# Habitat Assessment for Giant Pandas in the Qinling Mountain Region of China

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# Habitat Assessment for Giant Pandas in the Qinling Mountain Region of China

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**ABSTRACT** Because habitat loss and fragmentation threaten giant pandas (*Ailuropoda melanoleuca*), habitat protection and restoration are important conservation measures for this endangered species. However, distribution and value of potential habitat to giant pandas on a regional scale are not fully known. Therefore, we identified and ranked giant panda habitat in Foping Nature Reserve, Guanyinshan Nature Reserve, and adjacent areas in the Qinling Mountains of China. We used Mahalanobis distance and 11 digital habitat layers to develop a multivariate habitat signature associated with 247 surveyed giant panda locations, which we then applied to the study region. We identified approximately 128 km$^2$ of giant panda habitat in Foping Nature Reserve (43.6% of the reserve) and 49 km$^2$ in Guanyinshan Nature Reserve (33.6% of the reserve). We defined core habitat areas by incorporating a minimum patch-size criterion (5.5 km$^2$) based on home-range size. Percentage of core habitat area was higher in Foping Nature Reserve (41.8% of the reserve) than Guanyinshan Nature Reserve (26.3% of the reserve). Within the larger analysis region, Foping Nature Reserve contained 32.7% of all core habitat areas we identified, indicating regional importance of the reserve. We observed a negative relationship between distribution of core areas and presence of roads and small villages. Protection of giant panda habitat at lower elevations and improvement of habitat linkages among core habitat areas are important in a regional approach to giant panda conservation. (JOURNAL OF WILDLIFE MANAGEMENT 73(6):852–858; 2009)

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The giant panda (*Ailuropoda melanoleuca*) is one of the world's most recognized endangered mammals. Giant panda populations historically occurred throughout most of southern and eastern China but remaining populations are now almost completely isolated from one another and distributed in 6 separate regions (i.e., Qinling, Minshan, Qionglai, Daxiangling, Xiaoxiangling, and Liangshan mountains). Habitat loss and degradation continue to threaten survival of the giant panda, and current reserves may not adequately protect habitat for giant pandas or areas important for dispersal and genetic exchange (Loucks et al. 2001, Xu et al. 2006*a*). Habitat fragmentation is isolating panda populations and is problematic even in protected areas (Liu et al. 2001; Xu et al. 2006*a*, *b*; Yin et al. 2006; Chen et al. 2007).

Because many protected areas are separated, identification of potential habitat linkages is important to increase connectivity and exchange among giant panda populations (Yin et al. 2006). The Qinling Mountains are important for giant panda conservation in China. According to the 3rd National Survey for Giant Panda, the Qinling Mountains contain approximately 20% of China's total population of giant pandas in the wild (State Forestry Administration 2006). However, giant panda populations in this mountain range occur in 4 different areas, which may become permanently separated into isolated populations (Loucks et al. 2003). Although some core areas for giant pandas are well-protected, additional areas may exist where habitat restoration may be used to expand giant panda habitat and where giant pandas may ultimately be reintroduced. Thus, our objectives were to determine habitat use and delineate important habitat areas of giant pandas in the Qinling Mountains of China. We chose the region containing Foping and Guanyinshan Nature Reserves as our focal study area. Habitat conditions and protection status varied substantially in this region, thus providing an ideal area to examine how land use and protection status influenced habitat use by giant pandas.

## STUDY AREA

Our study region encompassed a 5,700-km$^2$ area in the Qinling Mountains of Shaanxi province (Fig. 1). We defined that region based on boundaries of a Landsat 7 Enhanced Thematic Mapper satellite image, which we used to develop digital map layers. That image area was centered on an important system of nature reserves that were established to protect the giant panda and other endangered species. The research area where we collected field data was contained within that region and included Foping Nature Reserve and Guanyinshan Nature Reserve (Fig. 1).

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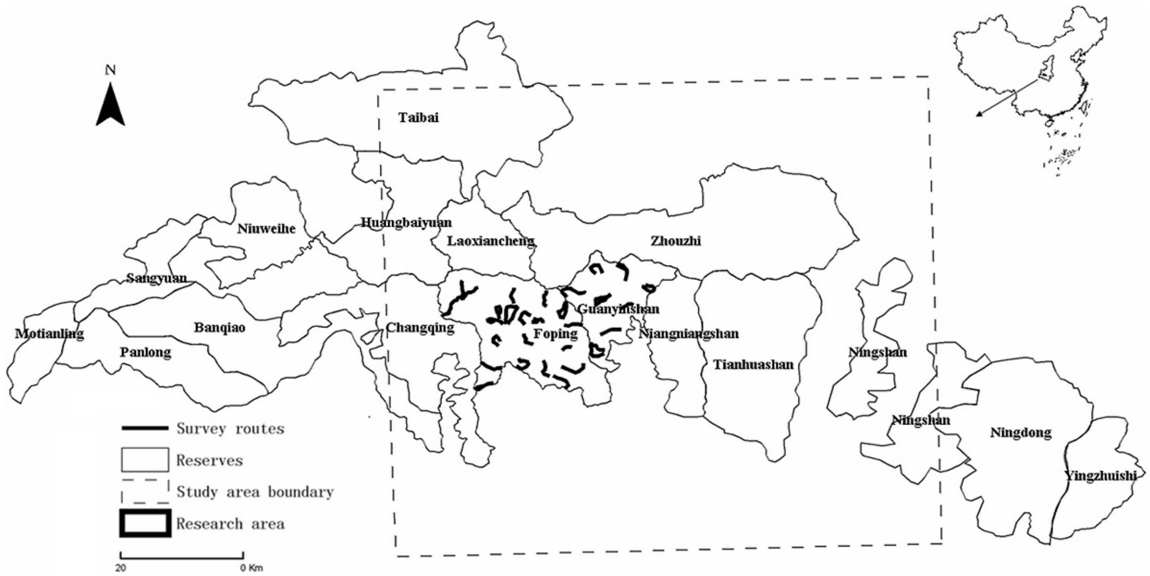


**Figure 1.** Nature reserves within region to delineate giant panda habitat, Qinling Mountains, China, 2006–2007. Field sampling occurred in Foping Nature Reserve and Guanyinshan Nature Reserve.

Foping Nature Reserve (33°32′–33°45′N, 107°40′–107°55′E) was established in 1978 by the State Council and under the leadership of the Ministry of Forestry primarily for protection of giant pandas. It was approximately 293 km$^2$ and was next to Longcaoping Nature Reserve on the east and was contiguous with Changqing Nature Reserve to the west and Zhouzhi and Laoxiancheng Nature Reserves to the north. Elevations ranged from 980 m to 2,904 m. Dominant vegetation types included deciduous broadleaf forest, mixed coniferous–broadleaf forest, coniferous forest, coniferous-shrubs, and meadows (Ren et al. 1998, Cuesta 2005, Liu et al. 2005). Foping Nature Reserve had mature, undisturbed forests ($\geq$50 yr old) in the western portion of the reserve (core protected area where most human access was forbidden; 43% of the nature reserve) with disturbance levels gradually increasing eastward with tourist zones and areas where human access was less restricted. The core area has been less affected by past timber harvesting than neighboring nature reserves.

Guanyinshan Nature Reserve (33°35′–33°45′N, 107°51′–108°01′E) was formally established in 2003. Timber harvesting occurred in Guanyinshan Nature Reserve from 1974 to 1998 and State highway 108 crossed the reserve. Elevation of Guanyinshan was between 1,150 m and 2,574 m. Mixed coniferous–broadleaf forest and deciduous broadleaf forest were the primary forest types. Habitat recovery in Guanyinshan Nature Reserve occurred to some extent through establishment of a trail monitoring system, strengthening protection of endangered species, stopping activities that harm forest resources (e.g., unlawful cutting of trees, collecting firewood, illegal hunting), and by improving management standards.

## METHODS

We assumed that giant pandas were distributed optimally in the landscape and that presence locations based on sign provided a representative sample of that distribution (Knick and Rotenberry 1998, Rotenberry et al. 2006). Giant pandas consume large amounts of bamboo and spend much of their time feeding (Dierenfeld et al. 1982). Consequently, scat locations represent a biologically meaningful measure of habitat use by giant panda, particularly at the coarse scale of our selected pixel size (85 m, see below). We conducted transect surveys to document presence of giant pandas from March 2006 to March 2007. We established 29 survey routes stratified according to local terrain condition and habitat characteristics within Foping and Guanyinshan Nature Reserves (Fig. 1). Transects ranged in length from 2 km to 7.5 km and averaged 3.9 km. Giant pandas in Foping Nature Reserve use higher elevations in the summer and areas at lower elevations during winter (Yang et al. 1997, 1998; Yang and Yong 1998; Liu 2001). For conservation planning, it is important to assess year-round habitat requirements. Therefore, we surveyed each transect 3 times, during spring (Mar–May), summer (Jun–Aug), and autumn–winter (Sep–Feb).

Due to steep terrain and complex topography, we established survey routes primarily along an existing system of trails monitored by reserve staff. Each transect consisted of walking a predetermined route to record locations of mammalian sign. We used colored strands of fabric material to flag transects. Transects typically followed ridgelines and streams and were away from maintained trails or roads. To increase sign detection, we limited search distance on either side of the transect to 2 m, resulting in a transect width of 4 m. For each observed sign of giant panda activity, we recorded longitude and latitude using a Global Positioning System (GPS) receiver. For each location, we recorded type of sign (i.e., scat, hair, scrape, claw marks, mark trees, foraging sign), weather conditions, and estimated age of observed sign. After completing data collection, we removed or marked (e.g., claw marks on trees) all sign to prevent double-counting.

**Table 1.** Variables and value range used in the Mahalanobis distance ($D^2$) model to determine habitat use for giant pandas in the Qinling Mountains of China, 2006–2007.

| Variable | Description | Classes or value range | Source |
|---|---|---|---|
| Elevation | Elevation (m) | 490.0–3,748.0 m | Consultative Group for International Agricultural Research-Consortium for Spatial Information (CGIAR-CSI) |
| Vegetation | Vegetation type | Mixed coniferous–broadleaf forest | Based on Cuesta (2005) |
| Bamboo | Bamboo type | *Bashania fargesii* | The Third National Survey for Pandas and Habitat |
| Slope | Slope steepness (°) | 1.2–48.7 | Calculated from elevation with the SLOPE command (ArcGIS® 9.2) |
| Aspects | Beers' transformation of aspect | −1.0–359.9 | Calculated from aspect based on Beers et al. (1966) |
| Terrain shape index | Measure of local topographic variability as a continuous variable indicating convex (<−0.05) or concave (>0.05) landforms | −68.0–144.0 | Calculated based on McNab (1989) |
| Relative slope position | Indicates where on a slope a pixel is located | 0.0–100.0 | Calculated from elevation based on Wilds (1997) |
| Topographic relative moisture index | Index of moisture considering the effects of slope position, aspect, and elevation | 0.0–60.0 | Calculated based on Parker (1982) |
| Proximity to roads | Distance to the nearest roads (m) | 0.0–7,438.8 | Calculated with ArcGIS® 9.2, spatial analyst tools Euclidean Distance |
| Proximity to streams | Distance to the nearest stream (m) | 0.0–1,813.7 | Calculated with ArcGIS® 9.2, spatial analyst tools Euclidean Distance |
| Proximity to small villages | Distance to the nearest residential areas (m) | 0.0–16,748.8 | Calculated with ArcGIS® 9.2, spatial analyst tools Euclidean Distance |

We generated data layers with a Geographic Information System (GIS) for 11 habitat variables. We chose those variables to represent unique aspects of giant panda habitat use based on their documented importance to giant pandas (Hu et al. 1985, Wei et al. 2000, Liu et al. 2005, Zhang et al. 2006; Table 1). In selecting habitat variables, we considered potential for bias if the model were used to predict potential impacts of habitat changes or to apply the model beyond the survey area. Therefore, we used simple, binary classifications for vegetation cover and bamboo and measured the physical and anthropogenic environment with continuous topographic indices and proximity measures. For vegetation cover, we used presence or absence of mixed coniferous–broadleaf forest as a design variable for vegetation type (Cuesta 2005). Bamboo is one of the most important components of giant panda habitat (Linderman et al. 2005). There were 2 dominant bamboo species in the Qinling Mountains, *Fargesia qinlingensis* and *Bashania fargesii*, the latter of which was the most dominant bamboo species in our study region (Pan et al. 1988). Therefore, we used presence or absence of *B. fargesii* to model bamboo presence and digitized its distribution in Shaanxi province based on the 3rd National Survey for Giant Panda (State Forestry Administration 2006).

We used a digital elevation model (DEM) with a resolution of 85 m × 85 m to calculate 6 topographic variables: elevation, slope, aspect, terrain shape index, relative slope position, and topographic relative moisture index (Table 1). Human activities within the study region were mostly associated with roads and agricultural and residential areas, so we calculated proximity to small villages and proximity to roads as anthropogenic variables. We calculated proximity to streams and determined stream courses using ArcGIS® 9.2 hydrology tools. We also used existing maps of rivers and streams to verify correct delineation of streams. We calculated distance (m) to streams, roads, and small villages with spatial analyst tools in ArcGIS® 9.2. We set the resolution of all GIS data layers based on the pixel size of the DEM layer (85 × 85 m).

We used the 11 habitat variables to calculate Mahalanobis distance ($D^2$), which formed the basis for our habitat model. Mahalanobis distance can be used to predict species occurrence based on location data and GIS data layers and has been used for numerous large-mammal studies, including American black bears (*Ursus americanus*; Clark et al. 1993) and elk (*Cervus elaphus*; Telesco et al. 2007). Mahalanobis distance is a multivariate statistic that describes a measure of dissimilarity, with lower values representing increasingly similar conditions to those of the sample locations (Rao 1952, Clark et al. 1993). An important advantage of this method is that only presence data are needed for model development (Clark et al. 1993). Additionally, unlike other techniques based on presence data (e.g., Ecological Niche Factor Analysis [Hirzel et al. 2002]), habitat availability need not be defined, avoiding possible biases due to a subjective definition of study area extent. We calculated Mahalanobis distance based on the following equation:

$$D^2 = (\underline{x} - \hat{\underline{u}})' \hat{\sum}^{-1} (\underline{x} - \hat{\underline{u}}),$$

where $\underline{x}$ is a vector of habitat characteristics for each pixel in the GIS grid, $\hat{\underline{u}}$ is the mean vector of habitat characteristics of the sample locations, and $\Sigma^{-1}$ is the inverse of the variance–covariance matrix calculated from the sample locations. Mahalanobis distance is the sum of squares of standardized scores and correlations among variables are compensated for by $\hat{\Sigma}$, to create new, uncorrelated variables (Clark et al. 1993). The square roots of the diagonal elements of $\hat{\Sigma}$ are the standard deviations of variables, which weight the variables. Because this method weights variables and uses an inverse variance–covariance matrix, correlations among variables are accounted for, thus eliminating the need to assess collinearity among the variables. Interactions among habitat variables are compensated for by nonzero covariances in the off-diagonal elements of the $\hat{\Sigma}$ matrix. A variety of habitat combinations can produce identical distance values (Clark et al. 1993). Although Mahalanobis distance provides an index of habitat use, we note that our study was not designed to determine habitat quality (Morrison and Hall 2002).

We determined multivariate habitat conditions ($\underline{x}$) of giant panda locations by overlaying them onto the 11 GIS layers and calculated $\Sigma^{-1}$ using SAS software (SAS Institute, Cary, NC). We then calculated $D^2$ for all pixels within the study region with ArcGIS® 9.2. To determine ability of our habitat model to discriminate between areas used by giant pandas and those randomly available, we developed a null model by generating 1,000 random locations within the 2 nature reserves where we conducted transect surveys. We then developed cumulative frequency distributions based on $D^2$ values associated with giant panda locations and those associated with null model locations. We identified the greatest difference between the 2 cumulative frequency graphs as the threshold value to classify giant panda habitat (Pereira and Itami 1991). We defined habitat with $D^2$ values below that threshold as habitat for giant pandas. The threshold $D^2$ value optimized the trade-off between correctly classifying habitat of giant pandas on the landscape while also providing the most specific geographic delineation of favorable habitat (Browning et al. 2005). Pixels with $D^2$ values below that threshold value represent more favorable habitat, whereas pixels with values above the threshold value are less favorable (Pereira and Itami 1991). We used additional threshold values to define habitat suitability classes based on $D^2$ values associated with percentages of giant panda locations: 25%, 50%, 80%, 95%, and 100.0%. Finally, we defined core habitat areas by delineating large, contiguous patches of giant panda habitat, using a minimum patch-size criterion of 5.5 km$^2$ (752 contiguous pixels). We based that area criterion on mean home-range area for male and female giant pandas in Foping Nature Reserve (Liu 2001). We calculated core habitat areas for the study region and both nature reserves.

Finally, we tested our habitat model with independent field data based on surveys conducted in 2008. Using predictions of our final model, we selected 10 random locations within each of the 6 classes of $D^2$ values for each nature reserve. Thus, we visited 120 test locations. At each test location, we centered a plot (85 × 85 m) on the targeted pixel. We located plot centers using a GPS receiver and recorded presence or absence of giant panda, sign type, and sign frequency. Finally, we used presence or absence of giant panda sign in test plots as the dependent variable in a logistic regression to determine whether occurrence of giant panda was more likely with decreasing values of $D^2$ for the test plots.

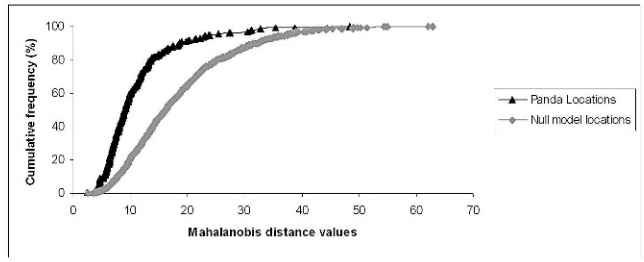


**Figure 2.** Cumulative frequency of Mahalanobis distance ($D^2$) values used to identify habitat areas for giant pandas in the Qinling Mountains of China, 2006–2007. The greatest difference between $D^2$ values of giant panda and null model locations occurred at $D^2 = 13.5$; values below this threshold represent giant panda habitat.

## RESULTS

We documented 247 giant panda locations (235 on Foping Nature Reserve and 12 on Guanyinshan Nature Reserve), representing scats (94.3%), feeding sign (1.6%), foot prints (2.8%), and direct observations (1.2%). Mahalanobis distance values for the study region ranged from 1.1 to 613.0, with a mean of 45.4 (SD = 37.7). Mahalanobis distance values corresponding to giant panda locations ranged from 2.4 to 48.4 ($\bar{x}$ = 11.0, SD = 6.6) whereas random locations had $D^2$ values that ranged from 2.7 to 62.9 ($\bar{x}$ = 18.2, SD = 9.7).

Based on cumulative frequency distributions of $D^2$ values for giant panda locations and null model locations, our habitat model effectively discriminated between areas typically used by giant pandas and those available (Fig. 2). The $D^2$ threshold value to identify giant panda habitat was 13.5 (Fig. 2); 80.1% of all giant panda locations had associated $D^2$ values below that value. The additional threshold values to define habitat classes based on percentages of giant panda locations were $D^2 < 6.7$ (25%), $D^2 < 9.0$ (50%), $D^2 < 13.5$ (80%), $D^2 < 23.7$ (95%), and $D^2 < 48.4$ (100.0%; Fig. 3). Thus, no giant panda locations occurred in pixels with $D^2$ values >48.4, which represented the sixth class. The 6 habitat suitability classes represented 5.9%, 9.7%, 24.7%, 37.7%, 21.2%, and 0.8%, respectively, of the area of Foping and Guanyinshan Nature Reserves (Table 2).

Using pixels with $D^2$ values below the threshold of 13.5, we estimated 733 km$^2$ of giant panda habitat in our study region of which approximately 483 km$^2$, or 65.9%, was protected by nature reserves. Likewise, 409 km$^2$ fit our definition of core giant panda habitat of which 306 km$^2$ (74.8% of the study region) was protected by nature reserves. We estimated that combined area of giant panda habitat in Foping and Guanyinshan Nature Reserves was 177 km$^2$, representing 40.3% of those reserves. The core area was approximately 122 km$^2$ in Foping Nature Reserve and 39 km$^2$ in Guanyinshan Nature Reserve, representing

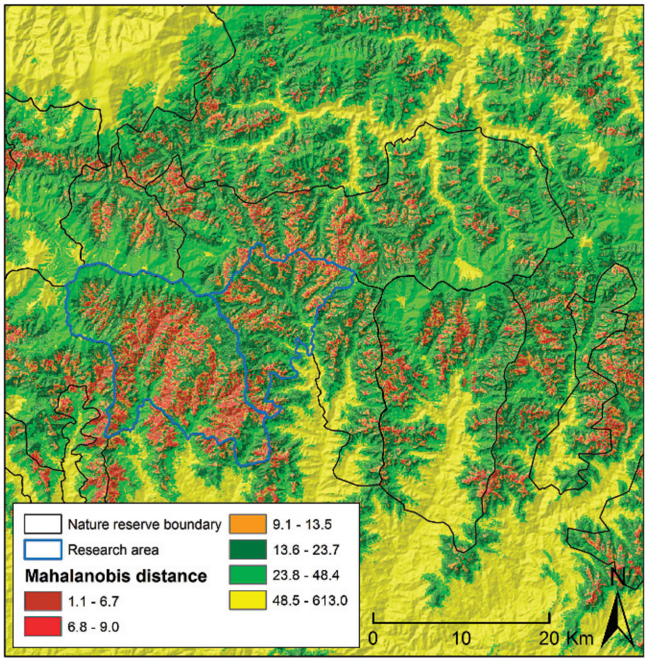


**Figure 3.** Six habitat suitability classes for the study region of giant panda habitat in the Qinling Mountains of China, 2006–2007. The 6 habitat classes were based on the following ranges of Mahalanobis distance ($D^2$) values: $1.1 \leq D^2 < 6.7$ for class 1; $6.7 \leq D^2 < 9.0$ for class 2; $9.0 \leq D^2 < 13.5$ for class 3; $13.5 \leq D^2 < 23.7$ for class 4; $23.7 \leq D^2 \leq 48.4$ for class 5; $D^2 > 48.4$ for class 6.

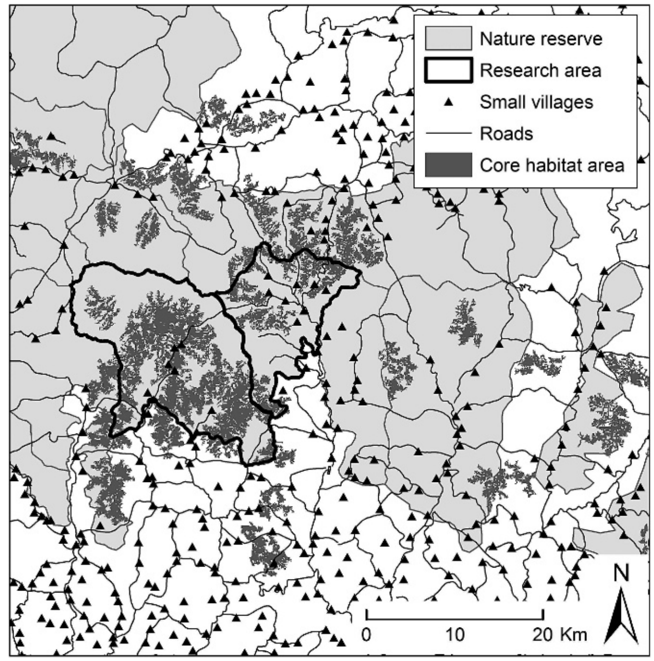


**Figure 4.** Core habitat areas for giant panda based on the Mahalanobis distance model and roads and small villages, Qinling Mountains, China, 2006–2007.

41.8% and 26.3% of each reserve, respectively. Core areas were patchily distributed (Fig. 4).

Our results indicate that giant panda habitat primarily represented areas at middle elevations, with gentle slopes, high forest cover, and away from areas with human activities (e.g., small villages). Habitat conditions associated with giant panda locations indicated that slope ($\bar{x} = 22.0$, SD = 4.4), elevation ($\bar{x} = 1,773$, SD = 240.5), and distance to small villages ($\bar{x} = 429.1$ m, SD = 334.5) were most influential; elevation and slope of the giant panda locations were moderately correlated with distance to the nearest village ($r = 0.37$, $P < 0.001$ and $r = 0.34$, $P < 0.001$, respectively), but slope was not correlated with elevation. Relative slope position ($\bar{x} = 81.1$, SD = 33.6), vegetation ($\bar{x} = 0.9$, SD = 0.3), topographic relative moisture index ($\bar{x} = 21.4$, SD = 9.6), and distance to roads ($\bar{x} = 2,522$ m, SD = 1,447) were moderately important. Distance (m) to streams, aspect, terrain shape, and bamboo distribution had weakest influence on our habitat model. Our field surveys to test model predictions resulted in 66 locations of giant pandas. Logistic regression of the test data indicated that presence of giant panda sign in test plots was more likely with decreasing $D^2$ values of the corresponding pixels ($P = 0.027$ and $\beta = -0.034$).

## DISCUSSION

Most giant panda locations (80.1%) occurred in areas that represented only 40.3% of the 2 nature reserves where we conducted our surveys, indicating that giant panda activity is limited to specific environmental conditions. Although elevation and slope were important variables, correlations with distance to the nearest village also suggested that these 2 variables represented areas where anthropogenic disturbance was low. Giant panda habitat occurred primarily in middle elevations, which have been well-protected by the reserve system. However, habitat also existed at lower elevations if anthropogenic influence was low (i.e., greater distances to villages and roads). The highest elevation of our sample locations was 2,445 m. Because Foping and Guanyinshan Nature Reserves have slightly lower elevations

**Table 2.** Percentage of panda and null model locations within 6 classes of Mahalanobis distance values ($D^2$) to identify giant panda habitat in Foping Nature Reserve and Guanyinshan Nature Reserve, China, 2006–2007.

| $D^2$ class | % of area | Frequency of locations | % locations | Frequency of null model locations | % of null model locations |
|---|---|---|---|---|---|
| Class 1: $1.10 \leq D^2 < 6.7$ | 5.9 | 60 | 24.3 | 61 | 6.1 |
| Class 2: $6.7 \leq D^2 < 9.0$ | 9.7 | 64 | 25.9 | 89 | 8.9 |
| Class 3: $9.0 \leq D^2 < 13.5$ | 24.7 | 74 | 29.9 | 232 | 23.2 |
| Class 4: $13.5 \leq D^2 < 23.7$ | 37.7 | 36 | 14.6 | 384 | 38.4 |
| Class 5: $23.7 \leq D^2 \leq 48.4$ | 21.2 | 13 | 5.3 | 223 | 22.3 |
| Class 6: $D^2 > 48.4$ | 0.8 | 0 | 0 | 11 | 1.1 |
| Total | 100.0 | 247 | 100.0 | 1,000 | 100.0 |

compared with other areas in our study region, our model may have underestimated giant panda habitat at higher elevations.

Approximately 733 $km^2$ of our study region contained giant panda habitat, of which a large proportion was protected by the nature reserve system (65.9%). Fragmentation of habitat was evident, because only about 409 $km^2$ of giant panda habitat occurred in larger patches (>5.5 $km^2$). Within our study region, Foping Nature Reserve represented the distributional center of giant panda habitat, containing a large percentage of giant panda habitat and core areas compared with the other reserves. Some habitat areas in our study region were not protected by reserves (250 $km^2$; 34.1% of all giant panda habitat), thus presenting opportunities for additional habitat protection and restoration.

The 3rd National Survey for Giant Panda indicated that within the current distribution of the species in China, population densities were greatest in the Qinling Mountains. We speculate that the extensive reserve system may play an important role in maintaining giant panda populations in the Qinling Mountains (Li et al. 2004). However, core areas are somewhat limited and fragmented (Fig. 4). Human disturbance can have a strong negative influence on wildlife habitat (Liu et al. 1999, An et al. 2006, Linderman et al. 2006). Indeed, our findings indicate that fragmentation of core areas was primarily a function of lower giant panda use of areas near roads and villages. Improving connectivity among core areas may be important to maintain integrity of giant panda habitat on a regional scale (Kindall and van Manen 2007).

Although much of the Qinling Mountains is protected by nature reserves, land-use history plays an important role in distribution patterns of species and biological diversity (Graham et al. 2006). Bearer et al. (2008) indicated that timber harvesting and fuel-wood collection may reduce giant panda use of forested habitats for several decades after harvests. Guanyinshan Nature Reserve was established recently and lack of giant panda sign in that reserve (12 out of 247 sign locations) suggests the potentially important influence of current and past anthropogenic disturbances on habitat use. However, our model predicted that 26.3% of Guanyinshan Nature Reserve may be considered core habitat. Thus, with proper protection and management (i.e., management of anthropogenic disturbance and forest restoration), the potential for range expansion is high, particularly if connectivity with other nature reserves is maintained or enhanced. This is supported by recent (2007) radiotelemetry data of 2 giant pandas that moved from Foping Nature Reserve into Guanyinshan Nature Reserve during summer (F. W. Wei, Chinese Academy of Sciences, unpublished data).

Bamboo is a key component to identify giant panda habitat (Linderman et al. 2005). However, detailed information on distribution of different bamboo species was limited, so we used data from the 3rd National Survey for Giant Panda (State Forestry Administration 2006). The coarse scale of bamboo data provided a landscape component to defining giant panda habitat within our study region. Although the combination of the topographic variables allowed us to identify specific topographic conditions associated with the fine-scaled occurrence of the primary bamboo species, development of spatial data layers to delineate bamboo distributions will be important for future model refinement.

As is true for any habitat model, our inference was limited to environmental conditions of giant panda locations we used to develop our model (Knick and Rotenberry 1998). Our test of the habitat model with independent data indicated that model inference within our survey area was acceptable. Thus, the model may be useful for assessing potential impacts of habitat changes on giant pandas if those new conditions were sampled previously. Given the different protection histories within different sections of Foping Nature Reserve and the recent protection of Guanyinshan Nature Reserve, we sampled areas along a wide gradient of anthropogenic influences. Because anthropogenic changes and the potential for habitat restoration are primary concerns regarding giant panda habitat, we believe that our model can be used to assess such changes within our study region. Of course, the habitat model only provides a coarse-scale assessment and additional field surveys at sites of interest will be important to assess conditions we could not measure remotely.

## MANAGEMENT IMPLICATIONS

Core habitat areas for giant pandas in our study region were patchily distributed and centered on Foping Nature Reserve. Thus, maintaining adequate protection of that reserve and establishing habitat linkages with neighboring reserves are important considerations. However, core habitat areas within Foping Nature Reserve were not only concentrated within the designated core area of the reserve, but were also extensive in areas designated as experimental and tourist zones. Access and use of those areas are less restricted compared with the core zone. With possibly more emphasis being placed on development of ecotourism capabilities in those 2 zones, our model predictions may be used to develop management policies that consider distribution of important habitat areas for giant pandas.

Compared with Foping Nature Reserve, Guanyinshan Nature Reserve was established recently so giant panda habitat there has a patchy distribution and occurs primarily at higher elevations where anthropogenic disturbance has been limited. However, potential for habitat improvement is high and expansion of the giant panda population in this area is likely if anthropogenic influences can be restricted at the lower elevations. Our habitat model also indicates that improving habitat linkages among reserves would further promote range expansion of the giant panda in this region.

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