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Habitat connectivity analysis for conservation implications in an urban area

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ABSTRACT

In urbanized areas, habitat loss and fragmentation resulting from urban growth and human activities may threaten the biological diversity. It is essential to maintain the connectivity in some isolated and fragmented habitat patches. In 2005, the orchard-based conservation with the legal binding was implemented in Shenzhen to mitigate the ecological threats from forest destruction and to protect the ecological diversity. It is critical to evaluate the efficiency of orchard habitat from the species' perspective for providing the reference for the habitat management. Based on graph-theoretic methods, we compared the habitats with or without orchards and evaluated the contribution of orchards to the whole network connectivity and its three fractions (intra, flux and connector), and then analyzed the species that could benefit the most from the habitat supplement. We identified the important landscape elements for serving the prioritized conservation. The results showed that orchard-based conservation was an efficient way in maintaining the functional connectivity, which mainly contributed to the intrapatch connectivity and species dispersal flux. The value of orchard incorporation was strongly related with the dispersal ability of threatened species. Our findings indicated that the orchard conservation would be more valuable for species with relatively weak dispersal abilities. We showed the key patches and links that most contribute to uphold functional connectivity in the reserve network. We believe that the assessment based on habitat functional connectivity can effectively serve the practical guidelines of habitat conservation and management in urban areas.

1. Introduction

Urbanization is the major threat of biodiversity due to the loss, fragmentation and degradation of natural habitats [1]. The fragmentation not only involves the direct extinction and reduction of native wildlife, but also alters multiple ecological processes, such as animal movement, predation, seed dispersal, genetic flow and nutrient cycling [2–4] and finally influences the function and services of urban ecosystems [5]. In most urban areas, biodiversity is only maintained in some isolated or fragmented vegetation patches where wildlife may expose to the new disturbance resulting from the human-dominated matrix [6,7]. Supplementing the habitat network and enhancing the landscape connectivity is likely to be the best responses to these issues [8].

Landscape connectivity has been defined as the degree to which the landscape facilitates or impedes dispersal movement of species among habitat patches existing in the landscape [9]. Connectivity can facilitate the movement of genes, individuals, species, and populations [10], mitigate the isolation of species-dwelling areas [11] and reduce the loss of biodiversity [12]. Common usage of this conception focuses on either structural aspect, where landscape connectivity corresponds to linear features of landscape that facilitate species dispersal such as corridors, or functional aspect, which is relative to the degree of movement or flow of organisms through the landscape matrix [13]. Thus, landscape connectivity depends not only on the landscape structure but also on the species movement abilities crossing landscape mosaics. Among the models used to evaluate landscape connectivity, graphs are thought to be promising due to the flexible visual representation and well-developed algorithms [14]. Some scholars have developed a series of graph-based metrics to quantify the network connectivity related to the species dispersal process [3,15–18]. These metrics have been proved to own the ability to serve the landscape planning and biological conservation [19–21].

As the first Special Economic Zone (SEZ) in China, Shenzhen has experienced the rapid urbanization process since the Reform and Opening-up. Shenzhen was only a small agricultural town 30 years ago; now it has already developed into a metropolitan region with the population of 10.35 million and the GDP of 951.09 billion RMB [22]. The urbanization rate in population is up to 100% in 2009 [23]. Rapid urbanization processes caused a series of ecological consequences [24,25]. Urban sprawl occupied a great number of

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forest land and simplified the composition and structure of forest vegetation. During the past three decades, the total area of forest lands decreased by about 20%. The native forest community has been replaced by the secondary shrubs and planted forests. Previous low mountainous areas where the forest vegetation concentrated became increasingly fragmented and isolated. As a result, many forest-dwelling species have become threatened. According to the assessment, 487 kinds of wild animals in Shenzhen are forest species, of which about 10% are the rare and endangered species [26]. Therefore, the conservation and supplement of forest habitat is in urgent need.

In the year 2005, Shenzhen Government promulgated a legally binding regulation to delimitate the basic ecological controlling areas (BECAs) for protecting the primary water source, scenic spots, nature reserves, wetland, seacoast, mountains, green space and basic farmland conservation areas in Shenzhen. BECAs cover 974 km^2 (half of the whole city area) and are dominated by forest vegetation. The regulation enjoying the legal protection strictly prohibited the pesticide application, fertilizer use and fruit harvest in orchard lands in BECAs (mainly including *Litchi chinensis Sonn* and *Dimocarpus longan Lour*). The role of orchard was converted from traditionally fruit harvest into potential habitat like forest for some species. To a certain degree, this stipulation could mitigate the ecological threats from forest destruction and maximize to preserve the ecological diversity and integrity. We think it is essential to assess the combination effects of two habitat types (forest and orchard) on the habitat network and quantify the contribution of orchard to the network connectivity.

In this study, we focus on the forest-dwelling species which may benefit from the orchard habitat. We tried to solve the following three questions: (1) How much do the orchard habitats contribute to the overall connectivity of the network and three connectivity fractions (intra, flux and connector)? (2) What kinds of species can benefit most from the orchard supplement? (3) Which landscape components (patches and links) that greatly contribute to the habitat connectivity should be given the conservation priorities after the habitat enlargement?

2. Materials and methods

2.1. Study area

Shenzhen is a coastal city in southern China, neighboring Dongguan and Huizhou in the north and Hong Kong in the south, flanked by the Daya Gulf in the east and the Pearl River Estuary in the west. It lies between 22°26′N and 22°51′N latitude and between 113°45′E and 114°37′E longitude and its location is shown in Fig. 1. Its total area is about 2020 km^2. With subtropical marine climate, the annual average temperature, precipitation and sunshine hours are 22.4 °C, 1933.3 mm and 2020 h, respectively. The rainy season is mainly concentrated from April to September. The high topography is found in the southeastern part of Shenzhen, and the northwestern portion is relatively lower. The landform is divided into three zones: the peninsula bordering gulf in the southeast, the seacoast and mountains in the center, and valleys and hills in the southwest.

The study area is rich in biological diversity. The dominant vegetation is evergreen broad-leaved mixed forests. There are 1889 kinds of wild vascular plants, among which 22 kinds belong to the nationally rare and endangered plants (e.g. *Cibotium barometz, Aquilaria sinensis, Glehnia littoralis, Camellia granthamiana, Dimocarpus longan*) [27]. There are known 530 kinds of terrestrial wild animals, including 389 kinds of birds, 37 kinds of mammals, 31 kinds of amphibians and 73 kinds of reptiles, of which there are five kinds of nationally protected class I wild animals (i.e. *Python molurus*, *Tragopan cabo*ti, *Neofelis nebulosa*, *Paa spinosa*, *Platysternon megalorcephalum*) and 43 kinds of nationally protected class ll wild animals (e.g. *Lutra lutra*, *Accipiter soloensis*, *Falco tinnunculus Linnaeus*, *Malayan pangolin*, *Macaca mulatta*) [26].

Shenzhen was municipalized in 1979 and was set up as the first Special Economic Zone (SEZ) in 1980. In the past three decades, due to preferential policies from the central government, Shenzhen City experienced the rapid urban development and caused the great land use changes. In 1980, urban lands and forests occupied 0.63% and 38.67% of the whole city area, respectively. By the year 2005, urban land increased to 33.52% and forests decreased to 29.81% (based on the Landsat TM, spatial resolution 30 m). Urban growth in a disorganized manner encroached upon a great number of forest lands and caused habitat fragmentation and isolation. As a result, the biodiversity is only maintained in isolated island-shaped mountains. In the year 2005, the orchard lands were up to 335.29 km^2 (16.87% of the total area). The orchard-based conservation with legal binding was implemented to mitigate the ecological isolation and protect the biological diversity.

2.2. Data processing

2.2.1. Land use thematic map

We used two scenes of cloud-free Landsat TM images with the resolution of 30 m × 30 m in August, 2005 to obtain land use thematic map as the primary data source. Other auxiliary data included topographic maps at a 1:50,000 scale between 1960s and 1970s, administrative boundary map at a 1:1,00,000 scale for 2005, aerial photographs with high resolution and field survey data to carry out the geometric correction and land use classification.

We obtained 389 evenly distributed ground control points (GCPs) with its exact locations and land cover information to perform the geometrical correction and classification. The second-order polynomial geometric model and nearest-neighbor

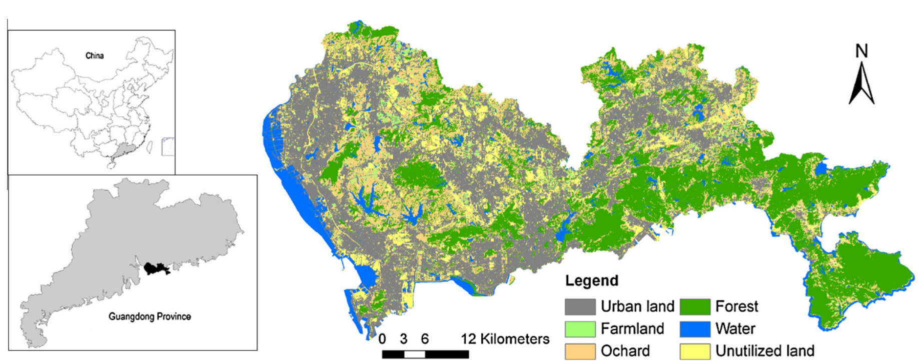

Fig. 1. Location of the study area and land use patterns.