Biodiversity-Oriented Security Patterns of Wetlands in Build-Up Areas

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Abstract: The wetland has the richest biodiversity among all the natural ecosystems. With the rapid growth of population and the extension of urban area, the shrinking and fragmentation of wetlands have consequently lead to the loss of wildlife. This paper proposed a framework for building the security pattern of wetlands for the biodiversity conservation. It took the build-up area of Haikou as study case, constructed a potential pattern in urban areas to protect both the wetland habitats and the migratory paths of wetland wildlife. We built the security patterns of wetlands and divided it into three units with different protection measures, which include the basic security pattern, moderate security pattern and optimal security pattern, accounting for 14.27%, 25.42% and 44.81% of the total area respectively. It is hoped that this spatial qualified approach could be applied in urban planning and design practices in the future.

1 INTRODUCTION

Wetlands are indispensable since they provide various ecosystem services, which include producing foods and materials, regulating the climate, removing pollutants, providing habitats for wildlife and so on (Costanza et al. 1997; Mitsch and Gosselink, 2007). Especially, the wetland contains the richest biodiversity among all the natural ecosystems (Pearee, 2002). The wetland provides habitats for 20% of the species in the Earth (Dugan,1993), although it only covers about 1% of the total surface.

However, wetlands have been facing the increasing risk of shrinking and fragmentation with population explosion and urban extension. Since early 20th century, more than half of the wetlands have been lost in North America, Europe, Australia, and China (Mitsch and Gosselink, 2007). Dredging, draining, and other human activities are the main driving factors of the losses and fragmentation (Gibbs, 2000). There is a terrifying trend that the wetland shrinkage led to the destruction of biodiversity directly or indirectly. A greater percentage of endangered or threatened species distributed in the wetlands area (Boyland and MacLean, 1998; Sun et al, 2017). The conflicts between wetland protection and development have become one of the most concerned topics in recent years. Some researchers believed that the conflicts between urban development and wildlife protection have reached a dangerous situation (Lemly et al, 2000). Many institutions and organizations are now strategically planning for the conservation of wetlands resources. Scientists, managers and volunteers have attempted to restore the degraded wetlands, but it is difficult to recover the wetland ecosystem structure and functions to original level.

As for the case study area, Haikou (110°32′–110°37′ E, 19°51′–20°01′ N) is invested for the research. It is the capital city of Hainan Province, located in the northern part of Hainan Island, and in the northern margin of tropical latitudes, with tropical island monsoon climate. Unique geographical location and climatic conditions of Haikou gave birth to many characteristic landscapes such mangroves and other types of wetlands, with rich biodiversity. However, as a result of industrial development, agricultural development and reclamation, etc Wetlands space have been suffering occupied or landfilled by urban construction. Invasion of alien species and the destruction of wetland ecosystems have caused a great loss of habitats of native wetland animals and plants, leading to the damage of biodiversity. The

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protection of wetland ecosystems of Haikou is imminent. Thus, further research is needed to provide reference for managers about how to utilize wetlands sustainably and provide suitable habitat for wildlife. Based on the background above, we attempt to build the biodiversity-oriented security patterns of wetlands in the build-up areas of Haikou.

2 STUDY AREA AND METHODS

2.1 Study Area

In this paper, we choose the build-up area of Haikou as the study area. The total area is 323.87km^2. There are two typical wetlands in the build-up area of Haikou, Wuyuan River Wetland and Yangshan Wetland (Figure 1).

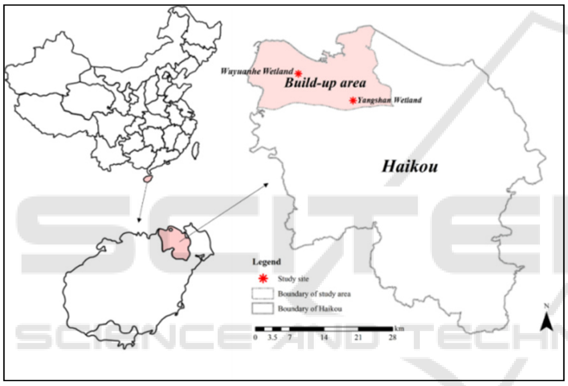

Figure 1: Location of the study area.

Wuyuan River is distributed in the northwest of study area, which adequates water resources, forests, shrubs with large evaporation and high humidity. The environment might provide excellent habitats for the living of wildlife. However, in recent years, some patches along Wuyuan River have been developed, and the native habitats for alien species such as Ampullariidae (*Pomacea canaliculate* which is well known as alien species) are increasingly ruined by human activities. This inevitably leads to the losses of the biodiversity along Wuyuan River.

Yangshan Wetland located in the southeast of study area. It belongs to natural volcanic wetland ecosystem bred by the volcanic ash soil and underwater diving through surface fissures of the volcanic landform. Yangshan wetland contains rivers, lakes, ponds, reservoirs, tropical swamps, and paddy fields, which is pregnant with the rich biodiversity.

2.2 Methods

We proposed a hierarchical framework with three steps. The framework includes identifying habitats and the potential migration paths in wetlands of wildlife, extending wetland biodiversity conservation from in situ conservation to overall conservation and increasing the connectivity of wetlands.

2.2.1 Step1- Define the Distribution of Core Habitats

The soil of wetlands saturated with water permanently or seasonally, such that it breeds the rich biodiversity. To build the security patterns of wetlands, the most urgent task is to protect the core habitats, for instance, existing wetlands and forests. For different wetlands, according to the formation mechanism of the wetlands, we define tropical swamps, paddy fields, volcanic ash soil and other elements as the core habitats. Forests mostly distributed around wetlands, are also of great importance for biodiversity conservation and maintain the ecological processes. The area of core habitats is displayed in Figure 2. The total area of wetlands is 33.65km^2, and the total area of forests is 50.12km^2.

Table 1: The indicators of wetlands importance evaluation.

Indicators	Extremely important	Moderately important	Generally important	Not important
Land use type	swamps, rivers, beaches etc.	paddy fields, forests etc.	farmland, shrubs, grasslands etc.	bare fields, urban areas.
Soil type	volcanic ash soil	absence	absence	other soil types
Distance to a river or lake (m)	<200	200-500	500-1000	>1000
Distance to the mangroves (m)	<100	100-200	200-500	>500
Distance to the tide line (m)	<50	50-100	100-200	>200

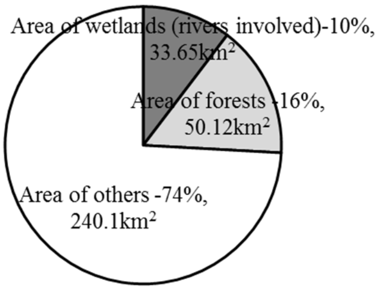

Figure 2: Area statistics.

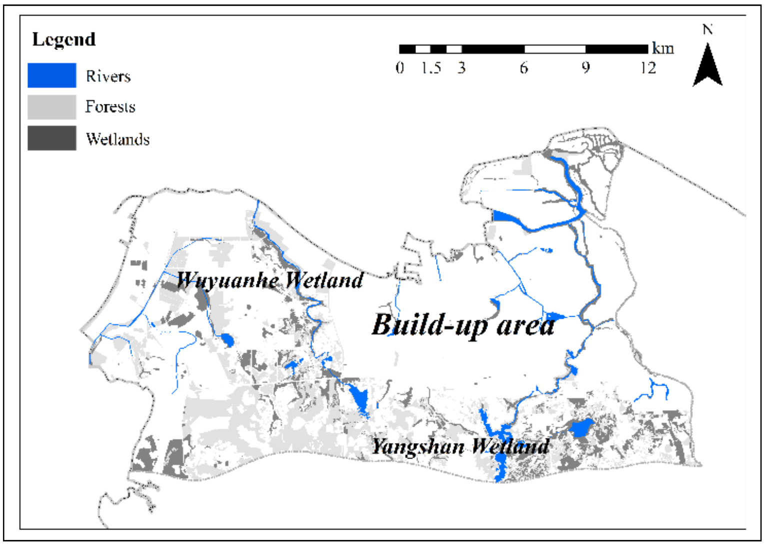

Figure 3: The distribution of core habitats.

Table 2: Suitability evaluation indicators of Great Egrets.

Indicators	Extremely suitable	Moderately suitable	Generally suitable	Not suitable
Land use type	wetlands, rivers, beaches et al.	paddy fields, forests et al.	farmland, shrubs, grasslands et al.	bare fields, urban areas.
Distance to a river or lake (m)	<200	200-500	500-1000	>1000
Distance to the urban areas (m)	>1000	600-1000	400-600	<400

As it can be seen from the Figure 3, the distribution of wetlands of Wuyuan River Wetland and Yangshan Wetland is fragmented, we selected specific indicators to evaluate the importance of the existing core habitats, the indicators are listed in Table 1.

2.2.2 Step2-Choose the Focal Wetland Species in the Study Area

Proposed by Lambeck in 1997, the focal species approach built on the single-species umbrella approach. The underlying premise is that well-chosen focal species provide a protective umbrella for other species (Lambeck, 1997). Birds are good indicators of the surrounding ecological environment (Zhao and Lei, 2002). In this paper, we referred to the wetland birds' directory of Haikou, combined with the vegetation and rivers characteristics of the study area, chose the Great egret as focal species. Great egret (Egretta alba) is a large, widely distributed egret species, distributed across most of the tropical and warm temperate regions of the world. It builds tree nests in colonies close to water, so it is an important indicator of wetlands biology.

We analyzed the habitat characteristics of Great egret and list the suitability evaluation indicators (Table 2) to evaluate the habitat suitability of Great Egrets.

2.2.3 Step3-Analyze Potential Migration Corridors of Great Egrets

Establishing paths for wild animals among wetlands could increase the connectivity of wetlands and consequently enhance the migration of wildlife. Based on environmental factors and human interference factors in the minimum cumulative resistance (MCR) model, we can get a resistance plane that reflects the potential and trends of species movements and identify the potential wildlife migration corridors.

The minimum cumulative resistance (MCR) model was proposed by Dutch ecologist Knappen and was applied to the study of species diffusion process (Knaapen et al, 1992). Based on the minimum cumulative resistance (MCR) model, the resistance factors and resistance coefficients of the Great egrets' movements are listed in Table 3. To identify the potential migration corridors, the resistance plane of the Great egret is established according to the factors as follows.

Table 3: Resistance factors and resistance coefficients of the Great egrets' movements.

Resistance factors	Resistance coefficients (1-100)
Wetlands, rivers, beaches etc.	1
Paddy fields, forests etc.	10
Farmland, shrubs, grasslands etc.	50
Bare fields, urban areas.	100

3 RESULTS

Based on the above methods, we built the security patterns of wetlands and divided it into three units with different protection measures (Figure 4), which include the basic security pattern, moderate security pattern and optimal security pattern. We have calculated the area of different security pattern units and listed in Figure 5.

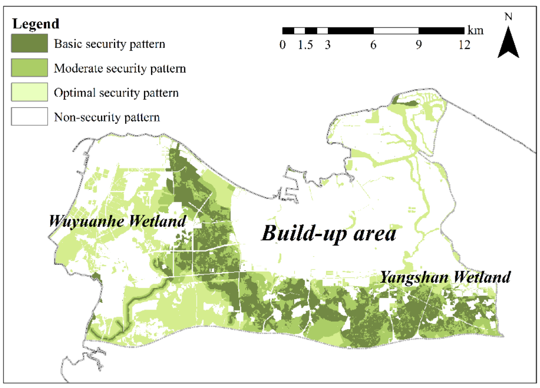

Figure 4: The security patterns of wetlands in Haikou build-up area.

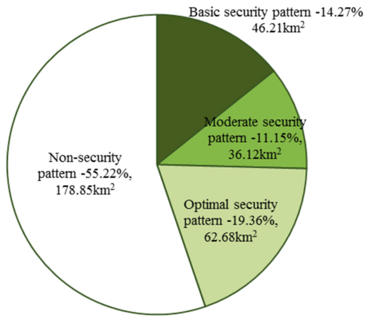

Figure 5: Area statistics of different security pattern units.

Basic security pattern is the basic line for protecting the wetland biodiversity in the study area and should be strictly protected. The area of the basic security pattern is 46.21km^2, accounting for 14.27% of the total area. It contained the core area of the Wuyuan River and the Yangshan Wetland, and the potential migration corridors. Swamps, paddy fields and rivers were included in this pattern. The corridors located in the southwest of the study area, which is the potential migration path for wildlife. Decision makers and managers should set up wildlife observation stations and rescue facilities to conduct scientific research in these areas, prohibiting any exploitation and construction activities.

Moderate security pattern aims to protect the existing wetland and surrounding ecological land patches, and reduce the continuing fragmentation of wetlands. The area of moderate security pattern is 36.12km^2, accounting for 11.15% of the total area. It located around the basic security pattern. Within these areas, forests, shrubs and grassland were staggered with wetlands, which might contribute to linking the existing wetland patches as a whole network. Thereby, urban development and construction should be limited in moderate security pattern to reduce the human disturbance of the basic security pattern.

Optimal security pattern is the buffer area between build-up area and natural habitats, which aims to control the excessive urban expansion and human activities in urbanization process. The area of the optimal security pattern is 62.68km^2, accounting for 19.36% of the total area. It contains a large area of forests and other land use types as grassland and farmland. The ecological lands in these areas have great effect on balance the relationship between construction and protection of natural habitats. In optimal security pattern, the dimension of urban construction should be controlled strictly to avoid the destruction from human activities.

4 DISCUSSIONS AND CONCLUSIONS

Over the past few decades, lot of wetlands was occupied by built-up areas with the rapid development of urbanization. The biodiversity-oriented security pattern of wetlands proposed in this paper might become a new perspective for urban wetland protection.

After the above analysis, this paper summarizes that the protection of wetlands and biodiversity should be based on the following aspects: 1) the larger wetland patches should to be protected and restored by establishing the nature reserves to enrich the wetland species and their suitable habitats. 2) In addition, to increase the connectivity of wetland reserves, small natural patches and migration corridors should be protected and human activities should be prohibited. 3) to limiting the urban expansion in the surrounding areas of wetlands to reduce the fragmentation of wetlands and human disturbances.

But it was no doubt that the nature reserve and conservation measures might influence the economic development and the income of local residents. Thus, for most of the developing regions, it is important to improve land utilization efficiency and reduce the occupation of wetlands and other ecological lands. The concept of Smart Growth Patterns may be the way to resolve the conflict between urban development and wetlands protection (Wey and Hsu, 2014; Duany et al, 2010), can be applied in different areas of the city: 1) In urban areas, it is suggested to increase the Gross Domestic Product (GDP) or the output value per unit area through the industry transformation should be increased, but not based on the development of ecological lands; 2) For the areas that are being developed, the pattern of low impact development is suggested to be utilized to minimize the disturbance of human activities. 3) Lastly, the undeveloped areas in the basic security pattern must be strictly protected to guarantee the well-balanced ecosystem service provided by ecological lands such as wetlands.

In the future, it is hoped that further researches on ecological security patterns are urgently needed to balance the relationship between urban development and wetlands conservation.

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