Practice and Consideration on Restoration of Sandbar-Lagoon Geomorphology: A Case Study on Fudu Estuary Sandbar

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Abstract. With the development and construction of the coastal economic belt, the marine ecological environment is under great pressure. The typical river mouth sandbar - lagoon hydro-geomorphological system is facing unprecedented threats, and it is extremely urgent to restore this typical geomorphological system. Taking the Fudu River Mouth Sandbar as a case study, combining with the characteristics of surrounding marine resources and the current situation of exploitation and utilization of sea area, this paper puts forward various ecological restoration measures including the construction of landscape ecological corridor, sandbar maintenance, demolition of reclamation works and structures, landscape park construction, on-line water quality monitoring, fisherman wharf reconstruction, etc. to solve the major problems in this area. This paper also suggests that, during the implementation of marine ecological restoration, the following measures should be taken, including to establish a library of coastline remediation and restoration projects within the study area, give full play to the technological advantages of universities and research institutes at the national and provincial levels, strengthen scientific and technological support, and implement the target-oriented responsibility system for marine ecological remediation and restoration by taking marine ecological remediation and restoration targets as indicators to assess cadres’ performance.

Keywords. Sandbar-lagoon hydro-geomorphology; marine ecology; remediation and restoration; Fudu River Mouth.

1. Background of Study

With the development and construction of coastal economic belt, the development activities such as marine engineering construction are increasing daily, which greatly promotes the economic development of coastal areas [1]. Since the sustainability of economic development was neglected, the importance and vulnerability of marine resources, environment and ecosystem were neither well understood nor emphasized in the past, the marine ecological environment has been greatly damaged and is under great pressure behind the rapid development of coastal economy [2-3]. Marine ecological restoration refers to the continuous recovery of the structure and function of ecosystem by making use of the self-repairing ability of nature to restore the damaged ecosystem to its original or similar structure and function with the assistance of appropriate artificial measures [4]. Since the beginning of
the 1970s, foreign countries have begun to study ecological restoration and accumulated experience with reference significance through continuous practice [5-7], which has made great progress. In China, although the development of terrestrial ecological restoration has been started early and effectively, the marine ecological restoration was started relatively late and is lack of related study.

The bars refer to a series of sand bars and islands distributed in parallel with the extending direction of the coastline, and the lagoons refer to shallow waters separated from adjacent sea areas by these bars while still connected or having connection with the sea. The sandbar and lagoon are interdependent and constitute the sandbar - lagoon system, which is a typical geomorphology of coastal accumulation and has great significance in research and landscape. In Liaoning Province, there are seven typical sandbar - lagoon systems, of which two in Yingkou City are the Fudu River Mouth Sandbar-Lagoon and the Xiongyue River Mouth Sandbar-Lagoon Systems, and the latter has been completely lost due to the reclamation on the east side of the river mouth and the dam construction on the west side. The more typical Fudu River Mouth Sandbar-Lagoon System (figure 1), because of its wonderful landscape, attracts numerous tourists and has the unique advantage in tourism development.

In the past decade, due to the extensive development and utilization of sea areas, the original sandbar - lagoon has been damaged by reclamation, which had a certain impact on the regional typical geomorphology and the sustainable development of social economy. Although the original geomorphological system of Fudu River Mouth Sandbar-Lagoon System has been damaged by reclamation, but the sandbar still exists. Through renovation, it is expected to be restored to the original natural state or even a state with a higher landscape value than before, thus to improve the comprehensive environmental quality at the river mouth, meet the public demand for leisure in close proximity to the sea and promote the sustainable development of local economy. Therefore, it is extremely urgent to restore the typical geomorphological system at the moment.

This study comprehensively analyzes the characteristics of marine resources and environment as well as the current situation of development and utilization of sea areas near the Fudu River Mouth in Yingkou City, Liaoning Province, explores the major problems for the restoration of typical marine geomorphological systems based on ecological concepts combining with the present situation of marine ecological restoration, puts forward key points of and countermeasures for ecological restoration to provides scientific basis and guidance for improving the laws, regulations, policies and plans related to marine ecological protection and restoration.

2. Overview of Study Area

Fudu River, located between latitude 39°57'45" - 40°06'37"N and 122°18'44"-122°56'46"E, rises in Laomao Mountain, Wanjialing Town in the northeast of Wafangdian City, with a total length of 45 km and a drainage area of 481 km². It is also the boundary river between Dalian and Yingkou in Liaoning Province.

The Fudu River Mouth area features the temperate monsoon climate with distinct winter and summer monsoon alternation, cold in winter while warm in summer. In summer, the southeast or south wind is dominant; while in winter, the north-northwest and north winds are dominant. Due to the effect of continental climate, there are very clear seasonal and inter-annual variations of water temperature.

Affected by the topography of Liaodong Peninsula, the waves in this sea area are mainly wind waves, and mostly to the southwest in summer and to the north in winter, with an average height of about 0.3 m. The coastal tidal current is mainly reciprocating current, and the rising tidal current is higher than the falling tidal current with an average tidal difference about 1.6 m. Due to the combined action of the after-pulse of the Yellow Sea warm current and the circulation of Liaodong Gulf, the coastal current mainly flows from north to south in winter, and from south to north in summer because of the influence of runoff and monsoon.
3. Major Ecological Problems in the Study Area

3.1. Reclamation Works Seriously Affect the Integrity of the Sandbar-Lagoon
As the lagoon between the land area and the natural sandbar is divided and surrounded by marine culture areas, construction channels and sites, the water exchange is thus affected, and the integrity of the geomorphological unit, i.e., the sandbar - lagoon system, is seriously threatened. Without cleaning and dredging, the lagoon will gradually disappear, resulting in environmental problems such as sand body argillization.

3.2. The Eastern Side of Sandbar Has Serious Erosion and Harsh Environment
Since the construction of river mouth dam has blocked the Fudu River sand from supplementing the existing beach and changed the local hydrodynamic conditions, the east side of the sandbar has serious erosion.

As the river mouth dam is built by piling stones and large stones are piled up around the dam, the gravel, after being eroded by the seawater, is then transported to the existing beach or river course, which seriously affects the beach environment of the bathing beach and tourists' experience in close proximity to the sea. Meanwhile, these large stones may also pose potential safety hazards to fishing boats sailing in the river course.

3.3. The Construction of Artificial Structures in the Middle of the Sandbar Has Divided the Complete Beach
The bathing beach management department has built a stone dam on the east side of the beach in order to slow down the trend of beach erosion. However, such protective measures do not fundamentally solve the problem of beach erosion, and the stone dam has divided the existing intact beach and reduced the unique landscape value of sandy coast.
3.4. The Sandbar Body Is Seriously Damaged due to the Construction of Reclaimed Artificial Island
Due to the particularity of river mouth area, with the abundant regional sediment source and complicated hydrodynamic environment, the natural landscape of sandbar - lagoon is created. However, the construction of river mouth dam and reclaimed artificial island will have different effects on local hydrodynamic environment and estuary sediment replenishment, which will further lead to the damage of sandbar body. If measures are not taken in a timely manner, this typical natural geological landscape may disappear.

4. Proposed Remediation and Restoration Measures

4.1. Demolition and Alteration of Artificial Structures
Demolish dams and reclaimed structures and restore the sea to its original natural state. Demolish 4 dams, including river mouth dam, temporary dams and construction roads, totaling 1,695 m. Demolish 1 unreasonable reclaimed structure and restore the sea area of 4.65 ha. Alter existing roads in the lagoon area into permeable structures to improve the water exchange capacity of lagoon waters, with 1,070 m roads to be altered and widen the lagoon water area to 62 ha.

4.2. Sand Beach and Sandbar Maintenance
Carry out high-quality sand beach and sandbar body maintenance to maintain the existing 732 m beach and improve the environment of the bathing beach; maintain the sandbar body to protect the integrity of sandbar - lagoon geomorphological unit with a length about 1,306 m. Carry out comprehensive environmental remediation of the bathing beach, clean up large blocks of gravel, garbage on the beach and randomly parked fishing boats to enhance the landscape value of the sandy coastline; improve the construction of tourist supporting facilities such as wooden trestles, featured landscape, benches and temporary bath rooms to improve tourists' experience of contact with seawater and promote the overall tourist quality.

4.3. Landscape Corridor Construction
Construct a coastal landscape corridor running through the whole area on the coast of Fudu River Mouth with a length not less than 2.0 km, of which the east end connects with the Gold Coast Corridor of White Sand Bay and the west end directly connects to the Fisherman's Wharf, thus connecting the Fudu River Mouth area with the Gold Coast Corridor of White Sand Bay to realize regional linkage and promote regional tourism. The landscape corridor will be composed of landscape revetments, near-water steps, leisure walkways, green plants, etc., and is used to provide the public and tourists with spaces for leisure, experience of being close to seawater, create a natural, ecological and green coastal environment, as well as build the beautiful coastal scenery.

5. Considerations and Suggestions

5.1. Establish a Library of Coastline Remediation and Restoration Projects
With the projects of “Blue Bay” and “Ecological Island Reef” as the carrier, actively strive to apply for the central financial funds to support the coastline remediation and restoration projects. Give priority to the remediation and restoration of coastlines with serious fragmentation, functional degradation and concentration through various ways including building marine parks, clearing and demolition of artificial structures, returning the marine culture area to beach, returning the reclaimed area to the sea, dredging and building ecological corridors, establish a comprehensive remediation and restoration mode with overall and coordinated planning for land and sea as well as addressing both the symptoms and root causes, and try the best to maintain the natural features and cultural characteristics of the coastline. Explore and establish a diversified financing mechanism for coastline remediation and restoration projects, absorb all kinds of social capital for project construction, strengthen the project organization, implementation and management, and improve the project operation mechanism.
5.2. Strengthen Scientific and Technological Support
Give full play to the technological advantages of universities and research institutes at the national and provincial levels, make key evaluation on the damage to tourism beaches, estuaries, bays, marine culture zones and islands, carry out research on key technologies of comprehensive remediation and restoration of typical marine ecosystem and sea area, and develop and formulate technical standards and specifications of remediation and restoration projects. Establish and improve the post-evaluation system of marine ecological remediation and restoration projects, and strengthen the post-supervision over such projects.

5.3. Implement the Target-oriented Responsibility System for Marine Ecological Remediation and Restoration
Authorities concerned should be responsible for the marine ecological remediation and restoration projects in their respective jurisdictions, truly incorporate the marine ecological remediation and restoration work into the agenda of marine ecological environmental protection of government departments at all levels, and take marine ecological remediation and restoration targets as indicators to assess cadres’ performance.

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