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Group size effect on vigilance and daytime activity budgets of the *Equus kiang* (Equidae, Perissodactyla) in Arjinshan National Nature Reserve, Xinjiang, China

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Abstract. Vigilance is recognized as the response to potential predation threats. Many factors influence vigilance behaviour, and the effect of group size has had a great deal of attention in recent years. The group size effect hypothesis proposes that there is a negative relationship between group size and vigilance, which has been proven ture for many birds and mammal species. However this relationship has not been investigated for a number of other species including the *Equus kiang*. The *E. kiang* is the largest wild ass in the world, and endemic to the Tibetan Plateau. Previous studies have reported its distribution and reproduction, but information about their behaviour especially their daytime activity budgets is still very limited. Also unknown is if the distinctive habitat of the Tibetan Plateau makes their behaviour different from other Equidae species. So in this paper, we discuss our behavioural observations of the daytime activity budgets and the group size effect on vigilance for the *E. kiang* population in the Arjinshan National Nature Reserve, Xinjiang, China. The results indicate that group size has a significant effect on the vigilance levels: with an increase in group size, both the group scan level decreased and group scan frequency increased. Our results also showed that *E. kiang* spent most of their time feeding (51.41 ± 2.74 %), followed by moving (22.49 ± 1.40 %), standing (19.62 ± 6.74 %), resting (18.41 ± 2.13 %), and other activities (8.64 ± 0.72 %). Their feeding behaviour showed three distinct activity peaks during the day: early morning (8:00-11:00), midday (14:30-15:30), and around sunset (18:00-19:30). During the peaks of activity, *E. kiang* spent most of their time feeding, and during the period of inactivity, *E. kiang* spent most of their time resting and standing. So the group size effect was supported for *E. kiang* by this study, and our results are consistent with research on other Equidae species.

Key words: Tibetan wild ass, behaviour rhythm, group scan frequency, group scan level

Introduction

Vigilance is commonly defined as a response to potential predation threats. A negative relationship between group size and vigilance level, called "group size effect" on vigilance (Lima 1995) has been reported in many species of birds (Pravosudov & Grubb 1995, Slotow & Rothstein 1995) and mammals (Li et al. 2009, Xu et al. 2010). Three main hypothesis have been proposed to explain the group size effect: the 'many-eyes' hypothesis or detection effect (Pulliam 1973), 'safety in numbers' hypothesis or dilution effect (Foster & Treherne 1981), and 'scramble competition' hypothesis (Beauchamp & Ruxton 2003).

The many-eyes hypothesis proposes that when animals gather in a group, the more eyes can detect a predator more quickly, so that individuals can benefit from the watchfulness of other group members and decrease their own vigilance (Pulliam 1973). The safety in numbers hypothesis states that the risk of a specific animal becoming prey should be diluted in large groups because the predator has the possibility for catching only one individual during an attack (Foster & Treherne 1981). The scramble competition hypothesis proposes that, as group size increases, individuals will compete for limited food resources, which leads to a decrease in vigilance (Clark & Mangel 1986, Beauchamp & Ruxton 2003). Both the many-eyes hypothesis and the safety in numbers hypothesis emphasize the role of predation risk in shaping vigilance levels, while the scramble competition hypothesis stresses the competition for resources for changes in vigilance (Beauchamp 2008).

Although the group size effect has been reported for many birds (Beauchamp 2008) and mammals (Elgar

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1989, Quenette 1990), it also has been rejected for other species, such as the Guatemalan howler monkey (*Alouatta pigra*) and swan goose (*Anser cygnoides*) (Treves et al. 2001, Randler 2003). So, it is worth further research to test the group size effect on vigilance for a wider variety of species.

Equus kiang are the largest of the wild asses in the world (Schaller 1998), and are endemic to Central Asia. Ninety-five percent of the world's *E. kiang* populations live in China on the Tibetan Plateau, at elevations between 2700 to 5300 m (Schaller 1998, StLouis & Cote 2008), but this species also can be found in Pakistan, India, and Nepal (StLouis & Cote 2008). *E. kiang* is classified as a Category I Protected Wild Animal Species under the Wild Animal Protection Law in China, and as "Endangered" in China Red Data Book of Endangered Animals (Wang 1998). The total population number of *E. kiang* has been estimated to be between 60000 to 70000 (Shah et al. 2008), and they are the only wild Equidae species on the Tibetan Plateau (Schaller 1998). Previous studies have been done of *E. kiang's* distribution and reproduction (Schaller 1998, Paklina & van Orden 2003, Sharma et al. 2004, Fox & Bardsen 2005, Bhatnagar et al. 2006, Musilova et al. 2008, StLouis & Cote 2008), but since these animals live in remote areas, their behavioral ecology is still poorly understood (StLouis & Cote 2008). In the Arjinshan National Nature Reserve in Xinjiang, China, the population of *E. kiang* is quite high, and group sizes ranging from 3 to 43 individuals can be easily observed, which makes *E. kiang* an ideal species to test for the group size effect on vigilance hypothesis. In addition, the diurnal time budget of *E. kiang* has not been studied before now, as well as whether their unique high elevation habitat would make *E. kiang's* behaviour different from other Equidae species.

So for this paper, we studied the impact of the group size effect on vigilance and the daytime activity budget of *E. kiang*, and tried to answer two questions: 1) if the group size effect on vigilance is supported by our data and 2) if the daytime activity budget of *E. kiang* is different compared to other Equidae species.

Material and Methods

The Arjinshan National Nature Reserve is located in southeast Xinjiang, along the borders with Tibet and Qinghai provinces. It is situated at the edge of the Qinghai-Tibet Plateau (Bleisch et al. 2009), and is contiguous with the Changtang Nature Reserve in Tibet and the Kekexili Nature Reserves in Qinghai (Li et al. 2006). The Arjinshan National Nature Reserve sits at an elevation that ranges from 4000 to 6000 m, and includes mountains with a permanent snow cover above 5500 m (Bleisch et al. 2009, Buzzard et al. 2010). The climate of the area is continental – dry and cold, with an average daily temperature fluctuated within –21 to 2.4 °C in winter and –3.4 to 21 °C in summer (Buzzard et al. 2010). Precipitation is rare and scattered, and falls frequently as snow or sleet, even during summer (Li et al. 2006, Buzzard et al. 2010). Detailed descriptions of the Arjinshan National Nature Reserve can be found in Butler et al. (1986) and Achuff & Petocz (1988).

Behaviour observation

In September 2011, behavioural observations were made using the group scan sampling method (Bateson & Martin 2005). We chose autumn (September) as the optimal period for our observations, since the climate in our study area can be very harsh in other seasons – in summers, flood and melting snow water make the roads difficult to traverse, and in winters, temperatures are very low with very strong winds – requiring great expense for researching *E. kiang*. Observations were conducted during daytime hours from 08:00 to 19:30. We randomly selected groups of *E. kiang* using binoculars, and then a telescope to observe their behaviour. We classified the animals into two categories, adults and young. Their activities were recorded while scanning animal groups at 10-min intervals and all the observations were done by the same person for consistency (Bateson & Martin 2005). *E. kiang's* activities were classified into five categories or patterns of behaviour: feeding, standing, moving, bedding, and other behaviours. Feeding was defined as biting, chewing, grazing, or swallowing food. Standing was defined as standing still, standing alert, or standing ruminating. Bedding was defined as sternal recumbence, including sleeping with closed eyes. Moving was defined as traveling and walking. And other behaviours were defined as all other activities, such as grooming, defecating and lactating with exception of mentioned above (Childress & Lung 2003, Li & Jiang 2008, Shi et al. 2011).

Scanning refers to an *E. kiang* standing and scrutinizing its surroundings. Instances where the animal was motionless with its head up were further regarded as vigilance according to Childress & Lung (2003). Group vigilance was estimated using group scan level (GSL) and group scan frequency (GSF). The GSL was defined as the percentage of individuals in the group that were engaged in scanning during the observation session; the GSF was measured as the percentage of intervals during which at least one *E. kiang* scanned (Li & Jiang 2008, Xu et al. 2010).

Each observation session began when a group of *E. kiang* was found, and ended when they ran out of sight or the group size changed. Since the *E. kiang* population is not fully habituated to people, the distance from the observer could affect their vigilance level, and thus could bias results. So for each observation session, we estimated the distance from the group to the observer, and took this into account when determining the level of vigilance. The distance to the observer was classified into three categories: 0-500 m, 500-1000 m, and >1000 m. Observation sessions with fewer than six scans were discarded. The observation time ranged from 10 to 190 min, with a median of 60 min.

Statistical analyses

The data for GSL and GSF were arcsine square-root transformed and then tested for normality with the one-sample Kolmogorov-Smirnov test. Because the data was normally distributed, we used the General Linear Model to test the effect of group size, distance to observer, and also their interaction impact on vigilance behaviour (Zar 1999). We used the one-way ANOVA combined with the post-hoc tests to detect the differences for various behaviour patterns in the diurnal time budget. All significant levels were set at P = 0.05. Data were analyzed using the SPSS 13.0 statistical package.

Results

A total of 1627 *E. kiang* were observed, from which we documented 74 behavioural sessions that equaled 6200 minutes of observations.

Group size had a significant effect on the vigilance level, but distance to the observer and the impact of their interaction impact did not (Table 1). The GSL decreased significantly with the increase group size, while the GSF increased with the increase group size (Fig. 1). *E. kiang* spent most of their time feeding (51.41 ± 2.74 %), followed by moving (22.49 ± 1.40 %), standing (19.62 ± 6.74 %), resting (18.41 ± 2.13 %), and other activities (8.64 ± 0.72 %) (Fig. 2). The one-way ANOVA showed that during the autumn, there were significant differences between the different pattern behaviour (One-way ANOVA: F = 548.145, P < 0.001). Time spent feeding was significantly more than any of the other four behavioural patterns, and there were no significant differences among standing, moving, bedding, and other behaviours (Fig. 2).

E. kiang's feeding behaviour showed three distinctive activity peaks during a day: early morning (8:00-10:30), midday (14:30-15:30), and around sunset (18:00-19:30) (Fig. 3). Periods of activity and inactivity alternated with period of feeding. Bedding for most of *E. kiang* occurred from 11:30 to 13:00,

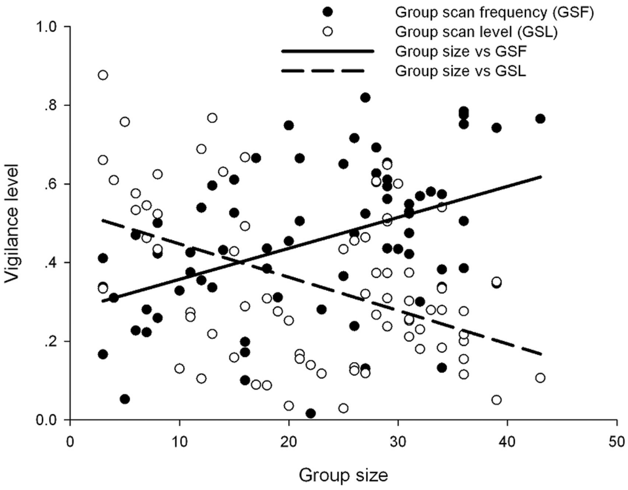

Fig. 1. Influence of group size on the group scan frequency and group scan level.

Table 1. Effects of group size, distance to the observer, and their interaction impact on the group scan level and the group scan frequency of *E. kiang*.

Factors	Group scan level	Group scan frequency
Group size	F = 2.026, P ≤ 0.047	F = 2.452, P = 0.017
Distance to the observer	F = 2.483, P = 0.108	F = 0.336, P = 0.718
Interaction of group size and distance to the observer	F = 1.159, P = 0.370	F = 0.957, P = 0.531

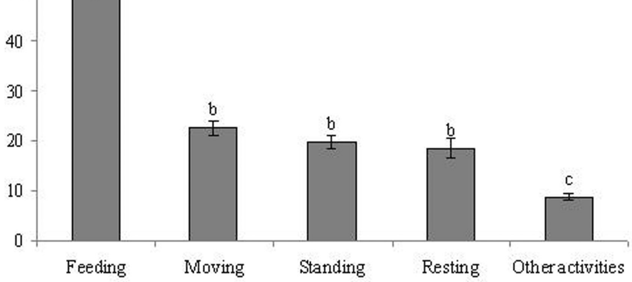

Fig. 2. Daytime activity budgets of the *E. kiang* in Arjinshan National Nature Reserve, Xinjiang, China. (Error bars show the standard error of means. Bars topped with the same letter are not significantly different p > 0.05).

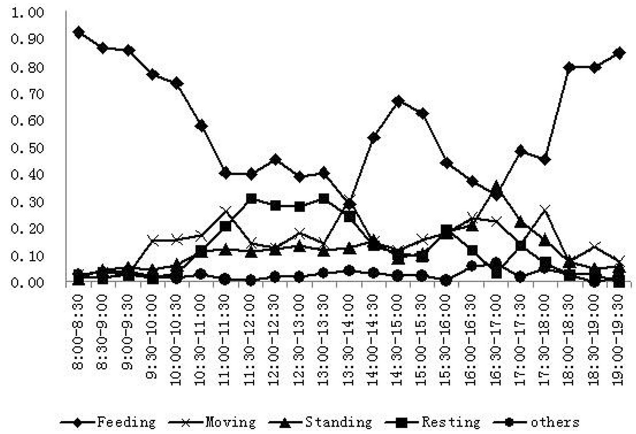

Fig. 3. Behavioral rhythm of the *E. kiang* in Arjinshan National Nature Reserve, Xinjiang, China.

and standing most often occurred from 16:30 to 17:00, when feeding was observed less often (Fig. 3). Other behaviours did not show significant differences during the daytime.

Discussion

Our results demonstrated that group size had a significant effect on the vigilance level of *E. kiang*, but the distances to the observer and their interaction revealed no impact. The GSL decreased significantly with an increase in group size, while the GSF increased with the increase in group size (Fig. 1). These results support the group size effect on vigilance, and are consistent with similar studies on *E. hemionus* (Bi et al. 2007), *Procapra picticaudata* (Li & Jiang 2008), *Aepyceros melampus* (Shorrocks & Cokayne 2005), and *Capra sibirica* (Xu et al. 2010).

All the three hypotheses of group size effect could provide explanations for these results (Pulliam 1973, Foster & Treherne 1981, Clark & Mangel 1986). The scramble competition hypothesis emphasizes the role of competition for resources, noting that group members will compete for limited food resources, which in turn will lead to a decrease in vigilance with an increase in group size (Clark & Mangel 1986, Beauchamp & Ruxton 2003). The many-eyes and safety in numbers hypotheses emphasize the role of predation risk in shaping vigilance levels (Pulliam 1973, Foster & Treherne 1981, Beauchamp 2008). Since this study was conducted in the autumn when food resources for the *E. kiang* were limited, the scramble competition hypothesis might be the most appropriate for explaining the group size effect results for this population of the *E. kiang*. However the other two hypotheses also could have an effect on their vigilance behaviour, as well.

Besides group size, other factors have also been reported to influence vigilance levels, such as an animal's sex (Li & Jiang 2008, Li et al. 2009, Xu et al. 2010). Studies have showed that the different sexes have different vigilance levels, and generally, males are more vigilant than females. For example, researches of *P. picticaudata* (Li & Jiang 2008), *P. przewalskii* (Li et al. 2009), and *C. sibirica* (Xu et al. 2010) showed that male individuals are more vigilant than females for these species. For *E. kiang*, sex may also have an impact on vigilance levels, but since it is difficult to distinguish between males and females, we could not detect the effects sex had on vigilance, or which sex is more vigilant. Therefore, the effect and animal's sex has on vigilance needs further study for *E. kiang*.

Our results also indicated that during autumn *E. kiang* spent more than half of the day feeding (Fig. 2), and this feeding behaviour had trimodal peaks of activity: early morning (8:00-10:30), midday (14:30-15:30), and around sunset (18:00-19:30). In addition, the periods of activity alternated with inactivity (Fig. 3), and during activity peaks, *E. kiang* spent most of their time feeding, while during period of inactivity, resting and standing (Fig. 3). These results are consistent with the studies of other Equidae species, such as *E. hemionus* (Bi et al. 2007), *E. przewalskii* (Souris et al. 2007), *E. asinus* (Lamoot et al. 2005), and *E. africanus* (Moehlman 1998). All these Equidae species spent the highest portion of their time feeding, with biomodal or trimodal feeding peaks in their diurnal time budgets. Since trimodal foraging peaks reflect an animal's adaptation to an environment with a limited food supply, these Equidae species spent more time feeding especially in autumn and winter, when food was limited. This, then, added a midday feeding peak, which gave them a trimodal pattern. Even for species, such as *C. sibirica*, that are most bimodal peak foragers, more time is spent for feeding in midday during heavy snows (Fox & Bardsen 2005).

In conclusion, we found that the group size effect on vigilance was supported by this study for *E. kiang*, and recognized that due to the time of year of our research, the scramble competition hypothesis may have had the greatest influence. We also found that group size had a negative effect on the GSL and a positive effect on the GSF; that *E. kiang* spent most of their time feeding; and that their feeding behaviour showed a pattern of trimodal peaks during autumn. All of these results are consistent with documented research on the diurnal time budgets of other Equidae species, and do not reflect any impact from the distinctive habitat of the Tibetan Plateau. We also recognize further research needs to be done to broaden our knowledge on behaviours, such as vigilance and the group size effect, of *Equus kiang*, as well as other species.

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