The winter habitat selection of red panda (*Ailurus fulgens)* in the Meigu Dafengding National Nature Reserve, China

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The red panda (*Ailurus fulgens*) is a scarcely known threatened mammal in Asia. Habitat fragmentation, poaching and human disturbance are the main threats currently faced by red pandas throughout their distribution range. We studied the habitat selection of the red panda in the Meigu Dafengding National Nature Reserve (MDNNR) in the Hengduan Mountains of China between December 2006 and February 2007. Our survey confirmed red panda presence in most of the MDNNR and also that they select a specific habitat type based on micro-habitats. The red pandas preferred mixed broadleaved and coniferous forest habitat with bamboo understorey, as bamboo was their main source of food. They preferred habitats with more than 45° slope and avoided habitats with 15–30° slope. They also preferred the southern aspect and avoided the northeast-facing aspect. We found that most red panda sign was close to a water resource. There are more than 10 villages in the Reserve and the villagers depend directly or indirectly on the Reserve for their livelihood. Livestock grazing, human disturbances, poaching, illegal wood and other forest product collection for local use or commercial purposes are all exerting pressure on the area. Our study on the habitat selection of the red panda for the winter season in the MDNNR will be helpful for further understanding of the ecology and also help to the government to devise a conservation strategy and habitat conservation planning for the Reserve.

Keywords: Habitat selection, red panda, resource uses, winter season.

THE red panda (*Ailurus fulgens*) is a globally threatened species that inhabits the Himalayas, including India, Nepal, China, Bhutan and Burma[1–6]. In China, the red pandas are extinct from the Gansu, Shanxi, Qinghai, and Guizhou provinces, and currently present in the Sichuan, Yunnan and Tibet provinces[3,7,8]. The Sichuan Province supports the largest populations of red pandas in the Liangshan Mountains and neighbouring Xiangling Mountains[7,9–11]. However, current status in the Province is lacking. The red panda populations are threatened due to habitat loss/fragmentation, anthropogenic activities and current changing climate throughout its distribution range[2,5,8,12,13]. The red panda is sympatric with the giant panda (*Ailuropoda melanoleuca*) in most provinces of China and both pandas are legally protected in China under the Wild Animal Protection Law[2,4,12,13].

Red pandas select specific habitat, the quality of which reflects the population performance. Most of the studies suggest that red pandas prefer the habitat of bamboo forest with fallen logs and tree stumps[5,7,14,15]; however, habitat selection of species could be different based on habitat quality and micro-habitat features[5,14,16,17]. Therefore, we focused our study in the Meigu Dafengding National Nature Reserve (MDNNR) in the Hengduan Mountains of Sichuan Province, China, to investigate habitat selection of the red panda, especially for the winter season. The study helps enhance our understanding of red panda habitat and their requirements, and also helps design a red panda management strategy at the regional level.

The study was carried out in MDNNR (Figure 1). The Reserve covers an area of 218.64 sq. km; however, our
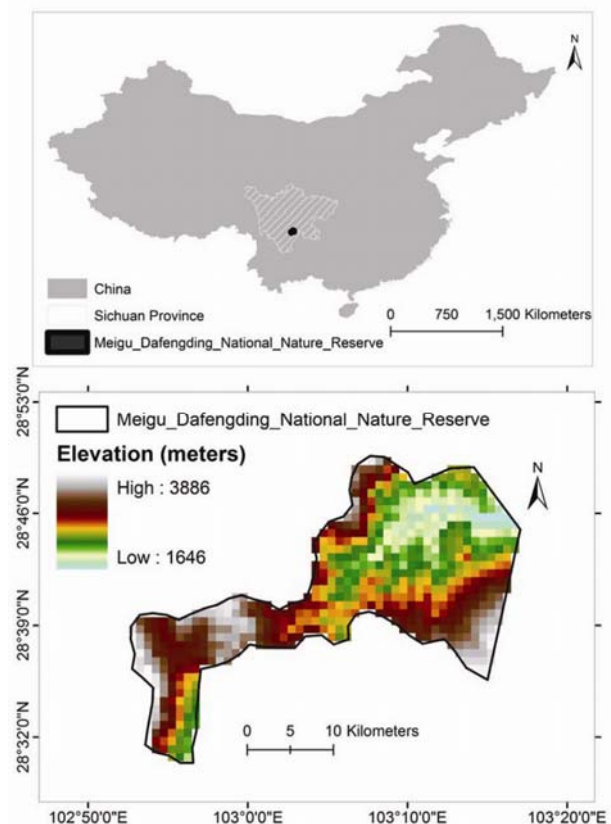
Figure 1. (Top) Map showing study area, Meigu Dafengding National Nature Reserve (MDNNR), Sichuan Province in the southern part of China. (Bottom) Map illustrating digital elevation modelling of MDNNR.

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Table 1. Habitat variables collected from the used and available plots

Variable	Definition and description
Slope aspect	Eight categories: North-facing (337.5–22.5°); northeast-facing (22.5–67.5°); east-facing (67.5–112.5°); southeast-facing (112.5–157.5°); southern-facing (157.5–202.5°); southwest-facing (202.5–247.5°); western-facing (247.5–292.5°); northwest-facing (292.5–337.5°)
Slope position	Three categories: lower slope, 2000–2500 m; mid-slope, 2500–3000 m; upper slope, 3000–3500 m
Slope	Four categories: Gentle slope, <15°; moderate slope, 15–30°; steep slope, 30–45°; very steep slope, >45°
Vegetation types	Five categories: Mixed broadleaved and coniferous forest, coniferous forest, broadleaved forest, evergreen fall broadly mixed forest, miscellaneous bush
Distance to water (m)	Four categories: <100 m, 100–250 m, 250–500 m, >500 m
Canopy	Visually estimated within 20 m × 20 m quadrant, four categories: <25%, 25–45%, 45–65%, >65%
Bamboo height (m)	Average height of culms in 1 m × 1 m sub-plots (five culms were measured randomly in each plot)
Bamboo cover	Average number of culms in 1 m × 1 m sub-plots (five culms were measured randomly in each plot)
Bamboo base diameter (cm)	Average basal diameter of culms in 1 m × 1 m sub-plots (five culms were measured randomly in each plot)
Tree density	The number of trees (>5 m in height) in 20 m × 20 m quadrant
Shrub density	The number of shrubs (height < 3 m) in 5 m × 5 m quadrant
Fallen trees density	The number of fallen trees (>15 cm diameter) in 20 m × 20 m quadrant
Lee condition	The Lee condition of 20 m × 20 m quadrant, three categories: good, common and bad

survey covered approximately 15 sq. km area in the central part of the Reserve (103°4′–103°6″E, 28°43′–28°45′N). The area represents an alpine zone climate having an average temperature of 10.2°C and annual precipitation of 1089 mm. The vegetation type in the reserve was categorized into (a) shrub and broadleaf forest (<1500 m); (b) mixed subtropical coniferous and broadleaf forest (1500–2500 m); (c) sub-alpine coniferous forest (2500–3000 m) and (d) alpine scrub meadows (3000–3500 m).

We surveyed the red panda habitat based on direct and indirect signs such as direct observation, scats, tracks, nesting sites and scraping sites[5,18,19]. We laid out the habitat use and available plots based on red panda sign or direct observation[5,18]. We collected habitat variables in both presence and absence plots within the study area. Presence plots were determined when we found signs or had direct observations, and available plots were laid out in a random direction 200 m from the presence plots[5,11,18–20]. We prepared three random plots (called available or absence plots) in a random direction (>200 m distance) from each presence plot. In total, we laid out 63 presence plots and 189 random plots. Each plot was a 20 × 20 m quadrant from which we collected habitat variables, as described in Table 1. Within each 20 × 20 m plot we also laid out a 5 × 5 m plot in one random corner for shrub measurement and a 1 × 1 m plot for herb measurement[5,11,18–20]. Different habitat characteristics were recorded at each plot and the variables were further categorized for analysis (see Table 1).

We used Vanderloeg and Scavia Resource Selection Index to assess the habitat preferences of red panda using the following formulae and calculations[9,21–23]. All analyses were conducted using SPSS software version 17.0 (SPSS Inc., USA) and Excel program.

Resource selection ratio (ω_i): $\omega_i = o_i/\pi_i$, $\pi_i = a_i/a_+$, where o_i is the selection ratio in i resource; a_i the available resources within i resource and a_+ the total resources that can be used.

Resource selection coefficient: $W_i = \omega_i/\sum \omega_i$. Resource selection index: $E_i = (W_i - 1/n)/(W_i + 1/n)$, where i is the grade of certain resources and n the number of grades of certain resources ($i = 1, 2, 3… n$).

Resource selection index scores were grouped into six categories ($-1 \leq E_i \leq 1$) as follows:

(I) $E_i = 1$, especially preferred (EP), indicating a complete preference of habitat characteristic.
(II) $E_i = 0.1 < E_i < 1.0$, preferred (P), indicating that red pandas showed a slight to strong preference for the habitat characteristic.
(III) $E_i = 0$, randomly selected (RS), indicating that red pandas did not show any preference, or avoidance of this habitat characteristic.
(IV) $E_i = -0.1 < E_i < 0.1$, almost randomly selected (AR), indicating a very weak preference, or avoidance of the habitat characteristic.
(V) $E_i = -1 < E_i < -0.1$, not preferred (NP), indicating a slight to strong avoidance of the habitat characteristic.
(VI) $E_i = -1$, not selected (NS), indicating complete avoidance of the habitat characteristic.

We conducted our research in an area of approximately 15 sq. km in the central part of the MDNNR (Figure 1). Our survey confirmed that the red panda is currently present in most of the forest area of the Reserve and selected specific micro-habitats of mixed broadleaved forest to coniferous forests. The red pandas preferred:

- Habitats with more than 45° slope ($E_i = 0.25$), and avoided areas with slopes of 15–30° ($E_i = <-0.08$; Table 2).
- Upper position of slopes ($E_i = > 0.02$), and avoided the lower hill slope position ($E_i = <-1$; Table 2).

Table 2. Different topographic variables selection function of red panda

Habitat variables	I	o_i/%	π_i/%	ω_i	W_i	E_i	Selection
Slope (°)	<15	22.22	25.37	0.8758	0.2111	–0.0843	AR
	15–30	22.22	32.84	0.6768	0.1631	–0.2103	NP
	30–45	16.67	19.40	0.8590	0.2071	–0.0940	AR
	>45	38.89	22.39	1.7370	0.4187	0.2523	P
Slope position	Lower	0.00	7.46	0.0000	0.0000	–1.0000	NS
	Middle	38.89	50.75	0.7663	0.3439	0.0206	AR
	Upper	61.11	41.79	1.4623	0.6561	0.3307	P
Slope aspect	North	0.00	1.49	0.0000	0.0000	–1.0000	NS
	East	0.00	1.49	0.0000	0.0000	–1.0000	NS
	Northeast	38.89	49.25	0.7896	0.0722	–0.2675	NP
	Northwest	5.56	2.99	1.8611	0.1703	0.1533	P
	West	11.11	7.46	1.4889	0.1362	0.0429	AR
	Southwest	11.11	4.48	2.4811	0.2270	0.2898	P
	Southern	16.67	4.48	3.7222	0.3405	0.4630	P
	Southeast	16.67	28.36	0.5877	0.0538	–0.3985	NP
Distance to water (m)	<100	16.67	22.39	0.7444	0.1782	–0.1675	NP
	100–250	38.89	22.39	1.7370	0.4159	0.2492	P
	250–500	16.67	31.34	0.5317	0.1273	–0.3251	NP
	>500	27.78	23.88	1.1632	0.2785	0.0540	AR
Lee condition	Good	83.33	76.12	1.0948	0.5603	0.2587	P
	Moderate	16.67	19.40	0.8590	0.4397	0.1425	P
	Bad	0.00	4.48	0.0000	0.0000	–1.0000	NS

EP, Especially preferred; P, Preferred; NP, Not preferred; AR, Almost random selection; RS, Random selection; NS, Not selected.

- Aspect of south, southwest and northwest, and avoided the southeast- and northeast-facing aspect.
- Habitat closer to a water resource ($E_i = 0.24$; Table 2).
- Bamboo habitat with 45–60% cover of bamboo density (Table 3).
- Bamboo forest 1.5–2.5 m in height (Table 3).
- Mostly mixed broadleaved and coniferous forest with relatively dense canopy cover ($E_i = 0.33$), and avoided evergreen fall broadly mixed forest ($E_i = -0.21$) and miscellaneous shrub ($E_i = -0.41$; Table 4).
- Relatively high tree density ($> 60/400$ m^2) and shrub density ($> 75/400$ m^2; Table 4).
- Habitat with fallen logs and high canopy cover ($> 65\%$; Table 4).

Habitat selection of animals is influenced by a complex range of interacting factors such as food, shelter, predation and habitat characteristics[5,24–27]. Our study confirmed that the red panda selected specific habitats in the winter season to maintain their body condition and physiology, to escape from predators, or for reproduction. The red panda preferred the more warmer southern aspect during winter to escape from cold weather and selected the relatively medium canopy cover areas (45–60%) with bamboo habitat for feeding and resting. Studies have also reported the red panda selected different habitats in different environmental conditions and seasons[3,23]. The apparent preference for steep sloping habitats shown in this study may be due to avoidance of the habitat of giant pandas. A previous study on the habitat use and separation of these species in the Xiangling Mountains has indicated that giant pandas preferred gentle slopes in order to minimize energy expenditure, while red pandas, being smaller and more agile, utilized steeper slopes[12]. The highest frequency of red panda sign was recorded (61%) in the upper slope position of the study areas and confirmed that red pandas prefer the upper slope in winter; another reason could be that the upper slope area is less disturbed by humans and supported dense stands of bamboo (*Bashania fangiana*), which is the preferred food of red pandas[3,5]. This bamboo species also served as food for the giant pandas resulting in competition between the pandas for food in the Reserve.

Vegetation structure of the area varies based on environment factors, including topography, climate and landform, which have significant influence on animal survival and distribution[26,27]. In this study, red pandas showed a preference for mixed broadleaved and coniferous forest, particularly areas with dense canopy, tree, shrub and fallen log cover. Such dense canopy covers provided shelter and protection from predators, and facilitated movement between the trees. Similar findings were recorded in previous studies by Han *et al.*[23] in Fengtongzhai Nature Reserve, China, and Panthi *et al.*[5] in Nepal.

There are more than 10 villages in the Reserve and the villagers directly or indirectly depend on the Reserve for

Table 3. Different height and diameter compositions of bamboo in the red panda habitat and selection pattern

Bamboo variables	I	$o_i/\%$	$\pi_i/\%$	ω_i	W_i	E_i	Selection
Bamboo height (m)	<1.5	11.10	23.90	0.464435	0.11715	–0.36184	NP
	1.5–2.0	38.90	25.40	1.531496	0.386309	0.214218	P
	2.0–2.5	33.30	25.40	1.311024	0.330696	0.138965	P
	>3.0	16.70	25.40	0.65748	0.165845	–0.20237	NP
Bamboo coverage (%)	15–30	16.70	23.90	0.698745	0.177637	–0.16922	NP
	30–45	22.20	22.40	0.991071	0.251953	0.003892	AR
	45–60	38.90	28.40	1.369718	0.348214	0.164179	P
	>60	22.20	25.40	0.874016	0.222195	–0.05888	AR
Basal diameter (cm)	<0.7	22.20	23.90	0.92887	0.228509	–0.04491	AR
	0.7–1.1	16.70	26.90	0.620818	0.152726	–0.24154	NP
	1.1–1.5	44.40	23.90	1.857741	0.457019	0.292805	P
	>1.5	16.70	25.40	0.65748	0.161745	–0.21434	NP

Table 4. Forest type and vegetation structure selection of red panda

Variable	I	$o_i/\%$	$\pi_i/\%$	ω_i	W_i	E_i	Selection
Vegetation type[a]	1	11.10	4.50	2.466667	0.56002	0.473698	P
	2	44.40	50.70	0.87574	0.198824	–0.00295	AR
	3	44.40	41.80	1.062201	0.241157	0.093293	AR
	4	0.00	1.50	0	0	–1	NS
	5	0.00	1.50	0	0	–1	NS
Tree density (culms/400 m^2)	<20	16.70	25.40	0.65748	0.164705	–0.20568	NP
	20–40	22.20	23.90	0.92887	0.232691	–0.03586	AR
	40–60	22.20	25.40	0.874016	0.218949	–0.06621	AR
	>60	38.90	25.40	1.531496	0.383655	0.210926	P
Shrub density (culms/400 m^2)	<25	16.70	25.40	0.65748	0.162473	–0.2122	NP
	50–25	16.70	25.40	0.65748	0.162473	–0.2122	NP
	75–50	22.20	25.40	0.874016	0.215981	–0.073	AR
	>75	44.40	23.90	1.857741	0.459074	0.294854	P
Fallen log density (culms/400 m^2)	<3	22.20	25.40	0.874016	0.218812	–0.06653	AR
	3–6	11.10	26.90	0.412639	0.103305	–0.41521	NP
	6–9	22.20	19.40	1.14433	0.286486	0.068009	AR
	>9	44.40	28.40	1.56338	0.391396	0.220451	P
Canopy (%)	<25	11.10	19.40	0.57217	0.153926	–0.23785	NP
	25–45	22.20	31.34	0.70836	0.190566	–0.1349	NP
	45–65	11.10	19.40	0.57217	0.153926	–0.23785	NP
	>65	55.50	29.85	1.8593	0.500195	0.333507	P

[a]Vegetation type code 1, Mixed broad-leaved and coniferous forest; 2, Coniferous forest; 3, Broad-leaved forest; 4, Evergreen fall broadly mixed forest; 5, Miscellaneous bush.

their livelihood. The area is under pressure from livestock grazing, illegal wood collection and collection of other forest products for commercial purposes. These are the main threats to the red panda habitats in the study area, which should be dealt with to conserve red panda. Thus our findings will be helpful to further understand the ecology and habitat of the red panda, and will also help the government to devise a conservation strategy and habitat conservation planning for the Reserve.

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