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Protection and Development of Tropical Biological Coasts

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Abstract: Tropical biological coasts are ecologically critical areas with high concentration of biological activities, which is of special value to the biodiversity and resource productivity of coastal zones. The rapid environmental fluctuation and increased human activities in the Anthropocene have endangered the ecological security and sustainable development of the coastal zones. This study mainly focused on the research progress and ecological risks of biological coasts, and we proposed some suggestions for their protection and management. Our suggestions include: reinforcing national strategic planning to save energy, reducing emissions, strictly controlling exploitation, and giving priority to protection, thereby maintaining and enhancing natural resilience; improving the monitoring network while conducting comprehensive surveys; promoting scientific management and establishing large offshore marine protected areas; and strengthening scientific research and personnel training. The national strategy of building maritime power along with the implementation of island and reef engineering projects in the South China Sea provides unprecedented opportunities for study the coral reefs in China.
Keywords: biological coasts; coral reefs; mangroves; ecologically critical areas; Anthropocene

1 Introduction

Coasts can usually be divided according to the dominant factors that shape them and according to their composition. Among different coast types, biological coasts include large benthic communities growing in the intertidal zone or in subtidal shallow water, and their biological processes significantly affect coastal development, sometimes even being the dominant factor in it [1]. Coral reef coasts and mangrove coasts are two typical types of tropical biological coasts. The study of biological coasts emphasizes the two-way interaction between dynamic coastal geomorphic and biological processes, and this discipline is called coastal biogeomorphology [2]. Biogeomorphic processes are one of the main response mechanisms of coastal ecosystems to global changes [3]. The special habitat environments of tropical biological coasts are often ecologically critical coastal areas with high concentration of various biological activities, which is of great value for maintaining the biodiversity and resource productivity of coastal zones [4]. This zone has very important ecosystem service functions, including high coastal biodiversity, high resource productivity, coastal erosion resistance and stability, coastal environment purification, and beautification [5]. The coastal zone is also confronted with the Anthropocene's rapid variation in the global environment and continuous increase in human activities, which poses a great threat to the ecological security and sustainable development of the coastal zone. Coral reefs, especially offshore coral islands and reefs of the tropical

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biological coasts, are particularly closely related to the maritime territory, maritime rights protection, and building maritime power, which has attracted special attention.

2 Status and characteristics of the world's typical tropical biological coasts

2.1 Status and characteristics of the world's coral reef coasts

Coral reefs coasts are highland submarine structures with wave resistance formed by the combination of *in situ* formation of carbonate skeleton from reef-building coral communities and various types of bioclasts filling and cementation [6]. They are the largest structures on Earth formed solely from plants and animals, and many of them are clearly visible from space. The primary productivity of coral reef ecosystems are very high, they have the most active calcification process of any ecosystem on Earth, and their total annual production is estimated at 9.29×10^9 t of $CaCO_3$ [7]. They have very high biodiversity and are often referred to as marine rainforests. The three widely recognized coral reef regions, where the water temperature in winter is always above than 18 ℃, include the Indo-Pacific region, wider Caribbean region, and the Red Sea [8]. As we are entering the new era of Anthropocene, the coastal zone faces the dual influence of population density (and consequent increase in developmental activities) and global environmental change, which is accelerating. Thus, global degradation of coral reefs is becoming increasingly significant, and this situation is becoming more severe each year [9,10]. Since 1970s, coral reef bleaching has become a common and serious problem [11], and the level of disturbance in coral reefs has gradually changed from low (mostly discontinuous and incidental disturbances) to high (continuous disturbances), and the balance between destructive and restorative forces has been disrupted [12]. Consequently, the live coral cover has declined by 40% in the Indo-Pacific area, and by 50%–53% in the Great Barrier Reef and the western Atlantic area [13]. Since 1998, series assessment reports have been published by the Global Coral Reef Monitoring Network (GCRMN) and the World Resources Institute (WRI). GCRMN has reported that as a consequence of global climate change, the share of medium and highly destructed coral reefs in total world coral reef area had reached 54% in 2008 [14], and WRI has reported that the share of medium and highly threatened coral reefs in total world coral reef area has reached 61%–75% in 2011 [15]. The coral reefs were already in a global decline, with Australia being the least and Southeast Asia the most affected by global climate change [10].

The Great Barrier Reef (GBR) is the largest coral reef ecosystem in the world. The GBR Marine Park was established in 1975 and has an area of 344 400 km^2, and its 2900 reefs and more than 900 reef islands extend over 2600 km. It has been the largest and best-managed coral reef protection area in the world for a relatively long time. It was added to the World Natural Heritage List in 1981. In 2004, the Australian parliament expanded the no-take area (NTA) of the GBR from 5%, as determined in 1981, to 33% [9]. In 2005, the Australian Research Council (ARC) established the center of excellence for coral reef studies (CoECRS) in order to conduct comprehensive research on coral reef management and sustainable use. Nevertheless, based on historical data analysis, Bellwood et al. [16] believed that the average live coral cover of the GBR has decreased from 40% to 20% in the past 40 years. De'ath et al. [17] analyzed the monitoring data from 2258 surveys of 214 coral reefs and found that the average live coral cover decreased from 28.0% in 1985 to 13.8% in 2012, as well as that tropical cyclones, coral predation by crown-of-thorns starfish (COTS), and coral bleaching accounted for 48%, 42%, and 10% of the estimated losses, respectively. United Nation World Heritage Committee (WHC) warned in 2012 that the GBR was under threat from coral reef decline, and they proposed new plans for coastal development and port dredging, drawing widespread attention from the government and scientific community. The Australian government's AUD 100 million worth "GBR 2050 protection plan" promises to improve water quality, ban dredger dumping, and restrict coastal port development. The plan was approved by WHC in 2015, and the decision was made not to list the GBR as an endangered heritage site. During the third global coral bleaching event from 2015 to 2016, Terry P. Hughes, the director of the Australian CoECRS, personally monitored the bleaching situation on the GBR by plane, which was widely covered by the media. In December 2016, he was named one of the "Ten people who mattered this year" by Nature and awarded the title of "coral reef sentinel" [18].

2.2 Status and characteristics of the world's mangrove coasts

Mangroves are characterized by dense salt-tolerant evergreen trees or shrubs growing on tidal flats above the mean sea level [19]. The global mangrove area does not exceed 180 000 km^2, representing less than 2% of the world's tropical forest resources [20]. South and Southeast Asia account for 41.5% of the total mangrove area, and Indonesia accounts for 23% [20]. The largest continuous mangrove area is the Sundarbans, located in the upper

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Bay of Bengal, on the delta of the Ganges, and covering more than 6000 km^2. As clearly shown by recent world satellite surveys, conversions of mangroves to aquaculture, to agriculture, and urban development areas are the main causes of mangrove destruction [20,21]. Since 1950, nearly 50% of the world's mangrove forests have disappeared as a consequence of inadequate ecological protection and large-scale land use conversion [22]. If the rate of mangrove loss (1%–2%) from 1980 to 2000 continues in the future, the entire mangrove community may disappear in the next 100 years [23]. The Indian Ocean tsunami event in 2004 and *The Blue Carbon Report* in 2008 became watersheds for the recognition of the importance of mangroves for coastal protection and climate change mitigation and adaptation, and from this moment, mangrove restoration projects gained international attention and broad support [24]. Today, most of the 70 mangrove countries are implementing recovery plans [20]. However, with the exception of projects whose main goal is timber production, other projects have generally been unsuccessful [25]. But the rate of mangrove loss is decreasing obviously. According to recent statistics obtained by remote sensing, the average annual loss rate of mangrove areas in the world in the period from 2000 to 2012 was about 0.16%, an order of magnitude lower than the loss rate in the period from 1980 to 2000 [26].

3 Status and characteristics of China's tropical biological coasts

3.1 The status and characteristics of China's coral reef coasts

China's coral reefs include two types, fringing reefs and atolls. Fringing reefs are intermittently distributed in coastal waters along Hainan Island, Taiwan Island and southwest corner of Leizhou Peninsula and some others. Total 128 atolls widely distribute in the South China Sea, and form the basis of South China Sea Islands. According to the range of geomorphic types, the total area of fringing reefs and atolls is about 30 000 km^2, accounting for about 5% of the total area of global coral reefs [1]. Depending on whether the reef flat is exposed at the lowest tide, the atolls can be drowned and emerged. Drowned atolls, such as Zhongsha Atoll and Reed Bank Atoll, account for about 5/6 of the total atoll area and for about half of the total number of atolls. Emerged atolls account for about 1/6 of the total atoll area and for about half of the total number of atolls, of which reef flats cover about 907 km^2, atoll lagoons cover about 4380 km^2, and 53 natural islands on the reef flat cover about 12 km^2. An important feature of coral reefs in the South China Sea is the fact that there are few smaller islands, and drowned atolls are widely distributed [1]. Coral reef islands, sand cays, reef flats, and lagoons in the South China Sea are important symbols and bases of China's maritime territory as well as important bases for marine fishery and other maritime activities [1].

In 2002, WRI calculated the extent of near-surface reef area in shallow waters based on 1 km resolution gridded data. They recorded that mainland China covered 900 km^2, Taiwan covered 700 km^2, and Xisha and Nansha Islands covered 5700 km^2, adding up to a total of 7300 km^2. This can be used for indicating the total area of coral reefs of China, and including these areas, China accounts for 2.57% of the total area of coral reefs in the world [27]. Among the 21 countries that account for more than 1% of the total coral reef area, China ranks eighth, after Indonesia, Australia, the Philippines, France, Papua New Guinea, Fiji, and the Maldives [28]. China's coral reefs and South China Sea Islands are of special significance for protection of maritime territories, resources, rights, and interests. China's coral reef surveying, monitoring, assessment, and protection management need to be strengthened in the future.

3.2 Status and characteristics of China's mangrove coasts

Mangroves are intermittently distributed in sheltered waters, such as embayments and estuaries on the tropical and subtropical coasts of Southeast China. From Hainan Island to the north, as latitude increases, the distribution area of mangroves and the number of tree species decrease, the main forest life form changes from trees to shrubs, and tree height and litter yield decrease, fully showing the influence of temperature on these communities. The continuous areas of mangroves greater than 6.67 km^2 (10 000 mu) include Qinglangang, Dongzhaigangr in Hainan, Zhenzhugang in Guangxi, Tongminghai of the Leizhou Bay in Guangdong, and Gaoqiao of the Yingluo Harbor. The total area of mangroves in China was about 420 km^2 in the 1950s and 228 km^2 in 2001, meaning it has been rapidly decreasing [29]. At present, various measures of protection and management have been undertaken. Since 1975, 18 mangrove nature reserves have been established in China, six of which are under state-level protection (Dongzhaigang in Hainan, Beilun Estuary in Guangxi, Shankou in Guangxi, Zhanjiang in Guangdong, Futian in Shenzhen, and Zhangjiangkou in Fujian), accounting for more than half of the total area of China's mangroves. Recently, Fan Hangqing et al. [30] reported that the second national survey of wetland resources carried out by the

State Forestry Administration showed that the mangrove area was 253 km^2 in 2013, which was an increase of more than 10% compared to 2001. China has initially curbed the dramatic decline in mangrove area in the context of continuous decline in global mangrove area. This is mainly because of the strict protection policies implemented by the government and large-scale artificial afforestation. The protection and ecological restoration of mangroves have received a lot of attention from the government. In April 2017, the general secretary Xi Jinping inspected the Jinwan mangrove in Beihai and instructed that we must respect science and fulfill our responsibilities to protect mangrove forests. During the 12th Five-Year Plan Period, each of the six national mangrove nature reserves received at least 25 million yuan of special funding from central and local governments, which greatly supported mangrove restoration. We still need to pay attention to the structural and functional degradation of mangroves in China and the extreme lack of suitable tidal flats for planting native mangrove species, which is a consequence of excessive land reclamation. The main mean of increasing the mangrove area in the future is to reduce aquacultural production in the mangrove forests [30].

4 Major ecological risks to tropical biological coasts

4.1 Major ecological risks to coral reef coasts

Since the late 1980s, the importance of coral reefs and the crisis they are facing have attracted widespread attention. Concerns have been raised about the effect of various coastal development activities on coral reefs, including sediment pollution, nutrient pollution, overfishing, direct damage from reef mining, and land reclamation. In 1994, the UN-IOC-ASPEI-IUCN Global Task Team investigating the implications of climate change on coral reefs reported that human activities are the main cause of coral reef crisis, and that the threat of climate change will only occur in the distant future [31].

In 1998, the coral reefs suffered serious bleaching events throughout the world as a consequence of sea temperature rise. The effective loss of global coral reefs was 16%, which was far higher than the 10% loss caused by human activities over the years, showing the extent of the effect of global climate change. This completely changed the agenda for coral reef protection.

In the period from 2015 to 2016, the occurrence of the global coral reef bleaching event with the longest delay and the same severity as that in 1998 (Fig. 1 and Fig. 2) once again confirmed that global warming has become the main threat to the sustainable development of coral reefs. It has been predicted that with the continuous or even enhanced global warming, large scale coral reefs may disappear around the middle of the 21st century. The International Coral Reef Initiative, founded in 1994 by the United States and seven other countries, has always been the most important international coordinating body for coral reef management and protection. The 2011 XL Catlin Seaview Survey and the 2017 50 Reefs Initiative sponsored by scientists and charities were the most innovative measures for coral reef management and protection [10].

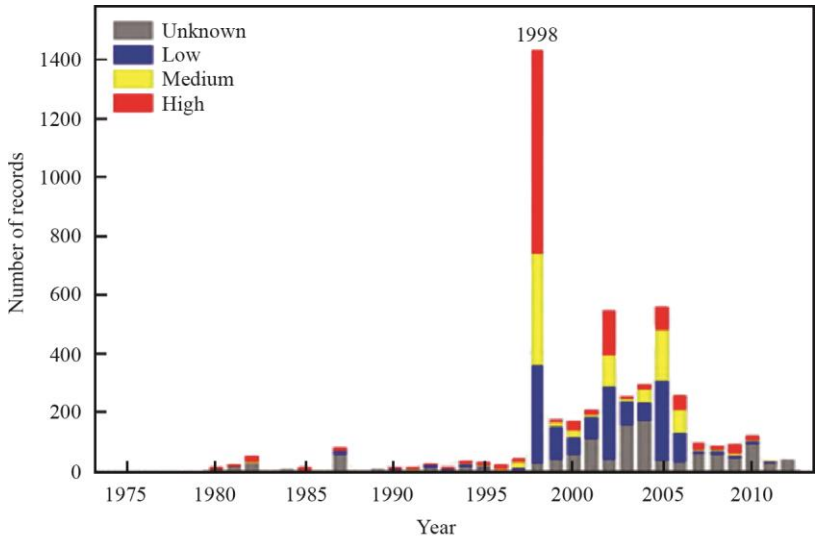

Fig. 1. Different degrees of coral bleaching recorded by the global coral reef database (ReefBase) (data after 2010 is lacking).

[10]

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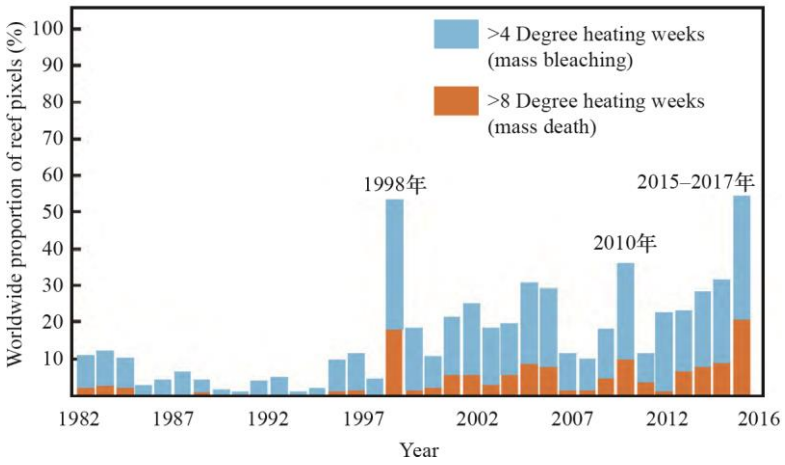

Fig. 2. The worldwide proportion of reef pixels (25 km^2) experiencing heat stress monitored by NOAA satellite in 1982–2016. [10]

4.2 Major ecological risks to mangrove coasts

The biggest threat to the mangrove ecosystem is the direct destruction of coastal habitats as a consequence of human coastal development activities which led to the deterioration of water quality and change in hydrological conditions (such as the decrease in fresh water runoff in the mangrove areas due to the construction of upstream dams of the Ganges River delta [32]). The disappearance of mangroves and ecological degradation led to the loss of important mangrove biogeomorphic functions in coastal ecologically critical areas, including attenuating waves, protecting coasts, capturing sediment, promoting siltation, and maintaining coastal stability. In addition, it led to the loss of their function as blue carbon sinks as well as the loss of their ability to offset the negative effect of sea level rise on coastal inundation. For a long time, people have underestimated the value of mangroves and ignored their social, ecological, and environmental benefits. Once the pressure of coastal development increased, people commonly cut mangroves down and repurposed the area for short-term economic benefits [33]. The effect of human activities on mangrove resources reached its peak in the 20th century. Since the 1980s, large-scale land use changes and the conversion of mangroves to agricultural land, aquaculture of species such as fish, shrimp, and shellfish, and coastal urban expansion, have been the main reasons for the disappearance of mangroves throughout the world. Since the 21st century, the loss rate of mangrove areas has decreased significantly, but it has not stopped. In the short- and medium-term future, with the continuous urbanization and increase in coastal population, land use change is expected to still be the major cause of mangrove loss [26]. In the context of the Anthropocene, the long-term threat of sea level rise and short-term sea level fluctuations alongside increasing human pressure along the coastal mangrove habitats have always been the main ecological risks of mangrove coasts [26].

5 Policy recommendations on protection and development of tropical biological coasts

Our suggestions on ecological protection and development strategies for China's tropical biological coasts, especially for offshore coral islands and reefs, are as follows.

(1) Proposing new measures for protection management strategies and planning at the national level. Under the guidance of the *Measures for the Management of Protection and Utilization of Coastal Zones* issued by the State Oceanic Administration in 2017, for tropical biological coasts, in order to maintain and enhance ecosystem resilience, more emphasis should be placed on saving energy, reducing emissions, strictly controlling exploitation, and priority should be given to protection.

(2) Strengthening ecological monitoring and carrying out comprehensive surveys, especially of Nansha Islands and other offshore coral islands and reefs.

(3) Strengthening scientific management of the existing coral reef protected areas and establishing new large offshore marine protected areas. Increasing the proportion of no-take areas, strengthening monitoring and evaluation of these areas, improving management effectiveness, and giving top priority to eliminating interference from human activities.

(4) Strengthening scientific research and personnel training, especially for offshore coral islands and reefs, in order to meet the scientific and technological needs for building maritime power. It is still true that "too few coral reef scientists spend too little time studying too few coral reefs" [34], and as reef-building corals grow below the low water spring tide, it is still difficult for most people to dive and study the coral reefs. There is an urgent need to mobilize more people towards knowing coral reefs, loving them, studying them, and finally, protecting them. Hatcher et al. [35] pointed out that the future of shallow tropical marine ecosystems depends on competition between two processes: the first one is the accelerating decline and disappearance of shallow tropical ecosystems, and the other one is for the constant improvement of coastal zone management from the ecology and sociology, including raising public awareness of the value of tropical marine ecosystem protection through public education.

References

[1] Zhang Q M. Status of tropical biological coasts of China: Implications on ecosystem restoration and reconstruction [J]. Oceanology et Limnologia Sinica, 2001, 32(4): 454–465. Chinese.

[2] Land-Ocean Interactions in the Coastal Zone. Report of the workshop focus 2: Mangrove biogeomorphology [R]. Townsville: Land-Ocean Interactions in the Coastal Zone, 1994.

[3] Pernetta J C , Milliman J D. Land-Ocean Interaction in the Coastal Zone: Implementation plan [R]. Stockholm: IGBP, 1995.

[4] Clark J R. Coastal zone management handbook [M]. Boca Raton: CRC Press, 1996.

[5] Zhang Q M. Mangrove and coral reef coastal resources of China and its development [R]. Hong Kong: Centre for Coastal and Atmospheric Research, The Hong Kong University of Science and Technology, 2000. Chinese.

[6] Stoddart D R. Ecology and morphology of recent coral reef [J]. Biological Review, 1969, 44: 433–498.

[7] Hopley D. Coral reefs [M]. Dordrecht: Springer, 2005.

[8] Finkl C W. Reef coasts [M]. Dordrecht: Springer, 2016.

[9] Zhang Q M, Yu K F, Shi Q, et al. A review of monitoring, conservation and management of global coral reefs [J]. Journal of Tropical Oceanography, 2006, 25(2): 71–78. Chinese.

[10] Zhang Q M, Zhao M X, Wang L R, et al. A Review of current status of coral reefs and their threats in the world [J]. Guangxi Sciences, 2017, 24(5):435–440. Chinese.

[11] Veron J E, Hoegh-guldberg O, Lenton T M, et al. The coral reef crisis: The critical importance of <350ppm CO_2 [J]. Marine Pollution Bulletin, 2009, 58(10): 1428–1436.

[12] Miller M W. Coral disturbance and recovery in a changing world [M]. Dordrecht: Springer, 2015.

[13] Birkeland C. Coral reefs in the Anthropocene [M]. Dordrecht: Springer, 2015.

[14] Wilkinson C. Status of coral reefs of the world [R]. Townsville: Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, 2008.

[15] Burke L, Reytar K, Spalding M, et al. Reefs at risk revisited [M]. Washington DC: World Resources Institute, 2011.

[16] Bellwood D R, Hughes T P, Folke C, et al. Confronting the coral reef crisis [J]. Nature, 2004, 429 (6994): 827–833.

[17] De'ath G, Fabricius K E, Sweatman H, et al. The 27–year decline of coral cover on the Great Barrier Reef and its causes [J]. Proceeding of the National Academy of Sciences, 2012, 109(44): 17995–17999.

[18] Cressey D. Terry Hughes: Reef sentinel [J]. Nature, 2016, 540: 510–511.

[19] Zhang Q M, Zhang Y C, Sun S J. Status and management of mangroves and mangrove coasts in China [C]. CAS HainanTropical Marine Biology Laboratory Station(Ed.). Tropical Marine Research V. Beijing: China Science Publishing & Media Ltd., 1997: 143–151. Chinese.

[20] Blasco F, Aizpuru M, Besnehard J. Mangroves, ecology [M]. Dordrecht: Springer, 2005.

[21] Blasco F, Aizpuru M. Depletion of the mangroves of Asia [J]. Wetlands Ecology and Management, 2001, 9(3): 245–256.

[22] Feller I C, Lovelock C E, Berger U, et al. Biocomplexity in mangrove ecosystems [J]. Annual Review of Marine Science, 2010, 2(1): 395–417.

[23] Duke N C, Meynecke J O, Dittmann S, et al. A world without mangroves [J]. Science, 2007, 317: 41–42.

[24] Kodikara K, Mukherjee N, Pulukkuttige J L. Have mangrove restoration projects worked? An in-depth study in Sri Lanka [J]. Restoration Ecology, 2017, 25(5): 705–716.

[25] Lewis R R, Brown B, Flynn L. Methods and criteria for successful mangrove forest rehabilitation [C]. Perillo G, et al (eds). Coastal Wetlands: An Integrated Ecosystem Approach. 2nd Edition. Chapter 24, Singapore: Elsevier, 2019.

[26] Friess D A, Rogers K, Lovelock C E, et al. The state of the world's mangrove forests: Past, present, and future [J]. Annual Review of Environment, 2019, 44(1): 1–27.

[27] Burke L, Selig E, Spalding M. Reefs at risk in southeast Asia [M]. Washington DC: World Resources Institute, 2002.

[28] Wilkinson C R. Status of coral reefs of the world [R]. Townsville: Australian Institute of Marine Science, 2002.

[29] Liao B W, Zhang Q M. Area, distribution and species composition of mangroves in China [J]. Wetland Science, 2014, 12(4): 435– 440. Chinese.

DOI 10.15302/J-SSCAE-2019.06.009

[30] Fan H Q, Wang W Q. Some thematic issues for mangrove conservation in China [J]. Journal of Xiamen University (Natural Science), 2017, 56(3):323–330. Chinese.

[31] Wilkinson C R, Buddemeier R W. Global climate change and coral reefs: Implications for people and reefs [R]. Gland: International Union for Conservation of Nature, 1994.

[32] Sarker S K, Reeve R, Thompson J, et al. Are we failing to protect threatened mangroves in the Sundarbans world heritage ecosystem [J]. Scientific Reports, 2016, 6(1): 21234.

[33] Zhang Q M, Sui S Z. The mangrove wetland resources and their conservation in China [J]. Journal of Natural Resources, 2001, 16(1): 28–36. Chinese.

[34] Hodgson G, Liebeler J. The global coral reef crisis: Trends and solutions, 5 years of reef check (1997—2001) [R]. Los Angeles: Reef Check Foundation, 2002.

[35] Hatcher B G, Johannes R E, Robertson A I. Review of research relevant to the conservation of shallow tropical marine ecosystems [J]. Oceanography Marine Biology, 1989, 27: 337–414.