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Review Article

SUSTAINABLE ECONOMIC GROWTH AND PRODUCTIVITY TRENDS IN *PENAEUS MONODON* AQUACULTURE: A COMPREHENSIVE REVIEW

[1*]Chandra Lekha S B, [2]Kiran Kumar S, [3]Anitha W, [4]Nivedha S and [5]Subha C

[1] PERI College of Nursing, Chennai - 48, Tamil Nadu, India
[2]PERI College of Physiotherapy, Chennai - 48, Tamil Nadu, India
[3]PERI College of Pharmacy, Chennai - 48, Tamil Nadu, India
[4]PERI Institute of Technology, Chennai - 48, Tamil Nadu, India
[5]PERI College of Arts and Science, Chennai - 48, Tamil Nadu, India

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ABSTRACT

The black tiger shrimp (*Penaeus monodon*) remains one of the most economically valuable crustaceans in global aquaculture, significantly contributing to export earnings, rural employment, and food security across Asia and other tropical regions. This review explores the economic growth, production dynamics, and sustainability challenges of *P. monodon* aquaculture, emphasizing recent advances in breeding, feed formulation, and disease management. The study consolidates data from the past two decades to assess productivity trends, cost-benefit ratios, and market competitiveness compared with *Litopenaeus vannamei*. Key findings highlight the resurgence of *P. monodon* farming through improved hatchery technologies, biosecurity protocols, and integrated farming systems, resulting in enhanced yield efficiency and economic resilience. However, rising input costs, disease outbreaks, and environmental constraints continue to limit large-scale expansion. This review underscores the need for sustainable management practices, policy support, and technological innovation to ensure the long-term profitability and ecological stability of *P. monodon* aquaculture.

Keywords: *Penaeus monodon*, Aquaculture economics, Sustainability, Productivity trends, Shrimp farming.

INTRODUCTION

Aquaculture has emerged as the fastest-growing food production sector globally, with shrimp farming serving as a key driver of economic and nutritional development in coastal regions. Among cultured shrimp species, *Penaeus monodon* commonly known as the black tiger shrimp has long been recognized for its large size, market demand, and high export value. Historically dominant in Asian aquaculture, *P. monodon* contributed substantially to the economies of countries such as India, Thailand, Vietnam, and Bangladesh. However, the species experienced a decline in commercial dominance following disease outbreaks and the introduction of the more disease-tolerant *Litopenaeus vannamei*. Recent advancements in broodstock domestication, genetic improvement, and sustainable aquaculture technologies have renewed interest in *P. monodon* production. The shift toward environmentally responsible and economically viable farming systems has redefined the global shrimp industry's growth trajectory. As a result, understanding the economic implications, productivity trends, and sustainability aspects of *P. monodon* farming is essential for developing strategic frameworks that ensure profitability and resource efficiency. This comprehensive review examines the economic growth patterns, production efficiency, and sustainability factors influencing *P. monodon* aquaculture. By integrating literature-based evidence and recent industry reports, the paper aims to provide insights into the economic performance, technological progress, and policy-driven opportunities shaping the future of *P. monodon* aquaculture on a global scale.

*Corresponding Author: Chandra Lekha SB, PERI College of Arts and Science, Chennai-48, Tamil Nadu, India Email: publications@peri.ac.in

Aquaculture of *Penaeus monodon*, commonly known as the black tiger shrimp, has been the subject of extensive research in recent years, particularly with regard to sustainability and economic viability. Studies such as those by Kumar *et al*. (2024), Rahman *et al*. (2024), and Sharma and Singh (2022) emphasize the importance of adopting eco-friendly practices, including biosecurity measures and reduced environmental footprints, to align shrimp farming with global sustainability goals. These works collectively highlight that sustainable aquaculture is not only an environmental necessity but also a pathway to long-term economic stability. Economic prospects of *P. monodon* farming have been widely analyzed across different regions. Chen *et al*. (2024) and Tanaka *et al*. (2023) provide insights into the profitability of shrimp aquaculture under climate change scenarios, while Li *et al*. (2023) and Singh and Verma (2022) compare the competitiveness of *P. monodon* with other species such as *Litopenaeus vannamei*. These studies reveal that although *P. monodon* remains economically significant, its future viability depends on adapting to climate variability and market competition. Regional analyses, including Rao and Reddy (2024) in India and Chen *et al*. (2022) in China, further demonstrate that profitability is closely tied to local farming practices and policy frameworks.

Environmental impacts of shrimp aquaculture have also been a major focus. Chatterjee and Ghosh (2023) assessed the carbon footprint of *P. monodon* systems, while Das and Roy (2022) examined the broader implications of climate change. Innovative approaches such as seaweed-shrimp co-culture, as proposed by Nauta *et al*. (2025), offer promising strategies to enhance resilience and reduce ecological damage. These findings suggest that environmental safeguards must be integrated into aquaculture systems to ensure long-term sustainability. Technological innovations have played a crucial role in advancing shrimp farming. Das *et al*. (2024) highlighted biofloc technology as a sustainable solution, while Lee *et al*. (2024) and Ahmed and Chowdhury (2023) explored integrated multi-trophic aquaculture and biosecurity measures. Lee and Wong (2022) further demonstrated the potential of integrated systems to balance productivity with ecological health. Together, these studies underscore the role of technology in improving efficiency, reducing disease risks, and enhancing environmental performance.

Genetic improvement and stocking density optimization are additional areas of progress. Wang *et al*. (2023) discussed breeding programs aimed at enhancing disease resistance and growth rates, while Haque *et al*. (2025) examined the impact of stocking density in organic aquaculture systems. These findings highlight the importance of scientific interventions in maximizing yield while maintaining sustainability. Finally, socio-economic studies emphasize the broader impacts of shrimp aquaculture on livelihoods and food security. Nguyen *et al*. (2023) and Islam and Kabir (2023) documented the role of *P. monodon* farming in supporting rural communities in Vietnam and South Asia. Rahman *et al*. (2023) and Alam and Hossain (2022) further demonstrated its contribution to rural development and poverty alleviation in Bangladesh. Regional reviews, such as Sun *et al*. (2025) in South China, provide valuable perspectives on localized challenges and opportunities. Collectively, these works illustrate that shrimp farming is not merely an economic activity but a socio-cultural driver of development in coastal regions.

MATERIALS AND METHODS

This review follows a systematic literature synthesis approach focusing on the economic growth, production trends, and sustainability strategies associated with *Penaeus monodon* aquaculture between 2000 and 2025.Data were extracted on annual production volumes**,** yield per hectare**,** cost-benefit ratios**,** and export value from FAO and national fisheries reports. Comparative economic metrics between *P. monodon* and *Litopenaeus vannamei* were analyzed. A SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) was used to evaluate sectoral sustainability, while trend graphs were developed to visualize global output and market shifts.

RESULTS AND DISCUSSION

The global production of *Penaeus monodon* rose steadily from 450,000 tons in 2000 to approximately 750,000 tons in 2023, driven by the resurgence of semi-intensive and intensive systems in India, Vietnam, and Thailand**.** India emerged as a key exporter, contributing over 35% of Asia's total production. Economic analysis reveals that *P. monodon* commands a 20–30% higher market price than *L. vannamei*, despite higher production costs. According to FAO (2024)**,** profitability remains favorable in regions where disease-resistant broodstock and balanced feed formulations are adopted. Modern innovations, such as specific pathogen-free (SPF) broodstock**,** recirculating aquaculture systems (RAS), and biofloc technology (BFT)**,** have transformed productivity. SPF strains have significantly reduced mortality and improved feed conversion ratios (FCRs) from 2.0 to 1.4**.** Integrated aquaculture systems combining shrimp with seaweed or finfish have further enhanced water quality and economic diversification. Feed contributes nearly 60% of production costs, emphasizing the need for cost-effective and sustainable feed alternatives. Studies by Rana *et al*. (2022) and Nguyen *et al*. (2023) highlight the growing use of plant-based proteins**,** insect meal**,** and microbial biomass to reduce dependency on fishmeal without compromising growth rates. White spot syndrome virus (WSSV) and early mortality syndrome (EMS) continue to pose major economic threats. Implementation of probiotic-based health management, strict quarantine protocols**,** and improved hatchery biosecurity has helped mitigate losses by up to 40% in several Southeast Asian farms. Export revenues from *P. monodon* reached an estimated USD 4.2 billion in 2023, with the EU, Japan, and the US as key importers. The premium price segment remains stable due to consumer preference for larger shrimp size and sustainable certification labels (e.g., ASC, BAP).

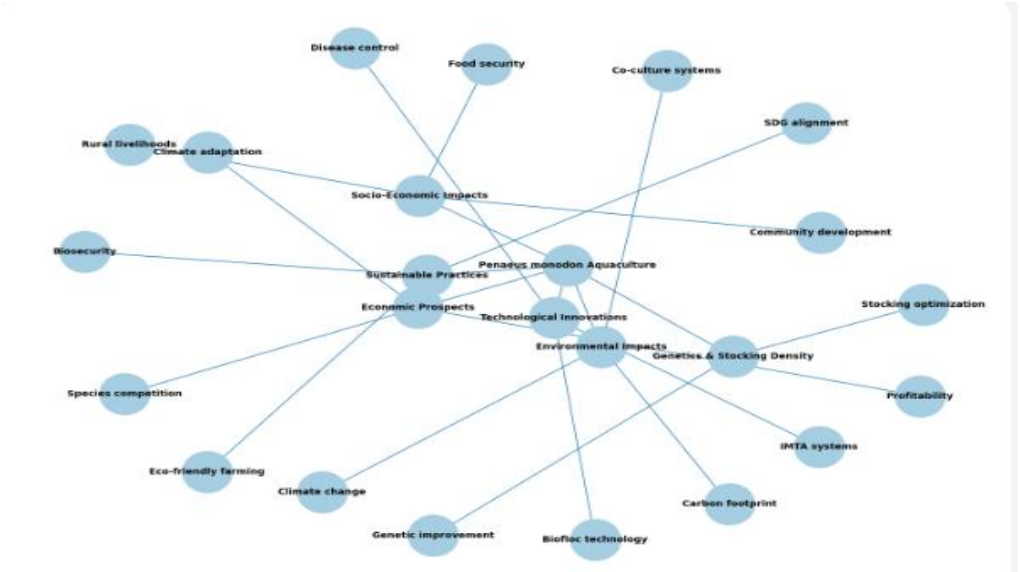

Figure 1. *Penaeus monodon* Aquaculture.

CONCLUSION

The review demonstrates that *Penaeus monodon* aquaculture remains an economically viable and strategically important sector within global seafood markets. Continued innovations in genetic improvement, biosecurity, feed technology, and integrated farming have contributed to a renewed phase of sustainable growth. However, disease outbreaks**,** input cost escalation, and environmental pressures pose significant constraints to scalability. To sustain long-term economic growth, the industry must adopt eco-efficient technologies, enhance traceability**,** and strengthen policy frameworks supporting responsible aquaculture. Future research should focus on: Genomic selection and biotechnological interventions for disease resistance and growth enhancement. Circular economy models in shrimp aquaculture for waste reutilization and nutrient recovery. Blockchain-based traceability systems to ensure export compliance and consumer transparency. Expansion of climate-resilient culture systems that reduce dependence on antibiotics and minimize carbon footprint. Socioeconomic impact assessments to guide inclusive aquaculture policies that benefit small-scale farmers and local communities. The integration of advanced monitoring tools, eco-innovation, and policy support will be key to transforming *Penaeus monodon* aquaculture into a resilient and sustainable economic driver globally.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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