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Vigilance behavior of common crane *Grus grus* in flocks during spring, summer, and autumn

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Abstract: Vigilance is a key behavioral element aimed to detect potential predators or rivals. In this study, we examined the vigilance levels of common cranes that exhibit flocking behavior during the spring, summer, and autumn seasons. We considered the influence of both social (age, presence of offspring, and flock size) and environmental factors (habitat type, time of day, and study period). Parents allocated more time for vigilance than nonparents and juveniles. The alertness of nonparents was lower in flocks of size 51–150 individuals compared to flocks under 50 and over 150 birds. Juveniles increased their vigilance at the end of the premigration period. Habitat type and time of day did not affect crane vigilance levels.

Key words: Scanning behavior, time budget, alertness, daily activity

1. **Introduction**

One of the main components of animal behavior is vigilance aimed at detecting potential predators or conspecifics in a group (Treves, 2000; Beauchamp, 2015). Alertness can occur during spare time when an individual monitors his/her surroundings or interrupts fitness-related activities such as searching for food or resting (Beauchamp, 2015).

Flock animals can reduce the time needed to detect danger from a predator with increasing group size by receiving alarm signals from conspecifics (Pulliam, 1973). However, the number of often aggressive contacts between individuals enhances as the group size rises which can also result in a growth in the duration and frequency of alertness (Beauchamp, 2001). The relationship between flock size and duration of vigilance was shown in some articles to be either negative (Aviles and Bednekoff, 2007; Xu et al., 2013; Li et al., 2015) or positive (Li et al, 2016) and a nonlinear U-shaped pattern (Yang et al., 2006; Wang et al., 2011). Moreover, in some cases, no relationship was confirmed (Sparling and Krapu, 1994) which indicates the presence of other factors.

Age serves as a social factor that affects behavior. Age differences are especially pronounced in species exhibiting prolonged parental care, where juveniles are less vigilant than adults (Tacha et al., 1987; Aviles, 2003; Wang et al., 2009; Zhou et al., 2010; Li et al., 2015). Low juvenile alertness is compensated by increased parental vigilance (Tacha, 1988; Alonso and Alonso, 1993; Beauchamp, 2015).

Vegetation cover serves as additional protection on the one hand (Aviles and Bednekoff, 2007) or as a visual barrier to detect potential predators on the other (Li et al., 2017) ultimately affecting the time spent in vigilance. Furthermore, there are differences in the level of alertness in different environments (Sparling and Krapu, 1994), which may be caused by a forced habitat change to a less familiar one (Jia et al., 2013). Further, the time of day can indirectly influence the alertness and behavior of animals. Species resting at night are hungry in the early morning and therefore their activity is mainly aimed at finding food during this period (Alonso and Alonso, 1992; Pravosudov and Grubb, 1998; Zhang et al., 2020). During the day, energy reserves are replenished. The decrease in hunger can lead to a change in their behavior and an increase in alternative activities such as vigilance (Pravosudov and Grubb, 1998). The daily activity of predators may also influence the behavior of prey during the day (Beauchamp, 2015), which can result in more frequent and longer periods of alertness at specific times of the day. Animal behavior changes during the season depending on their annual cycle (Alonso and Alonso, 1993; Aviles and Bednekoff, 2007; Zheng et al., 2015). For example, it may be due to increased time spent on other activities such as feeding before migration resulting in less time spent on vigilance (Metcalfe and Furness, 1984).

In this article, we examine the time allocated to vigilance by the common crane (*Grus grus*) in flocks

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during spring, summer, and autumn in the central part of Russia. Common cranes form flocks while their quantitative and qualitative composition is not constant in different seasons of the annual cycle. In the breeding season, families are territorial while subadults (up to 3–4 years old) lead a flocking lifestyle in small groups. In July–August single adults who lost a partner or chicks or clutch or did not breed for whatever reasons join the flocks of subadults while increasing flock size by the end of July. From August –early September flocks congregate at the premigration staging areas. Families with chicks join at this period. At the end of September, these flocks may contain birds that started migrating from more northern latitudes (Meine and Archibald, 1996; Markin, 2013). This species exhibits prolonged parental care, and the family unit breaks up only in the late winter or the onset of spring migration (Meine and Archibald, 1996; Alonso et al., 2004). The time budget of common cranes is known primarily at wintering grounds in Spain (Alonso and Alonso, 1992; Alonso et al., 2004; Aviles and Bednekoff, 2007), Pakistan (Abrar et al., 2017), and China (Yang et al., 2006). Studies assessing offspring survival and time budget differences between juveniles during spring, summer, and autumn do exist, however, they do not consider other factors such as habitat type, time of day, study period, and flock size (Nowald, 2001).

The goal of this study is to investigate the level of vigilance of common crane flocks and to identify the factors that influence it to improve our understanding of their behavior.

2. Methods

2.1. Study area

The study was conducted in the center part of Russia, mainly in the Ryazan (54.6949, 40.8659), Moscow (55.3117, 40.0640), and Vladimir (55.2257, 41.5720) regions from July to September 2020 and from April to October 2021. The congregations were usually near settlements and roads so the impact of human disturbance was approximately the same in all sites of the study and therefore was not considered.

2.2. Data collection

When a flock was found, we waited for several minutes before recording behavioral data in case our arrival had any influence on crane behavior. A flock consisted of two or more cranes occurring up to 200 m apart as used by other authors in similar studies (Yang et al., 2006; De-Jun et al., 2011; Wang et al., 2011; Xu et al., 2013). Behavioral observations were conducted in daylight hours at the foraging sites on days when there was no heavy rain or snow. In each flock we selected focal individuals randomly which were observed with a telescope (SVBONY SV28 20–60 × 80 mm), actual observation times ranged from 3 min to 16 min with an average of 10 min, and the activities were recorded to the nearest second on a voice recorder. The time spent on vigilance was converted into proportions of the total observation time. Vigilance behavior was defined as prolonged head up while standing straight and short head up during other activities (Li et al., 2017).

We noted the age of focal cranes based on their head and neck color: subadults and adults (Ad) (these categories were grouped due to inherent difficulty in distinguishing them from a distance) or juveniles (Juv) (Johnsgard, 1983). If possible, we determined the social unit of adults as single or paired without juveniles or a parent with one or two juveniles. Our sample included 64 juveniles (636.7 min) and 298 adults (3063.8 min) of which there were 220 single individuals, 43 individuals from pairs without juveniles, 15 individuals from families with one juvenile, and 20 individuals with two juveniles.

For each observation, we noted the habitat type: uncut meadows (439.8 min), plows (1734.5 min), sown fields (97.7 min), stubbles (1096.3 min), winter crops (125.7 min), unharvested grain fields (125.4 min) and puddles at the foraging area (81.1 min).

The number of individuals in the flock was considered at each observation. There are studies where crane flocks were divided into several groups depending on the number of individuals (Aviles, 2003; Yang et al., 2006). In one study flocks were classified into large (>10 birds) and small (<10 birds) (Aviles, 2003), in another: families and flocks which, in turn, were divided into six categories (5–9, 10–19, 20–29, 30–49, >50) (Yang et al., 2006). However, in the first study, the maximum number of individuals in a flock was not indicated while in the second it was 87 individuals which were several times less than in our case (546 individuals). In our study, we separated flocks into three categories: small (<50 birds), medium (50–150 birds), and large (>150 birds).

The period of observation was divided into periods: the first stage (April–May) was the arrival time from the wintering grounds; the second stage (June, July, and the first half of August) was the time of small summer groups; the third stage (the second half of August –the first half of September) was the formation of aggregations, which included nonbreeding and family individuals with juveniles; the fourth stage (the second half of September–the early October) was the formation of flocks, which may include birds from more northern latitudes that have started the migration. Observation time of day was divided into morning (from dawn to 11:00 a.m.)–the arrival time from roosting sites to the onset of daytime rest, noon (11:00 a.m.–15:00 p.m.)–

the daytime rest period, afternoon (from 15:00 p.m. to departure for roosting sites) – the arrival time from resting areas to departure to the roosting site.

2.3. Statistical analyses

We used the nonparametric Mann-Whitney U-test (U and Z statistic, p-level) to divide the cranes into social units. Vigilance was compared: 1) individuals from pairs without juveniles and single adults, 2) parents with one and two juveniles, and 3) adults and juveniles. Further, we separated the sample into social units based on these results.

Generalized Linear Model (GLM) with a negative binomial distribution (family = negative.binomial) was used aided by the lme4 package (https://CRAN.R-project.org/package = MuMIn[1]) in the R version 3.6.3 (https://www.R-project.org[2]). The proportion of vigilance out of the total observed time was used as dependent variables in models. Independent variables were chosen based on published studies that found their relationship with the vigilance of different species of cranes at the wintering grounds. The habitat types, flock size, time of day, and period were used as independent variables. For each social unit (parents, nonparents, and juveniles) we used separate models. Models were compared using the dredge function of the "MuMIn" package (https://CRAN.R-project.org/package = lme4[3]) in R. The best model was selected using the corrected Akaike criterion adjusted for small samples ($_{\Delta}$AICc) (Burnham and Anderson, 2002), ranking the models from the most to least likely. Models with Akaike delta ($_{\Delta}$AICc) less than 2 were selected as candidate models. The Tukey post-hoc test (PHT) based on the selected model was used to compare vigilance across flock sizes and between adults and juveniles using the lsmeans package (Lenth and Lenth, 2018) in R.

3. Results

The Mann-Whitney test displayed no difference in vigilance between paired without juveniles and single adults (U = 4567, Z = 0.36, p = 0.72) and between parents with one and ones with two juveniles (U = 135.5, Z = 0.47, p = 0.64). Therefore, we divided samples into juveniles, parents, and nonparents for future analysis. Parents (median = 21%; 25%–75%: 9%–32%; n = 35) were more vigilant than nonparents (median = 10%; 25%–75%: 6%–18%; n = 43) and juveniles (median = 8%; 25%–75%: 4%–14%; n = 64) from August to October (Figure 1).

In the first period, flock sizes ranged from 2 to 50 birds, in the second and the third periods' flock sizes increased to 228 and 338, respectively. Flock sizes in the fourth period were the largest and ranged from 50 to 546 birds. In the first two periods, the studied flocks consisted of nonbreeding individuals only. Adults with juveniles were encountered only in the third and fourth periods. Thus, we analyzed nonparents during four periods, and parents and juveniles during the third and fourth stages. The dependence of vigilance on the flock size was carried out only for nonparents.

1 Bartoń K (2013). MuMIn: Multi-model inference. R package version 1.9.5 [online]. Website https://CRAN.R-project.org/package=MuMIn [accessed 10 January 2020].

2 R Core Team (2020). R: Language and Environment for Statistical Computing. R Foundation for Statistical Computing [online]. Website www.R-project.org [accessed 10 January 2020].

3 Bates D, Maechler M, Bolker B, Walker S, Haubo Bojesen Christensen R et al. (2016). lme4: Linear Mixed Effects Models using "Eigen" and S4. R package version 1.1–12 [online]. Website https://CRAN.R-project.org/package=lme4 [accessed 10 January 2020].

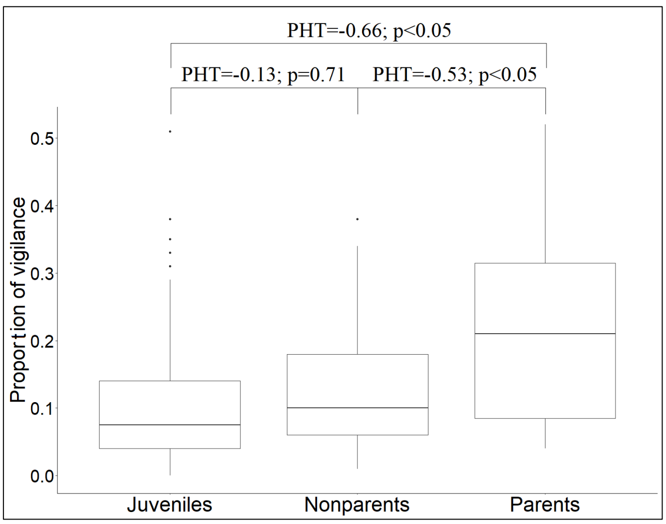

Figure 1. Vigilance proportion of each social unit.

When comparing models of vigilance dependence of nonparents on the factors, the suitable model was found to contain only one predictor - flock size (Table). The Tukey post-hoc test calculated from the selected model showed cranes were less vigilant in medium-sized flocks (51–150 individuals) than in small and big ones (Figure 2).

Similarly, the model was chosen and constructed to analyze the vigilance of juveniles. The period was the only influencing factor (Table). Juveniles spent more time vigilant in the fourth period (the second half of September–early October) than in the third (in the second half of August–the first half of September) (Figure 3).

When analyzing models of parental vigilance, our selected factors did not affect the vigilance proportion. No statistically significant relationship was found between the vigilance of cranes and the habitat type and time of day.

4. Discussion

The results of our study demonstrated differences in vigilance behavior proportion between cranes of the different social units. Flock size influenced the level of vigilance of nonparents in the spring, summer, and autumn periods. The vigilance of juveniles was greater at the end of the premigration period compared to the beginning.

Same as at the wintering grounds (Tacha, 1988; Alonso and Alonso, 1993; Li et al., 2013), in our study, parents were more vigilant than nonparents and juveniles during the premigration period. Moreover, the presence of juveniles affected vigilance proportion but not their number in the family (one or two) as was previously shown at wintering grounds (Alonso and Alonso, 1993; Li et al., 2013). These results confirm that parents' increased alertness is aimed to protect at protectingtheir offspring. In addition, families,

Table. Parameter estimates and their standard errors (SE) from selected models containing variables that contributed to the proportion of time spent on vigilance, including model performance, medians variables with 25th and 75th percentiles, and sample size (n).

Parameter	Estimate ± SE	ΔAICc	weight	median	25%–75%	n
Nonparents						
Group	–	1.8	0.24	–	–	–
Big comparison	–	–	–	13%	11%–25%	22
Medium	–0.88 ± 0.18	–	–	6%	2%–9%	61
Small	–0.17 ± 0.14	–	–	13%	7%–20%	180
Juveniles						
Period	–	1.52	0.28	–	–	–
Period 3 comparison	–	–	–	5%	4%–11%	43
Period 4	0.63 ± 0.22	–	–	14%	6%–22%	21

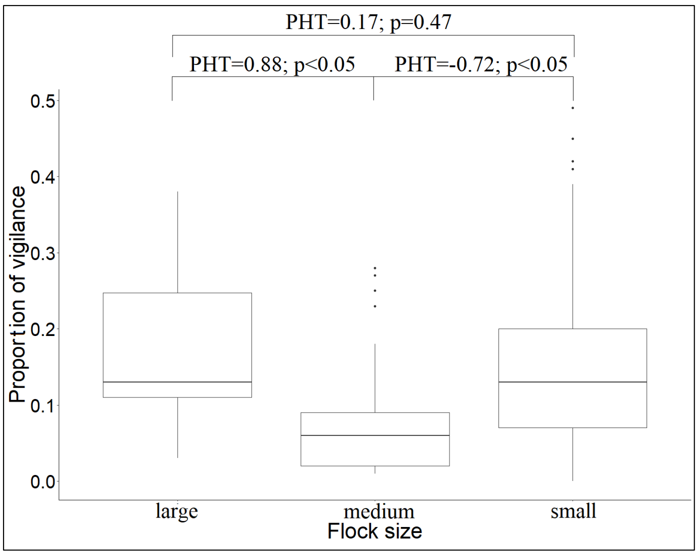

Figure 2. Vigilance proportion of nonparents in each flock size.

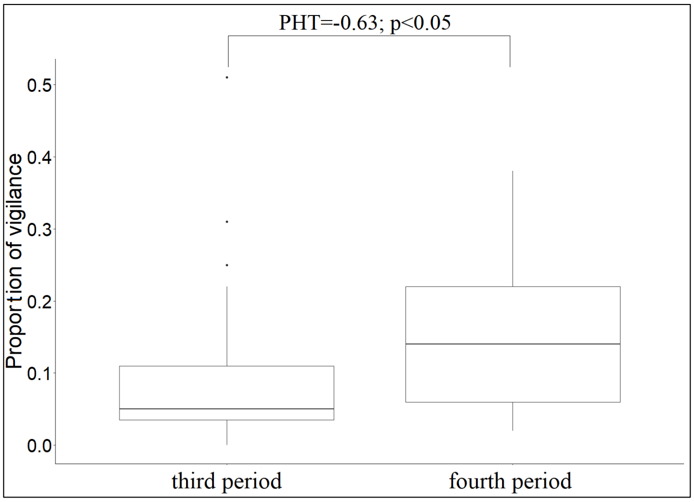

Figure 3. Vigilance proportion of juveniles in each period.

as a rule, are on the periphery of the flock (Bautista et al., 1995) which increases the risk of predation, resulting in higher vigilance than birds in the center flock.

In our study, the time allocated to vigilance of nonparents was not significantly higher than that of juveniles. These findings are inconsistent with crane behavior at the wintering grounds (Alonso and Alonso, 1993). Firstly, it may be because juveniles explored new, little-known areas associated with the transition from marshes and forests to agricultural fields in the autumn, through prolonged alertness. Secondly, socialization was observed during their wintering periods where juvenile birds were frequently subjected to adult pressure to establish a flock hierarchy (Alonso et al., 2004). Once a hierarchy is established in a flock, subordinate birds show more vigilance than dominant ones (Pravosudov and Grubb, 1999). We assume that these factors can increase the level of alertness of juveniles and reduce the difference in vigilance with nonparents. For cranes overwintering in Spain, the difference in time budget between juveniles and nonparents was less pronounced at the end of the season when juveniles separated from family and became more independent (Alonso and Alonso, 1993).

The dependence of vigilance on flock size was analyzed only for nonparents. It was the only social unit that was observed in a flock size smaller than 50 individuals. In contrast to the wintering areas where groups of cranes consisting only of parents with their offspring were found (Alonso and Alonso, 1993; Yang et al., 2006), in the breeding areas they were seldom seen separately from flocks. This is because parents and their offspring gradually move away from their nesting site as the chicks mature (Markin, 2013). Thus, before joining a flock families stay in territories adjacent to their nest which are often difficult to investigate. The dependence of vigilance proportion on flock size is controversial in the literature due to the use of different assessment methods. According to some studies, the time spent on alertness decreased with an increase in the flock size (Aviles and Bednekoff, 2007; Li et al., 2015), in others, it increased (Li et al., 2016) or a relationship was not found (Sparling and Krapu, 1994). According to Yang et al. (2006) and Wang et al. (2011), the U-shaped pattern of dependence most accurately reflects the relationship between flock size and the vigilance proportion of individuals. Our results also confirmed these findings. This pattern considers the trade-off between vigilance aimed at predator detection and vigilance directed towards conspecifics, where a decrease in the former and an increase in the latter occur with increasing flock size. The optimal flock size of common cranes at wintering grounds in China was 20–30 individuals (Yang et al., 2006) while our results showed 51–150 individuals and the maximum size of wintering flocks was several times smaller than in our study. Therefore, the optimal flock size may depend on other factors such as the distance between individuals in the flock and the area used by the flock which needs to be studied in future research.

The vigilance of juveniles was increased toward the end of the premigration period. The time budget of juveniles was previously described to reach the level of wintering adults in March and the average vigilance percentage was 15.15% (Alonso and Alonso, 1993) which is larger than in our study. Thus, juveniles show an increase in the time spent on alertness as they mature. Moreover, the increase in juvenile vigilance at the end of the premigration period can be due to the increase in flock size in this period when aggressive behavior towards them from adults rises (Aviles, 2003; Alonso et al., 2004). In addition, before migration, some birds show excitement that can be passed between individuals and influence their migratory restlessness (Newton, 2012). This effect can also be seen in juveniles at the end of the premigration period. However, flock size was found not to influence juvenile vigilance in some articles (Aviles and Bednekoff, 2007).

In conclusion, a flocking lifestyle allows individual vigilance to be decreased. However, increasing flock size raises internal conflicts between conspecifics. Hence, when considering the relationship between flock size and the proportion of vigilance behavior, nonlinear dependencies should be considered as well and the density of the cluster should be considered. In addition, reactions to certain factors may be different depending on age and the presence of offspring.

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