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Analysing Consequences of Aquaculture in Coastal Water Bodies of Ba Ria– Vung Tau, Vietnam on Sustainable Development Goals for Environmental Management

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aquaculture is vital for global food security and economic growth, particularly in coastal regions like Ba Ria – Vung Tau, Vietnam. This province has seen significant aquaculture growth, with production rising from 10,687 tons in 2010 to 20,486 tons in 2022. Key species farmed include brackish water shrimp, marine finfish, and mollusks, using methods such as cage culture, pond farming, and Integrated Multi-Trophic Aquaculture (IMTA). However, aquaculture poses environmental challenges, including conflicts over coastal space, waste management, and habitat

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degradation. Species like oysters and mussels help improve water quality and support balanced ecosystems, while marine finfish farming can cause nutrient overload and eutrophication. Sustainable practices like IMTA, waste management, and sustainable feed use are essential to mitigate these impacts. Aligning aquaculture with Sustainable Development Goals (SDGs), especially SDG 14 (Life Below Water), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action), is crucial for sustainable coastal management. This requires robust regulations, multi-stakeholder collaboration, and the integration of scientific research into policy. By ensuring aquaculture practices support SDGs, Ba Ria – Vung Tau can enhance environmental stewardship, economic resilience, and the sustainable coexistence of human activities with marine ecosystems.

Keywords: SDG; aquaculture; environmental management; mitigated impact; coastal waters; Ba Ria – Vung Tau.

1. INTRODUCTION

In recent decades, aquaculture has emerged as a vital component of global food security and economic development, particularly in regions endowed with abundant coastal resources[1,2,3]. Ba Ria – Vung Tau, a province nestled along the southeastern coast of Vietnam, stands as a prime example of such a region, where aquaculture plays a pivotal role in the local economy and livelihoods of coastal communities [4]. However, alongside its economic benefits, aquaculture brings forth a myriad of environmental implications [5] that warrant careful consideration and management to ensure the sustainable development of coastal ecosystems [4].

This discussion aims to delve into the consequences of aquaculture activities in the coastal waters of Ba Ria – Vung Tau, examining their intricate interplay with the Sustainable Development Goals (SDGs) for environmental management. As nations worldwide strive to achieve the SDGs set forth by the United Nations [6], understanding the implications of aquaculture on these goals becomes imperative, particularly in regions where its impact is pronounced.

Throughout this discourse, we will navigate through the complexities of aquaculture in Ba Ria – Vung Tau, scrutinizing its effects on marine biodiversity, water quality, coastal ecosystems, and the broader socio-economic fabric of the region. By contextualizing these impacts within the framework of the SDGs, we seek to elucidate both the challenges and opportunities that arise at the nexus of aquaculture and sustainable development.

Moreover, this discussion aspires to foster dialogue among policymakers, researchers, industry stakeholders, and local communities, aiming to chart a path toward more sustainable aquaculture practices in Ba Ria – Vung Tau. By synthesizing diverse perspectives and harnessing collective expertise, we endeavor to identify actionable strategies and policy interventions that align with the principles of environmental stewardship and inclusive development.

This paper is emphasized the importance of adopting a holistic approach to aquaculture management that prioritizes environmental sustainability, social equity, and economic resilience. By critically examining the consequences of aquaculture in coastal waters of Ba Ria – Vung Tau through the lens of the SDGs, we aspire to pave the way for a more harmonious coexistence between human activities and marine ecosystems, thereby advancing the cause of sustainable development in the region and beyond [2,7,8].

2. BACKGROUND OF AQUACULTURE VS. SDG

Aquaculture's contribution to achieving the SDGs is a complex and multifaceted subject, dependent on various species, systems, and contexts in which it operates [7]. It is not merely about cultivating fish and seafood but about understanding the intricate relationships that link aquaculture to value chains, product markets, national economies, and socio-economic structures. Governance also plays a pivotal role in determining how aquaculture can be harnessed to meet global development objectives. To fully grasp the potential of aquaculture in contributing to the SDGs (Fig. 1), it is necessary to unpack its diverse functions and the values it generates across different spatial and temporal scales.

One of the most pressing challenges facing the world today is how to sustainably feed a growing population. The United Nations projects that the global population will reach 9.8 billion by 2050 [9], which will place enormous pressure on the planet's resources. Aquaculture, the farming of aquatic organisms such as fish, crustaceans, mollusks, and aquatic plants, presents a promising solution to this challenge [1]. By providing a reliable source of high-quality protein, aquaculture can play a significant role in addressing SDG 2: Zero Hunger. This goal aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture. Aquaculture's ability to produce large quantities of nutritious food in a relatively small area makes it a key player in global efforts to combat hunger and malnutrition.

The sustainable production of fish and seafood is particularly important in the context of global food security. Fish is one of the most nutrient-rich foods available, providing essential omega-3 fatty acids, high-quality protein, vitamins, and minerals [10]. These nutrients are crucial for human health, particularly in developing countries where diets may be deficient in essential nutrients. By increasing the availability and accessibility of fish and seafood, aquaculture can help improve nutrition and reduce the prevalence of malnutrition and related health issues [11]. This directly supports SDG 3: Good Health and Well-being, which seeks to ensure healthy lives and promote well-being for all at all ages.

However, aquaculture's contribution to the SDGs is not uniform and varies depending on the species being farmed, the systems used, and the socio-economic and environmental contexts in which it operates [12,13]. The farming of certain species, such as carnivorous fish, may require large amounts of feed, often derived from wild fish stocks, which can have negative environmental impacts and reduce the overall

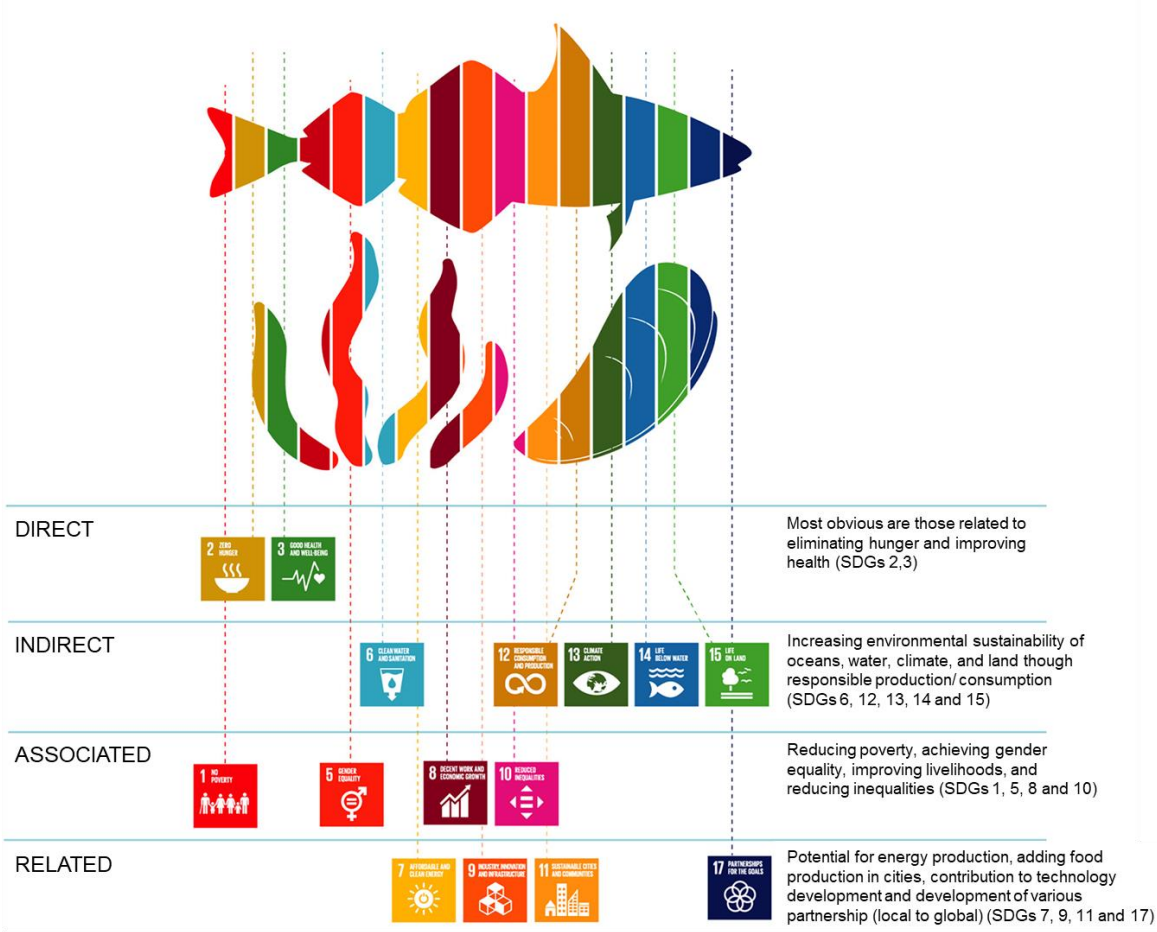

Fig. 1. Aquaculture's main contributions to the Sustainable Development Goals [7]

sustainability of the system [14]. In contrast, farming herbivorous or omnivorous species, or those that require little to no external feed inputs, such as bivalves and seaweed, can be more sustainable and have a lower environmental footprint [15,16,17].

The systems used in aquaculture also play a critical role in determining its sustainability and contribution to the SDGs [18]. Traditional open-water systems, such as net pens and cages, can be associated with environmental challenges, including water pollution, habitat degradation, and the spread of diseases to wild fish populations. On the other hand, more advanced systems, such as recirculating aquaculture systems (RAS), integrated multi-trophic aquaculture (IMTA), and land-based aquaculture, offer greater control over environmental impacts and can be more sustainable in the long run [19]. These systems allow for better waste management, reduced water usage, and the potential for more efficient resource use, making them more aligned with the principles of sustainable development.

The context in which aquaculture operates is also crucial in determining its contribution to the SDGs. In developing countries, where food insecurity and poverty are more prevalent, aquaculture can play a transformative role in improving livelihoods and promoting economic development [20]. Small-scale aquaculture operations, in particular, can provide income and employment opportunities for rural communities, contributing to poverty reduction and social equity [21]. These operations often involve family-based farming practices, which can empower women and other marginalized groups by providing them with economic opportunities and greater control over household resources [22]. This supports several SDGs, including SDG 1: No Poverty, SDG 5: Gender Equality, and SDG 8: Decent Work and Economic Growth.

In contrast, large-scale commercial aquaculture operations, while contributing to national economies and global food production, may not always deliver the same social benefits [1,23]. In some cases, these operations can lead to the displacement of local communities, loss of traditional livelihoods, and environmental degradation [7,24]. Therefore, it is essential to consider the social and environmental context in which aquaculture operates to ensure that its benefits are equitably distributed and that it contributes to sustainable development in a holistic manner.

The value chains associated with aquaculture also play a significant role in determining its contribution to the SDGs [25,26]. Value chains encompass the entire process from production to processing, distribution, and consumption of aquaculture products. A well-functioning value chain can ensure that aquaculture products reach a broad market, providing income and employment opportunities along the way [27]. However, value chains can also be complex and may involve multiple stakeholders, each with different interests and levels of power [26,28]. Ensuring that value chains are inclusive and benefit small-scale producers and vulnerable groups is essential for maximizing aquaculture's contribution to the SDGs.

Product markets, whether targeting exports or domestic consumption, significantly impact aquaculture's role in sustainable development. In many developing nations, a large share of aquaculture production is aimed at export markets, generating valuable foreign exchange and boosting national economic growth. However, this reliance on exports can expose producers to global market fluctuations, threatening local food security and economic stability. Conversely, fostering robust domestic markets can distribute the benefits of aquaculture more widely, enhancing local food security and nutrition [7,13,29,30]. Governments play a crucial role in this process through policies, regulations, and investments that promote sustainable practices and equitable distribution of benefits [31].

Socioeconomic structures and the fabric of society also influence aquaculture's contribution to the SDGs. In societies with high levels of inequality, wealth, resources, and power are often concentrated in the hands of a small, privileged group, while the majority of the population has limited access to these benefits. When aquaculture is introduced in such a context, the economic gains, such as profits from fish or shrimp farming, may primarily benefit those who already have the capital, land, or connections to invest in and control the industry [32,33]. Ensuring that aquaculture development is inclusive and benefits all members of society is essential for achieving the SDGs [7]. This requires a focus on social equity, gender equality, and the empowerment of marginalized

groups, as well as efforts to reduce poverty and promote decent work and economic growth.

Aquaculture has the potential to make significant contributions to the SDGs, particularly SDG 2: Zero Hunger and SDG 3: Good Health and Well-being [7,34]. However, realizing this potential requires a nuanced understanding of the diverse functions and values generated by aquaculture across different species, systems, and contexts. By considering the entire value chain, from production to consumption, and ensuring that aquaculture is developed in a socially and environmentally sustainable manner, it is possible to harness its full potential to contribute to global food security, nutrition, and sustainable development [35].

3. OVERVIEW OF AQUACULTURE IN BA RIA – VUNG TAU

3.1 Production

During the 2010-2020 period, total aquaculture production increased from 10.687 tonnes (in 2010) to 20.486 tonnes (in 2022). Production of fish increased from 2010 to 2018 and decreased in 2019 and recovered again in the following years. Production of shrimp has increased trend although a decrease in production was observed in 2011 and 2014 because of the disease outbreak. In addition, the structural shift in aquaculture and the production volume of other species have also contributed to the increase in aquaculture production of these species during the 2019-2020 period (Fig. 2).

3.2 Total Aquaculture Area

The aquaculture area in Ba Ria – Vung Tau fluctuated slightly, ranging from 6.7 to 7.1 thousand hectares, accounting for approximately 0.59-0.68% of the total aquaculture area in the country. Specifically, according to 2020 data, the aquaculture area is divided into districts and cities as shown in Table 1. The area allocated for aquaculture according to the plan is 5,562 hectares with an additional 1,201 hectares used for integrated farming. Among this, the area for brackish water aquaculture is 3,863 hectares, with 392 hectares using high technology for aquaculture. The area for brackish and seawater fish farming is 358 hectares, the mollusk farming area is 205 hectares, and the sea cage farming area is 174 hectares with a total of 12,702 cages. The production of brackish and seawater aquaculture reached 10,833 tons, whereas sea farming produced 3,504 tons, primarily concentrated in coastal districts and cities.

3.3 Culture Form and Species

In Ba Ria – Vung Tau, various forms of aquaculture culture along the coastal areas and open sea. Shrimp farming in coastal ponds ranges from super intensive farming to semi-extensive farming (shrimp farming combined with mangrove), suspended rope culture for mollusks, and cage farming for fish, lobsters, and mollusks. The various forms and species of coastal aquaculture are summarized in Table 2. Major aquaculture areas distributed in the Dinh, Cha Va, Mo Nhat, Co May Rivers, located in Ba Ria City, Vung Tau City, Phu My Town and Long Son district, primarily featuring extensive brackish water shrimp farming and mollusk farming on land, whereas cage farming and mollusk farming are prevalent on rivers and estuaries. Although the coastal aquaculture zoning plan has been implemented since 2021, the development process still faces many challenges related to farming zones, farming methods, techniques, seed quality, feed, waste management, and environmental protection.

Table 1. The aquaculture area by district in Ba Ria – Vung Tau in 2020

No	District	Area (ha)	Percentage (%)
1	Con Dao	1	0.02
2	Chau Duc	184	3.30
3	Dat Do	745	13.40
4	Long Dien	505	9.08
5	Xuyen Moc	609	10.95
6	Phu My	693	12.47
7	Ba Ria City	1,275	22.92
8	Vung Tau City	1,549	27.86
	Total	**5,562**	**100,00**

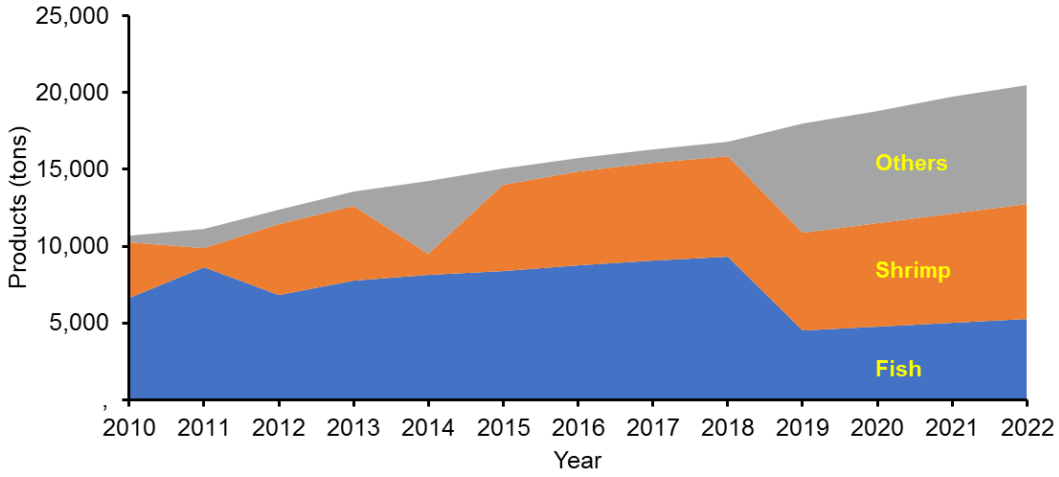

Fig. 2. The fluctuations in aquaculture production in Ba Ria – Vung Tau [4]

4. EFFECTS OF AQUACULTURE ON ENVIRONMENTAL CARRYING CAPACITY IN BA RIA – VUNG TAU

4.1 Culture of Filter Species

Filter species such as oysters and mussels, cultivated in Vung Tau, provide numerous benefits that enhance the environmental carrying capacity of aquaculture systems. Bivalves filter large volumes of water as they feed on plankton and organic particles, which helps reduce suspended solids, improve water clarity, and decrease turbidity, creating a healthier environment for other aquaculture species. Additionally, bivalves absorb excess nutrients like nitrogen and phosphorus, common by-products of other aquaculture operations. By removing these nutrients, they help prevent eutrophication and harmful algal blooms, maintaining a balanced ecosystem.

Through their filtration of organic matter and reduction of algal blooms, bivalves also help maintain higher dissolved oxygen levels in the water, which is essential for the survival and growth of many aquaculture species. Furthermore, bivalves produce bio-deposits (feces and pseudo-feces) that settle on the seafloor and can be broken down by benthic organisms, naturally managing waste and reducing the accumulation of organic matter, thereby helping to maintain a clean and healthy environment.

In the IMTA systems, bivalves serve as natural biofilters, cleaning the water of waste products generated by other cultured species, such as fish or shrimp. This integration boosts resource efficiency, enhances overall productivity, and reduces the need for artificial filtration systems. Improved water quality and environmental conditions resulting from bivalve filtration can also reduce the need for expensive water treatment and management interventions, thereby lowering operational costs and increasing the economic viability of aquaculture operations [19,36,37].

Moreover, bivalves contribute to carbon sequestration by incorporating carbon into their shells and tissues, which helps mitigate climate change by reducing the amount of carbon dioxide in the water and atmosphere, indirectly supporting a more stable aquaculture environment.

In summary, filter species cultivated in Vung Tau significantly enhance the environmental carrying capacity of aquaculture systems by improving water quality, nutrient cycling, and ecosystem health. These benefits support higher stocking densities, enable diverse aquaculture practices, and promote more sustainable and economically viable operations. Therefore, it is recommended to increase the total area dedicated to the culture of filter species in Ba Ria – Vung Tau.

4.2 Culture of Marine Finfishes and Lobster

Marine fish cultured in Ba Ria – Vung Tau included various species such as Cobia, Barramundi, Red snapper, Pompano, Golden rabbitfish. Lobsters cultured in Ba Ria – Vung Tau included ornate spiny lobster and scalloped

Table 2. Features of aquaculture practices in coastal areas of Ba Ria – Vung Tau province, Vietnam [4]

Culture species		Form of farming	Seed sources	Seed sizes (cm)	Market sizes (kg)	Feed used	Supporting information
Fish	Cobia	Cages	Domestic: Khanh Hoa, Ninh Thuan, Binh Thuan, Ba Ria – Vung Tau	8-20	3-10	Pellet, Trash fish	>3 kg
	Barramundi	Cages	Domestic: Khanh Hoa, Ninh Thuan, Binh Thuan, Ba Ria – Vung Tau	5-10	0.5-1.5	Pellet, Trash fish	
	Pompano	Cages	Domestic: Khanh Hoa, Ninh Thuan, Ba Ria – Vung Tau Imported: China	3-8 3-5	0.5-1.5	Pellet, Trash fish	>0.5 kg
	Rabbitfishes	Cages	Domestic: Khanh Hoa	2-5	0.3-0.5	Pellet, Trash fish	Seed collected from nature
	Red snapper	Cages	Domestic: Khanh Hoa Imported: Taiwan	5-10	0.5-2.0	Pellet, Trash fish	>0.5 kg
	Grouper	Cages	Domestic: Khanh Hoa, Ninh Thuan, Binh Thuan, Imported: Taiwan, Indonesia, Malaysia	6-12 4-6	0.8-1.5	Pellet, Trash fish	>0.8 kg
Shrimp	Penaeid shrimp White leg shrimp	Ponds	Domestic: Khanh Hoa, Binh Thuan, Ba Ria – Vung Tau Imported: Indonesia	Post larvae 10 days		Pellet, Trash fish	
Lobster	Lobster	Cages	Domestic: Binh Thuan Imported: Indonesia	6-8	*Panulirus homarus*: > 0.2 kg *Panulirus ornatus*: > 0.8kg	Trash fish, pellet	Seed collected from nature
Bivalvia	Oyster, mussels	Raft, longline, and rack	Domestic: Khanh Hoa	0.7-1	10-22 Inds/kg	Natural	

spiny lobster. For the marine fish culture, pellet food was mainly used whereas trash fish was used as food for lobster culture. The culture of marine finfish and lobster in Vung Tau can have significant effects on the environmental carrying capacity of aquaculture systems. These effects can be both positive and negative, depending on the practices used and the management of the operations.

Waste production is one of the most concerning effects of marine fish and lobster farms in Ba Ria – Vung Tau aquaculture area. These farms produce waste in the form of uneaten feed, feces, and metabolic by-products, which can accumulate in the water and sediments below the farm. This organic waste increases nutrient levels, particularly nitrogen and phosphorus, leading to eutrophication. The larger amount of waste production when trash-fish was used as food for lobster compared to pellet food for marine finfish culture. The nutrient loading has elevated nutrient levels which stimulate the growth of phytoplankton and harmful algal blooms (HABs), which can deplete oxygen levels in the water and release toxins, harming marine life and aquaculture species. This may be the main reason for the mass mortality of the fish cultured in Ba Ria – Vung Tau in 2016 – 2017. The decomposition of organic waste and increased biological activity from nutrient loading can deplete dissolved oxygen levels in the water, creating hypoxic conditions that are stressful or lethal to aquatic organisms. In addition, intensive marine fish culture often involves high stocking densities, which can facilitate the spread of diseases and parasites among cultured fish and wild populations. This can lead to outbreaks that are difficult to control and may require the use of chemicals and antibiotics, further impacting the environment. The fish disease has often outbreaks at aquaculture in Ba Ria – Vung Tau in the past ten years mostly related to the increasing nutrient loading into the culture areas. On the other hand, when the disease occurs, the farmers use chemicals, and antibiotics to control it. This can lead to the accumulation of these substances in the surrounding environment, potentially harming non-target species and disrupting ecosystems. The installation of fish cages and other infrastructure can alter natural habitats, disrupt local ecosystems, and impact biodiversity.

However, the culture of marine fish and lobster in Ba Ria – Vung Tau also has some positive effects on the environment and economy. When marine fish culture is integrated with other species such as bivalves, waste products from fish can be utilized as nutrients by these filter feeders [19,36,37]. This approach can help mitigate nutrient loading and improve overall water quality, enhancing the environmental carrying capacity. With proper management and sustainable practices, marine fish culture can provide significant economic benefits and contribute to global food security. Sustainable practices include optimizing feed efficiency, using environmentally friendly feed, and implementing effective waste management systems.

To minimize the negative impacts and enhance the positive effects of marine fish culture on the environmental carrying capacity of aquaculture systems, several strategies can be implemented. It is recommended using high-quality, low-pollution feeds that are efficiently converted into fish biomass can reduce waste production [38]. Another strategy is choosing appropriate sites with good water circulation and away from sensitive habitats can minimize environmental impacts. Good aquaculture practices should be applied such as maintaining optimal stocking densities can reduce the risk of disease outbreaks and minimize environmental stress. In addition, implementing waste collection and treatment systems, such as sediment traps, can help manage organic waste and nutrients. In the long term, regular environmental monitoring and strict regulatory frameworks can ensure that aquaculture practices do not exceed the carrying capacity of the local environment.

Therefore, marine fish and lobster culture in Ba Ria – Vung Tau can significantly impact the environmental carrying capacity of aquaculture systems. Whereas it poses several challenges related to nutrient loading, oxygen depletion, disease transmission, chemical use, and habitat degradation, these can be mitigated through sustainable practices, integrated aquaculture approaches, and effective management strategies [39].

5. ALIGNING AQUACULTURE WITH SDGS FOR ENVIRONMENTAL MANAGEMENT

Aligning aquaculture with the SDGs is essential for promoting environmental management and ensuring the long-term sustainability of coastal and marine ecosystems [7,40]. Aquaculture, the farming of fish, shellfish, and aquatic plants, has

become a critical component of global food production, contributing to food security, livelihoods, and economic development. However, its rapid expansion has also raised concerns about environmental degradation, including habitat destruction, water pollution, and biodiversity loss. To address these challenges, it is vital to align aquaculture practices with the SDGs, particularly those related to life below water (SDG 14), responsible consumption and production (SDG 12), and climate action (SDG 13) [7,41].

The relevance of various SDGs to aquaculture and coastal management cannot be overstated. SDG 14, which focuses on conserving and sustainably using the oceans, seas, and marine resources, is directly connected to aquaculture. Sustainable aquaculture practices can help reduce the pressure on wild fish stocks by providing an alternative source of seafood. However, if not managed properly, aquaculture can contribute to the overexploitation of resources, pollution, and habitat destruction. Therefore, aligning aquaculture with SDG 14 involves promoting practices that protect marine ecosystems [7,42], such as adopting integrated multi-trophic aquaculture (IMTA) [37,43], which mimics natural ecosystems by farming multiple species together to enhance nutrient recycling and reduce environmental impact [44].

SDG 12, which emphasizes responsible consumption and production, is also highly relevant to aquaculture [8]. The goal encourages sustainable practices throughout the production and consumption chain, from feed sourcing to waste management. Sustainable aquaculture practices include using environmentally friendly feed, reducing the use of antibiotics and chemicals, and implementing waste management systems that minimize pollution. By aligning with SDG 12, aquaculture can contribute to a circular economy, where resources are used efficiently, and waste is minimized.

Climate action (SDG 13) is another critical area where aquaculture must align with the SDGs [7,41]. Climate change poses significant risks to aquaculture, including rising sea temperatures, ocean acidification, and extreme weather events. Conversely, aquaculture can also contribute to climate change if not managed sustainably, through greenhouse gas emissions and the destruction of carbon-sequestering habitats like mangroves. To align with SDG 13, the aquaculture industry must adopt practices that mitigate its carbon footprint, such as improving energy efficiency, reducing emissions, and protecting blue carbon ecosystems [7,41].

To mainstream sustainable practices into aquaculture policy and planning, several strategies can be employed for Ba Ria – Vung Tau, Vietnam. Firstly, developing robust regulatory frameworks that enforce environmental standards is crucial. Governments and regulatory bodies should establish clear guidelines for sustainable aquaculture, including limits on stocking densities, water quality standards, and habitat protection measures. These regulations should be based on scientific research and regularly updated to reflect new knowledge and technologies.

Secondly, fostering multi-stakeholder collaborations is promoted for sustainable aquaculture. This includes engaging industry companies, local communities, environmental organizations, and research institutions in the planning and decision-making processes. Collaborative approaches can help ensure that aquaculture practices are socially acceptable, economically viable, and environmentally sustainable [7,45].

Finally, integrating scientific research into policy and planning is essential for mainstreaming sustainable aquaculture practices. Research on the environmental impacts of aquaculture, the effectiveness of different management practices, and the socio-economic implications of aquaculture can inform policy decisions and help design effective strategies for sustainability. Governments and industry should invest in research and development to innovate and improve aquaculture practices, ensuring they align with the SDGs and contribute to the broader goals of environmental management and sustainable development.

Thus, aligning aquaculture with the SDGs is vital for promoting environmental management and ensuring the sustainability of coastal and marine ecosystems. By analyzing the relevant SDGs and implementing strategies to mainstream sustainable practices into policy and planning, the aquaculture industry can contribute to a more sustainable and resilient future.

6. CONCLUSION

Aquaculture in Ba Ria – Vung Tau significantly supports local economies and food security.

However, its environmental impacts pose significant challenges that necessitate careful management to align with SDGs. Sustainable practices, such as IMTA, offer a way to balance economic growth with environmental preservation. By incorporating diverse species that complement each other ecologically, IMTA can reduce waste and improve overall ecosystem health. Implementing robust regulatory frameworks is also crucial for mitigating negative environmental impacts and ensuring long-term sustainability. Effective management practices will facilitate the harmonious coexistence of economic development and marine ecosystem preservation, strengthening the resilience of coastal communities and environments. Other countries have recognized the importance of sustainable aquaculture, and Ba Ria – Vung Tau can benefit from adopting the best practices observed globally. Without proper management, the region risks undermining both its economic gains and environmental integrity, making sustainable approaches imperative.

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DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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