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Habitat Selection by Red Panda (*Ailurus fulgens fulgens)* in Gaoligongshan Nature Reserve, China

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ABSTRACT

From August 2008 to January 2009 we studied habitat selection of red panda (*Ailurus fulgens fulgens*) in Gaoligongshan Nature Reserve using resource selection functions and resource selection index. Red panda preferred coniferous forest and broad-leaved coniferous forest on eastern and northern slopes located in the mid and upper parts of the hillside in the rainy season, containing larger diameter trees (>30 cm), a low tree density (<6/20 m^2), high density bamboo (>70/m^2 and 40~70/m^2) and few stumps (<3/400 m^2). In the dry season, red panda preferred coniferous forest and broad-leaved coniferous forest on eastern and southern slopes in mid and upper parts of the hillside, containing larger diameter trees (15~30 cm), good hiding conditions (visibility <10 m), a small number of stumps (<3/400 m^2) and a high bamboo density (>70/m^2 and 40~70/m^2).

INTRODUCTION

Habitat protection is the key to protect wildlife. Habitat provides food, water and other resources necessary for shelter, reproduction and protection from predators (Yan *et al.*, 1998; Ouyang *et al.*, 2002; Wu *et al.*, 2003; Liu *et al.*, 2004). Patterns of habitat selection reveal habitat characteristics preferred by the species, habitat requirements, the complex relationship between species; and their environment provides a scientific basis for developing effective protection and management measures.

Red panda (*Ailurus fulgens*) are rare and specialized animals inhabiting the Himalayas in China, Nepal, India, Bhutan and Burma. China is critical to red panda and home to 6000–7000 animals (Miles and John, 1984; Zhang *et al.*, 2002; Han *et al.*, 2004). Although red panda were once found in Sichuan, Yunnan, Tibet, Qinghai, Gansu, Guizhou and Shanxi (China), they are now confined to Sichuan, Yunnan and Tibet only. Red panda is listed as Category II species in Chinese Wild Animal Protection Law, as Endangered by the IUCN, and in CITES Appendix I (Wei *et al.*, 1995; Yang *et al.*, 2007). Red panda is threatened by deforestation, habitat loss, fragmentation, illegal trade and hunting, fishing and other external environmental pressures (Zhang, 2005; Liu *et al.*, 2011).

Many studies have been conducted on habitat selection of red panda, but most focused on the subspecies mainly found in Sichuan (*A. f. styani*), and conjunct habitat between red panda and giant panda (*Ailuropoda melanoleuca*) (Wang *et al.*, 1998; Wei *et al.*, 1999a; Wei *et al.*, 2002; Zhang *et al.*, 2004; Qi *et al.*, 2009). Little is known regarding habitat selection by the nominate subspecies *A. f. fulgens* inhabiting Yunnan and surrounds (Hu, 1998; Zhang and Shi, 1999; Sangay *et al.*, 2011; Saroj *et al.*, 2012) or habitat differences between these two sub-species . Because of some shortcomings in design or methodology, some research results cannot fully reflect the micro-habitat selection of the nominate subspecies of red panda and fail to reveal the key factors affecting the micro-habitat selection of the nominate subspecies of red panda. Therefore, it is necessary to study the habitat selection of the nominate subspecies of the red panda. and Study the difference of habitat selection between the two subspecies is helpful for better protection and management of red panda. Resource selection functions can describe the habitat preferences of animals using the ratio of available resources to utilized resources (Wei *et al.*, 1995; Yang *et al.*, 2006). This method is crucial to understanding overall patterns of habitat selection and developing conservation and management strategies for threatened wildlife.

From August 2008 to January 2009, we established observation points throughout Gaoligongshan Nature Reserve in Yunnan to describe habitat selection patterns of red panda using resource selection functions and resource selection index. Because the climate difference between

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rainy season and dry season is obvious, the selection of habitat will change accordingly, hence we studied the selection of habitat of red panda both in rainy season and dry season. Our aim was to describe differences in habitat selection of nominate subspecies of red panda in rainy and dry seasons, and the habitat preferences of this subspecies in greater detail and compare the differences between *A. f. styani* and *A. f. fulgens* in habitat selection using published accounts of *A. f. styani* habitat selection and our data.

MATERIALS AND METHODS

Study area

Gaoligongshan Nature Reserve (24°56'~28°22' N, 98°08'~98°50' E) spans 400 km from north to south, has a total area of 4052 km^2, and is the largest forest and wildlife nature reserve in Yunnan, China. The reserve has a higher altitude in the north and lower altitude in the south: the highest elevation is 5128 m above sea level, and the minimum altitude is 720 m. The dry season from November to April of the following year, is characterized by abundant sunshine and less precipitation. May-October is the wet season. Sunshine hours account for 40% of the whole year. Relative humidity is about 20% higher than that in dry season. The operational zone within the reserve covers 30 km^2 and is concentrated 2800–3400 m above sea level at Fengxue Yakou (Fig. 1); the terrain is steep and complex and the climate changes with altitude. The average temperature at Fengxue Yakou is 7°C, the highest is 12.5°C in August and the lowest is -0.5°C in January. The snow period is from December to March. The vegetation has been well-preserved and includes: (1) cool coniferous forest (elevation 2800~3400 m) dominated by scattered Yunnan hemlock (*Tsuga dumisa*) and huashan pine (*Pinus armandii*), understory shrubs include bamboo and azalea (*Rhododendron protistum*) and cover varies but is generally up to 70%; and (2) cold temperate shrub (altitude 3200~3400 m) mainly containing bamboo, Sorbus, rhododendrons, an upper story of fir (*Abies delavayi*) and lower story of herbaceous plants.

Field plots and data acquisition

Identifying traces of red panda

It is difficult to observe microhabitat selection by red panda directly in the field. Previous studies have indirectly measured red panda microhabitats using feces and evidence of feeding (Zhang, 2005). Here, Traces of eating are hard to judge, so here we did not use this as a basis for judgment. we used direct observation of red panda and feces as indicators of habitat use.

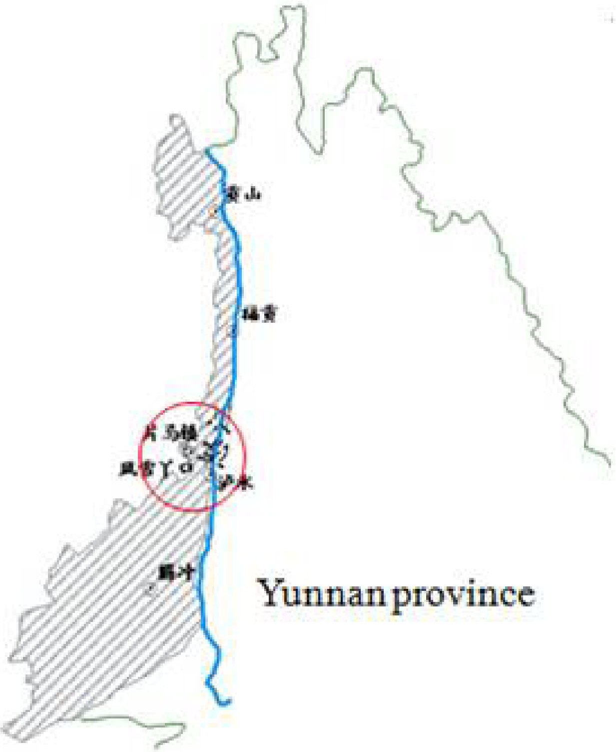

Fig. 1. Study area-Fengxue Yakou (the circle).

Microhabitat plots

We adopted the survey methods of Wei *et al*. (1995) used in Yele Nature Reserve. We crossed different vegetation types in the study area randomly, and established 12 transects, transects basically cover the research area. A site where a red panda or evidence of red panda habitat use was located formed the center and three separate plots were established: a 1 m × 1 m plot, a 20 m × 20 m plot and two 2 m × 10 m plots. We also set a 1 m × 1 m plot at the center of 1 / 4 plots of the 20 m × 20 m plot (i.e. 10 m × 10 m square plot). Within all plots we measured 18 variables, including i. Canopy density: canopy density of the 20 m × 20 m plots, divided into three categories of <50%, 50~75% and > 75%. ii. Slope: the slope of the 20 × 20 m plots as <40°, 40~60°, and >60°. iii. Aspect: the aspect of 20 m × 20 m plots as east (45~135°), south (135~225°), west (225~315°) or north (315~45°). iv. Slope position: the position of the entire 20 m × 20 m plot, divided into upper slope (slope of the hill or the top), middle slope (slope of the mountain or the middle) and lower slope (valley or slope bottom). v. Vegetation types: named by the appearance of dominant species, including conifer, coniferous forest, shrub grassland and bare land. vi. Bamboo density (plants / m^2): the average bamboo in five 1 m × 1 m plots. vii. Bamboo height: the average height of bamboo in cm in five 1 m × 1 m plots (five bamboos were measured in each plot). viii. Tree density: the average number of trees in two 2 m × 10 m plots. ix. Tree DBH: the average diameter in cm at breast height of a tree closest to the center in each 10 m × 10 m plot. x. Tree distance (m): the average distance of a tree closest to the center in each 10 m × 10 m plot. xi. Fallen log density (plants): the average number of fallen trees in four 10 m × 10 m plots. xii. Fallen log size (cm): the average diameter of fallen trees closest to the center in each 10 m × 10 m plot. xiii. Fallen log distance (m): the average distance of a fallen log closest to the center in each 10 m × 10 m plot. xiv. Stump density (plant): the average number of tree stumps in four 10 m × 10 m plots. xv. Stump Size (cm): the average diameter of a tree stump closest to the center in each 10 m × 10 m plot. xvi. Stump distance (m): the average distance of a tree stump closest to the center in each 10 m × 10 m plot. xvii. Water distance (m): straight distance to the nearest water source in 20 m × 20 m plots classified as <500 m or > 500 m. xviii. Hiding conditions: the average maximum distance to a point 10 m high from each side in the 20 m × 20 m plots, classified as <10 m, 10~20 m or >20 m.

Contrast sample

To ensure the contrast sample adhered to the principles of randomness, we established the same number of contrast samples across the study area and measured the same habitat factors. In order to capture information about the impact of habitat selection by red panda, we used a Z-shaped transect line in the study area; the length of the line covered the study area. We set plots every 150 m along each line (with three independent plots) ensuring that the area of the contrast sample covered the entire study area (Zhang, 2005).

Data analysis

All statistical analyses were done in SPSS v17 (SPSS Inc., Chicago, USA). Statistical analyses included a single sample Kolmogorov-Smirnov test (for all data) to determine normality, independent-samples T test, Mann-Whitney u test, correlation analysis, a resource selection index and resource selection functions.

Meaning of resource selection functions (RSFs)

Resource selection function has obvious advantages compared to other methods of studying animal habitat preferences. It can better describe species' preferences for using habitat resources and calculate the ratio of utilized resources to available resources (Zhang, 2005; Yang *et al.*, 2007). The specific calculation method is as follows.

For a resource i in habitats, species have a selection rate of ωi =oi/πi, where oi is the proportion used in resource i, and πi= ai/a+, a + is all available resource units, and ai is the unit in which resource i can be used.

Because species' habitat selection is often constrained by many factors, such as food, shelter and hydrothermal conditions, the resource selection function is generally expressed as a linear logarithmic model including several independent habitat variables: $\omega(x) = \exp(\beta_0+\beta_1x_1+\beta_2x_2+\ldots+\beta_kx_k)$, where X represents different independent habitat variables and β represents selection coefficient. Then, the probability of species choosing habitats is: $T(x) = \exp(\beta_0+\beta_1x_1+\beta_2x_2+\ldots+\beta_kx_k)/[1+\exp(\beta_0+\beta_1x_1+\beta_2x_2+\ldots+\beta_kx_k)]$, When the value of T(x) is 1 or 0, that is to say, the selection coefficient β can be estimated by logistic regression coefficient (Wei *et al*.,1999; Zhang, 2005).

Logistic regression was first used in multivariate analysis in 1967. Now it is a standard statistical method to study the relationship between binary response variables (e.g. yes and no) or ordered response variables and a set of independent variables. At present, there are fixed modules in most statistical softwares (e.g. SPSS, SAS, etc.) (Hu and Du, 2002).

Method of calculating resource selection index

(1) Resource Selection Rate ωi

For resource i, species selection rate is: ωi=oi/πi, πi= ai/a+, where oi is the proportion used in resource i, a+ is all available resource units, and ai is the unit in which resource i can be used.

(2) Resource Selection Coefficient Wi and Resource Selection Index Ei

Wi=ωi /∑ωi ωi as resource selection rate

Ei= (Wi-1/n) / (Wi+1/n) n is the rank number of certain resources

Ei value is between - 1 and + 1,. If Ei > 0.1 means love, Ei = 1 means special love, Ei = 0 means random choice, Ei < 0.1 means almost random choice, Ei < - 0.1 means dislike, Ei = - 1 means no choice.

RESULTS

Habitat selection in the rainy season

Resource selection functions

Ensuring independence of variables in the resource selection function, we conducted correlation analysis between pairwise variable relationships. Two variables contain the same information if the correlation coefficient is greater than 0.5; when this occurred only one variable of greater biological significance was chosen for regression analysis. The correlation coefficient of the two sets of variables exceeded 0.5 (Table I).

Tree stump density, tree stump size and tree stump distance were measures of tree stump habitat use in this study. To take into account the importance and independence we tested the contribution of these three factors to habitat selection by red panda using principal component analysis. We believe that tree stump density and tree stump distance have greater biological significance hence these two factors were retained. Overall, we selected 17 environmental factors for the logistic regression: canopy density, slope, aspect, slope position, vegetation type, density of bamboo, bamboo height, tree density, tree DBH, tree distance, fallen log density, the size of fallen trees, fallen log distance, stump density, tree stump distance, distance to water source and hiding conditions.

Table I. Habitat variables with significant correlation coefficient between each other.

Habitat variables	Correlation coefficient levels	Significant
Tree stump density and Tree stump size	0.725	0.00
Tree stump size and Tree stump distance	0.542	0.00

We normalized all parameters and did a logistic regression analysis using the forward / conditional method (based on assumptions for the probability of the likelihood ratio test and forward stepwise selection variables). The habitat model indicated that aspect, bamboo density, tree density, tree diameter at breast height and tree stump density explained red panda habitat selection (Table II). The red panda habitat resource selection function is logit (P) = -2.223-15.946 × tree diameter at breast height +6.828 × tree density -4.933 × bamboo density +4.615 × stump density +2.432 × slope. According to resource selection functions, red panda habitat selection probability is $P = e^{logit (P)} / (1 + e^{logit (P)})$. Correct model prediction was 95%.

Table II. The variables in the equation.

Variable and constant	Selection coefficients β	Standard error	Wald Chi-square	*P*
Aspect	2.432	1.650	2.173	0.140
Bamboo density	-4.933	3.010	2.685	0.101
Tree density	6.828	3.958	2.975	0.085
Tree size	-15.946	9.596	2.762	0.097
Tree stump density	4.615	2.999	2.367	0.124
Constant	-2.223	1.801	1.524	0.217

Five factors play the most significant role in red panda habitat selection: aspect, bamboo density, tree density, tree size and tree stump density. According to the absolute number of the selection coefficient and the results of enter fitting, the five factors which significantly contribute to habitat selection can be ordered by their importance as tree size, tree density, bamboo density, stump density and aspect. The influence of tree size is the most important and key factor; tree density, bamboo density and stump density have greater impact and are second critical factor; the aspect is a secondary factor.

Habitat selection parameters

Habitat resource selectivity, the selection coefficient and selection index for red panda are shown in Table III. The results of the resource selection index show that red panda prefer a canopy density greater than 75%; slope of 40~60°; a western and northern aspect; slope position of 2800~3400 m; mixed coniferous and coniferous forest; a bamboo density greater than 70/m^2 and 40~70 plants per square meter; bamboo height of less than 6 m; tree density of less than 6 plants / 20 m^2; a tree DBH of more than 30 cm; tree distance of less than 1 m and 1~3 m, a fallen log density of less than five roots / 400 m^2 and 5~10 roots / 400 m^2; fallen trees size of 20~40 cm; distance to fallen tree of less than 2 m and 2~4 m; stump density of 3 / 400 m^2; tree stump size of less than 30 cm; distance to stump of 3~5 m; and distance to water of less than 500 m. For hiding conditions, red panda prefer visibility less than 10 m.

In summary, the best habitat for red panda in the rainy season contains large diameter trees (>30 cm), a small tree density (<6 / 20 m^2), large bamboo density (> 70 / m^2 and 40~70 plants / m^2), few stumps (<3 / 400 m^2), an upper slope facing east or north and coniferous forests or mixed coniferous forest.

Habitat selection in the dry season

Resource selection functions

After correlation coefficient analysis (Table IV) we selected 13 environmental factors for the logistic regression: canopy density, slope, aspect, slope position, vegetation type, bamboo density, bamboo height, tree size, tree distance, fallen log size, stump density, water distance and hiding conditions.

Using identical methods as for our rainy season analysis we identified the following significant habitat variables: bamboo density, tree size, tree stump density and hiding conditions (Table V). The resource selection function for the dry season is logit (P) = -0.058-3.585 × tree size -2.088 × concealed conditions +1.569 × stump density -1.084 × bamboo density. According to the resource selection functions, the selection probability of red panda is P = elogit (P) / (1 + elogit (P)); the model correctly predicted 89.7%.

Table III. Habitat selection by the red panda in Gaoligongshan Nature Reserve

Habitat factors	Category (i)	Expected proportion used (πi) n=(30)	Proportion used (oi)	Resource selection rate (wi)	Resource selection coefficient (Wi)	Preference (Ei)	Use
	<50	0.06667	0.03333	0.49993	0.20166	-0.24613	NP
Canopy (%)	50~75	0.40000	0.26667	0.66668	0.26892	-0.10696	NP
	>75	0.53333	0.70000	1.31251	0.52943	0.22729	P
	<40	0.23333	0.06667	0.28573	0.11321	-0.49293	NP
Slope (°)	40~60	0.70000	0.86666	1.23809	0.49056	0.19083	P
	>60	0.06667	0.06667	1.00000	0.39623	0.08621	AR
	45~135	0.53333	0.60000	1.12500	0.30474	0.09868	AR
Aspect	135~225	0.16667	0.06667	0.40000	0.10835	-0.39528	NP
	225~315	0.10000	0.10000	1.00000	0.27088	0.04009	AR
	315~45	0.20000	0.23333	1.16667	0.31603	0.11665	P
Slope	2800~3000	0.40000	0.43333	1.08333	0.50485	0.20463	P
position	3000~3400	0.53333	0.56667	1.06250	0.49515	0.19531	P
	>3400	0.06667	0.00000	0.00000	0.00000	-1.00000	NS
Vegetation	mixed broadleaf-conifer forest	0.23333	0.23333	1.00000	0.46512	0.16505	P
type	coniferous forest	0.66667	0.76667	1.15000	0.53488	0.23214	P
	Thicket	0.10000	0.00000	0.00000	0.00000	-1.00000	NS
Bamboo	<40	0.16667	0.03333	0.20000	0.08397	-0.59756	NP
density	40~70	0.73333	0.86667	1.18182	0.49618	0.19632	P
	>70	0.10000	0.10000	1.00000	0.41985	0.11486	P
Bamboo	<4	0.13333	0.16667	1.25000	0.35140	0.02639	AR
height	4~6	0.30000	0.53333	1.77778	0.49977	0.19978	P
	>6	0.56667	0.30000	0.52941	0.14883	-0.38266	NP
	<6	0.03333	0.43333	13.0000	0.90179	0.46024	P
Tree density	6~10	0.33333	0.36667	1.10000	0.07631	-0.62745	NP
	>10	0.63333	0.20000	0.31579	0.02191	-0.87667	NP
	<15	0.66667	0.10000	0.15000	0.01345	-0.92241	NP
Tree size	15~30	0.30000	0.60000	2.00000	0.17937	-0.30029	NP
	>30	0.03333	0.30000	9.00000	0.80717	0.41547	P
Tree	<1	0.30000	0.33333	1.11111	0.42150	0.11680	P
distance	1~3	0.53333	0.60000	1.12500	0.42677	0.12292	P
	>3	0.16667	0.06667	0.40000	0.15174	-0.37437	NP
Fallen log	<5	0.53333	0.63333	1.18750	0.41007	0.10323	P
density	5~10	0.20000	0.26667	1.33333	0.46043	0.16012	P
	>10	0.26667	0.10000	0.37500	0.12950	-0.44041	NP
Fallen log	<20	0.46667	0.43333	0.92857	0.34491	0.01707	AR
size	20~40	0.36667	0.50000	1.36364	0.50651	0.20620	P
	>40	0.16667	0.06667	0.40000	0.14858	-0.38338	NP
Fallen log	<2	0.50000	0.56667	1.13333	0.42149	0.11679	P

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Habitat factors	Category (i)	Expected proportion used (πi) n=(30)	Proportion used (oi)	Resource selection rate (wi)	Resource selection coefficient (Wi)	Preference (Ei)	Use
distance	2~4	0.30000	0.36667	1.22222	0.45455	0.15385	P
	>4	0.20000	0.06667	0.33333	0.12397	-0.45783	NP
Tree stump	<3	0.70000	0.80000	1.14286	0.49485	0.19502	P
density	3~5	0.20000	0.16667	0.83333	0.36082	0.03960	AR
	>5	0.10000	0.03333	0.33333	0.14433	-0.39568	NP
Tree stump	<30	0.23333	0.50000	2.14286	0.60342	0.28832	P
size	30~50	0.50000	0.26667	0.53333	0.15018	-0.37878	NP
	>50	0.26667	0.23333	0.87500	0.24640	-0.14996	NP
Tree stump	<3	0.60000	0.70000	1.16667	0.40314	0.09479	AR
distance	3~5	0.36667	0.26667	0.72727	0.25131	-0.14030	NP
	>5	0.03333	0.03333	1.00000	0.34555	0.01799	AR
Water	<500	0.93333	0.96667	1.03571	0.67442	0.14851	P
distance	≥500	0.06667	0.03333	0.50000	0.32558	-0.21127	NP
Hidden	<10	0.53333	0.80000	1.50000	0.65563	0.13467	P
conditions	10~20	0.36667	0.16667	0.45455	0.19868	-0.43128	NP
	>20	0.10000	0.03333	0.33333	0.14570	-0.54872	NP

Four factors play a significant role in habitat selection by red panda in the dry season: bamboo density, tree size, tree stump density and hiding conditions. According to the absolute number of the selection coefficient and the results of enter fitting, the four factors which significantly contribute to habitat selection can be ordered by their importance as tree size, hidden conditions, tree stump density and bamboo density. The influence of tree size is the most important key factor; hiding conditions has greater impact and is the second critical factor; and tree stump density and bamboo density are secondary factors.

Table IV. Habitat variables with significant correlation coefficient between each other.

Habitat variables	Correlation coefficient levels	Significant
Tree density and Tree size	-0.561	0.00
Fallen log size and Fallen log density	0.602	0.00
Fallen log size and Fallen log distance	0.563	0.00
Tree stump density and Tree stump size	0.826	0.00
Tree stump density and Tree stump distance	0.648	0.00

Habitat selection parameters

Habitat resources selectivity, the selection coefficient and selection index of red panda are provided in Table VI. The P indicates that red panda's preference, NP indicates no preference and AP indicates random choice. In summary, the best habitat for red panda in the dry season contains larger diameter trees (15~30 cm), well concealed conditions (visibility <10 m), a small tree stump density (<3 / 400 m^2), high bamboo density (> 70 / m^2 and 40~70 plants / m^2), upper slopes facing east or north with coniferous forests or mixed coniferous forests.

Table V. The variables in the equation.

Variable and constant	Selection coefficients β	Standard error	Wald Chi-square	*P*
Bamboo density	-1.084	0.371	8.511	0.004
Tree size	-3.585	0.743	23.284	0.000
Tree stump density	1.569	0.363	18.718	0.000
Hiding conditions	-2.088	3580.674	0.000	1.000
Constant	-0.588	318.992	0.000	0.999

DISCUSSION

Habitat selection by red panda (A. f. fulgens)

Wildlife will adopt different habitat selection strategies across different seasons because of seasonal changes in habitat, weather patterns, different physiological requirements and trade-offs between different habitat factors. Understanding seasonal changes in habitat selection is important for understanding seasonal variation in environmental factors and the scientific conservation and management of species (Zheng *et al*., 2006). In Gaoligongshan Nature Reserve, tree size, bamboo density and stump density have a major impact on red panda habitat selection both in the rainy and dry seasons. Red panda has the same requirements regarding the density of bamboo and tree stumps in the rainy season and dry season and these two factors are crucial to red panda because they determine its food supply and ability to reproduce.

Table VI. Habitat selection by the red panda in Gaoligongshan Nature Reserve.

Habitat factors	Category (i)	Expected proportion used (πi) n=(63)	Proportion used (oi)	Resource selection rate (wi)	Resource selection coefficient (Wi)	Preference (Ei)	Use
	<50	0.14286	0.01587	0.11111	0.04652	-0.75505	NP
Canopy (%)	50~75	0.12698	0.14286	1.12500	0.47105	0.17121	P
	>75	0.73016	0.84127	1.15217	0.48243	0.18277	P
	<40	0.14286	0.04762	0.33333	0.13029	-0.43794	NP
Slope	40~60	0.63492	0.77778	1.22500	0.47883	0.17914	P
	>60	0.17460	0.17460	1.00000	0.39088	0.07946	AR
	45~135	0.71429	0.80952	1.13333	0.35897	0.17895	P
Aspect (°)	135~225	0.07937	0.07937	1.00000	0.31674	0.11776	P
	225~315	0.11111	0.09524	0.85714	0.27149	0.04121	AR
	315~45	0.09524	0.01587	0.16667	0.05279	-0.65131	NP
	2800~3000	0.38095	0.39683	1.04167	0.47496	0.17521	P
Slope position	3000~3400	0.52381	0.60317	1.15152	0.52504	0.22334	P
	>3400	0.09524	0.00000	0.00000	0.00000	-1.00000	NS
Vegetation type	mixed broadleaf-conifer forest	0.34921	0.38095	1.09091	0.49470	0.19488	P
	coniferous forest	0.55556	0.61905	1.11429	0.50530	0.20506	P
	Thicket	0.09524	0.00000	0.00000	0.00000	-1.00000	NS
	<40	0.17460	0.04762	0.27273	0.11196	-0.49715	NP
Bamboo density	40~70	0.77778	0.90476	1.16327	0.47753	0.17783	P
	>70	0.04762	0.04762	1.00000	0.41051	0.10375	P
	<4	0.20635	0.14286	0.69231	0.24793	-0.14692	NP
Bamboo height	4~6	0.47619	0.57143	1.20000	0.42975	0.12635	P
	>6	0.31746	0.28571	0.90000	0.32231	-0.01681	AR
	<6	0.19048	0.58730	3.08333	0.77031	0.39594	P
Tree density	6~10	0.50794	0.33333	0.65625	0.16395	-0.34062	NP
	>10	0.30159	0.07937	0.26316	0.06574	-0.67052	NP
	<15	0.55556	0.11111	0.20000	0.04516	-0.76139	NP
Tree size	15~30	0.19048	0.55556	2.91667	0.65851	0.32785	P
	>30	0.25397	0.33333	1.31250	0.29633	-0.05876	AR
	<1	0.28571	0.30159	1.05556	0.39434	0.08384	AR
Tree distance	1~3	0.52381	0.58730	1.12121	0.41887	0.11371	P
	>3	0.19048	0.09524	0.50000	0.18679	-0.28174	NP
	<5	0.71429	0.79365	1.11111	0.48780	0.18812	P
Fallen log density	5~10	0.19048	0.19048	1.00000	0.43902	0.13684	P
	>10	0.09524	0.01587	0.16667	0.07317	-0.64000	NP

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Habitat factors	Category (i)	Expected proportion used (πi) n=(63)	Proportion used (oi)	Resource selection rate (wi)	Resource selection coefficient (Wi)	Preference (Ei)	Use
	<20	0.42857	0.33333	0.77778	0.25271	-0.13758	NP
Fallen log	20~40	0.31746	0.41270	1.30000	0.42238	0.11783	P
size	>40	0.25397	0.25397	1.00000	0.32491	-0.01280	AR
	<2	0.57143	0.58730	1.02778	0.36634	0.04717	AR
Fallen log	2~4	0.28571	0.31746	1.11111	0.39604	0.08597	AR
distance	>4	0.14286	0.09524	0.66667	0.23762	-0.16763	NP
	<3	0.39683	0.71429	1.80000	0.68354	0.34440	P
Tree stump	3~5	0.50794	0.25397	0.50000	0.18987	-0.27419	NP
density	>5	0.09524	0.03175	0.33333	0.12658	-0.44954	NP
	<30	0.26984	0.69841	2.58824	0.78216	0.40236	P
Tree stump	30~50	0.47619	0.25397	0.53333	0.16117	-0.34815	NP
size	>50	0.25397	0.04762	0.18750	0.05666	-0.70942	NP
	<3	0.79365	0.77778	0.98000	0.31562	-0.02730	AR
Tree stump	3~5	0.12698	0.14286	1.12500	0.36232	0.04167	AR
distance	>5	0.07937	0.07937	1.00000	0.32206	-0.01720	AR
	<500	0.73016	0.82540	1.13043	0.63597	0.11970	P
Water distance	≥500	0.26984	0.17460	0.64706	0.36403	-0.15737	NP
	<10	0.73016	0.85714	1.17391	0.56474	0.25767	P
Hidden	10~20	0.22222	0.12698	0.57143	0.27490	-0.09607	AR
Conditions	>20	0.04762	0.01587	0.33333	0.16036	-0.35037	NP

In our study area, sheath bamboo and yunlong bamboo are the main feeding plants for red panda. The density of sheath bamboo is mostly greater than 40 plants / m^2, while the density of yunlong bamboo is mostly less than 40 plants / m^2, too low for red pandas to conceal themselves and avoid predators.

Stump density may be a habitat factor related to social and reproductive behavior. In the breeding season, red panda engage in marking behavior as a kind of olfactory communication of home range (Yang *et al*., 2006) and social class (Eason *et al*., 1999; Liu *et al*., 2004). In the estrus season, marking has other functions like gender identification, sexual selection and signaling information to conspecifics (Doty, 1986; Alock, 1989). The opposite sex is stimulated by sniffing these markings and they also induce synchronized estrus (Liu *et al*., 2004). Red panda mark using urine and information-secretion (Lan *et al*., 2011; Teng *et al*., 2013), and similar to the conclusions of Hu (1998). We believe that the density of stumps has important implications for the habitat choice of red panda. Red panda usually selects habitat with a stump density of three stumps / 400 m^2; habitat with a stump density greater than 3 / 400 m^2 is likely influenced by humans and red panda avoids these areas. Most of the time wildlife remains in concealed locations, and the ability to hide is particularly important to survival, especially for red panda. Bamboo is a food source of poor nutritional quality and therefore red panda must minimize energy expenditure (Wei *et al*., 1995) and spend a great deal of time resting. Tree branches and holes are primary resting places for red panda and large diameter trees having a strong bearing capacity are required. There is little difference in the choice of tree diameter in the rainy and dry seasons, and during both seasons red panda preferred a diameter greater than 15 cm.

Tree density is important to red panda in the rainy season. A large tree density is indicative of secondary forest where food resources are relatively scarce and the diameter at breast height is small. Red panda prefers habitat comprising a large tree density (representing primeval forest patches) with good hiding conditions and abundant food resources.

For the choice of slope direction, because of red panda preference for warmth, it will choose the sunny slope according to different seasons to ensure that its energy consumption is minimized. Red panda avoids too hot and too cold environments because of their small body size, and relatively low temperature and damp conditions of the study area means that red panda loses heat to the environment quickly. Retaining body heat is therefore very important for the red panda (Johnson *et al*., 1988).

Fallen trees were found to be important for red panda habitat selection. Fallen trees include partially collapsed logs between trees and fallen logs. These logs are extremely important for habitat selection by red panda, and the majority of red panda feces were in fact found around logs. For saving energy, red panda does not move too far away from its home range area, hence the place where feces were found is usually in the range of their activities, which is the preferred habitat also. Other habitat factors were found to play an important role in habitat selection in other red panda populations, such as water distance (Han *et al*., 2004) and human disturbance (Wang *et al*., 1998; Zhang *et al*., 1999) but were not important to the habitat preferences of red panda inhabiting Gaoligongshan. This is likely because this area contains abundant water resources all the year round and human interference in the nature reserve is minimal.

Comparison of habitat selection by A. f. fulgens *and* A. f. styani

The majority of studies into habitat selection by red panda have focused on *A. f. styani*. For example, red panda in the Xiangling Mountains prefers high density *Bashania spanostachya* (greater than 20 / m^2), shorter and smaller bamboo (less than 260 cm; base diameter of less than 12 mm), and coniferous forest with a canopy density greater than 50% (Wei *et al*., 2002). In the Liangshan Mountains , vegetation type, water distance and human disturbance are the main ecological factors driving habitat selection by red panda; red panda prefers evergreen deciduous broad-leaved forest with a moderate density of *Qiongzhuea macrophylla* and moderate canopy density (Wei and Hu, 1992; Wei *et al*., 1995). In the Qionglai Mountains , water distance, bamboo base diameter and shrub density are key habitat selection factors for red panda, and slope, tree stump density and the density of fallen trees are second key factors (Zhang *et al*., 2002). Also, in these mountains, red panda prefers coniferous forests or mixed coniferous forest comprising a larger base diameter of cold bamboo (greater than 4 mm) and a canopy density greater than 80% (Yang *et al*., 2006; Zhang *et al*., 2009).

While there is variation amongst the habitat preferences of red panda inhabiting different mountain ranges, several similar habitat requirements are apparent. Red panda generally prefers habitat close to water with good bamboo growth on a southern slope . However, *A. f. styani* requires a high shrub density, large tree stumps and many fallen logs; whereas *A. f. fulgens* requires a certain tree diameter and a low density of tree stumps and fallen trees. *A. f. styani* is found at lower altitudes (1400–3400 m) where there is a well-developed understory shrubbery, the large dense shrub provides a good shelter for red panda. A high number of tree stumps and fallen logs often results from human interference, thus red panda habitat selection avoids human interference. *A. f. styani* are also faced with interspecific competition from giant panda as these animals are sympatric in most areas and this competition may cause a narrowing of the red panda niche. *A. f. fulgens* inhabits higher altitudes (2000–3600 m) where there is less understory hence red panda is mainly found in tree branches. Therefore, tree size and density become key habitat factors and selection for certain shrubbery characteristics is relaxed.

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Statement of conflicts of interest

The authors have declared no conflicts of interest.

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