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DISPERSAL HISTORY OF AN INVASIVE RODENT IN HUNGARY – SUBFOSSIL FINDS OF *RATTUS RATTUS*

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The origins of the black rat *Rattus rattus* can be placed in the Indian Peninsula and its occurrence in Europe is a result of a westward expansion. Based on archaeozoological finds, this rodent came into the Mediterranean and other parts of Europe before the Roman Period, as a commensal species associated with trade, although it was also introduced in many other parts of the continent during that time. After a depression in the population there is an increase in number of rat finds dating to the 11th century in Europe. The same tendency was observed in Hungary. The earliest rat remains in the country were recovered from sites dated to the Roman period (3–4th century AD) from inside and outside the territory of the Empire as well. Remains outside the *limes* (the border of the empire running along the right bank of the Danube) indicate that the Danube River did not pose a barrier in the expansion of rats. Records from the Roman period were followed by a gap of ca. 1000 years when the appearance of black rat was detected again at medieval Hungarian sites (from the 14th century onwards) reaching large numbers at sites dated to the Ottoman period (16–17th century).

Keywords: Hungary, archaeozoology, black rat, expansion routes, flotation

INTRODUCTION

The rodent genus *Rattus* is one the most specious genus of mammals comprising 66 species (MUSSER & CARLETON 2005). Four species of this genus have been widely scattered by humans throughout the world (ATKINSON 1985, MUSSER & CARLETON 2005): *R. rattus* (LINNAEUS, 1758), *R. exulans* (PEALE, 1848), *R. norvegicus* (BERKENHOUT, 1769) and *R. tanezumi* (TEMMINCK, 1844). These species have caused a variety of problems for humans such as the destruction of stored food and crops and transmission of diseases such as plague, leptospirosis and typhoid (MEERBURG *et al*. 2009). Furthermore, they seriously impact on biological diversity, especially on islands where the endemic fauna has been driven to extinction due to predation by alien rats. The most harmful invader for native seabird communities seems to be the black rat on islands (e.g. JONES *et al*. 2008). Thus, the Global Invasive Species Database (2009) lists black rat as one of the top 100 species on the World's Worst Invasive Alien Species List (www.issg.org/database).

The origin of the black rat is in the Indian Peninsula (NIETHAMMER 1975). Due to its subtropical origins, the black rat depends on warm, sheltered habitats in

close contact with humans in the cooler and wetter climates of the temperate zone in Europe.

The exact time when black rat spread out beyond its native range is still disputed. TCHERNOV (1968) claimed that the black rat reached Israel approximately 40,000 years ago with the origin of commensalism dating to ca. 17,000–12,000 BP (based on remains from Israeli caves). However ERVYNCK (2002) considers these finds unreliable (because of uncertain stratigraphic integrity) and reckons the oldest archaeological black rat bones recovered still come from Israeli caves/rock-shelters but date to ca. 12,000–10,200 BP as described by TCHERNOV (1984). TCHERNOV concluded that these rats are real commensals and that it was human sedentism that promoted the shift from wild-living to a commensal way of life in this species. As ERVYNCK (2002) suggested, however, these finds may represent prey remains left behind by owls (since they originate from cave deposits) and may thus derive from a wild-living rat population. Even if the Israeli finds do not represent a commensal population, they still show that the wild-living black rat reached the Near East during the transition from the Pleistocene to the Holocene (ERVYNCK 2002). Furthermore, ERVYNCK (2002) considers that the oldest commensal rat remains come from Syria (Tell Selenkahiye) dated to 2500 BC as well as there are other finds from this region (so-called Mesopotamia). Black rat remains have also come to light at the much earlier open air site of Ohalo II (Jordan) (ca. 19,400 BP) (BELMAKER *et al.* 2001). Based on the recently published results of phylogeographic investigations, commensalisms arose multiple times among geographically dispersed populations of black rats (APLIN *et al.* 2011). Thus, the later presence of black rats in the Near East around the 2nd millennium BC could be due to the maritime trade links emerging between the Indus valley and Mesopotamia at that time (ARMITAGE 1994). The black rat reached Egypt during the Ptolemaic (323–330 BC) period and appeared again in Roman times thanks to the intensive maritime trade activity between south India and the Mediterranean (ARMITAGE *et al.* 1984). From that time, the black rat started to disperse into Europe as well. Although there are a few black rat finds before the Roman times in Europe – the most reliable finds come from southwestern Slovenia and date to between 1100–800 BC (TOŠKAN & KRYŠTUFEK 2006) – there is an increase in the number of black rat remains from the Roman period all across Europe. The mechanism for the spread of this rodent was analyzed in numerous articles (ERVYNCK 2002, AUDOIN-ROUZEAU & VIGNE 1994, ARMITAGE *et al.* 1984, ARMITAGE 1994) and there is a recently published summary concerning rat immigrations into the Mediterranean islands as well (RUFFINO & VIDAL 2010).

This present article concerns recently retrieved archaeozoological finds from Hungary and contributes new information to complement what is known about the expansion route of this species into Europe.

MATERIALS AND METHODS

There are two methods to collect animal bones on archaeological excavations: large bones are picked up by hand while smaller ones (hard to see in the sediments) are recovered by sieving or flotation of soil samples (O'CONNOR 2004). The latter methods, appropriate for recovering small mammal (e.g. rat) bones in archaeological deposits were applied by myself using flotation on eight sites dated from the Mesolithic up to the Middle Ages (12–13th century) [Jásztelek I; Vörs–Máriaasszonysziget; Körösladány 14; Százhalombatta–Földvár; Budapest, District III., Csúcshegy–Harsánylejtő; Budapest District III., Szentendrei Road 139, Aquincum; Budapest, District III., Bécsi Road 310; Budapest, District XI., Kőérberek, Tóváros-lakópark]. In addition, I searched the literature for reliable archaeozoological finds, focusing on the most reliable existing records. I checked faunal lists of cave- and open air archaeological sites from Hungary where flotation was carried out and small mammals were analyzed [Aszód–Papi földek (KORDOS 1982*a*); Vésztő (KORDOS 1976); Berettyóújfalu–Herpály (KORDOS 1980–1981, 1982*b*, 1983); Sopron–Krautacker (KORDOS 1987); Remetehegy rockshelter (KORMOS & LAMBRECHT 1914)]. Furthermore, there are additional data originating from excavations where bones were collected by hand (so-called hand-collected materials) and studied by the author [Budapest, District XVII., Péceli Road; Dusnok–Szúnyogosi dűlő; Buda Castle, Teleki Palace]. Since it is relatively easy to see bones from this size rodent by eye during excavations, major skeletal elements of rats are often collected together with large mammal bones. Finally, all of these sites were evaluated from the viewpoint of presence/absence of black rat remains (Table 1, Fig. 1).

Archaeozoological data are considered reliable if the appropriate methodology is used during the excavation (AUDOIN-ROUZEAU & VIGNE 1994). This includes sampling appropriate features (e.g. sediment of pits, wells, houses with reliable chronology) and the use of sieving or flotation. The best way to ensure contemporaneity between the bones and archaeological levels is direct radiometric dating. Unfortunately, this was not possible in any of the cases used in this analysis. Thus, the remains were dated on the basis of the stratigraphy of the cultural layers from which they were recovered. Finally, it is very important to obtain information on the origins of the assemblages. Rodent remains may represent naturally trapped animals. Some, however, may have been killed by humans as pests or prey. Hunting rats for food is well documented at some archaeological sites – for example, consumption of *R. exulans* in Hawaii (KIRCH & O'DAY 2003). Furthermore, it is important to exclude the possibility of intrusion and not to sample features with signs of either recent or subfossil bioperturbations. Black rat is not commonly a burrower (EWER 1971) but is a scansorial species in the wild. The commensal form prefers living above ground as well.

The species identification of rat remains – for distinguishing the black rat from the brown rat (*R. norvegicus*) – was performed using dental characters as described by MILLER (1912) and the morphological characteristics of cranium and mandible (WOLFF *et al.* 1980). Finally four dental measurements were taken and compared with dental dimensions of modern black rats and brown rats from Hungary, Romania, Ukraine, Serbia and Croatia (deposited in the Hungarian Natural History Museum, Budapest) (see Table 3).

RESULTS

Fossil finds

Materials from central Hungary from the lower-Pleistocene levels of Kisláng, contained one rodent bone which was identified as "? *Rattus* sp.". This identification was considered uncertain by KRETZOI (1954). It is a dubious datum according to KORDOS (1994) as well because chronologically different levels were mixed in the same deposit. Furthermore, I re-checked the material from Kisláng (deposited in the Geological Institute of Hungary) and this specimen could not be found.

Table 1. Archaeological sites in Hungary with small mammal fauna investigations. Sites numbered from 1 to 12 are open air sites where flotation was used; Sites numbered 13, 14 and 16 are open air sites with hand collected materials; Site numbered 15 is a cave site where flotation was used.

Site	Period	References
1. Jásztelek I	Mesolithic	This paper
2. Aszód–Papi földek	Neolithic	KORDOS 1982*a*
3. Vörs–Máriaasszony-sziget	Neolithic	This paper
4. Körösladány 14	Chalcolithic	This paper
5. Vésztő	Neolithic-Chalcolithic and Bronze Age	KORDOS 1976
6. Százhalombatta–Földvár	Bronze Age	This paper
7. Berettyóújfalu–Herpály	Neolithic and Bronze Age	KORDOS 1980–1981, 1982*b*, 1983
8. Budapest, District III., Csúcshegy–Harsánylejtő	Neolithic, Chalcolithic, Bronze Age, Iron Age, Roman	This paper
9. Sopron–Krautacker	Early and Late Iron Age	KORDOS 1987
10. Budapest District III., Szentendrei Road 139, Aquincum	Roman	KOVÁCS 2009
11. Budapest, District III., Bécsi Road 310	Roman	This paper
12. Budapest, District XI., Kőér berek, Tóváros-lakópark	Medieval (12th–13th c.)	This paper
13. Budapest, District XVII., Péceli Road	Roman (Sarmatian)	KOVÁCS 2009
14. Dusnok–Szúnyogosi dűlő	Roman (Sarmatian)	This paper
15. Remetehegy rockshelter	Medieval	KORMOS & LAMBRECHT 1914
16. Buda Castle, Teleki Palace	Medieval-Ottoman Turkish	KOVÁCS 2009

Table 2. Archaeological sites in Hungary with black rat finds. MNI: Minimum Number of individuals; *flotation was carried out; **not identified to the species level

Site	Period	Century	Taxon	Bones (MNI)	References
13. Budapest, District XVII., Péceli Road	Roman (Sarmatian)	3rd c. AD	*R. rattus*	crania (3)	KOVÁCS 2009
10. Budapest, District III., Szentendrei Road 139, Aquincum*	Roman	4th c. AD	*R. rattus*	mandible (1)	KOVÁCS 2009
14. Dusnok–Szúnyogosi dűlő	Roman (Sarmatian)	4th c. AD	*R. rattus*	cranium (1)	This paper
		4th c. AD	*Rattus* sp.**	pelvis (1)	This paper
15. Remetehegy-rockshelter*	Medieval	14th c.	*R. rattus*	mandibles (2)	KORMOS & LAMBRECHT 1914
16. Buda Castle, Teleki Palace	Medieval	14–15th c.	*R. rattus*	cranium (1)	KOVÁCS 2009
	Medieval – Ottoman Turkish	15–16th c.	*R. rattus*	crania (2)	KOVÁCS 2009
	Ottoman Turkish	16–17th c.	*R. rattus*	crania (8)	KOVÁCS 2009

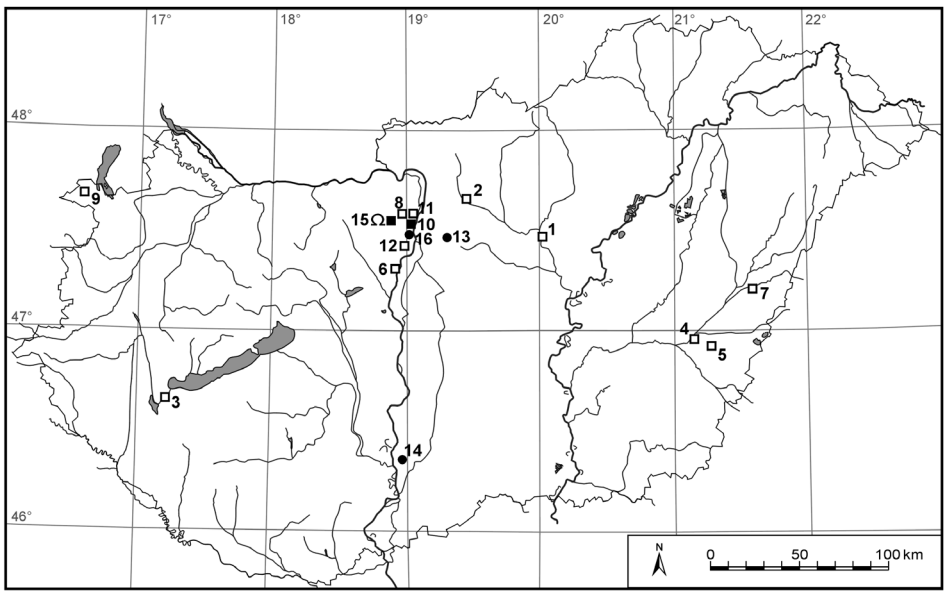


Fig. 1. Investigated archaeological sites in Hungary with small mammal fauna. □ = open air sites with using flotation method, black rat absence; ■ = open air/cave sites with using flotation method, black rat presence; ● = open air sites with hand-collected materials, black rat presence

Table 3. Standard descriptive statistics for samples of modern *R. rattus*, modern *R. norvegicus* and archaeological specimens. Abbreviations: LM1 – length of the first upper molar; BM1 – breadth of the first upper molar; Lm1 – length of the first lower molar; Bm1 – breadth of the first lower molar.

dental measurements	sample	mean (mm)	min-max (mm)	SD	N
LM1	modern *R. norvegicus*	3.1	2.6–3.62	0.2	39
	modern *R. rattus*	2.94	2.68–3.27	0.15	28
	archaeological *R. rattus*	2.96	2.79–3.15	0.1	15
BM1	modern *R. norvegicus*	2.17	1.9–2.37	0.1	39
	modern *R. rattus*	1.93	1.76–2.08	0.09	28
	archaeological *R. rattus*	1.97	1.88–2.1	0.06	15
Lm1	modern *R. norvegicus*	2.96	2.66–3.37	0.16	39
	modern *R. rattus*	2.77	2.58–3.02	0.13	27
	archaeological *R. rattus*	2.76	2.73–2.81	0.03	4
Bm1	modern *R. norvegicus*	1.85	1.48–2.08	0.12	39
	modern *R. rattus*	1.68	1.49–1.84	0.08	27
	archaeological *R. rattus*	1.62	1.56–1.68	0.05	4

Subfossil finds

There are very few Holocene open air archaeological sites in Hungary where sieving/flotation method was carried out. I have found only one published article and three unpublished manuscripts with analyzed small mammalian assemblages dating from the Neolithic until the Iron Age. Among the eight sites analyzed by the author, there was only one site with black rat remains (Budapest District III., Szentendrei Road 139, Aquincum).

In spite of the presence of synanthropic small mammals at these sites (e.g. *Mus musculus*), black rat was absent almost everywhere. For example in the huge material from the Iron Age site (9th–1st century BC) from Sopron–Krautacker (NW Hungary) pits and houses were sampled and a rich small mammal fauna was identified lacking any black rat remains (KORDOS 1987).

So far, altogether 5 sites yielded black rat remains in Hungary (Table 2). At two of these sites, flotation was carried out but in all other cases the remains originate from hand-collected materials. All these remains, however, were recovered from well-documented, reliable archaeological layers.

The identification of these subfossil remains was clear using dental and cranial morphology. Furthermore dental dimensions of these specimens corresponded to those observed in modern *R. rattus* and were smaller than for modern *R. novegicus* (see Table 3).

The earliest finds from Hungary come from a Roman period Sarmatian settlement dated to the 3rd–4th century AD, described by the present author (KOVÁCS 2009). The site, "Budapest, District XVII., Péceli Road", is situated near the left bank of the Danube (Fig. 2). This Sarmatian settlement was located outside the official frontier of the Roman Empire – in the territory of the so-called 'Barbaricum'– next to the *limes*, the border of the empire running along the right side of the Danube. The settlement consisted of many houses, pits and graves. Among the archaeological finds recovered at the site exported Roman products indicate that

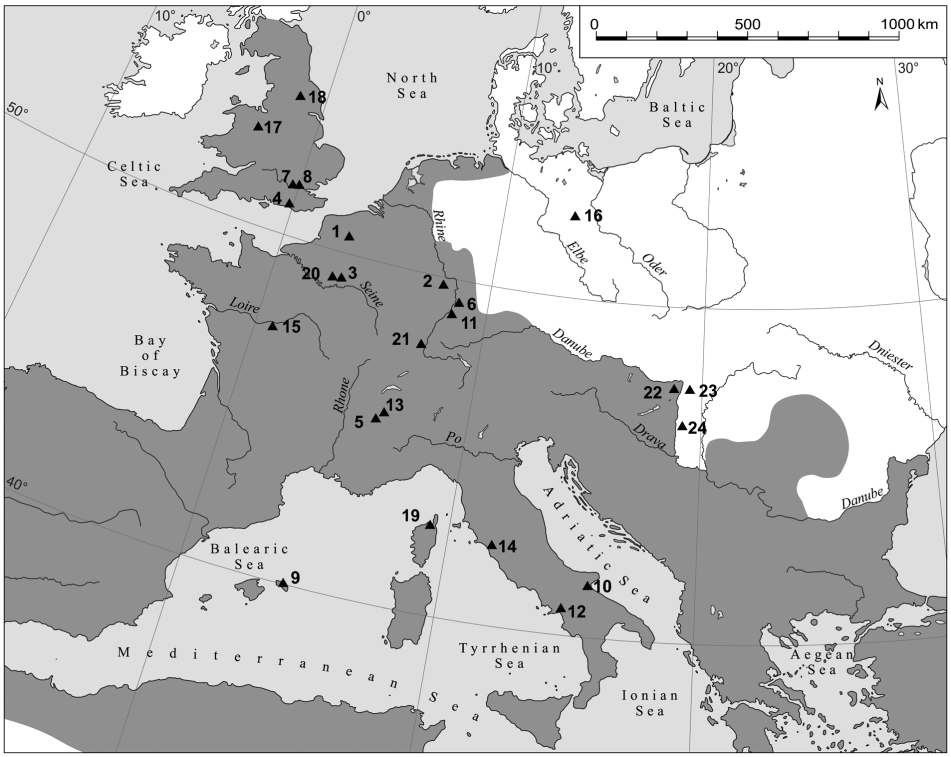
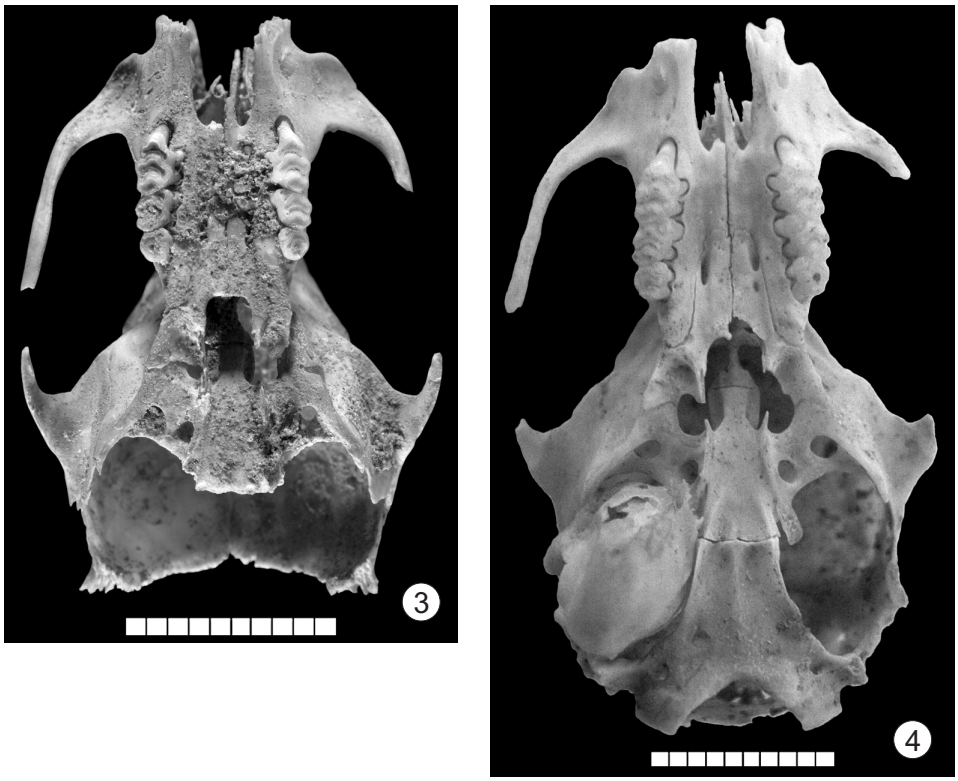


Fig. 2. Archaeological black rat remains from the Roman Period in Europe (after AUDOIN-ROUZEAU & VIGNE 1994) complemented with Hungarian finds (shaded areas: expanse of the Roman Empire). 1: Arras–Beaudimont, France; 2: Bad Kreuznach, Germany; 3: Baron Buisson-Saint-Cyr, France; 4: Beddingham, Britain; 5: Les Ilettes–Annecy-le-Vieux, France; 6: Ladenburg, Germany; 7: Londres–Crosswall, Britain; 8: Londress–Frenchurch, Britain; 9: Taula Torralba d'en Salort–Menorca, Spain; 10: Ordona, Italy; 11: Pforzheim, Germany; 12: Pompei, Italy; 13: Portout, France; 14: Sette Finestre – Grosetto, Italy; 15: Thésée et Pouillé, France; 16: Waltersdorf, Germany; 17: Wroxeter, Britain; 18: York–Skeldergate, Britain; 19: Monte di Tuda–Crosica, France; 20: Senlis, France; 21: Sierentz–Landstrasse, France; 22: Budapest, District III., Szentendrei Road 139., Aquincum, Hungary; 23: Budapest, District XVII., Péceli Road, Hungary; 24: Dusnok–Szúnyogosi dűlő, Hungary

there were trade connections between the Sarmatians and Romans (KOROM 2006). Three rat skulls (Fig. 3) were discovered in this hand-collected material coming from three bee hive-shaped pits which contained kitchen refuse. The pits were dated to the 3rd century AD based on the stylistic features of the ceramics (KOROM pers. comm.).

There are two other rat remains from sites lying beyond the *limes*: one rat skull (Fig. 4) and one pelvis were described by the present author from the Roman period site of Dusnok–Szúnyogosi dűlő (central South Hungary). The site is located next to the Danube on its left bank (Fig. 2) where a 4th century AD Sarmatian settlement was excavated (MÉSZÁROS 2010). Remains of houses, pits and graves were found at the site. Black rats were recovered in the central part of the settlement among the hand-collected contents of two refuse pits.

So far, black rat remains from Waltersdorf (Eastern Germany) represent the only data known from outside the territory of the Roman Empire in Europe (TEICHERT 1985) (Fig. 2). The two new records from Hungary outside the *limes* lay



Figs 3–4. Skull (ventral view) of one of the black rats from site: 3 = Budapest, District XVII, Péceli Road (Roman Period); 4 = Dusnok–Szúnyogosi dűlő (Roman Period). Scale bars 10 mm

closer to the border of the Roman Empire than the site of Waltersdorf. In the case of the Hungarian finds, the presence of black rats outside the empire does not come as a surprise. During Roman times, different types of connections emerged between the two banks of the Danube such as local trade activity between Romans and Sarmatians as well as long-distance trade routes across the *Barbaricum*. Furthermore, Sarmatians sometimes staged raids against the empire. Last but not least, Romans supplied their military stations scattered along the routes crossing the *Barbaricum* (VADAY 1998). It seems that the river did not represent a barrier for rats and they had many opportunities to be delivered into areas East of the Danubian *limes*.

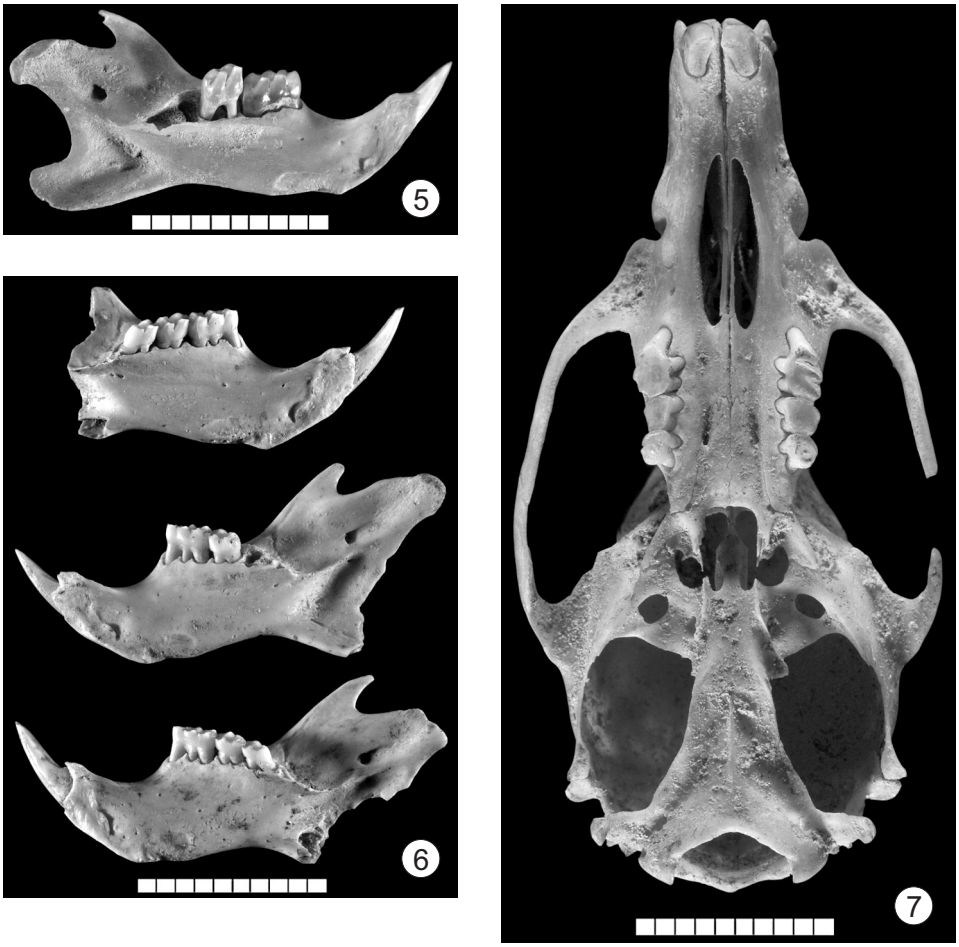
One black rat bone (Fig. 5) originates from within the territory of the Roman Empire in Hungary, from *Pannonia Inferior* (Fig. 2). It was recovered from the Civil Town of Aquincum (KOVÁCS 2009). This is the only such remain recovered using flotation from among the open air sites under investigation here. Aquincum was an important crossing-point between the road from East to the West (across the Danube) and the road running North to South along the Danube. Aquincum consisted of a legionary fortress, a Military Town and a Civil Town where merchants and craftspeople lived (ZSIDI 2003). Evidence of black rat was recovered from the fill of a drain situated along the southern wall of the town, dated to the 4th century AD based on stylistic dating (LÁNG 2002). The Roman town offered suitable habitats for this subtropical rodent with its heated stone houses. However, it is worth mentioning that the presence of black rats outside the Roman Empire means that these animals were able to occupy rural settlements as well during the 3rd–4th century AD and found appropriate habitats in those settlements too. Thus, their distribution was not only restricted to urban habitats.

Unfortunately, after the Roman period, there is no open air site with small mammal assemblages in Hungary until medieval times. In addition there are no data concerning black rat recovery from hand-collected material either. This time period is called the Migration period in Hungary and it is characterized by occupations by a variety of usually short-lived cultures of both Eastern and Western origin with populations continuously on the move in the wake of the Roman occupation. The former settlements in the Barbaricum on the left bank of the Danube became rare while most towns were abandoned on the right bank in the former territory of late Roman Pannonia Province.

As observed in Britain and Western Europe (ARMITAGE 1994, AUDOIN-ROUZEAU & VIGNE 1994), after the Roman period, rat populations may only have survived in small numbers – there are no data from the post-Roman period until Medieval times from Europe in spite of extensive sieving carried out at excavations in the territory of the Western Roman Provinces. It seems that environmental

conditions were not suitable for rats in Northern Europe and with the decrease in trade activities the replenishment of rat populations became inadequate (ARMITAGE 1994). This may have been true for the Hungarian populations as well but the absence of black rat remains is primarily due to the lack of sieving on sites of this whole period. A *de facto* absence could be established only on the basis of systematically sieved, representative samples.

There is only one site from the Middle Ages with small mammal material: the site of "Budapest District XI., Kőérberek, Tóváros-lakópark" analyzed by this au-



Figs 5–7. 5 = Lingual side of mandible of the black rat from the site of Budapest, District III, 139 Szentendrei Road. Aquincum (Roman Period); 6 = Mandibles of black rats from the site of Remetehegy rockshelter (Medieval Period); 7 = Skull (ventral view) of a black rat from excavations at Buda Castle (Medieval period). Scale bars 10 mm

thor. The site is dated to the 12–13th century (HORVÁTH *et al.* 2005). In spite of the presence of commensal house mouse (*Mus musculus*) rat was absent (Fig. 1).

There is another small mammal assemblage originating from a sieved find material from the site of Remetehegy rockshelter (NW Hungary) (KORMOS & LAMBRECHT 1914) (Fig. 1). It was a cave site where sediment flotation was carried out on sediments from different levels. Three black rat mandibles (Fig. 6) recovered from the medieval stratum of the cave dated to the 14th century (based on ceramics typo-chronology). These remains were described as *Epimys rattus* L. (a synonym for *Rattus rattus*).

Finally, relatively many black rat finds were recovered from the hand-collected material of Buda Castle (KOVÁCS 2009) (Fig. 1). One skull was recovered from a pit dated to the 14–15th century (Fig. 7). Two skulls were identified in the assemblage from the 15–16th century level of a medieval well. Finally, the remains of eight specimens were recovered from seven pits dated to the 16–17th century Ottoman period. The animal bone material from one of these pits was published by DARÓCZI-SZABÓ (2004) in which the species list contained remains of rats described as *Rattus* sp. After revision these remains were more precisely identified as *Rattus rattus* (KOVÁCS 2009).

Based on these finds, it seems there was a stable population of black rats at the time of the Ottoman occupation of the Buda Castle. This strong population seems to have been due mainly to increased trade activity. Buda was an important administrative and commercial center of the Ottoman Empire resulting in the continuous replenishment of the introduced black rat population. Furthermore, since the so-called "Little Ice Age" began around this period (BRADLEY & JONES 1993), buildings in the territory of the Buda Castle probably offered suitable shelter for the rats, protecting them against the cold.

DISCUSSION

Unfortunately, information on prehistoric black rats is somewhat limited in Hungary – partly because of poor quality sampling and the lack of regular sieving on excavations (there is only one site where flotation was carried out and rat remains recovered: Budapest, District III., Szentendrei Road 139, Aquincum). The absence of rats may also be caused by difficulties in identification and the fact that "hamster-size animals" are sometimes considered intrusive specimens and as such excluded from the faunal analysis.

The identification of subfossil specimens presented here was clear: molar and cranial morphology fitted well with the modern *R. rattus*. Furthermore dental

measurements of these specimens were close to modern *R. rattus* and were smaller than for modern *R. norvegicus*.

There are very few data on black rats from Hungary but they fit within what has been observed in the existing archaeozoological record in continental Europe. The tendency for the expansion of black rat populations during the Roman Period and then again in the medieval period could be followed in this region too.

Finds from the 3rd–4th century AD in Hungary suggest that there were populations of black rats in the territory of the provinces of the Roman Empire and the Barbaricum as well. ARMITAGE *et al.* (1984) found black rats in the Roman London from the same time period. In Europe, black rat finds come mostly from the Mediterranean coast, and from inland settlements along the main commercial roads and rivers (Rhône, Rhine, Loire, Danube, Drava) (AUDOIN-ROUZEAU & VIGNE 1994) (Fig. 2). Most of the finds occur within 10 km of sea coasts and river banks where rat colonies could have been established and reinforced through passive transport on ships (MCCORMICK 2003). This is true for the Hungarian finds as well: they tend to come from settlements along the Danube. The presence of black rats outside the territory of the Roman Empire in the rural settlements of Sarmatians indicates that living conditions for this commensal animal were appropriate outside Roman towns as well. Furthermore, it means that the Danube did not act as a barrier but rather a corridor in the distribution of black rats. Since the black rat is not a good swimmer (RUSSELL *et al.* 2008) it is unlikely that it swam across the river but rather were transported to the other side by human means such as on boats. Due to different kind of connections between peoples living in the Empire and Barbaricum, rats could have been transported to the other side accidentally, as unseen passengers.

During the 6–8th centuries AD there is an absence of black rat in Britain and Central Europe as well (ARMITAGE 1994). In Hungary there are no finds of black rats on sites from this period but this absence may reflect the lack of sieved materials from sites of this period. These centuries are called the Migration period in this area as a variety of different mobile pastoralist cultures from Eastern and Western areas settled down for short periods and long-term permanent settlements became rare in Hungary.

After a time gap of almost 1000 years, rats re-appeared on medieval sites in Hungary. Based on results published by AUDOIN-ROUZEAU and VIGNE (1994) the population density of rats increased in Western Europe from the 11–13th centuries, probably due to climatic changes, urban growth and intensive trade activity. It seems that in Hungary the rat population increased only from the 14th century possibly in relation to delayed urbanization. Aside from the size-selective effect of excavation methodology (inadequate sampling strategies for small mammal bones)

low numbers prior to the 14th century could indeed be connected with the fact that in Hungary there were no large, concentrated towns during the Middle Ages comparable to those that flourished in the western part of Europe. However, many black rat finds come from the Ottoman period in Hungary from the Buda Castle. The potential role of the Danube as a corridor in mediating inadvertent rat transport is consonant with the fact that during the Ottoman Turkish occupation "in 1571, one quarter of the Buda customs revenue originated from dues paid for wheat and barley; an estimated 1,000 metric tons was shipped up the Danube from the south on board 437 boats." (TÓTH *et al.* 2010).

In spite of the lack of sieving, black rats recovered from the two main periods in Hungary are the same as the "peaks" of rat occurrence everywhere in Europe. Based on the data presented here, black rat was introduced to the territory of present-day Hungary by the Romans 1600 years ago. Rat populations were then reinforced or reintroduced ca. 1000 years later in medieval times. In order to clarify what happened with rat populations during this time gap, additional investigations are required, including systematic sampling on archaeological sites from the Migration Period.

Nowadays, this species has been restricted again to isolated localities in Hungary – mostly in the south-western part of the country (HORVÁTH 1998) and the ports along the Danube River in Budapest (JABIR *et al.* 1985). This tendency began in the second half of the 19th century and continues until today (JABIR *et al.* 1985). While the sparse population of black rat was probably the result of its weak replenishment during the Migration Period (and probably the rarity of appropriate settlements) today the rarity of this rat species is mainly connected to the presence of its aggressive competitor, the brown rat (*Rattus norvegicus*). This latter rat species reached Europe early in the 18th century (ENTZ 1906, ROBINSON 1984). The exact time of its arrival in Hungary is not known but it seemed to be a common species by the first half of the 19th century (HANUSZ 1888). Besides the presence of brown rat, many other factors may also contribute to the present day rarity of black rats in Hungary today, including modern pest control.

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