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Flight responses of blue sheep in Ningxia Helan Mountain National Nature Reserve

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Abstract. Ecotourism and off-road recreational disturbances can be threats to wildlife inhabiting protected areas. Here we investigate flight response patterns in blue sheep (*Pseudois nayaur*) inhabiting the Ningxia Helan Mountain National Nature Reserve, China. We found that flight initiation distance (distance at which animals begun fleeing a slowly approaching human) and final flight distance (distance at which the blue sheep stopped fleeing) varied across the reserve and was a function of the level of tourism in each focal area. In areas of heavy ecotourism, blue sheep allowed humans to approach closer, fled at a slower speed and did not flee as far compared to sheep inhabiting areas with less intense ecotourism. Flight initiation distance did not vary seasonally but final flight distance did. There was no group size effect on the flight responses. Both flight initiation distance and final flight distance were negatively correlated with the number of daily tourists, and positively correlated with the distance to anthropogenic constructions such as houses and roads. Blue sheep appear to have remained in areas with large anthropogenic disturbances because of abundant water, and have habituated to the presence of tourists in areas of heavy ecotourism. Moderate ecotourism may not cause blue sheep population decline.

Key words: flight initiation distance, final flight distance, areas, groups, season

Introduction

Increasing ecotourism and off-road recreational disturbances can be threats to wildlife inhabiting protected areas (Stankowich 2008). Ecotourists often want to encounter wildlife, especially rare and timid species. Increased visitation to natural environments leads to economic incentives for conservation, but can alter ecological communities (Hidinger 1996, Karp & Root 2009). Environmental managers are therefore faced with the challenge of developing policies that promote the coexistence of ecotourism and wildlife (Knight & Gutzwiller 1995, Fernandez-Juricic & Schroeder 2003). Understanding how wildlife in protected areas responds to human activity is essential to the development of these management policies (Miller et al. 2001).

Wildlife often view humans as predators (Frid & Dill 2002, Fernandez-Juricic & Schroeder 2003) and animal population size and diversity tend to decrease in areas frequented by humans (Griffiths & Van Schaik 1993), especially near heavily used trails. This behavioral response may be predation avoidance (Hidinger 1996, Karp & Root 2009). To ensure access to resources in areas frequently disturbed by people, wildlife species are known to modify their behavior and adapt to anthropogenic disturbances (Tigas et al. 2002, Ditchkoff et al. 2006, Li et al. 2009). Several studies have found that flight initiation distance decreases as a result of repeated exposure to humans (Burger & Gochfeld 1991, Lord et al. 2001, Miller et al. 2001). Under the stay or flee trade-off, individuals of wildlife populations should obtain a fitness benefit from their decision (Cooper Jr. & Frederick 2007, Stankowich 2008).

To avoid selection pressure arising from predation and intraspecific competition, individuals of wildlife populations tend to form larger groups (Gerard & Loisel 1995, Krause & Ruxton 2002), because the dilution of risk in larger groups should lead to decreased vigilance for their members (Recarte et al. 1998, Burger et al. 2000). Conversely, some investigators have also found animals were more alert (Aastrup 2000, De Boer et al. 2004) or fled longer distance in larger groups (Stankowich & Coss 2007),

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and attributed this result to increased vigilance in larger groups (Aastrup 2000). Wildlife have also been shown to decrease their anti-predator behavior during the mating season, to spend more time and energy finding a potential mate (Reimers & Colman 2006, Ciuti et al. 2008), but they increase their alertness during the lambing season (Aastrup 2000). The effects of group size on flight response might have species-specific differences or responses may vary toward social or environmental factors such as the level of exposure to humans and feeding competition (Stankowich 2008).

Helan Mountain is the eastern boundary of blue sheep's (*Pseudois nayaur*) distribution (Liu et al. 2007a), and blue sheep are the most abundant species in the Ningxia Helan Mountain National Nature Reserve, China. Since the establishment of the reserve in 1988, and the movement of 100000 livestock out of the reserve in 1997 (Wang et al. 2005), the number of blue sheep within the reserve has increased and population density was estimated approximately five sheep per km^2 in 2003 (Liu et al. 2007b).

The blue sheep's range on the reserve is from 1500 to 3000 m, however, they mostly inhabit areas lower than 2000 m (Wang et al. 1998). Thus, this species has a higher likelihood of contacting humans, especially in areas with continuously flowing water (Zhang et al. 2012). Despite being well adapted to the rocky terrain and a lack of geographical barriers in the reserve, blue sheep inhabit limited sections of the reserve only (Wang et al. 2006). The home range of an adult male blue sheep is typically around 3.7 km^2 and for females and juveniles it is typically 2.9 km^2 and 1.6 km^2 respectively (Cui 2007). The low home range size of the blue sheep may be related to high levels of intraspecific competition experienced during recent population expansion (Gill et al. 2001, Liu et al. 2007b). There is spatial heterogeneity in water, forest cover and levels of human activity across the reserve (Di 1986), therefore some spatial heterogeneity related to blue sheep density and demography is expected. Wolves (*Canis lupus*) and leopards (*Panthera pardus*) have been locally extinct since the 1980s and a lack of other large-sized carnivores (Wang & Schaller 1996) means that predator pressure is low. The absence of predators and increased chances to contact humans may mean that blue sheep exhibit unique flight responses towards humans within the reserve (Lima & Dill 1990).

Wildlife populations with different human histories respond differently to anthropogenic disturbances (Stankowich 2008). Given increasing levels of ecotourism and the uneven distribution of this disturbance across the blue sheep reserve, an understanding of the impacts of human activity on this ungulate is now needed to guide management and future developments (Tarlow & Blumstein 2007). We measured blue sheep responses to slowly approaching humans at five localities within the reserve and expected that (1) flight responses of blue sheep will vary among different areas, different seasons and different group sizes; (2) different response of blue sheep is related to the number of daily tourists and distance to anthropogenic disturbance; and (3) populations of blue sheep that remain in areas with heavier anthropogenic disturbance do so because these areas provide excellent resources (e.g. water).

Material and Methods

Study area

Surveys were carried out from March 18 to December 5 in 2010, across three management stations (Dashuigou, Suyukou and Maliankou) within Ningxia Helan Mountain National Nature Reserve (38°21′-39°22′ N, 105°44′-106°42′ E). We did not survey the northern part of the reserve because of low densities of blue sheep (Zhang et al. 2012). The reserve comprises mountainous and rocky areas at elevations of 1000-3556 m and lies between the eastern Yinchuan Plain and western Alashan Plateau. The climate is characterized as cool and dry and vegetation is temperate arid and semi-arid upland types. Hunting has been banned since the foundation of the reserve in 1988. The average annual temperature is –0.9 °C and rainfall is 420 mm (Shitanjing weather station in the reserve). Four vegetation types can be found in the study area: (1) mountain grassland (1400-1600 m), dominated by *Stipa breviflora* and *Ajania ruticulosa*, interspersed by *Salsola laricifolia*, *Ptilagrostis pelliotii*, *Convolvulus ortschakovii* and *Oxytropis aciphylla*; (2) mountain woodland steppe (1600-2000 m), dominated by large patches of *Prunus mongolica*, at some place distributed with the grasses *Stipa bungenana* and *S. grandis*, sparsely with Siberian elm (*Ulmus pumila*); (3) mountain conifer forest (1900-3000 m), dominated by Chinese pine (*Pinus tabulaeformis*) and Qinghai spruce (*Picea crassifolia*); (4) sub-alpine shrublands and meadows (3000-3556 m) occur at the highest elevations, dominated by *Caragana jubata*, *Salix cupularis*, *Kobresia* spp., *Arenaria* spp., and *Polygonum viviparum* (Di 1986). As vegetation in the blue sheep range is sparse, conditions for sheep sighting were excellent (Liu et al. 2008).

Blue sheep in the reserve mainly feed on graminoids in summer and autumn, and increase the amount they feed on trees and shrubs in spring and winter (Liu et al. 2007a). Most of the groups in this study comprised only 2-5 blue sheep, group size had no seasonal variation (Liu et al. 2009). Some male blue sheep live with females throughout the year, but most males will only contact females in the rutting period (November and December). Male adults often visit multiple female groups to find mate chances during this time (Li et al. 2007).

The first focal area within the reserve is Suyukou National Park, founded in 1997. More than 100000 tourists access this park each year using a 17 km road that cuts across an area frequented by blue sheep. The second focal area, Dashuigou, contains a 14 km unrestricted road and attracts 5000 tourists each year. Tourists pass through the two roads mostly by cars, but sometimes walk along the road, especially when blue sheep are seen. The third focal area, Maliankou, contains a road along the foot of the mountain infrequently used by tourists, blue sheep only inhabit one side of this road. These are the only parts of the reserve open to tourism, a permit is required to enter the reserve outside of these designated tourist areas.

Given the differences in anthropogenic disturbance across these focal areas, we divided them into five sections: (A1) Suyukou on-trail, the 17 km road in Suyukou National Park and 500 m either side; (A2) Suyukou off-trail, a 67 km^2 area within Suyukou National Park; (A3) Dashuigou on-trail, the 14 km road and 500 m either side; (A4) Dashuigou off-trail, a 589 km^2 area within Dashuigou protection and management station; and (A5) Maliankou, a 379 km^2 area.

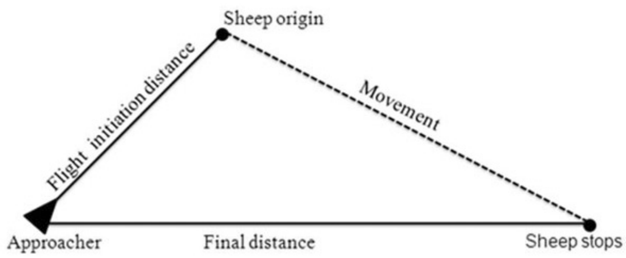

Fig. 1. Method for calculating flight initiation distance and final flight distance of blue sheep when approached by a human. The solid black triangle represents the approaching human and indicates the direction of their approach. The positions of the focal blue sheep before and after flight are represented by the black circles.

Data collection

We selected line transects in A2, A4 and A5 according to topography and walked these from the entrance to the end of each valley. In A1 and A3 we rotated to survey the road and nearby areas. We used flight initiation distance and final flight distance to evaluate flight response of blue sheep, and used humans as 'predators' (Stankowich & Blumstein 2005, Stankowich & Coss 2007). We used final flight distance instead of distance moved in Stankowich & Coss (2007), because final flight distance was easier to record via rangefinder directly. When blue sheep were encountered we recorded the following data: date, distance between blue sheep and the researcher, GPS coordinates, cluster size and the angle to the line transect in each group was recorded. We measured the angle of the line transect using a compass. A researcher wearing camouflage clothing and a hat would then approach the group at a consistent speed of 0.5 m per second. When blue sheep moved, the distance between the researcher and the sheep (as measured to the centre of the group) was recorded as the flight initiation distance. We also recorded the relative speed of the movement (quick versus slow). When the blue sheep stopped or slowed their flight away from the researcher the distance between the sheep and the researcher was recorded as the final flight distance (Fig. 1). The distance between blue sheep and the observer, flight initiation distance and final flight distance were measured by a Bushnell Yardage Pro laser rangefinder (Bushnell Corporation, Overland Park, USA) and were accurate to the nearest 1 m.

The number of tourists in the survey days in A1 and A3 were recorded at the entrance to these areas, and the number of visitors to other areas was obtained from management records. The distance from water and anthropogenic constructions (such as the houses or roads) was measured by the rangefinder directly if it was within 500 m, otherwise we measured it using Arcgis v9.2 (ESRI 2006), based on a map of the reserve and the GPS coordinates of blue sheep encounters. The actual length of each line transect was also measured using GPS and Arcgis v9.2. As we were unable to mark or identify individual blue sheep we rotated our surveys of the five sections to avoid repeated sampling (Miller et al. 2001) and did not measure blue sheep which had been disturbed (Stankowich & Coss 2007).

Data analysis

We discarded trials where the researcher appeared in front of blue sheep suddenly such as when turning a cliff corner (3 cases) and excluded data where we were uncertain the sheep were moving in response to the human (4 cases). We also did not record the final flight distance if the sheep fled to a refuge where the final flight distance could not be measured (15 cases). We

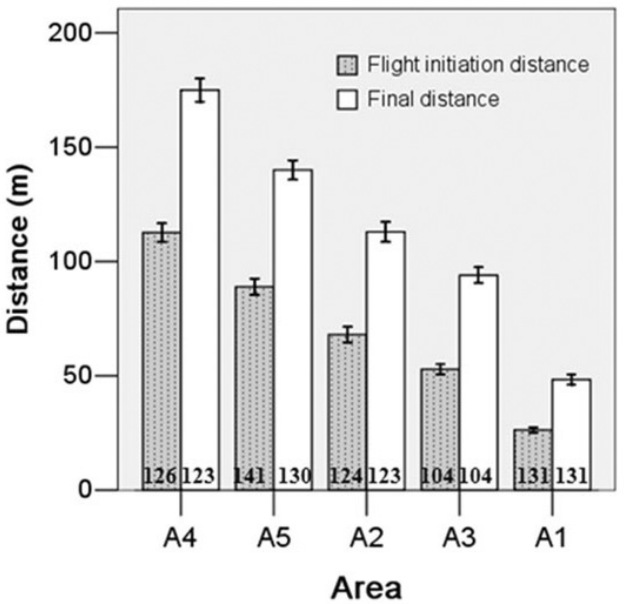

Fig. 2. Flight initiation distance and final flight distance for blue sheep across five sections of the reserve (mean ± standard error). A1: Suyukou on-trail, A2: Suyukou off-trail, A3: Dashuigou on-trail, A4: Dashuigou off-trail, A5: Maliankou. Numbers at the foot of the bar represent the number of records of the group.

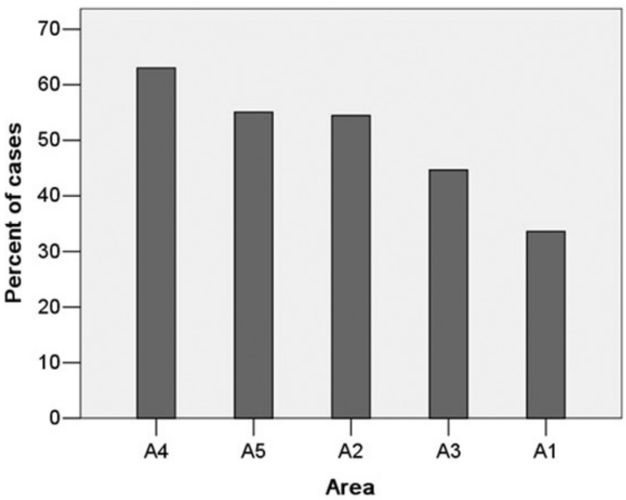

Fig. 3. Percentage of quick flight blue sheep across the five survey sections. A1, A2, A3, A4 and A5 have the same meaning with Fig. 2, and in the latter figures and Table 3.

split the year into spring, summer, autumn and winter according to the Encyclopedist Committee of Ningxia (1998). Mean (± standard deviation) group size in the reserve was 4.89 ± 6.75 so we divided group size into four classes: 1 sheep, 2-4 sheep, 5-9 sheep and > 9 sheep. Using the length of the transects, the distance between blue sheep and the observer, cluster size and the angle to the line transect, we calculated the density of blue sheep in each area each season using Distance v6.0 (Thomas et al. 2009).

We took the square root of the flight initiation distance

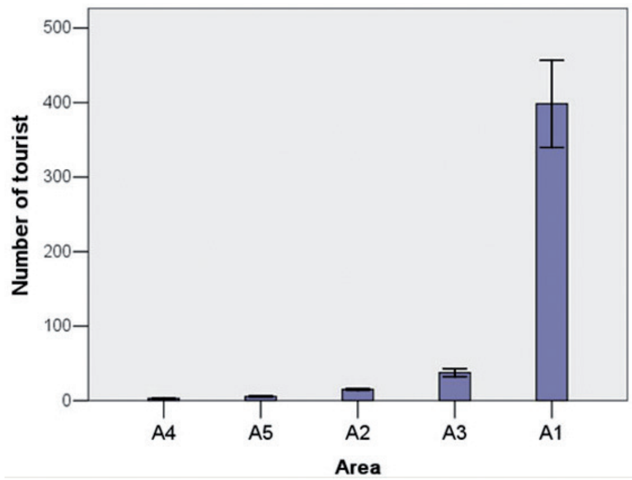

Fig. 4. Number of tourists (March 18 to December 5 in 2010) in the five sections of the reserve (mean ± standard error).

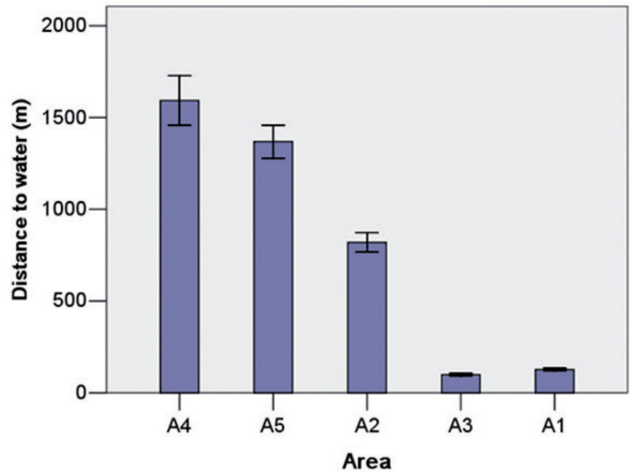

Fig. 5. Distance from water to encountered blue sheep across our five survey sections (mean ± standard error).

and final flight distance data to satisfy a normal distribution. With the flight initiation distance and final flight distance as dependent variables, general linear model (multivariate) was employed to analyze differences across different sections, group sizes and season. We used multiple comparisons (Dunnett's T3 as variances were not equal) to analyze the difference between pairs of sections, group sizes and season. We used linear regression to look for relationships between flight response (flight initiation distance and final flight distance) and the number of tourists. Pearson correlations were used to look for relationships between number of tourists and distance to anthropogenic constructions. We used one-way ANOVA to analyze differences in the estimated population density across sections and seasons. We used the Kruskal-Wallis H test to determine differences in the distance to water within each area.

All statistical analyses were done in SPSS v13.0 (SPSS Inc. Chicago, USA).

Table 1. Flight initiation distance and final flight distance (m) for blue sheep in different group size (mean ± standard deviation).

Groups	Flight initiation distance	Final flight distance
1 sheep	75.37 ± 45.89	118.70 ± 9.27
2-4 sheep	66.97 ± 44.45	108.94 ± 61.39
5-9 sheep	71.81 ± 48.49	116.48 ± 61.92
> 9 sheep	76.27 ± 48.84	126.98 ± 67.20

(F = 2.28, P = 0.03), but did not vary among group sizes (F = 1.79, P = 0.10). There was no significant interaction among area, season and group size (P > 0.05). Flight initiation distance and final flight distance were different between each pair of sections (P < 0.05). Blue sheep remained the farthest distance from the approaching person in area A4. In contrast, two on-trail sections (A1 and A3) had the shortest flight initiation distance and final flight distance (Fig. 2). Multiple comparisons revealed that blue sheep fled farther in summer and autumn than spring (mean ± standard deviation: 121.46 m ± 66.98 in summer, 119.42 m ± 56.42 in autumn, 101.12 m ± 65.88 in spring), but there was no detectable difference between seasons for flight initiation distance (P > 0.05). Both flight initiation distance and final flight distance was

Table 2. Results of linear regression of flight response (flight initiation distance and final flight distance) to number of tourists. B: regression coefficients; S.E.: standard error; Sig.: significance value; Person: number of tourists. Significant results (P < 0.05) are bold.

Seasons	Variables	Flight initiation distance			Final flight distance		
		B	S.E.	Sig.	B	S.E.	Sig.
Spring	Constant	8.74	0.29	**0.00**	10.82	0.29	**0.00**
	Person	–0.14	0.02	**0.00**	–0.15	0.02	**0.00**
Summer	Constant	9.51	0.23	**0.00**	12.16	0.25	**0.00**
	Person	–0.23	0.03	**0.00**	–0.27	0.03	**0.00**
Autumn	Constant	9.23	0.20	**0.00**	11.82	0.23	**0.00**
	Person	–0.20	0.02	**0.00**	–0.22	0.03	**0.00**
Winter	Constant	9.07	0.22	**0.00**	11.63	0.25	**0.00**
	Person	–0.28	0.04	**0.00**	–0.32	0.04	**0.00**

Table 3. Observed number, Distance 6.0 results about estimated density and 95 % confidence interval for density, coefficient of variation [CV (%)] and AIC in five sections seasonally (Model: half-normal + cosine).

Sections	Seasons	Observed number	Density (sheep/km^2)	95 % confidence interval for density	AIC	CV (%)
A4	Spring	68	2.69	1.37-5.26	260.20	34.4
	Summer	216	6.60	4.01-10.89	557.06	25.2
	Autumn	118	6.61	3.57-12.26	337.32	31.0
	Winter	109	5.18	2.45-10.97	330.61	38.2
A5	Spring	96	6.17	3.63-10.49	374.94	26.6
	Summer	127	6.88	4.53-10.44	500.00	21.2
	Autumn	247	11.72	6.78-20.25	400.34	27.7
	Winter	287	15.91	9.78-25.89	469.11	24.7
A2	Spring	243	24.68	12.88-47.3	272.98	32.9
	Summer	212	27.98	15.47-50.63	371.05	29.3
	Autumn	111	15.36	9.10-25.93	269.07	26.0
	Winter	244	16.51	7.20-37.87	373.77	43.3
A3	Spring	127	31.62	11.97-83.52	205.66	48.7
	Summer	178	22.44	11.05-45.55	340.68	36.5
	Autumn	148	11.22	6.43-19.57	273.73	27.7
	Winter	97	14.88	7.50-29.53	258.75	33.5
A1	Spring	95	30.49	11.53-80.61	273.74	50.90
	Summer	164	26.88	15.02-48.12	287.86	29.70
	Autumn	104	19.07	12.15-29.92	266.98	22.80
	Winter	189	13.06	6.64-25.70	426.22	34.90

Results

More than 20 groups in each section per season were recorded resulting in 626 cases of flight initiation distance and 611 cases of final flight distance. We found that flight responses varied among the five sections (F = 45.31, P < 0.01) and the four seasons similar between pairs of group sizes (Table 1). In A1 and A3 the majority of blue sheep fled slowly but in A2, A4, and A5 the majority fled rapidly (Fig. 3).

The number of tourists to each area is presented in Fig. 4. Both flight initiation distance and final flight distance were negatively correlated with the number of tourists regardless of season (Table 2), and the number of tourists was negatively correlated with distance to anthropogenic constructions ($r = -0.52$, $P < 0.01$). A1 and A3 had nearer distances to water ($\chi^2 = 972.21$, $df = 5$, $P < 0.001$) (Fig. 5). A1, A2, A3 had similar density of blue sheep ($P > 0.05$), but higher than A4 and A5 ($F = 5.67$, $P = 0.01$), A4 and A5 had a similar blue sheep density ($P > 0.05$) (Table 3), and there was no seasonal variation in density across all focal sections ($F = 0.64$, $P = 0.60$).

Discussion

Our results show that blue sheep remain in areas of heavy anthropogenic disturbance which are frequented by tourists. Individuals of wildlife populations can change flight responses to minimize the cost of the disturbance and maximize the chance of survival (Tarlow & Blumstein 2007). We found that in areas of increased human contact blue sheep began fleeing at a closer distance from the stimulus and also stopped fleeing sooner. A number of factors explain this pattern. First, as the population of blue sheep has increased over the last decades they have come to occupy nearly all the reserve (Liu et al. 2007b), however, increased anthropogenic disturbances may have made it difficult for blue sheep to locate and move to alternative suitable habitat (Gill et al. 2001). Second, water is an important factor known to influence mammals inhabiting arid or semi-arid areas such as this reserve (Dickman et al. 2001). Sections A1 and A3 were closer to water, providing not only ample access to water but also forage (Dickman et al. 2001). Third, blue sheep display less vigilance towards regular and non-lethal actions such as vehicles (Chanchani et al. 2010, Jiang et al. 2011), ecotourism would be a similar non-lethal threat to blue sheep, so it is likely their behavior would show a similar pattern. In addition, predator pressure is low in the reserve (Wang & Schaller 1996).

The focal areas in this study were inhabited by blue sheep at high and medium density (Zhang et al. 2012). Our density estimates are higher than those found by Liu et al. (2007b) due to our study method in which we maximized blue sheep encounters by choosing valleys with more blue sheep for our line transects. Our measure of blue sheep density also shows that blue sheep have not moved from areas of high anthropogenic disturbance (A1 and A3) to areas with less disturbance (A4 and A5), and had no net seasonal migration. The population density of blue sheep was greatest in areas containing higher levels of ecotourism and thus disturbance (A1 and A3). This trend may be due to added perceptions of safety from living near humans with a decrease in the natural level of predators. In areas of medium anthropogenic disturbance eastern bluebirds (*Sialia sialis*) have shown to have highest fitness (Kight & Swaddle 2007), but we cannot determine how anthropogenic disturbance provided positive benefits to the blue sheep. Zhang et al. (2012) suggested that heavy anthropogenic disturbances such as coal mines destroy plants and surrounding environments in the northern part of the reserve, resulting in the lowest population density of blue sheep.

No matter risk dilution in larger groups lead to a reduced flight response, or increased vigilance in larger groups lead to longer flight initiation distances, these hypotheses are based on anti-predator tactics. Predators of blue sheep have been absent from the reserve since the 1980s, this lack of natural predators coupled with the strict ban on hunting, may have caused the blue sheep to develop their own unique flight responses in the reserve. Due to the mountainous terrain of the reserve, blue sheep herd sizes are smaller than other areas (Liu et al. 2009), and members often isolate themselves from one group, and form a new group with other blue sheep after a while (Li et al. 2007). Solitary blue sheep might feel they are still in a group so that had similar flight responses with others. Animals in larger groups often become alert via their companions (Stankowich & Coss 2007). Larger groups have a greater chance of containing particularly vigilant animals that stimulate animals to flee longer distances from a disturbance (Taylor & Knight 2003). Likewise, we found that blue sheep in the reserve (except the solitary blue sheep) tend to remain farther from humans when in larger groups (Table 1). When graminoids, the preferred food of blue sheep, flourish in summer and autumn (Di 1986), blue sheep can spend more energy on escaping (Liu et al. 2007a). Blue sheep will switch to more moderate flight responses in the winter and spring when the quality of graminoids decline forcing blue sheep to feed on more trees and shrubs, which are scarce of nutrients and are harder to digest. Blue sheep form bigger groups during the breeding season (Schaller 1977). We discovered blue sheep spent less time and energy on anti-predator behavior during the rutting period, which has also been shown on a natural population of mouflon (*Ovis orientalis musimon*) in Sardinia (Ciuti et al. 2008), more precautions should be taken to minimize disturbing blue sheep during calving.

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