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Bird Diversity in the Buffer Zone of the Largest Coastal Nature Reserve of China and Conservation Implications

Xuanlu Li,[1] Xian Zhang,[2] Xinrong Xu,[1] Shicheng Lv,[3] Yongqiang Zhao,[2] Danxi Chen,[1] Chenxi Hou,[1] Bingyao Chen[1]* and Guang Yang[1]*

[1]*Jiangsu Key Laboratory for Biodiversity and Biotechnology, College of Life Sciences, Nanjing Normal University, Nanjing 210023, China*
[2]*Tongling Freshwater Porpoise National Nature Reserve, Tongling 244161, China*
[3]*The National Yancheng Rare Birds Nature Reserve, Yancheng 224333, China*

ABSTRACT

Buffer zone (BZ) of nature reserve is usually ignored in protecting bird diversity. Yancheng Rare Birds National Nature Reserve, the largest coastal reserve of China, supports higher bird diversity, but the buffer zone (BZ) function and its avian fauna composition remained unclear. In December 2010, we investigated the bird diversity in BZ of Yancheng reserve covering 188.8 km transect line. As a result, 50 species belonging to 26 families and 13 orders were identified. The general bird diversity index H in BZ is 2.291 with evenness of 0.583, and three orders *viz.*, Ciconiiformes, Passeriformes and Charadriiformes, showed high bird diversity (H > 1). Considering high bird diversity and preference of 32 protected species including endangered red-crowned (*Grus japonensis*) and grey cranes (*Grus grus*), the northern BZ should be now considered to be priority protected area and even upgraded to core area. Although relationship index (I) between aquaticulture area and cultivated fields was 0.688, the dominant species compositon in aquaticulture area (five species comprised 75.3%) and cultivated fields (two species comprised 73.6%) was significantly different. Therefore both the habitats were equally important for bird conservation, and should be given the same protection efforts. Under the influence of natural forces and anthropogenic activities, the habitats are continuously changing. Therefore, we suggest monitoring the bird diversity annually, so that we can take targeted and effective protection measures.

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BC, XZ, XX, SL and YZ performed field survey and birds identification. XL, BC, DC and CH analyzed the data. BC, XL, XZ and GY wrote and revised the paper.

Key words
Buffer zone, bird diversity, Yancheng reserve, dominant species.

INTRODUCTION

In many places around the world, the ecosystems are being pressured by rapid population growth and economic development (Lu *et al*., 2007). Human activities, such as reclamation changed natural environments and drastically reduced local biodiversity (Beardsley *et al*., 2009; MacGregor-Fors, 2011; MacGregor-Fors *et al*., 2009; Khan *et al*., 2015; Shakeel *et al*., 2015). The conservation of ecosystem services is highly focused on the protection of biodiversity. Biodiversity is a combination of habitat diversity, species diversity, and genetic diversity, and so on, representing an indicator of environment variation (Larsen *et al*., 2011). Due to birds' relative sensitivity to environmental changes, they can be used to evaluate trends of change in environment (Lindenmayer *et al*., 2000; Liu *et al*., 2004a; Reis *et al*., 2012); bird diversity has become an important estimator for ecological conditions (Larsen *et al*., 2011). In China, some related research has been carried out, such as the report of investigation on birds in Datian National Nature Reserve, Hainan Preliminary (Liu *et al*., 2004b), the seasonal variation of large and small Sugan Lake (wetland) bird diversity (Bao *et al*., 2007), the bird diversity and the protection of the Daxiao zhan river Wetland National Nature, Heilongjiang River (Zhou *et al*., 2011).

With the purpose of protecting the red-crowned crane (*Grus japonensis*), migratory birds, and the coastal wetland habitats, Yancheng Rare Birds National Nature Reserve (Yancheng Reserve) was established in 1983, and upgraded to national reserve in 1992. Yancheng Reserve is the largest coastal wetland nature reserve in China, which covers 2472.6 km^2 areas. The reserve supports a high diversity of 1665 faunal species, including 394 bird species (Lv *et al*., 2007). The population of resident birds in the Reserve reaches almost half a million. Due to unique geographical location, Yancheng Reserve is an important migration corridor and transit station for many migratory birds, annual number of migratory birds was approximately 3 million (Lv *et al*., 2007), including the world's largest red-crowned crane migratory population of 1128 in winter of 1999-2000 (Wang *et al*., 2000). While the core area of Yancheng

* Corresponding author: chby2632@163.com
gyang@njnu.edu.cn
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Reserve is only 225.96 km^2 its environmental capacity however fails to support such a large number of birds. For instance, the available food for the grey cranes and red-crown cranes decreased by 25.32% from 1992 to 2006 (Tang *et al*., 2010), and they were found foraging in the northern buffer zone (BZ). The BZ therefore played an important role in sustaining and protecting the bird diversity.

Ecology of several flagship species has been studied within the core area, such as the distribution (Lv *et al*., 2006), habitat selection of the red-crowned crane (Sun and Liu, 2011; Wang *et al*., 2016), their food resources availability over the year (Tang *et al*., 2010), and breeding habitat selection of the black-beaked gull (*Larus saundersi*) (Jiang *et al*., 2002). The bird diversity and community composition in BZ however remained unclear. Additionally, in recent years, expanding economic development in this area has converted the natural landscape to aquaculture and cultivated fields (Lu *et al*., 2007). The study of bird species diversity in the BZ is important to understand the impacts of habitat/ environmental change and conservation of birds.

The present study is focused on bird species diversity in the buffer zone of Yancheng Reserve, with the objectives of identifying the endangered species distribution and importance of different habitats to provide guidance for conservation management of Yancheng Reserve and other wetland reserves.

MATERIALS AND METHODS

Study sites

Yancheng Reserve is situated in the coastal area of Jiangsu Province, East China, 32°34'N to 34°28'N and 119°48'E to 120°56'E, with a 582 km long coastline and 4530 km^2 area. The reserve is located in the transition belt between the warm temperate and the northern subtropical zones. The climate is hot and humid in summer, and dry and cold in winter. The natural vegetation in the area is comprised of mudflats (with algae), salt-works, reed grasses, seep weeds, and ponds (Li *et al*., 2006). The reserve includes southern and northern buffer zones, the former has mainly been developed for aquaculture, and the latter comprises of a variety of habitats, such as cultivated fields, aquaculture, reed-grass community, and mudflats. Of these, cultivated fields and aquaculture are the dominant habitats as these respectively occupy 39.6% and 51.3% of the total study area. The northern buffer zone was therefore selected as the study area that covers 224.9 km^2 areas.

Field work

Field survey was conducted during 15th-30th December, 2010 when the migratory birds had arrived. Our field survey covered all the habitat types except the mudflats, due to safety factor and the difficulty of conducting transect line surveys.

Restricted by local terrain and man-made aqueducts, we designed the parallel survey lines (approximate transect line) as for as possible (Fig. 1); total length of transects was 188.8 km. The distance between adjacent transects was approximately 1 km.

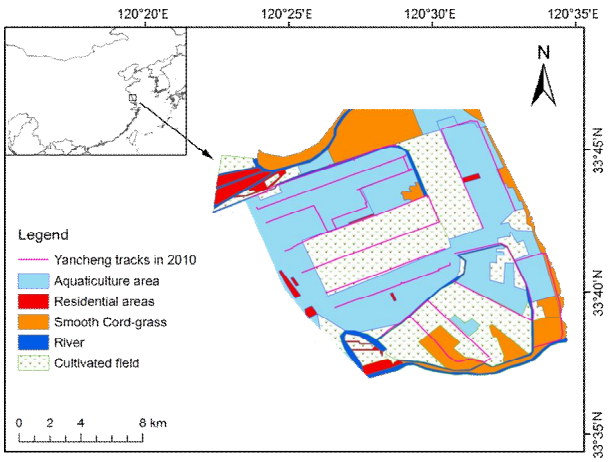

Fig. 1. The map of study area and GPS tracks of approximate transect lines.

Three researchers were trained on the identification of bird species in advance. The survey started at 7:30 to 8:30 and lasted until 13:00 to 16:00 h, depending on the length of survey line selected. The transect lines were walked at the speed of 2-3 km/h. Due to very few trees, shrubs, and absence of crops in cultivated fields during winter, the visibility was very good. Therefore, the scan range might have reached 100-150 m on both sides of the transect lines. When birds were spotted, the time, habitat types, species of the bird, and numbers were recorded. Photographs of the unidentified species were taken, by using Canon EOS-1Ds Mark II or III digital camera with a 100-400 mm zoom lens and 1.4 X Tele-converter, for further identification. "A field guide to the birds of China" (edited by Phillips Machinnon "A checklist on the classification and distribution of the birds of China" (Zheng 2011) were used, and website of China Bird Gallery (http://old.wwfchina.org/birdgallery) was visited to identify the species.

Data analysis

We evaluated the bird diversity using the Shannon-Wiener diversity index (Song *et al*., 2006; Yang *et al*. 2009).

$$H=-\sum Pi\ln Pi,$$

whereas *Pi* is the probability of the number of *i* species of individual bird species (purpose) in one sample area against the number of all bird species. The degree of homogeneity was determined by using Pielou index (Sun *et al.*, 2002), $J=H/H_{MAX}=H/\ln S$, whereas *S* is the number of species in the sample area, H_{MAX} for the maximum diversity values, $H_{MAX}=\ln S$.

We also used these indexes to evaluate diversity and evenness of seven of the 13 bird orders identified: six orders were not included for the reasons that only one species was observed of Pelecaniformes, Piciformes, and Galliformes, or only a few species of orders Podicipediformes, Lariformes, and Falconiformes were identified relative to the total number of individuals observed. To compare the bird diversity in the two dominant habitats of aquaculture and cultivated fields, a correlation analysis was conducted with Smith correlation coefficient (Yang *et al*., 2009), I=2C/ (A+B), where C is the number of species in both the communities A and B are the numbers of bird species in each of the two communities. We determined the dominant, common and occasional species based on number of birds and percent, *i.e.* with over 200 individuals or ≥10% percent as dominant species, 50-200 individuals or ≥5% as common species, <50 or <5% as occasional species.

RESULTS

Fifty bird species belonging to 26 families and 13 orders were identified in the northern buffer zone of Yancheng Reserve (Table I); one bird species belonging to order Falconiformes could not be identified up to family or species level; Passeriformes with the maximum number of species (n=17), and Pelecaniformes, Piciformes and Galliformes with only one species (Table I). Although several species of Podicipediformes were observed, but only the little grebe (*Tachybaptus ruficollis*) could be identified.

Of the 50 species, one and three birds have been listed respectively in Grade I and Grade II of Chinese National Key Protected Wild Animal Species, 28 bird species have been listed as Jiangsu provincial protected birds. Twenty four bird species are Cosmopolitan, six species distributed in the Oriental realm, and 20 species occur in Palaearetic realm. Based on the inhabitation pattern analysis, 24, 20, 3 and 3 species are respectively are winter migrant, resident, summer migrant, and passage migrants. Three bird species are listed as threatened according to IUCN Red List of Threatened species 2015.2 *viz.*, *Grus japonensis* (endangered), *Numenius madagascariensis* and *Calidris tenuirostris* (vulnerable), and *Paradoxornis heudei* are listed as Near Threatened; *Grus japonensis* is listed in the Appendix I and *Grus grus, Fulica atra* and *Gallinula chloropus* are included in the Appendix II of the Convention on International Trade of Endangered Fauna and Flora (CITES) (Table I).

A total of 8076 individuals were observed; 7738 (95.8%) and 5534 (68.5%) could be identified respectively to order level and species level. The number of bird species in Passeriformes, Lariformes, Anseriformes, Gruiformes, and Charadriiformes added up to 72.2% of all the birds identified to order level. *Grus grus* and *Passer montanus* made up the majority, with 1168 and 1504 individuals respectively, adding up to 51.7% of all the birds identified to species level.

In general, bird diversity in the northern buffer zone was 2.291, with evenness of 0.583 (Table II). Diversity index in the seven main orders was: Ciconiiformes showed the highest diversity (H=1.471), followed by Charadriiformes and Passeriformes (H >1.000). Coraciiformes, Columbiformes, Gruiformes and Anseriformes showed the value of H below 1 (Table III).

Difference in aquaculture area and cultivated fields

Thirty-two species each were recorded from both the aquaculture habitat and cultivated fields; in all 42 species were counted; 22 species being common to both the habitats with a correlation coefficient I=0.688.

Aquaculture habitat showed a higher bird diversity and evenness than cultivated fields (Table II). *Parus montanus* was equally abundant in both the habitats. In aquaculture habitat, five abundant species (ranging between 5.8% and 21%) added up to 75.3% of the total number of birds; the proportion of four waterfowl species reached 52.3%. In contrast, two abundant species *Grus grus* and *G. japonensis* comprised 73.6% of total number of birds in the cultivated fields.

DISCUSSION

Method bias

The previous research on bird diversity focused on the identification and counts of bird species. Very few considered the parallel or transect survey lines due to the limitation of local terrain or vegetation. The northern BZ of Yancheng Reserve affords good visibility, and roads are straight. We therefore designed the approximate transect lines in northern BZ, which may have had a little bias.

Conservation implication

With increasing human disturbance and fragmentation of wetland landscape, the proportion of

Table I.- Bird species in the northern buffer zone of Yancheng's Rare Birds National Nature Reserve in December 2010.

Order	Family	Species	Distribution	Inhabit pattern	IUCN/CITES	Protection status
1. Gruiformes	1,Gruidae	*Grus japonensis*	Pa	Win	E/I	National I
		Grus grus	Pa	Win	II	National II
	2.Rallidae	*Fulica atra*	Co	Res	II	
		Gallinula chloropus	Co	Res	II	
2. Charadriiformes	3.Scolopacidae	*Numenius madagascariensis*	Co	Sum	V	Provincial
		Actitis hypoleucos	Pa	Sum		Provincial
		Calidris tenuirostris	Co	Tra	V	Provincial
		Tringa erythropus	Co	Win		Provincial
	4.Recurvirostridae	*Recurvirostra avosetta*	Pa	Win		
3. Podicipediformes	5.Podicipedidae	*Tachybapus ruficollis*	Co	Res		Provincial
4. Pelecaniformes	6.Phalacrocoracidae	*Phalacrocorax carbo*	Co	Win		
5. Lariformes	7.Laridae	*Larus ridibundus*	Co	Win		Provincial
		Larus canus	Co	Win		Provincial
		Larus vegae	Co	Win		Provincial
6. Ciconiiformes	8.Ardeidae	*Nycticorax nycticorax*	Co	Res		Provincial
		Ardea cinerea	Co	Res		Provincial
		Egretta garzetta	Or	Res		Provincial
		Mesophoyx intermedia	Or	Res		Provincial
		Botaurus stellaris	Pa	Res		Provincial
	9.Threskiornithidae	*Platalea leucorodia*	Co	Win		National II
7. Anseriformes	10.Anatidae	*Anas poecilorhyncha*	Pa	Res		Provincial
		Anas clypeata	Pa	Win		Provincial
		Anser fabalis	Pa	Win		Provincial
		Cygnus cygnus	Pa	Win		National II
		Aythya ferina	Pa	Win		Provincial
		Mergus merganser	Pa	Win		Provincial
8. Piciformes	11.Picidae	*Dendrocopos major*	Pa	Res		Provincial
9. Coraciiformes	12.Alcedinidae	*Alcedo atthis*	Co	Res		
		Ceryle rudis	Or	Tra		
	13.Upupidae	*Upupa epops*	Co	Res		Provincial
10. Galliformes	14.Phasianidae	*Phasianus colchicus*	Co	Res		
11. Columbiformes	15.Columbidae	*Streptopelia orientalis*	Co	Res		
		Streptopelia chinensis	Or	Res		
12. Passeriformes	16.Motacillidae	*Motacilla alba*	Co	Sum		
	17.Pycnonotidae	*Pycnonotus sinensis*	Or	Res		
	18.Passeridae	*Passer montanus*	Co	Res		Provincial
	19.Paridae	*Parus major*	Co	Res		Provincial
	20.Turdidae	*Turdus merula*	Co	Res		
		Turdus naumanni	Pa	Win		
	21.Muscicapidae	*Monticola solitarius*	Co	Tra		
		Phoenicurus auroreus	Pa	Win		
	22.Corvidae	*Pica pica*	Co	Res		Provincial
		Cyanopica cyana	Pa	Res		Provincial
	23.Laniidae	*Lanius schach*	Or	Res		
		Lanius sphenocercus	Pa	Win		
	24.Sylviidae	*Paradoxornis heudei*	Pa	Res	NT	Provincial
	25.Sturnidae	*Sturnus cineraceus*	Pa	Res		
	26.Emberizidae	*Emberiza melanocephala*	Pa	Win		Provincial
		Emberiza rustica	Co	Win		Provincial
		Emberiza pallasi	Pa	Win		Provincial
13. Falconiformes		Unidentified				

The classification refers to Zheng (2011)
Distribution: Pa, Palaearetic realm; Or, Oriental realm; Co, Cosmopolitan species.
Habitation pattern: Sum, Summer migrant; Win, Winter migrant; Res, Resident; Vag, Vagrant; Tra: Transient.
IUCN/CITES: NT, Near threatened; V, vulnerable; E, endangered; I and II, CITES Appendix I and II

Table II.- Bird diversity of *H*, *J*, and *I* indices and dominant species in the Northern Buffer Zone and different habitats of Yancheng Rare Birds Nature Reserve.

	Whole northern buffer zone	Pi	Aquaculture	Pi	Cultivated field	Pi
Number of birds	5172		2362		2810	
Bird Diversity (*H*)	2.291		2.279		1.822	
Bird Evenness (*J*)	0.583		0.658		0.526	
Bird Correlation Coefficient (*I*) between both habitats			0.688			
Dominant species	*Passer montanus*	0.291	*Passer montanus*	0.230	*Grus grus*	0.394
	Grus grus	0.226	*Mergus merganser* *	0.210	*Passer montanus*	0.342
	Mergus merganser	0.096	*Numenius madagascariensis*	0.110		
	Numenius madagascariensis	0.057	*Actitis hypoleucos* *	0.102		
	Actitis hypoleucos	0.047	*Larus vegae* *	0.101		
	Larus vegae	0.046				
	Egretta garzetta	0.042				

Table III.- Bird orders diversity *H* and *J* indices in the Northern Buffer Zone of Yancheng Rare Birds Nature Reserve.

	N	***Pi***	**ln*Pi***	***Pi*×ln*Pi***	***H***	***J***
Coraciiformes	10	0.001	-6.645	-0.009	0.773	0.704
Columbiformes	129	0.017	-4.088	-0.069	0.693	1
Ciconiiformes	291	0.038	-3.274	-0.124	1.471	0.821
Gruiformes	1465	0.191	-1.658	-0.316	0.646	0.466
Charadriiformes	1006	0.131	-2.034	-0.266	1.282	0.797
Galliformes	19	0.002	-6.003	-0.015	-	-
Lariformes	1200	0.156	-1.858	-0.290	-	-
Passeriformes	2163	0.281	-1.268	-0.357	1.009	0.382
Pelecaniformes	1	0.000	-8.948	-0.001	-	-
Anseriformes	1269	0.165	-1.802	-0.297	0.583	0.362
Piciformes	1	0.000	-8.948	-0.001	-	-
Podicipediformes	179	0.023	-3.760	-0.088	-	-
Falconiformes	5	0.001	-7.338	-0.005	-	-
Unidentified Order	329					

suitable habitat decreased, for instance, the suitable habitats of *G. japonensis* declined from 28.2% in 1987 to 13.5% in 2007 (Sun and Liu, 2011). The environmental capacity of core area of Yancheng Nature Reserve could not however support so many birds (Li, 2007). Previous researches had suggested expanding the core area (Li, 1997; Wan *et al*., 2000). The northern BZ was connected with the core area, and supported over 50 species including 32 key protected species. For instance, most grey cranes and 11% red-crowned cranes foraged in northern BZ. In 2012, *G. virgo* was also found there (B. Chen unpublished data). Therefore, the northern BZ should be now considered to be priority protected area and even upgraded to core area.

The aquaculture habitat and cultivated fields were the main habitat of birds in northern BZ. Although, correlation coefficient of both habitats was high (*I* =0.688), dominant species are quite different. This indicates that both habitats were equally important for birds, and both should be given the same protection status.

Given the limited resources for taking protection measures, taking effective measures for the protection of becomes a priority. Conservation of 32 protected species, 16 resident/summer migrants and 15 winter migrants including grade I and II protected species calls for judicious utilization of over the years. This would be possible if the northern buffer zone is also upgraded to the status of *core area*. To further understand the occupancy of birds and seasonal variations, periodic bird surveys during all the seasons must be conducted. Influenced by water and soil erosion, ground subsidence, and sea level rise, the wetlands are shrinking annually. Furthermore, anthropogenic activities have also changed the landscape/habitat types and the area. For instance, a natural freshwater lake in northern BZ that supported thousands of birds annually has now been transformed into aquaticulture ponds since 2011. At present it is not known how the birds have adapted to these changes. We

suggest monitoring the habitat change and bird diversity annually both during summer and winter times, so that we can take targeted and effective decisions to affect protection measures to counter anthropogenic changes.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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