Summer habitat selection and impacts of human disturbance on leopard cats (Prionailurus bengalensis)

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ABSTRACT
Introduction: As a consequence of habitat loss and degradation, the leopard cat (Prionailurus bengalensis) in China has become endangered and in need of urgent protection. In situ conservation of leopard cats must be based on an understanding of their habitat selection patterns. We studied the summer habitat of leopard cats using line-transect surveys in the northern Taihang Mountain region surrounding Beijing, China. We compared used plots with non-used plots in elevation, tree canopy, and 20 other ecological variables, and used Vanderploeg's Scavia's resource selection index (VSI) to analyze habitat preferences.

Outcomes/other: Results show that tree canopy, tree height, tree density, and stump quantity of used plots were significantly lower than non-used plots in summer, and that leopard cats preferred habitats located on northern, flat slopes with lower slope, shrub-dominated, dry soil, and less fallen-wood. Leopard cats had a strong tendency to use habitats near human disturbance areas with moderate levels of disturbance intensity.

Conclusion: The results suggest that future conservation efforts should emphasize: (1) strengthening the protection and management of forest fringe shrub habitats to improve summer habitat suitability, and (2) environmental education and animal protection campaigns to promote community biodiversity conservation.

Introduction

The leopard cat (Prionailurus bengalensis), a small cat species, is distributed in east, south, and southeast Asia (Ross et al. 2015). In China, leopard cats are widespread and have a strong ecological adaptability (Luo, Zhu, and Li 1995). However, due to habitat loss and fragmentation, leopard cat populations in many regions of China have declined and even become extirpated in some regions (Han et al. 1995; Wei 2006; Liao et al. 2018). The leopard cat has been listed in CITES Appendix II and as a vulnerable species (VU) in the China Biodiversity Red List, and is now a national second-class protected specie in China, which means they are in need of effective protection.

In situ conservation is the most effective way to protect endangered wildlife when it is based on a thorough understanding of the ecological characteristics of the species, particularly its preferred habitat (Yang et al. 2003). Wildlife habitat selection and utilization are related to such key influencing factors as food abundance, water quantity, shelter from disturbance, and interspecific competition (Morr 2003; Panthi et al. 2012; Pradhan, Saha, and Khan 2001). Among these factors, food availability is one of the most important determinants of habitat selection and utilization (Jiang, Jian Zhang, and Stott 2010), especially for predators who base habitat selection on maximizing food and acquisition (Wasko and Sasa 2012). Moreover, human activities can affect food availability thereby affect wildlife habitat selection (Jiang, Zhang, and Ma 2007). As an example, Petroelje et al. (2019) reported that some top prey species preferred habitats with human activities that subsidized food sources such as hunter-killed prey, livestock carcass dumps, refuse and landfills, showing their ability to adapt to anthropogenic influence.

Moreover, wildlife habitat selection is a system of stable behavioral strategies which allows some species to adapt more readily to environmental changes (Aryal et al. 2014), and have relatively flexible responses to interspecific and intraspecific interaction and competition (Jiang, Zhang, and Ma 2008). Pérez-Barbería, Hooper, and Gordon (2013) reported that, at low population densities, individual-red deer (Cervus elaphus) selected more suitable habitat, while at higher densities some individuals had to select suboptimal habitats that were relatively avoided in the past. Wysong et al.
(2020) stated that predator–prey relations make predators select preferred habitats where their prey occurs, but small or medium-sized carnivores will avoid the most suitable habitats to avoid interactions with larger apex predators in their home range and habitats.

Habitat selection of leopard cats has attracted the attention of many researchers for several decades. A survey in Malaysian commercial forest reserves carried out by Mohamed et al. (2013) showed that leopard cats preferred habitat with low canopy density and a low ratio of climax plant species to pioneer plant species. Oh et al. (2010) reported that habitat selection by Tsushima leopard cats (P. b. euptilurus) was influenced by weather and human activities. Leopard cats would choose human buildings as a shelter during bad weather, and rely on the food provided by human communities in the winter when food resources were scarce, which meant they did not avoid communities and villages. A study in Thailand found that the behavior of leopard cats was not affected by roads and traffic density (Sean et al. 2007). However, in another study area in Korea, leopard cats tended to choose habitats away from roads (Rho 2009). These studies provide important information for leopard cat protection and habitat management.

Compared with other areas in the world, little research has been conducted on leopard cats in China. Previous studies in China mainly have focused on biological research, taxonomic differentiation among subspecies, population size, distribution, and diet analysis (Wei 2006; Liu et al. 2018; Luo, Zhu, and Li 1995; Han et al. 1995; Shao et al. 2019). Studies on the habitat selection of leopard cats, especially in regions near large cities such as Beijing, are rare. Such studies, however, could reveal ecological characteristics of leopard cats under anthropogenic impacts and be used to identify suitable habitat so that wildlife managers might reduce unnecessary development activity in the habitat and improve the efficiency of in situ conservation. When habitat is protected, it could reduce the interactions between human and wildlife, which has a positive effect on not only wildlife population management and protection but also animal disease prevention and control because free-roaming pets like cats and dogs have the potential to transmit pathogens to leopard cats (Chen et al. 2019).

In this study, we analyzed the summer habitat selection of leopard cats in the Northern Taihang Mountain region around Beijing, China. We predicted that the summer habitat selection of leopard cats is related to numerous variables, but most importantly to food abundance. Moreover, we predicted that human disturbance, an important factor in the study area, will play a significant role in affecting the habitat selection of leopard cats through changes in food abundance balanced by natural avoidance behavior. The results can provide information for in situ conservation of leopard cats, as well as management of wildlife habitat and wildlife-compatible human development.

**Study area**

We conducted this study in the northern Taihang Mountain (N: 36°01 ’–42°37’, E: 113°04 ’–119°53’) in the Capital Circle region around Beijing, China (Figure 1). Influenced by the sub-humid, warm temperate continental monsoon climate, the study area is characterized by a hot rainy season with an average annual temperature of 13.5°C and average annual precipitation of 700 mm. The highest precipitation occurs in July (132.3 mm) and the lowest in December (4.4 mm). Vegetation in the mountains occurs in elevational belts, with deciduous broad-leaved forest distributed below 700 m, mixed coniferous broad-leaved forest between 700 and 1500 m, and coniferous forest between 1500 and 2000 m. Fruit trees are planted in the valleys and alluvial terraces, which is one of the main deciduous fruit tree regions in China. Over 70 mammal species occur in the region, including leopard (Panthera pardus), red fox (Vulpes vulpes), leopard cat, jackal (Cuon alpinus), yellow weasel (Mustela sibirica), Siberian polecat (Mustela eversmanni), and raccoon dog (Nyctereutes procyonoides) (Ning 2012; Zhou 2012).

**Methods**

**Surveying variables and definitions**

The investigation was conducted from 10 July to 31 August 2019. After considering land use, geographic factors, vegetation type, and human disturbance, 74 survey grid cells (10 km×10 km) were selected out of 315 grid cells (10 km×10 km) in the study area (Figure 1). Within each of the 74 grid cells, we established two-line transects that were approximately 3 km in length and perpendicular to the mountain ridge. The distance between the two line transects was greater than 3 km. We ensured that all habitat types were contained in the field survey areas.

The investigators walked each line transect and determined which areas were used based on activity signs of leopard cats, such as feces, footprints, shelters, etc. When a sign was located, a 20 m × 20 m sign-centered “used” plot was established. When no signs were found, a 20 m × 20 m nonused plot was established at the beginning, middle, and ending of a line transect. Five 4 m × 4 m small plots were set in the center and four corners of used and nonused plots respectively.

Based on reported studies about leopard cat (Mohamed et al. 2013; Rajaratnam et al. 2007) and other mammals (Zhou et al. 2013; Wang et al. 2014; Tang 2014), 22 variables were selected to describe the
summer habitat of leopard cats. The classification, definition, and determination methods are summarized in Table 1.

**Data analysis**

The Mann–Whitney U test was used to compare differences in 11 continuous variables between used plots and nonused plots, including elevation, tree canopy, tree DBH, tree height, tree density, shrub height, shrub canopy, ground-plant cover, stump quantity, fallen-wood quantity, and withered grass cover. A Chi–square Test was used to compare the differences in 11 discrete variables between used plots and nonused plots, including slope aspect, slope gradient, slope position, vegetation type, concealment, Lee condition, soil moisture degree, distance from the nearest water source, distance from the nearest residential area, distance from nearest anthropogenic disturbance and disturbance intensity (Tong et al. 2010).

We used Vanderploeg & Scavia’s Resource Selection Index (VSI, Zhou et al. 2013) to analyze the habitat preferences of leopard cats. VSI can be used for both continuous and discrete variables. The VSI is calculated as follows:

\[ W_i = \frac{n_i}{P_i}, \quad E_i = \frac{W_i - \frac{1}{n}}{W_i + \frac{1}{n}} \]

In the VSI, \( w_i \) is the resource selection coefficient, \( E_i \) is the resource selection index. In the formula, \( r_i \) is the number of plots with a certain ecological factor used by leopard cats; \( P_i \) is the sum of plots with a certain ecological factor; \( n \) is the number of items in a variable. Results for the VSI are interpreted as follows:

- \( E_i = 1 \), especially preferred (EP), indicating a complete preference of the habitat characteristic.
- \( 0.1 < E_i < 1 \), preferred (P), indicating a slight to a strong preference for the habitat characteristic.
- \( -0.1 < E_i < 0.1 \), almost randomly selected (AR), indicating a very weak preference, or avoidance of the habitat characteristic.
- \( E_i = 0 \), randomly selected (RS), indicating that leopard cats did not show any preference for or avoidance of this habitat characteristic.
- \( -1 < E_i < -0.1 \), not preferred (NP), indicating a slight to strong avoidance of the habitat characteristic.
- \( E_i = -1 \), not selected (NS), indicating complete avoidance of the habitat characteristic.
Table 1. Definition and description of summer habitat variables of the leopard cat.

| Ecological variables | Main definition and description |
|----------------------|---------------------------------|
| Biological factors   |                                  |
| Vegetation type      | Wider vegetation types: tree, shrub, meadow and farmland |
| Tree diameter at breast height (DBH) | Average DBH of trees closest to the center point (DBH > 10 cm, up to 1.3 m high) in 20 m x 20 m plots |
| Tree height (m)      | Average height of trees closest to the center point (DBH > 10 cm) in 20 m x 20 m plots |
| Tree density         | Number of trees (DBH > 10 cm) in 20 m x 20 m plots |
| Shrub height (m)     | Average shrub height in 20 m x 20 m plots |
| Shrub canopy (%)     | Average shrub canopy in 20 m x 20 m plots |
| Ground-plant cover (%) | Average ground-plant coverage in 20 m x 20 m plots |
| Stump quantity       | Number of stumps in 20 m x 20 m plots |
| Fallen-wood quantity | Number of fallen-wood in 20 m x 20 m plots |
| Withered grass cover (%) | Average withered grass coverage in 20 m x 20 m plots |
| Concealment          | At the height of 1 m, the visual distance of the sample ground in four directions is classified into three categories: good, moderate and bad from long to short |
| Abiotic factors      |                                  |
| Elevation (m)        | Elevation at the center point of the plot |
| Slope aspect         | Four categories: east slope (45° ~ 135°), south slope (135 ~ 225°), west slope (225 ~ 315°) and north slope (315 ~ 45°) |
| Slope gradient (°)   | Three categories: gentle slope (≤30°), moderate slope (30 ~ 60°) and steep slope (≥60°) |
| Slope position       | Three categories: lower slope (including valley), middle slope (including mountainside), upper slope (including ridge) |
| Lee condition        | Windbreak intensity classified into three categories: good, moderate and bad |
| Soil moisture degree | Soil moisture degree is classified into three categories: wet (can form a lump), relatively wet (can form a lump but will loosen after loosing grip), and dry (cannot form a lump) |
| Disturbance factors  |                                  |
| Distance from nearest water source | The horizontal distance from the plot to the water source (spring, river and other water bodies, without snow) with three categories: near (≤ 500 m), moderate (500 ~ 1000 m), and far (≥ 1000 m) |
| Distance from nearest residential area | The horizontal distance from the plot center to the nearest community. Three categories: near (≤ 500 m), moderate (500 ~ 1000 m), and far (≥ 1000 m) |
| Distance from anthropogenic disturbance | The horizontal distance from the sample land to the nearest community (like traveling, transporting, farming or grazing), three categories: near (≤ 500 m), moderate (500 ~ 1000 m), and far (≥ 1000 m) |
| Disturbance intensity | Three categories: strong (vegetation destroyed, or existing frequently human activities), moderate (vegetation disturbed, less human activities) and weak (almost no disturbance and change) |

Results

Comparison between used and nonused summer habitats

Results for continuous variables of used plots (n = 26) and nonused plots (n = 251) are shown in Table 2. Tree canopy (25.0 ± 5.3%), tree height (6.2 ± 1.6 m), and tree density (8.2 ± 2.2/plot) in used plots was significantly lower than those in nonused plots (P < 0.01). The number of tree stumps (0.2 ± 0.1/plot) in used plots was significantly lower than that in nonused plots (P < 0.05).

There were highly significant differences among slope position, vegetation type, and soil moisture degree (P < 0.01) between used plots and nonused plots (Table 3). Leopard cats preferred to select a lower slope (54.17%) with dry soil (50.00%) and shrub (80.77%) covered.

Analysis of resource selection index (VSI) of ecological factors in summer

Leopard cats preferred shrub and avoided farmland and meadows (Table 4). They preferred habitats with low or medium tree canopy (<50%), high tree DBH (>30 cm), and low tree height (<5 m), and avoided habitats with high tree canopy (>50%), high tree height (>5 m). They preferred low tree density (<20/plot), avoided moderate tree density (20 ~ 60/plot), and did not select high tree density (>60/plot). Leopard cats preferred habitats with high shrub height (>2 m), high shrub cover (>75%), medium ground-plant cover (25 ~ 50%), fewer than 3 fallen-woods, and 5 tree stumps. Leopard cats tended to choose habitats with medium concealment and avoid high concealment.

Leopard cats preferred habitats with an elevation higher than 800 m and avoid those lower than 800 m (Table 5). They preferred north, flat, and gentle slope under bad Lee condition, and avoided west, gentle, and middle slope. Leopard cats preferred dry soil and avoided wet soil.

Leopard cats tended to choose habitats with a medium distance from water and avoid habitats far from water. They preferred habitats near to anthropogenic disturbance with a moderate disturbance...
intensity and avoided habitats with weak disturbance intensity (Table 6).

Thus, the characteristics for habitat selection of leopard cats are as follows: low tree canopy (<50%), low tree height (<5 m), thick DBH (>30 cm), sparse tree density (<20/plot), high shrub height (>2 m), high shrub cover (>75%), moderate ground-plant cover, and withered grass cover (25 ~ 50%), less than 3 stumps, less than 5 fallen-woods, moderate concealment, dry soil, bad Lee condition, and above 800 m, located in the north, flat, and lower slope. Moreover, leopard cats showed a preference for habitats near to anthropogenic disturbance with moderate disturbance intensity.

### Discussion

Habitat selection is an adaption to the environment (Aryal et al. 2014) that allows animals to survive, reproduce, and perpetuate their species. Habitat selection is influenced by many factors (Tong et al. 2010) such as food abundance, vegetation type, elevation, temperature, landform, and roads (Zhang and Ma 1999; Oh et al. 2010; Bashir et al. 2014). Previous studies have shown that leopard cats are widely distributed and are broadly adapted to a wide variety of habitat, and in different areas, their habitat has included a great diversity in vegetation type, including meadow, shrub, evergreen broad-leaved forest, mixed forest, and coniferous forest (Oh et al. 2010; Rabinowitz 1990).
Table 4. Resource selection index (VSI) for biological factors in the summer.

| Biological factors | Item          | survey plot number(n) | sample number | used plot number(n) | utilization ratio(%) | selection coefficient(w) | selection index(E) | Selection |
|--------------------|---------------|------------------------|---------------|---------------------|----------------------|--------------------------|---------------------|-----------|
| Vegetation type    | Arbor         | 153                    | 0.552         | 5                   | 0.033                | 0.177                    | −0.061              | AR        |
|                    | Shrub         | 112                    | 0.404         | 21                  | 0.188                | 0.852                    | 0.620               | P         |
|                    | Meadow        | 4                      | 0.014         | 0                   | 0.000                | 0.000                    | −1.000              | NS        |
|                    | Farmland      | 8                      | 0.029         | 0                   | 0.000                | 0.000                    | −1.000              | NS        |
| Tree canopy (%)    | <25%          | 102                    | 0.368         | 15                  | 0.147                | 0.426                    | 0.261               | P         |
|                    | 25 ~ 50%      | 51                     | 0.184         | 7                   | 0.137                | 0.398                    | 0.228               | P         |
|                    | 50 ~ 75%      | 50                     | 0.181         | 1                   | 0.020                | 0.058                    | −0.623              | NP        |
|                    | >75%          | 74                     | 0.267         | 3                   | 0.041                | 0.118                    | −0.360              | NP        |
| Tree DBH (cm)      | <10 cm        | 87                     | 0.375         | 8                   | 0.092                | 0.300                    | 0.091               | AR        |
|                    | 10 ~ 20 cm    | 70                     | 0.302         | 1                   | 0.014                | 0.047                    | −0.685              | NP        |
|                    | 20 ~ 30 cm    | 30                     | 0.129         | 2                   | 0.067                | 0.218                    | −0.069              | AR        |
|                    | >30 cm        | 45                     | 0.194         | 6                   | 0.133                | 0.435                    | 0.270               | P         |
| Tree height (m)    | <5 m          | 41                     | 0.177         | 9                   | 0.220                | 0.716                    | 0.483               | P         |
|                    | 5 ~ 10 m      | 115                    | 0.496         | 5                   | 0.043                | 0.142                    | −0.276              | NP        |
|                    | 10 ~ 20 m     | 69                     | 0.297         | 3                   | 0.043                | 0.142                    | −0.276              | NP        |
|                    | >20 m         | 7                      | 0.030         | 0                   | 0.000                | 0.000                    | −1.000              | NS        |
| Tree density       | <20           | 133                    | 0.480         | 22                  | 0.165                | 0.699                    | 0.473               | P         |
|                    | 20 ~ 40 cm    | 68                     | 0.245         | 3                   | 0.044                | 0.186                    | −0.145              | NP        |
|                    | 40 ~ 60 cm    | 37                     | 0.134         | 1                   | 0.027                | 0.114                    | −0.373              | NP        |
|                    | >60           | 39                     | 0.141         | 0                   | 0.000                | 0.000                    | −1.000              | NS        |
| Shrub height (m)   | <1 m          | 94                     | 0.359         | 10                  | 0.106                | 0.259                    | −0.125              | NP        |
|                    | 1 ~ 2 m       | 159                    | 0.607         | 13                  | 0.082                | 0.199                    | −0.252              | NP        |
|                    | >2 m          | 9                      | 0.034         | 2                   | 0.222                | 0.542                    | 0.238               | P         |
| Shrub cover (%)    | <25%          | 72                     | 0.260         | 6                   | 0.083                | 0.205                    | −0.098              | AR        |
|                    | 25 ~ 50%      | 98                     | 0.354         | 8                   | 0.082                | 0.201                    | −0.108              | NP        |
|                    | 50 ~ 75%      | 64                     | 0.231         | 5                   | 0.078                | 0.192                    | −0.130              | NP        |
|                    | >75%          | 43                     | 0.155         | 7                   | 0.163                | 0.401                    | 0.232               | P         |
| Ground-plant cover (%) |            | 83                     | 0.300         | 5                   | 0.060                | 0.154                    | −0.237              | NP        |
|                    | 25 ~ 50%      | 61                     | 0.220         | 10                  | 0.164                | 0.420                    | 0.253               | P         |
|                    | 50 ~ 75%      | 47                     | 0.170         | 4                   | 0.085                | 0.218                    | −0.069              | AR        |
|                    | >75%          | 86                     | 0.310         | 7                   | 0.081                | 0.208                    | −0.091              | AR        |
| Number of stumps   | <3            | 251                    | 0.906         | 26                  | 0.104                | 1.000                    | 0.600               | P         |
|                    | 3 ~ 6         | 20                     | 0.072         | 0                   | 0.000                | 0.000                    | −1.000              | NS        |
|                    | 6 ~ 9         | 2                      | 0.007         | 0                   | 0.000                | 0.000                    | −1.000              | NS        |
|                    | >9            | 4                      | 0.014         | 0                   | 0.000                | 0.000                    | −1.000              | NS        |
| Number of fallen-wood |            | 240                    | 0.866         | 24                  | 0.100                | 0.457                    | 0.157               | P         |
|                    | 5 ~ 10        | 24                     | 0.087         | 1                   | 0.042                | 0.191                    | −0.272              | NP        |
|                    | >10           | 13                     | 0.047         | 1                   | 0.077                | 0.352                    | 0.027               | AR        |
| Wither-grass cover (%) |            | 233                    | 0.841         | 22                  | 0.094                | 0.295                    | 0.082               | AR        |
|                    | 25 ~ 50%      | 14                     | 0.051         | 2                   | 0.143                | 0.446                    | 0.281               | P         |
|                    | 50 ~ 75%      | 6                      | 0.022         | 0                   | 0.000                | 0.000                    | −1.000              | NS        |
|                    | >75%          | 24                     | 0.087         | 2                   | 0.083                | 0.260                    | 0.019               | AR        |
| Concealment        | Bad           | 109                    | 0.396         | 9                   | 0.083                | 0.281                    | −0.085              | AR        |
|                    | Moderate      | 76                     | 0.276         | 11                  | 0.145                | 0.492                    | 0.193               | P         |
|                    | Good          | 90                     | 0.327         | 6                   | 0.067                | 0.227                    | −0.190              | NP        |

In this study, habitat selection of leopard cat reflected not only natural ecological requirements but also influence from human disturbance and human activities. We found that leopard cats in northern Taihang Mountain preferred habitats with shrub vegetation and avoided habitats with trees, which is probably related to their prey. Predators prefer habitats with high prey density (Davidson et al. 2012). As carnivores, leopard cats primarily prey on small rodents (Han et al. 1995; Rajaratnam et al. 2007), so their habitat selection will be mainly determined by the spatial distribution of rodents. Small rodents are more abundant in early successional and highly disturbed habitats, and studies have found that most of rodent species in Taihang Mountain are more likely to live in shrub habitat (Si 2017; Huang et al. 2019), such as Niviventer confucianus and Apodemus peninsulae (Fan et al. 2020; Bao, Li, and Shi 2005), which were the main prey species of leopard cats in our study area. By providing suitable habitat for prey, shrub habitat provides an abundance of food for leopard cats. Hence, leopard cats had a tendency to choose shrub habitats. Similarly, Oh et al. (2010) reported that leopard cats preferred to use mountain ridges because the dense shrubs growing on ridges could be preferred habitat for prey. The highly consistent spatial
Table 5. Resource selection index (VSI) for abiotic factors in the summer.

| Abiotic factors | Item | survey plot number (n) | sample number | used plot number (r) | utilization ratio (r/i) | selection coefficient (w) | selection index (E) | Selection |
|-----------------|------|------------------------|---------------|---------------------|------------------------|---------------------------|---------------------|----------|
| Elevation (m)   | <400 | 77                     | 0.278         | 7                   | 0.091                  | 0.205                     | −0.100             | AR       |
| 400 ~ 800       | 93   | 0.336                  | 5             | 0.054               | 0.121                  | −0.348                    | NP                  |
| >800            | 107  | 0.386                  | 14            | 0.131               | 0.475                  | 0.310                     | P                   |
| Total           | 277  |                        |               | 0.444               |                        |                           |                     |
| Slope aspect    | East | 53                     | 0.194         | 5                   | 0.094                  | 0.259                     | −0.019             | AR       |
|                 | West | 61                     | 0.223         | 3                   | 0.049                  | 0.135                     | −0.298             | NP       |
|                 | South| 68                     | 0.249         | 6                   | 0.088                  | 0.243                     | −0.015             | AR       |
|                 | North| 91                     | 0.333         | 12                  | 0.132                  | 0.363                     | 0.184              | P        |
|                 | Total| 273                    |               | 0.364               |                        |                           |                     |
| Slope gradient(°) | Gentle | 195                     | 0.704         | 23                  | 0.118                  | 0.547                     | 0.243              | P        |
|                 | Moderate | 57                     | 0.206         | 1                   | 0.018                  | 0.081                     | −0.607             | NP       |
|                 | Steep | 25                     | 0.090         | 2                   | 0.080                  | 0.371                     | 0.054              | AR       |
|                 | Total | 277                    |               | 0.215               |                        |                           |                     |
| Slope position  | Upper | 90                     | 0.333         | 7                   | 0.078                  | 0.265                     | −0.114             | AR       |
|                 | Middle| 107                    | 0.396         | 4                   | 0.037                  | 0.127                     | −0.447             | NP       |
|                 | Lower | 73                     | 0.270         | 13                  | 0.178                  | 0.607                     | 0.291              | P        |
|                 | Total | 270                    |               | 0.293               |                        |                           |                     |
| Soil moisture degree | Dry | 75                     | 0.271         | 13                  | 0.173                  | 0.597                     | 0.283              | P        |
|                 | Relatively | 118                    | 0.303         | 11                  | 0.093                  | 0.321                     | −0.019             | AR       |
|                 | Wet | 84                     | 0.426         | 2                   | 0.024                  | 0.082                     | −0.605             | NP       |
|                 | Total | 277                    |               | 0.290               |                        |                           |                     |
| Lee condition   | Bad   | 102                    | 0.368         | 11                  | 0.108                  | 0.491                     | 0.191              | P        |
|                 | Moderate | 91                     | 0.329         | 7                   | 0.077                  | 0.275                     | −0.096             | AR       |
|                 | Good | 84                     | 0.303         | 8                   | 0.095                  | 0.340                     | 0.010              | AR       |
|                 | Total | 277                    |               | 0.280               |                        |                           |                     |

Table 6. Resource selection index (VSI) for disturbance factors in the summer.

| Disturbance factors         | Item | survey plot number (n) | sample number | used plot number (r) | utilization ratio (r/i) | selection coefficient (w) | selection index (E) | Selection |
|-----------------------------|------|------------------------|---------------|---------------------|------------------------|---------------------------|---------------------|----------|
| Distance from nearest water source(m) | Near | 176                    | 0.635         | 18                  | 0.102                  | 0.404                     | 0.096              | AR       |
|                             | Moderate | 54                     | 0.195         | 7                   | 0.130                  | 0.512                     | 0.211              | P        |
|                             | Far | 47                     | 0.170         | 1                   | 0.021                  | 0.084                     | −0.597             | NP       |
|                             | Total | 277                    |               | 0.253               |                        |                           |                     |
| Distance from nearest residential area (m) | Near | 78                     | 0.282         | 9                   | 0.115                  | 0.404                     | 0.095              | AR       |
|                             | Moderate | 128                    | 0.462         | 11                  | 0.086                  | 0.301                     | −0.052             | AR       |
|                             | Far | 71                     | 0.256         | 6                   | 0.085                  | 0.296                     | −0.060             | AR       |
|                             | Total | 277                    |               | 0.286               |                        |                           |                     |
| Distance from anthropogenic disturbance (m) | Near | 167                    | 0.687         | 20                  | 0.120                  | 0.598                     | 0.284              | P        |
|                             | Moderate | 40                     | 0.165         | 1                   | 0.023                  | 0.125                     | −0.455             | NP       |
|                             | Far | 36                     | 0.148         | 2                   | 0.056                  | 0.277                     | −0.092             | AR       |
|                             | Total | 243                    |               | 0.200               |                        |                           |                     |
| Disturbance intensity       | Weak | 123                    | 0.488         | 7                   | 0.057                  | 0.192                     | −0.269             | NP       |
|                             | Moderate | 75                     | 0.298         | 11                  | 0.147                  | 0.495                     | 0.195              | P        |
|                             | Strong | 54                     | 0.214         | 5                   | 0.093                  | 0.313                     | −0.032             | AR       |
|                             | Total | 252                    |               | 0.296               |                        |                           |                     |

characteristic of habitat selected by leopard cats suggests that prey distribution can have a strong impact on the habitat selection of predators.

The landform is also an important factor in the habitat selection of leopard cats. One study found that leopard cats preferred to move through valleys (Lee et al. 2017). Similarly, in this study leopard cats showed a tendency to use lower slopes, which generally make up valley topography in the Taihang Mountain regions. This preference might be explained by the need for efficient movement and antipredator behavior. Leopard cats spend most time resting and moving on the ground (Rabinowitz 1990); therefore, they tend to choose habitats with a gentle slope, fewer stumps, and fallen-woods to avoid obstacles on the ground, which might hinder them from hunting or getting away from dangers quickly. Moreover, there are prey rodents, leopard cat’ preferred food, living in such habitats because of many human activities here (Liu et al. 2018).

Temperature regulation might also affect habitat choice by leopard cats. Preference of carnivores for temperature also affects their habitat selection; in the summer many carnivores avoid high temperatures in the daytime by nocturnal activities (Marinho et al. 2018). In this study, leopard cats preferred to choose the northern slope, which is shadier in the summer time and could help leopard cats avoid high temperature.

The anthropogenic disturbance may significantly affect habitat selection by wildlife (Ge et al. 2015). Our study area is located near Beijing, one of the largest cities in China where development has been proceeding rapidly, and the level of urbanization has been close to 65%. The main kinds of human disturbance in the study area are farming, animal husbandry, collection of medicinal plants, and transportation. Our research
found that leopard cats tended to choose habitats near human disturbance with moderate disturbance intensity, which indicates that leopard cats in Taihang Mountains could tolerate and even adapt to human activities in their habitats. Similar results were reported by other studies, e.g., Sean et al. (2007) found that leopard cats in Thailand were not affected by roads and vehicles, and Mohamed et al. (2013) reported that leopard cats in Malaysian Borneo preferred to occur in areas with high human disturbance intensity. Although roads are known to cause negative impacts on wildlife, some studies have documented animals’ more complex responses to this anthropogenic disturbance. Habitats close to roads can contain a large number of small mammals (Meunier et al. 1999), and roads could increase the spatial overlap of predators and prey, so predators can use roads to improve predation rate (Demars and Boutin 2018). Moreover, some animals can also use roads to increase travel efficiency, which may be positive for their survival (Muhly et al. 2019; Mumma et al. 2019). Hence, in this study, choosing habitats crossed by dirt roads suggests that leopard cats may use roads for higher movement efficiency and more abundant food resources.

Human communities provide good habitats for rodents like Rattus norvegicus and Mus musculus, and in recent years, increasing agricultural activity has helped small rodent populations expand (Ye et al. 2015), which can be used as food species by leopard cats. Leopard cats also occasionally prey on poultry and eat garbage (Han et al. 1995), leading them to use habitats with high disturbance.

Habitat selection is also influenced by interspecific competition (Suhling 1996; Jiang et al. 2009; Jiang, Jian Zhang, and Stott 2010), especially among species with similar food niche. In Taihang Mountainous regions of this study, there are sympatric species such as leopard (Panthera pardus), red fox (Vulpes vulpes), jackal (Canis alpinus), yellow weasel (Mustela sibirica), and raccoon dog (Nyctereutes procyonoides), which have similar food niche with leopard cat (Ye et al. 2015; Han et al. 1995). Therefore, leopard cats need to avoid and reduce competition with co-occurring species. As the results of interspecific competition and niche partitioning, leopard cats are inclined to select and utilize habitats closer to human communities, which means that leopard cats have a relatively higher tolerance of anthropogenic influence compared with the above mentioned sympatric predator species. Further studies of the entire carnivore community might help elucidate these relationships.

Overall, our study demonstrates that the habitat selection of leopard cats in Taihang Mountainous regions in northern China was determined by both natural ecological factors and anthropogenic factors. With regard to natural factors, in the summer leopard cats preferred to choose habitats with shrub vegetation and lower air temperatures, and avoided habitats with abundant ground obstacles such as stumps or fallen woods. Food resources were the key factor influencing habitat selection and shrub habitats are known to support more small mammal prey species used by leopard cats. In addition, human disturbance appeared to attract leopard cats, likely because of increased prey abundance in areas with human activity. As the main areas of human disturbance, communities, agricultural lands, and roadsides have been shown in other studies to have high densities of preferred rodent prey species, so leopard cats showed a preference for habitats near human disturbance areas with moderate levels of disturbance intensity. Niche differentiation caused by human disturbance also induces leopard cats to occur in areas near human activities with less competition from other native carnivores which prefer to avoid human disturbance.

Conservation policy and suggestion

Most of the distributed areas of leopard cats are not within reserves or key monitoring areas, so we should enhance the monitoring, protection, and management of those areas to maintain habitat suitability. In our study, leopard cats showed a strong tendency to use habitats near human and communities, so we need to promote animal conservation and environmental education to improve wildlife conservation and minimize negative interactions with wildlife such as the loss of domestic animals. On the other hand, species related to special habitat types can be good indicators by providing information of particular environment for wildlife managers (Carignan and Villard 2002), and top predators can be ideal indicator species because they can represent the changes of food webs (Ramirez et al. 2014). Hence, leopard cats are the potential to be indicator species for peri-urban nature ecosystem assessment. Further study is recommended on estimating the density of the population of leopard cats, which can reflect the ecosystem restoration and protection effectiveness.

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