Eld's Deer Translocated to Human-Inhabited Areas Become Nocturnal

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Abstract As human populations expand and nonhuman animals decline, understanding the interactions between people and wildlife is essential. For endangered species, appreciating the effect of human disturbance can be important for their conservation. However, a human disturbance angle is often absent from ecological research, despite growing evidence of the negative impact of non-fatal human interference. Here, we monitored Hainan Eld's deer living within a reserve and translocated animals living amongst villagers. We show that translocated deer deviated from a crepuscular activity pattern and became increasingly nocturnal, and most active when villagers were not. It appears that translocated deer adapted over time to human disturbance and this pattern is similar to that of other species during periods of hunting. People do not pose an actual threat to Eld's deer, but their presence triggered a response akin to predator avoidance and may be interfering with broader aspects of their biology and conservation.

Keywords Eld's deer · *Cervus eldi hainanus* · Ungulates · Reintroduction · Human disturbance · Activity pattern

INTRODUCTION

The impact of human disturbance on wildlife is a major consideration in the management of many species. As human populations continue to expand and the populations of countless nonhuman animals decline, understanding the interactions between people and wildlife is essential. The effect of human disturbance on wildlife depends on the nature of the disturbance (e.g., hunting, hiking) and natural history of the focal species (e.g., nocturnality, habitat specificity). For example, human disturbance can prevent

animals from accessing certain resources (Vistnes et al. 2008), interfere with reproductive activity (Beale and Monaghan 2004; Arroyo and Razin 2006), displace animals from certain areas (Bejder et al. 2006), or result in the fatality of animals even when the disturbance itself is non-fatal.

For many animals, human recreational and subsistence use of the environment is analogous to predation and capable of initiating similar behavioral responses (reviewed by Frid and Dill 2002). For example, the activity of people such as tourists or bird observers has been shown to affect nesting success in kittiwakes *Rissa tridactyla* and guillemots *Uria aalge* (Beale and Monaghan 2004). Predation and disturbance can elicit similar behaviors such as increased vigilance and the formation of larger groups (Lima and Dill 1990; Roberts 1996; Papouchis et al. 2001; Fernández-Juricic and Schroeder 2003). It has been shown that vigilance behavior in red deer *Cervus elaphus* varies between recreational sites and sites unfrequented by people (Jayakody et al. 2008).

Given that human disturbance alters the behavior of wildlife, it is likely that changes to the habits of animals will be affected. When to forage is a critical decision for animals. Day length, temperature, and the presence of predators all impact upon the optimal feeding time for many species and exert an evolutionary affect on daily activity rhythm. Biological rhythms are the result of long-term adaptation and physiological processes, and are relatively stable, but can be modified by external factors such as extreme weather events, climate, or the presence of other species. For species of conservation concern, changes to patterns of foraging, reproduction, and sociality may have a profound impact on their survival, especially in cases where animals are re-introduced to areas and forced to share space and resources with people.

Hainan Eld's deer *Cervus eldi hainanus* is an endangered species and was reduced to 26 animals in 1976 because of hunting. Through protection and regulation the population now numbers over 1,000. A single predator-free reserve was initially established but its limited size restricted population growth (Song and Li 1995) and so translocations were conducted to key sites where deer were historically present. Many of the translocation sites are located in agricultural areas managed by small ethnic communities and villages. As a species that was, at least until the last 15 years, heavily hunted by humans, these reintroductions allow us to investigate aspects of behavior and ecology not possible for other species. For example, it is not known how these animals respond to the presence of humans and their vehicles and whether the impact from human disturbance will likely be a significant inhibitor of the success of newly established populations.

The presence of predators or perceived predators has been shown to impact upon the foraging behavior of deer. Deer are often reported to feed during twilight. For example, white-tailed deer *Odocoileus virginianus* (Beier and McCullough 1990) and roe deer *Capreolus Capreolus* (Cederlund 1989) show a crepuscular activity pattern that is shaped by predators within the area (Leuthold 1977). However, activity patterns in arctic reindeer *Rangifer tarandus* inhabiting an archipelago free from predation for at least 5,000 years (van der Knaap 1989) do not show distinct peaks in activity at sunrise and sunset (Loe et al. 2007).

Here, we monitored the behavior of deer living in a predator- and human-free reserve, and translocated deer occupying an area inhabited by approximately 4,000 villagers. It is possible that inhabiting an environment with “human predators” (in addition to village dogs and farm animals) means Eld's deer would need to adjust their rules for habitat selection and experience a tradeoff between “fitness enhancing” and “survival-enhancing” activities (Lima and Dill 1990); whereas the “control” population (the source population within the reserve) would not. Specifically, we asked the following: what is the activity pattern of deer living in a predator-free environment? Do deer alter their activity pattern when sharing open space with villagers? Would any new activity pattern become fixed over time? What is the relationship between the activity patterns of the local villagers and translocated deer?

STUDY AREA

This study was conducted within Datian Nature Reserve (DNR, 108°47'–108°49'E, 19°05'–19°07'N; 30–80 m above sea level) and around the locality of Chihao (108°48'–108°53'E, 18°58'–19°03'N; 140–680 m above sea level). Both sites are located in western Hainan Island, China (Fig. 1), share the same climate and vegetation structure, and contain no natural predators of Eld's deer. Datian is a 13.14 km² reserve for Eld's deer, enclosed by a 2.8 m

Fig. 1 Location of study area. DNR Datian Nature Reserve. CHR Chihao region, the site of translocated deer

fence, staffed by park rangers and contains few residents. Chihao comprises approximately 100 km² of open area adjoining Datian and is inhabited by approximately 4,000 people. The climate of both sites is hot and dry; mean temperature in January (the coldest month) is 18.4°C and July (the hottest month) 29.1°C. Normal annual precipitation is 1,012 mm and evaporation 2,522 mm, with most rainfall occurring during the wet season from July to October. Four hundred and fifty species of plants characterize the region. Datian contains six types of vegetation: deciduous monsoon forest (40%), thorny shrubland (19%), dry savanna (16%), cultivated grassplot (15%), shrub grassland (6%), and cultivated woodland (5%). Although the two areas comprise similar natural vegetation, Chihao has been heavily modified for agricultural production, it is characterized by deciduous monsoon forest (35%), shrub grassland (25%), houses and farmland (21%), cultivated woodland (14%), and dry savanna (6%).

Residents of Chihao belong to the Li ethnic minority and are indigenous to Hainan. They are impoverished and agriculture is the main form of income and subsistence. Consequently, the area is a patchwork of rice paddies, small plantations, crops, remnant forest, and grasslands. Some areas are cultivated continuously and others are rotated whereby a patch of regrowth is burned, managed for 1 year and then abandoned for 2–3 years. This system of land management is favorable both to deer and domesticated animals such as goats and cattle as it promotes the emergence of fresh tender foliage and grasses. Chihao also contains a number of reservoirs that deer utilize.

METHODS

Deer Translocation and Monitoring

Male Eld's deer are larger than females (males: 100 kg, females: 60 kg), and regrow bow-shaped antlers every year. Reproductive activity takes place from February to June and 80% of births occur between September and November (Song and Zeng 2003). They inhabit monsoon forest and grasslands, eat large varieties of plants, foraging on their shoots, leaves, also some species' flowers and fruits. We captured Eld's deer using a nylon net and fitted them with radio collars following approval from the Animal Welfare Committee of the Institute of Zoology, Chinese Academy of Sciences. At Datian we collared one female and two males (collars: MOD-335, 150–152 MHz, 140 g, Telonics Inc., Arizona, USA) and released them on site. The animal was considered active (feeding, watering or moving) when radio signals were 55 bmp, and inactive (lying, standing or ruminating) at 105 bmp. We monitored

these animals from October 2001 to September 2002 for a full 72 h around the 15th day of each month, and all three deer were monitored through the 12 months. In July 2005, we collared a further 19 animals at Datian, three males and two females wore the same collars as above, seven males and seven females wore a different model (SMRC-1, 151–152 MHz, 160 g, Lotek Wireless Inc., Newmarket, Canada). These animals were then translocated to Chihao where 112 individuals had been translocated in March 2005. These animals were considered active (feeding, watering or moving) when radio signals were 70 bmp, and inactive (lying, standing or ruminating) at 45 bmp. We had monitored these animals for 13 months from November 2005 for a full 72 h around the 15th day of each month. Telemetry signals were obtained using a portable receiver and three-element hand-held Yagi antenna (Telonics Inc., Arizona, USA). Data obtained from the two different models were highly correlated ($r = 0.796$, $P < 0.001$, $N = 24$). Therefore, circadian activity and feeding rhythms of the deer was pooled after standardization. Of the animals collared and translocated to Chihao one collar failed to function, three deer died, and four deer left the study area. Therefore, we obtained continuous data from seven animals (13 months) and incomplete data (2–6 months) from four animals.

Deer Activity

The activity of each animal (when within range) was monitored for 1 min every 10 min. The active state recorded over each minute was used to represent activity states for the whole 10 min. Hourly and half hourly activity rates were calculated using the formula:

$$AR = \frac{\sum_{i=1}^n Ti}{60n} \quad \text{and} \quad AR = \frac{\sum_{i=1}^n Ti}{30n}$$

where, AR is hourly activity rate (or half-hour rate), n is total number of deer whose signals are received completely over a given hour (or half hour), Ti is total active minutes of individual i in the hour (or half hour). AR in a given hour (or half hour) was the average of three values recorded over 3 days.

Activity of Local Villagers

We collected data on the activity patterns of local residents at Chihao using questionnaires written in Chinese (contact author for a copy). In December 2007 and January 2008, we delivered questionnaires to primary schools in the area (the majority of adults are illiterate) once a month and asked students to record the activity of their family for the following 3 days (this 3 day period coincided with the time we

were also monitoring deer). For simplicity we divided each “day” into 24 units and had students simply mark which units they and their family members were active. We delivered 260 questionnaires and retrieved 211 available questionnaires including data on 912 adults. To calculate AR of human activity for a given hour we divided the total number of people working in field by the total number recorded in that hour, then averaged the result across 3 days.

Statistical Analyses

Deer activity rates over 24 h at Datian and Chihao followed a normal distribution. To test differences in activity rhythms between Eld’s deer at Datian and Chihao, we standardized the 24-h AR (average = 0, deviation = 1) of deer in the two habitats to eliminate any differences in data resulting from the use of two types of radio-collars. We divided 24 h into two time periods: day (07:00–19:00) and night (19:00–07:00) and used a chi-square test to look for differences. Mean hourly activity rates were compared using a paired *t* test. We used ANOVA and *t* tests to examine changes in daily activity rhythms between months in Chihao based on half-hour activity rate data. All significant *P* values are less than 0.05. To show the relationship between deer and human activity we compared the inactivity rate of deer (IR) instead of the AR to human activity, expressed as $IR = 1 - AR$. We standardized data on ARs of human and IRs of deer, present those data in one figure (average = 0, deviation = 1) and used a Pearson correlation test on this data.

RESULTS

Differences in Activity of Source and Translocated Populations

Deer activity patterns within the reserve at Datian showed a distinct bimodal and “outstretched crepuscular” distribution (Fig. 2a). Two peaks in activity were observed between 05:00–12:00 and 15:00–22:00 with the greatest amount of activity taking place during the latter period ($P < 0.001$). Deer were mostly inactive from 23:00 to 03:00. Oppositely, translocated deer at Chihao were mostly nocturnal and active from 18:00 to 07:00, predominantly active around 19:00 and relatively inactive during the day (Fig. 2b).

When plotted together (Fig. 2c) it is clear that while the populations were both most active around 17:00, translocated deer have adopted a different pattern of behavior ($\chi^2 = 13.63$, $df = 1$, $P < 0.001$). Deer at Datian spent almost an equal amount of time active during the day and night (ratio day:night = 1:0.8) but translocated deer diverged from this standard (day:night = 1:2.3 at Chihao).

Fig. 2 Activity patterns of Eld’s deer inhabiting the reserve of Datian (a), Chihao (b), and a standardized comparison (c). DNR: Datian, without human disturbance. CHR: Chihao, with human disturbance

When the rates of activity were standardized and compared, we found that diurnal activity of the translocated deer was significantly lower (two-tailed paired *t* test, $t = -4.493$, $df = 11$, $P = 0.001$) and nocturnal activity significantly higher than deer in Datian ($t = 4.475$, $df = 11$, $P = 0.001$).

Change in Deer Activity Following Translocation

We obtained 13 consecutive monthly curves of 24-h activity rates at Chihao. The curves became smoother over time, implying that along with deer dwelt longer, their feeding schedule became regular (Fig. 3a). From our third observation month an obvious activity peak appeared at dusk; and from the 4th month activity rates of nighttime

Fig. 3 Variation in daily activity rhythm (a), activity rates (b), and daily foraging time (c) of Eld's deer at Chihao from November 2005 to November 2006. Sunrise and sunset are marked (a). D daytime, from sunrise to sunset; E evening, 2 h after sunset; N night, from 2 h after sunset to sunrise. “*” mark a significant increasing comparing with previous month (b, c)

began to dominate. In the first 4 months, the lowest activity rate in the morning come forth in 1–3 h after sunrise, while in latter 9 months, it appeared within an hour after sunrise. Activity in the final 4 months of observation was similar. By the final month a clear bimodal peak in activity emerged between 18:00–21:00 and 02:00–06:00 (Fig. 3a).

The pattern of deer activity at Chihao changed over the course of our study and trends towards greater nocturnality (Fig. 3b) and activity (Fig. 3c) were detected. In the first 3 month of our investigation, night time activity rates were low (0.19, 0.17, and 0.15) and night-to-day ratios were similar (1.73, 1.70, and 1.67; Fig. 3b). The daily sum of total foraging time was less than 3.9 h (Fig. 3c), however, in the 3rd month the mean monthly activity during the early evening (2 h after sunset) increased sharply ($P < 0.001$). Following this shift in behavior, deer activity continued to fluctuate for four subsequent months. For example, compared to February night activity increased in March (to 0.25, $P < 0.05$), evening rates declined, but the time spent foraging during the day increased (4.9 h, $P < 0.05$). After this period, the overall pattern stabilized with higher activity rate during the evening and night. We were able to compare activity levels of translocated deer over a full year. Using data in November 2005 and November 2006 we found that activity levels were generally higher 1 year later ($t = 3.759$, $df = 23$, $P < 0.05$) and that this was mainly due to an increase in nocturnal activity

(day: night = 1:3.2 (November 2006) vs. 1:1.73 (November 2005); $t = 7.516$, $df = 11$, $P < 0.05$).

Relationship Between Deer and Villager Activity

The pattern of deer activity was opposite to that of the villagers living in the area. Villagers were active from 07:00 to 18:00 and more active in the morning than afternoon. Daily activity commenced at 06:00 and activity rates peaked at 10:00 (Fig. 4). From 20:00 to 06:00 the villagers were inactive. The daily schedule of the villagers was regular and the rhythm we obtained was representative of a normal day in any month. We collected data on villager behavior over a 2 month period only but we are confident that intra-annual activity is stable given consistent day lengths and temperatures in this sub-tropical region and were able to compare human and deer activity over the course of our study. We found an increasingly dependent relationship between human activity and deer inactivity (see Fig. 5).

DISCUSSION

The daily activity patterns of animals are influenced by a number of factors including energy demand (maintenance, growth and reproduction), optimal feeding location and

Fig. 4 Activity patterns of local villagers (a) and deer in synchrony (b)

Fig. 5 The fit between plots of circadian inactivity rhythm in Eld's deer (dashed line) and activity rhythm of local villagers (solid line). The 4 periods are all dry and non-rut season. Pearson correlations are shown ($N = 24$)

timing, community dynamics, social activity, and environmental conditions (Aschoff 1963; Horn and Rubenstein 1984). For deer species, peak activity usually occurs over 4 h around sunrise and sunset (Georgii and Schröder 1983; Pépin et al. 2006). Here, we found that Eld's deer inhabiting a reserve unfrequented by people deviated from this trend and were active for two much longer periods of time (approximately 7 h each). The period of relative inactivity at noon that we observed is typical of tropical species that spend the hottest part of the day resting. The animals inside the reserve spent 60% of their foraging time feeding during daylight hours and this suggests that when possible, day time foraging is preferred.

Chihao, like Datian, contains no natural predators of Eld's deer, is similar in climate and geography, but contains resident people. The deer translocated to Chihao did not behave like the animals at Datian and became increasingly crepuscular and then nocturnal. After dark, translocated deer engaged in over 100 min of continuous

feeding and then fed consistently throughout the remainder of the night. These deer still foraged during the day (approximately 33% of the time spent foraging was done during day light hours) but their overall activity pattern was inversely related to that of the Li villagers.

We did not begin observing the deer until 3 months following the translocation, but our data still detected an adjustment phase. During the initial observation period, translocated deer still showed good activity from 10:00 to 12:00, akin to their reserve-dwelling counterparts. Despite a clear trend towards increased utilization of the night, initial stages of our observation of the translocated population showed this period to be slightly unstable. This could be characteristic of an adjustment or adaptation phase or could be explained by biology. For example, the period of instability coincided with rutting (March to May) and rutting behaviors may involve “head down” postures that result in higher recorded rates of activity. Towards the end of the dry season (June and July) fodder was reduced and

of less quality resulting in increased foraging and a need to forage during the day. These factors could explain the erratic changes in behavior we detected, and therefore, it is difficult to accurately determine the month deer began adapted to the human disturbance.

The response to human disturbance we found for Eld's deer is analogous to white-tail deer response to human hunting activity (Kilgo et al. 1998). Our results also concur with studies that show wildlife perceive human disturbance as a predation risk (Frid and Dill 2002; Beale and Monaghan 2004). However, our research shows that this “disturbance = predation risk” principle was not applied in every aspect. Female Eld's deer were found to use agricultural land frequently, but males tended to avoid these areas. This sexual difference just opposite to that found for male and female fallow deer *Dama dama* where females abandoned disturbed areas and males remained (Ciuti and Apollonio 2008). Further research is needed to tease out reasons for an effect of sex on the use of disturbed areas by Eld's deer.

MANAGEMENT IMPLICATIONS

As is the case for changes in resource dynamics and climate, human activity can influence wildlife; however, a human disturbance element is often absent from ecological field research. This is surprising because the impact of human disturbance can sometimes play a more important role in the persistence and reproductive success of wildlife than traditional measures of habitat quality such as tree height or slope. The need to consider human disturbance assumes even greater relevance in the management of highly endangered species. Human disturbance is very difficult to remove from shared habitat and human-wildlife conflict is inevitable, particularly in densely populous nations such as China. Here, it is clear that humans had an impact on the behavior of deer, but further data is needed on the longer-term consequences to reproductive success (Arroyo and Razin 2006), social behavior (de la Torre et al. 2000), and population growth (Bejder et al. 2006) as has been found for other species. Our findings that this ungulate species was able to establish a new activity pattern and minimize conflict with humans may excite many conservationists. However, our results do not indicate whether this level of impact is detrimental to translocated deer (Bejder et al. 2006) or if this disturbance resulted in changes in landscape use (Vistnes et al. 2008). The general shift towards nocturnal activity observed in this translocated population is markedly different from other deer species and highly abnormal. It is therefore likely that other factors such as reproductive behavior (e.g., rutting,

copulation, conflict), reproductive success, social interactions and group dynamics will be affected.

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