Advances in Urban River Landscape Ecology Research

Surong XU
Henan Technical College of Construction
Zhengzhou, 450001, China.
Email: zhouzhenmin@ncwu.edu.com

Abstract: It is an inevitable trend to realize the sustainable development of "natural-human-water" through multi-scale and multi-disciplinary research on urban rivers with the principle of landscape ecology. Firstly, from the viewpoint of landscape ecology, and combined with the characteristics of urban rivers, the paper puts forward urban river landscape ecological theory and research framework. Secondly, the basic problems of urban river landscape ecology are studied. Finally, the theoretical development of urban river landscape ecology is studied, including the theory of urban river landscape ecosystem complexity, classification method of wetland and riverine ecosystem, and modeling of patch age and heteromorphosis. The research results have certain reference value for ecological river construction and river landscape ecology development.

1. Introduction
A river is a four-dimensional space and temporal heterogeneity. The urban river landscape ecology deals with the pattern, process, gradient, scale, directionality, connectivity and dynamics of river landscape, emphasizes the interaction of different scale patterns and processes, carries out functional evaluation, simulation and prediction of river landscape, and provides quantitative information and analytical tools for river protection, restoration and management (Janusz.et al. 1999, Xia JH and Yan ZM. 2004).

It should be pointed out that traditional landscape ecologists pay attention to terrestrial ecosystems, which only regards a river as a landscape element and boundary, neglects river landscape, and ignores the differences between river landscape and terrestrial landscape (Che SQ. 2001). Due to ignorance of the differences, it is difficult to reveal the physical mechanism of river landscape (Gerd Sparovek, et al.2002).

The main objectives of urban river landscape ecology is to understand the relationship between spatial pattern and ecological process, and emphasize the spatial and temporal changes of landscape (Armando et al 2002). Therefore, in view of obsolete and unsustainable features of the current urban river planning (Li MH et al.2003), it is necessary to carry out the analysis of river structure, function, dynamic changes and the interaction among rivers and other natural elements in order to achieve the sustainable development of "nature-human-water body".

The study of urban river landscape ecology focuses on small scale river characteristics, and mainly aims at urban river water environment improvement, ecological construction, waterfront landscape design and corridor effect (Wang and Li. 2003). At present, urban rivers are generally polluted due to urbanization (Johnson L B and Host G E. 2010). The relevant study results above have played an important role in understanding and analyzing urban rivers. However, it has not deeply studied in the comprehensive analysis of river and geology, climate change, land use modes, animal and botany
migration, the interaction among river water quantity and quality, river evolution, and the influence of population, social and economic development on river evolution. Therefore, based on the analysis of previous research results, this paper puts forward the research framework of urban river landscape ecology, and analyzes the basic research contents and theoretical development of urban river landscape ecology. The present research results have certain reference value for ecological river construction and river landscape ecology development.

2. Research framework of urban river landscape ecology

Urban river corridor could be regarded as a connective system to carry out research on its structure, function and dynamic change, and analyze the interaction and mechanism among different river corridors (Nilsson C, et al. 2007.). In the process of integrated analysis of river spatial structure and ecological characteristics, the relevant characteristic index factors should be selected to synthetically analyze the structure, function and dynamic change of river landscape, and determine the state of the river. The natural and human driving mechanism on river changes should be analyzed so as to formulate appropriate urban river landscape planning and optimization scheme. Through systematic analysis, a research framework for urban river landscape ecology has put forward, as shown in Fig. 1.

![Fig. 1 A research framework for urban river landscape](image)

The research framework includes the river landscape pattern, ecological characteristics, physico-chemical characteristics, selection and identification of various index factors, definition of river landscape ecology, target planning, sustainable development analysis, cost-benefit analysis, and river landscape diagnosis, as well as river landscape optimization, which has an important reference value for improving urban river landscape ecology research.

3. Basic contents of urban river landscape ecology research

3.1 Scale

Urban river landscape features usually show significant differences with scale variations (Schindler S, et al. 2014). Therefore, for a specific river landscape ecological research, it is necessary to determine the appropriate research scale and corresponding research methods to obtain the best research results. According to the relative size of river landscape research scale, it can be divided into three scale types: small, medium and large (Fig. 2)
The small scale river landscape ecology research mainly consists of river channel, levee and riverside vegetation, which is usually carried out through river landscape environment planning design. Modern landscape environment planning and design take visual landscape image, environmental ecological greening, public behavior psychology as three elements of planning and design (Cullum C, et al. 2016).

The study of meso-scale river landscape ecology could cover the distribution pattern and ecological effect of all rivers in the urban area (Edge C B, et al. 2017). From the view of landscape level, the urban area should include two parts, i.e., the urban and suburban regions. On this scale, taking the city-wide river as a whole, using the knowledge and methods of landscape ecology and other related disciplines to carry out the river landscape ecological planning, adjustment and construction, then, a reasonable river landscape pattern would be achieved.

Large-scale river landscape ecological research aims to study the characteristics and changes of river landscape on the basin scale (Whited D C, et al. 2012), focusing on the study of land use change pattern in the basin to analyze the situation of soil erosion, human disturbance and so on. Comprehensive planning of regional landscape is carried out based on heterogeneity, integrity and coordination of watershed landscape.

The study of urban river landscape belongs usually meso-scale landscape ecological planning (Erst ST, et al. 2012), but, owing to the different size of urban development, the specific research scale should be determined in combination with the scope of specific urban areas.

3.2 River landscape heterogeneity and ecological effects
River landscape heterogeneity includes discontinuous distribution of abiotic factors, patch distribution of biological populations and cluster distribution of ecosystems (Tag wireyi P. 2014). The formation is mainly controlled by the following factors:

1. Transformation of geological, topographic and geomorphological properties. In the longitudinal direction, there are three river reach forms i.e., the river valley confined reach, the semi-constrained reach and the unconstrained reach. The river channel type includes single channel type and branch type (Datryt, et al. 2016). The riverbed includes the braid-shaped, straight, curved and winding-shaped, etc. The change of river shape indicates the variation of ecological conditions such as hydrological situation, hydraulic power, hydrochemistry and river bed substrate (Demarchil, et al. 2016). The variation of hydro-geomorphological properties also forms different kinds of habitat patches, thus forming different river landscapes.

2. Spatial variation of environmental gradients (soil, moisture, heat, etc.) in longitudinal, lateral, vertical directions.

3. Dominant Regional classification of hydro-geomorphological and ecological processes. The theory of functional process emphasizes the longitudinal differentiation of hydro-geomorphological processes. The river periodic expansion and contraction cycle is beneficial to the maintenance of heterogeneity. Under the action of biological processes, the ecological geomorphic units of different evolution stages define the heterogeneity boundary in ages.
3.3 Patch structure of river landscape

Patch characteristics of river ecological landscape are three-dimensional and hierarchical (Eros T, et al. 2017). Longitudinally, there are high-grade hydro-geomorphic patches such as valley-constrained shape, branched and floodplain-developed patch sequences; straight river reach scale, bifurcated and meandering river reach sequences; deep-shallow beach sequences of river-bay scale.

Transversally, there are patch sequences from river bed system to floodplain system, terrace system and water flow type, semi-static type, hydrostatic type, terrestrial type patches formed by hydrological connectivity difference.

Laterally, there are patch sequences from river bed system to floodplain system, terrace system and water flow type, semi-static type, hydrostatic type, terrestrial type patches due to hydrological connectivity difference.

Vertically, there are alluvial aquifer, laminar zone, riparian patch sequences. Habitat and biome patches are formed through interaction among hydrographic and geomorphological patches and biological processes. Some patches are formed under the dominant action of biological processes, such as beaver damming in stream systems, stream patches caused by large-scale dead logs, etc. There are also environmental heterogeneity patches, such as nutrient patch sequences which are formed under the difference between nutrient and nutrient cycling status.

4. Theoretical development of urban river landscape ecology

4.1 The key properties of urban river landscape

Urban river landscape ecology is different from terrestrial landscape ecology on the basis of theory. Scientific identification and theoretical development of river landscape ecology need to accurately understand its key properties. The obvious difference between river ecological landscape and terrestrial landscape is that as a key landscape element, the river is non-stationary and highly dynamic. Although the river hydrology and hydrodynamics provide some methodology basis, the observation data are only the space-time fragment and the instantaneous state of the high dynamic river landscape, and new dynamic analysis tools are needed. Under the control of river action, the connectivity of river landscape is three-dimensional space, but the longitudinal connectivity is much higher than the lateral and vertical connectivity, and there are significant differences from the connectivity of terrestrial landscape. Structurally, ecosystem complexes constitute integrated ecological elements of river landscape. Multiple ecosystem aggregation states are repeated, such as ecosystem complexities at different succession stages, aquatic, wet, xerophytic ecosystem complexes formed by water gradients. As river landscape pattern as concern, the complex ecosystem is distributed in series chains or clusters. In the process, the interaction between hydro-geomorphological processes and ecological succession is the main dynamic mechanism of river landscape evolution and function maintenance. For dynamics, it has the features of complex dynamics including hydrological cycle/non-periodic changes and geomorphic evolution, disturbance dynamics, aquatic, wet, terrestrial ecological succession. For gradients, hydro-geomorphological elements are combined with ecological gradient elements, which constitute compound gradients.

4.2 Important theory development of river landscape ecology

Based on the dynamic theory of gradient patches, REC focus on the longitudinal pattern of rivers, and takes the large hydro-geomorphological patches and their functional process areas (functional process zones, FPZ) as the analysis objects. The definition of large scale hydro-geomorphological patches are based on hydro-geomorphological variables, as a physical templates of FPZ, which affects habitat, species distribution, community regulation, and ecosystem structure and function. According to REC theory, three hierarchical structures are divided, i.e, river networks and their basins, hydrographic and geomorphological patches and their functional area, biological and abiotic patches. The synthesis of FPZ in the nature and ecological connotation of hydrology and geomorphology provides a clear identification basis for the definition of different FPZ dominant hydrological processes, hydrodynamic
and ecological processes and their functions, thus, provides a direct scientific basis for the monitoring and management of different types of FPZ. REC attempts to provide analytical tools for describing the river dynamics of hierarchical ecological, hydro-geomorphological patches, which emphasizes the interaction of hydro-geomorphological processes and their control role in river landscape patterns and functions.

5. Conclusions
As a valuable natural continuous space in cities, the study of urban river structure, function, dynamic change and interaction mechanism should be carried out by using landscape ecology principles and systematic methods.

Based on the requirements of sustainable landscape planning, this paper carried out a comprehensive study on urban river landscape ecology, put forward the research framework of urban river landscape ecology, and under this framework, the basic problems of urban river landscape ecology are studied, and the theoretical development trend of urban river landscape ecology was predicted. The results have provided a theoretical basis for the ecological construction of urban rivers.

ACKNOWLEDGEMENTS
The study was supported by the National Natural Science Fund of China (No.50579020).

Declaration of Competing Interest
The author declare that I have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Reference
[1] Armando Apan, Steven R Raine, Mark S. Paterson. 2002. Mapping and analysis of changes in the riparian landscape structure of the Lockyer Valley catchment Queensland, Australia[J]. Landscape and Urban Planning. 59: 43-57.
[2] Che SQ. 2001. Study on the green corridors in urbanized areas[J]. Urban Ecological Study. 25(11): 44-48.
[3] Church M. 2002. Geomorphic thresholds in riverine landscapes[J]. Freshwater Biology. 47(4): 541-557.
[4] Cullum C, Rogerskh, Brierley G. 2016. Ecological classification and mapping for landscape management and science: foundations for the description of patterns and processes[J]. Progress in Physical Geography. 40 (1): 38-65.
[5] Datryt, Pellah, Leigh C.2016. A landscape approach to advance intermittent river ecology[J]. Freshwater Biology. 61(8): 1200-1213.
[6] Demarchil, Bizai S, Pigay H. 2016. Hierarchical object-based mapping of riverscape units and in-stream mesohabitats using Li-DAR and VHR imagery[J]. Remote Sensing. 8(2): 97.
[7] Ellmore J R, Baxter C V, Connolly P J. 2015. Spatial complexity reduces interaction strengths in the meta-food web of a river floodplain mosaic[J]. Ecology. 96(1): 274-283.
[8] Edge C B, Fortin M J, Jackson D A. 2017. Habitat alteration and habitat fragmentation differentially affect beta diversity of stream fish communities[J]. Landscape Ecology. 32 (3): 647-662.
[9] Erst S T, Olden J D, Schick R S. 2012. Characterizing connectivity relationships in freshwaters using patch-based graphs[J]. Landscape Ecology. 27 (2): 303-317.