ISSN: 3007-9640 DOI: https://doi.org/10.70114/acmsr.2026.9.1.P73

Ecological-Restoration-Oriented Planting Design for Urban Waterfront Parks: A Case Study of Shuhe National Wetland Park in Ju County

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Abstract. Urban waterfront parks are important components of urban ecosystems and provide multiple functions, including ecological regulation, recreation, physical activity, and cultural interpretation. Under current conditions, waterfront spaces face a series of problems, such as habitat fragmentation, biodiversity loss, and ecological degradation. Using ecological restoration as its theoretical framework, this study examines Shuhe National Wetland Park in Ju County, Shandong Province. Field surveys and a literature review were used to systematically identify the principal challenges facing planting design in urban waterfront parks. A three-stage strategy is proposed: ecological matrix restoration, plant community reconstruction, and landscape-function enhancement. The study argues that planting design in urban waterfront parks should shift from an emphasis on visual beautification to an ecological-function-centered approach. By establishing near-natural plant community structures, increasing the proportion of native species, and strengthening ecosystem services, ecological restoration and landscape quality can be improved synergistically. The findings provide theoretical guidance and practical insights for ecological renewal in comparable urban waterfront spaces.

Keywords: Ecological restoration; urban waterfront park; planting design; plant community; ecosystem services

1. Introduction

Urban waterfront parks are not only important places where urban residents can engage with nature, but also essential buffers for maintaining urban ecological security. At the urban scale, they provide ecosystem services that include biodiversity conservation, stormwater regulation, and thermal-environment improvement [1-2]. However, rapid urbanization has left many urban waterfronts facing ecological problems such as shoreline hardening, water-quality deterioration, and habitat fragmentation. Conventional planting schemes that prioritize landscape aesthetics can no longer meet the practical needs of ecological restoration; restoration design must also define a reference ecosystem, establish measurable objectives, and create a long-term monitoring mechanism [3-4]. Achieving a coordinated improvement in ecological restoration and landscape quality within limited urban waterfront space has therefore become an urgent issue in landscape architecture.

In recent years, ecological restoration has attracted extensive attention in landscape architecture. It has evolved from single-purpose environmental remediation into systematic reconstruction based on reference ecosystems and designed to restore ecological processes while delivering social benefits [2,19]. In this context, planting design for urban waterfront parks must shift from merely pursuing visual appeal to balancing ecological function with landscape experience, and from arranging individual plants aesthetically to constructing integrated, multi-layered plant communities and habitats [9-10]. Taking Shuhe National Wetland Park in Ju County, Shandong Province, as a case study, this paper explores planting-design strategies for urban waterfront parks guided by ecological restoration principles and seeks to inform comparable projects.

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2. Study Area and Methods

2.1 Study Area

Shuhe National Wetland Park is located along the upper reaches of the Shuhe River in the urban area of Ju County, Rizhao City, Shandong Province. The planned park extends 15.3 km and covers 1,180 ha, including 856 ha of landscaped green space and 324 ha of water. Its pearl-necklace structure links 11 landscape functional zones and 50 landscape nodes [5]. Construction began in 2007, sections opened to the public free of charge from 2008 onward, and the park was designated a national AAA tourist attraction in 2012. A subsequent Rizhao municipal plan proposed advancing the pilot development of Shuhe National Wetland Nature Park [5-6]. Ju County has a warm-temperate monsoon climate, with a long-term mean annual temperature of approximately 12.1 degrees C and annual precipitation of approximately 750 mm [8]. The regional zonal vegetation is dominated by warm-temperate deciduous broad-leaved forest, and the Shuhe River runs through Ju County from north to south. Historical development left parts of the park and its surroundings with homogeneous habitats, low plant diversity, and degraded ecological functions. In recent years, Ju County has promoted watershed restoration through integrated river management, ecological planting belts, and wetland restoration. Public monitoring data indicate that the number of plant species along the Shuhe River increased from 293 before restoration to 425 afterward, while 137 bird species representing 89 genera, 47 families, and 17 orders have been recorded in the wetland park [7].

2.2 Research Methods

This study combined the following methods: (1) field survey: plant species, community structure, and spatial distribution in Shuhe National Wetland Park were systematically investigated to document species composition, growing conditions, and planting patterns; (2) literature review: existing research on ecological restoration and waterfront planting design was reviewed to establish the theoretical analytical framework; and (3) comparative case study: planting-design cases from comparable urban waterfront parks in China and abroad were compared to identify transferable design lessons.

3. Current Challenges in Planting Design for Urban Waterfront Parks

3.1 Limited Plant Diversity and Insufficient Use of Native Species

Planting schemes in urban waterfront parks commonly lack sufficient diversity. To create an immediate visual effect, designers often rely excessively on a small number of fast-growing, easily maintained plants, resulting in simple community structures and a low proportion of native species. Studies of urban green spaces show that increasing both the proportion of native plants and the volume of understory vegetation generally improves habitat use and species occupancy among multiple animal groups [9-10]. In the early development of Shuhe National Wetland Park, for example, planting was dominated by ornamental trees such as red maple (*Acer palmatum 'Atropurpureum'*), flowering peach (*Prunus persica 'Duplex'*), and flowering cherry (*Cerasus spp.*). Insufficient attention was paid to species representative of local vegetation, leaving room to improve the ecological adaptability of plant communities.

3.2 Simple Community Structure and Weak Ecological Function

An ideal near-natural plant community should have a multi-layered structure comprising trees, shrubs, herbs, and groundcovers, while creating heterogeneous habitats connected to the river corridor. Complex understory structure and a high proportion of native vegetation significantly influence urban animal diversity, and an intact riparian vegetation belt can support water-quality protection, shading, and habitat maintenance [10-12]. Many waterfront parks, however, are still dominated by specimen planting, mass planting, and row planting. Their vertical structure is simple, their horizontal

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distribution is uniform, and they lack the structural heterogeneity characteristic of natural communities. Consequently, they cannot fully deliver ecosystem services such as water conservation, water purification, and biodiversity maintenance.

3.3 Neglect of Ecological Links between Vegetation and Hydrological Processes

The ecological functions of riparian plants are closely related to their positions within hydrological processes. Riparian zones are ecological interfaces between terrestrial and aquatic systems, and their species composition and ecological processes are jointly regulated by flood frequency, water-level fluctuation, soil moisture, and channel morphology [11]. Submerged, free-floating, floating-leaved, emergent, and hygrophilous plants are adapted to different water depths and inundation durations. Appropriate placement can facilitate pollutant interception, nutrient transformation, and habitat creation [13-14]. Some existing plans, however, do not precisely match plant niches to water-level gradients, which can reduce plant survival or prevent ecological functions from being fully realized.

3.4 Excessive Emphasis on Short-Term Visual Effects and Neglect of Long-Term Succession

Urban waterfront parks are usually built within short project cycles, and planners and contractors may use large-caliper stock and fast-growing trees extensively to obtain rapid visual results. This approach not only increases construction costs but can also overlook long-term ecological processes such as community succession, species assembly, and state transitions [17]. Restoration outcomes are uncertain, and full recovery is often constrained by historical land use, landscape connectivity, and available species pools. Short-term increases in vegetation cover should therefore not be equated with restoration success [19]. Continuous monitoring and adaptive management are needed to improve the self-maintaining capacity of plant communities [18].

4. Planting-Design Strategies Based on Ecological Restoration

4.1 Ecological Baseline Assessment and Site Diagnosis

Ecological-restoration-oriented planting planning should be grounded in a scientific assessment of the site's ecological baseline and should translate restoration objectives into measurable indicators [1-2]. The assessment should cover: (1) hydrological conditions, including water level, flow direction, flow velocity, and inundation duration; (2) soil conditions, including texture, pH, organic matter content, and contamination; (3) vegetation conditions, including existing species, spatial distribution, and growth status, with identification of native vegetation requiring priority protection; (4) ecological sensitivity, including areas requiring special protection or priority restoration; and (5) the reference ecosystem, defined using historical evidence and nearby healthy habitats to determine the intended direction of recovery in community composition, structure, and function.

4.2 Restoration of Native Plant Communities

Native plants are important components of regional biodiversity and a foundation for building stable plant communities. Species selection should prioritize native plants adapted to local climatic, hydrological, and soil conditions, supplemented appropriately by ornamental plants with clearly defined ecological functions and manageable risks. Empirical studies of urban green spaces show that increasing the proportion of native vegetation and the volume of the understory can improve habitat quality for multiple animal groups [10]. Community construction should follow regional zonal vegetation and the target ecosystem, simulating the species composition, functional traits, and spatial patterns of natural communities to form a multi-layered tree-shrub-herb-groundcover structure [2].

In riparian areas in particular, plant types should be arranged according to the water-level gradient:

Submerged and floating-leaved species suited to the relevant water depth can be placed below the normal water level; emergent and hygrophilous species tolerant of water-level fluctuation can be used in the drawdown zone; hygrophilous trees, shrubs, and herbs can be placed on the bank slope; and

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terrestrial areas can be based on plant communities typical of the region. This matching of water-level gradient and plant ecological type should be verified against flood frequency, inundation duration, soil conditions, and pollutant loads [11,13-14], enabling riparian vegetation to perform more effectively in pollutant interception, water-quality improvement, and habitat creation.

4.3 Synergistic Improvement of Plant Diversity and Ecosystem Services

The ecological objective of planting planning should extend beyond simply increasing species richness and should instead pursue coordinated improvements in ecosystem services. Action can be taken in the following areas: (1) water purification: establish continuous riparian vegetation buffers of sufficient width and appropriate structure, and configure wetland plants according to pollutant type and hydrological pathway to intercept sediment, nitrogen, phosphorus, and other nonpoint-source pollutants [12-14]; (2) biodiversity conservation: increase native plants, understory vegetation, nectar plants, and food plants to provide food and habitat for birds, insects, and other organisms [3,9-10]; (3) carbon sequestration: increase healthy tree canopy and biomass under the principles of matching species to site and applying life-cycle management, thereby strengthening carbon storage and sequestration by urban trees [15]; and (4) urban heat mitigation: increase tree shade, canopy continuity, and evapotranspiration to improve the local thermal environment, while evaluating actual cooling performance at the site scale through long-term monitoring [16].

4.4 Dynamic Succession and Adaptive Management

Ecological restoration is a long-term, dynamic, and uncertain process, and planting design should follow the principles of community succession and species assembly [17, 19]. During the initial stage, pioneer or fast-growing species may be used in moderation if they can rapidly establish cover without suppressing later community development. During the middle stage, monitoring results should guide the addition of key species from the target community, enabling community structure and function to approach the reference condition gradually. During long-term maintenance, an adaptive-management cycle of objectives, implementation, monitoring, evaluation, and adjustment should be established so that the plan can be continually revised by comparing management measures with ecological responses [2, 18].

5. Optimization Pathways for Planting Design in Shuhe National Wetland Park

5.1 Diagnosis of Existing Conditions

Field investigations and literature analysis identified the following major problems in the planting plan for Shuhe National Wetland Park: (1) plant diversity can still be improved. Public monitoring data indicate an increase in plant species after restoration [7], but some areas remain dominated by a small number of ornamental trees; (2) community structure is incomplete. In some areas, a simple tree-lawn structure dominates, with insufficient continuity between the shrub and groundcover layers; (3) riparian planting lacks refinement. The drawdown zone and bank transition zone require further optimization, and the integrity of aquatic plant communities should be improved; and (4) vegetation density is excessive in certain areas, restricting normal growth of individual plants and the long-term stability of the community.

5.2 Optimization Strategies

(1) Increase the proportion of native plants and enrich species diversity.

Recommended species include suitable natives of warm-temperate deciduous broad-leaved forests and riparian zones, such as Chinese arborvitae (*Platycladus orientalis*), Japanese pagoda tree (*Styphnolobium japonicum*), Siberian elm (*Ulmus pumila*), and suitable poplars (*Populus spp.*) in the tree layer, together with weeping forsythia (*Forsythia suspensa*), wintercreeper (*Euonymus fortunei*), and dwarf lilyturf (*Ophiopogon japonicus*) in shrub or groundcover layers. Public information

ISSN: 3007-9640 DOI: https://doi.org/10.70114/acmsr.2026.9.1.P73
indicates that 160,000 square meters of groundcover, including weeping forsythia and wintercreeper, has already been added along the park [7]. Building on this work, the proportion of native plants, understory volume, and functional-trait diversity should be increased further to improve habitat for urban fauna [10]. The detailed species list should still be reviewed against on-site hydrology, soil, nursery availability, and potential invasion risks.

(2) Reconstruct the vertical structure of plant communities. Replace the simple tree-plus-lawn structure in selected areas by adding shrub, herb, and groundcover layers beneath the tree canopy to create multi-layered communities. In riparian transition zones, establish an ecological gradient of aquatic plants, hygrophilous shrubs and herbs, and riparian trees, forming a continuous transition from water to land. Public information indicates that 65,000 square meters of aquatic plants, including cattail (*Typha orientalis* C. Presl) and aquatic iris, has already been added along the park [7]. Future work should refine combinations of emergent, floating-leaved, and submerged plants according to water depth, inundation duration, and pollutant loads, rather than expanding planting solely for visual effect [14].

(3) Strengthen ecosystem-service functions. In areas frequently used by birds, suitable native berry-producing plants, nectar plants, and structurally complex understory vegetation can provide food and shelter for wildlife [9-10]. A total of 137 bird species has been recorded in Shuhe National Wetland Park, including Baer's pochard, sometimes called the panda of the bird world in Chinese media [7]. Planting optimization should also prevent intensive recreation from disturbing sensitive habitats. In stormwater collection areas, vegetated buffers, rain gardens, or surface-flow wetlands can be installed to treat initial runoff through sedimentation, filtration, uptake, and microbial transformation [13].

(4) Establish dynamic monitoring and adaptive management. Develop a long-term monitoring program for plant communities and regularly evaluate species composition, vegetation cover, community stability, water quality, habitat use, and maintenance inputs. Monitoring results should guide replanting, thinning, weeding, and water-level management, forming a traceable closed loop of monitoring, evaluation, decision-making, and implementation [18]. Zonal management should also be applied according to objectives such as ecological protection, restoration, public education, and appropriate use, with measurable ecological targets and intervention thresholds defined for each zone [2].

6. Conclusions

Planting planning for urban waterfront parks is shifting from a singular focus on landscape aesthetics toward coordination between ecological function and landscape experience. Using ecological restoration as the theoretical foundation and Shuhe National Wetland Park in Ju County, Shandong Province, as a case study, this paper systematically examined ways to optimize planting planning in urban waterfront parks. The results indicate that: (1) ecological-restoration-oriented planting planning should be based on an assessment of the site's ecological baseline and should integrate hydrology, soil, vegetation, and human use into decision-making; (2) restoring near-natural native plant communities is an important means of improving the ecological benefits of planting planning, and community construction should be based on the species composition, structure, and function of a reference ecosystem; (3) planting objectives should move beyond aesthetic effects alone and pursue coordinated improvements in water purification, biodiversity conservation, carbon storage, and the thermal environment; and (4) ecological restoration is a long-term dynamic process, so planting design should respect succession and establish a closed-loop system of design, implementation, monitoring, evaluation, and adjustment.

Experience from Shuhe National Wetland Park shows that ecological planting belts, supplementary groundcover and aquatic planting, and integrated river management can improve riparian vegetation cover and habitat conditions. Public monitoring data also indicate increases in recorded plant and bird species following restoration [7]. The strategic framework proposed in this

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study can inform ecological restoration in comparable urban waterfront areas. Future research should strengthen quantitative assessment of plant community structure, function, and ecosystem services across successional stages and should combine long-term monitoring, remote sensing, and digital landscape technologies to improve the evidence base for planting-design decisions.

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