



Sex Ratio, Habitat Selection and Foraging Behavior of Mandarin Duck in Water Systems of Poyang Lake, China

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ABSTRACT

From February to March 2017, November 2017 to March 2018 and November 2018 to March 2019 we used the point count method to survey the sex ratio, habitat selection and foraging behavior of Mandarin duck (*Aix galericulata*) in water systems (Raohe River, Ganjiang River and Xiuhe River) of Poyang Lake, Jiangxi Province, China. We recorded 162 individuals and determined 141 by gender: the sex ratio was 1.07. There was no significant male bias ($n = 141$, $p = 0.210$). Habitat selection results indicated that Mandarin duck tended to choose habitat with vegetation cover (2.40 ± 0.84) on riverbanks, with shoal proportions of $8.00 \pm 6.00\%$, water velocity of $0.16 \pm 0.12\text{m/s}$ and wider river widths of $190.90 \pm 113.80\text{m}$. The foraging habitats were far from sources of disturbance such as mine factory (2.70 ± 0.48), village ($286.10 \pm 168.97\text{m}$) and road ($114.50 \pm 105.01\text{m}$). Our study showed that riverbank vegetation ($Z = -2.614$, $P = 0.009$), distance to village ($Z = -2.859$, $P = 0.004$) and road ($Z = -2.085$, $P = 0.037$) in the foraging habitats were significantly higher than in control plots, indicating that Mandarin duck clearly preferred habitats with higher vegetation cover remote from both village and road. Principal component analysis indicated that water flow speed, distance to village, river width, vegetation cover, distance to mine factory and shoal proportion were the main factors for habitat selection. The results suggested that safety was the primary factor in habitat selection. The main foraging method was up-ending (61.54%); the duration of each up-ending foraging behavior was $1.92 \pm 0.83\text{s}$ and foraging frequency was $14.67 \pm 4.43\text{times/min}$. This foraging strategy may be determined by food distribution and morphological structure.

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Authors' Contribution

SMQ designed and revised the paper. HWY, ZYJ and SMQ collected and analyzed the data. HWY wrote the paper.

Key words

Water system of Poyang Lake, Mandarin duck, *Aix galericulata*, Habitat selection, Foraging behavior

INTRODUCTION

Anseriformes, an important ecological group of water birds, are very sensitive to wetland changes and can act as an indicator species of wetland environmental quality. Previous studies of Anseriformes include population size and distribution (Fang *et al.*, 2019a), foraging behaviors and foraging habits (Hill and Eills, 1984; Liu, 2011; Cervencel and Fernandez, 2012), habitat selection (Nummi and Pöysä, 1995; Sun *et al.*, 2018), overwintering ecology (Yang, 2013) and breeding ecology (Wang *et al.*, 2019). Factors influencing habitat selection of Anseriformes include topography and geomorphology (Nummi and Pöysä, 1995), vegetation (Sebastián *et al.*, 2013), disturbance factors (Sun *et al.*, 2018) and shelter factors (Fan *et al.*, 2017). Habitat selection may change with season (Sebastián *et al.*, 2013). The foraging behavior of Anseriformes is affected by factors such as food abundance (Cervencel and Fernandez, 2012), age (Yang, 2013), gender (Hill and Eills, 1984) and water depth (Yang, 2013). Studies of Anseriform habitat selection and

foraging behavior are very significant in habitat management and bird conservation.

The Mandarin duck (*Aix galericulata*) belongs to the Anatidae family of Anseriformes, and its global population is estimated as 65,000–66,000 individuals. Mandarin duck is listed in the second category of the nationally protected wild species in China. It breeds mainly in eastern Russia, Japan, Korea and northern China, and overwinter mainly in Burma, northeastern India and the Yangtze river in China. It occasionally breeds in the wintering areas of Fujian, Yunnan and Guizhou, China (Fang *et al.*, 2019a). Studies of Mandarin duck include population size and distribution (Fang *et al.*, 2019a), behaviors (Fang *et al.*, 2019b) and breeding ecology (Jin *et al.*, 2010; You *et al.*, 2017). Behaviors in the overwintering stage have been studied (Yang, 2013), but there is no research into the habitat selection and foraging behavior of Mandarin duck in the water system of Poyang Lake. Thus, the objective of our study was as follows: (1) to establish the factors influencing habitat selection of Mandarin duck; and (2) to understand its foraging behavior strategy. The results will provide basic data on habitat use and foraging behavior strategy of Mandarin duck in the water system of Poyang Lake, and provide a scientific basis for habitat management and future protection of the species.

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MATERIALS AND METHODS

Study area

Poyang Lake (115°49' E–116°46' E, 28°11' N–29°51' N), located in the North Jiangxi Province, is the largest freshwater lake in China. Five river systems (Xiuhe River, Ganjiang River, Fuhe River, Xinjiang River, Raohe River) and their tributaries, combined with Poyang Lake, form a radial water system known as the water system of Poyang Lake (Yu *et al.*, 2011). The basin area of the water system of Poyang Lake is 162,200 km², equivalent to 97% of the land area of Jiangxi Province (Zhou *et al.*, 2018). The study area has a subtropical monsoon climate, with an average annual temperature of 16.3–19.5 °C; frost-free periods range from 240 to 307 days; and the duration of daily temperature stability over 10 °C is 240–270 days. The basin has typical subtropical forest plant communities and abundant bird resources. This research area located in some river sections in Ji'an, Wuyuan, Xiushui and Jingdezhen. The vegetation was dominated by bamboo forests, coniferous forests, and by mixed broadleaf and coniferous forests. The water was clear and had a relative large velocity.

Bird surveys

From February to March 2017, November 2017 to March 2018, and November 2018 to March 2019, we used a point count method in the river sections of the Raohe River (Jingdezhen and Wuyuan), Ganjiang River (Ji'an) and Xiuhe River (Jing'an) in the water system of Poyang Lake. Observations were made using binoculars (×8) and monoculars (×20–60), and the number and gender of Mandarin duck were then recorded. A total of 19 sample points (10 habitat points and 9 control points) was selected in the survey, along a total length of approximately 141 km. Among them, 10 samples (5 habitat points and 5 control points) were selected for the Raohe River, with a length of approximately 70 km; 6 samples (3 habitat points and 3 control points) were selected for the Ganjiang River section, with a length of approximately 35 km; and 3 samples (2 habitat points and 1 control points) were selected for the Xiuhe River section, with a length of approximately 36 km (Fig. 1). After we found foraging Mandarin duck, seven habitat parameters were recorded (Table I). Within the range of 2–5 km from the foraging habitat, we also selected the regions where Mandarin duck have never been found in recent years, as control plots, and recorded the corresponding data. The foraging pattern, behavior duration of each foraging event, foraging times and foraging interval of Mandarin duck were recorded by animals focus sampling. The foraging patterns of Mandarin duck were divided into

(1) feeding from the water surface; (2) dipping with only head submersed; (3) dipping with head and neck submersed; and (4) up-ending (tipping-up/tilting, foot stamping) (Tatu *et al.*, 2007).

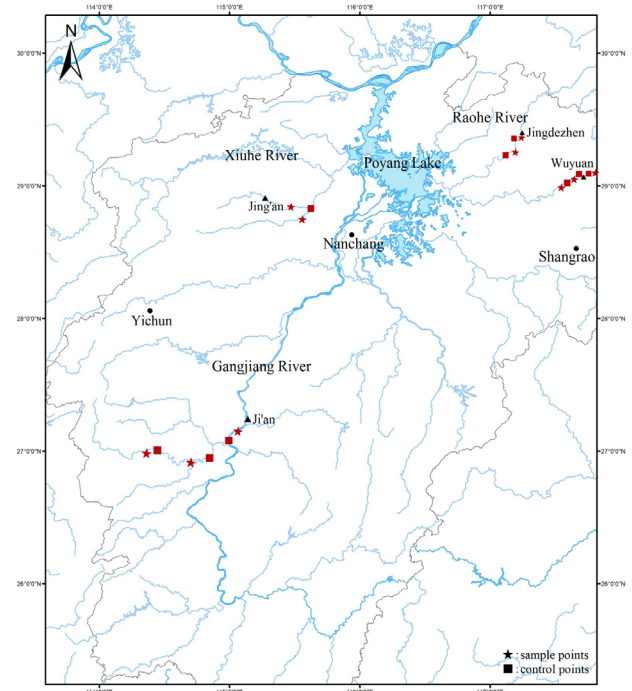


Fig. 1. Locations of the survey areas in three rivers of Poyang Lake.

Data analysis

A binomial distribution test was used to examine if sex ratio (♂:♀) of Mandarin duck significantly showed. If the data fitted normal distribution, we compared differences in habitat factors between habitats and control plots using the independent sample t-test. If the data did not fit, the Mann–Whitney U test was used. Factors determining habitat selection of Mandarin duck were identified using principal component analysis (PCA). Values were expressed as means ± standard deviation at the $\alpha=0.05$ significance level. Statistical analyses were completed using Excel 2016 and SPSS 21.0.

RESULTS

A total of 162 Mandarin duck was recorded in this survey, with a sex ratio of 1.07 ($n=141$). Sex ratio was 0.79 ($n=73$) in Wuyuan; 1.50 ($n=50$) in Ji'an; and 1.25 ($n=18$) in Jing'an. The binomial distribution test indicated that there was no significant bias in the three regions or in the overall sex ratio (Table II).

Table I. Habitat parameters and measurement methods.

Habitat parameters	Measurement
Water flow speed (m/s)	Measured by stopwatch, the time for a floating object to move 1 m was recorded (mean of 5 consecutive recordings).
River width (m)	Distance between the two banks of the river.
Vegetation cover of riverbank	Vegetation cover of riverbank within 20×20 m plots centered on a habitat of Mandarin duck, estimated by eye. We divided vegetation cover into three ranks: 1 (<10%); 2 (10%–20%); and 3 (>20%).
Shoal proportion (%)	Shoal proportion within 20 × 20 m plots centered on the Mandarin duck, measured by eye.
Distance to mine factory	Distance to the nearest mine factory from the watercourse center. We divided distances into three ranks: 1 (<250 m); 2 (250–500 m); and 3 (>500 m).
Distance to village (m)	Distance to the nearest village from the watercourse center.
Distance to road (m)	Distance to the nearest road from the watercourse center.

Table II. Population and sex ratio of Mandarin duck in Poyang Lake water system.

Survey site	Population	Male	Female	Sex ratio	n	p
Wuyuan	88	33	40	0.83	73	0.483
Ji 'an	52	30	20	1.50	50	0.203
Jing 'an	18	10	8	1.25	18	0.815
Jingdezhen	4	—	—	0.00	—	—
Total	162	73	68	1.07	141	0.210

Note: Some individuals did not distinguish gender.

Habitat selection

Mann–Whitney U tests showed that vegetation cover of two banks ($Z=-2.614$, $P=0.009$), and the distance to village ($Z=-2.859$, $P=0.004$) and road ($Z=-2.085$, $P=0.037$) were significantly higher than in the control plots, and there were no significant differences in other parameters (Table III).

The first two components met the criterion of

eigenvalue > 1 and the third (0.981) was close to 1; together they explained 81.26% of the variance in habitats by using the PCA method. This result indicated that the first three principal components contained most messages of habitat parameters and may reflect the habitat selection of Mandarin duck (Table IV). The contribution rate of the first principal component was 38.28%, and the absolute value of factor load mainly included water flow speed and distance to village. These factors were related to water environment and distance to disturbance. The contribution rate of the second principal component was 28.95%. The factors with larger absolute value of factor load included river width, vegetation cover of riverbank and distance to mine factory, and these were related to shelter. The third principal component contribution rate was 14.02%, and the shallow shoal proportion had the highest absolute value of factor loading (Tables IV and V). Comprehensive analysis of the above factors indicated that the safety factors (shelter and disturbance) were the most important in determining habitat selection by the Mandarin duck.

Table III. Comparison of habitat parameters between foraging habitats and control points for Mandarin duck.

Parameters	Habitats (n=10)		Control plots (n=9)		Z	P
	Mean	SD	Mean	SD		
Water flow speed (m/s)	0.16	0.12	0.09	0.09	-1.239	0.215
River width (m)	190.90	113.80	142.11	70.67	-0.939	0.348
Vegetation cover of riverbank	2.40	0.84	1.33	0.50	-2.614	0.009*
Shoal proportion (%)	8.00	6.00	5.00	7.00	-1.281	0.200
Distance to mine factory	2.70	0.48	2.78	0.67	-0.804	0.421
Distance to village (m)	286.10	168.97	75.44	72.94	-2.859	0.004*
Distance to road (m)	114.50	105.01	42.67	61.70	-2.085	0.037*

Note: * There are significant differences between foraging habitat and control plots.

Table IV. Eigenvalues and contribution rates of habitat selection factors of Mandarin duck ($n=10$).

Principal component	Eigenvalue	Percent of total variance (%)	Percent of cumulative variance (%)
1	2.680	38.28	38.28
2	2.027	28.95	67.24
3	0.981	14.02	81.26
4	0.668	9.55	90.80
5	0.413	5.90	96.71
6	0.185	2.64	99.35
7	0.046	0.66	100.00

Table V. Correlation of habitat variables with the first three principal components derived from habitat selection of Mandarin duck ($n=10$).

Habitat variables	Principal components		
	1	2	3
Water flow speed (m/s)	-0.956	0.111	0.141
River width (m)	-0.117	-0.830	-0.082
Vegetation cover of riverbank	0.237	0.786	0.364
Shoal proportion (%)	-0.049	0.081	0.949
Distance to mine factory	-0.407	0.760	-0.116
Distance to village (m)	0.922	0.160	0.029
Distance to road (m)	0.442	-0.517	-0.468

Foraging behavior

The foraging patterns of Mandarin duck were mainly up-ending (61.54%), followed by dipping with head and neck submersed (31.25%), feeding from the water surface (11.54%) and dipping with only head submersed (7.69%). The duration of each up-ending foraging behavior was 1.92 ± 0.83 s, the foraging frequency was 14.67 ± 4.43 times/min and the foraging interval was 5.83 ± 3.19 seconds/time.

DISCUSSION

Sex ratio of Mandarin ducks

Donald (2007) indicated that, among 22 species of Anseriformes, the sex ratios of 14 species are male biased and that 8 species are balanced (Donald, 2007). The sex ratios of Common Pochard *Aythya ferina* and Baer's Pochard *A. fuligula* in Northern Ireland are 2.57 and 1.94, respectively (Evans and Day, 2001), both of which indicate obvious male skewness. The sex ratios of Common Teal *Anas crecca* and Falcated Teal *A. falcata* in Poyang Lake,

China, are 1.54 and 1.09, respectively. Another study in Poyang Lake indicates that Scaly-sided Merganser *Mergus squamatus* has a sex ratio of 0.66, indicating female bias; this is related to female records, including a number of sub-adults. The sex ratio of Mandarin duck in Taiwan (2.10) (Sun *et al.*, 2011) and northeastern Germany (1.86) (Bellebaum and Mädlow, 2015) indicate male bias. The sex ratio of Mandarin duck in our study was balanced (1.07), and similar to that of Guizhou province (1.14) (Fang *et al.*, 2019b). The possible explanations of different sex ratios include: (1) female and male ducks had different mortality in different regions; (2) males and females arrived in breeding or wintering areas at different times; and (3) males and females did not choose exactly the same habitats.

Habitat selection

The results indicated that, in some river sections, Mandarin duck tended to choose a river with a proper velocity, wider river width, and had higher vegetation cover and shallow banks. They selected foraging habitats far away from disturbance (mine factory, village and road). The greater distance from village and road effectively reduced the interference of human activities, improved the shelter of habitat and guaranteed safety. In addition, moderate water flow can purify water, maintain a good water environment, guarantee the quality of the habitat and provide food. However, water flow that was too fast was not a suitable habitat for Mandarin duck because the turbulence might cause them to consume too much energy when foraging. The wider channels and different shoal size slowed down water speeds. Mandarin duck avoided areas that were too close to the mine factory, because they were easily frightened by the running of machinery and vehicles, and this affected their daily activities.

Food, water and shelter are three of the main factors determining habitat selection by wildlife, and human disturbance has a serious impact on the concealment of habitats (Fleskes *et al.*, 2016). PCA results showed that the primary factor influencing Mandarin duck habitat choice was safety. Safety when foraging and resting was an important factor in Mandarin duck survival during the winter period. They were likely to select habitat that had further distance to village, mine factory, road and higher vegetation cover. In this way, they could avoid the interference of human activities and other animals, and gain more safety habitat. This is consistent with the results of Sun *et al.* (2018), who found that the primary factor affecting night and foraging habitat selection of the Whooper Swan *Cygnus cygnus* is safety (distance to disturbance sources, height of vegetation). Disturbance is the most important factor in foraging habitat selection of

the Bar-headed Goose *Anser indicus* (Yang *et al.*, 2013). Mandarin duck winter activities, such as foraging and resting, are inseparable from the water environment. They have certain water quality requirements, and our PCA results indicated that a suitable water environment was also an essential element of Mandarin duck habitats.

Foraging behavior

Up-ending foraging was the main foraging strategy adopted by Mandarin duck in this study. When using up-ending, they entered the water to approximately 1/4–3/4 of their body length and foraged at a depth of approximately 15.6–42.5 cm (Zhang, 2001). This indicates that Mandarin duck can feed on aquatic plants at some depth. This differs from the Tundra Swan *C. columbianus* in the lotus pond of Poyang Lake, which mainly forages from the water surface and dips with head and neck submersed. The water depth in the foraging area is 8.5–10.5 cm and 27.5–33.75 cm. The Swan Goose *A. cygnoid* mainly forages from the water surface and sediment at a water depth of 7.5–9.9 cm (Zhang *et al.*, 2019). These differences mainly relate to variations in food distribution and the shape of water birds. The Mandarin duck is a medium-sized water bird and can feed on aquatic plants, small fish and shrimps by up-ending feeding (Jiao *et al.*, 2012). However, Tundra Swan and Swan Goose are larger, and mainly feed on plant tubers, roots and zooplankton. The duration of each up-ending foraging event of Mandarin duck (1.92 s) is less than that of Tundra Swan and Swan Goose in the lotus pond (3.92 s and 3.75 s, respectively). The foraging frequency (14.67 times/min) are greater than those of Tundra Swan and Swan Goose (7.18 times/min and 7.37 times/min, respectively) (Zhang *et al.*, 2019). The possible reason for these differences is that Mandarin duck can find and access its small food items easily, so they had greater foraging frequency. Tundra Swan and Swan Goose lived in shallow lotus ponds and had, with difficulty, to dig for (and then clean) their food. The foraging behavior of Mandarin duck recorded in our study only represented a small sample size. The foraging strategy and influencing factors of Mandarin duck in the water system of Poyang Lake need to be studied further.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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