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Cover Page Footnote
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Study on Greenway Plant Landscape Based on Bird Habitat Conservation - A Case Study of Wenyu River - North Canal Greenway in Beijing

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Abstract

In recent years, rapid urbanization is leading to a sharp decrease of bird diversity in city. The plant landscape in the greenway plays an important role in habitat conservation. This paper aims to explore the effects of plant landscape planning for the bird habitat conservation in urban greenway, and to study the design methods of greenway plant landscapes based on bird habitats conservation.

Wenyu River - North Canal, a river located in the east of Beijing with uninterrupted green spaces along the coast, has the potential to become the migration channel for migratory birds. Dongjiao Wetland Park is an important node.

At the macro level, the program investigated the vegetation pattern of Wenyu River-North Canal by using GIS technology and analyzed the distribution and ecological connectivity of different bird habitat types in the greenway. The results show that along the Wenyu River-North Canal, the distribution of habitats for some bird groups is uneven and some habitat types are poorly connected.

At the micro level, a field study was conducted in Dongjiao Wetland Park in combination with actual projects, in which the forest form distribution and plant species composition were analyzed and the bird biotope was mapped. The results show that in the Dongjiao Wetland Park, the plant community is dominated by arbor-herb type; evergreen plants, shrubs and food plants are lacking; grasslands habitats and wetlands habitats were small and the area disturbed by human is large.

According to the analysis results, aiming at bird habitat conservation, a vegetation landscape optimization plan of Wenyu River-North Canal Greenway and a plant landscape reconstruction design of the Northern Park of Dongjiao Wetland Park were proposed, including protecting important habitat patches, optimizing plant community structure and selecting plant species.

Introduction

In recent years, rapid urbanization is leading to a sharp decline of urban biodiversity. In fact, the surrounding areas of Beijing have been an important stopover for migratory birds since ancient times. However, urban bird diversity is declining. As an important part of urban green space, a greenway can connect the fragmented habitats in cities and play an important role in protecting urban biodiversity. Among them, plant landscape plays an important role in habitat conservation. Greenways with higher plant diversity have higher ecological stability. At the same time, a variety of plant species can provide food and shelter for many animals, such as birds and insects.

In this study, we selected the Wenyu River-North Canal Greenway and Dongjiao Wetland Park as the study area. We analyzed the status of bird habitats within the greenways of Beijing and explored the method of bird habitat conservation in urban greenway through plant landscape from different scales.

Background and Literature Review

Literature review

Urbanization will gradually change the landscape conditions of urban bird habitats and the species composition of urban birds, thus leading to the undesirable development of urban bird communities (Ikin 2012). Habitat connectivity can serve as a corridor for urban birds, with positive implications for increasing bird population and diversity (Fernández-Juricic 2000; Fernández-Juricic and Okimäki 2001). Therefore, the construction of green corridors with diverse habitats can greatly improve the connectivity between urban habitats and is an important green infrastructure in cities (Beier 2010). Among them, the riverside greenway can provide unique habitats for birds, which is irreplaceable (Gentry 2006). The land use, vegetation coverage and vegetation structure in the greenway have important influence on the structure and behavior of urban bird communities (Mason 2007). In addition, attention should be paid to the protection of the surrounding original habitat during the greenway construction, which is conducive to the rapid promotion of the greenway biodiversity (Kang 2015).

Within the green patches, vegetation characteristics are the most important factors affecting the quality of bird habitat. A large number of studies have supported that vegetation characteristics of habitats have a significant impact on the distribution of birds. The greater the vegetation coverage in the habitat - the greater the density and diversity of the bird communities (Beissinger 1982; James 1982). The higher the abundance of shrubs and herbaceous, the higher the diversity and richness of urban birds in the park. The average age and height of trees and the density of shrubs in the habitat also have effects on the richness of birds. (Ferenc 2014). In addition, the ratio of native plants to exotic plants can also affect urban bird community composition and bird diversity (Burghardt 2009).

Study area and site selection

Beijing (39°54'20" N, 116°25'29" E) is located in the mid-latitude area, with a total area of 16800 km2 (Beijing Statistics Information Website, 2019). Located in the northern part of the North China Plain, Beijing is a typical sub-humid warm temperate continental monsoon climate. The Wenyu River-North Canal Greenway is located in the northeast of Beijing, with a total length of 88.27 kilometers. According to the planning of Beijing green space system, it is one of the most important corridors in Beijing, and an important part of the outer ring water system and the second green belt separation of Beijing. It covers two important river corridors in the "five rivers and ten roads" green corridor planning (Beijing municipal commission of planning and natural resource, 2019). The Wenyu River-North Canal River Greenway passes through the urban built-up area to the suburbs, with obvious urbanization gradient change of surrounding land and diverse habitat types, and has the potential to become the migration channel for migratory birds.

Dongjiao Wetland Park is an important node in the Wenyu River-North Canal Greenway. It belongs to the four major country park projects identified by the Beijing Green Space System Planning (2004-2020) (Beijing municipal commission of planning and natural resource, 2019). The planned area of Dongjiao Wetland Park is about 118 hectares, including 34.5 hectares in the Northern Park and 83.5 hectares in the Southern Park.

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Goals and Objectives

The main goal of this paper is to explore the strategies of greenway plant landscape design based on bird habitat conservation.
The objectives are to:
1. Analyze and evaluate the distribution of bird habitats in the Wenyu River-North Canal Greenway;
2. Analyze the plant landscape composition of Dongjiao Wetland Park; and
3. Propose an optimization plan of plant landscape aiming at bird habitat conservation.

Methods

We obtained September 2017 landsat8 satellite images of Wenyu River-North Canal greenway, and analyzed them by supervised classification using GIS. We divide the five habitat types including thick forest, open forest, grassland (including farmland), building land and water body. The forest land, with vegetation coverage more than or equal to 70%, is thick forest and the forest land with vegetation coverage less than 70% is open forest. Taking 1000m as the distance threshold, we used the Conefor 2.6 to analyze the connectivity of bird habitat patches, and regarded the number of components (NC), the integral index of connectivity (IIC), and the value of node importance (dIIC) as the connectivity indicators to evaluate the distribution status.

NC is the number of components. A component is a set of nodes in which a path exists between every pair of nodes. As a landscape gets more connected, it will present fewer components.

IIC is a binary index for connectivity analysis. It is given by:

$$IIC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{a_i \cdot a_j}{1+nl_{ij}}}{{A_L}^2}$$

(1) *where n is the total number of nodes in the landscape, ai and aj are the attributes of nodes i and j, nlij is the number of links in the shortest path (topological distance) between patches i and j, and AL is the maximum landscape attribute. IIC ranges from 0 to 1 and increases with improved connectivity.*

dIIC is the importance of an existing node for maintaining landscape connectivity according to IIC. It is calculated as a percentage as:

$$dIIC = \frac{IIC - IIC_{remove}}{IIC} \times 100\%$$

(2) *where IIC is the integral index value of connectivity when all the initially existing nodes are present in the landscape and IICremove is the integral index value of connectivity after the removal of that single node from the landscape. The higher dIIC the more important that node is for landscape connectivity (Pascual-Hortal & Saura 2006).*

We conducted a field survey on the plant landscape of Dongjiao Wetland Park in August 2018. We adopted the grid method to evenly set 54 sample points. The location, habitat type, community appearance (coniferous forest/broad-leaved forest/ theropencedrymion), community structure type and canopy density of each sample were recorded. The name, family, genus, life type, height, crown breadth, breast

diameter/ground diameter, growth vigor, species origin (native /exotic/ invasive), reproduction mode (cultivation/wild), and ornamental characteristics of each plant were recorded.

Based on the sample survey, we conducted a detailed survey of the Northern Park, the demonstration area of the Dongjiao Wetland Park, and mapped the plant distribution map of the Northern Park. According to the living habits of birds, we divided the Northern Park into 13 regions based on a 200m×200m grid, and studied the distribution characteristics of plant landscape in different unit regions.

Results

Distribution of Bird Habitats in Wenyu River-North Canal Greenway

In general, the total area of Wenyu River-North Canal Greenway defined in this study is 200.99km^2. In the bird habitat of the Wenyu River-North Canal, the open forest habitat is 97.37km^2, accounting for the largest proportion of the total greenway area of about 48%. The second largest area is building land, with 67.36km^2, accounting for 34% of the total greenway area. The areas of thick forest, grassland and water body are no more than 10% of the total greenway area (Figure 1).

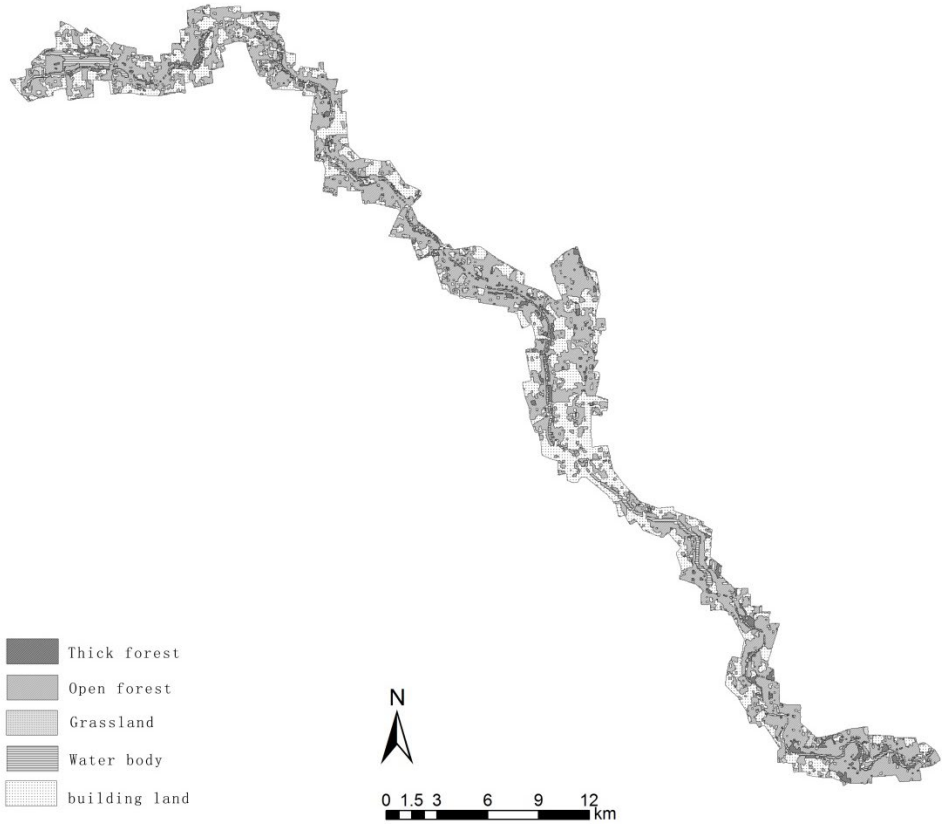


Figure 1. Bird habitat distribution in Wenyu River-North Canal Greenway

After analyzing the connectivity of each type of habitat, we found that the water body is the habitat type with the highest connectivity, with an IIC value of 0.10464, followed by building land, open forest, thick forest and grassland (Table 1).

The water bodies of the Wenyu River-North Canal Greenway are basically continuous, which supports that the analysis results are generally consistent with the actual situation. Water bodies can provide habitat and food for swimming birds and wading birds. According to the analysis, although the water bodies area in the corridor is small, but its connectivity is high. The open forest habitat has the largest area and high connectivity. Most of the scansorial birds such as Woodpecker, songbirds such as Azure-winged Magpie, and terrestrial birds such as Common Pheasant are active in open forest habitats. So we can speculate that the living conditions of these birds are better in the Wenyu River-North Canal Greenway. The thick forest habitats can provide hiding places for some birds that are afraid of humans. Grass and farmland can provide food for many kinds of birds. They provide food such as grains, grass seeds and insects. However, these two types of habitats are small in size and low in connectivity. Birds living with human habitats mainly live in and with buildings, such as Eurasian Tree Sparrow and Barn Swallow. The large area and high connectivity of building land also reflect the encroachment of human activities on bird habitat in the process of urbanization. Therefore, in the Wenyu River-North Canal Greenway, we can consider the building land as a negative habitat.

Table 1. Connectivity of Bird habitats of Wenyu River-North Canal Greenway

Type of land use	Area（km2)	Proportion	IIC	NC
Thick forest	11.28	6%	0.05365	11
Open forest	97.05	49%	0.060302	44
Grassland	9.65	5%	0.048949	17
Water body	8.43	4%	0.10464	22
Building land	72.22	36%	0.081008	1
Total	198.63			

IIC: integral index of connectivity
NC: number of components

Plant Landscape Characteristics of Dongjiao Wetland Park

According to the field survey, the Dongjiao Wetland Park is rich in plant species, with 186 species (including cultivars and varieties) of 133 genera from 55 families recorded. The dominant families with more than 8 species are *Compositae* (22 species, 31.42%), *Rosaceae* (20 species, 28.57%), *Salicaceae* (11 species, 15.71%), *Leguminosae* (9 species, 12.86%) and *Oleaceae* (8 species, 11.43%). The number of plant species is evenly distributed, and the frequency of all species is less than 20%.

51 species of trees, 25 species of shrubs and 110 species of herbs were recorded in the Dongjiao Wetland Park. The richness index of shrub layer is low, and the evenness index of tree and shrub layer is low. A total of 134 cultivated plants and 52 wild plants were recorded in the park. The cultivated plants include 51 species of cultivated trees, 25 species of cultivated shrubs and 58 species of cultivated herbs.

In the Dongjiao Wetland Park, exotic plants are widely used, while native plants are scarce. There are 160 species of exotic plants (including cultivars and varieties) in this park, accounting for 86.02% of the total

number of plants; 26 species of native plants, accounting for 13.68% of the total number of plants. There were 11 invasive species (including cultivars and varieties) belonging to 8 genera from 7 families, accounting for 5.9% of the total number of plants. The families with multiple invasive species include *Chenopodiaceae* (3 species), *Amaranthaceae* (2 species) and *Compositae* (2 species).There are 46 species of food plants (including cultivars and varieties) in the Dongjiao Wetland Park, accounting for 24.73% of the total number of plants, including 34 species of trees and 12 species of shrubs.

In the Dongjiao Wetland Park, the plant community is dominated by arbor-herb type. Among the 54 samples, arbor- herb type, arbor- shrub - herb type, shrub- herb type have 37, 16 and 1 communities respectively. No community of arbor- shrub type or herb type was observed.

According to the plant distribution map of the Northern Park of Dongjiao Wetland Park, the area of trees is 125,496.173 m^2. The arbor patches in the west, north, and central regions are small; the arbor patches on the south and east sides are large and connected. The area of shrub is 24,716.881 m^2. There are strips of shrubs in the north and other patches are relatively scattered and small. The cultivated herb area is 47539.5598 m^2, and the aquatic herb area is 14485.3148 m^2. They are distributed in a linear strip along the lakeshore and roads in the park, with small and discontinuous areas. The wild herb area is 120297.741 m^2, which is widely distributed and forms a coherent distribution pattern (Figure 2).

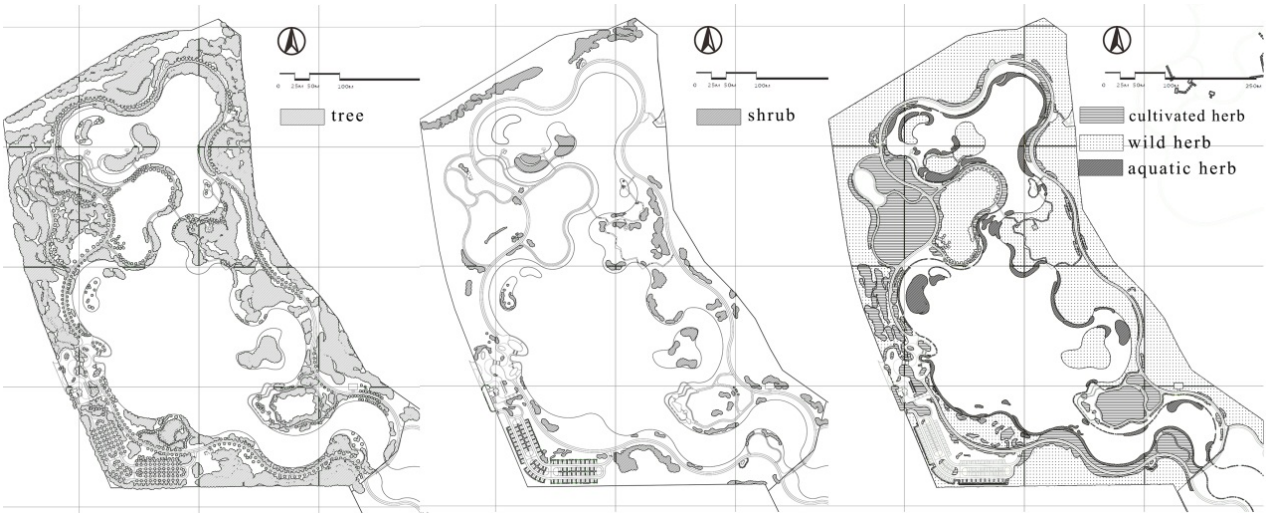


Figure 2. Plant distribution in the Northern Park of Dongjiao Wetland Park

There are a large number but few species of food trees. Food trees are distributed among all 13 grid regions. The patches of food trees are larger in the north, but smaller and more fragmented in the middle and south. There are few species of food shrubs. Food shrubs were distributed among all the 13 grids, but the patches were few in number and small in area, without a coherent pattern (Figure 3).

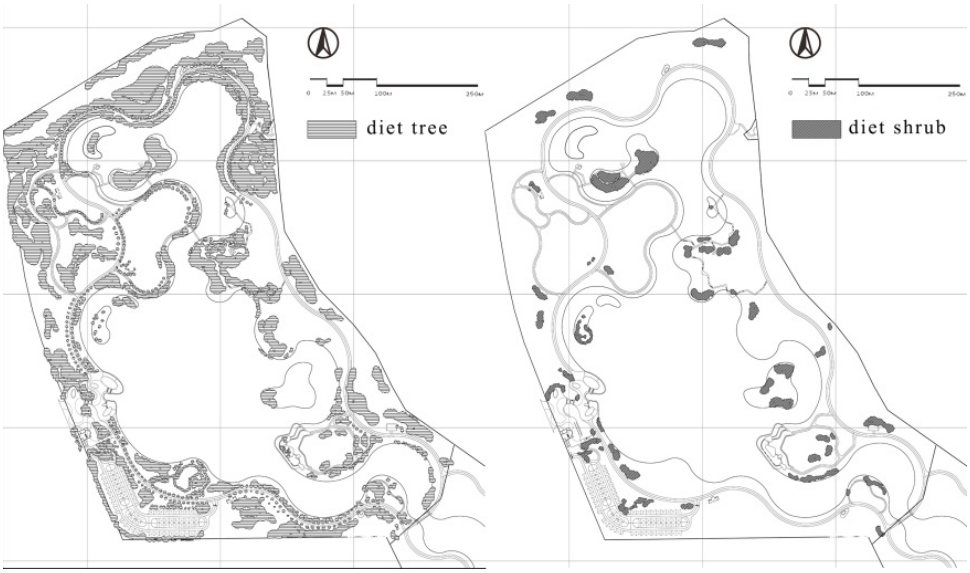
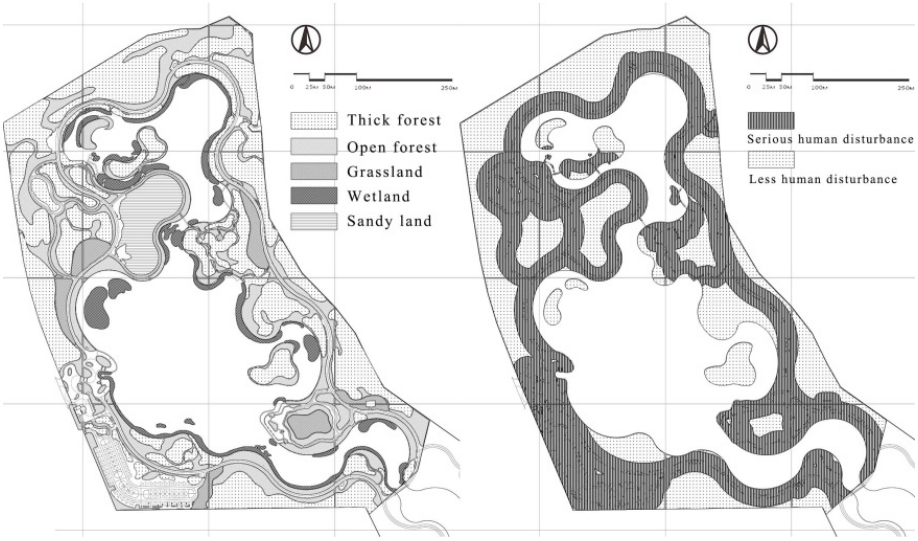


Figure 3. Food plant distribution in the Northern Park of Dongjiao Wetland Park

According to vegetation types, canopy characteristics and underlying surface conditions, the habitat of the Northern Park was divided into five types: thick forest, open forest, grassland, sandy land and wetland. Thick forest is the forest land with canopy density more than or equal to 0.7; open forest is the forest land with canopy density less than 0.7. In the Northern Park of Dongjiao Wetland Park, the habitats of thick forest and open forest are widely distributed and continuous, distributed in all 13 200m×200m grids. The habitats of grassland, sandy land and wetland are distributed are dotted with small area and poor continuity. Among the 13 200m×200m grids, there are grassland habitats in 5 grids and sand habitats in 1 patch. The wetland habitats are spread along the lakeshore and are distributed among 7 grids (Figure 3a).

The main entrance area located on the western edge of the lake, the plank road area in the north of the wetland, and the surrounding area of the eastern landscape tower are regions with serious human disturbance. The areas with less human disturbance in the park mainly include the woodlands far away from road and five unreachable islands in the lake (Figure 3b).



a. Distribution of habitat types b. Degree of human disturbance

Figure 3. Birds living conditions in the Northern Park of Dongjiao Wetland Park

Discussion

Vegetation Landscape Optimization Plan of Wenyu River-North Canal Greenway

In order to improve the connectivity of bird habitats in the greenway, the important habitat patches in the greenway should be protected and modified appropriately. In order to analyze the contribution of each habitat patch, the importance value (dIIC) of each habitat patch was divided into 5 levels according to the method of natural breaks, which were very low, low, medium, high and very high (Figure 4). The patches with very high importance value in thick forest habitats, grassland habitats, open forest habitats and water body habitats are 7, 6, 1, and 1respectively. Because the building land has some negative effects on urban bird diversity, the importance value of building land patches was not calculated in this study.

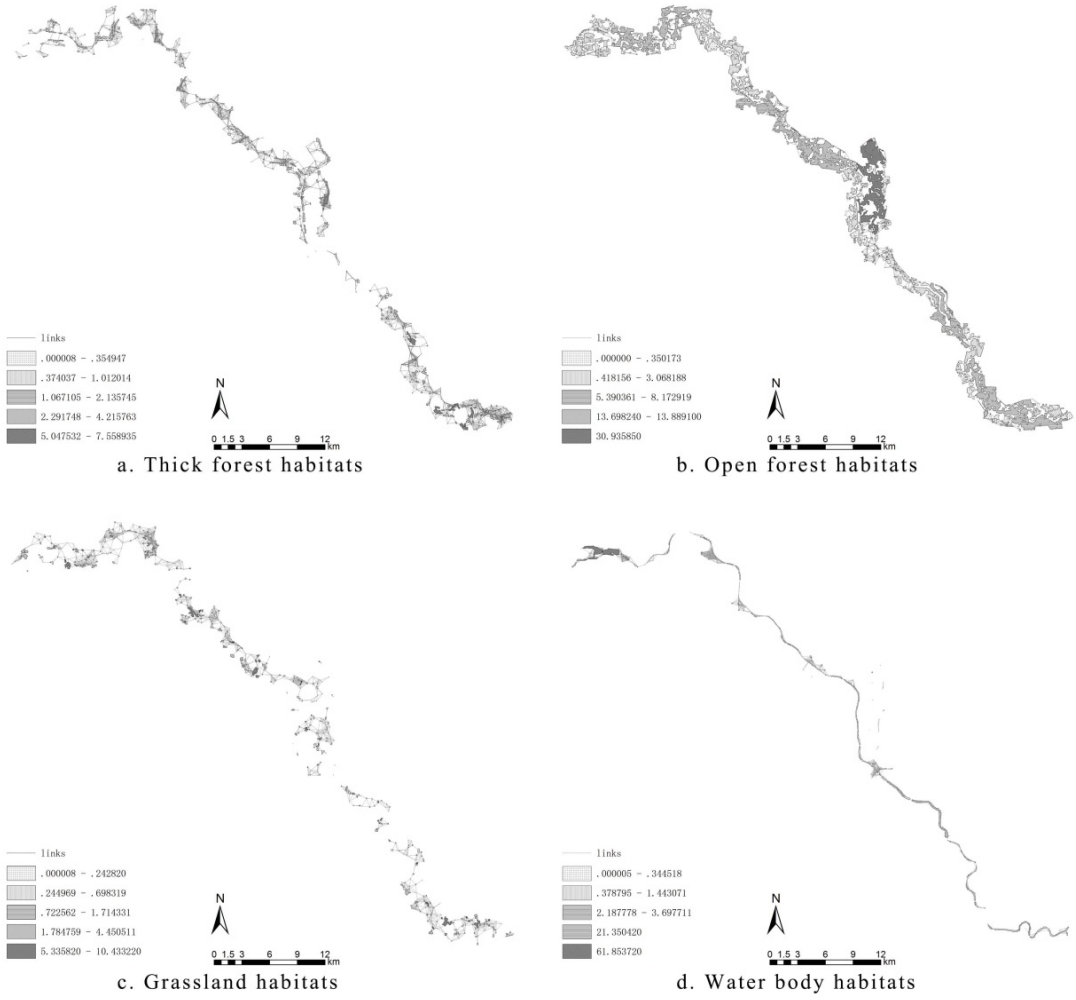


Figure 4. Distribution of habitat importance levels in Wenyu River-North Canal Greenway

According to the level of IIC value of habitat patches, we divided the protection level of each habitat. The following Table shows the number of patches that need to be protected (Table 2). Patches with very high importance value should be first-level protected areas, habitat protection areas should be established, and all construction activities should be prohibited to avoid human disturbance. Patches with high importance value should be second-level protected areas that allow human activity but do not change their vegetation type. Areas with medium importance value should be given special consideration with regard to urban

construction. For open forests, patches with low and very low importance value can be transformed into thick forests and grasslands selectively. While for thick forest and grasslands, patches with low and very low importance value should be protected and expanded appropriately, which to enhance integral index of connectivity and reduce the number of components of the forest and the grassland to optimize habitat distribution.

Table 2. Patches in first-level and second-level protected area

	Patches number of thick forest	Patches number of open forest	Patches number of grassland	Patches number of water body
first-level protected areas	392,410,513,620,627,653,684	307	177,220,272,305,352,561	101
second-level protected areas	82,99,279,331,342,369,378,407,410,413,481,545,548,628,646,650,659	251,485	40,69,76,79,88,97,101,103,134,172,175,218,249,275,285,292,295,482,483,484,495,496,528,575,580	345

Plant Landscape Reconstruction Design of the Northern Park of Dongjiao Wetland Park

We carried out bird habitat conservation in the Northern Park of Dongjiao Wetland Park from two aspects: plant species selection and plant structure optimization.

First of all, we adjusted the species composition of the plant, focusing on increasing the species of food shrubs, such as *Cotoneaster horizontalis*, *Rosa multiflora*, *Physocarpus amurensis*, and *Lespedeza floribunda*. At the same time, we also considered the landscape effects of different seasons. After the adjustment, the number of food shrub species will reach 25, which is twice as much as that before, and the projected area of food shrubs will account for 90.14% of the total shrub area.

By adjusting the vegetation structure, we optimized the distribution of community types and habitat types. Through thinning, the coverage of trees in the North Park will be reduced to 38.72%. Two open grassland habitats will be added on the north side of the lake, and several forest gaps were created in the forest. After optimization, the ratio of projected area of evergreen trees to deciduous trees will be 1:3.58.

By increasing shrubs extensively, the coverage of shrubs in the North Park will reach 18.75%. We focused on adding shrubs on both sides of the road to create a distribution pattern combining strip and point to block human disturbance. By increasing the number and species of shrubs, the number of shrub type communities will increase.

We have retained most of the wild herbs in the park, and added some high wild herbs to provide shelter for birds. We added cultivated herbs along the road to enhance the ornamental appeal. Emergent and floating plants were added to the revetment to provide shelter for water birds. The length of the revetment covered by plants in the northern park will reach 3,275.85m (Figure 5).

Figure 5. Plant distribution in the Northern Park of Dongjiao Wetland Park after optimization

Conclusion

This study shows that plant landscape planning can be used as a key means of bird habitat conservation in greenways. Scientific landscape layout planning, community structure design and plant species selection play an important role in solving the existing problems of biodiversity protection in Beijing urban greenway and providing reference for the planning and construction of Beijing urban greenway in the future. The renovation of Dongjiao Wetland Park has been under construction. We will evaluate the positive role of plant landscapes in bird habitat conservation during the follow up observations in Dongjiao Wetland Park.

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