

# Basic Concepts and Practices of Marine Ranching: A Review from Theory to Practice

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**Abstract** A marine ranch refers to a designated area in the ocean that, through artificial control and management, provides a favorable living environment for marine organisms, achieving sustainable use of marine biological resources. This paper deeply explores the basic concept of marine ranching, including its definition, main components and functions, types, and their characteristics. At the same time, it introduces the main theories of marine ranching and thoroughly analyzes the application of these theories in actual operation. Through actual cases, it shows the application of various marine ranches and discusses the challenges and solutions in the practice process. Overall, the global application of marine ranching has yielded significant economic benefits and also played a positive role in protecting the marine ecological environment and promoting the development of the blue economy.

**Keywords** Marine ranching; Theory and practice; Aquaculture technology; Global application; Blue economy

With the rapid development of the global economy and the increasing needs of human life, the ocean economy, as a new economic growth point, is becoming increasingly important. Among them, marine ranching, as an important part of the marine economy, has received widespread attention from governments and research institutions around the world.

Marine ranching, as the name suggests, is created in the ocean similar to ranches on land, used for breeding various marine organisms such as fish, shellfish, and seaweed (Amundson et al., 2023). It not only can greatly improve the utilization efficiency of marine resources, improve the marine ecological environment, but also effectively increase the income of fishermen, drive the development of the marine economy, and even have a positive role in promoting local economic transformation and optimizing the industrial structure. From the perspective of human social development, marine ranching is an important practice of efficiently integrating the marine ecosystem with the economic system. It represents a new type of marine resource utilization method and is an important means for humans to respond to resource pressure and achieve sustainable development (Li et al., 2019).

However, how to efficiently and scientifically construct and manage marine ranches, how to ensure ecological benefits while improving economic benefits, and how to make marine ranches better serve socio-economic development are all important issues currently faced by the construction and development of marine ranches.

Therefore, this paper aims to comprehensively explore the basic concept and practical application of marine ranching, especially in-depth research and analysis of practices in China and globally, hoping to provide theoretical guidance and practical reference for the development of marine ranching, further promote the scientific construction and management of marine ranching, and promote the high-quality development of the marine economy.

## 1 Basic Concept of Marine Ranching

### 1.1 Definition of marine ranching

Marine ranching is often viewed as a "farm" in the ocean. It is proposed based on the concept of ranching on land, aiming to achieve more efficient and scientific use of marine resources, provide food, biological products, and

ecological services, etc., through human intervention and management, employing efficient and environmentally friendly breeding methods to cultivate and manage marine organisms in specific sea areas (Britannica, 1998). Therefore, the concept of marine ranching is to designate a part of the ocean as a "ranch", where marine organisms are bred and collected. Marine ranching usually involves releasing aquatic organisms in areas of the ocean that have a certain degree of environmental protection, and then collecting them at an appropriate time. Through this method, humans can increase the yield of marine biological resources while protecting biodiversity.

The modern marine ranching platform "Changqiong No.1", currently the most intelligent cage system in China (Figure 1). Here, 1,000 tons of fish can be raised each year with a designed lifespan of 10 years, equivalent to 100 ordinary cages, but only 4 workers are needed for daily operations.



Figure 1 "Changqiong No.1" marine ranching platform in the sea area near Daqin Island, Shandong Long Island (Photo by Wang Kai)

Taking the opportunity of developing and constructing modern marine ranches, Dalian Changdao County in Liaoning Province is making every effort to build a "blue granary" at sea. At present, Changdao County has approved more than 10 national-level marine ranch demonstration zones (Figure 2).



Figure 2 The distant view of the marine ranch in Haishan Town, Changdao County (Photo by Yao Jianfeng, Xinhua News Agency)

## 1.2 Main components and functions of marine ranching

The main content of marine ranching includes the release, cultivation, and collection of marine organisms. Release usually involves artificially hatching and cultivating aquatic organisms and introducing them into the marine environment. Cultivation involves monitoring and managing the marine environment to ensure the growth and reproduction of seedlings. Collection is the capture and collection of mature marine organisms at an appropriate time (Bartley, 2008; Bell, 2008).

Marine ranching mainly consists of three components: aquaculture facilities, aquaculture organisms, and aquaculture management. Aquaculture facilities mainly include cages, nets, buoys, anchoring equipment, etc. (Figure 3); aquaculture organisms mainly include various marine organisms such as fish, shellfish, and seaweed; and aquaculture management includes feeding, disease control, and growth environment monitoring of the aquaculture organisms (Liu et al., 2022).

The main functions of marine ranching include: providing food and biological products, such as seafood, seaweed products, etc.; improving the marine ecological environment, such as reducing the excess nutrients in seawater by absorbing nutrients through the growth of marine organisms, to reduce the occurrence of harmful biological events such as red tide; providing recreational and tourism services, such as creating marine sightseeing agriculture and marine experiential tourism.



Figure 3 Artificial reefs and marine ranching (Photo by Michail Patakos)

## 1.3 Types and characteristics of marine ranches

Depending on the type of aquaculture organisms and aquaculture methods, marine ranches can be divided into fish farming ranches, shellfish farming ranches, seaweed farming ranches, etc. These different types of marine ranches have their own characteristics and requirements. For example, fish farming ranches need to consider the environmental requirements of fish species, such as temperature, salinity, dissolved oxygen, etc.; shellfish farming ranches need to provide suitable sediment and water quality conditions; seaweed farming ranches need to consider light, nutrients and other growth factors (Salvanes, 2001).

At the same time, according to their location and scale, marine ranches can also be divided into nearshore small-scale aquaculture ranches, offshore large-scale aquaculture ranches, etc. (Seaman and Lindberg, 2019). Nearshore small-scale aquaculture ranches are generally close to the shore, convenient for management and transportation, but face relatively large environmental pressures and risks of natural disasters; offshore large-scale aquaculture ranches are located in sea areas far from the shore. Although their management and transportation are more complex, they can better utilize marine resources, and their environmental impact is relatively small.

In general, marine ranching is a comprehensive marine resource management method that combines environmental protection and aquaculture concepts, aiming to improve the utilization rate of marine biological resources, protect marine biodiversity, and achieve sustainable development of the ocean.

## 2 Theoretical Basis and Application of Marine Ranching

The theoretical basis of marine ranching involves multiple disciplinary fields, including oceanography, ecology, aquaculture, environmental science, etc. The construction and management of marine ranching mainly rely on the following theories as the foundation (Yang, 2017).

### 2.1 Ecosystem services theory and its application

A marine ranch is a man-made and managed marine ecosystem that can provide various ecosystem services, such as food production, carbon emission mitigation, biodiversity protection, etc. (Yang, 2016). Understanding and applying the ecosystem services theory can help us better evaluate and optimize the functions and benefits of marine ranching. In the design and management of marine ranching, the provision of ecosystem services can be optimized by choosing different farming organisms and adjusting farming methods and management strategies. For example, by polyculturing different types of organisms such as fish, shellfish, and algae, multiple ecosystem services such as food production, nutrient cycling, carbon absorption, etc., can be achieved.

### 2.2 Steady state theory and its application

The stability of marine ranching is key to its sustainable and efficient operation. The steady state theory focuses on how a system maintains a relatively stable state through self-adjustment under changing environmental conditions (Yang and Ding, 2022). Using this theory can help us better understand and control the biological and environmental dynamics of marine ranching. In the operation and management of marine ranching, it is necessary to regularly monitor the growth status of aquaculture organisms, water quality parameters, etc., and timely adjust management measures such as feed supply and disease control to maintain the stable operation of the ranch.

### 2.3 Diversity-stability hypothesis and its application

This theory advocates that the stability of an ecosystem increases with the increase of its biodiversity. In marine ranching, increasing the diversity of aquaculture organisms can enhance system stability and reduce the occurrence of diseases. When selecting aquaculture organisms and designing aquaculture models, the number of biological species and interspecies interactions can be increased as much as possible to improve system stability and disease resistance. For example, adopting a fish-shellfish-algae polyculture model can not only improve the efficiency of food production but also enhance system stability through interspecies interactions.

## 3 Practical Applications of Marine Ranching

The practical application of marine ranching around the world shows a rapidly developing trend, covering a wide range of geographical areas and biological species. The number of marine ranches is constantly increasing, with a variety of species, mainly including various marine creatures such as fish, shellfish, and algae.

According to data from the United Nations Food and Agriculture Organization, the global marine aquaculture output reached 114.5 million tons in 2018, of which the output of fish farming accounted for about half of the total output (Chen et al., 2019). With the continuous advancement of aquaculture technology and the increasing environmental protection requirements, ecological and intelligent marine ranches are receiving increasing attention.

Among these marine ranches, China is the largest marine aquaculture country, with a marine aquaculture output reaching 49.0 million tons in 2018, accounting for about 43% of the total global marine aquaculture output (Chen et al., 2020; Liu et al., 2022). Countries like Norway, Chile, Indonesia, and Vietnam are also important countries for marine aquaculture. As of June 7, 2022, China had 153 national-level marine ranch demonstration areas.

### 3.1 Practical cases of various marine ranches

#### 3.1.1 China's deep-sea intelligent marine ranch

The "Guoxin 1" a large-scale 100,000-ton smart fishery breeding workboat built by Qingdao Beihai Shipbuilding Co., Ltd. under China Shipbuilding Group (Figure 4).

This project is the world's first 100,000 ton smart fishery large-scale breeding workboat, with a total length of 249.9 meters, a molded width of 45 meters, a molded depth of 21.5 meters, a load capacity of 100,000 tons, and a

displacement of 130,000 tons. The ship has a total of 15 breeding cabins, with a breeding water volume of 80,000 cubic meters, and carries out breeding production of high-end economic fish species such as large yellow croaker, with an annual production of high-quality large yellow croaker of 3 200 tons. The "Guoxin 1" uses the suitable sea area of the deep sea for breeding, avoiding natural disasters such as typhoons and red tides, and is known as a "mobile marine ranch".



Figure 4 "Guoxin 1" sailing at sea (Author: Li Chen Source: China Science News Release time: 2022, 11, 27, 17: 54: 29)

"The Guoxin 1" is equivalent to the fish yield of a pond fishery of more than 5000 acres. It's comparable to over 50 factory-style recirculating aquaculture workshops each covering 2000 square meters, and can replace more than 3000 near-shore "fish rafts". As Researcher Xu Hao stated: "Enclosed aquaculture vessels will lead marine aquaculture into the modern era of large-scale, industrialized, automated, and intelligent fishing."

### 3.1.2 Multi-layer marine ranching in the netherlands

The Dutch offshore farming company has implemented a three-layer polyculture system of seaweed, shellfish, and fish in the North Sea (Figure 5). This system is a semi-submersible mussel farm developed by the Dutch offshore service company OOS Group for mussel farming in the North Sea. This semi-submersible mussel farm will adopt new energy technologies such as solar panels, wind turbines, and tidal turbines. The first semi-submersible mussel farm, named "OOS Cees Leenaars", will be 76 meters long and 32 meters wide. It will use wind energy, solar energy, and electric power, charging the supply ships that capture and transport mussels to land, achieving zero-carbon dioxide emission operations.

### 3.1.3 Norway's open fish farming ranch

Norway is the world's largest fish farming country, and its open fish farming ranch, such as the Marine Harvest company's fish farming ranch, is one of the most well-known cases worldwide (Figure 6).

Norway's marine farming system: Norway is the largest exporter of salmon in the world, and its marine aquaculture industry is very developed. Norway's aquaculture industry pays high attention to the protection of the marine ecology and sustainable development, implementing strict environmental monitoring and management systems to ensure that aquaculture activities have the least impact on marine ecology. Marine Harvest Company is one of the largest fish farming companies in Norway, with more than 50 farms worldwide, including open farming

ranches and enclosed aquariums. Its open farming ranch is located on the west coast of Norway, one of the largest open fish farming ranches in the world. This ranch produces over 400,000 tons of salmon each year, accounting for 20% of the global salmon market share.



Figure 5 The semi-submersible mussel farm powered by renewable energy, designed by the Dutch OOS (Photo source: International Ship Network) (eworldship.com)

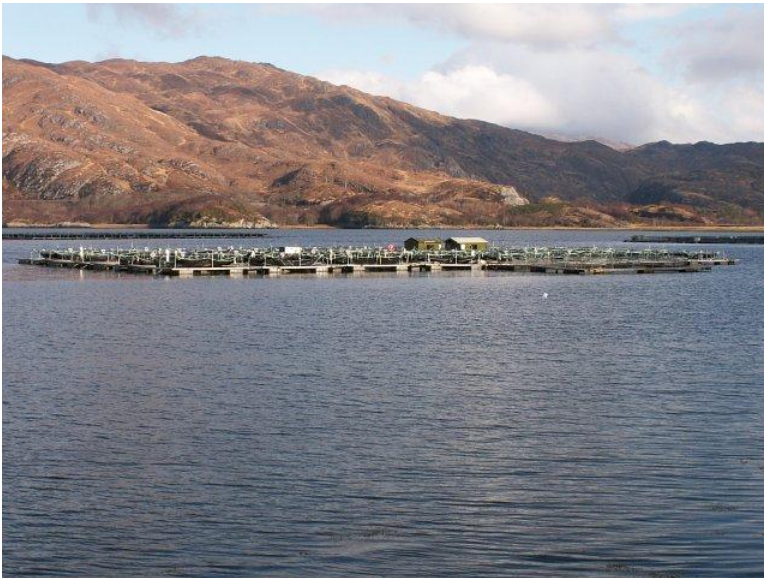


Figure 6 Mowi operation on Loch Ailort, Scotland, one of the oldest Atlantic salmon farms. (photo from Marine Harvest company's website)

#### 3.1.4 Canada's shellfish and fish mixed farm

Canada's Fanny Bay Oysters company carries out a shellfish and fish mixed farming project in British Columbia. Fanny Bay Oysters is a shellfish farming company in British Columbia, Canada (Figure 7). It has launched a project for shellfish and fish mixed farming in the province. The goal of this project is to enhance farming efficiency, reduce environmental impacts, and provide more product choices. Fanny Bay Oysters' mixed farming project mainly includes species like bass, salmon, and clams.

The company's farm is located on the cold water coast of British Columbia, where the water temperature and quality are very suitable for the growth of shellfish and fish. The company uses modern technology and equipment to ensure the best growing environment for shellfish and fish. The company also employs sustainable farming methods to minimize environmental impact.



Figure 7 Shellfish farm on the cold water coast of British Columbia (photo from Fanny Bay Oysters company's website, Canada)

### 3.1.5 Thailand's marine shrimp farm

Thailand is the world's largest marine shrimp farming country, and its marine shrimp farming ranch, like the shrimp farming ranch of Charoen Pokphand Foods, is one of the largest shrimp farming ranches in the world. Charoen Pokphand Foods is a large agricultural company in Thailand and one of the world's largest shrimp farming companies. The company owns several shrimp farming ranches in Thailand and other countries, including the Charoen Pokphand Foods shrimp farming ranch. The company's shrimp farming ranch uses modern technology and equipment to ensure the best growth environment for shrimp. The company also employs sustainable farming methods to minimize environmental impact.

### 3.1.6 New Zealand's deep sea fish farm

New Zealand's King Salmon company's deep sea fish farming ranch is one of the most advanced deep sea fish farming ranches in the world. King Salmon company is one of the largest deep sea fish farming companies in New Zealand, and also one of the most advanced deep sea fish farming companies in the world. The company's salmon varieties include King salmon, Ōra King salmon, and Regal salmon, which are all New Zealand's unique varieties, famous for their excellent quality and taste.

King Salmon company's salmon farming ranch is located in the Marlborough Sounds area of South Island, New Zealand, a picturesque bay with clear waters and abundant marine resources. The company uses modern technology and equipment to ensure the best growth environment for salmon. The company also employs sustainable farming methods to minimize environmental impact.

The above cases are the results of the combination of theory and practice. For instance, China's deep-sea intelligent marine ranch "Guoxin 1" applies the theory of steady state and ecosystem services, adopts scientific and technological means for precise and intelligent management, achieving high-quality development of the marine economy. Through automated monitoring and precision measurement, precise management of the marine ranch is achieved, improving the intelligence level of ecological ranch operation management.

The Norwegian marine farming system well realizes the application of the diversity-stability hypothesis in practice. In the selection of farming organisms and the design of farming patterns, Norway fully considers the impact of biological diversity on system stability, achieving a win-win situation for ecological, economic, and social benefits.

## 3.2 Challenges and solutions in the practice of marine ranching

In the practical application of marine ranching, the challenges mainly include the uncertainty of environmental changes, the difficulty of disease prevention and control, and the continuous updating of technology and equipment. To this end, we can effectively cope with these challenges through measures such as strengthening

scientific research, continuously innovating farming technologies and management models, establishing a comprehensive disease early warning and prevention and control system, and guiding and encouraging enterprises to upgrade technology and equipment.

Excessive farming density and environmental pollution are major challenges faced by marine ranches. The solution is to implement strict environmental monitoring and management, control farming density, and reduce the impact on the environment.

Prevention and control of diseases in farmed organisms is also a problem. The solution is to use polyculture, increase biodiversity, and enhance the system's stability and disease resistance.

The economic benefits and social acceptance of marine ranches are key to successful implementation. The solution is to improve the productivity and product quality of marine ranches, and through public education and propaganda, enhance the economic benefits and social acceptance of marine ranches.

## **4 Impact and Value of Marine Ranches**

### **4.1 Economic, environmental, and social Impact of marine ranches**

The development of marine ranches not only helps to increase the total amount of the marine economy but also promotes the high-quality development of the marine economy. Taking China as an example, in 2021, China's marine economy total volume first broke through 9 trillion yuan, and the construction of marine ranches played a significant driving role (Li et al., 2019). Additionally, marine ranches can provide job opportunities, contributing to the socio-economic development of coastal regions (Zhou et al., 2019).

From an environmental perspective, through ecological farming, marine ranches can effectively reduce the pollution of the marine environment and protect the marine ecological environment. Simultaneously, marine ranches are an important carrier of biodiversity, playing a positive role in maintaining marine biodiversity.

From a societal perspective, marine ranches can provide a large amount of marine product, meet people's food needs, and improve the quality of people's lives. Also, through participating in the construction and management of marine ranches, people's environmental awareness can be enhanced, promoting the harmonious development of society.

### **4.2 Value and significance of marine ranches**

The value and significance of marine ranches mainly reflect the following aspects: firstly, marine ranches are important carriers for promoting marine economic development, stimulating the rapid development of the marine economy, and improving economic benefits. Secondly, marine ranches have an important value in maintaining the marine ecological environment and protecting marine biodiversity, and are effective ways to achieve sustainable use of the sea. Moreover, marine ranches can provide a large amount of high-quality marine products, meet people's food needs, and improve people's quality of life.

Lastly, the construction and management of marine ranches can enhance people's environmental awareness, promoting the harmonious development of society. In the future, we need to continuously improve the technological level of marine ranches, realize the intelligent, refined management of marine ranches, to better play their economic, environmental, and social value.

## **5 Conclusions and Prospects**

Marine ranches, as an essential part of marine economic development, not only play a crucial role in promoting economic development, providing employment opportunities, meeting human food needs, but also have indispensable value in protecting the marine ecological environment and maintaining marine biodiversity. The construction and management of marine ranches require scientific theoretical support and practical operations, and the technologies, equipment, personnel, and other factors involved have a key impact on the successful operation of marine ranches. From the practice cases worldwide, we can see the organic combination of marine ranch theory and practice, as well as the challenges and solutions encountered in the process.



Looking ahead, the development trend of marine ranches will be ecological farming and intelligent management. Digitalization and systematization will be the driving forces, and new technologies like new marine ranch equipment and intelligent monitoring systems will serve the construction and management of marine ranches better (Yang and Ding, 2022). At the same time, achieving the effective integration of new energy and marine ranches, such as using deep-sea wind power technology to supply power to marine ranches, will be an important direction for future marine ranch construction.

Worldwide, all countries need to grasp these development trends, driven by technological innovation, to promote the development of marine ranches, better play the role of marine ranches in promoting economic and social development, protecting the marine ecological environment, and make a greater contribution to the harmonious coexistence of humans and the sea.

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