Muitos humanos
– passaros! → humanos influenciam negativamente a quantidade de passaros

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Effects of landscape structure, habitat and human disturbance on birds: A case study in East Dongting Lake wetland

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ABSTRACT

The study of birds responded to the environmental factors will contribute to the understanding of habitat selection and biodiversity conservation. East Dongting Lake, which is an important wintering habitat and pathway for migratory birds in the East Asian-Australasian Flyway, was taken as a case study. The aims of this study were to identify: (1) whether there were any relationships between environmental variables and bird species in East Dongting Lake wetland; (2) which variable(s) could be the critical one(s) markedly correlating with the birds. We applied direct multivariate analysis combined with partial analysis to quantify the effects of environmental variables on bird species in this study. The results indicated that landscape structure (explaining 40.95% of the variation), habitat index and human disturbance (75.58%, 51.97%, respectively) were significantly associated with the bird abundance while the individual effect of habitat-level variables was more evident than the others. Among the seven chosen environmental variables, five critical variables markedly related to the richness of birds ($P < 0.05$) with the impact intensity in the order of sedge area > water area > reed area > patch density > distance to residents. No obvious indication was found in our study to prove that landscape diversity and distance to road had significant correlations with the bird species abundance. The results would provide potential insights into protecting the bird diversity and the restoration of the bird habitat in East Dongting Lake wetland.

1. Introduction

Wetland bird, an important component part in the wetland ecosystem, plays a vital role in maintaining ecological system stability and is a good indicator of environmental change in the wetland ecosystem (Mistry et al., 2008; Reid et al., 2013). Birds are among the most iconic of ecological assets and very sensitive to changes of the surrounding habitat (Devictor and Jiguet, 2007; Wu et al., 2011). Information on birds is very commonly available in that birds are taxonomically well known and easily censused (Larsen et al., 2012). What is more, understanding how bird species respond to the environment factors is one of the key issues for the management and conservation of the wetland bird habitat.

It is traditionally a central issue to study the relationship between birds and the environmental factors of their habitats in ecology (Hinojosa-Huerta et al., 2013; Dong et al., 2013). Previous studies showed that the surrounding environment of bird species was very complex and many factors should be taken into consideration, such as land use (Chapman and Reich, 2007; Dallimer et al., 2010; Brambilla et al., 2012), landscape structure (Pino et al., 2000; Dauber et al., 2003; Banks-Leite et al., 2011; Ortega-Álvarez et al., 2013), habitat gradients (Kujawa, 2002; Pearch-Higgins and Grant, 2006; MacGregor-Fors et al., 2010; Chandler and King, 2011), road (Peris and Pescador, 2007; Summers et al., 2011; Butler et al., 2013), human disturbance (Blumstein et al., 2005; Smith et al., 2008; Cui et al., 2009). In general, at a local scale, the focus was on the impact of the within-habitat factors on bird populations (Söderström et al., 2001; Newton, 2004; Hendrickx et al., 2009), while at a broader scale land-use variables and the structure and composition of landscape were investigated theoretically (Wretenberg et al., 2010; Cerezo et al., 2011; Hanspach et al., 2011).

East Dongting Lake wetland is an important wintering habitat for East Asian migratory birds. In recent years, more and more domestic and foreign scholars have paid attention to the study of East Dongting Lake wetland extensively (Xu et al., 2005; Ying et al., 2007; Balen et al., 2011). In the current studies of avian

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in East Dongting Lake, experts mainly focus on resource, community structure and diversity. However, up till now, little work had been undertaken to study the relationship between birds and environmental variables. Over the past few years, the community structure and diversity of bird species in East Dongting Lake has changed, especially after the operation of the Three Gorges Dam (Wang et al., 2012; Cong et al., 2012; Zhao et al., 2012). These might have resulted from many factors, such as local climate change, dam construction (Wu et al., 2013), road construction, and closed management of the nature reserve. What is more, landscape fragmentation and habitat loss in East Dongting Lake in recent years would also be two reasons (Anteau et al., 2012; Quesnelle et al., 2013). Therefore, it is urgent to achieve the deeper understanding of the bird–environment relationship and identify the critical variables.

Modeling approaches are of vital importance in species–environment studies. In particular, direct multivariate analysis, such as canonical correspondence analysis (CCA) and redundancy analysis (RDA), were widely used (Vandvik and Birks, 2002; Heikkinen et al., 2004; Dallimer et al., 2010). These methods can appropriately identify factors that influence the diversity of species community composition. However, it is still difficult to distinguish the sole effect of each independent variable because of multicollinearity and complicated relationship between the environment factors. Partial analysis with a stepwise selection procedure is an extension of direct multivariate analysis and can solve the problems better than other methods (Heikkinen et al., 2004; Zhang et al., 2011). This method has been used to estimate the independent contribution of each variable or different groups of variables to species components in many kinds of research fields. Consequently, we mainly focus on direct multivariate analysis combined with partial analysis to quantificationally identify the possible environmental factors and their effects on bird species in our study.

By employing direct multivariate analysis combined with partial analysis, we determined the independent and joint effects of landscape structure, habitat index and human disturbance on bird species. Specifically, the following questions were addressed: (1) whether changes in bird community could be associated with selected environmental variables; (2) how much did the effects of three groups of environmental variables differ; and (3) which variable(s) could be the critical one(s) markedly correlating with the bird abundance? Understanding the relationship between birds and variables would provide potential insights into protecting the bird diversity and the restoration of the bird habitat in East Dongting Lake.

2. Materials and methods

2.1. Study site

This study was conducted in East Dongting Lake Nature Reserve, which is situated in the southern bank of the middle Yangtze River, Yueyang City, Hunan Province, China (approximately 28°59′–29°38′ N, 112°43′–113°15′ E) (Li et al., 2013). The total area is about 1900 km^2, including water area of 654 km^2, core area of 290 km^2 and buffer area of 364 km^2. East Dongting Lake lies in the subtropical monsoon climate zone, with high accumulative temperature, abundant heat and precipitation, and longtime sunshine. It is recorded that the annual average temperature of the region ranges from 16.4 to 17.0 °C, and the frost-free period from 259 to 277 d. What is more, East Dongting Lake Nature Reserve was listed as one of China's 30 most important wetlands in the Ramsar Convention in 1992. Because of its special geographical position, unique climate conditions and topography, East Dongting Lake provides appropriate eco-environment for a wide variety of flora and fauna. Especially along with the water level reduces in winter, the grass lands expose and provide abundant food for birds. East Dongting Lake gradually has become an important wintering habitat and pathway for East Asian migratory birds.

2.2. Bird survey

Winter is a critical period for most birds because exposed grass lands provide lots of food for birds in winter season and habitat availability may affect the occurrence and abundance of many species (Caprio et al., 2009). Hence, in this study, bird surveys were carried out in the study area in winter (dry season) during the period after the operation of the Three Gorges Dam Project (lasting from 2006 to 2011) based on point counting (Buckland et al., 2001; Wu et al., 2011). Samplings were conducted from November to February to record wintering species and each site was sampled once or twice a year. Based on our long term experience, 15 representative sampling sites were investigated (Fig. 1). To exclude year-to-year variation in bird patterns, we recorded the same sampling sites by same method every year. It is well known that the distribution of birds may differ between years (Johnson, 2008). However, the difference seemed negligible in our study. The bird surveys were carried out within a radius of 1 km of the sampling site each year on fine weather without rain or significant wind (Chapman and Reich, 2007).

Birds were observed by monocular (Nikula 10 × 42) and binocular (Swarovski). During surveys, the geographical position of each site was also recorded by using a handheld global positioning system (GPS; Vista). To estimate the densities of individual species, a list of all species was collected.

2.3. Environmental variables

Our assumption was that the relationship between bird species and environment should be investigated at the landscape, habitat and human levels. On the basis of previous studies (Yuan et al., 2013), three groups of explanatory variables were recorded to be possible influential factors for each sampling site: (1) landscape structure, (2) habitat index and (3) human disturbance. Two landscape structure variables included in the study were patch density (PD), landscape diversity (using Shannon's diversity index, LD). Based on the information of the birds' life habits and the components of wetland habitat, three habitat cover variables were calculated: water area (WA), reed area (RA), sedge area (SA). As for human disturbance variables, distance to road (D_1) and distance to residents (D_2) could be representative. All variables were calculated for each grid circle within 1 km radius.

The matrix variables in each study site were derived from TM images obtained by satellite Landsat in 2006 and 2007, and CCD (Charge-coupled Device) images taken by Environmental Satellite-1A/1B with visible spectrum cameras from 2008 to 2011. The time of images was synchronized with that of bird surveys. Both TM and CCD have spatial resolution of 30 m. The images were converted into grid format after interpretation with Likelihood Classification by means of ArcGIS 9.0, and the calculations of landscape and habitat variables were executed using Fragstats 3.3 (Heikkinen et al., 2004; Dallimer et al., 2010).

2.4. Date analysis

Firstly, the changes of the bird community structure, quantity, and biodiversity were analyzed after the operation of the Three

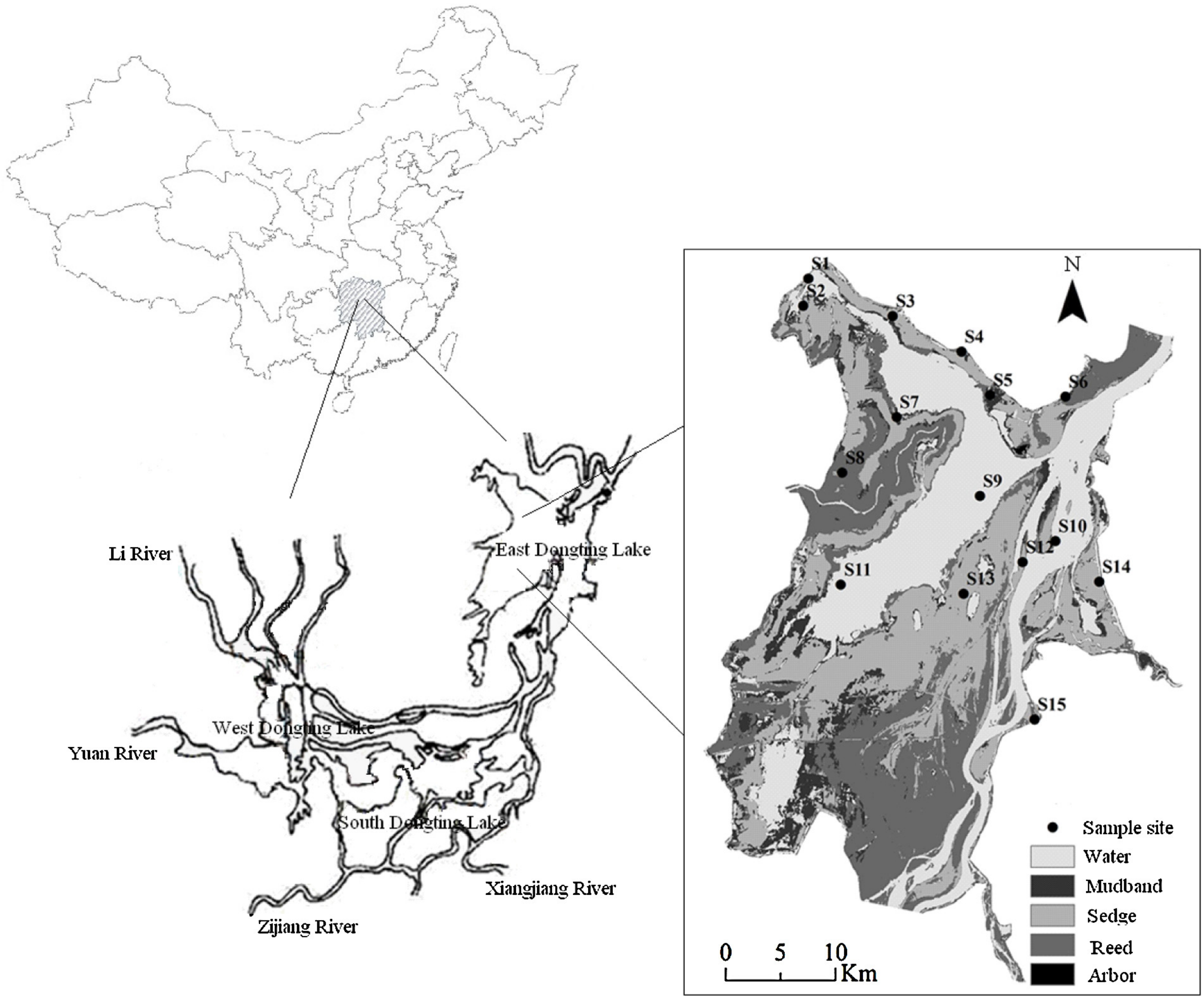

Fig. 1. Sample sites of bird survey in East Dongting Lake. S1 – Caisang Lake; S2 – Small West Lake; S3 – Siba Beach; S4 – Dingzi Dyke; S5 – Junshan Lake; S6 – The outside; S7 – Tuanzhou Beach; S8 – Zhuzi Estuary; S9 – Baihu Lake; S10 – Laoshuwei; S11 – Xingfu Beach; S12 – Meitan Bay; S13 – Hongqi Lake; S14 – Chunfeng Lake; S15 – Baota Lake.

Gorges Dam (from 2006 to 2011). Species diversity index was calculated by using the following formula Eq. (1) (Wu et al., 2011):

$$H = -\sum P_i \ln\ P_i \quad (1)$$

where H is Shannon–Wiener index; P_i is equal to n_i/N; n_i is the number of ith species; and N is the total population.

To define dominant species, the dominance index was calculated by using the following formula Eq. (2) (Lin et al., 2011):

$$Y = \frac{n_i f_i}{N} \quad (2)$$

where Y is the dominance index of each species; and f_i is occurrence frequency of species i. When $Y \geq 0.0\ 2$, the species would denote dominant ones.

To understand the multivariate bird–environment relationship, the species square matrix of the sum standardization-transformed abundance was used as a response variable in a preliminary detrended correspondence analysis (DCA). The largest gradient length of the first DCA axes indicated that canonical correspondence analysis (CCA) was appropriate for these data. Moreover, for those environmental variables, we applied $\log_{10}$-transformation ($\log_{10}(x+1)$). CCA was performed to reveal the relationships between bird species and environmental factors and identify relevant parameters that influence the diversity of bird species community composition (Ter Braak and Šmilauer, 2002; Gunnarsson et al., 2006). Forward selection procedures were then applied to select the variables with significant influences ($P < 0.05$) and to exclude the variables that did not effect significantly ($P > 0.05$). After forward selection procedures, partial CCA was executed to determine the independent influence of each variable when a significant variable was used as definitive one while the others were used as covariables. The proportion of explained variation (net effect) was measured by using the ratio of particular canonical eigenvalues to the sum of all eigenvalues in partial CCA procedures (Lososová et al., 2004). (Partial) CCA and Monte Carlo permutation test with 999 permutations were performed to evaluate the significance of variables separately.

All the analyses were carried out in CANOCO 4.5 (Ter Braak and Šmilauer, 2002; Lepš and Šmilauer, 2003). Statistical significance was kept at $P < 0.05$ for all analyses.

3. Results

3.1. Species diversity and composition

In this study, we mainly focused on Anatidae birds which account for about 70% of the total population in East Dongting Lake. In total, 20 species of Anatidae birds were encountered

Table 1
Number of species and Shannon–Wiener Diversity of birds in East Dongting Lake.

Year	Number of species	Shannon–wiener diversity
2006	17	1.9578
2007	14	2.0054
2008	18	1.7587
2009	17	1.9077
2010	18	2.0156
2011	20	1.9010

during the six years (Table 1). After the operation of the Three Gorges Dam, the bird species community structure, quantity, and biodiversity indeed had changed. 20 species were identified in 2011, while only 14 species were identified in 2007. More specifically, Greylag Goose (*Anser anser*) did not occur in 2009, while Common Shelduck (*Tadorna tadorna*), Northern Shoveler (*Anas clypeata*) and Common Merganser (*Mergus merganser*) did not occur in 2007. Among with the 20 species, Common Pochard (*Aythya ferina*) and Common Goldeneye (*Bucephala clangula*) were only recorded in 2011. The total population varied every year (Fig. 2). The bird population increased year by year but decreased in 2011. Especially, the total population of Anatidae birds in 2010 was obviously higher than the other years. By calculating the diversity index of each year, the highest and lowest diversity index values were found in 2010 and 2008, respectively.

3.2. Species dominance

The bird distribution varied in different sites and the dominance index of each species ranged from 0 to 0.1920 (Table 2). Among the 20 species, there were five dominant species in our survey: Bean Goose (*Anser fabalis*, Y= 0.1466), White-fronted Goose (*Anser albifrons*, Y= 0.0404), Lesser White-fronted Goose (*Anser erythropus*, Y= 0.1920), Falcated Duck (*Anas falcate*, Y= 0.0413) and Green-winged Teal (*Anas crecca*, Y= 0.0208). Lesser White-fronted Goose with the highest dominance index value was the most dominant species in East Dongting Lake. Five dominant species occurred on at least 40% of sites and accounted for approximately 81.28% of the total richness. Hence, the five dominant species were included as representatives in the species–environment relationship analysis.

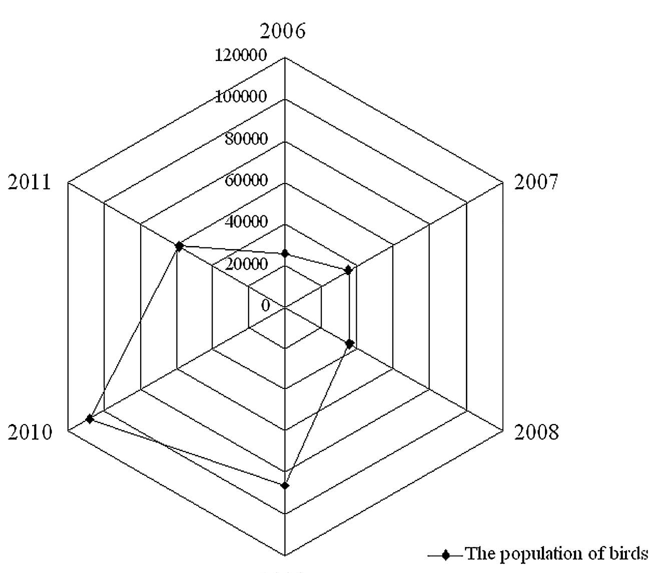

Fig. 2. Changes of the population of birds in East Dongting Lake.

Table 2
List of bird species and dominance in East Dongting Lake (mean value).

Species	Amount	Dominance
Cygnus columbianus	1424	0.0058
Anser cygnoides	53	0.0001
Anser fabalis	19,516	0.1466
Anser albifrons	11,660	0.0404
Anser erythropus	33,241	0.1920
Anser anser	176	0.0003
Tadorna ferruginea	1508	0.0070
Tadorna tadorna	713	0.0021
Anas penelope	1804	0.0042
Anas falcata	11,916	0.0413
Anas strepera	2292	0.0066
Anas crecca	5137	0.0208
Anas platyrhynchos	1509	0.0061
Anas zonorhyncha	2429	0.0098
Anas acuta	5676	0.0131
Anas clypeata	184	0.0004
Aythya ferina	318	0.0006
Bucephala clangula	36	0.0000
Mergellus albellus	341	0.0006
Mergus merganser	271	0.0003

3.3. Environmental variables and correlation analysis

The environmental variables were shown in Table 3. According to the correlation analysis of all the environmental variables, PD was positively correlated with RA, D_1 and D_2 at 5% significant level. LD was positively correlated with WA, D_1 and D_2 at 5% significant level and negatively correlated with SA. SA had a significant negative correlation with WA and RA. There was a positive correlation between RA, D_1 and D_2 at 1% significant level (Table 4).

3.4. Canonical correspondence analysis (CCA)

The results of the CCA were shown in Table 5. The eigenvalues of the first two canonical axes were much higher than the other two axes. The all canonical axes explained 88.6% variance of species data and 100% variance of species–environment relation, among which the cumulative explanation of the first two axes reached 62.8% of species data and 70.8% of species–environment relation. Moreover, Monte Carlo permutation tests for the first and all

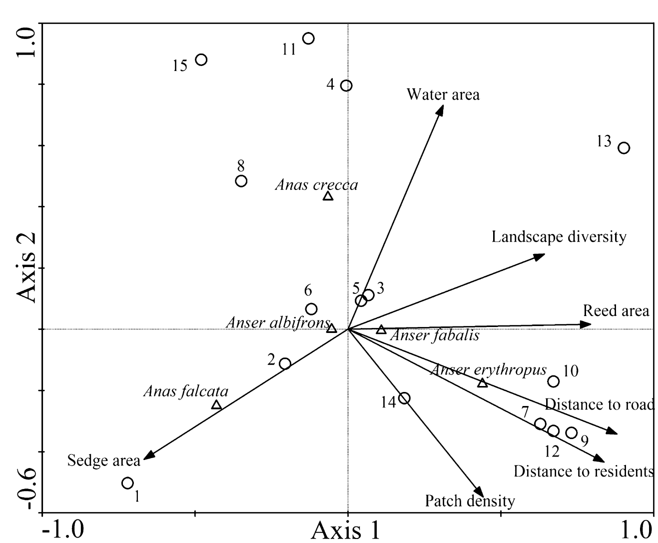

Fig. 3. CCA ordination diagram of species distribution and environmental factors in East Dongting Lake. Environmental variables were represented by solid lines with filled arrows. Samples were represented by open circles, whereas species were meant by triangles.

Table 3
Analysis of the environmental variables.

Environmental variables	Patch density	Landscape diversity	Water area	Reed area	Sedge area	Distance to road	Distance to residents
Unit	n/100 ha	–	ha	ha	ha	km	km
Minimum	1.274	0.042	0.01	0.011	0.085	0.201	0.381
Maximum	29.927	5.409	2.66	2.237	3.119	12.732	14.286
Mean	16.021	1.184	0.661	0.861	1.426	3.066	4.014
Standard deviation	8.087	1.228	0.781	0.712	1.024	3.442	3.709

Table 4
Correlation analysis of all the environmental variables.

Environmental variables	Patch density	Landscape diversity	Water area	Reed area	Sedge area	Distance to road	Distance to residents
Patch density	1						
Landscape diversity	0.31	1					
Water area	0.052	0.498*	1				
Reed area	0.313*	0.215	0.178	1			
Sedge area	−0.231	−0.435*	−0.793**	−0.686**	1		
Distance to road	0.359*	0.426*	−0.155	0.688**	−0.305	1	
Distance to residents	0.449*	0.414*	−0.142	0.668**	−0.317	0.948**	1

* Correlation at the 5% significant level.
** Correlation at the 1% significant level.

Table 5
CCA ordination summary and correlation coefficients between environmental factors and ordination axes.

Summary of CCA ordination	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalue	0.442	0.312	0.257	0.053
Species–environment correlations	0.967	0.965	0.964	0.674
Cumulative % variance of species data	36.8	62.8	84.2	88.6
Of species–environment relation	41.5	70.8	95.0	100.0
Patch density	0.428	−0.529	−0.088	0.208
Landscape diversity	0.622	0.237	0.021	0.332
Water area	0.301	0.706	−0.271	0.298
Reed area	0.768	0.015	−0.115	−0.296
Sedge area	−0.645	−0.410	0.443	−0.076
Distance to road	0.851	−0.331	0.109	−0.114
Distance to residents	0.810	−0.419	0.158	0.002
Test of significance of first canonical axis		P = 0.002		
Test of significance of all canonical axes		P = 0.001		

canonical axes were highly significant (P = 0.002, PY = 0.001, respectively). For species–environment relation, approximate 41.5% and 29.3% of the variation were respectively explained by axis 1 and axis 2. On the whole, the first two canonical axes could explain the relationship between species and the environmental variables well. All environmental variables except SA were positively correlated with axis 1. There was a negative correlation between axis 2 and PD, SA, D_1 and D_2 (Fig. 3). The biplot of the overall species distribution and environmental explanatory variables was shown in Fig. 3.

3.5. Forward selection and partial canonical correspondence analysis (partial CCA)

Forward selection of environmental variables suggested that the effects of three groups of explanatory variables differed with each other. (1) Landscape structure variables including PD and LD statistically explained approximately 40.95% of the variation (PY = 0.027). (2) Habitat index variables including WA, RA and SA accounted for 75.58% of the variation (PY = 0.001). (3) Human disturbance variables including D_1 and D_2 statistically explained about 51.97% of the variation (PY = 0.007) (Table 6). What is more, forward selection was employed in this study to identify variables of significant influence. In this procedure, PD, WA, RA, SA and D_2 were checked out to be the major variables markedly correlating with the abundance and distribution of bird species (PY < 0.05).

Partial CCA was carried out to calculate net effect of each explanatory variable. Percentages of variation explained by each particular variable were shown in Table 5 without the other shared explanatory variables. PD alone accounted for 35.38% (PY = 0.013) of the variation in the bird date, while WA solely explained 56.92% (PY = 0.001) of the variation, RA capturing 48.69% (PY = 0.003), SA capturing 61.94% (PY = 0.001), D_2 capturing 30.65% (PY = 0.001), respectively. The effects of LD and D_1 did not reach a significant level.

The statistical significance of each species responding to the five major environmental variables was tested by producing t-value biplots based on the CCA procedure. The relationship between single species and a particular environmental variable was shown in Fig. 4. PD had a significant positive correlation with Falcated Duck and a significant negative correlation with Green-winged Teal (Fig. 4a). Bean Goose and White-fronted Goose were significantly positive correlated with WA, RA and SA while Lesser White-fronted Goose and Falcated Duck were significantly negative correlated with the three environmental variables (Fig. 4b–d). As for D_1, there was a significant negative correlation between Lesser White-fronted Goose and Green-winged Teal with it (Fig. 4e). The cumulative explanation of the five major variables was up to 80.43% (PY = 0.001) of the variation.

4. Discussion

4.1. The variety of bird species and the possible influence factors

The bird surveys were carried out during the period after the operation of the Three Gorges Dam Project (from 2006 to 2011).

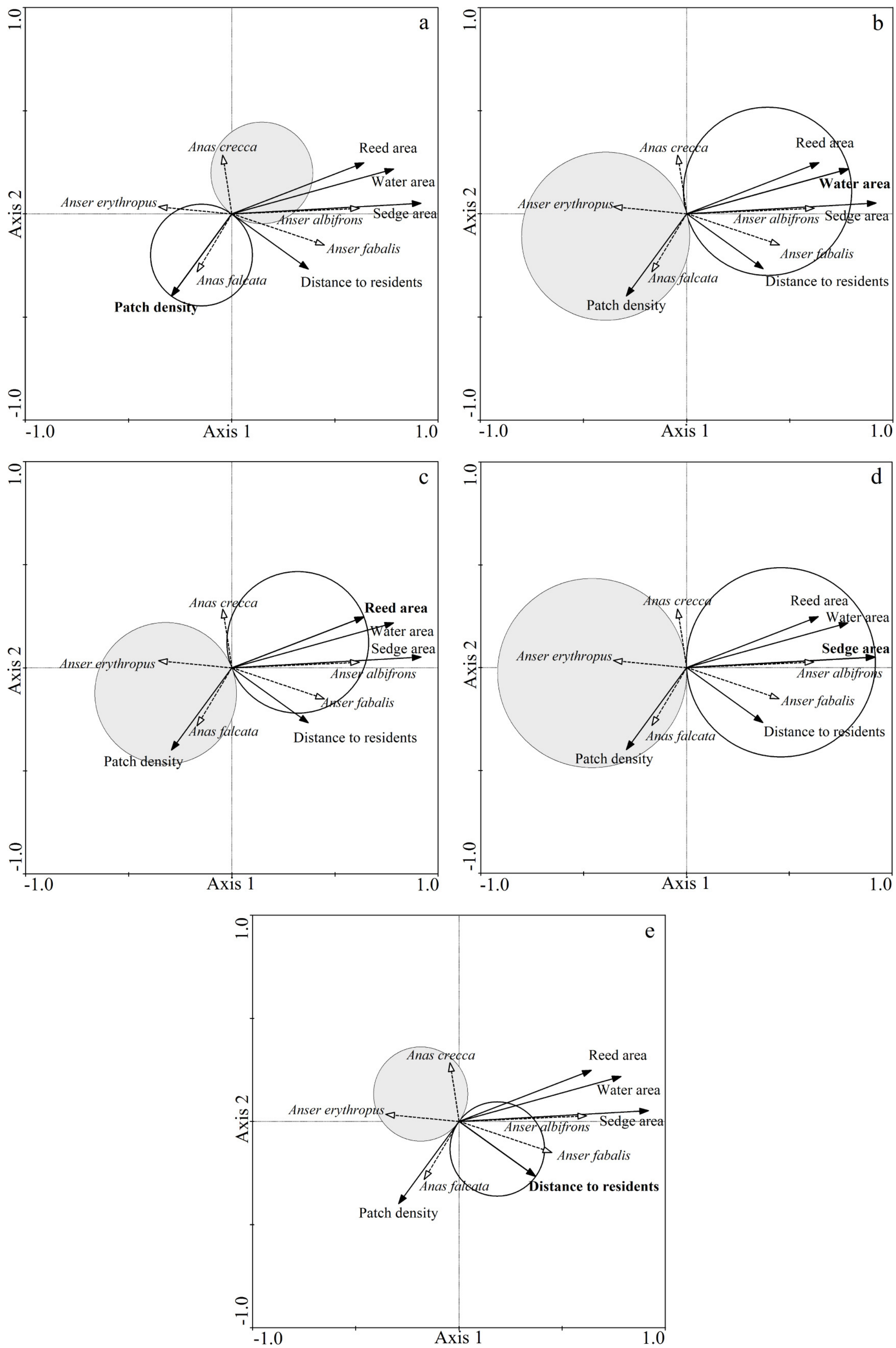

Fig. 4. *t*-Value biplots of the five main environmental variables. (a) Patch density, (b) water area, (c) reed area, (d) sedge area and (e) distance to residents. The dashed lines with unfilled arrows indicated each species, and the solid lines with filled arrows represented environmental variables. The circles filled with gray color represented negative correlation while the transparent ones represented positive correlation.

Table 6
Effects of environmental variables on species abundance. Eigenvalues, *P*-value and *F*-ratio were obtained from the partial CCA.

Environmental variables	Eigenvalue	Sum of all eigenvalues	Net effect %	*P*-value	*F*-ratio
Patch density	0.075	0.212	35.38	0.013	3.85
Landscape diversity	0.016	0.153	10.46	0.509	0.80
Water area	0.181	0.318	56.92	0.001	9.24
Reed area	0.130	0.267	48.69	0.003	6.66
Sedge area	0.223	0.360	61.94	0.001	11.40
Distance to road	0.031	0.168	18.45	0.147	1.61
Distance to residents	0.061	0.198	30.65	0.036	3.13
Landscape structure	0.095	0.232	40.95	0.027	2.44
Habitat index	0.424	0.561	75.58	0.001	7.22
Human disturbance	0.148	0.285	51.93	0.007	3.79

East Dongting Lake wetland is an important wintering habitat and pathway for East Asian migratory birds. The total bird population increased year by year in our study. Firstly, it might be indirectly due to the hydrological changes of the Three Gorges Dam especially water replenishing in dry season which would affect the changes of water area and some landscape variables (Zhao et al., 2012). Secondly, changes in bird numbers might correlate with the closed-off management in East Dongting Lake (since 2006) which contributed to reduction in human disturbance. However, the population decreased in 2011, when the water level happened to be low in East Dongting Lake. The total population of birds varied every year. Then, we should validate our hypothesis that the bird species were related to the environmental factors including landscape structure, habitat and human disturbance in this study.

4.2. The rationality of the research method

Many models were developed to reveal the response of bird species to environmental variables (Swagemakers et al., 2009). In this paper, direct multivariate analysis and partial analysis were employed to study the relationship between environmental variables and bird species in East Dongting Lake. Firstly, DCA was carried out to decide which direct multivariate analysis to choose for the bird species diversity data, whether linear or unimodal response model. The largest gradient length of the first DCA ordination axis was 4.014, which indicated that unimodal response model was appropriate (Ter Braak and Šmilauer, 2002). Thus, CCA combined with separate partial CCA were adopted in this study. The methods could well analyze and quantify the joint and the sole effects of these selected variables. Moreover, the results demonstrated that the abundance of bird species indeed was associated with environmental variables.

4.3. The role of study scale

Numerous researches on bird revealed that study scale would be an important element and many studies focused on an intermediate scale with sample plots of about 500 m × 500 m to 2 km × 2 km (Heikkinen et al., 2004). While in this paper, we focused on the scale of the radius of 1 km. To determine whether the scale could affect the results of our study, further studies with different scale scenarios should be carried out. To some extent, it is important to study the effects of these variables within multiple spatial scales simultaneously. Many similar studies showed that bird data from at least two years would make the results reliably (Fuller et al., 1997; Söderström et al., 2001). In our study, we mainly focused on the bird–environment relationship based on bird surveys in winter from 2006 to 2011. In order to reduce the error caused by inaccuracy, we used the mean value in our study. Thus, the dynamics of the bird species would probably be a minor factor in our study.

4.4. The effects of environmental variables on bird species

Studies of relationship between bird species and environmental variables were mainly concentrated on landscape-level, habitat-level and human-level (Seoane et al., 2004; Chapman and Reich, 2007; Smith et al., 2008; Gomez-Sapiens et al., 2013). Though the explanatory variables were attached more weight, other variables should not be neglected. In this study, the three groups of explanatory variables were confirmed to markedly correlate with the abundance of birds with different explanation abilities. The results showed that the solely effect of habitat-level variables was more evident than the effects of the other two group variables (Luna-Jorquera et al., 2012; Yuan et al., 2013). Similar results were obtained by Heikkinen et al. (2004) in a two-year study conducted in a south-western Finland.

At the landscape-level, PD significantly correlated with the bird species abundance. Along with the increase of PD, the degree of landscape fragmentation increases, thereby affecting bird abundance. As for the habitat-level, WA, RA and SA were confirmed to be important variables (Fig. 4). These results may partly associate with the living habits of each bird species. The environmental variables selected in our study were of high representativeness which could well interpretate the species–environment relationship. However, more comprehensive aspects should be considered in the next work. The bird species abundance was found to decline in proximity to the road in previous studies (Summers et al., 2011). Nevertheless, in our study, there was no significant correlation between road and bird species. The discrepancy between our results and those previous studies may partly due to the particular feature of the natural wetland and covariables used in this study. No significant correlations between some variables like LD, D_1 and species were found in our study. Nonetheless, it did not imply that those variables were of no importance in determining species community compositions. It can be only concluded that the correlation did not reach a significant level in this study. Hence, further work is needed to determine the effects of the variables.

4.5. Conservation implications

The findings of this study are consistent with the previous study (Yuan et al., 2013). As for sampling sites, we only selected 15 sites in our study. However, these sites are of good representativeness and have little influence on the result of this study. This paper is expected to provide some references for bird conservation and habitat restoration. It is suggested that the regulatory authorities and environmental protection agencies should take landscape, habitat and human level factors into consideration when implementing biodiversity conservation and habitat restoration in East Dongting Lake.

We believe that conservation will succeed if more comprehensive and scientific conservation strategies are developed by using multi-scale assessments (Vera et al., 2011). On one hand, habitat-level factors are confirmed to be the most key variables. Anatidae birds prefer to inhabit shallow as well as the open water area. According to our study, the wetland administrator should pay attention to habitat ecological restoration, such as planting vegetation in shallow water areas to provide food and living conditions for birds. On the other hand, rainfall between November and December may contribute to habitat replenishment, although smaller in magnitude than the volumes of water received from the upstream. We still suggest the manager to supply abundant water and guarantee appropriate water area to meet habitat requirements, especially in drought years. Furthermore, we must avoid too much human disturbs or carry out close management in some important habitats. Our study suggested that even within the same foraging guild, subtle differences still exist in the habitat selection. We should take other variables that we have not addressed directly in our study, such as hydrological regime, sediment regime, and contamination.

Along with the better understanding of bird–environment relation, success of biodiversity conservation is likely to improve. Therefore, to some extent, a further study should be carried out to quantify the effects of more comprehensive variables and influence ranges of each environmental factor on wetland birds in East Dongting Lake.

5. Conclusions

In summary, the species variation was significantly associated with landscape structure, habitat index and human disturbance while the individual effect of habitat-level variables was most evident. Among the seven chosen environmental variables, five critical ones markedly related to bird species with patch density alone accounting for 35.38% of the variation in the bird data, while water area individually explaining 56.92%, reed area capturing 48.69%, sedge area capturing 61.94%, distance to residents capturing 30.65%, respectively. No obvious indication was found in our study to prove that landscape diversity and distance to road had significant correlations with bird species.

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