Wetlands (2013) 33:227–232
DOI 10.1007/s13157-012-0371-z

ARTICLE

Time Budgets of Wintering Red-Crowned Cranes: Effects of Habitat, Age and Family Size

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Received: 18 October 2012 / Accepted: 23 December 2012 / Published online: 11 January 2013

Abstract The red-crowned crane (*Grus japonensis*) is an endangered species only found in East Asia. Due to wetland loss and degradation, many cranes have changed their wintering feeding habitats from natural grasslands to artificial wetlands, such as rice fields. Thus we want to know whether cranes relocate the time budgets with respect to habitat, and also with the age and family size. This study was conducted in Yancheng Nature Reserve during winters 2009 and 2011. We found cranes devoted more time to feeding but less to vigilance in grasslands, whereas the pattern was opposite in farmlands. Compared to juveniles, adults spent less time feeding but more time being vigilant. Cranes showed a similar time budget between different family sizes. These results indicate cranes relocate their behavioral time budgets according to their feeding habitats, which are closely related to human disturbance. We suggest reducing human activities in farmlands during the wintering period, as well as conserving natural wetlands in the wintering areas, to safeguard and ensure the wild population of red-crowned cranes.

Keywords Feeding · Human disturbance · Parental investment · Red-crowned crane · Time budgets · Vigilance

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Introduction

Habitat loss and degradation due to human industrial and economic development have been considered as one of the most important factors influencing wild birds' survival (Owens and Bennett 2000). The loss of natural wetlands has resulted in many waterbird species change their feeding habitats to depend on artificial wetlands, thus leading to a relocation of time budgets to adapt the new habitat (Czech and Parsons 2002; Elphick 2010; Wood et al. 2010). For certain species, due to the increased human disturbance in artificial wetlands, they have to spend more time vigilant to detect potential threats from human activities. Consequently, they might have not enough time to feed, leading to insufficient energy and nutrition intake, and therefore individual starvation and population declines (Ma et al. 2010; Wang et al. 2011).

The development and utilization of natural wetlands also occurs in China coastlines, especially after 'China's Coastal Development' program rose to National Developmental Strategy in 2009 (Wood et al. 2010). This resulted in decreased population of wetland birds such as the red-crowned cranes (*Grus japonensis*), which are probably the most endangered crane in the world (Su 2008; Ma et al. 2009). In Yancheng Nature Reserve, the largest wintering area of the migratory population of cranes in China, the natural wetlands are also utilized for industrial and agricultural developments. In the core zone of this nature reserve, natural wetlands (wormwood beaches and tidal grasslands) have decreased from 109 km^2 in 1984 to 29 km^2 in 2008, a reduction of 73 %, whereas the artificial wetlands (partly reed beds) have increased from 6 km^2 in 1984 to 48 km^2 in 2008, an increase of 8 times (Wang 2012). In the buffer zone and experimental zone, the loss of natural wetlands is even more serious. In this case, the feeding habitats of some

cranes have moved from natural wetlands to artificial wetlands, especially rice fields (Ma et al. 1998; Ma et al. 1999; Lv 2009).

When moving to a new habitat, animals might relocate their time budgets so as to adapt the new environment (Czech and Parsons 2002; Wood et al. 2010). For cranes, they will increase vigilance to scan their surroundings leaving less time to feed and can coordinate their vigilance so as to increase detection ability when moving to artificial habitats (Wang et al. 2011; Ge et al. 2011). Thus, high frequency of vigilance can be observed among crane populations in disturbed habitat.

The family group is the basic unit of cranes, and a family group is usually composed with of two adults with or without juveniles (Miller 1973; Ellis et al. 1996). According to the 'group size effect' (Pulliam 1973; Beauchamp 2003), individuals living in a larger family should spend less time in vigilance due to detection and dilution effects. Juveniles which are less vigilant (Marchetti and Price 1989) could at least provide dilution benefits and potential detection effects to the whole group. Thus, vigilance decreases with increasing family size of the cranes. However, parental care should also be considered (Lazarus and Inglis 1978; Rosa and Murphy 1994). When accompanied by juveniles, adult animals would spend extra time in parental care, such as vigilance for predators or human disturbance (Lazarus and Inglis 1978), leading to increased vigilance compared to adults with no juveniles. Thus, it is uncertain how family group size affects vigilance, especially for adults.

Wang et al. (2011) found that both human disturbance and flock size could affect the vigilance behaviour of red-crowned crane, increasing vigilance when under high human disturbance and in small groups. However, this paper only classified two levels of human disturbance, high disturbance in buffer zone and low disturbance in core zone. This simplified classification might neglect the possible effect of habitat types. It also reported on the effect of a continuous range of group size, from 1 to 46 (Wang et al. 2011), minimizing the possible effect of family group, which is the basic unit containing 2 to 4 individuals (Ma and Li 2002). During the winters of 2009 and 2011, we focused on the family group of wintering red-crowned crane in Yancheng Nature Reserve, and explored the hypothesis that the habitat, age and family size affect the time budgets of this endangered crane.

Methods

Study Area

This study was conducted in the Yancheng Nature Reserve (32°34′–34°28′ N 119°48′–120°56′ E) in Jiangsu Province, China. Yancheng is the largest wintering area for the western population of red-crowned cranes (Wang 2008). The reserve was founded in 1983 for conservation of red-crowned cranes and other wetland birds 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 about 2,400 km^2. Mean temperature in winter is about 4 °C and varies from −8 °C to 16 °C. Snow covers the ground occasionally in winter (December to February). The reserve is dominated by *Phragmites communis*, *Suaeda salsa*, and *Imperata cylindrica*. The red-crowned cranes mainly utilize three habitat types in the nature reserve: tidal grassland, reed beds, and farmland. The grassland is a kind of natural wetland, which was mainly located in the core zone with little human disturbance; reed beds are semi-natural, and found in both core zone and buffer zone; whilst farmland is completely artificial, and mainly occurs in buffer zone and experimental zone. We considered habitats that are located in the buffer zone and experimental zone to have high human disturbance, because in these areas, there is year-round activity. They own farms and plant crops, generating activities such as plowing, sowing, and harvesting. Fishing is also very common in these areas. Comparably, the core zone is uninhabited and the number of visitors is restricted. Reed harvesting or fishing is only allowed during particular seasons thus reducing human disturbance. During winter, these activities are even more restricted due to the occurrence of red-crowned cranes.

Study Species

The red-crowned crane, which is listed on Convention on Migratory Species and CITES, has a population of less than 2,750 individuals (BirdLife International 2012). The breeding areas of the cranes are in East Asia, including Japan, North Korea, South Korea, eastern Russia, Mongolia, and northeastern China, while the wintering areas are in Japan, South Korea and the eastern coasts of China (Masatomi et al. 2007; Wang 2008; Lee and Yoo 2010). Red-crowned cranes migrate from north-eastern China to Yancheng in late October and overwinter in the reserve until early March (Su 2008). Wintering cranes are gregarious and live in small family groups. Family groups are composed of two adult cranes, with or without juvenile cranes, whilst larger aggregations are made up of several family groups (Wang et al. 2011).

Behavioral Observations

We selected family groups for observations and conducted this study in January and February 2009, and from November 2010 to March 2011. Cranes were located during regular route surveys and locations were recorded with a

GPS. The route was not repeated on the same day in order to avoid replicated sampling. Observations were not made on days with rain, snow or strong winds to lessen bias caused by the effect of extreme weather.

Focal samplings were carried out using binoculars (8× 56) or a telescope (20~60×63). At the beginning of each focal observation, date, time, location, habitat type (farmland, reed beds, grassland), age (adult or juvenile) and family size (including 0, 1, or 2 juveniles) were recorded. We usually selected one adult and one juvenile from a family group, and sometimes sampled all group members if all individuals were easily visible. Observations were usually made 300 m away from the focal individuals, to reduce observer effects (Li 2011).

MP3 recorder was used to record the behavioral events for 30 min unless we lost sight of the focal individual. Actual observation time ranged from 10 to 30 min, with an average of 27.3±0.2 min. We distinguished three behavioral states: feeding, vigilance, and other behaviors. Feeding refers to a crane excavating foods, swallowing or drinking. Vigilance refers to a crane stretching the head upwards while looking around. Other behaviors include preening, walking, running, leaping, resting, fighting, and calling.

Data Analysis

From the timed sequences of events, time spent feeding and vigilance were summed respectively across the focal observation and expressed as a percentage of total observation time. We arcsine square-root transformed these data so as to normalize data. Then we use a mixed linear model to quantify the effect of habitat, age, family size and time of the day and all their second-order interactions on feeding and vigilance. We included year and group ID as a random factor to control for potential effects of pseudo-replication, because we made multiple observations in the same group. There is no significant difference in all second-order interactions (at least $P>0.15$), so in the final model, we only included the habitat types (grassland, reed beds, farmland), age (adult, juvenile), family size (2, 3 or 4 members) and the time of the day (morning, noon, afternoon). Statistical analyses were carried out with SPSS 18.0 (level of statistical significance was set at 0.05) and data were reported as mean ± SE obtained from the statistical models.

Results

A total of 10,046 min with 368 sets of focal observations comprising 45 sets for nonparents, 57 for parents with one juvenile, 121 for parents with two juveniles, and 145 for juveniles. During the wintering period, red-crowned cranes spent nearly 90 % of their diurnal time in feeding and vigilance. Model results indicated that habitat ($F=4.14$, df=1,360, $P=0.02$) and age ($F=28.61$, df=1,360, $P<0.01$) greatly influenced feeding, whereas family size ($F=1.03$, df=2,360, $P=0.36$) and day time ($F=2.04$, df=1,360, $P=0.13$) had no effect (Table 1, Fig. 1). Cranes spent 75.9 % of their time feeding in grasslands, 70.1 % in reed beds, and 66.7 % in farmlands; and the adult cranes spent less time feeding than the juveniles (Fig. 1).

On the other hand, vigilance was significantly affected by habitat ($F=11.42$, df=1,360, $P<0.01$) and age ($F=42.03$, df=1,360, $P<0.01$), but not family size ($F=1.15$, df=2,360, $P=0.32$) or day time ($F=1.16$, df=1,360, $P=0.31$) (Table 2, Fig. 2). Cranes spent 28.4 % of their time being vigilant in farmlands, 19.7 % in reed beds, and 16.9 % in grasslands; and juveniles contribute less to vigilance than the adult cranes (Fig. 2).

Discussion

The results showed a significant effect of habitat on feeding and vigilance of red-crowned cranes; they spent more time feeding and less time being vigilant in grasslands, and comparably they devoted more time to vigilance and less to feeding in farmlands. This behavior pattern might be caused by human disturbance but not the presence of food types in the different habitats. Red-crowned cranes are omnivorous and prefer to forage on small fish or shellfish, which were usually found in tidal grasslands (Ma et al. 1998; Ma et al. 1999). Cranes also feed on rice or wheat, although these foods accounted for a small proportion of their diet (Dong et al. 2005; Lee et al. 2007). Dong et al.

Table 1 Effects of habitat, age, family size, and day time on feeding of red-crowned cranes (*Grus japonensis*) in Yancheng nature reserve during winters 2009 and 2011

Term	Estimate	SE	df	t	P
Intercept	1.20	0.04	360	29.03	0.00
Habitat[a]					
Farmland	−0.10	0.04	360	−2.68	0.01
Reed beds	−0.08	0.03	360	−2.40	0.02
Age	−0.15	0.03	360	−5.35	0.00
Family size[b]					
2-member family	−0.00	0.04	360	−0.07	0.94
3-member family	−0.05	0.03	360	−1.40	0.16
Day time[c]					
Morning	−0.06	0.04	360	−1.60	0.11
Noon	0.00	0.03	360	0.07	0.95

[a] The reference category for habitat is 'grassland'

[b] The reference category for family size is '4-member family'

[c] The reference category for day time is 'afternoon'

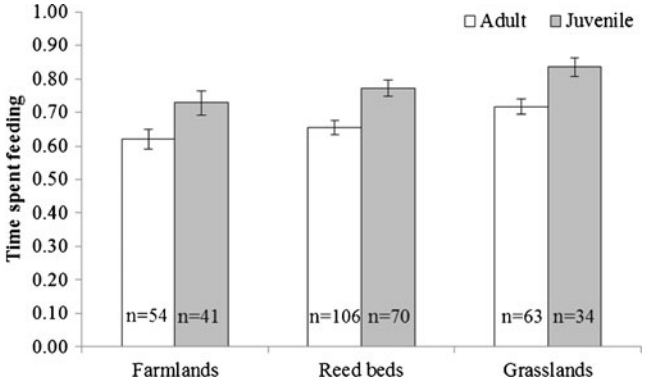

Fig. 1 Effects of habitat and age on feeding of red-crowned cranes (*Grus japonensis*) in Yancheng nature reserve during winters 2009 and 2011

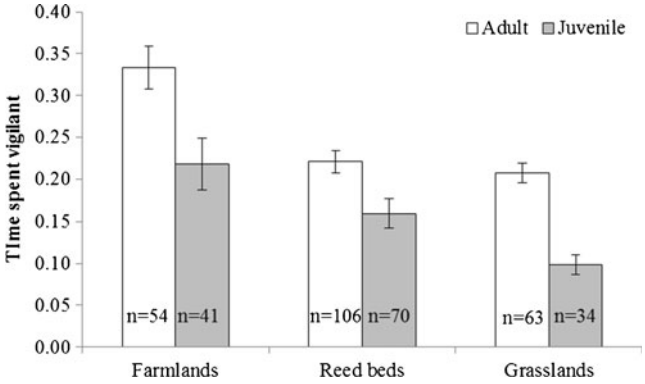

Fig. 2 Effects of habitat and age on vigilance of red-crowned cranes (*Grus japonensis*) in Yancheng nature reserve during winters 2009 and 2011

(2005) found that the density of food (animals, such as crabs) in grasslands was about 400 g/m^2, much more than that in farmlands (plant seeds, such as rice and wheat) ranging from 7.5 to 60 g/m^2. Even if rice or wheat is easier to find and handle than zoobenthos, it is difficult to compensate for the lower food availability and lower nutritional value in farmlands. Therefore, the shortened feeding time and prolonged vigilance time in farmlands might be caused by human disturbance. Human disturbance is usually considered to be similar to predation risk (Frid and Dill 2002); animals should behave more vigilantly under higher predation risk or human disturbance (Beauchamp 2003; Wang et al. 2011). The grassland habitat is located in the core zone of Yancheng Nature Reserve, in which human activities are prohibited. In contrast, the farmland is mainly located in the buffer zone, where human activities such as cultivating and harvesting often occur, and reed beds are located in both zones with medium human disturbance. Therefore the increased vigilance from grassland, through reed beds, to farmland, may be simply a reflection of the increasing intensity of human activities.

Table 2 Effects of habitat, age, family size, and day time on vigilance of red-crowned cranes (*Grus japonensis*) in Yancheng nature reserve during winters 2009 and 2011

Term	Estimate	SE	df	t	P
Intercept	0.30	0.03	360	9.52	0.00
Habitat[a]					
Farmland	0.13	0.03	360	4.54	0.00
Reed beds	0.03	0.02	360	1.35	0.18
Age	0.14	0.02	360	6.48	0.00
Family size[b]					
2-member family	−0.03	0.03	360	−1.02	0.31
3-member family	0.02	0.03	360	0.83	0.41
Day time[c]					
Morning	0.04	0.03	360	1.52	0.13
Noon	0.02	0.02	360	0.85	0.40

[a] The reference category for habitat is 'grassland'

[b] The reference category for family size is '4-member family'

[c] The reference category for day time is 'afternoon'

Movement to artificial wetlands is probably caused by the limited carrying capacity of the core zone of this nature reserve (300 to 400 individuals) (Dong et al. 2005; Lv 2009). Most cranes select the core zone as night resting sites, some of them spend the whole day feeding and resting in these sites, while others have to fly to the buffer zone (usually farmland and reed beds) to feed in the morning and go back in the afternoon (Lv 2007). When the whole wintering population is larger than 500 individuals, the proportion feeding in artificial wetlands usually accounts for more than 50 % of the population (Lv 2009). This suggests due to the limited natural wetlands, cranes have to move to artificial wetlands, even though there is lower food availability and increased human disturbance.

Adults in family groups spend less time feeding and more time being vigilant than their juveniles. This observation was also documented in other cranes such as sandhill cranes (*Grus Canadensis*, Tacha 1988), common cranes (*Grus grus*, Alonso and Alonso 1993; Aviles 2003; Aviles and Bednekoff 2007), and black-necked cranes (*Grus negricollis*, Cangjue et al. 2007). Compared with adults, juvenile birds often have different time budgets due to lack of experience in foraging and escaping from predators (Weathers and Sullivan 1989). Juveniles could obtain adequate food supplies from longer time feeding to meet developmental needs (Ma and Li 2002). Adults spent less time feeding, but they were more efficient in catching and handling food. Studies on domestic red-crowned cranes showed that food-handling proficiency was superior in adults (Ma et al. 2000).

Wang et al. (2011) found that red-crowned cranes spent less time vigilant with the increasing of flock size, but we did not find this effect of family size. This might be due to the different range of group sizes, the former from 1 to 46

individuals, whereas the latter only 2 to 4 individuals. Our result agreed with the findings of Alonso and Alonso (1993) in which no family size effect on time budgets was found in common cranes, and the presence of juveniles made parents more vigilantly than non-parents. In some species, such as barnacle geese (*Branta leucopsis*), the presence of juveniles contributed to family vigilance, and thus allowed a decrease in family vigilance (Black and Owen 1989). Moreover, no significant difference was found in feeding and vigilance between parents and nonparents. This pattern might be a tradeoff between group size and parental effects. Juveniles spent less time in vigilance, just about 67 % of adults, and might devote little to enlarge the detection range or ability of the family group. However, at least they could strengthen the dilution effect, which is only related to flock size (Beauchamp 2003). Therefore the presence of juvenile cranes could probably reduce the vigilance of the group members. Juveniles of red-crowned cranes do not leave their parents until the beginning of spring breeding (Ma et al. 2000). Before the family breaks up, juveniles have to learn enough skills to ensure their survival, especially learning how to scan their surroundings and escape from potential threats (Ma and Li 2002). Consequently, parents who should take more responsibility for their safety would increase vigilance. The tradeoff between group size effects and parental effects thus made a non-significant vigilance trend across family size.

Generally, the vigilance behavior of these cranes was affected by habitat and age, but not family size or the time of the day. Adult cranes, especially the parents, were more vigilant, spending more time monitoring the environment, whereas juveniles were constantly observed feeding. In light of these results, we make the following recommendations for conservation efforts. First, we suggest a decrease or more stringent limit on human activities in the nature reserve, especially in the farmlands since human disturbance affects the time budget of cranes. Decreasing human activities may lead to an increasing feeding time for the wintering cranes. Second, farmlands, especially rice fields, should also be kept unplowed until birds leave in early March. A study in Korea has indicated that unplowed farmlands can provide more foods for red-crowned and white-naped cranes, *Grus vipio* (Lee et al. 2007). Furthermore, conservation and restoration measures on wetlands (e.g. control of invasive *Spartina alterniflora*) to protect the core zone, helping ensure the remaining population of red-crowned cranes.

Acknowledgments The study was financially supported by National Nature Reserve Remote Sense Investigation and Assessment during 2000–2010 (No. STSN-7) and Key Projects in the National Science and Technology Pillar Program during the Eleventh Five-Year Plan Period (No. 2008BAC39B03). We also thank Guy Beauchamp, Liying Su, Cheng Huang and Shicheng Lv for helpful discussions, and Eve Fernandez for language polishment. The field observation was supported by Jing Li, Xuelei Jiang, Jie Zhu, and Hui Wang.

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