Pakistan J. Zool., vol. 46(4), pp. 941-951, 2014.

Habitat Use of Sichuan Sika Deer in Forest, Bush and Meadows in the Tiebu Nature Reserve, Sichuan, China

Cheng Zhao,[1] Jie Hu,[2] Yanhong Li,[2] Jianghong Ran,[3] Jinke Guan,[2] Chengzhong Yang,[4] Yuanqing Xiong[5] and Bisong Yue[3]*

Cheng Zhao and Jie Hu equally contributed to this study

[1]*Key Laboratory of Bio-resources and Eco-environment (Ministry of Education), College of Life Sciences, Sichuan University , Chengdu 610064, P. R. China*

[2]*College of life Sciences, China West Normal University, Nanchong 637002, P. R. China*

[3]*Sichuan Key Laboratory of Conservation Biology on Endangered Wildlife, College of Life Sciences, Sichuan University, Chengdu 610064, P. R. China*

[4]*Chongqing Key Laboratory of Animal Biology, College of Life Sciences, Chongqing Normal University, Chongqing 400047, China*

[5]*Sichuan Ruoergai Forestry Bureau, Aba 624500, P. R. China*

Abstract.- Sichuan sika deer, *Cervus nippon sichuanicus*, is a threatened subspecies of sika deer distributed in the northern Minshan mountains on the eastern Tibetan Plateau. Compared with other subspecies, Sichuan sika deer lives in a special environment which is composed of a mosaic of forest, bush, and meadow located between plateau meadows and alpine valleys. In order to get strategic information about the relationship of Sichuan sika deer and the environment, we conducted our study on habitat use of Sichuan sika deer in the Tiebu Nature Reserve from March to November 2011. Generalized Linear Mixed Models and an information-theoretic approach were used in our data analysis. Our results indicated that all three types of vegetation were necessary for Sichuan sika deer. In forest, Sichuan sika deer preferred the sites with a high density of herbs. In bush, Sichuan sika deer's occurrence was significantly correlated with greater distances from habitations and shorter distances to water. In meadows, Sichuan sika deer preferred the sites with gradual slopes and proximity to water. Water and disturbance could be treated as key factors that influence the habitat use of Sichuan sika deer in meadow and bush habitat. Food availability may affect the habitat use of Sichuan sika deer in forest and bush. Thus, protecting all three vegetation types is one of the important objectives for the conservation of the endangered Sichuan sika deer. Building some wooden water tanks in meadows and bush and controlling areas of human and livestock activity could increase the suitability of areas Sichuan sika deer need.

Keywords: Habitat use, key factor, protection, Sichuan sika deer, Tiebu Nature Reserve

INTRODUCTION

Sichuan sika deer, *Cervus nippon sichuanicus*, is a subspecies of sika deer, *Cervus nippon*, which was described by Guo *et al*. (1978). It belongs to the Cervinae, Cervidae, Artiodactyla (Corbet and Hill, 1991). The wild populations of Sichuan sika deer are threatened, and some populations have already disappeared (Guo, 2000; Guo and Zheng, 2000). Accordingly, it is classified as a Category I Protected Wild Animal Species in China, and listed as Endangered in the IUCN Red List of Threatened Subspecies (Smith and Xie, 2009). At present, the Sichuan sika deer is distributed in only three isolated areas: the Tiebu region (102°46′-103°14 E′, 33°58′-34°16′), the Baxi region (103°08′-103°35′E, 33°33′-33°46′N), and the Baihe region (103°59′-104°10′E, 33°05′-33°20′N), which are all located in the northern Minshan mountains of the eastern Tibetan Plateau (Guo, 2000). Given that the Sichuan sika deer is rare in the wild with only about 850 individuals in total in China (Guo, 2000), a wise protection program is necessary and urgent.

Successfully protecting a rare species depends on understanding the interactions between the organism and its environment. A wise protection plan requires strategic information on the biological needs of the species or subspecies of concern (Wong *et al*., 2004), of which knowledge on habitat use is

* Corresponding authors: bsyue@scu.edu.cn

0030-9923/2014/0004-0941 $ 8.00/0

essential to understand its ecological requirements (Zhang *et al*., 2009; Nadeem *et al*., 2013). There have been many studies of habitat use of other subspecies of sika deer. In Jiangxi Province, China, previous research reported that sika deer prefer habitat with abundant food, close to water, and far from human disturbance (Yang *et al*., 2002; Fu *et al*., 2006a,b). The key factors affecting sika deer habitat use in Japan include human activity (Kamei, 2010), distance to forest edge (Takatsuki, 1989; Tsukada *et al*., 2009), snow depth (Kaji *et al*., 2000), and vegetation cover (Sakuragi *et al*., 2003). However, research about the Sichuan sika deer has been mainly focused on morphology (Guo *et al*., 1978), distribution (Guo, 2000; Guo and Zhen, 2000), behaviour (Guo *et al*., 1991; Guo, 2003; Liu *et al*., 2004; Qi *et al*., 2010; Yang *et al*., 2012), and food habits (Guo, 2001, 2002), but only Guo (2000; 2001; 2003) focuses on some aspects of habitat. As the geographic range of each subspecies includes various local environments, habitat use must necessarily differ accordingly. Thus, since the Sichuan sika deer is distributed in a special area located between plateau meadows and alpine valleys in the eastern Tibetan Plateau, a research focus on the habitat use of the Sichuan sika deer is required.

Many studies have developed models to identify key environmental factors that affect species' habitat use (Guisan and Thuiller, 2005; Hortal *et al*., 2006). For wild species, the key environmental factors are diverse and vary spatially and temporally over different seasons (Sakuragi *et al*., 2003; Marshal *et al*., 2006; Ciarniello *et al*., 2007; Chen *et al*., 2012; Zhao *et al*., 2012; Zhao *et al*., 2014). In a complex environment, when animals choose a habitat, they have to consider many factors, such as food quality and availability, shelter, environmental conditions, and threats from potential predators (Sih, 1980; Werner et al., 1983). However, each vegetation type may not always contain an adequate mixture of those factors (Orians and Wittenberger, 1991). In our study area, the environment is mainly composed of three vegetation types--forest, bush and meadow—which Guo (2000) determined were three vegetation types that the Sichuan sika deer needed. Forest and bush may be treated primarily as habitat for concealment; while shrub grassland may be treated primarily as a food patch (Guo, 2000). Thus, the key factors influencing deer's selection of habitat patches within different vegetation types are likely to differ. Finding out the key factors in the three vegetation types could provide information about how different habitat patches are used within different vegetation types and could help us to give suggestions for the protection and management of these vegetation types to maximize their value as Sichuan sika deer habitat.

So, to get more information about the Sichuan sika deer's relationship with the three vegetation types, we carried out our fieldwork on microhabitat use by Sichuan sika deer in each of those three vegetation types in the Tiebu Nature Reserve. The main objectives of our study were (1) to understand Sichuan sika deer habitat use across the three vegetation types, (2) to find out the key factors which affect habitat use of Sichuan sika deer in these different vegetation types, and (3) to provide suggestions for protection and management based on the key factors in the different vegetation types.

MATERIALS AND METHODS

Study area

Fieldwork was carried out in the Tiebu Nature Reserve, Ruo'ergai County, Sichuan Province, China (34°02′-34°12′N, 102°58′-103°11′E) (Fig.1), where elevation ranges from 2,450m to 3,800m above sea level. The reserve is located in the dry valley of the Bailong River. The annual precipitation is around 650mm, with ninety percent of the rainfall occurring in the wet season from April to October. Mean annual temperature in the study area is 6.7°C with the extreme low recorded of -18.9℃. The Tiebu Nature Reserve covers about 260 km^2. The study site was in a mosaic of forest, bush, and meadow, with forest occurring mainly on shady slopes, and bush occurring mainly in sunny slopes. The dominant plants in forest were *Pinus tabulaeformis*, *Picea* spp, *Abies* spp., *Betula platyphylla*, *Fargesia nitida*, *Rhododendron* spp., *Lonicera* spp., and *Ribes* spp. The dominant plants in bush are *Berberis* spp., *Hippophae rhamnoides*, *Caragana* spp., *Cotoneaster* spp., *Ajania* spp., and *Bothriochloa ischaemum*. The dominant plants in

meadow are

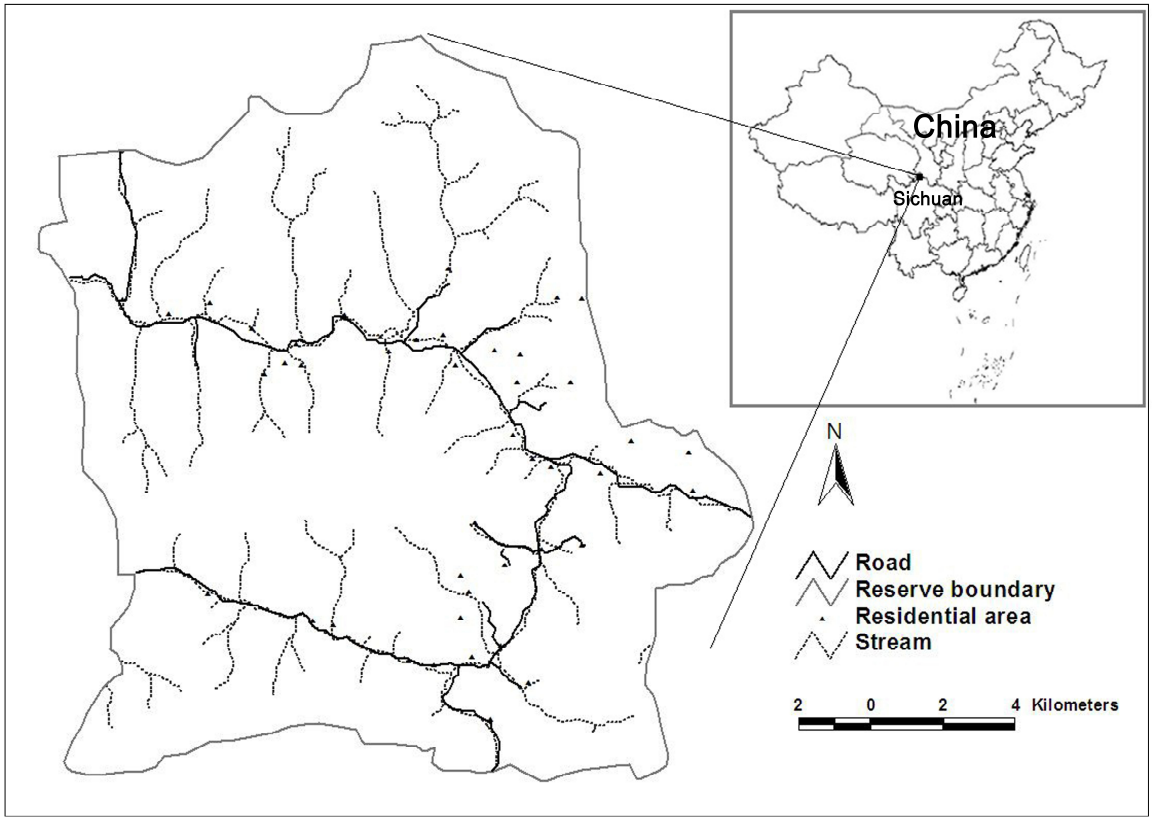

Fig 1. Map of the Tiebu Nature Reserve showing the distribution of key elements. The inset shows its location within Sichuan Province of China.

Rhododendron spp., *Cotoneaster* spp., *Spiraea* spp., Gramineae spp., *Carex* spp., and *Kobresia* spp. There are several thousand people living in this reserve, more than ninety percent are Tibetan, and most of them are herdsmen and farmers. More than 5,000 livestock (mainly cattle and goats) graze within the reserve.

Sampling method and variable design

Dueser and Shugart (1978) created a detailed sampling technique for small mammals combining plots of various sizes and shapes, as well as small transects, which later proved to be applicable for most terrestrial vertebrates (Morrison *et al*., 1992; Morrison, 2002).

As far as was permitted by the nature of the terrain in our study area, we established transects along altitudinal gradients, ensuring that each transect sampled the representative vegetation types. Vegetation sampling plots were centred on signs of sika deer (sightings of deer, faeces, and physical remains (skin, bones, or corpse)) along transects with an average distance not less than 100m between them. Sampling plots centred on deer sign were termed “habitat use plots”. Control plots were established at every 100 m change in elevation along transects. Since the local environment is mainly composed of three vegetation types (forest, bush, and meadow), which have already been reported as important to Sichuan sika deer (Guo, 2000), numerous vegetation sampling plots (habitat use plots and control plots) were established in all three vegetation types along these transects.

After each sampling point location was established, the vegetation type was determined, then, following the method of Dueser and Shugart (1978), a sampling plot consisting of three independent sampling units with associated subplots

was established and centred on the point location of deer sign or point location of control plots (Fig. 2): one 20m×20m (400m^2) plot was centred on the location and subdivided into four equal 100m^2 square subplots. Five 1m^2 herbage subplots were placed with one centred on the point location and four distributed at the centre of each of the 100m^2 subplots. The two 20 m^2 rectangular subplots (2 m×10 m) were both centred on the point location and placed perpendicular to each other as shown in Figure 2 (Wei *et al*., 2000). Within each sampling plot, seventeen vegetation and physical location variables were measured with various subplots as defined and described in Table I. We sampled a total of 292 plots from March to November 2011: 121 plots in forest (66 habitat use plots, 55 control plots), 82 plots in bush (44 habitat use plots, 38 control plots), and 89 plots in meadow (48 habitat use plots, 41control plots).

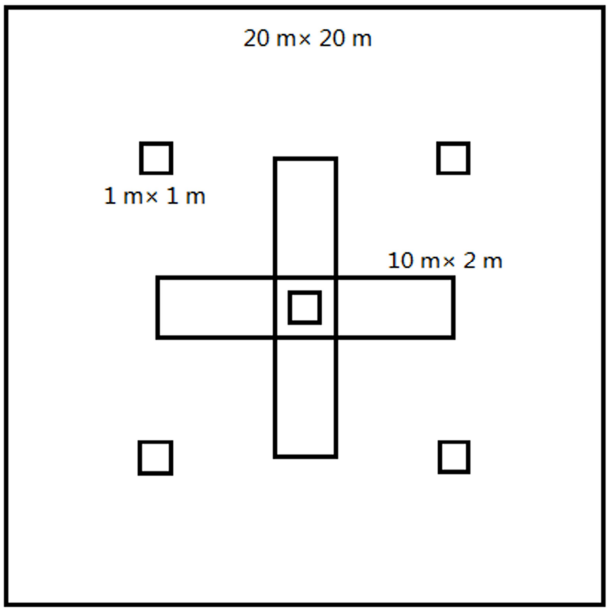

Fig. 2. Microhabitat plot sampling configuration

Data analyses

In order to understand differences between habitat use plots and control plots in the three vegetation types, we conducted independent sample T tests and Mann–Whitney U tests to compare variables between habitat use plots and control plots within each vegetation type. Assuming that the deer

Table I.- Description and definition of 17 variables calculated in the microhabitat sampling plots.

Variable	Definition and description
EL, Elevation (m)	The elevation measured at the centre of the 400 m^2 plot
SL, Slope	Five grades, including <15°, 15-<30°, 30-<45°, 45-<60°, and ≥60°
SA, Slope aspect	Aspect of each 400m^2 plot, defined by nine categories: northern slope (337.5-22.5°), northeastern slope (22.5-67.5°), eastern slope (67.5-112.5°), southeastern slope (112.5-157.5°), southern slope (157.5-202.5°), southwestern slope (202.5-247.5°) western slope (247.5-292.5°), northwestern slope (292.5-337.5°), and no slope aspect (i.e., the plot is on flat land)
CC, Concealing condition	Mean greatest distance with clear line of sight looking eastward, southward, westward, and northward at a height of 1.0m at the centre of the 400 m^2 plot, four categories: <10m, 10-<20m, 20m-<40m, and ≥40m
TC, Tree canopy cover*	Percent tree canopy cover through looking up from the centre of the 400 m^2 plot, four categories: <25%, 25%-<50%, 50%-<75%, ≥75%
TD, Tree density*	Number of trees in 400 m^2 plot
TH, Tree height (m) *	Average height of trees in 400 m^2 plot, defined by six categories: <10m, 10-<15m, 15-<20m, 20-<25m, 25-<30m, and ≥30m
DBH, Tree diameter at breast height (cm) *	Average diameter at breast height (DBH) of the trees in 400 m^2 plot
SC, Shrub cover (%)**	Average percent shrub cover in two 20 m^2 rectangular subplots, four categories: <25%, 25%-<50%, 50%-<75%,≥75%
SD, Shrub density**	Average number of shrubs in two 20 m^2 rectangular subplots
SH, Shrub height (m) **	Average height of shrubs in two 20 m^2 rectangular subplots, defined by five categories: 0-<1m, 1-<2m, 2-<3m, 3-<4m, ≥4m.
HC, Herb cover (%)	Average percent herb cover in five 1.0 m^2 subplots, four categories: <25%, 25%-50%, 50%-75%,>75%
HH, Herb height (cm)	Average height of herb in five 1.0 m^2 subplots, divided into five categories: <25cm, 25-<50cm, 50-<75cm, 75-<100cm, ≥100cm
DW, Distance to water source (m)	Measure straight-line distance from the sampling plot centre to the nearest water source; five categories: <200m, 200-<400m, 400-<600m, 600-<800m, and ≥800m
DF, Distance to forest edge (m) ***	Measure straight-line distance from the sampling plot centre to the nearest forest edge, divide into five categories: <150m, 150-<300m, 300-<450m, 450-<600m, ≥600m
DR, Distance from roads (m)	Measure straight-line distance from the sampling plot centre to the nearest road, divide into five categories: <200m, 200-<400m, 400-<600m, 600-<800m, ≥800m
DH, Distance from habitations (m)	Measure straight-line distance from the sampling plot centre to the nearest residential area, five categories: <200m, 200-<400m, 400-<600m, 600-<800m, ≥800m

Note: *only recorded in forest plots, **only recorded in bush and forest plots, ***only recorded in meadow plots

sign plots represented samples of habitat use by the sika deer within each vegetation type, we modeled habitat use and control plot variables with binomial GLMMs (logit-link). Since some environmental factors show dramatic changes from Match to November, and only a part of area were established transects, we included "date" and "location" as random effects to take into account. We used an information-theoretic approach (Burnham and Anderson, 2002) to determine the suite of factors that influence habitat use of Sichuan sika deer. Correlation analysis was first conducted to test independence between variables. For those variables with a correlation coefficient above 0.5, we only kept the variable with clear biological meaning in the subsequent analysis in order to reduce multi-collinearity (Zhang *et al*., 2011; Torres *et al*., 2012). Afterwards, we chose *a priori* 20 candidate models for each vegetation type. Inclusion of variables in the candidate set of models was based on field knowledge and published research on sika deer habitat use (Takatsuki *et al*., 1989; Takatsuki, 1992; Guo, 2000; Yang *et al*., 2002; Sakuragi *et al*., 2003; Fu *et al*., 2006a, b). We calculated the Akaike information criterion (AIC) to evaluate model fit to find out the best habitat use model for each of the three vegetation types. All analyses conducted using R software.

RESULTS

Independent sample T tests and Mann–Whitney U tests gave essentially the same results (Table II). In the forest, only two variables, herb height and herb cover, showed significant differences between habitat use plots and control plots. In the bush, six variables *viz.*, distance to water, concealing condition, shrub height, shrub cover, herb cover, and distance from habitations, showed significant differences between use plots and control plots. In the meadow, four variables *viz.*, slope, distance to forest edge, distance to water, and herb cover, showed significant differences between use plots and control plots.

The best model of habitat use by Sichuan sika deer in forest included two variables--tree density and herb cover; however, only herb cover was common to all the top ten models (Table III). The best model of habitat use in bush included three variables: distance to water, distance from habitations, and herb cover (Table IV). The best model for habitat use in meadow included three variables-- slope, distance to water, and distance to roads; while distance to water was the only factor common to the top ten models (Table V).

In forest, Sichuan sika deer occurrence (as indicated by deer sign) was significantly correlated with greater tree density and greater herb cover (Table VI). In bush habitat, Sichuan sika deer occurrence was significantly correlated with greater distances from habitations, and shorter distances to water as well as correlated with greater herb cover (Table VI). In meadow, Sichuan sika deer occurrence was significantly correlated with more moderate slopes, shorter distances to water, and greater distances from roads (Table VI).

DISCUSSION

Habitat use in forest

Forest, especially denser forest (*i.e.*, high tree density), may reduce exposure to adverse climatic conditions and, therefore, may serve the deer primarily as a habitat for protection from inclement weather and also as a safe resting place concealed from potential human intruders and from some predators (Ager *et al*., 2003; Mysterud and Østbye, 1999). Tree density showed a significant correlation in the final model of our results which indicated that Sichuan sika deer use forest sites with a higher density of trees than control plots. The lack of a significant difference between use plots and control plots may indicate that the local forest in the reserve has a suitable tree density for Sichuan sika deer. In addition, herb cover also showed significant correlation in forest habitat use for the Sichuan sika deer and was higher in use plots than control plots. This strongly suggests that while forest offers relatively little food compared to meadows, the deer still choose to be in forest sites with higher herb cover which is likely associated with higher levels of food. This phenomenon may represent a trade-off between food needs and safety needs or a strategic optimal selection of sites which meet minimum safety needs as well as offering some food. In the ideal case, a habitat which provides both high levels

Table II.- Comparison of each variable (Mean±SD) between habitat use and control plots in the three vegetation types..

Variable	Forest		Bush		Meadow	
	Habitat use	Control	Habitat use	Control	Habitat use	Control
EL	2759(148)	2776(137)	2741(165)	2794 (196)	2795 (192)	2869(232)
SL	3.17(1.25)	3.36(1.56)	2.91(2.03)	3.33(1.49)	2.04(1.36)**	2.98(1.65)**
SA	4.09(2.71)	3.84(2.97)	5.36(2.03)	5.33(2.02)	4.88(2.21)	5.49(2.34)
CC	2.56(1.07)	2.22(1.05)	3.05(0.95)*	2.56(0.70)*	1.33(0.47)	1.27(0.44)
TC	2.20(0.81)	2.05(0.97)				
TD	13.00(6.81)	11.24(4.77)				
TH	3.91(1.29)	4.16(1.24)				
DBH	29.17(12.99)	28.36(11.18)				
SC	1.58(0.70)	1.73(0.80)	2.97(0.83)**	2.39(0.50)**		
SD	4.02(1.84)	3.71(2.19)	7.02(2.26)	6.00(2.24)		
SH	2.38(0.87)	2.29(0.92)	2.61(0.76)*	2.17(0.92)*		
HC	2.70(0.96)**	2.18(0.96)**	3.30(0.68)*	2.67(1.18) *	3.67(0.75)*	3.27(1.07)*
HH	1.45(0.64)*	1.20(0.45)*	1.38(0.48)	1.28(0.46)	1.23(0.51)	1.27(0.54)
DW	1.48(0.77)	1.47(0.86)	1.53(0.83)***	2.61(1.14)***	1.42(0.57)*	1.95(1.09)**
DF					1.42(0.61)*	1.88(1.10)*
DR	3.86(1.55)	3.49(1.70)	3.38(1.69)	3.44(1.75)	3.58(1.49)	3.32(1.78)
DH	4.11(1.08)	3.84(1.51)	4.03(1.00)*	3.06(1.66) *	3.85(1.32)	3.66(1.54)

Note: Values are given as the mean with standard deviation in parentheses.
Asterisk(s) in habitat use column indicate the result of Mann–Whitney U test; asterisk(s) in control column indicate the result of independent samples T test.
* Significance at 0.05, ** Significance at 0.01, *** Significance at 0.001.

Table III.- Summary of the top 10 GLMM model sets predicting the presence of Sichuan sika deer in forest.

Model	K	AIC	ΔAIC
HC+TD	2	-173.772	0
HC+CC+TD	3	-173.244	0.528682
HC+CC	2	173.204	0.568604
HC	1	-173.193	0.57903
HC+TD+EL	3	-173.02	0.752086
HC+EL	2	-172.651	1.121417
HC+CC+TD+EL	4	-172.552	1.22022
HC+CC+DR	3	-172.486	1.286578
HC+TD+DH	3	-172.406	1.366549
HC+TD+DR	3	-172.357	1.415394

Table IV.- Summary of the top 10 GLMM model sets predicting the presence of Sichuan sika deer in bush.

Model	K	AIC	ΔAIC
DW+DH+HC	3	-184.902	0
DW+DH+HC+SH	4	-184.806	0.096523
DW+DH+HC+SD	4	-183.726	1.175979
DW+DH+HC+CC	4	-183.705	1.197211
DW+DH+HC+SA	4	-183.419	1.483313
DW+DH+HC+HH	4	-183.071	1.831644
DW+DH+HC+SH+CC	5	-182.957	1.945768
DW+DH+HC+SL	4	-182.934	1.96846
DW+DH+HC+DR	4	-182.923	1.978974
DW+DH+HC+SH+SL	5	-182.806	2.096523

of food and safety may be best, but, in this case, the herb biomass in forest is far less than meadow (Takatsuki, 1989, 1992). Thus, we hypothesize that Sichuan sika deer prefer forest with relatively high tree densities and higher herb cover to reduce the energetic cost of time spent hiding in the forest or to reduce overall risk by reducing the foraging time in meadow needed to satisfy their energetic needs. The difference between those two options depends on whether the deer are expected to maximize net energetic gain or to minimize risk. It is this difference which may explain where they are most

likely to spend their time. However, such hypotheses require additional behavioural and energetic evidence. The results of this study provide a greater appreciation of a number of aspects of vegetation use and the patterns of habitat use and, thus, raise interesting new questions and critical hypotheses which can lead to a deeper understanding of what the Sichuan sika deer need and how they respond to variable features of their environment to meet their needs.

Table V.- Summary of the top 10 GLMM model sets predicting the presence of Sichuan sika deer in meadow.

Model	K	AIC	ΔAIC
DW+SL+DR	3	-138.587	0
DW+SL+DR+DF	4	-137.989	0.597655
DW+SL+HC+DR	4	-137.097	1.489761
DW+SL+DR+HC+HH	5	-136.885	1.701843
DW+SL+DR+DF+HC	5	-136.338	2.248883
DW+SL+DR+HC+HH+DF	6	-136.017	2.570597
DW+SL+DR+HC+HH+DF+SA	7	-134.233	4.354512
DW+SL+HC	3	-133.247	5.339687
DW+DR+DF	3	-133.213	5.373906
DW+DR+HC	3	-132.561	6.026423

Table VI.- Estimated coefficients and standard errors for the variable in the best models of habitat use in the three vegetation types.

Variable	Forest	Bush	Meadow
Intercept	-1.901± 0.695**	-1.057± 0.968	0.923± 0.527
Slope			-0.432± 0.133**
Tree density	0.055± 0.024*		
Herb cover	0.564± 0.169**	0.737± 0.507	
Distance to Water		-1.700± 0.385***	-1.086± 0.369**
Distance from roads			0.588± 0.213**
Distance from habitations		0.977± 0.326**	

Note: * Significance at 0.05, ** Significance at 0.01, *** Significance at 0.001

Habitat use in meadow

Meadow habitat appears to be the main food patch for Sichuan sika deer. Our research indicated Sichuan sika deer prefer meadow on gradual slopes, which not only contain a high density of herbs, which we assume equates to abundant food, but also provide a clear view of the surrounding area, which allows the deer to detect the approach of potential danger at a distance great enough to ensure time to withdraw to safe hiding places. Distance from a water source appears to be a key factor which influences the deer's choices of which meadow areas to use, which says that only meadows relatively close to a water source are seen as "meadow habitat" by the deer. This interpretation accords with the study by Guo (2000) who reported that meadows with a long distance to water were seldom used by Sichuan sika deer. Although distance from roads was contained in the final best model of meadow use by Sichuan sika deer, the difference between used and control plots in meadow was not significant. Two reasons may lead to this situation. First, while Sichuan sika deer may often avoid foraging near roads in the daytime, they may feel safer foraging in meadow close to roads at night (Guo, 2003), when they are less likely to be seen by people. Second, in our field work, we sometimes observed clusters of Sichuan sika deer feeding in meadow close to roads in daytime. An individual deer foraging close to a source of danger, such as roads, must spend more time watching for threats and less time feeding; however, if a group of deer forage together in such a situation, more eyes watching for threats can give each deer more time to feed while also reducing their risk and may also lower their stress (the increased safety of foraging in groups is well known, *e.g.*, Bertram, 1978). Meadow sites which have high forage value but which are close to roads are inherently more risky than similar sites far from roads. But if previous foraging has reduced the return on safer sites, the foraging value of these risky sites may increase in relative value to the deer. By foraging at night and/or in groups, the deer can reduce risk enough to allow them to use the high forage, but risky, sites. The deer's use of such risky meadow sites shows that microhabitats should not be seen as having fixed variables, but rather that the deer alter their use of different sites within a vegetation type in response to changes in the relative benefits and risks of different sites, which may change according to conditions which depend on site variables and on

the demographics and perceptions of the deer themselves.

It is well known that a single vegetation type may not contain an adequate mixture of factors needed (Orians and Wittenberger, 1991). Therefore, deer, which depend on forest for protective cover and open areas like meadows for food, may select feeding sites in meadows that are near to forest cover (Williamson and Hirth, 1985; Tufto *et al*., 1996). It has been reported that Japanese sika deer don't dare to use meadow more than 200m away from forest (Takatsuki, 1989; Tsukada, 2009). However, during our field work, we often found Sichuan sika deer using areas in meadows farther than 200m away from forest. Despite the fact that distance to forest edge was significantly smaller in use plots than control plots (Table II), in our results, distance to forest edge (DF) was not included in the final best model of meadow habitat use (Table V). These different responses of Sichuan sika deer feeding in sites farther away from forest cover must be seen within the interactions among key factors in adjacent vegetation types. For example, the Sichuan sika deer may feed farther away from forest cover in response to special local environmental situations, such as where a big bush patch on a sunny slope in the meadow provided hiding cover for the deer. Or, the deer feeding in a meadow farther from forest cover in the case where the risk of being in the open may be mitigated by the deer having longer clear views so that any potential threats can be detected at a greater distance.

Habitat use in bush

In bush habitat, proximity to water and distance from habitations were the key factors. This result is the same with research in Jiangxi (Yang *et al*., 2002; Fu *et al*. 2006a, b). In our study area, bush vegetation is mainly located on sunny slopes, with water sources being further away than on shady slopes. Bush vegetation close to habitations was treated as a firewood resource and was heavily used by local people. Thus, Sichuan sika deer avoided using bush vegetation near habitations. Previous studies reported that vertical cover and lateral cover (in our study area, forest could be treated as vertical cover and bush could be treated as lateral cover) have different functions for ungulates. Lateral cover decreases predation risk by reducing prey detectability (Tufto *et al*., 1996). This explains why Sichuan sika deer use bush with higher shrubs and denser shrub cover (Table II), as these environments provide better concealing conditions, which is also supported in our results (Table II).

Large areas of bush vegetation, as a special environment for forest edge animals, have particular value for Sichuan sika deer. Bush vegetation can be treated as a secondary food patch for Sichuan sika deer since they have been recorded feeding on 65 kinds of shrubs as well as 134 kinds of herbs and 13 kinds of trees (Guo, 2001). Thus bush vegetation serves these sika deer both as a source of food as well as providing protection against predators and humans. Guo (2002) claimed that food availability is a key factor limiting the population of Sichuan sika deer. Thus, in our study area, large areas of bush are likely to contribute to support higher densities of Sichuan sika deer. If we change these bush patches into forest, the food availability would be reduced. On the other hand, if we change these bush areas into big pastures, not all of the meadow pastures will serve as suitable food sources for the deer, since some areas of large pastures will be too far from forest (or large bush patches) to satisfy the deer's need for safety in nearby dense habitat. So, these big bush patches may be a valuable and even necessary component of a healthy habitat mix for Sichuan sika deer that includes forest, meadow, and bush vegetation types. The observations of this study as well as those of Guo (2002) show that the deer regularly use some portions of all three vegetation types, which strongly suggest that a pattern of mixed use of all three vegetation types is what constitutes the overall "best habitat" as selected by the deer. What we were able to discover about the sika deer's habitat was in the context of the study site in the Tiebu Nature Reserve and limited to one eight-month period from spring to fall. Study of how the sika deer habitat use changes during winter is needed for a more complete picture of their habitat needs over the entire year. And further study and monitoring of year to year variation in habitat use would not only be very interesting but valuable for developing an effective long-term conservation management plan.

Protection and management suggestion

Based on the research of Guo (2000) and the findings from our study, we confirm that forest, bush, and meadow all contribute in significant ways to make up the overall habitat required by Sichuan sika deer. Our research showed that the key use factors differ in each vegetation type. So, these three vegetation types should be protected to maintain the habitat which sustains these special and endangered deer. Therefore, a conservation plan for the Sichuan sika deer should provide methods necessary to protect and manage these three habitat types in an appropriate spatial mixture to which the deer respond to best.

For example, in meadow and bush habitat, water could be treated as the most important limiting factor affecting the habitat use of Sichuan sika deer. In field research, we found that sika deer used the water in wooden water tanks, which had been built by farmers for use by livestock grazing in meadow areas. Thus, building some wooden water tanks in bush and meadow areas could possibly increase the areas of use by Sichuan sika deer.

Of even greater concern, human presence and activities, such as cutting firewood in forest and grazing livestock in meadows, can have significant direct and indirect effects on the temporal and spatial pattern of use of the three vegetation types by Sichuan sika deer; therefore, some control over the types and intensity of human activities in these vegetation types is necessary. In particular, food availability has a significant influence on the population of Sichuan sika deer (Guo, 2002). Increasing numbers of livestock is very likely to alter and possibly damage the meadows, which will decrease the food sources needed to maintain the sika deer population in this area. To maintain the environment and natural vegetation in the Tiebu Nature Reserve, controlling the livestock population and where they graze is necessary, but may be difficult to do. With increasing economic development in the area, the local environment is changing. Land reclamation will lead to further loss of meadow and bush, cutting firewood will continue to alter deer habitat in forest and bush, and road building will increase the extent of local disturbance. So, how to maintain the present environment becomes an even more important challenge.

Animal conservation is a long term continuous effort, which requires more information about the environment and animals of concern, like the Sichuan sika deer. Therefore, scientific field work in the places where these animals live and where they are increasingly threatened must continue if we are to have any hope to save these special animals, which are a unique part of the natural legacy of China.

ACKNOWLEDGEMENTS

This study was supported by the Sichuan Provincial Science and Technology Department (2008JY0157), Key Laboratory of Southwest China Wildlife Resources Conservation (Ministry of Education) Open Fund (XNYB09-01), National Science and Technology Support Project of china (2012BAC01B06) and Research Program of China (973 Project: 2011CB111503). The authors thank Forestry Protection Department Office of Sichuan Province, Ruoergai Forestry Bureau, and Management Office of Tiebu Nature Reserve.

Conflict of interest declaration

We declare that the article (Habitat use of Sichuan sika deer in forest, bush, and meadows in the Tiebu Nature Reserve, Sichuan, China) has not been submitted nor it will be submitted to any other Journal.

Cheng Zhao, Jie Hu, Yanhong Li, Janghong Ran, Jinke Guan, Chengzhong Yang, Yuanqing Xiong, and Bisong Yue.

REFERENCES

AGER, A.A., JOHNSON, B.K., KERN, J.W. AND KIE, J.G., 2003. Daily and seasonal movements and habitat use by female Rocky Mountain elk and mule deer. *J. Mammal.*, **84**: 1076-1088.

BERTRAM, B.C.R., 1978. Living in groups: predators and prey. In: *Behavioural ecology*: *an evolutionary approach* (eds. J.R. Krebs and N.B. Davies), Blackwell Scientific Publications, Oxford, pp. 64-96.

BURNHAM, K.P. AND ANDERSON, D.R., 2002. *Model selection and multimodel inference: a practical information-theoretic approach*, 2nd Edition. Springer-Verlag, New York, USA

CHEN, W., WU, Q.G., HU, J.C., LU, X. AND YOU, Z.Q.,

2012. Seasonal habitat use of Chinese goral (*Naemorhedus griseus*) in a subtropical forest. *Russ. J. Ecol.*, **43**: 256-260.

CIANIELLO, L.M., BOYCE, M.S., SEIP, D.R. AND HEARD, D.C., 2007. Grizzly bear habitat selection is scale dependent. *Ecol. Appl.*, **17**: 1424-1440.

CORBET, G.B. AND HILL, J.E., 1991. *A world list of mammalian species*. Oxford University Press, London, UK.

DUESER, R.D. AND SHUGART JR. H.H., 1978. Microhabitats in forest floor small mammal fauna. *Ecology*, **59**: 89-98.

FU, Y.Q., HU, J.C., GUO, Y.S., ZHU, H.B., LIU, W.H. AND WANG, Y.S., 2006a. Habitat use of sika deer in spring at Taohongling Natural Reserve. *Chinese J. Zool.*, **41**: 60-63.

FU, Y.Q., JIA, X.D., HU, J.C., GUO, Y.S., ZHU, H.B., LIU, W.H. AND WANG, Y.S., 2006b. Summer habitat selection by sika deer in Taohongling Nature Reserve, Jiangxi Province. *Sichuan J. Zool.*, **25**: 863-865.

GUISAN, A. AND THUILLER, W., 2005. Predicting species distribution: offering more than simple habitat models. *Ecol. Lett.*, **8**: 993-1009.

GUO, Y.S., 2000. Distribution, numbers and habitat of Sichuan sika deer (*Cervus nippon sichuanicus*). *Acta Theriol.*, **20**: 81-87.

GUO, Y.S., 2001 Study on the food habitat of Sichuan sika deer (*Cervus nippon sichuanicus*). *J. Sichuan Teach. Coll.*, **22**: 112-119.

GUO, Y.S., 2002. Determination of sika deer's food resources and loading capacity in Tiebu Nature Reserve Sichuan, China. *Acta Theriol.*, **22**: 257-262.

GUO, Y.S., 2003. Daily activity rhythm and time budget of Sichuan sika deer. *Acta Theriol.*, **23**: 104-108.

GUO, Y.S., HU, J.C., LUO, D.H., SE, K., REN, S.P. AND ZHOU, H.F., 1991. Studies on the social behaviour of *Cervus nippon sichuanicus*. *Acta Theriol.*, **11**: 165-170.

GUO, Y.S. AND ZHENG, H.Z., 2000. On the geological distribution, taxonomic status of species and evolutionary history of sika deer in China. *Acta Theriol.*, **20**: 168-179.

GUO, Z.F., CHEN, E.Y. AND WANG, Q.Z., 1978. A new subspecies of sika deer from Sichuan—*Cervus nippon sichuanicus* subsp. *Acta Zool.*, **24**: 187-192.

HORTAL, J., BORGES, P.A.V. AND GASPAR, C., 2006. Evaluating the performance of species richness estimators: sensitivity to sample grain size. *J. Anim. Ecol.*, **75**: 274-287.

KAJI, K., MIYAKI, M., SAITOH, T., ONO, S. AND KANEKO, M., 2000. Spatial distribution of an expanding sika deer population on Hokkaido Island, Japan. *Wildl. Soc. Bull.*, **28**: 699-707.

KAMEI, T., TAKEDA, K., IZUMIYAMA, S. AND OHSHIMA, K., 2010. The effect of hunting on the behaviour and habitat utilization of sika deer (*Cervus nippon*). *Mammal. Study*, **35**: 235-241.

LIU, K., SHI, H.Y. AND HU, J.C., 2004. Daily activity rhythm and time budget of Sichuan sika deer (*Cervus nippon sichuanicus*) in spring. *Acta Theriol.*, **24**: 282-285.

MARSHAL, J.P., BLEICH, V.C., KRAUSMAN, P.R., REED, M.L. AND ANDREW, N.G., 2006. Factors affecting habitat use and distribution of Desert Mule Deer in an arid environment. *Wildl. Soc. Bull.*, **34**: 609-619.

MORRISON, M.L., 2002. *Wildlife restoration: techniques for habitat analysis and animal monitoring*. Society for Ecological Restoration and Island Press, Covelo, CA, USA.

MORRISON, M.L., MARCOT, B.G. AND MANNAN, R.W., 1992. *Wildlife habitat relationships: concepts and applications*. University of Wisconsin Press, Madison, Wisconsin, USA.

MYSTERUD, A. AND ØSTBYE, E., 1999. Cover as a habitat element for temperate ungulates: effects on habitat selection and demography. *Wildl. Soc. Bull.*, **27**: 385-394.

NADEEM, M.S., ZAFAR, S., KAYANI, A.R., MUSHTAP, M., BEG, M.A. AND NASIR, M.F., 2013. Distribution and roosting habitats of some microchiropteran bats in Rawalpindi district, Pakistan. *Pakistan J. Zool.*, **45**: 565-569.

ORIANS, G.H. AND WITTENBERGER, J.F., 1991. Spatial and temporal scales in habitat selection. *Am. Nat.*, **137**: S29-S49.

QI, W.H., YUE, B.S., NING, J.Z., JIANG, X.M., QUAN, Q.M., GUO, Y.S., MI, J., ZUO, L. AND XIONG, Y.Q., 2010. Behaviour ethogram and PAE coding system of *Cervus nippon sichuanicus*. *Chinese J. appl. Ecol.*, **21**: 442-451.

SAKURAGI, M., IGOTA, H., UNO, H., KAJI, K., KANEKO, M., AKAMATSU, R. AND MAEKAWA, K., 2003. Seasonal habitat selection of an expanding sika deer, *Cervus nippon*, population in eastern Hokkaido, Japan. *Wildl. Biol.*, **9**: 141-153.

SIH, A., 1980. Optimal behavior: can foragers balance two conflicting demands? *Science*, **210**: 1041-1043.

SMITH, A.T. AND XIE, Y., 2009. *A guide to the mammals of China*. Hunan Education Press, Changsha, China.

TAKATSUKI, S., 1989. Edge effects created by clear-cutting on habitat use by sika deer on Mt. Goyo, northern Honshu, Japan. *Ecol. Res.*, **4**: 287-295.

TAKATSUKI, S., 1992. A case study on the effects of a transmission-line corridor on Sika deer habitat use at the foothills of Mt. Goyo, northern Honshu, Japan. *Ecol. Res.*, **7**: 141-146.

TORRES, R.T., VIRGÓS, E., SANTOS, J., LINNELL, J.D.C. AND FONSECA, C., 2012. Habitat use by sympatric red and roe deer in a Mediterranean ecosystem. *Anim. Biol.*, **62**: 351-366.

TSUKADA, H., FUKASAWA, M., KOSAKO, T., NAKAMURA, Y. AND HANAFUSA, Y., 2009. Effect of distance from farm periphery on the risk of forage damage by sika deer (*Cervus nippon*). *Grassl. Sci.*, **55**: 193-199.

TUFTO, J., ANDERSEN, R. AND LINNELL, J.D.C., 1996. Habitat use and ecological correlates of home range size in a small Cervid: the roe deer. *J. Anim. Ecol*., **65**: 715-724.

WEI, F.W., FENG, Z., WANG, Z. AND HU, J.C., 2000. Habitat use and separation between the giant panda and the red panda. *J. Mammal*., **80**: 448-455.

WERNER, E.E., GILLIAM, J.F., HALL, D.J. AND MITTELBACH, G.G., 1983. An experimental test of the effects of predation risk on habitat use in fish. *Ecology*, **64**: 1540-1548.

WILLIAMSON, S.J. AND HIRTH, D.H., 1985. An evaluation of edge use by white-tailed deer. *Wildl. Soc. Bull*., **13**: 252-257.

WONG, S.T., SERVHEEN, C.W. AND AMBU, L., 2004. Home range, movement and activity patterns, and bedding sites of Malayan sun bears, *Helarctos malayanus*, in the rainforest of Borneo. *Biol. Conserv*., **119**: 169-181.

YANG, C.Z., XIAO, Z., GUO, Y.S., XIONG, Y.Q., ZHANG, X.Y. AND YUE, B.S., 2012. Alarm signals of the Sichuan sika deer, *Cervus nippon sichuanicus*. *Zool. Sci*., **29**: 423-427.

YANG, Y.W., ZHANG, S.Y. AND CHEN, A.X., 2002. Characters of habitat used by sika deer in winter and spring in south China. *J. Northeast Forest. Univ.*, **30**: 57-60.

ZHANG, Z.J., HU, J.C., YANG, J.D., LI, M. AND WEI, F.W., 2009. Food habitat and space-use of red pandas, *Ailurus fulgens*, in the Fengtongzhai Nature Reserve, China: food effects and behavioural responses. *Acta Theriol*., **54**: 225-234.

ZHANG, Z.J., SWAISGOOD, R.R., ZHANG, S.N., NORDSTROM, L.A., WANG, H.J., GU, X.D., HU, J.C. AND WEI, F.W., 2011. Old-growth forest is what giant pandas really need. *Biol. Lett*., **7**: 403-406.

ZHAO, C., LI, Y.H., LI, D.Y., GUAN, J.K., XIONG, Y.Q. AND HU, J., 2014. Habitat suitability assessment of Sichuan sika deer in Tiebu Nature Reserve during periods of green and dry grass. *Acta Ecol. Sin.*, **34**: 135-140.

ZHAO, C., LI, Y.H., HU, J., YAO, G., HE, Q., LI, H.Y., LUO, F., WANG, X.H. AND LI, F., 2012. Feeding site selection of Long-billed Plover in winter in the middle Jialing River. *Sichuan J. Zool*., **31**: 22-26.

(Received 9 October 2013, revised 25 February 2014)