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WATERBIRD DISTRIBUTION PATTERNS AND ENVIRONMENTALLY IMPACTED FACTORS IN RECLAIMED COASTAL WETLANDS OF THE EASTERN END OF NANHUI COUNTY, SHANGHAI, CHINA

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The eastern end of Nanhui County is one of the most important coastal wetlands for waterbirds. It is also the key reclamation site in the Yangtze River Delta. In 2005, a reclamation project was completed here. A part of reclaimed area was converted into three types of artificial wetlands: urban lake wetlands; extensive fish ponds; and abandoned wetlands. To examine the effects of different management of these wetlands on the conservation of waterbirds, a study was conducted from 2009 to 2011. A total of 41,493 waterbirds corresponding to 91 species from 15 families were recorded. Two species, Black-faced Spoonbill *Platalea minor* and Falcated Duck *Anas falcata*, meet the international conservation Ramsar criterion of >1% of global population size. The extensive fish ponds contain the highest species richness and evenness, followed by abandoned wetlands and urban lake wetlands. Non-metric Multi-dimensional Scaling ordination plot revealed partition with four distinct clusters apparent. The first and the second clusters were positively correlated with deep water area, anthropogenic disturbance, distance to the seawall, and mean water level. The third cluster had no direct relationship with any environmental factors. The fourth cluster was correlated with vegetation area, shallow water area, and bare muddy area.

Key words: coastal reclamation, urban lake wetlands, extensive fish ponds, abandoned wetlands

INTRODUCTION

It has been widely recognized that human civilization now has a much more significant impact on earth surface changes than natural disturbances (Herold *et al*. 2005). Dynamic landscape changes have occurred in coastal areas at an astonishing rate in recent decades, especially with the tremendous expansion of human population and economic development in these areas (Barter 2002, Xie 2004). One of most important human activities in coastal areas is wetland reclamation, which serves a variety of purposes, including agriculture, industry development, and human resettlement (Dalby 1957, Glue 1971, Davidson *et al*.1991, Suchaneck 1994, BirdLife International 2004). However, coastal reclamation can negatively affect waterbirds, which depend on wetland habitats. Artificial wetlands provide alternative or complementary habitats for waterbirds throughout their life stages (Weber & Haig 1996, Elphick & Oring 1998, Connor & Gabor 2006). The role of artificial wetlands and their effects on the conservation of waterbird diversity is a hot research topic in recent years, with most studies focusing on the comparison between artificial wetlands and natural wetlands, and whether artificial wetlands can completely replace the role of nature wetlands in waterbird diversity conservation (Ogden 1991, Guillemain *et al*. 2000, Ma *et al*. 1999, Tourenq *et al.* 2001, Ma *et al.* 2004). Less research has concentrated on how to provide high quality habitats in artificial wetlands for waterbirds through effective management techniques (Ma *et al* 2010, Erwin 2002).

The eastern end of Nanhui County, in the municipality of Shanghai, located on the northern coast of the mouth of the Yangtze River, which is one of the 50 most ecologically sensitive areas in the world (Maff *et al*. 2000). It is a vital stopover site for shorebirds in northern and southern migrant periods and a wintering habitat for waterfowl (Niu *et al.* 2011, Zhang *et al*. 2011, Guo *et al*. 2010, Ge *et al*. 2006). However, this area is also one of the key reclamation sites in the Yangtze River Delta due to rapid urbanization and economic growth since economic reform in 1978. The latest coastal reclamation project in this area was initiated in 1999 and completed in 2005, and included 13 km^2 of intertidal mudflats and salt marshes enclosed by seawalls constructed for agricultural or industrial purposes (Li 2003). Under public pressure for biodiversity conservation, the government restored some reclaimed areas as artificial wetlands to compensate for the loss of natural wetlands.

Between September 2009 and August 2011, we conducted a study in this area to examine the effects of different management patterns on these artificial or restored wetlands for the conservation of wintering waterbirds and migratory shorebirds. We compared species richness, abundance, and waterbird community composition among different types of artificial wetlands, so as to understand which types of wetlands have better effect on waterbird conservation, and what are the major environmental factors affecting waterbird community composition.

METHODS

Study area

The eastern end of Nanhui County is located in the mouth of the Yangtze River, Shanghai, Eastern China (30°50′04′′–31°06′47′′N 121°50′50′′–121°51′40′′E). The north side is the south trough of the Yangtze River Estuary and the south side is Hangzhou Bay. The Yangtze River transports sediment and forms extensive coastal marshes with fresh to brackish water, tidal creeks, and intertidal mudflats around Shanghai (Yang *et al.* 2002, Ding 2003).

It is characterized by a northern subtropical monsoon climate that is mild and humid. The mean annual temperature of the region is 15–16°C. Mean annual precipitation is 1222.2 mm. The latest reclamation project was carried out above 0m tidal level and completed in 2005. A new district in Nanhui County named Lingang was created in 2003 within the latest reclamation region.

After reclamation began, the area was enclosed by a sea wall resulting in the loss of tidal water in the mudflats. As water level depends on rainfall and human input, consequently, some mudflats turned into dry land, and others evolved into different types of artificial wetlands. We divided the wetlands into three types according to water source and land use including A) urban lake wetlands, B) extensive fish ponds, and C) abandoned wetlands (Fig. 1).

Urban lake wetlands included two man-made lakes, Dishui Lake and Shiji Lake, managed for both human resorts and biodiversity conservation objectives, with the Dazhi River (a main river course connecting lake to sea) acting as the water source. Drainage in

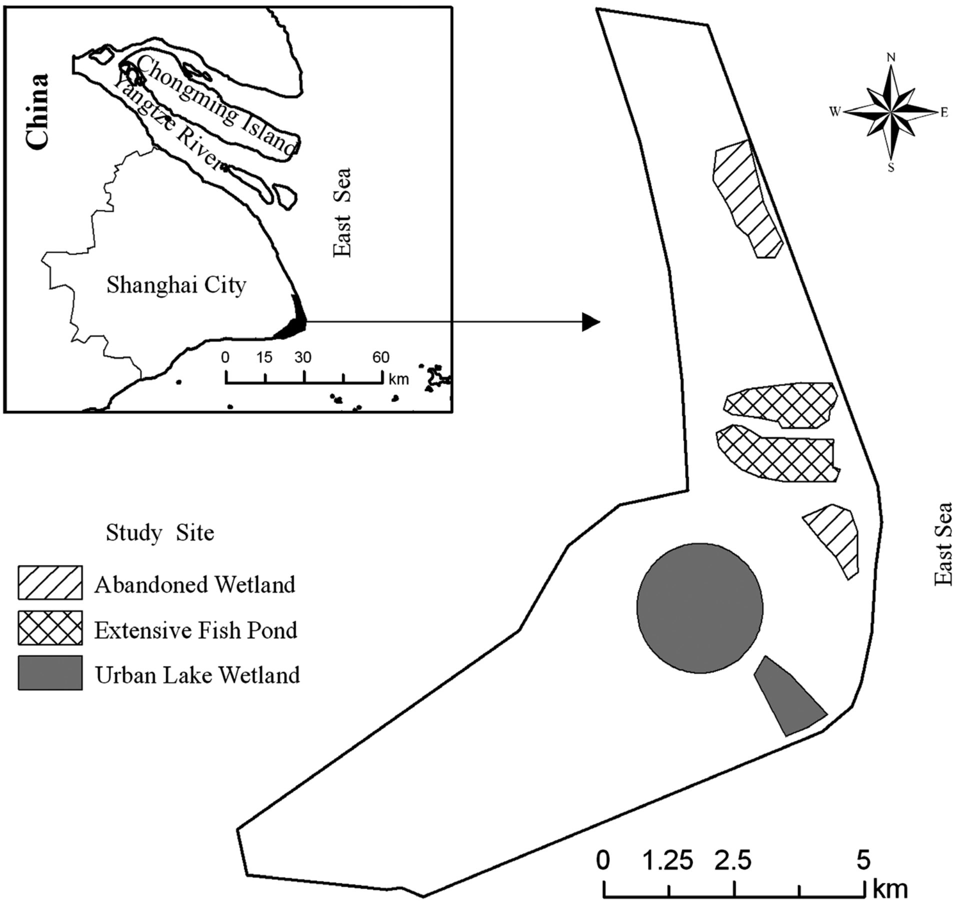

Fig. 1. Location of study sites in Nanhui County, Shanghai.

these wetlands occurs into the two lakes, Dishui Lake (located in the new district of Lingang) and Shiji Lake (located in a sea-watching park). These wetlands were constructed for the purpose of being urban landscapes for recreation and flood control. Few reed beds were found in the lakes and hard banks and vegetation surrounding the lakes included manually cultivated lawns and trees.

Extensive fish ponds were created as part of an ecological restoration experiment and fish harvest, with water sources controlled by local farmers and local conservation agency. At the beginning of 2009, the habitat transformation project was completed. The local conservation agency and researchers were responsible for controlling the vegetation area, water area and height of the water level in different seasons, which increased habitat heterogeneity within shoal areas, shallow water areas, reed areas, and deep water areas. Vegetation was dominated by reeds *Phragmites communis*. These fish ponds acted predominantly as harvest regions.

Abandoned wetlands were abandoned naturally without human interference, with water sources depending entirely on rainfall and located near the seawall. After reclamation, when the mudflat was undergoing natural succession, they partially dried. Vegetation included reed, smooth cordgrass *Spartina alterniflora*, Canada goldenrod *Solidago canadensis*, and saline seepweed *Suaeda glauca*.

Six wetland study sites were characterized among these three types of wetlands. The first two urban lake wetland sites were named urban lake wetland1 (uw1) and urban lake wetland2 (uw2), followed by extensive fish pond1 (ep1) and extensive fish pond 2 (ep2). The final two were named abandoned wetland1 (aw1) and abandoned wetland 2(aw2).

Waterbird surveys

Waterbird surveys were conducted from September 2009 to August 2011. Four seasons were identified according to the patterns of passing and wintering migrants in Nanhui County: autumn (mid-August to early November), winter (early November to mid-March), spring (mid-March to mid-May), and summer (mid-May to early August). Ten timed surveys were carried out at every site during every season. These surveys were conducted during suitable weather conditions by using bicycles. Waterbirds were identified and counted using binoculars (8×50) and telescopes (32×), with most counts comprised of individual birds but flocks larger than one hundred individuals estimated by counting blocks of 10, 20, 50, or 100 birds and finding similarly sized groups in the flock (Rapold *et al*.1985). A complete count of all waterbirds present at each site was conducted.

Habitat and environmental characteristics

All environmental factors monitored are shown in Table 1. Almost all of the factors changed every season except the vertical distance from the region to the seawall, so fieldwork was carried out to obtain 20 water level measurements at each site. This allowed estimation of total areas of shallow water cover and deep water cover. GPS trajectory calculations provided area estimates of bare muddy area and vegetation area. Vegetation cover was obtained by visual observation. We calculated the vertical distance from the region to the seawall from the Landsat TM image and classified anthropogenic disturbance into 5 ranks according to road conditions, house conditions and human activities surrounding the site.

Table 1. Environmental factor descriptions and abbreviations.

Environmental factors	Abbreviation	Measuring unit
Shallow water cover area	SW	%
Deep water cover area	DW	%
Bare muddy area	BM	%
Vegetation area	VA	%
Mean water level	MWL	m
Vegetation coverage	VC	%
Vertical distance from the region to the seawall	DS	km
Anthropogenic disturbance	AD	1-5

Data analysis

A dominance species accumulation curve (PRIMER 6.1.6) was used to compare relative species evenness and richness among different wetlands. High values on the y axis and low values on the x axis of the cumulative dominance curve plot indicated communities with few species dominating.

Abundance data were first transformed into densities (number of birds per ha) to allow comparison among wetlands of different sizes. Densities were square-rooted transformed to down weight numerically dominant species that could have given erratic counts over replicates samples within a site. Data were tested for homogeneity of variance with the Levene test (SPSS 18.0) but transformations did not stabilize variances. As a result, differences in waterbird species and densities among the six wetlands were tested with the non-parametric Kruskal-Wallis test, followed by post-hoc Games-Howell multiple comparison test. Differences were determined for total birds and functional guilds. We grouped species into six main guilds: 1) diving birds (diving duck and cormorants), 2) herons, 3) dabbling ducks, 4) shorebirds, 5) corncrakes, and 6) terns.

Variations in waterbird community composition were evaluated by Non-metric Multi-dimensional Scaling (NMDS) (PC-ORD) and Spearman's rank correlations were used to examine the relationship between each environmental variable and NMDS axis. Environmental factors that were significantly correlated with one or more axes were overlaid on the ordination plot as vectors; the angle and the length of the vector denote the direction and strength of the relationship.

RESULTS

Waterbird community composition

A total of 41,493 individuals, corresponding to 91 species from 15 families were recorded during census counts. Six species were exclusively found in urban lake wetlands (Velvet Scoter *Melanitta fusca*, Smew *Mergullus albellus*, Eurasian Curlew *Numenius arquata*), Black-headed Gull *Larus ridibundus*, East Siberian Gull *Larus vegae*, and Caspian Tern *Hydroprogne caspia*. Eighteen species including Black-faced Spoonbill *Platalea minor*, Tundra Swan *Cygnus columbianus*, and Whimbrel (*Numenius phaeopus*) were exclusively found in extensive fish ponds. Three species (Mandarin Duck *Aix galericulata*, Little Curlew *Numenius minutus*, and Red-necked Phalarope *Phalaropus lobatus* occurred only in abandoned wetlands. Overall, the waterbird community was dominated by Coot *Fulica atra*, Falcated Duck *Anas falcate*, Eurasian Wigeon *Anas penelope* and Gadwall *Anas strepera*, which represented 48.7% of all individuals recorded. The majority of waterbird species (n=78) were recorded only occasionally (<1% of the total number). Dabbling ducks represented 35.6% of all individuals recorded, corncrakes represented 26.9%, shorebirds represented 17.3%, and diving birds represented 11.3%. There was only 0.9% terns recorded at study sites.

The numbers of Black-faced Spoonbill and Falcated Duck, which were recorded in at least two surveys met the criteria of international wetland (Ramsar) assessments of bird population sizes >1% of estimated global flyway population (Wetlands International 2013). In particularly, Black-faced Spoonbill was classified as an endangered species by IUCN (2012), with an estimated global population of approximate 2700 individuals until 2012 (Hong Kong Bird Watching Society 2012), and 35 individuals were recorded in extensive fish ponds. The over-wintering Black-faced Spoonbill population was present from the middle of October to late April in Nanhui County. Other passing Black-faced Spoonbills were recorded in July and stayed for one or two weeks. The population of Falcated Ducks was present during the winter and flew away in late April.

Waterbird distribution patterns in three types of wetlands

The extensive fish ponds hold the highest species richness and evenness (Fig. 2) with more shorebirds species and herons in ep1 than shorebirds and herons in ep2, yet both contributing to total diversity. This was followed by aw1 with diving birds and corncrakes. Urban lake wetland 1(uw1) had lower species richness and evenness (Fig. 2) with diving birds and dabbling ducks contributing to total diversity. The uw2 had the lowest species richness and evenness (Fig. 2) with diving birds and cormorants contributing to total diversity.

Total species richness (Kruskal-Wallis test $\chi^2_{(0.05\ 5)} = 5.721$ p = 0.678) was not significantly different among the three types of wetlands (6 samples) (Table 2). Diving bird species richness was highest and shorebird species richness was lowest in urban lake wetlands (uw1 and uw2). Shorebird species richness was the highest in extensive fish ponds (ep1 and ep2). Diving birds' species richness was the greatest in aw2 and herons' species richness was greatest in aw1. Species richness of terns was the lowest in all of the 6 sites.

Table 2. Species richness [Mean (SE)] at three types of wetlands in Nanhui County, Shanghai.

Functional guild	Urban lake wetlands		Extensive fish ponds		Abandoned wetlands	
	uw1	uw2	ep1	ep2	aw1	aw2
Total birds	5.00(0.41)	5.45(0.32)	13.27(1.19)	3.60(0.38)	4.42(0.30)	8.22(0.48)
Diving birds	1.50(0.19)	2.17(0.17)	1.55(0.19)	0.55(0.14)	1.80(0.12)	1.27(0.13)
Herons	0.83(0.17)	1.15(0.20)	3.98(0.37)	1.00(0.19)	0.90(0.13)	2.78(0.30)
Dabbling ducks	1.10(0.26)	0.62(0.15)	2.13(0.32)	0.63(0.21)	0.80(0.22)	0.45(0.19)
Shorebirds	0.05(0.05)	0.10(0.06)	4.38(0.86)	1.20(0.26)	0.02(0.03)	2.30(0.36)
Corncrakes	0.62(0.12)	1.33(0.10)	0.98(0.14	0.20(0.06	0.90(0.11)	1.20(0.13
Terns	0.15(0.07)	0(0)	0.25(0.09)	0.05(0.03)	0(0)	0.18(0.06)

There were significant differences in total waterbird density among the three types of wetlands (6 samples) (Kruskal-Wallis test $\chi^2_{(0.05\ 5)} = 17.636$ p = 0.003). Total waterbird density was higher in the two extensive fish ponds than the other areas (Table 3). The densities of all guilds were different among the 6 sites. Densities of diving birds were higher in uw2 than ep2 (post hoc $p < 0.001$), similar to other samples. Densities of herons were higher in ep1 than in other areas (post hoc $p < 0.05$). Densities of dabbling ducks were similar in uw1, ep2, rw2, and aw1 but had significant difference between ep1 and aw2 (post hoc $p < 0.05$). Densities of shorebirds were higher in the two extensive fish ponds (ep1 and ep2) than the two urban lake wetlands and aw1 (post hoc $p < 0.01$) but similar to aw2. Densities of corncrakes were higher in uw2 than the two extensive fish ponds and uw1 (post hoc $p < 0.01$) but similar to the two abandoned wetlands.

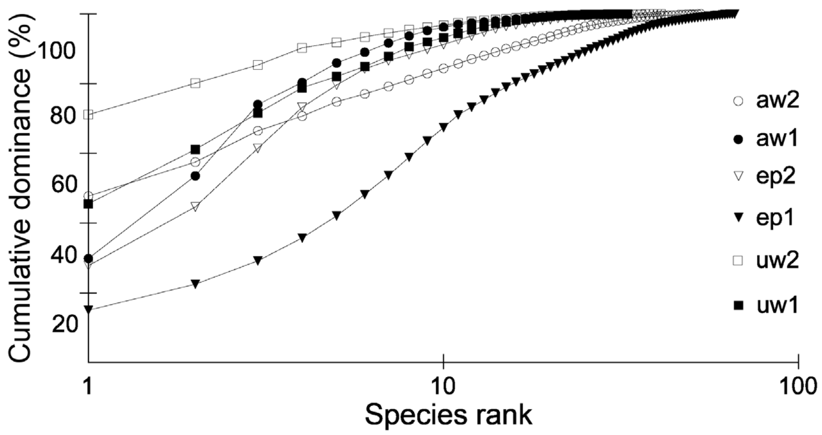

Fig. 2. Species cumulative dominance curve for 6 study sites.

Table 3. Species density [square-root transformed (SE)] at three types of wetlands in Nanhui County, Shanghai

Functional guild	Urban lake wetlands		Extensive fish ponds		Abandoned wetlands	
	uw1	uw2	ep1	ep2	aw1	aw2
Total birds	2.03(0.29)	2.23(0.23)	2.98(0.24)	2.36(0.4)	1.93(0.25)	2.16(0.18)
Diving birds	0.84(0.29)	0.97(0.07)	0.67(0.09)	0.38(0.13)	0.79(0.07)	0.66(0.08)
Herons	0.23(0.13)	0.25(0.04)	1.11(0.12)	0.18(0.03)	0.29(0.04)	0.67(0.06)
Dabbling duck	1.16(0.05)	0.42(0.10)	1.00(0.2)	1.05(0.36)	0.89(0.25)	0.26(0.09)
Shorebirds	0.01(0.32)	0.06(0.04)	1.31(0.21)	0.97(0.27)	0.01(0.01)	0.65(0.1)
Corncrake	0.33(0.07)	1.75(0.23)	0.87(0.16)	0.17(0.08)	0.98(0.16)	1.25(0.22)
Terns	0.11(0.06)	0	0.17(0.07)	0.09(0.06)	0	0.02(0.01)

Impacts of environmental factors on community composition in three types of wetlands

NMDS ordination resulted in three dimensions. The proportion of variance extracted by each axis was reasonable for each (axis1 = 0.38; axis2 = 0.23; axis3 = 0.18). Axis 1 was positively correlated with mean water level (MWL), deep water cover area (DW), vertical distance from the region to the seawall (DS), and negatively correlated with shallow water area (SW). Axis 2 was negatively correlated with vegetation coverage (VC) and vertical distance from the region to the seawall (DS). Axis 3 was positively correlated with mean water level (MWL), vertical distance from the region to the seawall (DS), and anthropogenic disturbance (AD).

The NMDS ordination plot revealed a noticeable partition between the three types of wetlands, as seen through four distinct clusters (Fig. 3). The first and the second clusters, in the upper-right quadrant of the plot, represent waterbird communities found in urban lake wetland 1 and urban lake wetland 2, respectively. Cluster 1 and cluster 2 were strongly correlated with deeper water area (DW), anthropogenic disturbance (AD), distance to the seawall (DS), and mean water level (MWL) (Tabel 4). The third cluster, in the upper-left quadrant of the plot, represents the waterbird community in restorative wetland 1 and has no direct relationship with any environment factors. The fourth cluster, in the lower-left quadrant of the plot, represents the waterbird community found in extensive fish pond 2, abandoned wetland 1, and abandoned wetland 2. Cluster 4 was strongly correlated with vegetation area, shallow water area, and bare muddy area.

Table 4. Correlation between environmental factors and three NMDS ordination axes (Significant correlations are marked in bold).

Environmental variable	Variable correlation(r)		
	Axis1	Axis2	Axis3
Shallow water cover area (SW)	**–0.69**	0.14	–0.31
Shallow water cover area (DW)	**0.59**	–0.09	0.33
Bare muddy area (BM)	–0.34	0.08	–0.22
Vegetation area (VA)	–0.33	–0.14	–0.16
Mean water level (MWL)	**0.65**	–0.01	**0.43**
Vegetation coverage (VC)	0.08	**–0.68**	–0.03
Vertical distance from the region to the seawall (DS)	**0.58**	**–0.40**	**0.51**
Anthropogenic disturbance (AD)	**0.67**	–0.21	**0.50**

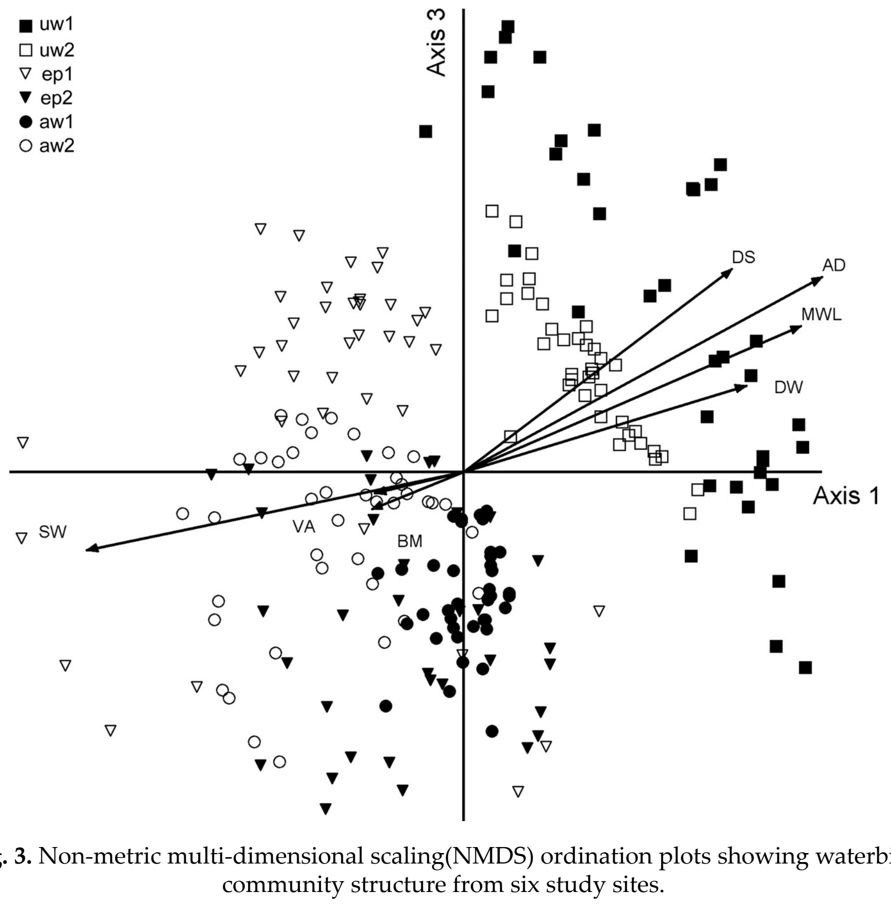

Fig. 3. Non-metric multi-dimensional scaling(NMDS) ordination plots showing waterbird community structure from six study sites.

DISCUSSION

Our results indicate that after reclamation, the Nanhui County coastal wetlands contain suitable habitat for wintering and migrant waterbirds. For example, it is an important destination for over-wintering dabbling and diving ducks. The dominant species are Eurasian Coot *Fulica atra*, Falcated Duck *Anas falcata,* Eurasian Wigeon *Anas penelope* and Gadwall *Anas strepera*. It also is a roosting site for shorebirds. Comparing these results to previous research by Tian-Hou Wang (Wang & Qian 1986), 17 new species were recorded including Pheasant-tailed Jacana *Hydrophasianus chirurgus*, Northern Lapwing *Vanellus vanellus*, and Oriental Pratincole *Glareola maldivarum*, *etc*. However, the Great Knot *Calidris tenuirostris* was a dominant species in 1984, but was rarely seen in this present study. We concluded that this was due to the loss of natural wide intertidal mudflats of coastline in the last 25 years, which was an important stopover site for Great Knot populations during long distance flyway. In contrast, the latest reclamation project was carried out at 0m tidal level, as now the depositing natural mudflats outside the seawall are short and can be submerged completely during spring tide. The mudflats in the seawall contain slow drying soils that attract Grey-headed Lapwing *Vanellus cinereus* and Oriental Pratincole, which prefer the arid beaches. Salinity was reduced as it is diluted by rainfall into the seawall and thus contributed to the appearance of Green Sandpiper *Tringa ochropus* and Pheasant-tailed Jacana. The density of shorebirds has decreased compared to the figures in 1984 and 2004 (Ge *et al.* 2006, Zhong *et al.* 2006, Wang & Qian 1986). Now the Nanhui County coastal wetlands have become a roosting site rather than a refuel site for shorebirds (Zhong *et al*. 2006, Heng *et al.*2011).

Two main urban wetlands accommodate the wintering dabbling ducks and other diving birds and corncrakes, with few herons present and shorebirds even rarer. Species evenness and richness are the lowest in these urban wetlands. NMDS analysis reveals that the waterbird community was strongly correlated with deeper water area, anthropogenic disturbance, distance to the seawall, and mean water level. The two urban wetlands with deeper water level and sufficient water area attract ducks and diving birds (Stapanian 2003). Less vegetation and deeper water level restrict the herons and the shorebirds to forage and rest here (Powell 1987, Baker 1979, Ntiamoa-Baidu *et al*. 1998, Collazo *et al.* 2002, Darell & Smith 2004). Two urban wetlands are located in the new district of Lingang, which is populated by few residents and characterized by overall low anthropogenic disturbance. The results suggest that urban lake wetlands designed for use in urban landscapes can be suitable habitats for waterfowl. However, as the resident population and human interference increases with urbanization, we suppose it would be difficult for these urban lakes to accommodate such numbers of waterbirds.

Almost all of the community characteristics including total waterbird species richness, total density, and evenness are the highest in the two extensive fish ponds (Fig. 2, Tables 1 & 2). Most of the shorebirds stay in ep1 and ep2, in addition to some in aw2. It is an important stopover for shorebirds to regain energy. It also contains a certain number of waterbird species found in other guilds, such as dabbling ducks, herons, corncrakes, and diving birds. NMDS analysis shows the partition between ep1 and ep2. Cluster 3 (ep1) seemingly has no direct relationship with either environmental factors, as it has the most complex waterbird community structure with the highest shorebird density, a certain number of species found in other waterbirds guilds, and a corresponding diverse habitat. Site ep2 is positively correlated with bare muddy area, vegetation area and shallow water area as it mainly contains shorebirds that prefer bare muddy areas (Davis & Smith 1998, Ge *et al*. 2006, Tang & Lu 2002, Niu *et al.* 2011), and the dabbling duck, which can forage in shallow water (Pöysä 1983). The Black-faced Spoonbill, which is listed as a endangered species by IUCN (2012), was recorded as a passing bird in the Yangtze estuary region in a previous study (Cai 2008). In this present study, we observed wintering Black-faced Spoonbill populations over two years, exceeding the 1% Ramsar criterion. On the premise of maintaining the stability of the environmental factors, the extensive fish ponds will be a principal wintering site for Black-faced Spoonbill.

On the other hand, the extensive fish ponds were managed by local farmers who must also consider obtaining economic profit. There is a contradiction between the protection of bird diversity and the aquaculture pond operating in it. During the harvesting seasons around the Chinese spring festival of winter, the pond managers drain the water in order to catch fish for commercial purposes. During this time, there were thousands ducks dominated by Falcated Duck roosting here. Afterwards, the pond remains dry until the next spring when water is re-injected for new cultivation. As such, the time to re-inject water is critical for migrant waterbirds in spring, as if the time is too late, the drought pond is unsuitable for shorebirds and herons.

Species richness and evenness in abandoned wetlands was lower than in extensive fish ponds and these wetlands mainly contain corncrakes. There are several differences between aw1 and aw1, for example, aw2 contains a number of shorebirds that are seldom present in aw1. Dabbling duck densities are also higher in aw1 than aw2. NMDS analysis demonstrates that waterbird populations were correlated with vegetation area, shallow water area, and bare muddy area. In a successional trajectory of these abandoned wetlands, as the water area is reduced, the water level draws down, and vegetation area increases gradually. These changes provide diverse habitats for the above waterbird guilds. Many studies have revealed vegetation can provide shelter and decrease anthropogenic disturbance, which occurs in artificial wetlands at both roosting and nesting sites (Hattori & Maeda 2001). Dense vegetation indirectly increases food for waterbirds (Anderson & Smith 2000) due to increases of invertebrates (Wiggins *et al.*1980, Rehfisch 1994).The previous study(Green *et al.* 2009) indicated that waterbird diversity had a declining trend because of the drawdown after the wetlands had been abandoned. In the present study, aw1 cannot recruit shorebirds easily due to the conversion of much of the wetland to dry land.

CONSERVATIONAL IMPLICATIONS

Artificial wetlands play an important supplementary habitat for waterbirds in the reclaimed coastal area of the Yangtze River Delta, as the different wetlands can accommodate different guilds due to distinct environmental factors (Niu *et al*. 2011, Zhang *et al.* 2011, Ge *et al.* 2006). According to the characteristics of the waterbird community at the reclaimed wetland in Nanhui County, during winter deep water cover should be maintained for wintering dabbling ducks and diving birds and sufficient shallow water areas need to be retained for shorebirds during migrant seasons (spring and autumn). Recommendations are as follows: 1) Construct a sluice from Dazhi River to the abandoned wetlands to maintain an adequate water supply, eliminate the impact of drought, cut off dense vegetation, and control the water level in spring allowing the formation of shallow and bare muddy areas; 2) Alter pond management strategies to provide a stable habitat for wintering duck and diving birds and migrant shorebirds, including changing the aquatic produce methods and adjusting the time and the speed of injecting water, to ensure sufficient shallow water cover area and bare muddy areas. The farmers who manage fish ponds need to be compensated when the economic benefits were reduced due to wildlife conservation; 3) Convert concrete banks into natural sandy soils with reed marshes in the lake area for the purpose of increasing habitat diversity required for waterbird roosting; and 4) Suggest that future governmental land use plans dealing with reclaimed regions convert more land into paddy fields and ponds and replace dry land areas.

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