SPECIAL TOPIC: Change of Biodiversity Patterns in Coastal Zone

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Sustainable utilization of biological resources from coastal wetlands in China

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The main utilization of biological resources from coastal wetlands in China and the major limiting factors on sustainable utilization of these resources are reviewed. Strategies for the sustainable utilization of coastal wetlands are proposed. These include further studies on saline agriculture and wetland ecosystems, optimizing methods for maximizing metabolic production from organisms, developing microbial resources and efficient utilization of biological genetic resources, and exploiting bioenergy from coastal wetlands.

coastal wetland, biological resources, sustainable utilization

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China is very rich in its coastal wetland resources. Following the implementation of a series of national regional strategies, China's coastal development has expanded at a rapid pace. In recent years, there has been considerable interest in the country's coastal wetlands from an economic standpoint and in terms of sustainable utilization of their biological diversity.

China's coastline extends over a length of 32000 km, of which the mainland coastline accounts for 18000 km, the island coastline for 14000 km, and with coastal wetlands spreading extensively along both these coasts. China's coastal wetlands adjoin four seas, and they encompass 11 coastal provinces, municipalities, and special administrative regions (excluding Taiwan), 53 coastal cities, and 237 counties, cities, and districts; the land surface area amounts to 2.42×10^6 hm^2. These coastline areas are undergoing dynamic change. Wetlands in areas along coasts rich in silt, for example, are rapidly expanding; it is estimated that the area of such coastal wetlands will increase by approximately 20000 hm^2 per year [1–4].

Tidal flats [5] are the coastal zones that are submerged at high tide but exposed at low tide; tidal flats also include the low-lying flood passage lands along rivers, lakes, reservoirs and ponds. Tidal flats include coastal beaches, riverbanks and lakesides; they are composed of silt, mud, sand, gravel, and pebbles. Tidal flats also include tidal mud shallows [5–8]. Tidal flats are essential for water conservation and purity, for protecting banks and reducing disaster loss, and for maintaining a local ecological balance. They also serve as buffer zones that allow adaptation to environmental changes.

Coastal wetlands are rich in biological resources, including genetic resources, individual organisms, and ecosystems that have practical and potential application values. These wetlands include plants, animals, and microorganisms, which provide important resources for human survival and development. Tidal flats provide the raw materials for clothing, food, building materials, fuels, and medicines; they offer materials for scientific research into coastal wetland protection, biology, genetics, and ecology. Furthermore, coastal wetlands have a distinctive aesthetic value; they can generate tourist interest and as good ecological environ-

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ments present opportunities for environmental greening [9].

1 Main uses of biological resources in coastal wetlands

The abundant coastal wetlands in China have been used for several thousand years and presently are being used in increasingly innovative ways. Current applications of these tidal flats are described in the following sections.

1.1 Coastal wetland aquaculture

At present, 2.42×10^6 hm^2 of China's coastal wetlands are available for aquaculture; of this area, 893700 hm^2 are already being used for that purpose. China was the first country in the world to introduce marine culture, and over the last 30 years its total output in marine culture has increased 29-fold. In 2009, China's marine culture amounted to an annual yield of 939000 tons of fish, 1102000 tons of crustaceans, 11398000 tons of shellfish, and 1549000 tons of seaweed. In terms of marine culture, China has the highest yield in the world, accounting for approximately 70% of the total global output. At present, China is the only country where the yield from marine culture exceeds that from marine fishing [1].

1.2 Coastal wetland cultivation

Coastal wetlands that have not been reclaimed are mainly used for cultivation and processing of reeds, *Suaeda* and laver. Newly reclaimed coastal wetlands have been mainly developed for cultivation and processing of economic saline plants, such as American ryegrass, *Helianthus tuberosus*, *Lycium chinense*, *Kosteletzkya virginica*, oil sunflowers, *Atriplex triangularis*, *Suaeda*, and *Salicornia bigelovii*. Coastal wetlands that were reclaimed a number of years ago are generally used for growing such crops as barley, sugar sorghum, cotton, rice and oilseed rape. Different intercropping methods have been developed, such as with barley-watermelon-cotton, barley-garlic-cotton and *Metasequoia glyptostroboides*-horse bean-watermelon. These methods yield good economic and ecological benefits [10–12].

1.3 Deep processing of coastal wetland resources

Deep processing of biological resources in coastal wetlands extends the conventional breeding and cultivation industrial chains. The development of marine medicine using biological resources in coastal wetlands is a promising way of generating innovative health products, biological and medical materials, and functional foods. In China, many marine health products including *duoxikang* (compound 25 EPA), squalene and tetrodotoxin have been approved for use, and additional drugs are currently undergoing clinical study. In addition to health products, such products as sea cucumber peptide nutrient capsule, spirulina capsule, chitin, and tachypleus amebocyte lysate (TAL) are made. In 2009, 67 different kinds of marine health products were being produced in China. The output value of these products has increased every year and now amounts to over US$5 billion (Figure 1) [1].

1.4 Coastal wetland protection

Having tropical, subtropical, and temperate zones, China is rich in biological resources and species. China is the northern limit of some tropical species and the southern limit of some temperate ones. Because China's coastal wetland biological diversity and biological resources are facing the dual threats of excessive human activities and global climate change, the Chinese government has implemented a series of policies and rules to better protect its coastal biological resources. China has established 33 national marine nature reserves with an area of about 1.86×10^6 hm^2 (Table 1), 21 national special marine reserves with an area of 275000 hm^2 (Table 2), and 7 national marine parks with an area of over 90000 hm^2 (Table 3).

In addition to these national reserves, special reserves and marine parks, there are 26 provincial reserves on the Chinese mainland; 12 coastal reserves in Taiwan; 4 coastal parks, 1 coastal reserve, and 1 Ramsar wetland in Hong Kong; and the Cotai ecological reserve in Macao. Many scientific and protection studies are currently being conducted in these national and local coastal reserves. In addition, opportunities for sightseeing and tourism are being developed in these areas, demonstrating the usefulness of such coastal biological resources.

1.5 Biological silt promotion

With the accelerated progress of industrialization, the Chinese government has reclaimed many coastal wetlands for the purpose of silt promotion. Silt-promoting methods include engineering promotion and biological promotion.

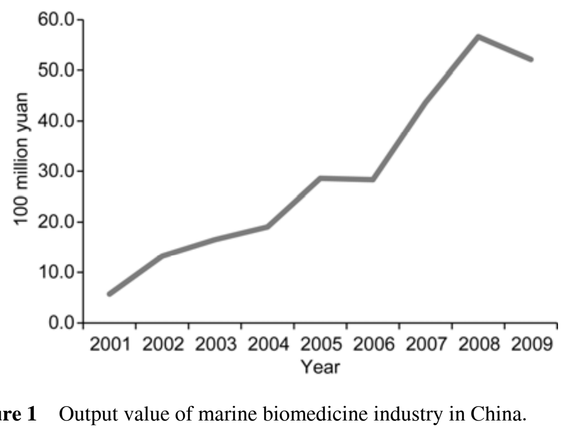

Figure 1 Output value of marine biomedicine industry in China.

Table 1 National marine nature reserves of China

Number	Name	Area (hm^2)
1	Yalujiangkou Coastal Marsh National Nature Reserve in Dandong	101000.00
2	Shedao—Laotieshan National Nature Reserve (Shedao: Snake Island)	14595.00
3	Shuangtaihekou National Nature Reserve (or Shuangtai Estuary)	128000.00
4	Dalian Spotted Seal National Nature Reserve (Phoca largha)	672275.00
5	Chengshantou Coastal Geomorphy National Nature Reserve	1350.00
6	Changli Gold Coast National Nature Reserve	30000.00
7	Palaeocoast and Wetland National Nature Reserve	35913.00
8	Binzhou Shell-Dyke Island and Marsh National Nature Reserve	43541.54
9	Rongcheng Swan National Nature Reserve	10500.00
10	Changdao National Nature Reserve	5015.2
11	Huanghe Sanjiaozhou National Nature Reserve (or Yellow River Delta)	153000.00
12	Yancheng Coastal Mudflat and Precious Fowl National Nature Reserve	284179.00
13	Dafeng Père David's Deer National Nature Reserve (Elaphurus davidianus)	2667.00
14	Chongming Dongtan Bird National Nature Reserve (or Chongming East Tidalflat)	24155.00
15	Jiuduansha Wetland National Nature Reserve	42020.00
16	Nanji Liedao Marine National Nature Reserve (or Nanji Isles)	20106.00
17	Shenhuwan Ancient Submarine Forest Relic National Nature Reserve	3100.00
18	Xiamen Precious and Rare Marine Species National Nature Reserve	39000.00
19	Zhangjiangkou Mangrove Forest National Nature Reserve	2360.00
20	Gangkou Sea Turtle National Nature Reserve in Huidong	1800.00
21	Neilingdingdao-Futian National Nature Reserve	921.64
22	Zhanjiang Mangrove Forest National Nature Reserve	20279.00
23	Zhujiangkou Chinese White Dolphin National Nature Reserve (Sousa chinensis)	46000.00
24	Xuwen Coral Reef National Nature Reserve	14378.00
25	Leizhou Precious and Rare Marine Species National Nature Reserve	46865.00
26	Shankou Mangrove Ecosystem National Nature Reserve	8000.00
27	Dugong National Nature Reserve between Yingpan Port-Yingluo Port of Hepu (Dugong dugong)	35000.00
28	Beilunhekou National Nature Reserve (or Beilun Estuary)	3000.00
29	Mangrove National Nature Reserve in Dongzhai	3337.00
30	Dazhoudao Marine Ecosystem National Nature Reserve	7000.00
31	Sanya Coral Reef National Nature Reserve	5568.00
32	Tongguling National Nature Reserve	4400.00
33	Xiangyajiushan Liedao National Nature Reserve	48478.00
Total		1857803.38

Table 2 National marine special reserves of China

Number	Name	Area (hm^2)
1	Mulishan-Mulijiao National Marine Special Reserve, Leqing, Haimen	1222.90
2	Ximen Isle National Marine Special Reserve, Leqing	3080.00
3	Ma'an Isles National Marine Special Reserve, Chengsi	54900.00
4	Zhongjieshan Isles National Marine Special Reserve, Putuo	20290.00
5	Yushan Isles National Marine Special Reserve, Zhejiang	5700.00
6	National Marine Special Reserve, Changyi	2929.28
7	Huanghekou National Marine Special Reserve, Dongying	92600.00
8	Lijin benthonic Fish National Marine Special Reserve, Dongying	9404.00
9	Estuary Seashell National Marine Special Reserve, Dongying	39623.00
10	Laizhouwan Mussel National Marine Special Reserve, Dongying	21024.00
11	Guangrao clamworm National Marine Special Reserve, Dongying	8282.00
12	National Marine Special Reserve, wendong	518.77
13	Huanghekou National Marine Special Reserve, Longkou	2168.89
14	Zhifudao National Marine Special Reserve, Yantai	769.72
15	Liugongdao National Marine Special Reserve, Weihe	1187.79
16	Tadao Bay Seacology National Marine Special Reserve, Rushan	1097.15
17	Sandy Coast National Marine Special Reserve, Muping	1465.20
18	Coastal wetland National Marine Special Reserve, Wulonghekou	1219.10
19	Wanmi Beach Marine Resources National Marine Special Reserve, Haiyang	1513.47
20	Xiaoshidao isle National Marine Special Reserve, Weihai	3069.00
21	Dabijiashan National Marine Special Reserve, Jinzhou	3240.00
Total		275304.27

Table 3 National ocean parks of China

Number	Name	Area (hm^2)
1	Hailing isle National Ocean Park,Guangdong	1927.26
2	Techeng Isle National Ocean Park,Guangdong	1893.20
3	Maowei National Ocean Park,Qinzhou	3482.70
4	Xiamen National Ocean Park	2487.00
5	Haizhou Bay National Ocean Park,Lianyungang	51455.00
6	Liugong Island National Ocean Park	3828.00
7	Rizhao National Ocean Park,Rizhao	27327.00
Total		93400.16

Biological silt promotion mainly uses the plants grown on high-tide beaches, such as *Scirpus triqueter* and reeds, to block waves and promote silt deposition. It has been observed that a reed beach with a height of 3 m can promote silt by an average of 1.8 mm/d. Where conditions are not suitable for reed growth, *Spartina alterniflora* (an invasive alien species in China) usually grows, and this exerts a great effect on farmland reclamation, wave reduction and bank protection, silt promotion, and soil improvement.

2 Main factors limiting sustainable use of China's biological resources in coastal wetlands

2.1 Environmental pollution

China's offshore marine ecosystems are deteriorating owing to the introduction of pollutants carried by rivers into the sea, and the drainage of terrigenous sewage into these areas. During the period of the Eleventh Five-Year Plan, pollutants carried by the main rivers—the Yangtze, the Pearl River, and the Qiantang and Minjiang rivers—rose to a total annual average amount of over 1×10^{-7} t. CODCr, ammonia nitrogen, and phosphorus in polluted water from drainage outlets constitute the main components in this regard. From observations in estuaries, gulfs, coastal wetlands, wetlands, mangroves, coral reefs, and seaweed beds in marine ecological monitoring regions (which account for a total area of 64000 km^2), it has been observed that healthy, sub-healthy, and unhealthy states accounted for 14%, 76% and 10%, respectively, of the area in 2010; the corresponding data for 2009 were 24%, 52%, and 24%. Over the last 5 years, it has been recorded that the area with water quality worse than grade 4 was greatest in 2010 at 48030 km^2.

In 2010, the results from monitoring in 66 marine breeding regions in China revealed that the proportions of their comprehensive environmental quality that were excellent, good, and acceptable were 55%, 30%, and 15%, respectively. The content of inorganic nitrogen and active phosphate in some breeding regions were high, and the eutrophication in these regions was serious. The content of chromium, copper, and fecal coliform bacteria was also high.

The shallow coastal wetland and wetland biological communities in northern Jiangsu were generally in a poor state, with lower population densities of plankton, spawning fish, and young fish. The biological diversity indexes of bottom-living organisms and plankton living in the intertidal zones of coastal wetlands and wetlands have undergone no obvious changes over the last 5 years. Red-crowned cranes, which winter in the wetlands of Yancheng, Jiangsu, showed an annual decrease in number, being reduced to 200 birds in 2010 compared with the number reported for 2006 [1,11,12].

If the pollution is not controlled at its source, the resulting sustainability of these biological resources will continue to deteriorate.

2.2 Rising sea level

Over the last 30 years, China's coastal sea level has increased by an average rate of 2.6 mm per year, which is greater than the global average. From 2000 to 2010, the coastal sea level in China was the highest in history—25 mm higher than in the 1990s [13].

In 2010, the coastal sea level was 67 mm higher than in an average year and was approximately the same as in 2009. These rising sea levels have been attributed to various factors, including climate change. The coastal sea levels in China have changed in line with clear regional and time characteristics. The levels of both the Bohai Sea (in February) and the Yellow Sea (in October) in 2010 were the highest they have been over the past 30 years (for those respective months). If the sea level were to rise by 0.5 m, 24% to 34% of the coastal wetlands would disappear. If the sea level were to rise by 1 m, 44% to 56% of coastal wetlands would disappear, converting tidal areas into subtidal zones [14].

2.3 Alien species invasion

The introduction of exotic species may be beneficial, but in some cases these species can become invasive and cause a decrease in biological diversity. China has introduced 89 coastal wetland and marine animal and 93 plant species from foreign countries, of which kelp, bay scallops (*Argopecten irradians*), and *Sciaenops ocellatus* have become major cultivated or breeding species. The plant *Casuarina* *equisetifolia* has become a main windbreak forest species. Sesame, potato and cotton have been cultivated in reclaimed coastal wetlands. Among the recently introduced species, *Spartina alterniflora* and *Mytilopsis sallei* are examples of ones that have harmed coastal wetlands. *Spartina alterniflora,* which covers 8000 hm^2 coastal wetlands in eastern Fujian, damages mangroves, drives away coastal wetland crustaceans and mollusks, and destroys the coastal wetland ecological environment. Historically, mud snails were absent from the coastal wetlands of Laizhou Bay, but following their introduction in 2001 they swiftly spread and increased their biomass. This resulted in the replacement of the dominant *Umbonium thomasi* (a local species of snail) and *Mactra veneriformis* by mud snails, leading to a noticeable decrease in their population densities. In early 1990s, *Mytilopsis sallei* was introduced to Maluan Bay, Xiamen, as feed for fish and shrimps. However, after its introduction, *Mytilopsis sallei* reproduced in large quantities, causing serious detrimental effects on the aquaculture in the bay.

3 Strategies for sustainable utilization of biological resources in coastal wetlands

3.1 Increased research on saline agriculture

To make better use of the distinctive coastal wetlands and their resources, research into saline agriculture should go beyond the developmental style of coastal wetland reclamation, improvement, and recycling [15,16]. We need to improve the varieties of animals and plants used in coastal wetland agriculture so as to lay the foundation for sustainable utilization of biological resources in such coastal areas. Meanwhile, it is necessary to reinforce efforts toward disease prevention and treatment of coastal wetland resources to ensure the sustainable development of saline agriculture.

3.2 Development and application of metabolites of coastal wetland organisms

It is important to promote research into the metabolites of coastal wetland organisms and conduct such studies on healthy, functional, oriented, high-quality products to improve the sustainable utilization of coastal wetland organisms. We should support longitudinal medical studies on metabolites, improve intensive processing techniques, and develop biological extraction technologies that meet international standards for screening and the application of metabolites.

3.3 Increased research into coastal wetland ecosystem

National ecosystem observation stations need to be established, with a special focus on long-term monitoring of existing state-level wetland nature reserves to provide the technical basis for the development of coastal wetlands. Studies on the structure and function of the coastal ecosystem and ecological restructuring need to be carried out to determine the following: the roles of saline soil agriculture and aquaculture in the ecosystem; ways to establish sustainable coastal ecosystems; and the interactive network among biological, physical, chemical, and biogeochemical factors for the resulting biological output. Such studies will help develop the agricultural industry in coastal areas.

3.4 Development of coastal wetland microbial resources and efficient utilization of genetic resources

It is necessary to conduct the sampling, registration, and collection of coastal wetland microbial resources, promote research efforts into determining the functional genes of coastal wetland microbes, and investigate the development of their secondary metabolites, enzymes and other active substances.

3.5 Development and utilization of coastal wetland biological energy

The advantage of cultivating coastal wetland saline plants is that they do not occupy space within mainland fields. Furthermore, using coastal wetlands as bioreactors for biological gas and liquid fuel can help counter the energy crisis.

Coastal wetland resources are distinctive land reserves in China, and their biological resources possess unique natural characteristics. Maintaining a balance of protection and utilization by implementing scientific programs will allow the development of coastal wetlands in a way that is harmonious with human development. Taking advantage of the biological resources in coastal wetlands in a sustainable manner will make a contribution to both nature and society in China.

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