Engineering Solutions to Mechanics, Marine Structures and Infrastructures

Eng. Solut. Mech. Mar. Struct. Infrastruct.
2024.1(4).9
ISSN：2960-0979
https://doi.org/10.58531/esmmsi/1/4/9

Review

Predicting the Future Development Trends of Intelligent Deep-sea Super-large Ocean Ranches Empowered by AI

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Academic Editor: Dapeng Zhang < zhangdapeng@gdou.edu.cn>

Received: 29 November 2024; Revised: 25 December 2024; Accepted: 26 December 2024; Published: 28 December 2024

Abstract: As global demands for sustainable aquaculture grow, deep-sea super-large ocean ranches emerge as a pivotal solution for high-efficiency, eco-friendly marine farming. These structures, located in deep-water environments, integrate cutting-edge technologies to address challenges in monitoring, management, and sustainability. This study explores the integration of artificial intelligence (AI) into these ranches, examining its transformative role in solving key scientific problems such as real-time environmental monitoring, precision feeding, and disease control. AI's application enhances data-driven decision-making, resource optimization, and operational efficiency, addressing both ecological and economic challenges. By reviewing the state-of-the-art in AI-powered aquaculture and predicting future trends, this paper highlights the potential of AI to revolutionize marine farming, ensuring global food security and advancing sustainable marine resource utilization.

Keywords:AI-empowered marine ranches; Smart aquaculture; deep-water farming; Environmental monitoring; Autonomous systems; Sustainable aquaculture; Unmanned operations; Marine farm automation.

1. Introduction

In recent years, the rapid development of artificial intelligence (AI) has enabled many industries to enhance production efficiency and reduce waste. Simultaneously, the scale of aquaculture in China has been continuously expanding, with aquaculture production steadily increasing (as shown in Table 1), demonstrating a positive growth trend. Deep-sea super-large ocean ranches represent an innovative leap in aquaculture, transitioning from traditional nearshore farming to offshore, deep-water environments. These facilities operate

Citation: Li T., Tian Y., Xue Y. Predicting the Future Development Trends of Intelligent Deep-sea Super-large Ocean Ranches Empowered by AI. Eng. Solut. Mech. Mar. Struct. Infrastruct., 2024, 1(4), doi: 10.58531/esmmsi/1/4/9

as integrated ecosystems designed for large-scale marine farming, leveraging advanced engineering and technology to optimize production and sustainability. Unlike nearshore systems, deep-sea ranches minimize environmental impact while addressing increasing global seafood demand. Traditional aquaculture faces significant challenges, including pollution, limited scalability, and low efficiency. In contrast, deep-sea ranches offer solutions such as improved water quality, reduced disease risks, and higher biodiversity preservation. However, their complex environment demands advanced technologies to ensure real-time monitoring, precise control, and sustainable practices.

To develop deep-sea ranches successfully, several scientific problems must be addressed:

1. Real-Time Environmental Monitoring[1]: Deep-sea environments are dynamic and difficult to monitor using traditional methods.

2. Optimized Feeding and Resource Management: Inefficient feeding leads to waste and environmental degradation.

3. Health Management and Disease Prevention: Early detection and intervention for fish health issues remain a challenge.

4. Operational Automation[2]: The harsh marine environment necessitates unmanned systems for safety and efficiency.

AI provides a suite of tools to address these challenges by enabling: Comprehensive and real-time environmental data collection and analysis; Precision resource management through predictive analytics; Automated health monitoring and intervention systems; Integration of autonomous systems for maintenance and operation.

This paper investigates how AI technology empowers the development of intelligent, deep-sea, super-large ocean ranches. It reviews existing applications, identifies gaps, and predicts future trends, emphasizing the intrinsic connections between AI methods and aquaculture advancements.

Table 1: National aquaculture production, 2017-2023 (unit: 10,000 tons)

	Marine aquaculture	Freshwater aquaculture
2017	2000.70	2905.29
2018	2031.22	2959.84
2019	2065.33	3013.74
2020	2135.31	3088.89
2021	2211.14	3183.27
2022	2275.70	3289.76
2023	2395.60	3414.07

Data source: Ministry of Agriculture and Rural Affairs of the People's Republic of China

2. Limitations of traditional technology in deep water super large ocean ranches

In recent years, the development of ocean ranches has reached a relatively mature stage, along with its associated application technologies. However, increasing environmental requirements and growing market demand have highlighted certain limitations of traditional

technologies.

2.1.Limitations of environmental monitoring and data collection

2.1.1 Insufficient real-time monitoring

Traditional environmental monitoring techniques often rely on periodic manual sampling and laboratory analysis, which fail to provide real-time environmental data. This limitation results in delayed responses to changes in key parameters such as water quality, temperature, and salinity in marine ranches. In particular, during sudden environmental changes or pollution events, traditional technologies may be unable to detect and respond promptly, thereby increasing the associated risks.

2.1.2 The coverage of data is limited

Traditional monitoring techniques typically cover only a portion of the pasture, making it challenging to comprehensively and precisely monitor the environmental conditions across an entire deep-water marine pasture. The deep-water environment is characterized by complex currents, temperature gradients, and varying chemical conditions. These variables significantly impact the health of farmed organisms; however, traditional monitoring methods struggle to detect these subtle changes.

2.1.3 High dependence on foreign countries

After decades of development, some of China's marine monitoring equipment has achieved independent research and development, reducing reliance on foreign technologies. However, certain high-demand and technically challenging equipment remains difficult to develop domestically and continues to rely on imports. For instance, the development of high-precision temperature and salinity depth measurement instruments has taken nearly 20 years, yet the production of key components—such as high-precision pressure sensor piezoelectric crystals and 1/10,000-precision quartz resonance sensors—still depends heavily on imports, making independent production challenging[3]. While 70% of offshore and conventional sensors are now domestically produced, over 80% of deep-sea and high-end sensors still rely on foreign suppliers[4].

2.2 Limitations of aquaculture management and production efficiency

2.2.1 High manual operation cost

Traditional breeding management is heavily reliant on manual operations, including feeding, cage maintenance, and disease monitoring, among others. This reliance results in elevated labor costs and hinders the enhancement of operational efficiency as farm sizes expand. Additionally, manual processes are prone to human error, which may cause issues

such as feed wastage, disease propagation, or equipment malfunction.

2.2 .2Low feeding and resource utilization efficiency

Traditional feeding technologies are frequently grounded in empirical knowledge and predetermined feeding quantities, lacking precise regulation of the real-time nutritional requirements of aquatic organisms. This inefficiency leads to both feed wastage and nutritional imbalances in the cultured species. The suboptimal use of resources not only escalates operational expenses but can also exert adverse environmental effects, exemplified by the eutrophication of water bodies due to residual feed.

2.2.3 Disease prevention and control is difficult

In deep-water marine ranches, the efficacy of conventional technologies for disease monitoring and prevention is constrained. Owing to the extensive diversity and scale of aquaculture, the etiology of diseases is complex, making it challenging for operators to promptly diagnose and treat them. This often leads to diminished quality and yield of aquaculture products, and in severe cases, results in substantial financial losses amounting to billions[5].

2.3 Limitations of equipment maintenance and operation

2.3.1Durability and maintenance difficulty of deepwater equipment

The deep-water environment is characterized by its complexity and severity, including strong currents, significant wave action, and corrosive seawater, among other factors. Traditional aquaculture equipment frequently struggles to maintain stable operation over extended periods in such conditions. Equipment failure can not only disrupt production but also pose severe safety risks. Furthermore, the maintenance of traditional equipment typically necessitates hazardous and expensive manual diving operations or frequent replacements in deep-water settings.

2.3.2 Low level of equipment automation

The majority of equipment in traditional technology exhibits a low level of automation and necessitates frequent manual intervention and oversight, making it challenging to meet the large-scale and high-efficiency demands of deep-water super-large marine ranches. For instance, conventional cage cleaning and maintenance operations typically require manual execution, failing to achieve automation and intelligent management.

2.4 Limitations of environment and sustainable development

2.4.1 Environmental pollution and ecological impact

Traditional technologies face significant challenges in effectively managing the

discharge of aquaculture waste, particularly in deep-water, large-scale aquaculture environments. The accumulation of waste can lead to ocean floor pollution and adversely affect the health of marine ecosystems. For instance, the release of nutrient-rich waste containing high levels of nitrogen and phosphorus can severely contaminate both the aquaculture water and adjacent water bodies [6]. In recent years, coastal farmers have started using phosphate-containing agents to capture mud snails [6]. Additionally, the limitations of traditional technologies in environmental monitoring and control increase the risk of unforeseen negative impacts on the surrounding ecosystem.

2.4.2 Resource consumption and unsustainability

The conventional deep-water ocean ranches operation model frequently entails substantial resource consumption, including extensive use of feed, medication, and energy. This not only escalates operational expenses but also exacerbates environmental pressures. Owing to the absence of efficient resource optimization techniques, traditional ranches struggle to implement sustainable aquaculture practices, thereby hindering the harmonious and sustainable development of both the environment and the economy over the long term.

2.5 Limitations of market response and supply chain management

2.5.1 Slow response to market changes

Traditional technologies have limited capabilities in market analysis and forecasting, making it challenging for ocean ranches to adjust production plans promptly in response to changing market demands. This imbalance between supply and demand can result in product overstocking or shortages, ultimately impacting economic efficiency.

2.5.2 Low supply chain efficiency

Traditional supply chain management technologies struggle to fully integrate and optimize all processes, from breeding to market. This inefficiency in logistics can result in increased product losses during transportation and a reduced shelf life, further diminishing market competitiveness. These drawbacks make traditional technologies outdated in the context of modern advancements, creating a significant gap in the digital era. To improve the quality and quantity of farming and meet market demands, it is essential to align with current developments and leverage digital technologies to drive the growth of marine ranches. With the rapid advancements in AI, marine ranches are now presented with new opportunities for transformative development.

3. How the Internet of Things improves the automated management of ocean ranches

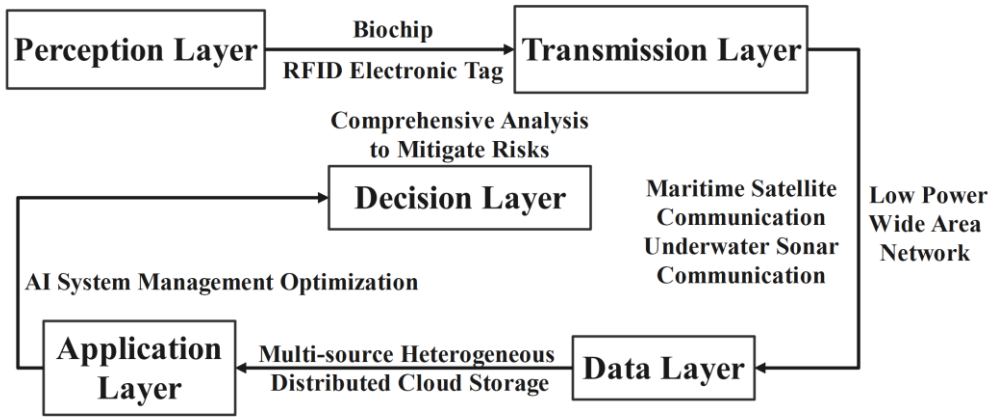

Figure.1. Automated Ocean Ranch Architecture

Illustrates the layered architecture of a smart ocean ranch enabled by AI. It includes sensing, data transmission, data processing, and decision-making layers. Introduces the overall framework of the AI-enabled smart ranch system and explains its operational flow.

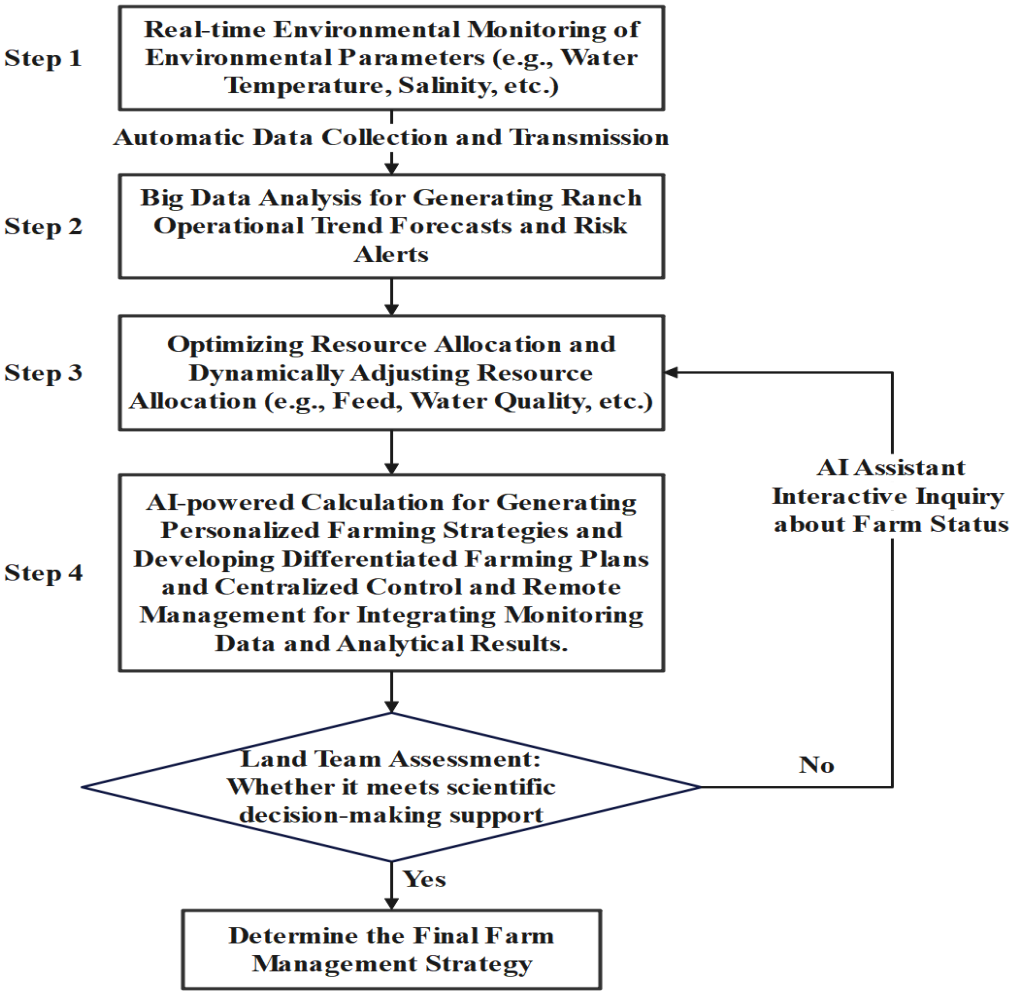

Figure.2.Environmental Monitoring Sensor Network

Visualizes the deployment of multi-parameter sensors and underwater drones for real-time monitoring of environmental parameters like salinity, pH, and dissolved oxygen. Highlights the technological foundation for data acquisition in the ranch system.

AI presents new opportunities for advancing the development of marine ranches. In an AI-enabled smart pasture system, a highly automated, intelligent, and sustainable marine farming system is established through the integration of advanced technologies and innovative management approaches. This facilitates the achievement of goals that are unattainable or challenging to accomplish with traditional technologies.

3.1 Sensing layer (data acquisition and monitoring)

3.1.1 Environmental monitoring sensor network

Multi-parameter Sensors: These sensors are deployed at the water's surface, various depths, and the seabed to monitor environmental parameters in real-time. They measure key factors such as water temperature, salinity, pH, dissolved oxygen, and nitrogen and phosphorus nutrients.

Underwater Drones and Automated Detectors: These devices are used for regular or on-demand inspections of cage conditions, biological health, seafloor sediments, and more. They provide monitoring data through visual feeds, sonar imaging, and other advanced technologies.

3.1.2 Biological monitoring and tracking

RFID Electronic Tags: Also referred to as RF tags, RF cards, or transponders[7][8], these tags are used for identification and tracking purposes.

Image and Video Surveillance Systems: These systems utilize cameras and machine vision technology[9]to monitor fish movements, detect behavioral abnormalities, and identify disease symptoms in real-time. They provide detailed health data to support precise management.

3.2 Transport layer (Data communication and transmission)

3.2.1 Wireless communication network

Marine Wireless Communication System: This system includes 4G/5G networks, satellite communication, and underwater sonar communication, enabling the transmission of data collected by the perception layer to the data center or cloud.

Low Power Wide Area Network (LPWAN): LPWAN supports large-scale, multi-point sensor data transmission, ensuring reliable and real-time delivery of environmental data from deep-sea ranches.

3.2.2 Data aggregation and relaying

Data Relay Station: Relay equipment deployed on the sea or land is responsible for collecting and forwarding data from various sensors, ensuring continuity and stability in data transmission.

Edge Computing: Edge computing devices installed on the ranch perform initial data processing and filtering. This reduces bandwidth requirements for data transmission and ensures the continued operation of essential functions during network outages. By utilizing edge computing technology, the system can alleviate network bandwidth and data center power consumption, reduce latency, and enhance service response[10].

3.3 Data Layer (Data storage and management)

3.3.1 Data Storage

Distributed Database: A distributed database supports the storage of large-scale, multi-source, heterogeneous data, ensuring data reliability and enabling fast retrieval.

Cloud Storage Platform: The cloud storage platform is designed to store historical data, large datasets, and video surveillance data, facilitating long-term data retention and backup. Compared to purchasing storage equipment, aquaculture enterprises can rent cloud storage services in stages based on the number of users. This approach avoids the risks associated with one-time investments, reduces operational costs, and allows for the immediate deployment of selected services, providing convenience and efficiency[11].

3.3.2 Data management and processing

Big Data Analysis Platform: The platform supports large-scale data storage, processing, mining, and visual analysis[12]. It is designed to facilitate the operation of complex algorithmic models, including biological growth models and environmental prediction models.

Data Security and Privacy Protection: Technologies such as encryption and access control are employed to ensure the security of sensitive data during transmission and storage.

3.4 Application layer(Intelligent application and decision support)

3.4.1 Intelligent feeding and breeding management

Intelligent Feeding System[13]: Powered by AI algorithms, this system utilizes optical, acoustic, and other sensor equipment to capture, process, and analyze images, sounds, and other information related to fish behavior[14]. It quantifies the degree of hungerof the fish, enabling precise determination of feeding times, frequency, and quantities[15].

Health Management and Disease Early Warning System: This system leverages machine learning and pattern recognition technologies to monitor and analyze the behavior and health data of farmed organisms. It identifies potential diseases promptly and provides

early warnings along with intervention recommendations.

3.4.2 Production and operation management

Intelligent Operation Scheduling System: This system uses AI to optimize the entire breeding process, including cage layout, harvest timing, and human resource scheduling, thereby comprehensively enhancing operational efficiency.

Resource Management and Sustainability: AI analyzes water and farming data to optimize resource use—such as feed, energy, and water—while minimizing waste emissions and ensuring the sustainability of the ranches.

3.4.3 Market analysis and supply chain management

Market Forecasting and Pricing System: Using AI-based data analysis, this system predicts market demand and price trends, enabling adjustments to production and supply chain plans.

Intelligent Supply Chain Management System: This system optimizes logistics and distribution processes from farm to market, reducing waste, improving efficiency, and ensuring product quality and freshness.

3.5 Decision-making level(Integrated analysis and senior management)

3.5.1 Decision support system

Comprehensive Analysis Platform: This platform integrates data from the perception layer to the application layer, providing comprehensive analysis reports on operational conditions, environmental impact, and market trends. It supports management's strategic decision-making.

Risk Management and Emergency Response: The AI system evaluates various risks, such as climate change, market fluctuations, and technical failures, and develops emergency plans to ensure the stable operation of the ranch under abnormal conditions.

3.5.2 Intelligent control center

Centralized Management Platform: The integrated control panel enables real-time monitoring of ranch operations, allowing for remote operation and management to ensure efficient and intelligent ranch performance.

AI-Assisted Decision Engine: Using AI algorithms for simulation and deduction, this engine helps decision-makers assess the potential impact of different strategies and optimize pasture management decisions.

The AI-enabled smart pasture architecture forms a highly integrated technical and management framework that encompasses the entire process, from data collection, transmission, and storage to analysis and decision support. Through this architecture, the deep-water super-large Marine ranch can achieve comprehensive intelligent management,

enhance production efficiency, reduce operating costs, and promote environmental sustainability. This approach not only accelerates the modernization of the ocean ranches industry but also offers a new path for the sustainable utilization of global marine resources.

4. Prediction of the development trend of intelligent deep water super-large ocean ranches enabled by AI

Enabled by AI, the development trend of deep-water super-large Marine ranches reflects a multi-dimensional evolution in intelligence, scale, sustainability, and globalization. These trends will drive the comprehensive transformation of Marine ranches, enhancing technological innovation, industrial model development, environmental protection, and market competitiveness.

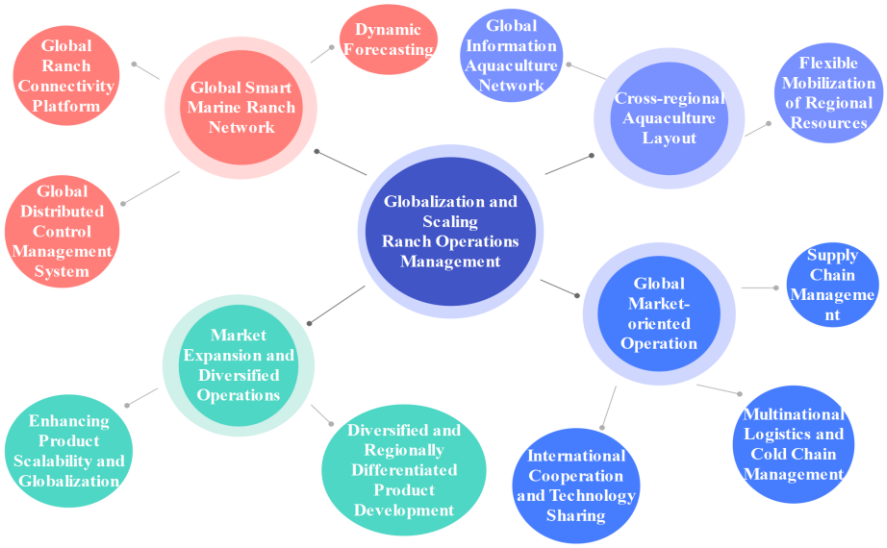

Figure.3. Intelligent Decision-Making System

Depicts the flow of data from collection to analysis and decision-making, emphasizing the role of AI in optimizing operations and resource allocation. Supports discussions on AI's role in enhancing precision management and sustainability.

4.1 Intelligent management

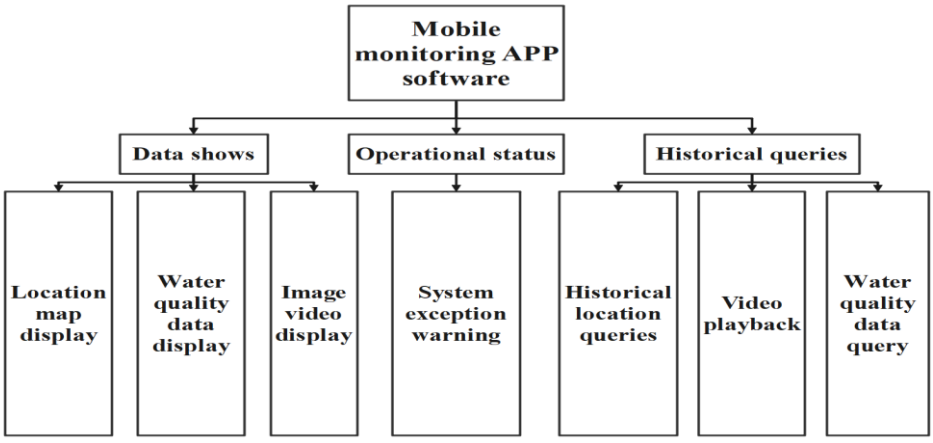

Figure.4. Automated Feeding and Health Monitoring System

Shows how AI-powered feeding systems and disease monitoring work collaboratively to

optimize aquaculture. Demonstrates AI's role in improving resource efficiency and maintaining fish health.

4.1.1 Data-driven decision making

Real-Time Environmental Monitoring: The AI system continuously monitors various environmental parameters of the Marine ranch, such as water temperature, salinity, pH, dissolved oxygen content, and ocean current speed, using a network of sensors and IoT devices[16]. All data is automatically collected and transmitted to a central database.

Big Data Analysis: The collected data is analyzed by AI algorithms to generate trend predictions and risk alerts. By comparing historical and real-time data, AI can identify patterns in environmental changes, predict potential issues (such as harmful algae blooms or deteriorating water quality), and enable proactive measures.

Optimize Resource Allocation: AI dynamically adjusts resource allocation based on factors such as the growth cycle of fish, environmental conditions, and market demand. It determines optimal feed amounts, water quality regulation measures, and harvest timing, maximizing economic benefits.

Personalized Farming Strategies: AI analyzes the specific conditions of each farming unit to develop personalized strategies for different species, such as fish, shellfish, or other marine life. This differentiated management approach can significantly improve yields and quality while reducing farming risks.

4.1.2 Precise feeding and health management

Intelligent feeding system: The AI-based feeding system can automatically adjust the feed amount and feeding time according to the feeding behavior and growth status of the fish, ensuring the maximum utilization of feed and reducing waste. At the same time, the system can also monitor the health status of the fish. If abnormal feeding or reduced activity is found, the AI will automatically issue an alarm and recommend appropriate measures.

Health monitoring and disease prevention: Through image recognition and sensor data analysis, the AI system monitors changes in the appearance, swimming behavior and physiological indicators of fish in real-time, and can detect diseases or injuries in time. Through the early warning mechanism of AI, prevention and control measures can be taken quickly to avoid the spread of diseases.

Automated diagnosis and treatment recommendations: AI can not only detect health problems, but also provide diagnostic results and treatment recommendations based on big data and medical knowledge base. For example, AI can recommend the use of specific drugs or adjust environmental parameters to alleviate problems. In addition, AI can track the effects of treatment and continuously optimize treatment plans.

4.1.3 Integrated management platform

Centralized control and remote management: All monitoring data and analysis results will be integrated into a comprehensive management platform, and managers can check the operation status of the ranch anytime and anywhere through computers or mobile devices. This platform not only provides real-time monitoring functions, but also generates detailed reports to help managers make scientific decisions.

Artificial Intelligence Assistant: Managers can interact with the AI assistant through natural language, such as asking about the current condition of the ranch, requesting the generation of analysis reports or developing new management strategies. The AI assistant can do complex data processing in the background and provide concise and clear recommendations to help managers get a better handle on ranch operations.

Intelligent management enables the smart deepwater super large Marine farm to significantly improve production efficiency, reduce operating costs, and minimize the impact on the ecological environment, thus promoting the sustainable development of the entire industry.

In the smart deep water super large Marine farm, automation and unmanned operations are an important development direction to improve efficiency, reduce costs and ensure safety.

4.2 Automation and unmanned operations

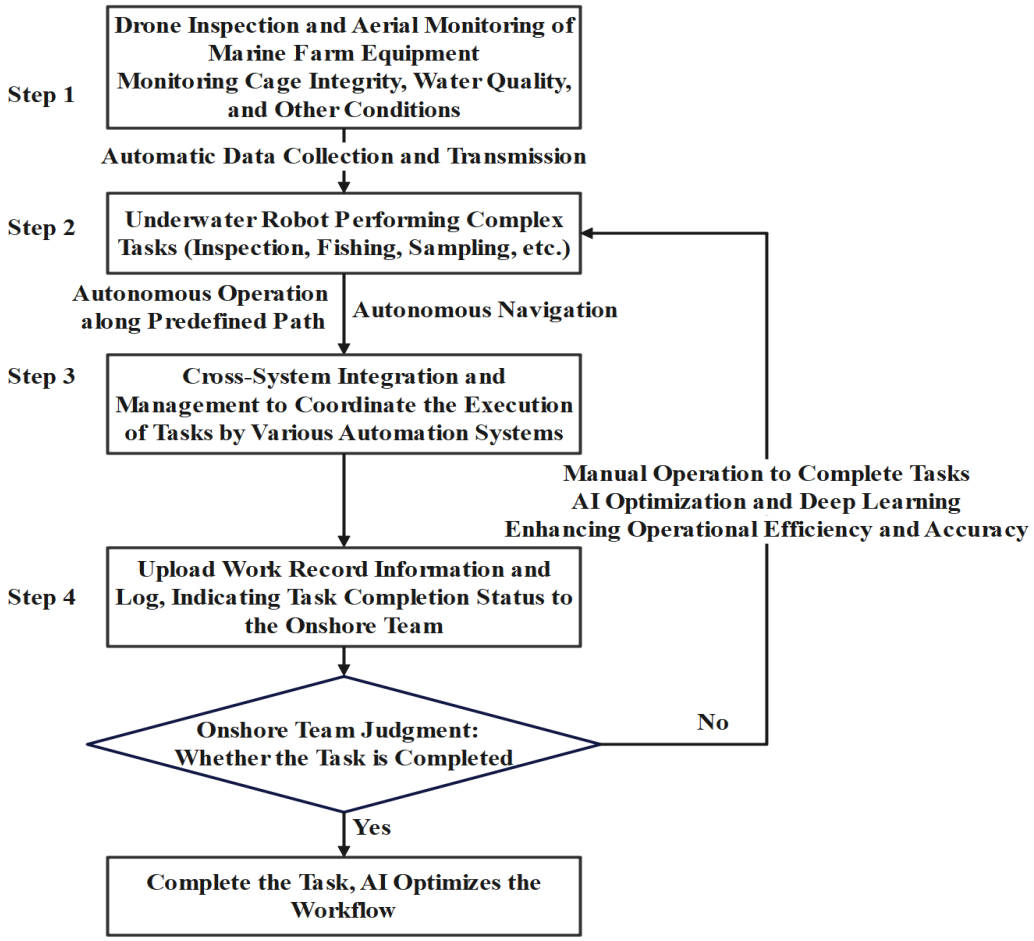

Figure.5. Autonomous Operations in Deep-Sea Ranching

Features drones, underwater vehicles, and automated systems performing tasks like feeding, cage cleaning, and maintenance. Discusses the advancements in automation and unmanned operations for safety and efficiency.

4.2.1 Automated farming facilities

Automatic feeding system: The traditional feeding method requires a lot of manpower, but the automatic feeding system can automatically adjust the amount, time and position of feed according to AI algorithm and real-time monitoring data. The system is usually composed of a central controller, automatic feeders and sensor networks, which can precisely meet the needs of farming organisms, improve feed utilization and reduce waste.

Automated cleaning and maintenance: Deep-water Marine ranches require regular cleaning of cages, removal of algae and attachments to maintain good water quality and a healthy farming environment. Automated cleaning systems use underwater robots or automatic cleaning devices to perform cleaning tasks on a regular or on-demand basis, reducing manual intervention and labor intensity. At the same time, these robots can carry out equipment inspections and identify and report potential equipment failures.

Environmental control system: The automated environmental control system is able to regulate key parameters such as water quality, oxygen supply and water flow based on real-time monitoring data to ensure an optimal growing environment. These systems integrate AI algorithms that automatically adjust parameters in response to environmental changes to ensure the healthy and efficient growth of farmed organisms.

4.2.2 Drones and underwater vehicles

Drone inspection and monitoring: Drones are an important part of modern ocean ranches, especially in deep-water farms. Drones are capable of conducting regular or on-demand aerial inspections to monitor the overall condition of the ranch, including cage integrity, surface water quality and sea surface float. Equipped with high-resolution cameras and infrared sensors, the drones can also carry out surveillance missions in bad weather or at night, providing round-the-clock security.

Underwater vehicles[17]:Underwater vehicles (such as ROVs: remote-controlled underwater vehicles) play a key role in the management of Marine ranches. These robots can dive into deep water and perform complex tasks such as cage inspection, fishing equipment operation, sampling and cleaning. Underwater robots can carry high-definition cameras, robotic arms and sensors to perform tasks with precision, reducing the risks and costs of manual diving.

Autonomous navigation and mission execution: Advanced underwater vehicles have autonomous navigation capabilities that allow them to perform tasks autonomously in complex Marine environments based on pre-set tasks and AI-generated paths. These robots can not only avoid obstacles,but also automatically return to the charging station or mother ship after completing the task, enabling unmanned continuous operation.

4.2.3 Automated harvesting and processing

Intelligent harvesting system: When the fish reaches the specifications required by the market, the automated harvesting system can be activated according to AI instructions. The system includes automated fishing equipment and a transport system that can quickly and efficiently transfer fish from cages to processing facilities or transport vessels. The entire process requires little human intervention, reducing fish injuries and stress reactions, and improving product quality.

Preliminary processing and sorting: After harvest, the automated system can also carry out preliminary processing and sorting. For example, conveyor belts and intelligent sorters can be used to sort fish of different specifications and qualities, or automatically scale and gut them. These operations can significantly reduce the need for manual operations, speed up production, and improve the standardization of products.

4.2.4 Safety and Fault management

Real-time fault detection and self-repair: The automated system is equipped with a comprehensive fault detection mechanism, which monitors the operating status of the equipment in real-time through the sensor network and AI algorithm. If an anomaly is detected, the system is able to automatically diagnose the problem and perform self-healing operations if possible. For example, if the AUV detects that the cage is broken, it can automatically patch it up, or mark the problem area for subsequent treatment.

Remote fault management: In the event that human intervention is required, the system is able to send fault information and suggested fixes to remote operators. These personnel can make repairs by remotely controlling robots or automated equipment without having to go to the site in person, further reducing labor risks and costs.

4.2.5 Integration and optimization of automation systems

Cross-system integration: Automation and unmanned operations are not limited to a single device or task, but are managed through a central control platform. This platform can coordinate the various automated systems (such as feeding, cleaning, monitoring, harvesting, etc.) to ensure that they perform their tasks at the best time to avoid conflicts and waste of resources.

AI Optimization and Learning: Automated systems are not static, and AI is constantly iterating on itself through deep learning1619The system gradually improves operational efficiency and accuracy based on historical data and new technologies. For example, by analyzing past feeding data, the system can adjust future feeding strategies to further improve feed utilization and growth rate.

Taken together, automation and unmanned operations will revolutionize the way Smart deepwater superfarms operate, dramatically increasing efficiency and reducing operating costs while improving safety and sustainability. This will not only help meet the growing global demand for aquatic products, but also drive the Marine farming industry to become

more modern and efficient.

4.3 Eco-friendly and sustainable development

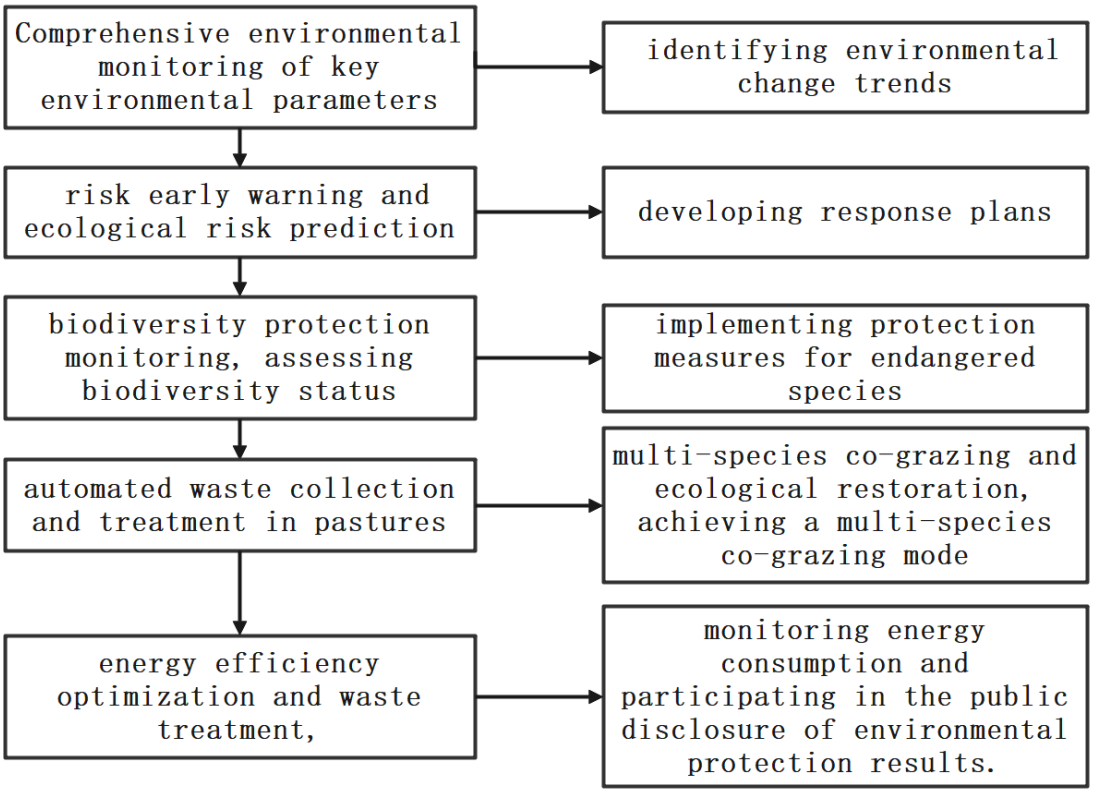

Figure.6. Eco-Friendly and Sustainable Practices

Visualizes waste management, clean energy utilization, and biodiversity conservation strategies supported by AI. Aligns with sections on sustainable development and environmental protection.

4.3.1 Environmental monitoring and ecological protection

Comprehensive environmental monitoring: The AI system continuously monitors key environmental parameters such as water quality, temperature, dissolved oxygen, pH and salinity through a network of sensors deployed around and inside the ranch. This data feeds back into a central control system in real-time to help identify trends in environmental changes and take measures in advance. For example, the system can detect early signs of seawater eutrophication and quickly adjust farming strategies or issue warnings to prevent harmful algae outbreaks.

Risk warning: AI is able to predict possible ecological risks, such as pest invasion, environmental degradation due to climate change, based on historical data and real-time monitoring results. Through these early warning mechanisms, managers can formulate

response plans in advance, such as temporarily reducing breeding density, adjusting the location of cages or suspending certain high-risk operations, to minimize the negative impact on the environment. Risk early warning is also used to reflect the ecological impact of Marine ranches on the ocean, so as to restrict the behavior of Marine ranches, so as to realize the premise that the development of the Marine economy will not damage the quality of seawater, Marine atmosphere, Marine fishery resources, and Marine minerals[20].

Biodiversity conservation: In an ecologically friendly ocean ranches, the conservation of native biodiversity is of Paramount importance. AI technology can monitor and analyze the status of biodiversity in ranches and surrounding areas, identify interactions between native and introduced species, and take necessary conservation measures. For example, AI systems can optimize the selection and number of introduced species to prevent them from posing a threat to local ecosystems.

4.3.2 Low-carbon and energy efficient technologies

Clean energy use: In order to reduce the carbon footprint of Marine ranches, many deep-water farming facilities will be powered by clean energy sources such as solar, wind and wave energy. AI can optimize the use of these energy sources, such as regulating energy production and storage based on weather forecasts to ensure efficient use of energy. In addition, AI can intelligently schedule energy use,such as concentrating energy-intensive farming operations during sunny hours, thereby reducing reliance on fossil fuels.

Energy efficiency optimization:The AI system can monitor the energy consumption of various types of equipment in the farm, identify high energy consumption equipment or unnecessary energy consumption,and provide optimization recommendations. For example, AI can suggest more efficient pumping systems or regulate the direction and speed of water flow to reduce energy loss. By optimizing the working patterns and timing of equipment, AI can significantly reduce overall energy consumption without affecting production efficiency.

Carbon emission Management: The energy consumption of fishing, breeding, processing, fishing equipment manufacturing, fishing feed and other links of fishery production has been calculated. The research shows that the energy intensity of aquaculture in China is 0.24 million tons of standard coal / 10,000 yuan output value, which is 1.26 times2122of the average agricultural value. Through the whole process monitoring of energy consumption and production activities, the AI system can accurately calculate the carbon emissions of ranches. And put forward the corresponding emission reduction measures.This includes optimizing feed formulations to reduce greenhouse gas emissions during production, or suggesting carbon offsetting through, for example, afforestation. AI can also help record and report carbon emissions data, supporting ranches in their applications for green certification or other environmental credentials.

4.3.3 Waste treatment and recycling

Automated waste collection: Marine ranches produce a lot of organic waste during

farming, such as fish manure, uneaten feed residue, and dead fish. An AI-controlled automated waste collection systems can collect this waste in real-time and centrally dispose of it. These systems can automatically adjust the frequency and method of collection according to the type and amount of waste, ensuring the cleanliness of the pasture environment and good water quality.

Recycling and recycling: The AI system can sort and treat the collected waste and turn it into useful resources. For example, fish waste can be treated and used as an organic fertilizer to be reused in a Marine ranch or nearby agricultural project. AI can optimize the process of waste treatment, improve the efficiency of resource utilization and reduce the environmental impact of waste discharge.

Intelligent water circulation system: semi-closed water circulation system or closed water circulation system are usually used in deep-water[23]The AI system is able to monitor the water quality in real-time and automatically adjust the operating mode of the water circulation system to ensure that the water quality is always in the best condition. The systems can also recover and treat wastewater generated during farming, purifying it and re-using it for farming through filtration and biological treatment technologies.

4.3.4 Integrated ecological management

Multi-species co-culture model:AI technology can help achieve multi-species co-culture, which can mimic the energy flow and material circulation of natural ecosystems and reduce resource waste. For example, AI can optimize the co-culture mix of fish, shellfish, algae and other aquatic organisms so that different populations interact and mutualize, thereby increasing overall farming efficiency and reducing pressure on the environment.

Ecological restoration projects: In some areas of the sea where the ecology is fragile or has been damaged, intelligent Marine ranches can be an important tool for ecological restoration. AI systems can design and implement ecological restoration schemes, such as reintroducing locally lost species, building artificial reefs or restoring seagrass beds. With long-term monitoring and adjustment, AI can help these restoration projects succeed and restore and enhance the functioning of local ecosystems.

Social responsibility and environmental certification: With the promotion of the concept of sustainable development, more and more consumers are concerned about the environmental protection of products and the social responsibility of production processes. AI can help Ocean Ranch record and demonstrate its efforts and achievements in eco-friendliness and sustainable development, and the data can be used to apply for environmental certification or promote it to the market, thereby improving the added value of the product and market competitiveness.

In general, eco-friendliness and sustainable development is one of the core goals of the Smart Deep Water Super Large Ocean Ranch. Through the empowerment of AI technology, the ranch can maximize its economic benefits while protecting the Marine ecological environment. This is not only in line with the global trend of sustainable development, but also helps ensure the long-term sustainable use of Marine resources.

In the future development of smart deep water super large ocean ranches, globalization and scale are the keys to promote industrial expansion and enhance competitiveness. Through cross-regional farming layout and international cooperation, AI-enabled Marine ranches can achieve broader resource integration and market coverage.

4.4 Globalization and scale

4.4.1 Cross-regional breeding layout

Global distribution of aquaculture network: The smart deep water Marine ranch is not limited to a single country or region, but can achieve cross-regional layout on a global scale. The environmental conditions of different sea areas are different, and through the analysis and optimization of AI technology, the ranch can choose the best breeding location according to the global market demand. AI can analyze many factors, such as climate, sea temperature, salinity and ecological environment, to provide scientific basis for the site selection of ranches, and ensure that ranches in different regions can give play to their geographical advantages.

Inter-regional resource scheduling: Based on the global layout, AI can help coordinate the resource scheduling between different regions. For example, when the farming environment in one region is affected by climate change or unexpected events, AI can quickly dispatch resources in other regions, ensuring the stability of the overall supply chain. This ability to share and dispatch resources across regions enables the smart ocean Ranch to cope with global market fluctuations and improve its resilience to risks.

Regional farming solutions: Marine ranches in different regions face different environmental challenges, such as the cold waters of the Arctic and the hot waters near the equator. The AI can develop a specific farming plan for each region, including suitable breeding species, feeding methods, disease control strategies, etc. This customized management approach can improve the productivity and product quality of ranches in different regions, and maximize the utilization of regional resources.

4.4.2 Global market operation

Global supply chain management: AI-enabled ocean farms can integrate global supply chain management systems, and all aspects can be optimized through AI, from raw material procurement and production planning to the transportation and sale of final products. AI can analyze demand changes in the global market and dynamically adjust production plans and logistics arrangements to meet market demand at the lowest cost and fastest speed. In this way, the ranch can achieve efficient supply chain management on a global scale and improve the market response speed of its products. Transnational logistics and cold chain management: Deep water Marine ranches often have to travel long distances for their products, and maintaining freshness and high quality is key. AI technology can optimize cross-border logistics and cold chain management, monitoring parameters such as temperature, humidity and time during transportation to ensure that products are still in top

condition when they arrive at their destination. AI can also adjust logistics routes and modes of transportation according to market demand and seasonal changes, improving logistics efficiency and reducing costs.

Global branding and Marketing: With the global development of Sea Ranch, it is essential to establish a unified global brand image and marketing strategy. AI can help analyze consumption habits, cultural differences and demand preferences in different markets to develop adaptable branding plans. For example, in markets that focus on sustainability, AI can help ranches emphasize their environmentally friendly and eco-friendly production methods, boosting brand value and market recognition.

4.4.3 International cooperation and technology sharing

Transnational technical cooperation: The development of smart ocean ranches requires the support of cutting-edge technologies, which are often distributed in different countries and research institutions. Through international cooperation, countries can share the latest research results in AI technology, sensor technology, automation equipment and environmental monitoring systems. AI can build a global cooperation platform, promote technological exchanges and cooperation among scientific research institutions, enterprises and governments of various countries, and accelerate technological innovation and application.

Standardization and mutual certification:With the advance of globalization, smart ocean farms need to follow international standards and certification systems. AI can help national ranches adapt to and comply with nternational standards,such as production norms,environmental protection requirements and product quality standards. At the same time,AI can promote mutual recognition of certification between different countries, reduce trade barriers, and enable products to enter the international market more smoothly.

Data sharing and joint research: Through AI technology, Marine ranches around the world can realize real-time sharing of data, including environmental monitoring data, farming results, market demand and so on. Countries can use this shared data to conduct joint research and explore new farming technologies and ecological protection methods. AI can also analyze global data to find potential market opportunities and ecological risks to provide references for countries.

4.4.4 Global Smart ocean ranches Network

Global Ranching Internet Platform: AI can build an Internet platform of global smart ocean ranches, connecting ranching distributed all over the world. The platform is able to gather production data, market dynamics and technological innovation information from various ranches around the world in real-time to form a global network of smart Marine ranches. Through the platform, ranch managers can share experience, technology and market information and work together to respond to changes in the global market and environment.

Smart supply chain and market platform: AI can also build a global smart supply chain

and market platform that integrates all links of the supply chain, from production, processing, transportation to sales, forming a closed-loop ecosystem. This platform can not only optimize the efficiency of the supply chain, but also respond to changes in market demand in real-time and adjust production and supply strategies. At the same time, the platform can also provide transparent product traceability services to consumers around the world, enhancing consumers' trust in products.

Global risk management system: Smart Ocean Farms face multiple global risks, such as climate change, environmental pollution and market fluctuations. AI can establish a global risk management system through the Global Pasture Interconnection platform, monitor and predict various potential risks in real-time, and provide countermeasures for ranches in different regions. The system can dynamically adjust risk management strategies based on global data, helping ranches prepare in advance and reduce losses.

4.4.5 Market expansion and diversification

Global market expansion: With the scale and globalization of Wisdom Ocean Ranch, the ranch will be able to access the international market more widely. AI can analyze the market demand in different regions of the world and help the ranch develop targeted market expansion plans. For example, in areas where there is a greater demand for high-end seafood, the ranch can focus on high-quality, differentiated product development to meet the needs of local consumers.

Diversifying product lines: The market diversity brought about by globalization has also prompted Sea Ranches to develop more diversified product lines. AI can suggest the development of new product varieties or forms, such as ready-to-eat seafood, functional food or processed products, according to consumption habits and market trends in different regions. By diversifying product lines, ranches can increase their income sources and enhance their market competitiveness.

Emerging markets and cross-border e-commerce: AI technology can also help ranches identify opportunities in emerging markets and cross-border e-commerce. As global consumer demand for seafood grows, especially in developing countries and emerging markets, ranches can use AI to analyze the potential of these markets and sell products directly to global consumers through cross-border e-commerce platforms, shortening supply chains and increasing profit margins.

The development trend of globalization and scale will make smart deep water super large Marine farms more competitive and adaptable. With the support of AI technology, these farms can achieve resource optimization, market expansion and technological innovation on a global scale, while coping with various challenges brought about by globalization.

In the future development of smart deepwater super large Marine farms, data-driven fine management will be the key to improving farming efficiency, reducing costs, and optimizing resource allocation. Through the deep integration of artificial intelligence and big data technology, ranch managers can make more precise decisions to maximize production

benefits.

4.5 Diversify products and markets

4.5.1 Data acquisition and monitoring

Comprehensive sensor network: Data-driven fine-grained management first relies on comprehensive sensor networks. These sensors can monitor a variety of key parameters in the pasture in real-time, including water temperature, salinity, dissolved oxygen, pH, water flow rate, light intensity, feed consumption, fish activity and growth status. These sensors are connected to each other through Internet of Things technology to form a seamless data acquisition system that provides AI with a constant stream of real-time data.

High-precision environmental monitoring: AI-driven ranch management requires rapid response to environmental changes, and high-precision environmental monitoring systems are key. Through underwater detection instruments and remote sensing technology, AI can accurately monitor changes in the microenvironment of ranches, such as the number of microorganisms in seawater and changes in nutrient concentration. This data helps managers understand the potential impact of environmental changes on farmed organisms, so that timely measures can be taken to prevent sudden ecological problems.

Biometric data collection: In addition to environmental data, AI can also collect the growth status, health status and behavior patterns of farmed organisms through image recognition, acoustic monitoring and behavioral analysis. For example, by using high-definition cameras and sonar devices installed in cages, AI can analyze the swimming speed, feeding behavior and stress response of fish in real-time to determine whether the fish are in a healthy state.

4.5.2 Data analysis and modeling

Big Data analysis platform: AI technology summarizes and processes massive data collected from various sensors, monitoring devices and external data sources (such as weather data, tide data, etc.) by establishing a big data analysis platform. The big data platform can clean, store and analyze these data, extract useful information and patterns, and provide scientific basis for the fine management of the pasture.

Biological growth models: AI can build growth models of fish and other farmed organisms based on historical data and biological theories. Through these models, AI is able to predict the growth rate, feed conversion efficiency and final yield of farmed organisms under different environmental conditions and management strategies. These models can help managers optimize feed delivery strategies, adjust breeding density, and develop harvesting plans to maximize productivity.

Environmental impact models: AI can also use big data analysis to build environmental impact models to predict the impact of different farming operations on the surrounding ecological environment. For example, when large amounts of feed are released or intensive fishing is carried out, AI can predict the likely impact of these operations on water quality,

the benthic environment or the nearby biome, and provide corresponding mitigation measures. These models can help balance production activities with environmental protection to achieve sustainable farming patterns.

4.5.3 Intelligent decision support system

Real-time decision support: By integrating real-time data and analytical models, AI can provide an intelligent decision support system for ranch managers.The system can automatically generate operational recommendations based on current environmental conditions and biological status, such as adjusting the feed rate, adjusting the water cycle rate, and changing the farming density. Managers can make timely and accurate decisions based on the system's suggestions to improve the precision of farming management.

Forecasting and optimizing decision making: AI can not only provide real-time decision support, but also optimize long-term strategic decisions based on historical data and predictive models. For example, AI can predict future market demand and climate change trends, and recommend ranches to adjust production plans, reserve resources or upgrade technology in advance. In addition, AI can simulate the effects of different management strategies to help managers choose the best course of action.

Adaptive management system: The management system of the smart Marine ranch should be self-adaptive and able to automatically adjust management strategies based on real-time data. AI can automatically optimize farming parameters based on continuous data feedback. For example, AI systems can automatically reduce feed delivery or activate emergency ventilation when they detect deterioration in water quality, ensuring the health of organisms and the stability of the environment. This adaptive management method can reduce human intervention, reduce management costs and improve management efficiency.

4.5.4 Fine production and breeding

Precision feeding management: Through AI and data-driven precision management, farms can achieve precision feeding. Based on the fish's growth stage, current environmental conditions and feeding behavior, AI automatically calculates the optimal feed amount and time for each feed to avoid overfeeding or feed waste. Precise feeding not only improves feed conversion, but also reduces environmental pollution problems.

Precise disease prevention and control: AI systems can monitor the health status of farmed organisms in real-time, identifying potential disease risks in advance through behavioral abnormalities, changes in feeding or other physiological indicators. Based on these monitoring results, the AI can recommend or automatically implement corresponding disease prevention and control measures, such as adjusting water quality, administering drugs or isolating sick fish. Through precise disease control, ranches can effectively reduce the risk of disease outbreaks and improve yield stability.

Production process optimization: Data-driven fine-grained management is also reflected in all aspects of the production process. AI can analyze the data of each production

link, identify bottlenecks affecting efficiency, and provide suggestions for optimization. For example, AI can optimize the timing of fishing and transportation to reduce biological stress responses and transportation losses, or optimize processing processes to reduce resource waste and energy consumption.

4.5.5 Cost management and resource optimization

Cost analysis and control: AI can conduct detailed analysis and control of various costs of pasture through data analysis. This includes feed costs, energy consumption, equipment maintenance, labor costs, etc. By identifying high-cost links, AI is able to provide optimization suggestions, such as choosing more efficient feed formulations, improving the working mode of equipment, automating certain labor-intensive tasks, etc., thereby reducing overall operating costs.

Resource allocation and scheduling optimization: AI is able to optimize the allocation and scheduling of resources inside and outside the pasture. For example, AI can intelligently dispatch boats, equipment and people based on real-time demand and resource availability to ensure that tasks are completed efficiently. AI can also predict future resource demand and, based on inventory and market conditions, optimize resource procurement and reserve strategies to avoid resource waste and supply chain disruptions.

Smart inventory management: The inventory management of feed, medicine, equipment and so on in the pasture can also be finely managed through AI.

AI can automatically adjust the inventory level according to the production plan, consumption speed and market supply, ensuring that the inventory is neither excessive nor short. Through intelligent inventory management, the ranch can reduce inventory costs and improve the efficiency of capital utilization, while ensuring continuity of production.

4.5.6 Data visualization and report generation

Real-time data visualization: To help managers better understand and utilize data, AI can generate real-time data visualization dashboards that show key metrics for the ranch. These dashboards can include information on water quality, feed consumption, growth rate, equipment status, etc., and visually present the operation of the ranch in the form of charts, maps, and 3D models.

Periodic report generation: AI can also automatically generate periodic management reports that summarize information such as the ranch's production data, cost analysis, environmental monitoring results and market dynamics. These reports can help managers review past operations, evaluate the effectiveness of management strategies, and provide data support for future decisions.

Abnormal event Alerts: When something abnormal happens to the ranch, such as sudden changes in water quality, equipment failure or an increase in abnormal fish mortality, the AI system can automatically generate alerts through data analysis and report them to the manager in the form of charts and text descriptions. This real-time alerting mechanism can

help managers respond quickly to problems and reduce potential losses.

4.5.7 Continuous optimization and learning

Self-learning and optimization: AI systems are capable of self-learning and can continuously optimize their own algorithms and models through continuous analysis of new data and feedback results. This self-optimization mechanism allows the farm management system to become smarter and more efficient over time, adapting to complex and changing environmental and market conditions.

Data-driven innovation: In the ongoing process of data analysis, AI systems may discover new patterns and patterns that drive pasture management innovation. For example, through big data analysis, AI may discover that certain trace elements or environmental conditions have a significant impact on the growth of farmed organisms, thus guiding the development of new feed formulations or environmental control technologies. This kind of data-driven innovation can continuously improve the competitiveness of farms.

Personalized and intelligent production management will become the core competitiveness of smart deepwater super large Marine farms. Through the in-depth application of AI technology, farms can achieve fine management of the breeding process, intelligent monitoring of the whole process and accurate market response. AI technology can not only improve production efficiency and product quality, but also help farms adapt to changing market demands and ensure sustainable economic and ecological benefits.

5. Economic and social benefits

Ai-enabled smart deep water Marine ranches show great potential in terms of both economic and social benefits. By improving production efficiency, optimizing resource utilization, reducing operating costs and promoting sustainable development, these smart farms not only bring direct economic benefits to enterprises, but also create a wide range of positive impacts for society.

5.1 Economic benefits

5.1.1 Improve production efficiency and profit

Automation and intelligent management:The introduction of AI makes the management and operation of Marine ranches more automated and intelligent. Through precise environmental monitoring, intelligent feeding and real-time risk management, farms can significantly improve productivity. Increased yields and improved product quality translate directly into higher economic returns.

Reduced operating costs:AI technology has achieved significant reductions in operating costs by optimizing resource allocation, reducing manual operations and reducing energy consumption.For example, intelligent feeding systems can reduce feed waste, and precise environmental control can reduce the cost of water quality regulation and medication use.

Improve market competitiveness: Through AI analysis of market demand, ranches can flexibly adjust production plans and product types, respond quickly to market changes, and

seize business opportunities. The high-quality and efficient production capacity enables the ranch to be more competitive in the international market, thus gaining a higher market share.

5.1.2 Promote innovation and industrial upgrading

Promoting technological innovation: AI-enabled ocean farms continue to promote innovation in production technology and management models through big data analysis and intelligent decision support. This not only improves the overall efficiency of the ranch, but also promotes the development of related technology industries, forming a technology spillover effect. Driving the development of related industries: The development of AI Marine ranch is not only limited to the farming itself, but also drives the coordinated development of upstream and downstream industries. Related industries, including intelligent equipment manufacturing, data analysis services, and logistics management, will all benefit from the technological progress and market expansion of Ocean Farm.

5.1.3 Sustainable economic growth

Efficient use of resources: AI technology helps ranches achieve efficient use of resources, such as optimizing the use of water and feed, thereby improving the sustainability of production. This efficient and environmentally friendly production method not only meets the needs of modern economic development, but also reduces resource waste and improves the long-term economic efficiency of the pasture.

Sustainable development model: Through precise environmental monitoring and ecological management, AI Ocean Ranch is able to achieve a balance between production and environmental protection, ensuring the sustainable use of resources. This sustainable development model is not only conducive to the long-term economic stability of the farm, but also provides a reference for the sustainable development of the entire industry.

5.2 Social benefits

5.2.1 Promote employment and social and economic development

Job creation: Despite the high degree of automation of AI technology, the scale and global expansion of smart ocean farms will bring a large number of technical and management jobs.Especially in the fields of data analysis, equipment maintenance and logistics management, the development of AI technology will create new job opportunities.

Drive the local economy: The construction and operation of Marine ranches will drive the development of the local economy, including the construction of infrastructure, the development of supporting service industries, and the overall economic vitality of local communities. At the same time, the profits of the farms will also be translated into local fiscal revenue to support the improvement of local public services.

5.2.2 Ensuring food safety and supply

Stable seafood supply: AI-enabled smart Marine farms can provide a stable supply of high-quality seafood through precise management and efficient production. This is an important contribution to a growing global population and an increasingly protein-hungry society.

Improving food safety: AI technology ensures the safety and quality of seafood through real-time monitoring and intelligent management.For example,the application of disease prevention, environmental pollution control and food traceability systems have all significantly improved food safety and provided consumers with more reliable products.

5.2.3 Environmental protection and sustainable development

Reduce environmental impact: Traditional Marine farming is often associated with environmental pollution and ecological damage, but AI technology can significantly reduce the negative impact of aquaculture activities on the Marine ecological environment through accurate management and monitoring. For example, by optimizing the amount of feed and controlling the discharge of waste, AI farms can effectively reduce the risk of water eutrophication and Marine pollution.

Promoting ecological balance: AI technology helps farms carry out real-time monitoring and assessment of the ecological environment, supporting the development of production while protecting the surrounding Marine ecosystem. This not only helps maintain Marine biodiversity, but also makes a positive contribution to global ecological protection and sustainable development.

5.2.4 Promoting international cooperation and global governance

Promote global cooperation: The AI-enabled Smart Ocean Ranch promotes international cooperation through the sharing of technology and experience. Countries can cooperate in areas such as AI technology, aquaculture management and environmental protection to jointly address global challenges such as climate change and depletion of Marine resources.

Support global governance: Through intelligent management and transparent operations, smart Marine ranches can better comply with international norms and standards and support the sustainable management of global Marine resources. This can help promote Marine governance and resource protection on a global scale.

5.2.5 Improving social well-being and quality of life

Improving public health: By providing high quality, healthy seafood, AI Sea Farm helps to improve the nutrition and health of the public. This has a positive effect on improving the human diet structure and reducing cardiovascular disease and other diseases associated with unhealthy diet. Improving the living environment: AI technology helps farms achieve sustainable production methods and reduce negative impacts on the environment, which in turn improves the living environment of surrounding communities. A good ecological

environment not only improves the quality of life of local residents, but also attracts more tourists and investment, which promotes the sustainable development of local society and economy.

In general, AI-enabled smart deep water Marine farms not only significantly improve economic benefits, but also bring profound positive impacts to society through ensuring food safety, promoting environmental protection, and promoting employment. The development of these Marine farms on a global scale will play an important role in promoting future economic growth, social progress and environmental protection.

6. Conclusion

The AI-enabled smart deep water super large Marine ranch represents a major transformation of future Marine resource development and sustainable fisheries and aquaculture. With the rapid development of artificial intelligence, automation, Internet of Things (IoT) and other technologies, Marine farms can not only significantly improve production efficiency, but also achieve better protection of the ecological environment through intelligent means.

First of all, AI technology makes the management and operation of ocean farms more intelligent. Through real-time monitoring and data analysis of the Marine environment, fish health and facility status, AI can optimize all aspects of the farming process, reducing feed waste, energy consumption and labor costs. This data-driven decision-making process has led to significant improvements in farming efficiency while reducing operating costs. In addition, the application of automation and robotics has made the operation and maintenance of deep-water Marine farms more convenient, especially in deep-sea environments, where AI and robots can perform high-risk or difficult tasks to ensure the safety and stable operation of farms.

Secondly, the environmental friendliness and sustainability of smart ocean farms deserve special attention. AI's real-time monitoring and data analysis capabilities help quickly identify environmental changes and help farming companies adjust their production strategies in a timely manner to reduce the negative impact on the ecosystem. By monitoring water quality, Marine biodiversity and other key ecological indicators, ranches are able to avoid overexploitation and maintain the health of Marine ecology. At the same time, smart Marine farms can also effectively reduce carbon emissions and reduce the farm's energy consumption through energy-saving measures and intelligent management systems. Compared with the traditional fishing model, this new farming method shows significant advantages in terms of ecological footprint and resource consumption. From the perspective of economic benefits, the smart deep water Marine farm has significant profit potential while meeting the growing demand of the global seafood market. Although the initial construction and technology investment is large, the optimization of production and management processes through AI technology can significantly reduce operating costs and improve product quality and output in the long run. Especially in the global context, the increasing demand for sustainable, healthy and high-quality seafood offers a broad market prospect for smart Marine farms. In addition, AI technology also supports the construction of traceability systems for products, helping enterprises establish brands and enhance market

competitiveness.

However, strong support from government policies and international cooperation are also needed to realize the comprehensive promotion and sustainable development of smart deep-water super-large Marine ranches. The government should promote the standardized development of the industry through policy incentives, financial input and legal supervision to ensure the rational use of resources and effective protection of the environment. At the same time, international cooperation can help establish unified industry standards and promote technology sharing and exchange of experience. This will not only contribute to the sustainable use of global Marine resources, but also provide collective solutions to global challenges such as climate change and environmental protection. In general, AI-enabled smart deep-water Marine ranches show great potential in multiple dimensions such as technology, environment and economy, and there is broad room for future development. With the continuous progress of technology, the strengthening of policy support and the deepening of global cooperation, this emerging industry will gradually become an important part of the global Marine economy and provide strong support for the sustainable development of Marine resources in the future.

Acknowledgments: I am very sincerely grateful to Dr. Dapeng Zhang for his guidance and direction of my research.

Funding: This work was financially supported by Program for Scientific Research Start-up Funds of Guangdong Ocean University(grant number 060302112008).

Conflict of interest: The authors of the article have consulted with each other and have no conflict of interest.

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