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ISSUES AND COUNTERMEASURES ON MUDFLAT WETLAND PROTECTION IN THE PEARL RIVER ESTUARY

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Abstract: The mudflat wetland of the Pearl River estuary belongs to deposited wetland. It provides a basic condition for essential existence of biological resources in the estuary. Along with the social and economic development of the Pearl River basin, the area of mudflat wetland in the estuary will be continuously reduced. It also faces various crisis and problems that cannot be ignored. The paper puts forward some suggestions on mudflat wetland protection in the view of water and land resources development, utilization and protection of the whole Pearl River basin, so as to protect natural ecology and biodiversity of the estuary and promote harmonious development between people and wetland.

Key words: The Pearl River, Estuary, Mud, Wetland, Protection

1. INTRODUCTION

The estuary of the Pearl River is situated in the central south of Guangdong Province of China. It is 150 km long from north to south and 100 km wide from east to west with water surface area 4,220 km^2 and the mainland water front 450km. It is one of the seven large river estuaries in China. There are 3 rivers converged, 8 river mouths and a network of waterways crisscrossed. It is one of the most complicated estuaries in the world. The coming water and sediment from 453,690 km^2 area of the Pearl River basin flow through the estuary. The sediment continuously deposits and gradually develops and forms mudflat wetland of the estuary under the long-term action of river and marine dynamic forces. The mudflat wetland is an active ecological system. It has kept a great quantity of aquatic organisms and plants according to its ecological superiority. Along with social and economic development of the Pearl River basin, the mudflat wetland of the estuary has faced various unignored crisis and problems. Thus, it is very important to study basic measures for the mudflat wetland protection, people and mudflat wetland existing together in harmonious, social and economic development and ecological environmental protection of the estuary.

2. NATURAL FEATURE AND ECOLOGICAL CHARACTERISTIC

2.1 NATURAL FEATURE

The estuary of the Pearl River is situated in the tropics of South Asia, south of the Tropic of Cancer where is a temperature climate, annual average temperature 22℃, annual accumulated temperature more than 6,000℃ and almost frost-free. The annual average sunshine is 15,554.2 h and annual mean precipitation 1,826 mm, mostly concentrated in the period from April to September.

The estuary is a type of having weak tides but more runoff. It is an irregular half-day tide. The mean annual tide difference is 0.86 – 1.69 m and the maximum 2.29 – 3.64 m. The

estuary is rich in runoff. The average runoff flowing into the sea for years is 326 × 10^9 m^3. The average sediment delivery for years is 85 × 10^6 t, which organic matter and colloid particles are 30.60×10^6 t, being the origin of main matter of the estuary.

The soil of mudflat wetland mainly is water caused salinized slime-swamp soil. It has the following characteristics. The particle is fine, usually is 0.05 – 0.005 mm fine silt or silt fine sand. Nutrient content is high. The total nitrogen content is 0.12% – 0.16%, total phosphorus 0.14% – 0.18%, total potassium 2.00% – 2.80%, organic matter 2.09% – 3.60% and pH value 6.7 – 8.4. The salt content is low, usually is 2‰ – 4‰.

The mudflat wetland has become an important component of ecological system of the Pearl River basin with the combination of such river, marine, favourable climate and fertile beach soil conditions.

2.2 TYPE AND SCALE OF WETLAND

The mudflat wetland of the Pearl River Estuary belongs to silt wetland. The estuary stretches to the sea in about 100km each year. According to the statistics in the beginning of 1980s, the mudflat wetland area of isobath less than 5m is about 380× $10^3$$hm^2$, area of isobath less than 3m is 82 × 10^3 hm^2 and area of isobath less than 2m is 43 × 10^3 hm^2.

2.3 ECOLOGICAL CHARACTERISTIC

2.3.1 Weak Ecological Environment

The mudflat wetland of the Pearl River Estuary is located in the transitional area among ocean, river and land. In the region, the interaction among natural resources, natural environment and human development are the most active, being a typical area of weak ecological environment. Under the crisscross action of marine ecological system and land ecological system, the ecological system of the estuary is easy to be disturbed and effected by natural and artificial factors. The unstability and weakness of ecological system are extremely obvious and the ecological environment of mudflat wetland is notably effected by seasons.

2.3.2 Higher Primary Productivity

The superior natural condition of the estuary is very important to the nutrition structure, biodiversity and substance cycle of ecological system. According to investigation that the content of chlorophyll-a of water surface area of mudflat wetland is in the range 0.90 – 5.80 mg/m^3 and the range of primary productivity is 150 – 580 $mgC/m^2 \cdot d$. The distribution of chlorophyll-a and primary productivity is getting reduced from wetland to the ocean.

2.3.3 Great Change in Biodiversity and Biomass in the seasons

The majority living things of mudflat wetland of the estuary are estuary variety. The average biomass is 300 – 400 g/m^2 and average perching density is 85 – 270 ind/m^2. The biodiversity and biomass of the mudflat wetland are greatly effected by ecological environment in the four seasons. The biomass of phytoplankton, the biomass of zooplankton and nekton are the maximum in summer during a year. Zoobenthon is the maximum in autumn and baby fish in spring. In the meanwhile, mudflat wetland has become a breeding region of various fishes and an important habitat of protected rare aquatic wildlife due to rich biological resources of bait, such as Sousa Chinensis and Acipenser sinensis.

2.3.4 Unique Geographical Environment and Huge Ecological Function in Mangrove

The existing area of mangrove in the estuary of the Pearl River is 1,900 hm^2, mainly including Inner Deep Bay Ramsar Wetland in Hong Kong, Futian mudflat wetland located at Shenzhen Bay, Dawei Bay wetland in Zhuhai and wetland in Qi'ao Island. There are more

than 10 kinds of trees of true mangrove and semi-mangrove, including Kandelia candel, Aegiceras corniculatum and Acanthus ilicifolius, forming a flora by taking Kandelia candel and Aegiceras corniculatum as a dominant kind. The mangrove of the estuary of the Pearl River not only have the functions in removing phosphorus from water, absorbing heavy metal of environment and purifying water, but also is the gathering place of living things of the estuary. There are rich resources of fishes, shrimps, crabs and shellfish under the overlap environment and more than 100 kinds of birds of Ardeidae and Anatidae perching in the mangrove. In addition, the mangrove wetland of the estuary is also an important stop for migratory bird return migrating from Oceania to north Asia. The vast wetland and rich zoobenthon have provided places for them to rest and food to eat. The maximum staying birds in a year is more than 200,000.

3. MAIN PROBLEMS FOR MUDFLAT WETLAND PROTECTION

3.1 CONTINUOUS REDUCTION OF NATURAL MUDFLAT WETLAND AREA

Along with the social and economic development, the sectors of urban construction, port and wharf, industrial and agricultural development and aquaculture continuously occupy the mudflat wetland. According to uncompleted statistics, the natural mudflat wetland of the estuary developed and utilized in 50 years are 60×10^3 hm^2, among which, 19×10^3 hm^2 developed in the period of 1950-1980, 15×10^3 hm^2 in the period of 1981-1989 and 26×10^3 hm^2 in the period of 1990-1999. Among the enclosed wetland, the utilization ratio is as high as to 69%. The reduction of natural mudflat wetland area has caused serious effects to flood control and the capacity for flood-tide inflow and withstanding typhoon and storm surge.

The continuous reduction and destruction of natural mudflat wetland, the mangrove is usually the first to be affected. For an example, the area of Futian mangrove in Shenzhen has been reduced from 304 hm^2 at the beginning of establishment of state protective zone to less than 160 hm^2, the area of mangrove in Zhuhai City reduced from 1,454 hm^2 to less than 110 hm^2. The reduction of mudflat wetland and mangrove of the estuary have greatly affected the ecological function of the estuary, especially affected the sustainable utilization of natural resources of the estuary.

3.2 CONTINUOUS DETERIORATION OF ECOLOGICAL ENVIRONMENT

The Pearl River Estuary is one of estuaries enduring the maximum environmental pressure in China. Since 1980s, the sewage and wastewater flowing into the estuary have continuously increased, ecological environment unceasingly worsened and ecological self-restoration capability weakened gradually. In the last 10 years, the dissolved oxygen at water bottom of mudflat wetland of the estuary is only 1 mg/dm^3 and that has reached to the minimum of zero record in 1996. In 2002, the chemical oxygen demand into the sea via the Pearl River Estuary is 1,154,271 t, phosphate 14,614 t, inorganic nitrogen 437,835 t, heavy metal 3,095 t, arsenic 448 t and petroleum 13,674 t. Owing to continuous increase of pollutant flowing into the estuary, eutrophication of water body has become obviously day by day, aggravated insufficient oxygen at lower part of the sea, weakened self ecological rehabilitation capability and become a fragile zone of water ecology. In addition, it also makes the nearby sea area as a sensitive and red tide frequently-occurring region.

3.3 CONTINUOUS DEGENERATION OF ECOLOGICAL FUNCTION

Due to the development and utilization of natural mudflat wetland in a large scale, it has changed and destroyed water ecological environment of wetland, led to the reduction of biodiversity and living crisis of water ecological population and gradually degraded the functions of ecological system. According to related data that water area of mudflat wetland of the Pearl River Estuary has changed greatly. The variety of winter phytoplankton has

reduced from 158 to 97 and biomass of phytoplankton reduced from 1711 $\times$ 10^4 Ind/m^3 to 100 $\times$ 10^4 Ind/m^3. The variety of summer zooplankton has reduced from 133 to 16 and biomass of zooplankton reduced from 233.9 mg/m^3 to 69 mg/m^3. The reduction of biological species of intertidal zone is obvious. The average biological biomass reduction is from 1,207 g/m^3 to 370 g/m^3 in the intertidal zone. The average perching density reduces from 887.35 Ind/m^3 to 84.78 Ind/m^3. The average perching density of zoobenthon biology reduced from 342 Ind/m^3 to 153.33 Ind/m^3. The annual average biomass and a catch of zooplankton have sharply reduced. A catch of fish has reduced from 251 kg/h in 1983 to 105 kg/h in 1992, reducing by 58%.

3.4 THE SITUATION OF FURTHER WITHERED AND DETERIORATION

While the continuous reduction of natural mudflat wetland area, it also faces further deterioration caused by coming water and sediment from the upper stream of the Pearl River. The temporal and spatial distribution of precipitation of the Pearl River basin is uneven. About 80% of annual rainfall are concentrated in flood season plus the action of tropical cyclone, causing frequent floods. Floods with hyper-concentrated sediment greatly effect deposition of natural mudflat wetland, easily causing continuous deterioration of the wetland where the elevation is higher. In addition, the mudflat wetland of the estuary is facing the crisis of the further withering and deteriorating because of the reduction of sediment delivery and regulated runoff at the estuary. The change of sediment and runoff come from quickening speed of control reservoirs construction in large and medium-size located on the main river, gradually obtained achievements of soil and water conservation ecological building conducted on the upper stream, and dredging works conducted in the lower reaches of the river.

4. ANALYSIS ON MAIN REASONS OF MUDFLAT WETLAND CRISIS

4.1 OVER EXPLOITATION MUDFLAT WETLAND

The estuary region of the Pearl River is one of developed economy and densely populated areas in China. According to statistics, the population of the estuary by the end of 2000 has exceeded 3.6 $\times$ 10^4. The GDP of the estuary region in 2001 is 736.3 $\times$ 10^9 Yuan RMB. The position and rich various natural resources of water, wetland, navigation and aquatic products are always the main motive force of estuary regional economic development. In history, people of the estuary of the Pearl River were used to enclose wetland for enlarging reclamation. The human's intervention and influence on estuary wetland were smaller, destruction and effects of wetland development and utilization and wetland ecological environment of the estuary were not serious because of low productivity. In the last 20 years, the economic development of the estuary region has speeded up, the urbanization development quickened, and infrastructure installations of agricultural reclamation, industrial development zone, port, and wharf like a raging fire. Moreover, the harnessing and management of the estuary are relatively lagging behind in addition to the influence of disordered wetland reclamation. The results are development and utilization of mudflat wetland have been promoted to a higher grade rapidly, and over development and utilization of wetland resources and extremely unbalanced protection of mudflat wetland, and in large mudflat wetland disappeared and area reduced.

4.2 RESOURCES EXPLOITATION AND UNCOORDINATED PROTECTION

The main reasons of development activity of water and land resources of the basin causing withered mudflat wetland are as follows:

The first is the effects of development and utilization of water resources cause withered mudflat wetland of the estuary. The water resources of the Pearl River are relatively rich.

Although the water resources utilization ratio is only about 17%, the total existing storage capacity of the Pearl River is greater than $57 \times 10^9 m^3$, of which, 39 large-sized reservoirs and 339 medium-sized reservoirs. Those reservoirs have changed natural runoff and sediment delivery, being one of important reasons of withered and deteriorated mudflat wetland of the estuary.

The second is the influence of dykes and navigation to the development and utilization of water front of mudflat wetland. At present, the existing dykes in the estuary region are 1,450 km and water front of port and wharf 100 km. The dykes can effectively protect the existing cultivated land and residents. Port and wharf works can play huge economic benefits. But their negative effects are to easily cause withered mudflat wetland and changed biological environment.

The third is severe disordered excavation of sediment resources that caused effects to mudflat wetland of the estuary. In the last 20 years, the development of infrastructure of the basin is rapid and the demand of construction-used sand has caused large activity on taking sand from the river. According to statistics that the annual sand-taking for construction only at the estuary region is $30 \cong 10^6 m^3$. The annual amount of sand-taking is more than 10 times of that of annual sediment delivery of natural bed load. Large quantity sand-taking has reduced the source of sediment of the wetland, causing complicated flow conditions in the estuary, quickened the evolution of wetland and withered mudflat wetland.

4.3 LIMITED CARRYING CAPACITY OF WATER ENVIRONMENT

Along with the rapid social and economic development of the Pearl River basin, the discharge of industrial and agricultural wastewater and domestic sewage are increasing day by day. The annual sewage discharge of the Pearl River basin has increased from 3.9×10^9 t in 1985 to 16.5×10^9 t in 2001, almost 4 times as high as before. In the estuary, it has increased from 1.6×10^9 t in 1985 to 9.5×10^9 t in 2001, almost 6 times as high as before. A huge amount of un-treated wastewater, sewage, oil, nutrient, and organic pollutant flows into the estuary. It has directly lead to the degradation of the capacity of self-purification in the river and the estuary, severe eutrophication of water body and frequent happening of red tides, the decline of carrying capacity in water environment, the decrease in the ecological function of mudflat wetland. In addition, events of boats and ships pollution at the estuary and oil spill on the sea occur from time to time. The leaked crude oil and diesel oil from two oil tankers in 1995 and 1998 were more than 1,500 t, severely polluted mudflat wetland of the estuary and destroyed animals and plants of the wetland and large-area landscape. Experts estimated that environmental damage caused by oil pollution of the oil tanker events would effect the ecological environment of mudflat wetland for 20 years.

4.4 WEAKENED AWARENESS AND MANAGEMENT MEASURES

The public and some management persons have been influenced for a long time by the traditional modes of thought on resources development and utilization. Instead of recognizing and accepting the protection of mudflat wetland resources and multi-function value of mudflat wetland of the estuary, they have become supporters and promoters of irrational development and utilization of mudflat wetland of the estuary. In addition, there is no sufficient an integrated plan, responsibility not clear, administrative duties overlapped and difficult conducting integrated management and management according to laws. The difference understanding on the protection of mudflat wetland has brought about the competition of creating land through filling the mudflat in a large scale in the surrounding areas of the estuary where had not been planned and approved, and the reclamation and occupation wetland water area against regulations. The ecological process of keeping normal

rehabilitation, regeneration and environmental self-purification of mudflat wetland has been destroyed in the estuary.

5. SUGGESTIONS AND COUNTERMEASURES

The estuary is an important component part of the Pearl River basin and ecological system of mudflat wetland of the estuary is an important component of ecological system of the Pearl River basin. It should conduct a study on protection measures of the wetland with a macro visual angle on development, utilization and protection water and land resources of the whole Pearl River basin, the social and economic development status and characteristics of mudflat wetland resources and ecological system of the estuary egion.

5.1 DETERMINING SUSTAINABLE MANAGEMENT TACTICS

The Pearl River estuary region is a flagship of the Pearl River basin economic zone. The economic development will further sharpen the contradictions between protection and development of mudflat wetland of the estuary. It will be very important for social and economic development of the estuary if we can rationally solve the relationship between protection and development of mudflat wetland. Determining tactics of taking protection as the main and adopting appropriate development of mudflat wetland are the requirements for ensuring social and economic sustainable development of the estuary. The tactics include first is to reduce the continuous reduction and withering of mudflat wetland of the estuary under the conditions of the public interest consideration. Second is to rationally develop mudflat wetland where affect flooding and the capacity for flood-tide inflow and scientifically utilize the water front of mudflat wetland under the conditions of ensuring the basic functions of sluicing and the capacity for flood-tide inflow of the estuary. Third is strictly control the development and utilization of mudflat wetland of the estuary, scientifically evaluate and utilize the effects of mudflat wetland and prevent the worsening of ecological environment under the guidance of reasonable protective objectives of mudflat wetland. Fourth is to amplify and improve legal system and strengthen the management of mudflat wetland of the estuary.

5.2 POLISHING MANAGEMENT SYSTEM

The management of the Pearl River Estuary is relatively complicated. Departments of land resources, marine and fishery, communications, water resources and local governments have participated in management. Poly-management has affected and weakened water administrative management according to law. In accordance with arisen problems in estuary and wetland management activities, Ministry of Water Resources and Guangdong Provincial Government have issued “Management Methodology for the Pearl River Estuary” and “Management Rules for Mudflat of Estuaries in Guangdong Province” respectively. Since the implementation of the two laws and regulations, the situation of examination and approval by too many departments, disordered development, mudflat wetland enclosure and occupation has been initially changed. The protection of mudflat wetland of the estuary and ecological system has been strengthened according to responsibilities of different related departments and law.

5.3 WORKING OUT AND IMPLEMENTING COMPREHENSIVE MANAGEMENT PLAN

The comprehensive management plan of the Pearl River estuary is an important component part of an integrated utilization and planning of the river basin. It should work out and implement the comprehensive management plan of the estuary quickly for the benefit of safety sufficient capacity of sluicing and flood-tide inflow, and improvement ecological environment of mudflat wetland. We have to make over plans and take all factors into

consideration including navigation, port and wharf, aquaculture and land resources development, rationally divide functions of mudflat wetland, coordinate regional interests and further protect mudflat wetland resources and ecological environment of the Pearl River Estuary.

5.4 STRENGTHENING WATER POLLUTION MANAGEMENT

The discharge of wastewater and sewage of the Pearl River basin is increasing yearly. While the building of infrastructure for sewage treatment is lagging behind. The water pollution has seriously threatened the ecological environment and ecological system of the estuary. If the total discharge of wastewater and sewage of the basin goes beyond the carrying capacity of water environment and water self-purification capability, the ecological system of mudflat wetland would be destroyed destructively. Thus, it should speed up the implementation of total pollutant discharge control system of the Pearl River basin, strengthen control and management of pollution exists, strengthen infrastructure building for industrial and domestic sewage treatment and prevent worsening ecological environment of the estuary directly caused by severe polluted water.

5.5 ESTABLISHING GUARANTEE MECHANISM

Along with the completion and putting into operation of water resources development projects of Tianshengqiao, Longtan and Baise, the coming water and sediment of the Pearl River basin will be changed greatly. It should fully consider the negative effects on biodiversity and mudflat wetland caused by the above projects. We have to establish in ensuring mechanism of water use for ecology and environment of the Pearl River basin, guarantee the water use for ecology and environment of mudflat wetland and the lower reaches of the river by scientific reservoir regulation and management system. In the meanwhile, it should adopt effective measures to guarantee the fish pass unimpeded.

5.6 STRENTHENING REHABILITATION OF ECOLOGICAL SYSTEM

The continuous degradation of ecological system of mudflat wetland in the Pearl River estuary will severely threaten social and economic sustainable development. It must pay great attention to the rehabilitation of ecological system of the mudflat wetland of the estuary, reestablish ecological environment of harmoniously getting along with people and nature and further protect natural ecology and biodiversity of mudflat wetland. The adopted measures are as follows: (a) To put more fishes and zoobenthos in water and gradually rehabilitate and increase aquatic biology of water economy and baits for aquatic animals' larva. (b) To strengthen the extension and exchange of aquatic biological flow and matter flow of enclosed artificial wetland and natural wetland in the estuary and increase bait source and reproduction space for aquatic biology of the estuary. (c) To create wetland environment for the enclosed wetland and provide habitants for biology. (d) To enlarge the area of mangrove and restore ecological function of natural mangrove. (e) To recover the irrational enclosed wetland into natural wetlands.

5.7 ESTABLISHING PILOT AREAS AND STRENGTHENING PUBLICITY AND EDUCATION

In order to push the protection work of mudflat wetland in the estuary, it should select typical mudflat wetland as a pilot area as soon as possible according to the characteristics of mudflat wetland of the Pearl River estuary. The main functions of the pilot area are as follows: (a) To explore and recover the methods and ways of ecological system of wetland, demonstrate a protection and rational utilization mode of ecological system and provide effective applied and management technology for the sustainable utilization of mudflat wetland resources. (b). To be as a scientific, technical and management training base of

wetland, it should provide high quality human resources for wetland scientific management and rational utilization. (c) To be as a window of publicity and education to the public on increasing the protective awareness of the whole people, it should organize the people of surrounding regions to study the knowledge and skill in wetland protection and rational utilization of wetland resources. (d) To be on show the distinctive ecological landscape and environment of mudflat wetland.

6. CONCLUSIONS

It is shown that study on various unignored crisis and problems of mudflat wetland of the Pearl River Estuary with the viewing from the visual angle of development, utilization and protection of water and land resources of the whole Pearl River basin. In order to further protect the natural ecology and biodiversity of the wetland and make harmonized development and protection of people and mudflat wetland, improvement measures on protection for mudflat wetland are indicated as follows: Firstly, determine sustainable management tactics of taking protection as the main and developing appropriately. Secondly, put the management system of wetland in order, strengthen the protection and management of mudflat wetland according to law. Third, quickly work out and implement the comprehensive management plan of the estuary, rationally divide the functions of mudflat wetland, scientifically utilize the water front. Fourth, strengthen control and management of water pollution of the basin, prevent further deterioration of ecological environment of the estuary. In addition, establish a guaranteed mechanism of water use for ecological environment of the basin, reduce the negative effects of water resources development. Moreover, adopt effective measures for the rehabilitation of ecological system of the wetland. Finally, establish a pilot area for wetland protection, strengthen the publicity and education on mudflat wetland protection to the public.

REFERENCES

Ming H. Wong, 2003, Pollution Ecology and Ecological Restoration (M). Beijing: Science Press.

Dong Zhaoying, 1984, Orientation of Mudflat wetland Resources and Its Development and Utilization of the Pearl River Estuary (A). Administrative Office of Leading Group of Integrated Survey on Coast and Mudflat wetland Resources of Guangdong Province: Collected Works on Integrated Survey and Study of Coastal Area and Mudflat wetland Resources of the Pearl River Estuary (1) (C), Guangzhou: Guangdong Science and Technology Publishing House, pp.75-84.

Guangdong Provincial Bureau of Marine and Aquatic Products, 2003, Guangdong Marine Environmental Quality Bulletin in 2002 (J). Marine and Fishery, No.5, pp.10-13

Luo Zhangren, Zheng Tianxiang, 2000, Port Group in Delta of the Pearl River (M). Nanjing: Hehai Press, pp.26.

Pearl River Conservancy Commission, Ministry of Water Resources, 2002,Water Resources Bulletin of the Pearl River Region in 2001, Pearl River Conservancy Commission, Ministry of Water Resources.