Gholamreza NADERI 1*, Mahmoud R. HEMAMI 2, Saeed MOHAMMADI 1, Borhan RIAZI 1, Mahmoud KARAMI 3, Mohammad KABOLI 3, Ali A. ALESHEIKH 4

1 Department of Environmental Sciences, Science and Research Branch, Islamic Azad University, Tehran, Iran, *e-mail: ghnadery@yahoo.com (corresponding author)
2 Faculty of Natural Resources, Isfahan University of Technology, Isfahan, Iran
3 Faculty of Natural Resources, Tehran University, Tehran, Iran
4 K.N.Toosi University of Technology, e-mail: Alesheikh@kntu.ac.ir

EFFECT OF VEGETATION AND SOIL CONDITIONS ON BURROW STRUCTURE AND SITE SELECTION OF RARE DESERT RODENT – IRANIAN JERBOA (ALLACTAGA FIROUZI)

ABSTRACT: The Iranian jerboa (Allactaga firouzi Womochel, 1978) is one of the rarest rodent species in the world and it has been reported exclusively from a single site in central Iran. Because of its restricted geographical distribution and habitat degradation, it has been classified as Critically Endangered in the IUCN Red List. From April 2007 to February 2009 on a small area (2200 ha) of semi-arid grazed steppe (altitude 2000 m, surface covered by bare soil and/or scarce shrub and grass vegetation) we studied the architecture structure of burrow system and burrow site selection of Iranian jerboa. Three types of burrows including temporary burrows, winter and summer burrows were detected in the studied habitat. Habitat characteristics such as the percentage cover of: bare soil, pebble and cobble and desert plant species like Anabasis aphylla, Artemisis siberi, and Peganum harmala, as well as the selected chemical soil parameters (content of calcium sulfate, calcium carbonate) were measured in the burrow sites and compared with similar variables measured at random plots in the non-burrow sites.

The principal component analysis successfully distinguished between the burrow sites and the non-burrow areas. The burrow site selection was mainly influenced by percentage cover of bare soil, vegetation type, soil texture and chemistry.

KEY WORDS: Iranian jerboa, habitat types, burrow structure, burrow site selection, micro-habitat conditions

1. INTRODUCTION

The Iranian jerboa (Allactaga firouzi Womochel, 1978) has been reported exclusively from a single site and is therefore one of the rarest rodent species in the world (Womochel 1978, Naderi et al. 2009). Because of its restricted geographical distribution and being threatened by habitat degradation, the Iranian jerboa had been classified as Critically Endangered in the IUCN Red List. However, due to the lack of enough information on the ecology of this species, its conservation status was changed to “Data Deficient” category in late 2008 (IUCN 2009). Based on geographic distribution and morphometric data of some specimens of this species from the Field Museum of Natural History, Shenbrot (2009) suggests that Allactaga firouzi and Allactaga hotsoni Thomas, 1920 have to be considered as conspecific and the Iranian jerboa should be accepted provisionally as a subspecies of A. hotsoni. However, according to the recent genetic and phylogenetic analyses there is a distinction between A. firouzi and A. hotsoni (Ghaderi et al. 2010). There is no available information on the ecology of this species except a recent study describing A. firouzi biological characteristics (Naderi et al. 2009).
This study shows that Iranian jerboa is active from 11:00 pm to 05:30 am from the early spring to late summer but in midsummer its active period is restricted from 9:00 pm to 4:00 am only. No individuals were observed after sunrise and before sunset. The active period of this species is much correlated with the moon rising time; so there were more individuals captured in complete darkness than after the rising of the moon. Aestivation has not been detected in the whole summer period of the field study and the hibernation started sometime late November and lasts to mid February. The breeding of this species usually occurs from April to May and the highest individual density is observed in late May. The Iranian jerboa is a good digger and runner, but it is not adapted to climbing or swimming. It digs long burrows on hard ground, using its incisors for breaking substrate, forelimbs for digging and collecting the soil under the body, hind feet for kicking the soil backward, and the snout for pushing and ramming the excavated soil. This jerboa species is well adapted to fast bipedal locomotion. The external characters of captured individuals of *A. firouzi* were also measured and were presented in Naderi *et al.* (2009; Table 1).

From direct observation and inspection of food residues found in wintering burrows by Naderi *et al.* (2009) and in present study, we have concluded that *Anabasis aphylla* L. and *Peganum harmala* L. foliage and seeds constitute the main feeding items of Iranian jerboa.

Jerroas use its burrows with a suitable microclimate as a safe refuge from predators and heat, for resting, rearing offspring, and for winter hibernation. Underground refuges, with their relatively stable microclimate, provide protection for small mammals from extreme temperatures prevailing on the surface of the desert habitats (Shenbrot *et al.* 2002). The common refuge type is the underground burrow, which usually varies in architecture from simple to complex structures (Hinze and Pillay 2006). Many rodent use burrow system such as *Dipodillus maghrebi* Schlitter and Setzer (Nel 1967), *Saccostomus campestris* Peters, (Ellison 1993), *A. hotsoni*, *Allactaga williamsi* Thomas, *Allactaga euphratica* Thomas (Çolak and Yiğit 1998) and *Meriones unguiculatus* Milne-Edwards (Scheibler *et al.* 2006). Simple burrows comprise of a single nest chamber and one or two entrance holes (Hinze and Pillay 2006). Whilst complex burrows comprise of several aboveground entrance holes joined with many interconnected tunnels below-ground (Mankin and Getz 1994). These complex systems may contain one or more nesting, hoarding and nursery chambers, or a combination of these structures. The complex systems may have other functions, such as providing shelter against predators, storing food items and gaining access to high-quality feeding sites through numerous entrance holes. Çolak and Yiğit (1998) identify four types of burrows for *Allactaga elater* Lichtenstein including temporary, summer, winter and reproduction burrows. The other important advantage of refuge is its use as a buffer for the animals against environmental extremeties of both temperature and humidity.

The studies on the habitat selection among rodents are rather numerous in the available literature (Rosenzweig 1974, 1981, Morris 1987); however there is no description of burrow sites or burrow site selection especially for *Allactaga* genus.

The information on small-mammal microhabitat utilization in burrow sites is based on straightforward standard methods usually by locating burrow stations where environmental variables are measured (*e.g.* Lachèr and Alho 1989). This technique poten-

---

**Table 1.** Measurements of external characters of *A. firouzi* (SD – Standard Deviation, N = 126 adults; after Naderi *et al.* 2009)

<table>
<thead>
<tr>
<th>Characters (mm)</th>
<th>Mean</th>
<th>Range</th>
<th>±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total length</td>
<td>309.15</td>
<td>269-350</td>
<td>12.97</td>
</tr>
<tr>
<td>Head and body length</td>
<td>117.74</td>
<td>101-129</td>
<td>8.09</td>
</tr>
<tr>
<td>Tail length</td>
<td>190.41</td>
<td>168-220</td>
<td>9.66</td>
</tr>
<tr>
<td>Hind foot</td>
<td>50.10</td>
<td>53-59</td>
<td>2.24</td>
</tr>
<tr>
<td>Ear</td>
<td>46.43</td>
<td>42-55</td>
<td>1.80</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>66.32</td>
<td>48-92</td>
<td>11.39</td>
</tr>
</tbody>
</table>
tially does not mask subtle patterns of habitat utilization, since one doesn’t need to see or capture animals and interrupt their normal activities. Rhodes and Richmond (1983) studied the influence of soil texture on nest site selection and burrowing activity by the pine vole (Microtus pinetorum Le Conte) and concluded that soil structural characteristics have strong effect on burrow site selection.

In order to elucidate the nest site selection of Iranian jerboa the underground life of this species has been investigated by 1) documenting the architecture and field characteristics of the burrow system of A. firouzi; 2) determining the effect of vegetation and soil conditions on the selection of burrow sites by this species.

2. STUDY AREA

The study was conducted from April 2007 to February 2009, in a small area of semi-arid steppe (2200 ha) located 20 km south of Shahreza, Iran (31°56’–31°43’N and 51°53’–52°02’E). The area has an altitude of about 2000 m a.s.l. and the climate which is markedly seasonal with a dry season between May and September (<10% of the annual precipitation). Also, the area has a mean annual precipitation of about 68 mm, and temperatures that vary between day and night and across seasons with mean monthly minima of 17.4°C and maxima of 38.0°C. The vegetation mainly constitutes shrub vegetation which cover ranges from 15 to 25%, and the canopy ranges from 5 to 25 cm in height. The vegetation types comprise different shrub species such as Anabasis aphylla, Artemisia siberi, Peganum harmala, Scariolla orientalis. The area is used by villagers as a grazing ground for domesticated sheep and goats. In the area, there is the Persian jerd (Meriones persicus) which is found in very low density and the predators such as common fox (Vulpes vulpes) and jackal (Canis aureous).

Based on dominant plant species, four major habitat types were identified in the study area namely, Anabasis type, Artemisia type, Peganum type and bare soil type.

3. METHODS

3.1 Structure of burrow systems

Fifteen burrows of Iranian jerboa were excavated in the study area during the study period. The burrows were carefully excavated by a spade and small shovel so as to maintain the original organization of the tunnels and the associated structures. The burrows studied were only those which were in use by the animals, namely the burrows that jerboas entered during the night (Shenbrot et al. 2002). The data on the length of tunnels, their junctions, chambers, and the maximum length of burrows, the depth of chambers below the ground, height, length, width and the position of chambers as well as the number of entrances were recorded and mapped (Fig. 1). All the measurements were made using a coil.
meter to the nearest 0.5 cm. Further burrow systems were not excavated, to minimize disturbance to the studied population.

3.2. Burrow site selection

The burrow densities were studied in four habitat types (see the Study area) via random transects. For identifying the burrows in the study area different methods were used including for example following the individuals in the late activity period at night, searching for unbound previous year burrows and looking for plugged soil with different colours and humidity from ambient soil. In each habitat type, the burrow numbers were counted in 36 random transects (transect length = 2 km). The microhabitat variables were measured in 66 burrow plots (presence) and the same number of the non-burrow plots (paired plots) (absence). The paired plots were selected randomly in about 500 meters away from the burrow plots (Naderi et al. 2009).

In each habitat type a 10 × 10 m square area surrounding the sampling points was plotted (e.g. burrows in burrow plots) and the following microhabitat variables were measured: BSC – bare soil percent, PEB – cover pebble cover, COB – cobble percent cover, AAC, PHC and ASC respectively for the percent cover of A. aphylla, P. harmala and A. siberi. The percentage of canopy cover at crown level was estimated with the aid of a squared hard paper frame (25 × 25 cm). The arithmetic mean of the measurements of each variable was considered as the variables for the burrow plots and the paired (non-burrow) plots. A one kg soil sample was taken from the centre of each plot for laboratory analysis of soil texture and of content of CaCO₃, CaSO₄, sand, pebble, silt and clay. Soil properties were studied independently of other mentioned microhabitats.

3.3. Data analysis

Structural differences in burrow systems and significant differences in burrow density was determined by ANOVA. A Two-way ANOVA was used to compare microhabitat variables between burrow and paired (non-burrow) plots across the whole study area with habitat type and the presence versus the absence of the burrows as fixed factors. The principal component analysis (PCA) was used to determine the most influential microhabitat variables (including BSC, AAC, ASC, PHC, PEB and COB) on the burrow site selection. To determine important microhabitat characteristics for burrow site selection within each habitat type, a paired t-test was used to compare microhabitat variables measured in burrow plots and paired (non-burrow) plots.

The 66 soil samples from the burrow presence plots were compared with the same number from the paired plots (non-burrow plots) by applying dependent t-student test. The SPSS 16.0 statistical package was used for statistical analysis.

4. RESULTS

4.1. Structure of burrow systems

The number of entrance holes in the excavated burrows ranged from one to nine per system and the number of tunnels ranged from 2 to 15, depending on the burrow system. The temporary burrow represents the simplest type which functions as an escape burrow (Fig. 1). These burrows have one nest chamber and a few (1–2) entrance holes per each burrow. The length of the system was smaller than in the summer or winter burrows. The summer burrows contained one nest chamber with a total length ranging from

<table>
<thead>
<tr>
<th>Feature</th>
<th>summer burrow (N = 5)</th>
<th>winter burrow (N = 5)</th>
<th>temporary burrow (N = 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (cm)</td>
<td>109 19.27</td>
<td>363.80 111.94</td>
<td>72.20 14.61</td>
</tr>
<tr>
<td>Number of entrance holes</td>
<td>2.60 0.54</td>
<td>5.20 1.30</td>
<td>1.20 0.44</td>
</tr>
<tr>
<td>Depth of nest chamber (cm)</td>
<td>59.60 8.29</td>
<td>84.20 9.03</td>
<td>41.20 9.78</td>
</tr>
<tr>
<td>Number of dead ends</td>
<td>0.71 0.91</td>
<td>2.61 1.35</td>
<td>0.54 0.25</td>
</tr>
</tbody>
</table>

Table 2. Mean (SD) values of physical characteristics of 15 burrow systems (Fig. 1) of A. firouzi.
Burrow site selection of Iranian jerboa

one to three meters. The length of the burrow may reach 4 ± 1.1 m, ending in a spherical nest chamber of 3.5 cm in diameter, and descending gradually to as deep as 23 cm without branching (Table 2). There was no stored food at the nest chamber, during the observation but dry stems and seeds of *A. aphylla* and *P. harmala* were found only in tunnels. This suggests that tunnel material may periodically be cleaned out and replaced with fresh material. This type of burrows was generally observed in the bare soil habitat type. Winter burrows contained a single nest chamber at various depths with the nest chambers had been dug deeper than both summer and temporary burrows (Fig. 1).

ANOVA showed that the mean length of tunnels in winter burrows is greater (*P* <0.001) than it is in others but there was no significant difference between the temporary and summer burrows (*P* = 0.6). The results show that the depth of nest chamber in winter burrows was deeper than the temporary and summer ones (*P* <0.001, *P* <0.05 respectively). Also there was a significant difference between summer and temporary burrow in the depth of nest chamber (*P* <0.05). The burrows of all three types were distributed at different distances (<1–30 m). The size of the nest chambers ranged from a minimum size of 10 × 8 × 15 cm to a maximum size of 17 × 14 × 15 cm.

### 4.2. Burrow site selection

The results showed that there are significant differences in burrow density between *Artemisia* type and the three other habitat types (bare soil, *Anabasis* and *Peganum*; ANOVA: *F* = 60.54, *P* <0.0; Fig. 2). The highest and lowest burrow densities were recorded in bare soil and in the *Artemisia* types respectively. Two-way ANOVA shows that the structural characteristics of the available microhabitats vary significantly between different habitat types (Table 3). Meanwhile Two-way ANOVA also shows that the effect of habitat was significant for all the habitat variables (*P* <0.002). In addition, the mean percentage cover of all the variables were sig-

<table>
<thead>
<tr>
<th>Presence/Absence Interaction</th>
<th>Habitat types Model Habitats</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Presence/Absence Interaction</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td></td>
</tr>
<tr>
<td>Presence/Absence Interaction</td>
<td>Habitat types Model Habitats</td>
</tr>
<tr>
<td>Bare soil</td>
<td></td>
</tr>
<tr>
<td>Anabasis</td>
<td></td>
</tr>
<tr>
<td>Peganum</td>
<td></td>
</tr>
<tr>
<td>Artemisia</td>
<td></td>
</tr>
</tbody>
</table>
| 0.759                       | <0.001                        | 172.62 0.011 3.841 <0.001 7.67 <0.001 60.072 Bare soil  
| 0.263                       | 0.002                         | 10.074 0.01 5.73 <0.001 7.74 <0.001 7.67 Anabasis  
| 0.244                       | 0.001                         | 5.753 0.12 1.24 <0.001 7.054 <0.001 7.038 Peganum  
| 0.14                        | 0.018                         | 18.593 <0.001 18.593 <0.001 12.25 <0.001 32.06 Artemisia  

### Fig. 2. Mean ± S.E. of Iranian jerboa burrow density in different habitat types dominated by: bare soil and plant species: *Anabasis aphylla*, *Peganum harmala*, *Artemisia siberi*.  

![Fig. 2. Mean ± S.E. of Iranian jerboa burrow density in different habitat types dominated by: bare soil and plant species: *Anabasis aphylla*, *Peganum harmala*, *Artemisia siberi*.](image_url)
significantly different between the burrow and the paired plots ($P < 0.02$).

The PCA analysis for microhabitat characteristics produced two components that together accounted for 51.6% of the variance. The first component (33.9% of the variance) was related positively to the percentage cover of bare ground and negatively related to percentage cover of $A. siberi$, and cobble and pebble contents in the soil. The second component (17.6 %) represents gradient from dominance by cobble to dominance by $A. aphylla$ (Fig. 3).

We detected significant differences among the measured microhabitats variables as determined by a paired t-test. Bare soil (BSC) ($t = 18.14; df = 65, P < 0.001$) and pebble (PEB) ($t = 16.58; df = 65, P < 0.001$) percentage cover are the most affecting variables in the selection of burrow sites so their percent cover in burrow plots were higher than in paired ones (Table 4). Two other variables ASC, and PHC indicated the least significant effect. On the other hand $A. aphylla$ and cobble percentage cover (i.e. AAC and COB respectively) showed no significant influence on the burrow site selection ($P > 0.005$). The T- test analysis affirmed that the burrow site selection was mainly influenced by soil properties since the CaCO$_3$ content was higher than in the sites selected for burrows from paired plots and CaSO$_4$ content were lower in burrow sites ($t = 35.69, P < 0.001$). The sand percentage cover was significantly different in the burrow plots as opposed to the non burrow plots ($t = 22.04, P < 0.001$) but there is no significant differences in silt, clay and pebble content between the burrow and the non- burrow plots (Fig. 4).


<table>
<thead>
<tr>
<th>Variables</th>
<th>Burrow Mean (SE)</th>
<th>Paired Mean (SE)</th>
<th>Paired t (df)</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSC</td>
<td>53.87 (1.8)</td>
<td>17.47 (0.9)</td>
<td>-18.14 (65)</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>COB</td>
<td>16.34 (1.3)</td>
<td>12.98 (0.8)</td>
<td>-1.93 (65)</td>
<td>0.057</td>
</tr>
<tr>
<td>PEB</td>
<td>3.18 (0.49)</td>
<td>27.5 (1.43)</td>
<td>16.58 (65)</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>AAC</td>
<td>10.28 (0.99)</td>
<td>18.77 (1.12)</td>
<td>6.25 (65)</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>ASC</td>
<td>3.71 (0.34)</td>
<td>7.2 (1.19)</td>
<td>2.76 (65)</td>
<td>0.007</td>
</tr>
<tr>
<td>PHC</td>
<td>5.45 (0.59)</td>
<td>2.77 (0.34)</td>
<td>-3.7 (65)</td>
<td>&lt;0.001***</td>
</tr>
</tbody>
</table>

Fig. 3. Mean values of Principal Component Analysis scores for microhabitats variables (left) and position of studied plots in respect to two PCs obtained by PCA analysis. Full and open circles show burrow presence and absence sites respectively. Percent cover of bare soil – BSC, of $A. aphylla$ – AAC, of pebble – PEB, of cobble – COB, of $A. siberi$ – ASC and of $P. harmala$ – PHC.
5. DISCUSSION

Iranian jerboa creates three separate types of burrow: temporary, summer and winter burrows. All of these burrows had a nest chamber but without feeding chamber and winter burrows had a larger surface area and were deeper. In general, the burrow system described by Çolak and Yiğit (1998) for *A. elater* was similar with the above described types of burrows except for the reproduction burrow. Scheibler *et al.* (2006) identify three types of burrow for Mongolian gerbil (*M. unguiculatus*) including summer, reproduction and winter burrows. The temporary burrows are plain tubes which are used to escape from predators during the night. This burrow was found to be similar with the temporary burrow system of *A. elater* but they are differed in their structures. No marked nest chamber was reported for temporary burrow of *A. elater* (Çolak and Yiğit 1998).

As Mankin and Getz (1994) reported that escape burrows, although slightly smaller than nesting burrows, had numerous (2–9) entrance holes to allow for a rapid entry or exit. There are however no reported data on the relationship between architecture of burrows and the social organization of *A. firouzi*. The summer burrows were observed to have a single nesting chamber and according to Çolak and Yiğit (1998) there are two types of summer burrows for *A. elater*: one had a lateral passage leading to the surface other than the main gallery and the second one was a burrow with a single exit.

We can say that, especially with regard to burrow site selection, Iranian jerboa is a microhabitat specialist and relies primarily on structural characteristics of its environment to select sites for burrow construction. Our results are in agreement with the general pattern described for most species of five-toed jerboas that use habitats which are characterized by hard soil and sparse vegetation (Shenbrot *et al.* 2008). There is no published information about burrow site selection of *Allactaga* species but some relatively similar findings for their habitat selection had been reported. For example, according to Brown (1980) *A. hotsoni* was caught in barren areas and there is a negative correlation between the percentage vegetation cover and the Hotson's Jerboa occurrence. He also found a significant correlation between the occurrence of *A. hotsoni* and the halophytic chenopod, *Seidlitzia rosamnus* Bunge. The investigation of habitat associations of *A. firouzi* (Naderi *et al.* 2009) showed that the overall pattern of habitat selection of this species is different from the pattern of burrow site selection. *A. firouzi* select *Anabasis* type for its activity out of the burrows but it selects bare and unvegetated areas for burrow construction. Our results are in agreement with other studies about the habitat selection of *A. hotsoni* (Brown 1980),

![Fig. 4. Percent content of different measured soil variables in burrow sites (punctuate bars) and non-burrow (paired) plots (white bars; standard deviation is given on the top of each bar).](image-url)
Pygerethmus pumilio Kerr (Shenbrot 1992, Shenbrot and Rogovin 1995) and Allactaga bullata Allen (Rogovin and Shenbrot 1995). The association of small rodents with vegetation variables that provide greater cover has also been shown in other studies ( Murúa and González 1982 and Shenbrot 2004). Our study is in agreement with this pattern, that the species seemed to prefer areas with highly uncovered than covered surfaces, which are probably related with the protection against the predators. Indeed the adaptation value of preferring bare soil cover most likely results from the possibility for better and faster entering to the burrows. Iranian Jerboa is also known to feed on A. aphylla plant matter (Naderi et al. 2009). Therefore, this species preferred locations with high food availability (Anabasis type) as well as enough uncovered soil especially in wintering burrows. As shown, microhabitat features are different in burrow sites from other parts of the habitat. As Simonetti (1989) reveals that food, predation, and microhabitat structure were the proximate factors shaping the selection of microhabitats. Selecting areas with relatively high CaCO₃ percentage in soil is necessary for the burrow stability which is presumed to be better in harder soil, as it is especially. In conclusion, we can say that some microhabitat variables such as the extent of the cover of A. aphylla and P. harmala (which are related to feeding grounds) and bare soils cover (which are related to anti-predator behaviour with regard to rapid escaping) are the most influential variables in habitat use by the Iranian jerboa.

ACKNOWLEDGMENTS: We would like to thank Dr Aliakbar Naderi who helped us in field work. We thank Dr Shenbrot, Dr Katakweba and Dr Hashim Mohammad for valuable comments on the earlier draft of the manuscript. Anonymous reviewer and Professor Anna Hillbricht-Ilkowska, editorial office of Polish Journal of Ecology provided useful comments.

6. REFERENCES


Received after revision July 2010