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Modern Fisheries Innovative Development Urgently Needs Chain Design and Original Innovation Drive (Postprint)

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Abstract

Modern fisheries represents a repositioning of the role of traditional fisheries in national economic development, and together with agriculture, forestry, and animal husbandry, constitutes a land-sea coordinated national food security guarantee system. The development of modern fisheries is of great significance for expanding new spaces and new resources, and ensuring the implementation of national food security. This article analyzes the current development status of China's fisheries from the perspectives of offshore environment, fishery resources, fishing, aquaculture, and processing; expounds on the development concept of achieving transformation, upgrading, and innovation-driven prosperity in modern fisheries through a full-chain design that integrates the industrial chain, problem chain, innovation chain, task chain, and value chain; elucidates the pathways to achieve leapfrog development of modern fisheries through original innovation-driven approaches from the perspectives of major scientific issues, major technical bottlenecks, and four major innovation projects; and proposes development ideas and recommendations for modern fisheries, with the aim of providing references for scientific and technological innovation and industrial development of modern fisheries in China.

Full Text

Preamble

Promoting Systematic Design and Innovation-driven Development for Modern Fishery

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Abstract

Modern fishery represents a redefinition of the role of traditional fishery in national economic development, constituting a national food security guarantee system that integrates land and sea alongside farming, forestry, and animal husbandry. The development of modern fishery is of great significance for expanding new spaces and resources and ensuring national food security. This paper analyzes the current development status of China's fishery from the perspectives of coastal environment, fishery resources, fishing, aquaculture, and processing. It elaborates the development concept of achieving transformation, upgrading, and innovation-driven prosperity in modern fishery through systematic design that integrates the industry chain, problem chain, innovation chain, task chain, and value chain. The paper also explains the pathways for leapfrog development of modern fishery through original innovation, focusing on major scientific issues, key technical bottlenecks, and four major innovation projects. Finally, it proposes development thoughts and recommendations to provide references for scientific and technological innovation and industrial development in China's modern fishery.

Keywords: modern fishery, systematic design, innovation-driven, technology-led, project demonstration

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Fishery constitutes an important component of China's broader agricultural sector and national economy. With 18,000 kilometers of continental coastline, China's fishery employed 20.1696 million people in 2015, with total aquatic production reaching 66.9965 million tons and gross output value of 2,201.994 billion yuan, ranking first in the world for many years. Compared with terrestrial agricultural products, fishery products consume fewer resources and cause less environmental pollution during production. Rich in protein and nine essential amino acids, fishery products represent a crucial pathway for human protein acquisition. As living standards improve and dietary consumption patterns evolve, the importance and health value of fishery products in China's food supply system will continue to increase.

Over the past two decades, China's fishery has achieved two major leaps: the first represented by artificial seed breeding and large-scale aquaculture, and the second characterized by improved varieties, ecological practices, engineering approaches, and high-value utilization. Currently, facing severe depletion of coastal fishery resources, ecosystem imbalance caused by overfishing, and declining food safety standards, modern fishery urgently needs to achieve a third leap represented by mechanization, automation, informatization, and intelligentization. China's modern fishery development covers the Bohai Sea, Yellow Sea, East China Sea, South China Sea, and major inland freshwater basins. Together with farming, forestry, and animal husbandry, it forms a national food security

guarantee system based on land-sea coordination, which is crucial for expanding new spaces and resources and ensuring national food security. Compared with traditional agriculture, modern fishery features spatial diversity, environmental diversity, species diversity, and demand diversity. Developing modern fishery requires systematic design that integrates the industry chain, problem chain, innovation chain, task chain, and value chain, making fishery a strategic foundation for economic development and prosperity in coastal and inland waters, and an important engine for fostering new business forms such as biological products, engineering equipment, and recreational fishery.

1. Analysis of Current Development Status of Modern Fishery

1.1 Deteriorating Coastal Environment and Serious Decline of Fishery Resources

Large-scale coastal reclamation, overfishing, wastewater discharge, and intensive offshore oil and gas development and transportation are the main causes of coastal environmental degradation. Over the past 40 years, large-scale coastal reclamation has caused cumulative losses of approximately 21,900 km² of coastal wetlands, equivalent to 50% of China's total coastal wetland area. The total amount of pollutants entering the sea from major rivers (Yangtze River, Pearl River, Yellow River, Min River, Qiantang River, etc.) has shown a fluctuating upward trend, increasing by 124.7% in 2014 compared with 2002. In 2014, more than half of China's coastal waters were polluted, with bays being the most severely affected areas.

Intensive human activities have led to severe depletion of fishery resources, serious damage to spawning grounds and migration channels, reduced biodiversity, and simplification of food web structure. The sustainable catch of fishery resources in China's jurisdictional waters is approximately 8-9 million tons, while the actual annual catch is about 13 million tons. The target species have shifted from large demersal and near-bottom species in the 1960s to small pelagic species such as anchovy, yellowfin scad, and mackerel, resulting in significantly reduced economic value.

1.2 Overfishing Causing Ecosystem Imbalance and Economic Resources Becoming Younger and Smaller

Fishery overfishing refers to fishing intensity exceeding reasonable levels, leading to fish stock degradation, declining catch quality, increased fishing costs, and fisher poverty. Overfishing disrupts ecosystem structure and function primarily by destroying the life cycles of economic species through rapid increases in fishing vessels and non-standardized fishing practices, preventing many species from forming fishing seasons and damaging top predators in marine food chains. This creates fragile and unstable food webs that ultimately destroy fishery ecosystem balance.

Overfishing has caused economic organisms to exhibit trends of younger age, lower value, and smaller size. Important economic fish resources in China's waters have declined over recent decades, with large yellow croaker, small yellow croaker, hairtail, and other economic fish resources experiencing comprehensive decline. Large and small yellow croakers have been listed as "vulnerable" species, while traditional target species such as mackerel, mullet, and perch have also been damaged. Meanwhile, the proportion of juvenile fish among major economic species has increased, showing trends of earlier sexual maturity and smaller individual size.

1.3 Basically Rational Aquaculture Species Structure but Impacting Coastal Ecosystems

China's aquaculture species structure features remarkable high diversity, with richness and evenness higher than other major aquaculture countries worldwide. There are 135 freshwater aquaculture species and 166 marine aquaculture species. Both freshwater and marine aquaculture feature diverse species with prominent dominant varieties, which is important for species and genetic diversity conservation, sustainable aquaculture ecosystem stability, and efficient biomass production. China's aquaculture trophic level is low and stable, primarily at trophic level 2 (accounting for 70%). Since ecological conversion efficiency is negatively correlated with trophic level, lower trophic levels yield higher conversion efficiency, enabling greater biomass output from China's aquaculture ecosystems.

Although aquaculture contributes only 0.71% of total chemical oxygen demand, 0.67% of total nitrogen, and 1.4% of total phosphorus entering the sea, large-scale aquaculture directly occupies spawning grounds and habitats of fishery organisms, affecting resource regeneration capacity and exacerbating coastal ecosystem vulnerability. According to the 2015 China Marine Environmental Status Bulletin, the environmental status of China's aquaculture areas has improved annually, with 35 red tide events discovered in jurisdictional waters covering approximately 2,809 km²—the lowest in five years. However, the health status of monitored marine ecosystems including estuaries, bays, tidal flats, coral reefs, mangroves, and seagrass beds remains concerning, with 14% in healthy condition, 76% in sub-healthy condition, and 10% in unhealthy condition.

1.4 Low Mechanization Level of Fishery Equipment and Urgent Need for Innovation in Aquaculture and Fishing Technology

China has made progress in fishery facilities, aquaculture engineering, fishing equipment, automatic control, and digital technologies. However, overall aquaculture equipment and key technologies remain relatively backward, with low application rates of information technology, digitalization, automation, and intelligentization in marine aquaculture. Most fishing equipment is imported, core competitiveness is weak, and there is a significant gap in mechanization levels of fishery facilities and equipment.

Technical specifications and standards for lake and pond aquaculture need to be established and improved, tidal flat aquaculture lacks artificial regulation technology, shallow sea bottom-culture organisms suffer from low survival rates and difficult harvesting, offshore deep-water aquaculture technology is still in its infancy, and new models and technologies for ecologically diversified enhancement aquaculture urgently need to be established. The overall equipment and technical level of distant-water fishing vessels is not high, and aquaculture and fishing technologies require urgent research and innovation.

1.5 Concerns over Aquatic Product Quality and Safety and Urgent Need for Innovation in Intensive Processing and High-value Utilization

Aquatic product quality and safety significantly impact the healthy development of China's fishery and national food security. However, China's aquatic product quality has faced criticism in recent years. Issues such as illegal use of banned or phased-out drugs, non-standardized medication during culture, serious pollution in some fishery waters, and lagging standardized production and testing have caused enormous economic losses to China's aquaculture industry and severely constrained fishery development.

Independent research, development, and manufacturing capabilities for aquatic product processing and circulation equipment have been initially established, with research and development conducted in preservation, pre-processing, primary processing, intensive processing, and by-product comprehensive utilization. However, the automation level of intensive processing equipment is poor, with high energy and material consumption. There remains a significant gap compared with international advanced levels in high-tech areas crucial for improving product quality and added value, such as processing enzyme engineering, high-pressure restructuring, cold sterilization, and membrane separation technologies.

2. Chain Design Leading Transformation and Upgrading

Current modern fishery construction and transformation of fishery development modes are highly unified, as accelerating modern fishery construction means accelerating the transformation of fishery development modes. Chain design aims to address the current status of modern fishery construction by integrating the industry chain, problem chain, innovation chain, task chain, and value chain to transform fishery development modes, achieving transformation from single species to entire industry chains and from entire industry chains to complete industrial systems, ultimately realizing transformation, upgrading, and prosperity in modern fishery.

(1) Industry Chain. Traditional fishery industries primarily consist of fishing, aquaculture, and processing, operating in an extremely dispersed and disordered state, resulting in delayed development in overall fishery resource utilization and

economic layout. Modern fishery construction will integrate existing industries to form efficiently operating industry chains, foster new business forms such as biological products, engineering equipment, and recreational fishery, promote economic development, and achieve national prosperity.

(2) Problem Chain. China's fishery industry still faces problems including an aquaculture seed industry system that cannot support industrial development needs, extensive aquaculture models with unreasonable structural layout, low mechanization and informatization levels of facilities and equipment, urgent need for breakthroughs in distant-water efficient fishing technology, insufficient fishery environment monitoring and comprehensive management technology, low engineering levels of habitat restoration and resource conservation, and low levels of intensive processing and high-value utilization of aquatic products. Addressing these major constraints on healthy industrial development will promote theoretical and technological innovation in modern fishery and realize engineering demonstrations of modern fishery industries.

(3) Innovation Chain. In response to current problems, innovation should be achieved in healthy aquaculture, friendly fishing, and green processing to enhance basic theoretical innovation capabilities in modern fishery, improved variety creation and new aquaculture object research and development capabilities, fishery mechanization and informatization equipment capabilities, precise management capabilities for healthy aquaculture, fishery environment management and resource conservation capabilities, distant-water fishing and new resource development capabilities, aquatic resource high-value and clean processing capabilities, and enterprise independent innovation and international competitiveness.

(4) Task Chain. Focusing on urgently needed theoretical foundation innovations to provide theoretical and data support for germplasm creation, disease control, model optimization, and resource conservation. Focusing on major common key technologies urgently needed in pre-production, mid-production, and post-production stages to create a batch of new varieties, technologies, equipment, models, and products, forming a complete industry chain technical system to support industrial transformation, upgrading, and regional demonstrations, and constructing regional blue granaries with land-sea coordination, ecological safety, and excellent quality in major modern fishery production areas.

(5) Value Chain. Establishing technical specifications and standards to achieve integration and mutual promotion of primary, secondary, and tertiary industries, expanding development space, and enhancing industrial competitiveness. Continuously providing efficient marine animal and plant proteins, improving intensive processing and comprehensive utilization levels of aquatic products, and promoting adjustment and optimization of national dietary nutrition structure. Improving living environments, developing recreational fishery, expanding tourism space, and enriching people's spiritual and cultural life.

3. Innovation-driven Approach for Leapfrog Breakthrough

Based on chain design, innovation-driven development focuses on major scientific issues and key technical bottlenecks, emphasizes technology leadership, highlights regional demonstrations, and implements four major innovation projects to lead and support the sustainable and healthy development of China's modern fishery industry, transforming China from the world's largest fishery country to the strongest.

(1) Major Scientific Issues. China's basic theories in genetic molecular mechanisms, disease control, and model construction are relatively weak, seriously constraining industrial development and efficiency improvement. Research must focus on major scientific issues such as aquaculture organism genomics, disease pathogenesis, and habitat restoration principles to achieve new understandings and theoretical breakthroughs that provide theoretical support for modern fishery construction.

(2) Major Technical Bottlenecks. China's technological foundation in major key facilities and equipment, informatization, and resource-environment management is very weak. Research must focus on major technical bottlenecks including improved variety creation, ranch construction, resource digital detection, clean production, and quality control to achieve breakthroughs in new varieties, facilities, technologies, models, and products, providing technical support for modern fishery construction.

(3) Four Innovation Projects. First, the **"Seed Industry Project"** focuses on pre-production chain needs, creating urgently needed superior germplasm, promoting modern industrial concepts for leapfrog development, further elucidating breeding theories and technologies, and constructing molecular breeding technology platforms suitable for aquatic organisms with high genetic polymorphism. Second, the **"Upgrading Project"** addresses rigid constraints of coastal resources and environment in mid- and post-production chains, embodying development concepts of protecting freshwater, precision land-based systems, optimizing tidal flats, conserving coastal waters, and green processing to create new varieties, technologies, equipment, models, and products and form a complete industry chain technical system. Third, the **"Expansion Project"** safeguards China's rights and interests in the South China Sea, open oceans, and polar regions, participates in international resource allocation, and realizes strategic concepts of expanding deep waters, developing distant-water fisheries, and accessing Antarctic resources. Under the international context of "fishing rights are sovereignty, presence is rights and interests," developing offshore deep-water aquaculture represented by marine aquaculture promotes rational utilization and development of marine biological resources, maintains healthy fishery development, declares maritime sovereignty, and provides discourse power in allocation and management of high seas fishery resources. Fourth, the **"Demonstration Project"** integrates demonstration achievements, highlighting industrial characteristics and regional features. In inland areas, it implements integrated

demonstrations of comprehensive aquaculture in the “Two Rivers and One River” basins and “oasis fishery” projects in saline-alkali waters of the “Three North” regions to strengthen water resource protection and comprehensive utilization. In the Bohai Sea area, it focuses on constructing land-sea coordinated ecological ranches to achieve coordinated development of habitat restoration, resource enhancement, and recreational fishery. In the Yellow Sea area, it implements precious seafood enhancement and tidal flat efficient development to form new industrial production models such as fishery-agriculture integration. In the East China Sea area, it implements enhancement of important fishery resources with emphasis on green processing and high-value utilization. In the South China Sea area, it focuses on intensive aquaculture facilities and technology system integration and application, and comprehensive utilization of tropical biological resources such as pearls and algal gums. Strengthening integrated innovation and technology transfer will form industrial clusters with three-industry integration and complete chains, building regional blue granaries.

4. Development Thoughts and Approaches

4.1 Development Thoughts

Modern fishery construction is a comprehensive, systematic project involving multiple disciplines with unique natural, economic, spatial, resource, and ecological attributes. Modern fishery construction must adhere to the development concept of “ecological priority, land-sea coordination, three-industry integration, and four-modernization synchronization” to achieve safe, efficient, and sustainable utilization of environmental protection and fishery resources. China must strengthen basic theoretical innovation capabilities in aquaculture genetics, immunology, and ecological restoration, improve capabilities in germplasm creation, disease prevention and control, nutritional feed, engineering equipment, precise management, resource conservation, new resource development, and high-value and clean processing. It must focus on breakthroughs in key common technologies including variety breeding, intelligent equipment, immune prevention and control, resource conservation and ranch construction, friendly fishing, and green processing. China should also construct a modern fishery science and technology innovation development strategy think tank, cultivate and gather core innovation and entrepreneurship teams, create modern fishery science and technology research and demonstration platforms, create a batch of new varieties, equipment, technologies, models, and products, form industrial clusters with three-industry integration and complete chains, and build regional blue granaries.

4.2 Development Recommendations

Modern fishery construction is a long-term systematic project involving major cognitive innovation, breakthroughs in key equipment and technologies, and regional and typical demonstrations. The new economic normal and “Maritime

Silk Road” construction have put forward new requirements for modern fishery. Breakthroughs must be achieved in aquaculture sea area carrying capacity assessment and productivity layout optimization, comprehensive utilization of marine aquaculture and biological resources, coastal habitat restoration and resource conservation, and comprehensive management and support guarantee for marine aquaculture.

(1) Conduct Sea Area Productivity and Carrying Capacity Assessment. Investigate the distribution and variation characteristics of biological productivity in typical aquaculture areas, comprehensively survey the biological productivity levels and development trends of China’ s aquaculture areas, and map the distribution characteristics of biological productivity in coastal aquaculture areas. Investigate the equipment, production models, and benefits of aquaculture facilities in typical Chinese sea areas, construct a database of China’ s coastal aquaculture production data, systematically assess the aquaculture carrying capacity of China’ s coastal waters, and provide basic data for optimizing aquaculture models and regional layouts.

(2) Optimize Industrial Structure and Rational Layout. Optimize and adjust the industrial structure to reduce excessive development and utilization of environmental resources. Based on marine aquaculture production models and benefits, systematically plan regional layouts, species, production methods, and scales for land-based aquaculture, shallow sea aquaculture, and marine ranch construction. According to the environmental characteristics of different sea areas (Bohai Sea, Yellow Sea, East China Sea, South China Sea), coordinate land-sea aquaculture production activities to achieve both healthy development of coastal aquaculture industry and environmental protection.

(3) Advance Aquatic Organism Breeding Projects. Conduct whole-genome selection breeding, molecular design breeding, and other breeding technology innovations. Integrate family selection, population selection, molecular marker-assisted selection, cell engineering, and whole-genome selection technologies to create new aquaculture varieties with high yield, superior quality, and disease resistance. Research and develop domestication and artificial breeding technologies for wild populations of new aquaculture objects, optimize ecological regulation technologies for seedling conservation, and form efficient, stable, and healthy seedling cultivation technical systems.

(4) Enhance Disease Immune Prevention and Ecological Control Capabilities. Develop new rapid on-site detection technologies for pathogens, study pathogen epidemic characteristics, blocking pathways, and control measures, and develop disease risk analysis and monitoring and early warning technologies. Develop safe and efficient vaccines, disease-resistant biological products, and safe and efficient drugs, create new immune prevention and ecological control technologies, and construct comprehensive disease prevention and control technical systems.

(5) Strengthen Land-based Efficient and Precise Aquaculture. Develop

intelligent and information-based industrial aquaculture system equipment, develop new energy utilization facilities and technologies, establish energy-saving industrial recirculating aquaculture technologies. Develop complete formula feeds and functional additives, research intelligent water quality regulation and feed 投喂 control technologies, construct complete process control equipment, and build digital factory and pond aquaculture and precise management systems.

(6) Develop Offshore Deep-water Facility Aquaculture. Develop large deep-water cage aquaculture facilities and intelligent supporting equipment suitable for offshore deep-water areas, research specialized and multi-functional engineering operation platforms, and integrate complete sets of equipment for precise monitoring, intelligent control, and mechanized operations. Evaluate and screen suitable species for offshore deep-water aquaculture, breakthrough seedling propagation and healthy aquaculture technologies, and construct new models for sea-land relay aquaculture and engineering development.

(7) Strengthen Ecological Aquaculture and Marine Ranch Construction. Develop new facilities for shallow sea aquaculture, establish new models for shallow sea ecological integrated aquaculture based on carrying capacity. Develop new facilities for coastal biological resource conservation and technologies for propagation and tagging of healthy seedlings of important fishery resources, develop fishery resource release management decision-making and effect evaluation technologies. With the goal of constructing large-scale ecological ranches in entire bays or offshore islands and reefs, research marine ranch habitat suitability evaluation, enhancement animal domestication and control technologies, develop key engineering facilities for marine ranch construction, research real-time monitoring and harvesting facilities and technologies, and breakthrough marine ranch ecological safety and environmental guarantee technologies.

(8) Promote Comprehensive Utilization of Biological Resources. Develop aquatic product quality preservation technologies and control technologies for allergens and spoilage organisms, develop new energy-saving equipment and technologies for processing, storage, and preservation, research ecological live transportation, cold chain quality maintenance, monitoring, and traceability technologies. Develop efficient energy-saving and water-saving processing, co-production development and comprehensive utilization technologies for active substances and bulk products, and develop comprehensive utilization technologies for processing waste. Conduct research on aquatic product risk indices, risk ranking, and benefit-risk balance, and establish risk early warning and whole-process quality safety prevention and control technical systems for key hazardous substances.

(9) Implement Habitat Restoration and Resource Conservation Plans. Based on comprehensive understanding of the current status of China's coastal environment and resources, implement habitat restoration projects, research and develop new facilities and technologies for habitat restoration and resource conservation, and establish resource and environmental restoration evaluation

technical systems. Strengthen fishery activity management and law enforcement to achieve sustainable utilization of China's marine fishery environment and resources.

(10) Establish Ecosystem-based Comprehensive Management. Develop aquaculture management systems covering environmental impact assessment, optimized feeding strategies, drug use specifications, aquatic animal transportation control, and aquaculture wastewater management and resource utilization. Develop watershed management measures such as strategic environmental assessment, defining environmental carrying capacity, and maintaining biodiversity. Establish and improve regular, systematic, and long-term survey and monitoring systems for aquaculture and the environment to provide data support for ecosystem-based aquaculture management. Strengthen the important role of science and technology in decision-making to achieve refined fishery management supported by science and technology.

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