Can Artificial Ecological Islands Alter the Biodiversity of Macroinvertebrate and Waterfowl? A Case Study in Fujin National Wetland Park, Heilongjiang Province, China

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Abstract

1. Many policies and studies globally have highlighted the pivotal role of wetland ecosystems regarding wetland biota and their ecological status. With the strengthening of wetland ecosystem management legislation and policy, wetland restoration should also consider increasing habitat diversity to improve biota. We explore whether the construction of artificial ecological islands can increase the diversity of wetland birds and macroinvertebrates before assessing the effects of actively constructing islands via human intervention on wetland protection. 2. We discuss changes in waterfowl and macroinvertebrate diversity (i) with and without islands, (ii) at different water level gradients surrounding the islands, (iii) on different island substrates, and (iv) at different time scales. We used ANOVA, ANOSIM and cluster analysis to test the differences. 3. The waterfowl and macroinvertebrate communities had spatially heterogeneous distributions and vary over time due to both natural and anthropogenic stresses. The establishment of islands significantly changed the community composition and biodiversity of the macroinvertebrate and the waterfowl. The waterfowl and macroinvertebrate communities had different compositions at different water levels. Macroinvertebrates are the main food components of waterfowl and are closely related to them, and overall, abundance and diversity of macroinvertebrates directly and/or indirectly affect the biodiversity of waterfowl. Potentially, the construction of islands could provide some co-benefits for the conservation of wetland birds and macroinvertebrates. Synthesis and applications. Establishing artificial ecological islands in broad open water areas and increasing the water level gradient and substrate diversity. It can increase the micro-habitat diversity by artificially increasing the heterogeneity of the water depth conditions of a habitat. These changes can accommodate aquatic organisms with different ecological niches to increase the biodiversity, affecting the ecological restoration of inland freshwater marshes and wetlands. As such, wetland parks can play a positive role in protecting important bird migration pathways in northeast Asia.

Introduction

Wetlands are important components of the natural landscape for their functions in cleaning and retaining water naturally and providing habitats and food sources for a wide variety of plant and animal species. As a result of economic development and human population growth, intensive agriculture (croplands), as well as changes in water use and availability, increasing urbanisation and infrastructure development, disease control (especially mosquitoes), aquaculture, etc., global wetlands continue to convert and degrade. Historical reports indicate a loss of 87% of the world's natural wetland area since the start of the 18th century (Davidson. 2014). What is more, the natural Wetland Extent Trends index, excluding human-made wetlands, declined by approximately 30% between 1970 and 2008 globally (Dixon et al. 2016). Losses of natural inland wetlands have been consistently greater, and at faster rates, than of natural coastal wetlands.

The severe loss of wetlands worldwide has significantly increased the threat to wetland-dependent organisms such as waterfowl (Gregory et al. 2010). For example, China has 65940 km^2 of wetlands, spanning multiple latitudes and accounting for about 10% of the world's wetland area, with abundant habitat types, species and quantities of biological resources. Over the past decade, however, 50% of China's bird population density has declined significantly, with inland waters and marshes experiencing the biggest declines. (Nanjing Institute of Environmental Sciences, 2018). To counter these negative trends, many wetland conservation and restoration projects worldwide aim to improve the wetland biome and increase the diversity of wetland birds (Platteeuw et al. 2010). How to increase wetland biodiversity rapidly is a hot topic in global discussions. In China, the basic state policy of ecological civilization construction (the Eighteenth National Congress of the Communist Party of China, 2012) highlights the pivotal role of wetland ecosystems and their ecological status for wetland biota. Thus, both protecting existing wetlands and creating and restoring the functions of degraded wetlands and their supporting aquatic environments are vital strategic areas for ecological civilization construction.

For wetland biological management, this importance has led to the goal of attracting diverse and abundant waterfowl communities from adjacent habitats. In addition, a variety of foraging habitats and suitable living conditions (water depth, vegetation, food) can improve the survival rate of individual birds, as well as the nesting rate and reproductive success rate of waterbirds in the area. The abundance and distribution of resources such as fish, plants and macroinvertebrates are critical to this end (Masero et al. 1999). However, for waterbirds, access to food resources such as macroinvertebrates and aquatic plants is constrained by water depth, and the required foraging depths vary widely among species (Taft et al. 2002; Wood et al. 2012). Additionally, hydrophytes, depth and substrate affect the abundance and distribution of macroinvertebrates (Al-Sayed et al. 2008; Di Giovanni et al. 1996). Consequently, manipulating the water depth and substrate in wetlands can be a valuable tool that provides habitats for multiple species.

Building artificial ecological islands (islands for short) is an important technique for improving wetland topography and providing a diversity of foraging depths for waterbirds (Burton et al. 1996; Wang et al. 2014). However, the biodiversity effects of building these islands have never been systematically assessed. Furthermore, almost 7 years after these islands were built, it is still unknown whether this technique for protecting biodiversity actually protects or promotes biodiversity growth. For comparative purposes, we therefore surveyed differences in bird and macroinvertebrate species richness and abundance between sites (Water with and without islands in the same wetlands). We hypothesized that when islands are built, there would be differences in the biodiversity components between sites. Whether biodiversity is affected by islands was assessed in Fujin National Wetland Park, and the wetland effects were quantified. From the perspective of restoration ecology, whether this wetland restoration project of building islands with human intervention represents a suitable strategy for improving waterfowl and macroinvertebrate habitats and increasing both their diversity and abundance were evaluated. This study proposes a technical example of wetland restoration via a project that provides technical support and a scientific basis for protecting wetland birds, increasing biodiversity and protecting and utilizing wetlands on the Sanjiang Plain.

Materials and Methods

Study Area and Artificial Ecological Islands

The Sanjiang Plain, located in northeast China, is the largest concentrated distribution area of freshwater marshes in China. It is not only an important ecological resource and environmental protection barrier, but also an important stopover site for many Palaearctic-realm migratory waterbird species. In past years, the wetland resources in Sanjiang Plain have been seriously degenerated or lost due to long-term excessive and unreasonable utilization and development. From 2000 to 2015, the total area of wetlands in the Sanjiang Plain decreased by 2508.56 km^2, the vegetation coverage of wetlands decreased from 91.8% to 74.0%, and the habitat area that is suitable for waterfowl decreased by 20.33%. These results indicate that the support capacity of waterfowl habitats in the Sanjiang Plain has decreased significantly in the past 15 years (Liu et al. 2018; He et al. 2017).

Fujin National Wetland Park (the park for short), which covers an area of 22 km^2, is located in the hinterland of the Sanjiang Plain, Heilongjiang Province, Northeast China (E 131°41'02.8"-131deg46'09.2", N 46deg53'18.8"-46deg56'18.5"). (National wetland park refers to a specific area approved by the state forestry administration and protected and managed in accordance with relevant regulations for the purpose of protecting wetland ecosystem, making rational use of wetland resources, carrying out wetland publicity, education and scientific research) (National Forestry and Grassland Administration. 2017).This area has a temperate continental monsoon climate with distinct seasons. There is less rain in spring and more in summer, and the temperature drops sharply and differs in autumn. The annual precipitation is approximately 608.6 mm, and the average temperature is -20.4degC in January and 22.2degC in July.

Before 2004, the park's cofferdams were crisscrossed and cultivated, the wetlands were almost all reclaimed, and the wetland resources were severely damaged. To fully protect the wetland ecosystem, the local government decided to strengthen wetland restoration projects in 2005, through water diversion, increasing vegetation diversity, the establishment of artificial ecological island and other measures to carry out ecological restoration of the wetland, which has become a successful example of China's conversion of farmland to forest wetland.

Due to the park's flat terrain and the relatively uniform distribution of various environmental factors, the vegetation is dominated by a single community, including *Phragmites australis* and *Typha* . The plant diversity is low, and can only provide a single resting and foraging habitat for animals; therefore, there are few animal species and waterfowl. To create good habitats for birds and other aquatic organisms, attract birds and increase the integrity of the wetland ecosystem of the park, the local government hired the Wildfowl and Wetlands Trust (WWT, The U.K.) and domestic experts to make a scientific plan and design for the park. The city also cooperated with the German government for technical and financial purposes regarding wetland biodiversity conservation and ecological environment restoration projects.

In this project, through the construction of ecological island, the purpose of increasing the micro-habitat types and enhancing the heterogeneity of various abiotic environmental factors such as hydrology and topography was achieved. These islands can provide habitats for more species of hydrophytes and increase the diversity of plants to improve primary production in wetlands. Wildlife diversity, such as benthic animals and fish, depends on plant growth; plant growth attracts birds that feed on them, and their settling achieves the purpose of having more biological species in a relatively smaller area. The project built 6 islands in the open waters of the park in 2011 and 2013, and 12 islands were created in total. To build the islands, canals were dug in the park; the canals were expanded, and the slope habitat was increased to strengthen the hydraulic connection among water patches. The original low-lying areas were dug to a depth of more than 2 metres according to the terrain, and as a result, the water levels were distributed in different layers and regions that were adapted to the requirements of different overwintering wildlife. At the same time, the excavated earth was designed according to the terrain and stacked on relatively higher ground to form soil substrate islands (SSIs) above the water. Pebbles were placed on some of the soil islands to form pebble substrate islands (PSIs). As a result, the original plateau is now more prominent, and there is always a certain area of land at the highest water level to achieve significant topographic differences. The island shape is the frustum of a cone, with the highest point of the island rising approximately 1 m above the water surface on average (Figure 2). The edge slope of each island is different, and the shallow water zone is very limited. The total island area was approximately 0.1 km^2 after it was built. Due to island collapse, the size of each island that extends out of the water currently varies from 200 m^2 to 5000 m^2.

Topographic changes can affect the formation of landscape patterns in the park in a way that the water, soil and other conditions also change; thus the diversity and distribution range of plants and animals in the park have been greatly enriched. Ecological islands provide a place for birds to forage, reproduce and rest. These structures, which have a good field of vision and are inaccessible to mammalian predators, can attract waterbirds, increasing the birds' nesting population and success rate. (Momose et al. 1998). Therefore, the structure and function of the wetland ecosystem has been gradually restored, and the biodiversity of the wetland has improved.

Methods

In order to observe birds of high abundance and variety, bird monitoring was conducted and macroinvertebrate samples were collecting in the summer of 2015-2017 (mid-August). In order to analyze the effect of human disturbance on bird distribution, we asked the park management center to provide the visitor data of the wetland park for three years as a reference. In order to investigate the heterogeneity of vegetation structure and composition, a field survey was conducted in July-August 2015.

Monitoring began a half hour before sunrise and sunset, lasting 3-5 hours (04:00–9:00, 15:00-18:00) for three successive days (days without heavy wind and rains). Due to domain and time limitations, we set one line transect (about 16.3 km) and chose four open water areas that were at fixed locations inside the park for bird spotting. Each site was visited at roughly the same time of day to reduce the noise from systematic patterns (e.g., regular diurnal bird movements) that would obscure the trends observed within the park (Figure 1). A 10X binocular (SWAROVSKI SLC 10x42 WB) was used to identify and count birds. Numbers and species of all birds present within 300 m on both sides of the transect were recorded. Birds flying forward were excluded, and only those feeding in and flying within the sampling areas were recorded, and the maximum observed value was used to calculate the abundance (Taft et al. 2002; John. 2000; Chang et al. 1995; Jing et al. 2007). We use field binoculars to identify bird areas (swimming, foraging, resting, etc.) between islands versus non-island areas.

Macroinvertebrate samples were collected in a 1 m^2quadrat from 20 sites with D-frame kick nets (30 cm aperture, 500 mm mesh) and then sieved with water. The retained macroinvertebrates were transferred into pre-labelled polyethylene containers. The faunal samples were fixed using buffered formalin (4%) and subsequently preserved using 70% ethanol. The organisms were identified and counted to the "species" level (Al-Sayed et al. 2008).

Due to the collapse of some islands, 9 islands (Figure 1) were selected. Survey sample points were set on those islands, and two depth gradients were established on each island, namely, a shallow water level area (depth $<$40 cm) and a deep water level area (40 cm$<$ depth $<$80 cm). Samples were randomly collected at each depth gradient, and repeated sampling was conducted in three directions in the shallow water habitat "around" the islands. To prevent disturbance caused by the migration of macroinvertebrates from the islands to the open water, 11 samples were randomly selected from an open-water area (50 cm $<$ depth $<$ 130 cm) that was far from the islands in the park. The distance between the open-water sampling points depends on the size of the floating raft between the sampling points, ranging from 100 to 300 meters. In total, 20 samples were taken (Figure 1).

At each sampling site, we calculated the mean macroinvertebrate abundance and recorded the species. For the benthic communities in each group identified by the cluster analysis, the average density and number of species (considering each taxon as a species) were determined. An initial multivariate analysis was performed using the standardized species matrix in a cluster analysis (Bray–Curtis hierarchical clustering), and non-metric multi-dimensional scaling (MDS) was performed using the similarity scores generated from the cluster analysis (Clarke. 1994). These analyses were performed to find any “natural groupings” based on the species matrix to check if the grouping was consistent with the artificial grouping results based on the species matrix (Butcher. et al. 2003).

We used Q-Q plots of the residuals in SPSS to compare the fit of the common distributions (normal, Poisson, negative binomial). The procedure indicated that the normal distribution fit the data well. We also calculated traditional measures of biodiversity, the Shannon-Wiener index (H’, log e) (Shannon. 1948), Margalef index (d) (Margalef. 1958) and Pielou evenness index (J) (Pielou. 1975) (species level). Due to the different sensitivities of different species of macroinvertebrates and waterfowl to environmental changes, one-way ANOVA was carried out at the order level to compare differences in the macroinvertebrates and waterfowl species abundance among the various sites in 3 years. The taxa abundances were log (x + 1) transformed to dampen the effects of the few most abundant taxa.

Analysis of similarities (ANOSIM) was used to evaluate the community similarity. Moreover, similarity percentage analysis (SIMPER) was used to determine the contributions of individual taxa towards the dissimilarity between and similarity within the groups identified by cluster analysis, both of which were included in the PRIMER V5.2 software package (Clarke. 1994; Clarke. 2006).

Pearson correlation test was carried out to prove the close relationship among waterfowl, plant and macroinvertebrate, both of which were included in the IBM SPSS Statistics 20 software package.

Results

Effects of artificial ecological islands on macroinvertebrates

In total, 12956 macroinvertebrate specimens were collected in the park; 85 taxa belonging to 13 orders and 6 classes were identified, most of which were arthropods (62 species, accounting for 72.94%). Mollusks were second with 15 species (17.65%). There were only 8 species (9.41%) of annelids. SIMPER analysis showed that only 3 species were the primary contributors at all sites, *Parafossarulus striatulus*(35.72%), *Palaemon modestus* (34.84%) and *Radi plicatula*(13.49%), with a cumulative contribution of approximately 84% and a total similarity of 38.17 (the list was truncated when 80% was reached).

The species and abundance of macroinvertebrate fauna in the park increased continuously in 3 years. The abundance of *Chironomus*larvae decreased, but those of Odonata and Rhynchobdellida Blanchard increased continuously (Figure 3).

The species abundance and diversity were higher in the island communities than in the open-water area. Regarding the two water levels on the islands, the richness in the shallow-water-level area was higher but not as evenly distributed as that in the deep-water-level area (Figure 4).

Two-way crossed ANOSIM showed that there were significant differences among the open-water area and island two levels regarding the macrobenthos community composition in 3 years (Table 1). ANOVA showed that in the 12 orders used as classifiers, the mean abundances of 8 orders in the open-water area and on the islands were statistically different (Table 2). Additionally, there were three orders of classifiers that were significantly different between the two island levels (Table 2). The hierarchical cluster dendrogram of the 20 macrobenthos communities assessed with SPSS software was basically consistent with the MDS. There were two groups: islands and open-water area (Figures 5 & 6). Due to the large changes in substrate, hydrophytes and depth in open-water area samples, the order was not relatively uniform.

Effects of substrate and construction time of the artificial ecological islands on macroinvertebrates

Following MDS, we placed island B into the SSI group, and the community composition differed significantly between the two substrates (Table 3, Figures 5 and 6). Seven taxa between the two were significantly different (Table 2). The PSI groups had more species and were more evenly distributed than the SSI. In the MDS results (Figure 7), the island group was divided into two groups (dimension 2), and the division was related to the different substrates. In the classification, PSI B was classified as a SSI. The possible reason is that island B has a large area, and a few stones were laid around the island. The outlying part of the island is covered with a few pebbles; only the part near the centre of the island is covered with more pebbles. It is also covered with cattails, reeds and other vegetation, making it similar to the soil islands. To explore the change trend in macroinvertebrate diversity with the extension of island construction time, we also compared the community compositions of the islands with two construction ages. The results showed that there were significant differences (Table 3), and 3 of the 12 orders were significantly different (Table 2). The species and diversity were higher on the islands that were built relatively later (Figure 7). Compared with the vegetation biodiversity and abundance on these islands, the PSIs were higher in plant species and biodiversity than SSIs although plant abundance was lower. In addition, the vegetation biodiversity on the PSI built first was higher than that on the PSI built later, while the vegetation biodiversity on SSI built first was lower than that on SSI built later. (Figure 8).

Effects of artificial ecological islands on waterfowl

In total, 5987 individuals were recorded, and 33 species identified in the park belonged to 8 families and 7 orders. SIMPER analysis showed that nine species contributed the most in three years: *Fulica atra* (15.49%), *Podiceps cristatus* (10.28%), *Chlidonias hybrida* (9.66%), *Egretta alba* (8.59%), *Aythya ferina*(8.47%),*Anas poecilorhyncha* (7.63%), *Podiceps ruficollis* (7.61%)*Chlidonias leucoptera* (6.83%) and

Anas platyrhynchos(4.85%), with a cumulative contribution of approximately 80% and a total similarity of 65.42.

Changes in the species composition of waterfowl in the shallow water areas that consisted of islands and deep water areas without islands are shown in Figure 9. There were more wading bird species than swimming birds in the park, but the wading birds were less abundant. Comparing the distribution of waterfowl at the two water levels, the number and abundance of species in the shallow water area were higher than those in the deep water area, Charadriidae, Scolopacidae and Ardeidae, for example. In contrast, the shallow water areas had more Podicipedidae and Rallidae.

Pearson correlation analysis showed that there was a negative correlation between the diversities (H') of waterfowl and macroinvertebrates (r = -0.997, P = 0.05). Therefore, the waterfowl and macroinvertebrate data were compared. The macroinvertebrate diversity index had an upward trend, but the waterfowl diversity index decreased (Figure 10). The possible reason for the effects on the composition of the waterfowl community is that summer is the peak tourist season in the park, and the number of visitors gradually increased during those years. The number of visitors was negatively correlated with the diversity ($r_{H'}$ = -1.000) and richness (r_d = -0.999) of waterbirds. Human activities interfere with the foraging behaviours of birds and reduce their activity space.

DISCUSSION

Effects of artificial ecological islands on macroinvertebrates

The macroinvertebrate community in the park was mainly composed of Mollusca, *Palaemon* and Lnsecta, possibly because the plant community was mainly composed of *Phragmites australis* ,*Typha orientalis* and *Myriophyllum* . The substrate was mostly silt that was rich in humus, which meets the requirements of some species for dissolved oxygen and organic debris. The park's artificially controlled water flow keeps constant, providing excellent conditions for slow-moving species, such as mollusks, to thrive (Zuo et al. 2016; Chen et al. 2014). With the regulation of farmland around the wetland park, it is forbidden to dump waste water into the park, which makes the water quality of the park relatively cleaner, and hydrophyte growth is thick. The abundances of *Palaemon (Exopalaemon) modestus* , Ephemerptera, Lestidae, Dytiscidae and other aquatic insects such as Nepidae, Belostomatidae and Haliplidae that are suitable for living in aquatic plants also increased. The macroinvertebrate species were abundant and dense, but the biomass was low, which was related to their geographical environment and the short amount of time that had passed since the farmland was converted to wetland. Regarding the increasing trend in the macroinvertebrate diversity, consistent with the works of Du and Lu, the diversity index showed an increasing trend with the extension of time since the construction of conservation engineering projects (Du et al. 2011; Lu et al. 2013). Over time, the ecological effects of these projects become evident.

We found evidence that the islands could affect the composition of macroinvertebrates. First, on the one hand, the islands changed the water depth, causing the islands to have a certain slope. The light and temperature at the bottom of the islands also changed, further influencing the distribution of sediment, primary productivity and hydrophytes and increasing the niche range of the plant species. At the same time, island creation increased the living area, provided diverse habitats for feeding and reproduction and created concealment conditions for macroinvertebrates. The living requirements of different species were met due to the different water levels, water temperatures and light levels (Wen et al. 2016; Carvalho et al. 2012; Freitas et al. 2011). On the other hand, most species live on the sediment surface, which is rich in oxygen and organic matter, and changes in water depth affect the amount of organic carbon, phytoplankton and sedimentary organic matter (Chen et al. 1975), which is conducive to the adjustment of community structure (Zuo et al. 2016; Chen et al. 2014; Du et al. 2011). Therefore, the establishment of islands increased the water depth gradient diversity, which significantly changed the community structure and distribution pattern of the macrobenthos.

Second, it is generally believed that macroinvertebrate species richness differs in different bottom environments (Lu et al. 2007); the community in pebble substrates was richer than that in fine sand substrates

(Xie et al. 2007). Therefore, when building the PSI, the park's designers chose larger stones as the covering, rather than fine sand or small stones, which ensured the stability of the matrix to a certain extent. In this study, the SSIs were surrounded with many hydrophytes, such as*Phragmites australis* , *Typha* and floating grass, and the bottom had loose debris that was rich in organic matter; these conditions provided a place for the macroinvertebrates to eat, breed and evade predators and made the substrate stable, reducing the impact of water level changes on the macroinvertebrates (Duan et al. 2007). Therefore, compared with the PSIs, with less vegetation and humus, the SSIs are more suitable for survival.

Third, the biomasses of the dominant species, such as *Typha* and*Phragmites australis* , on the island increase each year, and as a result, only single species of hydrophytes exist. *Phragmites australis* are shallow-rooted scattered plants that have a strong ability to secrete oxygen from their roots, and these conditions can meet the respiratory needs of mollusks, such as Gastropoda, which require high dissolved oxygen levels. However, due to their high growth density, the stems and leaves do not decompose easily (Zuo et al. 2016), and the amount of organic detritus they produce is relatively small; therefore, the abundance and diversity of all macroinvertebrate species were not as high as those on the islands that were constructed relatively later.

Finally, plants are more likely to survive on the soil island (which has a high abundance), but as the soil island ages, the plants tend to become more homogeneous, while the stone island has been scoured by water for a long time, which makes it less stony and more conducive to plant survival. For example, SIMPER analysis showed that the three most contributing species on the island, which was built in 2011, were*Phragmites australis* (50.63%), *Scutellaria scordifolia*(16.01%) and *Inula japonica* (8.38%). However, the top three contributing plants on the soil island built in 2013 were *Carex bohemica* (20.62%), *Calamagrostis epigeios* (19.15%) and*Phragmites australis* (15.93%). Due to mowing a year ago, soil island J has the highest plant biodiversity, species and abundance compared with other soil islands. The number of macroinvertebrate species was negatively correlated with plant abundance (r = -0.689, P = 0.04), as well as, ageing of islands leads to a loss of attractiveness for plant and birds (Scarton et al. 2013). Therefore, it is recommended that wetland parks conduct reed-cutting work regularly to promote the increasing diversification of hydrophytes.

Effects of artificial ecological islands on waterfowl

In addition to providing habitat and increasing the abundance of macroinvertebrates, artificial islands are also important breeding grounds for waterfowl. Macroinvertebrates provide an important food source for waterfowl, especially during the breeding season when birds lay eggs and broods. This may be due to the particularly high demand for protein during egg development of waterfowl (Joyner 1980; Murkin and Kadlek 1986).

Patra described the interactions occurring among macrophytes, macroinvertebrates and waterfowl in freshwater wetlands as a complex interdependency (Patra. et al., 2010). The low-water areas of the islands may have increased the temperature of the water and/or the light penetrating the water column, thereby promoting the growth of aquatic plants and increasing the food source for birds.(van den Berg et al., 1997;Zimmer et al., 2000).The increased density of aquatic vegetation will provide a carbohydrate-rich food source for waterfowl, which is important for the gathering and migration of waterfowl in the fall (Baschuk 2010; Baldassare and Bolen 2006). At the same time, the higher density of aquatic vegetation will also increase the number of habitats available for invertebrates, which may increase the abundance of invertebrates and further increase the abundance of bird food (van den Berg et al. 1997; Hornung and Foote 2006). The dynamic changes of bird communities were indirectly influenced by macroinvertebrates through the impact of vegetation decomposition on vegetation habitats (Wilson 1990;Schneider et al., 1981;Backwell et al., 1998). Macroinvertebrates indirectly influence the dynamic change of bird community by decomposing vegetation to change vegetation habitat. (Wilson 1990; Schneider et al. 1981; Backwell et al. 1998; Patra. et al., 2010). In the present study, changes in the aquatic substrate conditions directly impacted the macroinvertebrates and aquatic macrophytes and initiated taxonomic changes in the waterfowl assemblages.

The structure and composition of the vegetation within the wetlands also appear to influence the distribution of waterbirds and their use of the wetlands (Desrochers and Ankney 1986; Rehm and Baldassarre

2007).Vegetation species such as Typha spp. and Phragmites australis are preferred by walking marsh birds because they provide dense cover and residual vegetation that allows the birds to move along the water surface (Baschuk 2010). For example, Botaurus commonly forage along the vegetation/water interface, concealing themselves in the vegetation and ambushing passing prey in the open water (Lor 2007; Rehm and Baldassarre 2007). The construction of artificial islands has created more vegetation/water edge that have increased the number of available foraging sites, reducing interspecies competition at these sites and allowing birds to proliferate in the wetlands.

Vegetation species such as Typh and *Phragmites australis* can reach up to 2.5 m in height in summer, providing deep, over-water nesting habitat for waterfowl species such as some of Anatidae, as well as marsh birds such as Podicipedidae and Fulica atra (Welling et al. 1988; Murkin et al 1997). The interspersion of emergent vegetation provides concealment during foraging. In addition, Cyperaceae on islands provide dry, upland habitat for nesting, which may increase the amount of upland nesting sites (Duebbert and Lokemon 1977, Swanson and Duebbert 1989). A large number of aquatic plants provide runways for birds to fly (Hua et al. 2009) and also play an important role in providing visual isolation between waterfowl breeding pairs during the breeding season. However, Typha was avoided by dabblers and divers, perhaps due to high stem densities and large amounts of residual litter. Dense emergent vegetation can hinder the movement of waterfowl and may also hinder their entry. Therefore, waterfowl may have avoided Typha as it did not provide favourable cover for thermal protection or nesting (Baschuk 2010). To sum up, it is suggested that the park should regularly control and manage the vegetation on the island.

Habitat selection by birds is strongly related to the food distribution, water depth and food availability. Water depth is the most important factor that limits the use of waterfowl habitat and affects the composition of nesting and thermal cover vegetation. Water depth limits the feeding behavior and energy consumption of waterbirds, which affects the availability and availability of food and determines whether the habitat can be used (Ma et al. 2010, Murkin et al. 1997). For example, the length of the waders' beaks and legs limits the gate's range in the shallows. (Nolet et al. 2002). Waterbirds with the same water depth and the same feeding habits need to reduce spatial niche overlap by utilizing habitats with different water depths, while the construction of artificial islands increases the types of available habitats (Zhang et al. 2014). Most waterfowl used the shallow water habitats most; Ardeidae, Charadriidae and Scolopacidae, due to their morphological characteristics and foraging strategies, were limited to feeding in the shallow water habitats, such as shallow water areas at the edges of islands that were less than 20 cm deep (Shao et al. 2016). It may also be related to the higher frequency of food (such as hydrophytes, zooplankton, fish and other invertebrates) in shallow waters (Xia et al. 2010). Anatidae, Podicipedidae and Rallidae generally feed on seeds, fish, and other foods, mostly use deep water areas. The preference for deeper water by the *Aythya ferina* and*Podiceps cristatus* was expected as these species require deep water to allow mobility during foraging and escape (Baschuk et al. 2012). During the whole observation period, the open water area changed within a small range, and the water depth was maintained at approximately 2-3.5 m. Because *Fulica atra* individuals that did not breed during the year also clustered on the water surface, the observed numbers remained high. The density of wading birds was negatively correlated with the water depth, while the density of swimming birds was positively correlated with the water depth (Baschuk et al. 2012). The change in water depth is an important factor for the formation of niche differentiation and the stable coexistence of waterbird communities (Shao et al. 2016). However, in this study area, the deepest water depth was only approximately 3.5 m. Due to topographic characteristics, the water depth did not change significantly, and the difference in the distribution of the bird habitats was not obvious.

The habitat selection by the waterbirds showed a "nesting pattern" in the spatial gradient. Wader's quantity of foraging was strongly related to water depth: if there was not enough water or the substrate was too dry, it was not easy to dig for food; furthermore, if the water level was too shallow, there were fewer large fish and more small fish, and the deep water area had more fish, but they were difficult to obtain (Zhang et al. 2014). For example, universal species (*Fulica atra*and Anatidae) usually choose deep water habitats, while obligate species (Charadriidae and Scolopacidae) choose shallow water habitats. The shallow water areas of artificial islands can solve this problem, providing more diverse water depth gradients for different birds to forage and inhabit, making them more competitive. Shallow water at the edge of the island with water depths of 10-20 cm can provide a series of water gradients that attract relatively more birds and promote bird diversity and richness (Colwell et al. 2000). An increase in surface area can increase the diversity of swimming birds, and water depth variation affects the diversity of waders (Hua et al. 2009). Island construction changed the original single topography of the wide open water and then changed the water depth, that is, the bird diversity increased by increasing the water depth gradient and increasing the available habitats for obligate species. By increasing the water depth heterogeneity of the habitat, the micro-habitat diversity increased to accommodate waterbirds with different ecological niches.

Whether a habitat is suitable for bird migration and reproduction determines the distribution level of birds. During the construction of water level management, the park provides a mosaic of deep and shallow wetlands, staggers the water level of the wetland complex, and creates a diverse range of habitats available in relatively close proximity. Artificial islands could be used as shallow wetland habitat to promote the use by dabblers, whereas the open-water area could be used as deep water habitat to promote the use by divers and marsh birds, thus creating a diverse wetland habitat. Wetland diversity will provide wide range of available habitats to waterfowl and help and promote avian biodiversity. The wetland park can play a positive role in protecting the important passage of bird migration in northeast Asia. Unfortunately, the number of visitors to the wetland park has been increasing for three years, which has disturbed the normal habitat of waterbirds. Therefore, the number and species of waterbirds in this study showed a downward trend. We also recommend that wetland parks separate tourist areas from bird breeding areas to reduce disturbance to birds. This study was conducted only in wetlands in China, and we did not study whether the increase in bird species was due to individual migration from adjacent sites or other factors. We also did not investigate whether the increase in birds came from other adjacent wetlands or was due to increased breeding rates. These need further study in the future. But the results clearly show that the island is useful in increasing the biodiversity of waterfowl and macroinvertebrates. It is not difficult to predict that over time; the ecological benefits of artificial wetland islands will become more and more prominent, which can provide reference for wetland restoration work around the world.

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