Marine Ranching: China's Blue Solution for Food Security

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Abstract: Facing global food challenges, China is pioneering an innovative solution to ocean resource management: marine ranching. This concept, transforming sections of the sea into managed underwater farms, stands at the forefront of China's food security and ecological preservation strategy. Led by institutions like the Institute of Oceanology under the Chinese Academy of Sciences, marine ranching goes beyond traditional aquaculture. It establishes managed ecosystems that not only yield food but also contribute to the restoration of marine biodiversity. This blue revolution addresses the urgent need for sustainable seafood production and aids in rehabilitating underwater ecosystems. China's practice in this field might have provided valuable reference for global sustainable ocean management.

Keywords: food security, marine ranching, ecosystem management, marine biodiversity

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In the vast expanse of China's coastal waters, a quiet revolution is taking place. Led by the visionaries at the Chinese Academy of Sciences (CAS) and other national research entities, marine ranching is transforming barren seabeds into thriving underwater ecosystems teeming with life. Welcome to the world of marine ranching—China's innovative approach to sustainable seafood production and ecological restoration.

The Seeds of Innovation

The roots of marine ranching are deeply entwined with China's long-standing relationship with the ocean. Our story began in the 1950s, when pioneering

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Chinese scientists first dreamed of "farming the sea". Notably, the late CAS Member ZENG Chengkui (1909.6.18–2005.1.20), a famous marine scientist in China, envisioned not just fish farms, but entire underwater ecosystems, cultivated to sustainably produce seafood while preserving marine biodiversity. By the 1980s, the concept of "marine ranching" had taken root in China.

Graphic: Dr. YANG's group

Wild sea cucumbers (*Apostichopus japonicus*) in various colors can be spotted resting along shorelines.

From Concept to Reality

Today, the marine ranching team at the CAS Institute of Oceanology has successfully transformed these early visions into a dynamic reality. The marine ranching concept has evolved into a multifaceted and sophisticated approach, yielding substantial ecological and economic benefits.

The Institute has led three major waves of China's marine aquaculture industry involving kelp, shrimps, and scallops. As we entered the 21st century, attention shifted to sea cucumbers, a species with significant ecological and economic value.

Graphic: Institute of Oceanology, CAS

ZENG Chengkui, a renowned marine scientist and late Member of the Chinese Academy of Sciences (CAS), pioneered the concept of "farming the sea".

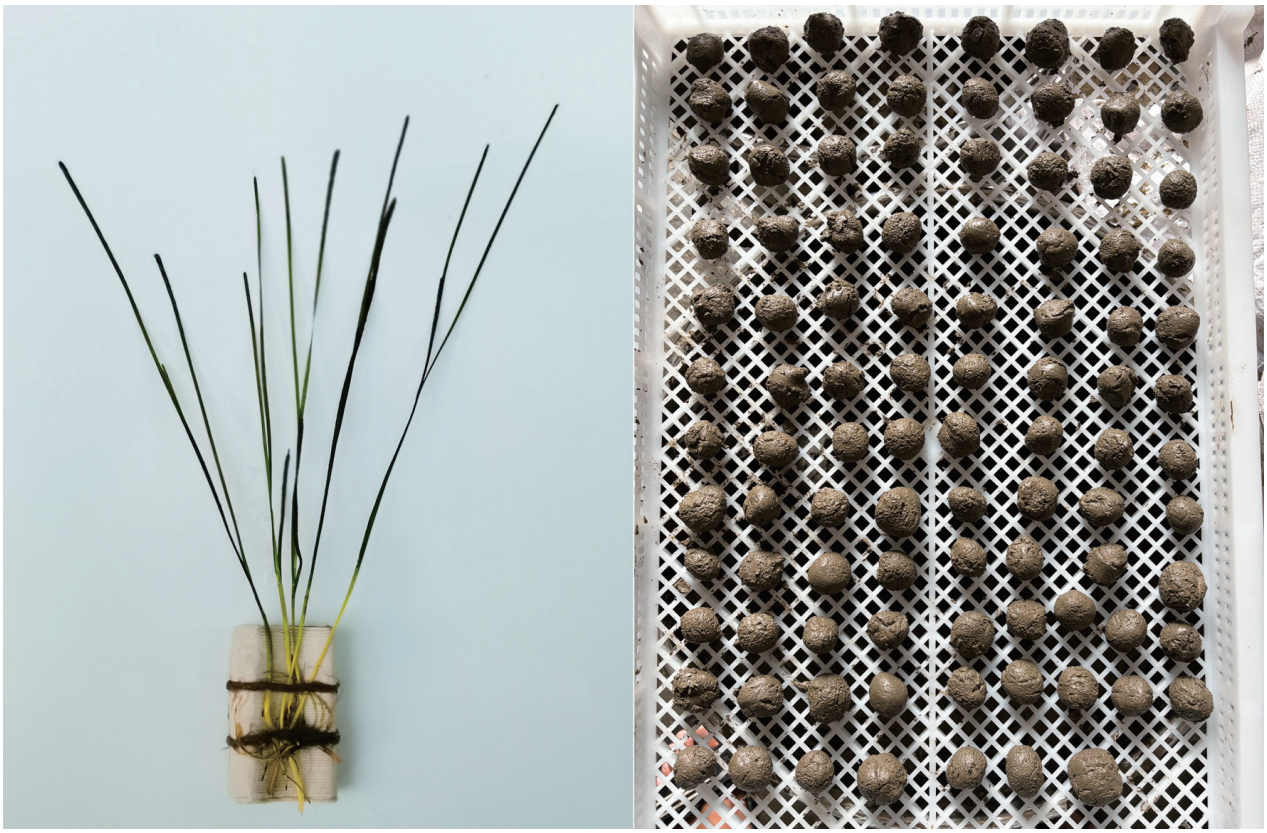
In 2017, we decoded the genome of the sea cucumber, leading to the development of the "*Dongke No.1*"—a new breed that grows faster and is more resilient to environmental stresses. This new breed has been effectively promoted in various aquaculture operations, contributing to increased yields and sustainable practices within the industry.

In parallel with species management, our marine ranching initiatives prioritize large-scale ecosystem restoration. As benthic organisms that consume diatoms and organic detritus, sea cucumbers are often referred to as the "cleaners of the sea floor," delivering essential ecological benefits. In their natural habitats—coastal rocky areas and seagrass beds—these creatures play a critical role in maintaining the health of underwater ecosystems.

Seagrass beds and oyster reefs serve as vital ecological oases, offering habitat and breeding grounds for numerous marine species while also acting as important carbon sinks that help mitigate climate change. However, these ecosystems face severe threats from coastal development, pollution, overfishing, invasive species, and extreme weather events like typhoons, all of which accelerate their degradation.

In response, the Institute of Oceanology has initiated an ecological restoration project targeting seagrass beds. By establishing specialized seed banks and optimizing storage conditions, we have increased seed survival rates to over 80%. Our tailored planting techniques, which include root and stem binding and mud-pellet methods, have significantly improved planting efficiency.

Restoration efforts consider regional species differences, employing eelgrass in northern waters and *Thalassia* in the south, with the ultimate goal of revitalizing marine ecosystems and enhancing the productivity of marine ranches. These restored seagrass beds not only provide food and shelter for marine organisms but also support ecologi-



Graphic: ZHOU Yi

The left image illustrates the root and stem binding method, while the right image demonstrates the mud-pellet method.

Graphic: ZHOU Yi

The seagrass bed is being repaired with mud-pellet method.

Graphic: ZHOU Yi

Comparison before (upper) and after (bottom) seagrass bed restoration.

cal balance and sustainable development through effective carbon sequestration.

To enhance habitat and resource conservation, we have constructed artificial reefs and living oyster reefs. Tailored solutions were developed based on the behavioral ecology of reef-dwelling species such as sea cucumbers, abalones, and False Kelpfish (*Sebastiscus marmoratus*). For example, we found that sea cucumbers prefer dark, creviced environments, which prompted us to design a multi-layered, plank-style reef structure that not only increased food availability but also expanded habitat space, doubling to tripling the sea cucumber yield per unit area.

Aligned with local marine conditions, we also designed eco-friendly reefs for oysters, algae, and other marine species, forming a comprehensive technical system that has been widely adopted and promoted.

"We're not just growing fish. We're rebuilding entire marine ecosystems from the seabed up," says Dr. YANG Hongsheng, director of the Marine Ranch Engineering Laboratory.

Nevertheless, perhaps our most notable achievement lies beneath the waves off the coast of Shandong Province. Here, in the waters around Furongdao Island, we have helped create a national-level marine ranch that serves as a model for the future.

Furongdao Marine Ranching: A Success Story

Beneath the waves of Shandong's coast lies a world where science and nature thrive in harmony. Imagine an underwater world where artificial reefs teem with fish, vast beds of seagrass sway in the currents, and shellfish filter the water to crystal clarity. This is the reality at Furongdao in Laizhou Bay, where nature and technology work in tandem.

Just over a decade ago, this area was barren. Rapid economic growth led to a surge in demand for seafood, and overfishing transformed the once fertile Laizhou Bay into an underwater desert. To restore the habitat and replenish resources, local entrepreneurs decided to establish a marine ranch through artificial reef placement and stock enhancement. However, faced with the vast sea, one had to ask: where should we build the ranch, and how?

The Institute of Oceanology conducted comprehensive surveys of the site's hydrology, environment, biology, and geology. Based on these studies, we scientifically planned the ranch's location and boundaries. The construction process followed a "sea farming before fishery" approach, creating artificial reefs on the seabed. Previously lifeless stones became thriving oyster habitats, with up to 481 oysters per square meter. These oysters filter large quantities of phytoplankton and organic debris, purifying

Graphic: SONG Kunzhi

The fishermen in the ranch harvest plenty of seafood.

Graphic: SONG Kunzhi

Underwater camera captures several specked fish swimming near a rocky coral reef in the Furongdao Marine Ranching in Laizhou Bay.

the water. Sea snails feed on the oysters, maintaining a balanced ecosystem, and their waste is consumed by sea cucumbers, keeping the seabed clean.

The ranch employs a multi-trophic aquaculture system: red algae are cultivated at the top layer, scallops in the middle, and sea snails, oysters, and sea cucumbers at the bottom. This layered use of the sea increases production efficiency. Red algae absorb excess nutrients like nitrogen and phosphorus, preventing eutrophication and algal blooms, while their photosynthesis absorbs CO_2 and releases oxygen, promoting shellfish growth. The detritus produced by algae and shellfish is then consumed by sea cucumbers.

Over more than a decade, species diversity in the ranch has increased by approximately 16%, and biological resources have grown sevenfold. The core area consistently maintains Class I water quality, and the average annual income of fishermen has risen from 50,000 to 170,000 CNY.

The ranch has also integrated with offshore wind power, creating a model for co-development. The biomass on the foundations of the turbines can reach 21 kg/m^2, and the annual clean energy production is 1.94 billion kWh, equivalent to a reduction of 1.525 million tons of CO_2 emissions.

The numbers speak for themselves. Local fishermen's incomes have more than doubled, but benefits go beyond economic returns. Marine ranches can also serve as carbon sinks, with each square meter of seagrass and oyster reef capturing as much carbon as a small tree.

Overall, Furongdao Marine Ranch has established a comprehensive marine ranching industry chain. This approach has synchronized business growth with increased fishermen's incomes, while simultaneously enhancing both ecological sustainability and production efficiency.

Towards a Sustainable Future

As impressive as these achievements are, CAS scientists see them as just the beginning. They're actively collaborating with international partners to share their knowledge and learn from others.

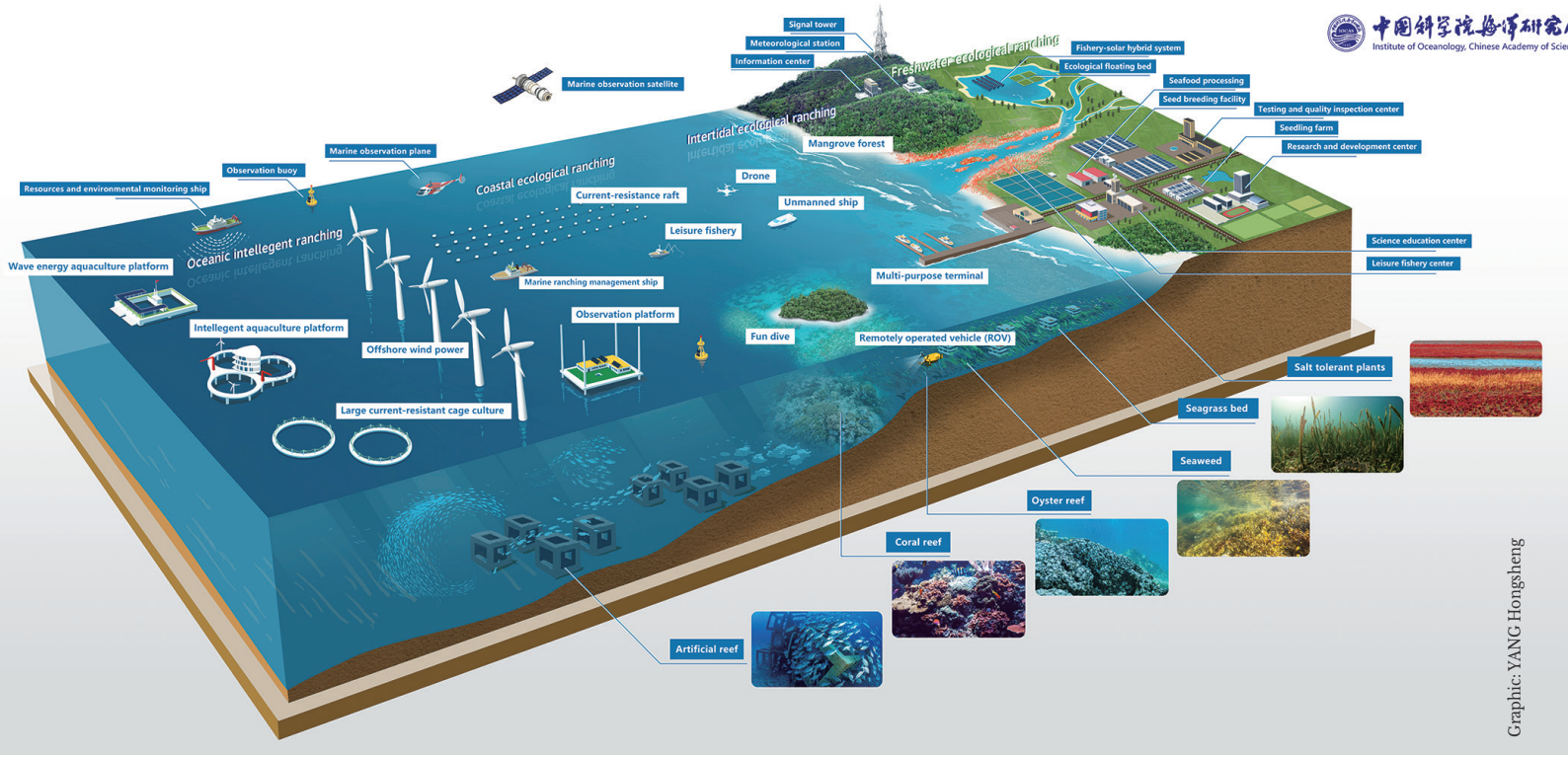
The Institute of Oceanology signed a collaboration agreement with the Indonesian National Research and Innovation Agency (BRIN) to establish the China-Indonesia Joint Laboratory for Marine Science. Together, they are developing and demonstrating marine ranches in Indonesia. Supported by China's intergovernmental science cooperation programs and international col-

Graphic: SONG Kunzhi

The integrated development of marine ranching and offshore wind power.

A close look at an aquaculture enclosure, part of the marine ranch, with neighboring wind turbines for generating clean energy offshore.

Graphic: SONG Kunzhi



Schematic illustration of the next-generation Marine Ranching 3.0 framework.

laboration projects, the Marine Ranch Engineering Laboratory has partnered with researchers from Belgium, and China's Hong Kong and Macau regions to study sea cucumber breeding and behavioral adaptations, the resilience of key benthic species under extreme conditions, and the roles of pheromones in echinoderms and fish in the context of global change.

During the project implementation, CAS researchers took multiple visits to the collaboration sites, conducting on-site investigations of marine ecological ranches such as those in Lombok Island. They exchanged research progress, shared findings, clarified collaborative research plans, and promoted the development of marine ranches from an international cooperation perspective.

In tandem with global outreach, CAS has launched the Marine Ranching 3.0 framework—a digitally-driven system that maximizes both ecological and economic benefits.

This next-generation model integrates habitat restoration, intelligent management, and the innovative use of clean energy through offshore wind farms, creating a holistic approach to marine resource management. In the Marine Ranch 3.0 phase, our goal is to build a comprehensive industrial technology framework for marine ranches, covering site selection, planning, habitat restoration, resource conservation, safety, and integrated development. At this stage, the core technological drivers for marine ranches are digitalization and systematic construction.

Digital technology plays a crucial role in resource and environmental monitoring. For example, to withstand the harsh marine environment, the team has developed a corrosion-resistant underwater video system and real-time environmental monitoring sensors integrated with the BeiDou Navigation Satellite System (BDS). This enables precise data collection, efficient transmission, and accurate analysis, greatly enhancing the ranch's ability to withstand natural disasters like green tides, typhoons, and heatwaves.

Systematic construction is essential for ensuring effective results. Led by the Institute of Oceanology of CAS, a consortium of 21 institutions has developed China's first national standard for marine ranch construction, titled "*Technical Guidelines for Marine Ranch Construction*". This standard encompasses key technical elements such as planning and layout prior to construction, habitat creation and species release during the building process, and project acceptance following completion. These guidelines have supported the establishment of 189 national marine ranch demonstration ar-

eas, covering all of China's coastal regions. Moreover, it may serve as a reference for other countries looking to develop their own marine ranches and further promotes the establishment of international standards in marine ranching.

The Marine Ranch 3.0 framework promises a more resilient future for marine ecosystems and coastal communities alike, driven by data, precision, and sustainable development. The integration of digital monitoring tools, such as underwater sensors and video systems, allows researchers to better understand and manage marine environments. These systems not only enhance productivity but also provide early warning systems for natural disasters, ensuring the long-term sustainability of marine ranches.

Suggestions for Future Development

The path forward for marine ranching is illuminated by two beacons: technological innovation and ecological sustainability. These guiding lights will lead us towards more efficient use of ocean resources while safeguarding the delicate marine ecosystems. To this end, CAS is spearheading a comprehensive approach to marine ranching development, focusing on four key areas: 1) Enhancing habitat creation and carrying capacity; 2) Developing advanced environmental monitoring and early warning systems; 3) Implementing cutting-edge information and smart technologies; 4) Pioneering integrated models that combine marine ranching with clean energy production.

But the vision doesn't stop there. To maximize both the ecological and economic benefits of marine ranching, we should pursue a three-pronged strategy.

First, we're doubling down on the preservation of original, high-quality genetic resources and the development of new species. This work isn't just about better seafood—it's crucial for ensuring national food security, promoting sustainable agriculture, and maintaining biodiversity.

Second, we should strengthen theoretical and technological innovation in marine ranching development. This means cracking the code on common key principles and developing integrated innovations in areas like fishery remote sensing, aquatic organism behavior control, ecological keystone species conservation, and high-efficiency artificial reef design.

Finally, we should foster a new era of multi-industry integration. Picture this: marine ranches that not only produce food but also serve as eco-tourism destinations, offshore wind farm sites, and even solar energy hubs. By weaving together these different industries, CAS is creating a new blueprint for sustainable coastal economies.

From "fish-tourism fusion" to "fishery-wind power integration" and "aquaculture-solar power combination," these innovative models are reshaping coastal landscapes and economies. The result? A more resilient, diverse, and profitable marine ranching industry that benefits both people and the planet.

Conclusion: A Global Blueprint for Sustainable Oceans

When concluding the recall of our explorations in marine ranching, one thing is clear: the future of food production may not only lie in the soil but also flourish beneath the waves. Since the first pioneering ideas in the 1950s to today's advanced underwater farms, CAS has been at the forefront of this blue revolution. As climate change and overfishing threaten ocean ecosystems worldwide, the innovative approaches developed in China offer promising solutions for a more sustainable balance between humanity and ocean ecosystems.

Marine ranching extends beyond feeding China; it presents sustainable strategies for addressing global food security and marine conservation. By focusing on both ecological restoration and food production, China's marine ranching efforts provide a potential model for sustainable management of ocean resources while ensuring food security for future generations.