

Research on the Digital-Intelligent Transformation Pathway of Traditional Fishery under the Rural Revitalization Strategy: A Case Study of Nine Cities in the Guangdong-Hong Kong-Macao Greater Bay Area

Yi Jiang, Qinqin Zhu, Yingying Zhong, Xiaoqing Zhang

School of Economics and Management, Dongguan University of Technology, Dongguan, Guangdong, China

Abstract: With the comprehensively advancing the Rural Revitalization Strategy in China, accelerating the digital-intelligent transformation of traditional fisheries has become a critical pathway to achieving agricultural modernization. This study focuses on nine cities in the Guangdong-Hong Kong-Macao Greater Bay Area as its research subject, centers on the current development status of fisheries, policy-driven mechanisms, and the process of digital-intelligent transformation. Through data analysis and questionnaire surveys, the research identifies key constraints in the transformation process, including structural disparities in technology adoption, digital literacy deficits among practitioners, and gaps in policy execution. These factors contribute to an uneven development pattern in fisheries digitization, characterized by upper-level strength with lower-level weakness. In response, the paper proposes a systematic transformation strategy encompassing three dimensions: strengthening the foundation of intelligent infrastructure, improving financial and policy support mechanisms, and cultivating a multi-level talent ecosystem. The study concludes that the Greater Bay Area's practices in building smart fisheries not only provide replicable experience for other regions but also offers concrete evidence and actionable pathways for cultivating new quality productive forces in China's agricultural modernization.

Keywords: Rural Revitalization; Digital-Intelligent Transformation; Traditional Fishery; Smart Fishery

1. Introduction

As early as 2003, Hu Jintao emphasized that issues relating to agriculture, rural areas, and rural people is of utmost importance to the agenda of the Communist Party of China (CPC). This reflects the nation's longstanding strategic focus on rural development and agricultural modernization, which are essential not only for improving the well-being of farmers and enhancing rural infrastructure, but also for safeguarding national economic security and social stability.

In the current era of rapid digitalization and intelligent technological advancement, these longstanding challenges are being met with new solutions. In January 2025, the State Council issued Comprehensive Rural Revitalization Plan (2024–2027), reaffirming the strategic priority of rural development. Chinese President Xi Jinping stressed the importance of leveraging both technological innovation and institutional reform to systematically enhance the modernization of agriculture and rural areas [1]. In the same year, the CPC Central Committee and the State Council issued the document titled "Opinions on Further Deepening Rural Reform and Advancing Comprehensive Rural Revitalization," commonly referred to as the No. 1 Central Document of the year further emphasized the need to regard science and technology as the core drivers of rural revitalization. These policies call for the aggregation of high-quality resources and a fundamental transformation of agriculture from a resource-dependent model to one driven by technology and ecological sustainability [2].

Within this context, Digital-Intelligent Transformation in agriculture has emerged as a key strategy to realize the goals of Rural Revitalization. As an integral component of agriculture, the traditional fishery sector urgently needs to adopt digital and intelligent technologies to move away from extensive, low-efficiency practices and toward a model of high-quality and sustainable development. The Guangdong-Hong Kong-Macao Greater Bay Area (GBA), with its advanced fishery sector and strong concentration of innovation resources, is strategically located along China's southern coast and serves as a vital hub connecting to global marine economies. It is also home to numerous leading high-tech enterprises and research institutions, offering a solid foundation for the transformation toward a smart fishery system.

Therefore, studying the current development status and transformation pathway of the fisheries in the GBA holds significant value for China's advancing fishery modernization and provides a replicable model for other regions.

2. Current Status and Analysis of the Fishery Sector in the Greater Bay Area

2.1 Overview of Fishery Development in the Greater Bay Area

2.1.1 Scale of Aquatic Production in the Greater Bay Area

Guangdong Province holds a pivotal position in China's fishery development. According to Guangdong Rural Statistical Yearbook 2024, the total aquatic product output in Guangdong reached 9.2402 million tons in 2023, representing a year-on-year increase of 1.03%, ranking second nationwide (see Table 1).

The nine cities within the Guangdong-Hong Kong-Macao Greater Bay Area (GBA) exhibited distinctive characteristics in aquatic production in 2023. The province's total aquatic output value reached 200.531 billion RMB, and its output volume accounted for a dominant share of the region, highlighting Guangdong's comprehensive strength in both aquaculture and fishing. These production figures and economic value form a solid foundation for the GBA's aquatic product supply.

The fishery production structure in the GBA demonstrates significant diversity. Coastal cities have capitalized on geographical advantages to develop marine aquaculture. For example, Zhuhai reported 159,400 tons of marine aquaculture output, while Huizhou reached 54,600 tons. In contrast, inland cities are primarily engaged in freshwater aquaculture. Foshan produced 797,100 tons of freshwater products, and Zhongshan followed with 393,300 tons. This dual-track model reflects a localized strategy of leveraging both marine and freshwater resources — a hallmark of the traditional fishery sector adapting to regional conditions.

Overall, the fishery production in the GBA aligns closely with market demand. Each city dynamically adjusts its production structure based on local resource endowments, effectively meeting consumption needs within and beyond the region. This flexibility not only promotes the healthy development of the fishery industry but also contributes to the evolution of a distinctive and balanced production pattern. Such a foundation is critical for advancing toward a smart fishery system under the broader goals of Digital-Intelligent Transformation and Rural Revitalization.

Table 1. Aquatic Production in the Nine Cities of the Greater Bay Area, 2023

Region	Total Output Value ($\times 10^8$ RMB)	Total Output ($\times 10^4$ tons)	Freshwater Area ($\times 10^4$ ha)	Freshwater Output ($\times 10^4$ tons)	Marine Area ($\times 10^4$ ha)	Marine Output ($\times 10^4$ tons)
Guangdong	2005.31	924.02	30.52	438.42	17.21	357.28
Guangzhou	129.91	48.37	1.65	34.51	0.48	9.32
Shenzhen	28.78	8.71	0.04	0.69	0.09	1.64
Zhuhai	100.57	35.86	0.99	18.66	1.49	15.94
Huizhou	63.27	22.01	1.53	14.73	0.15	5.46
Dongguan	11.58	5.20	0.36	4.44	—	—
Zhongshan	96.39	39.49	2.00	39.33	—	—
Jiangmen	267.78	91.95	4.09	54.84	1.91	29.95
Foshan	195.56	80.27	3.53	79.71	—	—
Zhaoqing	98.95	52.93	3.22	52.62	—	—

Data source: Guangdong Rural Statistical Yearbook 2024

2.1.2 Cognitive Perception of Digital-Intelligent Transformation Among Fishery Practitioners in the Greater Bay Area

(1) Awareness of Digital-Intelligent Technologies.

Despite possessing relatively strong resource endowments, the traditional fishery sector in the Greater Bay Area (GBA) faces a significant challenge in terms of cognitive gaps regarding Digital-Intelligent Transformation. According to a questionnaire survey conducted across the nine cities of the Pearl River Delta, approximately 27.44% of fishery practitioners reported being "very familiar" with the application of digital technologies in the industry—such as intelligent aquaculture systems, Internet of Things (IoT) for fisheries, and big data analytics. This segment represents the early adopters who are leading the transformation process.

However, another 27.44% indicated they were "completely unfamiliar" with these technologies. When combined with those who were "slightly familiar" (22.18%) or "somewhat familiar" (22.93%), over 70% of respondents demonstrated only limited or no understanding of digital technologies in fishery applications (see Figure 1). These findings highlight a significant asymmetry of information and a clear cognitive gap within the fishery workforce.

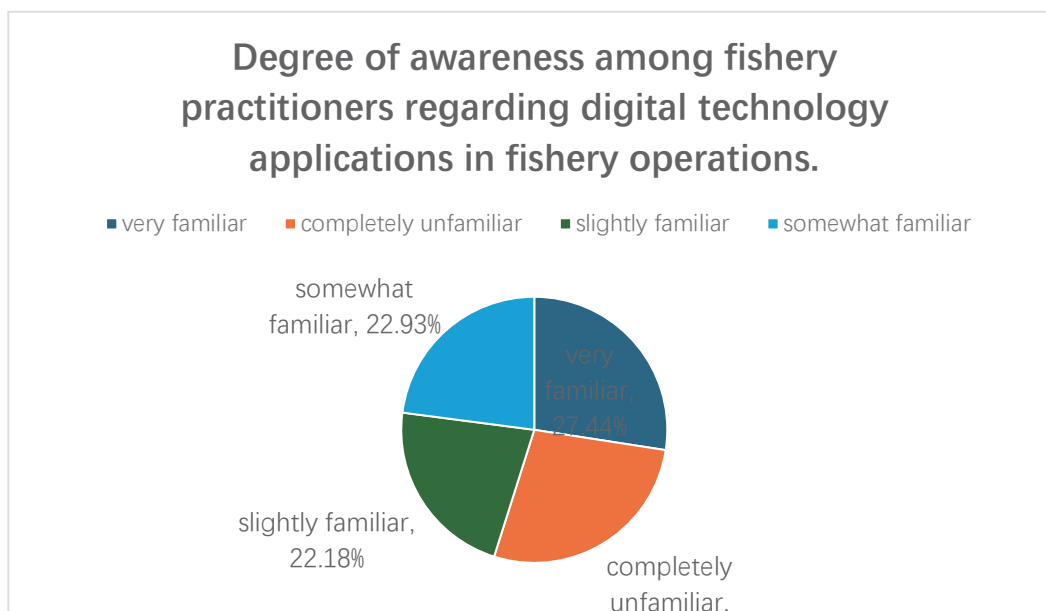


Figure 1. Degree of awareness among fishery practitioners regarding digital technology applications in fishery operations.

(2) Perception of the Importance of Digital-Intelligent Transformation.

From the perspective of attitudinal cognition, nearly 47.75% of respondents recognized digital technologies as either "very important" or "important" to the future development of the fishery sector. This suggests an initial foundation for digital awareness, with respondents acknowledging the potential of smart tools in enhancing quality and efficiency—such as intelligent equipment improving fishing productivity and big data analytics optimizing aquaculture management.

Nevertheless, 31.95% held a "neutral" stance, while 20.3% (including "unimportant" and "completely unimportant") expressed negative attitudes. These figures point to a persistent path dependency at the grassroots level. In particular, small-scale traditional fishers remain hesitant about the costs, benefits, and operational feasibility of adopting new digital tools, favoring experience-based, manual approaches (see Figure 2).

In summary, the traditional fishery in the Greater Bay Area possess a solid foundation in terms of resource structure and production capacity system. However, at the cognitive level, there are significant disparities in digital literacy among the fishery workforce. The transition path exhibits an unbalanced characteristic of being driven from the top down and followed from the bottom up.

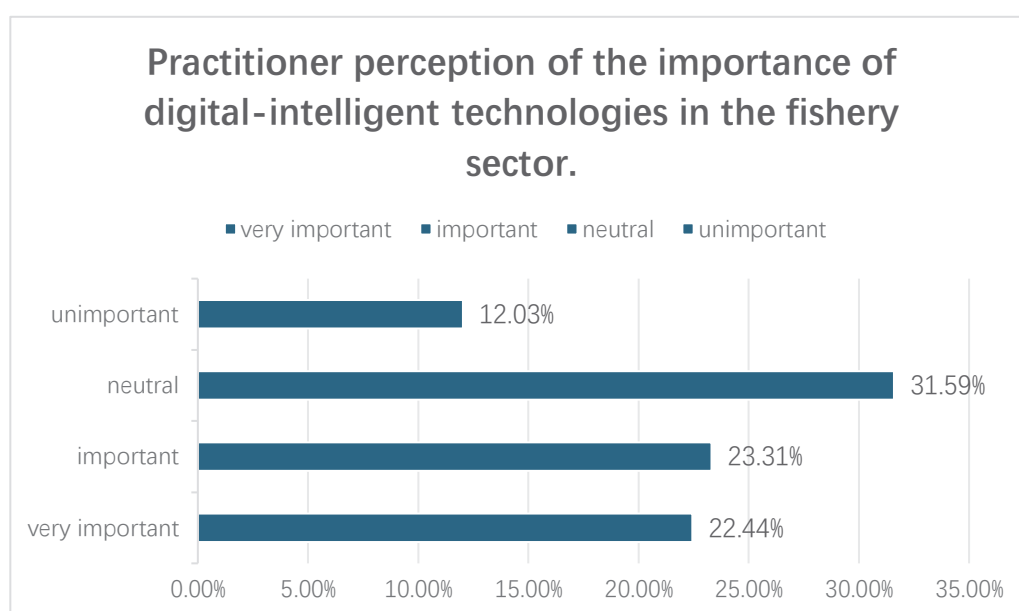


Figure 2. Practitioner perception of the importance of digital-intelligent technologies in the fishery sector.

2.2 Policy Analysis in Fishery

As the overarching policy blueprint for issues relating to agriculture, rural areas, and rural people, the No. 1 Central Document serves as a critical instrument in guiding the direction of agricultural development, the adoption of new technologies, and the structural upgrading of related industries[3]. To build China into a strong maritime nation, the central government has issued top-level policy directives to promote intensive and sustainable aquaculture. These efforts provide systematic guidance for the transformation of the traditional fishery sector.

Building on the previous analysis of the Greater Bay Area's fishery development, it is evident that the region has established a diversified industrial structure and a solid foundation for Digital-Intelligent Transformation. However, industrial upgrading is not an organic or spontaneous process — it evolves under sustained policy guidance and institutional support. Therefore, a detailed analysis of the central-level policy framework, especially the fishery-related content in the No. 1 Central Documents from 2021 to 2025, is essential for understanding the institutional logic and strategic pathway behind the ongoing transformation. As summarized in Table 2, the central government has progressively articulated its intentions and strategic approach to upgrading the fishery sector through digital and intelligent technologies.

2.2.1 2021: Initial Policy Framing — Smart Fishery Enters the National Agenda

In 2021, the foundational policy framework for smart fishery was first introduced. The No. 1 Central Document explicitly proposed the development of "smart agriculture" and called for the construction of an agricultural big data system. It emphasized the integration of next-generation information technologies—such as the Internet of Things (IoT), 5G, and artificial intelligence—into agricultural production. According to the policy document, strategic efforts should focus on promoting modernization and technological upgrading of fishery equipment, with financial subsidies provided to accelerate technological upgrading within the traditional fishery system [4].

2.2.2 2022: Focus on Green and Sustainable Development — Initial Deployment of Smart Fishery Technologies

The No. 1 Central Document (2022) emphasized the stabilization of fishery production and enhancement of ecological efficiency. It advocated the development of green and healthy aquaculture and promoted sustainable fishery practices [5]. The government launched the "Five Major Green Aquaculture Technology Promotion Actions" and initiated the construction of national demonstration zones for eco-friendly aquaculture. These initiatives laid the groundwork for the practical application of green sensings, environmental monitoring, and intelligent control systems in smart fishery.

2.2.3 2023: Expansion of Spatial Boundaries — Upgrading Intelligent Equipment

In 2023, the focus shifted toward spatial expansion and the development of deep-sea resources. The policy called for the accelerated development of large-surface ecological fisheries, the construction of modern marine ranches, and the promotion of deep-sea cage farming and aquaculture vessels [6]. This marked a strategic shift from coastal to deep-sea aquaculture and imposed higher demands on intelligent regulation systems, underwater sensing technologies, and remote operational capabilities.

2.2.4 2024: Standardization of Infrastructure — Toward Smart Aquaculture Models

The No. 1 Central Document (2024) concentrated on modernizing aquaculture infrastructure and promoting intensive production methods. It proposed standardized upgrades of large-scale pond systems and encouraged the development of factory-based recirculating aquaculture systems (RAS). The government also reiterated the need to accelerate smart agriculture development. These measures emphasized digital infrastructure upgrades and the wide-scale application of intelligent control technologies, facilitating a shift from quantity-driven expansion to quality-driven enhancement [7]. According to The State of World Fisheries and Aquaculture 2024 report by the Food and Agriculture Organization of the United Nations (FAO), aquaculture has become the dominant mode of production globally, with rising consumption ensuring food security. Meanwhile, as sustainable development has become a universal imperative, it generates market opportunities, development impetus, and international references for the digital-intelligent transition of China's traditional fishery. [8].

2.2.5 2025: Strategic Leap — "New Quality Productive Forces" Drive Comprehensive Smart Fishery Upgrades

In 2025, the No. 1 Central Document (2025) introduced the concept of "new quality productive forces" in agriculture, marking a new stage in China's agricultural science and technology strategy [9]. The document explicitly called for the cultivation of new productive capacities in the fishery sector, strengthening aquatic seed systems, developing facility-based aquaculture, and building a smart fishery industry chain covering breeding, farming, processing, and distribution. Furthermore, it emphasized the expansion of application scenarios for artificial intelligence, big data, and low-altitude remote sensing technologies in both production and regulatory activities. These efforts aim to comprehensively elevate the digitalization, intelligence, and sustainability of the fishery sector, driving its high-quality development to a new level.

In summary, since 2021, the Chinese central government has continuously reinforced its policy support for smart fishery development through top-level design. It has established a systematic policy roadmap ranging from infrastructure

construction and ecological orientation to deep-sea expansion, facility standardization, and the cultivation of new quality productive forces. This evolving policy framework offers strong institutional guarantees and technological traction for advancing Digital-Intelligent Transformation in the Greater Bay Area's fishery sector, enabling its transition from a traditional fishery model toward a smart, green, and efficient production system.

Table 2. Fishery-Related Policies in China's No. 1 Central Documents (2021–2025)

Year	Key Policy Measures Related to Fishery
2021	Proposed development of smart agriculture; construction of rural big data systems; integration of IoT, 5G, and AI into production; modernizing fishery equipment with government subsidies.
2022	Emphasized stable and high-quality fishery production; promoted healthy aquaculture; launched five major green aquaculture technology initiatives and national demonstration zones.
2023	Focused on expanding ecological fishery in large water bodies; promoted marine ranches, deep-sea cages, and aquaculture vessels.
2024	Encouraged standardization of large-scale pond aquaculture; supported factory-based recirculating systems; reinforced digital infrastructure and smart control applications.
2025	Introduced "new quality productive forces" in agriculture; emphasized full-chain smart fishery development; expanded AI, big data, and remote sensing applications.

2.3 Summary of the Current Status of Digital-Intelligent Transformation in the Fishery Sector

Based on the systematic review of the Greater Bay Area's fishery development foundation, practitioner cognition, and national policy support, it is evident that the region possesses both industrial capabilities and institutional backing to drive the digital-intelligent transformation in fishery. However, the actual implementation process faces multiple obstacles, including structural disparities in technology application, limited awareness of digitalization, and gaps between policy formulation and practical implementation. These current realities fail to align with China's imperative for green and high-quality development in fishery. As critical gaps in the nation's fisheries modernization[10], they create a dilemma: despite well-developed top-level planning, effective implementation mechanisms remain lacking.

2.3.1 Structural Disparities in Technology Application

Field research reveals that some large-scale fishery enterprises in the Greater Bay Area, leveraging strong capital and technological capabilities, have already implemented fully digitalized operations across the entire production process — from water quality monitoring and automated feeding to logistics management — forming relatively advanced smart aquaculture systems. In contrast, most small and medium-sized fishery operators lack the capital base and risk tolerance to undertake such transformation, primarily due to high initial equipment costs, complex maintenance requirements, and long return cycles. Survey data shows that 51.9% of respondents expressed neutral or negative attitudes toward the importance of digital technologies. This reflects widespread reliance on traditional methods, with many operators preferring manual and experience-based practices, and remaining skeptical about the tangible benefits, cost control, and feasibility of digital systems. These concerns significantly weaken both the region's transformation willingness and technological penetration.

2.3.2 Insufficient Digital Cognition

A lack of digital literacy among practitioners has become a key bottleneck. Although nearly half of respondents recognize the importance of digital technologies, over 70% have only limited or no understanding of their application. This has resulted in a vicious cycle of "low awareness — investment hesitation — technological stagnation." Such cognitive gaps hinder the adoption of smart tools at the grassroots level and severely limit the expansion of digital technologies in aquaculture.

2.3.3 Policy-Practice Gap

Despite China's annual No. 1 Central Document has consecutively mandated smart fishery development for five years, with policy pathways evolving from "technology adoption" to "whole-industry-chain coordination", the "last-mile" problems remain between central strategies and local execution. Key supporting measures — including subsidies, technical training systems, and data-sharing platforms — are still underdeveloped, limiting the full release of policy potential and delaying real transformation on the ground.

3. Challenges Facing the Digital-Intelligent Transformation of Traditional Fishery

At the turning point of a global digital wave, the Greater Bay Area's traditional fishery stands at a critical juncture. Driven by China's Rural Revitalization Strategy, the region — with its vast market size, economic dynamism, and tight regional linkages — is transitioning toward a modern, innovation-oriented fishery industry. However, the path to full digital-intelligent transformation remains fraught with challenges.

3.1 Inadequate Infrastructure for Intelligent Development

Technological underdevelopment is one of the primary obstacles. Compared to leading fishery nations such as Norway and Japan, China's fishery sector shows significant gaps in digital capability. Most aquaculture operations in the Greater Bay Area still rely heavily on manual labor, and intelligent equipment is both insufficient in quantity and inconsistent in quality. For example, although deep-sea cage systems in Zhuhai are relatively advanced, they remain vulnerable to typhoons. Furthermore, the self-sufficiency rate of core smart devices (e.g., sensors, automated equipment) is low, with most reliant on high-cost imports, highlighting the lack of indigenous innovation and intellectual property. Digital applications are generally limited to resource monitoring, environmental assessments, and economic statistics, with minimal penetration in areas such as disease control, feeding automation, and integrated production systems.

3.2 High Costs Limiting Technology Adoption

The introduction of intelligent equipment is essential for digital transformation, yet high costs are a major barrier. Urbanization in the region has led to rising costs for land, labor, and energy. Frequent land leasing and renewal cycles further discourage investment in expensive, long-term equipment. For small-scale operators, the costs of acquiring and maintaining advanced systems — such as smart sensors, automated feeders, and environmental control platforms — are often prohibitive. In addition to initial procurement costs, ongoing expenditures for equipment maintenance, software updates, energy consumption, connectivity fees, and malfunction repairs create sustained financial pressure on aquaculture farmers. These impose significant financial burdens on aquaculture operators during their digital-intelligent transition. Achieving cost-output equilibrium while enhancing fish farmers' income — particularly enabling small-scale aquaculturists to participate in the digital transformation — has emerged as a critical priority.

3.3 Shortage of Skilled Personnel

Human capital is another critical constraint. Firstly, traditional fishers, accustomed to manual operations, are often reluctant to adopt new tools and concepts. Even among new-generation practitioners, gaps remain in knowledge absorption and technology application. In addition, digital talent in cross-disciplinary areas—such as AI-driven aquaculture or big-data fishery—is severely lacking across the Greater Bay Area. Furthermore, grassroots fishery extension systems are also underdeveloped, with aging technical teams and inadequate replacements. Moreover, incumbent fishery technicians exhibit overspecialization in traditional domains, lacking interdisciplinary expertise in digital technologies and modern aquaculture. The grassroots agricultural extension system fails to deliver timely, effective technical support to producers. Consequently, advanced digital solutions struggle to gain traction at the operational level, significantly impeding the advancement of modern fisheries.

4. Development Pathways for the Digital-Intelligent Transformation of Traditional Fishery

With strong policy support and growing enterprise engagement, the digital transformation of the Greater Bay Area's traditional fishery is poised to make significant breakthroughs during the 15th Five-Year Plan period. To accelerate this transition, it is essential to leverage blockchain, big data, and integrated platforms, while promoting smart detection, digital fish farms, and intelligent management models [11]. Three strategic pathways are proposed below.

4.1 Strengthening Digital and Intelligent Infrastructure

A weak infrastructure foundation remains a primary barrier to transformation. Firstly, modernization of fishery equipment must be prioritized. Governments at all levels should actively promote smart aquaculture systems—such as factory-based recirculating aquaculture and ecological three-dimensional models—to improve productivity and sustainability. Upgrades should also extend to fishing vessels and community fishery organizations through digital transformation initiatives, enabling real-time monitoring and intelligent control across the entire production process.

Secondly, modern fishery port economic zones should serve as core carriers for transformation. These zones can consolidate regional fishery resources, host IoT-based networks covering docks, anchor areas, trading zones, processing areas, and cold chains, and act as central data nodes to coordinate upstream and downstream activities. Through digital port infrastructure and intelligent platforms, a radiating effect can be created to support smart transformation across broader marine and industrial areas.

Thirdly, fishery resource information platforms must be enhanced. By introducing advanced data analytics and mining algorithms, large-scale fishery data can be utilized for forecasting demand, tracking price trends, and optimizing production planning. This will strengthen decision-making in fishery monitoring and enhance producers' economic outcomes.

4.2 Reducing Transformation Costs Through Financial Support

To reduce cost burdens, financial and tax-based mechanisms must be reinforced. On the one hand, coordinated funding should support smart fishery development across the region. Existing subsidy policies (e.g., tax exemptions for aquaculture processing and offshore fishing) should be strictly enforced to alleviate pressure on businesses. Special funds should be allocated to incentivize the integration of IoT, AI, robotics, and other advanced technologies.

On the other hand, policy-driven risk compensation funds and expanded insurance coverage should be developed to lower operational risks and attract more social capital into modern fishery ventures. Innovative usage models such as leasing and sharing platforms can also reduce upfront costs. Low-frequency, high-cost equipment can be rented instead of purchased, improving capital efficiency and broadening accessibility for small-scale operators.

4.3 Cultivating Talent and Promoting Innovation

Talent cultivation for smart fishery constitutes a strategic imperative aligned with national development goals and a critical priority shaping the modernization of fisheries in the Greater Bay Area. Primarily, Universities should develop specialized curricula in fishery big data, AI, and smart aquaculture, while establishing scholarships, industry-education platforms, and flexible recruitment systems to attract top talent[12].

Meanwhile, a diversified training framework should be promoted. For grassroots workers, practical training on smart equipment and data applications is essential. For middle and senior-level managers, programs in strategic planning and innovation should be emphasized.

Furthermore, relevant governments should guide enterprises and social institutions to carry out smart fishery training. Enterprises are encouraged to conduct internal training to improve the professional ability and comprehensive quality of employees; Social institutions should carry out training and certification services for the whole industry to improve the overall level of the industry.

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