



Flock size and human disturbance affect vigilance of endangered red-crowned cranes (*Grus japonensis*)

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ABSTRACT

Vigilance is used to detect predators and monitor rivals. We studied red-crowned cranes (*Grus japonensis*) in Yancheng Biosphere Reserve, China, to examine changes in the allocation of time to vigilance as a function of flock size in areas with different levels of human disturbance. There was low level of human activity in the core area of the reserve whereas more human activity occurred in the buffer zone. Vigilance decreased linearly with flock size but to significantly different extent in the two areas, with a more pronounced decrease in the more disturbed area. In smaller crane flocks, vigilance was higher in the more disturbed area. Vigilance also varied in a non-linear fashion with flock size first decreasing and then increasing in larger flocks. Increase in vigilance in larger flocks was accompanied by an increase in fighting suggesting that vigilance in large flocks was aimed partly at monitoring rivals. The effect of human disturbance on vigilance suggests that less time is available for foraging in more disturbed areas. Nevertheless, moving to less disturbed areas may not be an option for the cranes given the increase in vigilance that would probably occur in areas with more cranes.

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1. Introduction

Animals spend much time feeding but they often stop foraging to scan their surroundings. Such scanning is referred to as vigilance, which may serve several functions. Vigilance may be used to monitor rivals and mates within the group but is most often viewed as an anti-predatory adaptation allowing individuals to detect and flee predators earlier in attack process (Krause and Ruxton, 2002; Caro, 2005). For animals living in groups, the allocation of time to vigilance decreases with group size given that more eyes and ears are available to detect predators (the many-eyes hypothesis: Pulliam, 1973) and that individuals in group dilute individual risk of attack (the risk-dilution hypothesis: Foster and Treherne, 1981). The time thus spared in groups could be used for other fitness-enhancing activities such as foraging (Caro, 2005). In addition to group size, several factors are known to influence the allocation of time to vigilance. In particular, vigilance is expected to increase in habitats with higher predation risk (McNamara and Houston, 1992; Ale and Brown, 2007).

While predation risk is often thought to reflect the activities of natural enemies such as predators, a broader view of predation risk now includes disturbance from human activities (Frid and Dill, 2002). Such disturbances range from hunting to the mere presence of tourists watching animals from a distance. Several studies have sought to determine whether animals are sensitive to disturbances from human activities and allocate more time to vigilance when the level of disturbance is higher. This is important in terms of conservation efforts because any increase in time spent vigilant would reduce the amount of resources obtained per unit time. Such resources are important to maintain individual fitness and ultimately to regulate population growth.

The results of these studies have been mixed thus far. Some studies have documented no changes in vigilance in more disturbed areas for some species (Caro, 1999), while others have documented an increase in vigilance but only at certain times of year (Duchesne et al., 2000), at given group sizes (Yasue, 2005), for one sex (Dyck and Baydack, 2004) or in particular years (Burger and Gochfeld, 1991). Nevertheless, some studies have found a general increase in vigilance in more disturbed environments (Manor and Saltz, 2003; Constantine et al., 2004; Randler, 2006; Jayakody et al., 2008; Benhaïem et al., 2008).

Manor and Saltz (2003) presented a framework to determine how vigilance ought to change with group size when human

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activities create different levels of disturbance. With higher disturbance, all group sizes may be affected equally and while vigilance still decreases with group size, the overall level of vigilance is higher at all group sizes. In contrast, disturbance may have a greater impact at larger group sizes given that vigilance in small groups is already at high levels in which case the slope of the decrease in vigilance with group size will be shallower but with the same intercept. It is also conceivable that animals habituate to increased disturbance so that vigilance remains the same regardless of disturbance level, which may explain some of the contradictory evidence reviewed earlier.

To address these issues, we examined changes in the allocation of time to vigilance as a function of group size in red-crowned cranes (*Grus japonensis*) wintering in areas with different levels of human disturbance. The red-crowned crane, which is listed on Convention on Migratory Species (CMS) Appendix 1 and CITES Appendix 1, winters along rivers and coastal marshes in north-eastern Asia (Ellis et al., 1996). A large proportion of the migratory population winters in the Yancheng Biosphere Reserve on the coast of Yellow Sea in eastern China. In order to integrate biodiversity conservation and economic development, the reserve was divided into three zones (Ma et al., 2009). This study was conducted in two areas of the reserve, the buffer zone and the core area (Fig. 1). In the buffer zone, there are about 400 year-round residents. They own farms and plant crops, generating activities such as plowing, sowing, and harvesting. Fishing is also common in the area. Numerous visitors access the area at any time. The main habitats in the buffer zone are farmland, such as rice and wheat fields,

and reed beds. In contrast, there are no residents in the core area, and the number of visitors is restricted. Farming or fishing is only allowed during particular seasons thus reducing the level of disturbance caused by human activities. During winter, all the above activities are even more restricted because red-crowned cranes are present. Main habitats in the core area are reed beds and grasslands. We examined how vigilance changes with group size in this species and determined whether the group size effect on vigilance was influenced by human disturbance level.

2. Methods

2.1. Study area

This study was conducted in the Yancheng Biosphere Reserve (32°34′–34°28′ N, 119°48′–120°56′ E) in Jiangsu Province, China. The reserve was founded in 1983 for conservation of red-crowned cranes and other waterbirds and was internationally recognized as a biosphere reserve by UNESCO in 1992. The coastline of the reserve is about 580 km long and the reserve area is approximately 2400 km². Mean temperature in winter is 4 °C and varies from –8 °C to 16 °C. Snow covers the ground occasionally in winter. The dominant plants are *Phragmites communis*, *Suaeda salsa*, and *Imperata cylindrica*.

Red-crowned cranes migrate from north-eastern China to Yancheng in late October and overwinter in the reserve until early March (Ma et al., 2000). The wintering crane population numbered

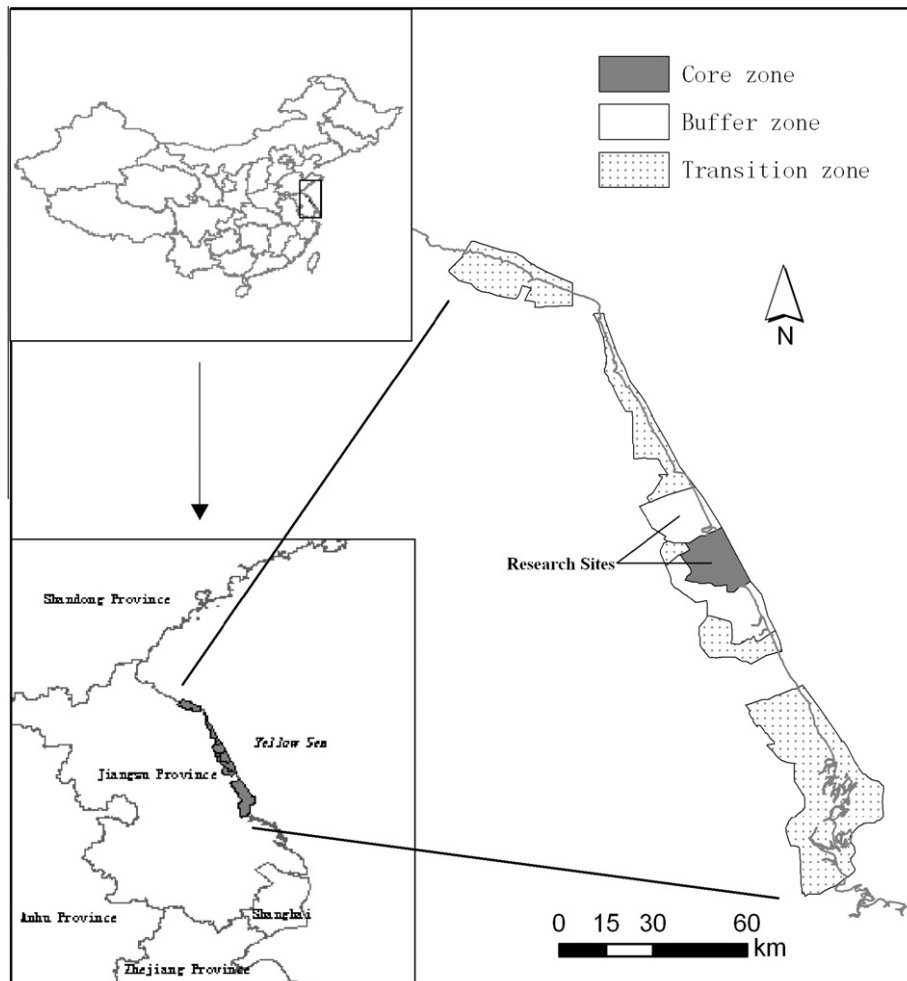


Fig. 1. Location and functional zones of Yancheng Biosphere Reserve.

more than 1000 cranes in 2001 (Ma et al., 2009), but fewer than 500 cranes remained in the 2010 winter survey.

2.2. Behavioural observations

The basic social unit of wintering cranes is the family and large groups consist of several families joining together (Ma et al., 2000). A family consists of two adult cranes with or without juvenile cranes. A family is easily recognizable because family members are close to each other and engaged in the same activities. In winter, juvenile cranes have almost reached adult size but are still easily identified through plumage traits. Behavioural observations were conducted from late December 2008 to early March 2009. Cranes were located during regular surveys in the reserve. The same route was not used more than once on the same day to avoid sampling the same flocks. Observations were not carried out on days with rain, snow or strong winds to lessen bias caused by extreme weather.

Once cranes were located, we carried out focal samples using binoculars (8 × 56) or a telescope (20~60 × 63). First, we counted the total number of birds present in each flock, including adults and juveniles. A flock of cranes consisted of two or more cranes occurring within at most 30 m from one another. Most individuals occurred within 10 m of one another but still maintained effective contact up to about 30 m. In flocks, we selected focal individuals randomly from the adult cranes present in the flock. In each flock, we sampled at most two adults, each belonging to a different family. We restricted observations to adult birds because juveniles in crane species tend to be less vigilant, e.g., *Grus canadensis* (Tacha, 1988), *Grus grus* (Alonso and Alonso, 1993; Aviles and Bednekoff, 2007). We did not distinguish between males and females because they have similar body size and plumage color.

Behavioural events were dictated onto a MP3 recorder. Observations lasted 30 min unless we lost sight of the focal individual or if flock size changed. Actual observation times ranged from 3 min to 30 min, with an average of 20.3 min (SE = 0.6). We distinguished six behavioural states: feeding, vigilance, preening, locomotion, fighting, and others. Feeding refers to a crane excavating foods or swallowing. Vigilance (or scanning) refers to a crane stretching the head upwards while standing erect or scanning around (Tacha, 1988). Preening includes combing feathers, shaking head, or stretching legs. Locomotion includes walking, running, leaping and flying. Fighting refers to chasing, pecking, and slapping between individuals. Other behavioural patterns include resting and calling.

2.3. Data analysis

From the timed sequences of events, percentage time spent vigilant was calculated as the sum of all scanning bouts divided by total observation time. Scan rate represented the number of scans per min of observation. Mean scan duration was obtained by dividing total time spent vigilant by the number of scans recorded during the focal observation. To normalize distributions, we used the arcsine square-root transformation for time spent vigilant and the logarithmic base 10 transformation for flock size and scan duration.

For the analysis of time spent vigilant and scan duration, we used a mixed linear model including area (core vs. buffer), centered flock size and the square of centered flock size (for non-linear trends) as fixed factors, and flock id as a random factor. Centered data, which is obtained by subtracting the mean from each flock size, reduced the correlation between the two flock size variables. We included the interaction between area and the two flock size attributes. Time of day was included as a categorical factor in an earlier analysis, but little effect was found and so this factor was

not considered any further. For the analysis of frequency data, which were highly skewed to the right, we use a mixed negative binomial regression model, with the same fixed and random factors, and the natural logarithm of focal observation duration as an offset to control for different lengths of observation. Final models were obtained by backward deletions of non-significant terms. Statistical analyses were carried out using SAS v. 9.1 (Cary, N.C.). The level of statistical significance was set at $p < 0.05$ throughout. Data are shown as mean (SE).

3. Results

We obtained 209 focal observations representing a total of 4233 min of observations. A total of 115 focal observations (55%) originated from the buffer zone while 104 samples (45%) were obtained from the core area. Flock size was 6.47 (0.70) ranging from 1 to 40 in the buffer zone ($N = 107$) and 9.52(1.06) ranging from 1 to 46 in the core area ($N = 82$). In reed beds, the habitat type common to the two areas, mean flock size did not vary significantly on the logarithmic scale between the two areas ($F_{1,66} = 0.19$, $p = 0.67$).

Mean percentage time spent vigilant was 23.6% (1.4%) and ranged from 0.2% to 98.9%. The mixed linear model indicated a

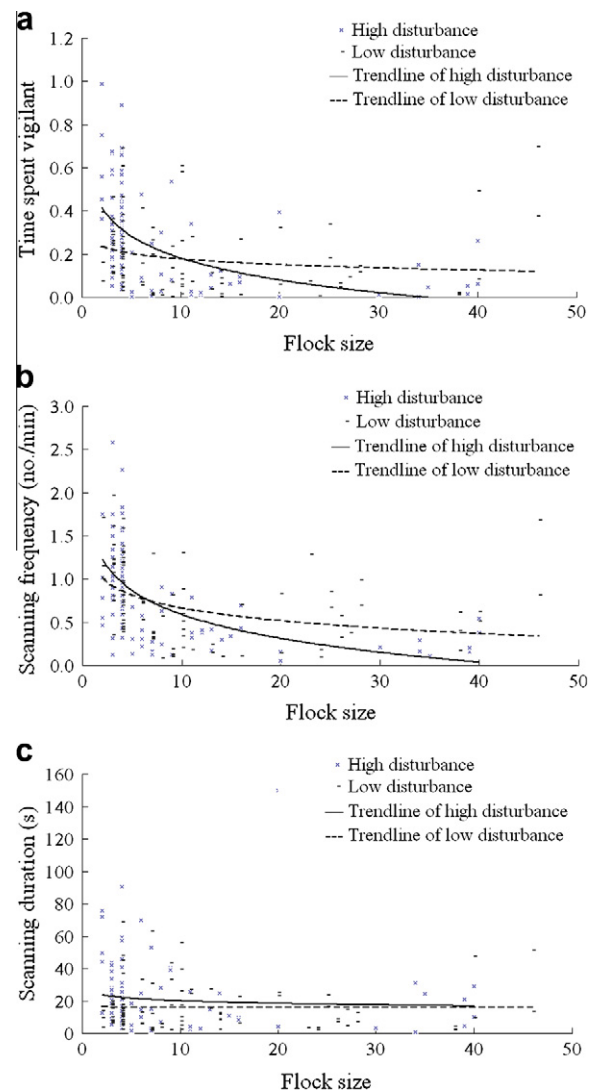


Fig. 2. Proportion time spent vigilant (a), scan frequency (b), and scan duration (c) as a function of flock size and level of human disturbance in red-crowned cranes wintering in Yancheng Biosphere Reserve, China.

non-significant effect of area overall ($F_{1,27} = 3.4$, $p = 0.08$) (Fig. 2). Vigilance decreased linearly with flock size ($F_{1,27} = 42.5$, $p < 0.0001$) but to significantly different extent in the two areas as revealed by a significant interaction between area and flock size ($F_{1,27} = 8.9$, $p = 0.006$). The linear decrease with flock size was more pronounced in the buffer zone (β (SE) = -0.51 (0.08), $p < 0.0001$) than in the core area (β (SE) = -0.23 (0.07), $p = 0.004$). Vigilance also varied in a non-linear fashion with flock size first decreasing and then increasing at larger flock sizes (Fig. 2; $F_{1,27} = 7.3$, $p = 0.01$). To compare vigilance in the two areas, we calculated contrasts using estimates of the model at specific flock sizes. Mean estimated time spent vigilant was significantly larger in the buffer zone than in the core area at flock sizes 1 ($p = 0.002$), 2 ($p = 0.001$) and 4 ($p = 0.005$) but not at flock sizes 10, 20 or 40 ($p > 0.05$). For cranes in flocks of one or two, which were the most commonly occurring flock sizes, the increase in time spent vigilant in the buffer zone was of the order of 10 percentage points (a relative increase of about of 40%).

Mean scan rate was 0.79 scans/min(0.03) and ranged from 0.053 to 2.58 scans/min. The mixed negative binomial regression model indicated a non-significant effect of area overall ($\chi^2 = 0.1$, $p = 0.74$). The number of scans per unit time decreased linearly with flock size ($\chi^2 = 41.4$, $p < 0.0001$) but to significantly different extent in the two areas as revealed by a significant interaction between area and flock size ($\chi^2 = 7.8$, $p = 0.005$). Number of scans per unit time decreased by a factor of about 5 (0.04) per unit flock size in the buffer zone and by a factor of about 2 (0.09) in the core area.

Mean scan duration was 19.1 s (1.3) and ranged from 0.7 to 149.9 s. The mixed linear model indicated a non-significant effect of area overall ($F_{1,27} = 2.4$, $p = 0.13$) and a significant linear decrease with flock size ($F_{1,27} = 6.9$, $p = 0.01$). The decrease in mean scan duration was similar in the two areas as revealed by the non-significant interaction between area and flock size.

Of all other behavioural patterns, fighting was the most prominent. The mixed negative binomial regression model indicated a non-significant effect of area overall ($\chi^2 = 2.0$, $p = 0.16$). The number of fights increased linearly by a factor of 9.1 with each unit flock size ($\chi^2 = 7.7$, $p = 0.005$). Time spent feeding (including locomotion, which probably serves to move between food patches) and time spent vigilant represented on average 96% of total observation time leaving little time for resting and preening.

4. Discussion

Flock size and level of disturbance caused by human activities influenced the allocation of time to vigilance in red-crowned cranes wintering in the Yancheng Biosphere Reserve, China. While the level of disturbance was not quantified, restricted access to the core area in comparison to the buffer zone must have reduced disturbance to a large extent. In addition, given their large sizes (up to 10 kg in body mass), cranes face no other threats in the reserve.

Disturbance level influenced time spent vigilant and scan frequency. Indeed, time spent vigilant and scan frequency decreased with flock size to a greater extent in the area with higher disturbance and vigilance adjustments to disturbance occurred mostly in the smaller and more common flock sizes. Higher vigilance levels have also been reported in some other species in response to disturbance caused by human activities (Manor and Saltz, 2003; Constantine et al., 2004; Jayakody et al., 2008). In the sandhill crane (*G. canadensis*), vigilance behaviour increased when birds were disturbed by human activities (Tacha, 1988). In small flock sizes, the relative increase in vigilance in the high versus the low disturbance area was about 40%. While the impact on food intake rate remains to be established, such an increase in vigilance prob-

ably entails a foraging cost given that vigilance and feeding are the two main activities of cranes in the winter. To evaluate these foraging costs further, it will also be necessary to monitor habitat use in marked cranes to determine how long individuals remain in disturbed areas and experience these costs.

Manor and Saltz, (2003) observed that adjustments in vigilance to disturbance by human activities occurred mostly in larger groups given that vigilance in small groups was already quite high in the mountain gazelle (*Gazella gazella*). However, in cranes, vigilance levels in smaller flocks, which hover around 20%, are rather low in the low disturbance area, thus providing ample room for increases in the high disturbance area. Low vigilance levels in small flocks (<20%) have also been reported in another crane species (Tacha, 1988). These low levels of vigilance may be related to the large sizes of cranes, which probably face a very limited array of predators. However, among a large number of avian species, body mass was not a significant predictor of vigilance in small flocks (Beauchamp, 2010) suggesting that other factors may also be involved.

All three measures of vigilance, namely time spent vigilant, scan duration and scan frequency, declined with group size, thus corroborating findings from a large number of studies in birds and mammals (Elgar, 1989; Caro, 2005; Beauchamp, 2008). The more unique aspect of vigilance in cranes is the increase in vigilance in the largest flocks. A similar pattern was also documented in common cranes (*G. grus*) (Yang et al., 2006). This u-shaped pattern has been predicted when vigilance is aimed not only at predators but also at other companions in the group (Beauchamp, 2001; Blumstein et al., 2001). While vigilance against predators is predicted to decrease with group size, vigilance aimed at rivals is expected to increase with the number of contacts with rivals, and thus group size, producing a u-shaped pattern. In cranes, the number of aggressive acts increased with group size indicating that visual monitoring of neighbours probably becomes an important component of vigilance in larger groups. Number of aggressive acts also increased with flock size in sandhill cranes (Tacha, 1988).

Generally, monitoring neighbours may be used to detect food stealers (Robinette and Ha, 2001; Coolen and Giraldeau, 2003) or potentially aggressive companions (Treves, 1999; Hirsch, 2002). Food stealing appears unlikely in cranes, which forage on rather smallish food items (Ellis et al., 1996). It is perhaps the case that cranes defend small feeding territories and that time must be taken to monitor potentially intrusive neighbours (Tacha, 1988).

Perhaps the most intriguing aspect of this u-shaped vigilance pattern is that habitat use must be limited by the number of cranes already foraging in the area because an increase in the number of birds must be a considerable cost in terms of allocation of time to vigilance given that feeding and vigilance are the two main activities in wintering cranes. Escaping human disturbance in one area by joining other birds in a less disturbed area may not be an option when the addition of more birds causes a large loss of foraging time. Interestingly, the mean group size of cranes did not differ in reed beds, the one habitat which was used in both buffer and core areas. In other species, smaller group sizes have been reported in more disturbed areas (Manor and Saltz, 2003) but this is not always the case (Berger et al., 1983). It may not always be possible for animals to escape human disturbance by foraging elsewhere (Gill et al., 2001) as seems to be the case in cranes. Future work should establish the fitness costs associated with human disturbance in cranes and to assess strategies that conservationists could use to reduce these costs.

In the light of these results, we make the following recommendations for conservation efforts. First, we suggest a decrease or more stringent limits on human activities in the buffer zone. Human disturbance affects the time budget of cranes, and decreasing human activities should lead to an increase in feeding time for the

cranes. Second, artificial wetlands should be protected in the buffer zone. Previous studies have shown that artificial wetlands, including farmland (rice field) and reed beds, are very important feeding habitats for the cranes (Ma et al., 1998, 2009), and in recent years much of the crane population inhabits artificial wetlands (Lv and Chen, 2006; Lv, 2007). Conserving these artificial wetlands provide a better feeding habitat for the cranes. Finally, farmland should be kept unplowed. A study in Korea has indicated that unplowed farmland provide more foods for red-crowned and white-naped cranes (*Grus vipio*) (Lee et al., 2007), so farmland, especially rice fields, should be kept unplowed until the red-crowned cranes leave in early March. The provision of additional feeding sites should allow cranes to distribute themselves among more habitats thus leading to a general decrease in bird density and a reduction in interference levels while feeding.

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