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Food Habits of the Great Gerbil (*Rhombomys opimus*) in the Southern Gurbantunggut Desert, Xinjiang, China

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Abstract.- We studied the diet of the great gerbil (*Rhombomys opimus*) on the southern edge of the Gurbantonggut desert, Xinjiang, China, for one year (2009 -2010) using fecal microscopic analysis. Our results demonstrated that this rodent consumed a long list of plant species, including 25 species belonging to 13 families. In spring, the major foods of the great gerbil were *Cares physodes* (45.21%) and *Erodium oxyrrhynchum* (15.25%). During summer, their ration consisted of *Corispermum* sp (28.16%), *Seriphidium santolinum* (17.98%), *Artemisia desertorum* (12.32%), *Ephedra przewalskii* (11.91%), and *Horaninowia ulicina* (10.29%). We found that *Haloxylon ammodendron* dominated their diet in autumn (81.53%) and winter (79.95%), but was eaten rarely during spring and summer. Analysis of the great gerbil's diet indicates a similarity rate as high as 0.99 between autumn and winter, whereas in other seasons, this index fluctuated between 0.23-0.28. Our investigations revealed that the great gerbils most often ate the dominant plant species near their burrows, and their diet varied according to the changes of these species and coincided with the variations in the plants' phenology, as well.

Key words: Great gerbil (*Rhombomys opimus*), fecal microscopic analysis, diet, similarity index analysis.

INTRODUCTION

Food is a vital source of nutrition and energy for an animal's living and breeding, and the quality and quantity of the fodder are the basic factors that influence the entire lives of all herbivorous species. The foraging activity is a key point of ecology and behavior of any animal. Therefore, the food selection by herbivorous animals is the most active field of investigation and analyses in foraging and behavioural ecology (Bilenea *et a1*., 1992; Cassin, 1994; Lawler and Stapley, 1998). Foraging behaviour varies according to the changes in habitat, and this is a crucial point of their adaption to their environment (Shang, 1998).

The great gerbil (*Rhombomys opimus*) belongs to the order Rodentia, family Muridae, and subfamily Gerbillinae. It is widespread on the Asian continent (Zhao *et al.*, 2001), and eat *Haloxylon ammodendron*, *Tamarix* sp. etc. (Dai *et al.*, 1999). To some extent, the great gerbil's activities, such as digging holes and foraging, improve the conditions of the water and the fertility of the soil, which in turn, are helpful for the growth of microorganisms, especially fungus. The great gerbil's vital activity promotes the plant biodiversity of herbaceous species in arid areas, and leads to the suppression of the sub-shrub cover (Jiang *et al.*, 2007; Yang *et al.*, 2006, 2009).

Many researchers have focused their investigations of the great gerbil on the topics of habitat, foraging, food storage, vigilance, territory, community, dispersion and diurnal activity rhythms (Zhao, 1981; Dai *et al.*, 1999; Mokrousov, 1978; Randall *et al.*, 2000; Burdelov *et al.*, 1964). Reports of their diet have been quite general in content: The great gerbil has a preferrence for eating stems, leaves and branches of *Haloxylon ammodendron*, *Tamarix sp*, *Callingonum* spp., *Caragana* spp., *Salsola* spp., *Reaumuria soongonica*, *Anabasis* spp., and *Nitraria* spp. etc, and the annual branches of *Haloxylon ammodendron* are their most favorite food source (Zhang *et al.*, 2001; Ma *et al.*, 1987; Wang and Yang, 1983; Zhao *et al.*, 2000, 2001). All of these previous studies have reported that

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Haloxylon ammodendron is the great gerbil's major food source in all seasons. However, the role and importance of other plant species in the great gerbil's diet remained undefined. Additionally, these earlier studies focused mostly on the general content of the diet, with a list of descriptions of the plant species, while the quantitative analysis of the seasonal changes in the great gerbil's food has been lacking until now. No study has investigated thus far if the content of their rations vary with seasons, or if *Haloxylon ammodendron*, which has the highest biomass and is the most important plant species in the arid desert, is the major food source for the great gerbil all year round.

In this study, we used the fecal analysis method for a quantitative investigation into the great gerbil's seasonal diet and its changes. Our results will be helpful for further understanding of the inter-species relationship between the great gerbil and *Haloxylon ammodendron*, which is the the "dominant species" in our study area.

MATERIALS AND METHODS

Study area

The Gurbantunggut Desert is situated in the central region of Junggar Basin in northern Xinjiang China, and is the largest desert of fixed and semi-fixed sands. Here, the average annual rainfall is 150 mm, the annual potential evapotranspiration rate is above 2000 mm, and the annual average temperature fluctuates between 6 and 10°C (Zhang *et al.*, 2005). Our study area lies along the southern edge of the Gurbantunggut Desert (44°31′N-44°33′E, 88°5′N-88°7′E). Here, the vegetation coverage varies between 15% and 50%. *Haloxylon ammodendron*, which is the dominant species, occurs in the middle and upper parts of the dunes. Burrows of the great gerbil are located in the lowlands, among the middle to lower parts of the dunes. The vegetation consists of dwarf shrubs, such as *Ephedra sp*, *Seriphidium santolinum*, and *Callingonum* spp., and perennial herbs including *Lithospermum sp*, *Artemisia desertorum*, and *Carex physodes*. The biological soil crust develops well under the vegetation. Water from snow melt and rainfall promotes the growth of the ephemeral and ephemeroid plants, such as *Erodium oxyrrhynchum*, *Lappula* sp, *Nonea caspica*, *Tragopogon sabulosus*, *Eremurus* sp and *Erysimum cheiranthoides* (Yang *et al.*, 2009).

Dung and referential vegetation collection

Field work was conducted in September of 2009 (autumn), January of 2010 (winter), May of 2010 (spring), and July of 2010 (summer). We did field focal observations of individual animals and recorded all plant species eaten by the great gerbil. In addition, we collected great gerbil pellets for a quantitative investigation of the diet using the fecal analysis method (Stewart, 1967; Johnson, 1982). We selected 15 burrows of the great gerbil with obvious life signs and collected fresh excrement randomly around these burrows for each season. At the same time, we collected all vegetation species in the study area. The collected pellet and vegetation samples were analyzed in the laboratory.

Pellet slide creation

In this study, the pellet samples were oven dried at 60 ℃ for 24 hours, then smashed and mixed in a blender. An appropriate amount of the mixture was put in a beaker, along with a saltpeter solution with a density of 20%, and was heated for 2-3 min in hot water. Then the mixture was set in a stationary status after distilled water was added, and the upper liquid was discarded. Finally, the mixture was colored with a safranine for 10-30 min, and dehydrated by using an alcohol solution with a different density. Xylene was used for making the slide (Williams, 1969; Stevens *et a1.*, 1987).

Referential vegetation slide creation

The standard microscope slides of the referential vegetation were made from collected plant samples from the study area. The collected plant samples were trimmed, then put in a beaker with a round bottom, along with a 50 ml saltpeter solution with a density of 10%, and boiled for 3 min to make the epidermis separate and float. When the epidermis and the mesophyll were separated, the saltpeter solution was discarded, and distilled water and an appropriate amount of ammonia were added, then the upper liquid was eliminated and the residual matter was colored with a safranine for 10-

30 min. Finally, the residual matter was dehydrated by using an alcohol solution of a different concentration. Xylene was used for making the slide (Williams, 1969; Stevens *et a1.*, 1987).

Microscopic examination of fecal slide

We used the frequency conversion method for microscopic examination. Twenty microscopic fields per slide were chosen randomly and examined at 10×10 magnification under an Olympus digital microscope (DP70). Plant fractions on the fields were recognized with a reference to the vegetation slides and recorded in terms of species. The identification of the fragments was based on the different features and dimensions of the epidermal cells, and other valuable taxonomical structures (*e.g.* trichomes, stomata form). All identifications were conducted by the same person to reduce inconsistencies due to observer bias.

The present frequency of each type of plant was calculated (F□the frequency of plant in 100 microscopic fields), and then converted into average density of each type of plant in each field (D) by using the following equation,

$$F=100(1-e^{-D})$$

and then D was converted to RD by the following equation,

$$RD = (D_i / \sum D_i) \times 100\%$$

Subsequently, the relative density (RD) of each plant species in the diet of the great gerbil was calculated (Johnson, 1982).

Similarity index of the diet content over seasons

Similarity index analysis was used for comparing the seasonal diet content according to Horn's methodology (1966):

$$R_0=\frac{[\Sigma(x_i+y_i)\ln(x_i+y_i)-\Sigma(x_i\ln x_i)-\Sigma(y_i\ln y_i)]}{[(X+Y)\ln(X+Y)-X\ln X-Y\ln Y]}$$

In which x_i is the percentage of RD of a plant in a season, y_i is the percentage of RD of the plant in other seasons, $X=\Sigma x_i, Y=\Sigma y_i$.

RESULTS

Changing of the diet content over seasons

In our study area, we collected 38 plant species from 16 families found around the observed burrows, and from these, the great gerbil ate 25 species of 13 families according to our field observations and laboratory analyses. In terms of plant families, species from Chenopodiaceae, Cyperaceae and Compositae were preferred by the great gerbil as their major food source in any season. Plants from Chenopodiacae were eaten in autumn (82.63%) and winter (80.74%), which was higher than in spring and summer. Plants from Cyperaceae were preferred in spring (45.21%); and Compositae plants were eaten most often in summer (30.41%). Boraginaceae and Geraniaceae were noted in spring, with a higher portion compared to any other season (11.09% and 15.25%, respectively). Cruciferae, Liliaceae, Apiaceae, and Euphorbiaceae were eaten only during spring (Table I).

So, the great gerbil had a considerably different diet throughout the seasons. In spring, 18 plant species were eaten, and most, the ephemeral species *Carex physodes, Erodium oxyrrhynchum*. *Soranthus meyeri*, *Allium pallasii*, and *Erysimum cheiranthoides* etc., were eaten only in spring. In summer, the food of the great gerbil was limited to 14 plant species. Among them *Corispermum sp*, *Seriphidium santolinum*, *Artemisia desertorum* and *Horaninowia ulicina* were the primary food sources, with *Horaninowia ulicina* and *Salsola paulsenii* noted in the diet only in summer. In autumn and winter, their food included mainly plants of the dominant species, such as *Haloxylon ammodendron* and *Ephedra przewalskii*, while the percentages of *Artemisia desertorum* and *Seriphidium santolinum* were gradually decreased from the summer amounts. The portion of *Haloxylon ammodendron* decreased sharply in spring, and was rarely noted in the diet in summer. *Ephedra przewalskii* was eaten in any season, though its percentage varied slightly over seasons because of its evergreen characteristics. *Haloxylon ammodendron* was a distinctly major food for the great gerbil during autumn and winter, because this species was more available than any others during these seasons, and therefore provided a higher quantity as a food source (Table I).

Table I.- The role of different plant species in the great gerbil diet.

Plant species	Relative density RD			
	Spring	Summer	Autumn	Winter
Cruciferae	**0.37**	-	-	-
Erysimum cheiranthoides	0.37	-	-	-
Liliaceae	**1.32**	-	-	-
Eremurus sp	1.13	-	-	-
Allium pallasii	0.19	-	-	-
Euphorbiaceae	**0.09**	-	-	-
Euphorbia turczaninowii	0.09	-	-	-
Graminae	**8.23**	-	**1.47**	**0.44**
Stipagrostis pennata	-	-	1.47	0.44
Stipa glareosa	8.23	-	-	-
Cyperaceae	**45.21**	**8.33**	**0.43**	**0.19**
Carex physodes	45.21	8.33	0.43	0.19
Compositae	**5.47**	**30.41**	**7.83**	**11.40**
Artemisia desertorum	-	12.32	5.21	6.73
Seriphidium santolinum	-	17.98	2.62	4.67
Echinops gmelinii	0.19	0.11	-	-
Tragopogon sabulosus	5.28	-	-	-
Chenopodiaceae	**6.82**	**44.25**	**82.63**	**80.74**
Haloxylon ammodendron	5.69	-	81.53	79.95
Ceratocarpus arenarius	0.28	0.11	1.10	0.78
Corispermum sp.	-	28.16	-	-
Horaninowia ulicina	-	10.29	-	-
Salsola paulsenii	-	5.58	-	-
Agriophyllum squarrosum	0.85	0.11	-	-
Polygonaceae	**0.47**	**1.34**	**0.29**	**1.39**
Calligonum mongolicum	0.47	1.34	0.29	1.39
Ephedraceae	**5.49**	**11.91**	**7.13**	**5.74**
Ephedra przewalskii	5.49	11.91	7.13	5.74
Geraniaceae	**15.25**	**0.11**	-	-
Erodium oxyrrhynchum	15.25	0.11	-	-
Apiaceae	**0.19**	-	-	-
Soranthus meyeri	0.19	-	-	-
Caryophyllaceae	-	**3.54**	-	-
Silene olgiana	-	3.54	-	-
Boraginaceae	**11.09**	**0.11**	-	-
Arnebia guttata	0.19	-	-	-
Lappula sp.	6.74	-	-	-
Nonea caspica	4.16	0.11	-	-

Table II.- The similarity coefficient analysis for great gerbil's diet spectrum.

	Summer	Autumn	Winter
Spring	0.27	0.24	0.23
Summer		0.25	0.28
Autumn			0.99

Similarity index of diet content over seasons

The diet of the great gerbil had an extremely high similarity between autumn and winter, when this comparative index rose to 0.99. However, this index was quite low between other seasons, when it varied between 0.23 and 0.28 (Table II).

DISCUSSION

Our results demonstrated that the diet of the great gerbil is quite abundant, and varies considerably with seasons. This is significantly different from the information reported by Zhao *et al.* (2005) from Inner Mongolia (China), where it was found that the major diet of the great gerbil in all seasons consisted only of epidermis and dry and green twigs from species *Kalidium* spp., *Nitraria* spp. and *Atriplex* sp. (Zhao *et al.*, 2000, 2001, 2005). The main cause for this difference in our results is that we studied the diet of the great gerbil in both fixed and semi-fixed sand desert areas, where it is impossible to find some halophytes species, such as *Tamarix* sp., *Nitraria* spp. and *Kalidium* spp. We believe that the great gerbil eats a very wide range of plant species. Their diet is determined by the plant composition in their environment; and it is, therefore, this difference in plant associations of the various habitats that resulted in the significant difference in the great gerbil's diet content, compared with that from Inner Mongolia.

The diet of herbivorous mammals is closely related to the exploitable amount of food resources in their habitat (Batali, 1985), and also has an influence on the seasonal diet of the great gerbil. In spring, ephemeral plants such as *Carex physodes* grew well with a density of 12.28 ind. m^{-2} (Yang *et al*., 2009), and became the major food resource for the great gerbil's diet in the habitat (Table I). Yang *et al.* (2009) reported that the density of *Carex physode*n at burrow sites (5.99 ind. m^{-2}) was significantly lower from that at randomly selected sites, indicating the feeding activity of this rodent can change the features of a plant community considerably. The major food species of the great gerbil in summer were: *Corispermum* sp, *Seriphidium santolinum*, and *Artemisia desertorum* (Table I). These plants were preferred because they were in good condition and had the greatest biomass. In autumn and winter, *Haloxylon ammodendron* was a major food of the great gerbil (Table I), because most herbaceous plants withered during autumn and shrubs were dormant. As a tree, *Haloxylon ammodendron* was much more abundant than any other shrubs in the study area. Therefore, *Haloxylon ammodendron*, even when withered, made up

81.53% of the whole diet content during autumn. Also, the great gerbil stored branches of *Haloxylon ammodendron* in their burrows in autumn and ate them in winter. As a result, this species also occupied 79.95% of the food of the great gerbil and rarely went out of burrows in winter (Table I). The percentage of *Ephedra przewalskii* in the great gerbil's diet was relatively stable across all seasons due to its evergreen nature, providing the same constant nutritional content irrespective of season. Therefore, *Ephedra przewalskii* was a valuable element of the diet in all seasons and was eaten fairly steadily year round (5.49% to11.91%) (Table I). At the end of winter and into early spring, the great gerbil was forced to feed on the green skin of *Ephedra przewalskii*. This part of *Ephedra przewalskii* has a bad forage palatability and is slightly toxic (Yin *et al.*, 2004), which is why this plant is eaten only in small amounts all year round. In the southern Gurbantunggut desert, ephemeral plants were the dominant species in spring, and annual plants and shrubs were the major plants in summer; in autumn and winter, withered perennial arbors and shrubs were the main plants (Zhang and Chen, 2002). Any seasonal differences in plant abundance lead directly to changes in the great gerbil's diet. The similarity index for their seasonal diet also demonstrated that the diet of the great gerbil changed considerably during the vegetation growth period (spring and summer), and was almost unchanged during autumn and winter (Table II).

It was already well known that the great gerbil ate a lot of *Haloxylon ammodendron* (Zhang *et al.*, 2001; Ma *et al.*, 1987; Wang and Yang, 1983; Zhao *et al.*, 2000, 2001). In contrast to previous studies, our results showed that the great gerbil did not eat *Haloxylon ammodendron* during summer (Table I). A possible reason for this is the higher risk from predators. When animals trade off between predator attack risk and food, they generally select safety from carnivores (Shang, 2005). Due to the great gerbil's need to leave the ground and climb to the higher branches for foraging *Haloxylon ammodendron*, the time needed to escape from predators (mostly birds of prey in our study area), as well as the general prey risk, increased considerably. Therefore, the great gerbils preferred to stay on the ground and eat the herbs and shrubs found there. Moreover, they always ate near their burrows to decrease their predation risk (Randall *et al.*, 2000). In our study area, *Haloxylon ammodendron* was located mostly in the middle and upper parts of the dunes, whereas the burrows were situated mostly in the middle and lower parts of the dunes. Therefore, there was a large distance (on average 15.5 m) between the burrows and the *Haloxylon ammodendron*, and foraging for this species would have lead to a much higher predation risk. During the spring and summer seasons when food resources were abundant on the ground and herbs (*Corispermum* sp., *Horaninowia ulicina* etc.) grew well, the great gerbil was satisfied with the vegetation that was available there. So the predatrion risk was a key factor in the lower consumption of *Haloxylon ammodendron* during spring and summer.

During this study we clarified the following findings: (1) The diet of the great gerbil is not fixed but varies considerably between different regions. The most abundant plant species became the major food source in a specific area; (2) Seasonal variations of the great gerbil diet are connected mostly to the seasonal changes of phenology of the plants and their abundance in the habitat; and (3) The great gerbil eats *Haloxylon ammodendron* mostly during autumn and winter and rarely in spring or summer in order to decrease the risk of predation.

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