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The effect of group size on the vigilance of Mongolian gazelle (*Procapra gutturosa*)

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Abstract. Group scan sampling and focal animal sampling was used to evaluate the relationship between the vigilance and group size of Mongolian gazelle (*Procapra gutturosa*) from July to August 2012 around Lake Dalai, Inner Mongolia, China. We recorded 348 groups, including 107 mixed groups, 54 male groups, and 187 female groups with juveniles. The total number of individuals observed was 2026, including 4 solitary males, and the group average size was 5.76 individuals. The index of the models for curve fitting revealed that the power model $Y = 2291.40^{-0.821}$ ($R^2 = 0.846$, P = 0.013, Y = vigilance distance and X = group size) was the best-fit model to represent the relationship between vigilance distance and group size. The cubic model $Y = 108.1 - 16.95X + 1.09X^2 - 0.023X^3$ ($R^2 = 0.826$, P = 0.019, Y = vigilance rate and X = group size) was the best-fit model to represent the relationship between vigilance rate and group size. While, the logarithmic model $Y = 35.84 - 6.26\ln X$ ($R^2 = 0.792$, P = 0.024, Y = vigilance time and X = group size) was the best-fit model to represent the relationship between individual vigilance time and group size. Results indicate that vigilance rate, individual vigilance time, and vigilance distance of Mongolian gazelle decreased significantly with increasing group size. Our research provides data on Mongolian gazelles' vigilance and which will further benefit gazelle conservation.

Key words: Lake Dalai, vigilance distance, vigilance rate, vigilance time, group scan sampling and focal animal sampling

Introduction

Grouping is an important social behavior in wild animals, especially ungulates (Li & Jiang 2008). For animals in groups, the individual could gain further information if it could assess public information about the environment from other group members (Rands 2010). Group characteristics such as group size could influence ungulate natality and mortality, and further influence the survival of the species (Durant 2000). Group size has a distinct effect upon the ESS (Evolutionarily Stable Strategy), individual effort should decrease as group size increases. Once group size has become sufficiently large, the change in evolutionarily stable strategy effort would be small with further increase in group size, therefore effort should be essentially independent of group size in large groups (Rands 2010).

Vigilance is commonly assumed to be a response to potential predation threats (Ratti & Habermehl 1977). Because most mammals, especially ungulates, rely on escape to avoid predation, when any member of the group detects a predator that information is transferred to other members of the group to reduce the chance of predation.

Three main hypotheses have been proposed to explain the group size effect on vigilance. The "scramble competition hypothesis" proposes that when resources are limited, a reduction in vigilance may allow individuals to allocate more time to foraging and so obtain a greater share of the resources available to the group. This situation may arise frequently in animals that exploit the standing crop of resources occurring in small amounts, such as seeds or fruits, or, more generally, resources that are not readily available and cannot be defended. Individuals in the group would compete for limited food resources, which leads to a decrease in individual vigilance with increasing group size (Clark & Mangel 1986, Beauchamp & Ruxton 2003, Rieucau & Giraldeau 2009). The "dilution effect hypothesis" states that the risk of being predated should be diluted in large groups because the predator could only prey on one individual during an attack and the probability of an individual becoming prey decreases as the group size increases (Foster & Treherne 1981, Partridge 1982). According to the "many eyes hypothesis" more eyes make it easier to detect a predator, and thus individuals decrease
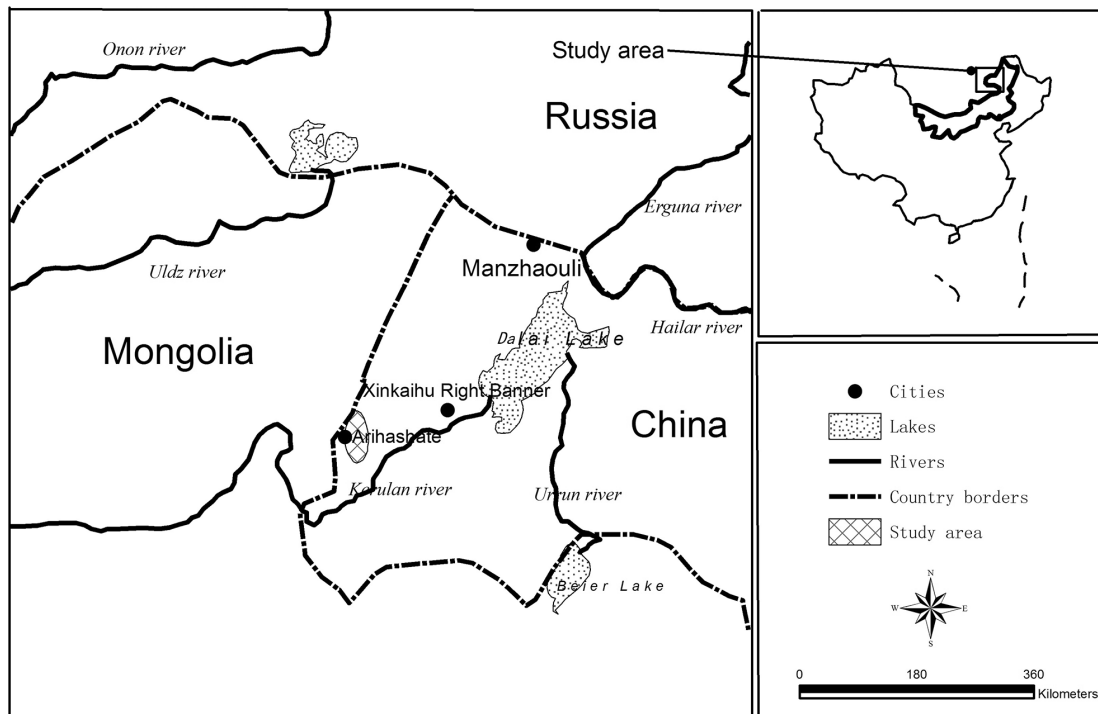
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Fig. 1. Location of study sites.

their own vigilance and benefit from other group members (Pulliam 1973). Many researchers have reported the effect of group size on animals' vigilance (McNamara & Houston 1992, Bednekoff & Lima 1998, Beauchamp & Ruxton 2003) and most of these studies have focused on birds and mammals (Treves et al. 2001, Randler 2003).

The Mongolian gazelle is an endemic herbivore on the steppe habitats in Eurasia and was listed as a Category II species in the National Protected Wild Animals of China in 1989 (Wang 2003). Previous study of Mongolian gazelles' behavior has focused on activity budgets, grouping, and migration (Gao et al. 1996, Lhagvasuren & MilnerGulland 1997, Liu et al. 2009, Liu & Qian 2011). However, the relationship between vigilance and group size of the gazelle have not been reported, and relative studies are urgently needed for population management and conservation on the species.

Here, we report the relationship between vigilance and group size of Mongolian gazelle using the motorcycle engine noise as an interference sources around Lake Dalai, Inner Mongolia from July to August of 2012. Our objectives were: (1) to construct a model that represents the relationship between vigilance time, vigilance distance, and vigilance rate and group size in Mongolian gazelle in order to evaluate effects of group size on vigilance, and (2) to provide recommendations for the conservation of this ungulate species.

Methods

Study area

The study area was located near the town of Arihashate, part of Xinbarhu Right Banner, northeastern China, 115°31′-117°43′ E, 47°36′-49°50′ N, near the border between Mongolia and China (Fig. 1). This area is a major part of the range of Mongolian gazelle. The average elevation is about 600 m to 800 m and it is in the cold temperate continental semiarid climatic zone. The average annual temperature is –3 °C, ranging from about –22 °C to –24 °C in January and about 35 °C to 40 °C in July. The frost-free period is 80 ~ 120 days and the annual precipitation varies between 250 ~ 380 mm, of which 70 % falls in summer. The grassland is categorized into five types according to the species composition: the *Stipa grandis Aneuropidium chinense* type, the *Stipa grandis Cleistogenes squarrosa* type, the *Cleistogenes squarrosa lespedeza* spp. type, the *Artemisia frigida* type and the *Aneuropidium chinense Stipa grandis--Herbs* type. The vegetative grow season begins in early May and ends the end of September (Pan 1992).

Data collection

We used the method of group scan sampling and focal animal sampling, from 8:00 a.m. to 3:00 p.m. from July to August 2012 (Martin & Bateson 1993). We stood or sat at a location where we did not detectably influence the gazelles' behavior and recorded group

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sizes using binoculars (8 × 42) and a single tube telescope (20 – 60 × 63). Then, we approached the group on a motorcycle at a speed of 20 km/h and when the gazelle became vigilant the motorcycle immediately stopped but the engine was not turn off. The vigilance distance was measured using a laser rangefinder. The group was observed for ten minutes and at the end of each minute we recorded the number of vigilance individuals and the vigilance time of three random vigilance individuals (if the group was less than three, we record the vigilance of all individuals). Vigilance was definite as a head-up posture and scanning (Childress & Lung 2003). Groups were defined following Heureux et al. (1995), Gao et al. (1996) and Oli (1996): at least two individuals gather together, distances less than 50 meters, showing coordinate activities, and walk in the same direction. We defined vigilance distance as the distance from the motorcycle to the nearest vigilance Mongolian gazelle. Vigilance rate (%) was definited as:

$$\text{vigilance rate (\%)} = \frac{\sum Yi}{10X} \times 100\ \%$$

Y_i = number of vigilance individuals at the end of each minute; 10 = recording time and X = group size. Vigilance time (%) was definited as:

$$\text{vigilance time (\%)} = \frac{\sum Yi}{10X} \times 100\ \%$$

Y_i = vigilance time of three random vigilance individual at the end of each minute; 10 = recording time and X = group size (when group size less than three, X = group size; when group size greater than or equal to three, X = 3). Typical Group Size (TGS) can reflect the community environment that the individual experienced (Gross et al. 1995), so we calculate TGS by Janman's method:

$$\text{TGS} = \frac{\sum n_i^2}{N}$$

n_i = the first i group size; N = total number of all groups.

Statistical analysis
We use a simple scatter-plot to evaluate the distribution of the data. Because the data had a non-linear distribution, we use curve estimation in regression to analyze the relationship between vigilance distance and group size, vigilance time and group size, and

vigilance rate and group size. We chose some possible models in curve estimation, then we compared the R^2 and P values, and selected the best model. Data were analyzed with an IBM SPSS 19.0 statistical package and significant differences were indicated by P < 0.05.

Results
We recorded 348 groups, including 107 mixed groups, 54 male groups, and 187 female groups with juveniles. Meanwhile we observed four solitary males. The total number of individuals was 2004. The largest group included 25 individuals and the average group size included 5.76 individuals and TGS was 7.32. 59 % of the groups were composed of four to seven individuals (Fig. 2).
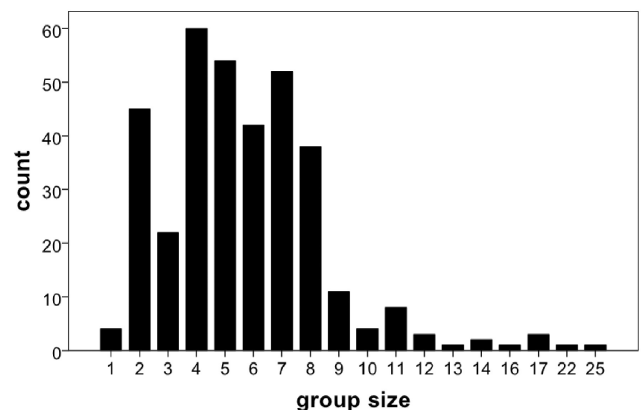

Fig. 2. Distribution of group size of Mongolian gazelle.

The curve estimation analysis indicated that no linear models fit the data for the relationship between
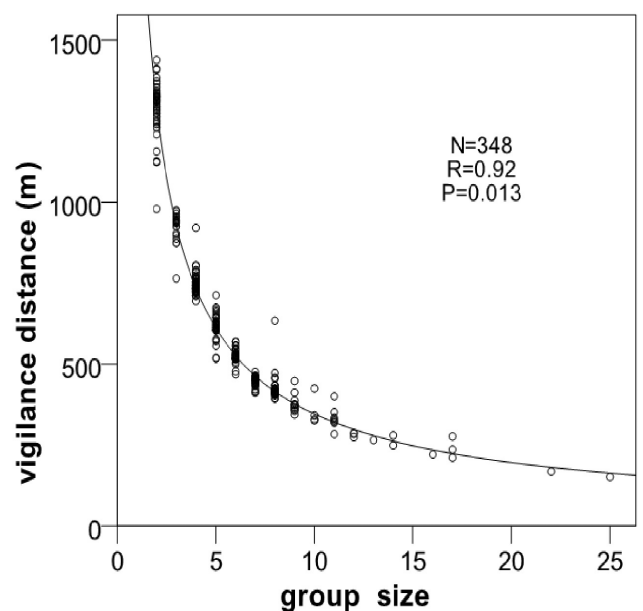

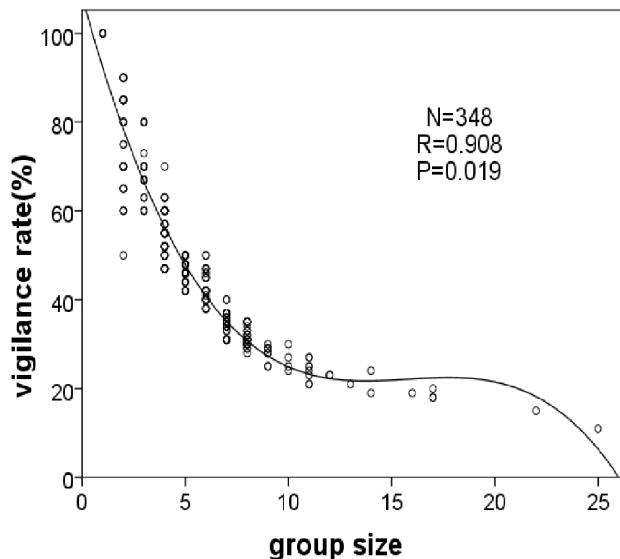**Fig. 3.** The relationship between vigilance distance and group size.

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Fig. 4. The relationship between vigilance rate and group size.

Fig. 5. The relationship between vigilance time and group size.

vigilance time, vigilance distance, and vigilance rate and group size based on comparing the R^2 and P value. The power model, $Y = 2291.40X^{-0.821}$ (Y = vigilance distance and X = group size, $R^2 = 0.846$, P = 0.013, Table 1A) was the best-fit model for the relationship between vigilance distance and group size (Fig. 3). This model indicates that vigilance distance decreased significantly with increase in group size up to 10 individuals then the vigilance distance decrease is not so obviously.

The cubic model, $Y = 108.1 - 16.95X + 1.09X^2 - 0.023X^3$ (Y = vigilance rate and X = group size, $R^2 = 0.826$, P = 0.019) was the best-fit model for vigilance rate and group size (Table 1B, Fig. 4). This model demonstrates that the vigilance rate sharply declined
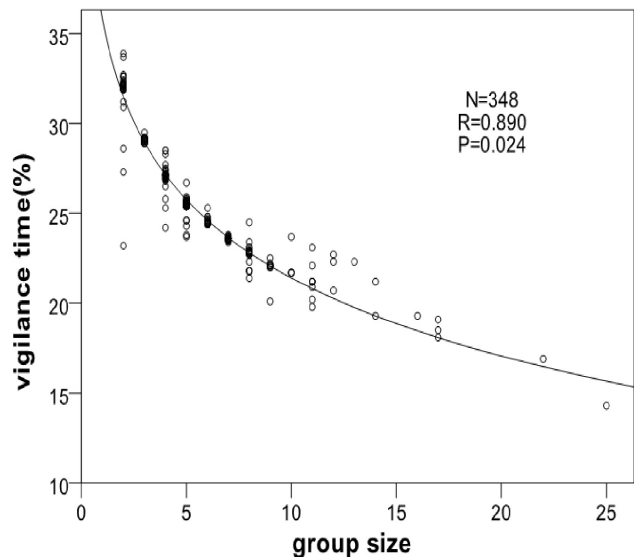
with increase in group size. When the group size was 10 to 19, the vigilance distance decrease was not so obvious. When the group size continues increasing, the vigilance distance sharply decreased with increasing of the group size.

The logarithmic model, $Y = 35.84 - 6.27\ln X$ (Y = vigilance time and X = group size, $R^2 = 0.792$, P = 0.024) was the best model for vigilance time and group size (Table 1C, Fig. 5). This model indicates that vigilance time decreased with increase in group size. In the model, the vigilance time sharply decreases with increase of group size, when the group size below 10. The vigilance time decrease is not so obvious when the group size is up to 10. Data indicated that the vigilance time changed in a certain range.

Table 1. The P & R value of each model.

A possible models of vigilance distance and group size, Y = vigilance distance, X = group size			
	linear	power	exponential
model	$Y = 78.98X + 1113.21$	$Y = 2291.40X^{-0.821}$	$Y = e^{-0.129X}$
R	0.418	0.92	0.79
P	0.476	0.013	0.147
B possible models of vigilance rate and group size, Y = vigilance rate, X = group size			
	linear	cubic	compound
model	$Y = -4.996X + 76.42$	$Y = 108.1 - 16.95X + 1.09X^2 - 0.023X^3$	$Y = 86.15*0.891^X$
R	0.57	0.908	0.714
P	0.443	0.019	0.164
C possible models of vigilance time and group size, Y = vigilance time, X = group size			
	linear	logarithmic	compound
model	$Y = -0.960X + 31.17$	$Y = 35.84 - 6.27\ln X$	$Y = 31.78*0.962^X$
R	0.62	0.890	0.68
P	0.336	0.024	0.192

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Discussion

Many studies have reported negative relationships between vigilance and group size (Beauchamp 1998, Treves et al. 2001, Bednekoff & Lima 2005, Dias 2006, Sansom et al. 2008). Treves (2000) reported that each member in a group spent less time vigilantly scanning compared to a solitary individual. Our research indicated a negative relationship between vigilance rate, vigilance time, and vigilance distance, and group size of Mongolian gazelle. The similar trend is reported in previous studies (Pulliam 1973, Li & Jiang 2008, Xu et al. 2010).

However, the question remains whether larger group size has a survival advantage? In evolutionary terms, animals would trend towards maximizing reproductive strategy (Davies et al. 2012). During the season of our study, the female Mongolian gazes are lambing, the juveniles are less able to detect and escape from predators, and the females have to leave the group to take care of the young, which is more conducive to the juveniles' survival (Ciuti et al. 2006). This will lead to the entire group scale become smaller. In our study, Mongolian gazelle group are mostly constituted of four to seven individuals, similarly to results reported for Przewalski's gazelle (Li & Jiang 2008). Previous studies have shown that the optimal group size is usually five to six (Thirdgood 1996). When the group size is less than five, the vigilance time of each individual increased significantly and when the group is more than seven, the vigilance time of each individual is not reduced significantly (Alados 1985, Thirdgood 1996). Our data fundamentally support this conclusion. Our research indicates that during the lambing period, the optimum group size of Mongolian gazelle is five to seven. In larger groups the gains in protection mostly comes from the addition of other group members rather than from further reduction in vigilance.

The "scramble competition hypothesis" emphasizes competing for limited food resources. While in this season the food resources are very easy to obtain for Mongolian gazelle in our study area, no competition for resources is assumed to take place. Our study is irrelevant to the "scramble competition hypothesis". With the "dilution effect hypothesis" and "many eyes hypothesis" the emphasis is on predation, stressing the role of predation vulnerability in shaping vigilance levels (Beauchamp & Ruxton 2003, Beauchamp 2008, Xu et al. 2013). Decrease in individual vigilance in large groups probably reflects increased safety caused by the presence of more eyes to detect threats and more bodies to dilute risk (Li et al. 2012). These two hypotheses possibly explains our results. In our opinion the "many eyes hypothesis" could be a better explanation for the results. Since there are more pairs of eyes to scan the surrounding environment, the opportunity to find a predator increased with group size. So the vigilance distance, vigilance rate, and vigilance time decreased with increasing group size. Because vigilance time is reduced, the time for other behaviors such as foraging, resting, and maternal behavior increased. This would benefit the survival of the individual and, further, the entire population. Which hypothesis is the correct explanation for our study results needs further study.

Our study showed that the larger group size of Mongolian gazelle had a smaller vigilance distance, this suggests that the larger group size of the Mongolian gazelle had a higher human interference tolerance, which could adapt to more extensive and frequent human activities.

Our study significantly increases thoughts for improving the management and protection of the Mongolian gazelle. First we should consider the vigilance distance of Mongolian gazelle in respect of planning and construction of the nature reserve; second we should propose reasonable arrangement of the habitat of Mongolian gazelle and the human interference in the buffer area of the nature reserve; and finally we should reduce human activities which could lead a negative impact of Mongolian gazelles' normal life as far as possible.

A number of factors are known to influence group size in mammals, including food density, gender, age, habitat, and social behavior, all of which can affect the vigilance behavior of Mongolian gazelle. However, in the current study we concentrate just on group size; other factors affects on Mongolian gazelles' vigilance need further study.

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