Pakistan J. Zool., vol. 52(4), pp 1355-1362, 2020 DOI: https://dx.doi.org/10.17582/journal.pjz/20190824090851

Habitat Selection of Scaly-sided Merganser under Multiple Area Scales in Water Systems of Poyang Lake, China

Zhi Yi Jin and Shao Ming Qin*

College of Life Science, Jiangxi Normal University, Nanchang 330022, China

ABSTRACT

Habitat selection of the Endangered Scaly-sided Merganser *Mergus squamatus* was studied in four rivers of Poyang Lake, Jiangxi Province, China at landscape and micro-habitat scales, from November 2017 to March 2018 and November 2018 to March 2019. At landscape scale, the main foraging habitats of this species include woodlands and farmlands. The largest proportion of woodland in the habitats was 88.70%. Proportion of shoals in foraging habitats at 500-m, 1000-m, 1500-m and 5000-m scales were larger than that in control plots, indicating that the presence of shoals is an important factor determining habitat selection of this bird. At micro-habitat scale, water flow speed (P=0.044), and distance to road (P=0.018) and village (P=0.001) were significantly greater than in control plots. Principal component analysis showed that safety factors (vegetation cover on both banks, distance to a mine factory and river width) were the three most important habitat factors, indicating that Scaly-sided Merganser had high requirements for shelter and safety. Twenty two species of fish belonging to eight families and three orders were identified in foraging areas of the Scaly-sided Merganser. We could identify only six fish species eaten by the merganser *viz.*, *Carassius auratus*, *Misgurnus anguillicaudatus*, *Noemacheilus fasciolatus, Silurus asotus*, *Tachysurus fulvidraco* and *Siniperca chuatsi*, which were relatively common and present in all the four rivers, indicating that this bird was an opportunist predator. It is important to reduce human activities and protect woodland and aquatic environments because Scaly-sided Merganser have high requirements for safety and water conditions under both landscape and micro-habitat scales.

Article Information
Received 24 August 2019
Revised 02 December 2019
Accepted 27 December 2019
Available online 31 March 2020

Authors' Contribution
SMQ designed and revised the paper. ZYJ and SMQ collected and analyzed the data. ZYJ and SMQ wrote and revised the paper.

Key words
***Mergus squamatus*, Scaly-sided Merganser, Multiple scales, Habitat selection**

INTRODUCTION

Food, water and shelter are three of the main factors determining habitat selection by wildlife (Jiang *et al*., 2012). Foraging habitat selection is important for bird survival and breeding (Guan, 2009). Water flow velocity, topography, wintering period and food availability primarily affect foraging habitat selection by water birds (Quan *et al*., 2001; Mckinney *et al*., 2007). For example, torrent ducks (*Merganetta armata*) prefer to forage in rivers with high water flow speed and land slope (Pernollet *et al*., 2013), the ruddy shelduck (*Tadorna ferruginea*) prefer to forage in wet farmlands during its middle wintering stage (Quan *et al*., 2001), but avoid farmlands during the early and later stages, whereas the harlequin duck (*Histrionicus histrionicus*) favor foraging in areas with high prey density (Mckinney *et al*., 2007). Studies on habitat selection of birds have been developed from a single scale level to multiple scales because of rapid developments in GIS and remote sensing techniques. Researchers often refer to geographic scales as 'landscape', 'patch' or 'micro-habitat' (Shu *et al*., 2004; Zhang *et al*., 2005; Xu *et al*., 2006; Cao *et al*., 2010; Xie *et al*., 2018). Landscape scale can demonstrate the variation in different habitat utilization by birds (Shu *et al*., 2004; Xie *et al*., 2018), while vegetation structure, water, food availability and shelter affect micro-habitat selection by animals (Cao *et al*., 2010).

The global population of the scaly-sided merganser *Mergus squamatus* (Anseriformes: Anatidae) has been estimated as 1000–2500 individuals (Shao *et al*., 2012). In China, the scaly-sided merganser is listed as a first-category nationally protected wildlife species and the International Union for the Conservation of Nature regards it as Endangered (Shao *et al*., 2012; Zeng *et al*., 2013). Wintering areas include a wide stretch along the south bank of the Yangtze River. Five water systems (Xiuhe, Fuhe, Xinjiang, Raohe, and Ganjiang Rivers) provide some of the main wintering grounds for this species in Jiangxi Province, China (Shao *et al*., 2012). Previous studies of wintering scaly-sided merganser have mainly analyzed population size (He *et al*., 2002), group characteristics (Shao *et al*., 2012), sex ratio (Zhi and Shao, 2019), home range and behavioral strategy (Zeng *et al*., 2013), and diet (Zhao and Pao, 1998). We are unaware of previous data on foraging habitat selection at multiple scales. Thus, the

* Corresponding author: 1048362673@qq.com
0030-9923/2020/0004-1355 $ 9.00/0

objectives of this study were to: 1) provide basic data on foraging habitat selection of scaly-sided merganser at both landscape and micro-habitat scales; and 2) reveal factors that determine foraging habitat selection. This information will provide basic data on which to base nature reserve construction and future conservation of this species.

MATERIALS AND METHODS

Study area

Poyang Lake (115°49'–116°46'E, 28°11'–29°51'N), located in north Jiangxi Province, is the largest lake in China (Che *et al*., 2018). The climate in the study area is sub-tropical, with an average annual precipitation of 1450–1550 mm and average annual temperature of 16.5–17.8 °C (Dai *et al*., 2014; Wang, 2014). The water area reaches a maximum of 41,225 km^2. The rich water system of Poyang Lake provides good food resources and ideal wintering habitats for water birds. We selected four water systems (Xiuhe, Xinjiang, Raohe, and Ganjiang Rivers) in Poyang Lake as our study areas to investigate habitat selection by scaly-sided merganser (Fig. 1). The vegetation of this region is dominated by broad-leaved deciduous forests and scattered farmland. For the most part, both banks of river were densely covered by trees. Because local people are unable to access some rivers easily, they provide safe environments for water birds. Shoals scattered along the river provide suitable resting areas for scaly-sided merganser.

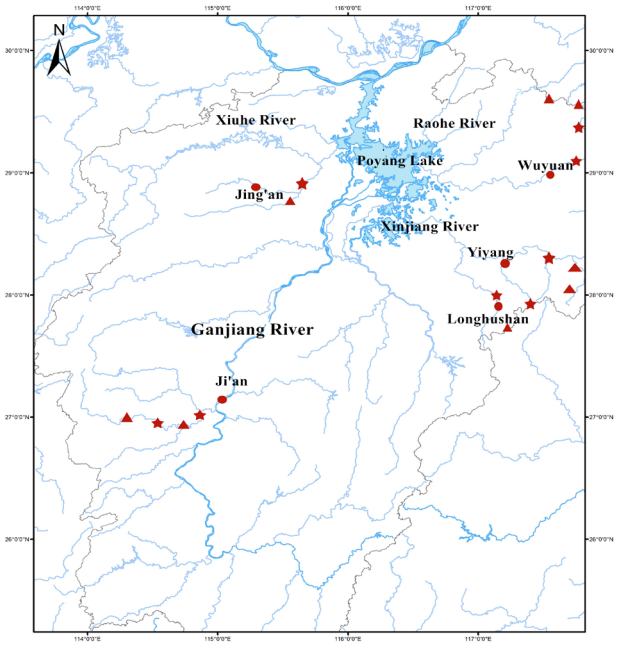

Fig. 1. Locations of the surveyed areas in four rivers of Poyang Lake. ★, means sample points; ▲, means control points

Data collection

From November 2017 to March 2018 and from November 2018 to March 2019, the foraging areas of scaly-sided merganser were located in the Xiuhe (Jing'an), Ganjiang (Ji'an), Xinjiang (Yiyang and Longhushan) and Raohe (Wuyuan) river sections. Our study sites covered the main wintering distribution sites of this bird in Jiangxi province. We also recorded the GPS locations of control plots in the rivers located within 5 km of each foraging area. We selected potential control plots at random within a distance of about 2 to 5 km to the foraging plots along the same river. The selection of potential plots was based on the reports that scaly-sided merganser were not observed in that area in recent years. We sampled 10 foraging plots and 9 control plots to determine micro-habitat parameters. Then we selected only eight (8) foraging plots and eight (8) control plots to determine parameters at landscape scale because some plots had similar parameters being a small distance apart.

We interpreted remote sensing images to identify the main habitats in our study area in 2018. Comparisons between foraging habitats and control plots were conducted using Landsat TM/OLI data. Habitats included farmland, woodland, grassland, water area, shoal, village and road. We measured the area of each habitat and control plot within a radius of 500 m, 1000 m, 1500 m, 3000 m or 5000 m from the center of each selected river. Micro-habitat parameters and measurement methods are shown in Table I.

The food of scaly-sided mergansers consists of aquatic arthropods, frogs, fish etc. We only analyzed the fish species because it was difficult for us to identify other prey species eaten by mergansers in the field observation due to the small size of other prey items. Fish were captured from foraging areas using a net in Yiyang, Longhushan and Wuyuan (Fig. 1). We identified the fish to species level according to the 'Synopsis of Freshwater Fishes of China and Zoological Systematics' (Zhu, 1995), and considered these fish as potential food resources of scaly-sided merganser. Distribution and preferred river depth layers of fish were obtained from the literature (Huang *et al*., 2013; Tu *et al*., 2016). Fish eaten by scaly-sided merganser were identified by photography using a digital camera (Nikon, 16.76 million pixels) or by observation using a telescope (Swarovski, ×20-60).

Data analysis

Factors determining micro-habitat selection by scaly-sided merganser were identified using Principal Component Analysis (PCA). The Kruskal-Wallis H test was used to compare differences in landscape and micro-habitat factors between foraging habitats and control plots.

Values are expressed as means ± standard deviation (SD), with P values <0.05 considered significant. Statistical analyses were completed using Excel 2010 and SPSS 22.0.

RESULTS

Foraging habitat selection of scaly-sided merganser at landscape scale

The maximum population size of scaly-sided mergansers ranged from 20 to 30 in Yiyuang, Wuyuan and Ji'an. And the maximum population size ranged between 10 and 15 in Jing'an and Longhushan. The main habitats within the foraging areas of scaly-sided merganser were woodland and farmland. The highest proportion of woodland recorded was 88.70%. Grassland and road proportions were very low. No grassland could be detected at the 500-m, 1000-m, 1500-m scales. Kruskal-Wallis H tests showed that shoal proportion was larger in foraging habitats than in control plots at 500-m, 1000-m, 1500-m and 5000-m scales (Table II, Figs. 2, 3).

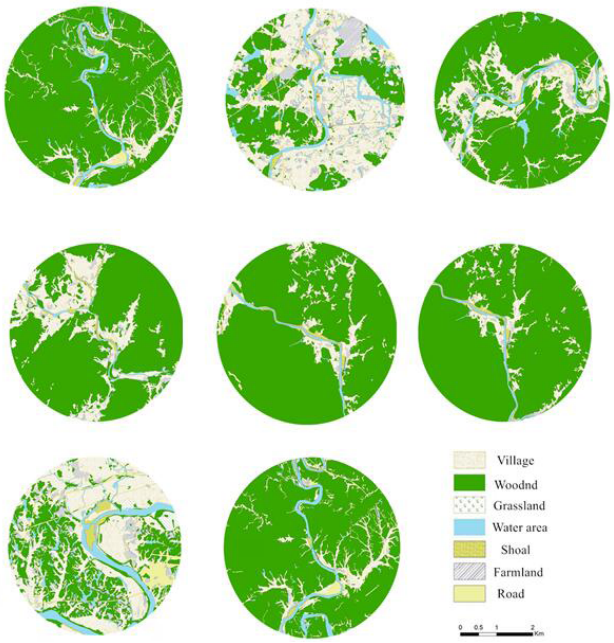

Fig. 2. Foraging habitats of scaly-sided mergansers at 5000-m scale.

Kruskal-Wallis H tests showed that water flow speed, and distance to road and village in the foraging habitats were significantly higher than in the control plots. No significant difference was detected in other factors (Table III).

The first three principal components met the criterion of eigenvalue >1 and together explained 82.45% of the variance in foraging habitats by using PCA method. This observation indicates that the first three principal components represented the total message of the seven parameters investigated (Tables IV, V). The first principal axis ordered sites by vegetation cover of the two banks, distance to mine factory, and river width. We considered these factors to be related to shelter and human disturbance. The second principal axis was ordered by water flow speed and distance to village. We considered these factors to be related to safety and the presence of water. The third principal axis was arranged by distance to road and was considered a safety factor. Thus, safety factors are important in the determination of foraging habitat selection of scaly-sided merganser.

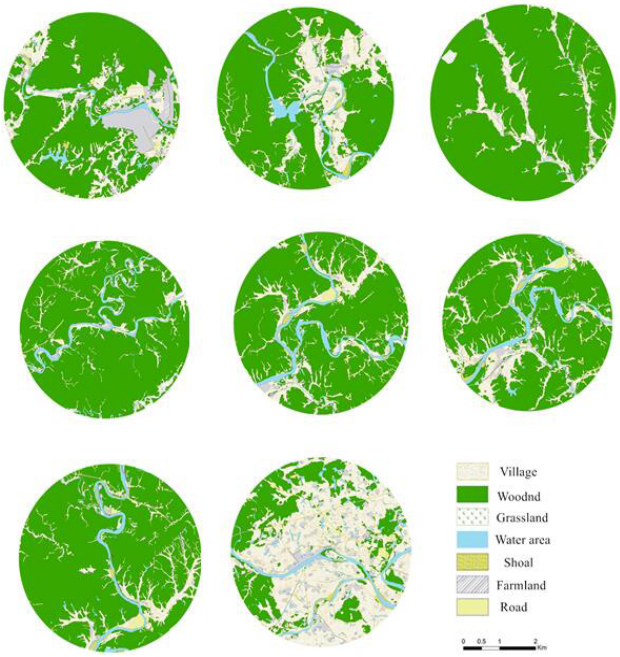

Fig. 3. Control plots at 5000-m scale.

Twenty two species of fish belonging to eight families and three orders were identified within the foraging areas of the scaly-sided merganser. Of these, 15 species of fish were present in all four of the river systems investigated during this study. Ganjiang River had the largest number of species of fish (21), Xiuhe River had the fewest species (18). Based on our observations and photographs taken in our study area, scaly-sided merganser mainly preyed on six species of fish: *Carassius auratus*, *Misgurnus anguillicaudatus*, *Noemacheilus fasciolatus*, *Silurus asotus*, *Tachysurus fulvidraco* and *Siniperca chuatsi* (Table VI).

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
Distance to road (m)	Distance to the nearest road from a foraging center of scaly-sided merganser.
Distance to village (m)	Distance to the nearest village from a foraging center of scaly-sided merganser.
Distance to mine factory	Distance to the nearest mine factory from a foraging center of scaly-sided merganser. We divided distances into three ranks: 1 (0–250 m); 2 (251–500 m); and 3 (>500 m).
Shoal proportion (%)	Shoal proportion within 20 × 20 m plots centered on a foraging area of scaly-sided merganser measured by eye.
Vegetation cover of two banks of river	Vegetation cover of the two banks of the river within 20×20 m plots centered on a foraging area of scaly-sided merganser, estimated by eye. We divided vegetation cover into three ranks: 1 (0–10%); 2 (10.01%–20%); and 3 (>20%).

Table II. Comparison of scale factors between foraging habitats and control plots for scaly-sided merganser.

Habitats (%)	Landscape scales									
	500 m		1000m		1500 m		3000m		5000 m	
	Habitat	Control	Habitat	Control	Habitat	Control	Habitat	Control	Habitat	Control
Village	29.24±17.11	24.31±13.95	28.91±16.50	22.89±15.43	26.75±17.21	23.44±16.88	22.35±14.66	22.52±18.33	20.43±15.09	18.73±14.44
Woodland	31.89±27.67	44.44±19.93	46.35±27.16	56.98±24.48	55.40±26.01	58.07±25.32	64.36±22.98	63.08±24.78	67.79±23.96	70.76±19.15
Grassland	-	-	-	0.06±0.17	-	0.18±0.37	0.15±0.24	0.16±0.24	0.33±0.64	0.13±0.15
Water area	19.43±11.86	17.48±8.93	11.80±7.89	11.71±4.89	9.07±5.76	10.24±5.02	6.30±4.33	7.09±3.38	5.04±3.91	4.70±2.12
Shoal	14.04±8.33*	2.85±3.83*	7.07±4.42*	1.34±1.54*	4.33±2.91*	0.76±0.70*	1.91±1.42	0.72±0.54	1.07±0.43*	0.51±0.34*
Farmland	4.47±4.64	10.07±9.89	4.85±5.44	6.36±7.26	3.49±3.73	5.94±6.76	2.81±3.25	5.05±4.98	2.68±3.47	3.85±3.69
Road	0.94±1.16	0.87±1.53	1.03±1.71	0.66±1.05	0.98±1.26	1.38±1.38	2.12±2.45	1.38±1.04	2.66±3.77	1.32±0.59

*P<0.05

Table III. Comparison of micro-habitat parameters between foraging habitats and control plots for scaly-sided merganser.

Parameters	Foraging habitats (n=10)	Control plots (n=9)	χ^2	P
	Mean±SD	Mean±SD		
Water flow speed (m/s)	0.21±0.09	0.12±0.07	4.066	0.044
River width (m)	182.7±88.01	142.11±70.67	1.928	0.165
Distance to road (m)	133.50±115.84	42.67±61.70	5.636	0.018
Distance to village (m)	299.40±114.41	77.67±77.38	10.676	0.001
Distance to mine factory	2.50±0.85	2.78±0.67	0.844	0.358
Shoal proportion (%)	9.70±14.00	5.00±7.00	0.611	0.434
Vegetation cover of two banks	2.30±0.82	1.56±0.73	3.628	0.057

DISCUSSION

The main ecological factors involved in wildlife habitat selection vary according to the geographic scale used in the research methodology (Cao *et al.*, 2010). Therefore, we paid particular attention to the scale in habitat selection in our study. Habitat types and their proportions are related to landscape scale, while micro-habitat scale relates to vegetation coverage, water flow speed, and distance to disturbance source. Our results

show that the preferred foraging habitat is the river within dense woodland and scattered farmland, which is similar to the findings in earlier literature (Wang *et al*., 2010). The highest proportion of woodland was present in the foraging areas and this proportion increased at larger scale. These observations show that scaly-sided merganser prefer to forage in rivers near woodland. The rich vegetation and its coverage provided safe shelter to avoid natural enemies and human disturbance. The proportion of shoals in the foraging area was larger than that in control plots at 500-m, 1000-m, 1500-m and 5000-m scales, although the shoal proportion in the rivers was low. Therefore, shoal was an important factor affecting scaly-sided merganser foraging habitat selection. Scaly-sided mergansers dive to catch fish or other prey and have high energy consumption but are able to rest in the shoals after they obtain sufficient food (Zeng *et al*., 2013). Furthermore, the shoals may also provide a suitable environment for fishes that constitute food for water birds. Scaly-sided merganser could always be detected in the rivers with scattered shoals although the shoal proportion was small and variable.

Water flow speed and quality, food availability, safety or shelter (vegetation coverage) and human disturbance are the main ecological factors that water birds use in micro-habitat selection. Safety and human distribution are also factors used by whooper swan *Cygnus cygnus,* mandarin duck *Aix galericulata* and bar-headed goose *Anser indicus* to select their foraging habitat (Jiao *et al*., 2012; Yang *et al*., 2013; Sun *et al*., 2018). Scaly-sided merganser preferred wide rivers with good water quality and rapid water flow (Liu *et al*., 2008). In our study, water flow speed, distance to the road and village were significantly higher than in control areas, indicating that water and human disturbance were important factors in determining foraging habitat selection of scaly-sided merganser. Principal component analysis also showed that safety (e.g., vegetation coverage, distance to mine factory, river width) was an important aspect of all three principal components, indicating that scaly-sided merganser had high requirements for shelter and safety. Vegetation on the banks of some sections of Fuliang River was felled and caused habitat loss for this species and we did not detect any merganser in these damaged sections. Water factors were also important in the second principal component, indicating that a good water environment was vital for merganser habitat selection. Previous studies have shown that modern industrial and agricultural development have degraded the aquatic environment and have caused increasing habitat loss for many water birds (Wang *et al*., 2010; Zhang *et al*., 2012). Thus, a good aquatic environment is needed to provide the wintering habitat for scaly-sided merganser.

Table IV. Eigenvalues and contribution rates of foraging habitat selection factors of scaly-sided merganser.

Principal components	Eigen value		
	Eigenvalue	Percent of total variance/%	Percent of cumulative variance/%
1	2.619	37.412	37.412
2	1.955	27.934	65.346
3	1.197	17.099	82.445
4	0.664	9.491	91.936
5	0.474	6.775	98.711
6	0.081	1.162	99.873
7	0.009	0.127	100.000

Table V. Correlation of habitat variables with the first three principal components derived from habitat selection of scaly-sided merganser.

	Principal components		
	1	2	3
Water flow speed (m/s)	0.321	0.932	-0.55
River width (m)	-0.723	0.201	0.012
Distance to road (m)	-0.014	0.208	0.895
Distance to village (m)	-0.109	-0.966	0.212
Distance to mine factory (m)	0.878	-0.259	-0.167
Shoal proportion %)	0.597	0.033	0.551
Vegetation cover of two banks of river	0.928	-0.052	-0.127

Food availability is an important factor in selection of the foraging habitat of scaly-sided merganser. Scaly-sided merganser are opportunists that choose their prey (Zeng, 2015), changing their diet composition in different habitats. In Russia, scaly-sided merganser mainly forage for *Esox lucius*, *Squaliobarbus ourriculus* and *Misgurnus anguillicaudatus*, whereas they mainly preyed on *Misgurnus anguillicaudatus* in northeastern China (Zhao and Piao, 1998). Scaly-sided merganser have a diverse diet and are able to select alternative prey species to satisfy their physiological energy requirements when their normal prey is absent. In our study, 22 species of fish were identified in four river systems of Poyang Lake. The food we observed for mergansers included six species of fish, which were common and present in all four river systems. The river systems in Poyang Lake are able to satisfy merganser food requirements because this bird is an opportunistic predator and is also able to switch to other abundant fishes or other preys such as aquatic arthropods, frogs etc. The scaly-sided merganser dives to prey on these fishes or other preys that live in the middle and low layers of the river.

Table VI. Fish species composition in foraging areas of scaly-sided merganser.

Species	Xiuhe river	Xinjiang river	Raohe river	Ganjiang river	Water situation	Preferred fish
I.**CYPRINIFORMES**						
Cyprinidae						
1. *Acanthorhodeus chankaensis*	+		+		Middle and upper lawyers	
2. *Acheilognathus macropterus*	+	+	+	+	Middle and upper lawyers	
3. *Hemiculter bleekeri*	+	+	+	+	Middle and upper lawyers	
4. *Carassius auratus*	+	+	+	+	Low lawyer	√
5. *Cyprinus carpio*	+	+	+	+	Low lawyer	
6. *Hemiculter leucisculu*	+	+	+	+	Middle and upper lawyers	
7. *Acrossocheilus parallens*		+		+	Middle and upper lawyers	
8. *Ctenopharyngodon idellus*	+	+	+	+	Middle and low lawyers	
9. *Squaliobarbus curriculus*	+	+	+	+	Middle and upper lawyers	
10. *Pseudobrama simoni*	+	+	+	+	Middle and upper lawyers	
11. *Abbotottina rivularis*	+	+	+	+	Low lawyer	
12. *Sarcocheilichthys kiangsiensis*		+		+	Low lawyer	
13. *Saurogobio dabryi*		+	+	+	Low lawyer	
14. *Squalidus argentatus*	+	+	+	+	Middle and low lawyers	
15. *Squalidus nitens*	+		+	+	Low lawyer	
Cobitidae						
16. *Misgurnus anguillicaudatus*	+	+	+	+	Low lawyer	√
Nemacheilidae						
17. *Noemacheilus fasciolatus*	+	+	+	+	Low lawyer	√
II. **SILURIFORMES**						
Sisoridae						
18.*Glyptothorax sinenses*	+	+		+	Low lawyer	
Siluridae						
19. *Silurus asotus*	+	+	+	+	Middle and low lawyers	√
Bagridae						
20. *Tachysurus fulvidraco*	+	+	+	+	Low lawyer	√
III. **PERCIFORMES**						
Percichthyidae					√	
21. *Siniperca chuatsi*	+	+	+	+	Low lawyer	
Eleotridae						
22. *Odontobutis obscura*			+	+	Low lawyer	

Scaly-sided merganser habitat selection was analyzed at multiple scales. Factors involved in selection differed among scale levels but were also mutually related. Changes in these factors would be expected to cause habitat loss for the birds (Zhang *et al*., 2012). We showed that scaly-sided merganser exhibited strong requirements for safety and for the properties of the aquatic environment at both landscape and micro-habitat scales. Thus, 1) It is important to protect the water environment and the forests on the banks of river. Forest destruction near foraging rivers of scaly-sided merganser must be reduced to provide a safe wintering habitat for this endangered species. 2) The proportion of shoals must be maintained. The presence of shoals in the river generates multiple areas with differing water flow speeds, producing a habitat with diverse currents. This variable habitat provides diverse foraging and resting areas

for different fishes ensuring that scaly-sided merganser obtain sufficient food (Wang and Yan, 2008). 3) Varying water speeds ensure water clarity and foraging efficiency of scaly-sided merganser (Wang *et al*., 2010).

ACKNOWLEDGEMENT

Funding for this project was provided by Chinese Natural Sciences Fund (31860611, YC2019-S120,31560597).

Statement of conflict of interest

The authors declare there is no conflict of interest.

REFERENCES

Cao, M.C., Liu, G.H., Shan, K., Hou, Y.X., Wang, M.C., Li, D.L. and Shen, W.M., 2010. A multi-scale assessment of habitat suitability of red-crowned crane at the Yellow River Delta Nature Reserve, Shandong, China. *Biodiv. Sci.*, **18**: 283-291. https://doi.org/10.3724/SP.J.1003.2010.283

Che, Y.J., Jiang, M.X. and Zhong, Y.X., 2018. The study on temporal and spatial variation of ecosystem service value in Poyang Lake ecological economic zone based on the variation of land utilization. *J. Jiangxi Norm. Univ.* (*Nat. Sci. Ed.*), **42**: 45-51.

Dai, N.H., Shao, M.Q., Jiang, J.H. and Guo, H., 2014. The preliminary study on bird diversity during non-breeding period of Poyang Lake region in Gongqingcheng city. *J. Jiangxi Norm. Univ.* (*Nat. Sci. Ed.*), **38**: 19-25.

Guan, X., 2009. *The research of breeding habitat selection of Chinese Merganser* (Mergus squamatus). Northeast Forestry University.

He, F.Q., Melville, D., Gui, X.J., Hong, Y.H. and Liu, Z.Y., 2002. Status of the scaly-sided merganser wintering in mainland China in the 1990s. *Waterbirds*, **25**: 462-464. https://doi.org/10.1675/1524-4695(2002)025[0462:SOTSMW]2.0.CO;2

Huang, L.L., Wu, Z.Q. and Li, J.H., 2013. Fish fauna, biogeography and conservation of freshwater fish in Poyang Lake Basin, China. *Environ. Biol. Fish*, **96**: 1229-1243. https://doi.org/10.1007/s10641-011-9806-2

Jiang, A.W., Zhou F., Qin Y., Liu N.F., 2012. 10-years of bird habitat selection studies in mainland China: A review. *Acta Ecol. Sin*., **32**: 5918-5923. https://doi.org/10.5846/stxb201108151194

Jiao, Z.X., Gao, Y.J. Zhang, J.H., Liu, S.X. and Liu, J.W., 2012. Initial exploration of overwintering Mandarin Duck habitat selection along the valley of Qinggan River of three gorges area. *Sichuan J. Zool*., **31**: 647-654.

Liu, Y., Yang, Z.J., Zou, B. and Yi, G.D., 2008. Wintering distribution and population size of scaly-sided merganser *Mergus squamatus* in Jiangxi Province. *J. North. Norm. Univ.* (*Nat. Sci. Ed.*), **40**: 111-115.

Mckinney, R.A., Mcwilliams, S.R. and Charpentier, M.A., 2007. Habitat characteristics associated with the distribution and abundance of *Histrionicus histrionicus* (Harlequin Ducks) wintering in southern New England. *Northeast. Natural.*, **14**: 159-170. https://doi.org/10.1656/1092-6194(2007)14[159:HCAWTD]2.0.CO;2

Pernollet, C.A., Pavez, E.F. and Estades, C.F., 2013. Habitat selection by Torrent Ducks (*Merganetta armata armata*) in central Chile: Conservation implications of hydropower production. *Waterbirds*, **36**: 287-299. https://doi.org/10.1675/063.036.0306

Quan, R.C., Wen, X., Yang, X.J. and Huang, T.F., 2001. Habitat use by wintering Ruddy Shelduck at Lashihai Lake, Lijiang, China. *Waterbirds*, **24**: 402-406. https://doi.org/10.2307/1522071

Shao, M.Q., Zeng, B.B., Tim, H., Chen, L.X., You, C.Y., Wang, H.B. and Dai N.H., 2012. Winter ecology and conservation threats of scaly-sided merganser *Mergus squamatus* in Poyang Lake Watershed, China. *Pakistan J. Zool*., **44**: 503-510.

Shu, Y., Hu, Y.M., Guo, D.F., Shan, K., Zhu, S.Y. and Wang, L.D., 2004. The change of habitat suitable for the red-crowned crane in Yellow River Delta. *Chinese J. Zool*., **39**: 33-41.

Sun, H., Yu, H.L., Li, Y.F., Ru, W.D., Gao, R.Y., Zhang, C., Zhang, Y.Q. and Hong, J.M., 2018. Habitat selection for the wintering of Whooper Swan in Sanmenxia. *Wetland Sci. Manage*., **14**: 50-53.

Tu, F.Y., Li, J.X., Han, W.J. and Huang, X.F., 2016. Species diversity and protection of fishes in Jiangxi. *Acta Agric. Univ. Jiangxiensis*, **38**: 975-985.

Wang, S.R., 2014. *Ecological security in Poyang Lake*. Science Press, Beijing.

Wang, X.G. and Yan, Z.M., 2008. Effect of hydraulic characteristics of confluent channel on physical habitat for fish communities. *J. Tianjin Univ*., **41**: 204-208.

Wang, Z.R., Shan, J.H., Li, Y.K., Tu, X.B., Jia, D.J., Hao, X., Song, Y.Z., Ying, Q., Sun, Z.Y. and Zhao, J., 2010. Winter population status and endangered factors of scaly-sided merganser (*Mergus squamatus*) in Jiangxi Province. *Sichuan J. Zool*., **29**: 597-600.

Xie, F.F., Liu, H.Y., Li, Y.F., Wang, J. and Liu, L., 2018.

Multi-scale overwintering habitat selection of red-crowned crane based on polar coordinate positioning at Yancheng Nature Reserve, Jiangsu Province, China. *Acta Ecol. Sin*., **38**: 5584-5594. https://doi.org/10.5846/stxb201708141456

Xu, J.L., Zhang, X.H., Zhang, Z.W., Zheng, G.M., Ruan, X.F., Zhu, J.G. and Xi, B., 2006. Multi-scale analysis on wintering habitat selection of Reeves's pheasant (*Syrmaticus reevesii*) in Dongzhai National Nature Reserve, Henan Province, China. *Acta Ecol. Sin*., **26**: 2061-2067. https://doi.org/10.1016/S1872-2032(06)60031-0

Yang, Y.F., Zhang, G.G., Lu, J., Liu, W. and Li, Z.J., 2013. Foraging habitat selection of bar-headed goose in winter at Caohai National Reserve in Guizhou. *Sci. Sylv. Sin*., **49**: 176-180.

Zeng, B.B., Shao, M.Q., Lai, H.Q., Jiang, J.H., Li, C. and Dai, N.H., 2013. The effects of gender and temperature on the wintering behavior of Chinese Merganser. *Acta Ecol. Sin*., **33**: 3712-3721. https://doi.org/10.5846/stxb201209291362

Zeng, Q., 2015. *Wintering habitat use and population estimate of Scally-sided Merganser* Mergus squamatus. Beijing Forestry University.

Zhang, G.G., Zhang, G.M., Zhang, Z.W., Guo, J.R., Wang, J.P. and Gong, S.L., 2005. Scale-dependent wintering habitat selection by brown-eared pheasant in Luyashan Nature Reserve of Shanxi, China. *Acta Ecol. Sin*., **25**: 952-957.

Zhang, Z.Q., Xia, J.H., Wang, A.P. and Luo, Z.H., 2012. Wintering habitat selection of scaly-sided merganser (*Mergus squamatus*) in Jiangxi Province. *Chinese agric. Sci. Bull.*, **28**: 29-32.

Zhao, Z.J. and Pao, Z.J., 1998. The foraging behaviour of the scaly-sided merganser *Mergus squamatus* in the Changbai Mountains and Xiao Xingangling Mountains of China. *Forktail*, **14**: 76-77.

Zhi, Y.J. and Shao, M.Q., 2019. Population size and sex ratio of wintering scaly-sided merganser *Mergus squamatus* in the Poyang Lake water system, Jiangxi Province, China. *Pakistan J. Zool*., **51**: 1067-1073. https://doi.org/10.17582/journal.pjz/2019.51.3.1067.1073

Zhu, S.Q., 1995. *Synopsis of freshwater fishes of China*. Jiangsu Science and Technology Publishing House, Nanjing.