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Diurnal Time Budgets and Activity Rhythm of the Asiatic Wild ass *Equus hemionus* in Xinjiang, Western China

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Abstract.- Studies on time budgets have shown that four factors may influence the daily activity budgets of the Asiatic wild ass: a) seasonal change of forage biomass and quality; b) diurnal and seasonal temperature variations; c) livestock movements and human activity; d) circadian period. In order to test these factors, the diurnal time budgets of the Asiatic wild ass was studied using the focal sampling method in Xinjiang Province (China) during 2007. According to our results, all four factors influenced the diurnal time budgets of Asiatic wild ass, which spent more than 45% (up to 66.77%) of their daytime feeding on pastures, and about one third resting (26.21%-38.06%) across all seasons. Moving, vigilance and "other" activities only made up less than 9% of the activity budgets in the most daytime of a year. Asiatic wild ass showed bimodal feeding activity in most seasons, but with longer daytime resting periods during hot months. In summer, especially during the rut, Asiatic wild ass devoted more significant time to "other" activities (suckling, moving, courting and agonistic behavior). However, the percentage of time for these activities was still notably lower than feeding and resting.

Keywords: Diurnal time, Asiatic wild ass, time budgets, *Equus hemionus*.

INTRODUCTION

Diurnal time budgets and their changes due to season, age and social status have been described in detail for a number of ungulate species (Chen *et al*., 1997; Colman *et al*., 2001; Bruno and Lovari, 1989; Leuthold and Leuthold, 1978; Maher, 1991; Moncorps *et al*., 1997; Zhang, 2000). The time budgets of every species is a result of interaction between internal (physiological state, behavioral ontogeny, body mass) and external (group size, natural cycle of day and night, habitat condition) factors (Boy and Duncan, 1979; Pepin *et al*., 1991; Owen-Smith, 1998). For adaptation to the environment, animals need to maximize their energy intake and vary their behaviors according to changes in forage quality and quantity, so the time spent on feeding and resting exhibit daily and seasonal variations (Dulphy *et al*., 1980).

Asiatic wild ass (*Equus hemionus*) inhabits desert and semi-desert environments in central Asia, Iran and India (Moehlman, 2008; Feh *et al*., 2002). This species is in Appendix I of CITES, and as is Endangered (EN) by IUCN. Some scientists believe that the population of Asiatic wild ass in Inner Mongolia (China) is probably sustained only by migration from Mongolia (Reading *et al*., 2001; Wang and Schaller, 1996). Kalamaili Mountain Ungulate Nature Reserve is the most important refuge of Asiatic wild ass in China. Its population size has reached as many as 3300 to 5300 individuals at present (Chu *et al*., 2009).

In the past decades, Asiatic wild ass has attracted attention of researchers from many countries (Reading *et al*., 2001; Oakenfull *et al*., 2000; Ge *et al*., 2003; Li *et al*., 2002; Feh *et al*., 2001; Chu *et al*., 1985; Chu *et al*., 2008; Liu *et al*., 2008, Xu *et al*., 2009), but there are vary few dealing with diurnal activities and time budgets of Asiatic wild ass. There are some studies *viz.* on *E. h. hemionus*) from inner Mongolia (Bi *et al*., 2007, on *E. h. kulan* from Kazakhstan (Rashek, 1964) and Turkmenistan (Solomatin, 1973).

The present paper describes the diurnal time budgets of Asiatic wild ass (*Equus hemionus*) and effect of season and time of day. We particularly investigated the hypothesis that daytime activities were influenced by the seasonal changes of forage conditions (quality and quantity), livestock

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movements, human activities, and circadian period.

MATERIALS AND METHODS

Study area

We collected data in the Kalamaili Mountain Ungulate Nature Reserve (44°36′ □ 46°00′N, 88°30′□90°03′E), located in the northeastern part of the Junggar Basin (Fig.1). This Basin is located in the tectonic depression between the Altai and Tian-Shan mountains in northwestern China. Kalamaili Reserve is situated closer to the Altai Mountains at an elevation of 600 - 1 470 m asl, with an average of 1 000 m. The reserve covers 1.8×10^4 km^2 of the desert plains and hills. National Highway 216 traverses the reserve.

The climate is harsh continental type. Winter is long and cold with uneven snow cover (thin on hills and deeper on plains); summer is hot and quite short. Average temperature in January is -24.3°C with an absolute minimum of -45°C. The average temperature in July is +20.5°C with an absolute maximum of +38.4 °C (Unatov, 1960). Kalamaili Reserve has 186.8 mm average annual rainfall, with the most noted during spring and early summer, and an annual evaporation rate of 2 090.4 mm.

This climate influences the vegetation of this region, which also has a number of specific characteristics. Ephemeral species appear during the rainy period. Vegetation growth begins late, and is of quite short duration (only 180 days). Plants remain vigorous during summer, and have only one dormant period through winter. Vegetation cover is quite sparse and consists mostly of desert shrubs (40-50 cm) and dwarf shrubs (10-15 cm) from the families *Chenopodiaceae, Ephedraceae, Tamaricaceae,* and *Zigophyllaceae* (Unatov, 1960). The most common tree in the reserve is *Haloxylon ammodendron*, and the typical shrubs are *Anabasis salsa*, *Atraphaxis frutescens*, *Calligonum mongolicum*, *Ceratocarpus arenarius*, *Ceratoides latens*, and *Reaumuria soongorica*. The following herbaceous species are mostly located under patches of shrubs such as *Allium polyrhizum*, *Chorispora tenella*, and some *Astragalus* species. Species from the genera *Sterigmostemum*, *Alyssum*, *Scorzonera*, *Erysimum*, *Eremurus*, *Sonchus*, and *Lappula* are common here. *Stipa glareosa*, *Phragmites australis*, *Achnatherum splendens*, *Bromus japonicus*, and *Leymus racemosus* are primary grasses in this reserve.

Asiatic wild ass and goitred gazelle (*Gazella subgutturosa*) are the most common wild ungulate species in the reserve. There are also much less often noted argali (*Ovis ammon*) in the surrounding mountains. In addition, Przewalski's horses (*Equus przewalskii*) have been reintroduced here over the last few years. Besides, 2000 herdsmen and 200,000 head of livestock stay in the reserve every winter (Liu *et al*., 2008; Chu *et al*., 2009). Carnivore activity is also a powerful factor having an impact on the activity budgets of herbivores, but carnivores are very rare in our study area (Xia *et al*., 2011). Therefore we won't consider this factor in the current paper.

Sampling design

The behavior of the Asiatic wild ass was investigated using the focal animal sampling method (Altmann, 1974) during 2007. The distance for observation was usually 500 - 1500 m. Both binoculars (magnification 8 ×) and a telescope (magnification 20 × - 60 ×) were used. Our observation periods were restricted by daytime hours, specifically, 0700 - 2000 in April-May (spring), 0700-2100 in June-August (summer), 0700-2000 in September-October (autumn) and 0800-1800 in November-March (winter).

We defined five behavioral categories *viz.*, feeding, resting, moving, vigilance, and "other". The latter category included drinking, suckling, agonistic behaviors and so on. Asiatic wild asses were categorized as feeding when they stood or walked slowly with their heads below shoulder level, and biting, chewing or swallowing food during walking with their muzzles close to the ground. Moving consisted of walking or running with the head at or above the shoulder level. Vigilance was noted when Asiatic wild ass typically standing and raising their head above the shoulder and scanned their surroundings. Resting was recorded when Asiatic wild ass were lying down or standing motionless for a long time (over 1 min) with the head at or above shoulder level and eyes partly or wholly closed.

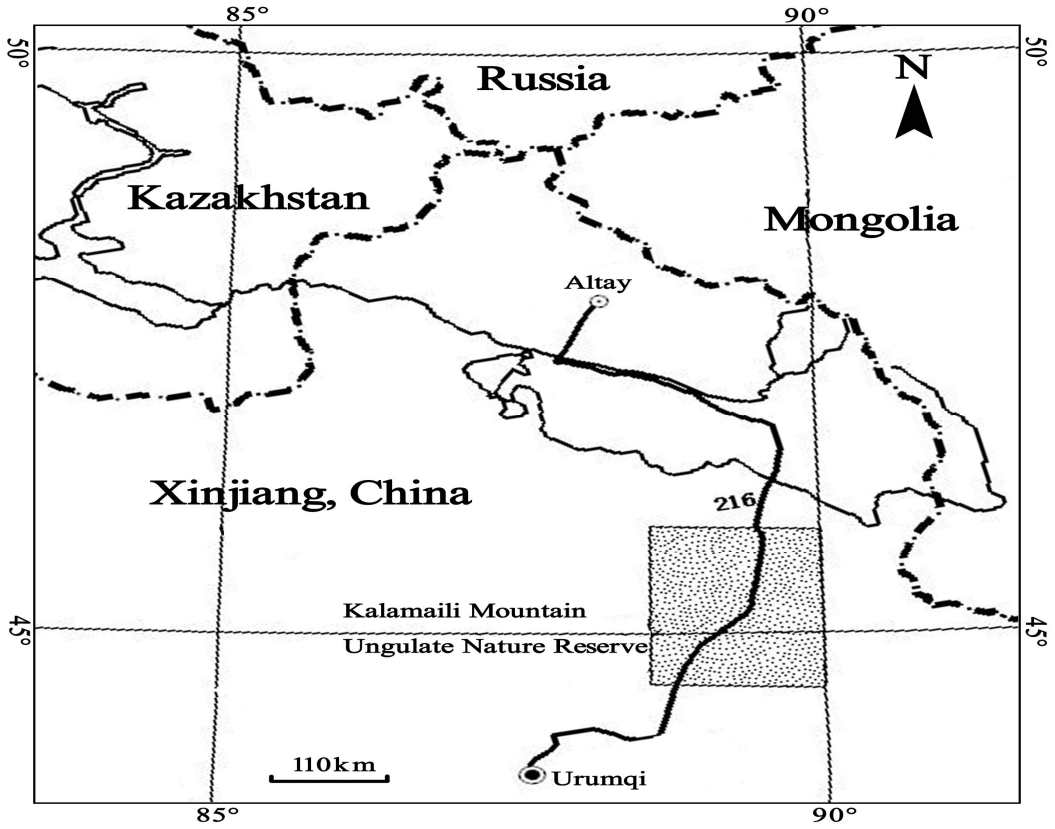

Fig. 1. The location of Kalamaili Mountain Nature Reserve

It was not feasible to mark each individual or to recognize them through particular sign. Therefore, we took only a few individuals from the group to observe, and took samples from as many groups as possible. In this way, we tried to reduce the possibility of pseudo-replication. A voice recorder was used to record the behavioral patterns and we took care to ensure that individuals were not influenced by our presence. Each sampled Asiatic wild ass was observed for 10 min. We collected data during the whole day from early morning until evening, so we sampled data of activity for every diurnal hour. In total, we conducted 2 760 focal samplings during 460 hours of observations. It was very difficult to distinguish sexes most of the time, and the number of foals and juveniles was very limited, so we didn't consider the difference of gender.

Data analysis

The Kolmogorov-Smirnov test was used for determining normal distribution. If the data were normally distributed, then one-way ANOVA combined with post-hoc tests was used to compare different behavior categories in each season. If the data were not normally distributed, a Kruskal-Wallis test was used to compare time budgets over seasons for each activity and daytime period. The level of significance was set at 0.05. All statistical analyses were carried out using SPSS 13.0 for Windows.

RESULTS

Seasonal variations of activity

Feeding was the principal activity (53.21%) and resting was the second most important activity (32.39%) of Asiatic wild ass during the whole year. Moving, vigilance and "other" activities only made up less than 9% of the activity budgets in daytime, except moving in winter (14.39%). Significant differences were found among various behavioral categories for every season (ANOVA, spring:

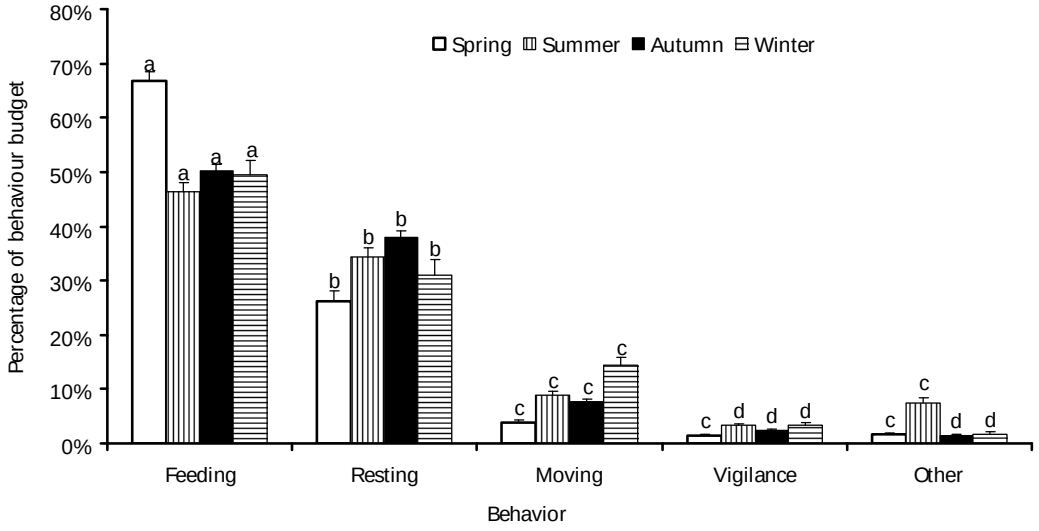

Fig. 2. Diurnal behavioral time budgets of Asiatic wild ass in different seasons. Error bars show the standard error of means. Bars across same seasons topped with the same letter are not significantly different ($p > 0.05$).

F=575.81, df=4, p<0.001; summer: F=231.99, df=4, p<0.001; autumn: F=1256.51, df=4, p<0.001; winter: F=119.18, df=4, p<0.001).

The time Asiatic wild ass spent feeding was the lowest in summer (46.26%) and the highest in spring (66.77%). In summer and autumn, time for resting was relatively high, with the percentage time of 34.28% and 38.06%, respectively; the percentage time spent resting was the lowest in spring (26.21%). Spring was also the time of year when vigilance was at its lowest level (1.55%). Asiatic wild ass moved most often during winter, spending 14.39% of their daytime budgets. "Other" activities were at their daytime high during summer only (7.39%) (Fig.2). Kruskal-Wallis tests showed significant variations in the percentage time on feeding (χ^2=59.98, df=3, p<0.001), resting (χ^2=25.21, df=3, p<0.001), moving (χ^2=70.11, df=3, p<0.001), vigilance (χ^2=14.24, df=3, p<0.001) and "other" activities (χ^2=67.19, df=3, p<0.001) over the year.

Daily variations of activity

As the two most important activities of Asiatic wild ass, feeding and resting had a covariance in all seasons. The proportion of feeding time remained high (□45%) through the whole day in spring, and only dropped between 14:00-15:00 to 27.62% (Fig.3). In summer and autumn, two peaks of feeding times (8:00-10:00 and 18:00-20:00) were commonly noted (Fig.3). In winter, the feeding time peaks were usual in midday (13:00-14:00) and evening (18:00-19:00) (Fig.3). For resting time, peaks alternated with feeding peaks in every season. Generally, the percentage time on resting was the lowest during the feeding peaks, and vice versa.

Kruskal-Wallis analysis showed significant differences in feeding durations through daytime hours: $\chi^2 = 85.59$, df = 13, $p < 0.001$ in spring; $\chi^2 = 113.20$, df = 14, $p < 0.001$ in summer; $\chi^2 = 154.41$, df = 13, $p < 0.001$ in autumn; and $\chi^2 = 23.31$, df = 10, $p = 0.01$ in winter. Likewise, significant differences in resting durations through daytime hours were found: $\chi^2 = 90.18$, df = 13, $p < 0.001$ in spring; $\chi^2 = 103.19$, df = 14, $p < 0.001$ in summer; $\chi^2 = 195.81$, df = 13, $p < 0.001$ in autumn; and $\chi^2 = 37.92$, df = 10, $p < 0.001$ in winter.

In summer, peaks in moving time of Asiatic wild ass were noted at 8:00-9:00, 15:00-16:00 and 19:00-20:00 (Fig.3). In autumn, the peaks appeared between 7:00-8:00 as well as 20:00-21:00 (Fig.3). In winter, the peaks were usual at 8:00-9:00 and 15:00-16:00 (Fig.3). The Kruskal-Wallis test showed that the portion of time spent on moving varied significantly through daytime hours: $\chi^2 = 44.31$, df = 13, p<0.001 in spring; $\chi^2 = 70.31$, df = 14, p<0.001

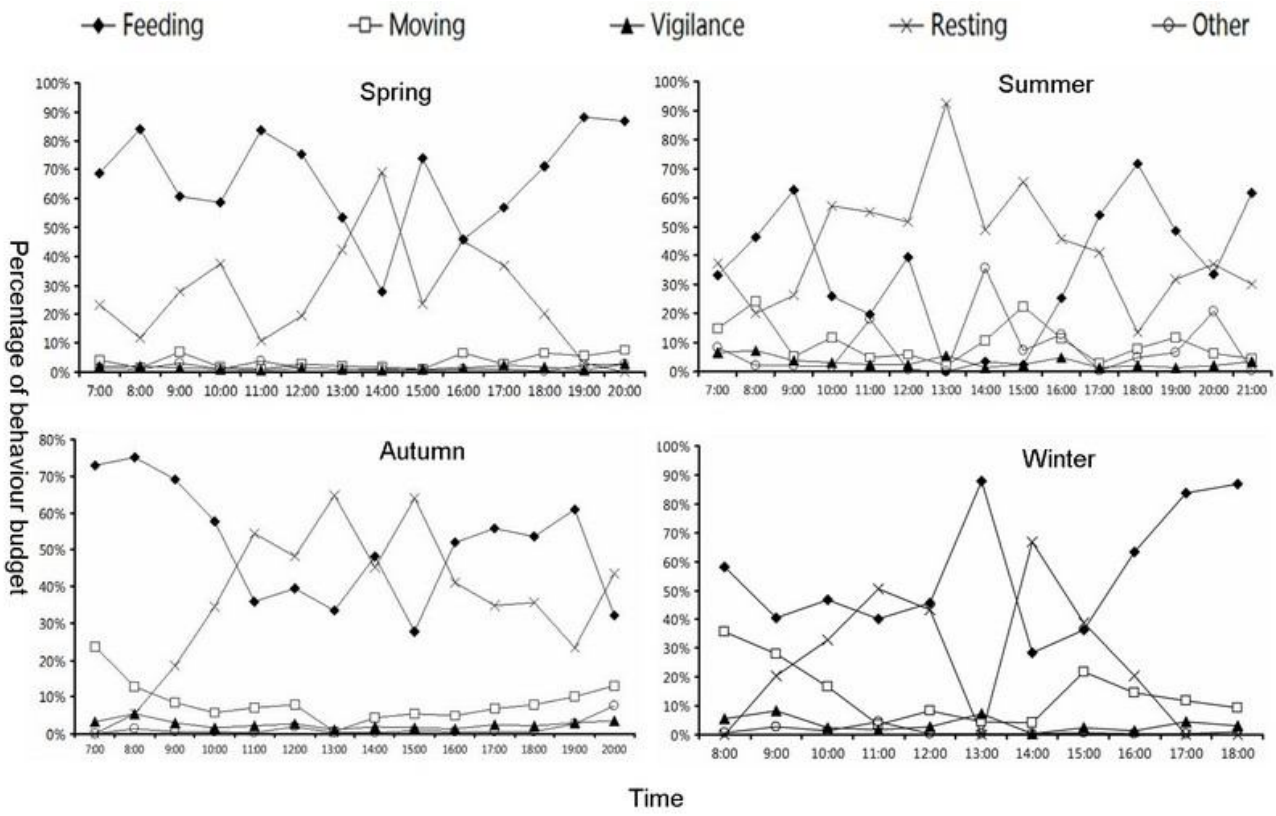

Fig. 3. Diurnal activity rhythm of Asiatic wild ass in different seasons.

in summer; χ^2 = 122.87, df = 13, $p < 0.001$ in autumn; and χ^2 = 52.76, df =10, $p < 0.001$ in winter.

Despite lower percentage time budgets spent vigilance, the Kruskal-Wallis tests indicated significant variations for vigilance through daytime hours: χ^2 = 42.18, df = 13, $p < 0.001$ in spring; χ^2 = 33.72, df = 14, p = 0.002 in summer; χ^2 = 97.27, df = 13, $p < 0.001$ in autumn; and χ^2 = 52.76, df = 10, $p < 0.001$ in winter.

DISCUSSION

Our study demonstrated that Asiatic wild ass living in this area had similar distribution of activities to other subspecies in Inner Mongolia (Bi *et al*., 2007), Kazakhstan (Rashek, 1964) and Turkmenistan (Solomatin, 1973), as well as for other equids such as Przewalskii's horse (*Equus przewalskii*) (Souris *et al*., 2007; Chen *et al*., 2008), domestic donkeys (*Equus asinus*) (Lamoot *et al*., 2005), and African wild ass (*Equus africanus*) (Moehlman *et al*., 1998).

Previous researchers proposed four factors influencing ungulate activity budgets: (a) seasonal changes in forage biomass and quality (Moncorps *et al*., 1997); (b) diurnal and seasonal temperature variations (Shi *et al*., 2003; Solomatin 1973); (c) livestock movements and human activity (Schaller, 1998); and (d) circadian period (growth and reproduction) (Duncan, 1980; Maher, 1991), which are discussed below.

Seasonal changes of forage biomass and quality

In spring, plants started to grow late because of low temperatures and overgrazing of domestic animals and wildlife in winter in this nature reserve; therefore, available food was quite poor during this season. As a consequence, Asiatic wild ass was forced to spend more time feeding to satisfy their energy and nutrient requirements. That is assumed to be why they spent the highest daytime feeding across a year (66.77%). During summer, the forage

situation changed considerably, quality and quantity of forage were better than other seasons (Xu *et al*., 2008). Therefore, Asiatic wild ass could obtain enough nutrients and energy in a shorter feeding time (46.26%). This phenomenon was also demonstrated in another population in Inner Mongolia (Lamoot *et al*., 2005; Bi *et al*., 2007). In autumn, forage quality and plant variety decreased compared to summer. The percentage time spent feeding did increase during this season when there is demand for nutrients as body fat in order to survive in the later harsh winter (Mautz, 1978; Adamczewski *et al*., 1987). In addition, the rest duration increased considerably to reach its maximum of the year. The low quality of dry and woody food demands significantly longer time for digestion, which may explain why the percentage time of resting reached a maximum this season (Fig. 2). In winter, Asiatic wild ass spent longer time feeding because forage quantity decreased sharply due to snow cover and a high density of livestock in the study area (Xu *et al*., 2008; Xia *et al*., 2011). Besides, Asiatic wild ass was forced to move more widely and often during winter in order to find enough suitable food due to the limited forage condition.

Diurnal and seasonal temperature variations.

Temperature may be another important factor which influenced the diurnal activities. During spring and autumn, temperatures were moderate which gave the Asiatic wild ass the possibility to graze most of the day. During summer, high temperatures usually occurred around midday. Resting generally means lower energy expenditure, which is a natural response to extreme ambient temperatures (Arnold *et al*., 2004). Presumably to avoid thermal stress, the Asiatic wild ass increased resting time and decreased feeding time during the hottest hours of summer. Similar results were also found for Przewalski's horse living in a similar environment (Zheng *et al*., 2001; Souris *et al*. 2007). Besides, Asiatic wild ass was driven to graze during the night with more moderate temperatures due to the high need for energy and protein for rearing young. The same results were reported by Rashek (1964), Duncan (1985) and Lamoot *et al*. (2005). Additionally, high temperatures are often positively correlated with an abundance of flies which force Asiatic wild ass to spend extra insect-repelling behaviors (tail whipping, body rolling or bathing in the dust *etc*.) to reduce harassment; these could also lead to decrease of feeding time (Duncan, 1992; Van Dierendonck, 1996; Souris *et al*., 2007). During the cold winter, the higher costs of thermoregulation increase ungulates' need for food (Moen, 1973). In particular, feeding behavior mostly occurred in the relatively warmer midday, less during frosty winter mornings, especially with strong winds, which were common during the cold season in the desert (Fig.3). The same phenomenon was noted for Asiatic wild ass in Turkmenistan, where low temperatures and very strong winds prevented their grazing almost completely during winter mornings and evenings (Solomatin, 1973; Sludskiy, 1963).

Livestock movements and human activity.

In this nature reserve, about 2 000 herdsmen and 200 000 head of livestock are present during winter (Liu *et al*., 2008, Chu *et al*., 2009). Human activities and livestock overgrazing resulted in forage resources for Asiatic wild ass becoming particularly poor. Besides, more suitable habitat in the reserve was occupied by livestock (Lin *et al*., 2012). Furthermore, the dietary overlap between Asiatic wild ass and livestock was 48.3% (Xu *et al*., 2008). These factors make the feeding conditions for Asiatic wild ass worse and worse. As a consequence, the percentage time feeding was relatively high. Disturbance from livestock and human activity caused the highest vigilance of Asiatic wild ass which reduces the time for feeding in winter (Fig.2). Such a phenomenon also was found for goitred gazelles in the same area (Xia *et al*., 2011). In addition, the uninterrupted snow cover forced individuals to expand their scope in searching for food. Therefore, time spent moving was at its highest in winter (Fig. 2).

Circadian period (growth and reproduction)

Circadian period also has a considerable effect on the time budgets of Asiatic wild ass. The most important is rutting period, which was noted in summer (Shah, 1993). During the rutting period, "Other" activities including suckling, agonistic and mating behaviors etc., which are connected to the

breeding cycle, increased at the expense of feeding time. Besides, the Asiatic wild ass had to spend a higher percentage of time in moving vigilance and searching for a suitable mate, only a minimal percentage time feeding during summer (46.26% of their daytime, compared to 66.77% in spring) (Fig. 2). In addition, the high need for energy and protein for rearing young may have been another important reason why Asiatic wild ass started feeding during the cooler night in summer as well as the temperature factor.

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