Turkish Journal of Zoology
http://journals.tubitak.gov.tr/zoology/
Research Article

Turk J Zool
(2017) 41: 924-930
© TÜBİTAK
doi:10.3906/zoo-1509-9

Food patch particularity and forging strategy of reintroduced Przewalski's horse in North Xinjiang, China

Zang SEN[1], Cao QING[2], Alimujiang KEREMU[1], Liu SHANHUI[1], Zhang YONGJUN[1], Hu DEFU[1,*]
[1]Laboratory of Noninvasive Research Technology for Endangered Species, College of Nature Conservation, Beijing Forestry University, Beijing, P.R. China
[2]Department of Ecology and Evolutionary Biology, Princeton University, Princeton, New Jersey, USA

Received: 16.09.2015 • **Accepted/Published Online:** 20.04.2017 • **Final Version:** 28.09.2017

Abstract: In 2001, Przewalski's horse (*Equus przewalskii*) was reintroduced into a Eurasian desert–steppe transitional area in China. Recent studies of Przewalski's horse have not examined the relationship between food patches and the horse's feeding choice behavior. This study aimed to study the vegetation communities of the reintroduction area and combine this information with feeding time data to explore the foraging strategy of Przewalski's horse. A total of 588 vegetation patches were surveyed, which were divided into 27 vegetation clusters. All vegetation clusters could be divided into feeding clusters, which constituted 59.23% of the study area, and nonforaging clusters, which constituted 11.14%. The remaining 29.63% was bare ground. Based on the degree of use by Przewalski's horse, the vegetation clusters can be divided into high-, medium-, and poor-utilization groups. Among these, the average foraging time per unit area of the high-utilization group was 1.59 times that of the medium-utilization group and 23.68 times that of the poor-utilization group. Based on the results, we can conclude that in desert grassland with low primary productivity, the feeding strategy of Przewalski's horse is first to satisfy its energy demands and then its demand for quality food.

Key words: *Equus przewalskii*, releasing site, food patches, TWINSPAN method, feeding habit, foraging strategy

1. Introduction

Przewalski's horse is the only existing real wild horse in the world (Mohr, 1971; Bouman, 1994). Its wild populations went extinct in China and Mongolia in the mid-20th century (Boyd and Houpt, 1994). In 2001, the wild horse was reintroduced into the Kalamaili Mountain Ungulate Nature Reserve in China, in a Eurasian desert–steppe transitional area. The vegetation of the reintroduction area has high spatial heterogeneity and shows mosaicism at different scales (Chu et al., 2008). The search efficiency and feeding costs of animals are influenced by plant distribution patterns, which thereby affect the feeding behavior of animals (Dumont et al., 2000; Hester et al., 2001; Hassall et al., 2002; Chapman et al., 2007). Recent studies of Przewalski's horse have focused on dietary analysis (Meng, 2007; Chen, 2008), habitat selection, and foraging behavior (King, 2002; Wang, 2004; Liu, 2013), but have not examined the relationship between food patches and the horse's feeding choice behavior.

Ecologists' research has been focused on patch-scale spatial heterogeneity (Wiens and Kotliar, 1990); animal feeding response to patchy food resources (Wallis and Daleboudt, 1994; Hudson et al., 1995); the impact of patch size, mass, density, height, biomass, etc. on animal feeding selection (Wang et al., 1990); the foraging strategy of herbivores to highly heterogeneous food resources (Li et al., 2003; Searle et al., 2005); and the ecological and evolutionary significance of herbivores' foraging behavior (Knegt et al., 2007). Clearly, suitable patch division for the target species, which reflects the animal's selection of resource patches, is an important prerequisite for research. In this study, we explore the foraging strategy of Przewalski's horse by employing the TWINSPAN method to study the vegetation communities of the reintroduction area and we combine this information with feeding performance data to evaluate the area's food resources, which are key to the wild horse's feeding ecology. This study will benefit conservation efforts by describing the adaptation of Przewalski's horses to the reintroduction area and providing a scientific basis for the eventual establishment of self-sustaining wild populations.

2. Materials and methods

The Kalamaili Mountain Ungulate Nature Reserve (KNR) is located in the eastern Junggar Basin, Xinjiang, China, and covers an area of 18,000 km^2. The main land forms are low

* Correspondence: hudf@bjfu.edu.cn

mountains, hills, and plains; the main surface substrates are loessial, sandy, and Gobi deserts; the elevation is 600–1464 m. The climate is the typical temperate continental arid type: the annual precipitation is only about 180 mm, but evaporation is as high as ≥2000 mm. Vegetation is sparse and uneven, mainly composed of superxeric or xeric shrubs, semishrubs, xeric annual and perennial herbs, and ephemeral plants. Dominant plants include *Ceratoides latens*, *Anabasis* spp., *Artemisia* spp., *Stipa glareosa*, and *Reaumuria soongorica*. The main ungulates are *Equus hemionus* and *Gazella subgutturosa* (Ge et al., 2003). The reintroduction site of Przewalski's horse is in the center of the protected area, where reintroduced groups of the horse roam freely and where the study was conducted in the summer (Figure 1).

In July to August 2013, we selected the main area of Przewalski's horse activity for the study. It has an area of 103.18 km^2, a north–south extent of 7.7 km, and an east–west extent of 13.4 km. According to the latitude and longitude, we set transect lines at intervals of 1 km, with 5 lines running east–west and 13 lines north–south. Personnel traveled along these lines on a motorcycle at low speed and observed the vegetation patches, stopping and recording GPS coordinates at points where the vegetation changed. Five equidistant quadrats of 1 × 1 m^2 within the vegetation patch were established, in which we measured and recorded the type, quantity, height, and cover of plants for each sample square. In total, 588 vegetation patches were measured. Observers tracked and kept a certain distance from the group of Przewalski's horses, usually >50 m, and did not interfere with their normal feeding activity. Binoculars were used to observe the horses' feeding behavior. Feeding times, feeding sites (GPS points), and vegetation characteristics were recorded immediately upon the horses leaving the site.

The following formulas were used to calculate the relative density, relative height, and relative coverage of each plant species within the quadrants:

$RD_i = (D_i / \Sigma D_i) \times 100\%$;

$RH_i = (H_i / \Sigma H_i) \times 100\%$;

$RC_i = (C_i / \Sigma C_i) \times 100\%$.

RD_i, RH_i, and RC_i are relative density, relative height, and relative coverage; D_i, H_i, and C_i are average density, average height, and average coverage of species i.

The importance value (IV) is calculated using the following formula for each plant:

$IV = 1/3(RD_i + RH_i + RC_i)$.

We calculated and recorded the length of occupation of each patch for each sample line according to the GPS coordinates of the vegetation patch boundaries using Garmin Base Camp software.

Data were processed using Excel and SPSS, and the importance value of each species was employed as an indicator. WINSPAN software (Hill and Šmilauer, 2005) was used to define and classify the vegetation patches into groups. The lengths of vegetation patches within each group were added, and we then obtained the lengths of the sample lines for each group. The following formula was used to calculate the area of each group:

$S_i = (l_i / \Sigma l_i) \times 103.18\ km^2$.

S_i is the area of group i; l_i is the length of group i.

The foraging times were divided by the areas of the corresponding groups to calculate the feeding time per unit area for each group. Univariate analysis of variance and multiple comparisons were then used to analyze the feeding time per unit area.

3. Results

3.1. Clustering and categorization of vegetation patches

A total of 29 species of plants were recorded in the surveyed 588 vegetation patches. The importance values of various

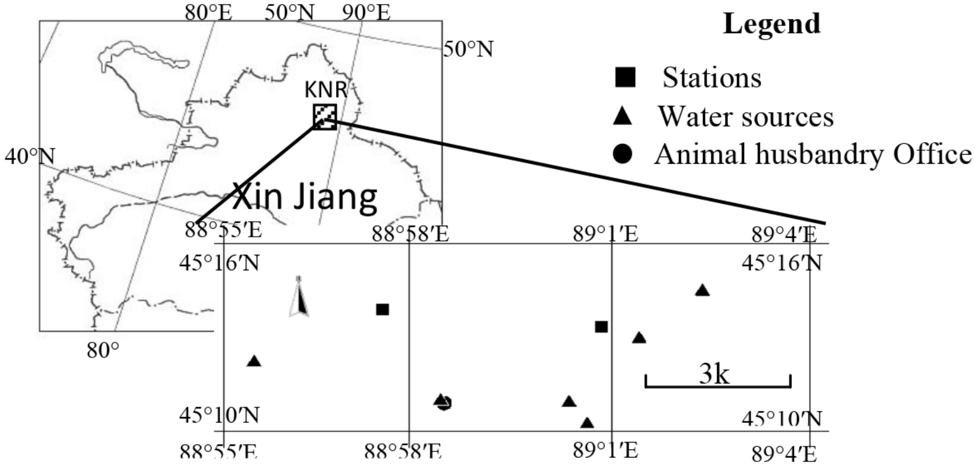

Figure 1. Study area.

plants are shown in Table 1. These were calculated by WinTWINS software, except for *Iris tenuifolin*, *Achnatherum inebrians*, *Eremosparton songoricum*, *Astragalus iliensis*, etc., of which there were few plants. In all, 21 kinds of plants are useful as indicator species reflecting the characteristics of the vegetation patches. All species of *Artemisia* were sorted as *Artemisia*.

According to the importance values of the indicator plant species, 588 vegetation patches were clustered into 46 groups by use of TWINSPAN, based on the *Flora of China* (Wu and Peter, 2012) classification principles and systems. Combining these with the analysis of vegetation patches, we used the sixth grade level to get 27 clusters. The characteristics of the vegetation patches after clustering are shown in Table 2.

After clustering, an importance value of ≥10 means that the plant species are dominant species in the group and also constructive species and major associated species for each group.

Among the clusters, there were 4 of an area larger than 4 km^2 (G9, G10, G11, and G12), 9 of an area greater than 1 km^2 and less than 4 km^2 (G5, G8, G13, G14, G17, G18, G19, G20, and G22), and 14 of an area less than 1 km^2 (G1, G2, G3, G4, G6, G7, G15, G16, G21, G23, G24, G25, G26, and G27). G11 had the greatest area (22.26 km^2) and G6 had the smallest (0.11 km^2). An area of 30.43 km^2 was bare of vegetation.

3.2. Foraging time per unit area

We observed 76 feeding bouts, totaling 1600 min. The GPS coordinates of the feeding sites, vegetation characteristics, and cumulative foraging times were used to calculate corresponding feeding times for each feed patch cluster. G4, G9, G10, G11, G12, G13, G14, G17, G18, G19, and G20 had corresponding feeding times—that is, they were feed clusters—and together accounted for 59.23% of the total area, while G1, G2, G3, G5, G6, G7, G8, G15, G16, G21, G22, G23, G24, G25, G26, and G27 did not have corresponding feeding times, hence were nonforaging clusters, and accounted for 11.14% of the total area. The rest, 29.63%, was bare ground. Among the ratios of feeding time to group unit area, G4 had the highest, 9.26 ± 1.54 min/km^2, and G9 had the lowest, 2.80 ± 0.49 min/km^2 (Figure 2).

Taking the square root of the time data ($P = 0.146 > 0.05$) indicates the homogeneity of variance. Univariate analysis of variance revealed $F = 13.515 > F_{crit} = 2.098$, so the data among the groups were significantly different. Duncan multiple comparisons of feed patches are shown in Table 3. G4 with 10 other groups was significantly different while among G9, G14, G19, and G20, there was no significant difference; however, G9, G14, and the other 7 groups were significantly different. Among G11, G12, and G13, the difference was not significant, but G12 differed significantly from the other 7 groups.

Table 1. The average importance values of various plants and indicator species.

Species	Average importance value	Indicator species	Species	Average importance value	Indicator species
Stipa glareosa	15.48	Y	*Eremosparton songoricum*	0.06	N
Ceratoides latens	11.98	Y	*Salsola ruthenica*	0.24	Y
Artemisia Linn.	17.20	Y	*Ceratocarpus arenarius*	0.29	Y
Goniolimon speciosum	2.52	Y	*Agriophyllum squarrosum*	0.23	N
Convolvulus tragacanthoides	4.31	Y	*Phragmites australis*	0.17	Y
Ephedra distachya	2.78	Y	*Caragana sinica*	0.28	Y
Kochiaprostrata (L.) Schrad.	0.68	Y	*Iris tenuifolia*	0.05	Y
Nitraria tangutorum	0.30	Y	*Ephedra equisetina* Bge.	0.07	N
Echinopsilon divaricatum	0.98	Y	*Tamarix chinensis* Lour.	0.30	Y
Haloxylon ammodendron	1.90	Y	*Halostachys caspica*	0.13	N
Allium mongolicum	0.97	Y	*Astragalus membranaceus*	0.04	Y
Calligonum arborescens	0.35	Y	*Achnatherum inebrians*	0.10	N
Reaumuria soongorica	1.71	Y	*Zygophyllum xanthoxylum*	0.05	N
Anabasis elatior Schischk	6.59	Y	*Kalidium foliatum*	0.01	N
Salsola sinkiangensis	0.40	N			

Table 2. The main features of vegetation patches after clustering (area unit: km^2; gross density unit: strains/m^2; gross coverage unit: %).

No.	Area	Total density	Total coverage	IV ≥ 10 (being listed in decreasing sequence of importance value)
G1	0.38	3–39	52.6–93.8	*Tamarix chinensis* Lour., *Reaumuria soongorica*, *Anabasis* Linn.
G2	0.53	16–21	56.3–63.5	*Haloxylon ammodendron*, *Ceratoides latens*
G3	0.96	4–22	23.8–40.3	*Anabasis* Linn., *Reaumuria soongorica*
G4	0.43	15–19	28.2–38.7	*Stipa glareosa*, *Reaumuria soongorica*, *Anabasis* Linn.
G5	1.03	4–27	10.9–42.2	*Haloxylon ammodendron*, *Reaumuria soongorica*, *Ceratoides latens*
G6	0.11	6–43	14.9–46.9	*Tamarix chinensis* Lour., *Haloxylon ammodendron*, *Agriophyllum squarrosum*, *Reaumuria soongorica*
G7	0.16	14–16	17.8–47.8	*Artemisia* Linn., *Haloxylon ammodendron*, *Reaumuria soongorica*, *Ephedra distachya*
G8	1.36	9–33	32.9–48.4	*Haloxylon ammodendron*, *Ceratoides latens*, *Stipa glareosa*
G9	9.44	6–28	23.0–45.6	*Artemisia* Linn., *Anabasis* spp., *Stipa glareosa*, *Convolvulus tragacanthoides*, *Ceratoides latens*
G10	5.83	8–37	16.9–43.9	*Artemisia* Linn., *Anabasis* spp., *Stipa glareosa*, *Reaumuria soongorica*, *Ceratoides latens*
G11	22.26	6–43	18.5–49.7	*Stipa glareosa*, *Artemisia* Linn., *Ceratoides latens*, *Anabasis* spp.
G12	9.56	6–40	15.1–42.4	*Artemisia* Linn., *Ceratoides latens*, *Stipa glareosa*
G13	3.45	9–31	14.3–41.0	*Artemisia* Linn., *Stipa glareosa*, *Convolvulus tragacanthoides*, *Ephedra distachya*
G14	1.50	12–31	19.5–41.7	*Convolvulus tragacanthoides*, *Stipa glareosa*, *Ceratoides latens*, *Artemisia* Linn.
G15	0.61	9–14	16.0–48.7	*Anabasis* Linn., *Convolvulus tragacanthoides*, *Stipa glareosa*
G16	0.61	19–61	18.6–41.0	*Stipa glareosa*, *Goniolimon speciosum*, *Artemisia* Linn., *Convolvulus tragacanthoides*
G17	1.92	7–29	16.6–43.3	*Ceratoides latens*, *Artemisia* Linn., *Stipa glareosa*, *Echinopsilon divaricatum*, *Goniolimon speciosum*
G18	1.54	8–18	17.8–58.0	*Ceratoides latens*, *Artemisia* Linn., *Stipa glareosa*, *Allium mongolicum*
G19	1.32	11–34	24.8–56.5	*Ephedra distachya*, *Haloxylon ammodendron*, *Stipa glareosa*, *Artemisia* Linn.
G20	3.51	8–29	16.4–48.3	*Artemisia* Linn., *Ephedra distachya*, *Ceratoides latens*, *Stipa glareosa*
G21	0.78	8–27	14.1–47.7	*Goniolimon speciosum*, *Stipa glareosa*, *Artemisia* Linn.
G22	1.75	8–27	22.3–51.7	*Goniolimon speciosum*, *Ephedra distachya*, *Artemisia* Linn., *Stipa glareosa*
G23	0.52	11–20	27.3–53.1	*Haloxylon ammodendron*, *Goniolimon speciosum*, *Ephedra distachya*
G24	0.76	8–18	23.8–56.8	*Goniolimon speciosum*, *Ephedra distachya*, *Haloxylon ammodendron*, *Ceratoides latens*
G25	0.29	12–13	26.7–39.3	*Goniolimon speciosum*, *Stipa glareosa*, *Kochiaprostrata* (L.) Schrad., *Haloxylon ammodendron*
G26	0.92	15–20	27.5–35.3	*Kochiaprostrata* (L.) Schrad., *Ephedra distachya*, *Stipa glareosa*, *Goniolimon speciosum*
G27	0.72	10–30	35.4–73.0	*Goniolimon speciosum*, *Phragmites australis*, *Ephedra distachya*

3.3. Quality of vegetation patches

Based on the foraging times per unit area of the vegetation patches (including the patches in which the horses did not feed, for which the foraging times per unit area was 0), 27 patch clusters were divided into 3 groups through use of the hierarchical clustering method: the longer feeding-time patch group (high-utilization patches), with feeding time per unit area of ≥6.1 min/km^2, including G4, G12, and G13; the moderate feeding-time patch group (medium-utilization patches), with feeding time per unit

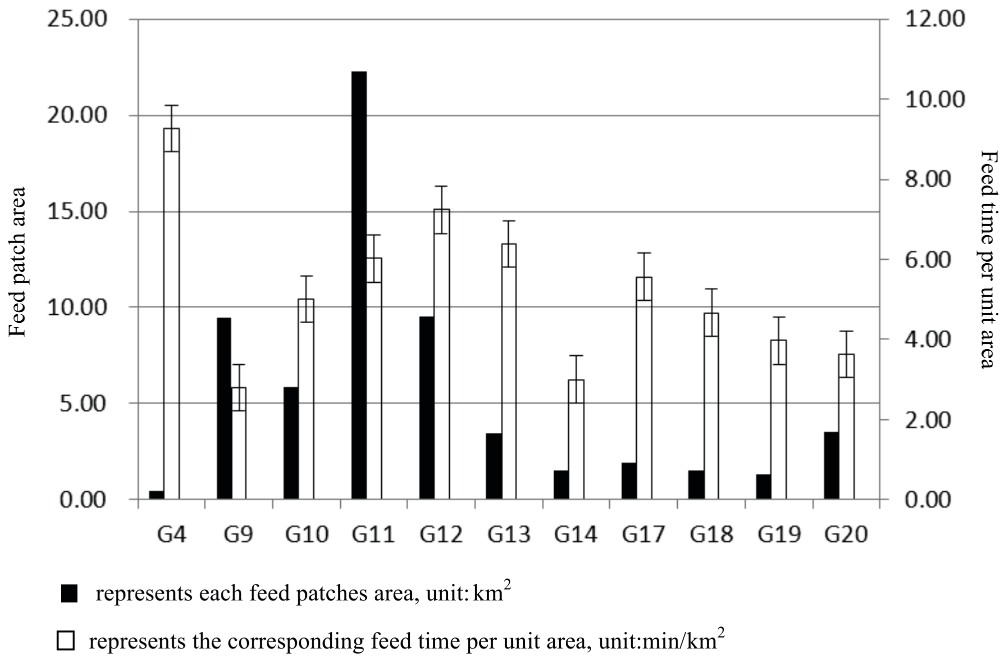

Figure 2. Feed patches area and the corresponding feeding time unit area. Black bars represent each feed patch area in km^2 while white bars represent the corresponding feeding time per unit area in min/km^2.

area of 3.1–6.1 min/km^2, including G10, G11, G17, G18, G19, and G20; and the low and-zero feeding time group (poor-utilization patches), with feeding time per unit area of ≤3.1 min/km^2, comprising G1, G2, G3, G5, G6, G7, G8, G9, G14, G15, G16, G21, G22, G23, G24, G25, G26, and G27. Among them, the average foraging time per unit area of high-utilization patches was 1.59 times that of the medium-utilization patches and 23.68 times that of the poor-utilization patches.

The areas of the high-utilization, medium-utilization, and poor-utilization groups were calculated and then divided by the investigation area. The proportion of the high-utilization group was 13.03%, the proportion of the medium-utilization group was 35.13%, and the proportion of the poor-utilization group was 22.21%.

4. Discussion

4.1. Classification of vegetation patches

Desert grassland typically has varying, sparse plant cover with a patchy distribution. In addition to plant diversity and productivity, plant spatial distribution pattern is an important factor affecting herbivore feeding behavior (Michiel and Wallis, 1996). In an environment with limited plant resources, patterns of plant spacing affect animals' feed search efficiency, which is the primary factor in their energy consumption (Parsons and Dumont, 2003). Here we applied the TWINSPAN method, using the relative density, relative height, and relative coverage of plant species to divide vegetation patches into 27 associations. This defined the differences among vegetation patches in the Przewalski's horse's habitat and provides a basis for understanding the food selection behavior of this species. The results showed that the 27 patches could be divided into high-utilization patches, medium-utilization patches, and poor-utilization patches, revealing strong selectivity of vegetation patches by the animals. Thus, this method is an informative way to analyze this species' habitat selection.

4.2. Clustering and categorization of vegetation patches

This study combining observations of Przewalski's horse feeding behavior and vegetation patch types shows that all vegetation patches could be divided into feeding and nonfeeding clusters. The former included G4, G9–14, and G17–20 and the latter included G1–3, G5–8, G15–16, and G21–27. We found that areas larger than 3 km^2 of vegetation patch types G11 (22.26 km^2), G12 (9.56 km^2), G9 (9.44 km^2), G10 (5.83 km^2), G20 (3.51 km^2), and G13 (3.45 km^2) were feeding clusters. The average area of a feeding cluster was 5.53 km^2, 7.47 times the average area of a nonfeeding cluster, which was 0.74 km^2. Theoretically, optimal feeding behavior achieves the maximum energy per unit time (Pyke, 1984; Donald, 1986). We know that the primary productivity of desert steppe is low: the average net primary productivity of Xinjiang desert grassland vegetation is 57.68 $gC/(m^2/year)$ (Yang et al., 2014), much lower than grasslands in general. Przewalski's horse chooses larger areas of vegetation patches as the best solution to the problem of accessing adequate food.

Table 3. The multiple comparisons of feed patches.

Group number	N	Subset of alpha = 0.05					
		1	2	3	4	5	6
9	5	1.6500					
14	4	1.7175					
20	4	1.8975	1.8975				
19	4	1.9700	1.9700				
18	5		2.1520	2.1520			
10	6		2.2317	2.2317	2.2317		
17	3			2.3400	2.3400		
11	5			2.4520	2.4520	2.4520	
13	4				2.5275	2.5275	
12	5					2.6880	
4	3						3.0267
Significance		0.071	0.059	0.090	0.094	0.167	1.000

4.3. Clustering and categorization of vegetation patches

Based on the degree of the horses' utilization of vegetation patches, patches could be divided into a high-utilization group (G4 and G12–13), having an average patch area of 4.48 km^2; a medium-utilization group (G10–11 and G17–20), having an average patch area of 6.07 km^2; and a poor-utilization group (G1–3, G5–9, G15–16, and G21–27), having an average patch area of 1.23 km^2. We found that the average area of all vegetation patches was 2.70 km^2, while the average areas of high-utilization and medium-utilization patches were not higher than the average of all patches. Therefore, there is no correlation between the average area of vegetation patches and use intensity by Przewalski's horse. Overall, large ungulates prefer nutritious grasses (Hofmann and Stewart, 1972). Duncan (1992) showed that domestic horses in the French Camargue Park like eating grasses and Chenopodiaceae. McInnis and Vavra (1987) concluded that the North American mustang chooses mainly Poaceae and Chenopodiaceae brome saltbush and other plants for food. Meng (2007) and Chen (2008) showed that KNR Przewalski's horses preferred Gobi *Stipa* and *Ceratoides*. Thus, from the perspective of the importance values of *Ceratoides* and *Stipa* for each analyzed patch, we find that *Stipa* and *Ceratoides* and other consumed plants have higher importance values in high-utilization vegetation patches; in particular, the small size of group type G4 received the greatest use ratio. Similarly, *Stipa* and *Ceratoides* importance values are lower in medium-utilization patches; rarely used and unused vegetation patches are mainly those with little or poor forage. This result confirms King's (2002) study, which found that in the Stan Nature Reserve in Mongolia, Przewalski's horse chooses mainly *Stipa* communities. It is worth noting that in G15, G16, G21, G22, and G25 patch types, *Stipa* had a relatively high importance value but was not eaten. We think that this was a consequence of these patch types' smaller areas.

Characterizing the use of vegetation patches reveals the feeding strategies of Przewalski's horse. The results show that in the Kalamaili Mountain Nature Reserve, the reintroduced horses' use of vegetation resources depends primarily on the area of vegetation patches. Those with contiguous vegetation become favored foraging grounds (feeding sites), and patches containing high-quality forage receive more intensive use. Therefore, in desert grasslands with low primary productivity, the feeding strategy of Przewalski's horse is to first satisfy its energy demand and then search for quality food.

Acknowledgments

This work was supported by a grant from the National Natural Science Foundation of China (30970545). The authors would like to thank Jiang Xinchun, Aidai, and Wang Yuan for their help with field experiments and the Altay Bureau of Forestry for its help and support.

References

Bouman J (1994). The History of Przewalski's Horse. Albany, NY, USA: State University of New York Press.

Boyd L, Houpt KA (1994). Przewalski's Horse: The History and Biology of an Endangered Species. Albany, NY, USA: State University of New York Press.

Chapman DF, Parsons AJ, Cosgrove GP, Barker DJ, Marotti DM, Venning KJ, Rutter SM, Hill J, Thompson AN (2007). Impacts of spatial patterns in pasture on animal grazing behavior, intake, and performance. Crop Sci 47: 399-415.

Chen J (2008). Utilization of Food, Water and Space by Released Przewalski Horse (*Equus przewalski*) with Reference to Survival Strategies Analysis. Beijing, China: Beijing Forestry University.

Chu HJ, Jiang ZG, Lan WX, Wang C, Tao YS, Jiang F (2008). Dietary overlap among kulan (*Equus hemionus*), goitered gazelle (*Gazella subgutturosa*) and livestock. Acta Zool Sinica 54: 941-954.

Donald P (1986). The effects of drought on Ngatatjara plant use: an evaluation of optimal foraging theory. Hum Ecol 14: 95-115.

Dumont B, Maillard JF, Petit M (2000). The effect of the spatial distribution of plant species within the sward on the searching success of sheep when grazing. Grass Forage Sci 55: 138-145.

Duncan P (1992). The nutritional ecology of equids and their impact on the Camargue. Ecological Studies 89: 1-287.

Ge Y, Liu C, Chu HJ, Tao YS (2003). Present situation of the *Equus hemionus* resources in the Karamori Mountain Nature Reserve, Xinjiang. Arid Zone Research 20: 32-34.

Hassall M, Tuck JM, Smith DW, Gilroy JJ, Addison RK (2002). Effects of spatial heterogeneity on feeding behaviour of *Porcellio scaber* (Isopoda: Oniscidea). Eur J Soil Biol 38: 53-57.

Hester AJ, Gordon IJ, Baillie GJ, Tappin E (2001). Foraging behaviour of sheep and red deer within natural heather/grass mosaics. J Appl Ecol 36: 133-146.

Hill MO, Šmilauer P (2005). TWINSPAN for Windows Version 2.3. České Budějovice, Czech Republic: Centre for Ecology & Hydrology and University of South Bohemia.

Hofmann RR, Stewart DR (1972). Grazer or browser: a classification based on the stomach-structure and feeding habits of East African ruminants. Mammalia 36: 226-240.

Hudson RJ, Fryxell JM, Wilmshurst JF (1995). Forage quality and patch choice by wapiti (*Cervus elaphus*). Behav Ecol 6: 209-217.

King SR (2002). Home range and habitat use of free-ranging Przewalski horses at Hustai National Park, Mongolia. Appl Anim Behav Sci 78: 103-113.

Knegt HJ, Hengeveld GM, Langevelde FV, Boer WF, Kirkman KP (2007). Patch density determines movement patterns and foraging efficiency of large herbivores. Behav Ecol 18: 1065-1072.

Li JS, Song YL, Zeng ZG (2003). Food selectivity and influencing factors in ruminants. Acta Theriologica Sinica 23: 66-73.

Liu S (2013). Study on habitat selectivities and community protection awareness of the reintroduced *Equus przewalskii* in Mt. Kalamaili Ungulate Nature Reserve. PhD, Xinjiang University, Urumqi, China.

McInnis ML, Vavra M (1987). Dietary relationships among feral horses, cattle, and pronghorn in southeastern Oregon. J Range Manage 40: 60-66.

Meng YP, Hu DF, Chen JL (2007). Studies on the food plants and foraging strategy of released Przewalski horse. In: Abstract Book of Fourth National Ecology and Conservation of Wildlife Symposium (in Chinese).

Michiel F, Wallis DV (1996). Effects of resource distribution patterns on ungulate foraging behaviour: a modelling approach. Forest Ecol Manag 88: 167-177.

Mohr E (1971). The Asiatic Wild Horse. London, UK: JA Allen.

Parsons AJ, Dumont B (2003). Spatial heterogeneity and grazing processes. Anim Res 52: 161-179.

Pyke GH (1984). Optimal foraging theory: a critical review. Annu Rev Ecol Syst 15: 523-575.

Searle KR, Thompson HN, Shipley LA (2005). Should I stay or should I go? Patch departure decisions by herbivores at multiple scales. Oikos 111: 417-424.

Wallis DV, Daleboudt C (1994). Foraging strategy of cattle in patchy grassland. Oecologia 100: 98-106.

Wang JJ (2004). Studies on the Comparative Behavior between Stalled and Reintroduced Przewalski Horse. Beijing, China: Beijing Forestry University (in Chinese).

Wang SP, Li YH, Wang YF (1990). Relationship between foraging areas of sheep (wether) and spatial heterogeneity of grassland landscape. Acta Ecologica Sinica 19: 431-434.

Wiens JA, Kotliar NB (1990). Multiple scales of patchiness and patch structure: a hierarchical framework for the study of heterogeneity. Oikos 59: 253-260.

Wu ZY, Peter R (2012). Flora of China. Beijing, China: Science Press.

Yang HF, Gang CC, Shao-Jie MU, Zhang CB, Zhou W, Jian-Long LI (2014). Analysis of the spatio-temporal variation in net primary productivity of grassland during the past 10 years in Xinjiang. Acta Prataculturae Sinica 23: 39-50.