



# Population Size and Sex Ratio of Wintering Scaly-Sided Merganser *Mergus squamatus* in the Poyang Lake Water System, Jiangxi Province, China

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## ABSTRACT

The line transect method was used to examine the population size and sex ratio of the scaly-sided merganser *Mergus squamatus* (the merganser) in four rivers of the Poyang Lake water system, Jiangxi province, China. Spatial and temporal variations in population size were ascertained for this endangered species. The Xiuhe, Fuhe and Raohe river systems exhibited large steady populations, with the maximum size ranging from 25 to 68 individuals for each river. Restoration and maintenance of suitable habitats for the scaly-sided merganser is imminent as the species is at risk of extinction due to its small population size. The total sex ratio of the merganser during the study period was 0.397 ( $n = 790$ ) and the average sex ratio was  $0.43 \pm 0.26$  ( $n = 148$ ) for each group, similar to the results obtained in previous years in Jiangxi province (0.378–0.4588). These data indicate that the wintering sex ratio of the merganser has been relatively steady over this period. The current results also revealed temporal and spatial variation in the sex ratio of mergansers, which is common among other duck species. The lower sex ratio in Xiuhe River indicated that the population in this river may include more sub-adults. Long-term data should be collected to test whether female mergansers are more likely to migrate north. The sex ratio of the merganser exhibited a tendency to decrease gradually from the early to late stages in each river, although only the Raohe River exhibited a significant difference among three stages, possibly due to differences in sexual migration time and mortality. We did not detect significant differences in the sex ratio of the scaly-sided merganser among different group sizes.

## Article Information

Received 22 November 2018

Revised 11 January 2019

Accepted 13 February 2019

Available online 11 April 2019

## Authors' Contribution

SM designed the research project and did the field work and revised the manuscript. ZY did the field work and wrote the manuscript.

## Key words

Population size, Sex ratio, *Mergus squamatus*, Poyang Lake water system, Scaly-sided merganser.

## INTRODUCTION

Population size and sex ratio are fundamental concepts in population demographics, affecting population growth, demography, and extinction (Liker *et al.*, 2014; Shao *et al.*, 2016). Knowledge about the population size and sex ratio within an animal population is important for predicting its population dynamics and sex ratio (Donald, 2007; Shao *et al.*, 2016). Although many previous studies have focused on population size and offspring sex ratios, knowledge about adult sex ratios is lacking. Adult sex ratios have been reported to affect divorce, infidelity, and co-operative breeding (Donald, 2007; Liker *et al.*, 2014). Spatial and temporal variations in sex ratio are common in many bird species because of differences in mortality, migration distance, migration time, and the likelihood of being shot between males and females (Owen and Dix, 1986; Donald, 2007; Sun *et al.*, 2011; Liker *et al.*, 2014; Shao *et al.*, 2016). Previous studies reported that the

adult sex ratio for 131 (65%) of 173 bird species differed significantly from 0.5, with the majority of these species showing positive bias towards males. Thus, among bird species, males appear to outnumber females by approximately 30 to 35%. Research has indicated that bird species categorized by the IUCN as globally threatened or near-threatened showed a significantly more male-skewed distribution (Donald, 2007).

Studies of sex ratios for 22 species of Anatidae revealed that 14 species were male-skewed, while eight species exhibited balanced sex ratios (Donald, 2007). The sex ratio among Anatidae in China remains poorly understood (Qian and Zhu, 1980; Shao *et al.*, 2016). The scaly-sided or Chinese merganser *Mergus squamatus* (the merganser) is regarded as an endangered species by the IUCN (red list of threatened species 2018-2) and listed in the first category of nationally protected wildlife species in China (Zheng and Wang, 1998; Liu *et al.*, 2008; BirdLife International, 2018). The wintering areas of the merganser are widely distributed in the south of the Yangtze River, while the northern area of Jiangxi province provides one of the main wintering grounds for many a species in China. The population is mainly distributed along the Xinjiang,

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0030-9923/2019/0003-1067 \$ 9.00/0

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Fuhe, Raohe and Xiuhe Rivers, and was recently found in Ganjiang River (Shao and Chen, 2017). The merganser prefers to inhabit in the rivers with mountainous forests. Due to human activities such as sand mining and water pollution, some habitat of the merganser has degraded or disappeared. The global population of this species has been estimated at 1,000-2,499 individuals (Shao *et al.*, 2012a, b; Shao and Chen, 2017). Many studies on the distribution and population size, diving behavior, time budgets and rhythm of this bird have been carried out in China (He *et al.*, 2006; Lin *et al.*, 2008; Ren *et al.*, 2008; Wang *et al.*, 2010; Shao *et al.*, 2010a, b, 2012a; Yi *et al.*, 2010; Shao and Chen, 2017). However, the population size dynamics and sex ratio of merganser remain unknown. Increased understanding of population dynamics and sex ratio of this species will provide basic data for conservation efforts. The objectives of the current study were: a) to understand the spatial and temporal variation in population size of the scaly-sided merganser; b) to identify spatial and temporal variation in the sex ratio of this species; and c) to verify the endangered status of this species.

## MATERIALS AND METHODS

### Study area

The population size and sex ratio of the scaly-sided merganser were determined in seven river sections (Xiushui, Jing'an, Yiyang, Longhushan, Yihuang, Fuliang, Wuyuan) of four water systems (Xiuhe River, Fuhe River, Xinjiang River and Raohe River) ( $114^{\circ}39' - 117^{\circ}51'E$ ,  $27^{\circ}34' - 29^{\circ}33'N$ ), at an elevation of 10–90 m above sea level in the Poyang Lake water system, Jiangxi province (Shao *et al.*, 2012a; Shao and Chen, 2017; Zhi *et al.*, 2019) (Fig. 1). The climate in the study area is sub-tropical, with an average annual temperature of  $18^{\circ}C$  and annual precipitation of 1816 mm. The vegetation of this region is dominated by broad-leaved deciduous forest and broad-leaved evergreen forest (Yi *et al.*, 2010; Shao *et al.*, 2012a; Li *et al.*, 2018; Zhi *et al.*, 2019). Common coexisting ducks in our area include the spot-billed duck *Anas poecilorhyncha*, mandarin duck *Aix galericulata*, and common teal *Anas crecca*. We considered the Longhushan section and the Erkou section as one section (Longhushan section) in the current study because these two sections are part of the same river in two counties.

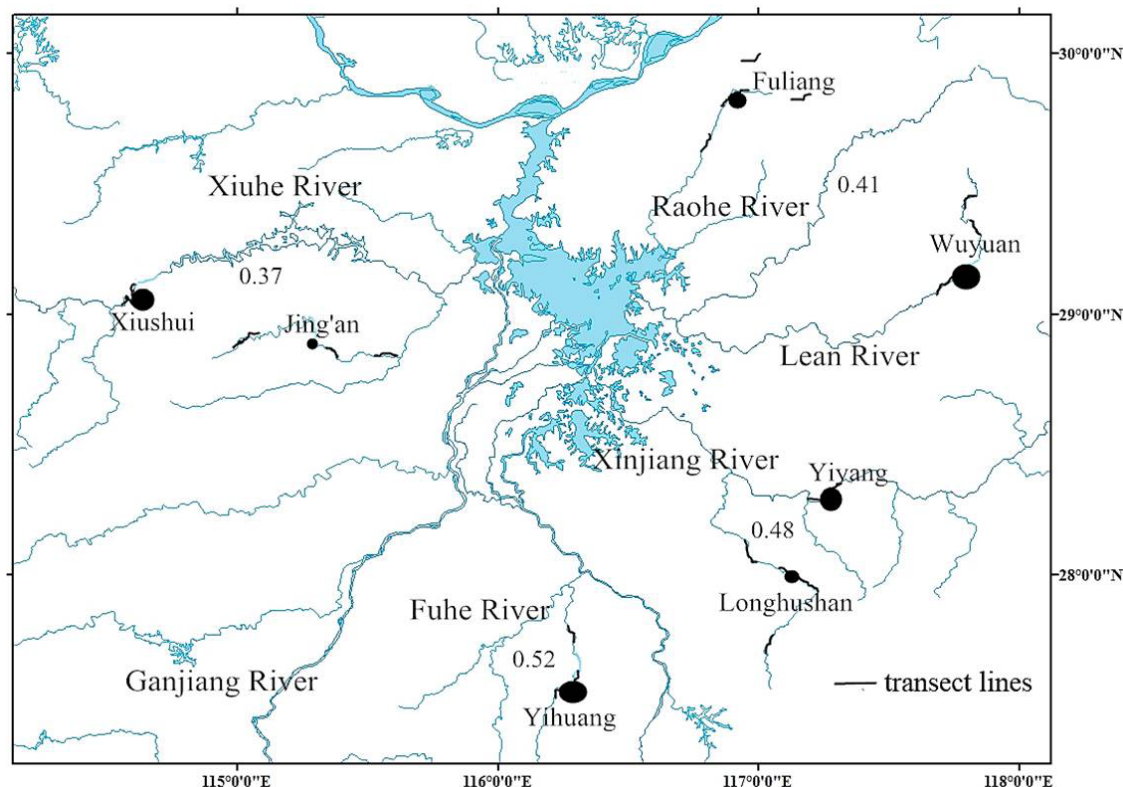


Fig. 1. Distribution of surveyed areas in four rivers of Poyang Lake water system in Jiangxi Province. Number in the map means sex ratio in that river; different-sized points mean different population size in the corresponding proportion. — means transect lines where we investigated the mergansers.

**Table I.- Population size of the scaly-sided mergansers in four river systems of Poyang Lake.**

River system	River section	November	December	January	February	March	Total
Xiuhe	Xiushui	68	27	9	23	16	143
	Jing'an	1	10	6	1	2	20
Fuhe	Yihuang	Nil	15	24	32	39	110
Xinjiang	Longhushan	12	10	15	10	6	53
	Yiyang	9	12	30	12	24	87
Raohe	Fuliang	8	6	1	8	9	32
	Wuyuan	15	13	25	14	18	85
Total		113	93	110	100	114	530

Nil, no scaly-sided mergansers were found in this month.

#### *Data collection and analysis*

The population size of the merganser was estimated in seven river sections of four river systems in the Poyang Lake water system during the wintering period from November 2010 to March 2014. The sex ratio was recorded in the same area from November 2010 to March 2011 (89 groups), December 2011 to March 2012 (48 groups), January 2013 (3 groups) and November 2017 (8 groups). The line transect method was used to record the population size and sex ratio of merganser. A total of 17 lines including one in Xiushui river section, three in Jing'an section, two in Yihuang section, three in Longhushan section, one in Yiyang section, four in Fuliang section and three in Wuyuan section were selected, with 4–7 km for each transect line. We divided the wintering period into three stages: Early (November), Middle (December, January and February) and Late (March). In the current study, the sex ratio refers to the proportion of males to the total number of birds. Birds recorded as female included females and sub-adults, because it was difficult to distinguish female and sub-adult mergansers due to their similar coloration (Shao *et al.*, 2012a). As such, the recorded sex ratio was likely to be substantially smaller than the actual ratio, because some males were recorded as sub-adult mergansers. We recorded group size and sex ratio when mergansers were observed. We regarded different groups when the distance between individuals was greater than 200 m. T-tests were used to test for differences in sex ratio along the four river systems because the data were not normally distributed. All significance levels were set at  $P=0.05$ . Data were analyzed using the SPSS 13.0 statistical package.

## **RESULTS**

#### *Population size dynamics*

From November 2010 to March 2014, the population

size of the scaly-sided merganser was examined in four river systems of Jiangxi province during each wintering period. The maximum population size recorded in each river during all investigations was regarded as the population size in that river (Table I). A total of 530 individual scaly-sided mergansers were recorded from November 2010 to March 2014. Spatial and temporal variations in population size of this endangered species were found. The Xiushui section (Xiuhe River), Yihuang section (Fuhe River), Yiyang section (Raohe River) and Wuyuan section (Raohe River) exhibited steady populations of mergansers. Of the sections examined, the largest population size (68 individuals) was recorded in Xiuhe River, followed by the Yihuang section (39 individuals), Yiyang section (30 individuals) and Wuyuan section (25 individuals) (Table I).

**Table II.- The maximum number of scaly-sided mergansers in three river sections of Poyang Lake water system.**

River section	2010–2011	2011–2012	2012–2013
Yihuang	39	15	21
Yiyang	30	9	Nil
Wuyuan	18	15	25

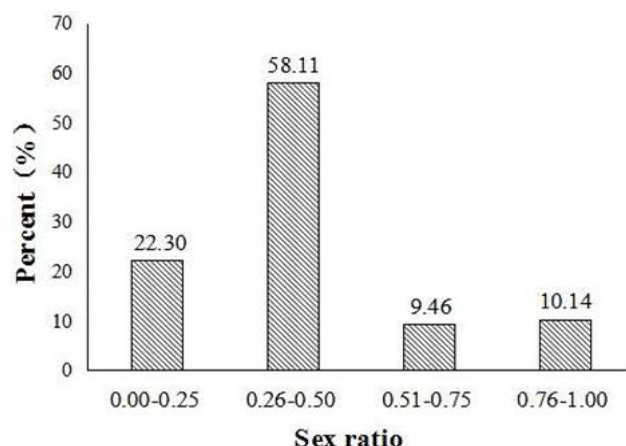
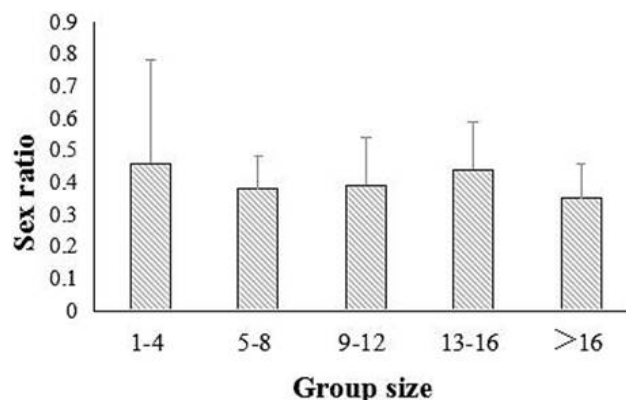
Nil, no investigation was conducted in this year.

#### *Maximum population size variation*

Population size of the species was steady each year in Yihuang, Yiyang and Wuyuan. In addition, we also recorded the population size of the species while conducting behavioral observations. Table II shows the maximum population size of the merganser for each year. Relatively small populations were found in 2011 and 2012 for three river sections (Table II).

**Table III.- Sex ratio of scaly-sided mergansers in four river systems of Poyang Lake during three wintering periods.**

Sex ratio	Xiuhe River	Fuhe River	Xinjiang River	Raohe River	Total
Early	0.42±0.27 (8)	-	0.67±0.24 (7)	0.49±0.18 (19)	0.51±0.23 (34)
Middle	0.41±0.38 (28)	0.54±0.17 (12)	0.45±0.23 (16)	0.36±0.22 (21)	0.42±0.29 (77)
Late	0.24±0.23 (10)	0.50±0.11 (8)	0.41±0.19 (12)	0.30±0.15 (7)	0.36±0.20 (37)
Total	0.37±0.34 (46)	0.52±0.15 (20)	0.48±0.24 (35)	0.41±0.0 (47)	0.43±0.26 (148)

**Fig. 2.** Sex ratio of scaly-sided mergansers in seven river sections of Poyang Lake water system.**Fig. 3.** Relationship between sex ratios and group size of scaly-sided merganser in Poyang Lake water system.

#### Sex ratio

The total sex ratio of the scaly-sided merganser was 0.397 ( $n = 790$ ) and the average sex ratio was  $0.43 \pm 0.26$  ( $n = 148$ ) for each group (Table III). The sex ratio of each group from 0 to 0.50 accounted for 80.41% (Fig. 2). The sex ratios in different river systems were significantly different ( $\chi^2 = 11.029$ ,  $df = 3$ ,  $P = 0.012$ ). The sex ratio in the Fuhe river was higher than that obtained in Xiuhe ( $\chi^2 = 6.948$ ,  $df = 1$ ,  $P = 0.008$ ) and Raohe rivers ( $\chi^2 = 7.510$ ,  $df =$

1,  $P = 0.006$ ). Of three stages, only the sex ratio during late winter stage was significantly different among four river systems ( $\chi^2 = 9.391$ ,  $df = 3$ ,  $P = 0.025$ ). The high sex ratio was found in the Fuhe and Xinjiang rivers, followed by the Xiuhe ( $\chi^2 = 6.388$ ,  $df = 1$ ,  $P = 0.011$ ) and Raohe rivers ( $\chi^2 = 5.736$ ,  $df = 1$ ,  $P = 0.017$ ) (Table III). In general, the sex ratios during early winter were higher in Xiuhe, Xinjiang and Raohe rivers, compared with the ratios obtained during late winter. However, significant differences were only detected in the Raohe river ( $\chi^2 = 7.939$ ,  $df = 2$ ,  $P = 0.019$ ) (Table III). Sex ratios in the Raohe river during the early stage were significantly higher than those during the middle ( $\chi^2 = 5.673$ ,  $df = 1$ ,  $P = 0.017$ ) and late stages ( $\chi^2 = 5.472$ ,  $df = 1$ ,  $P = 0.019$ ).

#### Relationship between sex ratio and group size

A total of 148 groups were observed during the study. Group size ranged from one to 21 individuals per group. No significant differences in sex ratios were detected among different group sizes ( $\chi^2 = 0.220$ ,  $df = 4$ ,  $P = 0.519$ ) (Fig. 3).

## DISCUSSION

#### Population size

The scaly-sided merganser exhibited a scattered population distribution. Less than 30 individuals were estimated in each river section in most cases. Our results revealed that spatial and temporal variation in the population size of scaly-sided mergansers was similar in each river section. In our study area, the Xiushui, Yihuang, Yiyang and Wuyuan sections exhibited relatively steady and large populations. However, during the last two years, we did not observe any scaly-sided mergansers in the Yihuang river section during two investigations, possibly due to human activity (sand mining and water pollution), and sand mining and water pollution affect the food abundance and living environment of merganser, indicating that this species may be vulnerable to disappearance because of its small population size and human activities (Shao et al., 2012a). Thus, the restoration and maintenance of suitable habitats for the species is imperative. Moreover, annual number counts and research on the habits of



**Table IV.- Literature data of sex ratios of scaly-sided mergansers in Jiangxi province or other regions.**

Regions	Investigation time	Sample	Avg. sex ratio	Total sex ratio	References
Whole Jiangxi Province	2010-2017	790	0.430	<b>0.397</b>	This study
Whole Jiangxi Province	2010.11-2011.3	432	0.423	<b>0.425</b>	Shao <i>et al.</i> (2012b)
Whole Jiangxi Province	2009.2	255		<b>0.4588</b>	Wang <i>et al.</i> , (2010)
Wintering area in China	2004-2006	117	0.340	<b>0.427</b>	He <i>et al.</i> (2006)
Yihuang and Wuning counties, Jiangxi province	2009.2	83	0.448	<b>0.446</b>	Li <i>et al.</i> (2009)
Whole Jiangxi Province	2006.12	82		<b>0.378</b>	Liu <i>et al.</i> (2008)
Qingjiang, Hubei Province	2016.12	38	0.553	0.553	Zhi <i>et al.</i> (2017)
Yuanling, Hunan Province	2014.1	26	0.530	0.423	Liu <i>et al.</i> (2014)
Jiangjin, Chongqin city	2012.12-2013.1	16	0.701	0.688	Hong <i>et al.</i> (2013)
Jiang'an, Jiangxi Province	2007.12	11	0.396	0.273	Lin <i>et al.</i> (2008)
Huangshi reservoir, Hunan Province	2008.3	8	0.500	0.500	Ren <i>et al.</i> (2008)

the scaly-sided merganser are necessary for conservation of the species. Previous studies reported that only four river systems of Poyang Lake contained scaly-sided merganser populations (Wang *et al.*, 2010; Shao *et al.*, 2012a, b). In recent years, steady scaly-sided merganser populations were also observed in Ganjiang River (one of the five Poyang Lake water systems). We estimated that the population in Jiangxi province was approximately 300 individuals, accounting for 12%–30% of the global population of this endangered species (Wang *et al.*, 2010).

#### Sex ratio

Temporal and spatial variations in sex ratio have been reported for many duck species. Fourteen of 22 species belonging to Anseriformes exhibited a male-skewed sex ratio, while the others exhibited a balanced ratio (Donald, 2007). Owen and Dix (1986) reported that wintering duck species exhibited a male-skewed sex ratio, particularly the common pochard *Aythya ferina* (29.5% female,  $n = 24,173$ ) and northern shoveler *Anas chlypeata* (39% females,  $n = 136$ ). Mandarin ducks also showed male-skewed bias for adults (average 2.10:1) (Sun *et al.*, 2011). In contrast, some species in Taihu, China, such as mallard *Anas platyrhynchos*, northern pintail *Anas acuta*, gadwall *Anas strepera*, greater scaup *Aythya marila*, smew *Mergellus albellus* and falcated duck *Anas falcata* have been reported to exhibit a female-skewed sex ratio in one year, and a balanced ratio in another year. Spot-billed ducks always exhibit a male-skewed sex ratio. Tufted ducks *Aythya fuligula* exhibit a balanced or male-skewed sex ratio. Eurasian wigeon *Anas penelope*, Baikal teal *Anas formosa*, and common teal always exhibit a female-skewed sex ratio. Northern shoveler, Baer's pochard *Aythya baeri* exhibit a male-skewed or female-skewed sex ratio in

different years (Qian and Zhu, 1980). Many duck species in Taihu, China also exhibit temporal variation in sex ratio between different months (Qian and Zhu, 1980). The sex ratio of common teals (60.66% male,  $n = 361$ ) is male-biased, while the falcated duck *Anas falcata* (52.10%,  $n = 286$ ), mallard (50.00%,  $n = 90$ ) and Eurasian wigeon (49.18%,  $n = 183$ ) were found to exhibit balanced sex ratios in Poyang Lake during the wintering period (Shao *et al.*, 2016). Our results also revealed temporal and spatial variations in sex ratio for the scaly-sided merganser. The overall sex ratio of the scaly-sided merganser was 0.397, which is similar to the results (0.378–0.4588) obtained in previous years in Jiangxi province when the sample size was above 80 individuals (Table IV). The data showed that the sex ratio of the merganser was relatively steady in different years in Jiangxi province. The sex ratio was below 0.5 because the data also included some sub-adults with similar coloration to the adult females. We were unable to draw general conclusions about sex ratio in other provinces because of the relatively small sample size in the current study (Table IV). Our results revealed that the sex ratio in 19.6% of groups was above 0.5, indicating that these groups were male-skewed. We also confirmed that more than 19.6% groups of this species were male-skewed because the females recorded in this study included some male sub-adults.

Our results revealed temporal and spatial variations in the sex ratio of scaly-sided mergansers, similar to results reported by Qian and Zhu (1980), Donald (2007) and Shao *et al.* (2016). The lower sex ratio in the Xiuhe River indicated that the population in this area may include more sub-adults. Future studies should test whether males and females have differential distribution across their winter range due to geographic or habitat segregation

(Humple *et al.*, 2001). Female ducks exhibited a tendency to migrate further south (Owen and Dix, 1986; Donald, 2007). The sex ratio in the Fuhe river during late stage or the whole wintering period exhibited a male-skewed sex ratio, which was higher than that obtained in other rivers (Xiuhe and Raohe Rivers). The Xiuhe and Raohe Rivers are located north of the Fuhe River. In future studies, we plan to collect long-term data to test whether the female mergansers migrate more northwards. The male ratio of the common teal, falcated duck and Eurasian wigeon all showed a tendency to initially increase and later decrease throughout the wintering period, while the mallard showed a continuous growth trend (Shao *et al.*, 2016). A previous study reported that the sex ratios of the mallard and pochard in Britain decreased gradually from the early stage to the wintering later stage, while other species including the Eurasian wigeon and tufted duck did not exhibit this tendency (Owen and Dix, 1986). The sex ratio of the scaly-sided merganser also exhibited a tendency to decrease gradually from the early stage to the late stage in each river, especially the Raohe River, in which a significantly different sex ratio was found among three wintering stages. There are several potential explanations for this pattern of results: 1) male mergansers arrived earlier in the wintering area in Jiangxi province; 2) males had a higher mortality rate during the whole wintering period; 3) males were found in lower proportions during the late stage, and may have left wintering areas early to occupy good breeding habitats. Qian and Zhu (1980) also found sexual variation in arrival time to wintering areas. In Jiangxi province, female common teals arrive in wintering areas early, and individuals observed in the early stage (from October to the middle of December) are almost all female. This phenomenon might indicate that the wintering birds in Jiangxi province have different wintering strategies regarding arrival time. Future studies should collect more data regarding sex ratio to understand general patterns of wintering strategies in Jiangxi province. Owen and Dix (1986) found significant differences in sex ratios for different flock sizes in all species studied, except mallard. In the current study, we did not detect significant differences in the sex ratio of the scaly-sided merganser among different group sizes.

#### ACKNOWLEDGEMENT

Funding for this project was provided by Chinese Natural Sciences Fund (31560597).

#### Statement of conflict of interest

The authors declare no conflict of interest.

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