Pakistan J. Zool., vol. 46(2), pp. 451-462, 2014.

Abundance, Distribution and Diversity Variations of Wintering Water Birds in Poyang Lake, Jiangxi Province, China

Mingqin Shao,* Jianhong Jiang, Hong Guo and Binbin Zeng
Jiangxi Provincial Key Lab of Protection and Utilization of Subtropical Plant Resources, College of Life Science, Jiangxi Normal University, Nanchang, Jiangxi 330022, China

Abstract.- Bird abundance, distribution, and diversity in five regions of Poyang Lake, Jiangxi Province were investigated from October 2012 to April 2013. A total of 68 species were recorded. Bean goose (*Anser fabalis*), Tundra swan (*Cygnus columbianus*), and swan goose (*Anser cygnoides*) were dominant in Poyang Lake during this study. Dominant species differed in the five regions, although bean goose was the common dominant species in four regions. Most dominant or common species had no significant differences among the five regions. Bird composition was similar among Poyang Baishazhou Natural Reserve (BSZ), Nanjishan Wetland Nature Reserve (NJS) and Duchang Migratory Bird Reserve (DC), and many species had similar preferences for these three regions. The number of species in DC was high for most times. Bird diversity was higher in mid-winter than in early or late winter with the exception of NJS. PWC and PHF had steady and high evenness index. Podicipediformes was very common in early or late winter in all study regions because shallow areas dominated in our study area during midwinter. The proportion of Gruiformes increased gradually in PWC, PHF, and BSZ from November. Charadriiformes had lower proportions in NJS and BSZ. The Anseriformes proportion rapidly increased in most regions in November and stayed high until March, then decreased gradually. Ciconiiformes had high proportion in PWC and PHF in October and January, indicating that this species migrated to breeding sites earlier; this may be related to its long hatching and incubation period. A repeatable and robust sampling protocol should be developed to monitor the birds studied here, and to report annually.

Key words: Wintering water birds, Poyang Lake, bean goose, Tundra Swan, Swan goose.

INTRODUCTION

Lakes provide important refueling stops for migrating water birds and critical habitats for wintering water birds (Mcparland and Paszkowski, 2007; Cui *et al*., 2013). Information on distribution and abundance of water birds is essential to provide guidelines for the management and conservation of wetlands (Guevara *et al*., 2012; Shao *et al*., 2014). Although there is abundant information about distribution and abundance of water birds in lakes around the world, basic ecological information such as wintering period and numbers of many species of water birds in China is lacking (Quan *et al*., 2002; Mcparland and Paszkowski, 2007; Guevara *et al*., 2012; Cui *et al*., 2013).

Poyang Lake in the north of Jiangxi Province is the largest freshwater lake in China. It is fed by the Ganjiang, Fuhe, Xiuhe, Raohe, and Xinjiang rivers (Xia *et al*., 2010; Shao *et al*., 2012). It is also an important wintering habitat and stopover site for migratory water birds in the East Asian-Australasian Flyway (Wu and Ji, 2002). Poyang Lake hosts 108 species of water birds and is an internationally important wetland (Wu and Ji, 2002). The rich food resources and good habitat in Poyang Lake attract approximately 500,000 water birds during the wintering period each year (Liu *et al*., 2011). Research on water birds in Poyang Lake has mainly focused on species lists; quantitative data on bird distribution and numbers were lacking (Fu *et al*., 1989; Sheng and Li, 2006; Huang and Guo, 2007; Tu *et al*., 2009; Zhang *et al*., 2011; Shan *et al*., 2012; Zhu *et al*., 2012; Cui *et al*., 2013). Earlier reports did not reflect water bird diversity and distribution in the lake because of their qualitative, small-scale nature. Many endangered species such as oriental stork (*Ciconia boyciana*) and Siberian crane (*Grus leucogeranus*) are found in provincial nature reserves in the lake (Shan *et al*., 2012). However, the status of these species in these reserves is unknown. Information on abundance and distribution of water birds in the lake is important

* Corresponding author: 1048362673@qq.com
0030-9923/2014/0002-0451 $ 8.00/0

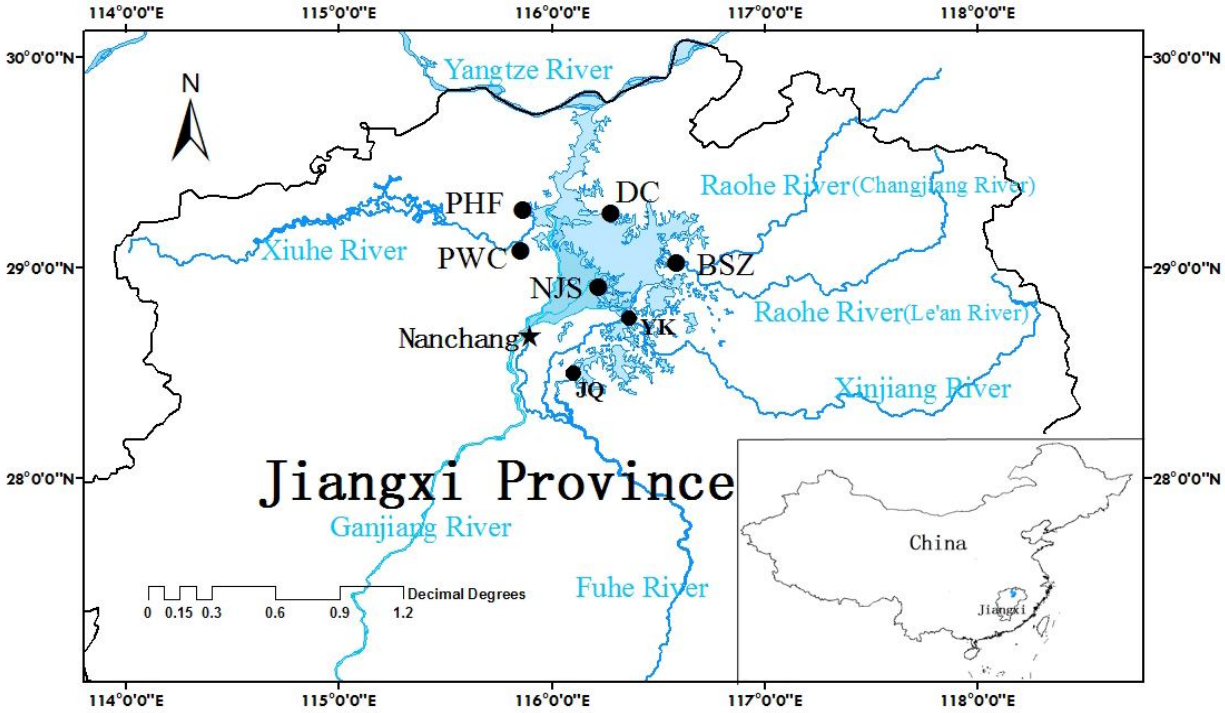

Fig. 1. Distribution of study area in Poyang Lake. For PWC, PHF, NJS, BSZ, and DC see Table I. YK, Yugan Kanshan Migratory-bird Nature Reserve; JQ, Jiangxi Qinglanhu Nature Reserve.

for taking conservation decisions and will enhance our understanding of the diversity of aquatic birds in Asia. The objectives of this study were to: (1) conduct multiple, extensive surveys to determine the abundance, distribution, and diversity of water birds across large-scale areas of Poyang Lake; (2) identify differences and similarities of water bird species diversity in different reserves; (3) provide primary information on migratory chronology of some water bird groups; and (4) provide basic data for water bird conservation and management in the lake.

STUDY AREA AND METHODS

Study area

Poyang Lake (E115°47′–116°45′, N28°22′–29°45′) occupies the middle and lower reaches of the Yangtze River in Jiangxi Province (Fig. 1). Its extent is about 173 km from south to north and 74 km from east to west (Zhu *et al*., 2012; Xia *et al*., 2010). Average water areas are 2,110 km^2 in spring, 3,900 km^2 in summer, 3,450 km^2 in autumn, and 1,290 km^2 in winter (Huang and Guo, 2007). The field site consisted of a deep water area, a shallow water area, mudflats, and grassland. Poyang Lake includes 14 nature reserves: Poyanghu Nature Reserve and Nanjishan Wetland Nature Reserve (NJS) are national reserves; Duchang Migratory-bird Nature Reserve (DC), Jiangxi Qinglanhu Nature Reserve, Poyang Baishazhou Nature Reserve (BSZ), and Yugan Kangshan Migratory-bird Nature Reserve are provincial reserves; the other eight are county-level reserves (Liu *et al*., 2011). Poyang Lake has a humid subtropical climate with an annual average temperature of 16.7–17.7°C. The average annual precipitation is 1,400–1,900 mm (Huang and Guo, 2007). The wetland vegetation in Poyang Lake is dominated by *Cares* spp., *Phragmites australis*, *Potamogeton* spp. and *Polygonum* spp. (Liu *et al*., 2006). The reserves surveyed in this study are listed in Table I.

Table I.- Nature reserves and lakes surveyed in five regions of Poyang Lake.

Nature reserve	Abbreviations*	Lakes surveyed	Time of survey
Poyanghu National Nature Reserve Wucheng (Four lakes)	PWC	Dahuchi, Baziqiang, Changhuchi, Zhushihu	October 14, 2012 to March 18, 2013
Poyanghu National Nature Reserve (Hengfeng) (Two lakes)	PHF	Shahu, Banghu	October 15, 2012 to April 13, 2013
Nanjishan Wetland National Nature Reserve (Eleven lakes)	NJS	Zhanbeihu, Sanhu, Changhu, Fengweihu, Sanniwan, Baishahu, Linghu, Shangbeijia, Xiabeijia, Beishenhu, Shentanghu	October 19, 2012 to April 8, 2013
Poyang Baishazhou Nature Reserve (Eight lakes)	BSZ	Zhuhu, Chemen, Rongqi, Sishilijie, Siwanghu, Xiaominghu, Daminghu, Biaoen	October 28, 2012 to April 2, 2013
Duchang Migratory Bird Nature Reserve (Ten lakes)	DC	Jishanhu, Zhongba, Xinmiaohu, Mayinghu, Huangjinzui, Binhu, Shuhu, Huamiaohu, Henggang, Xihu	November 4, 2012 to April 10, 2013

*PWC and PHF belong to Poyanghu National Nature Reserve. We divided them into two regions because they are located in two counties and were investigated at different times.

Data collection

Six water bird surveys of one or two days duration were conducted from October 2012 to April 2013 for each of the four reserves at intervals of 20 to 30 days (Table I). We also conducted supplemental investigations in some parts of NJS on 14 January, 9 March, and 8 April, 2013. A water bird survey was not conducted at Biaoen during the first investigation in BSZ. One to five fixed observation points were selected in each lake to count the number of water birds with binoculars (8×) and a Swarovski HD spotting scope (20–60×). The distance between any two points was at least 2.5 km to avoid double counting. On each visit, all species of birds were identified as far as possible, within an approximately 1000 m radius (Quan *et al.*, 2002; Pescador and Peris, 2009). Three fixed points (Shahu, Siwanghu, and Zhongba) varied by not more than 30 m depending on water level, to count water birds in the same area. Two species of Snipe were merged into *Gallinago* spp. because of difficult discrimination in the field. Direct counting was used for water birds with small populations. For species with large populations, a representative sample was counted and extrapolated to the entire population (Howes and Endagama, 1995; Nores, 2011).

Data analyses

The number of each water bird species in each region was fixed as the maximum value from six investigations, except NJS where there were eight investigations, over this wintering period. We adopted the maximum value method to avoid repeated counting (Howes and Bakewell, 1989). Water bird species representing over 10% of the total number of birds were regarded as dominant species in each region, and those with 1–9.99% of the total were labeled as common species (Niu *et al*., 2011). Only 27 species, the dominant or common species for any region, were further analyzed in order to avoid problems of statistical performance due to data shortage (Pescador and Peris, 2009). Bird diversity was calculated using the Shannon-Wiener Index: $H' = \Sigma (P_i) (\log_2 P_i)$, where P_i is the proportion of species *i* in the community. We examined the evenness using Pielou's evenness index: $J' = H' / H_{max}$, where $H_{max} = \log_2 S$, and S is the number of species in the community. A Kruskal–Wallis test evaluated bird abundance differences among different regions when data did not meet the requirements of parametric tests (Zar, 1999). An analysis of variance (ANOVA) test was used to analyze the abundance of other bird species. Principal Component Analysis (PCA) was also used

for ordination analysis of the study areas and the 27 represented species using the summarized number from six surveys. Values presented are means ± SE, and p-values < 0.05 are considered significant.

RESULTS

Water bird resources

A total of 68 species belonging to 6 orders were recorded from October 2012 to April 2013. Of the 68 species, 45 were winter visitors, 10 were migrants, six residents, and seven summer visitors (Table II). Four orders had the most species during our survey—25 species of Charadriiformes, 21 species of Anseriformes, 11 species of Ciconiiformes, and seven species of Gruiformes. Four species—black stork (*Ciconia nigra*), oriental stork (*Ciconia boyciana*), Siberian crane (*Grus leucogeranus*), and hooded crane (*Grus monacha*)—are listed in the First Category of the National Key Protected Wildlife Species in China. Six species are listed in the Second Category of National Key Protected Wildlife Species in China (Table II). Siberian crane and Baer's pochard (*Aythya baeri*) are listed as critically endangered species and the oriental stork is listed as an endangered species by the International Union for the Conservation of Nature (IUCN). Bean goose (*Anser fabalis*), Tundra swan (*Cygnus columbianus*), and swan goose (*Anser cygnoides*) were dominant in Poyang Lake, accounting for 18.40%, 13.29%, and 10.58% of total bird numbers respectively (Table II).

Regional variation of water birds

The least number of species (37) was detected in NJS. The other four regions had varying number of species, from 44 to 46 (Table II). Bean goose, greater white-fronted goose (*Anser albifrons*), Tundra swan, and eurasian spoonbill (*Platalea leucorodia*) were dominant in PWC, accounting for 17.36%, 16.40%, 11.51%, and 10.99% of total numbers in this region, respectively. Pied Avocet (*Recurvirostra avosetta*), bean goose, and swan goose were dominant in PHF, accounting for 14.55%, 10.73%, and 10.01% of total numbers respectively. Bean goose, swan goose, and Tundra swan were dominant in NJS, accounting for 25.16%, 21.10%, and 11.06% of total numbers, respectively. Tundra swan and common black-headed gull (*Larus ridibundus*) were dominant in BSZ, accounting for 32.79% and 20.62% of total numbers. Bean goose and dunlin (*Calidris alpina*) were dominant in DC, accounting for 23.72% and 10.39% of total numbers (Table II). The number of common species varied from 9 to 16 in five study regions. Great crested grebe (*Podiceps cristatus*), spot-billed duck (*Anas poecilorhyncha*), and spotted redshank (*Tringa erythropus*) were the common species in all five regions (Table II).

Of the 27 dominant or common species across all regions, significant differences were detected for 10 species (Table III). Spot-billed duck, ruddy shelduck (*Tadorna ferruginea*), and dunlin had greater abundance in DC. Grey heron (*Ardea cinerea*) and bean goose were more abundant in NJS and DC. Common black-headed gull had greater abundance in BSZ and DC. Eurasian spoonbill and hooded crane were concentrated in PWC and PHF. Common teal (*Anas crecca*) was more abundant in PHF and DC, and falcated duck (*Anas falcata*) was more abundant in PHF.

The bird composition was similar for BSZ, NJS, and DC. Many species had similar preferences for these three regions (Fig. 2). PWC and PHF were different; eurasian spoonbill, pied avocet, and spotted redshank preferred PHF while greater white-fronted goose preferred PWC.

Bird diversity

The number of species in DC was high during most surveys (Table IV). In general, the number of species during the last survey was the lowest (13-22). The bird diversity index was high in PWC (2.79-3.24). Bird diversity values generally were higher in mid-winter than in early or late winter, with the exception of NJS. PWC and PHF had steady and high evenness indices (0.59-0.80).

Dynamics of main water bird groups

Podicipediformes was very common in early or late winter in all study regions (Fig. 3). The proportion of Gruiformes increased gradually in PWC, PHF, and BSZ from November. Charadriiformes had lower proportions in NJS and BSZ (Fig. 4). The Anseriformes proportion showed a rapid increase in most regions in November that

Table II.- Checklist of wetland birds in five regions of Poyang Lake.

Order, Species name	Scientific name	PWC	PHF	NJS	BSZ	DC	Total	Status	PROT	IUCN
Podicipediformes										
Little grebe	*Tachybaptus ruficollis*	175*	54	105	152*	235*	721	R		
Great crested grebe	*Podiceps cristatus*	420*	500*	634*	180*	215*	1949*	W		
Total		**595**	**554**	**739**	**332**	**450**	**2670**			
Pelecaniformes										
Dalmatian pelican	*Pelecanus crispus*	4	0	0	0	0	4	W	□	**VU**
Great cormorant	*Phalacrocorax carbo*	11	32	80	58	27	208	W		
Total		**15**	**32**	**80**	**58**	**27**	**212**			
Ciconiiformes										
Grey heron	*Ardea cinerea*	98	130*	1110*	136	230*	1704*	R		
Purple heron	*Ardea purpurea*	1	0	3	0	1	5	S		
Great egret	*Egretta alba*	116	16	0	3	3	138	W		
Intermediate egret	*Egretta intermedia*	11	20	0	6	8	45	S		
Little egret	*Egretta garzetta*	62	78	8	46	34	228	S		
Cattle egret	*Bubulcus ibis*	0	1	0	0	3	4	S		
Chinese pond-heron	*Ardeola bacchus*	0	0	1	0	0	1	S		
Black-crowned night heron	*Nycticorax nycticorax*	0	0	0	1	6	7	R		
Black stork	*Ciconia nigra*	1	1	0	0	9	11	W	□	
Oriental stork	*Ciconia boyciana*	388*	136*	205*	63	0	792	W	□	EN
Eurasian spoonbill	*Platalea leucorodia*	1842**	809*	1022*	9	305*	3987*	W	□	
Total		**2519**	**1191**	**2349**	**264**	**599**	**6922**			
Anseriformes										
Tundra swan	*Cygnus columbianus*	1930**	305*	2075**	4495**	1951*	10756**	W	□	
Swan goose	*Anser cygnoides*	450*	1101**	3960**	1145*	1905*	8561**	W		VU
Bean goose	*Anser fabalis*	2910**	1180**	4721**	1168*	4910**	14889**	W		
Greater white-fronted goose	*Anser albifrons*	2750**	440*	836*	1100*	835*	5961*	W	□	
Lesser white-fronted goose	*Anser erythropus*	0	1	0	0	0	1	W		VU
Greylag goose	*Anser anser*	100	40	550*	430*	150	1270*	W		
Ruddy shelduck	*Tadorna ferruginea*	10	0	0	133	295*	438	W		
Common shelduck	*Tadorna tadorna*	0	5	0	0	1	6	W		
Eurasian wigeon	*Anas penelope*	0	210*	0	0	22	232	W		
Falcated duck	*Anas falcata*	2	300*	0	50	0	352	W		NT
Baikal teal	*Anas formosa*	0	0	0	0	1	1	W		
Common teal	*Anas crecca*	50	620*	79	54	281*	1084*	W		
Mallard	*Anas platyrhynchos*	17	20	2	1	0	40	W		
Spot-billed duck	*Anas poecilorhyncha*	415*	316*	130	226*	720*	1807*	R		
Northern pintail	*Anas acuta*	0	3	0	0	0	3	W		
Northern shoveler	*Anas clypeata*	0	54	1	0	0	55	W		
Common pochard	*Aythya ferina*	300*	0	0	0	0	300	W		
Baer's pochard	*Aythya baeri*	0	0	0	0	35	35	W		CR
Tufted duck	*Aythya fuligula*	20	0	0	0	200	220	W		

Table II continued

Order, Species name	Scientific name	PWC	PHF	NJS	BSZ	DC	Total	Status	PROT	IUCN
Greater scaup	*Aythya marila*	0	0	0	0	2	2	W		
Common merganser	*Mergus merganser*	0	0	0	0	15	15	W		
Total		**8954**	**4595**	**12354**	**8802**	**11323**	**46028**			
Gruiformes										
Siberian crane	*Grus leucogeranus*	158	364*	350*	15	15	902*	W	□	**CR**
White-naped crane	*Grus vipio*	237*	361*	2	6	6	612	W	□	**VU**
Common crane	*Grus grus*	131	39	66	326*	88	650	W	□	
Hooded crane	*Grus monacha*	154	302*	13	4	0	473	W	□	**VU**
Brown crake	*Amaurornis akool*	0	0	0	3	2	5	S		
Common moorhen	*Gallinula chloropus*	3	0	13	25	6	47	R		
Common coot	*Fulica atra*	200*	0	109	71	90	470	W		
Total		**883**	**1066**	**553**	**450**	**207**	**3159**			
Charadriifromes										
Black-winged stilt	*Himantopus himantopus*	0	1	10	0	5	16	W		
Pied avocet	*Recurvirostra avosetta*	700*	1600**	375*	10	1953*	4638*	P		
Northern lapwing	*Vanellus vanellus*	65	52	345*	46	467*	975*	W		
Grey-headed lapwing	*Vanellus cinereus*	24	17	0	4	17	62	S		
Long-billed plover	*Charadrius placidus*	0	0	0	0	1	1	W		
Little Ringed plover	*Charadrius dubius*	6	0	0	1	44	51	R		
Kentish plover	*Charadrius alexandrinus*	100	3	6	34	77	220	P		
Lesser sand plover	*Charadrius mongolus*	0	4	0	0	1	5	P		
Snipe	*Gallinago* spp.	5	1	3	3	6	18	P		
Black-tailed godwit	*Limosa limosa*	450*	9	0	0	50	509	P		NT
Bar-tailed godwit	*Limosa lapponica*	0	4	0	0	0	4	P		
Eurasian curlew	*Numenius arquata*	2	0	0	1	1	4	W		NT
Spotted redshank	*Tringa erythropus*	1626*	1000*	1135*	805*	1826*	6392*	W		
Common redshank	*Tringa totanus*	0	3	0	0	20	23	W		
Marsh sandpiper	*Tringa stagnatilis*	0	6	32	4	40	82	W		
Common greenshank	*Tringa nebularia*	20	22	25	7	63	137	W		
Green sandpiper	*Tringa ochropus*	0	0	2	4	1	7	W		
Wood sandpiper	*Tringa glareola*	0	2	0	8	2	12	P		
Common sandpiper	*Tringa hypoleucos*	15	0	1	4	3	23	W		
Red knot	*Calidris canutus*	0	0	0	0	1	1	P		
Red-necked stint	*Calidris ruficollis*	0	0	0	0	2	2	P		
Temminck′s stint	*Calidris temminckii*	0	0	0	20	0	20	P		
Dunlin	*Calidris alpina*	130	620*	640*	22	2150**	3562*	W		
Herring gull	*Larus argentatus*	3	5	8	3	12	31	W		
Common black-headed gull	*Larus ridibundus*	653*	207*	108	2827**	1354*	5149*	W		
Total		**3799**	**3556**	**2690**	**3803**	**8096**	**21944**			

Notes: Status: R, residents; S, summer migrants; W, winter migrants; P, passage migrants. **/*: dominant/common species in Poyang Lake. PROT=protected animal in China: I, First Category of National Key Protected Wildlife Species in China; II, Second Category of National Key Protected Wildlife Species in China; IUCN: CR, critically endangered species; EN, endangered species; VU, vulnerable species; NT, near threatened species.

Table III. - Mean ± SE (n=6) of dominant and common water birds in five regions of Poyang Lake

Species	PWC	PHF	NJS	BSZ	DC	F^*	*p*
1. Little grebe	57±33	9±9	53±14	95±20	106±35	2.440	0.073
2. Great crested grebe	99±66	131±84	104±59	126±19	82±30	0.126	0.972
3. Grey heron	59±14	51±17	437±128	72±19	139±34	7.289	0.000
4. Bean goose	1159±467	438±206	2235±699	478±209	2813±847	3.747	0.016
5. Spot-billed duck	155±64	82±49	90±20	84±32	350±109	3.338	0.025
6. Spotted redshank	570±245	363±172	598±142	135±100	372±293	0.853	0.505
7. Oriental stork	131±73	63±26	58±33	14±10	0±0	9.138	0.058
8. Eurasian spoonbill	508±284	376±124	206±166	2±2	84±49	10.048	0.040
9. Tundra swan	437±306	74±48	402±336	1867±705	523±295	4.569	0.334
10. Swan goose	114±74	251±181	1578±604	521±219	359±309	6.336	0.175
11. Greater white-fronted goose	686±430	99±70	284±143	434±183	353±134	2.798	0.592
12. Greylag goose	17±17	11±7	105±90	80±70	26±25	0.817	0.936
13. Ruddy shelduck	3±2	0±0	0±0	38±23	158±45	16.216	0.003
14. Eurasian wigeon	0±0	68±43	0±0	0±0	6±4	6.699	0.153
15. Falcated duck	0±0	100±63	0±0	22±10	0±0	9.720	0.045
16. Common teal	12±8	193±97	9±5	20±10	87±42	9.554	0.049
17. Common pochard	50±50	0±0	0±0	0±0	8±8	3.109	0.540
18. Siberian crane	41±24	81±57	72±36	7±3	3±3	8.128	0.087
19. White-naped crane	53±38	79±57	1±0	2±1	2±1	7.677	0.104
20. Common crane	51±23	9±6	9±6	197±64	39±18	8.213	0.084
21. Hooded crane	54±23	74±49	4±2	1±1	0±0	13.057	0.011
22. Common coot	47±33	0±0	22±18	17±12	16±15	8.477	0.076
23. Pied avocet	135±114	327±258	60±60	3±2	398±316	3.754	0.440
24. Northern lapwing	23±11	23±9	125±56	17±7	151±72	5.785	0.216
25. Black-tailed godwit	82±74	2±2	0±0	0±0	11±8	8.350	0.080
26. Dunlin	22±22	103±103	107±107	4±4	437±345	12.037	0.017
27. Common black-headed gull	155±106	76±41	18±18	615±445	659±196	15.193	0.004

Notes: *: Species 1-6 were tested by ANOVA; species 7-27 were tested by Kruskal–Wallis test.
Abbreviations used: DC, BSZ, Poyang Baishazhou Natural Reserve; Duchang Migratory Bird Nature Reserve; NJS, Nanjishan Wetland Nature Reserve; PHF, Poyanghu National Nature Reserve; PWC, Poyanghu National Nature Reserve Wucheng.

Table IV.- Community parameter variations of water birds at different times in Poyang Lake.

Index	Areas	First	Second	Third	Fourth	Fifth	Sixth
Number of species	PWC	19	29	22	24	20	20
	PHF	17	28	16	23	27	13
	NJS	12	20	26	20	19	13
	BSZ	27	24	24	25	28	19
	DC	27	28	29	28	28	22
Shannon-Wiener (*H'*)	PWC	3.18	2.89	3.24	3.24	3.06	2.79
	PHF	2.86	3.10	2.63	3.10	3.79	2.52
	NJS	2.93	2.72	2.77	2.54	2.36	1.80
	BSZ	2.44	2.00	2.77	2.79	2.92	3.2
	DC	2.06	2.76	2.95	3.11	3.76	2.55
Pielou (*J'*)	PWC	0.75	0.59	0.73	0.71	0.71	0.64
	PHF	0.70	0.65	0.66	0.68	0.80	0.68
	NJS	0.82	0.63	0.59	0.59	0.56	0.49
	BSZ	0.51	0.44	0.60	0.60	0.61	0.75
	DC	0.43	0.57	0.61	0.65	0.78	0.57

For abbreviations see Table III.

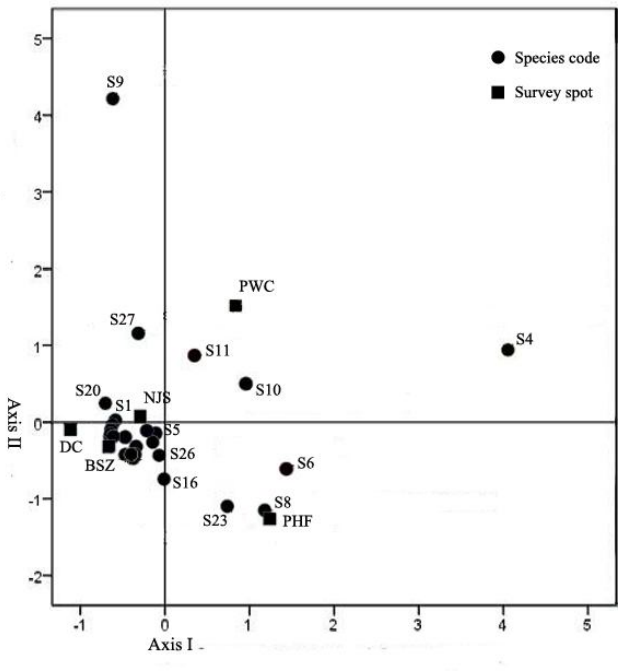

Fig. 2. PCA ordination plots of five sampling regions and dominant or common species in Poyang Lake in a two dimensional ordinal space (See Table III for species codes)

stayed high until March, then decreased gradually. Ciconiiformes had high proportion in PWC and PHF in October and January.

DISCUSSION

Water bird resources

The number of species recorded during this investigation (68) was larger than that recorded at Nanjishan National Nature Reserve and Kangshan (Sheng and Li, 2006; Zhang *et al.*, 2011). Earlier investigations on water birds in Poyang Lake were conducted only once or twice in only one region during the whole wintering period. Our study had a larger scope and conducted multiple times. The number of species observed during this study was more than that recorded in the surrounding provinces, such as at Chongming Island (Shanghai; 49 species) and at two lakes in Anhui (43 species) (Zhao *et al.*, 2003; Chen *et al.*, 2011). The result was similar to that recorded in the Huaihe River Basin of Anhui (61 species) (Bao *et al.*, 2011). The number of species in this study were the same as water birds observed in Shanghai (37 common species) and the Huaihe Basin in Anhui (47 common species), owing to the similar climate and habitats (Zhao *et al.*, 2003; Bao *et al.*, 2011). Bean goose, Tundra swan, and swan goose were the common dominant species between this study and that of two lakes in Anhui (Chen *et al.*, 2011). Spot-billed duck, herring gull (*Larus argentatus*), and Saunders's gull (*Larus saundersi*) were the dominant species at Chongming Island (Zhao *et al.*, 2003). The spot-billed duck was a common species in this study and Saunders's Gull was replaced by the common black-headed gull.

The relationship between water birds and regions

Population of most of the dominant and common species was not significantly different among the five regions. Bean goose was the common dominant species in four of the regions, and the third most abundant species in other region (BSZ) (Table II). The Tundra swan and swan goose were dominant species in more than one region during this study. The dominant species in all five regions were dominant or common species in other regions as well, indicating high correlations of species composition among the five regions.

Further analysis of the summarized abundance of water birds in different regions of Poyang Lake indicated that Tundra swan, swan goose, bean goose, greater white-fronted goose, and common black-headed gull each accounted for more than 4.0% of the total number of individuals in BSZ. Each of these five species also accounted for at least 4.0% of the total number of individuals in DC. In NJS these five species were well represented, although grey heron and spotted redshank were also common in this region. These three regions had similar bird compositions (Fig. 2). Swan goose, bean goose, Eurasian spoonbill, pied avocet, and spotted redshank each accounted for more than 10% of the total number of individuals in PHF. Bean goose, greater white-fronted goose, Eurasian spoonbill, Tundra swan, and spotted redshank each accounted for more than 9% of total number of individuals in PWC. Thus the bird composition in PWC and PHF was different from other regions (Fig.2).

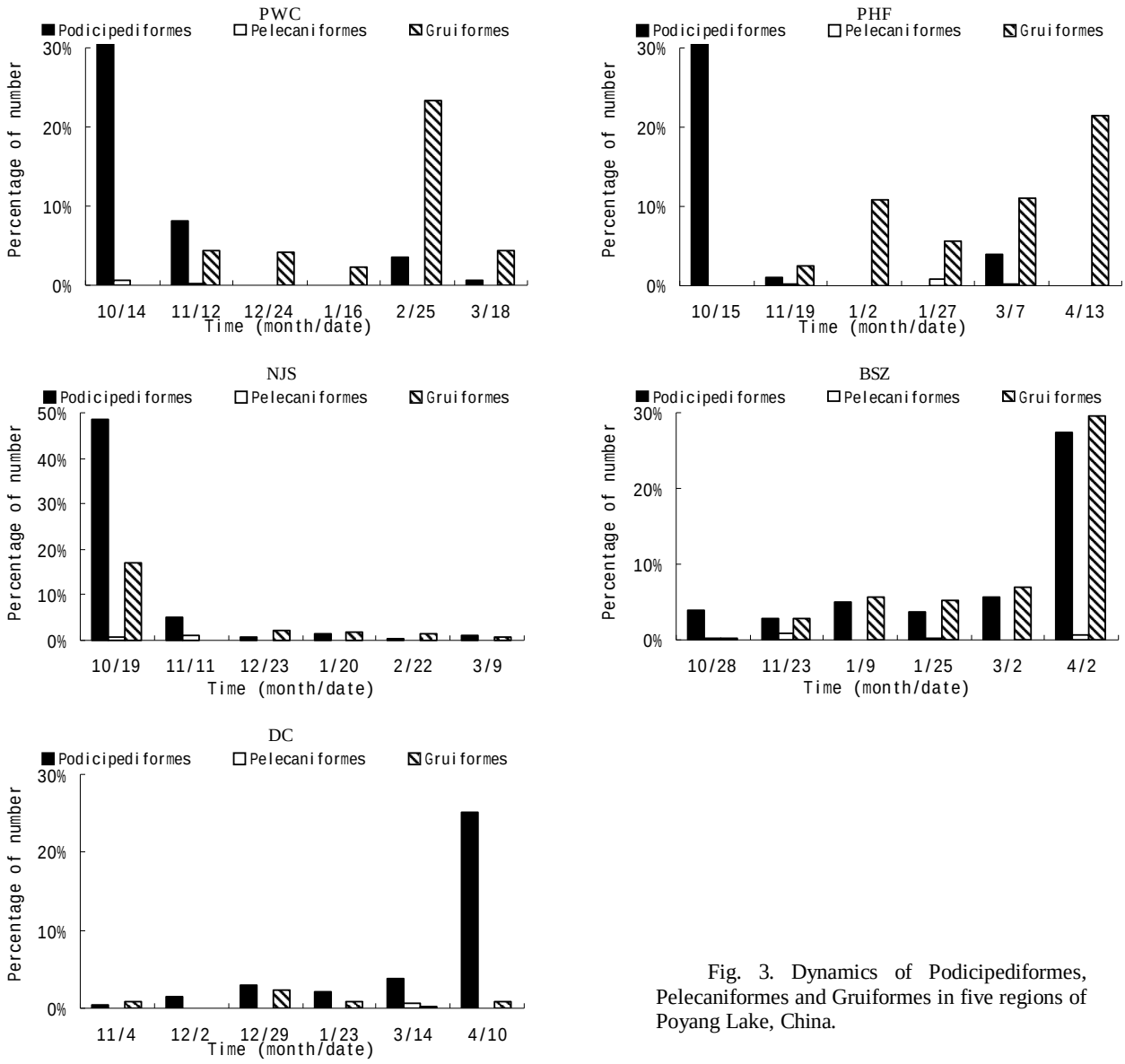

Fig. 3. Dynamics of Podicipediformes, Pelecaniformes and Gruiformes in five regions of Poyang Lake, China.

Dynamics of main water bird groups

Number of main water bird groups reached their maximum at different times, indicating the temporal separation of species at wintering sites (Andrei *et al.*, 2006; Chen *et al.*, 2011). Shallow areas dominated in our study area during midwinter, decreasing suitable habitat and, thus, abundance of Podicipediformes (Zhang *et al.*, 2011). The large numbers of other wintering water birds may also play a role in the low proportion of Podicipediformes in midwinter. Grey heron was the most dominant species of Ardeidae except during the first survey in PWC, when a large number of great egret (*Egretta alba*) were observed. The summer migrants of this order were only found in early April, except for little egret and Chinese pond-heron, which were also observed at other times. More than 100 grey heron were observed in PHF on 15 October, suggesting that this species was an early winter migrant in Poyang Lake. High and steady abundance of four crane species was seen in Poyang Lake. Siberian crane was mainly distributed in NJS,

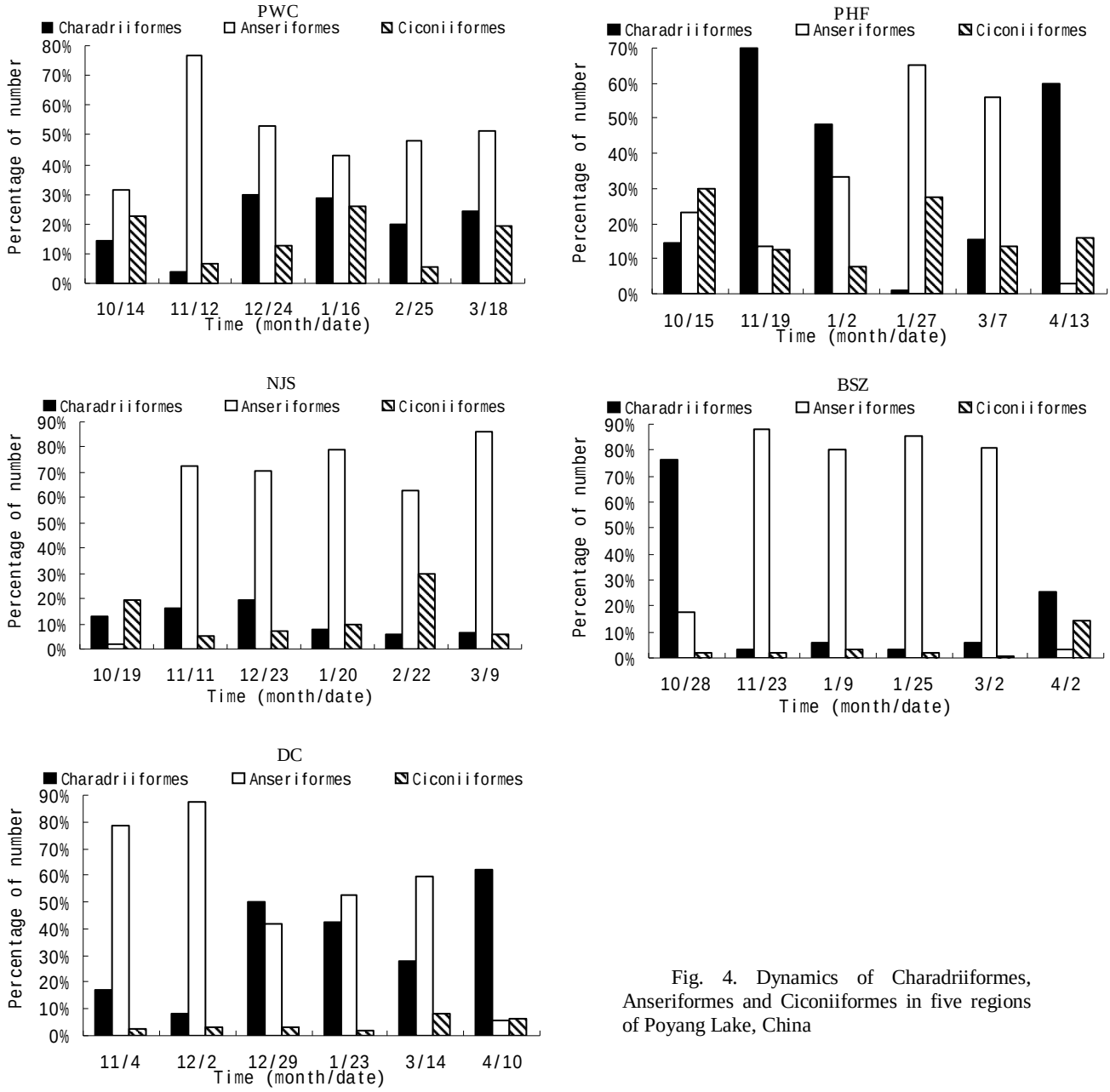

Fig. 4. Dynamics of Charadriiformes, Anseriformes and Ciconiiformes in five regions of Poyang Lake, China

PWC and PHF but varied in their preference for various lakes of the two reserves. Siberian crane mainly concentrated in Beishenghu of NJS in late December (Beishenghu 182 individuals, other lakes 18 individuals). This species scattered to other lakes in late January (Sanhu 30, Baishahu 35, Linghu 2, Shangbeijia 48, Beishenghu 14). The drastic decrease of abundance in Beishenghu was related to low water level; in January most areas of Beishenghu were dry and enough food could not be found (personal observation). About 350 Siberian cranes were observed in Sanhu in late March; perhaps this species selected Sanhu as their main stopover site; this species was not observed in other

regions at that time during this study. The movements of Siberian crane among different small lakes within one region should be further studied. The frequent movements of Siberian crane suggest that we should consider conservation of habitats for this species at a larger scale. The common crane maintained high abundance and wide distribution in four nature reserves during this study. Many individuals of this species were also distributed outside the nature reserves (personal observation). The white-naped crane (*Grus vipio*) and hooded crane (*Grus monacha*) were mainly distributed in Banghu, Shahu, Zhushihu, and Dahuchi. We found more individuals of these two species in PHF than in other regions (Table III). Cranes migrate in flocks, and many of the cranes that had scattered to other regions gathered in PWC and PHF to prepare to migrate in late February or early March. A mixed group of cranes (Siberian crane: 51 individuals, white-naped crane: 3 individuals) were found in mid-April in PHF. Further research is needed to see if these cranes breed in the surrounding habitats of Poyang Lake.

Pied avocet, Northern lapwing, spotted redshank, and Dunlin were the main species of Charadriiformes, although this order had rich species diversity. Bean goose, swan goose, Tundra swan, greater white-fronted goose, and spot-billed duck were the main species of Anseriformes. These birds migrated gradually to Poyang Lake in mid-October and showed a rapid population increase in most regions in November, keeping high proportion in middle March in our study. In Anhui, Anseriformes peaked in late February and decreased rapidly in early March (Chen *et al.*, 2011). This difference could be explained by annual variations in migration. Oriental storks were mainly distributed in NJS, PWC and PHF, beginning in late November or December, indicating that this species is a winter migrant in Poyang Lake. The abundance of oriental stork peaked in January and February and decreased drastically in March, indicating that this species migrated to breeding sites earlier; this may be related to its long hatching and incubation period (Yang *et al*., 2007). We also detected some oriental storks in PHF in mid-April. These individuals may breed in the surrounding suitable habitats of Poyang Lake, nesting on high-voltage towers (Zhang *et al.*, 2012).

In conclusion, Poyang Lake has rich water bird diversity and is an important wintering habitat for many endangered birds. About 90% of all Siberian cranes, 50% of all white-naped cranes, and 60% of all swan geese in the world selected Poyang Lake as their wintering habitat (Wu and Ji, 2002). However, little quantitative research on water birds in Poyang Lake has been reported. A repeatable and robust sampling protocol should be developed to monitor the birds studied here, and to report annually. In addition, the habits of many endangered species such as the oriental stork and cranes are not known. Further research should focus on how and why these endangered species select lakes, their local movement patterns among lakes, and behavior adaptations.

ACKNOWLEDGEMENTS

Funding for these projects was provided by Chinese Natural Sciences Fund (Grant No. 31260517, 31101651). This manuscript benefited from comments provided by three reviewers.

REFERENCES

ANDREI, A. E., SMITH, L.M., HAUKOS, D.A. AND SURLES, J.G., 2006. Community composition and migration chronology of shorebirds using the saline lakes of the Southern Great Plains, USA. *J. Field Ornithol.*, **77**:372-383.

BAO, F.Y., WANG, S., WANG, M. AND ZHENG, W., 2011. Field survey on wetland waterbird in Huaihe River Basin in Anhui, China. *Chinese J. Zool.*, **46**: 117-125.

CHEN, J.Y., ZHOU, L.Z., ZHOU, B., XU, R.X., ZHU, W.Z. AND XU, W.B., 2011. Seasonal dynamics of wintering water birds in two shallow lakes along Yangtze River in Anhui Province. *Zool. Res.*, **32**: 540-548.

CUI, P., XIA, S.X., LIU, G.H., WU, J.D., ZENG, N.J., WU, X.D., WEN, S.B., LUO, S.J., JI, W.T. AND LEI, F.M., 2013. Population dynamics of wintering water birds in Poyang Lake. *Sichuan J. Zool.*, **32**: 292-296.

FU, D.Y., DING, T.M., HU, P.Y. AND ZHENG, Q.Z., 1989. A survey of birds in the Poyang Lake hill-lines area. *Jiangxi Sci.*, **7**: 32-43.

GUEVARA, E.A., SANTANDER, T. AND DUIVENVOORDEN, J.F., 2012. Seasonal patterns in aquatic bird counts at five Andean Lakes of Ecuador. *Water birds*, **35**:636-641.

HOWES, J. AND BAKEWELL, D., 1989. *Shorebird studies*

manual. AWB Publication, Malaysia.

HOWES, M. AND ENDAGAMA, P., 1995. *Farmers, forests and fuel: towards a new biomass energy strategy for Sri Lanka*. Intermediate Technology Publications, London.

HUANG, J.G. AND GUO, Z.Y., 2007. The wetland biodiversity and its conservation counter measures in the Poyang Lake. *Res. S. W. Conserv.*, **14**: 305-306, 309.

LIU, X.Z., FAN, S.B. AND HU, B.H., 2006. *Comprehensive and scientific survey of Jiangxi Nanjishan Wetland Nature Reserve*. Chinese Forestry Press, Beijing.

LIU, C.L., TAN, Y.J., LIN, L.S., TAO, H.N. AND TAN, H.R., 2011. The wetland water level process and habitat of migratory birds in Lake Poyang. *J. Life Sci.*, **23**: 129-135.

MCPARLAND, C.E. AND PASZKOWSKI, C.A., 2007. Water bird assemblages in the Aspen Parkland of western Canada: the influence of fishes, invertebrates, and the environment on species composition. *Ornithol. Sci.*, **6**:53-65.

NIU, J.Y., HENG, N.N., ZHANG, B., YUAN, X. AND WANG, T.H., 2011. Water bird habitat-selection during winter and spring in reclaimed coastal wetlands in Nanhui Dongtan, Shanghai. *Zool. Res.*, **32**: 624-630.

NORES, M., 2011. Long-term water bird fluctuations in Mar Chiquita Lake, Central Argentina. *Water birds*, **34**: 381-188.

PESCADOR, M. AND PERIS, S., 2009. Seasonal and water mass size effects on the abundance and diversity of water birds in a Patagonian National Park. *Waterbirds*, **32**: 25-35.

QUAN, R.C., WEN, X.J. AND YANG, X.J., 2002. Numbers of migratory water birds at Lake Lashihai, China. *Waterbirds*, **25**: 239-244.

SHAN, J.H., MA, J.Z., LI, Y.K., QIAN, F.W. AND TU, X.B., 2012. Population and distribution of the Siberian crane (*Grus leucogeranus*) wintering in the Poyang lakes over the past decade. *Zool. Res.*, **33**: 355-361.

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.

SHAO, M.Q., SHI, W.J., ZENG, B.B. AND JIANG, J.H., 2014. Diving behavior of scaly-sided mergansers *Mergus squamatus* in Poyang Lake watershed, China. *Pakistan J. Zool.*, **46**: 284-288.

SHENG, X.H. AND LI, D.S., 2006. Present situation of birds resource in Kangshanhu Nature Reserve for migrators and their protection. *Jiangxi F. Sci. Tech.*, **34**: 42-44, 50.

TU, Y.G., YU, C.H., HUANG, X.F., SHAN, J.H., SUN, Z.Y. AND WANG, Z.R., 2009. Distribution and population of the overwintering Anatidae waterfowl in the Poyang Lake. *Acta Agric. Univ. Jiangxi*, **31**: 760-764, 711.

WU, Y.H. AND JI, W.T., 2002. *Study on Poyang Lake National Nature Reserve in Jiangxi*. Chinese Forestry Press, Beijing.

XIA, S.X., YU, X.B. AND FAN, N., 2010. The wintering habitats of migrant birds and their relationship with water level in Poyang Lake, China. *Res. Sci.*, **32**: 2072-2078.

YANG, C., ZHOU, L.Z., ZHU, W.Z. AND HOU, Y.X., 2007. A preliminary study on the breeding biology of the oriental white stork *Ciconia boyciana* in its wintering area. *Acta Zool. Sin.*, **53**: 215-226.

ZAR, J.H., 1999. *Biostatistical analysis*. Prentice-Hall Inc., Englewood Cliffs, New Jersey.

ZHANG, X.R., SHAO, M.Q., XU, T., JIAN, M.F., NI, C.Y. AND HU, B.H., 2011. Study on bird diversity in Nanjishan National Nature Reserve, Jiangxi Province during non-breeding period. *Sichuan J. Zool.*, **30:** 649-653.

ZHANG, Y., SHAO, M.Q., ZENG, B.B. AND JIANG, J.H., 2012. Study on bird diversity in electric transmission lines of Jiangxi Province. *J. Anhui Agric. Sci.*, **30**: 14750-14752, 14843.

ZHAO, P., YUAN, X., TANG, S.X. AND WANG, T.H., 2003. Species and habitat preference of water birds at the Eastern end of Chongming Island (Shanghai) in winter. *Zool. Res.*, **24**: 387-391.

ZHU, Q., LIU, G.H., ZENG, N.J., WU, J.D., JIN, J.F. AND ZHAN, H.Y., 2012. Number and distribution of water birds wintered during 2007 to 2009. *Wetland Sci. Mana*, **8**: 52-56.

(Received 12 June 2013, revised 6 January 2014)