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Source: Waterbirds, 39(1):108-113.
Published By: The Waterbird Society
DOI: http://dx.doi.org/10.1675/063.039.0114
URL: http://www.bioone.org/doi/full/10.1675/063.039.0114

Group Size Effects on Vigilance of Wintering Black-necked Cranes (*Grus nigricollis*) in Tibet, China

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Abstract.—Vigilance is a behavior in birds that is used to detect predators and monitor rivals, and it can be affected by several environmental and social factors, including group size. Here, Black-necked Cranes (*Grus nigricollis*) were observed in winter in the Yarlung Zangbo Nature Reserve, Tibet, China, to examine the effect of group size on vigilance behavior at both the individual and group levels. At the individual level, individual Black-necked Cranes in large social groups spent less time in vigilant behavior than when in small family groups. At the social group level, the proportion of vigilant individuals decreased, while the proportion of intervals that at least one individual was vigilant increased, with increasing group size. There was a significant group size effect on vigilance behavior in wintering Black-necked Cranes at both of these levels. *Received 30 July 2015, accepted 6 November 2015.*

Key words.—Black-necked Crane, flock size, group size, *Grus nigricollis*, Qinghai-Tibet Plateau, vigilant behavior.

Waterbirds 39(1): 108-113, 2016

Animals often stop feeding to raise their heads and scan their surroundings. Such scanning is referred to as vigilance, which may be used to monitor conspecific rivals or mates, but is most often viewed as a behavior for the detection for potential predators (Beauchamp 2015). For animals living in groups, due to the effects of 'more eyes and ears' and 'safety in numbers', the allocation of time to vigilance is usually found to decrease with group size (Pullman 1973; Elgar 1989).

Group size effects can be found at both the individual and group levels in both mammalian and avian species. At the individual level, individuals have been found to behave less vigilantly in larger groups, spending less time in vigilant behavior, such as scanning less frequently (Li *et al.* 2009; Wang *et al.* 2011). At the group level, the proportion of vigilant individuals has been found to decrease with increasing group size; however, group vigilance efficiency (usually expressed as proportion of time intervals at least one group member is vigilant) has been found to increase (Li and Jiang 2008; Xu *et al.* 2013). Many studies on the effects of group size have been conducted at the individual or group level, but few have studied both.

Black-necked Cranes (*Grus nigricollis*) are globally vulnerable (International Union for Conservation of Nature 2015) and are the only plateau breeding crane species in the world (Li and Li 2005). Recent studies on vigilance behavior of this species have shown a significant group size effect at the individual level in the wintering population in the Yunnan Province of China (Kuang *et al.* 2014) and at the group level in the breeding population in the Xinjiang Autonomous Region of China (Xu *et al.* 2013). Here, we observed a wintering population in Tibet to test whether group size has an effect on vigilance at both individual and group levels.

Methods

Study Area

This study was conducted in Yarlung Zangbo Nature Reserve (Reserve) (28° 40' to 30° 17' N, 87° 34' to 91° 54' E) on Qinghai-Tibet Plateau, China. The Reserve was established in 2002 for protecting the largest wintering population of Black-necked Cranes as well as the alpine wetland ecosystem on which they depend. The Reserve ranges from 3,500 m to 4,500 m in elevation and encompasses about 6,140 km^2. The Reserve is dominated by a semi-arid monsoon climate, but experiences occasional snowfall in winter. The mean temperature in January is -4.7 °C, but ranges from -14.0 °C to 8.0 °C. The Reserve area is primarily alpine meadows dominated by *Sophora moorcroftiana*, *Ceratostigmn minus*, *Aristida triseta*, *Orinus thoroldii*, *Pennisetum centrasiaticum*, and *Stipa purpurea*. Black-necked Cranes mainly use three habitat types in the Reserve: waterside, meadows, and

farmland (Bishop *et al.* 1998; Bishop and Li 2002; Song *et al.* 2014). Our observations were conducted mainly in farmland, where farm activities like grazing, plowing or irrigation were common.

Study Species

Black-necked Cranes (hereafter, cranes) have a global population of about 11,000 individuals (Farrington and Zhang 2013; International Union for Conservation of Nature 2015). Their primary breeding area is the Qinghai-Tibet Plateau and its adjacent regions, while the wintering areas are mainly in south-central Tibet, the Yunnan-Guizhou Plateau in southwest China, India and Bhutan (Li and Li 2005; Qian *et al.* 2009; Farrington and Zhang 2013; Khan *et al.* 2014). Black-necked Cranes migrate from breeding areas to the central part of the Yarlung Zangbo Nature Reserve in early December and overwinter in the Reserve until early April (Bishop *et al.* 1998; Cangjue *et al.* 2007). Wintering cranes have two social units: family groups and social groups. Family groups consist of two adult cranes, with or without one or two juveniles, while social groups are made up of several juveniles or combined family groups (Li and Li 2005).

Behavioral Observations

Cranes were located during regular route surveys (Pengbo River route, Kazi route, Hutougou route) and locations were recorded with a GPS. The route was not repeated on the same day to avoid duplicate sampling. Observations were not made on days with snow or strong winds to lessen any bias caused by the effect of extreme weather. "Vigilance" behavior was defined as a crane stretching its head upward while looking around.

To measure vigilance at the individual level, we recorded how much time individual focal cranes spent in vigilant behavior from December 2012 to March 2013 using a video camera. For each observation, we recorded date, time, location, habitat type (mostly farmland), age (adult or juvenile) and group type (family group, social group). We also assigned each group an independent identification number. In winter, juvenile cranes had almost reached adult size but were still easily identified through plumage characteristics. We did not consider group (family or social) size as an independent variable since the social groups observed in winter were usually rather small (generally only two family groups). The average group size was 3.2 (Range = 2-4) individuals for family groups and 6.2 (Range = 4-8) for social groups. Depending on group type, we usually selected one to four individuals from each group. The average recording duration was 3.6 ± 0.2 min (Range = 1-9 min).

At the group level, we used the scan sampling method (Li and Jiang 2008; Xu *et al.* 2013) to collect field data from December 2006 to March 2007. We scanned each member of the focal group at an interval of 1 min, and tried to observe the group as long as possible until group size changed or the group flew away. The average group size was 19.1 (Range = 2-58) individuals, and the average scan sampling duration was 217 ± 41 min (Range = 32-607 min).

Data Analysis

Time spent by each focal individual in vigilant behavior was summed across observations and expressed as a proportion of total observation time. Vigilant rates were defined as the number of vigilant behaviors observed per min. We used arcsine square-root transformation to normalize the data of time spent in vigilant behavior. Then we used a mixed linear model to quantify the effects of group type and age on time spent in vigilant behavior and vigilant rate. We included group identification number as a random factor to control for potential effects of pseudo-replication. There was no significant difference in all second-order interactions ($P > 0.05$), so in the final model, we only included the three main factors.

For the group samples from 2006, we calculated two variables: the proportion of individuals observed in vigilant behavior and the proportion of intervals that at least one individual was vigilant. We used a linear regression model to express the relationship between ln transferred group size and these two collective vigilance variables. All statistical analyses were carried out with SPSS (SPSS, Inc. 2010). The level of statistical significance was set at $P = 0.05$, and data were reported as mean ± SE.

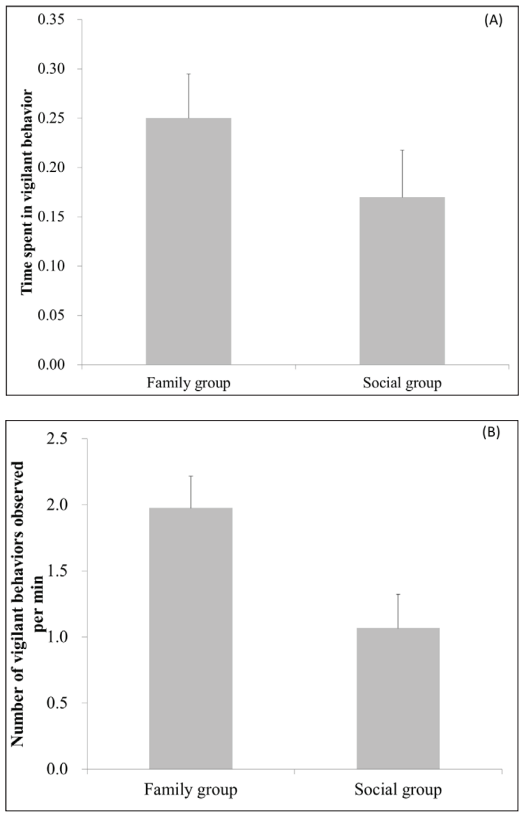


Figure 1. Vigilance difference of wintering Black-necked Cranes between family group and social group in Tibet: (A) time spent in vigilant behavior and (B) vigilant rate (number of vigilant behaviors observed per min).

RESULTS

A total of 398 min with 109 focal observations were collected, comprising 38 observations for family groups vs. 71 for social groups, and 95 for adults vs. 14 for juveniles. During the wintering period, cranes spent about 22% of their diurnal time in vigilant behavior. Group type ($F_{1, 37} = 5.495$, $P = 0.03$) and age ($F_{1, 89} = 13.82$, $P < 0.01$) greatly influenced time spent in vigilant behavior (Fig. 1A). Cranes spent more time in vigilant behavior when in family groups (25 ± 5%) than in social groups (17 ± 5%). Adult cranes (29 ± 3%) spent more time in vigilant behavior than juveniles (13 ± 5%). Similarly, both group type ($F_{1, 28} = 6.814$, $P = 0.01$) and age ($F_{1, 85} = 14.626$, $P < 0.01$) influenced vigilant rate significantly (Fig. 1B). Cranes scanned 1.98 ± 0.24 times per min when in family groups, nearly twice the time spent by each individual when in the larger social groups (1.07 ± 0.26 times per min). Adult cranes (2.08 ± 0.16 times per min) scanned more frequently than juveniles (0.97 ± 0.28 times per min).

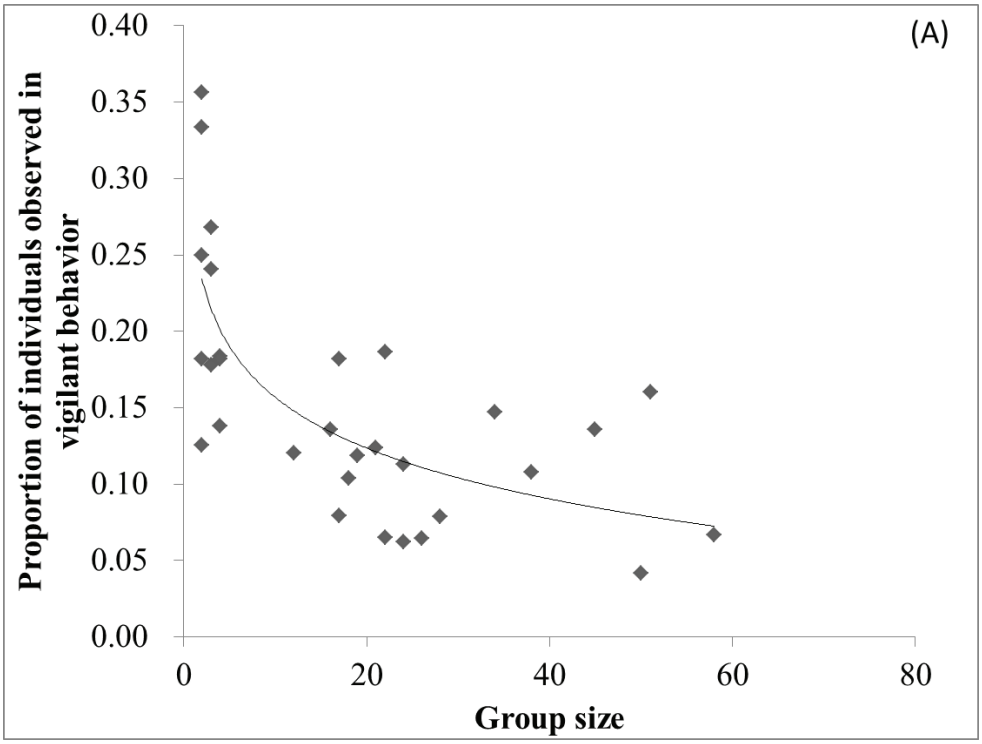
At the group level, we collected 30 scan samples. We found a significant effect of group size on both the proportion of individuals vigilant (0.151 ± 0.014; $F_{1, 28} = 31.418$, $P < 0.01$, $R^2 = 0.529$; Fig. 2A) and the proportion of intervals at least one individual was vigilant (0.717 ± 0.042; $F_{1, 28} = 88.082$, $P < 0.01$, $R^2 = 0.759$; Fig. 2B). With increasing group size, the proportion of individuals vigilant decreased while the proportion of intervals that at least one individual was vigilant increased.

DISCUSSION

The group size effect, namely the negative relationship between group size and vigilance, has been reported in many kinds of mammals and birds (Elgar 1989; Beauchamp 2003, 2008). We found a significant group size effect in the Tibetan wintering population of Black-necked Cranes, which has also been observed in other Black-necked Crane populations (Xu *et al.* 2013; Kuang *et al.* 2014) and other crane species including Sandhill Cranes (*G. canadensis*) (Tacha 1988), Common Cranes (*G. grus*) (Yang *et al.* 2006; Aviles and Bednekoff 2007), Red-crowned Cranes (*G. japonensis*) (Ge *et al.* 2011; Wang *et al.* 2011), Hooded Cranes (*G. monacha*) (Li *et al.* 2015) and Siberian Cranes (*G. leucogeranus*) (Yuan *et al.* 2014). Black-necked Cranes, as well as other cranes, are large birds with a body weight around 5 kg, and very few predators can prey on adult individuals except humans. However, natural threats to their eggs and chicks, such as feral dogs (*Canis familiari*), foxes (*Vulpes ferrilata*), and mountain raptors (including *Buteo hemilasius* and *Aquila chrysaetos*), are common in Tibet (Li and Li 2005). Thus, living in larger groups could provide additional detection and dilution benefits to each individual of the group (Beauchamp 2003), especially the chicks and juveniles that are less vigilant than adults.

Scramble competition for food could also lead to a low level of vigilance (Lima *et al.* 1999; Beauchamp and Ruxton 2003; Randler 2005), and this might be another source of the group size effect in this population. Black-necked Cranes spent most of their diurnal time feeding in barley (*Hordeum vulgare*) and spring wheat (*Triticum* spp.) stubble, and the waste cereal grains, especially wheat, comprised the majority of the cranes' diet (Bishop *et al.* 1998; Bishop and Li 2002). Due to post-harvest farming activities, including plowing and livestock grazing, the feeding resources of waste cereal grains are usually limited (Bishop and Li 2002). Thus, when feeding in larger groups, Black-necked Cranes are probably facing direct food competition with conspecific individuals. In most cases, feeding and vigilance are mutually exclusive, and when cranes spend more time feeding, vigilance would decrease accordingly (Beauchamp and Ruxton 2003).

The group size effect is significant at both the individual and group levels in the Yarlung Zangbo Nature Reserve population, which is consistent with two similar studies in other populations (Xu *et al.* 2013; Kuang *et al.* 2014). At the individual level, Kuang *et al.* (2014) reported a negative relationship between group size and three vigilance parameters (time spent vigilant, vigilant rate and



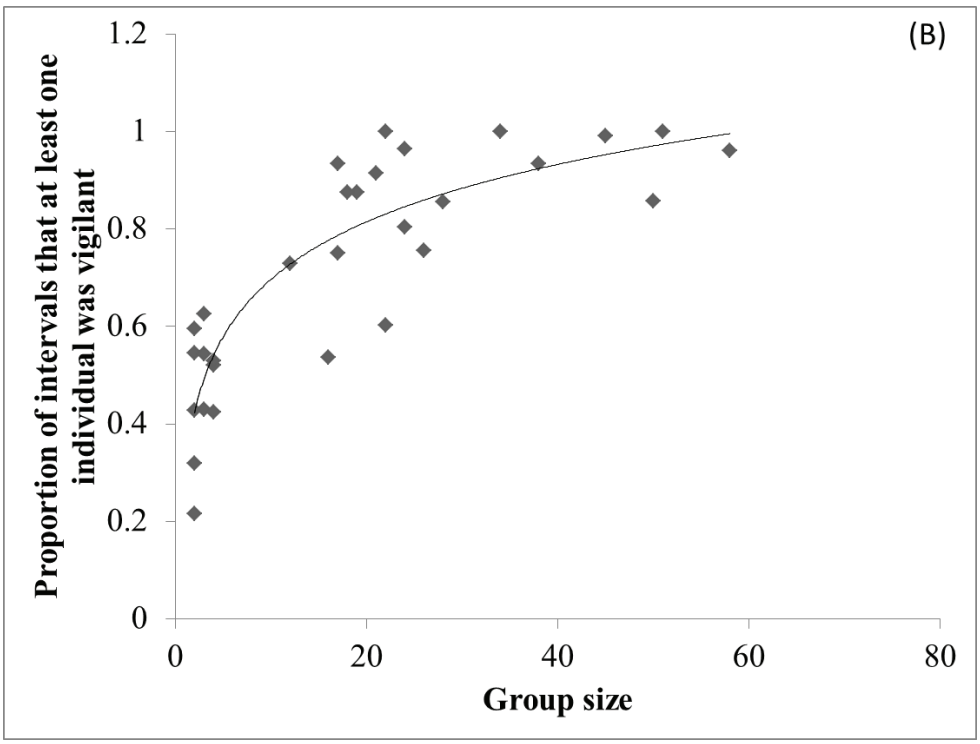


Figure 2. Group size effects on collective vigilance of wintering Black-necked Cranes in Tibet: (A) proportion of individuals observed in vigilant behavior and (B) proportion of intervals that at least one individual was vigilant.

vigilant duration) in a wintering population on the Yunnan-Guizhou Plateau. However, the time adult cranes spent vigilant in their study was only about 15%, much less than in our current study, which accounted for nearly 30%. We attribute this to a difference in human disturbance levels, which has been considered a determinant factor influencing vigilance (Ge *et al.* 2011; Wang *et al.* 2011; Li *et al.* 2013, 2015). Kuang *et al.* (2013) conducted their study in a natural habitat where human disturbance was extremely low, whereas our study was conducted on farmlands where human disturbances, especially agricultural activities, were common.

At the group level, Xu *et al.* (2013) reported a significant group size effect, namely that with increasing group size, the proportion of individuals vigilant decreased and the proportion of intervals that at least one individual was vigilant increased in a breeding population in Xinjiang. However, the average proportion of individuals vigilant (0.30-0.40) was much higher than in our current study (0.15), whereas the average proportion of intervals that at least one individual was vigilant (0.33-0.47) was much lower in Xu *et al.* (2013) than in our current study (0.72). However, in this previous study (Xu *et al.* 2013), the group size ranged from 2 to 13, with an average of 5.3, which was much lower than documented here.

We found a significant effect of group size on vigilance of Black-necked Cranes at both the individual and group levels, and both predation and scramble competition hypotheses can explain this effect. More studies on vigilance of Black-necked Cranes are warranted. Future studies should assess if group size effects exist during the breeding season, if group size effects interact with predation risk or human disturbance, and if individuals synchronize or coordinate their vigilance with group members.

Acknowledgments

We received financial support from the Nanjing University Outstanding Young Teachers Scholarship for Overseas Study (2012), Ministry of Science and Technology of China (2009; No. 647), NSFC (No. 31000174, No. 31360141) and National Nature Reserve Remote Sensing Investigation and Assessment during 2000-2010 (No. STSN-7). We thank Professor Lu Xin and Dr. Li Fengshan for their kind suggestions about this study. We also thank Jiabu for his field help.

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