Forage and bed sites characteristics of Indian muntjac (*Muntiacus muntjak*) in Hainan Island, China

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Microhabitat factors associated with forage and bed sites of Indian muntjac (*Muntiacus muntjak*) were examined and compared in Hainan Island from 2001 to 2002. Habitat characteristics at forage and bed sites were measured by tracking five radio-collared adult muntjacs (three females, two males) and locating from fresh sign or muntjac flushed during transect surveys. Among six available habitat types, Indian muntjac preferred shrub grassland and thorny shrubland, and used dry savanna in proportion to its availability. Muntjac avoided woods, cultivated grassplot and deciduous monsoon forests. Comparing forage sites with bed sites, food availability was greater at forage sites. For bed sites, taller trees with larger canopies, taller shrubs, denser shrub canopy covers and concealment covers were essential factors. No seasonal difference (wet season vs. dry season) was found in food abundance at either forage sites or at bed sites. During the wet season, canopy closure for both types of sites was higher and at bed sites concealment cover was higher than during the dry season. Principal component analysis indicated that tree height, d.b.h. and maximum canopy diameters were important factors in habitat selection. The different microhabitat characteristics at forage and bed sites can be a clue to understanding the survival strategy of Indian muntjac, a small-bodied ungulate, in savanna woodlands.

Keywords: Bed sites; forage sites; Hainan Datian National Nature Reserve, China; Indian muntjac; *Muntiacus muntjak.*

Introduction

Indian muntjac (*Muntiacus muntjak*) is a solitary, forest-dwelling ruminant and inhabits dense shrub cover in the broad-leaved forests in south-east China (Sheng 1992). Of its 15 subspecies (Ohtaishi & Gao 1990), four have been documented in China, including *M. m. vaginalis*, *M. m. menglalis, M. m. yunnanensis,* and *M. m. nigripes* (Ma & Wang 1988). Until now, neither the biological and population characteristics nor the ecological adaptation of the Indian muntjac have been documented. Nevertheless, each year in China an estimated 140 000–150 000 Indian muntjacs are hunted for their meat throughout their range (Sheng & Lu 1985). There has been little research on the Indian muntjac. Barrette (1977) studied the subspecies *M. m. malabaricus* in Wilpattu National Park, Sri Lanka. Barrette determined that Indian muntjacs are forest ruminants that come out in the open very seldom and only when escape cover is readily available. More recently, Sheng (1992) suggested that the Indian muntjac's biological characteristics are similar to Reeve's muntjac's (*M. reevesi*) in that both species inhabit dense shrub cover in forested parts of southern China (Sheng 1992; McCullough *et al.* 2000).

Field observations indicated that small ungulates tend to be solitary or pair-forming selective browsers, taking such items as flowers, twigs, fruits, and seed pods (Hofmann & Stewart 1972; Jarman 1974; Hofmann 1989). Small forest-dwelling ungulates choose to inhabit and hide in thick cover to avoid predation (Jarman 1974; Geist 1974). Studies on Reeve's muntjac in Taiwan and at an introduction site in England revealed that dense vegetation cover was essential (Chapman *et al.* 1985; Chapman *et al.* 1993; McCullough *et al.* 2000). Optimum habitat for deer has been described in terms of the amount and locations of cover and forage areas (Schmitz 1991; Mysterud & Østbye 1995). Consequently, animals choose different habitat sites for foraging or for bedding (Huot 1974; Mysterud 1996). Only when the habitat requirements

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of animals both for foraging and for bedding have been well documented, can we understand the real preferred habitat of this species. Indian muntjac is sympatric with Eld's deer (*Cervus eldi*) in Hainan Datian National Nature Reserve of 1314 ha in size. The Reserve has been fenced by wires of 2.8 m in height and harbored the last group of Eld's deer which is endangered in the field. Recent estimation on population size of the Eld's deer and Indian muntjac confirmed over 800 deer (Yuan *et al.* 2001) and 700 Indian muntjac (Teng *et al.* unpubl. data) wandering within limited region of the reserve. Potential competition on habitat use can exist between the two ungulates. Habitat use of the Eld's deer has been well investigated (Song & Li 1991, 1994), however, the habitat relationship of Indian muntjac has not been documented. Detailed understanding of habitat use of Indian muntjac is required to address whether the two ungulates are potential competitors within the reserve. Moreover, the knowledge on habitat use of Indian muntjac will also provide guidelines in habitat management for the reserve managers. The objective of our study was to identify and describe any differences in forage and bed sites of Indian muntjac (*M. m. nigripes*) in the savanna woodland of Hainan Island, China. We also sought to assess the important components of these forage and bed sites.

Methods

Study area

The present study was conducted in Hainan Datian National Nature Reserve, located in the western part of Hainan Island, China (19°05′–19°17′N, and 108°47′–108°49′E). The reserve covers 1314 ha with elevations ranging 30–80 m a.s.l. The reserve is enclosed by a 2.8-m high wire fence in order to prevent the animals from poaching. Indian muntjacs naturally occur in the whole reserve and they constitute a self-sustaining population since 1986. The small and seasonal Ezha River crosses west to east across the center of the reserve. In the dry season, a nearby reservoir outside the reserve supplements the water supply.

The climate is hot and dry with an average annual temperature of 24.6°C. July and January are the warmest and coldest with mean temperatures of 29.1 and 18.4°C, respectively. Annual precipitation averages 1012 mm with most rainfall occurring during the wet season, from July to October

Vegetation types are tropical arid grassland and shrub communities with woodland savannas. Six vegetation types in the study area include: (1) dry savanna dominated by *Tridax procumbens*, *Waltheria americana*, *Sida acuta* and *Borreria articulata*, (2) shrub grassland characterized by *Heteropogon contortus*, *Imperata cylindrica* and sedges, interspersed other plants including *Helicteres isora*, *Croton laui* and *Eriglossum rubiginosum*, (3) deciduous monsoon forests dominated by *Albizzia procera*, *Lannea coromandelica*, *Bombax ceiba* and *Aporosa chinensis*, (4) thorny shrubland with *Streblus ilicifolius*, *S. asper*, *Harrisonia preforata* and *Polyalthia cerasoides*, (5) cultivated grassplot dominated by *Strlosanhes gracilis* and *Pennisetam purppureum*, and (6) woods of *Eucalyotus cxserta*.

In addition to Indian muntjac, other mammals in the reserve include Eld's deer, wild boar (*Sus scrofa*), Chinese ferret badger (*Melogale moschata*), Small Indian civet (*Viverricula indica*), Masked palm civet (*Paguma larvata*) and Crab-eating mongoose (*Herpestes urva*). Eld's deer, and wild boar are quite common, but carnivorous species are hardly seen in the field. A survey, conducted in 2000, indicated that the population size of Eld's deer has increased to over 800 at present (Yuan *et al.* 2001). It is estimated that there are a couple hundreds of wild boars (Yuan, pers. comm.) and 700 muntjacs (Teng *et al.* unpubl. data).

Habitat availability

We established six line transects to collect information on habitat availability. Transects ranged in length from 3.5 to 6.4 km for a total of 24.2 km. Those transect traversed the whole study area in the direction from north to south for some transects and east to west for others, and covered all the habitat types. On these transects, a total of 112, 4×4 m^2 plots were randomly selected to record habitat types. When more than two habitat types occurred in one plot, we recorded the dominant habitat (covering more than 50% of the plot). The proportion of those random plots in each habitat type was used as the percent of that particular habitat type in the total study area.

Locating forage and bed sites

Five adult muntjacs (three females, two males) were captured with net-traps during October 2001 and fitted with radio-collars (MOD 335, Telonics, Inc., Mesa, Arizona, USA). The radio-collars were equipped with activity switches that, by changing the number of signals per time unit, indicated whether animals were active or inactive. We located all five muntjacs twice every week and located muntjacs for 32 weeks. Usually we located muntjacs during dawn and dusk when they are most active. Using triangulation, we approached the collared muntjacs within 100 m. Then, by stalking the animals, we visually located their position and recorded their activities at that moment. Muntjacs were undisturbed by observers almost in all cases at the time of visual contact. For muntjacs flushing before we visually observed them, an effort was made to locate their bedding or foraging site. Usually the exact bed site could be identified by flattened vegetation, often while the bed feels warmer than any other plots. We identified forage sites by fresh bite marks on plants. We distinguished bites in the previous minutes from those taken the previous day by juices in the remainders of plants. Bite marks on plant by Indian muntjacs from other animal were determined by observation on muntjacs feeding action or by evidence of muntjacs' fresh pellets next to the feeding site. If more than one muntjac were flushed, only one position was measured. In order to keep the data independent, the same radio-collared muntjac was never located more than once a day. In addition, once a week we searched the six transects for fresh forage and bed sites. Whenever we flushed muntjac or found fresh pellets or tracks, the adjacent area of 10 m × 10 m was carefully checked to identify fresh forage or bed sites using the same procedure for radio-collared animals.

Habitat characteristics measuring at forage and bed sites

Fourteen habitat characteristics were measured at the center of each muntjac forage and bed site. We used point-quarter sampling technique (Goldsmith & Harrison 1976) to determine d.b.h. of trees (cm), tree height (m), maximum canopy diameter of trees (m), and shrub height (m). We used 3×3 m^2 plots to determine shrub density, tree density, and percent of new shoots to the total twigs below 1 m (%). We sampled 1×1 m^2 quadrates to determine herb height (cm), herb biomass (g), and herb cover (%). We determined herb cover using a 0.3×2.5 m cover density board marked off in 0.5 m intervals (Nudds 1977). Canopy closure of shrubs (%) was determined by counting the number of points under canopy closure at 0.5-m intervals at 15 m line intercept transects. We used a 2.5-cm × 2.0 m hardwood cover pole to measure concealment cover (%). The procedure followed that of Griffith & Youtie (1988). Distance to nearest human settlement (m), and water resource (m) were determined from 1 : 10 000 maps.

Statistical analyses

We tested for differences in bed and forage sites of radio-collared muntjac with sites observed along transects for un-collared ones using non-parametric comparisons, with no significant differences ($z = -0.865$, $P > 0.05$). We also pooled data got from radio-collared male and female muntjacs since a Mann–Whitney U-test did not reveal any significant differences between them ($z = -1.249$, $P > 0.05$). The two sets of data were then pooled by season (dry and wet) for data analyses. A chi-square goodness-of-fit test was employed to examine whether the proportion of bed and forage site locations per habitat differed from habitat availability. Bonferroni confidence intervals were calculated to determine which habitats were preferred or avoided (Neu *et al.* 1974; Marcum & Loftsgaarden 1980; Byers *et al.* 1984). If the muntjac selected a habitat type, Bonferroni confidence interval was calculated by the following formula:

$$\overline{P}_i - Z_{a/2k}\sqrt{\overline{P}_i(1-\overline{P}_i)/n} \le P_i \le \overline{P}_i \le Z_{a/2k}\sqrt{\overline{P}_i(1-\overline{P}_i)/n}$$

where, $\overline{P}_i$ is the proportional usage of a habitat category i and n is the total number of used observations; $z_{a/2k}$ is the upper standard normal table value corresponding to a probability tail area of $a/2k$; a is the level of significance (0.10 in this paper); k is the number of categories tested.

If expected proportional availability (P_w) of one habitat lies above the upper limit of the use confidence interval, then it is truly used less than expected, it is 'avoided' by animals; if its proportional availability lies below the use lower confidence interval, it is selected more than expected and it is 'preferred'.

Differences between forage and bed sites characteristics were tested by the non-parametric tests (Mann–Whitney U-tests). A Mann–Whitney U-test was also used to test whether forage sites and bed sites differed seasonally. Ten significantly different variables between forage and bed sites were subjected to a principal component analysis (PCA) to identify which habitat variables accounted for the greatest variance.

Results

We sampled 112 plots to determine overall availability of each habitat type in the study area. From October 2001 to September 2002 we located 426 sites used by muntjac: 279 forage and 147 bed sites. The chi-square goodness-of-fit test indicated a significant difference between overall habitat availability and usage (x^2 = 656.19, d.f. = 5, $P < 0.05$). Indian muntjacs used all six habitat types, but showed a strong preference for shrub grassland and thorny shrubland ($P_w < P_i$). Three habitat types, woods, cultivated grassplot and deciduous monsoon forests were avoided ($P_w > P_i$). Dry savanna was used in proportion to its availability (Table 1).

When we tested for microhabitat differences between forage sites and bed sites, we determined that forage sites were characterized by a higher percent of new shoots than bed sites (49.9% vs. 39.4%, $P = 0.000$), but herb biomass was not higher ($P = 0.399$). Forage sites were associated with higher density trees (P =

Table 1 Availability and usage percentages of each habitat type

Habitat type	Expected proportion used (P_w) n = 112	Actual proportion used (P_i) n = 426	Plots of expected used	Plots of actual used	Bonferroni interval for P_i	Preference
Dry savanna	0.165	0.143	70	61	$0.104 \le P_i \le 0.182$	0
Deciduous monsoon forests	0.396	0.157	169	67	$0.116 \le P_i \le 0.198$	–
Thorny shrubland	0.189	0.350	81	149	$0.296 \le P_i \le 0.404$	+
Shrub grassland	0.055	0.303	23	129	$0.251 \le P_i \le 0.355$	+
Cultivated grassplot	0.147	0.038	63	16	$0.016 \le P_i \le 0.060$	–
Woods	0.048	0.009	20	4	$-0.002 \le P_i \le 0.020$	–

+, indicates that observed usage is significantly higher than expected ($P < 0.05$); –, indicates that observed usage is significantly lower than expected ($P < 0.05$); 0 indicates observed usage in proportion to its availability.

Table 2 Characteristics (mean ± SD) of forage and bed sites of Indian muntjac in tropical savanna of southern China

Variable	Forage sites n = 279	Bed sites n = 147	Z	P
TH	10.0 ± 6.2	11.7 ± 5.2	–3.716	0.000
TBD	23.5 ± 10.2	26.8 ± 9.6	–3.083	0.002
TCD	3.6 ± 1.6	4.4 ± 1.7	–4.658	0.000
SBH	132.5 ± 69.6	148.4 ± 59.1	–3.676	0.000
HDD	252.0 ± 349.5	271.8 ± 272.8	–3.678	0.000
WD	127.7 ± 146.3	157.5 ± 179.5	–4.999	0.000
TD	2.5 ± 1.9	2.0 ± 1.7	–3.150	0.002
SHD	8.4 ± 4.6	6.4 ± 5.2	–4.530	0.000
HH	17.8 ± 18.8	18.3 ± 12.7	–1.267	0.205
HB	169.1 ± 215.0	147.1 ± 143.0	–0.844	0.399
CC1	54.5 ± 21.7	61.6 ± 23.4	–3.901	0.000
HC	37.9 ± 23.4	42.8 ± 26.9	–0.466	0.641
TP	49.9 ± 20.6	39.4 ± 18.4	–4.902	0.000
CC2	28.7 ± 19.1	77.5 ± 4.9	–15.334	0.000

Total sample sizes for sites by muntjacs are given for 2001 and 2002 combined. P-values are two-tailed.
CC1, canopy closure of shrubs (%); CC2, concealment cover (%); HB, herb biomass (g); HC, herb cover (%); HDD, distance to the nearest human settlement (m); HH, herb height (cm); SBH-average height of the nearest shrub within each of the four quadrants (m); SD, Standard Deviation; SHD, shrub density (no./9 m^2); TBD, average d.b.h. of the nearest tree within each of the four quadrants (cm); TCD, average maximum canopy diameter of the nearest tree within each of the four quadrants (m); TD, tree density (no./9 m^2); TH, average height of the nearest tree within each of the four quadrants (m); TP, percent of new shoots to the total twigs below 1 m (%); WD, distance to the nearest water resource (m).

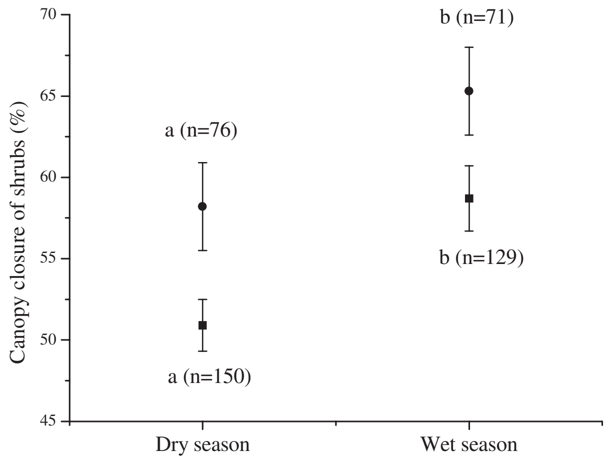

Fig. 1. Canopy closure (mean with error bar) of shrubs at forage and bed sites during dry and wet seasons. The same legend key with the different letters suggested a significant difference at $P < 0.05$ between dry and wet seasons. (■), forage sites; (●), bed sites.

0.002) and shrubs (P = 0.000) than bed sites. Indian muntjac bed sites had significantly taller (P = 0.000) and larger canopy (P = 0.000) trees, and taller shrubs (P = 0.000). Shrubs showed significantly more canopy cover at the bed site than the forage site (P = 0.000). Concealment cover was greater for bed sites than for forage sites (P = 0.000). Additionally, most bed sites were located farther away from the human settlement (P = 0.000) and water resource (P = 0.000) than forage sites (Table 2).

During the wet season, Indian muntjac tended to use habitats with a higher percent canopy cover at both forage (z = −3.610, P = 0.000) and bed sites (z = –2.628, P = 0.009; Fig. 1) than during the dry season. Concealment cover at bed sites was relatively more abundant during the wet season than the dry season (z = −3.847, P = 0.000), however, we found no seasonal differences in concealment cover for forage sites (z = −1.076, P = 0.282; Fig. 2). We found no seasonal differences in food abundance for forage sites (z = −0.211, P = 0.833) or at bed sites (z = −0.295, P = 0.768; Fig. 3).

Results of a principal component analysis showed that the first three principal components explained 59.3% of the total variance among all forage sites habitat variables (Table 3). The first principal component accounted for 28.7% of the variance, with positive loadings for average height of the nearest tree, average d.b.h. of the nearest tree, average maximum canopy diameter of the nearest tree, percent of new shoots to the total twigs below 1 m, and distance to water resource. We calculated negative loadings for shrub density, canopy cover of shrub, tree density, average height of the nearest shrub and distance to human settlement. For bed sites, the first three principal components explained 60.2% of the variance. The first principal component was positively related to average height of the nearest tree, average d.b.h. of the nearest tree, average maximum canopy diameter of the nearest tree, tree density, average height of the nearest shrub, and canopy closure of shrub. The first component was negatively correlated with distance to water resource, shrub density, percent of new shoots to the total twigs below 1 m, and distance to human settlement.

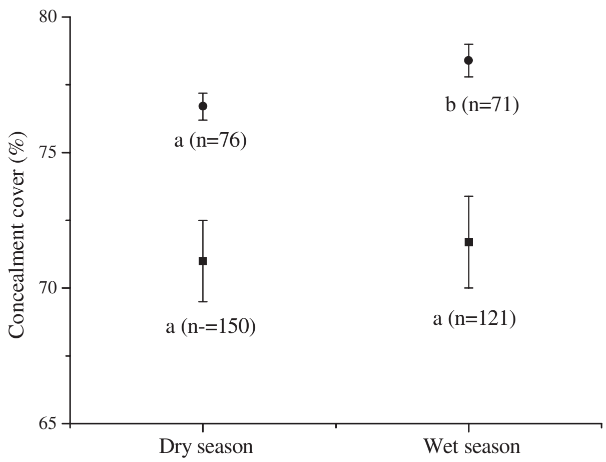

Fig. 2. Concealment cover (mean with error bar) of forage and bed sites during dry and wet seasons. The same legend key with the different letters indicated a significant difference at $P < 0.05$ between dry and wet seasons. (■), forage sites; (●), bed sites.

Discussion

The results of this study showed that both food availability and vegetation cover were very important for Indian muntjac habitat selection. Our results are similar to those of Barrette (1977) from his study of *M. m. malabaricus*, a subspecies that also inhabits tropical forests. Utilization of habitat is often determined by the availability of cover and food (Henry 1981; Putman 1988; Schmitz 1991; Mysterud & Østbye 1995; Bernice & David 2002). In general, the feeding habits of muntjacs corresponded to that of small African forest

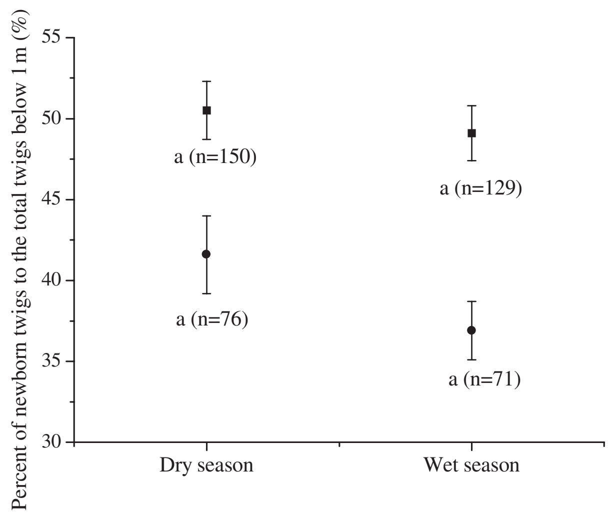

Fig. 3. Percent of newborn twigs to the total twigs below 1 m (mean with error bar) of forage and bed sites during dry and wet seasons. The same legend key with the different letters indicated a significant difference at $P < 0.05$ between dry and wet seasons. (■), forage sites; (●), bed sites.

Table 3 Results of principal component analysis (PCA) for forage and bed sites

	Eigenvectors					
	Forage sites			Bed sites		
Variable	I (28.7)*	II (48.3)	III (59.3)	I (28.0)	II (48.1)	III (60.2)
TH	0.743	0.358	0.114	0.859	–0.050	–0.139
TBD	0.800	0.384	0.071	0.899	–0.133	–0.115
TCD	0.820	0.266	0.132	0.919	–0.124	–0.059
TD	–0.098	–0.323	–0.043	0.044	–0.096	0.746
SBH	–0.229	0.670	–0.179	0.020	0.789	0.069
SD	–0.704	0.361	0.282	–0.380	0.321	–0.214
CC1	–0.658	0.527	0.191	0.012	0.778	–0.129
TP	0.002	–0.608	0.495	–0.302	–0.671	–0.117
WD	0.140	–0.511	0.006	–0.416	–0.419	–0.331
HDD	–0.034	–0.128	–0.821	–0.015	–0.092	0.654

*Cumulative proportion of variance explained (%).
CC1, canopy closure of shrubs (%); CC2, concealment cover (%); HB, herb biomass (g); HC, herb cover (%); HDD, distance to the nearest human settlement (m); HH, herb height (cm); SBH-average height of the nearest shrub within each of the four quadrants (m); SHD, shrub density (no./9 m^2); TBD, average d.b.h. of the nearest tree within each of the four quadrants (cm); TCD, average maximum canopy diameter of the nearest tree within each of the four quadrants (m); TD, tree density (no./9 m^2); TH, average height of the nearest tree within each of the four quadrants (m); TP, percent of new shoots to the total twigs below 1 m (%); WD, distance to the nearest water resource (m).

ruminants that are 'selector of juicy, concentrated herbage' (Hofmann & Stewart 1972; Teng *et al.* unpubl. data). These kinds of food items are more abundant in shrub habitats than in deciduous monsoon forests of the study area (Song & Li 1994). Therefore, it was not surprising that the muntjacs preferred shrub habitat to deciduous monsoon forests.

The muntjacs were primarily 'nibblers' (Barrette 1977), feeding on tender leaves, twigs, seed pods and shrub fruits. These food items have higher protein and accessible plant cell content (Gonzalez-Hernandez & Silva-Pando 1999) and tend to be small, distinct, and spatially scattered foliage (Jarman 1974). At our study area, muntjacs were recorded feeding on more than 200 species of plants (Teng *et al.*, unpubl. data). Food availability was best indicated by percent of new shoots below 1 m and herb biomass. The positive relations of the habitat use to the habitat variables indicative of food abundance (Table 3) explained the importance of food abundance when animals selected their habitat. Additionally, the higher availability of new-grown shoots at forage sites than at bed sites indicated that muntjacs will select those areas that allow them to acquire food resource most efficiently (MacArthur & Pianka 1966).

Bed sites located under denser canopy cover than forage sites in the study area (Tables 2 and 3). This result is similar to studies on Reeve's muntjac in both its native habitat in Taiwan (McCullough *et al.* 2000) and at an introduction site in England (Chapman *et al.* 1985). Selection of a high percentage of ground cover is also a strategy defending against predators for ungulate calves (Gerlach & Vaughan 1991; Bowyer *et al.* 1998; Bowyer *et al.* 1999). For Indian muntjac, a high percent of canopy closure could be an antipredator strategy: in a forest or woodland, inhabiting dense cover can minimize visual detection (Geist 1974) and scent might not spread so much because of less wind in the closed microsite (Mysterud & Østbye 1995). In our study, no predation on Indian muntjac was detected; however, wild boar and some small-bodied carnivores might be taken as main predation pressure against muntjac young. Muntjacs selected denser sites for resting for their concealment value and that those sites offer less forage only because they are more closed than forage sites.

Small-bodied deer like roe deer often bedded at feeding sites (Mysterud 1996). Indian muntjac at Hainan Island, however, did not show this behavior during our observation. It did mean the animal never foraged at or around bed sites. During both dry and wet season, the food availability indicated by percentage of new-grown shoots at forage sites was significantly higher than bed sites. At bed sites, shrubs have more cover than at forage sites (Table 2).

Seeking dense canopy cover for bedding is an important thermal strategy in winter (Armstrong *et al.* 1983; Schwab & Pitt 1991; Mysterud & Østbye 1995) and provides a means to avoid heat stress during summer (Sargeant *et al.* 1994). Temperature in the tropics is relatively constant, and might not be as important a factor as in the temperate zone. It is therefore unlikely that temperature influences the muntjac selection of high canopy closure at bed sites.

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