
A zoogeographical analysis of rodent fauna of Jordan

Mohammad A. Abu Baker* and Zuhair S. Amr

Department of Biology, The University of Jordan, Amman, Jordan.

* Corresponding author: ma.abubaker@ju.edu.jo

Department of Biology, Jordan University of Science and Technology, Irbid, Jordan

ABSTRACT

The rodent fauna of Jordan is highly heterogenous, totaling 28 species and originating from three zoogeographical affinities: Palaearctic, Afrotropical, and Oriental, in addition to several wide-ranging, Eastern Mediterranean and introduced species. The distribution of rodents in Jordan represents a reflection of their global distribution ranges and habitat preferences. For several species, Jordan lies at the edge of their distribution ranges (e.g. *Apodemus* sp., *Nannospalax ehrenbergi*), other have wide distribution (e.g. *Jaculus jaculus*), while some are represented by relict populations (e.g. *Eliomys melanurus* and *Acomys russatus lewisi*). Species associated with the temperate forest of northern Jordan includes *Sciurus anomalus* and two wood mice, *Apodemus mystacinus* and *A. flavicollis*, while non-forested areas are represented by *Nannospalax ehrenbergi* and *Microtus guentheri*. Strict sand dwellers include *Gerbillus cheesmani* and *G. gerbillus*. Petrophiles associated with sandstone or black lava deserts are exemplified by *Acomys russatus*, *A. r. lewsi*, *H. indica* and *S. calurus*. Others including: *Jaculus jaculus*, *G. nanus*, *G. henleyi*, *Meriones crassus*, and *M. libycus* are all desert-adapted species with a wide distribution occurring in areas of scarce vegetation, wadibeds, and marabs with clay, loess, or gravel surfaces. A single species, *Gerbillus dasyurus*, exhibits a wide range of distribution over diverse habitat types. Species composition is characterized by substantial variability of rodent assemblages due to habitat requirements and replacements of sibling species.

Key words: Habitat preference, Jordan, Rodents, Zoogeography.

INTRODUCTION

Jordan sits at the crossroads between three zoogeographical affinities: the Palaearctic, Oriental, and Sudanian Penetration. Despite its limited area, biodiversity in Jordan is remarkable due to the high habitat heterogeneity within several biogeographical regions (Amr, 2012). As the largest groups of mammals worldwide as well as in the Eastern Mediterranean region, rodents play an important role in establishing the ecosystem's biodiversity and food webs. Not only are they prey for avian and mammalian predators,

but they are also consumers of seeds and green plants. Rodents are also able to alter the species composition of plant communities thereby altering the vegetation of an area by selective feeding (Chaline, 1977). Rodents are the most diversified group of mammals inhabiting temperate, arid and semi-arid habitats in North and East Africa, the Levant and the Arabian Peninsula (Harrison, 1972; Lay, 1983; Harrison & Bates, 1991; Wilson & Reeder, 2005; Granjon et al., 1999; Scott & Dunstone, 2000; Abu Baker & Amr, 2003b; 2004).

Our knowledge on rodent diversity in Jordan is a result of continuous efforts over the past 15 years. Several systematic accounts have been conducted yielding a great deal of data on the diversity, systematics and ecology (Abu Baker & Amr, 2003a; 2003b; 2004; 2008; Yousef & Amr, 2005; Amr et al., 2004; 2006; Amr, 2008; Atallah 1977; 1978; Harrison & Bates, 1991; Qumsiyeh, 1996; Amr, 2000; Benda et al., 2010; Amr, 2012; Amr et al., 2018). The rodents of Jordan are represented in eight families (Cricetidae, Dipodidae, Gliridae, Hystricidae, Muridae, Myocastoridae, Sciuridae, and Spalacidae) with 20 genera and 28 species. Species of this order are diverse, inhabiting a wide variety of habitats, ranging from extremely arid to mountainous and cold environments. The majority of rodents are nocturnal or crepuscular; however, some are strictly diurnal (e.g. squirrels). The diet of most rodents is primarily granivorous and herbivorous, but a few species feed on insects or land snails. Most of the rodents in Jordan are relatively small in size, with the exception of the Indian crested porcupine and the introduced coypu (Wilson et al., 2016).

This paper aims to summarize the diversity and ecology of the rodents of Jordan and zoogeographical affinities. The spatial patterns of distribution were analyzed based on past and updated records of all the rodents in Jordan.

MATERIALS AND METHODS

In Jordan, four biogeographical regions are identified: The Mediterranean region; which, has the highest rain fall and altitude and the most fertile soil. It includes the mountain ranges between Irbid in the north and Ra's an Naqb in the south. This region is dominated by oak, pine and pistachio trees. The Irano-Turanian region which surrounds the Mediterranean region, except in the north, is characterized by lower altitudes with poor soil and dominated by *Raetam* sp., *Anabasis* sp. and *Artemisia* sp. of vegetation. The Saharo-Arabian region comprises the majority of the total area of Jordan and has the lowest rain fall and poorest soils. Diversified subdivisions of vegetation types occur based upon habitat type such as hammada, saline, sandy and mud flat (Al-Eisawi, 1996). The Sudanian region is characterized by being the warmest region, occurring in the most southern and southwestern parts of the country, low rain fall and mostly saline or sandy soil. The dominant vegetation is *Acacia* sp. and *Haloxylon persicum* (Disi & Amr, 1998; Disi et al., 1999).

Rodent distribution by habitat type

The biogeographic zones were further subdivided into eight sub-regions based on the distinguished habitat aspects such as substrate types, land cover, and vegetation (Fig. 1, Table 1). These are:

Temperate Mediterranean forests

These include the Aleppo pine and evergreen and deciduous oak forests. The Aleppo pine forests (*Pinus halepensis*) covers small areas mainly in Dibbin forest, Ajlūn and Zai and is mainly associated with evergreen oak (*Q. calliprinos*), strawberry tree (*Arbutus andrachne*), Pistachio (*Pistaia palaestina*) and *Pyrus syriaca*. The soil is white calcareous and/or Terra Rosa with average annual rainfall 500-700mm.

Non-forest Mediterranean region (including agricultural fields)

These areas may be classified as secondary (degraded) forests due to intense pressure of logging and deforestation for agriculture, urban development, and grazing over the years. These areas are not covered by forests, but contain some bushes and shrubs that are considered non-forest Mediterranean habitats and contains shrubs and bushes that are found in all Mediterranean regions.

Desert rocky slopes and boulders (including basaltic fields in the Lava Desert)

This habitat is represented by the rocky areas in Jordan including the mountains and boulders that support rock-dwelling species. This area lies mostly within the Saharo-Arabian region of the south where weathered sandstone and granite mountains and eastern regions of the country basaltic boulders originated from ancient volcanic activities.

Wadi beds, marab, and sabkha

These areas are represented by dry water courses (run-off), flat low land areas and depressions of land with high salty soil. The substrates may be of various origins, mostly calcareous, loess, or sandy. The vegetation cover is highly dependent on the season. Dominant plants include: *Artimesia* sp., *Origanum* sp., *Achillea fragrantissima*, *Nitraria retusa*, *Tamarix* sp., *Retama raetam*, and *Atriplex* sp.

Sand dunes and sandy sheets

These areas are composed of soft sand dunes and/or wind-blown sand that are stabilized by healthy vegetation cover of shrubs and bushes (sand dunes fixatives). The main species that characterize this type include *Haloxyton persicum*, *Retama raetam*, *Calligonum comosum*, *Neurada procumbens*, *Hammada scoparia* and *Seidlitzia rosmarinus*.

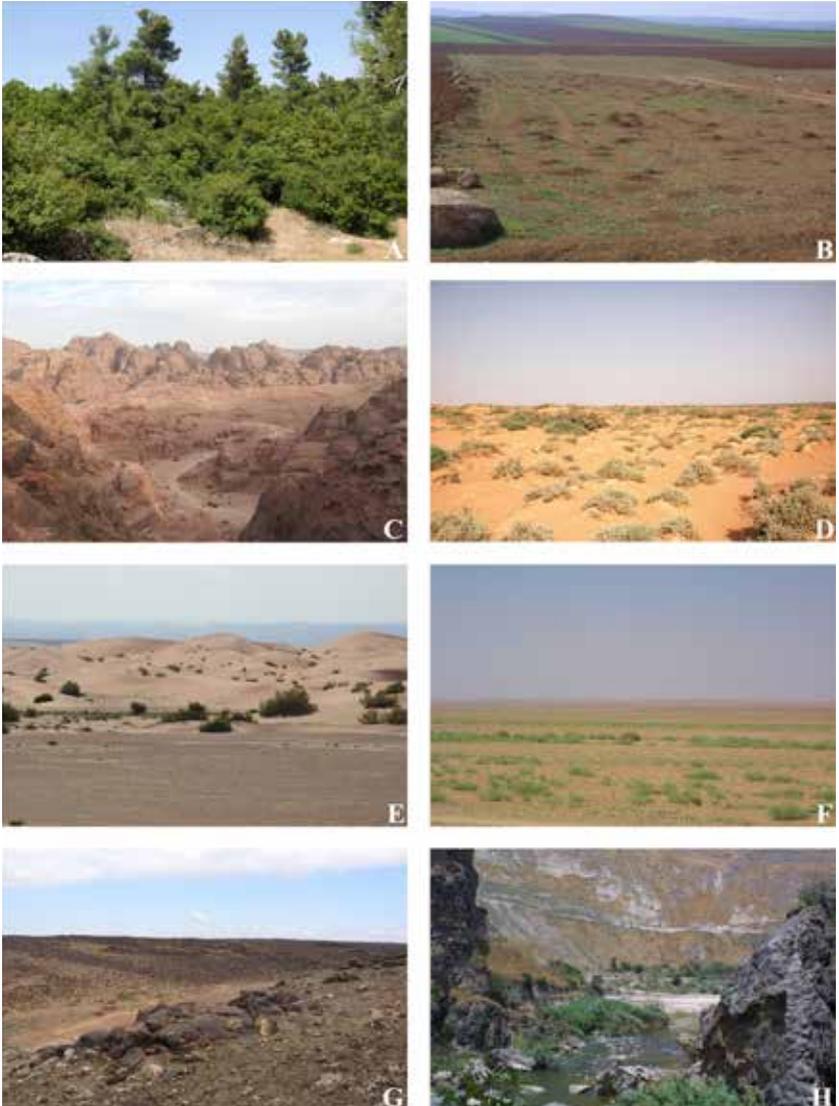


Figure 1: Habitat types: A: Temperate Mediterranean habitat with abundance of evergreen oak (*Quercus* sp.) and pine forests in northern Jordan. B: non- forest Mediterranean habitat with agricultural fields. C: Desert rocky slopes and sandstone mountains. D: Wadi-beds with silt dunes and loess substrates. E: Sand dunes with *Haloxylon shrubs* and *Acacia* trees in Wādī ‘Araba. F: Open Hamada in eastern Jordan with ample bushes of *Seidlitzia rosmarinus*. G: Bolders of black lava desert in eastern Jordan. H: The riparian habitat at the Yramouk River Basin in northern Jordan.

Open hammada desert: these are flat deserts of clayey loam covered by gravel. Vegetation is dominated by low shrubs of *Seidlitzia rosmarinus*, *Astragalus spinosus*, and some annual shrubs and succulent plants as; *Spergularia diandra*, *Herniaria hirsute* and *Anthemis deserti*.

Steppe and gravel/pebble vegetation: This is the largest vegetation type by area within Jordan. It is represented by the open shrubby and flat deserts covered with bare gravel and/or pebbles bordering the semi-temperate and true desert areas. The vegetation of the area is often poor and concentrated in water sheds and small wades with higher soil moisture. The main species of plants in this habitat type include: *Anabasis articulata*, *Retama raetam*, *Astragalus spinosus*, *Tamarix* sp., *Achillea fragrantissima*, *Artemisia sieberi* and *Zilla spinosa*.

Riparian/water vegetation: these habitats are confined to the limited temporary or permanent stream systems. These habitats and reed vegetation offers suitable habitats few aquatic mammals.

One hundred and thirty sites covering all vegetation types and habitats were visited during the past years and rodents and/or rodent remains were collected. Rodents were often trapped using Sherman folding live-traps (23 × 9 × 9 cm) during different seasons in which traps were baited with mixed oatmeal and pea nut butter, set in the late afternoon and checked in the following morning. Jerboas were spotted at night by the automobile lights and hand torches and caught with regular insect nets. Owl pellets were collected from different localities and analyzed for rodent's skull remains, they were identified to species level based on skull morphology and dental features. Species geographic ranges for the rodents of Jordan were obtained from Harrison & Bates (1991) and Osborne & Helmy (1980) with subsequent updates provided in Amr (2012). Eight main habitat types were recognized for the purpose of the similarity analysis.

The number of overlapping species between each pair of habitats was used to calculate the similarity index using the formula: $\frac{2C}{N_1 + N_2} \times 100$, where C is the number of overlapping species between two habitats, N1 is the total number of species present in habitat 1 and N2 is the total number of species present in habitat 2 (Krebs, 1999). Species within 57 selected sites were classified based on similarity of rodent species composition using cluster-analysis (cosine similarity measure, UPGMA algorithm) using PAST 3.2, 2018 software.

RESULTS AND DISCUSSION

Zoogeographic origins and habitat preferences of rodents in Jordan

The distribution of rodents in Jordan represents, to a large extent, a reflection of their global distribution ranges and habitat preferences. The rodent fauna

of Jordan (excluding the four introduced species: *Rattus rattus*, *R. norvegicus*, *M. msuculus*, and *Myocastor coypus*) consists of assemblages from different zoogeographical affinities and biogeographic ranges: Palaearctic (12 species), Oriental (5), Saharo-Arabian (10), and wide-Ranging. Nineteen of the recorded species occur in a single zoogeographic region, whereas, four species occurred in two regions, and only one species ranged widely over three regions. Nine, three, and seven species were restricted or had most of its range within the Mediterranean, Irano-Turanian, and Saharo Arabian region, respectively (Amr et al., 2018).

The eastern and southeastern parts of Jordan are largely arid and semi-arid with low productivity, yet, the local habitat heterogeneity have contributed to the relatively high species richness that includes two jerboas, four gerbils, three jirds, one dormouse and one species of spiny mice. Species associated with the temperate forest and non-forested areas of northern Jordan exhibited the highest species richness with a total of ten species, including a single species of squirrels (*Sciurus anomalus*), two wood mice, *Apodemus* sp., a single species of mole rat (*Nannospalax ehrenbergi*), one vole (*Microtus guentheri*), most of which are wide-ranging species toward the north of Jordan. The steppe areas contained nine species, followed by the sandy habitats with seven total species. The low species richness within the non-forest Mediterranean habitats (5 species) is likely in-part due to the agricultural activities and development associated with urban expansion. Strict sand dwellers include two hairy-footed psammophiles only found in the sand dunes are: the easterly-ranging *Gerbillus cheesmani* in the southeast and eastern Jordan is replaced by the westerly-ranging, Saharan *G. gerbillus* in Wādī 'Araba. The two species are separated by the Sharah Mountains in southern Jordan. The riparian habitat ranked the lowest in terms of species richness with only one species (*Nesokia indica*) while the remaining habitats contained 5–6 species (Table 1).

Several species (Fig. 2) have confined distributions to preferred habitats including: petrophiles (*Acomys russatus*, *A. r. lewsi*, *H. indica* and *S. calurus*), psammophiles (*G. andersoni*, *G. gerbillus*, and *G. cheesmani*), and forest-dwellers (*S. anomalus*, *Apodemus mystacinus* and *A. flavicollis*). Other species including: *Jaculus jaculus*, *G. nanus*, *G. henleyi*, *Meriones crassus*, and *M. libycus* are all desert-adapted species with wider ranges of distribution in habitats of scarce vegetation, wadi beds, and marabs with clay, loess, or gravel surfaces provide foraging grounds and shelter (Scott & Dunstone, 2000; Abu Baker & Amr, 2003a; 2003b; 2004; 2008). A single species, *Gerbillus dasyurus*, exhibited a wide range of distribution over diverse habitat types (Table 1).

The similarity index analysis indicated that the highest average similarity was within the steppe and gravel/pebble areas (33.13%) which represent the transition zone bordering the temperate/semi temperate habitats from

the west and the true desert areas from the east (Amr et al., 2018). The temperate forests ranked second in terms of overall similarity (26.21%), this area exhibited the highest species richness due to its high productivity and vegetation cover and the fact that it included several widely-distributed species. The lowest overall similarity occurred in the riparian vegetation which is confined to the limited water vegetation areas in Jordan with only one species recorded (Amr et al., 2018).

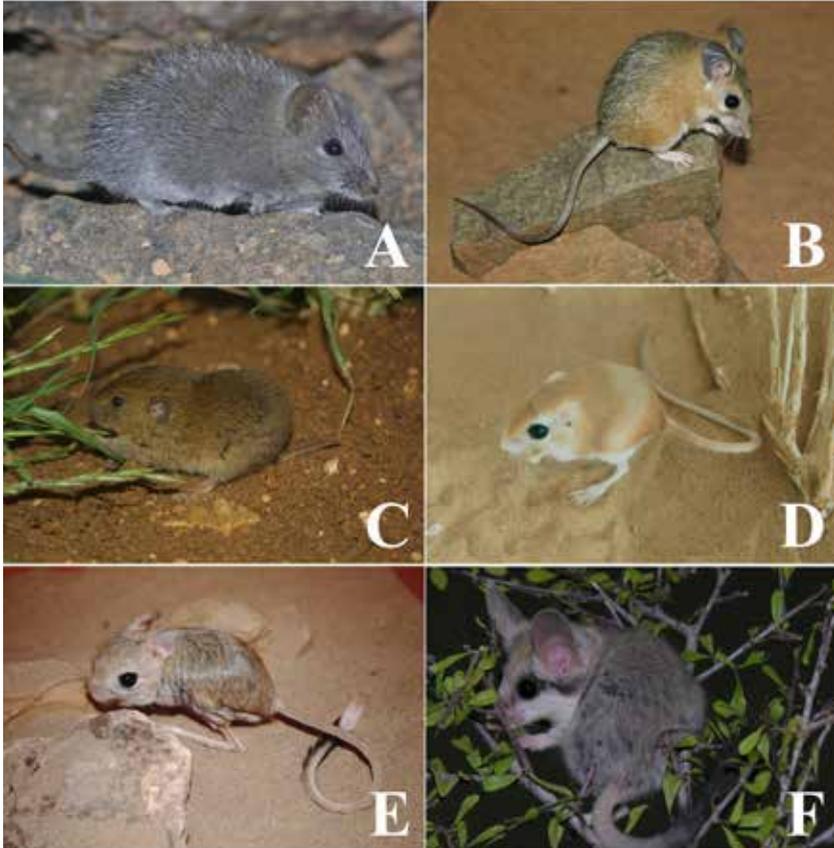


Figure 2: Representative rodents of Jordan: A: *Acomys russatus lewisi* from the rocky basaltic fields in Northeastern Jordan. B: *Acomys dimidiatus* from the rocky slopes and sandstone mountains. C: *Microtus guentheri*, an inhabitant of the agricultural fields and nonforest Mediterranean areas. D: *Gerbillus gerbillus*, from the sand dunes of Wādi 'Araba. E: *Jaculus jaculus*, a generalist of the open deserts. F: *Eliomys melanurus*, an inhabitant of forested areas and a relict of vegetated wadis in the deserts of Jordan.

Species composition at the local scale

An analysis of 57 local assemblages throughout Jordan showed that species richness ranged from a lone species at 6 sites to 6 species at 2 sites. Mean species richness per site was 2.96, with a mode of 3. Approximately 11% of the sites had a single species, 61% had 2 or 3 species, and 28% supported 4-6 species (Fig. 3). The most abundant species were, *Gerbillus dasyurus* (at 21 sites), *Meriones crassus* (15), *Gebillus nanus* (14), *Jaculus* (13), and the least abundant were *Sekeetamys calurus* and *Allactaga euphratica*, each recorded at a single site. The results suggested that species incidence is highly dependent on habitat requirements.

Several assemblages of rodents were recognized among the study sites by their strict habitat preferences: sites within forested areas (*Sciurus anomalus* and *Apodemus* sp.), nonforest Mediterranean habitats and agricultural field (*Meriones tristrami* and *Microtus guentheri*, and *Nannospalax ehrenbergi*), rocky sites (*Gerbillus dasyurus*, *Acomys* spp.), sandy sites (*Gerbillus cheesmani*), densely vegetated wadis (*Psammomys obesus* and *Eliomys melanurus*), open gravel plains (*Jaculus* and *G. henleyi*), and in addition to species (*Meriones crassus* and *G. dasyurus*) that ranged over several habitat types. These assemblages were composed of species of similar zoogeographic origin and rarely included closely-related species.

Results of cluster-analysis of species composition indicated that three main groups with 6 assemblages were distinguished (Fig. 4). The distinguished assemblages at the 60% level of similarity represent a critical point where these assemblages can also be distinguished by the habitat types. These assembles are: 1.inhabitants of agricultural fields and non-forest Mediterranean, 2. forests, 3. steppe vegetation, 4. rocky areas, 5. open deserts, and 6. sandy areas (Fig. 3).

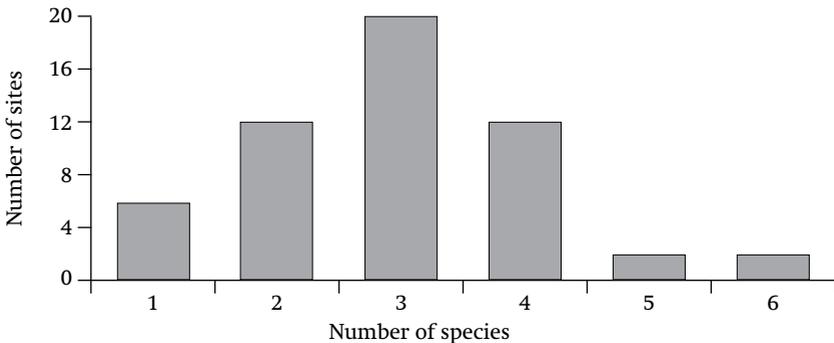


Figure 3. Frequency of coexisting species among 57 study sites. 1 = agricultural fields and non-forest Mediterranean, 2 = forests, 3 = steppe vegetation 4 = rocky areas, 5 = open deserts and 6 = sandy areas.

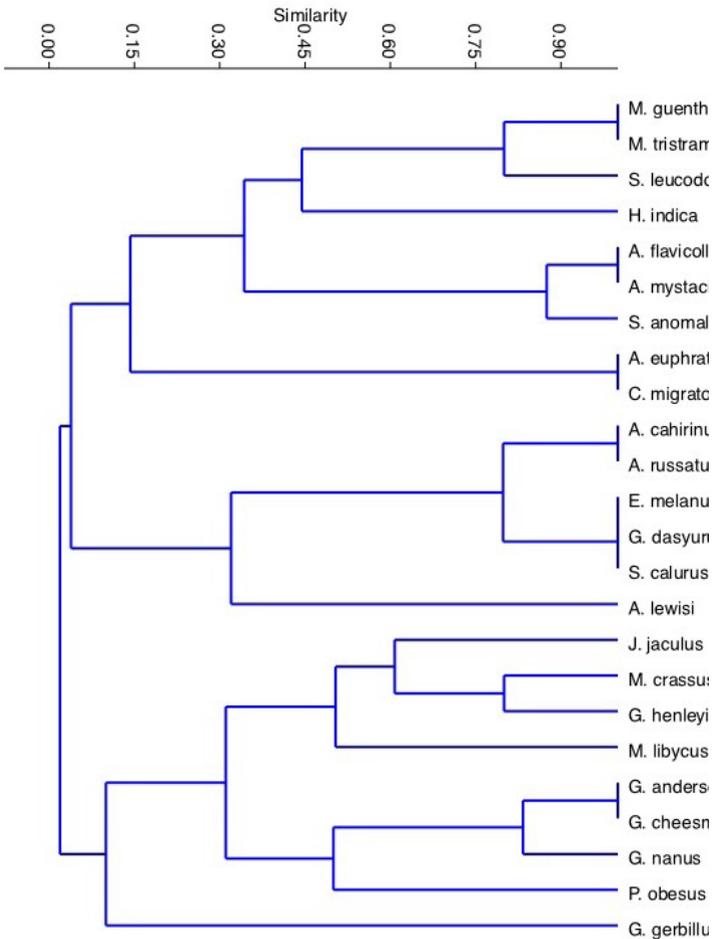


Figure 4: Cluster-analysis of rodent species within 57 sites based on their similarity.

Conclusion

The rodent diversity of Jordan is relatively high, consisting of 28 species. It is considered as mixture of three zoogeographical affinities (Palearctic, Afrotropical, and Oriental), with some wide-ranging Eastern Mediterranean species. Jordan constitutes the most southern range of distribution for some rodents (e.g. *Apodemus mystacinus*, *A. flavicollis*, *Nannospalax ehrenbergi* and *Microtus guentheri*), while it represents the most northern distribution range for some Arabian and African forms (e.g. *S. calurus*, *Acomys russatus* and *G. gerbillus*).

TABLE 1. Species distribution, richness, percentage of rodents across the main habitats.

Biogeographic regions Habitat	Mediterranean			Saharo-Arabian			Irano-Turanian	
	Med. forest/forest fields	Non-forest Med. and agr. fields	Rocky slopes and boulders (including semiarid Med.)	Flat hammada deserts	Sandy areas and sand dunes	Wadi beds, marab, sabkha	Open gravel/pebble Steppe vegetation	Riparian/water veg.
<i>Sciurus anomalus</i>	(+)							
<i>Eliomys melanurus</i>	+		+					
<i>Allactaga euphratica</i>							+	
<i>Jaculus jaculus</i>				+	+	+		
<i>Cricetulus migratorius</i>	+	+					+	
<i>Microtus guentheri</i>	+	+						
<i>Acomys dimidiatus</i>			+					
<i>Acomys russatus russatus</i>			+					
<i>Acomys russatus lewisi</i>			+				+	
<i>Psammomys obesus</i>					+		+	
<i>Sekeetamys calurus</i>			(+)					
<i>Meriones crassus</i>				+	+	+	+	
<i>Meriones libycus</i>				+	+	+		
<i>Meriones tristrami</i>	+	+					+	
<i>Gerbillus andersoni</i>					(+)			
<i>Gerbillus cheesmani</i>					(+)			
<i>Gerbillus dasyurus</i>	+		+	+		+	+	
<i>Gerbillus</i>					(+)			
<i>Gerbillus henleyi</i>				+				
<i>Gerbillus nanus</i>						+		
<i>Apodemus mystacinus</i>	(+)							
<i>Apodemus flavicollis</i>	(+)							
<i>Nesokia indica</i>								(+)
<i>Hystrix indica</i>	+	+	+				+	
<i>Nannospalax ehrenbergi</i>	+	+					+	
Species richness	10	5	7	5	7	5	9	1
% (out of 24 total species)	41.67	20.83	29.17	20.83	29.17	20.83	37.5	4.17

REFERENCES

- Abu Baker, M. & Amr, Z. 2003a. A morphometric and taxonomic revision of the genus *Gerbillus* in Jordan with notes on its current distribution. *Zoologische Abhandlungen (Dresden)*, 53, 177–204.
- Abu Baker, M. & Amr, Z. 2003b. Rodent diversity in the Northeastern Desert of Jordan, with special reference on the ecology of *Gerbillus cheesmani*. (Mammalia: Rodentia). *Casopis Národního Muzea, Rada prirodovedná*, 172 (1–4), 141–152.
- Abu Baker, M. & Amr, Z. 2004. The rodents (Mammalia: Rodentia) of Wadi Ramm, southern Jordan: New records and notes on distribution. *Arab Gulf Journal of Scientific Research*, 22 (1), 9–20.
- Abu Baker, M. & Amr, Z. 2008. Mice of the genus *Apodemus* in Jordan. *Vertebrate Zoology*, 58 (1), 127–135.
- Al Eisawi, D. 1996. *Vegetation of Jordan*. Regional Office for Science and Technology for the Arab States, UNESCO, Cairo, 284 pp.
- Amr, Z. 2000. *Mammals of Jordan*. United Nations Environment Programme. Amman, 116 pp.
- Amr, Z. 2008. Biodiversity of reptiles and mammals in the Eastern Desert. In: Dutton, R. & Shahbaz, M. (Eds.), *Jordan's Arid Badia: Deepening our Understanding*. Smith Gordon & Co., Cambs, pp. 155–173.
- Amr, Z. 2012. *Mammals of Jordan*, 2nd Edition. Al Rai Press. Amman, 308 pp.
- Amr, Z., Eid, E., Qarqaz, M.A. & Abu Baker, M. 2006. The status and distribution of the Persian Squirrel, *Sciurus anomalus*, in Dibbeen Nature Reserve. *Zoologische Abhandlungen (Dresden)*, 55 (1), 9–17.
- Amr, Z.S., Abu Baker, M. & Rifai, L. 2004. Mammals of Jordan. *Denisia*, 14, 437–465.
- Amr, Z.S., Abu Baker, M.A., Qumsiyeh, M. & Eid, E. 2018. Systematics, distribution and ecological analysis of rodents in Jordan. *Zootaxa*, 4397 (1): 1–94.
- Atallah, S.I. 1977. Mammals of the Eastern Mediterranean: their ecology, systematics and zoogeographical relationships. *Säugetier kundliche Mitteilungen*, 25 (4), 241–320
- Benda, P., Lučan, R.K., Obuch, J., Reiter, A., Andreas, M., Bačkor, P., Bohnenstengel, T., Eid, E.K., Ševčík, M., Vallo, P. & Amr, Z.S. 2010. Bats (Mammalia: Chiroptera) of the Eastern Mediterranean and Middle East. Part 8. Bats of Jordan: fauna, ecology, echolocation, ectoparasites. *Acta Societas Zoologicae Bohemicae*, 74, 185–353.
- Chaline, J. 1977. Rodents, evolution, and prehistory. *Endeavour*, 1 (2), 44–51.
- Disi, A.M. & Amr, Z.S. 1998. Distribution and ecology of lizards in Jordan (Reptilia: Sauria). In: Fritz, U., Obst F.J. & Andreas, B. (Eds.), *Faunistische Abhandlungen, Staatliches Museum für Tierkunde Dresden*, 21 (Suppl.): *Contribution to a "Herpetologia arabica"*, Nr. 6, 43–66.

- Disi, A.M. & Hatough-Bouran, A. 1999. Biodiversity of the terrestrial vertebrate fauna of Petra (Jordan). *Casopis Národního muzea, Rada přírodovědná*, 166 (1–4), 83–98.
- Granjon, L., Bonnet, A., Hamdine, W. & Volobouev, V. 1999. Reevaluation of the taxonomic status of North African gerbils usually referred to as *Gerbillus pyramidum* (Gerbillinae: Rodentia): chromosomal and biometrical data. *Zeitschrift für Säugetierkunde*, 64 (5), 298–307.
- Harrison, D.L. & Bates, P.J. 1991. *The Mammals of Arabia*. Harrison Zoological Museum, Kent, 354 pp.
- Harrison, D.L. 1972. *The Mammals of Arabia*. 3. *Lagomorpha and Rodentia*. E. Benn, London. 382–670 pp.
- Krebs, C.J. 1999. *Ecological Methodology*. 2nd Edition, Benjamin Cummings, Menlo Park, 620 pp.
- Lay, D.M. 1983. Taxonomy of the genus *Gerbillus* with comments on the applications of generic and sub-generic names and an annotated list of species. *Zeitschrift für Säugetierkunde*, 48 (6), 329–354.
- Osborn, D.J. & Helmy, I. 1980. The contemporary land mammals of Egypt (including Sinai). *Fieldiana Zoology*, 5, 1–579.
- Qumsiyeh, M.B. 1996. *Mammals of the Holy Land*. Texas Tech University Press, Lubbock, 389 pp.
- Scott, D.M. & Dunstone, N. 2000. Environmental determinants of the composition of desert-living rodent communities in the north-east Badia region of Jordan. *Journal of Zoology*, 251 (4), 481–494.
- Wilson, D.E. & Reeder, D.M. 2005. *Mammal Species of the World. A Taxonomic and Geographic Reference* (3rd edition). Johns Hopkins University Press, Baltimore, 2142 pp.
- Wilson, D.E., Lacher, T.E., Jr & Mittermeier, R.A. 2016. *Handbook of the Mammals of the World. Vol. 6. Lagomorphs and Rodents I*. Lynx Edicions, Barcelona, 987 pp.
- Yousef, M. & Amr, Z. 2005. Altitudinal stratification and habitat selection of rodents in Dana Nature Reserve, Jordan. *Zoology in the Middle East*, 34 (1), 13–18.