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Current Situation, Problems and Countermeasures of Marine Ranching Development in Guangdong Province, China

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Abstract Combining the literature review and marine field investigation in the sea area, this article summarized the development and current situation of marine ranching at home and abroad. It analyzed the construction process of artificial fish reefs, proliferation and release, and national-level marine ranching demonstration areas, as well as the current development situation and existing problems of marine ranching-related industries in Guangdong Province. Guangdong has built 50 ecological artificial reef areas, 3 large-scale artificial reef demonstration areas, 1 local artificial reef area and 15 national marine ranching areas, with a total sea area of 1 499.68 km², and 2.004 million m³ of reefs. However, there are some problems in Guangdong marine ranching, including imperfect management mechanism, inconsistency in development concept and understanding, unclear rights and responsibilities in using sea area, lack of construction technology standards and specifications, low scientific and technological level and limited industrial development. In view of these problems, this article came up with countermeasures, including insisting on ecology-prioritized development, and strengthening the coordination of multiple departments; creating a management mode conducive to market-oriented operation; breaking through the issue of sea area ownership; establishing a technical standard system for marine ranch construction in Guangdong; strengthening the research on the basis of high-quality construction and key common technologies of Guangdong marine ranching; establishing industrialization modes of Guangdong marine ranching according to local conditions. Understanding the development status of marine ranching in Guangdong and exploring the development strategies of marine ranching industry by referring to the relevant experience at home and abroad can provide references for the effective management, efficient and sustainable development of marine ranching in Guangdong and the integration of three industries in the development of marine ranching in Guangdong.

Key words Marine ranching, Artificial reef, Enhancement and release, Industrial integration, Ecological priority

1 Introduction

Marine fishery is an important part of China's modern agriculture and marine economy. However, the current marine fishery has such problems as extensive development mode, habitat degradation and decline of fishery resources^[1–2]. Coastal countries are actively exploring the path of sustainable development of fishery, then marine ranching appears and has gradually become a major fishery development strategy for many coastal countries^[3–4]. Marine ranch is a fishery model based on the principles of marine ecosystems in specific sea areas, through measures such as artificial reefs, proliferation and release, builds or restores places required for marine organisms to reproduce, grow, feed or avoid enemies, proliferate and conserve fishery resources, improve the ecological environment of the sea area, so as to realize the sustain-

able utilization of fishery resources^[5]. Marine ranching has gradually developed into a breakthrough and a new model for conservation of resources, restoration of the environment, transformation and upgrading of fisheries, and integration of multiple industries in coastal areas^[6–8]. The purpose of marine ranching construction is first to restore and improve marine biodiversity and fishery resources, so as to ensure the sustainable and stable growth of fishery resources, and second to protect the marine ecosystem and achieve sustainable development of marine fisheries while utilizing marine resources in a sustained and high-efficient manner^[9]. China always attaches great importance to the construction of marine ranching and related technical research^[10–13]. Since 2002, the central government has allocated special funds for supporting the construction of marine ranching. By 2022, more than 300 marine ranches have been built, including 153 national-level marine ranching demonstration areas, with a sea area of 2 506.95 km². In 2006, the State Council issued the *Outline of Action for the Conservation of China's Aquatic Living Resources*, which clarified that the development of marine ranching has become an important policy for China to restore offshore fishery resources, restore fishery water environment and promote sustainable development of offshore fisheries^[14]. The No.1 Central Document in 2017 and 2018 clearly proposed of building and developing modern marine ranching. The No.1 Central Document in 2019 further emphasized the need to promote the construction of marine ranching.

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Guangdong is located on the coast of the South China Sea and is a major marine province with developed economy in China^[15]. With the economic development of marine fishery, there appears the decline of offshore fishery resources and the degradation of fishery ecological environment, which affects the protection and sustainable utilization of marine biological resources, and restricts the high-quality development of marine fisheries. Guangdong Province actively explores measures to restore fishery resources. In 1981, Guangdong started to carry out pilot projects for the construction of artificial reefs, and in 2001, it promoted the construction of large-scale artificial reefs in Guangdong in the form of a motion of the National People's Congress. Guangdong is the first province in China to develop marine ranches with artificial reefs as the major work and it has made considerable achievements. On the basis of summarizing the development and current situation of marine ranching at home and abroad and the development history of marine ranches in Guangdong, we analyzed the existing problems and scientific and technological needs in the construction of marine ranching in Guangdong, and came up with development countermeasures of marine ranching development, so as to provide references for the management and industrialization development of marine ranching in Guangdong.

2 Development history and current situation of marine ranching at home and abroad

2.1 Foreign marine ranching

The origin of foreign marine ranching can be traced back to the year 1795. Japanese fishermen used wooden frames and sandbags to make reefs and put them into the sea to achieve the fish-collecting effect^[16]. Japan and the United States were the first countries to realize that the construction of artificial reefs is an effective measure to protect and enhance fishery resources and to develop and utilize fishery resources^[17-18]. Later, the United States, Japan, Norway, the United Kingdom, and Finland carried out fish proliferation and releasing experiments and technical research^[19-24]. In the late 1960s, Japan first implemented large-scale cultivation of fishery in coastal waters. During 1971 - 2000, the construction of foreign marine ranching mainly focused on artificial reefs and enhancement and release, and the large-scale construction of marine ranching was promoted through the formulation of laws, programs and plans^[25-34]. In 1999, Japan developed a high-rise reef with a reef height of 30 m. By 1997, 64 countries had carried out marine species proliferation activities, involving 180 species^[35]. By 2000, the area of artificial reefs built in South Korea was 18 542 ha, and more than 2 400 artificial reefs were built in the United States. Since 2001, many foreign countries have formulated relevant measures to promote the construction of marine ranches. The function of artificial reefs has gradually changed from a single function of trapping fish to the functions of resource conservation and habitat restoration, and marine ranches have gradually changed to ecological ranching. Norway, Japan, South Korea and the EU have formulated the *Marine Ranching Law*, *Basic Law of Fisheries*,

Basic Plan for Aquaculture, *Small-scale Marine Ranching Promotion Plan*, *Basic Plan on Ocean Policy and European Marine Biotechnology Roadmap*, to promote high-quality construction of marine ranches and sustainable development of fisheries^[36-38]. Foreign countries regulate and promote construction of ecological marine ranches by means of legislation and formulation of plans. The marine ranching research started to expand to the deep water area, and carried out the ecological research on the seamounts based on the creation of upwelling to improve the productivity of the sea area^[39-40]. Besides, they also carried out research and development of large and super large reefs mainly for trapping and proliferating pelagic fishes and migratory fishes in the water depth of more than 100 m^[41]. By 2017, Japan has built artificial reef areas in more than 12% of the fishery area near the coast, including a total of 5 886 artificial reefs with a sea area of 4.67×10^4 km² and a volume of 5.396×10^7 m³ of artificial reefs. By 2018, South Korea has built 7 689 ha of seaweed beds and planned to build a total of 35 000 ha seaweed beds by 2030 to restore coastal ecosystems.

2.2 Domestic marine ranching

In China, the concept of marine ranching was first proposed by researcher Zhu Shuping in 1947. In his opinion, water is the ranch for fish, and in 1963, he proposed the concept of "marine farming"^[42]. In 1965, Zeng Chengkui *et al.*^[43] put forward the idea of "making the ocean a farm for growing seaweed and shellfish, and a pasture for raising fishes and shrimps", and in 1978, they proposed that the development of China's marine aquatic production must take the road of "marine farming"^[44]. In the 1930s, Zhejiang and Jiangsu provinces carried out experiments on fish proliferation and release and marked release in the coastal areas, which were gradually promoted^[45-46]. In 1979, the Qinzhou area of Guangxi put China's first group of experimental single artificial reefs, marking the beginning of China's practical exploration of marine ranching construction^[47]. Since then, China has gradually carried out the experimental release of artificial reefs and related technical researches. In 1983, Feng Shunlou^[48] introduced the construction of artificial reefs into marine ranching, and proposed to build marine ranches based on artificial reefs. In 1984, artificial reefs were listed as national development projects. Based on artificial reefs, combined with artificial seaweed beds and artificial fry release, marine ranches were built experimentally^[49]. In the 1990s, the nationwide construction of artificial reefs was interrupted due to various reasons such as lack of funds and management experience^[50-51]. After entering the 21st century, China has once again set off an upsurge in the construction of artificial reefs^[52-53]. Coastal cities across the country are actively carrying out activities such as the construction of marine ranches and artificial reefs, and the proliferation and release of fishes^[54]. Since then, China's marine ranching construction has entered a stage of comprehensive development. Since 2009, China has gradually improved relevant standards for the construction and management of marine ranches, which provided guidance for China's standardized construction and management of marine ranches. The regulations and standards

such as *Several Opinions of the State Council on Promoting the Sustainable and Healthy Development of Marine Fisheries*, *Marine Ranching Classification*, *National Marine Ranching Demonstration Area Construction Plan (2017 – 2025)*, and *Specifications for Management of National Marine Ranching Demonstration Areas (for Trial Implementation)* were promulgated to promote marine ranching construction. Since 2015, the Ministry of Agriculture and Rural Affairs has organized the construction of national-level marine ranching demonstration areas. The *Outline of the 14th Five-Year Plan (2021 – 2025) for National Economic and Social Development and Vision 2035 of the People's Republic of China* specially proposed the goal of construction of marine ranching and development of sustainable pelagic fisheries. In 2021, China issued the first national standard for marine ranching, namely, *Technical Guidelines for Marine Ranching Construction* (GB/T 40946-2021)^[55]. Over years of development, by July 2022, China has established 153 national-level marine ranching demonstration areas with a sea area of 2 506.95 km² (Table 1).

Table 1 Construction of national marine ranching demonstration areas in coastal areas of China

Coastal areas	No. of proliferative type	No. of protective type	No. of recreational type	Total	Sea area km ²
Shandong (incl. Qingdao)	41	0	18	59	434.29
Liaoning (incl. Dalian)	27	6	1	34	256.01
Hebei	18	1	0	19	98.68
Guangdong (incl. Shenzhen)	0	15	0	15	1 250.45
Zhejiang	0	10	1	11	170.93
Guangxi	0	3	1	4	167.79
Hainan	0	2	2	4	4.62
Jiangsu	1	2	0	3	77.79
Fujian	0	1	1	2	8.39
Shanghai	0	1	0	1	14.40
Tianjin	0	1	0	1	23.60
Total	87	42	24	153	2 560.95

3 Current development situation of marine ranching in Guangdong

Guangdong is located in the southernmost part of mainland China, with a sea area of 420 000 km² and a coastline of 4 114.3 km, ranking first in China^[56]. Guangdong has 1 963 islands and reefs with a total area of 1 513.2 km² and island coastline of 2 378.1 km, showing a good foundation for the marine ranching construction. However, since the 1970s, offshore fishery resources have declined, and Guangdong has actively explored measures for resource conservation and fishery proliferation. In 1981, it launched a pilot project for the construction of artificial reefs. The development of marine ranching in Guangdong can be divided into the following three stages.

3.1 Simple artificial reef and proliferation and release stage (1981 – 1989) In 1981, Guangdong put suspended artificial reefs in Daya Bay for experimental research^[57]; during 1981 – 1987, it carried out pilot projects for the construction of artificial

reefs in Huiyang, Nan'ao, Shenzhen, Dianbai, and Zhanjiang^[58]. In 1983, Feng Shunlou, an expert from the South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, proposed to the central government to "build artificial reefs and create a new situation in China's marine fisheries". The central leaders at that time issued three important instructions on December 21, 1983, March 1, 1984, and March 8, 1984, and promoted the construction of artificial reefs nationwide with Guangdong as the starting point. During 1984 – 1985, Guangdong carried out the construction of artificial reefs in Nan'ao. The effect evaluation showed that the plankton biomass in the reef area was 2.9 times that of the nearby waters, and the catch yield was 6.6 times that of the nearby non-reef areas^[59]. In 1985, Guangdong started to carry out marine proliferation and release, and conducted the release experiments of *Feneropenaenus chinensis*, *Penaeus penicillatus* and *Penaeus merguensis* in the Pearl River Estuary and Zhanjiang waters; during 1986 – 1988, the scope of shrimp release experiments was expanded to Huizhou, Zhuhai, Shanwei and other regions; in 1989, shrimp release was promoted in coastal areas of the whole Guangdong Province^[60].

3.2 Combination stage of artificial reef construction and proliferation and release (1990 – 2013)

In the 1990s, the construction of artificial reefs was basically at a standstill across the country. Since 1994, the release species has been gradually enriched, including 4 species of fish, 3 species of shrimp, 3 species of shellfish and 1 species of echinoderms. In 1997, Guangdong carried out a pilot study on the marked release of *Acanthopagrus schlegelii* and *Pagrus major* in Daya Bay. Since 2000, in order to prevent fishing activities from affecting the survival rate of released seedlings, Guangdong decided to start proliferation and release during the fishing moratorium. During 2000 – 2001, Guangdong used waste hulls, reinforced concrete and other reefs in the Shuangshan waters of Yangjiang City and Dongao waters of Zhuhai City to carry out artificial reef construction test, becoming the first province to restart artificial reef construction. In 2001, the *Resolution of the Standing Committee of the Guangdong Provincial People's Congress on the Construction of Artificial Reefs to Protect Marine Resources and Environment* decided to build 50 ecological and quasi-ecological artificial reefs in the coastal waters of Guangdong from 2002 to 2011^[61], making Guangdong the first province in China to promote the construction of large-scale artificial reefs in the form of a motion of the National People's Congress. In 2006, the State Council issued the *Outline of Action for the Conservation of Aquatic Living Resources in China*, proposing that fishery resource proliferation measures include proliferation and release, artificial reefs and marine ranches. Guangdong started to implement the marine ranching construction based on the construction of large-scale artificial reefs and supplemented by proliferation and release. Guangdong simultaneously developed artificial reef construction and proliferation and release, providing a good habitat for the reproduction of released organisms and wild organisms. Guangdong has formed a high-efficient model of fishery ecological restoration with the marine ranching construction as the main carrier, which effectively improved the effectiveness of aquatic species proliferation and release. In 2013, Guangdong has

expanded 5 provincial and municipal fry proliferation and release bases, and implemented "one law enforcement vessel for one reef area" to manage artificial reef areas.

3.3 Construction stage of large-scale artificial reef demonstration areas and marine ranching demonstration areas (2014 to the present) In 2014, the Standing Committee of the Guangdong Provincial People's Congress approved the Guangdong Provincial People's Government *Report on the Handling of the Proposal for the Construction of Artificial Reefs to Protect Marine Resources and Environment*, stating that the construction of artificial reefs to protect marine resources and the environment is a long-term and arduous task. After the proposal was closed, the people's governments at all levels and all relevant departments should conscientiously sum up experience, consolidate the hard-won achievements of the proposal handling, and ensure that the strength remains unchanged, the policy is not cancelled, the investment is not reduced, and the support is in place. In 2015, Guangdong Province invested 150 million yuan to launch the first batch of "Large-scale Artificial Reef Demonstration Area Construction Projects", and determined to take Huizhou Dongshanhai, Zhuhai Miaowan and Maoming Dianbaifangji Island as the construction areas of the first large-scale artificial reef demonstration areas in Guangdong. Over the years, Guangdong has attached great importance to the marine ranching construction, insisting on taking the marine ranching construction as an important measure to protect marine biological resources, change the way of fishery development, increase the income of fishermen, and vigorously build a blue granary.

During 2015 – 2022, Guangdong was approved to build 15 national-level marine ranching demonstration areas (Table 2). By June 2022, Guangdong has built 5 national-level and 64 provincial-level original and improved breeding farms for aquatic products, and 6 resource proliferation (protection) stations (centers) directly under the ministry and provincial fishery authorities, and basically formed a four-level proliferation and release fry supply system: "National Genetics and Breeding Center-National Improved Breed Farm-Provincial Improved Breed Farm-Proliferation Station". More than 40 species of marine economic species can be proliferated and released through artificial breeding. The annual fry production of marine fishes and shrimps is about 270 million and 26.85 billion, respectively. The annual production of sea treasures such as marine shellfish, sea cucumber, sea urchin and abalone is about 10.35 and 1.03 billion, respectively. With more than 40 years of construction, there are currently 50 ecological artificial reef areas in Guangdong, with a built area of 237.723 km²; 3 large-scale artificial reef demonstration areas, the reef construction area of 10.080 km², and the construction and release reefs of 450 000 m³; one local artificial reef area, with a built reef area of 1.430 km² and the construction and release reefs of 277 800 m³. The existing 15 national-level marine ranching demonstration areas (Table 2) in Guangdong are all conservation types, with a total area of 1 250.45 km², accounting for 35.71% of the total number of conservation marine ranching demonstration areas (42) in the whole country. The proposed reef volume is 1 276 200 m³, the seaweed bed area is 92.21 ha, and 5.4 billion aquatic organisms are proliferated and released.

Table 2 Construction of national marine ranching demonstration areas in Guangdong Province

Name of demonstration area	Approval year	Sea area//km ²	Volume of artificial reef // ×10 ⁴ m ³	Area of seaweed bed//ha
NMRDA in Wanshan Sea Area	1 st batch in 2015	312.00	6.27	13.34
NMRDA in the East Sea of Guiling Island	1 st batch in 2015	20.28	6.51	26.68
NMRDA in Sea Area of Nan'ao Island	2 nd batch in 2016	30.00	5.50	13.34
NMRDA in Zhelangjiao West Sea Area of Shanwei	2 nd batch in 2016	21.00	5.30	13.34
NMRDA in Jinxiang South Sea Area of Lufeng	3 rd batch in 2017	32.00	4.90	0
NMRDA in Shanwai East Sea Area of Yangjiang	3 rd batch in 2017	68.00	4.70	0
NMRDA in Dafangji Island Sea Area of Maoming	3 rd batch in 2017	33.08	5.99	0
NMRDA in Jianghong Sea Area of Zhuxi	3 rd batch in 2017	67.00	3.84	6.25
NMRDA in Naozhou Island Sea Area of Zhanjiang	4 th batch in 2018	4.38	4.26	6.00
NMRDA in Wailingding Island Sea Area of Zhuhai	4 th batch in 2018	9.83	3.80	6.25
NMRDA in Dapeng Bay Sea Area of Shenzhen	4 th batch in 2018	7.48	2.76	0
NMRDA in Xiaoxingshan Island Sea Area of Huizhou	5 th batch in 2019	9.60	2.85	0
NMRDA in Qingzhou Island Wind Power Integration Sea Area of Yangxi	5 th batch in 2019	497.30	40.80	4.00
NMRDA in Bomao Sea Area of Wuchuan	5 th batch in 2019	19.40	2.57	3.00
NMRDA in Nanpeng Island Sea Area CGN of Yangjiang	6 th batch in 2021	119.10	27.56	0
Total		1 250.45	127.62	92.21

Note: National Marine Ranching Demonstration Area is abbreviated as NMRDA; the ecological type of all demonstration areas is conservation type.

4 Technological needs

4.1 Site selection of marine ranching The sea area for marine ranching construction should be an important fishery water area, with few competing organisms and predatory organisms, and

suitable for algae transplantation and proliferation and release organisms to inhabit, breed and grow. The marine ranching construction in Guangdong is mainly based on artificial fish reefs. The artificial fish reefs used are basically reinforced concrete struc-

tures, and the weight of a single reef is about 50 t. Artificial fish reefs need to be placed on the seabed, and there are certain requirements for the geological structure of the seabed. Therefore, proper site selection is the premise of marine ranching construction. For the marine ranching in Guangdong, there are still problems such as insufficient basis for site selection for development and construction and insufficient basis for evaluating the carrying capacity of ecosystems. It is necessary to further improve the site selection technology to improve the science of the marine ranching construction, including the evaluation of the ecological basis, the site selection principles and influencing factors, and the ecological carrying capacity. It is necessary to combine engineering, marine biology, and physical oceanography to study the site selection technology of artificial reef marine ranching from seabed topography, geological structure, hydrology, water quality, and planning compliance; research and develop resources and environmental survey comprehensive assessment and ecosystem carrying capacity assessment technology, develop and construct suitable site selection technology, establish and verify the big data analysis model of marine ranching resources and environment, grasp status quo of marine resources and environment, the conditions and parameters for the suitability of development and construction sites, and the level of ecosystem carrying capacity, establish the evaluation and development of marine ranching ecosystem carrying capacity with indicator characterization, visualization and early warning levels, and make reasonable selection of sites for the development and construction of marine ranches, fully exploit the potential of the ecosystem, and effectively prevent and solve problems such as insufficient basis for selecting marine ranching sites and overloading of the ecosystem.

4.2 Ecological process and mechanism of marine ranching

The marine ranching, as a new type of fishery model, can form a three-dimensional development model of "water and underwater facilities-fishery organisms-ecological environment" from the water surface to the seabed. Its purpose is to restore habitat, conserve fishery resources, and promote the integration of the three industries. Only on the premise of satisfying the ecological carrying capacity of the sea area and moderate development to achieve moderate disturbance can marine ranching achieve high-quality construction, sustainable development, and optimal ecological benefits. Thus, it is particularly important to reveal the small-scale ecological processes and mechanisms of marine ranching, the analysis of ecosystem structure and functions, and the ecological regulation mechanisms for the construction of high-quality marine ranching. At present, the research on the ecological process and mechanism of marine ranching in Guangdong is weak, and the marine ranching construction in some areas tends to be homogeneous or low-quality. Through identifying key elements of marine ranching ecosystems and their influencing factors, grasping the common technical parameters of habitat degradation, fishery resource decline and food web degradation, analysing the ecological efficiency of the marine ranching food web and the loss rate of food web flow, the replenishment rate of proliferating organisms and the natural growth rate of wildlife, exploring the influencing factors of disturbing marine ranching ecosystems and the constraints restricting restoration,

finding the evolution mechanism of marine ranching ecosystems, marine pasture ecological regulation mechanisms, and ways of increasing carbon sinks, designing marine ranching construction goals, construction content, construction methods, balanced layout and industrial development mode in high standard, properly determining the type and scale of marine ranching construction, and implementing characteristic and differentiated construction, it is able to effectively solve the problem of high-quality construction and sustainable use of marine ranches.

4.3 Smart monitoring and forecasting and early warning of marine ranching

Relevant data information is the basic data basis for the evaluation of marine ranching construction effects, real-time status control and protection management. With the help of this information, it is able to monitor the ecological environment and fishery organisms of marine ranching in a timely, accurate and comprehensive manner. At present, Guangdong marine ranching lacks an effective monitoring system, and there is an urgent need for information-based, smart and digital monitoring and evaluation technology and equipment. However, the technical research of smart monitoring and forecasting and early warning system is weak, and the technology and equipment are insufficient. It is necessary to improve the technology of "environmental mining and monitoring-resource exploration-acoustic survey-remote sensing monitoring" in marine ranching, develop an online monitoring system for water environment based on the Internet of Things (IoT) technology, a remote visual observation system for biological and biological community status, research and develop a forecasting and early warning decision-making system based on environmental parameters and biological parameters, use data processing system and analysis technology to establish Guangdong marine ranching database with massive data processing capacity, build a digital platform for Guangdong marine ranching, and promote the construction of a visual, smart and information-based system for monitoring and evaluation of marine ranching in Guangdong.

5 Problems

5.1 Imperfect management mechanism of marine ranching

To play a role in the conservation of fishery resources and achieve sustainable and long-term benefits, marine ranching needs scientific management of their resource conservation, production and related activities^[62]. At present, the management mechanism of marine ranching in Guangdong is not perfect, the overall layout is insufficient, and there is still a lack of scientific demonstrations in the planning and layout of marine ranches, reef site selection, construction scale, biological selection, as well as environmental carrying capacity. In addition, Guangdong has not promulgated a plan for marine ranching construction. Compared with Shandong, Hainan, Guangxi, and Liaoning, Guangdong lacks overall planning at the planning level. The marine ranching construction of Guangdong is of conservation type, and the support it has received is still in the construction stage. Due to the lack of guidance and management of relevant norms and systems, the management and maintenance of marine ranches after the completion of the project is still not perfect. Because of the limited management funds,

there are difficulties in the follow-up and monitoring of resources and environment, operation and maintenance after the marine ranching construction. It is difficult to scientifically evaluate the marine ranching construction, and there is a lack of necessary maintenance in the built reef area. As a result, the long-term benefits of marine ranches could not be brought into full play.

5.2 Inconsistency between development concepts and understanding The marine ranching construction is a complex and systematic project involving multiple disciplines. At present, there are still big discrepancy in the understanding of marine ranching in Guangdong at the management level, scientific research level and practitioner level. In consequence, the focus of the development of Guangdong's marine ranch industry has diverged, and the original intention of marine ranching construction has been deviated from the formulation of marine ranching management strategies, technical research and business models. At the management level, there is still an idea that marine ranching is equivalent to cage farming, not realizing the importance and role of marine ranches in promoting fishery resource conservation and fisheries transformation, which is not conducive to Guangdong to coordinate and accelerate the marine ranching construction. At the scientific research level, there is a lack of overall concepts and systematic development thinking, and the existing technologies are scattered, so that it is difficult to effectively support the construction, development and utilization of marine ranches in Guangdong. Practitioners' understanding of marine ranching focuses on economic benefits while ignoring its ecological benefits. Consequently, the benefits of marine ranch resource conservation and proliferation, ecological protection and restoration, fishery transformation and upgrading, and the integrated development of the three industries have not been brought into full play.

5.3 Unclear rights and responsibilities of using sea areas The development characteristics of Guangdong marine ranching are not prominent, the convergence is strong, and there is a lack of downstream industry development and product development such as recreational fishery. The main reason is that the rights and responsibilities of marine ranching are unclear. Clear definition of property rights is an important factor to ensure the marine ranch construction in Guangdong. The construction materials of Guangdong marine ranching basically come from government input, and marine ranching is both a public welfare project and an economical project. However, the current relevant laws, regulations and policies in Guangdong lack provisions on marine benefits. As a result, there is currently a contradiction between the income and benefits of Guangdong marine ranching, and it is difficult to confirm the rights of the sea area to enterprises, accordingly leading to low enthusiasm for enterprises to participate.

5.4 Lack of construction technical standards and regulations The construction theory and technical standard system have not yet been established in Guangdong marine ranching. At present, although Guangdong has issued technical specifications such as *Technical Specifications for the Construction of Artificial Reefs in Guangdong Province* and *Technical Regulations for the Investigation and Evaluation of the Construction Effects of Artificial Reefs in Guangdong Province*. However, in practice, there is no unified,

scientific, meticulous and comprehensive construction standard to support the construction of high-standard marine ranches and artificial reefs. There is a lack of scientific planning for the layout of marine ranching in Guangdong, and also lack of standards for marine ranching construction. The proportion and scale of the proliferation species lack technical support. In practice, there is a single species of breeding, and the structure of the biological community is simple; the ecological functions such as seaweed beds, seagrass beds, and shell beds are insufficient.

5.5 Low scientific and technological level At present, Guangdong has made progress in marine ranching habitat creation, ecological carrying capacity evaluation and artificial reef construction. However, some key technologies have not yet been broken through and cannot provide comprehensive and systematic scientific and technological support for the efficient and scientific construction and management of marine ranches, such as behavioral control and tracking techniques for marine ranching species, dynamic prediction technology of fishery resources, prediction technology of sustainable output of marine ranches, big data platform and forecasting and early warning technology, marine ranching effect evaluation technology, and new artificial reef development technology adapted to high sea conditions, etc.

5.6 Restricted industrialized development The development of marine ranching industry should take marine ranching as the core, promote the development of five major industries of fishery (aquaculture, fishing, processing, stock enhancement, recreational fisheries), integrate culture, tourism, manufacturing, Internet and other industries, and realize the coordinated integration of primary, secondary and tertiary industries. The degree of industrialization of Guangdong marine ranching is low, the participation of enterprises is low, the industrial chain is incomplete, there are no branded products, and the market is not sound. One reason is that there is no active market guidance. Due to the large initial investment of marine ranching and long-term benefits, few enterprises participate without policy support and market guidance, which cannot promote market maturity. Another reason is the restriction of relevant management regulations and the ownership of the sea area. The artificial reef areas proposed by the Guangdong Provincial People's Congress are all ecological public welfare reef areas. However, according to the relevant provisions of the *Artificial Reef Management Regulations of Guangdong Province*, development and operation activities cannot be implemented. Such unclear responsibilities and rights in the construction of Guangdong marine ranching lead to the dislocation of the main body of the construction, the difficulty of management and maintenance, and the difficulty of development.

6 Implications of foreign and domestic typical cases of marine ranches for Guangdong

6.1 Seto Inland Sea marine ranch in Japan The Seto Inland Sea is not only the largest spawning and breeding water area along the coast of Japan, but also an experimental area for the development of Japan's proliferation fishery. From 1955 to 1958, Japan began to put artificial reefs in the Seto Inland Sea, and in 1963, it

set up the National Center for Cultivated Fisheries, and conducted cultivated fishery experiments at the Seto Inland Sea as the beginning of the construction of marine ranches. Japan has incorporated the construction of artificial reefs into legal provisions by enacting the *Law on Special Measures for Environmental Protection in the Seto Inland Sea* and other laws, so that the construction and management of marine ranches in the Seto Inland Sea can be governed in compliance with laws^[63]. Japan has established 5 *Pagrus major* acoustic domestication marine ranches in Oita Prefecture of Seto Inland Sea, and established Takashima-Shiroishi Island Marine Ranch in Okayama Prefecture, to improve the habitat of fishery organisms by placing artificial reefs and building seaweed beds, and use acoustic domestication equipment to domesticate and manage ranching objects. In 2015, Japan implemented the Satoumi Plan in the Seto Inland Sea^[64], that is, to enhance the primary productivity and replenishment of various groups of water in the marine ranching area, and restore the marine ecosystem through biological spillover effects. The expenses of artificial reef construction were jointly borne by the central and local governments. After the artificial reef area is completed, it would be purchased by the county where it is located, and the right to use it would belong to the local fishery association. The marine ranching areas in Seto Inland Sea were managed by local fishermen's associations. They carried out proliferation and release in artificial reef areas every year, and did relevant basic investigations and effect evaluations. After the artificial reefs were placed and the target species were proliferated and released, the acoustic domestication technology was used to promote the target fish to stay in the marine ranching area. Seto Inland Sea marine ranching technology is still in development stage. It mainly studies fishery habitat construction technology, resource biological management technology, biological breeding technology, biological engineering and electronic engineering technology, *etc.* It integrates technologies such as carrying capacity assessment, artificial reef construction, proliferation and release, behavioural control and domestication of ranching species into the marine ranch management system.

6.2 Marine ranch in Shandong Province In 2005, Shandong Province launched the *Action Plan for Restoration of Fishery Resources*^[65]. In 2014, it started to implement the strategy of "Marine Granary"^[66]. In 2015, it started the construction of the marine ranch observation network^[67]. In 2016, it implemented the construction of the shore-based "four ones" project (one exhibition hall, one monitoring room, one research institute, and one experience hall)^[68]. In 2017, Shandong started the construction of multi-functional offshore platforms, and formulated and implemented the *Marine Ranching Construction Plan of Shandong Province (2017–2020)*. In 2018, it issued the *Three-Year Plan for the Demonstration and Construction of Marine Ranches in Shandong Province (2018–2020)*, to improve the standard and informatization level of marine ranching construction in Shandong. In 2019, it issued the *Comprehensive Pilot Program for the Construction of Modern Marine Ranches in Shandong Province*, proposing an information-based and smart construction plan for modern marine ranches. Besides, Shandong has promulgated such management systems and technical standards as *Artificial Reef Management*

Measures of Shandong Province, Technical Specifications for Background Investigation of Artificial Reef Construction, Technical Specifications for Ecological Artificial Reef Construction, Interim Measures for the Pilot Management of Marine Ranching Platforms, Interim Measures for the Management of Recreational Sea Fishing in Shandong Province, Interim Measures for the Management of Marine Ranching Observation Network in Shandong, and Specifications for the Construction of Marine Ranches. The marine ranching construction of Shandong focuses on the R&D of marine engineering equipment, the information-based observation network, and the development of tourism and leisure products. Relying on the marine ranching, it continuously extends the industrial chain, and the integrated development of the three industries walk in the front row of the whole country. Focusing on marine ranching, Shandong's engineering manufacturing industry, information industry, leisure industry, cultural service industry, and marine food processing industry are developing vigorously. In marine ranches, there are also many supporting facilities, including marine picking experience area, marine ranch sightseeing experience area, marine dining banquet hall, and shore supporting services. It has registered such brands as *Fisherman Fishing, Haodangjia, and Rongcheng Seafood*, forming a new economic format with marine ranching as the core. By June 2022, Shandong has built 129 marine ranch demonstration projects above the provincial level, with a total area of 90 000 ha, and a total of 19.3 million m³ of artificial reefs. Shandong Province has built 59 national-level marine ranching demonstration areas, accounting for 38.6% of the total national marine ranching demonstration areas, including 41 proliferative marine ranches and 18 recreational marine ranches.

6.3 Implications for marine ranching construction in Guangdong (i) Focusing on top-level design. The construction of both Japan's Seto Inland Sea and China's Shandong marine ranching adhered to high-level planning, introduced innovative policies, and improved the construction promotion mechanism. They formulated relevant laws and plans to ensure the construction of marine ranches from a legal perspective, and proposed development direction of marine ranching from the top level, thus laying the foundation for the rapid development of marine ranching. Guangdong should combine its own resources and environmental endowments, absorb and integrate their successful experience, focus on top-level design, actively establish feasible pilot programs, and optimize the establishment of pilot projects for the construction of modern marine ranches, establish a sound work coordination mechanism, organize and ensure the smooth implementation of key projects, and effectively contribute to the construction of modern marine ranches.

(ii) Adhering to market oriented principle. The local fishermen association of the Seto Inland Sea took its own measures to manage marine ranches. Shandong marine ranching construction adhered to market-oriented principle. All 59 national-level marine ranching demonstration areas have no conservation type, but are proliferative and leisure types, with a high degree of marketization. The market occupies a dominant position, and enterprises obtain considerable economic benefits in marine ranches. These further promote corporate investment, and the marine ranching con-

struction is in a virtuous circle, thereby promoting the healthy development of marine ranches. In view of this, Guangdong should follow the basic principle of *market-oriented, government-led* in the marine ranching construction, and give full play to the decisive role of the market in resource allocation, make clear the dominant position of enterprises in the marine ranching construction, and the government will give necessary guidance and support, improve relevant rules and regulations, build a construction management mechanism with clear ownership, clear responsibilities, standardized management, strong guarantees, and efficient operation, so as to realize the market-oriented operation of marine ranching in Guangdong.

(iii) Innovating the construction model. The marine ranching technology of Seto Inland Sea continues to innovate. In recent years, through the research and development of giant artificial reefs, it has gradually explored the construction of marine ranches in the deep sea, and has gradually integrated technology into the management system. The marine ranching construction of Shandong focuses on enterprises, and vigorously builds and implements the joint development model of "leading enterprises + cooperatives + fishermen + scientific research units". With the support of government policies and projects, leading enterprises play a leading role in uniting fishermen, breeders, fishery enterprises and other entities to form contiguous concentrated sea areas to achieve mutual benefit and win-win goal. In view of the differences in natural and economic environment, Guangdong should actively make innovation in the construction model on the basis of improving the development of the original type of marine ranches, and explore the integrated development of marine ranching and offshore wind power and a new model for the construction of dam reef marine ranching; bring into full play the platform integration role of marine ranching, and promote the integrated development with tourism, leisure fishing and other industries; develop comprehensive recreational fisheries such as fisherman's family tourism, continuously expand the channels for fishermen to increase their income, and promote the integrated development of marine ranching.

(iv) Strengthening scientific and technological support. Shandong has about 20 scientific research institutions at or above the provincial level in the field of marine ranching, involving marine ranching site selection^[69], ecological capacity^[70], biological proliferation^[71], engineering equipment^[72], monitoring IoT^[73]. These researches cover basic research in the early stage of construction, biological proliferation and control during construction, and development and utilization after construction. Guangdong should strengthen its scientific and technological innovation, improve its scientific and technological support capabilities, give full play to the scientific and technological strengths of Guangdong's sea-related and fishery-related scientific research institutes and universities, set up major scientific research projects on marine ranching, carry out special research on marine ranching, make breakthroughs in key technologies such as the construction and deployment of artificial reefs, proliferation and release, recreational fisheries, and ranching monitoring and management, accelerate the transformation of cutting-edge technologies and improve the development level of modern marine ranches in Guangdong.

7 Recommendations

For the present and some time to come, Guangdong should vigorously develop modern marine ranches, and adhere to the ecological priority, innovation-driven, technology-led, and demonstration-driven principles^[76], to realize safe, efficient, intelligent and modern marine ranch resource conservation and ecological environment protection, and realize modernization with intelligence and promote industrialization with informatization.

(i) Insisting on ecology-prioritized development, and strengthening the coordination of multiple departments. The marine ranching construction should adhere to the ecological priority^[77]. In the context of many problems facing the existing fishing and aquaculture industry, the marine ranching construction should stress habitat restoration and resource restoration, scientifically evaluate the ecological carrying capacity of the sea area, and determine a reasonable scale according to the ecological capacity. In the marine ranching operation, it is prohibited to develop projects that are not conducive to the marine ecological environment and resources. The marine ranching construction involves many departments, such as development and reform, finance, maritime affairs, fishery, environmental protection departments. It is recommended that the Guangdong Provincial People's Government should coordinate with the competent department of marine fisheries, jointly promote the marine ranching construction with other departments, and incorporate the marine ranching construction into the key work of Guangdong's marine economic development and marine ecological civilization construction.

(ii) Creating a management mode conducive to market-oriented operation. Guangdong marine ranching is mainly for public welfare, and its construction and management are led by the government. Management and protection mainly rely on local fishery and fisheries administration departments. Due to limited manpower and material resources, the follow-up management effect is not good. The marine ranches invested and constructed by the government belong to the public property, which easily leads to the "tragedy of the commons". At the management level, it is necessary to break the current state of management of marine ranches in Guangdong, undertake the management and maintenance of marine ranches in the later stage according to the management method of "government guidance, industry linkage, and social undertaking", and actively guide local groups (such as village committees, associations, enterprises, etc.). to fully mobilize the enthusiasm of market resources, capital and relevant entities. It is recommended to actively guide fishermen to participate in the construction and management of marine ranches in an appropriate manner, and fully protect the rights and interests of local fishermen. In addition, Guangdong should actively introduce competent and responsible enterprises into the construction, development and management of marine ranches by formulating preferential policies.

(iii) Solving the issue of sea area ownership. The marine ranching construction has a large scale and high investment, and more personnel and capital should be introduced under the leadership of the government to accelerate the construction. To introduce social organizations to undertake the investment, operation and

management of marine ranches, it is urgent to clarify the issue of sea area and resource ownership allocation, and clarify the property rights of marine ranches and protect the rights and interests; establish a management system with clear ownership, and implement the method of the party who makes investment will benefit and be responsible for management. In addition, it is required to establish a property rights management system that is conducive to environmental protection, to integrate the interests of producers and environmental protection parties.

(iv) Establishing a technical standard system for marine ranching construction in Guangdong. At present, the construction of marine ranches in Guangdong still relies on artificial reefs, proliferation and release and other technical systems. There is no independent technical system, technical reserves are insufficient, and it lacks a complete set of marine ranching industry standards. Many scientific and technological problems need to be tackled urgently, which requires multidisciplinary expertise and technology to formulate unified technical standards and operating specifications, to ensure that the marine ranching construction in coastal areas of Guangdong is carried out in a scientific, standardized and orderly manner. On the basis of researches the classification of marine ranching construction standards, Guangdong should promptly formulate standards or specifications for relatively mature technical means with less discrepancy. For links with weak foundations but seriously restricting the effectiveness of marine ranches, it is feasible to first formulate technical guidelines to strengthen technical guidance.

(v) Strengthening the research on the basis of high-quality construction and key common technologies of Guangdong marine ranching. It is recommended to integrate scientific research forces such as research institutes, universities, and related enterprises in Guangdong, concentrate advantages and unify understanding, and overcome urgent technical problems in marine ranching construction and industrial development. In addition, it is recommended to improve the innovation ability of Guangdong marine ranching, establish a technical model, industrialization demonstration area and research base for the overall development and construction of Guangdong marine ranches, and effectively support the marine ranching development.

(vi) Establishing industrialization modes of Guangdong marine ranching according to local conditions. Guangdong has about 200 excellent bays, a tidal flat area 2 042.7 km², rich wind energy, ocean energy and other resources, the development potential is huge^[78]. It is recommended to combine the natural resource endowment, industrial base, and economic foundation of Guangdong coastal areas, focus on the main line of marine ranching construction and resource conservation, and promote the regional comprehensive development of marine ranches. Besides, Guangdong may conduct pilot construction of marine ranching observation platforms, support the construction of a number of marine ranching demonstration areas that combine public welfare and business, recreational fishing and eco-tourism, water platforms and aquatic organisms that can be monitored, and three-dimensional fish, shellfish and algae aquaculture. In addition, it is recommended to accelerate to make up the short board of marine ranching develop-

ment, establish a long-term mechanism for marine ranching construction management and industrial development with enterprises as the main body, promote the establishment of an investment and financing mechanism with enterprises as the main body, stimulate the enthusiasm of enterprises to invest in the marine ranching construction and encourage fishermen to change production and increase their income, build and improve the multi-industry integrated development model of "marine ranching + deep-water cages, marine ranching + offshore wind power, marine ranching + recreational fisheries"^[79], and promote the characteristic, branding, and differentiated development, so as to form a high-quality development model of modern marine ranching with clear ownership, clear responsibilities, standardized management, strong guarantees, efficient operation, equitable benefits and Guangdong characteristics.

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5.5 Promoting the construction of online marketing service system and actively guiding consumer behavior

The starting point of marketing reform in the digital era is still customer demand. It is necessary to complete the reshaping of the marketing system with customer demand as the core, and win consumers by being close to customer demand and accurately perceiving the changes of customer demand. At present, the important content of innovative marketing service for enterprises is to promote the construction of network marketing service system, and to establish diversified marketing service models, including experiential marketing, one-to-one marketing, global localized marketing, relationship marketing, chain marketing and so on, in order to adapt to the actual needs of different consumer groups, guide consumer behavior, and establish the new marketing model dominated by marketing services. The construction of the network marketing service system is huge and complex. In order to ensure that the marketing service system plays its due role in the development of enterprises, and to better improve the competitiveness of enterprises, it is necessary to consider various factors for systematic analysis.

The future development of consumer economy needs the joint efforts of the government, the market and consumers to establish a new cycle of the economic system from top to bottom.

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(From page 10)