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Optimization of Wetland Plant Selection and Configuration in Urban Water Environment Ecological Restoration Projects

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Abstract: In urban water ecological restoration projects, the selection and configuration of wetland plants are crucial for water quality improvement, ecological diversity enhancement, and landscape beautification. Different plants have different characteristics, and a scientific and rational selection and optimization of plant species is needed. This paper proposes an optimized plant selection and configuration scheme for urban water ecological restoration based on the ecological characteristics and pollutant removal performance of wetland plants. It analyzes the diversity, removal mechanisms, and configuration modes of wetland plants, taking into account ecology, aesthetics, and cost-effectiveness, to provide scientific evidence for wetland plant configuration and support water environment management decision-making.

Keywords: Wetland plants; Water environment restoration; Plant configuration optimization; Pollutant removal; Ecological restoration

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1. Introduction

Nowadays, urban water environment pollution is severe and is hindering sustainable development. Industrial and domestic wastewater has put tremendous pressure on the aquatic ecosystem, leading to deteriorating water quality and ecological imbalance. Wetlands, which are eco-friendly restoration measures, are widely used. The selection and rational configuration of wetland plants are crucial to the removal of pollutants and the stability of the ecosystem. Choosing suitable wetland plants and configuring them scientifically and effectively is the key to efficiently restoring urban water environments. In this context, this paper systematically explores the optimal configuration strategies of wetland plants in water environment restoration, providing scientific references for solving urban water pollution problems.

2. Current status of urban water environment pollution and the demand for wetland restoration

The problem of water environment pollution in cities has become increasingly serious in the context of accelerating urbanization and has already begun to harm the stability of ecological systems and the quality of human life. The sources of water pollution are diverse, including industrial wastewater, domestic sewage, agricultural runoff, and urban surface runoff. When various pollutants enter the water body, they not only cause a significant deterioration of water quality but also cause damage to the diversity of aquatic organisms and the functioning of ecological systems. The excessive release of nutrients such as nitrogen and phosphorus can lead to the eutrophication of water bodies, causing excessive algal growth and the formation of water blooms, further degrading the habitat of aquatic plants and fish, and gradually destabilizing the ecosystem [1]. The heavy metals, organic pollutants, and microplastics generated during urbanization have a cumulative effect, not only accumulating in the food chain but also posing a long-term potential threat to human health.

Among various water body restoration methods, wetland restoration has attracted widespread attention due to its eco-friendly nature, relatively low cost, and long-term ecological benefits [2]. Wetland systems possess superior pollutant removal functions through multiple mechanisms, including physical, chemical, and biological processes, and are effective in removing nitrogen, phosphorus, organic matter, and some heavy metals. Wetland plants, as the core constituent parts of the wetland system, play a crucial role in restoring the environment by adsorbing, depositing, and transforming pollutants through their root systems. The surface of plant roots provides a good habitat for microorganisms, further enhancing the wetland's pollutant degradation capacity. Different types of wetland plants have unique features in terms of pollutant removal efficiency, adaptability, and ecological functions.

The urgent need for urban water environment restoration requires the implementation of wetland restoration projects, which are largely dependent on the scientific configuration of wetland plants. The scientific configuration of wetland plants not only significantly improves the efficiency of pollutant removal, but also improves the ecological structure of water bodies and enhances the overall environmental quality of the city. The plant selection and configuration in urban water body restoration projects should be based on the plant's ecological adaptability, pollutant removal capacity, and contribution to the stability of the overall water ecosystem [3]. In addition to the ecological value, the planting of wetland plants also needs to consider their aesthetic value, balancing ecology and landscape to achieve a win-win situation of ecological and social benefits. Therefore, it is of great practical significance and potential application value to deeply study the strategies of wetland plant selection and configuration optimization in urban water environment restoration.

3. Ecological characteristics and pollutant removal mechanisms of wetland plant selection

Wetland plants play a crucial role in the process of urban water environment restoration. Their ecological characteristics have a direct impact on the efficiency of pollutant removal. Wetland plants can effectively remove nutrients such as nitrogen and phosphorus from water bodies, as well as some heavy metal pollutants, through the absorption, transfer, and degradation of their roots, stems, and leaves. These plants have a strong tolerance to pollution, especially in micro-polluted and heavily polluted water bodies, where they show high adaptability [4]. Some root systems that are well-developed, such as reeds and cattails, can adsorb suspended particles and heavy metals, and other pollutants through their extensive root network, forming a natural filtration system. Wetland plants can secrete a variety of organic compounds during their growth, providing nutrients for microbial communities and further promoting the degradation and transformation of pollutants. The ecological adaptability and diversity of these plants provide a rich selection for water environment restoration.

The core mechanism by which wetland plants play a role in pollutant removal is the synergistic action of physical, chemical, and biological processes [5]. Physical adsorption, achieved through the interaction between plant roots and sediment interfaces, can effectively capture suspended solids, heavy metals, and many more. Chemical precipitation relies on the compounds secreted by plant roots, which undergo complex oxidation-reduction reactions with water pollutants, thereby removing organic pollutants and heavy metals from the water. The microenvironment of the plant root zone creates suitable conditions for the proliferation of microorganisms, especially the alternating distribution of anaerobic and aerobic environments in the root zone, which enables microorganisms to efficiently degrade organic matter and transform nitrogen, phosphorus, and other pollutants, further enhancing the effect of water purification. The multi-faceted role mechanism of wetland plants makes them highly adaptable and flexible in responding to different types and concentrations of pollutants.

The selection of wetland plants should not only take into account their ability to remove pollutants but also consider the mutual suitability between plants and the environment, especially the importance of biodiversity for the long-term stability of wetland ecosystems. The combination of different wetland plants is beneficial for improving the resilience of the entire ecosystem, so that the wetland ecosystem can show higher resilience when facing pollution pressure [6]. Combining salt-tolerant plants with those that have a high tolerance to heavy metals can achieve more efficient purification effects for different polluted environments. Selecting suitable wetland plants and properly configuring them can help build a stable and sustainable ecosystem in water body restoration, achieving a balance between plants, microorganisms, and the water environment, thus providing a solid ecological foundation for the long-term management of urban water pollution.

4. Patterns and principles of wetland planting

The planting pattern and principles of wetland plants directly affect the overall performance of water body restoration, and in wetland restoration projects, a reasonable planting pattern can maximize the purification function of wetland plants and ensure the stability and diversity of the ecological system. Common wetland planting patterns include community-based, layered, and belt-shaped methods [7]. The community-based planting focuses on the community structure of plants, and usually, multiple plants are planted in a larger area to enhance the purification effect through the synergistic action of plants. This method is suitable for large-scale wetland restoration projects and can effectively enhance the resilience and stability of the system. The layered planting method, on the other hand, divides the plants into layers based on their height, root distribution, and growth habits, forming a multi-layer structure above ground, on the surface, and underground, which can improve the filtration efficiency of water flow and promote the decomposition and absorption of pollutants.

In the process of wetland plant configuration, adhering to scientific planting principles is crucial to ensuring the restoration effect. When planting wetland plants, the first thing to consider is the ecological adaptability of the plants, and suitable plants for the local water environment should be selected to ensure their stability in the polluted environment. It is necessary to ensure the diversity and stability of the plant community structure to improve the resilience and restorative capacity of the entire wetland system [8]. Different plants have different removal efficiencies for pollutants, and a diverse plant combination can form a complementary system. For example, plants with well-developed root systems can effectively adsorb solid pollutants, while plants with strong resistance to pollution can survive and continue to play a restorative role in environments with higher pollution loads.

Another important principle in wetland planting is to focus on the organic combination of water purification function and landscape function. Wetlands are not only an important part of water body restoration but also a key node in the urban green space landscape. Therefore, when planting, consideration should be given to aesthetic effects [9]. By combining plants of different colors, heights, and shapes, a rich sense of layering can be created, enhancing the aesthetic value of the wetland and improving the ecological awareness and sense of participation among citizens. In response, a rational wetland planting configuration should also consider the economic feasibility of cost and maintenance, scientifically configuring plants to reduce the need for subsequent management and maintenance, thus achieving a balance between ecological, social, and economic benefits.

5. Optimization strategies for plant configuration in urban water environment restoration

In the restoration of the urban water environment, the optimization strategy of plant configuration is of great importance, which directly determines the purification effect and long-term stability of the wetland ecological system. The core of optimizing plant configuration lies in selecting suitable plant species based on the characteristics of different pollutants and the actual water environment and scientifically designing their distribution patterns. Analysis of the types and concentrations of water pollutants can effectively combine plants with different decontamination abilities to form a multi-functional purification system [10]. In water bodies with high nitrogen and phosphorus content, plants with high nutrient absorption capacity, such as cattails and reeds, can be given priority to accelerate the control of eutrophication. In water bodies with severe heavy metal pollution, plants with heavy metal adsorption ability, such as water lilies and artemisia, can be planted to improve the removal of heavy metals.

The diversity and growth habits of wetland plants are different, and a rational planting strategy can effectively enhance the resilience of the ecological system so that it can maintain a stable purification effect in the face of pollutant impacts or changes in hydrological conditions. Different species, shapes, and growth periods of plants can be introduced to construct a multi-layered, multi-functional ecological structure [11]. Combining floating plants, submerged plants, and emergent plants can make them effective in different water depths and habitats, which not only enhances the comprehensive removal of pollutants but also enhances the interactions between plants and improves the self-regulatory capacity of the wetland ecosystem, ensuring that it has strong resilience under various external interference and achieves sustainable water environment restoration effects.

Plant configuration optimization also needs to consider the combination of ecological restoration and urban landscape functions, paying attention to the coordination of ecological benefits and aesthetic value. Wetlands, as part of the city's green infrastructure, not only bear the function of water quality purification but also serve as an important component of the urban ecological landscape [12]. During the optimization of plant configuration, consideration can be given to factors such as plant height, color, and seasonal changes to design plant communities with a sense of hierarchy and aesthetic effects, thereby enhancing the diversity of the wetland landscape. Rational plant configuration can also reduce the management cost of wetlands and reduce the maintenance needs of subsequent restoration projects. By implementing plant configuration optimization strategies, wetlands will no longer be mere tools for water environment governance but can become ecological landscape nodes in the city, thereby enhancing the public's environmental awareness and ecological literacy and providing strong ecological support for the sustainable development of the city.

6. Evaluation of the implementation effect of wetland planting configuration

The implementation effect assessment of wetland planting is an important link to ensure that urban water environment restoration projects achieve their expected results. It is also a key means to verify the scientificity and effectiveness of planting optimization strategies. The evaluation content usually covers multiple dimensions, including water quality improvement, ecosystem stability, and landscape effects [13]. In terms of water quality improvement, the main focus is on monitoring the removal rates of major pollutants such as nitrogen, phosphorus, chemical oxygen demand (COD), and heavy metals in water bodies. Long-term tracking of pollutant concentration changes is carried out to evaluate the actual effects of wetland plants in removing organic pollutants, controlling eutrophication, and reducing heavy metal content. Data on water quality improvement can be obtained through regular sampling and laboratory analysis, which can determine whether the wetland plant configuration has effectively achieved the degradation and removal of pollutants, thereby providing the scientific basis for further configuration adjustments.

When assessing the stability of wetland ecosystems, it is important to focus on the growth of wetland plants, biodiversity, and the activity of microbial communities. The healthy growth of wetland plants indicates that they have strong adaptability and purification capabilities. The biodiversity index reflects the resilience and regeneration capacity of the ecosystem. The activity of microbial communities is a key reference factor for assessing the internal biological remediation capacity of the wetland system, as microorganisms play a core role in pollutant degradation [14]. When evaluating the effectiveness of wetland plant configuration, one can observe parameters such as plant coverage and species richness to measure the stability of the system, and can also use molecular biology techniques to detect the diversity and activity of rhizosphere microorganisms to analyze the contribution of microbial-plant synergistic action to the efficiency of pollutant removal.

As an indispensable part of the urban ecosystem, wetlands are not only capable of providing ecological benefits in water environment restoration but also play an active and important role in improving the urban landscape and living environment for residents. Assessing the aesthetic effects, landscape hierarchy, and seasonal changes of wetland planting can determine whether the wetland planting configuration has effectively improved the overall landscape quality of the city [15]. By conducting public feedback surveys, the situation of the wetland ecological restoration project in residents' environmental awareness and ecological literacy can be understood, and the social impact of the project can be evaluated accordingly. A scientifically reasonable wetland planting configuration is not only capable of achieving ecological restoration functions but also should enhance the public's sense of identification and participation in ecological protection through its landscape effects, ultimately achieving the comprehensive benefits of urban water environment governance.

7. Conclusion

The scientific and rational planting of wetland plants in urban water environment ecological restoration is of great significance. Selecting plants with strong adaptability and high purification ability, optimizing the configuration mode and evaluating it, can improve water quality, restore ecological balance, and enhance the urban landscape and residents' ecological awareness. Its successful implementation is a manifestation of sustainable development and ecological civilization construction in cities. In the future, wetland restoration technologies and planting strategies will continue to be optimized to provide more scientific and comprehensive solutions for urban water body restoration, thereby contributing to urban ecological construction.

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