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Yangtze Wetlands: Roles in Herbaceous Plant Biodiversity and Conservation Strategies

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Abstract. Wetlands in the middle and lower reaches of the Yangtze River are China's largest freshwater composite wetland group and a global biodiversity hotspot, as well as an ecological security barrier and life support system for the Yangtze River Economic Belt. As an important carrier for the distribution and reproduction of herbaceous wetland plants, they play an irreplaceable role in maintaining the biodiversity of regional herbaceous wetland plants and the balance and stability of ecosystems. Focusing on the biodiversity of herbaceous wetland plants in the wetlands of the middle and lower reaches of the Yangtze River, this paper analyzes the core role of these wetlands in maintaining such biodiversity from three dimensions: habitat provision, genetic diversity conservation, and ecosystem diversity maintenance. Combined with the current status of ecological conservation of herbaceous wetland plants in the wetlands of the middle and lower reaches of the Yangtze River, it sorts out the major threats posed by habitat fragmentation, biological invasion, environmental pollution and climate change. On this basis, specific conservation measures are put forward targetedly, such as promoting wetland ecological restoration, improving the scientific management system, and strengthening the prevention and control of invasive species.

Keywords: Ecological restoration, Wetland plant diversity, Wetlands in the middle and lower reaches of the Yangtze River, Plant community, Conservation measures

1. Introduction

Wetlands are ecosystems on Earth with unique hydrological, soil and vegetation characteristics. Although wetlands account for only 6% of the Earth's land area, they provide habitats for 40% of known species and support their survival and reproduction [1], and store 30% of the Earth's available freshwater [2]. As the core component of wetland ecosystems, there are more than 2,800 species of wetland plants in China, supporting the survival of over 50% of waterbirds and 30% of freshwater fish [3]. There are about 5,923 species of vascular wetland plants in China, with herbaceous plants accounting for about 85%. As an indispensable part of wetland ecosystems, herbaceous plants have a profound impact on maintaining the ecological balance of wetlands, promoting ecosystem restoration and constructing wetland landscapes. Riparian wetland vegetation has ecological and environmental functions such as pollutant interception, filtration and erosion control. Therefore, wetland herbaceous plants play a vital role in improving the lake water

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environment, protecting biodiversity and maintaining ecological service functions. There are numerous river, lake and shoal wetlands in the middle and lower reaches of the Yangtze River, and the aquatic plants in these shoal wetlands provide abundant food resources and suitable living environments for various migratory birds, fish and other aquatic organisms, playing an important ecological role.

In recent years, affected by the dual impacts of human activities and natural environmental changes, the wetland ecosystems in the middle and lower reaches of the Yangtze River in China have been damaged to varying degrees, and the wetland area has been shrinking continuously. According to statistics, since the 1950s, the area of reclaimed lakes in the middle and lower reaches of the Yangtze River has exceeded 13,000 square kilometers, equivalent to 1.3 times the total area of China's five major freshwater lakes. More than 1,000 lakes have disappeared due to reclamation, with a reduction of 36 billion cubic meters in flood storage capacity [4]. Wetland degradation has led to the continuous deterioration of ecological functions, as well as problems such as the simplification of wetland plant community structure and the decline in species richness, which seriously threaten the health of wetland ecosystems and the security of regional biodiversity.

At present, Chinese scholars have carried out a great deal of research from the perspectives of wetland functions, types, community dynamics and ecological restoration [5], providing an important basis for understanding the distribution characteristics and maintenance mechanisms of wetland plant diversity. However, most existing studies focus on the overall animal and plant diversity, and the special research on the diversity of herbaceous wetland plants in the wetlands of the middle and lower reaches of the Yangtze River is still unsystematic. In addition, the existing conservation measures are relatively macro, lacking precise and implementable conservation technologies and restoration plans for plant diversity.

Based on this, taking the biodiversity of herbaceous plants in the wetlands of the middle and lower reaches of the Yangtze River in China as the research object, this paper discusses the important role of wetland ecosystems in plant species maintenance, community stability and habitat provision, analyzes the major threats currently facing the diversity of herbaceous wetland plants in the middle and lower reaches of the Yangtze River, and puts forward scientific and feasible conservation and restoration measures.

2. The significance of wetland conservation in the middle and lower reaches of the Yangtze River for plant biodiversity

Wetland ecosystems are an important part of global biodiversity and ecosystem services, and wetlands have long been known as the "kidneys of the Earth" [6, 7]. Wetlands in the middle and lower reaches of the Yangtze River are the core support area for China's ecological security, economic development and climate regulation, and are also known as the "kidneys of the Yangtze River", serving as a "natural gene bank" and "survival refuge" for plant biodiversity. Plant species diversity is a basic condition for maintaining ecological health and stability, and plays an important role in sustaining the service functions of community ecosystems.

2.1. Provision of a stable living and reproduction environment

Aquatic plants are the core link of the nutrient cycle in lake ecosystems. The rhizomes of herbaceous wetland plants can fix wetland soil, slow down water flow and reduce the rate of sediment deposition in wetlands. Their photosynthesis provides energy for wetland microorganisms and benthos, constructing a synergistic symbiotic system of "herbaceous wetland plants -

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microorganisms - animals", which supports the survival of animal groups such as waterbirds and freshwater fish in the basin and further promotes the biodiversity of the entire wetland ecosystem.

In terms of community structure, the wetland ecosystems in the middle and lower reaches of the Yangtze River have formed a vertical layered structure of "floating plants - emergent plants - herbaceous wetland plants - shrubs" [7]. This structured community layout not only improves space utilization efficiency, but also constructs interdependent ecological relationships. For example, emergent plants block strong light and slow down water flow for floating plants, and herbaceous wetland plants fix soil for shallow-rooted plants. Plants at different levels form a stable symbiotic system through nutrient competition and spatial complementarity. From 1986 to 2020, the area of aquatic plants in lake groups larger than 10 square kilometers in the middle and lower reaches of the Yangtze River ranged from 2,541.58 to 4,571.42 square kilometers, accounting for 15.99% to 28.77% of the total lake area, mainly distributed in the lake groups of the main stream basin of the Yangtze River, followed by the Poyang Lake basin, Dongting Lake basin, Taihu Lake basin and Han River basin [8]. Such a highly diverse plant community is formed relying on the stable habitat conditions and complete community structure of wetlands. The climate in the middle and lower reaches of the Yangtze River belongs to the northern subtropical humid climate zone, characterized by distinct monsoons, four clear seasons, mild climate and abundant rainfall. The mild climate, stable hydrological supply and fertile soil provide a continuous and stable environment for the growth, flowering, fruiting and seed dispersal of wetland plants, ensuring the natural reproduction of plant populations.

2.2. Conservation of genetic diversity: safeguarding species evolution

The core of the wetlands in the middle and lower reaches of the Yangtze River in maintaining the genetic diversity of herbaceous wetland plants lies in providing a material basis for the species evolution of herbaceous wetland plants by ensuring population size and promoting gene flow. The Minimum Viable Population (MVP) theory points out that any species needs to maintain a certain population size to avoid problems such as inbreeding and loss of genetic variation, and to ensure the genetic vitality of the population. As a concentrated distribution area of plants, wetland conservation measures keep wetland plant populations above the MVP threshold by delimiting protected areas and restoring habitat connectivity. Field surveys show that the natural population density of Phragmites australis in typical shoals of Poyang Lake and Dongting Lake reaches 80-120 plants per square meter, and the population size of a single patch generally exceeds 10^4 plants, which is much higher than the MVP threshold of endangered herbaceous wetland plants [9], providing a quantitative guarantee for the preservation of genetic diversity. As a concentrated distribution area of herbaceous wetland plants, the wetlands in the middle and lower reaches of the Yangtze River provide sufficient living space for them with large areas of continuous habitats, effectively avoiding the loss of genetic diversity caused by genetic drift and inbreeding.

At the same time, the wetlands in the middle and lower reaches of the Yangtze River have formed a water network system with the main stream of the Yangtze River as the core and various lakes and marshes interconnected. This hydrological connectivity serves as a natural carrier for gene flow of herbaceous wetland plants. Water flow drives the dispersal of plant propagules among different wetland patches, promoting gene flow among different geographical populations. Such gene flow can increase the genetic variation of populations, enhance the adaptability of plants to environmental changes, and provide raw materials for species evolution. In addition, the diverse habitat conditions in wetlands can also induce genetic differentiation of plants, promoting the formation of new varieties and new species.

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2.3. Maintenance of ecosystem diversity

The wetlands in the middle and lower reaches of the Yangtze River form a unique watershed ecological barrier through hydrological connectivity, material cycle and energy flow. As the core primary producers of this ecosystem, herbaceous wetland plants are an important carrier of wetland ecosystem diversity. The wetlands in the middle and lower reaches of the Yangtze River provide unique habitats and breeding grounds for a large number of animals and plants, and are especially inhabited by many rare, endangered and endemic species, such as birds including the Black-necked Crane (Grus nigricollis), Black Stork (Ciconia nigra) and Red-crowned Crane (Grus japonensis), which have extremely high conservation value worldwide [10]. Wetland herbaceous plants also shape diverse microhabitats by changing hydrological conditions, regulating soil environments and constructing physical structures.

Wetland nature reserves are specific areas established to protect wetland ecosystems and their biodiversity, aiming to maintain the ecological functions and natural state of wetlands. The wetland nature reserves such as Poyang Lake, Dongting Lake and Honghu Lake established in the wetlands of the middle and lower reaches of the Yangtze River have maintained the structural integrity of wetland ecosystems through the protection and restoration of herbaceous wetland plant communities. For example, Xixi National Wetland Park has achieved a significant restoration of degraded wetland plant diversity by introducing native herbaceous wetland plants and reconstructing wetland vegetation communities, and more than 400 species of wetland higher plants have been recorded so far [11].

3. Problems faced by wetland conservation

The survival of the biodiversity of herbaceous wetland plants in the wetlands of the middle and lower reaches of the Yangtze River is facing multiple threats from human interference and natural changes. The prominent problems faced by the wetlands in the middle and lower reaches of the Yangtze River, and the consequent threats to the maintenance of herbaceous wetland plant diversity, community structure and type, vegetation development and distribution, and ecosystem service functions are described as follows.

Habitat fragmentation is the primary problem currently facing wetland conservation in the middle and lower reaches of the Yangtze River, whose core driving factor is high-intensity human interference, causing devastating damage to the living environment of herbaceous wetland plants.

3.1. Habitat fragmentation

Habitat fragmentation mainly stems from human activities such as reclamation for farmland and urban construction. Shallow lakes in the middle and lower reaches of the Yangtze River have been affected for a long time by factors such as dyke and sluice construction, lake reclamation for farmland, overexploitation of resources and continuous input of pollutants, leading to the isolation of rivers and lakes, changes in hydrological regimes, a sharp reduction in area, a decline in regulation and storage capacity, frequent flood and waterlogging disasters, aggravated water pollution and eutrophication, the spread of invasive species, vegetation degradation, a decline in biodiversity and the deterioration of ecological service functions. These in turn affect the regional water security, food security and ecological security, and restrict the high-quality development of the Yangtze River Economic Belt. In the middle and lower reaches of the Yangtze River, the area of cage culture in many lakes accounts for more than half of the total lake area, which has gradually

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damaged the lake habitats and caused a series of ecological and environmental problems. In the Taihu Lake basin, there are 498 embanked lakes, 239 lakes affected by reclamation, with a reduction of 529 square kilometers in lake area, and 165 lakes have disappeared due to reclamation, accounting for 23.3% of the original number of lakes in this area [12].

In terms of agricultural production, to expand the cultivated land area, large-scale lake reclamation for farmland and marsh reclamation activities were carried out in the wetland concentration areas of the middle and lower reaches of the Yangtze River. Large-scale reclamation has caused irreversible changes in the pattern of coastal wetland systems. Large-scale reclamation has led to the complete disappearance of the original natural lake bays and riparian zones, which are concentrated distribution areas of various aquatic plants. The six major lake groups in the middle and lower reaches of the Yangtze River basin play an important role in flood resistance, runoff reduction, flood storage and drought prevention, pollution degradation, climate regulation and water resource regulation.

In terms of urban construction, port construction and real estate development have led to a rapid reduction in large, contiguous wetland areas, resulting in the division, blockage and fragmentation of wetlands and the degradation of wetland functions. In addition, fishing, trawling and other fishing operations can also damage submerged plants and affect their colonization and growth. Remote sensing monitoring of large aquatic plants in 98 lakes larger than 50 square kilometers in the middle and lower reaches of the Yangtze River by Landsat satellites shows that the number of large aquatic plants in the lakes of the middle and lower reaches of the Yangtze River showed an obvious overall downward trend from 2010 to 2021 [13]. Some rare herbaceous wetland plants are on the verge of extinction due to habitat changes.

3.2. Proliferation of invasive species and decline in biodiversity

There are many factors threatening biodiversity, among which biological invasion is the second major threat factor after habitat destruction. At present, there are as many as 152 species, 84 genera and 39 families of alien invasive wetland plants in China. In terms of the life forms of invasive plants, emergent plants account for 57.24%, submerged plants 27.63%, floating-leaved plants 9.87%, and free-floating plants 5.26% [14].

Common invasive aquatic herbaceous plants in the wetlands of the middle and lower reaches of the Yangtze River include Water Hyacinth (Eichhornia crassipes), which has an extremely fast reproduction rate. It covers the water surface, blocks waterways, consumes dissolved oxygen in water, leading to the mass death of fish and native aquatic plants. Honghu Lake once suffered from the proliferation of the invasive Water Hyacinth, which covered a lake area of 13 square kilometers with a total biomass of about 120,000 tons, occupying the ecological niches of other aquatic plants in Honghu Lake [14]. Smooth Cordgrass (Spartina alterniflora) overgrows in coastal tidal flats and estuarine wetlands, occupying the living space of native plants, destroying migratory bird habitats and changing the wetland ecological structure. Such invasive species are particularly common in wetlands such as the middle and lower reaches of the Yangtze River in China, causing serious impacts on the water environment and the species diversity of wetland plants. Such invasive herbaceous wetland plants will quickly replace native plants and become monodominant communities, leading to a sharp decline in the species richness of herbaceous wetland plants in the wetlands of the middle and lower reaches of the Yangtze River and further affecting the balance of wetland ecosystems.

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3.3. Climate change

Global climate change leads to drastic changes in hydrological processes such as droughts and floods, which in turn affect the hydrological state of wetlands, putting many wetland plants at risk of extinction in a short period of time [14].

The 4th IPCC Report emphasizes that the global average surface temperature has risen by 0.4~0.8 ℃ in the past century, reaching the peak in 1,000 years [15]. Climate warming has accelerated the watershed hydrological cycle, leading to uneven precipitation distribution in the middle and lower reaches of the Yangtze River and frequent extreme weather such as droughts and floods, which have seriously changed the water environment conditions on which herbaceous wetland plants depend for survival. Taking Honghu Lake in China as an example, the consecutive droughts in winter and spring of 2011 caused the water surface area of Honghu Lake to decrease by about two-thirds compared with previous years. After the start of the plum rain season in 2016, continuous heavy rainfall caused the water level of Honghu Lake to be above the warning water level for 26 consecutive days, with an average water depth of up to 3.8 meters and an average water transparency of only 0.82 meters. The light under such environmental conditions is far from meeting the growth and development needs of submerged plants, and high temperatures have also accelerated the rot and death of submerged plants [4]. Climate warming also leads to an increase in the evaporation of wetland soil and a rise in soil salinity, causing salt stress to herbaceous wetland plants in the coastal wetlands of the Yangtze River Estuary and affecting their growth and reproduction.

4. Measures to strengthen wetland conservation and enhance biodiversity

Promoting wetland ecological restoration is the core measure to enhance plant biodiversity. In terms of habitat protection, in response to the serious damage to habitats, wetland habitat connectivity restoration is carried out. Isolated wetland patches are connected by demolishing artificial dykes in wetlands and building ecological corridors, so as to restore the hydrological connectivity of wetlands and ensure the dispersal of plant propagules and gene flow. Taking Hangzhou Xixi Wetland as an example, by implementing the bird habitat restoration project in Lianhuatan, the wetland has not only restored its original biodiversity, but also significantly improved its ecological functions. The project has successfully restored the landform and plant communities in the Lianhuatan area, making it a major habitat and viewing spot for waterbirds.

At the same time, human activities have a significant impact on wetland ecological conservation. Land development, pollutant discharge and overutilization of water resources are the main threat factors. Land development damages animal and plant habitats, and the discharge of industrial wastewater, pesticides and fertilizers pollutes the water quality and soil of wetlands, destroying the balance of wetland ecosystems. Soil restoration aims to restore the healthy state of soil through a series of technical measures to improve soil structure, increase soil fertility and control soil pollution. Specific measures include the adoption of soil pollution control technologies, such as solidification and stabilization of heavy metal-contaminated soil and bioremediation of organic-contaminated soil, to effectively remove or reduce the content of harmful substances in the soil. At the same time, soil fertility restoration technologies are implemented to increase soil nutrient content and water and fertilizer retention capacity through rational fertilization, soil texture improvement and other means, providing good conditions for the growth of wetland plants [16]. In addition, water resource management is optimized to ensure the stable and sustainable utilization of wetland water

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resources and prevent further damage to wetland ecosystems caused by overexploitation and pollution.

5. Conclusion

In summary, focusing on the biodiversity of herbaceous wetland plants in the wetlands of the middle and lower reaches of the Yangtze River, this paper clarifies that the wetlands in this area form the core support for the survival of herbaceous wetland plant diversity from three levels: habitat, genetics and ecosystem. It systematically analyzes the core role of these wetlands in maintaining the biodiversity of herbaceous wetland plants, and confirms that they provide a stable living and reproduction environment for herbaceous wetland plants, ensure the genetic vitality of populations, and are an important carrier of watershed ecosystem diversity. At the same time, the study clarifies that habitat fragmentation, alien species invasion and climate change are the main factors currently threatening the diversity of herbaceous wetland plants in this area, and these factors interact with each other, leading to the simplification of plant community structure and the decline in species richness. Targeted specific conservation measures are put forward, such as promoting wetland ecological restoration, restoring hydrological connectivity, and strengthening the prevention and control of invasive species.

This study still has certain limitations. It does not carry out a differentiated analysis of the diversity of herbaceous wetland plants in lake wetlands of different basins, lacks targeted conservation research on specific species, and fails to construct a quantitative evaluation system for diversity conservation combined with long-term monitoring data. Future research can carry out differentiated surveys of cross-basin wetlands, clarify the key points and difficulties of diversity conservation in different regions, and construct a biodiversity prediction model based on multiple factors such as hydrology, soil and climate. At the practical level, the precise implementation of wetland conservation can be promoted, exclusive species conservation plans can be formulated in combination with local realities, so as to improve the scientificity and effectiveness of the conservation of herbaceous wetland plant diversity in wetlands.

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