

A Study of Pathways for Industrial Chain Integration in Zhanjiang's Marine Ranches: An Ecology-Industry-Technology Integration Perspective

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Abstract: Marine ranch management provides a scientific approach to the effective management of fisheries and marine ecosystems. As one of the first National Demonstration Cities for Innovative Development of the Marine Economy, Zhanjiang boasts the longest coastline and the largest maritime area in Guangdong Province, endowing it with unique resource and locational advantages for the development of modern marine ranches. This paper explores pathways for integrating the marine ranch industrial chain in Zhanjiang from the perspective of the convergence of ecology, industry, and technology. This study aligns with the objectives of building a modern marine economic system, promoting the efficient use of marine resources, and developing the blue marine economy, while focusing on the core issue of how to achieve systematic integration and high-quality development of marine ranches in Zhanjiang. Through an analysis of the current situation, an industry chain analysis, and pathway modeling, this paper constructs a full-industry-chain integration mechanism and a high-quality development strategy model tailored to Zhanjiang's local conditions.

Keywords: Zhanjiang; Marine Ranches; Ecology; Industry; Science and Technology

1. Introduction

In recent years, Zhanjiang has actively promoted the construction of the 'Blue Granary' and the optimisation of its marine economic structure. The year 2025 marks a pivotal stage in the city's efforts to advance high-quality development and build a modern marine industrial system. The Municipal Party Committee and Municipal Government have explicitly proposed the 'Four Greens and One Blue' development strategy - namely, green industry, green agriculture, green

energy, green ecology, and the blue marine economy - as a guiding principle for building a modern coastal economic belt that prioritises ecology, integrates industries, and is driven by science and technology.

Against this backdrop, marine ranches, as a new model of marine fisheries integrating ecological restoration, improved aquaculture efficiency [1,2], and the sustainable utilisation of resources, have become an important practical tool for achieving the strategic objectives of the 'Four Greens and One Blue' initiative. Zhanjiang has established multiple provincial- and national-level artificial reef and ecological enhancement pilot zones in nearshore waters such as Leizhou Bay, Naozhou Island, Wuyang, and the Nansan Islands, initially forming a development pattern characterised by pilot projects at specific sites and phased implementation across broader areas. However, the city's marine ranches still face a fragmented industrial chain, limited resource integration, and insufficient use of advanced equipment and smart technologies. Systematic research is therefore needed to enhance the overall industrial value chain, ecological functions, and regional competitiveness.

2. Survey of the Current Status and Case Analysis of Zhanjiang's Marine Ranches

2.1 Current Status of Zhanjiang's Marine Ranches (SWOT Analysis)

Strengths: A long coastline, numerous harbours, and good water quality make the area suitable for deep-sea and offshore aquaculture. The South China Sea is rich in biological resources and supports high-value species such as golden pomfret, grouper, and large yellow croaker. Zhanjiang has a relatively large number of national-level marine ranch demonstration zones, and its equipment deployment is comparatively advanced. A preliminary industrial chain covering seed production, aquaculture,

equipment, processing, cold-chain logistics, and sales has already taken shape.

Weaknesses: The area is highly exposed to typhoon damage. Typhoons occur frequently between May and October and can damage fish cages, cause fish escapes, and increase disease outbreaks, resulting in substantial losses. Core technologies for deep-sea and offshore intelligent equipment, underwater monitoring, and disease early-warning systems remain dependent on external suppliers. The adoption rate of high-quality strains is relatively low, and supplies of high-quality locally bred fry remain insufficient.

Opportunities: Initiatives such as 'Maritime Power', 'Food Security', and the 'Comprehensive Food Perspective' have elevated deep-sea and offshore aquaculture to the level of national strategy, accompanied by continued increases in funding from central and provincial governments. Rapid advances in intelligent, digital, green, and low-carbon technologies also create substantial opportunities for the localisation and intelligent upgrading of deep-sea and offshore aquaculture equipment.

Threats: Extreme weather events are intensifying. Global warming is contributing to greater typhoon intensity and frequency, while storm surges, red tides, and other disasters are occurring more often, thereby increasing aquaculture risks. Regional competition is also strong, as Hainan, Fujian, Shandong, and other provinces continue to expand deep-sea and offshore aquaculture, increasing the risks of product homogeneity and price competition.

2.2 Distribution of Typical Marine Ranches

Located on the Leizhou Peninsula and surrounded by the sea on three sides, Zhanjiang City boasts extensive nearshore waters and abundant marine biological resources, providing a solid natural foundation for the development of marine ranches. In terms of spatial distribution, Zhanjiang's marine ranches generally exhibit characteristics of a coastal layout, resource-oriented development, concentrated clusters in key areas, and multi-regional coordination. They are primarily distributed along the eastern and western coasts of the Leizhou Peninsula and in the waters surrounding Zhanjiang Bay, forming certain spatial linkages with traditional aquaculture, fisheries production, and coastal tourism.

In terms of regional characteristics, coastal areas such as Leizhou and Xuwen have favorable

marine resource conditions and a solid foundation in traditional fisheries and aquaculture, making them key areas for marine ranch development. These areas are particularly well-suited for the development of eco-friendly marine ranches focused on ecological aquaculture, artificial reefs, stock enhancement, and fishery resource conservation. By improving marine habitats and enhancing the capacity for fishery resource replenishment, these ranches facilitate a transition from traditional fishing to resource-conservation-oriented and eco-friendly fisheries. Zhanjiang Bay and the areas surrounding the city center, meanwhile, possess advantages in transportation, scientific research, markets, and industrial support infrastructure. Within the marine ranch industry chain, these areas are better suited to undertake functions such as scientific and technological R&D, technology commercialization, product processing, cold-chain logistics, brand marketing, and comprehensive services, thereby fostering industrial collaboration with the outlying aquaculture production zones.

From a spatial structure perspective, Zhanjiang's marine ranches are not simply distributed as isolated, scattered points but are gradually forming an interconnected industrial spatial system comprising "resource aquaculture zones-processing and distribution zones-technology service zones-consumer markets." However, there remains an imbalance in development levels among different regions; some marine ranch projects still place too much emphasis on the aquaculture production phase, with insufficient integration into areas such as value-added processing, brand marketing, recreational fisheries, and the realization of ecological product value. Therefore, in the future, interregional industrial chain synergy should be further strengthened. Using key marine ranches as nodes and supported by the comprehensive service and technological innovation capabilities of Zhanjiang Bay, efforts should be made to promote the formation of a spatial layout characterized by "ecological aquaculture and resource restoration along the western and peninsular coasts, industrial processing and technological services in the eastern region and Zhanjiang Bay, and multi-node coordination," thereby achieving the optimal allocation of marine resources, industrial elements, and technological factors, and providing spatial support for the integration and high-quality

development of Zhanjiang's marine ranch industrial chain.

Through on-site visits to key marine ranch areas such as Leizhou Bay and Naozhou Island, we

gained an understanding of the current status of marine ranch construction, operational models, and industrial linkages. The survey results are shown in Table 1.

Table 1. Survey Findings on the Development of Marine Ranches in Zhanjiang

Area Name	Administrative District	Type and Level	Distribution Characteristics and Notes
Waters off Naozhou Island	Potou District, Zhanjiang	National-level Marine Ranch Demonstration Zone	Located off the south-eastern coast of Zhanjiang, with good water quality and abundant seagrass beds; suitable for deep-water cage aquaculture and artificial reef deployment.
Leizhou Bay	Leizhou	Provincial-level / Key Aquaculture Area	A large area with moderate water depth; one of the foundational zones for Zhanjiang's marine ranch development and suitable for farming high-volume fish species.
Suixi River Estuary	Suixi County	National-level Marine Ranch Demonstration Zone	An ecological restoration pilot zone where artificial reefs, stock enhancement and restocking, and fry breeding are carried out in parallel.
Wuchuan Bomao Marine Area	Wuchuan	National-level Marine Ranch Demonstration Zone	A smart cage aquaculture platform has been established, integrating the Internet of Things with an automated feeding system.
Liusha Bay	Wuchuan	Municipal-level Modern Fisheries Development Corridor	Facing western Guangdong; promotes the integrated development of coastal cultural tourism and fisheries tourism and has substantial tourism potential.
Nansan Island Waters	Suixi County	Key Area for Ecological Conservation and Stocking	Combines mangrove restoration with aquaculture ecosystem development and serves as a model for blue-carbon initiatives.
Wailuo Waters, Xuwen	Xuwen County	Modern Marine Ranch Project under Construction	Facing the Qiongzhou Strait; a pilot area for deep-sea aquaculture development with substantial spatial development potential.

3. Industry Chain Analysis and Problem Diagnosis

3.1 Analysis of the Industrial Chain

3.1.1 Seedling rearing

Zhanjiang has established conservation centres on Naozhou Island for original strains of Naozhou yellow croaker, white-fleshed shrimp, and golden pomfret. The city currently has 480 aquatic seedling farms, including 17 provincial-level or higher aquatic improved-strain or original-strain farms, accounting for 23.6 percent of the provincial total. Among them, two are national-level aquatic improved-strain farms, representing 33.3 per cent of the provincial total. In 2024, the city produced 169.4 billion aquatic fry covering 60 aquaculture species, including golden pomfret, white shrimp, grouper, oysters, and bivalves, accounting for approximately 13 per cent of the provincial total. Conservation of wild broodstock for local Naozhou yellow croaker, Zhanghong fish, and serranid species has helped overcome bottlenecks in localised breeding. 'Zhongxing No. 2', 'Haijingzhou No. 1', and the Mexican scallop 'Orange-Yellow No. 1' have passed the new-variety evaluation of the Ministry of Agriculture and Rural Affairs; to date, 10 new aquatic varieties from Zhanjiang have been approved by the Ministry. Hatcheries also provide farm-level

technical guidance on aquaculture and integrated fish-shrimp farming, forming a closed-loop system that covers germplasm conservation, breeding, hatchery production, and end-user promotion.

3.1.2 Aquaculture production

Through models such as mangrove-coupled farming of blue crabs and mud crabs, high-density pond shrimp farming, bottom-sown oyster farming on tidal flats, and mixed shellfish-algae farming, Zhanjiang promotes multi-trophic ecological aquaculture and uses fisheries to support water purification. The city has advanced aquaculture infrastructure, with six large truss-type aquaculture platforms, including Hengyi No. 1, Zhanong No. 1, and Zhanjiang Bay No. 1, as well as 3,451 HDPE deep-water net pens, accounting for 54 per cent of Guangdong's total net pen capacity.

3.1.3 Processing and distribution

Zhanjiang is home to more than 200 aquatic product processing enterprises and six national-level leading agricultural enterprises, including Guolian Aquatic Products. These enterprises use advanced processing techniques and have established aquatic product industrial parks, extending production from fresh products to ready-to-cook meals, dried seafood, and aquatic health products, thereby increasing added value. Annual processing capacity exceeds 1 million

metric tonnes. Cold-chain warehouses at onshore fishing ports and refrigerated lorries on major routes are connected to dedicated cold-chain lines serving Zhanjiang Port and the high-speed railway station. At sea, vessels link fishing ports directly with the landing docks of deep-sea aquaculture farms. Together, these facilities support Zhanjiang's development as an international seafood cold-chain distribution hub and form a supply chain linking production-area cold stores, regional distribution centres, and supermarkets nationwide.

3.1.4 Brand marketing

Regional public brands include 'China's Capital of Golden Pomfret', 'China's Capital of Prawns', and 'China's Capital of Oysters'. Geographical Indication (GI) products include Zhanjiang Oysters, Naozhou Large Yellow Croaker, and Leizhou Blue Crab, while corporate brands include those developed by leading agricultural enterprises such as Guolian Aquatic Products, Hengxing Aquatic Products, and Haiwei Agriculture.

Offline marketing includes promotions in supermarkets nationwide, fresh-food retail chains, and catering supply chains, including the direct supply of pre-prepared dishes to seafood restaurants, as well as exhibitions and sales at the Zhanjiang Seafood Festival. The fisheries sector also collaborates with the culture and tourism sector to develop marine ranch sightseeing and angling, maritime fishing tourism, and seafood harvesting experiences with on-site sales. Online, products are promoted and sold through social media and e-commerce platforms, while cross-border e-commerce exports are also being developed.

3.1.5 Ecological restoration

At the Liusha Bay National-level Restocking Marine Ranch, 1,040 concrete artificial reefs, including shelter reefs and bait reefs, have been deployed. Across Zhanjiang, more than 8,000 reefs with a total volume of 293,700 cubic metres have been installed to create underwater habitats for marine life. A coupled model has also been adopted in which artificial reefs surround deep-sea aquaculture platforms, shellfish are farmed in the upper layer to purify the water, fish are raised in mid-level net pens, and reef structures at the bottom help break down uneaten feed, forming a closed-loop ecological cycle known as the distinctive Liusha Bay model. During the 14th Five-Year Plan period, 41 kilometres of coastline were restored, 22,000 mu of unauthorised

nearshore aquaculture areas were phased out, and a planning strategy of 'thinning out nearshore areas and utilising offshore areas, reducing nearshore capacity and expanding deep-sea and offshore capacity' was implemented. The structure of the marine ranch industry chain in Zhanjiang City is shown in Figure 1.

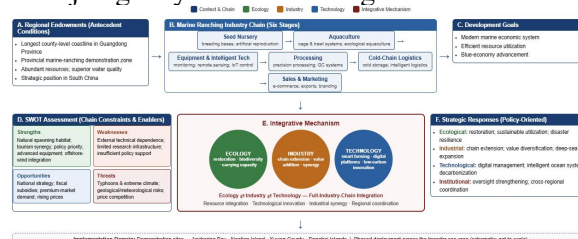


Figure 1. Diagram of the Marine Pasture Industry Chain Structure in Zhanjiang City

3.2 Problem Diagnosis

Marine ranches still face a fragmented industrial chain, low levels of resource integration, and insufficient use of advanced equipment and smart technologies. Although four major aquaculture clusters - Zhanjiang Bay, Leizhou Bay, Liusha Bay, and Caotan Bay - have been established, most continue to develop in relative isolation, with limited coordination by leading enterprises and fragmented operations among small and medium-sized aquaculture operators. The links among seedling production, aquaculture, processing, cold-chain logistics, and sales remain weak, and a fully integrated industrial chain covering seed production, aquaculture, equipment, processing, and cultural tourism has yet to be established.

In terms of resource integration, marine-space use remains fragmented, coordination in marine-use planning among stakeholders is insufficient, and synergy between deep-sea and nearshore aquaculture remains limited. The levels of scale, standardisation, and intensification are still relatively low, making it difficult to build an overall competitive advantage.

In terms of technological equipment and smart infrastructure, although a few large-scale intelligent platforms such as Zhanjiang Bay No. 1 and Haiwei No. 2 are already in operation, most fish cages still rely on traditional gravity-fed systems. The deployment of underwater monitoring, intelligent feeding, disease early-warning, and big-data management systems remains limited, and the overall level of digital and smart management is relatively low. At the same time, collaboration among industry, universities, and research institutions is not yet

sufficiently deep, and the commercialisation of key technological achievements in breeding, ecological restoration, and typhoon-resistant equipment remains slow, limiting technology-driven development.

4. Construction of an Ecology-Industry-Science and Technology (EIT) Integration Model

4.1 Model Construction Logic

The marine ranch industrial chain in Zhanjiang City actually corresponds to three nested systems: First, an ecosystem based on marine biological resources, the marine environment, and ecological carrying capacity; second, an industrial system composed of entities such as aquaculture enterprises, processing enterprises, logistics companies, brand-name enterprises, and fishermen; and third, a technological system supported by technologies such as high-quality strain breeding, smart aquaculture, environmental monitoring, cold-chain preservation, product traceability, and digital marketing. Following the integration logic of “ecology as the foundation, industry as the core, and technology as the driver,” a weighted coupling approach is used to quantitatively synthesize multidimensional indicators, ultimately achieving a comprehensive measurement of the level of high-quality development in the fisheries sector [3]. The three-dimensional integrated industrial chain framework for “ecology, industry, and technology” in Zhanjiang’s marine ranches is shown in Figure 2.

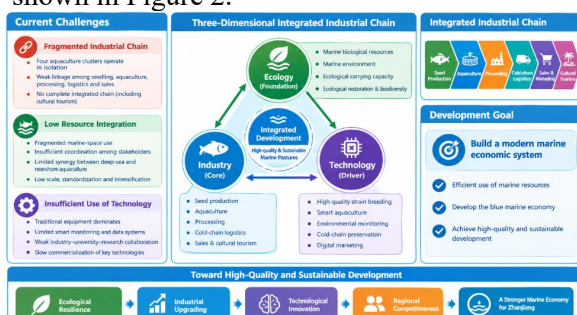


Figure 2. Diagram of the “Ecology-Industry-Technology” Three-Dimensional Integrated Industrial Chain Framework for Zhanjiang’s Marine Pastures

4.2 Comprehensive Evaluation Model for the Three Major Subsystems

$$Ht = \alpha Et + \beta It + \gamma Tt \quad (1)$$

Ecological dimension (E): covers ecological restoration capacity, biodiversity conservation,

carbon sink potential, and related indicators.

Industrial dimension (I): covers aquaculture output value, product value-added, branding levels, and the integrated development of fisheries and tourism. Science and technology dimension (T): covers digital fisheries, smart monitoring, the adoption rate of new technologies, and the development of data platforms. Let the comprehensive development indices for the three subsystems — ecological, industrial, and technological — of the Zhanjiang Marine Pasture Industry Chain in year t be denoted by Et , It , and Tt , respectively.

A comprehensive evaluation using the EIT integration model yields an industrial chain integration efficiency rating and a high-quality development potential index. Here, α , β , and γ represent the weights assigned to the three dimensions, respectively, and $\alpha + \beta + \gamma = 1$.

$$Et = \sum_{j=1}^{mE} wEjxEjt \quad (2)$$

$$It = \sum_{j=1}^{mI} wIjxIjt \quad (3)$$

$$Tt = \sum_{j=1}^{mT} wTjxTjt \quad (4)$$

4.3 Standardized Model for Indicators

Prior to calculation, the raw indicators for each dimension must undergo standardization to eliminate differences in units and orders of magnitude among various indicators, thereby ensuring the consistency and validity of data processing. Weights for each dimension are determined by constructing a judgment matrix using the Analytic Hierarchy Process (AHP), combining scores from industry experts to assign weights, and verifying consistency.

The model ultimately outputs two types of core evaluation results: Industrial Chain Integration Efficiency Levels. Based on the Ht composite score, these can be classified into three tiers: inefficient coordination, moderate coupling, and efficient integration. This intuitively reflects the degree of synergy and compatibility among the ecological, industrial, and technological systems, while clearly identifying weaknesses in industrial chain development.

High-Quality Development Potential Index. By quantifying the composite score, this index objectively evaluates the future upgrade potential of marine pastures, providing a reference for regional marine pasture ecological governance, industrial layout, and technology-driven

development.

4.4 Mechanism of Three-Dimensional EIT Integration

The three major systems—ecology, industry, and technology—do not operate in isolation but form a closed-loop, coupled relationship in which they constrain, support, and empower one another. A healthy marine ecological environment ensures a stable supply of fishery resources, providing the foundational conditions for industrial development; the economic benefits generated by the industry can, in turn, support investments in ecological restoration projects and technological R&D, thereby enhancing marine governance capabilities; technological innovation, through green aquaculture, smart monitoring, and digital management, reduces the ecological impact of aquaculture production while continuously improving industrial efficiency, ultimately achieving a virtuous cycle of “ecological stabilization, industrial quality enhancement, and technological empowerment.” This integration mechanism effectively addresses the practical challenges in traditional marine ranch development, such as the conflict between ecological and economic interests and the disconnect between technology and industry. Since the three systems—ecology, industry, and technology—are not simply additive but interact with and constrain one another, a coupling model is further introduced. A three-system coupling model is adopted:

$$C_t = 3 \left[\frac{EtItTt}{(Et + It + Tt)^3} \right]^{\frac{1}{3}} \quad (5)$$

Here, C_t represents the degree of coupling among the ecological, industrial, and technological subsystems in year t , where $C_t \in [0, 1]$. The closer C_t is to 1, the stronger the interaction among the three systems; conversely, the closer it is to 0, the weaker the relationship among them.

5. Pathways for the Integration and Development of the Marine Pasture Industry Chain in Zhanjiang City

The integration of the marine ranch industry chain in Zhanjiang City is not merely about expanding aquaculture scale; rather, it is premised on the stability of marine ecosystems, centered on industry chain extension and value-added growth [4], and driven by technological innovation, with the aim of transitioning from a “resource-utilization model” to an “ecology-industry

integration model.” Based on Zhanjiang’s marine resource endowments, the foundation of its fisheries industry, and the evaluation results of the “ecology–industry–technology” integration, the integration of the industrial chain can be summarized into five interconnected development pathways: ecology-based, processing-driven value-added, brand-enhancement, technology-enabled, and ecological value realization. These five pathways are not mutually exclusive but collectively form a complete system through which the marine ranch industrial chain extends from the production end to the value end, and from economic value to ecological value.

5.1 An Ecology-Based Development Path: Strengthening the Ecological Foundation of the Marine Pasture Industry Chain

The “ecological foundation-building” approach serves as the fundamental path for the development of marine ranches in Zhanjiang City. At its core is the principle of “prioritizing ecology while balancing conservation and utilization.” By improving the marine ecological environment and enhancing resource carrying capacity, this approach provides a stable ecological foundation for aquaculture production and the extension of the industrial chain. Specifically, efforts should be made to strengthen ecological surveys and dynamic monitoring of marine ranch waters, establishing a monitoring system that covers water quality, seabed conditions, biological resources, and ecological carrying capacity; reasonably control aquaculture density and scale; and promote models such as ecological aquaculture, recirculating aquaculture systems, and multi-trophic-level integrated aquaculture. At the same time, measures such as the construction of artificial reefs, stock enhancement and release, and seaweed bed restoration should be implemented to improve marine habitats and enhance the self-repair capacity of marine ranches.

The key to this approach lies not merely in increasing ecological investment, but in establishing a cyclical mechanism of “ecological restoration — resource enhancement — green aquaculture — industrial returns,” thereby transforming ecological improvements into a long-term foundation for industrial development.

5.2 A Value-Added Development Path: Promoting the Shift of the Industrial Chain

from “ Selling Resources ” to “ Selling Products”

The key to further developing the marine ranch industry chain in Zhanjiang lies in breaking away from the traditional model — which focuses primarily on the sale of primary aquatic products—and extending the industry chain into processing, cold-chain logistics, and end markets. Therefore, a complete industry chain encompassing “ marine ranch aquaculture-primary processing-deep processing-cold-chain logistics-end sales ” should be established. Priority should be given to developing industries such as pre-prepared meals, ready-to-eat seafood, frozen prepared foods, high-value-added marine foods, and the comprehensive utilization of seafood by-products to increase the value-added of seafood. At the same time, efforts should be made to strengthen the development of cold storage facilities, cold-chain transportation, sorting and packaging, and standardized distribution systems to reduce product wastage and distribution costs.

On the production side, links between processing enterprises and aquaculture operators can be strengthened through methods such as contract farming, guaranteed minimum purchase agreements, and long-term partnerships. This will enable processing demands to guide the selection of fry, aquaculture species, and production standards, thereby forming a synergistic industrial chain model of “ market demand-contract production- large- scale aquaculture-refinement and deep processing.”

5.3 Brand-Driven Development Path: Achieving a Leap in the Market Value of Marine Pasture Products

Value-added processing addresses the issue of “ product value,” while brand enhancement addresses the issue of “ market premium.” Therefore, a marine ranch brand system should be further developed based on the extension of the industrial chain. Zhanjiang City can explore the formation of a three-tier brand structure comprising “regional public brand + corporate brand + product brand,” transforming the distinctive features of Zhanjiang ’ s marine resources, the advantages of ecological aquaculture, and product quality into brand competitiveness. Efforts should be made to strengthen product quality standards, packaging design, brand promotion, and marketing, with a focus on expanding sales channels such as

supermarkets, e-commerce, live-streaming, new retail, and the food service supply chain.

At the same time, a product quality traceability system covering the entire process — from “ seedstock to aquaculture to processing to logistics to sales ” — should be established, enabling consumers to identify product origins, aquaculture methods, and quality information. Through digital marketing and brand promotion, market awareness of marine ranch products should be enhanced, driving a shift from traditional price competition to competition based on quality, brand, and reputation.

5.4 A Technology-Driven Development Path: Enhancing Industrial Chain Efficiency Through Digitalization and Technological Innovation

The technology-driven approach serves as a crucial pillar for promoting the large-scale and highly efficient development of the first three approaches. Its core lies in embedding technological innovation into every link of the marine ranch industry chain to achieve the digital transformation of production, management, and business operations [5]. In the seedling stage, efforts should focus on strengthening the breeding of high-quality strains and the selection of superior varieties; in the aquaculture stage, online water quality monitoring, smart feeding, environmental early warning systems, and automated equipment should be promoted; in the processing stage, the technical capabilities for automated sorting, processing, and quality inspection should be enhanced; in the logistics stage, smart cold-chain systems and digital warehousing should be developed; and in the sales stage, big data, e-commerce, and digital marketing should be leveraged to improve market responsiveness.

More importantly, universities, research institutes, and enterprises should be encouraged to form a technology transfer chain encompassing “ research — pilot testing — application — commercialization” to ensure that scientific and technological achievements do not remain confined to the laboratory. By building a digital marine ranch platform, the sharing of ecological, production, market, and product quality data can be achieved, providing information support for collaborative decision-making across the industrial chain.

5.5 A Development Pathway Focused on

Realizing Ecological Value: Building a New Model Where Industrial Development Contributes to Ecological Conservation

The “Ecological Value Realization” pathway is the result of the further integration of the first four pathways. Its goal is to transcend the traditional dichotomy that “ecological conservation requires investment, while industrial development generates revenue” and to directly convert ecological advantages into economic value. On the one hand, marine ranches can be integrated with industries such as recreational fisheries, coastal tourism, science education, and fishing culture to form a composite industrial model of “marine ranches + tourism + fishing experiences + science education.” On the other hand, mechanisms for realizing the value of ecological products should be explored to transform the ecological benefits generated by marine ecological restoration, fishery resource enhancement, and ecological aquaculture into identifiable, measurable, and tradable economic value. This will ultimately create a feedback mechanism of “ecological improvement — industrial value-added — increased income for farmers and fishermen — reinvestment in ecology,” enabling industrial profits to be reinvested in marine ecological conservation and achieving the integration of ecological, economic, and social benefits [6].

There is a clear progressive relationship among these five pathways: laying an ecological foundation is the prerequisite; value-added processing is the core of industrial chain extension; brand enhancement is a key means of value realization; technology empowerment is the driving force throughout the entire process; and the realization of ecological value is the ultimate goal of industrial chain integration.

Therefore, the integration of Zhanjiang’s marine ranch industrial chain should not adopt a single-industry expansion model but rather form a closed-loop development model of “ecological foundation-building — industrial chain extension — brand enhancement — technology empowerment—value reinvestment in ecology.” Among these, ecological foundation-building and value-added processing constitute the priorities for near-term development; brand enhancement and technology empowerment serve as key drivers for industrial upgrading; and the realization of ecological value represents the strategic direction for medium- to long-term development.

6. Policy Recommendations and Institutional Safeguards

6.1 Financial Support

Provide financial subsidies to small and medium-sized aquaculture operators for the purchase of smart cages, underwater monitoring equipment, and environmentally friendly aquaculture facilities, thereby expanding the adoption of advanced equipment. Training in digital fisheries technologies should also be organised to strengthen operators' capabilities in smart aquaculture [7,8].

6.2 Institutional Innovation

Encourage leading enterprises, cooperatives, and small and medium-sized aquaculture farmers to sign cooperation agreements covering guaranteed minimum purchase prices and profit-sharing, and promote the 'enterprise + base + aquaculture farmer' model to integrate small-scale farmers into the entire industrial chain, thereby sharing risks and benefits. Ecological restoration achievements, carbon sink contributions, and industrial spillover effects from marine ranches should be incorporated into local government performance appraisal systems. Policy incentives such as tax relief and priority access to land and maritime-use rights should be provided to model ranches, leading enterprises, and technological innovation entities [9].

6.3 Technology Empowerment and Smart Management

Building on existing platforms such as Zhanjiang Bay No. 1, the city should establish a Zhanjiang Marine Ranch Big Data Smart Management Platform integrating water-quality monitoring, intelligent feeding, disease and pest early warning, carbon sink measurement, and market trading to achieve end-to-end digital and smart management. An integrated government-industry-academia-research-user platform should also be established, guided by the government, led by enterprises, supported by universities and research institutes, involving aquaculture operators, and backed by financial and service support. This would help connect the innovation, industrial, capital, and talent chains. In collaboration with the South China Sea Fisheries Research Institute and other research institutions, a specialised task force for marine ranch technology R&D should focus on bottlenecks

such as typhoon-resistant aquaculture equipment, ecological restoration technologies, the cultivation of high-quality fry, and the quantification of carbon sink fisheries, thereby promoting the local application of scientific research outcomes.

6.4 Synergistic Efforts through Policy Mechanisms and the Industrial System

Integrate policies across fisheries, ecology, cultural tourism, and finance, and introduce dedicated support policies for Zhanjiang's marine ranch industry. A synergistic policy framework covering tax incentives, insurance subsidies, and talent recruitment should be created to address policy fragmentation [10]. A full-chain industrial system centred on marine ranch aquaculture should be developed together with related industries such as aquatic product processing, cold-chain logistics, brand marketing, and fisheries-tourism integration [11]. This would create a closed-loop industrial chain encompassing seedling breeding, ecological aquaculture, deep processing, brand sales, and cultural and tourism experiences, thereby increasing product value-added and industrial competitiveness.

7. Conclusion

Based on an analysis of the current state of the marine ranch industry in Zhanjiang, this paper systematically reviews the development status, industrial strengths, and construction achievements of the city's marine ranches. Using SWOT analysis, it examines the strengths, weaknesses, opportunities, and threats affecting their development. In response to persistent problems such as a fragmented industrial chain, limited resource integration, and insufficient advanced equipment and smart management capabilities, the paper proposes an integration pathway centred on ecology-industry-technology convergence. It recommends developing a smart management system that integrates ecology, industry, and technology; providing government subsidies to small and medium-sized aquaculture farmers; and promoting the 'enterprise + base + farmer' model to integrate small-scale farmers into the entire industrial chain. These measures are intended to create a three-dimensional closed-loop system in which technology empowers industry, industry supports ecological restoration, and a healthy ecosystem underpins development. With their implementation, Zhanjiang's marine

ranches are expected to become an important driver of local economic development and to provide useful experience for similar regions.

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