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Healthy urban streams: The ecological continuity study of the Suzhou creek corridor in Shanghai

Yunfang Jiang [a], Tiemao Shi [b,*], Xixi Gu [c]

[a] The Center for Modern Chinese City Studies, School of Urban and Regional Science, 500 Dongchuan Rd., East China Normal University, Shanghai, China
[b] School of Architecture and Urban Planning, Shenyang Jianzhu University, Shenyang, China
[c] Shanghai New Hong Kong Real Estate Development Limited Company, Shanghai, China

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ABSTRACT

The urban river corridor is an important ecological space that is known for its landscapes and ecological continuity. Compared with the natural river, the urban river is seriously affected by human activities, which are constructed with the hope of recreating a similar natural environment and are uniquely designed so that ecological specialists, landscape experts and scientists could study both the surrounding environment's ecological effects and the continuity degree of the river corridor area. A system, including 10 indices urban river corridor, is established. This assessment method adapts the Analytic Hierarchy Process, GIS data analysis and GIS space technology, and is combined with these methods based on quantitative and qualitative analyses. Using the results obtained by studying the Suzhou River Corridor and the assessment of ecological continuity is completed and the spatial distribution characteristics are approved, thus it allows future development throughout the corridor. Eventually, a development policy is proposed. Firstly, a method to improve the landscape connectivity among the river's greenways is needed. Secondly, a high value area with ecological continuity related to the river greenway is planned along the river greenway. Thirdly, a sufficient natural area is needed to give the area a river corridor influence, maintain the river's ecological continuity, and keep this natural area undisturbed by zoning. Lastly, the plant species distribution need to link ecological traits and landscape matrix. The study of this assessment method provides a rational development path and decision-making basis for the construction of healthy and sustainable urban river corridors.

1. Introduction

As an important factor in the natural geography of urban landscapes, the river corridor plays a significant ecological role and creates urban ecological security patterns with its blue corridor and greenway. Because of the vast differences between the research and planning stage, internationally, there is no clear, unified concept of what each principal, urban river corridor should encompass. Landscape ecology experts define an urban river corridor as a broadband corridor including a river and a floodplain or a river and part of the highland region (Forman & Godron, 1986; Karr & Scholsser, 1978; Johnson, 1971; Schlosser & Karr, 1981a, 1981b; Wistendahl, 1958; Wilson, 1967). In conservation biology, the river corridor is regarded as a linear habitat, a potential biological migration corridor, and a means to increase the connectivity between habitat patches as well as to ease the negative impact of habitat fragmentation (Merriam, 1984). In river ecology, based on a functional analysis of the ecological continuous dimension of a river corridor, the concept of a river corridor system framework – as a zonation concept, a river continuum concept, etc. – was inferred. Petersen (1992) suggested that the river and its surrounding land were riparian zones, or buffer zones, when taking into account the entire river basin and a very long river channel. An important feature of this type of development concept is the continuity of the river corridor to ensure that the local ecosystem will flourish.

With the emergence of the environmental crisis, the United States, Europe, and many other countries have begun to pay attention to the issues surrounding a river's ecological restoration as well as future environmental management (Loucks, 1998). From 1998 to 2001, the United States convened experts in this field from five Federal agencies and had the panel publish a book, titled *Stream corridor restoration*: *Principles*, *Processes*, *and Practices*, for using cross-disciplinary results to form interagency occupation standards and promote the protection of river corridors (FISRWG, 2001). The urban river corridor protection panel had many comprehensive functions in the comparison among natural river corridors (Cook, 1991; Fabos, 2004; Grey & Deneke, 1978). In urban areas, with the improvement of river environments and the adjustment of the urban economy and land use, the redevelopment of urban waterfronts became a global phenomenon after the 1970s and

* Corresponding author at: No.9, Hunnan East Road, Hunnan New District, Shenyang City, Liaoning 110168, China.
E-mail addresses: jyunfang@126.com (Y. Jiang), tiemaos@sjzu.edu.cn (T. Shi).

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1980s (Zhang, Feng, & Peng, 2002). The river protection and restoration movement, combined with positive changes in greenway planning, gradually almost became a how-to guide for open space planning the world over after the 1980s (Fabos, 2004).

From the aspect of urban river corridor restoration, the ecological environment assessment of river corridors has become an important tool and process for protecting and making river policies. River corridor continuity assessment is often included in the assessment of river health, river habitat, or river ecosystem. River health assessment involves a comprehensive evaluation of river hydrology, biology, and habitat conditions, providing basic data and information feedback for adaptive management of rivers to promote their sustainable development (Karr, 1999; Leppard & Munawar, 1992; White & Ladson, 1999). The Australian government has adapted the Index of Stream Condition (ISC) to assess physical features significantly influenced by the surrounding catchment (White & Ladson, 1999). Based on the environmental and ecological data, the river health index (RHI) for the Suzhou creek has been adapted to assess the urban river health status from the aspects of hydrological condition, channel physical form, riparian zone, water quality, and aquatic life among diverse sites (Che, Yang, Wu, Shang, & Xiang, 2012). The Dendritic Connectivity Index (DCI) has been developed to quantify the longitudinal connectivity of river networks for measuring connectivity in habitat and assess the cumulative impacts of multiple barriers to determine priorities for restoration (Cote, Kehler, Bourne, & Wiersma, 2009). Assessment in the riparian zone of habitat pays focuses instead on investigating the corridor width, riparian vegetation, and soil conditions in Australia's habitat prediction model (Greenway, 2003). The Urban River Survey (URS) by the United Kingdom Environment Agency integrates river habitat assessment with urban river morphology, riparian zone, and other habitat factors (Fox, Naura, & Raven, 1996). The assessment of the Australian riparian condition in Rapid Appraisal of Riparian Condition (RARC), with vegetation as the foundation of the riparian zone, involved an assessment system of five parts: vegetation, vegetation coverage, woody debris, native species, and exotic species status (Ladson, White, Doolan, Finlayson, Hart, Lake, & Tilleard, 1999).

Landscape indicators focus on biology, water chemistry, hydrology, geography, physical composition assessment, and analysis of spatial variation and characteristics of the surrounding catchment from the perspective of the river or stream corridor landscape pattern, which provides a broader quantitative assessment of the riverine status (Gergel, Turner, Miller, Melack, & Stanley, 2002). The extant state of landscape elements and the connectivity between the elements are two key components of expressing the ecological relevance patterns in river corridor areas. The extant state of landscape elements is expressed by two evaluation indices in the technical manual of China's National Environmental Protection Agency, termed as the biological abundance index and the vegetation coverage index (HJ/T192-2006, 2006). The dimensions of its spatial interaction are represented as the relationships among landscape elements. Vannote (1980) proposes the concept of the river continuum and was the first to study the correlation between water flow continuity and the distribution continuity of biological components. Gregory, Swanson, Mckee, and Cummins (1991) further proposes three-dimensional structures based on the concept of the riparian zone as an ecosystem, which includes the longitudinal (from upstream to downstream), lateral (from river channel to aggraded flood plain), and vertical (from river runoff to groundwater) dimensions. Ward (1989) et al. puts forward a four-dimensional spatial structure theory on river corridors, which includes the longitudinal, lateral, vertical, and time dimensions.

The ecological continuity research of urban river or stream corridors should not be limited solely to rivers, floodplains, vegetation zones, and key nodes for continuity control; it must also be expanded to related interactive areas of the river corridor and the connectivity of the regional ecological infrastructure (Zhang, 2004). The spatial concept of linking suitable patches of habitat to a network is a promising means of achieving a sustainable condition in terms of biodiversity, while also acknowledging the need for and reality of other land uses existing around the protected areas (Ahern, 1995). Moreover, the ecological function of the urban river corridor is related to the width of the corridor and its internal structure. Noss (1993) argues that the habitat quality, human use, the goal of certain species protection, corridor length, etc. determine the width of the corridor. Csuti (1991) claims that if the width of the corridor is <1200 m, then it is difficult to have an inner habitat. Pace (1991) proposes that the width of the river bank and the watershed corridor should be approximately 402–1609 m. Tzolova (1995) suggests that when assessing the visual diversity (natural richness) and visual disconnection (anthropogenic impact) of the landscape, the grade of the homogeneous landscape should be <1000 m and the comparatively diverse landscape should range between 1000 and 3000 m. Ahern (1995) argues that, in terms of the landscape area, the area of small streams is 1–100 km^2, corresponding to the implementation and management orientation. Thus, from the perspective of landscape ecological function and structure, the width of an urban stream corridor and its related functional region should be approximately 1000–3000 m in an optimal state.

Planning has increasingly involved assessment methods in spatial planning processes. Sustainability Appraisal (SA) is mandatory for the preparation of regional spatial strategies, development plans, and supplementary planning documents. The Urban River Corridors and Sustainable Living Agendas (URSULA) projects (UK) take Sheffield river corridor as an example. Here, three scenarios are formed using visual simulation technology, and an integrated model for SA is constructed, through experts' assessment logics using a Bayesian network approach and a broad range of environmental, social, and economic indicators, to optimize different design elements of urban river corridor redevelopment (Kumar, Rouquette, & Lerner, 2012). The UK landscape character assessment method creates a planning path and an assessment method for landscape planning after considerable research and practice; it has become a major tool for landscape spatial pattern protection and decision making in landscape development (CASNH, 2002; Swanwick, 2011; Tyldesley et al., 1999; Zhang, 2011). The availability of landscape character assessment involves scale classification, landscape feature extraction diversity, and a separate decision-making process (Lin, 2012). The method has been integrated into regional planning and landscape space planning processes, and it has become an important research tool for rational planning and policy making.

The preliminary study of urban river health is considered an evaluation tool for river management. Combined with landscape analysis theories and methods, by analyzing the relationship among spatial elements of landscape ecological factors and with the aim of ensuring sustainable development of urban rivers at the regional and urban levels, this paper studies the ecological structure and function of the healthy balance of the urban river ecological system. Given the rapid development of urban construction, the issues surrounding ecological protection and sustainable development of the Suzhou creek corridor and its surrounding areas in Shanghai are becoming increasingly complicated. The urban stream should be restored and developed to a healthy pattern. The analysis and assessment method in the ecological continuity research for this urban river corridor area will have a key role in guiding policy making on landscape planning and in advancing regional regeneration.

2. Materials and methods

2.1. Study area and data collection

The Suzhou creek corridor is an important river that crosses many districts from east to west in the metropolis of Shanghai. The comprehensive improvement plan for the Suzhou creek environment identifies it as an ecological corridor, in terms of being closely linked to public life as a space for leisure and recreation. In 1994, the Shanghai urban green