Mangroves at the Intersection of Ecological Protection and Targeted Poverty Alleviation[i]

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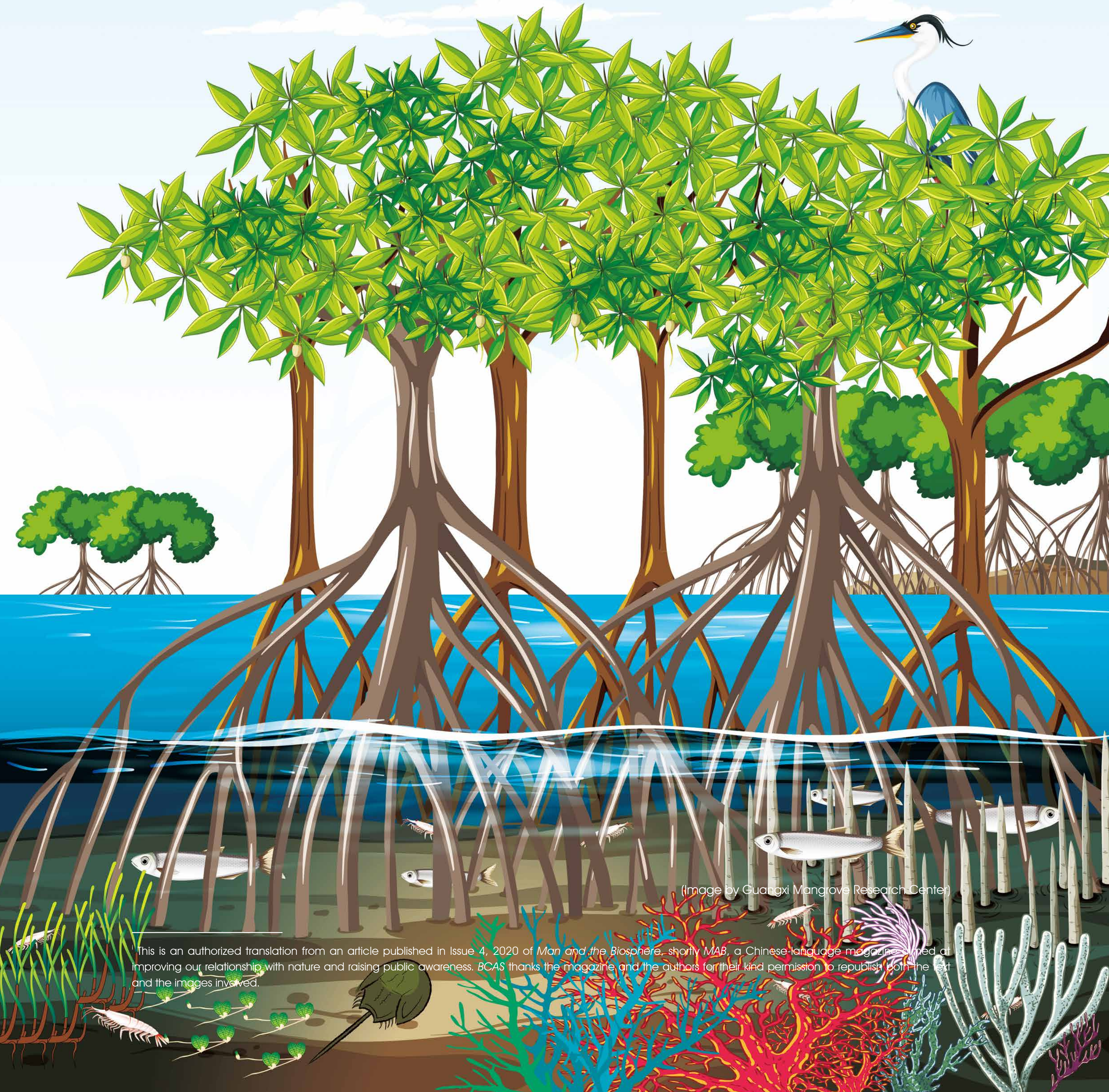

(Image by Guangxi Mangrove Research Center)

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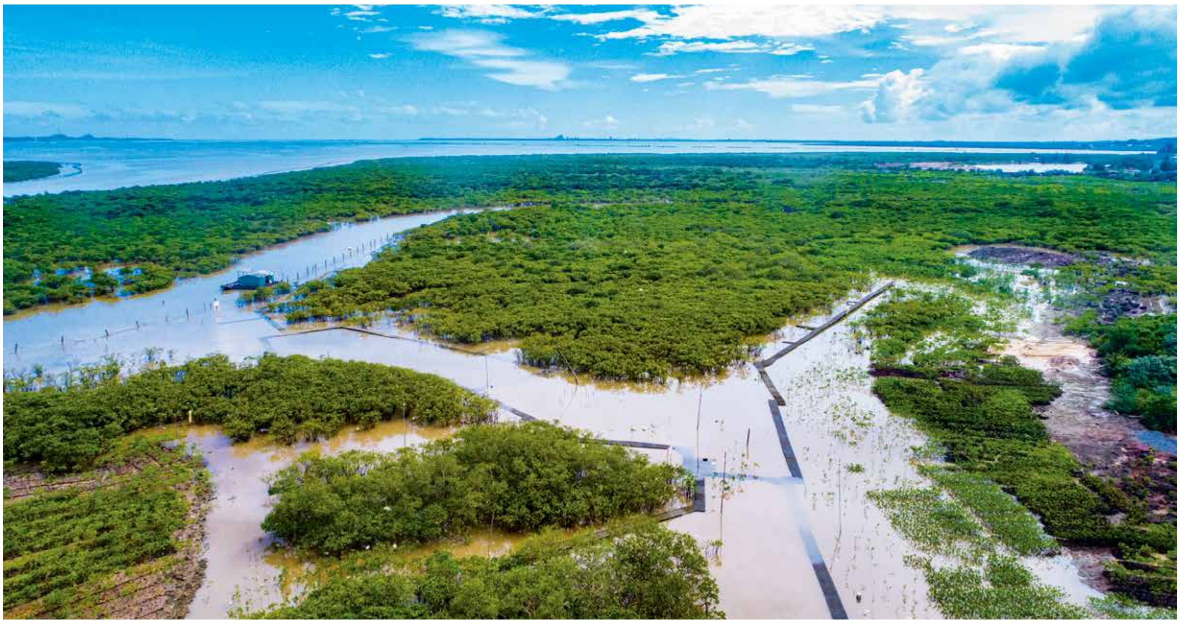
Mangroves are woody trees or shrubs that guard the coastlines and offer shelters for a plethora of living things. They bear the brunt of strong ocean waves and thrive despite twice-daily flooding by ocean tides. However, we have witnessed a vast loss of mangrove forests due to human causes, mainly the need to improve people's livelihoods. It is becoming increasingly urgent to balance the need for economic development and ecological protection of mangrove forests. After all, it is a shame if our next generation loses the chance to lay eyes upon such beautiful sights.

Since 1975, 50%~60% of mangrove forests in Thailand have been converted into shrimp farms, and about 50% of mangrove forests in the Philippines have been transformed into brackish fish ponds and shrimp ponds. The Indonesian government has proposed a plan to double mangrove shrimp production, which may encourage shrimp producers to destroy another 600,000 hectares of mangroves for building new shrimp ponds between 2012 and 2030.

From 1980 to 2000, 12,923.7 hectares of mangrove forests disappeared in China, of which 97.6% give way to shrimp ponds. With the decline of mangrove forests, marine animal resources within the mangrove ecosystems have dropped by 65%, accompanied by significant functional degradation. Reportedly, the global mangrove area has fallen sharply from 18.8 million hectares in 1980 to 15.2 million hectares in 2005, representing an approximate 20% of area loss. Notably, more than half of mangrove loss is due to aquaculture.



A new way of underground mangrove eco-farming provides shelter for decreasing mangrove biodiversity and the livelihood of the local farmers. (Photo by SU Bo, *MAB*)

Can Aquaculture Leave Mangrove Untouched?

In 1999, more than 2,000 *mu* (one hectare equals 15 *mu*) of mangroves from Zhakou Town, Hepu County, Guangxi Province, were destroyed to build aquaculture ponds. The local authority believed that mangroves were worthless. Replacing them with aquaculture is the right thing to do to ensure development, the highest priority. This incident made us intensely aware that the causes of ecological problems are economic problems. Hence, we should consider economic factors when we try to solve ecological problems. Ecologists should make achievements in their research fields and be responsible for awakening people's ecological awareness and exploring new models that protect the environment and care for livelihoods.

In 2005, the Guangxi Mangrove Research Center (GMRC) won the financial support from the UNEP/GEF project for its initiative and has since embarked on a journey of ecosystem protection under the program entitled "Reversing Environmental Degradation Trends in the South China Sea and the Gulf of Thailand."

In 2007, given the strategic significance of ecological farming in global mangrove protection, Global Environment Facility (GEF) specially arranged additional funds and designated GMRC to work out solutions to this global problem. At the beginning of research and development, we established the following principles:

(1) Do not cut or enclose mangroves, and do not change the natural topography of mangrove tidal flats;

(2) To create a really functioning ecology under the mangroves, rather than merely an economy literally "under" the mangroves in a spatial sense. The new model must be conducive to the restoration and maintenance of mangroves and the biodiversity of their ecosystems;

(3) Providing livelihoods will help increase the conscious awareness of protecting mangroves.

To restore the marine ecosystem, we decided to start with behavior simulations of the marine aquaculture animals and carry out the "large mesh

The locals are trained to implement diverse eco-farming methods to enhance their incomes. (Photo at the lower right corner by courtesy of Dr. FAN Hangqing; others by SU Bo, *MAB*) fenced tidal flat ecological breeding" experiments in the Beilun Estuary National Nature Reserve in Guangxi. In the project, we set up water-blocking sandbags in the tidal trench to retain water at low tides and constructed three artificial fish nests for Chinese gudgeons and one artificial crab nest for mangrove crabs in the test area, in which Chinese gudgeon and mudskipper fries are sown with sea worms and mangrove clams at the bottom.

We found that, although the model of "large mesh purse seine ecological farming in tidal flats" can breed aquaculture species, it has the following shortcomings: the output per unit area is meager; litter and floating debris will block the mesh, and the net will collapse during typhoon surge; when the tide is low, the mouse will enter the beach and bite the barrier, causing the farmed animals to escape; the catch rate of the farmed fish and crabs is low, usually in the range of 10%～30%; daily management frequently tramples on tidal flats, causing strong disturbance to mangrove seedlings and benthic animals, which is not conducive to biodiversity restoration.

However, we realized that the benthic fish, such as Chinese gudgeon of high market prices, which can survive and grow in buried wooden boxes, may represent a good choice for our further exploration. Sufficient dissolved oxygen and excellent water quality may allow a considerable breeding density of the fish. Given that water should flow in the nest when the tide is low, it naturally occurred to us that building an "underground real estate" for benthic fish under the mudflat soil is the most feasible method.

The Birth of Buried Pipeline-based Mangrove Eco-farming

To make it happen, we first sought to find a test site that can store water, a site covered with mangroves and endowed with the basic conditions for residential management and protection. After investigation and comparison, we finally selected a test site at Xiaolongmen, Gongche Town, Dongwan City, Fangchenggang City, Guangxi, with a mangrove tidal flat area of 3.44 *mu*. We used bricks instead of wooden planks to build underground nests in the experiment, chose PVC pipes to supply constant water, and installed vertical tubes with holes for oxygen and natural animal bait supply.

In December 2010, a national team of evaluation experts paid an on-site investigation and concluded that the yield of Chinese gudgeons was 120 kg/*mu*, its survival rate was 94%, its recapture rate was 90%, and the growth cycle was only half of that of traditional aquaculture. This aquaculture mode is suitable for mangrove aquaculture and can be extended to other marine aquaculture scenarios.

We also found that the omnivorous snake eel and Japanese eel, which are very expensive in the market, can also grow in our buried pipeline-based eco-forming system. Natural small animals in the sea can enter through the stomata to supplement the system with raw food. The tide supplies the aquaculture water, and the water quality elements are equal to that of the natural sea area. So, our team demonstrated the feasibility of using mangrove buried pipelines for "eco-farming," and applied for an invention patent for that. Then, we started a pilot test.

We chose the Shijiao secondary mangrove forest in the Beilun Estuary Nature Reserve in Guangxi as the pilot plant. In order to reduce human interference and speed up ecosystem restoration, we set up large mesh fences around the test site to prevent surrounding villagers from entering the test site to collect aquaculture animals and erected forest plank roads to minimize human interferences to the tidal flats during daily management.

In addition, we used our exclusive patented technology, "piston open cannula," and set up small refuge pits to provide natural marine animals with a sheltered habitat at low tide. Our observation shows that the open cannula offers shelter for at least ten benthic species, such as Chinese gudgeon, mudskipper, and two different mangrove crabs. The abundance of top marine animals in the experimental area is 3-6 times higher than the surrounding natural forests. The pilot test area was a severely degraded mangrove area. Its mangrove coverage in 2011 was less than 10%. By 2015, the coverage had reached 75%, and by 2020, the partial coverage had exceeded 95%. The structure and function of mangroves and their ecosystems had recovered fully and rapidly, achieving the win-win goal of eco-farming and ecosystem rehabilitation.

At the "Asia-Pacific Mangrove Restoration and Sustainable Management Incentive Mechanism Seminar" held in Beihai from October 29 to 31, 2012, experts from various countries gave a written evaluation for the pilot plant. "The mangrove *in situ* eco-farming and conservation system established by Dr. FAN Hangqing and his team from the Guangxi Mangrove Research Center is unique and original instead of a derivative of other existing ones," says the evaluation. "As far as we know, there is no similar system anywhere else in the world. This very mangrove eco-farming system is so far the first one that imposes no impact on the mangrove itself. The unique system may find wide applications in other mangrove ecosystems throughout the Asia-Pacific region."

Later, we spotted several new problems in the pilot test. For example, the brick-built breeding infrastructures will crack and leak after two or three years; the low level of standardization in building components poses challenges to mass production and promotion; the high-density breeding in the pipeline could easily cause disease outbreaks. We also noticed that we could use the abandoned shrimp ponds because the precious coastal space resources and tidal energy are not fully utilized if these ponds merely function as reservoirs.

Eco-farming Promotes Integrated Restoration of Coastal Wetlands

In 2015, GMRC was awarded the "Research and Demonstration of Damaged Mangrove Ecological Conservation Based on Buried Pipeline Ecological Farming System" by the National Marine Public Welfare Industry Scientific Research Project. In December 2016, GMRC established the "Guangxi Mangrove Research Center Pearl Harbor Ecological Experimental Station" to provide stable support for the project.

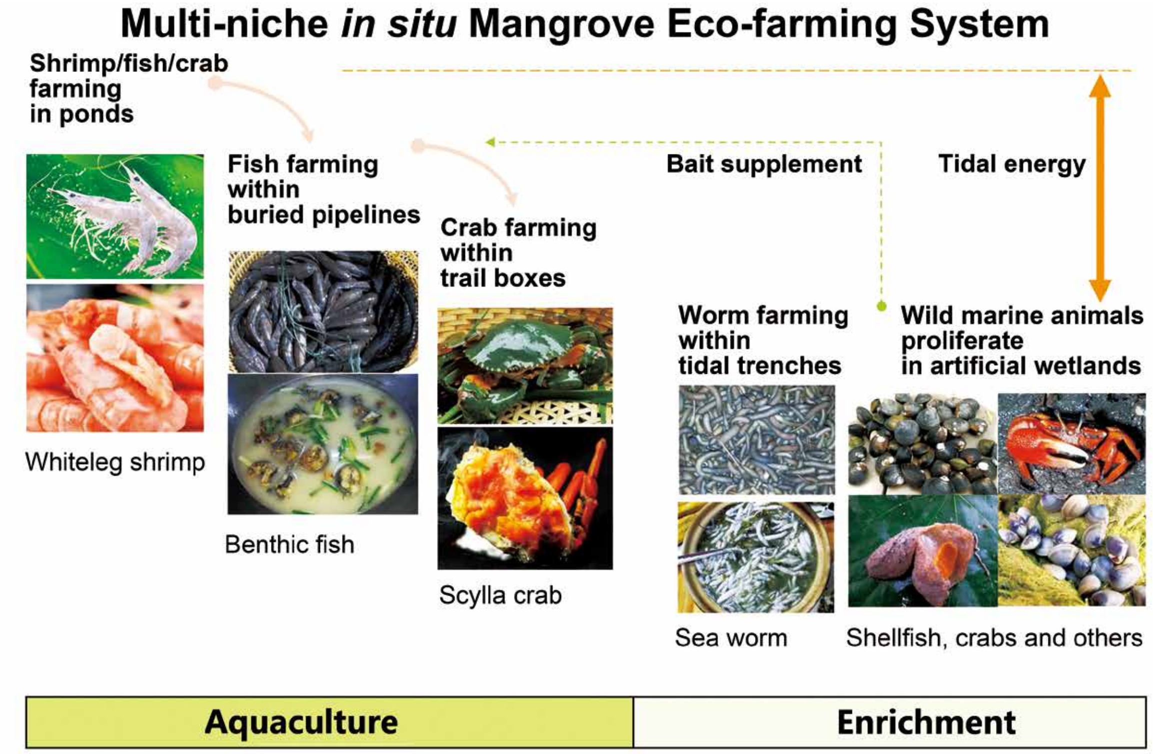
To solve the problems found in the pilot test, our team designed exchange tubes, fishway isolation devices and cover nets, and commissioned relevant manufacturers to carry out standardized production of these critical components, eliminating the problem of facility cracking and leakage. Through experiments, we found over ten species suitable for mangrove eco-farming and developed three species (Chinese gudgeon, Japanese eel, and mangrove crab) for mangrove in-situ eco-farming practices.

We then found that the survival rate of Chinese gudgeon and mangrove crab increased to over 80%, the catch rate of the final products increased to 95%, and the product quality became close to that of the natural ecology. By applying two sets of buried pipeline-based eco-farming systems for each *mu* of mangrove beach, we achieved an annual output of 75 kg/*mu* on average. The output value of each *mu* reaches 9,000 yuan, which is 22.5～45 folds to the natural seafood value that the same area of mangrove forest can produce.

We then used the abandoned shrimp ponds for supplying water to the buried pipelines of the *in situ* eco-farming aquaculture system in the intertidal zone. We wondered if it is possible to restore mangroves and carry out eco-farming in the shrimp ponds without damping its current function to supply water. Our observation showed that the water level of the abandoned shrimp ponds became critically low after several consecutive days of net water supply to the buried pipelines, which could endanger the farmed animals within the ponds.

To solve this problem, we built a shelter ditch at the bottom of the abandoned shrimp pond, carried out a multi-species ecological polyculture experiment after grasping the basic water level. As a result, our team established the "tide-absorbing hybrid eco-farming model for sustainable mangrove restoration from abandoned shrimp ponds." According to this new model, we planted mangroves in the abandoned shrimp ponds, and carried out hybrid eco-farming simultaneously without interrupting the constant water supply from the ponds to the buried pipeline system in the intertidal zone. Together, this new model realizes the integrated ecological restoration and rational utilization of multiple resources of the sea and wetlands.

Seven carnivorous fish fries and two omnivorous fries were primarily chosen for hybrid eco-farming within abandoned shrimp ponds. After three years of exploration, the average annual catch can reach 46 kg per *mu*. The mangroves in the shrimp ponds have also grown well. After the long-term natural competition, the rational allocation of scientific parameters of the breeding population has also been established.



Tidal energy is employed to create rising and falling tides in abandoned shrimp ponds together with external electricity. Natural seawater supplies water flow for shrimp ponds, buried pipelines, and crab cages. The aquaculture sediments are for salt-tolerant plants. The aquaculture tailwater enters the artificial mangrove wetlands for partial purifications instead of directly discharging into the sea – part of the purified water can be reused for eco-farming. The artificial wetlands are used for wild marine animals' proliferation (without bait feeding) or low-density tide-absorbing ecological polyculture to restore biodiversity. Through multi-niche coupling, abandoned shrimp ponds can be converted into mangrove wetlands. These models of eco-farming would reduce aquaculture pollution, build coastal leisure and education sites, create ecological employment, and promote the sustainable return of ponds to mangroves or wetlands. (Image by Guangxi Mangrove Research Center)

Advancing to the Future – Shrimp Pond Mangrove Eco-farming

China is extremely short of intertidal beaches that are suitable for mangrove afforestation. To expand the mangroves area, we can only ask for space from abandoned shrimp ponds along the coast. On the Chinese southeast coast ranging from Zhejiang to Hainan, there are approximately 240,000 hectares of aquaculture ponds, of which at least 10% were once mangrove tidal flats. If we can rewind 5% of these aquaculture ponds into mangrove wetlands, there would be over 10,000 hectares more along the coast. It is convincing that abandoned shrimp ponds will be the main battlefield for ecological restoration of mangroves in China for a long time to run. In most cases, it is not simply through pushing down the dikes, introducing water, and planting trees. To ensure long-term stability, we need to consider the residents' livelihoods when advancing the coastal ecological projects.

To this end, we have drawn a blueprint for the "shrimp pond mangrove eco-farming," in which hybrid and integrated eco-farming will help mangrove restoration and enhance the local population's economic incomes. Additionally, this new model of eco-farming provides a paradigm for public ecological education.

At present, the Guangxi Zhuang Autonomous Region has incorporated the "shrimp pond mangrove eco-farming" into the work plan of the autonomous region government and has arranged a major innovation-driven development project to conduct research and demonstration.

(Translated by YAN Fusheng)