Changes of Coastal Wetland Ecosystems in the Yellow River Delta and Protection Countermeasures to Them

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Abstract Coastal wetlands in the Yellow River Delta are typical new wetland ecosystems in warm temperate zone. In recent years, influenced by natural and human factors, these coastal wetlands in the Yellow River Delta have undergone changes of landscape fragmentation, vegetation degradation, pollution, species reduction, and harmful exotic species invasion. These changes have influenced sustainable and healthy development of marine economy of the Yellow River Delta. To protect natural ecological environment of the Yellow River Delta, the authors recommended that it should establish and improve policies, laws and regulations of wetland protection; carry out wetland resource investigation and assessment and monitoring; strengthen comprehensive protection and control of wetland; reduce wetland degradation and promote sustainable use of wetland.

Key words The Yellow River Delta, Coastal wetland, Ecosystem, Changes, Protection countermeasures

The wetland ecosystem consists of biological factors (including humidogene, aquatic plants and animals, water birds, and microorganism) and non-biological environment factors (such as sunshine, water and soil) closely-interrelated through material cycle and energy flow. Compared with non wetland ecological environment, wetland ecological environment has high humidity and even is covered by water yearly. Thus its features include short of oxygen; significant peat formation or gleying process; high thermal capacity, poor heat conductivity and poor nutrition. As the youngest wetland ecosystems in China, the coastal wetlands in the Yellow River Delta have superior geographical location and ecological environment, which provides favorable conditions for survival of various wetland plants and animals and keeping high biodiversity degree. However, due to vulnerability of wetland ecosystem, frequent occurrence of the Yellow River zero flow, natural disasters like storm tide along the bank of the Yellow River, high degree of development and utilization of wetland, serious environmental pollution, as well as human factors, the wetland ecosystems in the Yellow River Delta are confronted with severe test. In this situation, the study on coastal wetland ecosystems in the Yellow River Delta, especially threats of wetland ecosystems, are of great significance to protection of the wetland ecosystems and comprehensive and healthy development of marine economy and society in Dongying City of Shandong Province.

1 General situations of the coastal wetland ecosystem of the Yellow River Delta

The Yellow River Delta (37°15′ to 38°15′N and 118°5′ to 119°15′E), situated between Bohai Bay and Laizhou Bay, is a sector delta in southwestern coast of Bohai Sea protruding to Bohai Sea. The Yellow River Delta takes Ninghai Town of Kenli County in Dongying City as its top point, starts from estuary of Taoer River in the north, reaches Zimai Channel in the south, covering an area of about 5 400 km^2[1]. Since the divagation of the Yellow River in 1855, it has gradually become the youngest coastal wetland ecosystem with ground forms of fluvial terrace, crevasse splay, slightly flat land, low lying land in rivers and mud flat. Due to diversity of wetland ecological environment, complexity of space structure and nutrition structure of wetland ecological environment, as well as regional difference, there is still no universal and standard wetland classification system. With reference to the wetland classification system stated in *Outline of Investigation on China's Wetland*, Tian Jiayi divided the coastal wetlands in the Yellow River Delta into shallow sea, mud flat wetland, river wetland, lake and reservoir wetland, pond wetland, paddy field and trench wetland, marsh and meadow wetland, and roadside wetland. Much of the existing coastal wetland of the Yellow River Delta was formed within 150 years. At outer fringe of the Delta, the coastal wetland is widely distributed. Along with deepening into the Delta inland, the wetland gradually becomes scarcely distributed. The total area of the coastal wetlands in Yellow River Delta is 747 139.4 hm^2. Except shallow sea wetland, other 8 types of wetland take up 24.45% of the total area of the Yellow River Delta[2]. In these 8 types of wetland, Dongying counties take up about 234 130.8 hm^2, accounting for 29.97% of the total land area of Dongying City[2].

2 Ecological environment of coastal wetlands in the Yellow River Delta

2.1 Climate of coastal wetlands in the Yellow River Delta

The Yellow River Delta is situated at middle latitude of the Northern Hemisphere and has temperate continental monsoon climate.

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Its mean annual temperature is from 12.3 to 12.8 ℃, annual average total radiant quantity is from 515 to 544 kJ · cm − 2, mean annual hours of sunshine are 2 682 hours, its frost-free period is 210 days, its annual precipitation is from 542.3 to 842 mm (mainly in summer, accounting for 63.9% of the whole year), its annual evaporation is 1 962.1 mm, its annual precipitation evaporation ratio is 3.6:1. In spring, the temperature rises rapidly and the evaporation is high, it is burning hot and rainy in summer, the sunshine is abundant in autumn, it is cold and dry with scarce rain and snow in winter[3].

2.2 Hydrological environment of coastal wetland of the Yellow River Delta Since the wetland is the transition zone of land system and open water ecological system, wetland is especially sensitive to changes of its water storage and movement, in other words, it is very sensitive to hydrological changes[4]. At present, 19 rivers including the Yellow River and Xiaoqing River flow through this area; there are three fresh water lakes (Mada Lake, Yazhuang Lake and Qingsha Lake) and reservoirs with storage capacity larger than 100 mllion m^3. These rivers, lakes and reservoirs play significant role in the entire ecological environment of the coastal wetland of the Yellow River Delta.

The Yellow River is the major river flowing through this area, passes through the whole middle part. Within this area, the Yellow River stretch is up to 282 km long. Yellow River has annual discharge of 366 40 million m^3 in this Delta, and annual average sedimentary loading of 921 million tons. Yellow River has abundant water and sand, which is the leading factor for forming and maintaining river system of this area. However, since 1972, Shandong section of the Yellow River dries up in nearly every spring[5], which exerts adverse influence on industrial and agricultural production and people's living standard of the Yellow River Delta. Xiaoqing River takes its rise in Muli Village of Ji'nan Province and injects to Laizhou Bay. The master stream is 237 km long, about 118.6 km flows through this area. The basin area is up to 2 732.3km^2, mainly including Xiaofu River, Shengli River, and Zihe River[2].

Mada Lake, situated in the boundary between Boxing and Huantai counties, is the largest lake of Xiaoqing River system. It consists of Xiaofu River, Wuhe River and Zhulong River, 7 km long from west to east and 4 km wide from north to south, with an area about 17 km^2. Yazhuang Lake is located in Zouping and Zhangqiu counties, functions as a lake for flood detention, and covers an area about 7 km^2. Qingsha Lake is a lake for flood detention, situated in Zouping and Huantai counties and covers an area of 11 km^2. During the period of non flood detention, it is used as grain field.

3 Changes of the coastal wetland ecosystems in the Yellow River Delta

3.1 Changes resulted from natural factors Wetland ecosystem features the plant and animal composition and community structure, landscape pattern in ecological environment, existence form and cycle of carbon, nitrogen and phosphorus, structure and process of chemical and physical elements, and relationship between elements. Changes of wetland ecological characteristics refer to structure, function of ecosystem and changes, weakening or imbalance of ecological process[6]. Changes of wetland ecological characteristics are mainly resulted from natural and human factors[7].

Natural changes of wetland ecological characteristics include vegetation evolution, sedimentation condition, and sedimentation process, *etc*. Ecosystem of the coastal wetland of the Yellow River Delta is very vulnerable. Natural factors influencing ecosystem of the coastal wetland of the Yellow River Delta include drying up of the Yellow River, rise of the sea level, storm surge, and low level of ecosystem development. Since the first drying up in 1972, the Yellow River dries up nearly every year. During 1972 and 2000, it dried up 21 times. The drying up of the Yellow River leads to following consequences: serious shortage of fresh water for human living and biological survival; reduction of crop yield due to lack of fresh water for irrigation and paddy field can not be planted any more; the Yellow River course shrinks, leading to high water level and risk even in small floor peak; wetland degradation; variation of ecological system; loss, migration or even extinction of rare endangered species[8]. The rise of sea level will directly flood large parts of coastal areas, lead to more storm surges and floods, and further deteriorate the wetland ecological environment. The coast of the Yellow River Delta is relatively not stable; shore silting and erosion happen rapidly[9]. When the incoming water and sediment of the Yellow River is high, the Delta will rapidly silt up, and wetland vegetation evolves to seaward wetland; with reduction of incoming water and sediment, major part of the Delta coast will be eroded and accordingly the wetland and vegetation of wetland will have certain degree of landward wetland. In future, the rise of sea level may lead to acceleration of erosion of the Yellow River Delta coast. Frequent storm surges will cause sea water to intrude into inland of the Yellow River Delta, lead to soil salinization of coastal wetland, and influence formation and evolution of vegetation in coastal wetland. Sea water intrusion resulted from storm surges causes wetland vegetation to degrade to bare land or saline vegetation due to soaking of high saltiness sea water[10].

3.2 Changes resulted from human factors Industrial and agricultural production activities including planting, aquaculture and oil exploration lead to significant changes in landscape pattern and ecological functions of coastal wetland of the Yellow River Delta, and severely disrupt the ecological environment of this wetland[11]. Ecological disruption of this coastal wetland is mainly manifested by water pollution, oil field development pollution, unreasonable development and utilization of resources, and invasion of exotic harmful species. Water pollution mainly destroys aquatic organism resources, affects survival of aquatic birds that eat fishes, shrimps, and shellfishes, damages habitat, breeding environment and conditions of birds, and influences bird diversity. Blowout and transmission pipeline leakage due to oil field develop-

ment discharge large volume of crude oil or other pollutants, which seriously reduces regional environmental quality[8].

With population growth and economic development, local residents of the Yellow River Delta have higher and higher demands for natural resources. As a result, there are problems of excessive reclamation of wetland, excessive grazing in wetland, and highly dense breeding, leading to significant changes in landscape pattern and type of the wetland, disruption of living environment of organisms, severely influencing normal survival of species, and bringing about invasion of more than 30 types of harmful species.

4 Protection countermeasures for the coastal wetland ecosystems in the Yellow River Delta

4.1 Establishing and improving policy and management system of wetland protection To strengthen protection and management of the ecosystem in the coastal wetland of the Yellow River Delta, the relevant authorities should gradually establish and improve proper wetland protection policies and legal systems with local characteristics within the frame of overall plan for land and resource utilization and on the basis of laws and regulations at the state level[12]. For example, it is possible to establish ecological compensation regulations for wetland development and utilization, and establish community participation mechanism for wetland protection in the manner of raising funds.

4.2 Carrying out investigation, assessment and monitoring of wetland resources The 3S-based Yellow River coastal wetland ecological environment database and information management system provide scientific basic for wetland utilization and management. On the basis of study of ecological characteristics of this coastal wetland, the ecological environment database and the information management system, we obtained multiple time phase wetland remote sense data, ecological environment element data and basic geographical data, and carried out dynamic monitoring of the coastal wetland of the Yellow River[13-14]. The dynamic monitoring activities include remote sensing and monitoring of time-space evolution characteristics and soil salinization, and the influence of oil field and salt field development on ecological environment of the coastal wetland of the Yellow River, *etc*[15].

4.3 Strengthening comprehensive protection and control of wetland and slowing down wetland degradation It is required to study key factors influencing changes of ecosystem characteristics of coastal wetland of the Yellow River Delta, strengthen comprehensive protection and control, and slow down degradation of coastal wetland of the Yellow River Delta. In recent several decades, the incoming water of the Yellow River has been decreasing mainly because excessive use of water in upstream areas of the Yellow River. Thus, it should strengthen centralized dispatching of water resource of the Yellow River, and ensure sufficient incoming water of the upstream areas. These are key problems to be solved urgently for protection of ecosystem of the coastal wetland of the Yellow River Delta[16].

4.4 Promoting sustainable use of the coastal wetland of the Yellow River Delta Protection of ecosystem of the coastal wetland of the Yellow River Delta should be based on sustainable utilization of its resources. And this needs formulating scientific resource development and utilization plan. For example, it is feasible to develop coastal wetland ecological tourism with the aid of beautiful natural environment and rich animal and plant species in the Yellow River Delta Natural Protection Zone and other wetland areas of the Delta. Through the coastal wetland ecological tourism, it can raise construction fund for the Yellow River Delta Natural Protection Zone, promote development of the natural protection zone, and coordinate the relationship between the protection zone construction and local social development[17].

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