaria

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Abstract: A description of three almost complete skulls of pond bat found in the Varteshka Cave (E23.55606° N43.14121°, 1160 m a. s. l., Chelopek Village, Vratsa Municipality, NW Bulgaria) is given. Analyses have been made to provide arguments that *Myotis dasycneme* is a member of the bat community of the area. Modelling of the climatic suitability based on records from Romania, Serbia, Croatia and Bosnia-Herzegovina showed that some regions of Bulgaria and the region of Western Stara Planina, in particular, could be favourable for its existence. The favourable areas are connected to those in Central and Eastern Europe.

Key words: Pond bat, *Myotis dasycneme*, range, subfossil, recent, new locality, Stara Planina Mts., Bulgaria.

Introduction

The pond bat *Myotis dasycneme* (Boie, 1825) is spread from the eastern coast of the North Sea to the Yenisei River in Russia (Horáček & Hanák 1989). The northern boundary of the range reaches about 60°N to the north and the south boundary varies between c.50°N and c.44°N (Roer 2001). The range core covers large areas of Russia, where the pond bat is one of the abundant species in bat assemblages (Iljin 1989, Horáček & Hanák 1989). In the peripheral range zone, in Western and Central Europe, the species occurs in small, partially isolated patches in lowland wetlands (Horáček & Hanák 1989, Ciechanowski et al. 2007). In the summer time, the main resting places are in buildings and trees (Ciechanowski et al. 2007). Maternity colonies range from a few dozens to several hundred individuals. In most hibernacula, single individuals, rarely groups, have been found (Ciechanowski et al. 2007). The pond bat mainly forages for insects over exposed smooth water surfaces. Foraging habitats may be up to 15 km away from daytime roosts. On the basis of banded specimens in Western Europe, regular seasonal movements up to 300 km between summer and winter shelters have been detected. The migratory routes are typically associated with linear landscape features (Limpens et al. 2000).

Modern surveys using a variety of registration methods (detectors, mistnets, roost inspection, gathering of dead specimens at bat-concentration sites, victims of road traffic) indicate that in some areas of Europe the species is not so rare as previously thought (Limpens et al. 2000, Lutsar et al. 2000, Baagøe 2001, Ciechanowski et al. 2007). Nevertheless, the species remains poorly known and relatively rare (Limpens et al. 2000). The main reason for its underestimation is the way of life and its environmental requirements. It usually hibernates in deep and narrow crevices, so it can often remain unnoticed during surveys. Although mist netting seems to be a suitable detection method in wetlands, it is effective only where medium-sized rivers and canals are available as a corridor for movement (Limpens

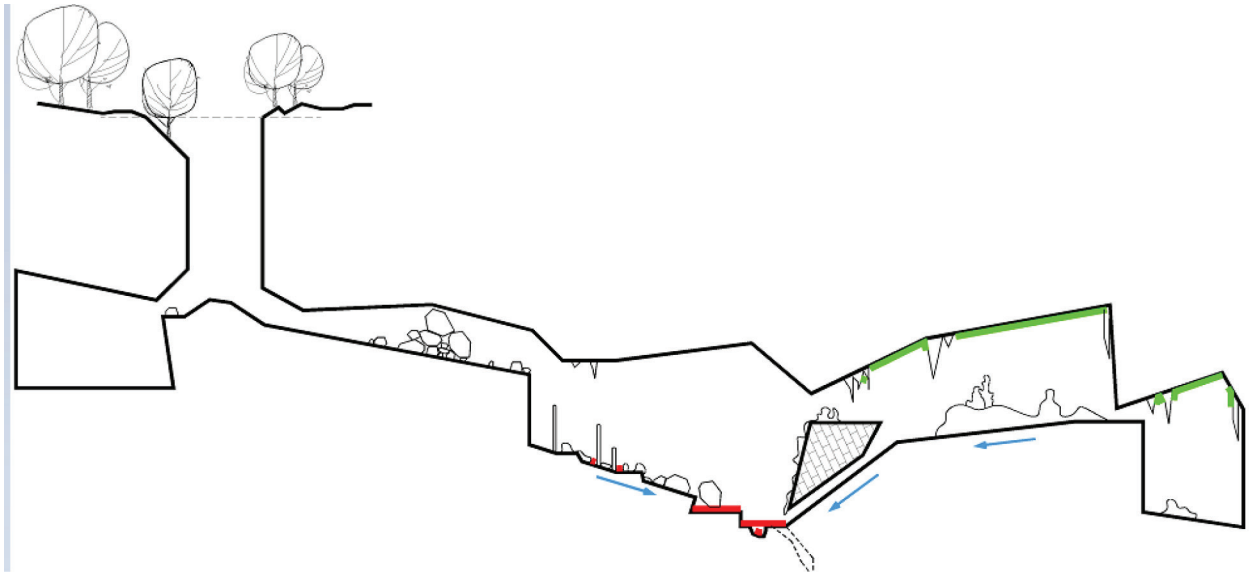

Fig. 1. A sketch of the longitudinal profile of the cave, with an indication of the place of the finds (red bars).

2001). At other potentially suitable sites, research should be based on inspecting potential roosts, discovering traces of its presence, combined with visual observations of feeding individuals (Limpens 2001). Such studies have not yet been carried out for the greater part of the species range (Ciechanowski et al. 2007). In this sense, the use of all possible methods of collecting information on the distribution of bats with a hidden lifestyle is particularly important. Careful examination of the surface in caves is one of these methods. There, a large number of remains can be gathered, allowing for the presence of many species inhabiting the area to be registered. The documentation of the finds, as well as their context, in most cases, allows narrowing the time range of the finds. This kind of data provides a reliable basis for analysing temporal changes in the distribution of rare and poorly known species.

So far, only a single record of the pond bat was reported from Bulgaria. It was based on a recording of the echolocation call from the surroundings of Rousse Town (30.09.1999, Krivina, 25.96/43.83, over the Danube River, see Limpens 2000). It represents, at the same time, the southernmost margin of the species distributional range. Nevertheless, in regard to possible confusion with other species (particularly *M. capaccinii*, which shows considerable overlap in most of the echolocation variables (e.g. van de Sijpe 2011). Benda et al. (2003)and Görföl et al. (2017) consider this record doubtful until supported by other line of evidence. Besides it, two Late Pleistocene records are available from Bulgaria: Bacho Kiro Cave (Woloszyn 1982) and Cave No. 4 of Garrot & Howe (1939) near Karlukovo (Horáček 1982, cf.).

Over the past few years, one of us (K.L.) conducted systematic surveys in caves in the Western Stara Planina Mountains. As part of these studies, a significant bone material of small mammals, including bats, has been collected. In its subsequent elaboration, it was found that some skulls collected from the Varteshka Cave belong to the pond bat. This communication aims to describe the material in order to certify its identification. Also, analyses have been carried out to verify the possibility of its present occurrence in the area.

Materials and Methods

Varteshka Cave (E23.55606° N43.14121°, 1160 m a. s. l.) is located on the western slope of a small valley. An eight-by-eight meters entrance opens up in a beech forest. The vertical entrance shaft is 25 m deep. The bottom is semi-lit, covered with forest soil, small stones, leaves and tree branches. The cave develops approximately in the south-north direction, parallel to the surface relief forms. The main gallery goes down and reaches to a high, elongated hall with a sloping floor. The bottom is uneven, rocky, with small terraced flats covered with tiny stones and sandy clay, sinter and stalagmites. It is wet but not very muddy. In the lower part of the hall, among large stones or in the niches below them, the main part of bones has been found (Fig. 1). The bones were on the surface or half-buried among the gullies. Besides *M. dasycneme*, the bone collection includes several other species of bats (Table 1) and rodents (*Glis glis*, *Myodes glareolus*, and *Apodemus flavicollis*). The second floor is a small hall. It is the primary site of hibernat-

Fig. 2. Skull of specimen No3/Vart/2018, dorsal, ventral and labial views.

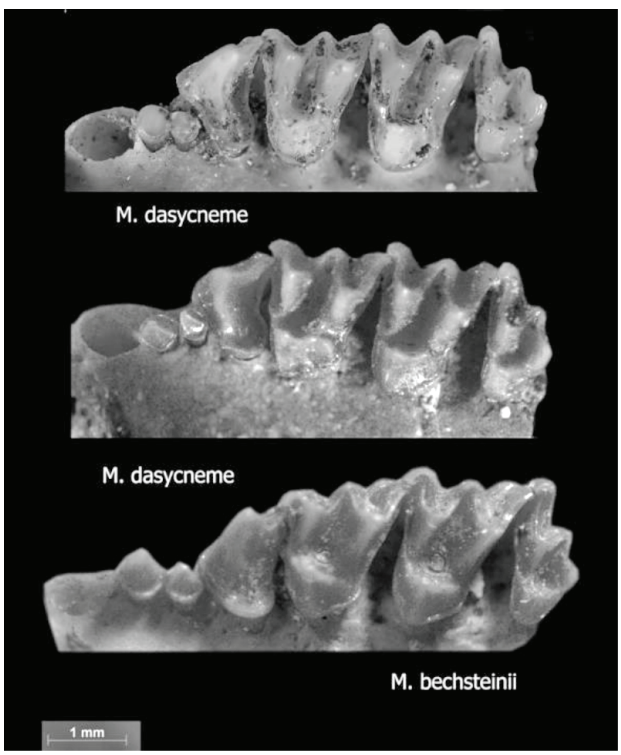

Fig. 3. Upper tooth rows of *M. dasycneme* (No1, 2/ Vart/2018) and *M. bechsteinii* (No11 /Vart/2018).

ing *Myotis myotis* / M. *blythii*. Here, bone findings missed.

The material belonging to *Myotis dasycneme* consists of three well-preserved skulls; only auditory bullae and some teeth are missing (Fig. 2). By the degree of tooth wear and the development of the sculpture of the skull, it can be said that the skulls belong to relatively young individuals. Skull dimensions are given to substantiate species determination and to serve as a comparison with other populations. Measurements were made on photographs taken with a Zeiss binocular.

As the exact age of the finds was unknown, further analyses were performed to estimate the likelihood of the current occurrence of the species in the area. For this purpose, the species' climatic suitability under present-day climatic conditions on the Balkan Peninsula was examined using ecological niche modelling. We applied the maximum entropy algorithm as implemented in the program package MaxEnt (Phillips et al. 2006) to obtain a multidimensional description in ecological space of the conditions where the species might occur, based on predictor variable values at locations where it has been recorded. The predictor variables were bioclimatic parameters, presented in the form of rasters with 2.5-arcminute-resolution of the WorldClim Global Climate Model (Hijmans et al. 2005). The model is based on data for species' registrations in Romania, Serbia, Croatia and Bosnia-Herzegovina synthesised in Görföl et al. (2017). Only those variables whose correlations were below 0.6 for the surveyed area were selected: Annual Mean Temperature, Mean Diurnal Range, Max Temperature of Warmest Month, Precipitation of Driest Quarter and Mean Temperature of Driest Quarter. MaxEnt was applied with its default settings and a logistic output, with suitability values ranging from 0 (unsuitable) to 1 (optimal) (Phillips & Dudík 2008). Six repetitions were made and evaluation metrics were summarised across the iterations. The relative variable importance was evaluated based on MaxEnt's built-in Jackknife functionality. The performance of the model was checked by the area under the receiver operating curve (AUC).

Results

The found skulls exhibit features typical of *Myotis dasycneme*. They are massive with a relatively short but broad rostrum. Lacrimal ridges well-developed, sagittal ridge missing. Among the European representatives of the genus, *M. bechsteinii* is the only species of similar size. These species, however,

differ well in the structure of the tooth rows (Fig. 3). In this respect, the available skulls show peculiarities characteristic of *M. dasycneme*: significantly shortened tooth rows as a consequence of the reduction and the overlapping of the small premolars; not visible or slightly visible in a side view of the middle premolar, resulting from its lingual shifting; large molars. Regarding measurements (Table 2), the available material is comparable to data from other parts of Europe (Roer 2001).

The results of the modelling indicated that the cave is located in an area which current climate is good enough for the species existence. The map of suitability scores revealed that this area, regarding its high appropriateness, is not isolated. It showed connectivity to the large territories of high climatic suitability within the species range, situated to the north and north-west (Fig. 5). In Bulgaria, favourable conditions exist in the northern and especially in the northwest parts. The obtained value of AUC = 0.87 indicated good overall performance of the model. The highest percentage contribution towards model fitting was from the Mean Temperature of Driest Quarter, followed by the Mean Diurnal Range and the Precipitation of the Driest Quarter (Table 3). As a whole, the modelling results showed that the distribution of the species in the area was determined by the conditions during the driest quarter – preferring moderate temperatures and precipitation. Also, the average 24-hour amplitude was of a significant influence: the species preferred areas of low diurnal range. These results suggested that the species is a mesophile, thriving under moderate environmental conditions.

Table 1. Skull material of bats collected in the Varteshka Cave (2017-2018).

Species	Number of skulls	%
Rhinolophus hipposideros	1	4.17
Myotis myotis	3	12.50
Myotis blythii	10	41.67
Myotis dasycneme	3	12.50
Myotis bechsteinii	4	16.67
Myotis mystacinus (s. l.)	2	8.33
Eptesicus serotinus	1	4.17

Table 2. Skull measurements of specimens of *Myotis dasycneme* found in the Varteshka Cave.

Measurement	No1	No2	No3
Crown length of C to M3	6.21	6.06	6.50
Crown length of P4 to M3	4.77	4.68	5.00
Condylobasal Skull Length	15.8	15.4	16.1
Condylo-Canine Skull Length	-	15.54	15.9
Crown length of M1 to M3	3.75	3.91	3.95
Total skull length	16.07	15.43	16.5
Zygomatic breadth	10.73	10.35	11.09
Breadth of interorbital constriction	4.73	4.56	4.76

Discussion

The presented findings, although belonging to individuals whose time of death cannot be precisely determined, give reason to believe that the species occurs in this part of the country today for numerous reasons.

The excellent preservation of the skulls and the lack of fossiliferous sediments in the cave are an indication that the finds are of subrecent or even quite recent age. The species composition of the accompanying material (Table 1), also composed of intact skulls, supports this assumption as well. All species occur in the area today (Popov 2007, Petrov et al. 2014). The cave is a place of hibernation for most of these species. Judging by the degree of preservation, some of the specimens appear to be the result of owl pellets. It is known that owls often hunt bats near their nursery and wintering colonies, especially during their formation (Sommer et al. 2009, Spitzenberger et al. 2014). It can be assumed that the material represents individuals that died during hibernation, as well as owl victims. The pond bat was represented by three individuals and was third in relative abundance in the bat bone assemblage (Table 1) and its abundance was comparable to that of other species, known to be living in the area today. Therefore, its presence in the cave could not be accidental. The surrounding landscape also corresponds to the preferred wintering sites of the species in this part of its range, for instance in Croatia (Tvrtković et al. 2001).

The location of the cave also gives arguments in favour of the assumption that the species currently inhabits the area. All findings of a similar taphonomic type (on the surface of cave galleries resulting from mortality during hibernation or accumulation of owl pellets) are within the contemporary range of the species (Horáček & Hanák 1989). Conversely, all findings that lie far south of the southern limit of the range are from the Late Pleistocene (Wołoszyn 1982, Horáček 1982, Horáček & Hanák 1989, Argenti et al. 2008). On this basis, bearing in mind that our materials are of Holocene age and practically modern, it can be assumed that the locality is within the range of the species, marking its southern border.

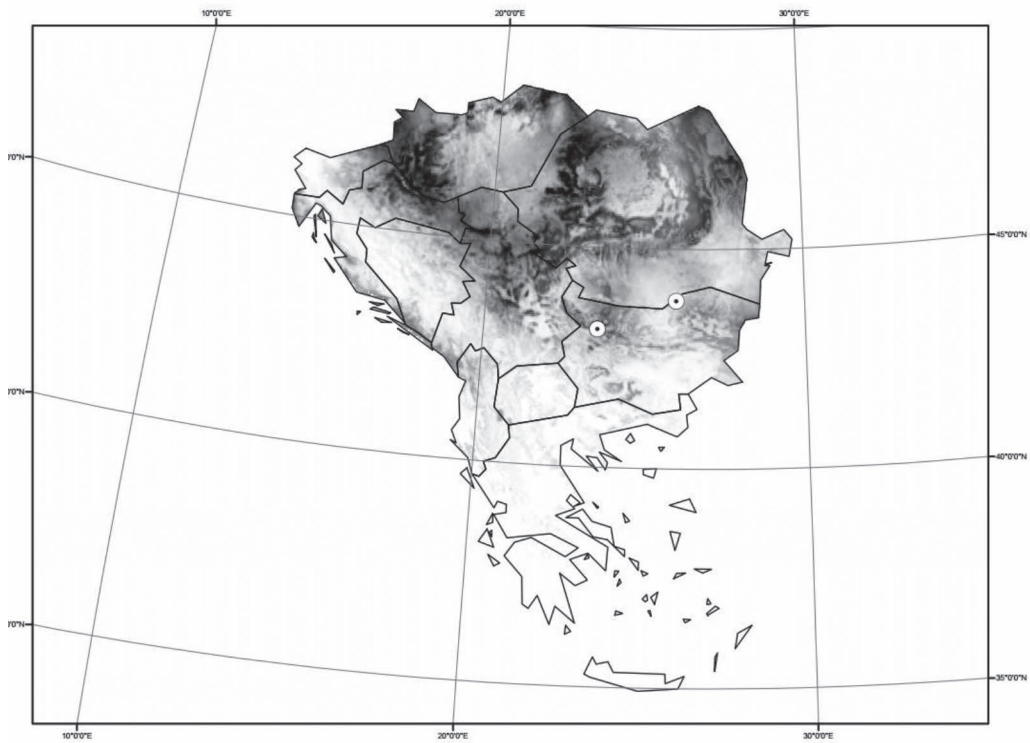

Fig. 4. Degree of climatic suitability, obtained by modelling based on data on species finds available in Görföl et al. (2017). The localities of the species in Bulgaria, not used in the modelling, are also shown. Country boundaries are only indicative Black - high suitability, white - low suitability.

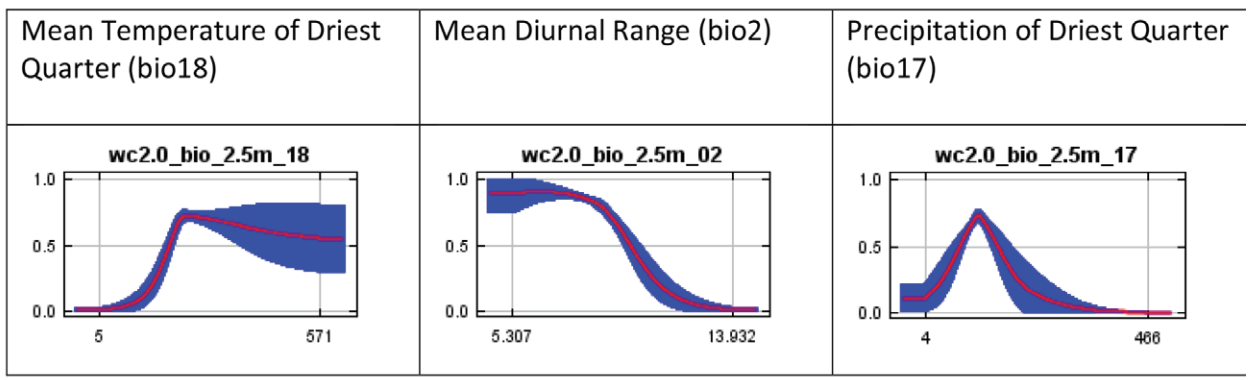

Fig. 5. Response curves showing how the predicted probability of presence changes as each bioclimatic variable is varied keeping all other environmental variables at their average sample value.

Table 3. Estimates of the significance of the bioclimatic variables for predicting of the distribution of *Myotis dasycneme* resulting from modelling with MaxEnt.

Variable	Percent contribution	Permutation importance
Mean Temperature of Driest Quarter	43.2	36.3
Mean Diurnal Range	31.2	42.4
Precipitation of Driest Quarter	18.8	12.7
Annual Mean Temperature	3.5	0.6
Max Temperature of Warmest Month	3.3	8

The results of the modelling show that the finding of *M. dasycneme* in the Western Stara Planina Region is quite logical. This region is one of the most humid in Bulgaria and the mountain conditions guarantee the low diurnal amplitude and moderate temperatures. The degree of climate suitability in the area of the locality, according to the model, is 67%. This percentage can be considered as the probability of species' occurrence in the area.

The finds reported here add new meaning to the alleged record of the species in the vicinity of Rousse. The geographic positions of the localities in Bulgaria are in agreement with the ecology of the species. As noted, the pond bat is an opportunistic

migrant with a length of registered migrations of up to 300 km. In Western Europe, the pond bat shows a tendency for migration between the lowland areas in the north and caves and underground sites in the hilly and mountainous regions in the south and south-east (Limpens et al. 2000). Both records from Bulgaria correspond to this pattern. It can be assumed, that in summer the species inhabits the Danube Plain and winters in the nearest karst areas in the foothills and mountainous areas to the south. The high density of karstic fissures and natural caves in the western part of the Stara Planina Mountains is probably the core of its wintering in this area.

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