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Diurnal Time Budgets and Behavioral Rhythms of White-Lipped Deer *Cervus albirostris* in the Qilian Mountains of Qinghai, China

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Abstract.- White-lipped deer (*Cervus albirostris*) is very important in the natural ecosystem of the Qinghai-Tibet Plateau, China. However, data on the diurnal time budgets of these "Vulnerable" animals' in the wild are still limited. Here, we used a focal sampling method to investigate the diurnal time budgets of the white-lipped deer in Qinghai, China during a one year period from June 2012 to April 2013. Results revealed that both males and females spend the majority of their time either feeding or resting throughout the year. The duration of both feeding (Z= 3.128, p= 0.002) and resting (Z= -2.426, p= 0.015) over the seasons were significantly different for females, while the duration of resting (Z= -2.062, p= 0.039) and vigilance (Z= 2.897, p= 0.002) were significant for males. Moreover, white-lipped deer showed a trimodal distribution of feeding activity during the warm season and a bimodal distribution in the cold season. Moreover, during the cold season gestating females devoted much more time to feeding, likely due to the increased energy demands of pregnancy and the reduced nutritional value of their forage. This data will help with future range-management of white-lipped deer on the Qinghai-Tibet Plateau and its seasonal-dependent cohabitation with local livestock.

Key words: Diurnal time budgets; white-lipped deer; *Cervus albirostris*; behavior rhythm.

INTRODUCTION

White-lipped deer (*Cervus albirostris* Przewalski 1883) is endemic to China and is a critical ungulate in the ecosystem of the Qinghai Tibet Plateau. It previously ranged across much of the plateau (Ohtaishi and Gao, 1990; Cai, 1988), but presently only occurs in small, fragmented populations in northwestern and southwestern Gansu, eastern, central, and southern Qinghai, eastern Tibet, western Sichuan, and northwestern Yunnan (Ohtaishi and Gao, 1990; Yu *et al*., 1990; Kaji *et al*., 1989, 1993; Schaller, 1998; Wu and Wang, 1999). The white-lipped deer is classified as " Vulnerable " (IUCN) and is currently listed as a Class I protected species under Chinese law. In the past this species was extensively hunted for its meat, antlers, and other organs, which were used in traditional Chinese medicine (Koizumi *et al*., 1993). Currently, competition with livestock is the white-lipped deer's largest threat due to the destruction of a large part of its natural habitat, which in turn has caused both decreased and fragmented populations of the wild ungulate throughout the plateau (Koizumi *et al*., 1993; Ohtaishi and Gao, 1990; Harris, 2007).

Diurnal time budgets are specific to each species and are uniquely modulated by both external and internal factors (Moncorps *et al*., 1997). The effects of internal (physiological state, behavioral ontogeny, and body mass) and external (group size, natural cycle of day and night, and environmental conditions) factors have been described in detail for many ungulate species (Duncan, 1980; Maher, 1991; Owen-Smith, 1998; Schaller, 1998; Xia *et al*., 2011). Diurnal behavioral time budgets play a major role in determining an animal's ability to adapt to seasonal and diurnal variations in environmental factors and have been instrumental in our understanding of the social organization, foraging ecology, and evolutionary relationships of many species of animals (Geist, 1974; Jarman, 1974; Schaller, 1977; Fox, 1992).

Data on white-lipped deer activity is limited, but includes studies on social organization and mating behavior (Miura *et al*., 1989; Cai and Liu,

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1992; Miura *et al*., 1993), parturition and neonatal care (Yu *et al*., 1993), and behavior patterns (He *et al*., 2001). However, these reports do not reflect the time budgets of the white-lipped deer living on the Qinghai-Tibet Plateau. In this paper we attempt to describe the diurnal time budgets of the white-lipped deer living on the Qinghai-Tibet Plateau and the influence of sex, season, and the time of day on their activities.

MATERIALS AND METHODS

Study area

We conducted our study in Yanglong Village, Qilian County, Qinghai Province, China (38°39.034' to ~38°40.338'N; 98°32.506' to ~98°33.586'E), located in the west of Qilian Mountains (Fig. 1), anywhere between 3821 to 5287 meters above sea level with an average elevation of 4000 meters. Four seasons are not distinct in the study area and the local climate can be divided into two seasons: a long winter and a short summer. The mean annual temperature is -3.08°C and the extreme recorded low temperature is -36.3°C. Annual precipitation varied from 218.9 to 359.1 mm where the majority of rain occurs from June through September. Alpine meadows were the primary feeding area for the white-lipped deer.

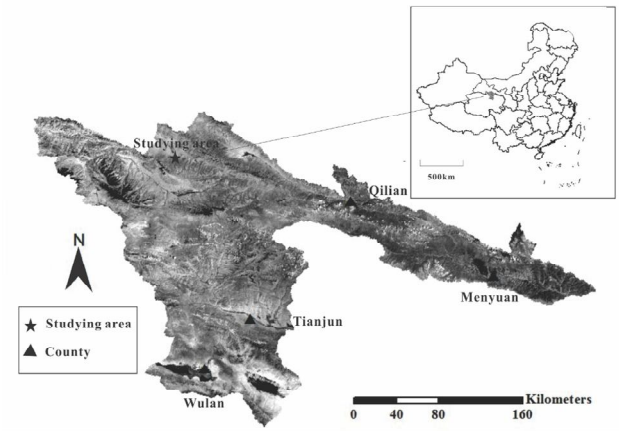

Fig. 1. Map of the study area in the Qilian Mountains, China.

Behavioral observations

The study was conducted between the months of June, 2012 through May, 2013 from 07:00-18:00 in December, January, March, and April (cold season) and 06:00-20:00 in June, July, and August (warm season). Observations were made via the focal-animal sampling method as described by Altmann (1974). The total number of deer observed was 52, 29 males (6 deer: 11 to 14 years old; 18 deer 4 to 10 years old; 5 deer: 1 to 3 years old) and 23 females (19 deer: 4 to 10 years old; 4 deer: 1 to 3 years old). Infant deer (1 to 3 years old) were excluded from the adult animal groupings. For each survey, we randomly selected an individual (focal) animal with binoculars and then used a telescope to observe its behavior. We noted the following parameters: date, time, weather. The behaviors of the focal animals were also recorded by Samsung voice recorders. We defined five behavioral categories: foraging, vigilance, resting, moving, and other activities (*e.g.*, drinking, excreting, jumping, grooming, and playing). White-lipped deer were categorized as foraging when standing with their head below shoulder level, biting or chewing vegetation, or when they were walking with their muzzles close to the ground. Vigilant was defined as watching with the head at or above the shoulder level while standing. Moving was defined as walking or running with their head at or above the shoulder level. Resting was recorded if the animal was lying down. Each observation bout lasted 10 minutes.

Statistical analyses

Behavioral data were not normally distributed (Kolmogorov–Smirnov tests for normality, $P<0.001$ and Bartlett-Box F tests for homoscedasticity, $P<0.05$). We, therefore, used the mean and Bootstrap Confidence Interval throughout the paper; bootstrap sample size was 10,000 and the confidence interval was set as 95%. Kruskal-Wallis tests were used to test for the differences of time budgets between the seasons for each activity and daytime period. The Mann-Whitney U-test was used to compare the different behavior categories during each season and for daytime budgets of both females and males. The level of significance was set at $P<0.05$. All statistical analyses were performed using the SPSS21.0 statistical package.

RESULTS

Diurnal time budgets

The five behavioral categories were significantly different from each other during each season for both females and males (Kruskal-Wallis test, warm-season, females: X^2= 145.51, *df*= 4, *P*< 0.001; males: X^2= 136.12, *df*= 4, *P*< 0.001; cold-season, females: X^2=129.72, *df*= 4, *P*< 0.001; males: X^2= 104.05, *df*= 4, *P*< 0.001).

There were no significant differences in feeding, moving, resting and "other" activities between males and females during each of the seasons, except that males were significantly more vigilant than females (Mann-Whitney U-test: *Z*= -2.210, *P*=0.027) (Table I).

Table I.- Diurnal activity budgets of female and male white-lipped deer.

Behavioral categories	Warm seasons		Cold seasons	
	Male	Female	Male	Female
Feeding	43.45% (35.70-51.33)[a*]	40.97% (34.25-47.63)[a*]	53.54% (47.29-59.94)[a*]	55.14% (48.62-61.43)[a**]
Moving	2.84% (1.37-4.72)[a*]	1.86% (1.26-2.57)[a*]	2.37% (1.50-3.46)[a*]	1.64% (1.04-2.36)[a*]
Resting	51.09% (42.57-59.55)[a*]	53.27% (45.91-60.62)[a*]	39.07% (32.20-45.81)[a**]	40.29% (33.46-46.98)[a**]
Vigilance	2.01% (1.17-2.98)[a*]	3.22% (2.21-4.37)[a*]	3.99% (2.79-5.40)[a**]	2.54% (1.81-3.42)[b*]
Others	0.61% (0.35-0.93)[a*]	0.74% (0.45-1.09)[a*]	1.03% (0.43-1.82)[a*]	0.46% (0.28-0.69)[a*]

Topped with the same letter: not significantly different between the males and females for each season. (p<0.05). Topped with the same number of *asterisk*: not significantly different between warm and cold seasons for each gender. (p< 0.05).

Seasonal variations in activity

There were significant difference in the duration of feeding (*Z*= 3.128, *P*= 0.002) and resting (*Z*= -2.426, *P*= 0.015) between the seasons for females, while no significant differences were found in moving (*Z*= -0.105, *P*= 0.908), vigilance (*Z*= -0.102, *P*= 0.919), and "other" activities (*Z*= -0.41, *P*= 0.682). For males, significant differences were observed between the seasons for the duration of resting (*Z*= -2.062, *P*= 0.039) and vigilance (*Z*= 2.897, *P*= 0.002) but not for feeding (*Z*= 1.755, *P*= 0.079), moving (*Z*= 1.277, *P*= 0.202), and "other" activities (*Z*= -0.49, *P*= 0.624) (Table I).

Daily variations of activity

During the warm season, both female and male white-lipped deer had three feeding and one or two resting peaks. The feeding peaks usually occurred in early morning, early afternoon, and evening (18:00–20:00). During the cold season, males showed only a morning (07:00–09:00) and an evening (17:00–18:00) feeding peak (Fig. 2), while resting was at its highest level during the middle of the day (10:00–13:00). Similarly, females also had two feeding peaks and one resting peak during the cold season (Fig. 3).

DISCUSSION

According to our data, feeding was the primary activity and resting was the second most important activity during both the warm and cold seasons. Moving, vigilance, and "other" activities comprised only a small part of the daytime activity budgets. Similar results have been noted for many other ungulate species, such as red deer (*Cervus elaphus*) (Pépin *et al*., 2006), Przewalski's gazelle (*Procapra przewalskii*) (Chen *et al.*, 1997), Tibetan antelope (*Panthalops hodgsoni*) (Lian *et al*., 2007), goitred gazelles (*Gazella subgutturosa*) (Xia *et al*., 2011), and Asiatic wild ass (*Equus hemionus*) (Xia *et al*., 2013). We did not find a statistical difference in any of the monitored activities between the genders during the warm season. Alternatively, during the cold season males spent more time moving, standing at vigilance and doing "other" activities, as compare to females, although only vigilance was significantly different. Previous studies have found that male Przewalski's gazelle (Chen *et al*., 1997) and Tibetan antelope (Lian *et al*., 2007) were more vigilant than females during the rutting period because of an increase in aggression and sparring activities. Similarly, with the rutting season for the white-lipped deer between September and November (the cold season) (Zheng *et al.*, 1989; Sheng and Ohtaishi, 1993), the higher vigilance rates of the males observed here may reflect intraspecific competition, where territorial males are

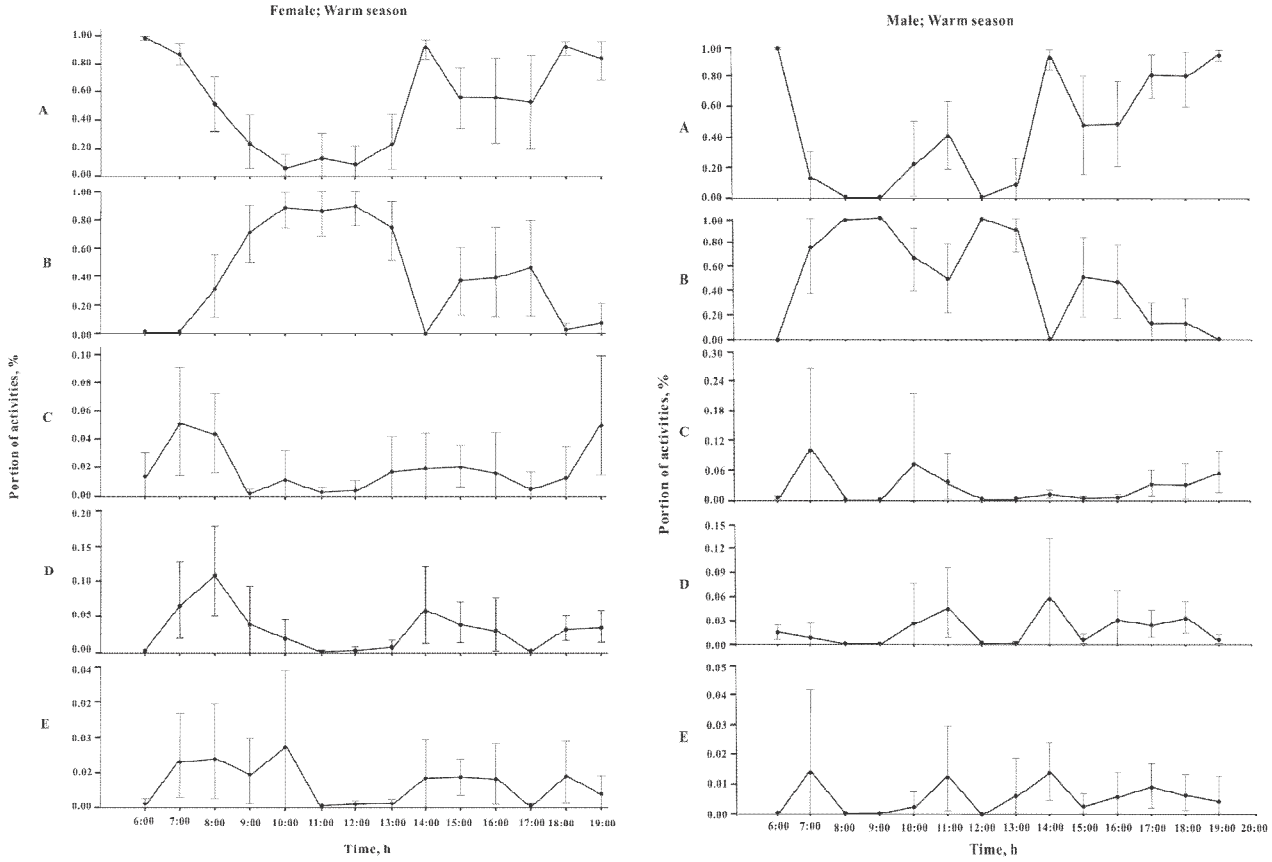

Fig. 2. Diurnal time budgets for the five main behavioral categories of female and male white-lipped deer during warm season. A: Feeding, B: Resting, C: Moving, D: Vigilance, E: "Other" activities. Bars show mean ± confidence interval.

watching for other males and for receptive females (Hart *et al*., 1992).

In this study, we observed considerable differences in the time budgets of the deer between the two seasons. Where June to mid-September is the plant-growing season, late September to May is the plant-withering season. The pasture has much more biomass in the warm season and a decreased biomass in the cold season. In order to satisfy their energy and nutrient requirements the deer have to increase their intake of food, and thus spend more time feeding during the cold season. Similar results have been found in other ungulates living in the plateau, such as the Przewalski's gazelle (Chen *et al*., 1997) and Tibetan antelope (Lian *et al*., 2007).

Our data also showed that the white-lipped deer spends the majority of their time resting during the warm season and less time resting during the cold season (Table I). Resting generally leads to a lower basic metabolic rate, which is a natural response to extremely high ambient temperatures (Arnold *et al*., 2004; Maloney *et al*., 2005). However, the mean annual temperature was -3.08°C in our study area, and there was no extremely high temperature measured during the warm season. In contrast, the cold season was severely cold, resulting in a large decrease in vegetation biomass. Hence, feeding became almost continuous during the daytime during the cold season. We suggest that this increased duration of feeding ultimately caused the decreased duration of resting in the cold season.

Both male and female deer showed a trimodal feeding pattern during the warm season, but a bimodal feeding pattern during the cold season. Some studies have reported that bigger ruminants have an increased number of feeding peaks during

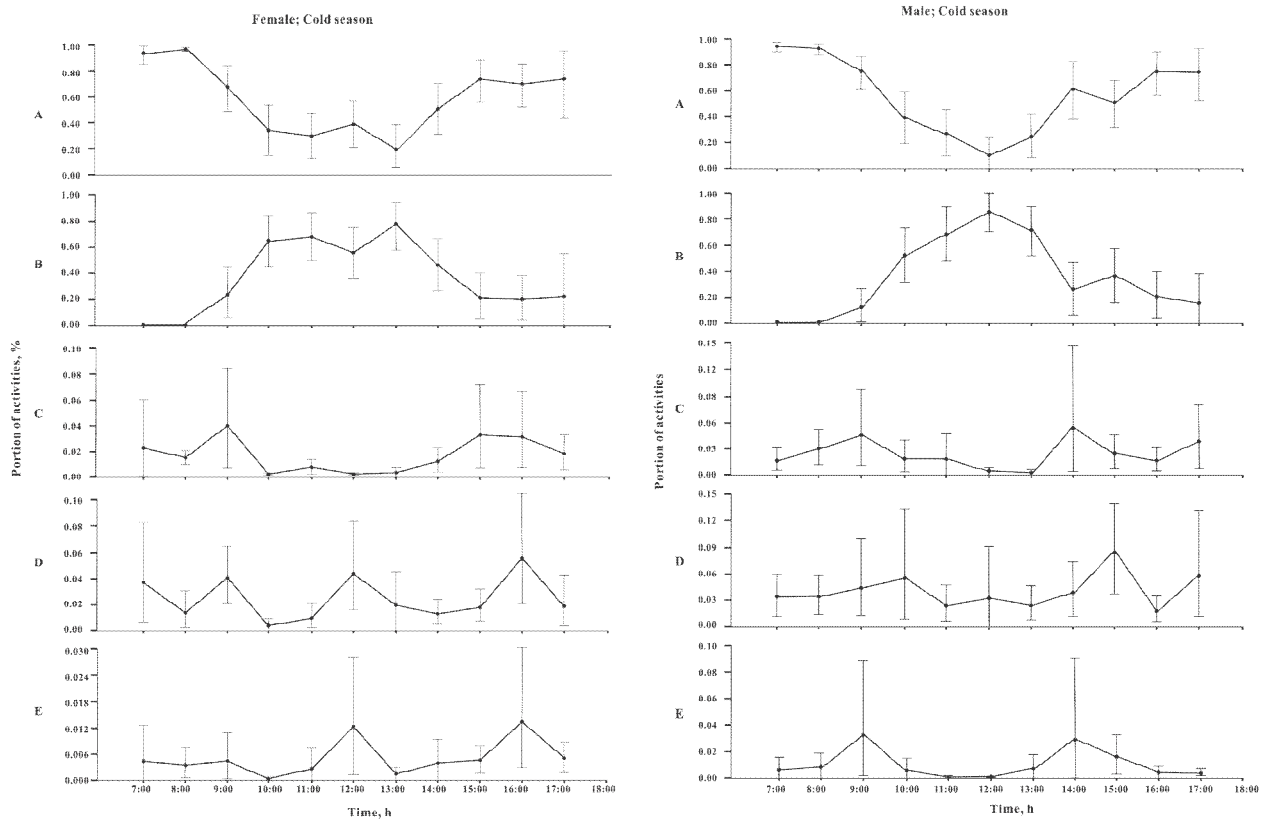

Fig. 3. Diurnal time budgets for the five main behavioral categories of female and male white-lipped deer during cold season. A: Feeding, B: Resting, C: Moving, D: Vigilance, E: "Other" activities. Bars show mean ± confidence interval.

the summer, such as: red deer (Georgii, 1981), European bison (*Bison banasus*) (Cabon-raczynska *et al.*, 1987), and Apennine chamois (*Rupicapra pyrenaica*) (Bruno and Lovari, 1989). White-lipped deer generally weigh 130-200kg and hence can be viewed as a large ungulate (Ohtaishi *et al*., 1993). The increased feeding peaks of the deer during the warm season also support the hypothesis that larger-bodied ruminants are less sensitive to temperature and can be much more active during the heat of the day (Du Toit and Yetman, 2005). We will not discuss the rest behaviors, because no special features were found between the deer and other ungulates.

It should be also mentioned that the effects of human activities on the behavior of deer should not be overlooked. With the rapid growth of human populations and an improvement in their living standards, the number of livestock stock grazing on meadow and steppes on the Qinghai-Tibet Plateau have increased in turn (Zhao and Zhou, 1999). Livestock often undergo competition with wild ungulates for food (Campos-Arceiz *et al*., 2004). In our study area, the local herdsmen practice a pastoral grazing system. As such, domestic animals graze these ranges from October-June (the cold season). Furthermore, Gramineae (*Kobresia pygmaea, Kobresia humilis, Kobresia capillifolia*) and Cyperaceae (*Sitipa purpurea, Elymus nutans, Poa. spp.*) are the primary food source of the white-lipped deer (Cai, 1988; Zheng *et al*., 1989). Incidentally, they are also the main food of Tibetan domestic sheep (Li *et al*., 2008) and domestic yak (Dong *et al*., 2004). Although speculative, this data suggests that a dietary overlap between livestock and white-lipped deer likely exists during the cold season. Although speculative, this data suggests that a dietary overlap between livestock and white-

lipped deer likely exists during the cold season. Consequently, feeding conditions would become particularly difficult for the white-lipped deer during this time, which might also contribute to the increased feeding and decreased resting durations in the cold season.

Taken together, we conclude that the best way to protect this "Vulnerable" animal would be for the local government to limit the grazing of livestock in the white-lipped deer's habitats, especially during the cold season. By reducing the competition for food and habitat we can better manage the declining populations of white-lipped deer.

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