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WETLANDS IN GUANGDONG PROVINCE: FUNCTIONS AND VALUES, USE AND MITIGATION

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Abstract: Wetlands are very special and economically quite important vegetation types in Guangdong, consisting of dike-pond ecosystem, mangrove forest, marsh vegetation and hydrophytic vegetation. Both the area and the quality of the wetlands are decreasing, as a result of social development. The structures of wetlands have been destroyed, and the functions of them have decreased consequently. The above wetlands have special and important contributions to upholding biogeochemical recycle, strengthening coasts to protect fields and villages, regulating environment, purifying environment, conserving biodiversity, providing energy, offering sites for biological research and education as well as tourism, and producing varied social materials and pro-ducts, etc. Since 1950, Guangdong Government has carried into execution a series of measures for protection and management of the wetlands, such as unified planning and management of wetlands, establishment of wetland natural reserves, exploration of rational wetland production modes, pollution prevention and environment protection of wetlands, restoration of wetlands, and establishment of artificial modes and wetland information systems, etc. The application of these measures has achieved to some extent as a reward. However, the effect is not as good as expected. Solving the problem depends on the struggle on two aspects. It is necessary firstly to further study the restoration of the degraded wetlands under the guidance of restoration ecology and follow the distributional and evolutionary laws of wetlands, and secondly to strengthen the collaboration among scientists, government and people in the protection and proper use of wetlands, to establish and strengthen the unified management department to realize the uniform control of wetlands, and to strengthen the studies and educations on wetland protection and exploration by enforcement of some necessary laws or policy.

Key words: wetlands; ecosystem; function; proper management
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1 Generalization

The 1971 Convention on Wetlands of International Importance is based upon the recognition of the ecological importance of wetlands and their economic, cultural, scientific and

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recreational values. It aims to control the world-wide progressive loss of wetland habits and to promote their conservation. Wetlands are defined as areas of marsh, fen, peatland or waters, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine waters with water depth below six meters at low tide[1-3]. Relevant authorities which have participated enthusiastically in Ramsar Convention meetings have identified six Ramsar sites in China's mainland (reconfirmed another site in Hongkong), wetlands of international importance, and have been playing a coordinating role in activities relating to wetland conservation, usage, management, evaluation guideline, mitigation measures, and whenever possible compensation.

1.1 Wetland Benefits

The benefits that wetlands provide to a society include, but are not limited to: water supply; flood control and flow regulation; prevention of saline intrusion to coastal aquifers and coastal water bodies; protection from natural forces through the provision of shoreline and bank erosion protection and windbreaks; sediment, and nutrient retention; source of natural products; energy production; water transport; gene pools; conservation and maintenance of biodiversity; recreation and tourism; socio-cultural significance; research and education; and maintenance of existing processes and natural systems. With world-wide wetlands degradation, the above services that wetlands provide to our society and economy are becoming more and more limited[4].

1.2 Wetland Distribution

Wetlands are very special and economically quite important vegetation types in Guangdong. It consists of dike-pond ecosystems, mangrove forests, marsh vegetation and hydrophytic vegetation. Dike-pond ecosystems constitute significant area in Zhujiang River Delta[5-7]. Mangrove forests distribute discontinuously along the coast of Guangdong Province. The largest area of mangrove forest can be found in the mouth area of Zhujiang River and the surrounding areas of Shenzhen and Hongkong. Newly artificial mangroves have grown quickly in the coastal areas of Zhanjiang and Shenzhen. Marsh vegetation includes: (1) seaside and river mouth marshes that are found in gulf areas of south Guangdong and in the lower mouth areas of Zhujiang River, Hanjiang River and Jianjiang River; (2) lower marshes that distribute in valley of hilly land, platform of sea shore and terrace of river bank in the central part of Guangdong Province and Leizhou Peninsula; and (3) mountain marshes that can be met in the mountain area between Yangjiang city and Yangchun city or in north Guangdong where it is often cloudy, humid, raining and the sunshine period is very short. Hydrophytic vegetation can be found in major rivers, lakes and the areas where ponds dominate.

1.3 Causes of Wetland Loss

The loss and degradation of wetlands is attributed to various factors as a result of social development, such as excessive use of water, over-grazing, fertilizing, vegetation destruction,

urban pollution , industrial contamination , reclamation of natural land , enclosing tideland or lake for cultivation and building reservoir , etc[8]. Among them , the reclamation , enclosing of tideland or lake for cultivation , infrastructure construction , vegetation destruction and environment pollution are the main factors for wetland loss.

1.4 Consequences of Wetland Loss

The loss of wetlands has brought about negative consequences. Firstly , structures of wetlands have been changed greatly , wetlands are disappearing and their biodiversity is decreasing. Secondly , the functions of wetlands are decreasing , especially on the aspects of energy flow and matter cycle , and the productivity has decreased seriously. Thirdly , the natural disasters occur more frequently without the protection of wetlands , the bank can be destroyed easily after the mangrove forest is cut away. Fourthly , the wetland loss influences the further use of wetlands. The environment and shipping will be greatly affected due to wetland loss.

2 Important Functions and Values

The functions of wetlands refer to their capacity of supporting and protecting the processes of natural ecosystems and the welfare of human beings directly or indirectly. This is called the indirect use value of wetlands in economy[9].

The value of wetlands is generally thought to be the value directly produced by the use of its resources , named the direct use value in economy.

The attributes of wetlands include all of their non-functional and non-in-use characteristics , which only offer to those characters that satisfy psychological needs of human beings , and do not provide concrete services and products , for example , culture , historical inheritance , aesthetics and biodiversity.

As to functions , first of all , wetlands support and uphold energy flow , which participates in biogeochemical recycle within ecosystems. And these functions are tightly correlated to physical , chemical and biological processes. A wetland ecosystem is mainly composed of photosynthesizing plants , first-level consumers that feed on plants , carnivorous animals that consume herbivorous ones , omnivorous animals , and decomposer that feed on dead plants and animals. They constitute food chains that are interwoven into a food net where the basic function of wetland and energy flow occurs. Different biological composition is provided with various functions in creating biological resources on different levels. These are important wealth for human activity , social development and cultural history. They are also one part of natural ecosystems for human living. Therefore , the study on structures and functions of wetland ecosystems is basic in sustainable use of this comprehensive resource[9,10].

In addition to the plentiful resources , wetlands provide the function of regulating environment and bringing in environmental benefits. For this reason , they are called "Na-tural Kid-

ney". Wetlands are natural reservoirs, which play an important role in regulating climate, replenishing ground water and reducing environmental pollution. Other functions include regulating river hydrographic net, reserving flood, preventing draught and controlling soil erosion, etc.

Wetlands have higher biodiversities, providing diverse habitats for many plants, animals and microorganisms. They are propagation and winter-through sites for some rare water birds. They are also important gene pools of biological species. Wetlands possess higher biological productivities and can continuously supply food, medicine, energy, water and different industrial raw materials.

Wetlands possess particular landscapes, and are important tourism resources, showing their great potential for developing wetland ecological tourism. Some wetlands are also experimental bases for research and education activities of human beings, and are natural culture inheritances.

In Guangdong Province, coastal mangrove forest ecosystem and dike-pond ecosystem are the major types of wetlands. Marsh vegetation and hydrophytic vegetation with limited areas can be met in some remote regions. Their important functions and values are described as follows.

2.1 Coastal Mangrove Forest Ecosystem

As a major source of coastal productivity and principal part of the ecosystem, mangrove forests are both a strong primary producer and a supplier of energy. They are also an important part regulating the balance of coastal marsh ecosystem. They continuously produce organic matter through photosynthesis that transfers solar energy into chemical energy, supply the consumer and decomposer with necessary substances. Taking the mangrove forest community in Futian, Shenzhen for example, the annual primary productivity of the community is 27.41t $\cdot m^{-2}$, the annual litter mass is 11.49 t $\cdot m^{-2}$, and the leaf litter occupies 73.64 %, showing that mangrove forests have higher productivities and litter amounts than the terrestrial forests and are a type of community having higher productivity and higher return rate[11,12].

Mangrove forests are able to facilitate silting-up, strengthen coast and protect fields and villages. The shadiness of a mangrove forest can reach higher than 90 %, with tightly tied compact canopy. Mangrove forests have a good wave-eliminating effect. The wave-eliminating fraction can reach more than 80 %. Further more, its developed root systems can buffer the current velocity and facilitate silting-up and protect beach. Wave-eliminating, current-buffering and silting-up promoting are three major functions of mangrove forests that help to realize the effect of preventing wind and wave, consolidating mud and sand, and protecting coast and bank. Because of their magnitude in height and breadth, mangrove forests can regulate coastal microclimate[13–15].

Mangrove forests can purify environment and absorb pollutants[12,16]. The soil under mangrove

forests provides sites for growth of mangrove plants, fixation and absorption of inorganic salt and water. There are many kinds of anaerobes, aerobes and other microbes that can decompose litters of mangrove forests, remains of other marine lives and the organic sewage that are drained into the area of mangrove forests. Organic nutrients are released for forests themselves and other lives within forests, realizing the matter conversion, purifying environment and avoiding enrichment of seawater. The soil specific gravity of mangrove forests (0—30cm) is 0.77t·m^{-3}. It contains N 7.8t, P 4.35t and K 18.55t per hectostere, indicating that the nutrient storage is very high. In addition, the soil and plants of mangrove forests can absorb and fix poisons along the food chain and purify the environment. Such mechanism can serve as enlightenment for construction of physical-biological sewage-disposing factory in coastal cities[17,18].

Mangrove forests are sites where many lives dwell, seek food and propagate. Mangrove plants with different growth forms and ecological magnitudes occupy different spaces. The complex layers provide important sites for consumers of different levels to dwell, seek food and propagate. The shallows beneath mangrove forests are ideal sites for fish, shrimps, crabs, shellfish and algae to live and reproduce, and so are considered as natural bases for breeding aquatics[19].

One of the significant ecological functions of mangrove forests is that it is an ideal place for different kinds of birds to dwell, to feed, to reproduce and is also a "gas station" for migratory birds to rest and replenish energy. In mangrove wetlands of Futian, Shenzhen, which is close to Hongkong, there are 189 species of birds, belonging to 18 orders and 44 families. Investigation shows that 60 birds are oriental species among the total 103 palaearctic species, and 26 widespread species; 23 species are rare and 21 belong to the second class[20,21]. Because of deterioration of the ecological environmental quality, the species number and individual amounts of birds are decreasing yearly. It is an effective way to safeguard these valuable birds by protecting this mangrove wetland ecosystem.

Mangrove forests are special marsh ecosystems representing the interim type between terrestrial and marine ecosystems. They differ from both terrestrial forests and marine ecosystems. The embryo germination, sulfur accumulation in plant (0.2%—0.5%) and diverse developed root systems are unique. Mangrove forests combine together the birds, reptiles, benthos and planktons that dwell in them as a whole. Their biodiversity is compared favorably with that of tropical rain forests. They are ideal sites for biological research and education[18].

Because of so many functions mentioned above, mangrove forests possess correspondingly many resources of economical values: fuel, raw materials for paper making industry, tannin, foods, crude drugs, fertilizer, aquatic breeding, tourism, purification of sewage and reduction of pollution.

2.2 Dike-pond Ecosystem

Dike-ponds distribute mainly in the area of Zhujiang River Delta. They are the most classical eco-agricultural engineering modes in China[22]. The components of a dike-pond ecosystem are different kinds of crops (mulberry, or sugar cane, or banana, or flower and plant) and domestic animals/ birds (pig, chicken, or duck) and fishes in pond. The fishes need forage supplied from the dike and the fertility of the dike soil can be maintained by adding pond's silt. Those constitute a sound system structure in which all parts can coordinate well with each other to ensure sustainable development of the ecosystem[23]. Their functions are summarized as follows.

2.2.1 Nutrient Balance Maintenance

The silt from pond bottom is dug and added to the surface of the dike in winter. The silt brings a great amount of organic matter and nutrient with it so that the soil fertility can be well preserved. Whenever it rains, the organic matter and nutrient will return into pond through surface flow, replenishing the fishpond with nutrition again. The crops and animals or birds provide the pond fishes with a plenty of organic foods such as deserted vegetables and excreta. At the same time, planktons in the pond are produced through photosynthesis, which in turn provide forage for the fishes.

2.2.2 Moisture Regulation

The silt brought onto dike contains 25 % water, which can fundamentally meet the need of dike-plants. Even in drought season the roots of dike-crops can get enough water from the pond.

2.2.3 Promotion of Soil Replacement

As the surface soil fraction goes back to the pond along with water flow and sinks to the bottom of the pond, it will, if it is not checked, as a result reduce breeding production, deplete the dissolved oxygen and then affect the fish growth. By laying the silt dug from pond bottom onto the dike, it will not only increase nutrient and water contents of the soil for corps and avoid the eutrophication of pond water, but also promote the soil renewal of both the dike and the pond bottom.

2.2.4 Regulation of Drought and Flooding

The form of a dike-pond system appears as bottomland. The dike is raised so that it is not easy to be flooded. During drought periods the root system can absorb water from the pond through soil capillaries. As the raining season comes, the pond plays an important role in storing up floodwater.

2.2.5 Enhancement of System Stability

Dike-pond systems unite several kinds of lives together in a unit to form a complex network that can enhance stability of the systems. It provides varied products to meet the social needs. It can deal well with the production risk and market risk.

Dike-pond systems are stable croplands with higher production. As estimated, they yield

25 %—50 % more when compared to the other dry croplands. The fish production comes out with 1500 kg·m^{-2} more than average. Unless a catastrophic flood occurs, production reduction will seldom occur in the dike-pond areas[24,25].

2.3 Marsh Vegetation

Plants of marsh vegetation are characterized with developed aerenchyma, asexual abi-lity, many adventitious roots and inset prey. As the marsh vegetation grows, the bog soil and remains of dead plants accumulate, making water shallow and elevating soil surface. As a result, a transitional moist habitat appears, which is an important stage for the community succession from hydro-system to terrestrial system. In addition, there are some ancient species in marsh vegetation, such as *Osmunda japonica* and *Equisetum debile*, which have a very high value in study of systematic evolution[5].

Plants of marsh vegetation are fiber-rich. They can be used both to weave straw mat, hat, bag and other hand-made articles, and as raw materials for papermaking and house construction. Containing plenty of tannin, their fruits can be used as raw material of dyestuff. Some plants are important herb medicines and green fertilizers.

Peat deposited and developed under the marsh vegetation can be used as fuel and organic fertilizer. It can also be used to produce insulating plate and other chemical pro-ducts after processed and refined.

2.4 Hydrophytic Vegetation

Plants in this wetland have relatively undeveloped root systems, intensively abnormal leaves floating on water surface, and a special way of reproduction (flowers are pollinated out of water and fruits under water). Most of them can be used as food, medicine, forage, and green fertilizer. Some plants, such as *Polygonum* spp., *Lemna polyrrhiza*, have the functions of killing destructive insects or driving out mosquitoes[5].

3 Proper Use of Wetlands

Guangdong Government has paid attention to the protection and management of wetlands since 1950. The government has organized several investigations on wetland resources. Furthermore, the government has legislated on proper use of wetland resources, which guide citizens and companies to rationally protect and explore wetlands. In addition, the citizens around wetlands have also explored ways on proper use of wetlands[26,27]. Those practices are briefly introduced as follows.

3.1 To Practice Unified Planning and Leadership on Wetlands

Environmental effects and values of wetlands must be evaluated before the wetlands are explored. Following this law, some wetlands in coastal belt and river mouth have been rationally used since 1980 with the wetlands remaining perfectly protected, as in Enping city and Zhuhai city. The main experience is that the wetlands resources in the city was firstly inves-

tigated to support the making of a detailed plan on proper use of wetlands for agricultural and industrial productions. The government must evaluate the effect of exploration on wetlands before the wetlands are explored. It is very important that only mayors can approve the access of wetlands.

3.2 To Establish Wetland Nature Reserves

There have been about 130 national nature reserves of wetlands in China by 1998. The reserves are distributed all over the country. Some of them are located in frail ecotones or key regions of some bio-resources. The management level of the reserves is different. The establishment of those reserves protects the wetland resources to a certain extent. To enforce the management of those reserves, some wetland reserves have begun to develop eco-tourism, and highlight the sustainable study of society, economy, and ecology of wetland ecosystems.

3.3 To Explore Rational Modes for Wetland Production

The citizens around wetlands had to reclaim land from wetlands to feed more people for the lack of land, and have already explored proper ways of using wetlands since 1909 in Zhujiang River Delta. They have founded dike-pond and other agroforestry modes, which have increased the human welfare and protected the environment at the same time. For example, the citizens earned 1 billion Yuan per year by feeding marine fish in coastal zone in Shantou city, and the farmers in Heshan city earn 0.5 billion Yuan per year by managing agroforestry modes in wetlands. In addition, the wetland modes brought job opportunities.

3.4 To Prevent Pollution and Protect Environment of Wetlands

Generally, the wetlands are drainage canals of wastewater. The wetlands can be easily polluted when the upper areas of a river are explored. As the government of Nan'ao county made rules to control water pollution, most of the wetlands were perfectly protected in 1990s.

3.5 To Establish Artificial Modes and Rehabilitate Wetlands

There are rich aquatic living resources in the wetlands. The farmers and fishermen in Zhanjiang city have simulated the structure of natural wetland ecosystems to recover the productivity of wetlands. As a result, the disappeared crabs and shellfish have re-inhabited the artificial wetlands again, increasing the output value. In addition, the fishermen in Yangjiang city have produced drugs from wetlands to increase benefits.

3.6 To Establish Wetland Information System to Direct Government Practice

Panyu city has established an information system on exploring and protecting wetlands, which is very helpful to direct government's decision-making.

4 Conclusion and Suggestion

Local governments have tried hard to mitigate wetland loss since 1987, and have obtained some good results as a reward. But the situation is still not as good as expected. For exam-

ple, the results of investigation show that the total area of wetland loss was 156 00 hm^2 from 1950 to 1997, of which 101 00 hm^2 were reclaimed during the period from 1950 to 1987, and 55 00 hm^2 were lost from 1988 to 1997. In Shenzhen city, the total area of wetland loss was 9 38 hm^2 from 1950 to 1997, of which 5 84 hm^2 were reclaimed from 1950 to 1987, the other 4 54 hm^2 were lost from 1988 to 1997. The wetlands reclaimed before 1987 were mainly for farming and after 1987 for urban construction.

The solution to the problem depends on the struggle of two aspects: firstly, to extend the restoration study of the degraded wetlands, which needs the guidance of restoration ecology; and secondly, to strength the collaboration among scientists, government and people in the protection and proper use of wetlands.

In the first aspect, the restoration of degraded wetland ecosystems must be under the guidance of restoration ecological principles. Under current situation, the restoration must follow the strip-distribution pattern of wetlands on space scale and natural succession process of wetlands on time scale.

One of the prominent characteristics of mangrove community is its strip-distribution pattern of different constructive species, parallel with the seacoast. The key element of this distribution pattern is tide, for its effect on the distribution of water and salinity. From low tide line to high tide line, water depth and salinity decline, and the species change consequently[28]. The strip-distribution pattern must be followed in the species choice and community reconstruction.

Following the natural succession process, the first step is the reconstruction of pioneer community with proper species. Native species are the first choice for dominant species. At the same time, some aliens, such as *Sonneratia apetala* Buch-Ham, *Avicennia marina* var. *australasica*, and *Sonneratia caseolaris*, etc., have been chosen as pioneer species for the restoration of mangrove forest in Shenzhen city[18], with a good restoration result. In view of ecological safety, the introduction of any alien must pass the safety exam first to avoid harmful intrusion. Following the succession law of wetland ecosystems, the restoration process can be stepped up by human activities. Through proper stand reconstructions, the species belonging to next succession stage can come into the community earlier. Combined with other engineering methods, the succession process can be stepped up considerably to achieve the expected restoration result[29].

In the second aspects, the restoration study and application still need the collaboration of government and people. The local government of Guangdong still needs to strengthen its work in the following aspects: (1) To establish and strength the unified management department so to realize the uniform control of the access of wetlands; (2) To amplify necessary laws and strictly enforce the laws; (3) To investigate and classify the wetlands, making a catalogue and an integrated plan on protection and use of wetlands; (4) To reorganize the reclaimed wetlands and marine projects and protect wetlands; (5) To strength the studies on

wetland protection and exploration; (6) To rehabilitate the destroyed coastal landscape and study the protection and restoration of mangrove forest; (7) To divide the correct county line and establish nature reserves; and (8) To educate and train people to protect wetlands.

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广东省的湿地:功能、价值、利用和湿地丧失的缓解措施

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摘要:广东的湿地生态系统包括基塘系统、红树林、湿生植被和水生植被等 4 种生态系统,是特别而有经济价值的植被类型,这些湿地类型分别在支持生物地化循环、保堤护田护村、调节气候、净化环境、生物多样性保育、提供能源、提供生物学科学教育基地和生态旅游地、生产多样化的社会经济原料和产品等方面有着独特而重要的作用。但随着社会的发展,其面积在减少,质量不断下降。结构破坏直接导致了功能的下降和丧失。自 1950 年起,广东省在其湿地的保护和管理方面陆续实施了统一规划管理、设立自然保护区、开发湿地生产模式、防治湿地污染、保护湿地环境、建设人工湿地、恢复湿地系统、建立湿地信息系统等一系列举措,并取得了一定的收效,但效果仍不理想。要从根本上解决广东湿地的保护和利用问题,一方面要在恢复生态学的指导下深化退化湿地的恢复研究,按照湿地生态系统在空间尺度上的条带分布规律和时间尺度上的演替规律,因地制宜、因时制宜地进行湿地恢复研究;另一方面要进一步加强科研工作者、政府以及民众三者在湿地保护和合理利用方面的合作,建立专门机构,通过法律和行政手段进行统一规划、管理,同时对湿地保育研究、教育给予政策上的倾斜、支持。

关键词:湿地;生态系统;功能;合理利用