

Nature-based Solutions (NbS) Habitat Design Practices and Technical Measures for Urban Waterfront Areas

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Abstract: Nature-based solutions (NbS) offer an innovative approach and a set of techniques in the design of urban waterfront areas. By preserving and restoring the integrity and quality of habitats, and harnessing natural ecological processes to address environmental challenges, NbS can provide a range of ecosystem services such as water purification, flood control, and biodiversity conservation. Additionally, NbS can enhance the sustainability and beautification of urban waterfront areas, while fostering opportunities for people to engage with nature. However, achieving NbS requires collaboration and participation from governments, planners, designers, and the public, in order to collectively promote the sustainable development and conservation of urban waterfront areas.

1. Introduction

Urban waterfront areas are the intersections of urban areas and bodies of water, which possess abundant ecological resources and diverse ecological services. However, due to urbanization and human activities, urban waterfront areas face numerous challenges, such as water pollution, loss of biodiversity, and habitat fragmentation. Traditional engineering approaches are no longer sufficient to protect and enhance the ecological environment of urban waterfront areas. Natural-based Solutions (NbS) is an approach that is based on the protection, restoration, and management of natural systems, and seeks to solve environmental problems by simulating natural processes and using natural resources. In the design and management of urban waterfront areas, NbS provides a feasible way to comprehensively consider ecological, social, and economic factors and achieve sustainable development goals. This paper aims to explore the application of NbS in habitat design of urban waterfront areas. Firstly, we introduce the principles and classifications of NbS, as well as the potential ecological services of urban waterfront areas and their relationship with NbS. Secondly, through case studies of NbS in urban waterfront areas, both domestic and foreign examples were used to demonstrate the effectiveness and feasibility of NbS in practice. Next, we describe in detail the techniques and measures for habitat design of urban waterfront areas, including biodiversity conservation and restoration, water quality improvement and water resource management, as well as planning and design of green infrastructure. Finally, we emphasize the importance of continuous management and evaluation to ensure the long-term benefits and sustainable development of NbS in urban waterfront areas. Through this research, it is hoped that this paper will provide references and guidance for habitat design of urban waterfront areas, and promote the harmonious coexistence of

urban and nature.

2. Nature's Solution in Urban Waterfront Areas

2.1. Principles and categorization of natural solutions (NbS)

Nature-based solutions (NbS) are an approach grounded in natural systems and ecological processes, aiming to address environmental issues and enhance ecosystem functionality. The principles and categorizations of NbS provide guidance and a framework to ensure its effective implementation in urban waterfront areas. The principle of naturalness emphasizes the emulation of natural systems and ecological processes, relying on and protecting natural resources to achieve solutions. The principle of multifunctionality focuses on providing multiple ecosystem services and considering diverse social, economic, and ecological factors. The principle of sustainability seeks long-term and sustainable development, taking into account the various needs and interests of society and ecosystems. Guided by these principles, the categorizations of NbS include the conservation and restoration of terrestrial and aquatic ecosystems, the management and utilization of natural resources, the use of natural systems within natural processes, as well as innovative NbS designs and technological applications. These categorizations offer different avenues for NbS implementation, allowing for localization and consideration of community needs and interests.

2.2. Potential ecological services in urban waterfront areas linked to NbS

Urban waterfront areas are important zones for urban development and are also rich ecological systems. They provide a wide range of potential ecological services such as water purification, flood control, biodiversity protection, and recreational opportunities. However, due to human activities and urbanization pressures, these potential ecological services face many threats and challenges. Against this backdrop, nature-based solutions (NbS) provide a feasible approach for protecting and enhancing the ecological services of urban waterfront areas. The core idea of NbS is to mimic natural processes and utilize natural resources to solve environmental problems and enhance ecosystem functions. In the design and management of urban waterfront areas, NbS is closely linked to potential ecological services. For example, by restoring wetlands and natural river conditions, NbS can improve water quality and provide ecological services for water purification. The plants and microorganisms in wetlands and rivers have natural purifying abilities, and they can remove harmful substances and nutrients, thereby reducing the concentration of pollutants in the water. In addition, constructing wetland ecosystems can provide habitats for biodiversity protection and enhancement. Furthermore, NbS can also help with flood control in urban waterfront areas. Measures such as restoring natural rivers or lakes and building wetlands or wetland protection belts can reduce the occurrence and impact of floods. The presence of natural wetlands helps to absorb a large amount of rainfall and gradually release it, thereby reducing peak flow and flood risk. Additionally, urban waterfront areas have recreational and leisure value. Through proper planning and design, NbS can create parks, trails, and recreational areas with natural landscapes, providing opportunities for people to interact with nature and promoting physical and mental health as well as community integration. In conclusion, nature-based solutions (NbS) can effectively protect and enhance the potential ecological services of urban waterfront areas. It provides sustainable solutions for water quality restoration, flood control, biodiversity protection, and recreational opportunities, fostering a more harmonious coexistence between urban spaces and water bodies and ecological systems.

3. Habitat Design Techniques for Urban Waterfront Areas

3.1. Biodiversity conservation and restoration

The design of habitats in urban waterfront areas serves as a crucial means of protecting and restoring biodiversity. By employing appropriate design techniques in these areas, habitats with suitable environments and conditions can be created to facilitate the habitation and reproduction of wild flora and fauna, thus safeguarding and enhancing biodiversity. One pivotal design technique is the creation of wetland environments with abundant vegetation. Wetlands serve as vital habitats for numerous species, offering abundant food resources and shelter. By establishing wetlands, such as vegetated lakes, ponds, and marshlands, in urban waterfront areas, a diverse range of aquatic and wetland organisms can be attracted, including birds, amphibians, reptiles, and insects. Furthermore, wetlands contribute to water purification and the growth of aquatic plants, providing essential ecological functions. Another significant design technique is enhancing vegetation diversity and vertical structure. Introducing a variety of plant species and emphasizing the hierarchical structure of vegetation, including trees, shrubs, herbaceous plants, and vines, can offer a greater range of habitat types and resource availability. The presence of different plant species can attract various types of insects, birds, and small mammals, enriching biodiversity. Simultaneously, an increase in vertical structure provides additional habitat space and food resources to meet the needs of different species. In addition to vegetation, ecological considerations for water bodies and the conservation and restoration of aquatic organisms should also be incorporated into the habitat design of urban waterfront areas. Initiatives to reduce water pollution, improve water quality, and protect and restore the habitat of fish, aquatic insects, and other water-dwelling organisms can promote diversity and abundance among aquatic species.

3.2. Water quality improvement and water resources management

In the realm of urban waterfront habitat design, enhancing water quality and effectively managing water resources are of paramount importance. The improvement of water quality facilitates the provision of clean water sources, maintenance of ecosystem health, and safeguarding of human well-being. Meanwhile, the effective management of water resources ensures sustainable water supply while alleviating pressure and conflicts surrounding water resources. To enhance water quality, a common design approach is the establishment of natural purification systems, such as wetland filtration and phytoremediation. Wetlands serve as natural purifiers, harnessing the synergistic interplay of biological, chemical, and physical processes to remove pollutants and nutrients from water. In urban waterfront areas, the restoration and creation of wetlands can be implemented to filter and purify the water from urban drainage systems. Additionally, phytoremediation serves as an efficient habitat design technique, whereby plants absorb organic matter and pollutants, converting them into nutrients required for plant growth through microbial degradation. Moreover, the design of urban waterfront habitats should also consider protection of water bodies and the maintenance of their natural flow. Preserving the natural flow and stability of water bodies is crucial to ensure the preservation of biodiversity and favorable living conditions for aquatic organisms. Moreover, the protection of water bodies provides residents and visitors with a beautiful and healthy environment, offering opportunities for recreation and leisure [1].

3.3. Green infrastructure planning and design

The planning and design of green infrastructure play a pivotal role in the ecological design of urban waterfront areas. Green infrastructure, as a nature-based solution, mimics natural processes

and harnesses the power of natural systems to provide various ecosystem services and enhance the sustainability of urban waterfront regions. When planning and designing green infrastructure, multiple aspects must be considered. Firstly, the selection and arrangement of vegetation are crucial. By introducing suitable plant species and configuring their placement, a diverse range of vegetation types and hierarchical structures can be created, providing habitats, food, shade, and other ecological functions. Moreover, vegetation can absorb carbon dioxide, filter harmful substances from the air, and contribute to aesthetically pleasing green landscapes. Secondly, the planning and design of water bodies are essential in urban waterfront areas, which often comprise rivers, lakes, ponds, and wetlands. In the planning of green infrastructure, the protection, restoration, and sustainable use of water bodies should be considered. This includes improving water quality, restoring wetlands and rivers to their natural state, and providing habitats for fish and aquatic organisms. Furthermore, water features and aquatic ecosystems can be designed to offer opportunities for appreciation and interaction. Additionally, the integration of humans and nature must be taken into account in the planning of green infrastructure. Creating sustainable urban waterfront areas requires meeting the needs and interests of people. Therefore, public participation and interests should be considered in the planning and design process. Convenient transportation systems and pathways, recreational spaces, and opportunities for education and environmental awareness should be provided. This can promote community cohesion and sustainable development.

4. Habitat Technical Measures for Urban Waterfront Areas

4.1. Riparian and mudflat protection and restoration

The conservation and restoration of riverbanks and intertidal flats is an important technical measure in urban waterfront habitat design. Riverbanks and intertidal flats are integral components of natural river systems, boasting rich biodiversity and ecological functionality. However, due to urbanization and human activities, many riverbanks and intertidal flats have suffered from degradation and destruction. To protect and restore the ecosystems of riverbanks and intertidal flats, various measures can be taken. Firstly, vegetation restoration and soil conservation of riverbanks can be implemented. By introducing appropriate plant species, such as riparian and wetland plants, the stability of riverbanks can be enhanced, and soil durability can be maintained. The root systems of these plants anchor the soil, reducing erosion and providing habitats, food, and shelter. In addition, protective measures such as constructing revetments and stabilizing vegetation can be taken to mitigate the impact of water flow on riverbanks. Secondly, the protection and restoration of intertidal flats are crucial. Intertidal flats serve as vital habitats for many rare plants and animals as they bridge the gap between rivers and land. In habitat design of urban waterfront areas, it is essential to conserve the ecological functionality and biodiversity of intertidal flats. This can be achieved by limiting development and damage to intertidal flat areas, and by preserving the natural hydrological conditions and water quality of these areas. Moreover, the introduction of adaptive plant species, such as halophytes, can aid in the restoration of damaged intertidal flats and improve water and soil quality [2]. In conclusion, the conservation and restoration of riverbanks and intertidal zones are vital technical measures in urban waterfront habitat design. By restoring vegetation and soil conservation along the riverbanks, and protecting the natural conditions and biodiversity of intertidal zones, it is possible to create healthy, stable, and diverse river and intertidal ecosystems. This will provide crucial ecological services and contribute to the preservation and enhancement of biodiversity. Not only does this help improve the environmental quality of urban waterfront areas, but it also provides people with a beautiful and sustainable living space.

4.2. Water quality improvement and water resources management

Improvement of water quality and management of water resources are crucial technical measures in urban waterfront habitat design. To enhance water quality, effective actions must be taken to reduce pollutant emissions and transmission. This entails establishing a comprehensive sewage treatment system to ensure efficient processing and purification of wastewater. Additionally, environmental conservation policies and regulations should be implemented to restrict industrial and agricultural activities that may pollute water environments. On the other hand, water resource management is an essential approach to ensure sustainable supply and proper utilization of water. The design of urban waterfront areas should consider the collection, storage, and distribution of water resources. Rainwater harvesting systems can collect and utilize precipitation, thereby reducing reliance on limited groundwater and surface water resources. Designing water circulation systems can simulate natural hydrological processes, thereby improving water resource efficiency. Furthermore, the development of water resource management plans is necessary to ensure a balanced supply and reasonable allocation, thus averting excessive exploitation and wastage of water resources. In conclusion, enhancing water quality and managing water resources are integral technical measures in urban waterfront habitat design. By reducing pollutant emissions and transmission, improving wastewater treatment systems, and establishing water resource management plans, we can ensure clean water sources and effectively balance water supply and demand. This will contribute to maintaining the health of ecosystems, protecting human well-being, and achieving a sustainable urban waterfront environment [3].

4.3. Green infrastructure planning and design

The planning and design of green infrastructure are indispensable components within the realm of urban waterfront habitat design. Green infrastructure, as a nature-based solution, utilizes natural processes and systems to provide a multitude of ecosystem services and enhance the sustainability of urban waterfront areas. When planning and designing green infrastructure, multiple aspects need to be considered. Firstly, the selection and arrangement of vegetation. By incorporating appropriate plant species and arranging their placement, a diverse range of vegetation types and hierarchical structures can be created, offering habitat, food, shade, and other ecological functions. Vegetation also absorbs carbon dioxide, filters harmful substances from the air, and provides an aesthetically pleasing green landscape. Secondly, the planning and design of water bodies. Urban waterfront areas often involve rivers, lakes, ponds, and wetlands. In the planning of green infrastructure, the protection, restoration, and sensible utilization of water bodies should be taken into consideration. This includes improving water quality, restoring wetlands and rivers to their natural state, and providing habitats for fish and aquatic organisms. Additionally, water features and aquatic ecosystems can be designed to offer opportunities for appreciation and interaction. Moreover, the planning of green infrastructure should also consider the integration of humans with nature. Creating sustainable urban waterfront areas entails meeting the needs and interests of people. Consequently, public engagement and interests need to be considered in the planning and design process. Providing convenient transportation systems, creating recreational spaces, and offering educational and environmental awareness opportunities are necessary. This can promote community integration and sustainable development. In conclusion, the planning and design of green infrastructure play a critical role in habitat design for urban waterfront areas. Through the judicious arrangement of vegetation, water features, and artificial structures, coupled with considerations of community engagement and climate change adaptation, an urban waterfront environment with ecosystem services, aesthetic appeal, and sustainability can be created, providing a high quality of life and experiences [4].

4.4. Biodiversity conservation and habitat restoration

Biodiversity conservation and habitat restoration are key technical measures in urban waterfront habitat design. Urbanization and human activities often lead to a decrease in biodiversity and habitat destruction. Measures must be taken to protect and restore species' habitats in order to protect biodiversity. The key to protecting biodiversity is ensuring the integrity and quality of habitats. This includes protecting natural habitats such as wetlands, rivers, and forests, as well as establishing artificial wetland and green space systems. Creating diverse habitats can provide the necessary living conditions for different species and promote interactions and ecological balance between species. Additionally, measures such as artificial islands, floating islands, and underwater structures can be implemented to provide habitats for aquatic life. Habitat restoration is also important. By repairing and improving damaged habitats, opportunities for species to reestablish and reproduce can be provided. Measures for habitat restoration include vegetation restoration, water body restoration, and soil improvement. In habitat restoration, it is important to consider the needs and suitable conditions for different species to guide their return and growth. Furthermore, monitoring and management efforts are necessary to ensure biodiversity conservation and habitat restoration work effectively. Timely detection of problems and measures to protect species can be achieved through monitoring species' population, distribution, and ecological status. Meanwhile, management plans and policies need to be developed and enforced, and the management and protection of waterfront ecosystems need to be strengthened for the conservation of biodiversity and restoration of habitats. In summary, biodiversity conservation and habitat restoration are pivotal techniques in the realm of urban waterfront habitat design. By safeguarding and restoring the integrity and quality of habitats, and conducting monitoring and management efforts, we can enhance biodiversity preservation and habitat restoration, thus upholding the health and equilibrium of ecosystems. This not only aids in sustaining the ecological functionality of urban waterfront areas but also provides a captivating environment where humans can coexist harmoniously with nature [5].

5. Conclusion

In light of the aforementioned, natural-based solutions (NbS) offer innovative approaches and techniques for the ecological design of urban waterfront areas. NbS harness the power of natural systems and ecological processes to address environmental challenges, ensuring water quality protection, habitat restoration, and the provision of ecosystem services, ultimately enhancing the sustainability and allure of urban waterfront regions. However, achieving NbS requires the collective efforts of governments, planners, designers, and the public, all working together to advance the sustainable development and conservation of urban waterfront areas.

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