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Report on China Mangrove Conservation and Restoration Strategy Research Project

executive summary

Preface

Mangroves are woody plant communities that grow widely in the intertidal zone along tropical and subtropical coasts. Although mangroves cover less than 1% of the total area of the world's tropical forests, they are one of the most biodiverse and productive marine ecosystems on Earth as well as one of the highest functioning ecosystems in terms of the ecological services provided. Having a variety of ecological functions, mangroves are able to withstand wind and waves, protect the coast, purify water, sequester and store carbon, regulate the climate, maintain biodiversity, protect aquatic resources, and support ecotourism and scientific research. Mangroves are known as "coast guard" and "land-making pioneer" owing to their important ecological, social, and economic values. However, over the past few decades, under the influence of human activities and climate change, mangrove ecosystems worldwide are facing serious problems such as area reduction, functional degradation, and biodiversity loss.

China is no exception. As a result of socioeconomic development, reclamation, aquaculture, and infrastructure construction, mangrove area has fallen sharply from nearly 50,000 hectares in the early 1950s to 22,000 hectares in the year of 2000, representing a 55% of area loss. Since the beginning of the new century, Chinese government has drawn greater emphasis on the protection and restoration of mangroves, while taking a variety of measures to protect and restore them. The area of mangroves has increased to approximately 30,000 hectares with 38 mangrove protected areas established at different levels and of distinct types, covering more than 75% of the existing natural mangroves. However, mangrove protection and restoration effort in China still faces many challenges, such as aquaculture development, the construction of seawalls, climate change, inadequate management, lack of public engagement, insufficient scientific support. These all result in the rapid degradation of mangrove ecosystems.

In order to empower mangrove conservation actions, "China Mangrove Conservation and Restoration Strategy Research Project" was initiated in2018. Through detailed analysis of the weaknesses in the mangrove management, protection and restoration endeavors, the project goals to study and evaluate the current status and potential threats to China's mangroves. In order to provide support for restoration programs like "*Blue Bay*" and "*Mangrove in the South, Saltcedar in the North*" (an ecological restoration project plans to grow mangrove forests in southern coastlines and saltcedar in northern arid area), this project studies new concepts and methods for the ecological restoration and sustainable uses of mangroves, drawing on successful cases abroad and at home. Also, the project formulates detailed and workable proposals for China's mangrove protection and restoration. The project will provide sound scientific support and decision-making references for the implementation of large-scale restoration actions, which will further promote the protection of China's mangrove ecosystems.

Funded by the Lao Niu Foundation, Paulson Institute and Shenzhen Mangrove Wetland Conservation Foundation, the project has engaged many experts and scholars in the field of mangrove research. A guiding committee has been established since the commencement of the project in November 2018. The guiding

committee is headed by Mr. Bao Daming, deputy director of Wetland Management Department of National Forestry and Grassland Bureau), and Ms. Niu Hongwei, Supervisor of the Ecological Conservation Program of Paulson Institute. Mr. Bao and Ms. Niu are jointly responsible for guidance, consultation and decision-making in the project. The project also established a research expert panel, which is led by Professor Wang Wenqing, deputy dean of the School of Environment and Ecology of Xiamen University. Other experts in the group include Fan Hangqing, research fellow of Guangxi Mangrove Research Center, Liao Baowen and Xin Kun, research fellows of Guangzhou Institute of Tropical Forestry of the Chinese Academy of Forestry Sciences, professor Chen Luzhen of the College of Environment and Ecology of Xiamen University, Peng Yisheng, associate professor from Sun Yat-sen University, and Zhou Haichao, associate research fellow from Shenzhen University, etc. In addition, many other experts from International Union for Conservation of Nature (IUCN), The Nature Conservancy (TNC), Global Environmental Institute (GEI), mangrove reserves, wetland parks and other relevant institutions in China, all made contributions to the project. In particular, the IUCN China Office and the IUCN Asia Regional Office in Bangkok provided the project substantial help when the expert team studied mangrove restoration in Thailand.

In May 2019, a conference was held in Nanning city and was attended by a panel of experts with a focus on project report compilation. In the conference, the status and problems in mangrove protection and management were reviewed and analyzed. Experts discussed the framework and contents of the project report, which helped the team to gain clearer understanding about the objectives, characteristics, and outcomes of the project. As the project was undergoing, “China Mangrove Protection and Development Forum” and Project Symposium, and other two meetings of guiding committee were organized. These symposiums and meetings were held to analyze problems and to put forward solutions in the progression of the project. In particular, the guiding committee meeting, held in July 2019, decided that due to the rapid development of mangrove conservation and restoration in the country and the urgent need for mangrove ecological restoration, the project’s original objectives, tasks, and plans should be adjusted. The final outputs and endeavors should align with the current progress of mangrove protection’s overall plan in China. The project also organized a field trip to Thailand for officials in charge of mangrove management and experts of mangrove research. In early 2020, the COVID-19 outbreak exerted an impact on many research efforts around the world and has undoubtedly affected this research. Despite the pandemic, the expert panel managed to keep working on the framework and contents of this report by adopting more feasible management measures.

In the light of the new mangrove protection and restoration condition globally and within China, and based on the current status of mangrove distribution and protection in China, Report on China Mangrove Protection and Restoration Strategy Research analyzes the causes to severe mangrove degradation in China’s coastal regions. From the perspectives of managers for protected areas, while considering community engagement, scientific monitoring, this report assessed shortcomings existed in current mangrove management system, alongside with their potential effectiveness in preservation outcome. Main problems of current ecological restoration projects in the country were examined, covering the aspects of target-setting for restoration, selection of restoration sites and criteria, adoption of restoration measures, and selection of tree species, etc.

The report provided a detailed analysis of the existing problems in the current restoration model, including primarily tidal flat afforestation and artificial restoration of mangroves, as well as the officially released and implemented afforestation standards (regional standards and industrial standards). Based on the above-mentioned contents, the report also analyzed and evaluated the objectives of mangrove ecological restoration in China, the selection of restoration methods and measures, and the application of restoration standards. It is proposed that the main goal should be to restore the integrity of the entire ecosystem and to maintain the ecological functions of mangrove ecosystem rather than expanding mangrove area aggressively. The focus should be on "converting ponds to forests", and it should be identified as the main strategy of mangrove ecological restoration in China. Consequently, relevant research, theories, technologies, standards, and practices should be applied and implemented. The report also examined the sustainable use of mangroves (ecological farming, ecotourism and blue carbon sequestration) and the bio-invasion issue, while making a series of practical and specific proposals for the management, rehabilitation, and sustainable use of mangroves.

Mangrove protection has been highly valued by General Secretary Xi Jinping, who made a field visit to the mangrove forest in the Golden Bay of Beihai, Guangxi on April 19, 2017. Xi learnt in detail the regulating role of mangroves as "guardians of the sea" and "forests on the sea" for the marine ecosystem, and commented that "it is imperative to respect science, implement responsibilities and save mangroves". From March 30 to 31, 2019, "*Topics in Focus*", an interview program by China Central Television (CCTV), aired a special report — "How to Save Mangroves", for two days, discussing the current status of the conservation and management of China's mangroves, as well as the existing problems and future work of mangrove conservation and restoration. Relevant departments are also working intensively on the mangrove restoration plan. All these efforts show that the Chinese government, the media and the public attach great importance to the protection and restoration of mangrove ecosystems. In the foreseeable future, China is about to embark on large-scale mangrove ecosystem restoration projects across the country.

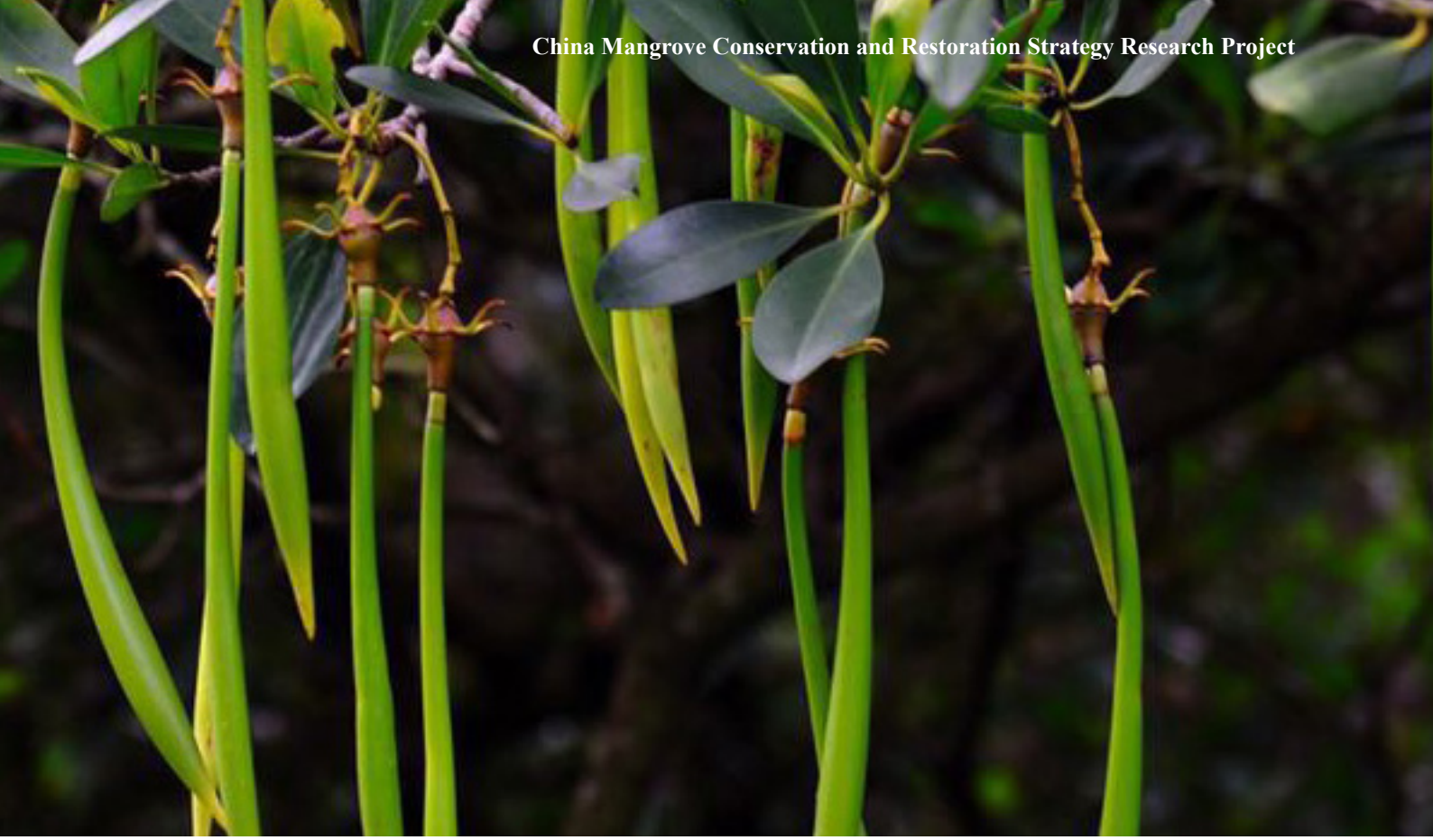
It is our sincere hope that the above-mentioned research results and policy recommendations will provide references for decision-making in the formulation, perfection, and scientific implementation of the restoration plans for the large-scale mangrove ecosystem project in China.

Organization Profiles

Paulson Institute, founded in 2011 by the former U.S. Treasury Secretary Henry Paulson, is a nonpartisan, independent "think and do tank" dedicated to fostering a U.S.-China relationship that serves to maintain global order in a rapidly evolving global landscape. Based on the reality that the U.S.-China relationship is the most important bilateral relationship in the world, Paulson Institute focuses primarily on the intersectional areas of economy, financial markets, environmental protection and policy initiatives of the U.S. and China, enabling balanced and sustainable economic growth. Paulson Institute is headquartered in Chicago with offices in Washington, D.C., and Beijing.

Lao Niu Foundation (full name: Inner Mongolia Lao Niu Foundation) is a foundation engaged in public welfare and philanthropy, which was established in late 2004 by Mr. Niu Gensheng and his family. Mr. Niu (the founder, former chairman and president of Mengniu Dairy Group) and his family donated their Mengniu Dairy Group corporate shares and the majority of their dividends to create the foundation. The vision of the Lao Niu Foundation is to "have grateful hearts and improve oneself by helping others," and to "be responsible for the earth under heaven by nurturing both people and nature." The Foundation's mission is founded on the belief that "education is fundamental to the nation, the environment is fundamental to life, and philanthropy is fundamental to society." The three primary focuses of the Foundation are environmental protection, cultural education, and championing the development of China's philanthropic sector.

Shenzhen Mangrove Wetland Conservation Foundation (MCF) was established in July, 2012. It is the first local environmental public foundation initiated by the private sector in China. The foundation was initiated by SEE Foundation, public-spirited entrepreneurs and relevant authorities in Shenzhen. Professor Lei Guangchun from the School of Ecology and Nature Conservation of Beijing Forestry University is the chairman of the board of directors, and Mr. Wang Shi and Mr. Ma Weihua serve as the co-chairs of the foundation. Since its establishment, the foundation has always focused on coastal wetlands, taking Shenzhen as the starting point, and is committed to the protection of coastal wetlands represented by mangroves and the public environmental education. With the support of partners such as government departments, experts and scholars, enterprises and non-profit organizations, the foundation has created a model of nature conservation with social participation.



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Project Introduction

The Research Project of China Mangrove Conservation and Restoration Strategy is one of the most important endeavors in the China Coastal Wetland Conservation Network. Officially started in November 2018, the project was jointly initiated by Paulson Institute, Lao Niu Foundation and MCF. After comprehensive evaluation of the problems in China's mangrove conservation and ecological rehabilitation, the project has made specific policy proposals in order to provide references for decision-making in protecting and restoring mangrove ecosystem in China. .

Project Objectives

The project aims to assess the current situation and threats faced with mangrove conservation in China and analyze the problems in the conservation and restoration work. Considering the status quo and needs of the ongoing mangrove conservation and restoration projects, the project also studies new concepts and approaches for the restoration and sustainable use of mangrove ecosystems, and proposes policy recommendations to conserve and restore mangroves in China.

Project Contents

- Evaluate the current situation and threats to the conservation and restoration of mangrove ecosystem in China;
- Identify and analyze the problems and their causes in the practice of mangrove ecological restoration in China;
- Based on the successful experience at home and abroad, adopt new methods in restoration and sustainable utilization of mangrove ecosystem;
- Put forward suggestions on the measures and policies for the protection and restoration of mangrove ecosystem.

Project Organizations and Institutions

Directing Organization	Wetland Management Department, National Forestry and Grassland Bureau
Implementation Organizations	Paulson Institute Shenzhen Mangrove Wetland Conservation Foundation (MCF)
Sponsor	Lao Niu Foundation

Project Members

Guiding Committee

Bao Daming	Deputy Director, Wetland Management Department of National Forestry and Grassland Bureau
Niu Hongwei	Director Paulson Institute Ecological Conservation Program
Lei Guangchun	Professor, School of Ecological and Nature Reservation, Beijing Forestry University Chairman, Mangrove Wetland Conservation Foundation
Fan Hangqing	Director, Guangxi Mangrove Research Center
Li Chengye	Professor, the Chinese University of Hong Kong
Tan Fengyi	Director, Futian-Chengda Mangrove Research and Development Center, Shenzhen Research Institute, City University of Hong Kong

Expert Panel

Wang Wenqing	Deputy Dean, Professor and Group Leader, School of Environment and Ecology, Xiamen University
Fan Hangqing	Director, Guangxi Mangrove Research Center
Liao Baowen	Chief Expert and Research Fellow, Institute of Tropical Forestry, Chinese Academy of Forestry
Chen Luzhen	Professor, School of Environment and Ecology, Xiamen University
Xin Kun	Research Fellow, Institute of Tropical Forestry, Chinese Academy of Forestry
Zhong Cairong	Senior Engineer, Administrative Bureau of Hainan Dongzhaigang National Nature Reserve
Zhou Zhiqin	Chairman, Haikou Duotan Wetland Research Institute
Peng Yisheng	Associate Professor, School of Environmental Science and Engineering, Sun Yat-sen University
Zhou Haichao	Research Associate, School of Life and Marine Sciences, Shenzhen University
Li Ruili	Research Associate, Shenzhen Graduate School, Peking University
Chen Qiuxia	Deputy Director and Research Fellow, Zhejiang Provincial Subtropical Crops Institute

Technical Guidance Committee

Lin Guanghui	Professor, Earth System Science Research Center, Tsinghua University
Wen Xianji	Program Director, World Wildlife Foundation Hong Kong
Wang Youshao	Deputy Director and Research Fellow, State Key Laboratory of Tropical Marine Environment Head of the Comprehensive Open Experiment Station of China Science Daya Bay Marine Biology
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Xu Fanghong	Director, Administrative Bureau of Guangdong Zhanjiang Mangrove State Nature Reserve
Su Bo	Former Director, Administrative Bureau of Guangxi Beilun Estuary National Mangrove Nature Reserve
Zou Fasheng	Deputy Director and Research Fellow, Guangdong Provincial Biology Resources Application Institute
Zhu Chunquan	Former Chief Representative in China, International Union for Conservation of Nature
Zhang Cheng	Director of South China Program, International Union for Conservation of Nature

Photos provided by: Gu Feng, Liu Yi, Zhang Yihui, Chen Yonghong, Li Xianliang, Zhang Zhiyong
Chen Duanming, Mo Xiaoliang

Overview of China's Mangrove Conservation and Management

According to the current situation of mangrove distribution and protection in China, the project analyzes the problems and main reasons of the serious degradation of mangroves in China. Deficiencies in mangrove conservation management in China and their possible impacts on conservation effectiveness are evaluated from the aspects of human resources, community participation and scientific monitoring.

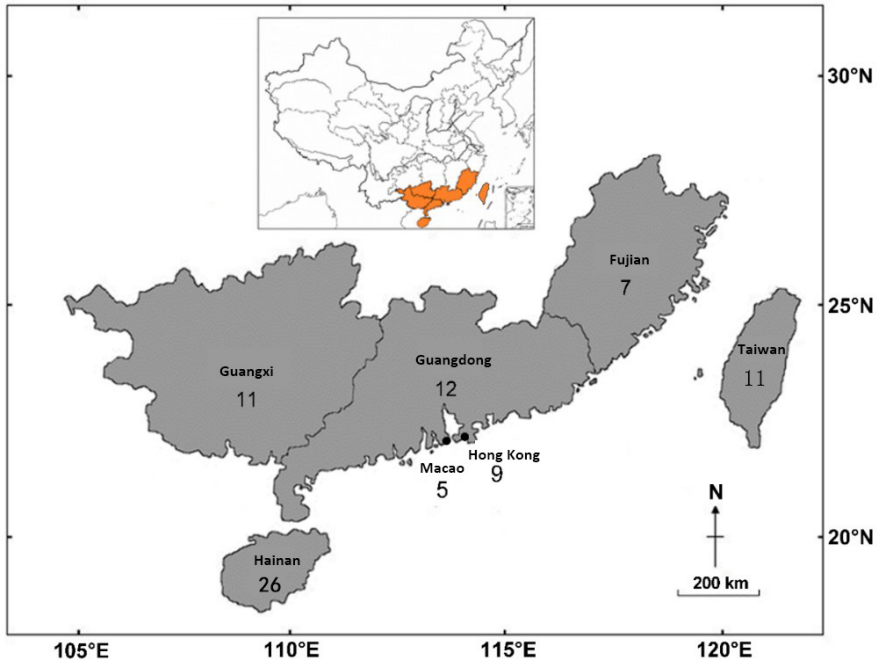
▼ Shenzhen Futian National Mangrove Nature Reserve, the smallest reserve in China and the only mangrove nature reserve that located in the urban region.

Species and Distribution of Mangrove Plants in China

Mangrove is a woody plant community growing in the intertidal zone of tropical and subtropical coast. It is one of the marine ecosystems with the highest biodiversity and productivity, and also one of the natural ecosystems with the highest ecological service function, which is of great significance for maintaining biodiversity.

Mangrove forests in China are growing in the northern edge of the global mangrove distribution. Limited by the low temperature, China has less mangrove species compared with other Southeast Asian countries, which are the center of global mangrove distribution. As latitude increases, the diversity of mangrove species gradually decreases. Hainan province has the most species of mangrove plants in China, including 26 true mangrove plants and 11 mangrove associates. Guangdong province ranks the second, with 12 species of true mangrove and 10 species of mangrove associates respectively. There are 7 species of true mangrove and 4 species of mangrove associates in Fujian province. Only one introduced mangrove plant, *Kandelia obovata*, can be found in Zhejiang province.

Mangroves in China are distributed in provinces of Hainan, Guangdong, Guangxi, Fujian, Zhejiang, as well as Hong Kong, Macao and Taiwan, ranging from Yulin Port (18°09' N) in Hainan to Shacheng Bay (27°20' N) in Fuding, Fujian. The northern boundary of artificially introduced mangrove plant is Ximen Island (28°25' N) in Yueqing, Zhejiang.

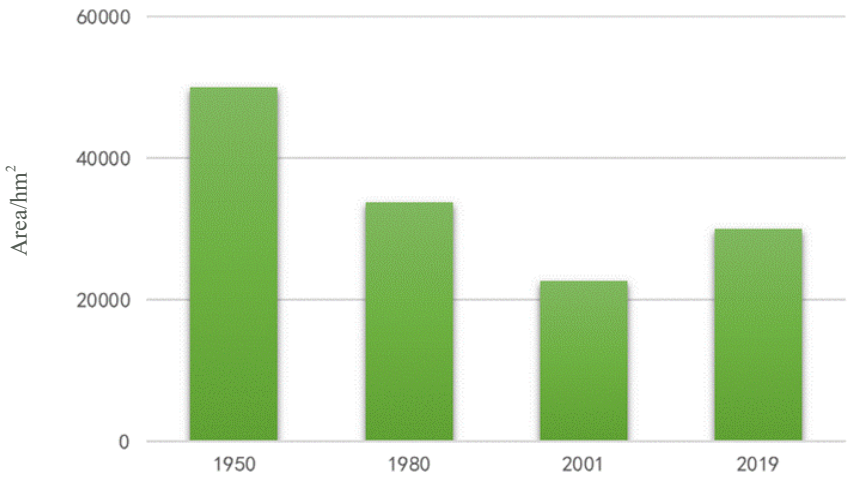


Distribution of mangroves in China
(numbers on the map stand for the numbers of true mangrove plant types)

Current Situation and Changes of China's Mangrove Wetlands

In the early 1950s, there were nearly 50,000 hectares of mangroves in China. After reclamation in the 1960s—1970s, aquaculture in ponds in the 1980s—1990s, and the urbanization process as well as port and wharf construction since the 1990s, the mangrove area in China decreased sharply to 22,000 hectares in 2000, only 45% that of the early 1950s.

Since the new century, the Chinese government has attached great importance to the protection and restoration of mangroves. Through strict protection and large-scale artificial afforestation, China has successfully curbed the sharp decline in mangrove area, which has increased to 30,000 hectares in 2019, at an annual growth rate of 1.8%, making China one of the few countries in the world with a net increase in mangrove area.



Changes of Mangrove Area in China

Major Threats to Mangrove Wetlands in China

Affected by global climate change and human activities, the degradation of mangrove ecosystem in China is significant, and the main reasons for the degradation are:

Mangroves fell after hydrodynamic changes in Shimei Bay of Wanning

Sea-land Barrier — The Seawall

Nearly 90% of mangroves are located outside artificial seawalls, and seawall construction is the most important reason for the loss of species diversity of mangrove plants and the reverse succession of community structure in China. In addition, because the mangrove forest in front of the seawall is extremely sensitive to sea level rise, the existence of seawall will greatly weaken the resilience of Chinese mangrove forest to sea level rise.

Aquaculture ponds adjacent to mangroves in Hainan province

Pollution by Aquaculture

Sewage discharge during pond clearance, featuring short duration and high concentration of pollutants, lead to the concentrated discharge of a large number of pollutants within short span of time. Consequently, mangroves are severely affected and sometimes die at a large scale. Besides, littering is another problem faced with mangroves grown around cities and towns.

***Spartina alterniflora* on the tidal flat outside the mangrove forest in Danzhou, Hainan**

Biological Invasion

Biological invasion has become one of the main factors influencing biodiversity. *Spartina alterniflora* from the U.S. and the native *Derris trifoliata* have posed a great threat to mangroves.

Law and Regulation System of Mangrove Wetland Protection in China

China has gradually established a relatively complete system of laws and regulations related to mangrove wetland protection from national to local levels. At the national level, the "Forest Law of the People's Republic of China", the "Marine Environmental Protection Law of the People's Republic of China" and the "Island Law of the People's Republic of China" all have provisions concerning mangrove protection and management. As most mangroves in China have been included in nature reserves as a type of wetland, the "Regulations of the People's Republic of China on Nature Reserves", the "Regulations on Wetland Protection and Management", and the "Wetland Protection and Restoration System Plan" are all directly related to the protection and management of mangrove wetlands. Local governments have formulated relevant implementation regulations and management regulations accordingly. Especially for Guangxi and Hainan provinces, they respectively promulgated and implemented the "Regulations on Mangrove Resources Protection in Guangxi Zhuang Autonomous Region" and the "Provisions on Mangrove Protection in Hainan Province". The vast majority of national nature reserves with mangroves as the main protection objects have also issued special management regulations, such as the "Administrative Measures of Shankou Mangrove Ecological Nature Reserve and Beilun Estuary National Nature Reserve in Guangxi Zhuang Autonomous Region".

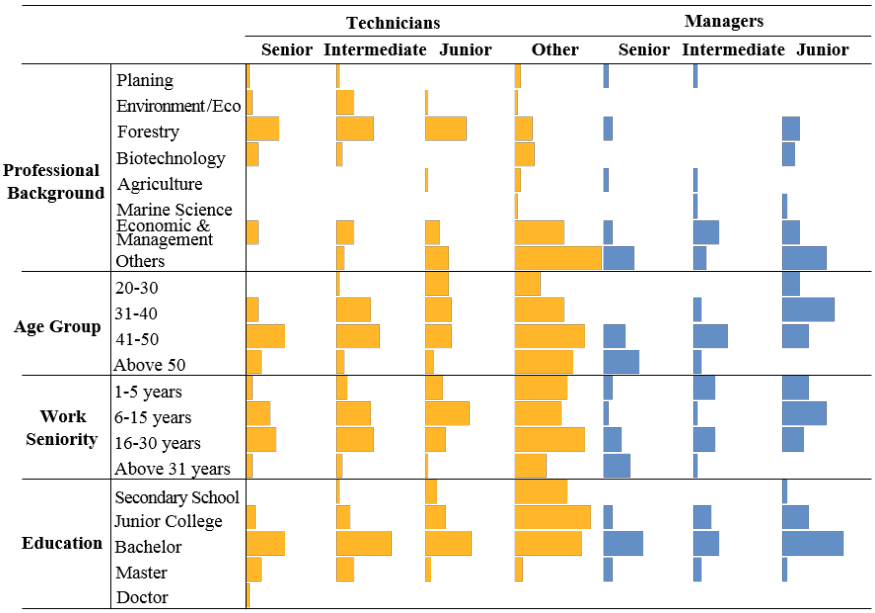
The implementation of the above laws and regulations has played an important legal role in managing mangroves in China, effectively curbing the occurrence of large-scale destruction and encroachment on mangroves. However, with the rapid development of China's economy and the change of protection concept, some of the above laws and regulations can no longer meet the needs of protection, management, and sustainable utilization of mangrove wetlands in China. There are some shortcomings: 1) The definition of mangrove and mangrove wetlands is unclear, and most laws and regulations equate mangrove wetlands with mangrove forests (woodlands with mangrove plants), while ignoring other components of mangrove wetlands, and failing to incorporate the concept of comprehensive ecosystem protection and management into the legislative system; 2) The existing laws and regulations do not clearly define various interference and destruction factors from the outside of mangrove wetlands, resulting in the lack of law enforcement basis and difficulty in curbing the degradation of mangrove wetlands; 3) There are no corresponding protection, management, and rational utilization regulations regarding to the characteristics of different mangrove wetlands, and there are too many restrictions on the sustainable utilization of mangroves, especially on the artificial mangroves outside the protected areas.

It is an important task to strengthen the construction of existing laws and regulations related to mangrove wetlands in order to meet the urgent needs of protection, restoration and sustainable utilization of mangrove wetlands with Chinese characteristics in the new period.

Management of China's Mangrove Protected Areas

Chinese mainland so far has established 38 protected areas (excluding Taiwan's Tamsui Estuary, Guandu and Hong Kong Mai Po), including 6 national nature reserves, (1 in Hainan, 2 in Guangxi, 2 in Guangdong and 1 in Fujian) that have mangrove as their primary conservation target.

Information of management personnel from 24 protected areas with special administrative offices has been collected. Comparing with the survey data of the year of 2010, the changes of management staff in 14 of these protected areas have been analyzed.



Statistic of technical and management personnel at protected areas

The analysis of human resources allocation and its rationality of mangrove protected areas in China shows that the personnel structure of mangrove protected areas in China cannot meet the needs of mangrove protection, management and education. There is also an urgent need for training of the personnel for improving capabilities in management and protection. Because of the special location of mangrove ecosystem, which is located in ecotone area between land and sea, the understanding and comprehensive management of this ecosystem require a rich theoretical knowledge of natural science, protection and restoration. Thus, higher educational requirement is needed for recruited personnel and professionals with diverse experience are encouraged to participate. At present, the management personnel of mangrove protected areas have low educational level and unreasonable professional structure. Among the existing management personnel, the proportion of graduate students is low. Forestry is dominant in professional background, and marine science professionals only account for 1% of the total. The lack of management personnel with backgrounds such as ecology, environment, and biology may limit the implementation of scientific decisions in protected areas.

Restoration of Mangrove Wetlands in China

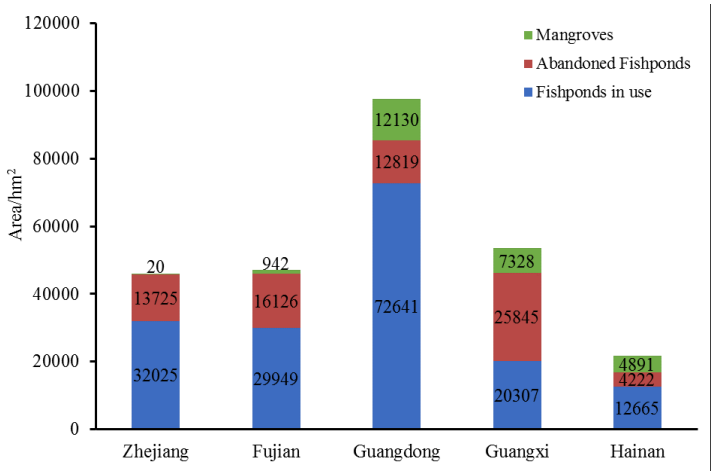
Since 2000, the Chinese government has attached great importance to the protection and restoration of mangroves, adopted various measures to protect and restore mangroves, and implemented the "*National Coastal Shelterbelt System Construction Project Plan (2016-2025)*", "*Mangrove in the South, Saltcedar in the North*" (grow mangrove forests in southern coastlines and saltcedar in northern arid area), and the marine ecological civilization construction strategy, etc. Between 2000 and 2019, the area of mangroves in China increased about 7,000 hectares. Beside natural expansion of small areas, natural restoration of abandoned fish ponds, and converting ponds to forests, more than 90% of them were reconstructed and restored through tidal flat afforestation.

After many years of restoration work, the remaining tidal flats suitable for direct afforestation in south China are very limited. According to experts' estimates, the total area of suitable tidal flats that meet the marine functional zoning in China does not exceed 6,000 hectares.

Some existing mangrove ecological restoration projects in China take vegetation restoration as the main, even the only goal, and pay less attention to the overall restoration of ecosystem structure and function. There are problems such as insufficient scientific evidence and inappropriate evaluation in selecting restoration sites, areas, measures, and tree species. Some sites are over-restored.

Converted to aquaculture ponds is the main cause of mangrove destruction in the world, which is also true in China. From 1980 to 2000, 12,923.7 hectares of mangroves disappeared in China, of which 97.6% were used to build fish ponds. Due to the large scale of aquaculture and lack of effective means to deal with pollution, aquaculture in southern China has fallen into a vicious circle of "scale expansion — aquaculture pollution aggravation — environmental degradation — frequent diseases — benefit decline". The success rate of aquaculture has been hovering around 35% for a long time, while 30% of fish ponds and shrimp ponds are left unused owing to poor aquaculture efficiency.

China now has a large area of idle aquaculture ponds and ponds within the red line of the nature reserve. Given the fact that tidal flat afforestation becomes increasingly difficult, it is one of the imperatives to convert those ponds to forests for ecological restoration of mangrove forests in the country.



Statistics of mangrove and fish pond area in the provinces that mangroves grow

Utilizations of Mangrove Wetlands in China

Farming and capturing of marine commercial species have contributed significantly to the revenue for the local communities around mangroves. Traditional farming methods not only encroach on a large area of mangroves, but also have become one of the major pollution sources in China's offshore waters. Frequent human activities have disturbed the habitat and foraging of waterfowl, and overfishing still exists in many places. With people's growing awareness of the importance of mangrove ecosystem, how to maximize the comprehensive benefits of mangroves to achieve a win-win situation of economic development and ecological protection has become a common challenge faced by the government and many mangrove nature reserve management agencies. At present, the utilization forms of mangroves in China are relatively simple, and some utilization modes with important ecological functions and ecological values still need to be developed. The most valuable aspects include:

Ecological Aquaculture

In view of the problems existing in traditional pond aquaculture, besides converting ponds to forests, it is necessary to innovate the culture mode to achieve ecological protection and economic development as well. At the same time, by standardizing the behaviors of farmers, zero emissions of pollutants from aquaculture can be achieved.

Ecological aquaculture is one of the ways to solve the dilemma of the existing aquaculture industry.

Ecotourism

As the world's most valuable natural landscape for ecotourism and popular science education, mangroves should be taken full advantage of in this respect in China. However, mangrove ecotourism in China is still in its primary stage. The content and form are relatively simple.

Mangrove wetlands are great places for bird watching

Mangrove Blue Carbon

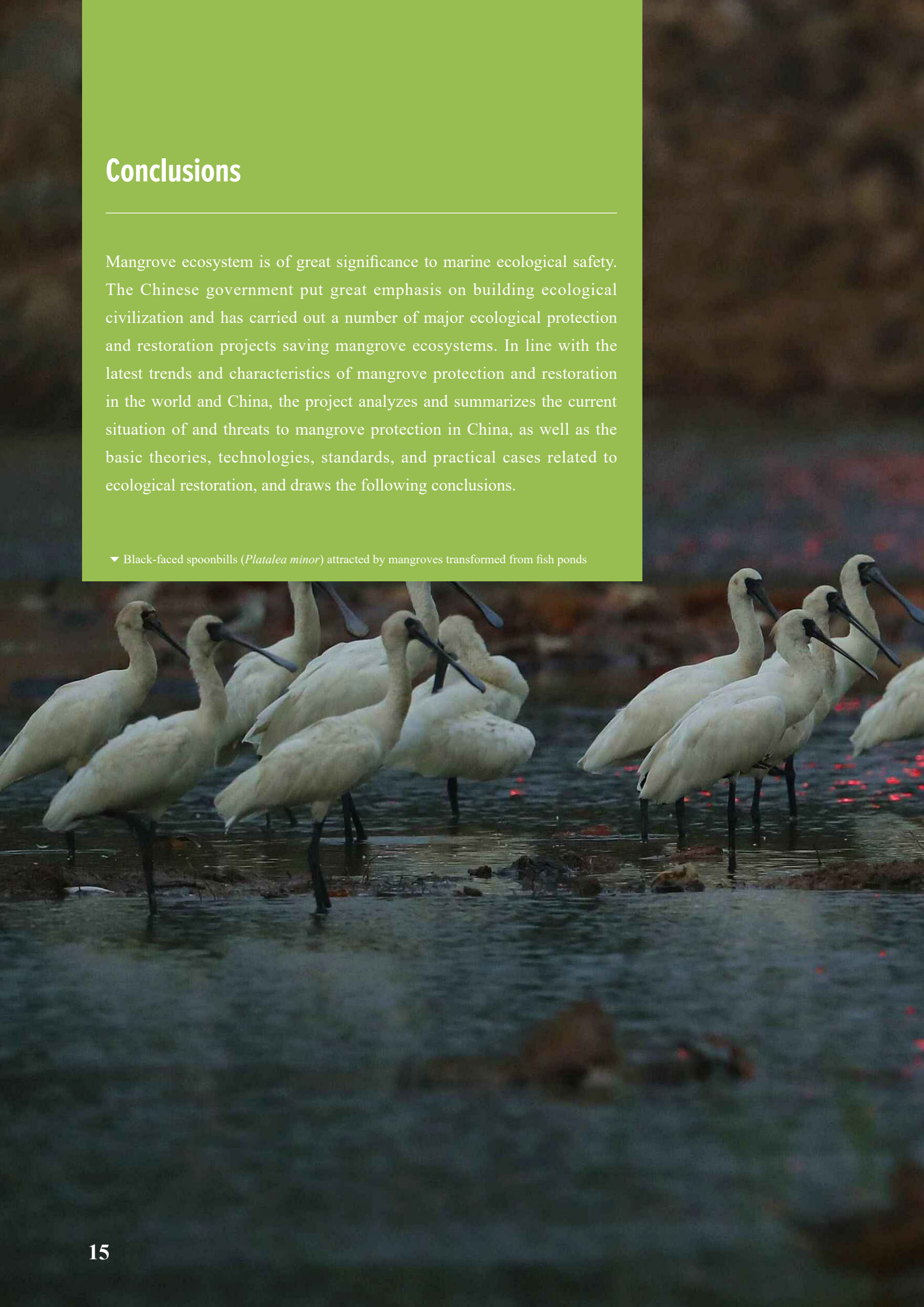
Mangrove is one of the densest carbon sinks on the earth, which can capture and store a large amount of carbon permanently buried in marine sediments. It is estimated that the total carbon storage of mangrove forests in China is 5.5TgC. However, challenges still exist in the research and development of mangrove "blue carbon" in China.

Mangrove wetland is one of the natural ecosystems with the strongest carbon sequestration capacity

mudflats of Shenzhen Bay Park

Conclusions

Mangrove ecosystem is of great significance to marine ecological safety. The Chinese government put great emphasis on building ecological civilization and has carried out a number of major ecological protection and restoration projects saving mangrove ecosystems. In line with the latest trends and characteristics of mangrove protection and restoration in the world and China, the project analyzes and summarizes the current situation of and threats to mangrove protection in China, as well as the basic theories, technologies, standards, and practical cases related to ecological restoration, and draws the following conclusions.



▼ Black-faced spoonbills (*Platalea minor*) attracted by mangroves transformed from fish ponds

Conclusion 1

Since 2000, China has successfully curbed the sharp shrinking of mangroves through effective protection and large-scale artificial afforestation. The area of mangrove forests is expanding steadily.

In the early 1950s, there were nearly 50,000 hectares of mangroves in China. After reclamation between the 1960s and 1970s, conversion to aquaculture pond activities between the 1980s and 1990s, and the urbanization fever since the 1990s with port construction, the mangrove area in China had dropped sharply to 22,000 hectares in 2000, which was only 45% of that in the early 1950s.

Since the new century, the Chinese government has attached great importance to the protection and restoration of mangroves. Through effective protection and large-scale artificial afforestation, China has successfully curbed the sharp decline of mangrove area, which increased from 22,000 hectares in 2000 to about 30,000 hectares in 2019, with an average annual increase of 1.8%, making it one of the few countries in the world with a net increase in mangrove area.

Chinese mainland has established 38 protected areas with mangroves as the main protection objects. Nearly 75% of natural mangroves have been included into the protected areas, far exceeding the world average of 25%. Mangrove is the most protected vegetation type in China.

Conclusion 2

The structure and functions of mangrove ecosystem in China are generally stable, but mangrove degradation remains obvious in some areas.

Affected by climate change and human activities, local areas of mangrove ecosystem in China are significantly degraded. Occasionally, the entire mangrove community dies. The mangrove community structure in some areas has undergone fundamental changes with the community structure reversed from mature plant community dominated by *Bruguiera gymnorrhiza* to pioneer plant community dominated by *Avicennia marina* and *Aegiceras corniculatum*. The damage of pests and diseases tends to increase. Mangrove biodiversity has decreased, and the survival status of some rare and endangered mangrove species in the wild is not optimistic. The main reasons for the degradation of mangrove ecosystem include: a. the pollution caused by saltwater aquaculture existed for a long time; b. *Spartina alterniflora* from the United States and the native *Derris trifoliata* pose a great threat to mangroves; c. the seawall construction threatens 90% of Chinese mangroves because they are located outside the seawall. The connection between mangrove ecosystem outside and inside of the seawall gets blocked by the physical structure. (see Appendix Tables 1 and 2 for species, distribution, and endangered status of mangrove plants)

Conclusion 3

China's scientific research achievements on mangroves are in the forefront of the world, but the ability to transform the research achievements into productivity and practice is not strong. There is a severe shortage of professionals for advanced management in protected areas. It is one of the pressing issues to establish a scientific management and monitoring system based on ecosystem management.

Although the mangrove area in China only accounts for 2‰ of the world's total, China's ranking for mangrove research is among the top of the world. Four of the five institutes with the most published academic papers on mangroves in the world are in China (No.1: Chinese Academy of Sciences, No.2: City University of Hong Kong, No.3: Xiamen University, No. 5 Sun Yat-sen University). The experience of mangrove protection, management, and sustainable utilization that China possesses is exactly what the countries along "The Belt and Road" urgently need. Some "The Belt and Road" regions such as Southeast Asia, the Middle East, and Africa, are the centers of global mangrove distribution.

There are now altogether 208 mangrove nature reserve managers in China. However, their educational levels are relatively low and the professional structure is still undesirable. In particular, there is a serious shortage of professionals in ecology, ocean and protected-area management. Among the existing 38 protected areas, 36.8% of them have not set up any special management organization, 18.4% have not compiled a master plan, 18.4% have no scientific research report, and 23.7% have no clear boundaries (see Appendix Table 3 for details).

Despite years of efforts, a complete and efficient monitoring and evaluation system of mangrove ecosystem is still to be established. The decision-making in mangrove protection, management and ecological restoration sometimes lacks sufficient scientific basis. Due to the lack of an effective community-based mangrove protection and restoration mechanism, the existing achievements of mangrove protection, restoration, and management in China are mostly realized by administrative approaches. Although some goals were achieved, there are still some problems such as high administrative cost, mostly short-term effects, and weak coordination, causing expected goals to fail.

Conclusion 4

At present, tidal flat afforestation is the main way of mangrove restoration in China, which has played an important role in significantly increasing mangrove area in China in the past two decades, but some key issues still need to be addressed urgently.

Since 2000, the area of mangrove forest in China has increased by about 7,000 hectares, most of which is realized by tidal flat afforestation. However, some mangrove ecological restoration projects take vegetation restoration as the main or even the only goal, thus paying less attention to the overall restoration of mangrove ecosystem structure and its functionality. There are some problems such as insufficient scientific evaluation in the selection of restoration sites, restoration areas, restoration measures, and tree species. A few sites were over-restored.

Among the 26 species of true mangroves in China, 13 species are rare and endangered, accounting for 50.0%. Among 11 species of mangrove associates, 4 species are rare and endangered, accounting for 36.3%. It is far higher than the average level of rare and endangered species of higher plants in China, which accounts for 15-20%, and it is also higher than the average level of rare and endangered species of true mangrove plants (16%) in the world.

Afforestation on tidal flats and conversion of ponds to forests are the primary methods to expand and restore mangroves. Tidal flat afforestation has been favored by local governments because of its relatively simple operation, large investment, quick feedback, and great social impact after successful afforestation. China has established a standard system for mangrove restoration based on tidal flat afforestation. However, tidal flat afforestation still faces many problems, including: relatively low effect, high cost, singular tree species, technical difficulty, unpredictable ecological risks, invasion of alien species, limited ecological function, and poor ability to defend against natural disasters as of artificial forest.

Conclusion 5

China's existing mangrove afforestation standards, restoration effectiveness evaluation system, and funding mechanism favor mangrove artificial afforestation. Practical and effective measures should be taken to foster natural restoration of mangrove ecosystem.

The problems of tidal flat afforestation in China are closely related to the domestic mangrove afforestation standards. There are 12 standards for mangrove afforestation that were officially released in China (4 industry standards and specifications, 8 local standards, see Appendix Table 4 for details). Even though these standards and specifications promote the growth of mangrove area, they still have some issues: a. most standards focus on vegetation restoration, while paying less attention to restoration of the whole ecosystem; b. there is a lack of technical standards for converting ponds to forests; c. artificial restoration is emphasized, while natural restoration is not specified; d. some specifications are not very clear about the requirements and design of project planning or the standards for afforestation operators; e. the guidelines ignore the investigation of environmental factors with insufficient background investigation of biodiversity; f. the project implementation and acceptance time is short; g. some standards overemphasize the use of seedlings cultured in containers; h. afforestation of single species is favored, while rational allocation of mixed forest is less practiced.

Different from terrestrial forests, the propagules of mangrove plants can spread along with water flow for a long distance, so they have high potential for natural restoration. Compared with artificial restoration, natural restoration has the advantages of fewer investment needed and a more stable community structure constructed. However, the existing mangrove restoration method still favors artificial tidal flat afforestation. The standard of mangrove restoration afforestation, the evaluation system of restoration effectiveness, and the funding mechanism should provide enough capacity for mangrove's natural restoration.

Conclusion 6

Converting ponds to forests should be the main battlefield for mangrove restoration in China. At present, relevant basic theories, technologies, standards, and cases are insufficient.

Enclosed aquaculture ponds built in early years constitutes the major reason for the destruction of mangrove forests in China. A considerable number of fish-ponds were formerly mangrove lands, providing the basic ecological conditions to restore mangroves. Due to the large-scale aquaculture and the lack of effective measures to deal with pollution, many aquaculture fish ponds are caught in a vicious circle of "expansion — pollution — degradation — disease outbreak — decline", and 30% of fish ponds and shrimp ponds went idle due to poor return. In addition, the total area of fish-ponds in mangrove protected areas in China exceeds 10,000 hectares, providing space for converting ponds to forests. Compared with tidal flat afforestation, conversion of ponds to forests has more advantages in restoring mangrove ecosystem functions. Converting ponds to forests should be the main battlefield of mangrove ecosystem restoration in China. In addition to the huge compensation required for collecting aquaculture ponds and the problem of farmers transferring jobs, we are not equipped with basic theory, technology, standards, and practical cases.

Conclusion 7

The choices of utilizing mangroves in China are relatively sparse. Sustainable utilization that can bring important service functions and ecological values of mangrove ecosystems still need to be developed.

Traditional pond culture is unsustainable. In addition to the implementation of converting ponds to forests, it is necessary to innovate the breeding method to achieve a win-win situation of ecological protection and economic development. At the same time, by standardizing the behavior of farmers, the regulated discharge of aquaculture pollution can be achieved. It is also necessary to further summarize and promote the technical models of "tidal pond aquaculture" and "in-situ ecological aquaculture with buried pipelines in mangroves" put forward by Guangxi Mangrove Research Center.

As the world's most valuable natural landscape for ecotourism and popular science education, mangrove ecosystem should play its due role in this respect in China. However, at present, mangrove ecotourism is still in the primary stage. From the perspective of content and format, most of the mangrove ecotourism programs lack creativity constituted with mostly self-guided sightseeing activity. The immersion experience and educational activities have not been incorporated.

Mangroves can capture and store a large amount of carbon that is permanently buried in marine sediments, making it one of the densest carbon sinks on the earth. The exploitation, maintenance, and promotion of blue carbon potential in coastal zone will help to make it the most economical and efficient way of carbon sequestration in the future. However, the research and development of mangrove "blue carbon" in China still faces the following challenges: a. there is a significant gap in the scientific data supporting the formulation of current emission reduction policies; b. the present situation of mangrove degradation affects the effective carbon sink function; c. suitable tidal flats for mangrove forest land is limited, and the area of coastal aquaculture ponds is large. Thus, it is urgent to consider the restoration mechanisms that preserve "blue carbon" functionality and provide sustainable livelihood.

Recommendations

When building ecological civilization in the future, the protection and restoration of mangroves in China will be further strengthened even though the restoration of mangrove ecosystems is usually very complicated. Considering the current situation, threats to China's mangroves, the problems of management, and the progress made so far, this project puts forward corresponding suggestions on mangrove protection, restoration, sustainable utilization, and management.

▼ Mangrove wetland

Recommendation 1

Future work is recommended to change the concept of conservation and strengthen the management of mangrove protected areas.

It is recommended that science literacy of the management personnel should be improved through introduction of advanced concepts and training. In addition, the construction of protected areas should be regulated, and the master plans, baseline scientific research and demarcation should be implemented. It should be noted that as one of the major work in mangrove nature reserve construction, monitoring should be stressed, by building national and provincial mangrove ecosystem research and monitoring field stations.

It is critically important to incorporate the concept of ecosystem management into the management of mangrove protected areas. We should manage and conserve the forest land, tidal flats, tidal valleys, shallow water areas, and fish ponds on the land side as a whole.

In the process of mangrove protection, restoration, and management, it is recommended to explore the establishment of community-based mangrove protection, ecological restoration, and management so that community co-management ca be promoted. We can encourage the community to actively participate in the protection and restoration of mangrove ecosystem while benefiting from it through the modes of conservation agreement and ecological compensation.

Recommendation 2

Set up the goals, models, and standard system of mangrove ecological restoration based on ecosystem restoration concept.

It is necessary to improve the existing criteria for tidal flat mangrove restoration and afforestation, and to reform current evaluation system of ecological restoration outputs, as well as the funding mechanism. At the same time, it is also necessary to set up a new standard system for the final evaluation of mangrove restoration efforts, which is primarily based on natural restoration and supplemented by artificial restoration. The general technical principles of mangrove ecological restoration in China include: expanding the restoration from vegetation to the overall structure and recovering the ecological functions of mangrove wetland ecosystem through the restoration of habitats for birds and benthos, and adopting the strategy of prioritizing natural restoration with the assistance of artificial restoration. While restoring the mangrove ecosystem, we can also create conditions to restore animal populations with economic benefits and to provide alternative livelihoods for residents living in the neighborhood. Specific measures include:

- Prepare technical standards for mangrove ecosystem restoration, and implement the ecological restoration principle of "natural restoration as the mainstay and artificial restoration as the supplement" in terms of restoration objectives and models, time arrangement, and performance evaluation;
- Enhance scientific research, break through the seedling cultivation technology of certain mangrove species, and apply it in mangrove ecological restoration projects;
- From the regional perspective, the priority restoration sites and targets should be scientifically evaluated and determined to avoid over restoration;
- Afforestation in intertidal zone should be carried out in a scientific way. Apart from a small amount of afforestation for the purpose of coastal protection, tidal flat afforestation should be gradually reduced. For all kinds of tidal flat wetlands, relevant departments should organize experts in mangrove research, marine hydrology, marine biology, and waterfowl research along with local residents to conduct strict scientific assessment. Other than mangrove habitat, other components of the ecosystem should also be taken into account when determining locations in tidal flat that are suitable for mangrove ecological restoration. It should be forbidden to carry out afforestation with filling mud in sea grass beds and in important waterfowl habitats;
- Converting ponds to forests should be the major battlefield of mangrove ecological restoration in China. We should enhance the research in theory and development in technology of converting ponds to forests, as well as the construction of demonstration sites. Breakthroughs should be made in solving how to quickly recover mangroves' ecological functions in the process of converting ponds to forests. The operational manual of converting ponds to forests should be compiled in time. In view of the high population density and great human interference in coastal areas, we should also take active intervention measures while relying primarily on natural restoration. Intervention measures include community participation, hydrological connectivity restoration, and artificial planting of seedlings, with the exception of afforestation after filling up fish ponds. (See Appendix Figure 1 for details).;
- We should be wary of exotic mangrove species for afforestation. Exotic species are prohibited in protected areas and strict scientific argumentation should be carried out for using them outside of protected areas;
- It is recommended to summarize the existing successful cases of mangrove restoration and research so that China can provide reference for mangrove restoration in "The Belt and Road" countries. China should establish a leading role in mangrove research, protection, and management worldwide.

Recommendation 3

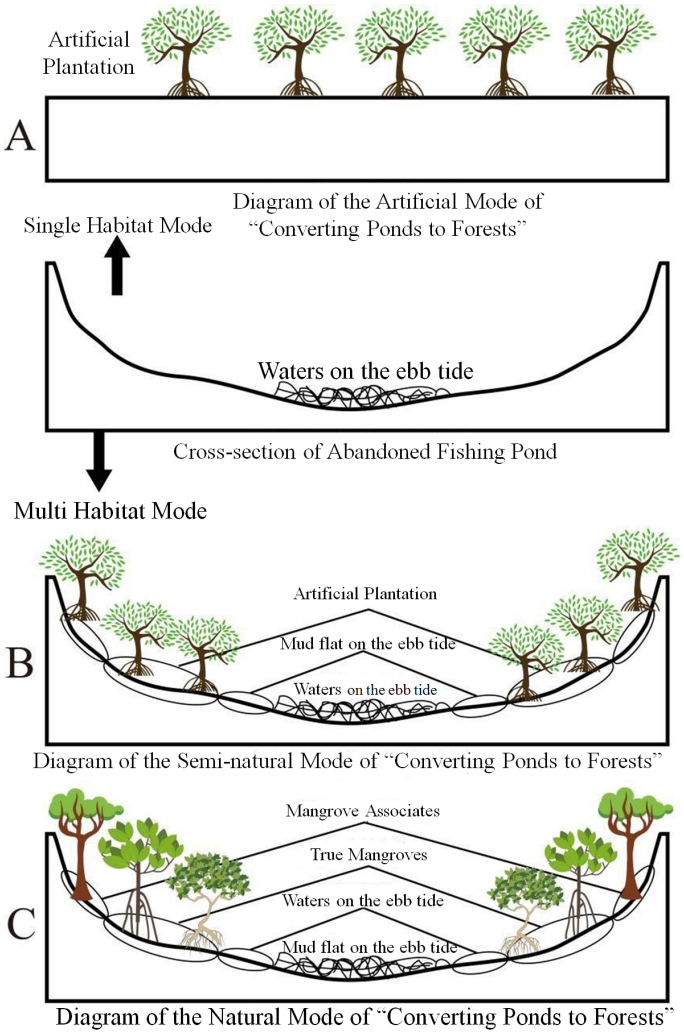
The third recommendation includes adjusting the management measures for mangrove wetland so that different treatment plans would be applied to strictly protected areas and accessible areas. Also, a diversified and sustainable utilization of mangrove wetland resources need to be fostered.

- Ecotourism and ecological aquaculture have become effective models of sustainable utilization of mangrove wetlands in China. For example, mangrove ecotourism should play a substantial role in the construction of Hainan International Tourism Island;
- Advancement in mangrove ecotourism can be made by building a professional ecotourism management team with high-quality interpreters. The team should enriching the content and innovate a new format of ecotourism while expanding the market, improving the quality of citizen science education, and promoting community and social engagement.
- Seafood farmers should develop innovative systems for aquaculture. They should be educated with standardized practices and be encouraged to develop sustainable aquaculture which can greatly reduce the sewage discharge of the aquaculture pond. Thus, sustainable aquaculture should be the focus of our research on sustainable utilization of mangrove in the future;
- It is recommended to systematically study the formation mechanism and spatial-temporal distribution of mangrove's contribution as blue carbon. Measurement standards and a systematic evaluation system for mangrove ecosystem need to be established. We should understand the development potential of mangrove blue carbon in China, and strengthen the research, development, and pilot study of mangrove protection so that we can improve ecosystem's carbon sequestration ability. Also, we should develop and demonstrate mangrove blue carbon trading projects;
- Studies on comprehensive evaluations of the value of mangrove ecosystem services in China should be strengthened. Simple and practical standards should be set up. A technical support system in ecological compensation that facilitates management and law enforcement should be established. The value assessment of the coastal protection function of mangrove (or coastal wetland) on the national scale in China should be carried out to provide scientific support for formulating China's coastline management plans, disaster prevention plans in national and local levels, and climate change response programs;
- Natural mangroves and artificially restored mangrove wetland resources in non-protected areas should be protected in different ways.Natural mangroves and mangrove wetland resources in protected areas should be regulated under strict protection. The artificial mangrove wetland resources outside of protected areas, however, should be free from unnecessary restrictions. Instructions should be provided to local communities so that artificial mangrove wetland resources outside of protected areas can be utilized in a scientific and sustainable way.

Appendix

Figure 1 Three Modes of "Converting Ponds to Forests"

At present, converting ponds to forests in China can be classified into the following three modes: artificial (A), semi-artificial (B) and natural (C). Among them, the natural mode makes use of the characteristics of mangrove plants. Seeds or hypocotyls of mangrove plants flow along with the water for a long distance, and settle in abandoned fish ponds or tidal flats and then grow into mangroves. The natural restoration of abandoned fish ponds requires artificial breaking of fish pond dikes. When hydrological channels are constructed, the propagules of mangrove plants would naturally float into fish ponds and develop into mangroves. Compared with artificial restoration, natural restoration is with lower investment and can develop healthier community structure.



Appendix Table 1 Mangrove Species and Distribution in seven Provinces and Regions in China

Species	Zhejiang	Fujian	Guangdong	Guangxi	Hainan	Hong Kong	Taiwan	IUCN
Kandelia obovata	introduced	√	√	√	√	√	√	LC
Bruguiera gymnorhiza		√	√	√	√	√	extinct	LC
Bruguiera sexangula		introduced	introduced		√			NT
B. s. var. rhynchopetala		introduced	introduced		√			VU
Rhizophora stylosa		introduced	√	√	√	extinct	√	LC
Rhizophora apiculata					√			VU
lamarkii					√			CR
Ceriops tagal			√	extinct	√		extinct	LC
Pemphis acidula					√		√	EN
Sonneratia caseolaris			introduced		√			LC
S. × gulngai					√			EN
S. × hainanensis					√			CR
Sonneratia ovata					√			CR
Sonneratia alba					√			LC
Xylocarpus granatum					√			VU
Lumnitzera racemosa		introduced	√	√	√	√	√	LC
Lumnitzera littorea					√			CR
Acanthus ilicifolius		√	√	√	√	√	√	LC
Acanthus ebracteatus			√	√	√			EN
Scyphiphora hydrophyllacea					√			EN
Acrostichum aureum		extinct	√	√	√	√	√	LC
Acrostichum speciosum			√		√			EN
Nypa fruticans					√			VU
Avicennia marina		√	√	√	√	√	√	LC
Aegiceras corniculatum		√	√	√	√	√	√	LC
Excoecaria agallocha		extinct	√	√	√	√	√	LC
Total (Native Species)	0	7	12	11	26	9	11	

CR:critically endangered EN:endangered VU:vulnerable NT:near threatened LC:least concern

Appendix Table 2 Species and Distribution of mangrove associates in China

Species	Zhejiang	Fujian	Guangdong	Guangxi	Hainan	Hong Kong	Taiwan	IUCN
Pongamia pinnata		extinct	√	√	√	√	√	LC
Hibiscus tiliaceus		√	√	√	√	√	√	LC
Thespesia populnea		introduced	√	√	√	√	√	LC
Heritiera littoralis			√	√	√	√	√	VU
Barringtonia racemosa		introduced	√		√		√	VU
Cerbera manghas		introduced	√	√	√	√	√	LC
Clerodendrum inerme		√	√	√	√	√	√	LC
Premna obtusifolia		introduced	√	extinct	√	√	√	LC
Dolichandrone spathacea			extinct		√			EN
Pluchea indica		√	√	√	√	√	√	LC
Hernandia nymphiifolia					√		√	EN
Total (Native Species)	0	4	10	8	11	8	10	

CR:critically endangered EN:endangered VU:vulnerable NT:near threatened LC:least concern

Appendix Table 3 Basic Information about China's Mangrove Protected Areas

Name	Level	Time of establishment	General Regulations	Regulatory Agency	Scientific Research	Demarcation
1.Longhai Jiulong River Estuary Provincial Mangrove Nature Reserve, Fujian	Provincial	1988	Yes	Yes	Yes	Yes
2.Ningde HuanSandu'ao Wetland, Waterfowl and Mangrove Nature Reserve, Fujian	County/ Municipal	1997	Yes	No	Yes	No
3.Quanzhou Bay Estuary Wetland Provincial Nature Reserve, Fujian	Provincial	2002	Yes	Yes	Yes	Yes
4.Zhangjiang Estuary Mangrove National Nature Reserve, Fujian	National	1992	Yes	Yes	Yes	Yes
5.Daya Bay Mangrove National Wetland Park, Guangdong	National	2017	Yes	No	Yes	No
6.Haifeng Bird Provincial Nature Reserve, Guangdong	Provincial	1998	Yes	Yes	Yes	Yes
7.Hailing Island Mangrove National Wetland Park, Guangdong	National	2014	Yes	Yes	Yes	Yes
8.Huizhou Huidong Mangrove Nature Reserve, Guangdong	County/ Municipal	1999	Yes	No	Yes	Yes
9.Leizhou Jiulong Mountain Mangrove National Wetland Park, Guangdong	National	2009	Yes	Yes	Yes	Yes
10.Maogang Mangrove Nature Reserve, Guangdong	County/ Municipal	2001	Yes	No	Yes	No
11.Maoming Shuidong Bay Mangrove Nature Reserve, Guangdong	County/ Municipal	1999	Yes	Yes	Yes	Yes
12.Shantou Wetland Nature Reserve, Guangdong	County/ Municipal	2001	Yes	No	Yes	Yes
13.Shenzhen Dapeng Peninsula Nature Reserve, Guangdong	County/ Municipal	2010	Yes	No	Yes	Yes
14.Shenzhen Neilingding Island-Futian National Nature Reserve, Guangdong	National	1984	Yes	Yes	Yes	Yes
15.Taishan Zhenhai Bay Mangrove Nature Reserve, Guangdong	County/ Municipal	2005	Yes	No	Yes	Yes
16.Yangjiang Pinggang Mangrove Nature Reserve, Guangdong	County/ Municipal	2005	No	No	No	No
17.Chengcun Haoguang Mangrove Nature Reserve, Yangxi County, Guangdong	County/ Municipal	2000	No	No	No	No
18.Zhanjiang Mangrove National Nature Reserve, Guangdong	National	1990	Yes	Yes	Yes	Yes
19.Zhuhai Qi'ao-Dangan Island Provincial Nature Reserve, Guangdong	Provincial	1989	Yes	Yes	Yes	Yes
20.Beihai Binhai National Wetland Park, Guangxi	National	2016	Yes	Yes	Yes	Yes
21.Maowei Sea Mangrove Autonomous Region Nature Reserve, Guangxi	Provincial	2005	Yes	Yes	Yes	Yes
22.Shankou National Mangrove Ecological Nature Reserve, Guangxi	National	1990	Yes	Yes	Yes	Yes
23.Beilun Estuary National Nature Reserve, Guangxi	National	1985	Yes	Yes	Yes	Yes
24.Nansha Wetland Park, Guangzhou	County/ Municipal	2004	Yes	Yes	Yes	Yes
25.Chengmai Huachang Bay Mangrove Nature Reserve, Hainan	County/ Municipal	1995	No	No	No	No
26.Danzhou Xinying Bay Mangrove Nature Reserve, Hainan	County/ Municipal	1986	No	No	No	No
27.Oriental Black-faced Spoonbill Provincial Nature Reserve, Hainan	Provincial	2006	Yes	Yes	Yes	Yes
28.Dongzhai Port National Nature Reserve, Hainan	National	1980	Yes	Yes	Yes	Yes
29.Lingao County Caiqiao Mangrove Nature Reserve, Hainan	County/ Municipal	1986	No	No	No	No
30.Lingshui Mangrove National Wetland Park, Hainan	National	2017	Yes	No	Yes	Yes
31.Qinglan Port Provincial Nature Reserve, Hainan	Provincial	1981	Yes	Yes	Yes	Yes
32.Sanya River Municipal Nature Reserve, Hainan	County/ Municipal	1989	No	Yes	No	Yes
33.Sanya Qingmei Port Nature Reserve, Hainan	County/ Municipal	1989	Yes	Yes	Yes	Yes
34.Sanya Tielu Port Nature Reserve, Hainan	County/ Municipal	1999	No	No	No	No
35.Nature Reserve of Korean Spindle Forest, Hainan	Provincial	1980	Yes	Yes	Yes	Yes
36.Xinying Mangrove National Wetland Park, Hainan	National	2005	Yes	Yes	No	Yes
37.Cangnan Long Port Mangrove Provincial Wetland Park, Zhejiang	Provincial	2018	Yes	No	Yes	Yes
38.Ximen Island National Marine Special Reserve, Zhejiang	National	2005	Yes	Yes	Yes	Yes

Appendix Table 4 Afforestation Standards for Mangroves in China

Standard	Level	Time of Release & Serial No.	Compilation Institute	Time of Examination	Qualification Requirement for Designer	Monitoring Requirement	Mode of Plantation	Baseline Survey	Recommended Species for Plantation
Technical specification for mangrove construction	Industry	LY/ T1938-2011	Yangtze River Basin Shelterbelt System Construction Management Office of State Forestry Administration, etc	≥3 years	No	Mangrove plant growth, community regeneration and succession, pests and diseases and exotic invasive species, biodiversity change, water purification effect, heat island reduction effect, wave and disaster reduction effect, ecotourism, etc. But there are no specific requirements or detailed rules.	The requirements of container seedlings and hypocotyls are specified.	No	17 species of true mangrove plants and 5 species of mangrove associates, including *Sonneratia apetala* and *Laguncularia racemosa*, but not *Sonneratia alba*, *Barringtonia racemosa* and *Sonneratia paracaseolaris*.
Technical specification for mangroves to control Spartina	Industry	LY/ T2130-2013	Institute of Tropical Forestry, Chinese Academy of Forestry	2-4 years	No	No	Container seedlings	No	9 species of true mangrove plants including *Sonneratia apetala* and *Laguncularia racemose*
Technical Guide for Mangrove Vegetation Restoration	Industry	HY/ T214-2017	Third Institute of Oceanography, State Oceanic Administration, Xiamen University	No	No	No	Hypocotyl planting is preferred	Yes	Risk assessment and monitoring are required for introducing alien species
Technical specification for mangrove afforestation in tidal flats with harsh conditions	Industry	LY/ T2972-2018	Institute of Tropical Forestry, Chinese Academy of Forestry	≥3 years	Expert review of mangrove afforestation technology should be organized	No	Primarily container seedlings	No	14 species of true mangrove plants and 5 species of mangrove associates, including exotic species *Sonneratia apetala* and *Laguncularia racemose*
Technical regulation for seedling raising of Sonneratia apetala in mangrove fores	Local	DNB440500/ 41-2003	Shantou Forestry Science Institute , Guangdong		—	—	Container seedling		
Technical specification for cultivation of Sonneratia apetala in mangrove fores	Local	DNB440500/ T41—2003	Shantou Forestry Science Institute, Guangdong	No	No	No	Container seedling	No	
Technical regulation of mangrove mulberry cultivation	Local	DNB440500/ T85-2004	Shantou Forestry Science Institute, Guangdong	No	No	No	Container seedling	No	
Technical regulation for seedling raising of Sonneratia apetala in mangrove forest	Local	DNB440500/ T84—2004	Shantou Forestry Science Institute, Guangdong	—	—	—	Container seedling	—	
Technical specification for mangrove afforestation	Local	DB44/ T284-2005	Institute of Tropical Forestry, Chinese Academy of Forestry	Fast-growing tree species for 1-2 years, slow-growing tree species for 2-3 years	Expert review of mangrove afforestation technology should be organized	Growth of seedlings	The quality standard of container seedlings is stipulated	No	*Sonneratia apetala* and *Laguncularia racemosa* are on the list, while introduction in the core area of nature reserves is prohibited.
Technical specification for mangrove afforestation	Local	DB33/ T920-2014	Institute of Subtropical Crops, Zhejiang Academy of Agricultural Sciences	≥3years	Grade C or above qualification and familiar with mangrove afforestation technology	Growth of seedlings	Hypocotyls / container seedlings	No	*Kandelia obovata*
Technical regulation of Kandelia obovataf afforestation	Local	DB35/ T1619-2016	Quanzhou Forestry Technology Promotion Center, etc	≥3years	No	Growth of seedlings	Hypocotyls / container seedlings	No	*Kandelia obovata*
Technical regulation for seedling raising of Sonneratia apetala	Local	DB45/ T1712-2018	Qinzhou Forestry Science Institute, Guangxi Zhuang Autonomous Region	—	—	—	Growth of seedlings		
Mangrove ecosystem restoration manual		Printed version, not officially published	Xiamen University, GEI, Dongzhai Port National Nature Reserve Administration	≥3 years	Experts with mangrove professional background should be involved	Mangrove vegetation, birds, benthos and fish	Hypocotyls, container seedlings and naturally transmitted seedlings	Yes	Most mangrove species in China

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