Chinese Birds 2013, 4(2):161–169
DOI 10.5122/cbirds.2013.0013

ORIGINAL ARTICLE

Behaviors of the Oriental White Stork (*Ciconia boyciana*) in a semi-natural enclosure

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Abstract Environmental factors affect animal behavior in a variety of ways. Compared to animals in the wild, captive animals are kept in narrow enclosures, suffer higher densities and are more intensely affected by human activities. Therefore, behavioral elasticity is likely modified to some extent in captive animals, which may negatively affect the possibility of successful release of endangered species in the wild. In our study we investigated the behaviors of the Oriental White Stork (*Ciconia boyciana*) in a semi-natural enclosure from 15 October 2005 to 8 September 2006 in Hefei Wildlife Park, China. The behavioral data were collected by instantaneous and scan sampling methods, and we analyzed the relationships between environmental factors and their behaviors. The amounts of time spent on maintenance behavior (foraging and moving) were at similar levels for birds reproducing multibroods (Group 1), birds reproducing one brood (Group 2) and birds without reproduction (Group 3). On the other hand, the amount of time spent on elastic behavior (defensive, breeding and preening) for Group 3 was lower than that for Groups 1 and 2. The behavioral pattern of the storks exhibited marked seasonal changes, which may be a function of ambient temperature, human disturbanc, and the length of daylight, but not of wind intensity. Our results provide basic data for future conservation measures of this endangered species.

Keywords *Ciconia boyciana*, time budget, human disturbance, re-introduction

Introduction

In days gone by, the Oriental White Stork (*Ciconia boyciana*) used to be widely distributed across eastern Asia, more specifically in Russia, China, Japan and Korea. At present this species is only found in Russia and China, where an estimated 3000 individuals still survive (Simon and Derek, 2002). The main threats are hunting, insecticide application, fragmentation and loss of habitat and human disturbance, particularly so during the last three decades. This bird is now listed as endangered in the China Red Data Book (Zheng and Wang, 1998) and has entered the IUCN Red List of Threatened Species (IUCN, 2011).

The Oriental White Stork is a migratory bird, breeding in northeastern Asia, wintering in southern areas near the Yangtze River in China (Wang and Yang, 1995). Recently, some Oriental White Storks were reported to breed in their wintering and stopover sites, such as Wuchang and Boyang lakes, Dafeng, Gaoyou and the Yellow River Delta (Xue et al., 2010), where some storks have remained for several generations. However, storks breeding in southeastern China show a low breeding rate, due to different weather conditions, extensive human activities and limited food resources (Hou et al., 2007; Yang et al., 2007).

As indicated, the protection of this species is an urgent issue. Up to now ex-situ conservation has been

Received 17 September 2012; accepted 20 February 2013

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the main conservation measure. In the 1980s, captive breeding of the Oriental White Stork was carried out in the Shanghai Zoo for the first time, where the number of captive storks has increased from 36, spread out over ten zoos in 1985, to 552 birds in 88 zoological gardens in 2004 (Ogawa, 2001; Ma et al., 2006), while its wild populations have declined in numbers (IUCN, 2011). It is anticipated that captive, reared storks will be released into the wild eventually (Collar et al., 2001).

However, rearing birds over long periods in captivity may have changed their behavior. Understanding animal behavior is fundamental for ex-situ conservation (Jiang et al., 2001). Most captive animals are raised in limited spaces with an abundant food supply but strong human interference, which might affect their behavior (Curio, 1996; Armstrong et al., 1999). Previous research on captive storks has focused on breeding ecology, activity budgets, disease prevention and management (Coulter et al., 1989; Catherine, 1990; Murata and Asakawa, 1999; Li et al., 2002). Activity budgets are affected by many limiting factors, such as population density (Caraco, 1979; Yasue, 2005), size of territory (Hixon et al., 1983), human disturbance (Thomas et al., 2003), food richness (Hussell and Quinney, 1987; Litzow and Piatt, 2003), sex, age and weather (Verbeek, 1972; Caraco, 1979). In addition to these factors, space is another key factor, which could affect social structures (Jiang, 2004).

The aim of our study was to investigate the behaviors of *C. boyciana* in a semi-natural enclosure in southeastern China over a period of a year, in order to understand the behavior in captivity, to compare these behaviors with those of storks in the wild at their southeastern breeding ground and to provide baseline information for conservation measures of this endangered species.

Methods

Study area

This study was conducted from 15 October 2005 to 8 September 2006 in a semi-natural enclosure at the Hefei Wildlife Park in Hefei City, Anhui, China (31°50′3″N, 117°10′2″E). The study area is located between a temperate and a subtropical climate zone. The mean annual temperature is 15.7°C, ranging from −8.5°C to 37.5°C with a mean annual precipitation of about 969.5 mm and mean annual evaporation of 1265 mm. Atmospheric humidity ranged from 74%–78% and the frost-free period lasted 150 days in Hefei City. Meteorological data were collected from the China Meteorological Data Sharing Service System (http://cdc.cma.gov.cn/).

The bottom of the enclosure is a circle with a diameter of 80 m, the top is completely covered by a nylon net supported by 12 small around pillars, 25 m in length and one big central pillar of 45 m. The enclosure for the storks covers an area of 0.5 ha. A pool is available in the middle of the enclosure. Three artificial nests were built on rocks, of which two nests were used in 2006. The dimensions of the first breeding nest are 2 m × 1.8 m and that of the second 1.8 m × 1.5 m. The smallest nest (1 m long and 1 m wide) was not selected by the storks for breeding. The main plants inside the enclosure were *Cinnamonum camphora*, *Sapium sebiferum*, *Pinus thunbergii*, *Robinia pseudoacacia* and a *Phyllostachys* sp. The following birds were kept together in the same enclosure: the Black Stork (*Ciconia nigra*), Red-crowned Crane (*Grus japonensis*), Swan Goose (*Anser cygnoides*), Ruddy Shelduck (*Tadorna ferruginea*), Black Swan (*Cygnus atratus*), Bean Goose (*Anser fabalis*) and Grey Heron (*Ardea cinerea*).

Data collection

Three male and three female Oriental White Storks were observed once a week from 15 October 2005 to 8 September 2006. Four birds established two mating pairs, while the two yearlings did not breed. These birds were assigned to three groups: a pair that produced three broods (Group 1); a pair that produced one brood (Group 2); a male and a female that were yearlings and did not breed (Group 3). We classified the behaviors of the storks into six modes: moving, breeding, defensive, foraging, preening and resting (Liu et al., 2001; Tian et al., 2005). Moving and foraging behaviors represent maintenance behaviors that are necessary for survival, while breeding, defensive and preening behaviors represent elastic behaviors not essential for survival (Jiang et al., 2001). Behavioral data were collected by means of instantaneous and scan sampling methods with 8 × 40 binoculars. All three groups were observed from 8:00–17:00 at five minute intervals once a week (Altmann, 1974). A total of 469 hours were spent on observations providing an average set of 5628 behavioral data for each stork and a total of 33768 observations for all storks. Each individual was identified by a different color ring on one leg. Age and sex of the individuals was

Fig. 1 (**a**) Habitat of Oriental White Storks in the Hefei Wildlife Park with two nest sites on artificial rock; (**b**) A brooding Oriental White Stork and another one guarding the nest.

gleaned from zoo records. The breeding season lasted from February to July.

Temperature was monitored by a mercury thermometer (Shuangyu B-2, Ningbo, China) at thirty minute intervals from 8:00 to 17:00 for the duration of our field work (Yang and Yang, 1996). All temperature readings were averaged as one mean for each month for the duration of the observations. Daylight time was obtained from the National Time Service Center (NTSC) at the Chinese Academy of Sciences (http://www.time.ac.cn/serve/sunriseset/). Wind velocity was classified by the Beaufort Wind Force Scale (0–12 grades: http://en.wikipedia.org/wiki/Beaufort_scale). We defined grade 0–1 as level 1, grade 2–3 as level 2, … and grade

10–12 as level 6 for a correlation analysis. We counted the number of the tourists in the zoo every ten minutes from 08:00 to 17:00, serving as an index of human disturbance. Monthly means were calculated for daylight time, wind velocity and the number of tourists in order to draw relationship graphs of behavior rhythm and the candidate factors at monthly intervals.

Data analyses

Activity budgets were based on an index for each behavioral mode. It was calculated by dividing the frequency of the behavior mode by the total number of behavioral frequencies and expressed as percentages. Temperature, wind velocity, daylight and number of tourists were selected as candidate variables in order to investigate the relationship between activity budgets and predictor factors. However, this may not provide valid results due to redundant variables when the predictor variables are highly correlated (Wold et al., 1984). Collinearity analysis was carried out to detect correlations among the candidate variables. Our results showed that the value of the variance inflation factor (VIF) for the four candidate variables (temperature, wind velocity, daylight and number of tourists) were 4.345, 3.093, 2.903 and 2.064 respectively. Because each of the VIF values was less than 10, collinearity was not significant among the different candidate variables (Senter, 2008).

Continuous variables were tested for normality (Kolmogorov-Smirnov test) and the results are presented as means ± standard errors. When the data met the assumption of normality, one-way ANOVAs were used to test time budgets among different groups and Pearson correlation coefficients were obtained to test the relationship between candidate variables and behavior frequency. When the data did not meet the assumptions of normality, a Kruskal-Wallis *H* and Spearman correlation were used for these analyses. All the statistical analyses were performed by Software SPSS 16.0 (SPSS Inc., Chicago, IL, USA).

Results

Behavioral budget proportions

The amount of time spent on maintenance behaviors (foraging and moving) accounted for 14.13% of total behavior time in Group 1, for 13.27% in Group 2 and for 13.49% in Group 3. The proportion of elastic behaviors, i.e., defensive, breeding and preening in Group 1 accounted for 33.34% for 37.60% in Group 2 and for 13.61% in Group 3 of total behavior time. These results suggest that the amount of time spent on foraging and moving, the so-called maintenance behaviors, was similar among the three groups, but the time spent on resting, defensive, breeding and preening behaviors was significantly different between the groups (Table 1). The proportion of time spent on all six types of behaviors did not show any significant sex-related differences (Table 2). The time spent on moving, resting, breeding and preening behaviors was significantly different between the breeding and non-breeding seasons, while the time spent on foraging and defensive behaviors was not (Table 3). Furthermore, differences in all six behavior modes were not explained by gender, so we could conclude that male and female storks show similar behavior budgets (Table 2). Defensive behavior in both males and females in driving out invading storks from the territory, as well as attendance at incubation, was observed in this experiment. Therefore our results, presented in Table 2, indicate that Oriental White Storks in the aviary were monogamous.

Table 1 Activity budget of different Oriental White Stork groups in the semi-natural enclosure in Hefei Wildlife Park

Behavior	Activity budget (%)			Statistics test	
	Group 1 (n = 58)	Group 2 (n = 58)	Group 3 (n = 50)	Chi-square or F values	p
Foraging	6.33 ± 4.25	6.25 ± 4.16	5.36 ± 4.50	2.85*	$p > 0.05$
Moving	7.80 ± 4.56	7.02 ± 3.52	8.13 ± 4.65	1.33*	$p > 0.05$
Resting	52.52 ± 17.67	49.13 ± 23.14	72.91 ± 8.35	51.07*	$p < 0.01$
Territorial	6.59 ± 3.15	6.90 ± 5.28	2.83 ± 2.27	40.79*	$p < 0.01$
Breeding	12.70 ± 19.73	17.24 ± 22.42	0.15 ± 0.47	39.53*	$p < 0.01$
Preening	14.05 ± 5.46	13.46 ± 8.03	10.63 ± 4.76	4.87†	$p < 0.01$

n: The number of observation days; * indicates the values from one-way ANOVA, † indicates Chi-square values from a Kruskal-Wallis H test. Group 1: paired storks with three broods); Group 2: paired storks with one brood); Group 3: no paired storks.

Table 2 Activity budget of Oriental White Stork of different sexes in a semi-natural enclosure in Hefei Wlidlife Park

Behavior	Activity budget (%)		Statistics test	
	Males ♀ (n = 94)	Females ♂ (n = 90)	Z or t values	p
Foraging	5.83 ± 4.11	6.26 ± 4.49	−0.74*	$p > 0.05$
Moving	7.81 ± 4.25	7.48 ± 4.33	−0.59*	$p > 0.05$
Resting	57.93 ± 18.98	56.01 ± 21.58	−0.25*	$p > 0.05$
Territorial	5.67 ± 3.78	5.65 ± 4.51	−0.48*	$p > 0.05$
Breeding	9.84 ± 17.29	11.64 ± 20.73	−0.40*	$p > 0.05$
Preening	12.92 ± 5.91	12.96 ± 6.83	−0.47ǂ	$p > 0.05$

* indicates the values from independent sample T test, and ǂ indicates Chi-square values from Mann-Whitney U test (Similar comments apply to Table 3)

Table 3 Activity budgets of Oriental White Stork between breeding and non-breeding seasons in a semi-natural enclosure in Hefei Wildlife Park

Behavior	Activity budget (%)		Statistics test	
	Breeding season (n = 138)	Non-breeding season (n = 46)	Z or t values	p
Foraging	6.95 ± 4.79	5.74 ± 4.09	−1.66*	$p > 0.05$
Moving	5.65 ± 3.51	8.31 ± 4.32	−3.80*	$p < 0.01$
Resting	41.19 ± 16.34	62.26 ± 18.68	−6.60*	$p < 0.01$
Territorial	6.18 ± 3.47	5.49 ± 4.34	−1.63*	$p > 0.05$
Breeding	25.07 ± 21.06	5.94 ± 15.66	−8.34*	$p < 0.01$
Preening	14.96 ± 7.02	12.26 ± 6.00	−2.34ǂ	$p < 0.05$

Temperature and behavior

The ambient temperature showed substantial annual variation throughout the year ranging from 1.8°C to 47.6°C, with minimum temperatures in January and February and maximum temperatures in July and August (Fig. 2a). There was significant positive correlation between temperature and preening (Spearman rank correlation: $r = 0.23$, $n = 178$, $p < 0.01$), as well as with resting behavior ($r = 0.18$, $n = 178$, $p < 0.05$) and a negative correlation between temperature and defensive behavior (Pearson correlation: $r = -0.23$, $n = 178$, $p < 0.01$), but no correlation with foraging ($r = 0.14$, $n = 178$, $p > 0.05$) and breeding behavior ($r = 0.07$, $n = 178$, $p > 0.05$)(Fig. 2a).

Daylight and behavior

Variation in the amount of daylight ranged from 665 to 907 min per day during the study period, decreasing from June to December and increasing from December to June (Fig. 2b). There was a significant positive correlation between daylight time and moving ($r = 0.22$, $n = 178$, $p < 0.01$) and between daylight time and defensive behavior ($r = 0.25$, $n = 178$, $p < 0.01$), but a significant negative correlation with foraging ($r = -0.16$, $n = 178$, $p < 0.05$) and breeding ($r = -0.19$, $n = 178$, $p < 0.05$), while no correlation with preening (Spearman rank correlation: $r = -0.008$, $p > 0.05$) and resting behavior ($r = 0.1$, $n = 178$, $p > 0.05$) was observed (Fig. 2b).

Wind velocity and behavior

Wind velocity during the study period did not show substantial variation within the first four levels, with a minimum velocity in January and a maximum velocity in August (Fig. 2c). There was no correlation between wind velocity and defensive behavior ($r = 0.09$, $n = 178$, $p > 0.05$), moving ($r = 0.01$, $n = 178$, $p > 0.05$), resting ($r = -0.13$, $n = 178$, $p > 0.05$), foraging ($r = -0.04$, $n = 178$, $p > 0.05$) or breeding behavior ($r = 0.07$, $n = 178$, $p > 0.05$), but significant positive correlation of wind velocity with preening behavior ($r = 0.22$, $n = 178$, $p < 0.01$) (Fig. 2c).

Human disturbance and behavior

A maximum number of tourists was recorded in April and the least in November with the number of tourists, counted every five minutes, ranging from 4 to 11 (Fig. 2d). There was a significant positive correlation between the number of tourists and breeding ($r = 0.18$, $n = 178$, $p < 0.05$), foraging ($r = 0.22$, $n = 178$, $p < 0.01$), preening ($r = 0.23$, $n = 178$, $p < 0.01$) and defensive behavior ($r = 0.19$, $n = 178$, $p < 0.01$), a significant negative correlation with resting behavior ($r = -0.28$, $n = 178$, $p < 0.01$) and no correlation with moving behavior ($r = -0.11$, $n = 178$, $p > 0.05$).

Discussion

Time budgets of animal behaviors are the result of evolutional adaptation to the environment, where individuals with the best activity budget could benefit from natural selection (Verbeek, 1972; Yang and Yang, 1996). Previous research showed that behavioral structure is positively correlated with space. A study on the Coral-billed Ground-cuckoos (*Carpococcyx renauldi*)

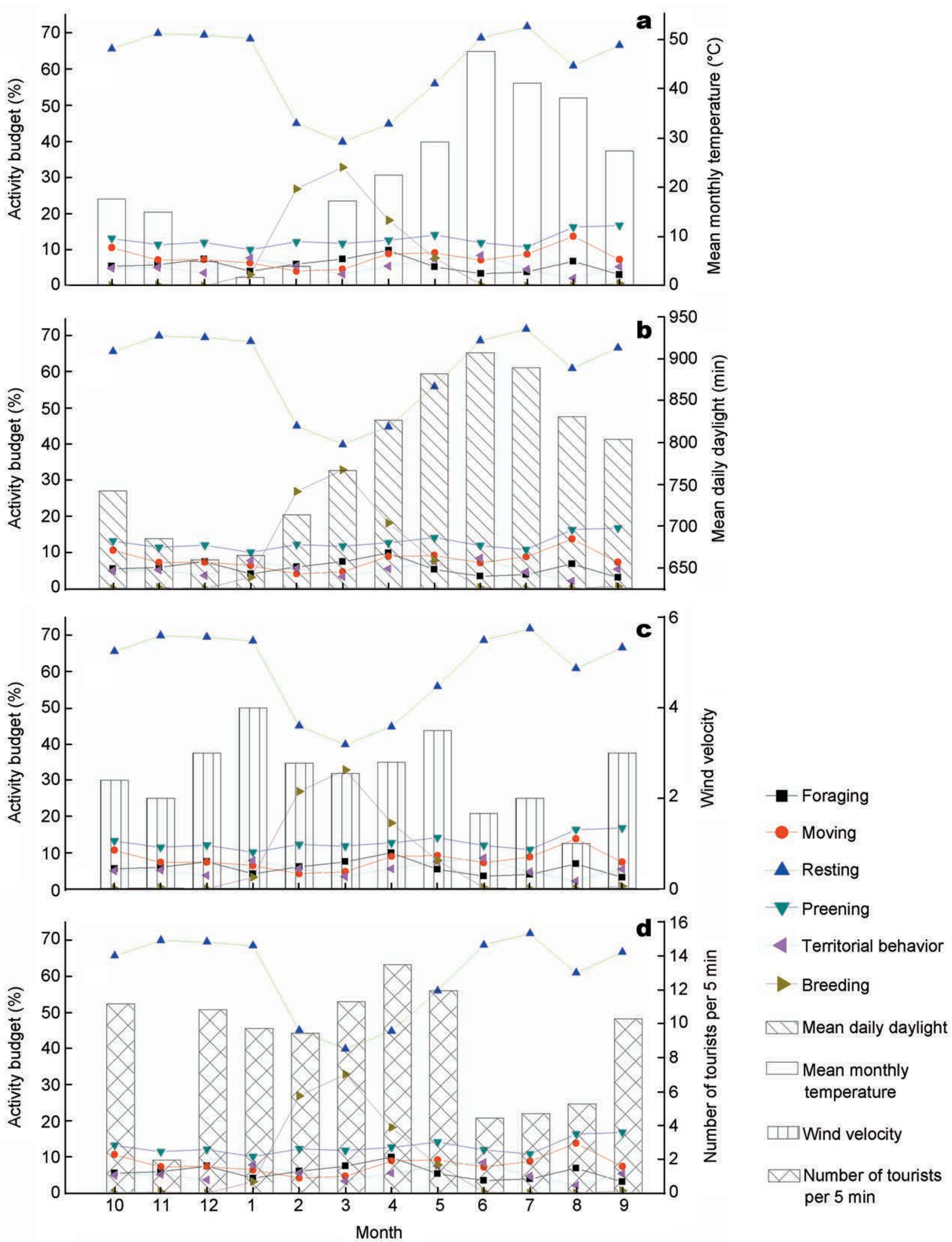

Fig. 2 Relationship analysis of factors affecting the behavior of Oriental White Storks from October 2005 to September 2006 in Hefei Wildlife Park. The factors affecting behavior consist of the following: (**a**) mean monthly temperature; (**b**) mean daily daylight; (**c**) wind velocity; (**d**) mean number of tourist recorded every five minutes.

suggests greater frequency of defensive calls are recorded with less space (Hughes, 1997). Our results also showed that Groups 1 and 2 spent 6.59% and 6.90% of their time on defensive behavior, respectively (Table 1), with both times much higher than the 2.05% spent by the Oriental White Storks in a cage (dimensions of the cage: 4 m long × 3 m wide and 7 m in height (Liu et al., 2001). The preening behavior in Group 1 was 14.05%, 13.46% in Group 2 and 10.63% in Group 3 of the total behavior time which was higher than similar behavior of storks in a cage (8.9%, reported by Tian et al. 2005). This means that elastic behavior increases with increased space. However, the time spent on maintenance behavior (foraging and moving) for Groups 1, 2 and 3 were 14.13%, 13.27% and 13.49% respectively (Table 1), i.e., quantitatively similar to that of captive storks (13.5%, reported by Liu et al., 2001). But, the wild storks at Wuchang Lake spent 61.8% of their time foraging and moving (Yang et al., 2007). The foraging time spent by the storks in our semi-natural enclosure during this study, i.e., 6.33% for Group 1, 6.25% for Group 2 and 5.36% for Group 3 (Table 1) and in a cage (6.4%, reported by Tian et al. 2005) were much lower than those of wild storks in Anqing. Previous research on the White Stork (*Ciconia ciconia*), a sister species of the Oriental White Stork, showed that the digestive efficiency of males and females differed in terms of time spent on foraging (Kwiecinski and Tryjanowski, 2009). The differences in foraging time were not recorded for the Oriental White Stork ($F_{94,2}= -0.74$, $p > 0.05$; Table 2). Food availability was probably the key factor that prevented such a difference since food was provided by humans (Whittingham et al., 2000). Therefore, there was no relationship between maintenance behavior and enclosure size.

When the temperature is high in the winter, the birds would spend more time in foraging for energy supplements. But when the temperature is very low, the increasing time spent on foraging may lead to greater energy loss than energy intake on the part of these birds. It is the reason why birds make trade-offs between feeding activity and energy loss (Cherel et al., 1988). Previous research on White Storks found that these birds would reduce time spent on foraging and moving in order to achieve the least energy loss in winter (Mata et al., 2001). In contrast, when the temperature was high, birds would increase the amount of time spent on foraging for energy intake. Our results indicated that defensive, preening and resting behavior are positive correlated with temperature (Fig. 2a); hence we speculated that temperature is an important factor for regulating the behavior of the Oriental White Stork. When the temperature is outside the usual threshold (too high or too low), this stork decreases the time spent on elastic behaviors (breeding, defensive and preening) and increase time on maintenance (moving and foraging) for a balance in energy consumption.

Human activities affect animal behavior by inducing negative social or physiological consequences (Thomas et al., 2003; Yasue, 2005). Hou et al. (2007) found that the Oriental White Stork in the wild tolerates human presence at a distance of 87.6 m for warning and 50.7 m to escape, but when the intensity of human disturbance increased or the distance between animals and people decreased, birds would give up foraging in order to escape. The Oriental White Storks in the semi-natural enclosure were disturbed by human activities. We found that breeding, foraging, preening, resting and defensive behavior was affected by human activities (Fig. 2d). One way of minimizing the interference of visitors is to increase the distance between visitors and storks and to teach visitors about the negative impact they might have on these birds in zoos and aviaries.

The size of the enclosure, human disturbance and environmental factors (temperature and daylight) affect the activity budget of the Oriental White Stork, hence more space and less human disturbance should be emphasized for this species in zoos.

Acknowledgements We would like to extend our sincere thanks to Hao JIANG, director of Hefei Wildlife Park, for his help on the behavior samples collection. We also thank Prof. Shengxian ZHONG for his help in correcting our English-language manuscripts. This research was supported by the National Natural Science Foundation of China (Grant No. 3087317, 30470257) and the Anhui Academic and Technical Leaders Fund.

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半圈养环境下东方白鹳的行为适应性研究

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摘要：环境因素会影响到动物行为的表达。圈养环境和野生环境相比，活动空间小、种群密度高，且人为干扰强度大。动物在圈养环境下往往表现出较多的刚性行为而丧失许多弹性的行为，并出现一些刻板行为，这可能导致动物在圈养条件下繁殖失败或存活率较低，还会影响到以后将其再引入到野外环境下的成功率。为了了解东方白鹳（*Ciconia boyciana*）在圈养环境下的现状，以及影响圈养个体的受胁因素，我们于 2005 年 10 月至 2006 年 9 月，在合肥野生动物园，对环境因子、人为干扰和自身繁殖周期等因素与行为之间的相关性进行了研究，通过瞬间扫描取样法采集行为数据。结果表明：繁殖多代组（组 1），繁殖一代组（组 2）和非繁殖组（组 3）相比，维持行为（觅食和运动）的比例没有变化，但是弹性行为（防御、理羽及繁殖）的比例在 3 组之间存在差异。相对于繁殖组，非繁殖组呈现出较少的弹性行为。同时，由于不同季节环境温度、人为干扰、日照时间的变化，使得不同行为的时间分配也随之发生变化。通过对东方白鹳在半圈养条件下行为时间分配和环境因子的相关性研究，希望能为这一濒危物种未来的保护提供基础数据。

关键词：东方白鹳，时间分配，人为干扰，再引入