

STRATEGY ON PROTECTION AND MANAGEMENT OF COASTAL ECOSYSTEMS IN CHINA

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Abstract

This paper describes the variety of marine biotic resources in China, deals mostly with some problems relating to protection and management of coastal marine ecosystems. Authors presented the background relating to international coastal marine ecosystem researching, and situation on marine biodiversity and bioresources utilization, as well as environmental status in coastal region. The efforts of the Chinese Government in conservation of the coastal bioresources are reviewed. Protection regulations and management steps of coastal ecosystems in China are described.

Key words : Coastal ecosystems, protection, management, China

The seas and oceans are the treasure house of living resources that are the important sources of protein for human beings. It is known that there are more than 200 thousand species of organisms in the world oceans, of which, about 19 thousand species are fishes and about 20 thousand crustaceans. Many marine organisms are of value for the development and utilization and provide human beings with rich food and resources for many other purposes such as extraction of medicines. The marine living resources contribute annually 22 percent of animal protein for the world. Coastal communities in the world rely on marine living resources for protein and cash income. The world ocean fishery were caught lands annually about 80-90 million tons of fishes and shellfishes, of which 95 per cent comes from the water under national jurisdiction, namely the 200 nautical miles exclusive economic zone and the waters over the continental shelf (SOA, China Ocean Agenda 21, 1996, China Ocean Press, Beijing). Human activities including fishery production are carried out mostly in the coastal waters. It is estimated that 25% of biological productivity and 90% of activities for fishes and other bioresources in the world are exploited in the coastal waters. Marine ecological damages due to overfishing and environmental pollution have resulted in decreasing biodiversity, declining commercial fishery resources and lower capacity for sustainable social and economic development. Population boom, resource depletion and environmental pollution have been exercising, more and more impacts on the seas and oceans, especially in the coastal waters.

Aquatic resources are generally under a state of crisis in the world as estimated by FAO since (Elliott, 1993). More than 45% of fisheries resources in the world seas and oceans are being overfished or at a stage of recovery from overfishing. Furthermore, harmful algal bloom events have increased in the past decades, bringing significant impacts not only on the ecosystems but also human health. This implies the development of new strategies to adapt production and consumption patterns to ensuring harmonization with the environment and to develop ecosystem-based management approaches are important, "Agenda 21" developed in the World Summit in 1992 calls on the coastal states to develop integrated coastal zone management. In the past decades, the scientific community in the world has made positive response to these challenges. Observations of coastal ecosystems and study of marine bioresources have become hotspots worldwide. Many international programs and projects including OSLR, LME, GLOBEC, LOICZ, JGOFS have been launched to address coastal ecosystems and bioresources.

Since the 1970's, the COMAR has promoted the research and the administration on coral reef, mangrove, coastal lagoon, estuary, seagrass bed and beach, especially the researches in the coastal shallow waters all over the world (Elliott, 1993). The project aims at making rational use of coastal resource and improving coastal management. Through the COMAR, the UNESCO and other international agencies have founded some regional inter-regional and international cooperation networks on coastal research (Elliott, 1993). In Asia scientists from twenty countries cooperated in the study and management of mangroves and set up the "International society for mangrove ecosystem" (Huang, 1998). In the Antilles area, ten island countries have developed a united program of coastal management, especially of coastal erosion with the technical support by Puerto Rico University. In South America, Argentina, Brazil, Chile, Peru and Uruguay an integrated management project developed the researches of the coastal ecosystem in the Temperate Zone (Elliott, 1993).

As a large developing coastal country, it is necessary to take the exploitation and protection of oceans as a longterm strategic task. In 1996, the Chinese government developed its sustainable ocean development strategy in China's Ocean Agenda 21(SOA, 1996). The contents include sustainable development the ocean and coastal areas, sustainable development of islands, conservation and sustainable utilization of marine living resources, integrated management of coastal areas and national jurisdictional waters, marine environmental protection and others.

1. Marine biodiversity and bioresources utilization

It is estimated that the number of species of life on the earth varies from five million to thirty million. Of these, 1.4 million species have been recorded up to present (Shen et al, 1990). About 200 thousand species are founded in the oceans, less than that on land. It is well known that diversity at higher taxonomic levels (Phyla and Classes) is much greater in the sea than on land or in freshwater : 34 Phyla and 73 classes in the marine environment compared with 15 Phyla and 33 classes on land (Briggs, 1994). In addition, many biological taxa are only found in marine ecosystems. Changes of marine biodiversity vary are obviously with regions, showing two geographical features and distribution steps : (1) Except Asteroidea (starfish) and Macrocystis, many marine organisms groups such as seagrass, coral, shellfish, shrimp, crab and fish, have counterparts on land. The species diversity in tropical zone is much higher than that in colder zones. For example, species in South China Sea is much richer than that in East China Sea, Yellow Sea and Bohai Sea. (2) In the tropical zone, species diversity of many organisms in the India-West Pacific Ocean, especially in the waters among the Philippines, Indonesia and east Australia (including the southern waters of South China Sea), may be with the highest value (Elliott, 1993).

By following the "The Convention of Biological Diversity" which was developed in the UNCED in 1992. China developed in 1994 by cooperation with UNDP "The Action Plan for Protecting Biodiversity in China" in more than two years of development (CWGE, 1994). A series of conservation objectives, measurements and action plans have been developed in this plan, which has become a soft law in China for taking actions to conserve biological diversity on land and in the sea. A committee of biodiversity conservation in China came

into exists in 1994. Forty-eight Conservation waters of marine species are designed and with the total area of 3,260,000 ha. One of them has been designated a member of the International Biosphere Protective Web under the Human and Biosphere Program of UNESCO. Of these, 15 Conservation Regions are protected at national level with the area of 3,100,000 (Chen, 1998). In the other hand, 'Fishery Law' and "The laws for aquatic Resources Propagation" have been decreed by the Chinese Government, by which sanctuary zones and closed season, as well regulations controlling fishing gear were formulated for relevant waters and fishing grounds. For example, the inlet of Daya Bay prohibited for shrimp fishing, and closed seasons from March to September are enforced to promote shrimp propagation. Another example is the establishment of a closed season for the fish, *Pseusiaena polyactis*, from June to September in the Yellow Sea from March to May in the South China Sea.

In the area of international cooperation, China has signed agreements with Japan and Australia for the protection of migrating birds and their habitats. In 9 bird banding stations along the Chinese coast 62,775 birds of 186 species have been banded and more than 400 birds, with longest flying distance of nearly 10 thousand km, have been recovered. Recently, UNDP, WB and NOAA have help China formulate such plans as "Plan for Biodiversity Protection in China" and "Action Plan for Protection of Large Marine Ecosystems in the Yellow Sea".

China is a big coastal nation located along the west Pacific Ocean, with 12 provinces and cities along the coast. There are Bohai Sea, Yellow Sea, East China Sea and South China Sea. Marine ecosystems in China are diverse and rich in living resources. However, there still exists a contradiction between population and resources, environment and development. China has taken many measures, with results, for the conservation of marine living resources. Covering warm temperature, subtropical and tropical zones, China's seas cross 38 divisions of latitude. Three million km³ of sea area, including a broad continental shelf and complex currents, such as the Kuroshi and the currents along the coast, are under the administration of China. China has 18,000km of coastline with more than 1,500 rivers such as the Changjiang and the Pearl River. Comprehensive biotopes and ecosystems support habitable conditions for species diversity (Huang, 1993). In China, 820 thousand km² fishing ground have been exploited. The area of shallow waters and intertidal zone is about 13 million-hectare (ha). According to science level at present, the waters of 2.6 million ha are used for mariculture, of them 938 thousand ha have been exploited (Huang, 2000). Coastal and shallow sea resources in some coastal provinces and cities in China are given in Table 1. China's seas also have some typical regional species as well as a great number of temperate and warm water species. The number of species increases from the north to the south. The South China Sea is the biggest sea in China, and with the richest biological species. For instance, of more than 2,500 fishes so far identified, there are only 300 species in the Yellow Sea, 1,000 in the East China Sea, but more than 1,500 in the South China Sea (Huang, 1994a). It is also one of important large marine ecosystems in the world. More than 20 thousand species are recorded in China Seas. Of them, 13.86 thousand species are founded in the South China Sea (Table 2) (Huang, 1994), some belonging to special groups. It was estimated that about 4.9 million tons of fish production could be landed from the South China Sea. The total capture production in three provinces along South China is more than 3 million tons at present (Table 3), and the mariculture production up to 2 million tons (Table 4), accounting for 30% of the total fishery production in China (Table 5). The coast of China is

Table 1 Coastal and shallow sea resources of the provinces and cities along the China coast

| Province | Length of mainland line (km) | Area of shallow sea (km ²) | Area of tidal zone (km ²) |
|-----------|------------------------------|--|---------------------------------------|
| Liaoning | 1,971.5 | 7,723.6 | 1,974.2 |
| Hebei | 421.0 | 2,610.0 | 1,167.9 |
| Tianjin | 153.0 | 1,593.3 | 370.3 |
| Shandong | 3,122.0 | 8,219.4 | 3,223.6 |
| Jiangshu | 953.0 | 10,121.6 | 5,090.4 |
| Shanghai | 172.0 | 5,453.5 | 904.2 |
| Zhejiang | 1,840.0 | 7,598.3 | 2,444.0 |
| Fujian | 3,051.0 | 3,970.0 | 2,069.0 |
| Guangdong | 3,368.1 | 10,586.2 | 2,041.9 |
| Guangxi | 1,083.0 | 2,596.6 | 1,005.3 |
| Hainan | 1,617.8 | 2,177.5 | 488.5 |

Table 2 The number of marine organisms recorded from South China Sea

| Kingdon | Phylum | Species | Kindom | Phyla | Species | |
|----------|-------------------|--------------|----------|-----------------|----------------|-------|
| Monera | Bacteria | 46 | Animalia | Porifera** | 71 | |
| | Actinobacteria | 17 | | Coelenterata** | 679 | |
| | Cyanobacteria | 106 | | Ctenophora* | 6 | |
| | Chloroxybacteria | 1 | | Platyhelminthes | 247 | |
| Protista | Bacillariophyta | 1,290 | | Nemertea** | 33 | |
| | Chrysophyta | 14 | | Nematoda | 9 | |
| | Xanthophyta | 2 | | Annelida | 584 | |
| | Pyrrophyta | 185 | | Sipuncula* | 33 | |
| | Ciliophora | 94 | | Mollusca | 2,002 | |
| | Sarcomastigophora | 2,067 | | Arthropoda | 2,380 | |
| | Fungi | Fungi | | 109 | Bryozoa** | 348 |
| Plantae | Algae | Rhodophyta | | 271 | Entoprocta** | 7 |
| | | Phaeophyta | | 84 | Chaetognatha* | 30 |
| | | Chlorophyta | | 142 | Echinodermata* | 380 |
| | Tracheo-phyta | Pteridophyta | | 11 | Urochordata | 110 |
| | | Gymnospermae | | 2 | Chordata | 2,171 |
| | | Angiospermae | 314 | Others | 13 | |
| Total | | 3,860 | | | | |

Table 3 Changes of total capture fishery production in Guangdong, Guangxi and Hainan provinces in China

Unit : ten thousand tons

| Year | Capture fishery production | Year | Capture fishery production |
|------|----------------------------|------|----------------------------|
| 1989 | 147.24 | 1994 | 260.09 |
| 1990 | 161.47 | 1995 | 237.74 |
| 1991 | 178.80 | 1996 | 318.24 |
| 1992 | 206.79 | | |

Table 4 Mariculture area and production in Guangdong, Guangxi and Hainan

| Year | Production (ton) | | | Area (ha) | | |
|------|------------------|---------|--------|-----------|---------|--------|
| | Guangdong | Guangxi | Hainan | Guangdong | Guangxi | Hainan |
| 1989 | 121,487 | 2,081 | 3,628 | 89,471 | 5,173 | 3,706 |
| 1990 | 137,919 | 3,348 | 4,204 | 92,351 | 5,433 | 3,713 |
| 1991 | 159,207 | 11,919 | 5,199 | 92,750 | 8,690 | 3,790 |
| 1992 | 175,664 | 23,725 | 7,371 | 93,290 | 14,560 | 3,990 |
| 1994 | 242,224 | 75,364 | 16,474 | 105,710 | 29,900 | 5,790 |
| 1995 | 357,950 | 147,514 | 14,773 | 116,150 | 41,000 | 6,930 |
| 1996 | 1,345,590 | 531,331 | 22,050 | 138,523 | 48,436 | 7,594 |

Table 5 Comparison of marine capture and culture production in China

| Year | Capture production | Culture production | Total |
|-------|--------------------|--------------------|-------|
| 1990 | 551 | 162 | 713 |
| 1992 | 691 | 242 | 933 |
| 1993 | 767 | 309 | 1,076 |
| 1994 | 896 | 346 | 1,242 |
| 1995 | 1,027 | 412 | 1,439 |
| 1998 | 1,497 | 860 | 2,357 |
| 2000* | 860 | 650 | 1,510 |

Unit : ten thousand tons. * The data in 2000 is estimated.

also a way-station for more than 200 species of migrants (Huang, 1994a), The living resources of China are an important component of marine source of food, industry and medicine.

The major problems in the marine fishery activities include the artificial alteration of resource structure of offshore commercial fishes due to overfishing and the decrease of fishery commercial value, this is the most significant cause of the decline in marine living resources. For example, the fishes *Pseudosciaena crocea*, *P. Polyactis*, *Trichurus huamela* and the squid *Speiella maindroni* were for a long time important catches for the Chinese fishing industry. Because of overfishing, such resources have declined since 1970's. The valuable *P. crocea* is no longer a fishery (Chu et al, 1997). In recent years, more than 7,000,000 ha of beaches and mudflats in China have been enclosed for land or cultivation. In contrast to the existing 20,000 ha of mangroves, it is estimated that more than 50,000 ha were growing in the 1950's. For coral reefs 80% have been destroyed along the 400km coastline of Hainan Island (Huang, 1993). The deterioration of water quality due to pollution and offshore movement of larval and spawning grounds and the alteration of population structure in some important mariculture areas and coastal and estuarine spawning grounds. The serious damages to typical marine ecosystems due to construction for marine and coastal engineering such as land reclamation and urbanization and the reduction of biodiversity have caused effects at different degrees on human health. The problems existing in marine living resources and marine ecosystems have affected the sustainable ocean development. The Chinese government has attached great attention to the conservation of marine biological resources. Series of measures such as pollution discharge control and closed fishing seasons and areas were adopted to enhance the protection and management of the coastal ecological environment and bio-resources.

In order to prevent the degradation of marine ecosystems and to maintain the sustainable utilization of the resources, it is imperative to reinforce the protection of the biological species and ecological environments. To establish marine protected areas and conservation zone of certain scale and quantity for the formation of regional and international networks of marine protected areas in a planned way and to protect marine biodiversity by taking proper measures ; to improve and perfect various effective technical measures of development and utilization for the rational utilization of commercial fishes ; to improve the legal systems for the conservation of marine living resources and for the reinforcement of the management in biological resource development and utilization ; to reinforce the regional and international cooperation for the maintenance of the marine ecosystems in a favorable state so as to form the international cooperation mechanisms for the conservation, research and management of the marine ecosystems.

2.Environment status in coastal sea

The monitored results showed that the change of inorganic nitrogen level was obvious in various sea areas (Qi et al., 2000). The highest values occurred in the East China Sea, with average of 1000 $\mu\text{g} \cdot \text{L}^{-1}$, followed by the South China Sea, with an average of 300 $\mu\text{g} \cdot \text{L}^{-1}$. The lowest appeared in the Bohai Sea and Yellow Sea, with an average level of 200 $\mu\text{g} \cdot \text{L}^{-1}$ Compared the nutrient level in some representative estuaries and bays, the highest values occurred in Changjiang estuary and Hangzhou Bay. The values in Laizhou Bay and the coastal waters along western Guangdong Province were lower (below 200 $\mu\text{g} \cdot \text{L}^{-1}$). The highest level of inorganic phosphorus occurred in Bohai Sea, the higher was in East China Sea, and the lowest in South China Sea. The results indicated that phosphate value in Hangzhou Bay was much higher than in other bays and estuaries. The lowest was in Daya Bay and Xiamen Bay (below 10 $\mu\text{g} \cdot \text{L}^{-1}$). Which showed that the water quality conditions in South China Sea (including Daya Bay) is better than others.

Based on data monitored at past 10 years, nutrient quality indexes were calculated with the eutrophication equation (Qi et al., 2000). The results indicated that the nutrient quality indexes (NQi) and phosphate quality indexes (PQi) for some areas along China seas in 90's

Table 6 Nutrient quality index (NQI) of most areas along the China seas in 90's

| Year | Liaodong Bay | Bohai Bay | Jiao-zhou Bay | Chang-jian Estuary | Hang-zhou Bay | Coastal area along Guangdong province | Pearl River Estuary | Beibu Bay | Coastal sea along Hainan Island |
|------|--------------|-----------|---------------|--------------------|---------------|---------------------------------------|---------------------|-----------|---------------------------------|
| 1990 | 2.25 | 2.49 | 3.82 | 1.82 | 2.89 | | 3.72 | | 1.66 |
| 1991 | 2.63 | 2.33 | 2.54 | 4.50 | 6.11 | 0.73 | 7.35 | | 2.68 |
| 1992 | 2.87 | | 2.84 | 3.73 | 4.72 | | 3.17 | | |
| 1993 | 2.38 | | 2.96 | 3.59 | 5.21 | | 3.65 | 2.09 | |
| 1994 | 2.58 | 1.71 | 3.08 | 3.88 | 5.07 | 2.43 | 3.96 | 1.42 | 1.69 |
| 1995 | 2.81 | 1.71 | 3.51 | 4.15 | 5.37 | 2.23 | 3.82 | 1.30 | 1.39 |
| 1996 | 2.77 | 2.86 | 2.00 | 5.35 | 5.37 | | 3.09 | | |
| 1997 | 2.83 | 4.40 | 3.15 | 5.41 | 5.54 | 1.88 | 3.87 | | |
| 1998 | 2.81 | 3.12 | 3.13 | 4.53 | 5.13 | 1.83 | 4.51 | 1.49 | 1.65 |
| Mean | 2.71 | 2.66 | 3.00 | 4.11 | 5.05 | 1.82 | 4.13 | 1.58 | 1.81 |

Table 7 Phosphate quality index (PQI) in most areas along the China seas in 90's

| Year | Liao-dong Bay | Bohai Bay | Jiaozhou Bay | Changjian Estuary | Hang zhou Bay | Coastal area along Guangdong province | Pearl River Estuary | Beibu Bay | Coastal sea along Hainan Island |
|------|---------------|-----------|--------------|-------------------|---------------|---------------------------------------|---------------------|-----------|---------------------------------|
| 1990 | 0.52 | 0.40 | 3.78 | 1.19 | 3.15 | | 1.32 | | 0.65 |
| 1991 | 0.98 | 1.03 | 2.00 | 1.80 | 5.48 | | 1.40 | | 1.10 |
| 1992 | 2.00 | | 1.70 | 1.40 | 1.93 | | 1.05 | | |
| 1993 | 1.10 | | 1.70 | 1.40 | 2.48 | | 1.20 | 0.50 | |
| 1994 | 1.40 | .75 | 1.52 | 1.50 | 2.74 | 0.74 | 1.27 | 0.32 | 0.78 |
| 1995 | 1.07 | 0.66 | 2.08 | 1.77 | 2.67 | 0.50 | 1.84 | 0.24 | 0.37 |
| 1996 | 1.00 | 0.89 | 0.84 | 1.55 | 2.60 | 0.34 | 0.69 | | |
| 1997 | 2.29 | 4.18 | 1.86 | 2.04 | 2.81 | 0.57 | 1.39 | | |
| 1998 | 1.80 | 0.93 | 1.33 | 2.60 | 3.33 | 0.53 | 1.60 | 0.40 | 0.53 |
| Mean | 1.35 | 1.26 | 1.87 | 1.69 | 3.02 | 0.54 | 1.31 | 0.37 | 0.69 |

were different from one to another (Table 6-7). Nutrient index in Hangzhou Bay, Changjiang estuary and Zhuangjiang (Pearl River) estuary were higher than in other sea regions, and up to eutrophication level. Meanwhile, there is a trend of annual increase. Much attention should be paid to environmental problems.

More and more attention has been paid to the ecosystems and biological resources in the estuaries in the world (Konx, 1986 ; Chu, 1995 ; Zhang, 1997, 1998). Phytoplankton, especially the red tide species and its bloom has become an important part of research in the estuarine ecosystem and biological resources. The Pearl River is one of the three big rivers of China, its dilution flow quantity through estuary into South China Sea reaches about $3 \times 10^9 \text{ m}^3$ (Han et al.1991 ; Huang et al., 1997). There are metropolitans such as Hong Kong, Macao, Shenzhen and Zhuhai locating along both sides of Pearl River estuary, Guangzhou and other cities to its north. Rapid economic growth and multiple human activities tend to increase pressure on the environment in the Pearl River estuary. In the past 20 years, environmental conditions, ecosystems and biological resources of the Pearl River estuary were broadly investigated for exploitation and protection. Many research results showed that the chlorophyll-a values varying with season and area, having a negative correlation with phosphorus. Besides, biodiversity and production in the estuary decreased with environmental changes from human impacts (Chan et al. 1987, Huang et al. 1995, 1997, Wang 1989). The variation of successions of population structure in different seasons were obvious because of changes of fresh-water quantity inflow that affects dilution, temperature, salinity and nutrient in the estuarine region. But the dominant population of phytoplankton in the same season was a little different to its annual variation (such as summer). In the Changjiang estuary where species composition of phytoplankton belonging to estuarine ecological types (Gu et al. 1995), low salinity species from coastal waters become the main part of communities. Phytoplankton biomass in the rainy seasons was far higher than that in the dry seasons. They considered that seasonal and yearly changes of the Changjiang's dilution were more important factors in determining changes of phytoplankton abundance. Similar features of phytoplankton composition, dominant species and change trend were found in the Pearl River estuary. Phytoplankton were mainly dominated by *Skeletonema costatum* and *Nitzschia pungens* in both estuarine zones in summer. Though the composition of dominant phytoplankton species in the Pearl River estuary varied with different years, the red tide organism *Skeletonema costatum* was always dominant and with the highest abundance, and became more and more the most dominant species (Table 8). This trend means that there are higher risks of red tide events and calls for higher attention. According to records, red tides occurred 20 times in the 1970's, but 300 times in the 1990's. It is obvious that various reasons can induce a red tide event, but more and more red tide events nowadays has revealed its close relationship to human activities such as irrational aquaculture development and higher pollution input. Red tides problem in the coastal waters in China has received wide concern and a large numbers of researches have been carried out. Why the red tide events due to *Skeletonema costatum* have outburst more and more frequently? What factors stimulate a red tidal bloom? What are the relationships to other biological species? These questions need to be answered through researches as soon as possible.

Main zooplankton dominant species of Pearl River estuary in summer were *Acartia spinicauda*, *Paracalanus crassirostris*, *Oithona rigida* and *Paracalculus aculeatus*. The results indicated that zooplankton abundance was correlated with phytoplankton. The variation trend of zooplankton gut pigment contents was coincided with chlorophyll a level in the water column (Tan et al., 2000). It provide insight on problems such as the red tide mechanism.

Of the phytoplankton samples collected in the cruise of summer 1999, 41 species of red tide organisms were found. Based on data reported, there were 472 times of red tide recorded in Hong Kong waters from 1975-1996, of these 38 times were brought about by *Skeletonema costatum*. The species usually dominated in the waters according to the previous survey, with maximum reaching 6.5×10^5

Table 8 Annual variations in phytoplankton composition and abundance in the Pearl River estuary in summer

| Year | Total species | Average amount (cells L ⁻¹) | Main dominant species |
|------|---------------|---|--|
| 1981 | 132 | 2.1 × 10 ⁴ | Chaetoceros pseudocurvisetus Chaet. lorenzianus Chaet. affinis Skeletonema costatum |
| 1987 | | 1.6 × 10 ⁵ | Chaetoceros affinis Skeletonema costatum Nitzschia pungens |
| 1996 | 116 | 1.1 × 10 ⁵ | Nitzschia delicatissima Skeletonema costatum Chaet. Pseudocurvisetus |
| 1999 | 130 | 6.3 × 10 ⁵ | Skeletonema costatum Nitzschia pungens Nitz. delicatissima Asterionella japonica |

cells/L and accounting for 97.6% of the total amount, especially in Victoria Harbor of Hong Kong during summer 1996 (Huang, 1997). The results investigated in the cruise indicated that dominant species was *Skeletonema costatum*, with an average of 2.8×10^5 cells/L and accounting for 45.0% of the total amount. It is a euryhaline and eurythermal species, and can quickly grow under eutrophic conditions. Most of other dominant species were also red tidal organisms. This is an environmental problem that should receive attention for the protection of the Pearl River estuary and Hong Kong waters.

3. Species conservation and monitoring network

Sanctuary zones and closed seasons as well regulations controlling fishing gear were formulated for relevant waters and fishing ground. Since 1979, 24 sites for artificial fish reefs have been identified in the coastal waters of China and 28,000 reefs and 99,137 m³ rocks have been laid out. The construction of fish reefs has attracted fishes and improved the ecological environment. More than 20 species of marine organisms are designated to be protected species such as *Cypraea (Cypraea) tigris*, *Cassis cornuta*, *Tridacna (Dinodacna) cookiana*, *Pin. maxima*, *Haliotis gigantea discus*, *Panulirus spp.*, *Tachypleus tridentatus*, *Thelenota ananas*, *Macrura reevesii*, *Pagrosomus major*, *Epinephelus subsp.*, *Chelonia mydas*, *Phoca canina*, *Chinese Polphin*, *Coilia ectenes*, *Bahaba flavolabiata* and *Chlamys farreri*. From the beginning of 70's, much attention has been paid to marine environmental monitoring in China to develop monitoring system of water, air and biological communities. About 20 annals of environmental quality about Chinese coastal waters and 40 annals of sea regions were published by the government and relevant agencies during recent 30 years. More than 60 marine environment and marine pollution monitoring stations have been set up (Huang, 1993; Xu, 1989). Such as Jiaozhou Bay Station, Daya Bay Station and Sanya Station established for the ecological observation by the Chinese Academy Sciences, in addition to many hydrological observation stations established by State Oceanic Administration. The network of monitoring stations has provided powerful service to strengthen marine environmental development, management and protection. Besides, about 20 natural protection zones have been established by the Chinese government, mainly in the representative coral reef waters and mangrove swamps (Table 9).

Table 9 A part of natural conservation regions in South China Sea

| Name of protect region | Locate position | Area (km ²) | Main protect target |
|---|---------------------------|-------------------------|---|
| Neilingding Island-Futian | Shenzhen, Guangdong | 870 | Mangrove, Rhesus monkey, bird |
| Gangkou Huidong turtle | Huidong, Guangdong | 800 | Turtle and their space of reproduction |
| Shankou mangrove ecology | Hepu, Guangxi | 4,000 | Mangrove ecosystem |
| Sanya coral reef | Sanya and Wanning, Hainan | 6,000 | Coral reef ecosystem |
| Dazhou Island marine ecology | Wanning, Hainan | 7,000 | Esculent swift and island ecosystem |
| Dongzaigang | Qionghsan, Hainan | 2,500 | Mangrove and their habitat |
| Weizhou Island coral reef and coastal landscape | Beihai, Guangxi | 8,000 | Coral reef ecosystem and varied marine bioresources |
| Dongsha Islands coral reef ecosystem | Dongsha Islands | 10,000 | Coral reef ecosystem |

4. Coral reef ecosystem

It is well known that the ecosystems of coral reef and mangrove are of high productivity and high biodiversity (Zou et al., 1996; Huang, 1998), and of high value in housing commercial species and sightseeing. These ecosystems are of significant importance for aquaculture and biodiversity conservation as breeding place for various organisms. It is worldwide phenomena that coral reef bleached by greenhouse effect recently. More and more damages from human activities on coral reef have been recorded. The coral reef and mangrove ecosystem had played important roles in local fishery and economic development. Decay of the coral reef was found by human activities and overuse e.g. the area of coral reef around Hainan, Xisha and Nansha islands, the area of mangrove in South China coast were reduced and ecosystems suffered from destroy. Consequentially, a tendency of coastal environment degenerating, marine resources declining took place, and coastline erosion accelerates.

Coral reef is an important ecosystem among the global marine ecosystems (Clive, 2000). Productive capacity in the coral reef area is much higher than the open sea. In the reef area, with a great number of reef-building organisms (corals, crustacean, mollusk, echinoderm, fishes, algae, etc.), coral reefs contribute to maintaining higher level of biodiversity. Coral reef is listed as a higher priority ecosystem for protection in 1980 in the World Conservation Strategy. At present, the "Global Coral Reef Monitoring Network" is playing an active role in reef monitoring and protection all over the world. In China, the central government has considered the coral reef research as a priority in the "9th Five Year Science and Technology Plan" and "China's Ocean Agenda 21" (Munoz-Chagin, 1997; Tracy, 1997). Coral reef in China is mostly distributed in the South China Sea. It is located at the northernmost part of the Indo-Pacific reef area and represents an important part of this area. In 1990, the central government of China approved the setting up of Sanya National Coral Reef Reserve; the reef resources and marine biodiversity in the Reserve have been protected successfully since then. The revised version of the "Marine

Environment Protection Law" stresses on the conservation of coral reefs. At the provincial level, Hainan's authorities approved the "Regulations Concerning the Conservation of Coral Reefs in Hainan" in 1998 (Yu et al, 1996). The laws and regulations have laid down a strong base for reef protection in the area. Nowadays, great attention is paid and great need is felt for building up an integrated marine environmental information system, to enhance efficiently in the coastal conservation and management, and in assessing, exchanging and disseminating actual information on the coral reef environment in Southern China.

Much efforts of management have been exercised by the Chinese government to protect the coastal ecosystems. First, laws and regulations have been promulgated to keep coral reefs and mangroves from being destroyed by enhancing public awareness on the importance of these typical ecosystems to sustainable development; secondly, more financial resources are used for scientific research on coral reefs and mangroves. In the mean time, much attention has been paid to biodiversity research and marine resource information collection. It is a long-term scientific research to restore the coral reefs and mangrove ecosystems. A lot of experiments have been done for different objectives such as for fisheries, power station pollution, in case of coastline erosion, over development, sightseeing construction and even on thorny starfish that feeds on corals.

4. Estuarine ecosystem

There are three big rivers in China, including Yellow River, Changjiang and Zhijiang (Pearl River). The Pearl River estuary is typical large subtropical estuary in China; it is reported that significant changes with the characteristic listed as follows have taken place on the environment, ecology and community composition. (1) Due to 8 branches influx to the Pearl River Estuary and its natural topography, the estuary can be divided into several kinds of ecosystems such as river mouth, island and islets, mangrove and intertidal, frontal ecosystems. The biodiversity in these ecosystems have a common tendency of decline. (2) The changed environment and overfishing caused by natural impacts and anthropologic activities have over-taken or reduced the fish production, particularly the catch rate of the commercial species in the Wanshan fishing ground, the largest fishing ground in the estuary. The fishes landed tend to be younger and smaller than the past. Most of the fishes landed are of shorter food chain species. The species-richness of *Penaeus orientalis* has diminished. The quantity of some commercial species of fish larva decreased. (3) Affected by the organic matter deposited in the sediment and influx of sea water, the seasonal low DO zone were determined in some parts of the estuary, especially in the bottom along the two side of the estuary. (4) The habitat of Chinese White Dolphin moved from South China coastal waters to only the waters around in the Nei Lingding in the Pearl River Estuary and with the tendency of number decline. The Chinese Dolphin is listed as the highest priority on the list of mammals under state protection (Huang and Liu, 2000). Several cooperative researches on Chinese White Dolphin between Guangdong Ocean and Fishery Department and Hong Kong had been carried out. The region from the west of Lantau Islands to Nei Lingding has designated as a conservation area for protecting Chinese White Dolphin. (5) With increasing population boom and industry development, the disposal of municipal sewage, industrial effluents and agricultural runoff has increased. Eutrophication caused by nitrogen and phosphorus loading in the Pearl River estuary, and the re-suspension of trace metals from the sediments have induced frequent algal blooms and red tide events in South China coastal waters, with occasional massive fish kills due to severe dissolved oxygen (DO) depletion or toxic red tides (Hodgkiss, 1995; Qi et al., 2000; Yin et al., 1999). For example, the red tide event occurred through March to April in 1998 extended from the coastal waters from the east of Pearl River Estuary-Hong Kong water area, Dapeng Bay, Guishan Islands to Yangjiang. The economic losses amounted to hundreds of million of RMB (Guangzhou Daily, 1998). Research on the environment and organism resources in the Pearl River Estuary has a significant importance either for the objectives of geology, estuarine type or economy. We should put much emphasis on the ecosystem and marine resources researches in the Pearl River Estuary to maintain its biodiversity and the sustainable utilization of resources.

5. Protection regulations and management measures

In order to protect and manage coastal ecosystems in an effective way, a series of marine environmental protection policies or laws and regulations have been established based on "Environment Protection Law of China", "Fishery Law of China", "Wildlifes Protection Law of China", "Aquatic Product Breed Protection Statute", "The laws for aquatic Resources Propagation" and "Fishery Water Quality Standard". The regulations related to oceans are listed mostly as follows:

- a. "National Marine Environmental Protection Law of P. R. China", Revised in Dec.1999
- b. "Regulations Concerning the Management of Marine Standardization", Jan. 1997
- c. "Regulations Concerning the Management of Marine Natural Protection Zone", May 1995
- d. "Provisional Regulations Concerning the Management of Sea Area Use", May 1993
- e. "Regulations Concerning the Dumping of Waste at Sea of P. R. China", Sept.1990
- f. "Regulations Concerning Environmental Protection in Offshore Oil Exploration and Exploitation of P. R. China". Sept.1990

Relevant water quality and discharge standards have also been established. Monitoring protocols, standard methods, intercalibration samples, quality control and quality assurance systems and EIA system for marine environment and ecology have been established and perfected, which has reached international level. Monitoring instruments have been improved. Human resources for high quality monitoring have been developed. All these assure environmental monitoring quality.

The measures to protect coastal ecosystems are as following:

- (1) A series environment protection laws and regulations and rules have been established and put into effect. Development of management system and human resources. Central government and local governments coordinate in the management system. Enhancement of public awareness for environment protection and ecological conservation.
- (2) Increasing national financial input to marine science and technology researches, and promoting the development of marine sciences and technology. Improving monitoring technique of marine environment and ecology. Developing auto-monitoring technique of coastal environment and ecology, ocean buoy technique, under water detecting technique, aviation and remote sensing technique. To realize 3-dimensional monitoring system of marine environment and ecology.
- (3) Scientific planning, and development of marine functional zonation scheme. The study of environmental capacity in different regions, and the control of total pollutants discharge and load. Control and manage the discharge of land-based pollutants according to marine environmental capacity.
- (4) Rectifying monitoring scheme more reasonably by giving more attention to monitoring residual toxins in marine organisms and geology monitoring, and attach importance to the research of new organic pollutants in medium.
- (5) Modernizing marine environment monitor, information transportation and management system. Establishing and perfecting the three systems such as information transformation, environmental quality information management and marine pollution source as soon as possible.
- (6) In the view of the international character of marine environment, expanding international cooperation and communion actively.

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