frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 01 April 2025
DOI 10.3389/fsufs.2025.1545263



OPEN ACCESS

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RECEIVED 14 December 2024
ACCEPTED 13 March 2025
PUBLISHED 01 April 2025

CITATION
Obi C, Dompreh EB, Manyise T, Tan SH, Woo SP and Rossignoli CM (2025) Overview of the fishery and aquaculture sectors in Malaysia.
*Front. Sustain. Food Syst.* 9:1545263.
doi: 10.3389/fsufs.2025.1545263



# Overview of the fishery and aquaculture sectors in Malaysia

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This study presents a literature-based review of Malaysia's fishery and aquaculture sectors, examining their historical development, production trends, contributions, and challenges. Unlike existing studies that focus primarily on production trends or environmental concerns, this paper provides a policy-oriented perspective, linking production challenges to governance, economic constraints, and gaps in small-scale aquaculture and private-sector involvement. The study show that in 2022, Malaysia's total fishery production reached 1.89 million metric tons, with aquaculture contributing 30%. While capture fisheries have stagnated due to overfishing and environmental pressures, aquaculture has expanded, playing a crucial role in post-Covid-19 recovery. However, sustainability remains a challenge due to climate change, water pollution, rising production costs, and regulatory barriers. To address these issues, the study recommends promoting sustainable fishing and aquaculture practices, enhancing research and development (R&D), streamlining regulatory frameworks, improving disease management, and expanding economic support and market access. These measures are essential to strengthening Malaysia's aquaculture sector and ensuring long-term food security and economic resilience.

KEYWORDS

**Malaysia, fishery, aquaculture, sustainability, food security, policy development**

## Introduction

Malaysia possesses a rich maritime heritage and extensive coastal resources that have historically played a crucial role in national economic development and food security. With approximately 4,675 kilometers of coastline and vast maritime territories spanning the South China Sea and the Straits of Malacca, the country enjoys unique geographical advantages for aquatic food development. These diverse marine ecosystems provide significant opportunities for both capture fisheries and aquaculture production, reinforcing Malaysia's potential as a key player in the global seafood industry.

In recent decades, Malaysia's fishery and aquaculture sectors have undergone rapid transformation, driven by technological advancements and strategic national development policies. The transition from traditional, small-scale operations to more modernized and commercialized systems has enhanced their role in the economy—improving nutrition, supporting rural livelihoods, and contributing to national GDP (Jumatli and Ismail, 2021). This evolution underscores the strategic importance of these sectors for Malaysia's long-term economic growth and food security.

Despite these advancements, Malaysia's fishery and aquaculture sectors face interconnected challenges and opportunities. Rapid urbanization, projected to reach 85% by 2040 (United Nations, 2018), is reshaping consumer demands and production strategies. The growing demand for more diversified and convenient fish products creates new market opportunities but also places increased pressure on production systems

(Reardon et al., 2014; Yusoff, 2015). Meanwhile, food insecurity and malnutrition persist, especially in rural communities where limited access to nutritious and affordable food exacerbates socioeconomic disparities (FAO, 2021a; Institute for Public Health, 2023).

Like several other fish-producing countries in Southeast Asia, the sustainability of Malaysia's fisheries and aquaculture is increasingly threatened by overfishing and resource depletion, climate change and environmental pressures, and economic constraints and market volatility (Ministry of Energy Transition and Water Transformation, 2017a). Coastal fishery resources both globally and across Southeast Asia, where Malaysia is located, have been fully exploited, with some species experiencing significant population declines (Escamilla-Pérez et al., 2021; Zhang et al., 2021; Fabinyi et al., 2022). Illegal, unreported, and unregulated (IUU) fishing remains a persistent issue, further stressing capture fisheries (Afriansyah et al., 2024; FAO, 2022). In Malaysia, marine capture fish stocks have declined in five out of the last six years, signaling an urgent need for improved fishery management strategies (Department of Fisheries Malaysia, 2019a; Department of Fisheries Malaysia, 2022).

Moreover, erratic weather patterns, rising sea temperatures, and ocean acidification are altering marine ecosystems and disrupting coastal fishery-dependent communities (Williamson and Guinder, 2020; Baag and Mandal, 2022). Additionally, habitat destruction due to coastal development, pollution, and declining water quality is further undermining fish stock replenishment and aquaculture viability (Vickram and Srivastava, 2024).

The aquaculture sector is increasingly constrained by rising production costs, including feed, land, and hatchery expenses, which disproportionately affect small-scale producers (Tan et al., 2024; Mansfield et al., 2024). In Malaysia, market access challenges and dependency on imported fish feed elevate financial risks, while limited government support for small aquaculture farms creates additional economic barriers (Mustafa et al., 2021).

Addressing these challenges will require the development and implementation of improved policy frameworks that promote sustainable practices, support economic viability, and ensure the long-term resilience of Malaysia's fishery and aquaculture industries. However, studies on sustainable fisheries production emphasize that effective policy interventions must adapt to long-term trends while mitigating present vulnerabilities (FAO, 2022). By examining past policy shifts and sectoral performance, decision-makers can implement targeted strategies that enhance resilience, optimize resource use, and promote sustainable growth in Malaysia's fishery and aquaculture sectors.

Therefore, this study offers a historical-to-contemporary overview of Malaysia's fishery and aquaculture sectors, providing an integrated policy-oriented analysis that links production trends with governance, economic challenges, and sustainability concerns. The study addresses a key gap policy dynamics and contemporary challenges of Malaysia's fisheries and aquaculture sector. Existing research in Malaysia predominantly focuses on technical aspects such as species productivity and environmental impacts (Dauda et al., 2018; Kurniawan et al., 2021; Tan et al., 2024), yet a broader policy-oriented analysis remains limited. By integrating historical trends, regulatory frameworks, and economic constraints, this paper provides a holistic perspective on sectoral sustainability and resilience.

To achieve this, the paper traces the development of Malaysia's fishery and aquaculture industries, highlighting key production milestones and contributions to the economy. It then examines critical issues, including overfishing, climate change effects, and economic constraints, providing an updated assessment of their impact on the sector. Finally, the study outlines prospects and strategic interventions to enhance sustainability of the sector. By addressing these objectives, this paper seeks to provide a more comprehensive and policy-relevant understanding of Malaysia's fishery and aquaculture sectors, guiding future policy reforms, research priorities, and investment strategies.

## Methods

This study adopts a thematic analysis literature review approach to explore the historical-to-contemporary development of Malaysia's fishery and aquaculture sectors. The review draws from a range of sources, including peer-reviewed journal articles, government reports, industry publications, and documents from international organizations, such as the Food and Agriculture Organization (FAO) and the Department of Fisheries Malaysia (DOF). The aim is to provide a broad and contextual understanding of the sector's evolution, key policy developments, and the challenges it faces.

Relevant literature was identified through searches in academic databases, including Scopus and Google Scholar, as well as government and institutional repositories. The selection process focused on studies related to fishery and aquaculture production, economic contributions, environmental impacts, and regulatory frameworks in Malaysia. Search terms included "Malaysia aquaculture," "fishery sector Malaysia," "sustainable aquaculture practices Malaysia," "capture fisheries Malaysia," and "policy framework fisheries Malaysia." While no strict timeframe was applied to government and policy reports, peer-reviewed articles published between 2010 and 2023 were prioritized to reflect recent policy and industry trends. The review primarily examines Malaysia's fishery and aquaculture sectors but incorporates comparative literature from other Southeast Asian nations to provide additional context. Only sources published in English and Malay were considered.

A thematic analysis was conducted to identify historical trends, key challenges, and policy gaps in the fishery and aquaculture sectors. Findings were grouped into broad thematic categories, including historical development, production trends, economic and environmental constraints, and governance challenges. Themes emerged iteratively, with multiple rounds of refinement ensuring consistency and alignment with the study's objectives. This approach allows for a structured understanding of the sector's evolution, linking past developments to current policy and sustainability concerns.

Despite efforts to capture a comprehensive overview, some limitations remain. The availability of literature varies across different aspects of the sector, with limited data on the role of the private sector, small-scale aquaculture, and unpublished industry assessments. Additionally, some policy reports and trade documents are restricted, making it difficult to obtain detailed insights into certain regulatory and market dynamics. These limitations are acknowledged in the discussion, highlighting areas where further research is needed to enhance understanding and inform policy development.

# Status of fishery and aquaculture in Malaysia

## Historical context

Malaysia's fishery and aquaculture sectors have undergone a remarkable transformation, evolving from traditional inshore fishing to a diversified, modern aquaculture industry. Prior to the development of aquaculture, Malaysia's fisheries industry relied heavily on inshore fishing, which was vital for local food security and coastal economies. Subsistence fishing dominated, with fish primarily sourced from shallow coastal waters, which had low nutrient levels, limiting their productivity (Firth, 1966). The sector lacked formal management, and most fish were caught for domestic consumption, with limited exports.

A significant shift occurred in the 1970s with the introduction of trawlers and mechanized fishing boats, which allowed access to offshore fishery resources. This transition was supported by government incentives, such as the 1971 National Agricultural Policy, which aimed to modernize the fisheries sector and promote offshore expansion (Department of Fisheries Malaysia, 1971). These efforts led to a substantial increase in catches, positioning Malaysia as a major fishing nation. However, by the early 1980s, fish production had peaked, and overreliance on inshore fisheries led to overexploitation. In response, the Malaysian government introduced deep-sea fishing initiatives and actively promoted aquaculture to ensure long-term sustainability (FAO, 1983).

Aquaculture in Malaysia began in the 1920s, with the introduction of extensive polyculture systems in ex-mining pools, where Chinese carp species (bighead, silver, and grass carp) were cultivated (Jumatli and Ismail, 2021). In the 1930s, shrimp-trapping ponds were developed in Johor, and by the 1940s, blood cockle culture gained popularity. The 1950s marked the expansion of freshwater fish culture in earthen ponds, followed by the emergence of semi-intensive shrimp farming in Johor in the 1970s. During this period, floating net cage culture for marine fish (e.g., green groupers) and raft culture for green mussels also emerged (Department of Fisheries Malaysia, 1975). The government's Aquaculture Development Program (1977) played a crucial role in expanding these systems, providing financial support and technical assistance to farmers (FAO, 1983).

By the 1980s, government and private sector investments led to the establishment of hatcheries and feed mills, facilitating higher production efficiency. The 1986 Economic Recovery Plan (ERP) further encouraged commercial aquaculture expansion, recognizing it as a key economic sector (Government of Malaysia, 1986). The 1990s saw a shift toward intensive commercial aquaculture, characterized by higher stocking densities, supplementary feeding, and improved disease management strategies. Integrated shrimp farms, spanning hatcheries to processing plants, were introduced, strengthening Malaysia's position as an exporter of farmed seafood (FAO, 1995).

In the 2000s, emphasis shifted toward food safety and fish health management, aligning with international standards for seafood exports. Key advancements included biosecurity measures, disease surveillance programs, and stricter regulations on antibiotic use (Department of Fisheries Malaysia, 2005). In 2010, the launch of the National Agro-Food Policy (NAFP) 2011–2020 positioned aquaculture as a high-value industry, promoting sustainable practices and technological innovations (Government of Malaysia, 2011). By 2020, Malaysia's aquaculture sector had expanded further, incorporating indoor aquaculture systems, diversified species farming (e.g., mud crabs, shrimp, tilapia), and improved feed formulations to enhance efficiency and sustainability (FAO, 2020).

## Fish production

Malaysia's fishery sector is comprised of three main subsectors: marine capture fisheries, aquaculture, and inland fisheries. Additionally, Malaysia produces a substantial quantity of ornamental fish and aquatic plants, contributing to the sector's overall value. In 2022, Malaysia's total fishery production amounted to 1.89 million metric tons (Table 1), generating a monetary value of RM 15.97 billion (USD 3.83 billion) (DOF, 2023). Marine capture fisheries remained the dominant source of production, accounting for 69% of total output. Of this, 88% originated from inshore coastal waters, while the remaining 12% came from deep-sea fishing operations.

Aquaculture contributed 30% of total fish production, with seaweed farming comprising 54% of aquaculture output, brackish water fish farming accounting for 26%, and freshwater fish farming making up 20%. Inland fisheries remained a minor contributor, producing only 1% of total fish production. Beyond food fish, Malaysia also produced 234 million ornamental fish and 24 million tons of aquatic plants, adding to the sector's economic significance. Notably, 97% of the total sector value came from food fish, while non-food fish, such as ornamental species, accounted for the remaining 3%.

The production trends in Malaysia's fisheries sector highlight the stagnation of marine capture fisheries and the increasing importance of aquaculture. Figure 1 illustrates the trajectory of fishery production from 1990 to 2022, showing that capture fisheries have plateaued, while aquaculture production has expanded significantly over the past two decades. This stagnation in capture fisheries raises critical questions about its causes. While resource overexploitation has played a role—particularly in inshore fisheries, where stocks are heavily exploited—other factors such as government policies, stricter fishing regulations, and market conditions have also contributed. The introduction of fishing quotas, seasonal bans, and marine protected areas (MPAs) has aimed to prevent further depletion of marine resources, but these measures have also limited the expansion of capture fisheries. Additionally, rising operational costs and declining fish prices in international markets have discouraged investment in the marine capture subsector, particularly in deep-sea fishing.

While aquaculture saw a surge in production from the mid-2000s to 2012, production began declining after 2012, a trend that can be attributed to several factors. One major challenge was disease outbreaks, particularly Early Mortality Syndrome (EMS) in shrimp farms, which significantly affected productivity and led to farm closures (FAO, 2024). Additionally, rising production costs—including feed prices, hatchery expenses, and biosecurity investments—made commercial aquaculture less profitable for small- and medium-scale producers (Mustapha et al., 2013). Environmental concerns, such as water pollution and land-use conflicts, also posed constraints, leading to stricter regulations on aquaculture expansion in certain regions.

Moreover, market saturation and fluctuating export demand affected the profitability of key aquaculture products, such as shrimp and tilapia. As regional competitors like Vietnam and Indonesia

TABLE 1 Sectoral production and value of fisheries sector, Malaysia (2022).

| Fishery sector | | Quantity (million tons) | Value (RM, million) | Value (USD$, million) | Employment |
|---|---|---|---|---|---|
| Marine capture | | 1.31 | 11,306 | 2,799 | 116,613 |
| | Inshore | 1.15 | 10,275 | 2,543 | 104,297 |
| | Deep sea | 0.16 | 1,031 | 255 | 12,316 |
| Aquaculture | | 0.57 | 4,016 | 994 | 20,925 |
| | Freshwater | 0.12 | 982 | 243 | 15,948 |
| | Brackish water | 0.15 | 2,788 | 690 | 3,423 |
| | Seaweed | 0.31 | 247 | 61 | 1,554 |
| In-land fisheries | | 0.01 | 144 | 36 | 11,149 |
| Total food fish | | 1.89 | 15,467 | 3,829 | 148,687 |
| | | | | | |
| | Ornamental fish | 234.49 | 454 | 112 | 926 |
| | Aquatic plant | 24.29 | 47 | 12 | 17 |
| Total non-food fish | | | 501 | 124 | 943 |
| Grand total | | | 15,968 | 3,952 | 149,630 |

USD conversion rate of 4.04, ornamental fish is presented in pieces while aquatic plants in bundles. Source: DOF (2023): Annual Fisheries Statistics 2022 (Volume 1).

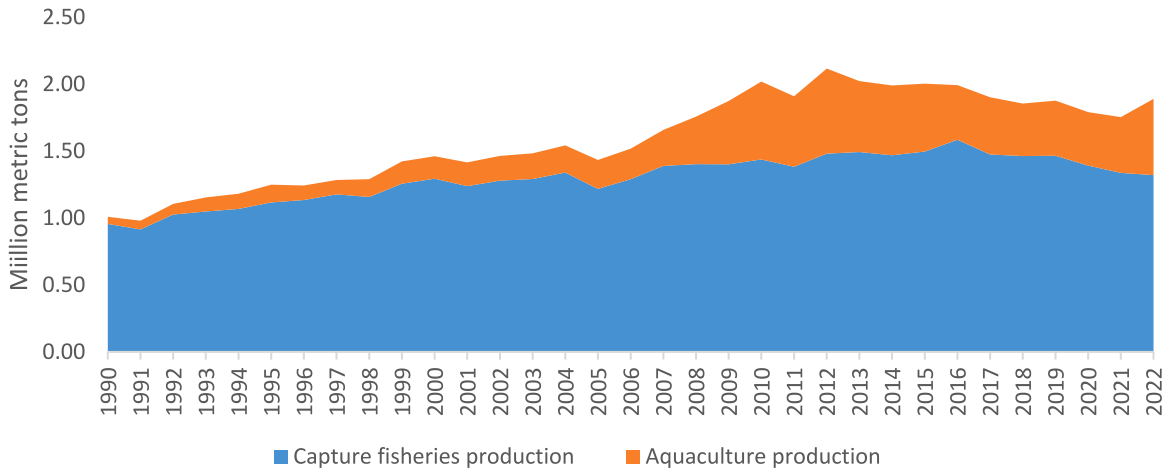


FIGURE 1
Total fishery production in Malaysia (1990 to 2022). Source: FAO (2023): Global production by production source (Fishstatj).

increased their seafood exports, Malaysia's export market share declined, further impacting production levels (Emam et al., 2021). Policy shifts also played a role, as the government prioritized food safety and stricter environmental compliance under the National Agro-Food Policy (NAFP) 2011–2020, leading to additional compliance costs for producers.

Despite the setbacks in aquaculture, 2022 marked a recovery, with production levels returning to pre-pandemic figures from 2019. This recovery was largely driven by aquaculture, particularly the expansion of seaweed farming and renewed investments in brackish water fish production. Government subsidies and financial incentives, including grants for sustainable aquaculture and R&D investments in disease-resistant fish strains, contributed to the sector's rebound (DOF, 2023).

Another critical factor was increased domestic demand for farmed seafood, which compensated for reduced export revenues. As global supply chains stabilized post-COVID-19 (Hashim et al., 2020), import restrictions were lifted, leading to a revival in regional trade opportunities. Additionally, technological advancements in indoor aquaculture systems, such as recirculating aquaculture systems (RAS) and biofloc technology, improved production efficiency and disease resilience, encouraging higher stocking densities without compromising water quality.

## Geographical distribution

Fish production in Malaysia varies significantly across states, with Sabah, Perak, and Selangor collectively accounting for nearly 60% of the total national output (DOF, 2023). Figure 2 illustrates the 2022 fish production performance across states, highlighting the differences in

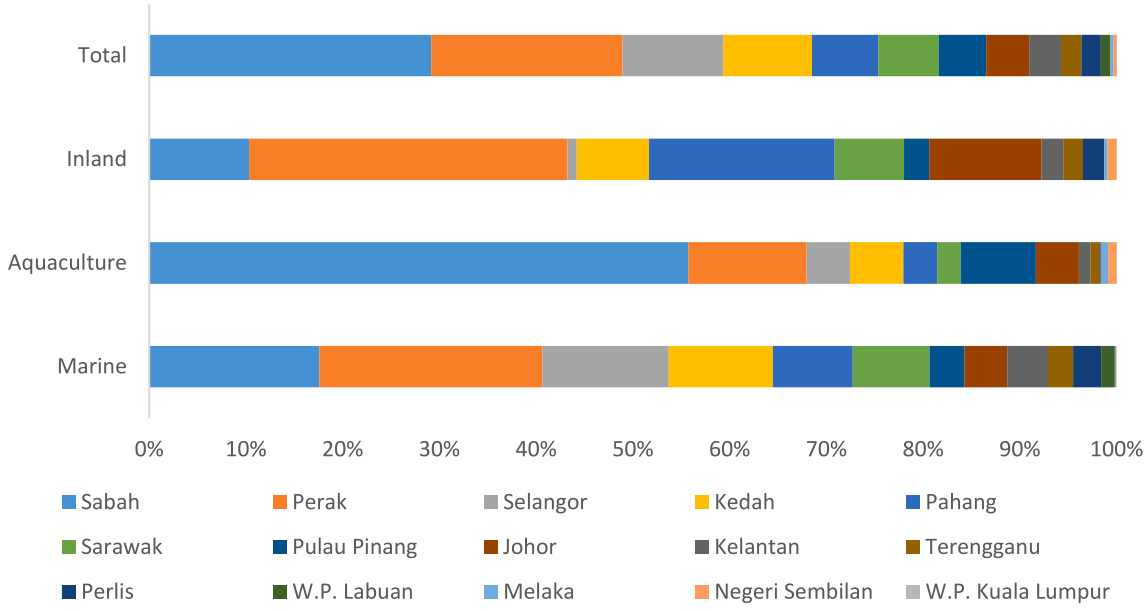


FIGURE 2
Fish production performance by state in 2022 (in percentage). Source: DOF (2023): Annual Fisheries Statistics 2022 (Volume 1).

marine capture, aquaculture, and inland fisheries. Sabah led in total fish production, producing 550 thousand metric tons, which represented 29% of the total national fish output. Perak followed, contributing 374 thousand metric tons (20%), while Selangor accounted for 10% (196 thousand metric tons). At the lower end, W.P. Kuala Lumpur, Negeri Sembilan, and Melaka collectively accounted for less than 1% of total production. In terms of marine capture fisheries, Perak is the top-producing state, accounting for 23% of the national marine fish output, followed by Sabah (18%) and Selangor (13%). These states, which are coastal and have well-developed fishing industries, continue to dominate marine fish production (Figure 2).

Aquaculture production is highly concentrated in Sabah, which leads the sector with 56% of the total national aquaculture output. Perak follows at 12%, while Pulau Pinang ranks third at 8%. Sabah's dominance in aquaculture is driven by its extensive coastal waters and large-scale commercial aquaculture farms, particularly for shrimp and seaweed farming. For inland fisheries, Perak leads with 33% of total inland fish production, followed by Pahang (19%) and Johor (12%). These states benefit from extensive river networks and freshwater ecosystems, making them ideal for inland capture fishing and freshwater aquaculture. Other states, such as Kedah, Sarawak, and Pulau Pinang, also contribute significantly to different segments of fishery production, reflecting Malaysia's diverse geographic and economic landscape in fisheries and aquaculture. The variation in production types across states underscores the importance of tailored regional strategies to support sustainable fishery development based on local ecological conditions and market demands.

Although Malaysia's fishery and aquaculture production has made substantial progress, it still lags behind several Southeast Asian nations. Malaysia falls behind countries like Indonesia, Vietnam, the Philippines, and Thailand, which exhibit significantly higher aquaculture production. In aquaculture, Indonesia leads the region with a substantial production of 14.61 million metric tons of aquaculture production and 21.81 million metric tons of total fish production in 2021 (Figure 3). This is followed by Vietnam and the Philippines, with aquaculture production above 2 million metric tons and total fish production above 4 million metric tons, respectively. While Malaysia's fishery and aquaculture production is lower than those of these leading countries, it still surpasses several others in the region, including Singapore and Lao PDR.

## Fisheries management and species

Malaysia's marine capture fish production system is supported by a diverse range of fishing gear and vessel operations spread across different fishing zones. The country has a total of 48,605 fishing vessels, operating in various designated fishing zones (A, B, C, and $C^2 + C^3$), each with distinct characteristics in terms of fishing methods and targeted species (DOF, 2023). Zone A is primarily used for traditional fishing and anchovy purse seine operations, accounting for the highest number of vessels (40,715). Zone B, which allows the use of purse seines, trawlers, and Kenka two-boat trawling systems, operates with 4,283 vessels. Zone C, which includes traditional fishing, purse seine, and trawling, has 2,881 vessels, while Zone $C^2 + C^3$, which incorporates longline fishing along with traditional and trawl fishing, operates with 726 vessels in deep seas.

The marine fish production system in Malaysia primarily targets a wide variety of species, with pelagic fish contributing the highest share (489,422 metric tons, 37% of total production) in 2022 (DOF, 2023). Pelagic fish include small schooling species like sardines and mackerels, which are commonly caught using purse seines and trawlers. Demersal species, which inhabit the seabed, account for 331,199 metric tons (25%) of the total marine fish production and are often caught using bottom trawling and traditional fishing methods. Trash fish, comprising low-value fish used for animal feed and fishmeal, make up 19% (242,069 metric

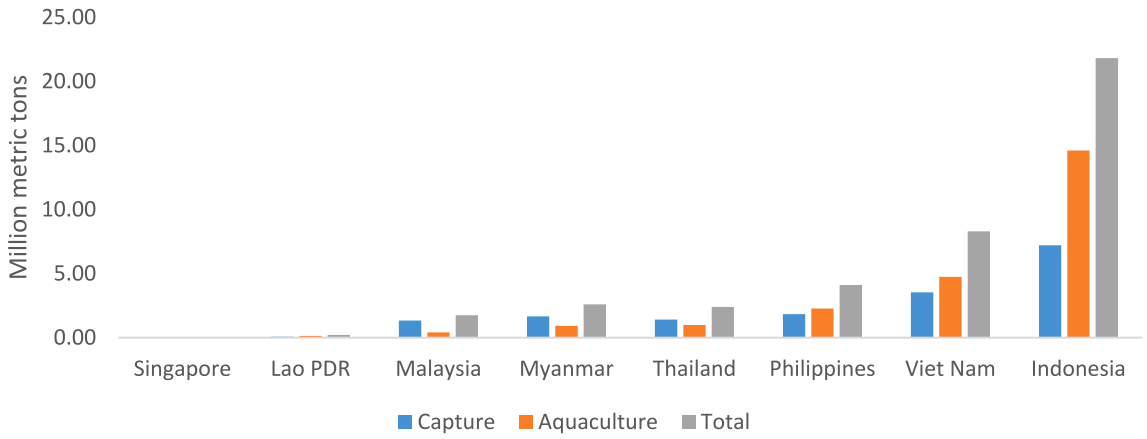


FIGURE 3
Fish production performance by country in 2021 (in million metric tons). Source: Authors compilation from FAO FISHSTAT.

tons) of the total marine fish production. Shrimp production, contributes 97,616 metric tons (7%). Cuttlefish, a high-value cephalopod species, accounts for 5% (62,704 metric tons) of marine fishery production. Other marine species, including miscellaneous small fish, crabs, and squid, contribute 4% (48,714 metric tons), while mixed fish categories add another 3% (36,691 metric tons).

Malaysia's aquaculture production system is structured across three main environments: freshwater, brackish water, and seaweed farming. Each system utilizes different culture methods suited to the specific species being cultivated (DOF, 2023). In 2022, freshwater aquaculture was primarily conducted in ponds (54.6%), followed by cages (21.3%), ex-mining pools (18.4%), and smaller contributions from cement/fiber tanks (4.8%), pen culture (0.6%), and canvas tanks (0.3%). These culture systems support a diverse range of freshwater species, with freshwater catfish (34.4%) and red tilapia (24.1%) being the most dominant, followed by river catfish (18.0%), bighead carp (3.4%), and black tilapia (3.3%). Other notable freshwater species include rohu, gift tilapia, river carp, and common carp, which collectively contribute to the overall sector.

In brackish water aquaculture, pond culture is the most widely used system, accounting for 67.0% of total production, followed by brackish water cages (17.8%) and mollusk farming (14.1%). Key brackish water species include seabass (29.2%), white shrimp (26.4%), cockles (12.7%), and tiger prawns (10.2%), all of which are major contributors to the sector's economic value. Other species such as milkfish, red snapper, mangrove snapper, and hybrid grouper are also cultivated but at lower production volumes. Meanwhile, seaweed farming, primarily using the longline method, accounted for 100% of total seaweed production in Malaysia.

To support the sustainability and expansion of the aquaculture sector, the Malaysian government has invested significantly in producing high-quality, disease-free fish seeds and reducing reliance on imported fry. In 2022, national fish fry production reached 9.7 billion pieces, with 8.7 billion produced by brackish water hatcheries and 1 billion by freshwater hatcheries (DOF, 2023). Of this total, 99.6% (6.9 billion pieces) were produced by over 600 private hatcheries, specializing in species such as grouper, snapper, seabass, oysters, marine shrimp, catfish, tilapia, and perch. The remaining 0.4% (43 million pieces) were produced by 20 major government hatcheries, which focus on catfish, red tilapia, carps, lobsters, seabass, and grouper.

Government hatcheries play a crucial role in the sustainability and development of the aquaculture sector by serving as centers for technology transfer, training, and technical support. They also contribute to stock enhancement programs, supporting wild fish populations to ensure long-term ecological balance (DOF, 2023). In addition, Malaysia continues to prioritize biosecurity measures and disease prevention strategies, investing in advanced water management systems and sustainable feed development to improve production efficiency while minimizing environmental impact. These ongoing efforts position Malaysia's aquaculture industry as a key driver of national seafood production, ensuring both economic growth and food security for the future.

## Contributions of the fishery and aquaculture sectors in Malaysia

The fishery and aquaculture sectors play a fundamental role in Malaysia's food security, economic development, and cultural heritage, serving as critical sources of employment, nutrition, and trade revenue. These sectors not only contribute significantly to domestic food production but also support export markets, sustaining livelihoods in coastal communities and generating substantial economic value.

### Employment and livelihoods

The fishery and aquaculture industries provide direct employment to a considerable segment of Malaysia's workforce, particularly in coastal and rural areas. In 2022, the two sectors directly employed 149,630 individuals, with marine capture fisheries remaining the largest employer (116,613 people), followed by aquaculture (20,925 people) (Table 1). Direct employment in marine capture fisheries is concentrated in states such as Sabah and Perak, while aquaculture employment is most prominent in Sabah and Sarawak, reflecting regional differences in fish production activities. Over the past decade,

direct employment in marine capture fisheries has declined, largely due to resource depletion, stricter fishing regulations, and rising operational costs (Mustafa et al., 2021). Conversely, the aquaculture sector has shown modest growth, presenting a viable alternative for sustaining rural employment.

## Nutritional importance and cultural significance

Fish and seafood constitute essential sources of protein and micronutrients in the Malaysian diet, with high levels of omega-3 fatty acids contributing to health and nutritional well-being. Fish consumption is especially significant in coastal regions, where access to alternative protein sources may be limited. In 2017, per capita fish consumption was 47.3 kg (Table 2), but this declined to 42.7 kg in 2020, likely due to supply chain disruptions during the COVID-19 pandemic (Chowdhury et al., 2021). However, by 2022, per capita consumption had rebounded to 46.22 kg for food fish and 36.04 kg for fish only, reflecting a post-pandemic recovery in fish production and trade. Malaysia's cultural heritage is closely tied to fishing and seafood consumption, with traditional fishing practices and seafood-based cuisine forming an integral part of national and regional identities (Goh et al., 2021). According to the Department of Statistics, Malaysia (2023), fish and seafood account for a significant proportion of household food expenditures, underscoring their centrality in Malaysian dietary habits. The high per capita consumption of fish—nearly double the global average—illustrates the sector's essential role in national food security and nutritional sustainability.

## Economic contribution and trade performance

Beyond its nutritional and livelihood benefits, Malaysia's fisheries sector is a significant contributor to the national economy, particularly through trade and exports. The total trade value of fish and seafood products has increased steadily, rising from RM 7.5 billion in 2017 to RM 11.55 billion in 2022 (Table 2), reflecting growing domestic demand and global market opportunities. The primary export commodities include processed fish, crustaceans, mollusks, and fish meal, with shrimp and prawns alone accounting for 29% of total exports in 2021, followed by crustaceans and mollusks (20%) and processed fish (17%). According to state statistics (DOF, 2023), Malaysia's largest seafood export destinations were China (26.8%), Singapore (19.5%), and South Korea (6.3%), while the primary sources of seafood imports were China (23.9%), Vietnam (12.03%), and Indonesia (12.01%).

Despite steady export growth, increasing demand for imported fish products has resulted in a widening trade deficit. The balance of trade (BOT) in the fisheries sector has remained negative, with fish imports surpassing exports. In 2017, the trade deficit was RM −1.19 billion, which expanded to RM −3.13 billion in 2022, primarily due to a sharp rise in imports, which grew from RM 4.34 billion in 2017 to RM 7.34 billion in 2022. The largest imported seafood categories include fresh, chilled, and frozen fish (33%), crustaceans and mollusks (18%), and fish fillets (12%). The increasing reliance on imported fish products can be attributed to factors such as price competitiveness, consumer preferences, and supply constraints in domestic production (Soh et al., 2021; Goh et al., 2021).

Despite these trade imbalances, the fisheries sector continues to contribute significantly to Malaysia's economy. Its contribution to agricultural GDP ranged from 12.4% in 2017 to 11.6% in 2022, while its share of national GDP declined from 1.2% in 2017 to 0.8% in 2022. This marginal decline suggests that growth in fisheries has been slower compared to other sectors, reinforcing the need for policy interventions to enhance productivity, sustainability, and competitiveness.

# Challenges to fishery and aquaculture in Malaysia

The fishery and aquaculture sectors in Malaysia face a range of challenges, from environmental vulnerabilities and economic constraints to regulatory hurdles and knowledge gaps.

## Environmental vulnerabilities

Environmental degradation poses a critical challenge to the sustainability of Malaysia's fishery and aquaculture sectors, driven by water pollution, habitat destruction, climate change, and overfishing. Water pollution, particularly from industrial wastewater and untreated aquaculture effluents, continues to threaten freshwater and coastal ecosystems. Regions such as Selangor and Johor, where industrial zones are located near rivers and coastal aquaculture farms, are particularly affected. A study by Kurniawan et al. (2021) highlights

TABLE 2 Contributions of the fishery and aquaculture sectors in Malaysia.

| Year | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Self-sufficient ratio (%) | 92.7 | 92.1 | 93 | 95.3 | 93.3 | 90.2 |
| Per capita consumption (KG) | 47.32 | 46.94 | 45.51 | 42.7 | 43.38 | 46.22 |
| Balance of trade (RM Bilion) | −1.19 | −1.24 | −1.07 | −1.3 | −1.96 | −3.13 |
| Trade value (RM Bilion) | 7.5 | 7.5 | 8.6 | 8.8 | 9.71 | 11.55 |
| Export (RM Bilion) | 3.16 | 3.15 | 3.78 | 3.75 | 3.88 | 4.21 |
| Import (RM Bilion) | 4.34 | 4.39 | 4.85 | 5.09 | 5.84 | 7.34 |
| Percent contribution to agriculture GDP (%) | 12.4 | 12.3 | 11.9 | 11.4 | 11.4 | 11.6 |
| Percent contribution to national GDP (%) | 1.2 | 1.1 | 1 | 0.9 | 0.9 | 0.8 |

that contaminated rivers have led to mortality rates of over 30% in freshwater aquaculture farms, significantly impacting small-scale producers. Additionally, the accumulation of aquaculture waste—such as excess feed and chemical runoff—has degraded water quality, reducing fish yields and increasing vulnerability to disease outbreaks. Despite existing environmental policies, enforcement remains inconsistent, and many smallholder aquaculture farms operate without effective wastewater treatment systems.

Climate change exacerbates these environmental risks, introducing new challenges such as rising water temperatures, flooding, and drought. Higher temperatures have been linked to increased occurrences of fish diseases, particularly bacterial and viral infections in shrimp farming, which caused significant losses in 2018 and 2020, leading to temporary import bans (Fathi et al., 2018). Additionally, Malaysia experiences frequent floods, with the 2014 Kelantan floods destroying over RM 50 million worth of aquaculture infrastructure (Department of Fisheries Malaysia, 2019b). Droughts have also disrupted fish farms, particularly in Pahang and Kedah, where prolonged dry spells have led to water shortages in aquaculture ponds. The sector's ability to adapt to climate-induced challenges remains limited, highlighting the need for investment in climate-resilient aquaculture systems and improved disaster preparedness strategies.

Overfishing remains a major concern in marine capture fisheries, threatening the long-term sustainability of fish stocks. Coastal fisheries in Sabah, Terengganu, and Perak have reported declining catches of key commercial species, reflecting excessive fishing pressure. While Malaysia has implemented fishing quotas and seasonal restrictions, compliance remains a challenge, especially among small-scale fishers who depend on daily catches for income. Additionally, illegal, unreported, and unregulated (IUU) fishing remains prevalent, further exacerbating stock depletion. A 2019 study by the Department of Fisheries Malaysia estimated that IUU fishing accounted for nearly 30% of total marine fish landings, indicating significant enforcement gaps. Strengthening surveillance, monitoring, and fisher compliance programs will be essential to improving marine resource management.

## Economic constraints

The economic viability of Malaysia's fishery and aquaculture sectors is increasingly threatened by rising production costs, market volatility, and regional disparities in infrastructure development. One of the most pressing concerns is the escalating cost of feed and seed, which can constitute up to 60% of total aquaculture production costs (Mustapha et al., 2013). The rising cost of imported fish feed, particularly for marine aquaculture species, has put financial pressure on small and medium-scale producers. Additionally, land costs and energy expenses have increased, further reducing profit margins.

Market volatility also poses a significant challenge. The shrimp industry, a major export earner, has been highly susceptible to price fluctuations, influenced by currency exchange rates and competition from regional producers such as Thailand and Vietnam. For example, in 2021, global shrimp prices fell by 18%, impacting Malaysian exporters who struggled to remain competitive. This volatility has led to a shift in aquaculture priorities, with many farmers abandoning high-cost freshwater and brackish fish production in favor of seaweed farming. Between 2019 and 2022, seaweed farming accounted for 74% of aquaculture production growth, while the volume of freshwater and brackish fish declined (Department of Fisheries Malaysia, 2022). This shift reflects a response to global market dynamics rather than domestic food security priorities, raising concerns about the long-term stability of Malaysia's fish supply.

Regional disparities in aquaculture infrastructure and market access further widen economic inequalities. Wealthier states such as Selangor, Penang, and Johor benefit from better processing facilities, transportation networks, and investment incentives, enabling them to achieve higher aquaculture productivity. In contrast, states like Kelantan, Terengganu, and Perlis face challenges such as poor infrastructure, inadequate cold chain facilities, and limited access to financing, which hinder their competitiveness. A comparative assessment of these regions highlights the urgent need for policies that promote equitable investment, financial support, and technological transfer to bridge the productivity gap.

## Regulatory and governance challenges

The regulatory environment governing aquaculture in Malaysia presents significant obstacles to sectoral growth, particularly due to compliance burdens, bureaucratic inefficiencies, and gaps in enforcement. While the government has introduced standards such as Good Aquaculture Practice (GAqP) and Malaysian Good Agricultural Practice (MyGAP), adoption rates remain low, particularly among small-scale freshwater aquaculture farmers. A study by Kamaruddin et al. (2023) found that only 37% of freshwater aquaculture farms were compliant with MyGAP standards, largely due to cost barriers and complex certification processes.

Bureaucratic inefficiencies further hinder sectoral growth. Farmers seeking permits and licenses for new aquaculture projects often face lengthy approval processes, delaying investment and increasing operational costs. For example, the process of obtaining GAqP certification can take up to 12 months, discouraging many farmers from pursuing compliance (Kartika et al., 2022). Additionally, inconsistencies in policy implementation across states create regulatory uncertainty, with some regions imposing stricter land use regulations that complicate farm expansion. Streamlining regulatory processes and providing financial incentives for certification compliance will be essential to improving the sector's competitiveness.

## Knowledge and research limitations

Malaysia's aquaculture sector faces significant gaps in research and development (R&D), limiting innovation and sectoral resilience. Although the government periodically releases fishery production reports, the data are often highly aggregated. The absence of household-level microdata restricts understanding of socioeconomic dynamics, preventing targeted interventions for small-scale producers and vulnerable communities.

Compared to neighboring countries such as Thailand and Indonesia, Malaysia's academic research output on aquaculture remains limited. Between 2014 and 2023, Malaysia-affiliated authors contributed only 395 articles to agricultural and biological science

TABLE 3 SWOT analysis of Malaysia's aquaculture policy framework.

| Strength | Weaknesses |
|---|---|
| • Comprehensive Policy Framework: Malaysia's aquaculture policies cover a wide range of areas including sustainability, fish health management, and quality standards, ensuring a holistic approach to sector development.<br>• Strong Private Sector Involvement: Key stakeholders such as Trapia Malaysia, Gold Coin Group, GST Fine Foods, and Malayan Flour Mills Berhad are actively engaged in the sector, driving innovation and investment.<br>• Robust Research Support: Institutions like Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Sains Malaysia (USM), Fisheries Research Institute (FRI), and Malaysian Agricultural Research and Development Institute (MARDI) provide critical research and development support.<br>• Industry Associations: Bodies such as the Malaysian Aquaculture Development Association (MADA) and the Malaysian Fish Farmers' Association (MFFA) advocate for policy support, collaboration, and industry standards. | • Environmental Challenges: Issues such as water quality degradation and habitat loss pose significant threats to sustainable aquaculture practices.<br>• Rural–Urban Disparities: Income growth and opportunities in rural areas lag behind urban regions, creating economic imbalances that affect the aquaculture sector.<br>• Implementation Gaps: There are sometimes inconsistencies and delays in policy implementation, which can hinder the effectiveness of the framework.<br>• Limited Coordination: Coordination among various stakeholders, including government bodies, private sector, and research institutions, can be improved for better policy outcomes. |
| **Opportunities** | **Threats** |
| • Technological Advancements: Adoption of new technologies in fish farming, aquafeed solutions, and monitoring systems can significantly enhance productivity and sustainability.<br>• Global Market Access: Increasing demand for high-quality aquaculture products globally presents opportunities for Malaysian producers to expand their markets.<br>• Sustainable Practices: Emphasizing sustainable and nature-positive practices can attract eco-conscious consumers and investors, boosting the sector's growth.<br>• Public-Private Partnerships: Strengthening partnerships between the public sector, private enterprises, and research institutions can drive innovation and policy effectiveness. | • Climate Change: Adverse climate conditions can impact water resources and fish health, posing risks to aquaculture operations.<br>• Regulatory Challenges: Changes in global trade regulations and standards can affect market access and competitiveness of Malaysian aquaculture products.<br>• Competition: Increasing competition from other aquaculture-producing countries may challenge Malaysia's market position.<br>• Social and Economic Instabilities: Fluctuations in the economy, political instability, and social issues can disrupt the aquaculture sector and affect policy implementation. |

Source: Authors compilation.

journals, a modest share of global research publications in Scopus. Notably, much of this output came from WorldFish, an international research organization headquartered in Malaysia. When excluding WorldFish contributions, Malaysia's independent research on aquaculture lags significantly behind its regional competitors.

Key research gaps include species-specific studies, disease control, and feed technology innovations. Thailand, for instance, has made significant advances in genetic improvement of tilapia, while Indonesia leads in research on shrimp disease management. Malaysia's relative underinvestment in aquaculture R&D has slowed the adoption of advanced breeding techniques, sustainable feed alternatives, and disease mitigation strategies. Successful collaborations, such as Thailand's partnerships between universities and aquaculture firms, demonstrate the potential of public-private research partnerships in driving sectoral innovation. Strengthening academic-industry linkages, increasing research funding, and fostering regional collaboration will be vital in enhancing Malaysia's aquaculture competitiveness.

## Prospect and policy for aquaculture development in Malaysia

As Malaysia's capture fisheries face stagnation due to environmental challenges, overfishing, and climate change, the aquaculture sector presents significant growth potential. The depletion of wild fish stocks, driven by increasing global demand from populous countries such as China and India, underscores the urgent need for sustainable aquaculture practices (Yusoff, 2015). Furthermore, Malaysia's rising urbanization and affluence, combined with a shift toward health-conscious dietary preferences, have fueled domestic demand for aquatic food. Despite this, Malaysia remains below self-sufficiency in fish production, with the self-sufficiency rate declining from 92.7% in 2017 to 90.2% in 2022 (Department of Fisheries Malaysia, 2022). This decline signals the need to expand aquaculture production to meet both domestic food security needs and export market opportunities.

Cultural preferences for high-value aquatic species such as shrimp and grouper, which Malaysia already produces in large volumes, add another dimension to market growth potential. Beyond domestic consumption, expanding intra-regional trade in Southeast Asia has improved market access and logistics, enhancing the movement of fish products across borders. The government's continued support through strategic policies and financial incentives further underscores Malaysia's commitment to strengthening aquaculture as a pillar of food security and economic resilience.

A detailed SWOT analysis of Malaysia's aquaculture policy framework (Table 3) highlights several key strengths and opportunities that reinforce the sector's potential for long-term growth. Malaysia benefits from a strong regulatory framework emphasizing sustainability, fish health management, and quality assurance standards, which provide a solid foundation for expansion (DOFM, 2024). The active participation of private sector stakeholders, including major industry players such as Trapia Malaysia and Malayan Flour Mills, has driven innovation and investment in fish farming

technology, feed formulation, and disease control measures. Additionally, Malaysia's research institutions—including UPM, UMT, and MARDI—have played an instrumental role in technological advancements, while industry associations like MADA and MFFA have contributed to policy advocacy and standardization efforts (MADA, 2023).

Despite these strengths, several persistent challenges continue to hinder the sector's development. Environmental risks, such as water quality degradation, habitat loss, and climate change, pose sustainability threats to aquaculture expansion. Additionally, economic disparities between urban and rural regions make it difficult to attract and retain skilled workers in rural areas, where many aquaculture operations are concentrated (Ministry of Energy Transition and Water Transformation, 2017b). Moreover, gaps in policy implementation and limited coordination among key stakeholders often reduce the effectiveness of existing aquaculture development plans (DOSM, 2023a).

Malaysia's aquaculture sector is poised to benefit from cutting-edge technological innovations that enhance production efficiency, sustainability, and resilience. Key technologies driving the sector's growth include:

1. Biofloc Technology (BFT): A microbial-based system that reduces feed costs and improves water quality, particularly beneficial for shrimp and tilapia farming (FAO, 2021b).
2. Recirculating Aquaculture Systems (RAS): A closed-loop water filtration system that minimizes water usage, making it ideal for urban aquaculture and inland fish farming (MARDI, 2023).
3. Automated Feeding and Monitoring Systems: AI-driven sensor technology and IoT-based monitoring devices optimize feed utilization, detect water quality changes, and reduce operational costs.
4. Genetic Improvement and Selective Breeding: Research-driven genetic enhancement programs have introduced faster-growing and disease-resistant strains of tilapia, catfish, and shrimp, improving yield efficiency.
5. Alternative Aquafeed Sources: The use of insect-based protein, plant-derived feeds, and algae-based nutritional supplements is reducing dependency on imported fishmeal, thereby lowering costs and improving sustainability (FAO, 2021a).

These innovations would provide Malaysia's aquaculture sector with the necessary tools to scale up production, enhance sustainability, and improve product quality for both domestic and export markets.

To counter the decline in Malaysia's self-sufficiency rate, several short- to medium-term interventions are necessary to strengthen the aquaculture sector and ensure a stable domestic fish supply:

1. Expanding Domestic Hatcheries and Seed Supply: Increasing the number of government-supported hatcheries can boost seed availability and reduce reliance on imported fry and fingerlings (DOFM, 2024).
2. Financial Incentives for Small-Scale Aquaculture Farmers: Expanding subsidies, low-interest loans, and grant programs will enable small farmers to adopt new technologies and expand operations.
3. Scaling Up Inland and Land-Based Aquaculture: Encouraging the development of RAS-based farming systems and intensive pond aquaculture can reduce pressure on coastal fish stocks while increasing overall fish output (FAO, 2021a).
4. Strengthening Biosecurity and Disease Control Measures: Investment in vaccines, water treatment innovations, and disease-resistant fish strains will mitigate production losses and enhance sectoral resilience.
5. Improving Market Access and Infrastructure: Strengthening cold chain logistics, distribution networks, and online trade platforms will enhance small-scale producers' access to regional and global markets.

Implementing these strategic interventions can help stabilize aquaculture production, reduce import dependency, and ensure the long-term sustainability of Malaysia's fisheries sector.

While Malaysia's aquaculture sector is well-positioned for growth, several external risks and challenges could hinder its market competitiveness. The impacts of climate change, including water scarcity, disease outbreaks, and unpredictable weather patterns, pose significant risks to fish farming operations. Additionally, regulatory complexities associated with global trade standards can present barriers to export expansion.

Malaysia also faces increasing competition from other aquaculture-exporting nations, such as Thailand, Indonesia, and Vietnam, which have stronger research capabilities, lower production costs, and more extensive export networks (DOSM, 2023b). Socioeconomic instability, fluctuations in feed prices, and currency exchange rates can further impact Malaysia's ability to compete in international markets. Addressing these challenges requires a long-term strategic vision that integrates sustainability, trade policy reforms, and market diversification strategies.

## Conclusion

This study has provided an in-depth overview of Malaysia's fisheries and aquaculture sectors, highlighting their role in national food security, economic growth, and rural livelihoods. While capture fisheries continue to play an important role, they face growing limitations due to overexploitation, illegal fishing, and production stagnation. Conversely, aquaculture presents significant potential for expansion, but it is constrained by environmental risks, regulatory challenges, and structural inefficiencies. To fully realize the potential of aquaculture as a sustainable solution to Malaysia's seafood demand, targeted policy interventions, technological advancements, and stronger institutional coordination are essential.

To address the decline in self-sufficiency, reverse stagnation in capture fisheries, and strengthen the role of aquaculture, the following strategic measures should be prioritized:

- Advancing Sustainable Aquaculture Technologies: The adoption of Recirculating Aquaculture Systems (RAS), Biofloc Technology (BFT), and AI-driven automated monitoring can enhance production efficiency, improve water management, and reduce disease outbreaks. Expanding the use of alternative aquafeeds, such as insect- and plant-based proteins, can lower dependency

on imported fishmeal, making aquaculture more cost-effective and environmentally sustainable.

- Strengthening Research and Development (R&D) Initiatives: Investment in R&D can drive innovation in fish breeding, disease prevention, and sustainable aquaculture systems. Expanding genetic research for disease-resistant fish strains and improving hatchery technology will ensure stable and high-quality production. Additionally, greater collaboration between government agencies, universities, and private-sector players will bridge knowledge gaps and improve industry-wide best practices.
- Enhancing Stakeholder Coordination and Institutional Support: The effectiveness of Malaysia's aquaculture policies depends on the alignment of government agencies, industry associations, and research institutions. Committees such as the National Aquaculture Development Committee (NADC) and Malaysian Fisheries Development Authority (LKIM) should play a more active role in policy implementation and farmer support. The Aquaculture Industry Development Working Group (AIDWG) should be further strengthened to facilitate collaboration among key stakeholders. Improving policy coordination and reducing bureaucratic inefficiencies will encourage private-sector investment and ensure smooth regulatory compliance.
- Mitigating Disease Risks and Strengthening Biosecurity Measures: Disease outbreaks remain one of the biggest threats to aquaculture sustainability. Establishing comprehensive disease-monitoring frameworks, including early detection programs, emergency response strategies, and enhanced biosecurity measures, will stabilize aquaculture production and reduce economic losses. Supporting farmers with disease-resistant strains and improved water management technologies will further mitigate risks.
- Improving Economic Support and Market Access: Expanding financial incentives, including targeted subsidies and low-interest loans, will increase investment in aquaculture infrastructure and allow small- and medium-scale farmers to adopt modern techniques. Strengthening domestic and export market access through enhanced cold chain logistics, improved trade agreements, and digital marketplace platforms will ensure higher profitability and competitiveness in global seafood markets.

By implementing these strategic measures, Malaysia can stabilize its self-sufficiency rate, enhance aquaculture productivity, and improve the economic sustainability of the fisheries sector. Moving forward, technological innovation, strong policy frameworks, and effective multi-stakeholder engagement will be critical in positioning aquaculture as a leading driver of Malaysia's food security and economic growth.

## Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://www.dof.gov.my/.

## Author contributions

CO: Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. EB: Investigation, Methodology, Writing – review & editing. TM: Data curation, Formal analysis, Writing – review & editing. ST: Data curation, Formal analysis, Writing – review & editing. SW: Data curation, Formal analysis, Writing – review & editing. CR: Conceptualization, Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing.

## Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was undertaken and funded as part of the CGIAR Research Initiative on Aquatic Foods and the CGIAR Research Program on Sustainable Animal and Aquatic Food Systems, both supported by CGIAR Trust Fund donors.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

## Publisher's note



## References

Afriansyah, A., Solihin, A., Bilqis, A., Prasetya, J. H., Tania, C., Hidayatulloh, A., et al. (2024). Tougher evidence-based policy does matter: deterring illegal fishing in the Arafura and Timor seas. *Coast. Manag.* 52, 112–126. doi: 10.1080/08920753.2024.2370062

Baag, S., and Mandal, S. (2022). Combined effects of ocean warming and acidification on marine fish and shellfish: a molecule to ecosystem perspective. *Sci. Total Environ.* 802:149807. doi: 10.1016/j.scitotenv.2021.149807

Chowdhury, A. J. K., John, A., Abdullah, R., Musa, N., and Ashraf, M. A. (2021). Impact of COVID-19 on aquaculture and fisheries in ASEAN countries: some aspects of challenges, mitigations for future strategies in Malaysia. *Desalin. Water Treat.* 241, 331–339. doi: 10.5004/dwt.2021.27792

Dauda, A. B., Natrah, I., Karim, M., Kamarudin, M. S., and Bichi, A. U. H. (2018). African catfish aquaculture in Malaysia and Nigeria: status, trends and prospects. *Fish. Aquac. J.* 9, 1–5. doi: 10.4172/2150-3508.1000237

Department of Fisheries Malaysia. (1971). National Agricultural Policy. Available online at: https://ekonomi.gov.my/sites/default/files/2020-03/Bahagian%20Satu%20%E2%80%93%20Sedekad%20Pembangunan%20di%20Bawah%20Dasar%20Ekonomi%20Baru%2C%201971-90.pdf

Department of Fisheries Malaysia. (1975). Annual fisheries report. Available online at: https://www.pmo.gov.my/dokumenattached/RMK/RM4.pdf

Department of Fisheries Malaysia. (2005). Fish health management guidelines. Available online at: https://ekonomi.gov.my/sites/default/files/2020-08/Chapter%20X%20-%20Agriculture%20and%20Rural%20Development.pdf

Department of Fisheries Malaysia. (2019a). Annual fisheries statistics report: Illegal, unreported, and unregulated (IUU) fishing in Malaysia. Department of Fisheries Malaysia. Available online at: https://repository.seafdec.org/bitstream/handle/20.500.12066/7070/6.1.1.pdf

Department of Fisheries Malaysia. (2022). Fisheries statistics I. Available online at: DOF.GOV.MY

Department of Fisheries Malaysia. (2019b). Annual fisheries statistics book(Volume 1). Available online at: https://ekkowunwkmj.exactdn.com/wp-content/uploads/2019/12/Perangkaan-Perikanan-Tahunan-2019-Jilid-1.zip

Department of Statistics, Malaysia. (2023). Poverty in Malaysia 2022. Available at: https://www.dosm.gov.my.

DOF. (2023). Annual fisheries statistics 2022 (volume 1). Available online at: https://ekkowunwkmj.exactdn.com/wp-content/uploads/2023/07/perangkaan-perikanan-2022-jilid-1-9.zip

DOFM. (2024). Demographic statistics Malaysia fourth quarter 2023. Available online at: https://www.dosm.gov.my/portal-main/release-document-log?release_document_id=8286&cat=stats_alert&type=pdf

DOSM. (2023a). Highlights: income expenditure poverty inequality. Available online at: https://www.dosm.gov.my/uploads/release-content/file_20230808214211.pdf

DOSM. (2023b). Labour force statistics report.

Emam, M. A., Leibrecht, M., and Chen, T. (2021). Fish exports and the growth of the agricultural sector: the case of south and southeast asian countries. *Sustain. For.* 13:11177. doi: 10.3390/su132011177

Escamilla-Pérez, B. E., Ortiz-Lozano, L., Molina-Rosales, D. O., and Espinoza-Tenorio, A. (2021). Cultural importance of marine resources subject to fishing exploitation in coastal communities of Southwest Gulf of Mexico. *Ocean Coastal Manag.* 208:105605. doi: 10.1016/j.ocecoaman.2021.105605

Fabinyi, M., Belton, B., Dressler, W. H., Knudsen, M., Adhuri, D. S., Aziz, A. A., et al. (2022). Coastal transitions: small-scale fisheries, livelihoods, and maritime zone developments in Southeast Asia. *J. Rural. Stud.* 91, 184–194. doi: 10.1016/j.jrurstud.2022.02.006

FAO. (1983). Aquaculture Development Program. Available online at: https://digitallibrary.un.org/record/3933884/files/b6720e.pdf

FAO. (1995). Integrated shrimp farming. Available online at: https://documents1.worldbank.org/curated/ar/839661468758680322/pdf/307820Malaysia01see0also0307591.pdf

FAO. (2020). Aquaculture innovations in Malaysia. Available online at: https://documents1.worldbank.org/curated/zh/617611574179512389/pdf/Agricultural-Transformation-and-Inclusive-Growth-The-Malaysian-Experience.pdf

FAO. (2021a). The state of food security and nutrition in the world 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Rome: FAO.

FAO (2021b). The state of world fisheries and aquaculture 2020. Rome: FAO.

FAO. (2022). The state of world fisheries and aquaculture 2022. Towards Blue Transformation. Rome: FAO.

FAO. (2023). Fishery and aquaculture statistics. Global production by production source 1990 - 2022 (Fishstatj). Available online at: www.fao.org/fishery/statistics/software/fishstatj/en

FAO. (2024). National Aquaculture Sector Overview, Malaysia. Text by Mazuki Hashim. Available online at: https://www.fao.org/fishery/en/countrysector/naso_malaysia%0A%0A (Accessed February 19, 2024).

Fathi, S., Harun, A. N., Rambat, S., and Tukiran, N. A. (2018). Current issues in aquaculture: lessons from Malaysia. *Adv. Sci. Lett.* 24, 503–505. doi: 10.1166/asl.2018.12051

Firth, R. (1966). Malay fishermen their peasant economy. The Shoestring Press, Connecticut, U.S.: Archon Books, 398.

Goh, E. V., Azam Ali, S., Roy Mitra, S., and McCullough, F. (2021). Understanding the patterns of fish and seafood consumption and its nutritional roles among a Malaysian population to inform sustainable development. *Asia Pacific J. Sustainable Agriculture Food Energy* 9, 1–13. doi: 10.36782/apjsafe.v9i1.86

Government of Malaysia. (1986). Economic recovery plan (ERP). Available online at: https://ekonomi.gov.my/en/economic-developments/development-plans/rmk/fifth-malaysia-plan-1986-1990

Government of Malaysia. (2011). National agro-food policy (NAFP) 2011–2020. Available online at: https://documents1.worldbank.org/curated/zh/617611574179512389/pdf/Agricultural-Transformation-and-Inclusive-Growth-The-Malaysian-Experience.pdf

Hashim, Z. H., Azra, M. N., Noor, M. I. M., Kasan, N. A., and Tan, S. H. (2020). Impact of COVID-19 on marine fisheries supply chains: Case study of Malaysia. *Adv. Food Sci. Sustain.* 6, 169–210. doi: 10.1016/bs.af2s.2021.08.002

Institute for Public Health (2023). Technical report National Health and morbidity survey (NHMS) 2022. Malaysia: Maternal and Child Health.

Jumatli, A., and Ismail, M. S. (2021). "Promotion of sustainable aquaculture in Malaysia" in Promotion of sustainable aquaculture, aquatic animal health, and resource enhancement in Southeast Asia: Proceedings of the international workshop on the promotion of sustainable aquaculture, aquatic animal health, and resource enhancement in Southeast Asia. eds. F. A. Aya, S. L. De La Peña and E. A. Tendencia (Tigbauan, Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center), 31–40.

Kamaruddin, R., Samah, R., Soon, J. J., Musa, R., and Nur Amin, N. A. (2023). Consumers' preference and willingness-to-pay for GAqP-compliant farmed fish produce: evidence from Malaysia. *Aquaculture* 568:739305. doi: 10.1016/j.aquaculture.2023.739305

Kartika, B., Parson, S. W., Kassim, Z., and Khan Chowdhury, A. J. (2022). Overview of halal freshewater aquaculture system: Malaysian perspective. *Water Conservation Management* 6, 01–05. doi: 10.26480/wcm.01.2022.01.05

Kurniawan, S. B., Ahmad, A., Rahim, N. F. M., Said, N. S. M., Alnawajha, M. M., Imron, M. F., et al. (2021). Aquaculture in Malaysia: water-related environmental challenges and opportunities for cleaner production. *Environ. Technol. Innov.* 24:101913. doi: 10.1016/j.eti.2021.101913

MADA (2023). Strategic plan 2023–2028. Kuala Lumpur: MADA.

Mansfield, E. J., Micheli, F., Fujita, R., Fulton, E. A., Gelcich, S., Battista, W., et al. (2024). Anticipating trade-offs and promoting synergies between small-scale fisheries and aquaculture to improve social, economic, and ecological outcomes. *NPJ Ocean Sustainability* 3:1. doi: 10.1038/s44183-023-00035-5

MARDI (2023). Annual report 2023. Serdang: MARDI.

Ministry of Energy Transition and Water Transformation. (2017a). Department of Irrigation and Drainage (coastal management). Retrieved March 19, 2024, from https://www.water.gov.my/index.php/pages/view/515?mid=290

Ministry of Energy Transition and Water Transformation (2017b). National Water Resources Policy. Putrajaya: Government of Malaysia.

Mustafa, M. G., Hamli, H., Rahim, K. A. A., and Rajaee, A. H. (2021). Status and trends in coastal fishery resources of Sarawak, Malaysia – a focus on a tropical deltaic estuary. *AACL Bioflux* 14, 2728–2740.

Mustapha, N. H. N., Aziz, A. A., and Hashim, N. M. H. (2013). Technical efficiency in aquaculture industry using data envelopment analysis (DEA) window: evidences from Malaysia. *J. Sustain. Sci. Manag.* 8, 137–149.

Reardon, T., Tschirley, D., Dolislager, M., Snyder, J., Hu, C., and White, S. (2014). Urbanization, diet change, and transformation of food supply chains in Asia. Michigan: Global Center for Food Systems Innovation, 46.

Soh, B. H., Lim, G.-T., and Chua, S. Y. (2021). Competitiveness of Malaysian fisheries exports: a constant market share analysis. *Malays. J. Econ. Stud.* 58, 175–198. doi: 10.3316/informit.262700594205680

Tan, S. Y., Sethupathi, S., Leong, K. H., and Ahmad, T. (2024). Challenges and opportunities in sustaining aquaculture industry in Malaysia. *Aquac. Int.* 32, 489–519. doi: 10.1007/s10499-023-01173-w

United Nations, Department of Economic and Social Affairs, Population Division (2018). World urbanization prospects: the 2018 revision, custom data acquired via website.

Vickram, D. R., and Srivastava, P. (2024). "Promoting Agroecology and sustainable fisheries for achieving food security" in Nature-based solutions in achieving sustainable development goals: Harmonizing nature and Progress (Springer Nature Switzerland: Cham), 41–62.

Williamson, P., and Guinder, V. A. (2020). Effect of climate change on marine ecosystems. *The Impacts of Climate Change*, 115–176. doi: 10.1016/B978-0-12-822373-4.00024-0

Yusoff, A. (2015). "Status of resource management and aquaculture in Malaysia" in Resource enhancement and sustainable aquaculture practices in Southeast Asia: Challenges in responsible production of aquatic species: Proceedings of the international workshop on resource enhancement and sustainable aquaculture practices in Southeast Asia 2014 (RESA). eds. M. R. R. Romana-Eguia, F. D. Parado-Estepa, N. D. Salayo and M. J. H. Lebata-Ramos (Tigbauan, Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center), 53–65.

Zhang, K., Li, J., Hou, G., Huang, Z., Shi, D., Chen, Z., et al. (2021). Length-based assessment of fish stocks in a data-poor, jointly exploited (China and Vietnam) fishing ground, northern South China Sea. *Front. Mar. Sci.* 8:718052. doi: 10.3389/fmars.2021.718052