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Current Status, Challenges, and Recommendations for the Shellfish Industry in Qingdao

Shenghu Zhu [1*], Tian Chen [1], Jiawen Liu [1], Mali Gong [1]

[1] School of Economics and Management, Dalian Ocean University, Dalian, Liaoning 116000, China
*Corresponding author Email: 1299261652@qq.com
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Abstract: The shellfish industry constitutes a vital component of Qingdao's marine economy, renowned for its long history and diverse species including clams, oysters, and scallops. This study systematically analyzes the current development status and prominent challenges facing Qingdao's shellfish industry based on data from the city's aquaculture germplasm resource census, regional aquaculture statistics, and representative case studies. It proposes targeted development strategies. Findings indicate that Qingdao's shellfish industry has achieved steady growth in total output, establishing an industrial structure dominated by clams, oysters, and scallops. This sector has also produced a number of superior varieties and renowned brands, including "Haida 1-4" and "Hongdao Clam." However, the industry's sustainable development faces severe challenges, including intensified ecological pressures in aquaculture zones (such as overcapacity farming and starfish blooms), frequent marine disasters, an incomplete industrial chain, and low product value-added. Therefore, this paper proposes that aquaculture activities should be scientifically assessed and planned around the core principle of "determining scale by capacity"; strengthening seed industry system construction and protecting local germplasm resources; promoting the industry's transition towards green, efficient, and facility-based operations; and enhancing market competitiveness through deepening processing and brand building. This study aims to provide theoretical foundations and practical references for the high-quality development of the shellfish industry in Qingdao and similar coastal regions across China.

Keywords: Shellfish farming; Qingdao; Sustainable development; Aquaculture capacity; Industry upgrading; Germplasm resources

1 Introduction

Qingdao City, blessed with natural harbors such as Jiaozhou Bay and Dingzi Bay, possesses outstanding marine resources and serves as a major shellfish farming and export base in China. [1]As a vital component of the coastal economy, the shellfish industry not only provides stable support for the local fishery economy but also acts as a key industrial vehicle for boosting fishermen's incomes and advancing the rural revitalization strategy. In recent years, driven by both sustained growth in market demand and continuous innovation in aquaculture techniques, Qingdao's shellfish farming has steadily expanded in scale and progressively optimized its industrial structure. This has fostered a regionally distinctive industry system centered on key species like clams, oysters, and scallops, with local brands such as "Hongdao Clams" gaining increasing recognition. [2]However, alongside rapid industrial expansion, a series of deep-seated structural issues and challenges in the new development phase have become increasingly prominent. Environmental pressures on aquaculture waters continue to intensify, with overcapacity farming emerging in localized areas. Certain shellfish germplasm resources face degradation risks, threatening local genetic diversity. Furthermore, constraints such as short industrial chains, low product value-added, and

intensifying domestic and international market competition collectively hinder the high-quality and sustainable development of Qingdao's shellfish industry. Although significant progress has been made in the overall research of China's shellfish industry, systematic studies on typical regions like Qingdao remain relatively weak. In particular, comprehensive analyses integrating the latest germplasm resource survey data, ecological environment assessments, and industrial upgrading pathways are notably lacking.[3]

Therefore, based on the 2021–2024 survey of aquaculture germplasm resources and aquaculture statistics in Qingdao City, combined with field research and case studies, this study aims to systematically analyze the current status and characteristics of the shellfish industry in Qingdao.[4] It seeks to precisely identify the core constraints and transformation challenges faced by the industry, thereby proposing a sustainable development strategy centered on "ecological priority, technology-driven innovation, and value chain extension." This study not only fills a gap in systematic research on regional shellfish industries but also provides theoretical references and practical models for fisheries transformation and upgrading, as well as policy formulation in similar coastal areas.[5]

2 Current Status of the Shellfish Industry in Qingdao

2.1 The shellfish industry in Qingdao holds a significant position within the fisheries economy.

The shellfish industry in Qingdao holds a pivotal strategic position within its marine fishery economic system. As a major shellfish cultivation and supply base in northern China, this industry not only serves as a stable contributor to local fishery economic output but also stands as a key pillar for ensuring regional food safety, promoting employment and income growth among coastal fishermen, and achieving rural industrial revitalization. Recent aquaculture statistics indicate that Qingdao's total shellfish production has shown steady growth, maintaining an average annual growth rate of approximately 2.7%. [6]This has established an industrial structure dominated by three major categories: clams (primarily Philippine clams), oysters (represented by Pacific oysters), and scallops. Clams and oysters together account for over 70% of total production, forming the industry's foundation. Oysters, with their approximately 30% share of output, serve as the core engine driving overall production growth.[7]

Shellfish farming activities in Qingdao exhibit high spatial concentration and functional differentiation, primarily concentrated in natural harbors such as Jiaozhou Bay, Dingzi Bay, Aoshan Bay, and Lingshan Bay. Huangdao District, leveraging the expansive waters of Lingshan Bay and Gongkou Bay, serves as the largest cultivation zone, producing oysters, scallops, clams, abalone, and cockles. [8]The waters of Aoshan Bay and Dingzi Bay in Jimo District form another core production area spanning 10,603 hectares, where clam cultivation holds an absolute dominance. Chengyang District and Jiaozhou City, encircling Jiaozhou Bay, have formed an intensive aquaculture zone focused on clams and oysters. Areas like Laoshan District emphasize premium and specialty aquaculture. Regarding aquaculture area dynamics, a slight contraction occurred in 2023 but rebounded in 2024, reflecting the industry's resilience in sustaining development amid adjustments.[9]

Total production has grown steadily over the past three years, with an average annual increase of approximately 2.7%. Clams and oysters together account for over 70% of the total output, while scallops consistently rank third. Among these, oysters contribute about 30% of the total production, emerging as the primary driver of overall output growth. [10]

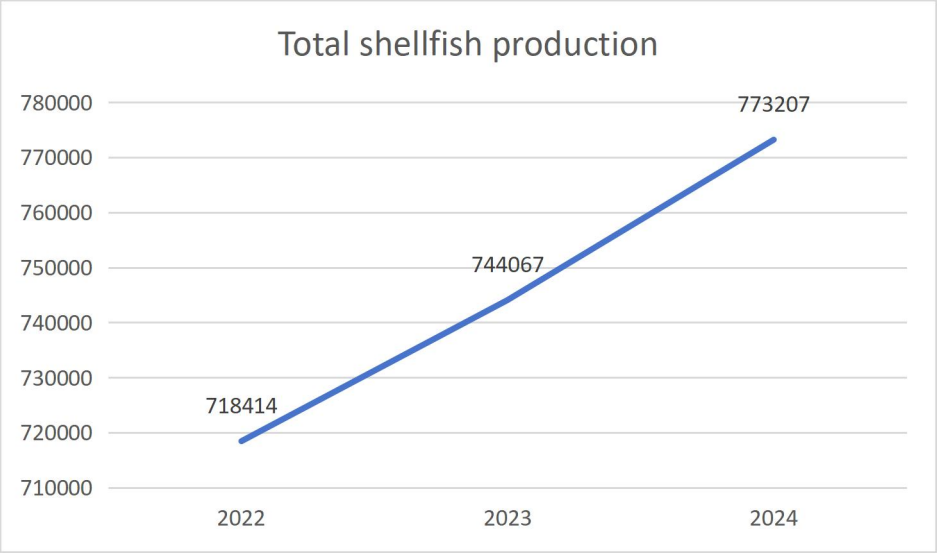
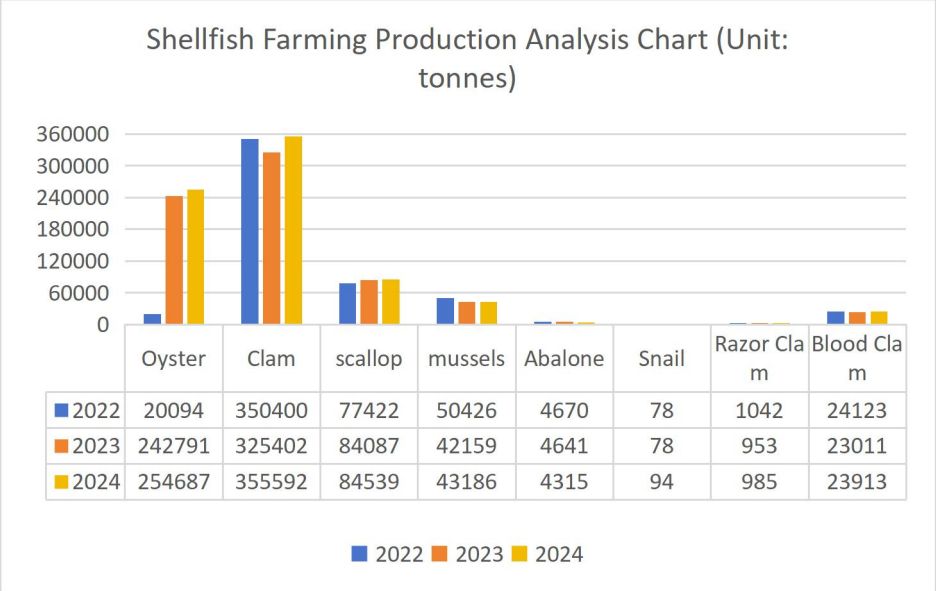


Figure 1: Total Shellfish Farming Production



	Oyster	Clam	scallop	mussels	Abalone	Snail	Razor Clam	Blood Clam
2022	20094	350400	77422	50426	4670	78	1042	24123
2023	242791	325402	84087	42159	4641	78	953	23011
2024	254687	355592	84539	43186	4315	94	985	23913

Figure 2: Analysis of Shellfish Farming Production in Qingdao

The total area experienced a slight contraction in 2023 before rebounding in 2024, with clam farming occupying the largest area followed by oyster farming. The area dedicated to oyster cultivation increased from 6,975 hectares in 2022 to 8,039 hectares in 2023.

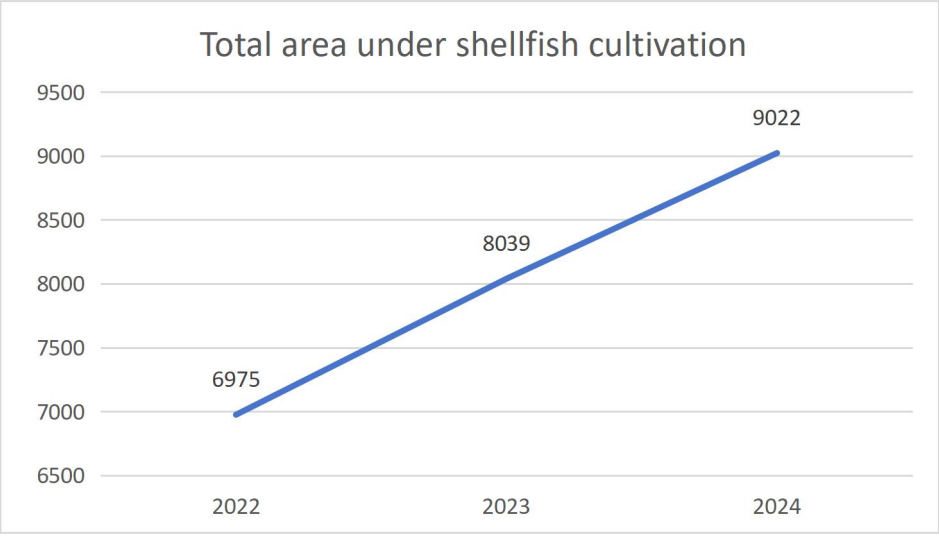


Figure 3: Analysis of Total Shellfish Farming Area

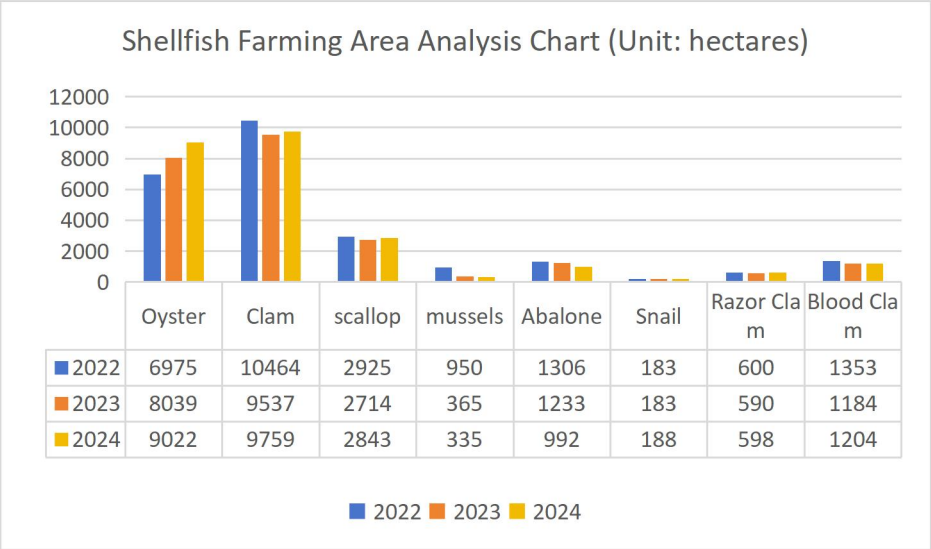


Figure 4: Analysis of Shellfish Farming Areas in Qingdao

As shown in Figures 1 and 2, both the aquaculture area and total production of shellfish in Qingdao exhibited a significant synergistic growth trend from 2022 to 2024. This synchronized upward trajectory clearly indicates that the overall scale of Qingdao's shellfish industry expanded steadily during this period, with increasingly active farming activities. The increase in production is not solely attributable to expanded farming areas but likely also benefits from improved farming techniques, the promotion of superior varieties, and enhanced management practices. This reflects the industry's initial transition from extensive to intensive growth. Qingdao boasts a long history of shellfish farming with a diverse range of species, including clams, oysters, scallops, and abalone. In recent years, driven by growing market demand and advancements in aquaculture techniques, Qingdao's shellfish industry has continuously developed and expanded. It now not only meets local market needs but also exports nationwide, becoming a shining emblem of Qingdao's marine economy.

2.2 Basic Information Census

To systematically understand the status of aquaculture germplasm resources, Qingdao City completed its first comprehensive census of basic aquaculture conditions in 2021. Building upon this foundation, the 2022 systematic germplasm resource survey further narrowed its focus, designating Pacific oysters (Crassostrea gigas) and Philippine clams (Ruditapes philippinarum) as priority species (☆). [11]It also conducted in-depth investigations on five major economic bivalve species: Scapharca broughtonii, and Scapharca subcrenata. This marks a new phase of precision and systematization in Qingdao's mollusk germplasm resource management.[12]

The statistical data in Table 1 clearly reveals the industrial structure and development trends of shellfish farming in Qingdao City. Pacific oysters dominate the industry, with both their farming area (115,139.3 mu) and production volume (152,911 tons) far surpassing others, serving as the core pillar of the industry. Clams (primarily Philippine clams) consistently rank second in both farming area and production volume, forming an important foundation of the industry. Notably, despite relatively low production volume (1,454.5 tons), the abalone's exceptionally high market price per unit (230 yuan/kg) propels its output value (335.42 million yuan) to second place, highlighting the immense potential of high-value-added species in enhancing the industry's economic efficiency. Concurrently, species like the scallop and the razor clam demonstrate stable, large-scale cultivation trends. However, the data also reveals imbalances in the seed supply system. For instance, seed production data is missing for several species like clams and razor clams(—), indicating strong reliance on external seed sources. This highlights the need to strengthen localized, large-scale seed breeding systems, providing clear direction for future seed industry development.

Table 1: Statistical Summary of Marine Shellfish Seed Production and Cultivation

species	Seedling yield (ten thousand seeds)	Cultivation area (mu)	Seedling quantity (ten thousand units)	Production (tonnes)	Farmgate price (RMB/kg)	Output value (ten thousand yuan)
Green-shelled abalone	—	950	10	47.5	200	950
Long-tailed skink	2863812	115139.3	177029092.7	152911	4.8	74293
Clam	—	38514	3818174	61246	6	37599
Gulf scallop	12000	328	680	772.4	8	633.6
Mussel	8000	450		22.5	6	13.5
Penglai Red No. 2	—	100	3000	600	7	420
Four-cornered clam	—	500	390	73.4	8	59.9
Venus clam	—	310	743.6	41.7	24	100
Clam	—	1266	35030	1364	7	938.6
Comb-toothed scallop	—	15605.87	311003.25	12220	10	12208
Chinese horse clam	500	569.2	49	16.6	81.4	
Wrinkled-disk abalone	6210	16757.41	623.26	1454.5	230	33542
Purple mussel	—	25.3	248	85	3	25.4

The shellfish industry in Qingdao holds a crucial strategic position within its marine fishery economic system. As a major shellfish cultivation and supply base in northern China, this industry not only serves as a stable contributor to the local fishery economy's output value but also acts as a key pillar in ensuring regional food safety, promoting employment and income growth for coastal fishermen, and achieving rural industrial revitalization. According to the latest aquaculture statistics, the 2024 shellfish farming landscape in Qingdao is dominated by three primary species: clams (Crassostrea gigas), oysters (Crassostrea ostrea), and scallops. Clam farming occupies over 40% of the total area, while oyster farming accounts for approximately 35%, together forming the foundation of Qingdao's shellfish industry. Jimo District, the largest farming area, leverages its expansive waters including Aoshan Bay and Dingzi Bay to cultivate 10,603 hectares of shellfish. This includes a balanced structure of 5,132 hectares for clams, 2,985 hectares for oysters, and 1,012 hectares for scallops. It also maintains a 30-hectare abalone farming zone, demonstrating the industry's diverse development characteristics.

Huangdao District, with Lingshan Bay and Gongkou Bay as its primary bases, boasts an aquaculture area of 9,465 hectares. It features a dominant oyster cultivation of 3,521 hectares, complemented by coordinated development of scallops (1,800 hectares), clams (1,414 hectares), and abalone (942 hectares), making it a key production area for high-quality shellfish products in Qingdao. Chengyang District, leveraging the northern waters of Jiaozhou Bay, cultivates across 4,543 hectares. It has established a dual-dominant model with clams (2,243 hectares) and oysters (2,223 hectares) equally prominent, demonstrating stable production capacity for traditional flagship species. As a key production area in the southwest of Jiaozhou Bay, Jiaozhou City has a farming area of 1,310 hectares, featuring 970 hectares of clams as its primary specialty, supplemented by oysters (200 hectares) and 140 hectares of razor clams. Laoshan District leverages Laoshan Bay for premium aquaculture, covering 144 hectares dedicated to high-quality shellfish production: 93 hectares for oysters, 31 hectares for scallops, and 20 hectares for

abalone. This represents the industry's direction toward enhanced quality and efficiency. In terms of species structure, Qingdao's shellfish industry has developed a distinctively layered and specialized variety system. Clams (primarily Philippine clams) serve as the foundational species, widely distributed across all production zones with a total area exceeding 9,700 hectares, forming the industry's solid foundation. Oysters (mainly Pacific oysters) act as the pillar species, covering approximately 9,000 hectares and leading the industry in technological innovation and brand development. Scallops serve as an important supplement, covering approximately 2,800 hectares and achieving large-scale production in Jimo District and Huangdao District. Abalone, as a high-value-added species, though occupying a small proportion of the total area, is concentrated in Huangdao District and Laoshan District, representing the direction of industrial upgrading and profit enhancement.

Table 2: Current Status of the Shellfish Industry in Qingdao

Region or Unit	Subtotal	Oyster	Bao	Snail	Blood Clam	mussels	Jiang Yao	scallop	Clam	Razor clam
Shandong Province	4817133	1657092	39290	10019	7342	277478	0	1017839	1351057	142965
Qingdao City	773207	254,687	4315	94	985	43,186	0	84,539	355592	23,913
Huangdao District	232,872	71,693	4,299	94	0	36,966	0	51,527	52,803	10,594
Laoshan District	1,925	835	1	0	0	0	0	1,089	0	0
Chengyang District	204,594	87,633	0	0	0	0	0	0	116,836	125
Jiaozhou City	75,785	8,458	0	0	0	0	0	0	65,032	2,295
Jimo City	258,03	86,068	15	0	985	6,220	0	31,923	120,921	10,899

Aquaculture practices exhibit diverse characteristics, encompassing tidal flat cultivation, raft-based suspended farming, bottom seeding enhancement, and intensive factory farming, reflecting an organic integration of traditional and modern techniques. Notably, traditional production zones for geographical indication products such as the ‘Hongdao Clam’ are progressively adopting modern production management standards while preserving their distinctive qualities. Qingdao hosts leading marine research institutions including Ocean University of China and the Institute of Oceanology, Chinese Academy of Sciences, providing robust technological support for shellfish innovation. This support manifests in breakthroughs in seedling propagation techniques, optimised farming models, and enhanced quality control. Each production area has developed differentiated pathways based on its resource endowments: Jimo District and Huangdao District focus on large-scale production and diversified development; Chengyang District and Jiaozhou City concentrate on consolidating and enhancing traditional superior varieties;

while Laoshan District specialises in premium, high-value-added development. This regionally tailored differentiation strategy has effectively boosted the overall competitiveness of Qingdao's shellfish industry.

This scientific regional layout and species configuration not only fully leverages the ecological advantages of each sea area but also establishes a solid foundation for Qingdao's shellfish industry to withstand market and natural risks, providing robust safeguards for the industry's sustainable development.

3 Analysis of Development Status and Characteristics of Major Aquaculture Species

3.1 Long Oyster Current Cultivation Scale and Production Volume in Qingdao City

The Pacific oyster (Crassostrea gigas) serves as the cornerstone species of Qingdao's shellfish industry, characterized by high industrialization and dominant market presence. According to the latest germplasm resource census data, the city currently hosts 366 Pacific oyster farming entities, with initial signs of industry concentration emerging. [13]Among these, seven entities operate farms exceeding 400 mu (approximately 26.7 hectares), while 15 entities manage farms larger than 300 mu (approximately 20 hectares). Driven by scale, key industry metrics are outstanding: annual seedling usage reaches 536.5 billion units, with local seedling production averaging 28.6 billion units annually. Total farming area spans 7,365 hectares, yielding 143,200 metric tons annually and generating an output value of 691 million yuan, securing a central position in northern China's oyster industry. [14]This robust growth stems from formidable seed industry innovation capabilities. Led by research institutions like Ocean University of China, a series of proprietary new varieties—including “Hai Da 1-4,” “Hai Yi 1-2,” and “Qian Yan 1”—have been successfully developed and promoted. These varieties generally exhibit economic traits such as rapid growth, large individual size, high glycogen content, and excellent meat quality, earning high market recognition. [15]They currently account for approximately 70% of the market share in northern oyster farming areas, serving as a key driver for industrial upgrading.

The cultivation model exhibits characteristics of both diversification and specialization. Cultivated species originate from naturally attached diploid oysters in marine areas, artificially bred diploid oysters, and triploid oysters.[16] Cultivation methods adapt to local conditions, encompassing bottom seeding enhancement, raft-based rope suspension, and net cage cultivation, forming a production system tailored to different marine environments.

Leading enterprises such as Qingdao Xiadelu Aquaculture Co., Ltd. have achieved large-scale, efficient production by leveraging the natural seedling-rearing area of Aoshan Bay. In 2024, the company's oyster farming area in the region reached approximately 2,985 hectares, yielding over 86,000 metric tons. By 2025, its planned cultivation area will expand to 26,000 mu (approximately 1,733 hectares), with an estimated 100-120 million ropes supporting 250 million oyster spat.[17] This demonstrates the company's formidable production organization capabilities and exemplary leadership effect.。

3.2 Philippine clam

The Philippine clam (Ruditapes philippinarum), particularly its GI-certified product “Hongdao Clam,” stands as Qingdao's most renowned traditional shellfish specialty. Industry surveys indicate the city currently has 32 clam farming entities, utilizing 30.314 billion seed clams annually. Cultivation spans 27,600 mu (approximately 1,847 hectares), yielding 34,300 metric tons with an annual output value of approximately 210 million yuan. Both cultivation area and production volume rank first among all shellfish species. Production is highly concentrated in the tidal flat areas of Jiaozhou Bay and Dingzi Bay, employing traditional tidal flat farming methods. The “Hongdao Clam” brand enjoys significant recognition, with stable farming areas exceeding 2,200 hectares and annual output surpassing 110,000 tons. Market supply and demand remain robust, with peak-season daily shipments reaching up to 300,000 jin (150,000 kg) in 2024.[18]

However, this industry's prosperity conceals a severe germplasm crisis. Over 90% of the seed stock in current farming areas relies on southern supplies. After migrating northward, southern populations gained competitive advantages in growth rate and survival rate, gradually encroaching on the ecological niche of local indigenous populations. Combined with historically unregulated harvesting, this has caused the local indigenous population to

decline sharply, bringing it to the brink of extinction. This situation has significantly impacted the genetic structure of local populations, resulting in severe loss of genetic diversity and rendering the germplasm foundation for sustainable industry development extremely fragile. Implementing systematic conservation and restoration plans for indigenous germplasm resources is now urgent.

Production efficiency analysis demonstrates its microeconomic viability. Taking Qingdao Xidayang Aquatic Products Co., Ltd.'s demonstration base as an example, its 300-mu aquaculture area achieved an average selling price of approximately ¥3.8 per jin during one production cycle. After deducting costs such as seedling fees, beach access fees, and marine area usage fees, the base achieved sales revenue of approximately 2.8 million yuan and a net profit of 1.315 million yuan, with an average profit per mu reaching 4,833 yuan. [19]This demonstrates sound economic benefits, providing economic incentives for achieving stable industrial development under conservation principles.

3.3 Scallops

Scallop farming constitutes a vital segment of Qingdao's shellfish industry, centered on the cultivation of comb scallops (Chlamys farreri) and bay scallops (Argopecten irradians). The city hosts 74 farming entities, utilizing 3.147 billion scallop seeds annually across 10,000 mu (approximately 1,000 acres) of aquaculture area. Annual production reaches 13,600 metric tons, generating an output value of approximately 130 million yuan. The primary cultivation method employed is modern cage farming.

Production exhibits regional clustering characteristics. Areas such as Fengjiahe Village along the coast of Aoshan Bay in Jimo District serve as core cultivation zones, boasting tens of thousands of mu of offshore farming areas. During peak periods, daily harvests can reach 100,000 jin. In 2024, Ao Shan Bay produced 31,900 tons of scallops across 1,012 hectares of aquaculture area.[20] Ling Shan Bay recorded higher output at 51,500 tons over 1,800 hectares, while Lao Shan Bay served as a premium cultivation zone yielding 1,089 tons. Regarding market dynamics, by 2025, some high-yield zones could achieve yields of 8,000-10,000 jin per mu. However, wholesale prices are projected to be approximately 5-6 yuan per jin, slightly lower than previous years, indicating the need to focus on market supply-demand balance and value enhancement.[21]

The industry's sustained growth stems from steady progress in superior strain breeding. Breeding bases like Qingdao Baxiandun Marine Delicacies Cultivation Co., Ltd. play a pivotal role. In 2023, the company produced 4.5 million scallop seedlings and preserved 1,000 kilograms of seed stock. In 2024, it further conducted cultivation tests on new strains such as “ZY,” “ZB,” and “PRR,” while systematically preserving superior varieties like the “Penglai Red ” series.[22] Preservation quantities exceeded 10,000 units for each strain, providing crucial seedstock assurance and technological outreach for germplasm renewal and disease prevention in the scallop industry.

3.4 Other Specialty Shellfish

Beyond the three dominant species, Qingdao is actively developing other high-value or ecologically functional specialty shellfish to diversify its product portfolio and explore new aquaculture models.

Cephalopods such as golden squid: As species for stock enhancement and potential aquaculture, Qingdao Jinshatan Aquatic Development Co., Ltd. has successfully achieved large-scale artificial breeding of golden squid and Manchurian squid in collaboration with experts from the Yellow Sea Fisheries Research Institute of the Chinese Academy of Fisheries Sciences. Between 2024 and 2025, thousands of broodstock were cultivated, yielding over 2.5 million fertilized eggs and more than 1 million hatched juveniles, with an average hatching rate of 87.5%. Successful stock enhancement trials integrated with seagrass bed ecological restoration were conducted, achieving significant ecological and resource recovery outcomes.

Scapharca broughtonii (Chinese cockle): As a highly valuable intertidal shellfish, successful cultivation trials were conducted in Jiaozhou Bay. Following promotion from 2022 to 2024, the cultivation area has exceeded 10,000 mu (approximately 667 hectares).[23] Its cultivation cycle is approximately 7-8 months, with seedling stocking density at 40-50 seeds per jin (500g), market size at 16-30 seeds per jin, and selling price ranging from 3.8-4.5 yuan

per jin. The statistical survival rate is 60%-80%, with daily harvests of 3,000-5,000 jin. with cultivation profitability reaching 50%-100%. This demonstrates strong economic viability and ecological adaptability, offering a new option for optimizing tidal flat utilization.

4 Challenges Facing the Shellfish Industry in Qingdao

While achieving remarkable accomplishments, Qingdao's shellfish industry now faces a series of severe and complex challenges to its sustainable development. These challenges span multiple dimensions — including ecological environment, market structure, and the industry's own capabilities — intertwining to form critical bottlenecks constraining the industry's advancement to higher levels.

4.1 Ecological and Environmental Pressures

The ecological and environmental pressures stemming from industrial expansion are becoming increasingly prominent, primarily manifested in aquaculture activities exceeding environmental carrying capacity and frequent natural and biological disasters.

Overcapacity in aquaculture has become a core environmental issue. Research indicates that the optimal farming density for Philippine clams in Jiaozhou Bay should be maintained below 1,000 clams per square meter, with the ideal range being 550-750 clams per square meter. However, current actual seeding densities far exceed this scientific threshold. This has led to water eutrophication, sediment organic matter overload, and deteriorating bottom environments, imposing sustained pressure on the bay's ecosystem material cycles and biodiversity. A striking example is the annual release of 6,000–8,000 truckloads of oyster spat attached to scallop shells in recent years (each 9.6-meter truck carrying 23,000–25,000 jin). In 2021 alone, the combined weight of scallop shells and oyster spat released reached 80,000 tons. This extensive production model, lacking ecological capacity assessments, underscores the urgency for scientific planning and refined management.

Second, the threat of marine disasters has become normalized. Qingdao's coastal waters frequently endure extreme weather events like typhoons and storm surges, which directly destroy aquaculture facilities, leading to mass escapes or deaths of shellfish. Additionally, harmful algal blooms like red tides occur frequently. The toxins they produce can accumulate in shellfish, triggering product safety crises and causing significant economic losses for farmers. The outbreak of biological disasters has amplified industry risks. For instance, Jiaozhou Bay has experienced multiple large-scale outbreaks of the starfish Asterias amurensis in recent years. As voracious predators of shellfish, the proliferation of starfish has dealt devastating blows to bottom-cultured species like clams and oysters, exposing the weakness of biological control capabilities under ecosystem imbalance.

4.2 Intensifying Market Competition

At the market level, Qingdao's shellfish industry faces increasingly fierce competitive pressure. Domestically, as shellfish farming techniques advance and scale expands in regions like the Bohai Rim and Southeast Coast, product homogenization intensifies competition. Areas such as Fujian and Liaoning have developed strong competitive advantages in oysters and scallops, while some regions hold comparative advantages in cost control or logistics efficiency. This continuously erodes Qingdao's traditional market share, driving price competition to fever pitch. The international market presents even more complex challenges. On one hand, Qingdao faces competition from high-quality shellfish products from neighboring countries like South Korea and Japan. On the other hand, export markets demand increasingly stringent requirements for seafood quality and safety, traceability, certification standards (such as ASC and BAP), and sustainability metrics. Green trade barriers and technical trade measures have emerged as new challenges, requiring the industry to comprehensively enhance its quality, safety, and environmental standards to maintain and strengthen its international competitiveness.

4.3 Industry Development Bottlenecks

Structural issues within the industry also constrain its high-quality development. The primary bottleneck is an incomplete industrial chain with weak coordination. Current industry strengths are concentrated in aquaculture production, while critical upstream and downstream segments lag behind. The upstream seed industry system

remains underdeveloped, with certain species (e.g., clams) overly reliant on externally sourced seedlings. Downstream, deep processing capabilities are weak, resulting in most products being sold in primary fresh forms. Low processing rates mean technological added value is underutilized. Concurrently, supporting service systems—including cold chain logistics, brand marketing, and modern supply chain management — are insufficiently developed, limiting the industry's overall risk resilience and value capture capacity.

Low product value-added serves as a concrete manifestation of these industrial chain shortcomings. Most shellfish products enter the market in raw or minimally processed forms, exhibiting weak brand premium potential and facing severe profit compression in distribution channels. Despite possessing regional brands like "Hongdao Clams," their brand value has yet to be translated into significant market premiums through systematic quality grading, standardized packaging, and narrative-driven marketing. Implementing a quality-based branding strategy to transition products from being sold by weight to being valued for quality and brand recognition has become an urgent priority for enhancing the industry's economic efficiency.

4.4 Recommendations for the Shellfish Industry Development in Qingdao

To effectively address the aforementioned challenges and propel Qingdao's shellfish industry from scale expansion toward a high-quality development phase that prioritizes both quality and efficiency alongside ecological harmony, this study proposes a systematic and actionable strategic framework encompassing three core dimensions: ecological conservation, industrial upgrading, and market expansion.

4.5 Implement Precision Management Based on Ecological Carrying Capacity

Ensuring ecological sustainability is fundamental to industrial development. The principle of "determining scale by capacity" must be established and strictly enforced to achieve dynamic equilibrium between aquaculture activities and marine ecosystems. Immediately conduct comprehensive precision assessments of aquaculture capacity in major bays such as Jiaozhou Bay and Aoshan Bay, comprehensively considering hydrodynamics, sedimentation, nutrient cycling, and biological carrying capacity. Based on assessment results, scientifically delineate no-farming zones, restricted-farming zones, and permitted-farming zones. Establish differentiated aquaculture capacity indicators by species and region to eliminate overcapacity farming at its source. Construct a real-time online environmental monitoring network covering key aquaculture areas, enabling routine monitoring of water quality (dissolved oxygen, pH, nutrients, harmful algal blooms, etc.), sediments, and aquaculture organism health indicators. Leverage big data and IoT technologies to enable early environmental risk warnings and trend analysis. Establish a robust multi-departmental marine disaster early warning and emergency response mechanism to enhance prediction accuracy and warning dissemination efficiency for typhoons, storm surges, and red tides. Concurrently, intensify research into the ecological mechanisms of harmful species outbreaks (e.g., starfish) and develop biological control technologies, forming an integrated "monitoring-warning-control" solution to systematically reduce losses from natural and biological disasters.

4.6 Promoting Modernization Across the Entire Industry Chain and Value Chain Enhancement

The future competitiveness of the industry hinges on its modernization level and value creation capabilities. Comprehensive upgrades toward greener, facility-based, and standardized operations must be pursued. Place germplasm resource conservation and innovation at the strategic core. Establish living gene banks and protected areas for superior native germplasm (e.g., indigenous clam populations, distinctive oyster strains). Intensify breeding efforts for stress-tolerant, high-yielding, and premium new varieties (e.g., triploid oysters, highly disease-resistant scallops), promoting modern biotechnologies like molecular marker-assisted breeding to achieve industrial and commercial scale in elite strain development. Encourage environmentally friendly facility farming models such as deep-water wave-resistant cages, ecological raft-based suspended culture, and multi-trophic level integrated aquaculture. Develop and promote standardized production protocols covering the entire process from "seedling-feed-environmental control-disease prevention-harvest," enhancing farming efficiency and product consistency. Develop and deploy rapid on-site detection technologies for pollutants (heavy metals, microorganisms,

algal toxins) in shellfish. Establish a disease surveillance and early warning network covering major production areas and species. Utilize blockchain and other technologies to build a comprehensive quality and safety traceability system from farm to table, earning market trust through exceptional quality and safety standards.

4.7 Optimize Product Structure and Strengthen Brand Marketing

Breaking free from the constraints of primary product competition hinges on enhancing product value-added and brand influence to achieve value-driven growth. Deepen processing and optimize product structure: Vigorously support R&D and industrialization of advanced shellfish processing technologies, prioritizing high-value-added directions such as ready-to-eat products, condiments, and extraction of functional bioactive compounds (e.g., glycogen, peptides, taurine). Guide farmers to moderately reduce the scale of highly homogenized species based on market demand, increasing the cultivation proportion of high-value and functional species like abalone, giant clams, and specialty squid to achieve diversified and premium product structures. Implement brand-building and market diversification strategies: Systematically elevate core regional public brands like “Hongdao Clam,” establishing rigorous brand usage standards and quality grading systems. Continuously host high-caliber seafood festivals, participate in premier domestic and international food expos, and leverage new media marketing to effectively communicate Qingdao shellfish's “ecological story” and “quality narrative.” Actively expand into domestic premium fresh markets, restaurant supply chains, and international high-standard export markets to reduce over-reliance on traditional wholesale channels. This will enhance brand premium pricing power and market resilience.

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