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Research on Optimization of Green Development Management of Mangroves based on Sustainable Development

-- Take Guangdong Province as an Example

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Abstract

As a key ecosystem in the land-sea transition zone, mangroves have core functions such as carbon sequestration, biodiversity maintenance and coastal erosion resistance, but their sustainable development faces multiple challenges. Taking Guangdong Province as an example, this paper analyzes the global mangrove area reduction (about 147,000 square kilometers in 2020) and the current status of mangrove management in China, revealing the core problems it faces, such as spatial conflicts, policy lags, weak technology and insufficient social participation. The study proposes a five-in-one countermeasure system of "spatial planning-technological empowerment-capital innovation-industrial integration-institutional coordination", including hierarchical protection, intelligent restoration, carbon sink trading, industrial complexes and provincial legislation, aiming to resolve the contradiction between ecological protection and economic development and promote the transformation of mangroves from single protection to "protection-utilization" coordination. The study provides a systematic solution for ecological governance in coastal areas and helps the construction of blue carbon economy and ecological civilization.

Keywords

Mangroves; Green Development; Management Optimization; Ecological Restoration; Blue Carbon Economy.

1. Introduction

Mangroves are shoreline and wetland plant communities in the coastal intertidal zone. They play an important role in purifying seawater, preventing wind and waves, fixing and storing carbon, and maintaining ecological diversity. They are an important carrier of the marine ecosystem with the highest production capacity of sea-land alternation and river flow into the sea. They are an important settlement place for the growth and reproduction of fishery ecological species and marine fisheries in the Haikou basin, and an effective barrier to the continued and sustainable development of island ecology. The mangrove community belt maintains a complex and highly productive food chain system and is a treasure trove of species genes and resources. It is known as the "coastal guard", "green lung of the ocean" and "magnetic core of the marine ecology" [1].

Since mangroves are a special ecosystem transitioning from land to sea, and are an important "line of defense" for protecting the safety of life and property in the sea and land, the protection and management of mangroves is quite strict not only at the national level, but also at the provincial, municipal, county (district) level, resulting in the phenomenon of "moving when

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hearing about the forest" and "competing with the forest for land" in coastal areas across the country [2]. So far, there is no effective long-term management mechanism for the symbiosis between mangroves and humans, which can influence the whole society to actively participate in the protection and utilization of mangroves and promote the sustainable development of mangroves in an all-round way. Therefore, it is of great practical significance to carry out in-depth research on the optimization of green development management of mangroves based on sustainable development [3].

2. Research Background and Development Status

1) Research Background

Due to human activities such as land reclamation and pollution, the global mangrove forests continue to shrink. In 2020, the total area was about 147,000 square kilometers, but 50% of the ecosystems are at risk of collapse (IUCN, 2024). China's mangroves are distributed in coastal provinces such as Guangdong (accounting for 40% of the country) and Guangxi, with a total area of less than 30,000 hectares. Although it has shown a recovery trend in recent years, Guangdong has a prominent degradation problem due to economic development, typhoon disasters and invasion of alien species such as Spartina alterniflora. Mangroves have a unique "viviparous phenomenon" and a developed root system, which can expand naturally through seed drifting, but the excessive expansion has led to improper introduction of alien tree species and habitat fragmentation due to insufficient technology. In addition, there are shortcomings in the policy implementation level, such as insufficient configuration of scientific research institutions, disconnection between restoration and local planning, and lagging regulations. It is urgent to build a coordinated mechanism between ecological protection and economic development.

2) Development Status

Since China launched the protection project for mangroves in 2001, it has gradually formed a policy framework with the Wetland Protection Law and the Mangrove Protection and Restoration Special Action Plan as the core. As a pioneer, Guangdong Province has issued local regulations such as the Zhuhai Special Economic Zone Mangrove Protection Regulations, strived for 1 billion yuan of central funds for restoration projects in Zhanjiang, Shenzhen and other places, and explored carbon sink trading mechanisms (trading volume of 220 million tons in 2024, ranking first in the country). Hainan, Guangxi and other places have also strengthened legislation to clarify protection boundaries and responsibilities [4].

However, the current management still relies on fiscal investment, and the market mechanism is weak; insufficient cross-departmental coordination leads to lengthy approval processes, and the contradiction between ecological protection and local development is prominent. Although Guangdong has made progress by establishing a mangrove fund and promoting the construction of "Green Guangdong", problems such as extensive scientific research and technology and insufficient research on local tree species restrict the efficiency of restoration. It is necessary to further integrate the "protection-restoration-utilization" chain to achieve sustainable development [5].

3. Existing Problems and Development Conflicts

Mangrove protection faces multiple contradictions, which are mainly reflected in the following four core issues:

1) Spatial utilization conflicts exacerbate ecological degradation.

In economically developed areas (such as Shenzhen), the contradiction between mangrove conservation areas and urban construction land is prominent. Suitable afforestation space is

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scarce and fragmented, and the cost of management is high. Historical reclamation (such as reclamation of tidal flats and reclamation of land from the sea) has led to a sharp decline in the area of mangroves. The conversion of ponds to forests is hindered by disputes over ownership of "ancestral forests" and "ancestral seas". Invasive alien species (such as Spartina alterniflora) and typhoon disasters have exacerbated habitat fragmentation, forming dead forests and patchy forests, which have increased the difficulty of restoration. In addition, the isolated forests formed by the natural expansion of drifting mangrove seeds have seriously affected the navigation and production safety of fishing ports. The lengthy land and sea use approval process has further intensified the contradiction [6].

2) Policy lags and mechanism defects constrain sustainability.

Current laws and regulations (such as the Wetland Protection Law) are out of touch with local development needs, and the demarcation of ecological protection red lines conflicts with local economic interests, resulting in a lag in the advancement of restoration tasks. There is a lack of a dedicated mangrove management mechanism at the national level. Although local regulations (such as Guangdong and Hainan) have detailed protection requirements, there are widespread problems such as unclear cross-departmental responsibilities and insufficient law enforcement basis. Social capital has low participation due to unclear carbon sink income paths and insufficient policy support. It is highly dependent on fiscal funds, and the market-based compensation mechanism is not yet mature, making it difficult to form a virtuous cycle of "protection-income".

3) Weak technology and funding gap limit restoration efficiency.

Insufficient investment in scientific research has led to a single selection of tree species, over-reliance on salt-tolerant varieties, lack of research on the adaptability of local characteristic tree species, and poor community resistance. Restoration technology is extensive, dredging of tidal channels and beach transformation rely on manual labor, and intelligent equipment (such as drone seeding and tidal energy sediment regulation devices) is not widely used. The cost of restoration is high and the efficiency is low. In terms of funding, special restoration of mangroves mainly relies on fiscal appropriations. Although Guangdong received 1 billion yuan in support from the central government in 2024, the province's restoration needs and funding gap are still seriously unbalanced, and the path to realize the value of ecological products has not yet been opened [7].

4) Lack of social participation exacerbates conflicts of interest.

The public and enterprises have insufficient knowledge of the ecological value of mangroves. Traditional fisheries (such as oyster pond farming) are in fierce conflict with ecological protection. The lack of alternative livelihood solutions exacerbates social resistance. Policy guidance is weak, and there is a lack of market-based incentives such as carbon sink trading and ecological compensation. Enterprises are worried that ecological red lines will restrict industrial development and have low enthusiasm for participating in restoration. In addition, local "restoration + development" models have not been explored enough, and the potential of industries such as eco-tourism and derivative product development have not been effectively integrated, resulting in difficulty in coordinating protection and utilization.

4. Coping Strategies

In order to resolve the multiple contradictions in mangrove protection and development, it is necessary to build a systematic response system from five aspects: spatial planning, technological breakthroughs, financial guarantees, industrial integration and institutional coordination, so as to promote the coordinated improvement of ecological benefits and economic and social benefits.

1) Optimizing spatial planning and hierarchical management

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By compiling a provincial-level special plan for the protection and utilization of mangroves, we will delineate key protection areas (ecological core areas), general protection areas (buffer zones) and integrated development areas (moderate utilization areas), and clarify spatial boundaries and functional positioning. For economically developed areas (such as Shenzhen and Zhuhai), we will explore "three-dimensional restoration" pilot projects and use the vertical space of intertidal zones to improve ecological carrying capacity; implement a special action for "patch forest integration" to focus on restoring fragmented habitats, remove invasive species such as Spartina alterniflora, and restore local dominant tree species (such as Kandelia candel and Avicennia marina). At the same time, we will establish a "mangrove seed drift warning system" to monitor the natural spread range and prevent isolated island forests from affecting waterway safety.

2) Strengthening scientific and technological support and intelligent restoration

Establish a provincial mangrove research institute, focus on key technologies such as typhoon-resistant tree species screening and tidal energy sediment regulation device research and development, and establish a wind resistance rating evaluation system and carbon sink difference model. Promote intelligent equipment such as "drone cluster seeding" and "quantum sensing carbon monitoring" to reduce the cost of manual restoration and improve afforestation efficiency. Build a mangrove germplasm resource bank to conserve local specialty varieties and avoid the monoculture of the community. Build a "typhoon damage prediction AI model" and a smart monitoring platform to warn of ecological risks in real time and realize dynamic resource supervision.

3) Innovative funding mechanisms and market-oriented approaches

Establish a provincial mangrove restoration fund, provide subsidies according to the restoration area, and attract social capital to participate through the "restoration + development" bundling model (enterprises provide ecological funds according to the investment amount). Explore the securitization of ecological products, issue green bonds or carbon sink futures, establish a "mangrove bank" trading platform, and promote carbon sink income pledge loans. Promote the "ecological beneficiary pays" system, impose protection surcharges on offshore pollutant dischargers, and strive for capital injection from international financial institutions. At the same time, allow prefecture-level cities to replace construction land indicators with restoration scale to ease land conflicts.

4) Promoting industrial integration and value transformation

Pilot the "Mangrove Economic Complex" in the integrated development zone, integrate eco-tourism, popular science education, carbon sink trading and ecological aquaculture (such as the "mangrove + oyster field" and "forest-fishery coupling" models), and create a full industrial chain demonstration park. Develop high-value-added derivatives, such as medicinal extracts (such as oleander) and cosmetic raw materials, and establish an "International Mangrove Product Certification System" to enhance market recognition. In response to traditional fishery conflicts, promote the "return ponds to forests + alternative livelihoods" program, guide fishermen to transform ecological management or participate in carbon sink dividends, and form a "protection-income-return" closed loop.

5) Improve the legal system and collaborative governance

Accelerate the formulation of provincial mangrove protection regulations, clarify the boundaries of ecological red lines, law enforcement responsibilities and punishment standards, and eliminate the loophole of "multiple management". Establish a joint mechanism of natural resources, forestry, environmental protection and other departments to simplify the approval process of land and sea use. Connect with the Global Mangrove Alliance, introduce international restoration standards and cross-border carbon trading rules, and enhance the global influence of governance. Through the "government guidance, market operation, and social participation"

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mechanism, encourage village collectives to invest in forest land management rights, share long-term ecological dividends, and build a sustainable protection paradigm.

5. Conclusion and Outlook

Mangrove protection is a core issue in the construction of ecological civilization. Studies have shown that the current management of mangroves faces bottlenecks such as space compression, policy disconnection, extensive technology and conflicts of interest, and it is in urgent need of systematic reform. Through hierarchical management, application of intelligent equipment, carbon sink financial innovation and "mangrove economic complex" and other countermeasures, ecological and economic benefits can be effectively integrated. As a pilot demonstration area, Guangdong Province's exploration provides a reference for the whole country, but it still needs to deepen the "protection and utilization coordination" mechanism in non-core areas and improve the value transformation path of ecological products. Future research should focus on cross-border carbon sink trading, community co-governance models and climate resilience improvement, promote the transformation of mangroves from "ecological barriers" to "green assets", and realize the organic unity of "green waters and green mountains" and "gold and silver mountains".

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