

Original Research Articles

Analysis on Economic Benefits of Chinese Abalone Industry — An Example From H Village, Lianjiang County, Fujian Province

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China is the world's leading producer of abalone, a valuable fisheries resource with significant economic, social, and ecological benefits. This study examines the economic performance of abalone aquaculture in H Village, Lianjiang County, Fujian Province—a pivotal region in the industry. Using survey data and cost-benefit analysis, the study reveals that while abalone farming in the region generates a cost-profit margin of 15.79%, it faces challenges such as rising feed costs, genetic degradation, and limited product differentiation. Sensitivity analysis highlights the industry's reliance on pricing and feed costs, with strategies for improvement including the development of advanced artificial baits, high-quality abalone varieties, optimized fiscal policies, and enhanced branding and deep processing. Findings underscore the critical need for innovation in production and marketing to sustain profitability amidst environmental and market challenges. This research contributes to understanding the dynamics of China's abalone aquaculture sector and proposes actionable strategies to enhance its sustainability and economic resilience.

1. INTRODUCTION

Aquatic products are a vital source of animal protein and play an integral role in global food security.¹ In recent years, China's marine aquaculture industry has experienced rapid development, driven by rising incomes and advancements in breeding technologies, which have fueled growing consumer demand for seafood.² Among marine products, shellfish stand out for their rich nutritional profile, including high levels of protein, vitamins, and micronutrients, making them an essential component of the sector's social and economic contributions.³

Abalone, a particularly valuable shellfish, is highly regarded for its tender, fresh, and non-greasy meat, as well as its substantial nutritional content, including protein and diverse amino acids. The strong market demand for abalone, coupled with technological advancements in aquaculture, has positioned China as the world's leading abalone producer, with annual production increasing year by year and currently exceeding 200,000 tons, accounting for over 85% of global abalone production.

As a cornerstone of China's marine aquaculture industry, abalone farming stimulates related industries such as breeding, equipment manufacturing, seaweed farming, feed production, processing, distribution, and prepared foods. It generates substantial economic, social, and ecological benefits while transforming abalone from a luxury item to an affordable product for the general population. Since its emergence in the 1980s, industry has evolved from being a magnet for capital investment to a mature sector characterized by both capital inflows and outflows. Government policies have shifted from promotion to regulation and optimization.⁴ Today, abalone aquaculture is a livelihood industry that addresses basic dietary and economic needs.

Extensive research on China's shellfish industry has explored its development at both national and provincial levels.⁵ Much of the domestic research on abalone farming focuses on technical aspects, including breeding technologies and aquaculture efficiency. Studies by Yang⁶ analyzed production trends, noting fluctuations in abalone yields and efficiency in China's marine shellfish sector, emphasizing the need for enhanced technical approaches. Other

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research has addressed broader economic and structural challenges, such as product homogeneity, low technological adoption, and supply chain inefficiencies.⁷ Recent studies, including those by Li et al.⁸ and Huang et al.,⁹ advocate for supply-side reforms and resource optimization to enhance the industry's resilience.

International research on mollusks aquaculture often focuses on sustainability and environmental impact. Rey-Valette et al.¹⁰ explored sustainability priorities among pearl oyster farmers in French Polynesia. Through surveys of pearl oyster farmers and other stakeholders in the industry, the degree of convergence in pearl oyster farming was assessed, providing references for the sustainable development of pearl oysters. Castagno¹¹ studied the ecological relationship between salt marsh restoration and shellfish industries in Massachusetts, USA, highlighting the mutual benefits of sustainable aquaculture and environmental restoration. Studies by Hamouda et al.¹² highlighted the importance of integrating aquaculture production processes with economic, social, and environmental factors for the development of the industry.

Despite these contributions, most research on abalone farming has prioritized technical aspects, with limited attention to economic factors such as cost structures and profit margins. Additionally, the industry faces significant challenges, including declining ecosystem quality, limited aquaculture space, and outdated processing technologies.¹³ Recent environmental risks and market price fluctuations have exacerbated inefficiencies, resulting in low resource utilization rates and a mismatch between production capacity and efficiency.

This study addresses these gaps by investigating the economic benefits of abalone farming in H Village, Lianjiang County, Fujian Province. Through structured interviews and surveys, it examines the current state of abalone farming, identifies key challenges, and proposes strategies to improve the industry's quality and efficiency. The findings aim to contribute to the sustainable development of China's abalone industry.

2. MATERIAL AND METHOD

2.1. STUDY AREA

H Village, located in Lianjiang County, Fuzhou City, Fujian Province, is a key hub for abalone production. It was selected for study as it represents a typical village in major abalone-producing regions. Situated at the northeastern tip of the Huangqi Peninsula, the village is surrounded by the sea on three sides, controlling a crucial passage in the north-south channel. Its subtropical climate, characterized by warm temperatures, ample sunshine, moderate rainfall, and the absence of harsh winters, creates an ideal environment for abalone aquaculture. With a longstanding history in the fishery sector, particularly in abalone farming, the village boasts a well-developed industrial chain.

H Village spans 0.74 square kilometers, housing 1,865 households with a total population of 6,995. It owns 155 fishing boats, and its primary industries include marine

fishing, aquaculture, and transportation, supported by facilities for refrigeration, ice-making, and other related services. Recognized as a significant fishing village in Fujian Province, abalone farming is its pillar industry, engaging 60–70% of the local workforce. The farming area covers 460 hectares, with operations led by two primary groups: individual breeders and farms. Individual breeders, constituting approximately 80% of the entities, operate farms under 2.67 hectares with annual outputs below 50 tons. In contrast, enterprise breeders, comprising about 20% of the entities, manage larger farms exceeding 4 hectares, producing over 150 tons annually.

2.2. DATA COLLECTION

Given the feasibility of data collection and the representativeness of the cases, the research team conducted fieldwork in August 2023. To ensure that the data accurately reflects the economic benefits of abalone farming, this study designed a structured questionnaire based on a cost-benefit analysis framework, focusing on collecting core economic indicators such as fixed costs (such as facility and equipment depreciation), variable costs (such as seedlings, feed, labor, etc.), and income. During this period, the research team used purposive sampling to select 11 representative abalone farming entities that covered different farming scales, main farming models, and regions. Through face-to-face semi-structured interviews, the research team collected detailed cost-benefit data from these entities, laying the foundation for a deeper analysis of the economic benefits of the abalone industry. This method ensured that the research could comprehensively and representatively reflect the industry's economic performance.

2.3. METHOD

2.3.1. COST-BENEFIT ANALYSIS

To examine the cost-benefit situation of the abalone industry, referring to the research by Gao et al.,¹⁴ the study further employs the cost-profit margin and marginal contribution rate as two indicators for calculation and analysis.

Cost profit ratio refers to the ratio of profits obtained by the operating entity to the cost and expenses. This indicator can reflect the profit level of livestock breeders in a certain period. The higher the indicator, the better the efficiency of the livestock breeders. The calculation formula is as follows:

$$BCR = TP/TC \quad (1)$$

In Equation (1), BCR is the cost profit margin, TP is the profit, and TC is the total cost.

The marginal contribution rate is the ratio of the difference between the product's selling price and its variable cost to the selling price. This indicator reflects the profitability of the breeder during a certain period. The calculation formula is as follows:

$$CMR = (P - V)/P \quad (2)$$

In Equation (2), CMR stands for the marginal contribution rate, P is the unit price, and V is the variable cost per unit.

2.3.2. SENSITIVITY ANALYSIS

To analyze the sensitivity of uncertainty factors—specifically cost and price factors—we focus on the cost-profit margin for abalone. This indicator represents the ratio of the percentage change in each uncertainty factor to the corresponding percentage change in the cost-profit margin, while holding all other factors constant. It effectively quantifies the sensitivity of the cost-profit margin to variations in these factors. A higher absolute value of the sensitivity coefficient indicates a greater fluctuation in the cost-profit margin in response to changes in the corresponding factor. Additionally, the sign of the coefficient (positive or negative) reveals the direction of the change. The formula for calculating sensitivity is as follows:

$$\alpha = (\Delta NP / NP) / \Delta X / X \quad (3)$$

Where α is sensitivity coefficient, $\Delta X / X$ is the ratio of changing influence factors, $\Delta NP / NP$ represents that change in net profit due to change in uncertainty parameter.

3. RESULTS

3.1. OVERVIEW OF CHINA'S ABALONE INDUSTRY

Since 2003, China's abalone production has demonstrated a significant and sustained upward trend, cementing the country's leading position in the global market. According to FAO FishstatJ, China's abalone production surpassed 50% of the global total for the first time in 2007, marking a milestone in its growing prominence within the international abalone industry. This growth trajectory has continued, with China's share of global abalone production reaching 87.19% by 2022. The share of global abalone production from China has grown by 129.67% compared to 2003. This exceptional growth highlights substantial advancements in abalone farming techniques and production efficiency in China, alongside increasing demand for Chinese abalone in both domestic and international markets¹⁴ (Figure 1).

Analysis of historical production data from the world's four major abalone-producing countries reveals divergent industry development patterns since 2002. China and South Korea have achieved remarkable growth through aquaculture-centered models, with China's production increasing from 9,810 tons to 228,200 tons (2003-2022) at an annual growth rate of 17.04%, while South Korea demonstrated a 138-fold increase from 160 tons to 22,200 tons (2002-2022). Both countries' advanced aquaculture systems have enabled rapid industry expansion and diversified development (Figure 2).

In contrast, Japan and Australia remain predominantly dependent on wild resource harvesting, with production constrained by natural resource availability and environmental factors such as kelp forest conditions and sea temperature variations¹⁵ in Japan, and strict quota management systems in Australia.¹⁶ While this harvest-dependent approach maintains market scarcity and brand premium for high-quality abalones, it inherently limits scalability potential, resulting in substantially lower production growth

compared to the intensive aquaculture models of China and South Korea.

From 2003 to 2023, China's abalone aquaculture production exhibited consistent growth, with an average annual growth rate of 17.04%. In 2023, national abalone production reached 245,000 tons, representing a 7.36% increase from 228,100 tons in 2022. The fluctuations in production growth since 2004 can be categorized into three distinct stages (Figure 3).

The first stage, from 2005 to 2011, was characterized by rapid expansion. Significant capital investment and the adoption of advanced aquaculture technologies during this period drove an annual growth rate exceeding 17%, with a peak of 35.38% in 2011. Abalone production increased from 17,700 tons in 2005 to 76,800 tons, achieving an average annual growth rate of 27.71%.

The second stage, from 2012 to 2019, marked a period of stable development. Building on the rapid growth of the previous stage, the abalone industry transitioned toward standardization, with production continuing to rise. However, growth rates fluctuated, averaging 10.31% annually, as production increased from 90,700 tons in 2012 to over 180,000 tons by 2019.

The third stage, from 2020 to the present, represents an adjustment phase. During this period, abalone production maintained positive growth, surpassing 200,000 tons in 2020 and consistently exceeding this level in subsequent years. This stability indicates that the industry's production capacity has reached a new plateau. However, the annual growth rate has gradually declined, likely influenced by the COVID-19 pandemic.

In addition to production growth, the total area dedicated to abalone aquaculture in China expanded steadily from 2003 to 2023, with an average annual growth rate of 8.92%. Since 2011, however, this growth rate has fluctuated, reflecting periods of expansion and contraction in the aquaculture area. In 2023, China's abalone aquaculture area reached 22.7 thousand hectares, marking an increase of 0.56 thousand hectares, or 32.82%, from the previous year.

China's abalone industry has demonstrated remarkable efficiency in yield per unit area.¹⁴ Over the past 20 years, with few exceptions, abalone production per unit area has generally increased, often recovering quickly from brief fluctuations. As shown in Figure 4, yield per unit area experienced notable volatility before 2010, initially rising and then declining. However, since 2011, breeding efficiency has improved significantly, resulting in sustained medium-to-high growth. By 2021, the unit yield reached a peak of 14.35 tons per hectare. Although the 2022 yield may have declined due to the pandemic's impact, it still reflects a 321.71% increase compared to 2003. Over the past two decades, the average annual growth rate has been 7.46%.

Abalone farming in China is primarily concentrated in Liaoning, Fujian, Shandong, Guangdong, and Zhejiang provinces, with Fujian and Shandong alone accounting for nearly 96% of total production. According to the China Fisheries Statistical Yearbook and the Annual Report of Fisheries Statistics in Lianjiang County, Fujian Province

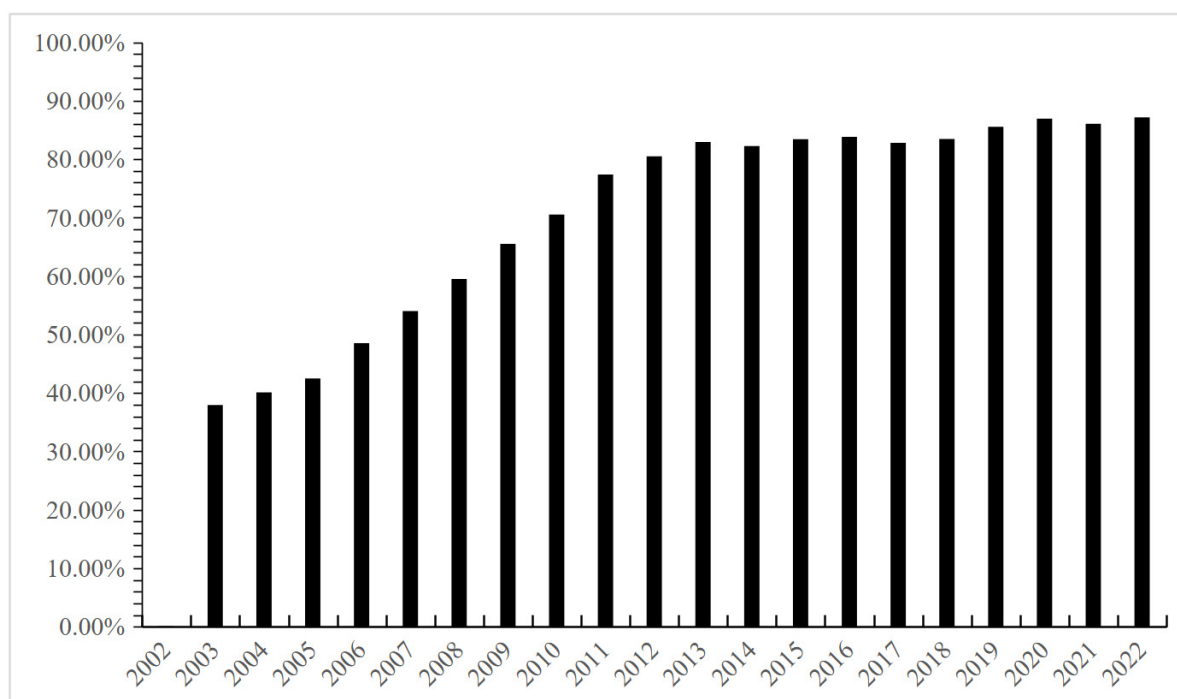


Figure 1. China's abalone production share, 2002-2022

Data: Fishstat]

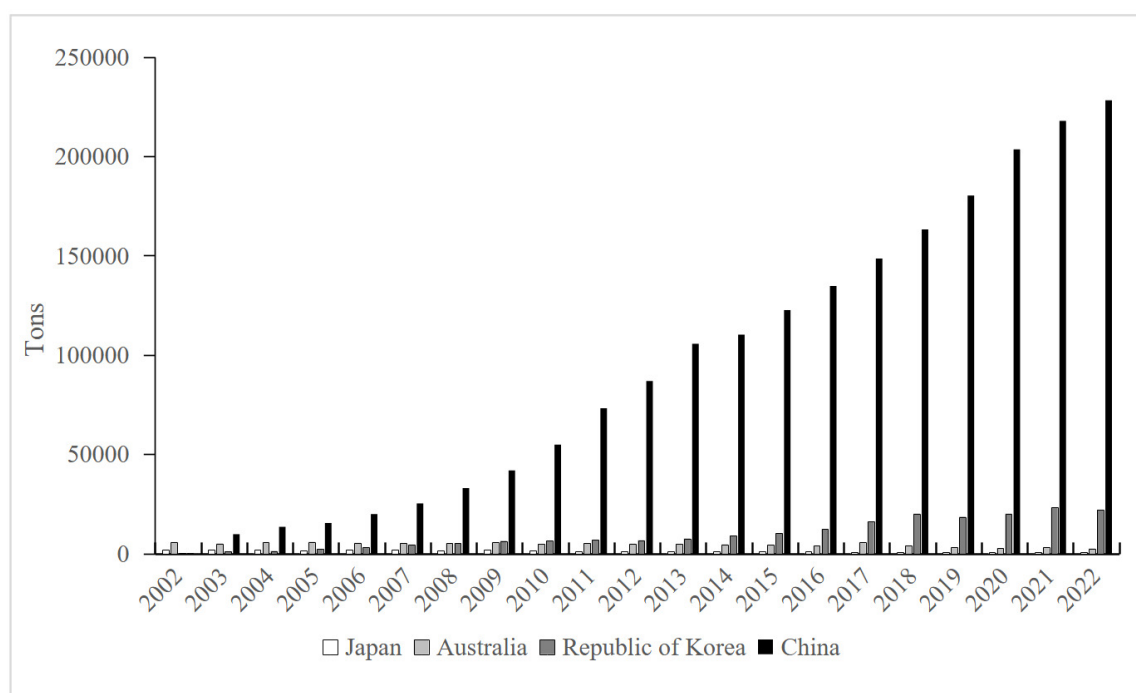


Figure 2. 2002–2022 Major Producing Countries' Abalone Production

Data: Fishstat]

consistently ranks first in both abalone aquaculture area and production. Between 2018 and 2023, although Fujian and Shandong had comparable aquaculture areas, Fujian's abundant resources and favorable climate resulted in significantly higher production. In 2023, Fujian's abalone aquaculture area reached 0.70 million hectares, comprising

30.92% of the nation's total aquaculture area, while Shandong accounted for 0.68 million hectares, or 30.07%. In the same year, Fujian produced 195,900 tons of abalone, representing 79.95% of the national total, while Shandong contributed 38,800 tons, or 15.84% (Figures 5 and 6).

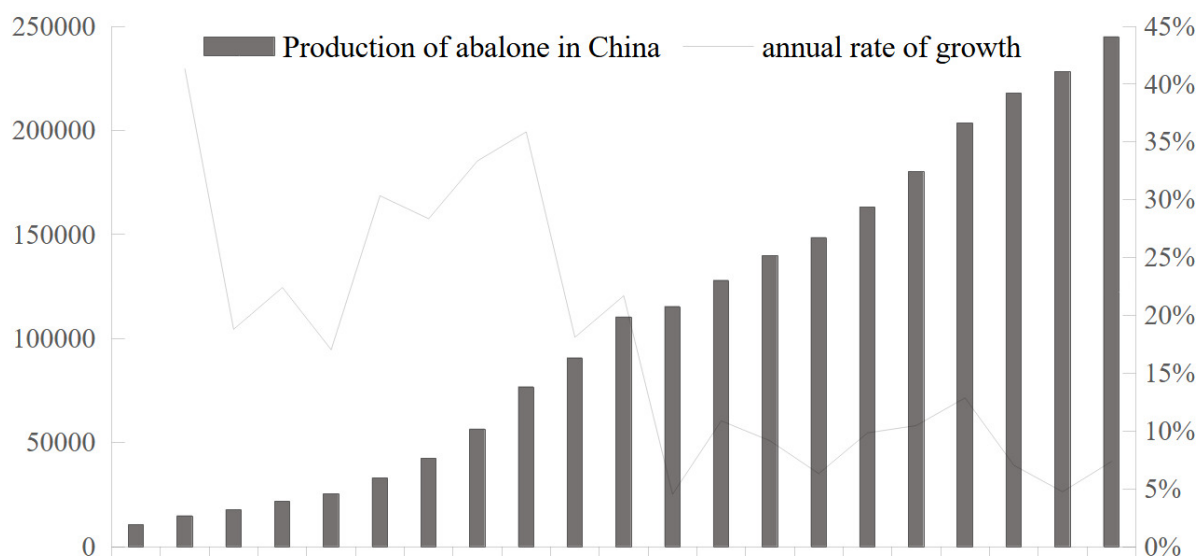


Figure 3. 2003-2023 Production and annual growth rate of abalone culture in China

Data: China Fisheries Statistical Yearbook

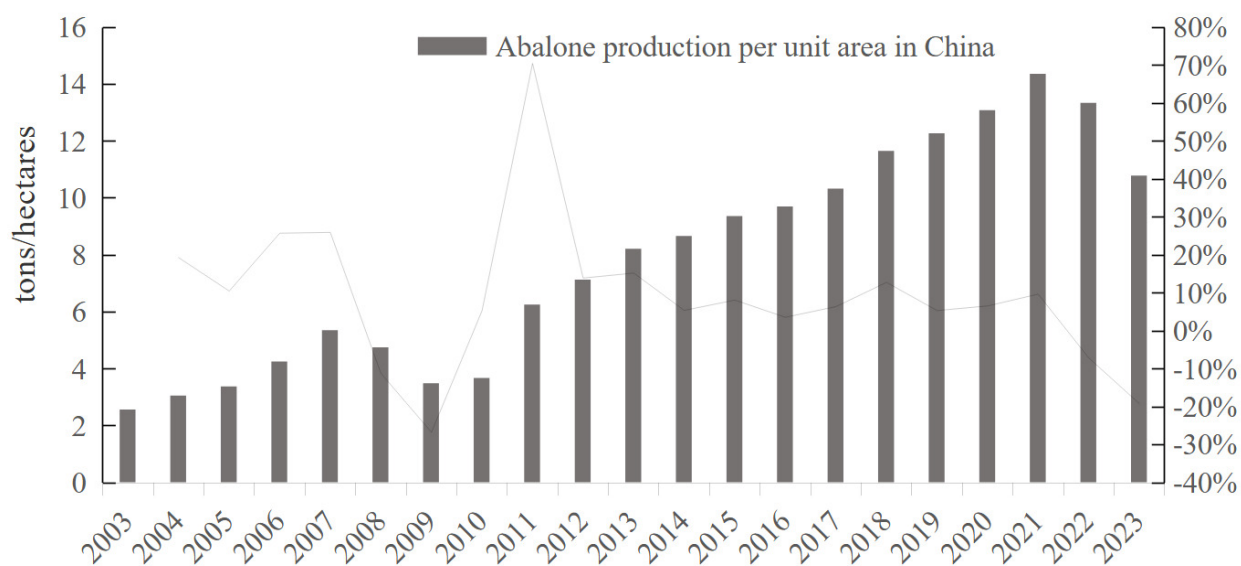


Figure 4. Production and growth rate of abalone per unit area in China

Data: China Fisheries Statistical Yearbook

At the county level, Lianjiang County stands out as China's leading abalone producer. In 2022, Lianjiang produced 54,200 tons of abalone, accounting for approximately 24% of the national output. The county's aquaculture area spans 1,500 hectares, consistently ranking it first among all counties in China. Over the years, Lianjiang has developed a comprehensive industrial chain centered around abalone, encompassing seedling cultivation, breeding, processing,

sales, branding, and dining. This integrated industry generates an output value nearing \$143 million and employs over ten thousand people. Lianjiang's focus on high-quality seedling cultivation, farm upgrades, advanced processing techniques, expanded sales channels, and regional brand development aligns with its ambition to establish itself as "China's Abalone Capital".

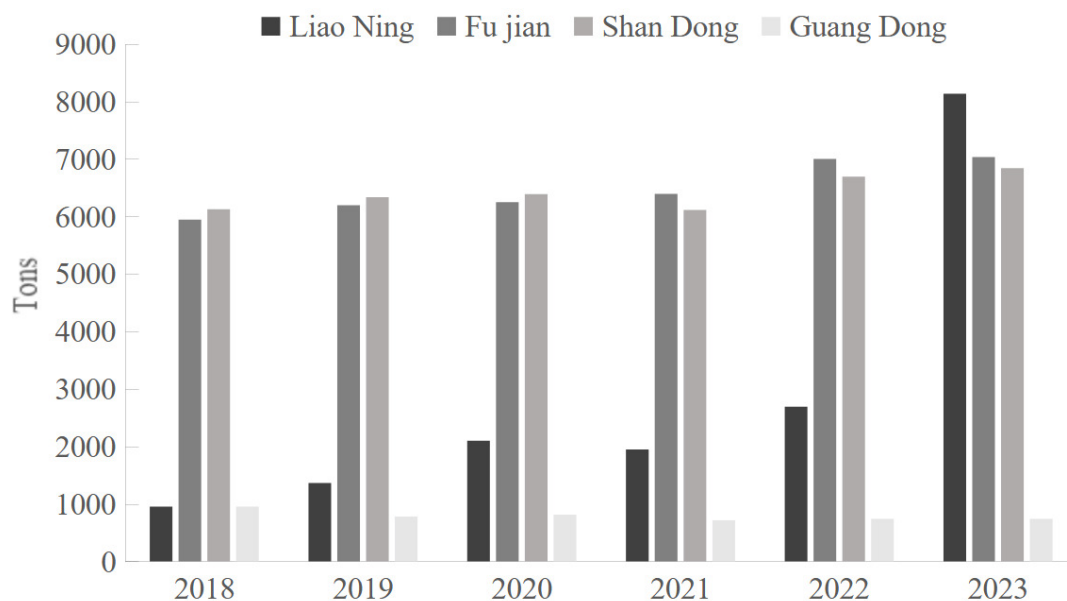


Figure 5. Main provinces of abalone aquaculture in China: area

Data: China Fisheries Statistical Yearbook

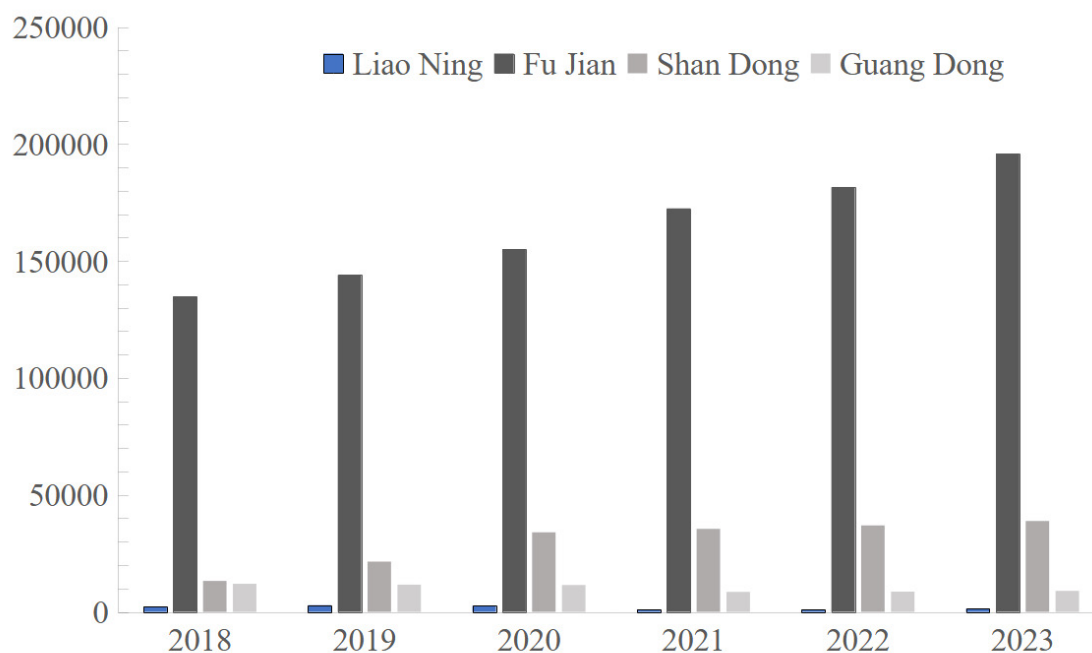


Figure 6. Main provinces of abalone aquaculture in China: production

Data: China Fisheries Statistical Yearbook

3.2. ECONOMIC BENEFIT ANALYSIS

3.2.1. COST-BENEFIT ANALYSIS

Abalone aquaculture is a capital-intensive industry, with total costs primarily comprising expenditures on seedlings,

labor, facilities, vessels, machinery, feed, and other fixed assets. The proportion of each cost component varies based on the scale of operations and the fixed assets of individual farmers. However, the total cost per farming entity typically exceeds 1 million yuan, with a unit cost of 76 yuan per kilogram of abalone produced.

Table 1. Cost structure and pond price of abalone culture

cost-benefit indicator	Amount (Yuan/kg)	Proportion of total cost (%)
seed expenditure	15.54	20.45%
feed expenditure	35.12	46.21%
labor expenditure	14.39	18.94%
Total fixed costs	10.94	14.40%
unit variable cost	65.06	85.60%
unit fixed costs	10.94	14.40%
total unit cost	76.00	100%
out-of-pond price	88.00	-

Table 2. Abalone Indicator Data

Indicators (symbols, units)	Research/Calculation Results
Unit selling price (P, yuan/kg)	88
Total unit cost (TC, yuan/kg)	76
Unit variable cost (TC, yuan/kg)	65.06
Cost-Profit Ratio (BCR, %)	15.79
Net profit margin on sales (%)	13.64%
Marginal Contribution Rate (CMR, %)	26.07

An analysis of the cost structure reveals that feed expenses are the most significant component, accounting for 46.21% of the total cost. Seedlings follow, contributing 20.45%, while labor costs constitute 18.94%. The least significant contributors are the depreciation of fixed assets and other fixed costs, which together account for 14.40% of the total (Table 1).

Using data from the survey—specifically the pond price of 88 yuan/kg, a total unit cost of 76 yuan/kg, and a unit variable cost of 65.06 yuan/kg—relevant indicators were calculated based on formulas (1) and (2) (Table 2). In terms of profitability, the unit profit for abalone aquaculture is 12 yuan/kg, with a cost-profit rate of 15.79%.

As shown in Table 3, the cost-profit margin and sales-profit margin (net profit/sales price) for abalone farming in H Village are comparatively lower than those of other aquatic species and historical benchmarks. This indicates significant room for improvement. The calculated marginal contribution rate for abalone is 26.07%, highlighting notable profitability potential relative to variable costs and strong industrial resilience. Specifically, assuming fixed costs remain constant, profitability would decline if unit variable costs increase by less than 26.07%; however, abalone farming would still remain profitable.

Table 3. Comparison of Profitability of Different Aquatic Product Cultivations

Aquaculture species	Cost Profit Ratio	Cost Profit Ratio
Abalone Culture in H Village, Lianjiang County	15.79%	13.64%
Factory Culture of <i>Penaeus vannamei</i> in Shandong Province	26.23%	20.28%
Large-scale culture of crab in Xinghua City	66%	37%
Culture of <i>Penaeus vannamei</i> in China	36.00%	25.00%
Turbot culture in 2010	31.14%	23.75%
2013-2018 Fish culture in high price range in China	21.45%	17.56%
2013-2019 Fish culture in low price range in China	25.63%	20.26%
pond culture of flounder	162.91%	61.96%
Pond-factory relay culture of flounder	19.24%	16.14%

3.2.2. SENSITIVITY ANALYSIS

Since fixed costs represent only 14.40% of total costs, a relatively small proportion with minimal impact on overall costs and the cost-profit margin, this study focuses on the sensitivity coefficients of variable costs and price factors (Table 4). As shown in Table 4, the cost-profit margin is most sensitive to changes in price and bait costs. Specifically, a 1% increase in price leads to a 7.33% increase in the cost-profit margin, while a 1% increase in bait cost resulted in a 3.41% decrease in the cost-profit margin.

The sensitivity coefficients for seed cost and labor cost are both within -2%, indicating that the cost-profit margin is comparatively less sensitive to these factors. A 1% increase in seed cost causes a 1.50% decrease in the cost-profit margin, whereas a 1% increase in labor cost leads to a 1.39% decrease. These findings highlight the greater influence of price and feed costs on profitability compared to other variable cost components.

4. DISCUSSION

4.1. ABALONE INDUSTRY TECHNOLOGIES AND MODELS

This study highlights that innovations in aquaculture technology and production process optimization have enabled China's abalone industry to achieve higher profit margins and expand its industrial scope. However, challenges such as rising aquaculture costs and product homogenization require urgent solutions.¹⁷ Technological advancements in aquaculture have demonstrated significant ecological and economic benefits. For example, Nobre et al.¹⁸'s study on the ecological and economic assessment of abalone multi-nutrient synthesis found that integrated multi-trophic aquaculture (IMTA) offers notable ecological and socio-economic advantages compared to single-species aquaculture.

Table 4. Sensitivity coefficient of cost profit margin

Indicators/Change Amplitude	-20%	-10%	10%	20%	Average Sensitivity Coefficient
Seedling	-1.56	-1.53	-1.47	-1.44	-1.50
feed	-3.73	-3.55	-3.24	-3.10	-3.41
Artificial	-1.44	-1.42	-1.36	-1.34	-1.39
Price	7.33	7.33	7.33	7.33	7.33

This aligns with this study's proposal to combine traditional seaweed-based feeds with nutritionally balanced artificial feed, addressing the issue of natural bait shortages, which, if left unresolved, could further increase production costs.¹⁸

Seedling quality remains a critical factor for the abalone industry. Wu and Zhang¹⁹'s research on abalone aquaculture in the Pacific Ocean identified seedling issues as a core challenge. Variations in the survival rates of dominant seedlings across aquaculture regions contribute to regional disparities in industrial development. Moreover, the degradation of germplasm resources has resulted in slower growth, lower survival rates, reduced resistance, and increased disease risks, all of which elevate aquaculture costs and decrease economic efficiency.¹⁹

Value chain dynamics and market structures also play a pivotal role in industry development.²⁰ in their study on the value chain structure of China's imported shellfish industry highlighted that business partnerships are the primary channels for accessing market information. However, traditional sales models focused on fresh abalone often lead to quality disparities due to insufficient processing technology and incomplete value chains. These findings align with this study's emphasis on improving product quality, advancing the deep-processing industry, enhancing branding efforts, and optimizing supply chain relationships to foster industrial growth.

Innovations in aquaculture models are another key driver of competitiveness.²¹ This study found that the large-scale implementation of the "southern abalone farming in the north" model has significantly enhanced economic benefits. By relocating abalone to northern culture areas during summer to avoid heat stress, this model accelerates growth, mitigates the impact of typhoons and red tides, stabilizes supply and prices across northern and southern markets, and strengthens the industry's competitive edge. Additionally, upgraded aquaculture facilities improve disaster resilience and economic efficiency.

Insights from international studies provide further context. Arita and Leung²²'s research on the technical efficiency (TE) of aquaculture farms in Hawaii revealed that many farms could enhance TE through facility modernization. This complements the findings of this study, which underscore the importance of modernizing traditional aquaculture facilities to promote scalability and economic gains in abalone farming. Kang et al.²³'s study on shallow-water abalone aquaculture in South Korea examined the influence of environmental factors such as particle size composition, organic matter and heavy metal content on aquaculture. While Kang (2015)'s research focuses on en-

vironmental influences, this study evaluates the economic efficiency of the Chinese abalone industry and addresses quality improvement challenges.

International perspectives further enrich the analysis. Gutiérrez et al.²⁴'s study on aquaculture production efficiency in the EU found that countries specializing in both freshwater and marine aquaculture lead in industrial development. While their research examines the combined efficiency of aquaculture and capture fisheries, this study focuses specifically on enhancing the economic efficiency of China's abalone industry.

In conclusion, while China's abalone industry has benefited from innovations in breeding technology and production models, challenges such as rising costs, seedling quality issues, and market inefficiencies remain pressing. Addressing these challenges through technological integration, value chain enhancement, and facility modernization will be essential for ensuring sustainable growth and long-term competitiveness.

4.2. DISCUSSION ON THE STUDY OF THE ECONOMIC BENEFITS OF THE INDUSTRY

This study examines the economic benefits of abalone aquaculture through an analysis of the industry in H Village, Lianjiang County. The findings provide insights into current economic conditions, identify key challenges, and explore future development potential. By focusing on economic benefits, this research enhances understanding of industrial development trends, highlights areas for improvement, and supports sustainable growth.

Sensitivity analysis plays a critical role in understanding economic dynamics. For example, Al-Masroori and Bose²⁵ use an improved ecological sustainability (ESD) framework to conduct a sensitivity analysis on the sustainability of fisheries development in Oman, and based on the comparative analysis results, guide fisheries managers in designing appropriate strategies to promote the sustainable development of local lobster, abalone, and shrimp industries, with similarities to the sensitivity analysis of the abalone industry in this article. Similarly, Johannesson and Jönsson²⁶ compared traditional cost-benefit methods with those incorporating contingent valuation, emphasizing the importance of liquidity in economic efficiency. In the context of abalone aquaculture, liquidity challenges arise from mandatory cash transactions for bait and credit-based purchasing, disrupting financial chains. The comparative analysis methods applied in this study, such as profitability comparisons and sensitivity coefficients, provide a robust framework for evaluating economic performance.

Comprehensive efficiency assessments require multidimensional approaches. Shephard²⁷ highlighted the relevance of factors such as benefit transfers, marginal costs, and supply chain ownership in evaluating economic efficiency. Similarly, Pagotto and Halog²⁸ assessed eco-efficiency in Australia's agri-food sectors using advanced techniques like data envelopment and material flow analysis, suggesting opportunities to refine abalone aquaculture evaluations by developing more comprehensive indices and economic indicators and conducting comprehensive data analysis. Zhong et al.²⁹ found through evaluating the ecological and economic efficiency of freshwater aquaculture that although the ecological efficiency of freshwater aquaculture in China is on the rise, it is still at a relatively low level, and there is a consistency between the level of ecological efficiency and the growth trend of economic benefits, which has brought some inspiration to the ecological protection of bivalve aquaculture waters and the growth of economic benefits. Following this approach, this study uses survey data and cost-benefit analyses of key farming regions to assess the economic benefits of abalone aquaculture. The analysis identifies critical issues in the abalone industry, including rising production costs, stable demand, and declining prices. The profit margin for local abalone production, approximately 16%, is relatively low compared to other aquatic products. Strategies to improve profitability include reducing feed costs and increasing selling prices. Using H Village as a case study, this research evaluates the strengths and weaknesses of China's abalone industry, addresses gaps in economic benefit analysis, and provides actionable insights for sustainable development.

4.3. DISCUSSION ON SUSTAINABLE AND DIVERSIFIED DEVELOPMENT OF ABALONE INDUSTRY

Looking toward the future, the upgrading of the abalone industry requires parallel advancement in sustainable farming practices and the integration of diverse sectors. As farming scales continued to expand, water body eutrophication issues became increasingly prominent, with frequent outbreaks of diseases, nutritional imbalances, and hypoxic conditions posing significant challenges to the industry, which was consistent with the findings of this study. Morash et al.³⁰ emphasized that substantial resource investment was needed to enhance the resilience of abalone farming systems and to establish efficient water recycling facilities, which might have necessitated moderate adjustments in short-term growth rates to ensure long-term sustainability. Nobre et al.¹⁸ analyzed the synergies between economic and ecological benefits and confirmed that the application of integrated multi-trophic aquaculture (IMTA) could effectively reduce nitrogen and carbon emissions while significantly increasing farming net profits. This suggested that promoting the transformation of abalone farming toward diversification not only brought significant social benefits, such as improving public water environments, but also aligned with the economic interests of farming practitioners.

Gao et al.,¹⁴ in their study on the transformation of China's abalone farming industry, pointed out that the

'land-sea coordinated' plan, based on the 'carbon neutrality' concept, could effectively mitigate the natural disaster risks and high mortality rates caused by high-density farming through the enhancement of farming mechanization and intelligence. This research approach, which assessed industry issues from the market perspective and proposed corresponding solutions, was similar to the approach adopted in this study. As one of the important economic species in marine farming, abalone products, with their excellent meat quality and rich nutritional value, were highly favored in both food and pharmaceutical markets. Suleria et al.³¹ indicated in their research that abalones were rich in various bioactive compounds with antioxidant, anti-thrombotic, and anti-cancer properties, demonstrating significant therapeutic potential as a source of bioactive molecules. These unique nutritional characteristics and substantial economic benefits collectively provided broad opportunities for further upgrading and value addition in the abalone industry.

CONCLUSION AND SUGGESTIONS

At the macro level, the abalone industry serves as a vital pillar of China's mariculture and broader fishery sectors. It plays a strategic role in advancing national initiatives, such as constructing a "blue grain silo," promoting a healthy China, and ensuring a stable supply of high-quality aquatic products. At the micro level, the industry is integral to local economies, particularly in areas like H Village in Lianjiang County, where it drives wealth creation and rural revitalization. However, alongside its economic contributions, the industry faces challenges such as rising production costs, seedling quality issues, and limited value chain integration. Addressing these challenges is critical to sustaining the industry's growth and competitiveness.

This study proposes four strategies to enhance the quality and efficiency of abalone farming while promoting its sustainable development. These include: advancing R&D and the application of artificial baits to address supply and cost issues; accelerating the selection, breeding, and popularization of high-quality abalone varieties; optimizing fiscal, tax, and financial support policies to alleviate funding constraints; and promoting deep processing and branding to improve product differentiation and market competitiveness. By implementing these strategies, the industry can strengthen its resilience and align with broader economic and environmental goals.

This research, grounded in survey data from representative abalone farming counties and employing cost-benefit analysis, provides a detailed evaluation of the industry's economic efficiency. Its innovative contribution lies in the use of micro-level data and comparisons with the profitability of other aquaculture species, such as marine fish and shrimp. The findings highlight both the strengths and the areas for improvement in the Chinese abalone industry, offering actionable insights to enhance its efficiency and sustainability.

Looking forward, the wide geographical scope, significant regional differences, and rapid development of China's

abalone industry necessitate further research. Expanding survey coverage, ensuring systematic data collection, and conducting multi-period comparisons will be essential for deepening understanding of the industry's dynamics. Such efforts will support the abalone industry in achieving sustainable growth, driving economic benefits, and maintaining its strategic importance within China's fisheries sector.

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AUTHORS' CONTRIBUTION

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No competing interests were disclosed.

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This research conducted in this paper does not involve any animal or plant experiments

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DATA AVAILABILITY STATEMENT

All are available upon reasonable request.

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