Frontiers in Environmental Research
Print ISSN: 2960-0251
Online ISSN: 2960-026X
DOI: https://doi.org/10.61784/fer3033

OPTIMIZATION OF RIPARIAN PLANT COMMUNITIES IN MOUNTAINOUS URBAN PARKS BASED ON THE CONCEPT OF REWILDING — A CASE STUDY OF CHONGQING URBAN AREA

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Abstract: This study examines the riparian zones of seven representative urban parks in Chongqing, exploring strategies for optimizing plant communities based on the concept of "rewilding." The findings indicate several issues in the current riparian vegetation, including a dominance of cultivated species (accounting for 80.57%), a simplistic community structure (with "tree + herb" combinations comprising 57.94%), and a scarcity of wild species (only 55 species, or 19.43%). These factors result in low biodiversity (average Shannon-Wiener index of 1.52), weak soil and water conservation capacity (soil erosion modulus of 312 t/(km²·a) in areas with a single structure), and landscape homogenization, all of which limit the ecological service functions of these areas. Rewilding refers to enhancing ecosystem self-regulation by reducing human intervention and actively introducing native species. Constraints to rewilding include excessive human interference, habitat fragmentation, invasive plant species, and outdated management practices.Based on this, a series of optimization strategies are proposed, including the selection of native wild plants, the development of multilayered plant communities, the implementation of tiered management and targeted control of invasive species, and the encouragement of public participation, aiming to provide scientific support and practical guidance for the ecological restoration of riparian zones in mountainous cities.
Keywords: Rewilding; Riparian zones; Native plants; Ecological service functions; Mountainous cities

1 INTRODUCTION

Urban waterfront zones are specific areas within cities that border rivers, lakes, or oceans and are classified as part of urban public green spaces [1]. As transitional zones between terrestrial and aquatic ecosystems, they fulfill multiple roles, including ecological regulation, recreational landscaping, and wildlife habitat provision, making them critical nodes for maintaining urban ecological balance. Chongqing, located in southwestern China, is considered a vital ecological barrier in the upper reaches of the Yangtze River due to its unique geographical features. The city's characteristic of being “embraced by mountains and surrounded by rivers” is evident not only in the Yangtze River, which traverses the entire municipality for 691 kilometers, but also in the presence of 374 rivers within its territory, each with a watershed area exceeding 50 square kilometers [2]. As a core component of the city's“blue-green space,”the stability of the ecological services provided by park waterfront zones holds particular importance for the development of the“City of Mountains and Rivers.”In recent years, with the acceleration of urbanization, the plant communities along the riverside park zones in Chongqing’s urban areas have been increasingly affected by human intervention, gradually revealing a contradiction between “landscape prioritization and insufficient ecological function.” For example, some areas rely excessively on a single cultivated species, reducing the natural growing space for wild native plants; community structures have become overly simplified, failing to harness the full ecological benefits of multi-layered vegetation; meanwhile, the unregulated introduction of exotic species poses a potential threat to the stability of local ecosystems. These issues not only hinder the core functions of riverside zones—such as water conservation and biodiversity protection—but also fall short of meeting urban residents’ growing demand for landscapes that reflect a sense of natural wilderness.

From an ecological perspective, plant communities with high species diversity are better able to maintain ecosystem stability [3]. The structural complexity and natural composition of riparian plant communities form the foundation of their ecological service functions. Currently, although the plant arrangements along the riparian zones of urban parks in Chongqing have been designed with landscape aesthetics in mind, there is still room for improvement in enhancing ecological resilience: surveys show that most riparian zones are dominated by artificially pruned tree-grass combinations, with limited use of shrubs and vines, resulting in a simplified vertical structure and reduced capacity for soil and water conservation; the proportion of wild plants is relatively low, and many are removed as “weeds,” which undermines the ecosystem's ability to regenerate itself; some invasive species, due to their strong adaptability, encroach on the habitats of native species, further diminishing the stability of the plant communities.These phenomena reflect an imbalance between "artificial control" and "natural restoration" in urban waterfront management, highlighting the urgent need for optimization through scientific principles and technological solutions.

Urban rewilding refers to the restoration of natural processes in urban areas by reducing human interference or implementing moderate restoration measures, thereby enhancing the wild characteristics of urban landscapes [4]. The concept of rewilding offers a new approach to resolving this contradiction. Rewilding does not mean returning to a primeval wilderness, but rather stimulating the system's self-regulation capacity by reducing artificial interventions [5]. Its core lies in promoting the natural succession of ecosystems and restoring the natural attributes and self-regulatory capacity of plant communities through minimizing unnecessary human interference, rather than pursuing "complete wilderness."Urban rewilding has gained increasing attention as a strategy to restore ecological processes and enhance biodiversity in cities [6].

For the waterfront greenbelts in urban Chongqing parks, the practical value of rewilding is reflected in three aspects:

(1) Leveraging the ecological adaptability of native plants to enhance the resilience of plant communities to mountainous climates and fluctuations in water levels;

(2) Enhancing soil and water conservation as well as microclimate regulation through the construction of multi-layered vegetation structures;

(3) Preserving a moderate degree of "wildness" in the landscape to fulfill citizens' desire for experiencing natural ecosystems. Spontaneous riparian vegetation plays a vital role in improving the urban ecological environment, increasing biodiversity, restoring natural shorelines, and supporting the development of beautiful rural ecologies and water environments. It holds significant potential for landscape applications. Not only does it help optimize the structure of urban ecosystems and maintain ecological service functions, but it also offers residents opportunities to connect with nature and improve their physical and mental well-being [7]. Moreover, it has broad application prospects in addressing global challenges such as biodiversity loss and climate change [8].

Based on this, the study focuses on the typical waterfront zones of urban parks in Chongqing, systematically exploring the implementation pathways of plant rewilding and its effects on enhancing ecological service functions, with the aim of providing scientific support for balancing the ecological and aesthetic aspects of waterfront landscapes.

The study selects the waterfront zones of seven representative urban parks in Chongqing (Xiuhu Park, Garden Expo Park, Central Park, Muxian Lake Park, Guanyintang Park, Xiuhu Auto Camping Park, and Bijin Park) as research subjects. These parks encompass a variety of design styles (such as natural wetland, open woodland and grassland, and urban leisure types), exhibit significant differences in water area (ranging from 0.043 to 0.53 km^2), and feature diverse site conditions in their waterfront zones (including terrain slope, revetment type, and water level fluctuation), which collectively reflect the common characteristics and regional features of waterfront zones in Chongqing's urban parks.The study will examine the current status of plant communities through field investigations, incorporate rewilding theory to develop optimization strategies, and ultimately create a scalable ecological restoration plan, offering practical guidance for the sustainable development of waterfront zones in mountainous cities.

2 OVERVIEW OF THE STUDY AREA AND RESEARCH METHODS

2.1 Overview of the Study Area

This study focuses on the waterfront zones of urban parks in Chongqing. The geographical scope lies between 106°14′–106°56′E and 29°33′–29°40′N. The area features a mid-subtropical humid monsoon climate, with an average annual temperature of 16–18°C and an average annual precipitation of approximately 1100 mm, mostly concentrated in the summer and autumn seasons. As a key ecological node in the upper reaches of the Yangtze River, Chongqing's urban area has a well-developed water system. The Yangtze River and Jialing River flow through the city, while secondary tributaries (such as Huaxi River and Liangtan River) and artificial lakes (such as those within parks) form a complex waterfront network, providing a natural foundation for the formation of waterfront zones in urban parks.

Seven typical waterfront zones in urban parks in Chongqing were selected as research subjects, including Xiuhu Park, Garden Expo Park, Central Park, Muxian Lake Park, Guanyintang Park, Xiuhu Auto Camping Park, and Bijin Park. These waterfront zones exhibit the following characteristics:

Habitat diversity: The water surface areas vary significantly (ranging from 0.043 to 0.53 km^2), with revetment types including natural mud banks, hard stone embankments, and ecological gabions. Terrain slopes range from 5° to 25°, and some areas form alternating wet and dry habitats due to seasonal water level fluctuations (ranging from 2 to 4 meters), offering diverse site conditions for plant rewilding.

Plant community foundation: The existing vegetation is primarily composed of cultivated species, such as bald cypress, red-leaf Loropetalum, and Bermuda grass. Wild species (such as Leersia hexandra, yellow iris, and Chinese wingnut) are mostly scattered in the transitional zones between land and water. The dominant community structure is"tree + herb"(accounting for 57.94%), while the "tree-shrub-herb" multilayer structure accounts for 19.31%. Vines are rarely used (less than 2%).

Differences in management approaches: Some parks (such as Guanyintang Park) adopt a more natural management style, preserving a greater number of wild plants; others (such as Central Park) prioritize landscape aesthetics, with frequent pruning (1–2 times per month), which inhibits the growth of wild plants.

Table 1 Basic Characteristics of Waterfront Belts in Seven Representative Parks in Chongqing Urban Area

Park Name	Water Area (km^2)	Shoreline Type	Slope (°)	Water Level Fluctuation (m)	Management Mode
Xiuhu Park	0.53	Natural mud + gabion	5–15	2–3	Naturalistic
Garden Expo	0.42	Hard stone + eco-bags	10–20	3–4	Landscape-oriented
Central Park	0.30	Hard stone	5–10	1–2	High-intensity trimming
Muxianhu Park	0.18	Gabion	15–25	2–3	Mixed
Guanyintang Park	0.12	Natural mud	5–15	1–3	Naturalistic

Note: The table shows data from 5 representative parks; the other 2 parks are not listed separately due to similar habitat characteristics.

2.2 Research Methods

2.2.1 Data sources and field survey

The research data were primarily obtained through field surveys, based on the author's previous research and verified using literature sources and publicly available data.

Plot setup: During the peak growing season, 233 plots were established across the riparian zones of seven parks, covering three habitat types: terrestrial zone (5–10 m from the shoreline, dominated by drought-tolerant plants); ecotone zone (±3 m from the shoreline, dominated by hygrophilous plants); and aquatic zone (water depth 0–50 cm, dominated by aquatic plants). A stratified sampling method was employed for each plot: within a 10 m × 10 m tree quadrat, two nested 5 m × 5 m shrub quadrats and five nested 1 m × 1 m herbaceous quadrats were set up to ensure the systematic nature and comparability of the data.

Survey content: Plant community characteristics: Record species names, number of individuals, height, diameter at breast height (for trees), coverage (for shrubs/herbs), and growth condition (healthy / fair / declining). Confirm scientific names of species with reference to the Flora of China； Environmental factors: Measure plot slope, soil pH, organic matter content (using the potassium dichromate oxidation method), and water transparency (using the Secchi disk method)；Human disturbance: Record pruning frequency, proportion of hard surface paving, and intensity of tourist activities, etc.

2.2.2 Rewilding potential and ecosystem service function assessment indicators

Based on the principle of "prioritizing natural recovery with moderate human guidance," an assessment indicator system is established:

(1) Rewilding Potential Assessment:

Species level: Screen native wild plant species (e.g., Pterocarya stenoptera, Roegneria ciliaris) and evaluate their suitability based on seedling recruitment rate (annual number of new seedlings / number of parent plants) and natural dispersal distance.

Community level: Assess the feasibility of rewilding by evaluating the integrity of the natural "tree-shrub-herb" stratification, litter retention (kg/m^2), and the effectiveness of invasive species control (reduction rate in invasive species cover).

(2) Ecosystem Service Function Assessment:

Supporting services (biodiversity): Quantified using the Shannon-Wiener Index (community diversity), Patrick Index (species richness), and Pielou's Evenness Index;

Regulating services: Soil and water conservation: Estimated soil erosion modulus ($t/(km^2 \cdot a)$) using the USLE model to compare the soil retention capacity of different community structures;

Microclimate regulation: Measured differences in air temperature and humidity between sample plots and non-vegetated areas on clear summer days (10:00–16:00);

Cultural services: Evaluated the social value of natural landscapes based on behavioral data such as visitor dwell time and frequency of photographic activity around the sample plots, combined with landscape assessments using the Analytic Hierarchy Process.

2.2.3 Data processing and analysis

Key indicators such as Importance Value (IV) and diversity index:

Importance Value for trees/shrubs: IV = (relative abundance + relative frequency + relative dominance) / 3

Importance Value for herbaceous plants: IV = (relative height + relative frequency + relative coverage) / 3

One-way analysis of variance (ANOVA) was conducted using SPSS 26.0 to compare differences in ecosystem service functions among plots with varying degrees of rewilding. Based on the logical framework of "current situation–problems–strategies," targeted rewilding pathways were proposed to ensure the practical applicability of the research findings.

3 CURRENT STATUS OF PLANT COMMUNITIES AND CONSTRAINTS ON REWILDING IN WATERFRONT ZONES OF URBAN PARKS IN CHONGQING

3.1 Composition and Structural Characteristics of Plant Communities

Based on on-site surveys and previous research data, a total of 283 plant species were recorded in the waterfront zones of seven urban parks in Chongqing, belonging to 99 families and 209 genera. Angiosperms were overwhelmingly dominant, with 271 species (95.76%), followed by gymnosperms with 7 species (2.47%) and ferns with 5 species (1.77%). In terms of origin, cultivated species made up 80.57% (228 species), while wild species accounted for only 19.43% (55 species). The wild species were primarily herbaceous, such as Leersia hexandra and Paspalum distichum. Only seven wild tree species were recorded, mostly sparsely distributed along the edges of the waterfront zones.

The community structure exhibits pronounced anthropogenic characteristics:Vertically, the two-layer structure of "trees + herbs" is the most prevalent, accounting for 57.94%, while the multilayer structure of "trees-shrubs-herbs" comprises only 19.31%. Pure herbaceous and pure arboreal structures account for 4.72% and 2.15%, respectively. Horizontally, the terrestrial layer is dominated by artificially cultivated trees (such as bald cypress and camphor), with a canopy coverage of 60%–70%. Vegetation coverage in the land-water ecotone varies considerably: in natural revetment areas, wild herbaceous plants can cover 50%–60%, whereas in hardened revetment areas, coverage is only 10%–20%. The aquatic layer is primarily composed of artificially introduced floating plants (such as water lilies and water hyacinths), while submerged plants (such as Myriophyllum) have a coverage of less than 30%.

Table 2 Proportions of Plant Community Structure Types in Chongqing Waterfront Belts

Structure Type	No. of Plots	Proportion (%)
Tree + Herb	135	57.94
Tree + Shrub + Herb	45	19.31
Pure Herbaceous	11	4.72
Others (e.g., shrub-herb)	42	18.03

In terms of dominant species, Taxodium distichum (importance value 0.21) and Cinnamomum camphora (0.18) are the absolute dominant species in the arbor layer, both occurring with a frequency of over 80%. In the shrub layer, Loropetalum chinense var. rubrum (0.19) and Ligustrum × vicaryi (0.17) are predominant, both being ornamental shrubs maintained through artificial pruning. In the herbaceous layer, cultivated lawn grasses such as Cynodon dactylon (0.23) and Ophiopogon japonicus (0.19) account for 65%, while wild herbaceous plants form only scattered patches during periods of reduced management. This species composition and structural pattern lead to high niche overlap within the community and relatively low resource use efficiency.

3.2 Assessment of Current Ecosystem Service Functions

3.2.1 Supporting services: weak capacity for biodiversity maintenance

The community diversity index indicates that the average Shannon-Wiener index is 1.52, with the "tree-shrub-herb" multilayer structure plots scoring significantly higher (2.13) than those with a "tree + herb" structure (1.27). The Patrick richness index is highest in Xiuhu Park (176 species) and lowest in Bijin Park (39 species). Additionally, the species evenness (Pielou index) in the waterfront zones of most parks is below 0.6, suggesting an overconcentration of dominant species and a lack of stability in biological communities.

In terms of habitat function, plots with high coverage of wild herbaceous plants (such as the water-land ecotone in Guanyintang Park) recorded 12 bird species and 28 insect species, whereas plots dominated by artificial lawns recorded only 5 bird species and 11 insect species, indicating a significant difference. This is closely related to the food resources (such as seeds and tender leaves) and shelter provided by wild plants, and also highlights the limited capacity of the current community structure to support biodiversity.

3.2.2 Regulating services: limited effectiveness in soil and water conservation and microclimate regulation

Soil and water conservation functions are closely linked to community structure. Sample plots with a multilayered "tree-shrub-herb" structure have an average soil erosion modulus of 186 t/(km²·a), while those with a "tree + herb" structure reach 312 t/(km²·a), indicating a 40.4% improvement in soil retention capacity for the former. In areas with hardened revetments, the absence of vegetation results in a soil erosion modulus as high as 425 t/(km²·a), with shoreline collapse frequently occurring during the rainy season.

In terms of microclimate regulation, measurements taken on clear summer days show that in multilayered vegetation areas with plant coverage exceeding 70%, the air temperature is 2.3℃ lower and humidity is 8.5% higher compared to areas without vegetation. In contrast, single lawn areas only see a temperature drop of 1.1℃ and a humidity increase of 3.2%. This indicates that the current waterfront zones dominated by artificial lawns have a relatively weak effect on regulating the local microclimate.

3.2.3 Cultural services: landscape homogenization and lack of natural experience

In terms of landscape composition, foliage plants account for 40.99% (such as Photinia × fraseri and Prunus cerasifera), and flowering plants make up 25.09% (such as Lagerstroemia indica and Rosa chinensis), while natural landscapes formed by wild plants constitute less than 10%. Surveys show that 72% of visitors find the waterfront area to have "homogenized landscapes," and 68% of respondents express a stronger preference for "scenery featuring the natural growth of wildflowers and grasses."

Recreational behavior data also supports this demand: in Xiuhu Park, where plots of wild herbaceous plants are preserved, the average visitor stay is 42 minutes, and the frequency of photo-taking is 2.3 times that of areas with artificial lawns. In contrast, in Bijin Park, where hardscape makes up a larger proportion and wild plants are scarce, the average visitor stay is only 18 minutes. This highlights the importance of natural and wild landscapes in enhancing the value of cultural services.

Table 3 Comparison of Ecosystem Services Among Different Community Structures

Structure Type	Shannon-Wiener Index (Mean±SD)	Soil Erosion Modulus t/(km²·a)	Cooling Effect (°C)
Tree + Shrub + Herb	2.13 ± 0.12	186 ± 21	2.3
Tree + Herb	1.27 ± 0.08	312 ± 35	1.1
Bare shoreline	—	425 ± 40	0

3.3 Major Constraints on Plant Rewilding

3.3.1 Conflict between human intervention intensity and the requirements of natural succession

Approximately 70% of riparian zones are mowed more than once a month. In landscape-oriented parks such as Central Park and Bijin Park, mowing occurs as frequently as once a week, making it difficult for wild herbaceous plants to complete their life cycles. Surveys have found that in areas with high management intensity, the survival rate of wild plant seedlings is less than 20%. In contrast, in "management blind spots" (such as crevices and corners of revetments), the seedling survival rate reaches 65%, indicating that excessive human intervention is the primary constraint on rewilding.

3.3.2 Habitat fragmentation and invasive plant disturbance

Hardened revetments account for 45% of the area, most of which are made of concrete. The high soil compaction (bulk density of 1.4–1.6 g/cm³) impedes root growth and seed germination. Meanwhile, 56 invasive plant species constitute 19.79% of the total species, with Class I highly invasive species (such as Alternanthera philoxeroides) reaching a coverage rate of 30%–50% in the water-land interface zone. These species crowd out native wild plants, leading to a vicious cycle of "invasive species dominance – native species decline."

3.3.3 Lag in management philosophy and technical systems

Interviews indicate that 65% of park managers prioritize "landscape tidiness" as their main objective and view wild plants as "messy and unorganized." Only 18% of managers are familiar with the concept of "rewilding." The current maintenance system lacks tiered management standards for wild plants and demonstrates limited understanding of the natural regeneration patterns of native species, leading to a lack of scientific guidance for rewilding efforts.

4 IMPLEMENTATION PATHWAY FOR REWILDING VEGETATION IN RIVERSIDE ZONES OF URBAN PARKS IN CHONGQING

4.1 Selection of Native Wild Plants and Near-Natural Configuration Models

Based on the habitat characteristics of riverside zones in Chongqing’s urban areas—such as water level fluctuations and soil moisture—and assessments of plant adaptability, three categories of core native wild plants have been selected to establish a rewilding species pool with a coordinated structure of trees, shrubs, and herbaceous plants.

Flood-tolerant trees: Chinese wingnut (Pterocarya stenoptera) is the preferred species, with a natural regeneration rate of 15%–20% observed in surveys. It can tolerate seasonal water level fluctuations of 3–5 meters. Its deep root system helps stabilize the soil, and its deciduous nature in winter allows for a light-permeable environment.

Hygrophilous shrubs: Chinese chaste tree (Vitex negundo) exhibits strong adaptability and tolerance to poor soil conditions, capable of growing even in the crevices of hardened revetments. In Guanyintang Park, its natural community coverage can reach up to 40%.

Wild herbaceous plants: At the water-land interface, Leersia hexandra is prioritized, with an importance value of 0.193 recorded in surveys. Its stolons can rapidly cover exposed soil. In the aquatic layer, Myriophyllum verticillatum is retained for its dense branching, which provides habitat for small fish, achieving a natural coverage rate of over 60%.

The configuration model adopts a "patchy mixed" design, reflecting the natural pattern of a multi-layered structure: the upper layer features Chinese wingnut (Pterocarya stenoptera) as the framework species, spaced 5–8 meters apart, interspersed with occasional Chinese tallow trees (Triadica sebifera) to introduce seasonal variation; the middle layer is dotted with Vitex negundo at a 20%–30% coverage rate, with no manual pruning; the lower layer retains 50% of wild herbaceous plants (such as Hemarthria altissima) on the terrestrial side, while the land-water interface is planted with yellow iris (Iris pseudacorus) and Leersia hexandra in a 6:4 ratio, and the aquatic zone allows for the natural growth of Myriophyllum. This model increases the vertical structural integrity of the community to 80% and reduces ecological niche overlap by 40% compared to the existing tree–grass structure.

Table 4 Evaluation of Native Species for Rewilding Potential in Chongqing Waterfront Belts

Species	Growth Form	Natural Recruitment Rate (%)	Flooding Tolerance (days)	Natural Coverage (%)
Pterocarya stenoptera	Tree	15–20	15–30	5–10
Vitex negundo	Shrub	10–15	5–10	30–40
Leersia hexandra	Herb	25–30	10–15	50–60
Iris pseudacorus	Herb	20–25	10–20	40–50

4.2 Community Structure Optimization and Habitat Restoration Techniques

4.2.1 Construction of stratified communities and proportion adjustment

To address the current issue of an excessively high proportion of the "tree-grass" structure (57.94%), the proportion of stratified community structures will be increased in phases:

Transformation Phase (1–2 years): In existing tree–grass structure plots, interplant 30–50 shrubs of Nandina domestica and Vitex negundo per 100 m² to establish a shrub layer. Retaining at least 50% coverage of wild herbaceous plants can significantly enhance insect diversity within two years [9]; therefore, 50% of the ground cover should consist of wild herbaceous species (e.g., Duchesnea indica, Digitaria sanguinalis), with only Class 1–2 invasive species being removed. This approach will increase the proportion of multilayered vegetation structure from 19.31% to 30%.

Stabilization Phase (3–5 years): Expand the coverage of shrubs and wild herbaceous plants through natural succession, aiming to achieve a multilayered structure proportion of 40%, with the "tree–shrub–wild herbaceous" combination accounting for no less than 25%. Monitoring in the pilot area of the Garden Expo Park showed that by the second year after interplanting, the Shannon-Wiener index increased from 1.27 to 1.83, approaching the level of natural riparian zones.

4.2.2 Ecological Restoration of the Land-Water Interface Layer

To address the habitat fragmentation caused by 45% of hardened revetments as noted in 3.3.2, a phased renovation strategy is implemented to restore 45% of these hardened structures:

Ecological bag restoration technique: For vertical hardened revetments (such as those in Bijin Park), one ecological bag unit is installed every 10 meters. Each bag is filled with native soil and decomposed leaf litter, and planted with yellow iris and pennywort. A 10 cm gap is left between bags to allow for natural colonization by wild plants. After six months, vegetation coverage can exceed 60%.

Optimization of natural revetments: For soft revetments (such as those in Xiuhu Park), retain 50% of naturally fallen trees (with a diameter of 10–20 cm) to create a "deadwood-plant" composite habitat. Surveys indicate that insect species richness in such areas is 30% higher than in areas without deadwood.

Management of water level fluctuation zones: In areas with an annual water level fluctuation of 2–4 meters, divide the 10-meter-wide zone along the shoreline into three bands: the deep-water zone (0.5–1 meter below normal water level) retains Myriophyllum; the shallow-water zone (within ±0.5 meter of the normal water level) is planted with Leersia hexandra; the high-water zone (0.5–1 meter above normal water level) is planted with Iris pseudacorus and Leersia hexandra, forming a continuous vegetative buffer strip.

4.3 Low-Intervention Management Technical System

4.3.1 Rewilding management technical system

Establishing a three-tier control system consisting of a core protection zone, a buffer zone, and a recreational zone is key to balancing the needs of wilderness and urban areas [10]. Based on ecological sensitivity and recreational demands, the waterfront is divided into three management zones:

Core Protection Zone (within 3 meters of the waterline): Artificial pruning is prohibited, allowing wild plants to grow naturally. Only Grade 1–2 invasive species (such as Alternanthera philoxeroides) are removed once a year in autumn. This zone should make up 30% of the area. A pilot project in Xiuhu Park showed that in the second year, coverage of wild herbaceous plants increased from 20% to 70%, and bird visitation frequency rose by 1.8 times.

Buffer Transition Zone (3–10 meters): Tall herbaceous plants are pruned once per quarter, maintaining a height of 30–50 cm to preserve a landscape that is natural yet not chaotic. This zone accounts for 50% of the area.

Recreational Display Zone (beyond 10 meters): Pruning is carried out once a month, with 5%–10% of wildflowers and grasses retained for visual appeal while ensuring visitor safety. This zone accounts for 20% of the area.

4.3.2 Sustainable control of invasive plants

To address the 19.79% proportion of invasive plants, a combined approach of "ecological replacement + targeted removal" is implemented:

For Grade 1–2 highly invasive species (such as Conyza canadensis), manual removal is followed by the planting of high-coverage native species (such as Iris pseudacorus) to suppress regrowth through competition. In the pilot area of Guanyintang Park, the coverage of invasive species decreased from 40% to 8% after one year.

For low-risk invasive species ranked levels 3 to 7 (such as Digitaria sanguinalis), restrict their spread without complete eradication, using them as pioneer plants to cover exposed soil, and allow native plant communities to naturally replace

them once they have stabilized.
Establish an "Invasive Plant Monitoring Register," recording species and coverage quarterly, and dynamically adjust control strategies accordingly.

Table 5 Classification and Management Strategies for Invasive Plants

Invasion Level	Example Species	Cover Threshold (%)	Management Strategy
Level 1 (Severe)	Alternanthera philoxeroides, Eichhornia crassipes	≤5	Manual removal + native replacement (Iris pseudacorus)
Level 2 (Strong)	Erigeron annuus, Bidens pilosa	≤10	Manual removal + native competition
Level 3–7 (Low)	Digitaria sanguinalis, Setaria viridis	≤30	Restrict spread, retain pioneer functions

4.4 Public Participation and Innovation in Management Mechanisms

Ecological Education and Experience: Install "wild plant interpretation signs" in rewilding areas (e.g., explaining the ecological functions of yellow iris and the natural regeneration process of Chinese wingnut). After the installation of educational signage, visitors' ecological awareness was significantly higher compared to areas without such signs [11]. A pilot program in Xiuhu Park showed a 35% increase in ecological knowledge among visitors in areas with interpretation signs.
Citizen Monitoring Teams: Recruit volunteers to regularly record plant growth and animal activity, creating a collaborative monitoring network of "professionals + public." The pilot in Central Park has collected over 200 valid observation records.
Optimization of Management Standards: Specify pruning frequencies and thresholds for invasive species control in different areas (e.g., coverage of Grade 1 invasive species ≤ 5%). Incorporate "ecological indicators" (such as the proportion of wild species) into the park evaluation system, replacing the sole focus on "landscape tidiness."

5 ANALYSIS OF THE RATIONALITY AND PRACTICAL EXPLORATION OF REWILDING PATHWAYS

5.1 Ecological Adaptation Logic for the Selection of Native Plants

Although wild native plants currently make up only 19.43% of the total species in the riparian zones of urban parks in Chongqing, their natural distribution and ecological traits provide a scientific foundation for rewilding strategies. Among flood-tolerant trees, Chinese wingnut (Pterocarya stenoptera) exhibits a 92% survival rate for mature individuals within a 3-meter water level fluctuation zone in the Garden Expo Park.
Hygrophilous shrubs also offer significant functional value. The natural growth of Vitex negundo in the crevices of hard revetments in Bijin Park demonstrates its potential as a pioneer species for habitat restoration, helping to create microenvironments that facilitate the establishment of other plants. Among wild herbaceous species, the stolons of Leersia hexandra can spread up to 1.2 meters per year on exposed muddy banks, enabling rapid ground coverage. For every 10% increase in its coverage, the soil erosion modulus can be reduced by 8%–10%.

5.2 Real Basis for Community Structure Optimization

The current "tree + herb" structure, accounting for 57.94% of the riparian zone, results in a low biodiversity index (Shannon-Wiener index averaging 1.52) and limited soil and water conservation capacity (soil erosion modulus of 312 t/(km^2·a)). In contrast, the corresponding indicators for "tree-shrub-herb" multilayer structure plots are significantly better (index of 2.13, modulus of 186 t/(km^2·a)), confirming the necessity of structural optimization.
The multilayer structure construction scheme is based on existing community characteristics: retaining dominant trees such as Taxodium distichum and Cinnamomum camphora to maintain landscape continuity, supplementing shrubs such as Vitex negundo (controlling height to below 1.5m) to enhance the mid-layer structure, and retaining 50% of wild herbs (such as Duchesnea indica and Digitaria sanguinalis) to enrich the groundcover.
This "patchy mosaic" pattern demonstrates the coordination of ecology and landscape, exhibiting 80% vertical structural integrity and a 40% reduction in niche overlap compared to a single structure. Restoration strategies for the water-land interface layer, such as using ecological bags to transform hard revetments and vegetation zoning in water level fluctuation zones, are all based on existing habitat characteristics (45% hard revetments, 2-4m water level variation), thus avoiding unrealistic, idealized designs.

5.3 Feasibility Analysis of Management Strategy Adjustment

The introduction of "low-intervention management" and "graded control" is intended to address the conflict between the current intensity of intervention and ecological requirements. Surveys indicate that the survival rate of wild plant seedlings in "management blind spots" (65%) is significantly higher than in frequently pruned areas (less than 20%), demonstrating that reducing unnecessary intervention aligns with natural regeneration processes. The allocation of 30% to core protected areas, 50% to buffer transition zones, and 20% to recreational display areas closely corresponds to tourist behavior—82% of tourist activities are concentrated more than 10m from the waterline, which not only secures growth space for wild plants but also sustains public engagement through the management of recreational zones.

The invasive plant control strategy is based on the current proportion of invasive species, which stands at 19.79%. "Manual removal + ecological replacement" is implemented for level 1-2 highly invasive species (such as alligator weed, *Alternanthera philoxeroides*), while the pioneer species function of level 3-7 low-risk species (such as crabgrass, *Digitaria sanguinalis*) is leveraged, thereby avoiding ecosystem disruption from a "one-size-fits-all" eradication approach.

The design of public engagement mechanisms, such as "wild plant interpretation boards" and "citizen monitoring teams," addresses the desire of 68% of visitors for "wild landscapes." Pilot programs in Xiuhu Park have demonstrated that providing interpretation boards boosts tourists' ecological knowledge by 35%, laying a social foundation for management model transformation.

6 CONCLUSION AND OUTLOOK

6.1 Main Conclusions

The riparian plant communities in Chongqing's urban parks are characterized by a dominance of cultivated species (80.57%), a simplistic structure (tree-herb ratio of 57.94%), and a scarcity of wild species (19.43%). This leads to three limitations in ecological service functions: a weak capacity to maintain biodiversity (Shannon-Wiener index averaging 1.52), limited effectiveness in soil and water conservation and microclimate regulation (soil erosion modulus of 312 $t/(km^2 \cdot a)$), and a lack of attractiveness in cultural services due to landscape homogenization.

The core constraints hindering rewilding efforts include: excessive artificial intervention (70% of areas pruned monthly) resulting in low survival rates for wild seedlings (less than 20%); habitat fragmentation (hard revetments accounting for 45%) limiting natural plant colonization; competition from invasive plants (accounting for 19.79%) squeezing the space for native species; and insufficient acceptance of "wild landscapes" in management approaches and public awareness (65% of managers prioritize "tidiness").

The proposed rewilding pathways are clearly targeted: the selection of native plants prioritizes the ecological adaptability of local species; the optimization of community structure addresses the needs of biodiversity and soil and water conservation; and the tiered management strategy balances ecological protection with recreational opportunities, creating a systematic approach tailored to Chongqing's mountainous and waterfront environment.

6.2 Future Directions

Conduct stress resistance experiments on native plants to determine the optimal tolerance thresholds of Chinese wingnut and yellow flag iris under prolonged flooding (15–30 days), providing more precise data for species selection; refine hard revetment restoration techniques and develop low-cost soil improvement solutions (such as microbial inoculation) to address the limitations of highly compacted soils (bulk density 1.4–1.6 g/cm^3); promote categorized pilot projects by prioritizing the testing of core conservation zone models in Guanyintang Park (natural wetland type) and exploring buffer zone management strategies in Central Park (open woodland-grassland type) to build a diverse base of practical experience; compile the "Chongqing Park Riparian Rewilding Maintenance Guide," incorporating indicators such as the proportion of wild species and the integrity of multilayered vegetation structures into the park evaluation system to drive a transformation in management philosophy.

By analyzing the characteristics of plant communities and the rewilding potential of waterfront zones in urban parks in Chongqing, this study proposes a pathway framework that is rooted in local conditions while resonating with cutting-edge concepts in ecological restoration, offering both theoretical insight and practical guidance for the "naturalization" of waterfront areas in mountainous cities.

COMPETING INTERESTS

This study did not involve any financial or non-financial conflicts of interest.

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