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Patterns of habitat selection and use by *Macaca mulatta tcheliensis* in winter and early spring in temperate forest, Jiyuan, China

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Abstract: The chosen habitat of any animal species comprises a range of environmental features that provide adequate resources for its continuous survival. Consequently, the criteria of habitat selection by animals, combines a wider spectrum of both environmental and extrinsic factors, with major prerequisites based on food resources, availability of shelter and suitable ethics for procreation. From this study, conducted in winter and early spring, at Mt. Wangwushan area, located on 35°05′–35°15′ N, 112°12′–112°22′ E, in Taihangshan Macaque National Nature Reserve (TMNNR), Jiyuan, Henan Province, we show by elaborative results that *Macaca mulatta tcheliensis* was specifically associated with the following habitat characteristics: (1) the average tree DBH (diameter at breast height) with over 15 cm; (2) the distance from human disturbance of less than 2000 m; (3) the distance to water with less than 1000 m; (4) the gradient of mountain slope of 15°∼40°; (5) which was markedly tarrying with the altitude ranges from 1000 m to 1300 m; and (6) where the canopy coverage was less than 60%. In addition, during this study, rhesus macaque mostly inhabited the sunny slopes of mountains than the shady areas. Results of the first five principal components analysis (PCA) accounted for the total variance of 68.88%, while the other factors showed insignificant effects on habitat selection by rhesus macaque in the temperate forest. In conclusion, these new results increase our understanding on the living status, under the harshest condition, in winter and early spring of *Macaca mulatta tcheliensis*, the subspecies of rhesus macaques as may be linked to its habitat selection and utilization, in the temperate forest.

Key words: Rhesus macaque; habitat selection; ecological factors; winter; temperate forest

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Introduction

Ecology provides the impetus to understanding factors and processes in determining the distribution and abundance of species in space and time (Brown et al. 1995; Greenwood et al. 1996). Habitat-selection behaviour as the identification procedure of preferred habitats by an animal is a fundamental topic in wildlife ecology, and best explains techniques on how mobile organisms adapt to changing conditions (Railsback & Harvey 2002). The following four criterions, in the classification of habitat selection as proposed by Johnson (1980) include: (1) the microhabitat, (2) the components of the home range, (3) the home range itself, and (4) the geographical distribution or regional level. The home range is more-or-less a restricted area where an animal moves during its normal activities (Harris et al. 1990). The third level features the particular habitat's attributes in a home range, influencing the animal to select the area. Habitat attributes may vary depending on the composition, spatial arrangement proportions and the animal species, including both environmental and extrinsic factors. In the biogeographic or continental spheres, it is well established that extrinsic factors of energetic constraints and concepts of seasonality in locating food are major determinants on the abundance of animal distribution and life historic traits of populations (Lindstedt & Boyce 1985; Jarvis et al. 1994; Ferguson 2002; Wiegand et al. 2008; Wilbert et al. 2000; Sichilima et al. 2008). Therefore, the patterns of food availability in the habitat and the seasonal energetic expense in locating food by animals may not only influence the levels of species' distribution in the habitat but also the quality and the criterion of selecting the home range, suitable for the population (Sichilima et al. 2008).

In the previous decades, ecologists devoted more efforts and concerns to understanding the forces behind both the typical habitat selection and the related implications associated with predator avoidance. It has been observed that some prey species benefit from adopting multiple environmental habitats in order to decrease vulnerability from predators (Lima 1998). For prey species therefore, predation pressure is one of the most important extrinsic factors influencing the spatial behaviour of individuals and habitat selection (Bos & Carthew 2003; Kotler 1997; Lima & Dill 1990).

Rhesus macaque which is listed as second class of key protected wildlife of China is the only non-human

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primate with a broader geographic distribution (Fooden 2000; Southwick et al. 1996), and their populations are found ubiquitously throughout mainland Asia; from Afghanistan to India and Thailand to southern China (Rowe 1996; Smith & McDonough 2005). The *Macaca mulatta tcheliensis* Milne-Edwards, 1870 is a subspecies of rhesus macaque endemic to China (Jiang et al. 1991; Zhang et al. 1991), and the majority of populations of this subspecies were confined mainly to the southern Mt. Taihangshan area (34°54′–35°16′ N, 112°02′–112°52′ E) which is near the boundary of Henan and Shanxi Provinces of China, and where a National Nature Reserve was established in 1998 (Lu et al. 2007). Climate in this region is hot, rainy, and humid in summers, while cold and dry in winter with the annual temperature ranging from –20 ℃ (–4 °F) to 40 ℃ (104 °F). Average annual precipitation was 641 mm (2.10 ft), with the heaviest rain recorded from June to August (Qu et al. 1993; Hu et al. 2004). This is similar to the climate of the Pakistan region where rhesus macaques are found, but the habitat in Pakistan is dominated by mixed evergreen and deciduous forests that are highly disturbed (Goldstein & Richard 1989), and which are also in proximity with habitat conditions of the Japanese monkeys, *Macaca fuscata* Blyth, 1875 (Wada & Ichiki 1980; Nakagawa 1989).

The long winter with poor food supply, in Mt. Taihangshan area, is recorded from November to March of every year and is predictably a crucial period for the survival of macaques in their life history (Song & Qu 1996; Lu et al. 2007). Zoogeographical habitat fragmentation and degradation by deforestation, together with the highway construction are major environmental factors impairing the macaque conservation (Lu et al. 2007). Unfortunately, the ecological knowledge in winter, on the spatial and foraging behaviours, habitat selection and utilization for this rarely studied subspecies is unknown.

The main aim of this research work was to provide information on habitat selection and use by this subspecies of rhesus macaque in the temperate forest during winter and early spring, and to get its possible conservation implications. Consequently, a wide range of environmental factors associated with this animal were investigated as follows; terrain, altitude of the area, slope of site, slope of face, gradient of the slope**,** the distance from water sources, human disturbance, size of canopy, concealment, and average tree DBH (diameter at breast height). The two major and specific questions to be addressed in this study were: (1) what are preferred habitats for macaque in winter and early spring and (2) what are major factors influencing habitat use?

Study area

The field work was conducted in Tiantan Station of Mt. Wangwushan area, located at 35°05′–35°15′ N, 112°12′–112°22′ E, in Taihangshan Macaque National Nature Reserve (TMNNR) which is about 40 km northwest from Jiyuan, Henan, China. The Reserve is about 56,600 ha in area, bordering the Yellow River in the south, and reaching the boundary of Shanxi Province. Continental and marine wind currents, with a prevalence of a northwest wind in winter and southeast wind in summer, ultimately influenced the monsoon type of climate in this study area. The region has four distinct seasons, i.e., summer, winter, spring and autumn, with the variation in sunlight whilst heat and precipitation mostly occurring simultaneously. The mean annual sunshine is 2367.7 h, with a total solar radiation of 118.17 kcal cm^{-2}, while the mean temperature is 14.3 ℃ in the plain areas, 14.9 ℃ in the foothills along the Southern Mt. Taihangshan, 13.2–14.0 ℃ in the lower hilly area, and 8.6–11.1 ℃ in the mountainous area. The mean annual precipitation for this area is 695 mm, and is 70 mm higher than in the plains, though precipitation exhibits both temporal and spatial variation. There are 1,698 species of vascular plants, belonging to 734 genera and 163 families in the Reserve and most of them belonged to seed plants (Song & Qu 1996; Lü et al. 2002; Lu et al. 2007).

The aim of this research was to study the habitats of *Macaca mulatta tcheliensis* inhabiting within the Tiantan Station of Mt. Wangwushan area in TMNNR. In the study area, there were 2 group species of macaque found and were differentiated by the codes of WW-1 and WW-2, respectively. Thirty nine (39) individuals were identified in the group of WW-1, while only eight (8) were identified in the group of WW-2. Since fewer individuals within WW-2 and it was seldom seen in studied area, we took WW-1 as focal troop. Our research protocol was permitted by the Administration of TMNNR, and had complied with animal care regulations and applicable national laws of China. In the course of field work and investigations, we exerted non invasive methods on the macaques.

Methods

Quadrat etablishment and survey

Field studies in the sites were conducted from November 2007 to February 2008, and from November 2008 to February 2009. Habitats used by macaque were located based on the activity evidence of its foraging, calling, playing and struggling etc. Using a portable GPS, every located site was geographically identified and parameters of latitude, longitude and altitude were recorded. A sampling quadrant of 10 m × 10 m (100 m^2) was subsequently marked to establish the area of a particular site. During the study period, total 296 quadrants (180 of 2007–2008 and 116 of 2008–2009, respectively) were identified and data collection was carried out in all sites. A similarly marked site, located 50 m away from the rest of study area was established for the purpose of a control quadrant (Young et al. 1991). In our study area, the early spring only accounted for few weeks after winter before the abundance of food resources were recorded and most other weather conditions in the habitat were still very similar to those of winter season. To this effect therefore, there was no major seasonal fluctuations worth the separate analyses in the habitats.

Though many ecological factors would exert influences on animal habitat selection and use (Bond et al. 2002; Bos & Carthew 2003), we mainly concerned those important factors for winter habitat use (Homan et al. 2000). In each located quadrat, necessary parametric measurements were calculated and recorded from the following environmental factors; topography, altitude of the site, slope position, slope direction, slope gradient**,** the distance from water sources,

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human disturbance, size of canopy, concealment, and the average DBH (diameter at breast height). The definition and categories of these ecological factors are as follows:

Topography: This referred to local topographical characteristics of the habitat, and was classified into hillside, ridge and valley of mountain.

Altitude: This referred to the a.s.l. height of the site where the activity traces were detected, and was categorised into three levels: ≤ 1000 m, 1000–1300 m, and ≥ 1300 m.

Slope position: This referred to a level of slanting of an angle on the surface of the mountain, to the horizontal surface, with different positions including upper, middle, and lower positions.

Slope-direction: This referred to which direction and level was the slope facing i.e. against or towards the sun, including; sunny slope (S 67.5° E – S 22.5° W), half sunny slope (N 22.5° E – S 67.5° E and S 22.5° W – N 67.5° W) and shady slope (N 67.5° W – N 22.5° E).

Slope-gradient: This referred to the extent of calculated slope in degrees, and was determined in three levels: gentle slope (≤15°); slight slope (15°–40°); steep slope (≥40°).

Distance from water source: This factor was classified into two levels, near (≤ 1000 m), and far (> 1000 m), based on the distance from the center of quadrant to water source.

Human disturbance: This factor reflects the extent of human disturbance including roads, buildings, other human activities, etc. and was divided into three levels: ≤ 1000 m; 1000–2000 m; ≥ 2000 m.

Canopy: This referred to the coverage degree of tree crown, and was defined in three categories, ≤ 30%, 30%∼60%, and ≥ 60%.

Concealment: This referred to the extent at which the selected habitat, sheltering macaques was hidden from the clear visibility. This factor was determined by the horizontal front view of the selected position within a visible distance. Concealments were expressed at three specific levels, with high (≥50 m), moderate (20–50 m), and lower concealment (≤20 m).

Average DBH: The DBH was referred to the "diameter at breast height", with the collected data of average DBH categorized at ≤15 cm, ≥30 cm, and 15–30 cm.

The Vanderploeg and Scavia's index (E_i) (Lechowicz 1982) was used to identify habitat use by macaque in study area:

$$E_i = [W_i - (1/n)]/[W_i + (1/n)]$$

where W_i is the selectivity coefficient (Chesson 1978), and n is the number of quadrant. The index W_i was calculated using the following formula:

$$W_i = (r_i/p_i)/\Sigma(r_i/p_i)$$

where p_i is the proportion of samplings in the i^{th} level, and r_i is the proportion of habitats in the i^{th} class. E_i is scaled between –1 and +1. When $E_i = -1$, macaque did not select this habitat (N); $-1 < E_i < 0$, macaque avoided this habitat (NP), when $E_i = 0$, macaque selected and used this habitat randomly (R), and $0 < E_i > 1$ indicates preferred this habitat (P), $E_i = 1$, macaque specially preferred the habitat (SP).

Data analysis

SPSS for windows (version 13.0) was adopted in data analysis. In order to determine how the effects of different factors influenced the macaque's habitat selection, the principal component analysis (PCA) was employed. Under the condition of eigenvalue > 1, the principal component was considered a crucial determinant in the habitat use by macaques.

Results

Preferred habitat of macaques

From this study, results showed that macaques usually chose habitats where the following characteristics were evident: (1) the average tree DBH was over 15 cm; (2) the distance from human disturbance was not less than

Table 1. Habitat selection by rhesus macaque at Mt. Wangwushan area in winter and early spring.

Item	i	p_i	W_i	E_i	Habitat selection	Item	i	p_i	W_i	E_i	Habitat selection
Topography	Hillside	194	0.66	0.98	P	Distance from water source	≤ 1000 m	285	0.96	0.99	SP
	Ridge	28	0.09	0.45	P		>1000 m	11	0.04	–0.42	NP
	Gully	74	0.25	0.90	P						
Altitude	≤ 1000 m	26	0.09	0.39	P	Human disturbance	≤ 1000 m	227	0.77	0.99	SP
	1000–1300 m	237	0.80	0.99	SP		1000–2000 m	66	0.22	0.87	P
	≥ 1300 m	33	0.11	0.57	P		≥ 2000 m	3	0.01	–0.94	NP
Slope position	Upper	84	0.28	0.92	P	Canopy (%)	≤ 30%	188	0.64	0.98	P
	Middle	104	0.35	0.95	P		30%–60%	105	0.35	0.95	P
	Lower	108	0.37	0.95	P		≥ 60%	3	0.01	–0.94	NP
Slope direction	Sunny slope	209	0.71	0.99	SP	Concealment	≥ 50 m	174	0.59	0.98	P
	Half sunny slope	77	0.26	0.90	P		20–50 m	103	0.35	0.95	P
	Shady slope	10	0.03	–0.49	NP		≤ 20 m	19	0.06	0.02	R
Slope gradient	≤ 15°	21	0.07	0.03	R	Average DBH	≤ 15 cm	9	0.03	–0.57	NP
	15°–40°	195	0.66	0.98	P		15–30 cm	235	0.79	0.99	SP
	≥ 40°	80	0.27	0.91	P		≥ 30 cm	52	0.18	0.80	P

Explanations: i – eigenvalue; p_i – quadrat number with i eigenvale; W_i – selection coefficient; E_i – selection index; P – preference; SP – special preference; N – no selection; R – random selection; NP – non preference.

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Table 2. The eigenvalue of habitat selection by rhesus macaque at Mt. Wangwushan area in winter and early spring.

Main component No.	Eigenvalue	Contribution rate (%)	Accumulative contribution rate (%)
1	1.930	19.300	19.300
2	1.475	14.751	34.051
3	1.265	12.651	46.702
4	1.216	12.160	58.862
5	1.002	10.018	68.880
6	0.856	8.562	77.442
7	0.727	7.270	84.712
8	0.666	6.655	91.367
9	0.521	5.210	96.577
10	0.342	3.423	100.000

Explanations: Numbers 1 to 10 refer to the first up to the tenth principal components.

Table 3. The rotated matrix of the eigenvector of habitat selection by rhesus macaque in Mt. Wangwushan area in winter and early spring.

Variables	Principal components				
	1	2	3	4	5
Topography	0.433	–0.600	–0.023	0.419	0.128
Altitude	–0.726	–0.018	0.301	0.244	–0.057
Slope site	0.421	0.326	–0.063	–0.472	0.182
Slope face	0.710	–0.471	–0.065	–0.255	0.059
Slope gradient	0.232	0.384	0.639	–0.218	0.147
Distance from water resource	0.355	0.600	–0.341	0.180	–0.120
Human disturbance	0.312	0.348	–0.278	0.671	0.009
Canopy	0.281	0.356	0.411	0.233	0.076
Concealment	0.377	–0.173	0.627	0.300	–0.129
Average tree DBH	–0.192	0.008	–0.050	0.138	0.942

2000 m; (3) the distance to the water source less than 1000 m; (4) the slope gradient was 15°–40°; (5) with the altitude ranging from 1000 m to 1300 m; and (6) the canopy cover less than 60%. Furthermore, macaques that occurred at Mt. Wangwushan area preferred sunny slopes in winter and early spring (Table 1).

Factors affecting habitat use of macaques

Results from the principal component analysis (PCA) revealed that 1–5 components, accounted for 68.88% on the total variance (Table 2). The first principal axis reflected effects derived from altitude and slope-direction, which represented the geographical traits of the selected habitat by macaques and was thus named as a geographical factor. The distance from the water source contributed more to the second principal axis and was regarded as water factor. A combination of slope gradient, concealment, and the average tree DBH, constituted the third and single factor known as foraging on the principal axis while the human disturbance factor, and the resting factor, were fourth and fifth principal components, respectively (Table 3).

Discussion

Rhesus macaques are regarded as habitat generalists, and their adaptive ability to marginal or degraded ecological conditions has been a key factor in allowing the species to survive in fragmented landscapes and highly populated areas (Lu et al. 2007; Song & Qu 1996; Wada & Ichiki 1980). In temperate regions therefore, cold and snow is prevalent in winter and this adversely limits foraging and other activities to a greater extent. This harsh period is thus regarded as a pivotal stage for mammals in their life history and compels them to adapt to new habitat use for survival (Homan et al. 2000). The habitat selection by this animal also takes into consideration the predation risks, abundance and quality of food resources which changed seasonally (Rueda et al. 2008).

Across all habitat types, the macaques subspecies on which this study was conducted, in winter and early spring, invested much of its time on the activities of foraging and resting, in addition to other characteristic behaviours of grooming, playing, moving around etc. (Seth & Seth 1986). A variety of biological and abiotic factors might have influenced the geographical distribution pattern of animals but food, water, and concealment were the three major components influencing the habitat selection, while the food resource factor was ranked highly essential (Ma et al. 2004). Mammals endemic to the temperate area easily adapted to the severe conditions during winter period and subsequently exhibit various adaptive patterns during habitat use and selection (Wilbert et al. 2000; Young et al. 1991). Similarly, during this field study, the activity traces of macaque were often found in ridges, with gentle and sunny slopes, suggesting two energy saving points that, in ridges, the animals easily moved from one place to another in order to physically reduce the energetic costs and also gained more energy for body temperature maintenance directly from the sun.

The *Macaca mulatta tcheliensis* is a phytophagous animal, feeding on plants and leaves of some trees, which are abundantly available during the summer period (Wada 1984; Ren et al. 2001; Hu et al. 2004). In winter, however, these food resources become scarce and the animal exhibits adaptive characteristic patterns of phytodiversity and increases the probability of finding alternative food items including scattered seeds such as acorns of cork oak (*Quercus variablis),* seeds of Oriental bittersweet (*Celastrus orbiculatus),* fruits of Date-plum (*Diospyros lotus),* tubers of some

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plants, barks of some trees and so on, which are usually found in the valleys or foot-hills (Strier 2000; Hanya 2004; Guo et al. 2007, 2008). In this research, we also found that macaques preferred the habitats with sunny slopes and canopy cover of less than 60%, intimating that incumbent tree species in these areas possibly had produced fruits, seeds, nuts, and cornes, which might have dropped and are still available on the ground during the winter period for macaques to eat. It is also suggested that the reason for a choice of habitats closer to human activities in winter by macaques might be probably targeted on food crop remains, like *Zea mays*, *Daucus carota*, *Brassica camperstris*, together with root crops like cassava and sweetpotato which farmers grow. Nevertheless, from a security perspective, the macaques would still select those taller trees, with stronger branches far away from humans as night-sleep sites (Guo et al. 2010).

Water was also another important factor affecting habitat use and selection by macaques in winter. The mean annual precipitation was 690 mm in study area, and was insufficient in winter (Song & Qu 1996; Hu et al. 2004). Our result showed that macaques were commonly seen searching and wandering in the valley and foot-hills, because there were some temporary water resources in such sites (Song & Qu 1996), and for several times, we observed macaque individuals drinking water *in situ* in the valley. It was, however, reported on two contrasts that *Rhinopithecus roxellana* Milne-Edwards, 1870 and *R. bieti* (Milne-Edwards, 1897) always take some little quantities of water (Li et al. 2006; Su et al. 1998), while it is evident that despite the Japanese macaque (*M. fuscata*) may be found very close to the hot-springs, they preferred gaining heat to drinking hot water (Suzuki 1965; Wada 1964).

Because the macaques are found in such a broad geographic area, it is difficult to specifically summarize their habitats precisely. Depending on the type of habitat the animals may be found, they are quadricpedal, predominantly arboreal or terrestrial (Seth et al. 2001). The result from this study indicated that in the northernmost part of Mt. Taihangshan area in China, rhesus macaques inhabit a secondary deciduous forest between 300 m and 1200 m a.s.l. (984 and 3937 ft) in a temperate climate with cold, snowy winters similar to the climate of the central, Midwestern United States (Qu et al. 1993; Lu et al. 2007). To make the macaque conservation compatible with our current policies and the local economic development, there is need for continuous protection of similar characteristic habitats as mentioned above. Therefore there is need for more ecological work to be carried out in the macaques foraging behaviour, in temperate habitats in order to further understand the varying adaptation characteristics of the animal.

From the current study, we got a primary understanding on ecological factors affecting habitat selection and use in winter and early spring of rhesus macaques in its northernmost distributed area. It was surprisingly that the result from PCA explained 68.88% of the variance of examined factors, which is partly because the examined factors had no close relationship between each other. This result also indicated that many other ecological factors possibly exert role on habitat selection and use of rhesus macaques. We should pay more attention on analyzing influences of the other ecological factors in the future researches.

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