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Discussion on the biodiversity protection planning methods based on urban–regional scale

Bangrui Yue**, Shilei Kang, Chang Jiang

Xi'an University of Architecture and Technology, Xi'an 710000, China. E-mail: bangruiyue@126.com

ABSTRACT

This paper explores the relationship between the spatial scale and biodiversity protection level and thinks that under the specifi c urban-region scale, landscape diversity is the key level to the macroscopic protection of biodiversity. Based on the systematicness and the otherness of urban–regional environment and the biologic fl ow and process, the protection pattern of biodiversity within urban–regional scale should be established. The author holds that seeking the "optimal landscape pattern"is one of the core missions of biodiversity protection planning. Based on that, the paper summarizes the two types of city space and their biodiversity planning and design in two ways: first, the"Urban-rural landscape pattern optimization approach"specific to the space of city matrix, which includes "agglomeration segregation","landscape", "green infrastructure", three models and five pattern optimization strategies; second, the "Nature reserve approach" specific to the space of natural matrix, which includes"reserve circle"and"protected area network"two modes and six reserve design principles.

Keywords: biodiversity protection; biodiversity planning; regional planning; landscape planning; urban planning; landscape pattern; landscape scale effects

1. Corresponding relationship between scale and biodiversity protection level

Scale plays an important role in biodiversity conservation and planning. In this paper, scale refers to the temporal and spatial refinement level of the research object, which is characterized by a certain time interval and spatial size, that is, temporal scale and spatial scale. Biodiversity research is constrained by the scale effect, and the research conclusions on various scales are usually only applicable to specific scale ranges. Arbitrary cross-scale abuse of the theory will lead to confusion and errors. Therefore, in biodiversity research, "natural phenomena should be recognized at the time and space scales, including the natural phenomenon itself, rather than imposing the man-made space-time scale framework on the nature".

Ecological research involves six scales in spatial scale: plot scale, patch scale, landscape, region scale, continent scale and global scale. However, in the practice of landscape planning and design, it mainly involves urbanregion scale, city

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park scale and city garden scale, as shown in table 01. In terms of space, the urban regional scale usually covers a specific geographical range of several square kilometers to thousands of square kilometers, including natural regional space (such as forests, rivers, etc.) And artificial regional space (such as towns, residential areas, etc.). In the study of biodiversity conservation planning at the urban regional scale, it is very meaningful to distinguish two types of regions from the perspective of landscape ecology: one is the regional space based on the city, and the other is the regional space based on the nature. (**Figure 1**) the problems and strategies faced by these two types of regions in biodiversity conservation planning are different: the former plays a key role in the construction of landscape pattern, while the latter plays a key role in the establishment of nature reserves. Therefore, in the study of urban regional biodiversity conservation planning, there are differences in the ways of nature reserves and urban and rural landscape pattern optimization.

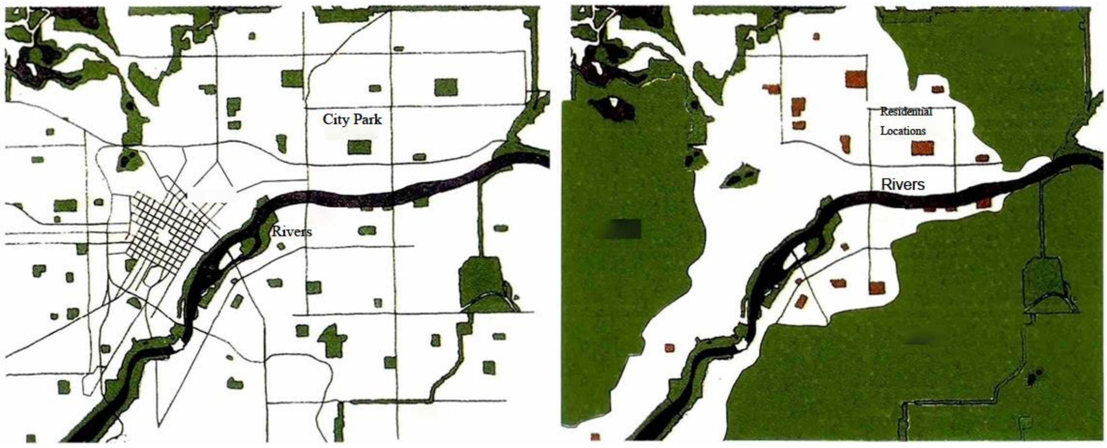

Figure 1. Two types of city region (left: City based region; right: Nature based region).

Biodiversity research includes four levels, namely genetic diversity, species diversity, ecosystem diversity and landscape diversity. The corresponding biodiversity protection is also carried out at five interrelated biospatial levels, namely (a) landscape or ecosystem complex level, (b) community level, (c) population level, (d) species level and (E) gene level. [1] There is a causal chain between the five levels of biodiversity conservation: the low level is the foundation of the high level, and the high level plays a dominant and regulatory role on the low level. Due to the dual effects of spatial scale effect and protection level causal chain, there is a certain corresponding relationship between the three large scales and five levels of biodiversity protection involved in landscape planning and design practice, as shown in **Table 1**.

2. Core tasks of biodiversity conservation planning at the urban regional scale

Firstly, the protection of landscape diversity is the key to the protection of biodiversity at the urban regional scale. According to previous studies, the main problems faced by biodiversity conservation at the urban regional scale are habitat fragmentation, islanding and homogenization of urban biota caused by urban barbaric growth. Biodiversity conservation methods applied at the species level or other lower levels can delay the reduction of species diversity, but can not fundamentally solve the problem. The research shows that the key level of biodiversity protection at the urban regional scale is the landscape level or the ecosystem complex level. In other words, the protection of the living environment (Habitat) of species is the key. Therefore, biodiversity at the urban regional scale should mainly rely on landscape ecology. Its main idea is to protect species diversity through landscape diversity protection, which has been agreed by the academic community.

Secondly, the protection of landscape diversity must be achieved by improving the landscape pattern. Landscape diversity includes the diversity of landscape elements, landscape structure and landscape function. It mainly studies the diversity of the number, size, shape, landscape type, respectively, and the connectivity and connectivity between patches [2]. Landscape ecology research shows that a certain landscape pattern will control or affect the ecological processes within the landscape (or region), including the movement of energy, matter and organisms in the landscape, as well as population dynamics, biodiversity and other ecosystem processes. By optimizing the elements and structures in the landscape pattern, the diversity of habitat (habitat patch), the heterogeneity of landscape structure (Habitat spatial structure) and the diversity of landscape functions (population reproduction, species migration, genetic variation, etc.) Can be increased.

Third, finding the “optimal landscape pattern” is the core task of biodiversity conservation planning at the urban regional scale. As far as landscape architecture planning and design is concerned, its object is the surface space system with land use as the main content and foundation. Any natural scientific achievements can only be applied by planning and design if they are transformed into spatial language one by one through “spatialization”. Therefore, the focus of biodiversity conservation planning at the urban regional scale should be to explore the most effective and optimal spatial approach to regional ecosystem and landscape protection, that is, to achieve the purpose of biodiversity conservation by controlling the spatial relationship of different ecosystems or landscape units (i.e. “landscape pattern”) in the region.

Fourth, the “optimal landscape pattern” of biodiversity at the urban regional scale will be mainly reflected in the following two aspects. First, habitat patch diversity. The diversity of habitat patches includes the type, quantity, size and shape of patches. The diversity of habitat patches is conducive to the settlement and survival of organisms from various sources, and the habitat patches of different regional types can support the survival of different species. The second is the diversity of habitat spatial structure. The diversity of habitat spatial structure should take into account the spatial distribution of different habitat types and the connectivity and connectivity of the same type of habitat [2]. In the urban regional spatial pattern, biodiversity protection is mainly realized through the maintenance of ecological ecotone and the construction of ecological network. Including: a. Ecological ecotone. Due to the edge effect, the ecotones of different scales and types show high biodiversity [3]. The habitat heterogeneity of the city and its peripheral areas is high, and the species of plants and animals at the edge of the habitat patch are extremely rich. For example, wetland ecotones such as urban riparian zone and lake riparian zone often form species enrichment areas. In the process of urban expansion, river solidification blocks the material circulation process between water organisms and the surrounding environment, and eliminates the natural ecological ecotone, resulting in the reduction of biodiversity. Therefore, at the urban regional scale, the maintenance of ecological ecotones between different habitats is of great significance to support biodiversity; b. Ecological network. Independent and scattered habitat patches are like isolated islands, which lack organic connection with each other, let alone the material circulation, energy circulation and information transmission between protected areas. Therefore, a biological corridor or stepping stone must be set between each habitat patch to make it an organic whole and biological protection network, so as to better play the function of biodiversity protection [4].

Table 1. Three spatial scales of landscape planning and design practice and their corresponding biodiversity protection levels

3 Main practice scales	Spatial scale range corresponding to biodiversity conservation level that can be directly affected by planning and design
Urban regional scale	(a) Landscape or ecosystem complex level, (b) community

	level, (c) population level, (d) number of species level square kilometers to thousands of square kilometers ($10^1 \sim 10^4$ km^2)
Urban park scale	(b) Community level, (c) population level, (d) number of species level hectares to hundreds of hectares ($10^1 \sim 10^3$ km^2)
Urban garden scale	(d) The number of species layer ranges from square meters to thousands of square meters ($10^1 \sim 10^3$ m^2)

3. Urban and rural landscape pattern optimization approach for biodiversity conservation planning at city regional scale

In the city region with the city as the matrix, if a regional mosaic bureau that meets the requirements of landscape diversity protection can perfectly realize the biodiversity protection at the city region scale, then this pattern is considered as the “optimal landscape pattern” for biodiversity protection. Taking the “optimal landscape pattern” as a reference, the process of adjusting and optimizing the actual landscape pattern is called “landscape pattern optimization”. In the urban-rural landscape pattern optimization planning for large regional biodiversity conservation, there are currently three planning modes as follows.

3.1. Three planning modes for urban and rural regional landscape pattern optimization

1) “Segregation between clusters” mode

In 1995, richardt.t. Forman proposed the landscape ecological planning pattern of “aggregatewith – outliers” (also known as “combination of centralization and decentralization”) (**Figure 2**), which is considered to be the best landscape pattern in ecology. It emphasizes that on the regional scale, planners should cluster land use by classification and retain small natural patches in the development area and built-up area, at the same time, some “stepping stones” for biological migration are distributed along the main natural boundary zone. As the first priority for protection and construction in the landscape planning of “separation between clusters”, it has the following characteristics: a. There should be several large natural vegetation patches in the pattern, which are the natural habitat necessary for species survival and water conservation; b. Natural patches should have enough width and a certain number of corridor connections to protect the water system and meet the needs of species' spatial movement; c. Build some small natural patches and corridors in the development zone or built-up area to ensure the heterogeneity of the landscape. Forman believes that this priority pattern is irreplaceable in ecological function and is a basic pattern of all landscape planning (Forman, 1995a) [5].

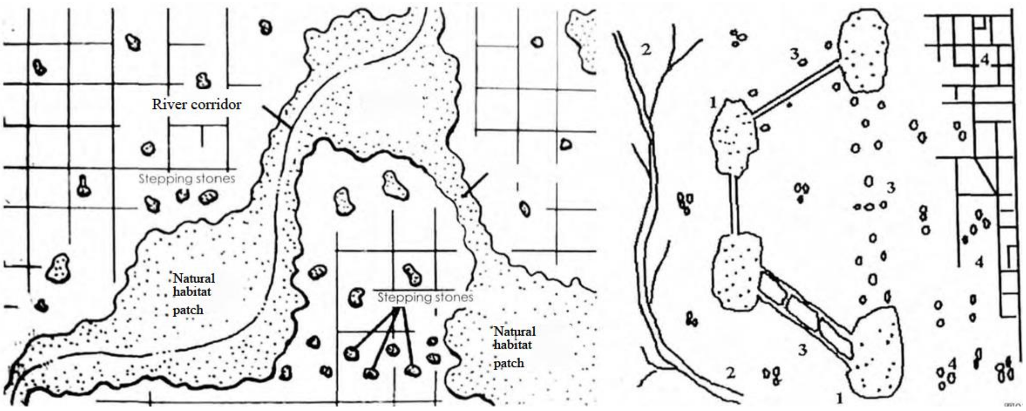

Figure 2. Two graphical representations of “segregation between clusters” mode.

Figure 3. Typical landscape security pattern and its components.

2) "Landscape security pattern" mode

Based on the minimum resistance surface (MCR) model proposed by knaapen et al. (1992), and with the help of surface diffusion technology of GIS, yu Kongjian has constructed a series of ecologically safe landscape patterns, called "surface model of landscape security", which is considered to be an effective way to realize Forman's idea of landscape pattern optimization for the protection of landscape biodiversity. The model proposed that the landscape pattern of ecological security should include the following components: a. The "source", which is the habitat of existing native species and the source of species diffusion; b. "Buffer zone" refers to the area surrounding the source, which is a relatively low resistance zone for species diffusion; c. "Connection between sources" (corridor), the most easily connected low resistance channel between two adjacent sources; d. "Radiation channel", a low resistance channel radiating from the source to the peripheral landscape; e. The "strategic point" is a "springboard" of key significance for communicating the links between adjacent sources. [6] (**Figure 3**) Yu Kongjian developed the above landscape security pattern into a regional ecological security pattern, which is mainly aimed at protecting and restoring biodiversity, maintaining the integrity of ecosystem structure and process, and realizing the effective control and continuous improvement of regional ecological environment problems on the basis of eliminating interference.

3) "Green infrastructure" mode

Green infrastructure is defined as a network of interconnected natural areas and other open spaces. In short, it is an interconnected green space network. The green infrastructure at the regional scale includes a wide range of diverse, native and recoverable natural ecosystems and landscape features, specifically including protected natural areas such as wetlands, woodlands, waters and wildlife habitats; protected land such as national and state parks, nature reserves, wildlife corridors and wilderness; forests, farmland, large farms and other productive land with protection value; and other protected open spaces such as parks, scenic spots and greenways. Regional green infrastructure can protect a large number of natural areas and connect a large number of isolated and broken lands (habitats), thus protecting and maintaining habitat diversity. Therefore, it has become an effective means of regional biodiversity protection. The regional green infrastructure is usually composed of a network mode connecting the ecosystem and landscape, including the following elements: a. The "hub", which is the main habitat of wild animals and plants, and also the "source" and "sink" of animals and plants, human and ecological processes in the whole large system; b. "Links" is the link to integrate the system; c. "Sites" refers to small wildlife habitats or sites for human recreation that are connected with the overall network or are independent. [7] although the protection of natural systems and biodiversity is an important goal of green infrastructure, it also has broader values, such as leisure health (greenway), production value (orchard) and economic value.

3.2. Five planning strategies for urban and rural regional landscape pattern optimization

The essence of the above models and ideas is to establish two sub regions within the urban regional scope. The first sub region is mainly used for the habitat of species, and its main function is to complete the protection and maintenance of biodiversity; another subregion is mainly used for various human development activities, and its main function is to meet various human needs. The “optimal landscape pattern” planning shall include the following strategies.

Strategy 1: establish a green infrastructure network covering the whole urban and rural areas by referring to the landscape security pattern mode, green infrastructure mode and other landscape pattern optimization ideas.

Strategy 2: delimit the rigid boundary of regional green infrastructure as the permanent green line of the city and the control boundary of urban construction to avoid the disorderly growth and spread of the city.

Strategy 3: within the coverage of regional green infrastructure, the largest and most types of natural vegetation patches should be retained, the habitat of existing native species should be protected, large-scale ecological corridors connecting these patches should be established, and the width and connectivity of the corridors should be ensured.

Strategy 4: in urban construction areas beyond the coverage of regional green infrastructure, some small natural patches should be retained or built as parks, leisure and open space systems.

Strategy 5: establish greenway systems of various scales in combination with urban green space system to connect green infrastructure with urban construction areas, urban space and rural space.

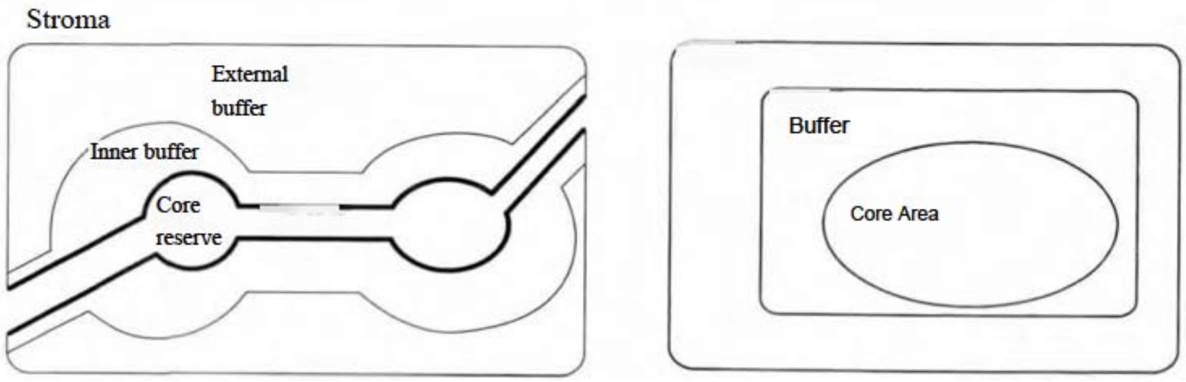

Figure 4. Two patterns of spatial pattern of Nature Reserve (left: circle pattern of Nature Reserve, right: network pattern of nature reserve).

4. Natural reserve approach to biodiversity conservation planning at city regional scale

Among the various ways to protect biodiversity in nature based on cities and regions, the most common way is to establish nature reserves. Natural reserves are usually located on the land, land water bodies or sea areas where “representative natural ecosystems, natural concentrated distribution areas of rare and endangered wildlife species, and natural relics of special significance” are located. By delimiting the boundary of the reserve and separating the human activity area from the nature reserve on a regional scale, human interference and damage to nature can be avoided to the greatest extent, so that the task of biodiversity protection is entrusted to the nature reserve itself. It has been more than 140 years since the establishment of the world's first nature reserve in 1872. The research on the reserve has changed from the traditional species centered protection approach (the target species approach) to the ecosystem centered landscape protection approach (the landscape approach). The underlying idea is that in order to maintain a species for a long time, not only the target species themselves and their populations should be considered, it should also consider its ecosystem and related processes; attention should be paid not only to the reserve, but also to the background matrix of the reserve.

4.1. Two patterns of nature reserve pattern

The planning of nature reserves presents two typical spatial patterns. The first is the "reserve layer mode", which is proposed based on the biosphere reserve idea of the United Nations "man and biosphere plan" in 1971. The layer mode holds that a scientific and reasonable nature reserve should be composed of three functional areas, namely, the core area, the buffer area and the experimental area (**Figure 4**). The biological communities and ecosystems in the core area are absolutely protected, and all human activities unrelated to protection are prohibited; the buffer zone can achieve biological, ecological and landscape consistency around the core area, and can carry out limited human activities; the experimental area is used to preserve the consistency with the core area and buffer area, allowing certain scientific research, recreation and even economic activities.

Table 2. Six principles of nature reserve design

Principle		Schematic illustration
Principle 1: large reserves are better than small reserves		When the migration rate and extinction rate of species in the large reserve are balanced, there are more species: the extinction rate of species in the large reserve is low
Principle 2: a single large reserve is better than several small reserves with the same total area		The large reserve has a high survival rate of species and a low survival rate of small species. The large reserve has more species than several small reserves
Principle 3: Several reserves close to each other are better than those far away		As close as possible to the reserve will increase the migration rate of species in the reserve and reduce the probability of species extinction
Principle 4: several conservation areas arranged in equal distance are better than those arranged in linear way		Equidistant arrangement means that animals in each reserve can migrate and settle between reserves. The linear arrangement of protected areas, the protected areas at both ends are far away from each other, reducing the possibility of species resettlement
Principle 5: the protected area with corridor connection is better than the independently distributed protected area		Species can spread in protected areas without crossing the "sea" of unsuitable habitats, thus increasing the chances of species survival
Principle 6: Circular reserve is better than thin and long reserve		The circular reserve can shorten the diffusion distance of species in the reserve. If the reserve is too long, when the local population extinction occurs in the reserve, the rate of species diffusion from the middle area to the remote area will be very low, which can not prevent the local extinction similar to the peninsula effect

The "protected area circle model" has been widely adopted in practice, but it also exposes some problems. Scholars point out that conservation planning usually simply delimits the scope of ecological protection areas, and rarely plans and designs ecological corridors that can promote species migration and exchange between habitats. As a result, it is difficult to stop the trend of population reduction and biodiversity reduction. Therefore, it is not advisable to focus the planning of natural reserves on a single reserve. In view of the defects of the circle protection mode, reed F. Noss and Larry D. Harris (1986) proposed the nodenetwork – modules – corridors mode for the design of the regional natural reserve network, also known as the "reserve network mode". [8] Based on the advantages of the circle model, this model focuses on the re linking of broken habitats, and believes that the protected areas can be connected with other isolated habitats through the habitat corridor, and finally the protected areas in different places can form a network of protected areas.

4.2. Six principles of nature reserve design

At the beginning of the development of nature reserves, it has been troubled by the lack of scientific theory. With the deepening of theory and practice, island biogeography, population ecology (compound population theory), population genetics and landscape ecology provide clear theoretical guidance for the practice of nature reserves. Among them, the island biogeography is particularly clear. As the nature reserve is similar to an island, it is surrounded by various habitats created by humans, and the species in the reserve are isolated to varying degrees. Reed F. Noss & Allen y. Cooper and others (1975) put forward the design principle of nature reserve to protect the maximum species diversity according to the species area relationship and balance theory of island biogeography. See Table 2 for the arrangement. These six design principles can provide clear guidance on how to reasonably design the spatial pattern of the reserve.

5. Summary

Starting from exploring the relationship between spatial scale and biodiversity conservation levels, this study obtains the following main points: first, the main feature of biodiversity conservation planning at the urban regional scale is that species diversity must be protected through the protection of landscape diversity, and finding an effective "optimal landscape pattern" is the core task of regional biodiversity conservation planning; secondly, according to the regional spatial type of urban matrix, the ways of urban and rural landscape pattern optimization are put forward, including 3 patterns and 5 pattern optimization strategies; thirdly, according to the regional spatial type of natural matrix, the natural reserve approach of biodiversity conservation planning is proposed, which includes 2 models and 6 design principles of natural reserves. In general, landscape ecology plays a fundamental role in biodiversity conservation at the urban regional scale. The basic principles of landscape ecology have clear guiding significance for biodiversity conservation planning at the urban regional scale.

Conflict of interest

The authors declare no conflict of interest.

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