



Time Budget and Activity Rhythm of the Mandarin Duck *Aix galericulata* in the Poyang Lake Watershed

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ABSTRACT

From January to March 2016, and in November 2016, we examined the effects of sex and ambient temperature on how time was budgeted, and activity rhythms were established in wintering Mandarin Ducks (*Aix galericulata*). This was done using instantaneous scan sampling in the Poyang Lake watershed in the Jiangxi province, China. The results showed that the Mandarin Ducks' predominant behaviors were resting (36.56%), swimming (21.75%), foraging (20.88%), and maintenance (15.58%), indicating that during the winter, Mandarin Ducks spend most of their time accumulating energy. Mandarin Ducks reduced their energy consumption by increasing time spent on resting behavior. Females spent more time resting than the males, and less time on maintenance and vigilance. No significant difference was found in the allocation of time to different behaviors under different ambient temperatures. Foraging behaviors peaked in the morning (10:00–10:59) and afternoon (15:00–17:30), which is like the foraging strategies of most Anseriformes. Mandarin Ducks increased their foraging time in the mornings and afternoons to get maximal energy for the long cold nights. Occurrences of foraging and swimming behaviors showed similar patterns, because foraging was often accompanied by swimming to find suitable foraging sites. The pattern of resting behaviors was opposite to that of swimming. Sex had little effect on daily activity rhythms, mainly because both were involved in the same tasks to support similar requirements.

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Authors' Contribution

ZYJ, CP and SMQ designed and wrote the paper. ZYJ and CB collected and analyzed the data.

Key words

Poyang Lake, Mandarin duck, Time budget and rhythm, Sex, Temperature.

INTRODUCTION

Time and energy spent on various activities can influence survival in birds (Orlans, 1961). Every species has its own suitable time budget and behavioral rhythm, and those with optimal budgets and rhythms are favored by natural selection (Caraco, 1979; Shao *et al.*, 2018). Knowledge about how time is budgeted by different birds is important for understanding their optimal time utilization patterns and adaptive strategies (Zhao *et al.*, 2013; Wu and Xu, 2017). Multiple factors affect the time budgets and rhythms of birds, including: temperature (Zeng *et al.*, 2013), time (Zhao *et al.*, 2013), water levels (Li *et al.*, 2013; Shao *et al.*, 2018), sex (Zeng *et al.*, 2013), and age (Jiang *et al.*, 2015b; Shao *et al.*, 2018). The Mandarin Duck (*Aix galericulata*) belongs to the Anatidae of Anseriformes and is the only species of the *Aix* genus distributed in China (Ruan, 1995). Mandarin Ducks were listed as an endangered species by Birdlife International in 2000, and since have been paid increasing levels of attention. It is also listed in the second category of the nationally protected wild species in China (Wang, 2011). It breeds mainly in Russia, Northern China,

and Japan. Wintering areas include eastern China, western and southern China, and Korea (Shurtleff *et al.*, 1997; Zhao, 2001). In recent years some Mandarin Ducks have also been found to breed in their wintering areas in Wuyuan and Jingan Counties in Jiangxi Province. Previous studies of wintering Mandarin Ducks analyzed topics of breeding ecology (Jin *et al.*, 2010; Wang, 2011), nest site selection (You *et al.*, 2017), and wintering habitat selection (Zhong and Chen, 1992). However, little is known about the behavioral ecology of this species during winter (Ruan, 1995). The behavioral strategies and influencing factors are unknown, because data are scattered and short-term in nature. More data need to be collected to explain these birds' behavioral mechanisms across their wide wintering range. Thus, the objectives of this study were to (1) provide basic data on time budget and daily rhythm of wintering Mandarin Duck in the Poyang Lake watershed; (2) reveal the effects of sex and temperature on this species' time budget and daily rhythm, and understand the survival strategy in their wintering area.

MATERIALS AND METHODS

Study area

Poyang Lake is the largest freshwater lake in China. It is formed by the Ganjiang, Fuhe, Xiuhe, Xinjiang, and

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Raohe rivers (Jiang *et al.*, 2015a; Shao *et al.*, 2018). The study area in Wuyuan County is in the Raohe river region of the Poyang Lake watershed in Jiangxi Province, China. The annual average temperature is 16.7°C and the annual precipitation is about 1816 mm. The area has a humid, subtropical climate (Wang, 2014; Jiang *et al.*, 2015a). Our study investigated Mandarin Ducks that were mostly active in an approximately 5 km section of the river section, which varied in width from 120 to 170 m. The vegetation was dominated by mixed mountain forests that provided high coverage. The dominant trees included *Pterocarya stenoptera*, *Liquidambar formosana*, *Castanopsis carlesii*, *Pinus massoniana*, some scattered bamboo forests, and others. Mandarin Ducks liked to rest among shallow shoals scattered in the water and forage around the shoals. This waterbird was difficult to spot amongst the dense forest and scattered shoals. We studied a population of about 35 Mandarin Duck individuals during one wintering period. Sympatric Anseriformes in this river included: Scaly-sided Merganser (*Mergus squamatus*), Chinese Spot-billed Duck (*Anas poecilorhyncha*), Mallard (*Anas platyrhynchos*), and others (Shao *et al.*, 2013). About 100 Chinese Spot-billed ducks and 20 Scaly-sided Merganser birds coexisted with the Mandarin ducks during the wintering period. These two species may be strong competitors for Mandarin ducks, as they have similar ecological requirements; for example, their rest sites (Fig. 1).

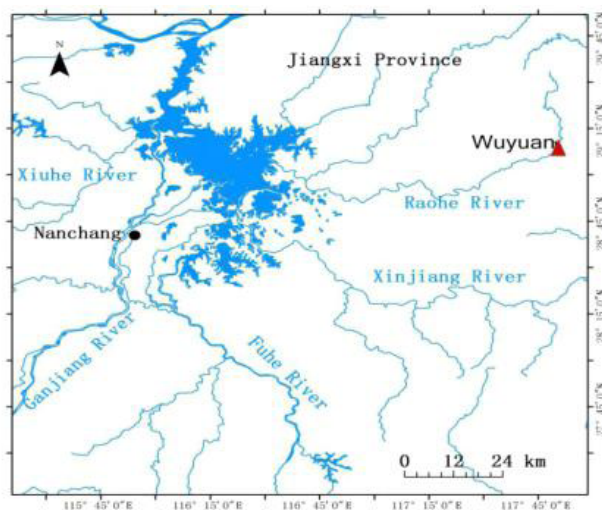


Fig. 1. Study area of Mandarin Duck (*Aix galericulata*).

Data collection

Instantaneous scan sampling with a Swarovski monocular telescope ($\times 20$ – 60) was used to observe the wintering behaviors of the Mandarin Ducks from January to March 2016, and in November of the same year. A total

of 28 days of field investigations were carried out in our study area, made up of 7 days in January; 9 in February; 7 in March; and 5 in November, each from 7:30–17:30. Activities were recorded every 5 min. To estimate the effect of sex and temperature (daily minimum temperature) on time budgets and rhythms in Mandarin Ducks, we collected and compared data by sex and temperature. Temperature was measured twice within each hour. Through observations and published literature, activities were classified as: foraging, resting, maintenance, swimming, vigilance, flying, social, and walking (Table I) (Shao *et al.*, 2010).

Table I.- Definitions of various behavior types of the Mandarin Duck *Aix galericulata* during wintering period.

Behavior classification	Definition
Foraging	Surface feeding, diving feeding, catching or swallowing food
Resting	Loaf, sleeping such as bill tucked under wing
Maintenance	Preening, stretching, bathing and flapping
Swimming	Rapid or slow movement in the water with no foraging behavior
Vigilance	Looking around and warning
Flying	Flying away to other place
Social	Chase or attack each other
Walking	Walking on the ground

Data analysis

We divided the temperature data into three types: $<6^{\circ}\text{C}$, 6 – 12°C , and $>12^{\circ}\text{C}$ according to the minimum temperature on the day that the data was obtained. A Kolmogorov-Smirnov test was used to examine if the values collected for percentages of time spent on different behaviors fitted a normal distribution. If the data fitted a normal distribution, we tested the differences between each group using a one-way ANOVA. The Kruskal-Wallis H test was used if the data did not fit a normal distribution (Chen *et al.*, 2015). All our results are expressed as mean \pm standard deviation ($\bar{x} \pm \text{SD}$), with $p < 0.05$ considered to be significant. Statistical analyses were conducted in MS Excel 2010 and SPSS 22.0.

RESULTS

Time budget

From a total of 28 days of behavioral observations, we recorded 12146 behavioral events (males accounting for 6215 of these, and females: 5931). Resting (36.56%), swimming (21.75%), foraging (20.88%), and maintenance

(15.58%) were the main wintering behaviors of the Mandarin Ducks. These four behaviors accounted for 94.77% of the total wintering behaviors for both sexes combined (Fig. 2).

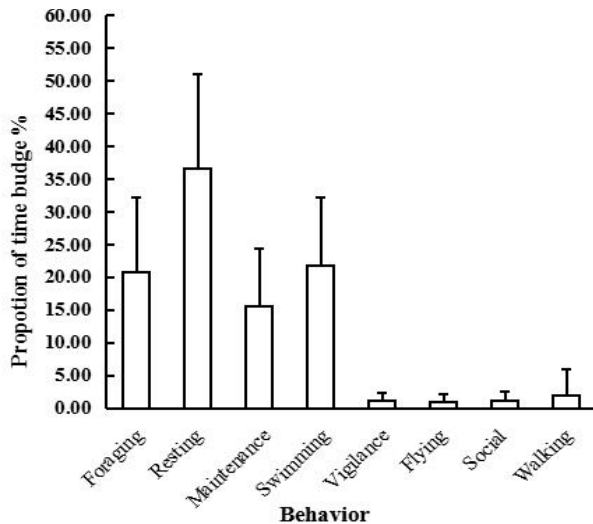


Fig. 2. Time budget (%) of wintering Mandarin Duck.

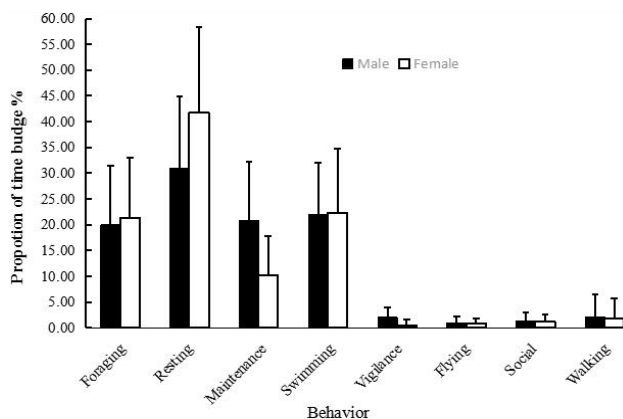


Fig. 3. Time budget (%) of wintering Mandarin Duck among different sex.

Effect of sex on time budget

As described above, males and females shared predominant behaviors of resting, swimming, foraging,

and maintenance. In males, these behaviors accounted for 93.67% of their total behaviors, and 95.66% of the females' (Fig. 3). Females spent more time resting than the males (females: $41.83 \pm 16.45\%$; males: $30.88 \pm 14.02\%$; $\chi^2 = 9.796$, $df = 1$, $P = 0.002$). Conversely, males spent more time on maintenance (females: $10.12 \pm 7.63\%$, males: $20.81 \pm 11.34\%$; $F = 16.783$, $df = 1$, $P = 0.000$) and vigilance (females: $0.47 \pm 1.11\%$, males: $2.04 \pm 1.92\%$, $\chi^2 = 18.016$, $df = 1$, $P = 0.000$).

Effect of temperature on time budget

The effects of temperature on time budgets of Mandarin Duck behaviors are listed in Table II. No significant difference was found under different temperatures.

Behavior rhythm

The proportion of time spent resting had an obvious peak from 12:00–12:59 and troughs from 10:00–10:59 and from 15:00–15:59. Foraging had two peaks in the day: from 10:00–10:59 and from 16:00–17:30, and one trough from 12:00–12:59. The proportion of time spent on maintenance peaked between 14:00 and 14:59. Time spent swimming peaked first from 10:00–10:59, then reached a trough from 12:00–12:59, before reaching a second peak from 15:00–15:59. Other behaviors showed no obvious peaks and troughs (Fig. 4).

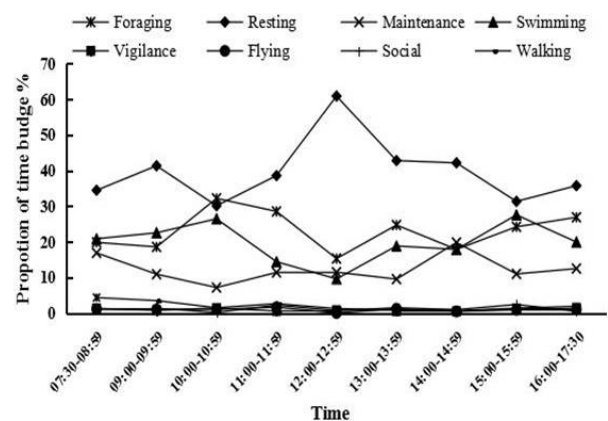


Fig. 4. The overall behavior rhythm of wintering Mandarin Duck.

Table II.- Time budget (%) of wintering Mandarin Duck under different temperature.

Temp.	Foraging	Resting	Maintenance	Swimming	Vigilance	Flying	Social	Walking
<6°C	17.60±8.07	31.65±9.18	18.63±4.16	26.71±7.35	1.53±0.40	1.69±0.45	1.36±0.54	0.82±3.26
6°C -12°C	18.51±7.26	41.69±10.08	14.46±4.21	20.50±7.56	0.87±0.32	0.68±0.45	0.76±0.27	2.54±3.26
>12°C	29.43±7.57	36.95±12.46	12.40±5.27	15.76±7.07	0.74±0.39	0.43±0.52	1.47±0.39	2.82±0.92

The rhythms of resting, foraging and swimming behaviors appeared to have similar peaks and troughs between the males and females. Maintenance behavior in males had two peaks from 7:30–8:59 and 14:00–14:59, contrasted with females, who had one peak between 14:00 and 14:59 (Fig. 5).

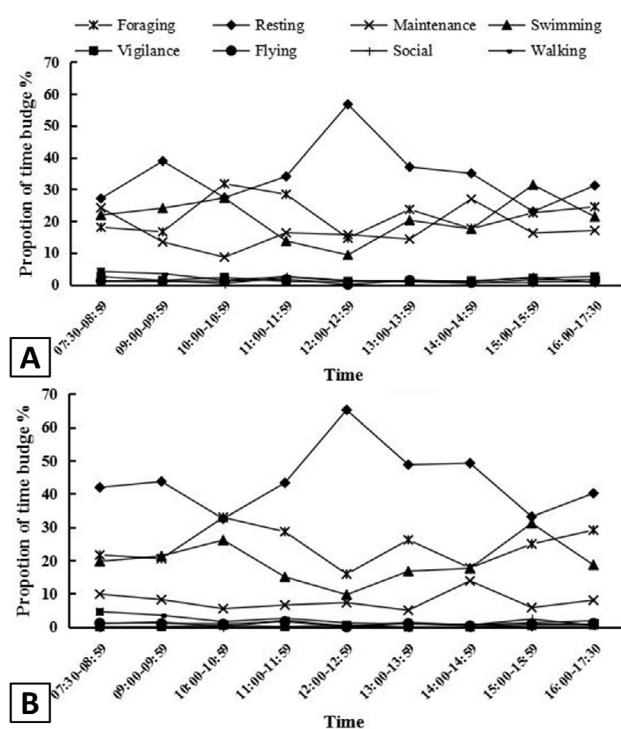


Fig. 5. The behavior rhythms of wintering male (A) and female (B) Mandarin Duck.

DISCUSSION

Main wintering behaviors

The main behaviors of Mandarin Ducks were resting, swimming, foraging, and maintenance, with resting making up the highest proportion. Studies on the Tundra Swan *Cygnus columbianus* (Shao *et al.*, 2018), Whooper Swan *Cygnus cygnus* (Dong *et al.*, 2015), and Mute Swan *Cygnus olor* (Meissner and Ciopcińska, 2007), also showed that resting accounted for the largest proportion of all the behaviors during the wintering period. This indicates that these birds and Mandarin Ducks share a strategy of increasing their resting time to cut down on energy consumption. While studies of the Sided-scaly Merganser (Yi *et al.*, 2010), Bar-headed Goose *Anser indicus* (Yang *et al.*, 2012), and Greater White-fronted Goose *Anser albifrons* (Owen, 1972), showed that foraging was the most frequent behavior in these birds. This suggests that these birds increase their energy storage by spending more

time on foraging. In this study, Mandarin Ducks spent a similar proportion of their time foraging as the Ferruginous Pochard *Aythya nyroca* (Muzaffar, 2004), and less than that of the Tundra Bean Goose *Anser fabalis* (64%) (Liu, 2011), Swan Goose *Anser cygnoides* (60.2%) (Zhang, 2009), and Tundra Swan (30.52%) (Shao *et al.*, 2018). Differences among these waterfowl are likely related to body size. The large-sized waterfowls, such as Tundra Bean Goose (3 kg), Swan Goose (3.9 kg), and Tundra Swans (5.5 kg) all exceed 3 kg. In comparison, other birds, such as Mandarin Ducks (0.5 kg) and Ferruginous Pochards (0.75 kg) are much smaller (Zhao, 2001). The small ducks spent a lower proportion of time on foraging due to less energy consumption. The swimming behavior of Mandarin Ducks was often accompanied by their foraging behavior (Yi *et al.*, 2010). Mandarin Ducks in this study spent more time foraging (20.88 %) and swimming (21.75%) than that of the same species in Fujian Province (foraging: 8.9%; swimming: 14.60%). This indicates that Mandarin Ducks in our study area spent more time foraging and seeking food, which might be related to differences in food resource availability and climate (Ruan, 1995; Yi *et al.*, 2010).

Effects of sex and temperature on time budget

Males and females spent different proportions of time on the main behaviors: resting, maintenance, and swimming. This differed from the result found for the Scaly-sided Merganser (Zeng *et al.*, 2013). These differences may be explained by one of the following: (1) females had to store more energy to prepare for their breeding in the following year and so they spent similar amounts of time on foraging and more time on resting behaviors; (2) male Mandarin Ducks needed to attract the females, so they spent more time on maintenance; and (3) male Mandarin Ducks performed the task of vigilance in the group, and so spent more time being vigilant (Zeng *et al.*, 2013).

Environmental factors affect animal behaviors, of which temperature has been found to have a very important effect on bird activities (Zeng *et al.*, 2013). Over the course of their evolution, birds have developed multiple regulation mechanisms to adapt to cold weather. Some birds improve their metabolic rate under low temperatures to benefit from a balance in body temperature (Qian and Xu, 1986). Other birds cut down on their energy consumption and heat loss by reducing their activity (Verbeek, 1964; Siegfried, 1974; Tian *et al.*, 2005). Studies on the Little Grebe *Tachybaptus ruficollis* and Great Crested Grebe *Podiceps cristatus* have shown that these birds spend more time on foraging during the latter stages of winter to accumulate enough energy for migration and breeding in the spring (Chen *et al.*, 2015). Our results did not find any significant difference

in time allocated to different behaviors under different temperatures.

Behavior rhythm

A pattern of two foraging peaks during the day is common in many birds (Boxall and Lein, 1989; Gibb, 2010; Dong *et al.*, 2015). This pattern could help birds prepare appropriately for overnight energy consumption requirements. Mandarin Ducks in our study had two foraging peaks. Tundra and Whooper Swans have also been found to have two foraging peaks (Yang, 2013; Dong *et al.*, 2015), whilst the Scaly-sided Merganser has three; indicating that waterfowl have multiple wintering strategies (Yi *et al.*, 2010). Mandarin Ducks and Whooper Swans cut down their energy consumption by resting more, while the Scaly-sided Merganser enhances their energy stores by adding a foraging peak. The foraging peak (10:00–10:59) of the Mandarin Ducks differed from that of the sympatric Scaly-sided Merganser (9:00–9:59). These two species with different foraging peaks could reduce inter-specific competition through niche separation (Zeng *et al.*, 2013). Compared with the foraging peak of White-headed Ducks *Oxyura leucocephala* (7:00–9:00), Mandarin Ducks and Scaly-sided Mergansers in our study area delayed their foraging peaks. In the case of White-headed Ducks, they had to avoid peaks in human disturbances (Zhao *et al.*, 2013). In our study area, the dense forests on both banks of the river provided safe environments for the two species. On the other hand, Mandarin Ducks and Scaly-sided Mergansers had relatively low overnight energy consumption due to the mild weather. In addition, fog in the morning resulting in poor light intensities reduced the foraging efficiency of the Mandarin Ducks and Scaly-sided Mergansers. Swimming behaviors showed similar variations in rhythm to the foraging behaviors, because foraging was often accompanied by swimming. The resting behavior peaks and troughs of Mandarin Ducks were opposite to that of its swimming behavior. Mandarin Ducks spent more time resting at noon, after they had gained enough energy in the morning from foraging and swimming. This bird could keep its body temperature up with the help of sunlight at noon (Zeng *et al.*, 2013). Daily behavioral rhythms had no significant differences between males and females, indicating that sex had little effect on behavioral rhythms in this bird. Both males and females performed the same tasks and demonstrated similar requirements during their wintering period.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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