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Review

Fish to finance: unraveling the economic threads of Bangladesh's Blue Economy

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Abstract: Bangladesh, with its extensive river network, vast coastlines, and rich maritime heritage, stands at the crossroads of a transformative Blue Economy. This comprehensive review explores the rich tapestry of Bangladesh's maritime journey. Commencing with a historical lens, it traces the nation's roots in fisheries, showcasing its transformation into a diversified and dynamic Blue Economy. The significance of this transition unfolds across the review, underscoring the sector's contributions to GDP, employment, and food security, while candidly addressing challenges such as overfishing and environmental impact. This work not only chronicles historical milestones but distills valuable lessons from both successes and setbacks, offering a nuanced understanding of the economic resilience embedded in Bangladesh's fisheries sector. Beyond a historical retrospective, the review navigates through the contemporary landscape, emphasizing diversification beyond fisheries. It illuminates economic opportunities in maritime trade, explores non-fish marine resources, and delves into the transformative role of aquaculture. The policy framework governing Bangladesh's Blue Economy comes into focus, dissecting government strategies, legal landscapes, and international collaborations. The review also champions environmental sustainability, highlighting the impact of Blue Economy activities on marine ecosystems and advocating for conservation measures, thus positioning Bangladesh as a steward of its rich maritime heritage. Financial mechanisms and investments emerge as pivotal elements, shaping the trajectory of Blue Economy projects, as evidenced by case studies that weave success stories and lessons learned into the narrative. Concluding with a forward-looking perspective, the study identifies emerging trends, growth opportunities, and strategies to tackle challenges, offering a comprehensive roadmap for sustainable development. In weaving together economic vibrancy, environmental stewardship, and future aspirations, this review illuminates Bangladesh's maritime odyssey as a beacon for the global Blue Economy community.

Keywords: sustainable development; economic resilience; resource diversification; environmental stewardship; financial mechanisms

1. Introduction

Bangladesh, with its intricate network of rivers, vast coastal areas, and a rich maritime heritage, stands at the crossroads of a transformative economic journey – the Blue Economy (Hasan *et al.*, 2018; Patil *et al.*, 2019). In

recent decades, the nation has witnessed a paradigm shift from traditional fisheries dominance to a diversified maritime landscape that encompasses fisheries, aquaculture, maritime trade, and emerging sectors like eco-tourism and blue biotechnology (Pauly, 2018; Bax *et al.*, 2022). This comprehensive review delves into this dynamic tapestry, meticulously tracing the evolution, dissecting the current state, and prognosticating the future of Bangladesh's Blue Economy (Bir *et al.*, 2020; Failler *et al.*, 2021).

The economic significance of Bangladesh's maritime activities has deep roots in its history (Hussain *et al.*, 2019; Hossain and Islam, 2021). The riverine and coastal communities, dependent on fisheries for their livelihoods, have shaped a cultural and economic identity intrinsically tied to the waters that crisscross the nation (Islam, 2003; Mozumder *et al.*, 2018; Rahman *et al.*, 2018). The historical reliance on fish as a primary protein source, coupled with the vibrant trade along river routes, laid the foundation for the nation's Blue Economy (Hossain, 2014; Hasan *et al.*, 2018). As we unravel the historical underpinnings, it becomes evident that the evolution of Bangladesh's Blue Economy is not a recent phenomenon but a gradual transition woven into the fabric of the nation's socioeconomic landscape (Rahman, 2017; Bhuyan, 2018). The historical resilience of the fisheries sector, coupled with the ingenuity of coastal communities, forms the backdrop against which contemporary economic threads are intricately woven (Mozumder *et al.*, 2018; Sultana *et al.*, 2021).

In recent decades, Bangladesh's Blue Economy has undergone a metamorphosis, expanding its horizons beyond the traditional realm of fisheries (Sharwar *et al.*, 2023). The fishing communities, once the sole custodians of the maritime domain, now share space with a burgeoning aquaculture sector, a thriving maritime trade, and innovative ventures into blue biotechnology (Uddin and Islam, 2019; Collins *et al.*, 2022). This shift from a fish-centric economy to a diversified maritime landscape is emblematic of the nation's adaptability and strategic vision (Askari *et al.*, 2021). The rise of aquaculture stands as a testament to this diversification (Ghose, 2014; Shamsuzzaman *et al.*, 2020; Dam Lam *et al.*, 2022). Pioneering practices in controlled environments, research-driven innovations, and the cultivation of high-value species have propelled Bangladesh into a global player in aquaculture (Hu *et al.*, 2019; Bunting *et al.*, 2023). The aquaculture sector not only complements traditional fisheries but also offers a sustainable alternative, reducing pressure on natural marine resources (Azad *et al.*, 2009; Smith *et al.*, 2021; Troell *et al.*, 2023).

Simultaneously, the maritime trade has witnessed a resurgence, with Bangladesh leveraging its strategic geopolitical location along the Bay of Bengal (Pattanaik, 2018; Taufiq and Mahzabeen, 2022). Ports have been modernized, trade corridors developed, and logistics streamlined to harness the full economic potential of maritime activities (Askari *et al.*, 2021; Iqbal, 2023). This resurgence not only contributes to the nation's GDP but also positions Bangladesh as a key player in regional and international trade dynamics (Kathuria and Malouche, 2016). The significance of Bangladesh's Blue Economy extends far beyond its shorelines. The economic impact reverberates through coastal communities, urban centers, and global markets alike (Hasan *et al.*, 2018; Failler *et al.*, 2021). The fisheries sector, once viewed primarily through the lens of sustenance, now contributes substantially to the national GDP, employment generation, and foreign exchange earnings (Rahman *et al.*, 2018; Shamsuzzaman *et al.*, 2020; Mozumder *et al.*, 2023b). Aquaculture, with its diverse range of products and export potential, augments this impact, ensuring a more resilient and versatile economic landscape (Jahan *et al.*, 2010; Bunting *et al.*, 2023). Furthermore, the maritime trade and transport sector has become an economic lifeline, connecting Bangladesh to global markets and facilitating the exchange of goods (Askari *et al.*, 2021; Mannan *et al.*, 2021; Fattah *et al.*, 2022). Ports have transformed into economic hubs, and strategic collaborations with neighboring nations and international organizations have opened new avenues for growth (Ngui, 2019; Haldar, 2022).

Yet, the journey of Bangladesh's Blue Economy has not been devoid of challenges. Overfishing, environmental degradation, and infrastructure gaps pose formidable hurdles on the path to sustainable development (Smith *et al.*, 2021; Sunny *et al.*, 2021; Shamsuzzaman *et al.*, 2022). The manuscript meticulously navigates through these challenges, dissecting their origins and exploring strategic interventions required for mitigation. Moreover, "Fish to Finance" unfolds the potential of emerging sectors within the Blue Economy. Eco-tourism initiatives that capitalize on the nation's scenic coastal areas, blue biotechnology ventures tapping into the pharmaceutical potential of marine resources, and the integration of technological advancements exemplify the innovative spirit propelling Bangladesh's maritime narrative (Islam *et al.*, 2020b; Abtahee *et al.*, 2023).

"Fish to Finance" emerges as a comprehensive inquiry into the economic intricacies of Bangladesh's Blue Economy. It seeks not only to unravel the threads of evolution but also to discern the economic tapestry that is being woven, thread by thread, as Bangladesh forges ahead into the future. As we embark on this exploration, the manuscript aims to provide a nuanced understanding, offering insights, analyses, and foresight that contribute to a deeper appreciation of Bangladesh's maritime odyssey. In doing so, it aspires to be a beacon

guiding policymakers, scholars, and enthusiasts alike towards a sustainable and prosperous Blue Economy future for Bangladesh.

1.1. Blue economy of Bangladesh

Bangladesh, situated in the delta region of the Ganges, Brahmaputra, and Meghna rivers, is blessed with a diverse and expansive maritime environment (Mirza *et al.*, 2003) (Figure 1). The Bay of Bengal, along its southern coastline, presents a mosaic of possibilities that have become central to the concept of the Blue Economy in the country (Rahman, 2017; Sarker *et al.*, 2019). The Blue Economy, a framework emphasizing the sustainable use of oceanic resources, is seen as a catalyst for economic growth, poverty reduction, and environmental conservation (Okafor-Yarwood *et al.*, 2020; Gill and Iqbal, 2021). The historical intertwining of Bangladesh's economy with its marine resources can be traced back centuries. The fertile delta has always been a source of abundant aquatic life, making fisheries a cornerstone of the nation's economy (Hossain, 2019; Lam *et al.*, 2022). The rich biodiversity of the Bay of Bengal has not only sustained local communities but has also been a source of trade and cultural exchange over the ages (Shamsuzzaman *et al.*, 2017a; Mukul *et al.*, 2018).

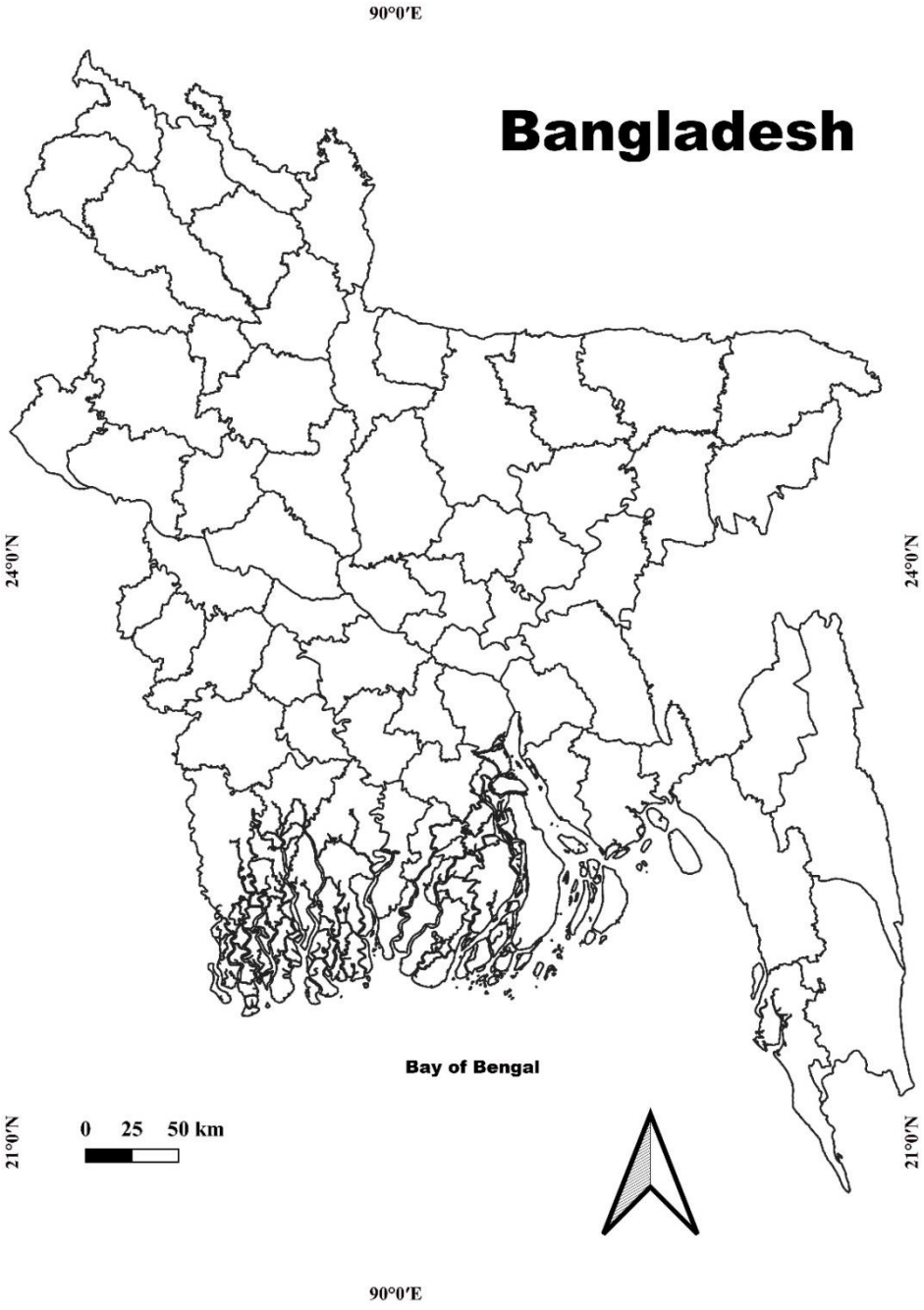

Figure 1. This comprehensive review focused on the Blue Economy of Bangladesh.

The significance of the maritime sector increased significantly in the latter half of the 20th century (Askari *et al.*, 2021). As the population burgeoned, reliance on marine resources for livelihoods and sustenance became even more pronounced. The fisheries sector emerged as a major contributor to the national GDP, providing employment opportunities for millions and addressing the nutritional needs of the population (Shamsuzzaman *et al.*, 2017a, 2020). In response to the growing importance of marine resources and the need for sustainable development, Bangladesh has strategically shifted its focus towards a comprehensive Blue Economy approach (Islam and Shamsuddoha, 2018). This evolution goes beyond traditional fisheries, encompassing various dimensions of maritime potential (Hussain *et al.*, 2019). The government has recognized the need to diversify economic activities and explore untapped opportunities in aquaculture, maritime trade, and other marine resources (Failler *et al.*, 2021; Sharwar *et al.*, 2023).

As Bangladesh strives for holistic economic development, the Blue Economy is increasingly being seen as a key driver. It is not merely an economic diversification strategy but a holistic approach to addressing challenges related to food security, poverty alleviation, and climate resilience (Woodhill *et al.*, 2022). The Blue Economy, therefore, is not only a response to economic needs but a vision for a sustainable and resilient future (Niner *et al.*, 2022; Sharwar *et al.*, 2023).

Understanding the background of Bangladesh's Blue Economy is paramount in unraveling the intricate tapestry of economic threads that weave through its maritime landscape. This article aims to explore the historical perspectives, current status, and future prospects, providing a comprehensive view of how Bangladesh's economic journey is intricately linked to the ebb and flow of its marine resources.

1.2. Significance of the Blue Economy in Bangladesh

The significance of the Blue Economy in Bangladesh cannot be overstated, as it plays a pivotal role in shaping the economic, social, and environmental landscape of the nation (Sharwar *et al.*, 2023). Nestled along the Bay of Bengal, Bangladesh is endowed with a vast maritime expanse that holds tremendous potential for sustainable development (Hussain *et al.*, 2019). Understanding the profound impact of the Blue Economy requires delving into various dimensions that collectively underscore its importance (Hassanali, 2020; Elegbede *et al.*, 2023). Historically, Bangladesh's economy has been predominantly agrarian, with agriculture serving as the backbone (Tabassum and Rezwana, 2021). However, the increasing population and limited arable land have propelled the nation to explore alternative avenues for economic growth (Rezvi, 2018). In this context, the Blue Economy has emerged as a strategic and comprehensive approach to harnessing the potential of marine resources, offering a diversification beyond traditional sectors (Islam and Mostaque, 2018).

The fisheries sector, in particular, has been a cornerstone of Bangladesh's Blue Economy (Bhuyan, 2018). With an extensive coastline and a network of rivers, the country's waters are teeming with a rich variety of fish and aquatic life (Rahat *et al.*, 2022). The fisheries industry not only contributes significantly to the national GDP but also plays a crucial role in providing employment to coastal communities, thereby addressing livelihood challenges (Ghose, 2014; Islam *et al.*, 2016; Taylor *et al.*, 2019). Beyond its economic contributions, the Blue Economy holds immense importance in ensuring food security and nutrition in Bangladesh (Bir *et al.*, 2020; Failler *et al.*, 2021). Fisheries serve as a primary source of animal protein for the population, playing a vital role in addressing malnutrition and improving overall public health (Bogard *et al.*, 2015; Shamsuzzaman *et al.*, 2017a; Rifat *et al.*, 2023). The holistic approach of the Blue Economy recognizes the interconnectedness of economic development, food security, and nutrition (Okafor-Yarwood *et al.*, 2020).

Poverty alleviation is another key facet of the Blue Economy's significance in Bangladesh (Failler *et al.*, 2019). Small-scale fisheries and related activities provide income generation opportunities for coastal communities, lifting them out of poverty and contributing to socioeconomic development (Mozahid *et al.*, 2018; Noman *et al.*, 2019; Fabinyi *et al.*, 2022). By diversifying economic activities beyond fisheries, the Blue Economy offers a pathway to enhance the standard of living in these regions. In the face of climate change, the Blue Economy emerges as a critical tool for climate resilience and adaptation (Sarker *et al.*, 2019; Chowdhury *et al.*, 2022). The marine resources act as a natural buffer against the impacts of climate change, providing both environmental and economic benefits (Gattuso *et al.*, 2018; Sarker *et al.*, 2019; Smith *et al.*, 2021). Coastal communities, often vulnerable to the effects of climate change, find resilience through the sustainable exploitation of marine resources (Ferrol-Schulte *et al.*, 2015; Rubekie *et al.*, 2022).

Moreover, the Blue Economy carries geopolitical and regional significance for Bangladesh (Rahman, 2017; Islam and Mostaque, 2018). The nation's maritime trade and connectivity contribute to its international standing and diplomatic relations (Ashikur and Rupom, 2022).. By actively participating in regional cooperation and international collaborations, Bangladesh strengthens its position in the Bay of Bengal region, fostering economic and strategic partnerships (Motaher and Khaled, 2022)

As Bangladesh embraces the Blue Economy, there is a growing awareness of the need to balance economic growth with environmental sustainability (Bhuyan, 2018; Islam and Mostaque, 2018; Patil *et al.*, 2019). Conservation of marine ecosystems, mitigation of environmental impacts, and the promotion of sustainable practices are integral to ensuring that the economic gains are not achieved at the expense of the environment (Islam and Shamsuddoha, 2018; Smith *et al.*, 2021; Ward *et al.*, 2022). Government commitment and visionary leadership have been instrumental in driving the Blue Economy agenda in Bangladesh (Sharwar *et al.*, 2023). The formulation of robust legal and regulatory frameworks, along with incentives and support mechanisms, reflects the policy impetus to foster sustainable practices and responsible development (Failler *et al.*, 2019, 2021; Sharwar *et al.*, 2023).

In alignment with global aspirations, the integration of the Blue Economy with Sustainable Development Goals (SDGs) is a crucial dimension (Wenhai *et al.*, 2019; Lee *et al.*, 2020). By addressing poverty, hunger, climate action, and other SDGs, the Blue Economy becomes a catalyst for achieving broader sustainable development objectives on a national and international scale (Sarker *et al.*, 2018; Shayan *et al.*, 2022).

The significance of the Blue Economy in Bangladesh is multifaceted and far-reaching (Askari *et al.*, 2021; Failler *et al.*, 2021). It is not merely an economic strategy but a holistic approach that intertwines economic prosperity, social well-being, and environmental stewardship (Bir *et al.*, 2020; Niner *et al.*, 2022). As Bangladesh continues to navigate its maritime journey, the Blue Economy stands as a beacon of sustainable and inclusive development.

1.3. Purpose and scope of the study

The purpose of this review article is to provide a comprehensive and in-depth analysis of the Blue Economy in Bangladesh, unraveling its economic threads and exploring the multifaceted dimensions that contribute to the nation's maritime development (Figure 2). The review aims to achieve the following objectives,

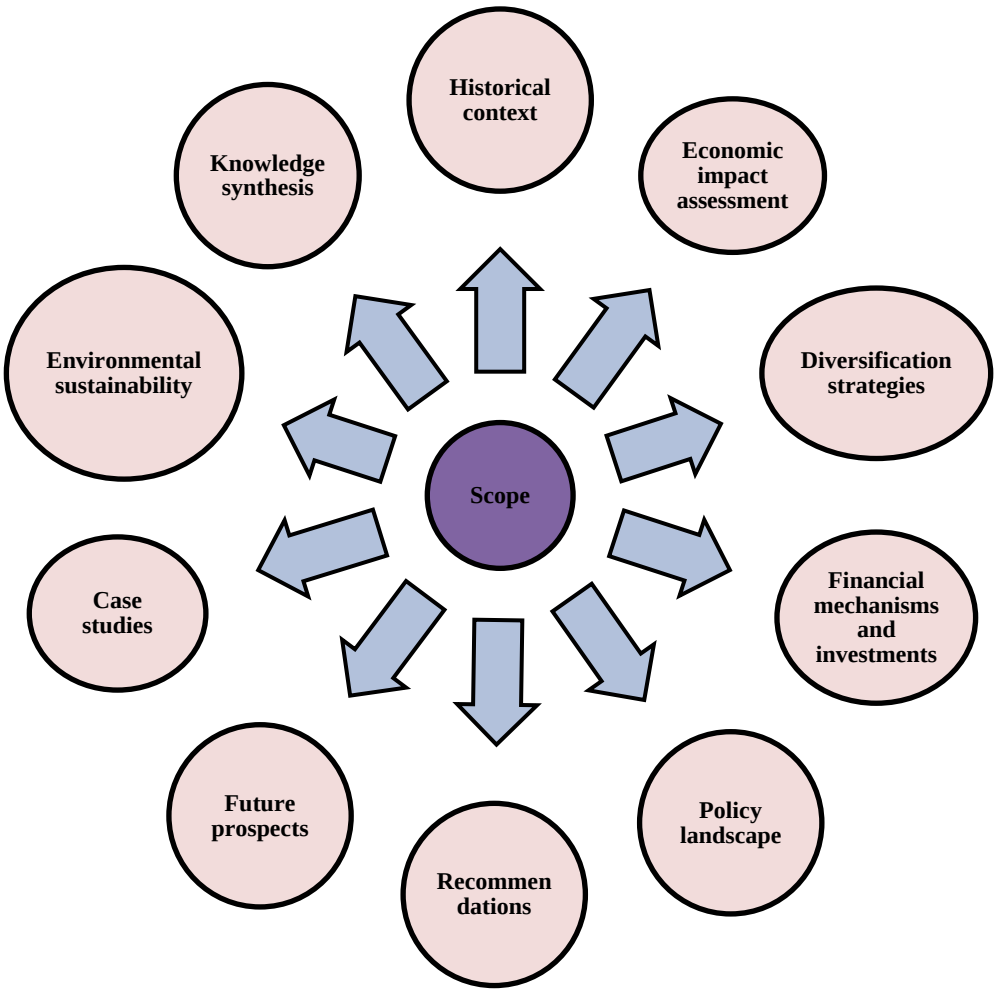

Figure 2. Scope and knowledge generation from the study.

1.3.1. Knowledge synthesis
Compile and synthesize existing knowledge and research on Bangladesh's Blue Economy, offering a consolidated resource for policymakers, researchers, and practitioners interested in the subject.

1.3.2. Historical context
Provide a historical context by tracing the evolution of Bangladesh's Blue Economy, examining key milestones, policy shifts, and initiatives that have shaped its current status (Islam and Mostaque, 2018; Failler *et al.*, 2021).

1.3.3. Economic impact assessment
Assess the economic impact of the Blue Economy, with a focus on sectors such as fisheries, aquaculture, maritime trade, and related industries (Wenhai *et al.*, 2019; Ahammed *et al.*, 2024). Explore how these sectors contribute to national GDP, employment generation, and poverty alleviation.

1.3.4. Diversification strategies
Investigate the efforts made by Bangladesh to diversify its economic activities beyond traditional fisheries, exploring the potential of other marine resources and activities such as aquaculture, maritime trade, and tourism (Failler *et al.*, 2019, 2021; Hussain *et al.*, 2019).

1.3.5. Policy landscape
Examine the policy frameworks governing the Blue Economy in Bangladesh, analyzing the government's strategies, legal and regulatory environment, and international collaborations (Failler *et al.*, 2019; Rahman, 2021; Sharwar *et al.*, 2023). Assess the effectiveness of these policies in promoting sustainable practices and responsible development (Rahman, 2021).

1.3.6. Environmental sustainability
Explore the environmental sustainability aspects of Bangladesh's Blue Economy, addressing challenges and discussing conservation measures (Islam *et al.*, 2018; Bir *et al.*, 2020; Sharwar *et al.*, 2023). Investigate how the nation balances economic growth with the protection of marine ecosystems.

1.3.7. Financial mechanisms and investments
Evaluate the financial mechanisms and investments associated with the Blue Economy, analyzing both public and private sector contributions (Tirumala and Tiwari, 2022). Examine challenges and opportunities in attracting investments for sustainable maritime development.

1.3.8. Case studies
Present case studies highlighting successful Blue Economy projects in Bangladesh, drawing lessons from both achievements and setbacks (Bir *et al.*, 2020; Failler *et al.*, 2021). Provide insights into best practices that can be replicated or adapted in similar contexts.

1.3.9. Future prospects
Discuss emerging trends, opportunities, and challenges in Bangladesh's Blue Economy, offering insights into the potential future trajectory (Failler *et al.*, 2021; Bhuyan *et al.*, 2022). Identify areas for improvement and innovation to ensure a sustainable and thriving Blue Economy.

1.3.10. Recommendations
Conclude the review with a set of recommendations for policymakers, stakeholders, and the broader community. Propose strategies for enhancing the effectiveness of Blue Economy initiatives, addressing challenges, and maximizing the positive impact on economic, social, and environmental fronts.

2. Historical perspectives
2.1. Evolution of Bangladesh's Blue Economy
The evolution of Bangladesh's Blue Economy is a narrative deeply embedded in the nation's historical and economic fabric. Understanding this evolution involves tracing the development of maritime activities, policies, and economic strategies over time. The historical evolution is shown in the figure 3.

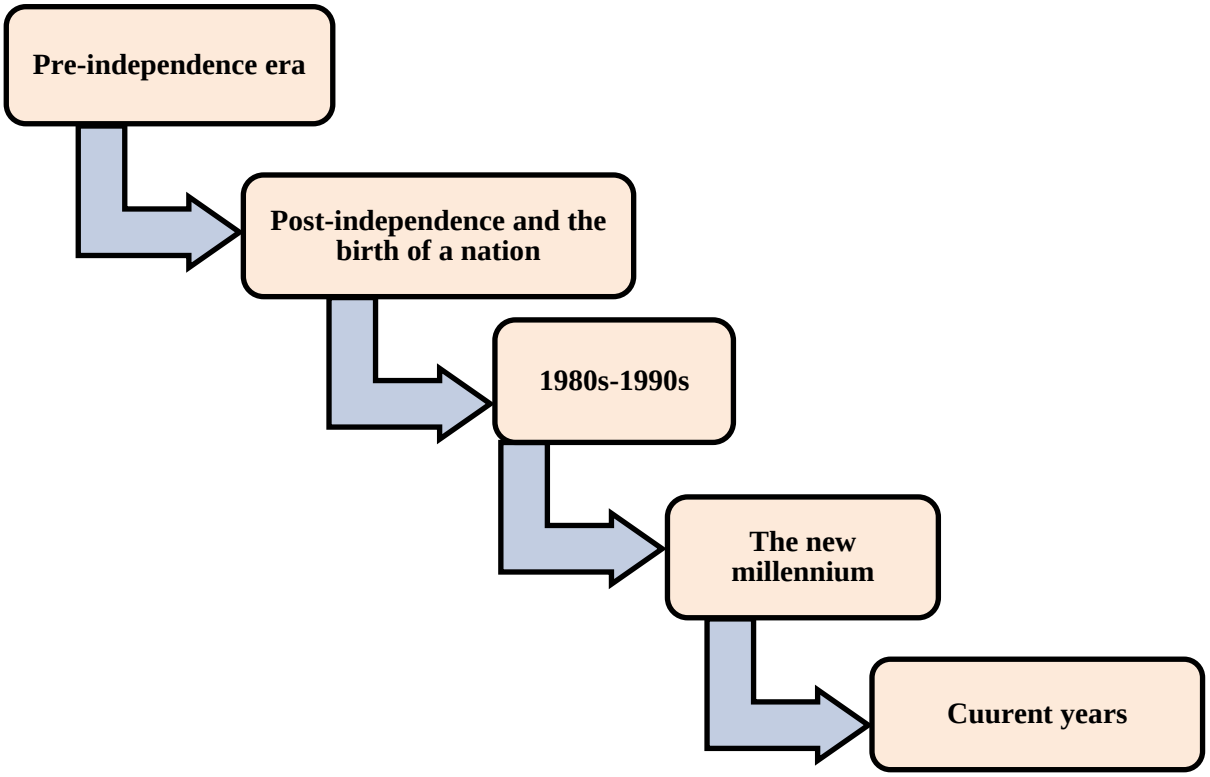

Figure 3. The historical perspective of Blue Economy in Bangladesh.

2.1.1. Pre-independence era

Fishing has been a fundamental part of the livelihoods of coastal communities for centuries (Islam *et al.*, 2017; Mondal *et al.*, 2018b; Rayhan *et al.*, 2023; Alam and Yousuf, 2024). Traditional fishing practices were prevalent, with small-scale fishing playing a crucial role in sustaining local economies (Chowdhury *et al.*, 2011; Shamsuzzaman *et al.*, 2017a).

2.1.2. Post-independence and the birth of a nation

In the early years following Bangladesh's independence in 1971, there was a recognition of the importance of the marine environment (Haque, 2019). Policies and initiatives began to emerge, laying the groundwork for the integration of maritime resources into the national development agenda (Wenhai *et al.*, 2019; Zhang and Chen, 2022).

2.1.3. 1980s-1990s

The 1980s and 1990s witnessed a heightened focus on the fisheries sector (Rahman and Ahmed, 2002; Ghose, 2014; Shamsuzzaman *et al.*, 2020). Policies were crafted to boost fish production, and efforts were made to enhance the capacity of the fishing industry (Hossain, 2014; Shamsuzzaman *et al.*, 2022; Mozumder *et al.*, 2023b). This period saw a shift from subsistence fishing to a more commercial and export-oriented approach.

2.1.4. The new millennium and blue economy concept

In the new millennium, there was a paradigm shift in conceptualizing the potential of maritime resources (Hasan *et al.*, 2018). The Blue Economy concept gained prominence, emphasizing a holistic approach that extended beyond traditional fisheries to include various marine sectors such as aquaculture, maritime trade, and tourism (Wenhai *et al.*, 2019; Failler *et al.*, 2021).

2.1.5. Government initiatives and international collaborations

The government initiated policy reforms to align with the principles of sustainable development and responsible resource management (Islam and Mostaque, 2018; Failler *et al.*, 2019). These reforms aimed to balance economic growth with environmental conservation. Bangladesh actively engaged in international collaborations

and agreements, seeking support and expertise to enhance its maritime capabilities and address challenges (Sharwar *et al.*, 2023).

2.1.6. Current scenario

Presently, Bangladesh is actively diversifying its Blue Economy initiatives, exploring the economic potential of aquaculture, maritime trade, and other marine resources. This marks a departure from the singular focus on traditional fisheries (Hasan *et al.*, 2018; Sarker *et al.*, 2018; Failler *et al.*, 2021; Sharwar *et al.*, 2023).

2.2. Key milestones and initiatives

The evolution of Bangladesh's Blue Economy has been marked by significant milestones and strategic initiatives, reflecting the nation's commitment to harnessing the potential of its maritime resources (Sarker *et al.*, 2018; Failler *et al.*, 2021). These milestones underscore the transformative journey from a predominantly agrarian economy to one that embraces the diverse opportunities presented by its expansive coastal and marine environment (Figure 4).

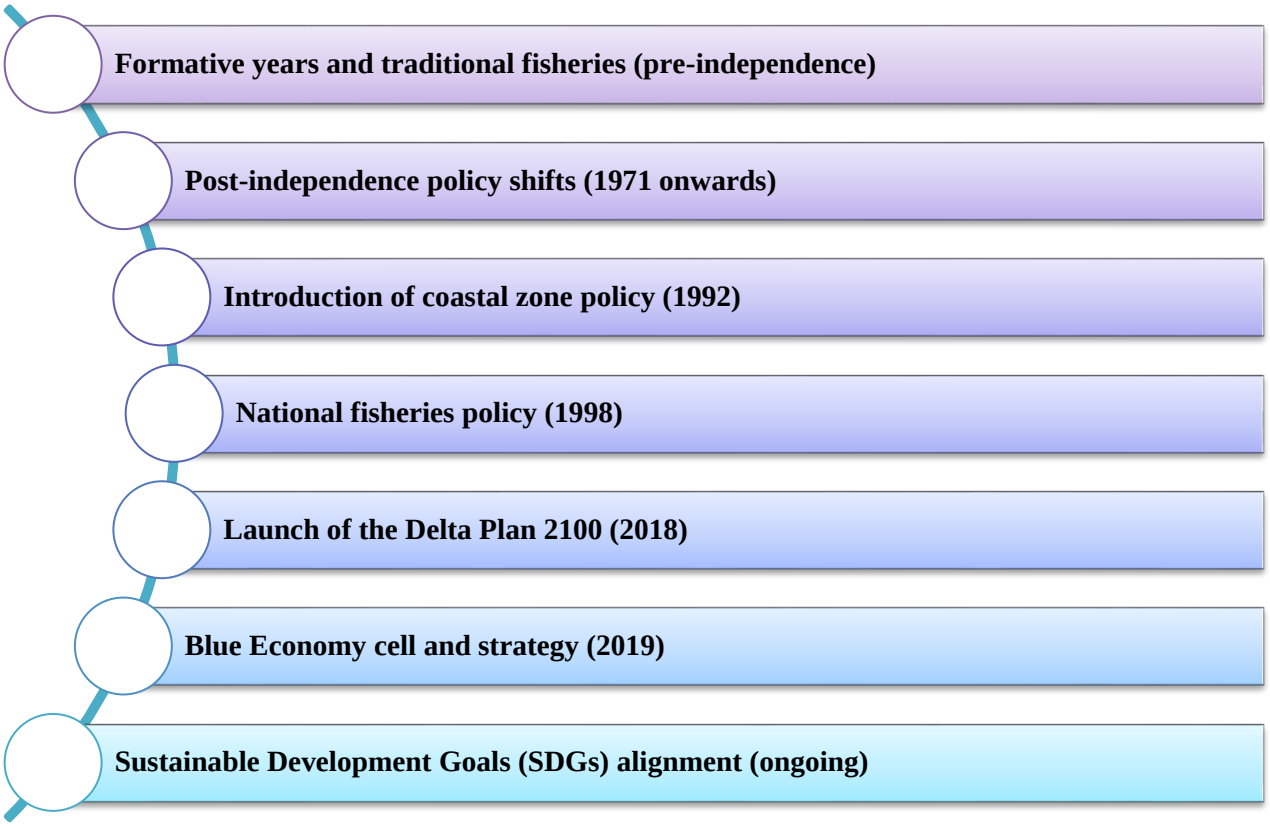

Figure 4. Key milestones and initiatives taken by the government of Bangladesh for Blue Economy.

2.2.1. Formative years and traditional fisheries (pre-independence)

The pre-independence era saw traditional fishing practices as a crucial source of livelihood along Bangladesh's rivers and coastal areas. Limited industrialization and reliance on artisanal methods characterized the early stages of the fisheries sector (Hossain, 2014; Mozumder *et al.*, 2023b).

2.2.2. Post-independence policy shifts (1971 onwards)

The post-independence period witnessed a paradigm shift in economic policies, leading to the recognition of the importance of the maritime sector (Askari *et al.*, 2021). In the 1970s and 1980s, policies were formulated to promote sustainable fisheries practices and marine resource management (Shamsuzzaman *et al.*, 2017b, 2017a, 2022).

2.2.3. Introduction of coastal zone policy (1992)

The formulation of the Coastal Zone Policy in 1992 marked a significant step towards integrated coastal zone management, acknowledging the need for a holistic approach to the Blue Economy (Ahamed *et al.*, 2020; Shampa *et al.*, 2023).

2.2.4. National fisheries policy (1998)

The National Fisheries Policy of 1998 laid down the framework for sustainable fisheries management, emphasizing conservation, aquaculture development, and community-based approaches (Rahman and Ahmed, 2002; Rahman *et al.*, 2018; Shamsuzzaman *et al.*, 2022).

2.2.5. Launch of the Delta Plan 2100 (2018)

The Delta Plan 2100, introduced in 2018, outlined a long-term vision for Bangladesh's water management, including strategies for harnessing the economic potential of the delta, thus aligning with the principles of the Blue Economy (Hasan *et al.*, 2020; Ashikur and Rupom, 2022; Kabir *et al.*, 2022).

2.2.6. Blue Economy cell and strategy (2019)

The establishment of the Blue Economy Cell within the Ministry of Fisheries and Livestock in 2019 demonstrated a dedicated institutional approach towards coordinating and implementing Blue Economy initiatives (Failler *et al.*, 2019, 2021). A comprehensive Blue Economy Strategy was introduced to guide sustainable development practices and maximize economic benefits (Spalding, 2016; Wenhai *et al.*, 2019).

2.2.7. Sustainable Development Goals (SDGs) alignment (ongoing)

The ongoing efforts to align Blue Economy initiatives with the United Nations Sustainable Development Goals (SDGs) highlight Bangladesh's commitment to achieving broader global development targets (Islam and Shamsuddoha, 2018).

2.2.8. International collaborations and agreements

Bangladesh has actively engaged in collaborations with international organizations and neighboring countries to promote regional cooperation, sharing knowledge, and best practices in Blue Economy development (Hussain *et al.*, 2018; Failler *et al.*, 2019; AftabUddin *et al.*, 2021). These key milestones and initiatives illustrate the dynamic evolution of Bangladesh's Blue Economy, reflecting a concerted effort to integrate economic growth with sustainable practices. The journey unfolds against the backdrop of changing economic priorities, environmental awareness, and a commitment to secure the well-being of coastal communities (Sarker *et al.*, 2019; Failler *et al.*, 2021).

2.3. Lessons from the past: successes and challenges

As we delve into the historical tapestry of Bangladesh's Blue Economy, an exploration of the lessons learned becomes imperative. This section aims to distill valuable insights from the annals of the nation's maritime journey, dissecting both the successes that propelled the Blue Economy forward and the challenges that necessitated strategic recalibration.

2.3.1. Successes

Fisheries sector resilience: The historical success of the fisheries sector serves as a testament to the resilience of Bangladesh's Blue Economy. The sector's consistent contribution to national GDP, employment generation, and nutritional security highlights its pivotal role in sustaining livelihoods and fostering economic growth (Askari *et al.*, 2021; Failler *et al.*, 2021; Troell *et al.*, 2023).

Strategic policy shifts: Examining successful policy shifts over time reveals the adaptive nature of Bangladesh's approach to the Blue Economy. The evolution from a primarily fisheries-centric focus to a more diversified strategy reflects a keen understanding of the need for economic versatility and sustainability (Islam and Mostaque, 2018; Failler *et al.*, 2019, 2021; Shamsuzzaman *et al.*, 2022).

International collaborations: Success stories emerge from collaborative efforts with international partners. Bilateral and multilateral agreements have not only facilitated knowledge exchange but have also opened avenues for technological advancements, enhancing the efficiency of maritime activities (Iqbal, 2019; Alam, 2021) (Figure 5).

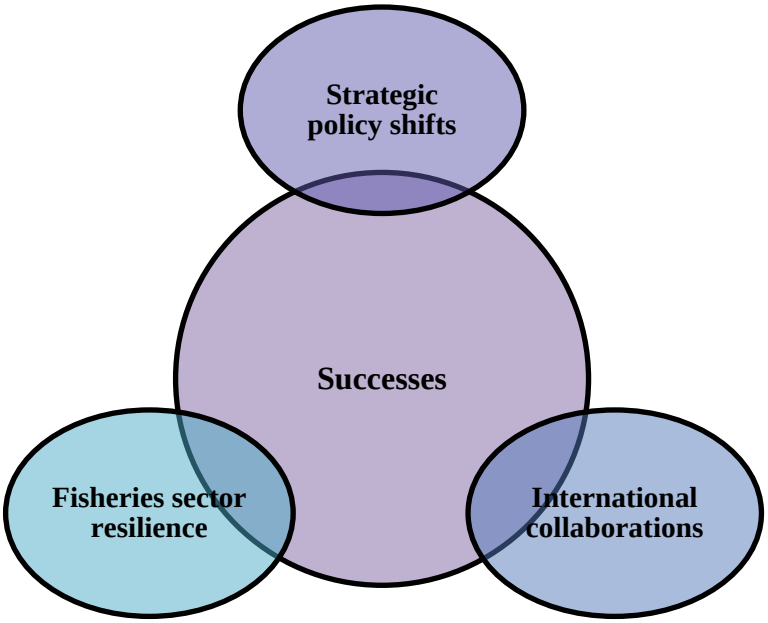

Figure 5. Success dimension for Blue Economy of Bangladesh.

2.3.2. Challenges

Overfishing and resource depletion: Historical overreliance on traditional fishing methods and overexploitation of marine resources pose challenges to the sustainability of the Blue Economy (Islam, 2003; Shamsuzzaman *et al.*, 2017b, 2017a). Lessons from the past underscore the need for stringent conservation measures to prevent resource depletion and maintain ecological balance (Lee *et al.*, 2021).

Infrastructure gaps: The historical development of the Blue Economy in Bangladesh has been hindered by inadequate infrastructure, hindering the full realization of its potential. Ports, processing facilities, and transport networks have often lagged behind the demands of a growing maritime economy (Bhuyan *et al.*, 2022; Sharwar *et al.*, 2023).

Environmental impact: Lessons learned from the past emphasize the delicate balance between economic development and environmental preservation. Unregulated practices have led to environmental degradation, necessitating a shift towards sustainable approaches that mitigate negative impacts on marine ecosystems (Hasan *et al.*, 2018; Sarker *et al.*, 2019; Sharwar *et al.*, 2023) (Figure 6).

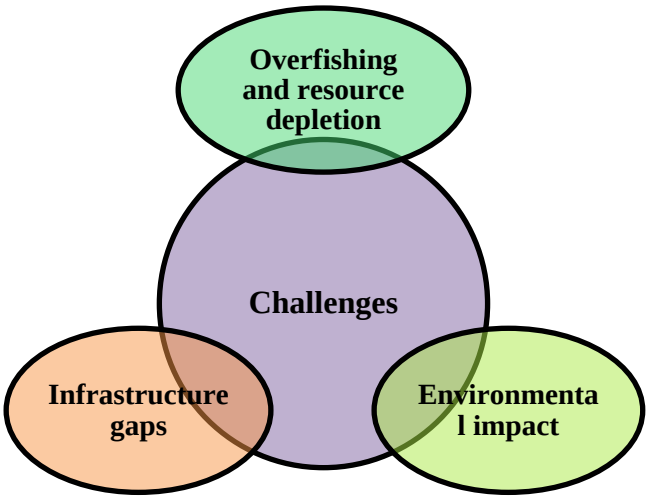

Figure 6. Challenges for Blue Economy development and sustain in Bangladesh.

2.3.3. Strategic adaptations

Community involvement: Successful Blue Economy initiatives often hinge on community involvement. Lessons from successful projects highlight the importance of empowering local communities, involving them in decision-making processes, and ensuring that the benefits of maritime activities are shared equitably (Hasan *et al.*, 2018; Failler *et al.*, 2019, 2021).

Technological innovation: The past provides a canvas of technological advancements that have positively impacted the Blue Economy. Lessons learned emphasize the importance of ongoing investment in research and technology to enhance productivity, reduce environmental impact, and ensure long-term sustainability (Bhuyan, 2018; Hasan *et al.*, 2018; Hussain *et al.*, 2018; Failler *et al.*, 2021).

Policy flexibility: Adaptable and flexible policy frameworks have proven instrumental in navigating challenges. Historical analyses showcase instances where timely policy adjustments have addressed emerging issues, underscoring the need for ongoing evaluation and adaptation in response to changing economic and environmental dynamics (Failler *et al.*, 2019; Rahman, 2021; Niner *et al.*, 2022) (Figure 7).

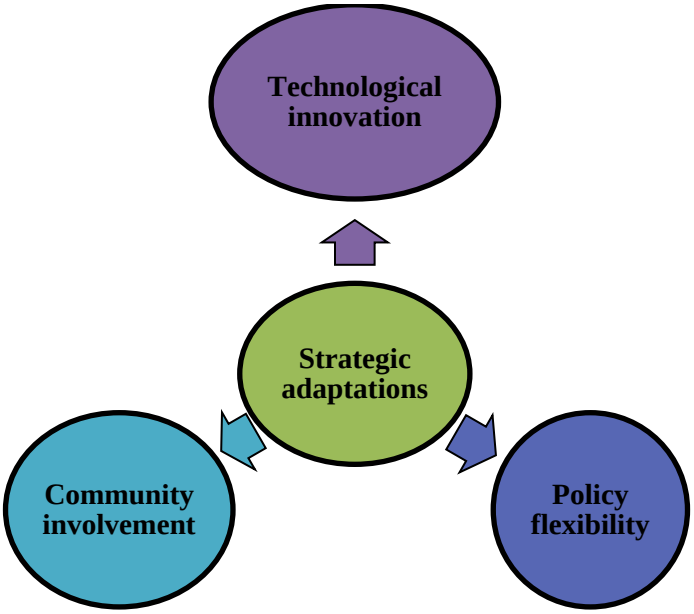

Figure 7. Strategic adaptations for Blue economy development in Bangladesh.

3. Economic impact of fisheries

3.1. Overview of Bangladesh's fisheries sector

The fisheries sector stands as a cornerstone of Bangladesh's Blue Economy, wielding significant influence on the nation's economic landscape. This section provides a comprehensive overview of the fisheries sector, delving into its historical significance, current state, and the multifaceted impact it has on the nation's economy (Hossain, 2014; Shamsuzzaman *et al.*, 2020; Sharwar *et al.*, 2023).

3.1.1. Historical significance

Bangladesh's reliance on fisheries dates back centuries, with the sector playing a crucial role in the livelihoods of coastal communities and contributing substantially to the nation's sustenance. The historical significance of fisheries is intertwined with cultural practices, economic activities, and dietary habits, forming an integral part of the country's identity (Ghose, 2014; Hossain, 2014; Rahman *et al.*, 2018).

3.1.2. Current state of the fisheries sector

Diverse marine resources: Bangladesh's fisheries sector is characterized by a rich diversity of marine resources, including various species of fish, shrimp, and other aquatic life. This diversity not only sustains local consumption but also fuels export-oriented activities, contributing to the national economy (Shamsuzzaman *et al.*, 2017a, 2020; Hasan *et al.*, 2021).

Contribution to GDP: A pivotal economic driver, the fisheries sector significantly contributes to the national Gross Domestic Product (GDP). The revenue generated from both domestic consumption and international trade positions fisheries as a key player in the economic fabric of Bangladesh (Shamsuzzaman *et al.*, 2017a, 2020).

Employment generation: Beyond its economic contributions, the fisheries sector serves as a major source of employment, particularly for coastal communities. From traditional fishermen to those involved in processing, marketing, and exporting, the sector supports livelihoods along the entire value chain (Rahman *et al.*, 2018; Shamsuzzaman *et al.*, 2020) (Figure 8).

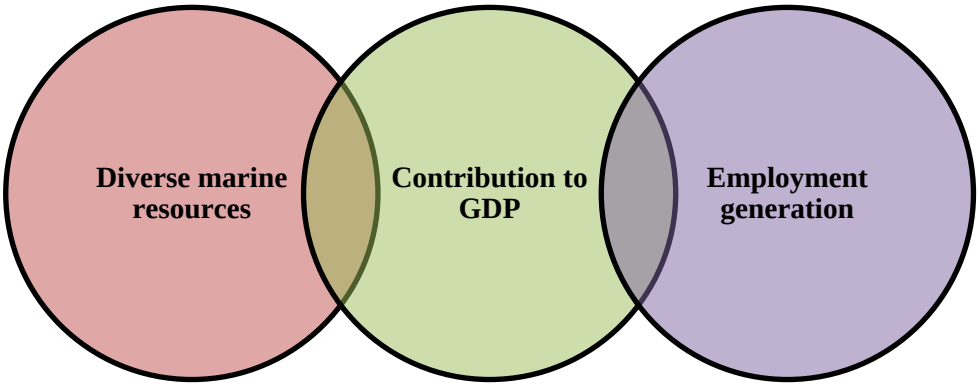

Figure 8. The current state and strength of fisheries sector in Bangladesh.

3.1.3. Impact on national economy

Foreign exchange earnings: Bangladesh's fisheries sector plays a crucial role in earning foreign exchange through the export of fish and seafood products. This has a direct impact on the country's balance of payments and contributes to the resilience of the national economy (Islam *et al.*, 2016; Shamsuzzaman *et al.*, 2017a, 2020; Azad and Azad, 2022).

Food security: The fisheries sector is fundamental to addressing food security challenges in Bangladesh. As a primary source of animal protein, fish is a dietary staple for a significant portion of the population, contributing to improved nutrition and public health (Islam *et al.*, 2016; Tran *et al.*, 2023).

Rural development: Beyond the coastal areas, the fisheries sector influences rural development by providing income opportunities in areas with limited alternative economic activities. This decentralized economic impact helps bridge regional development disparities (Al-Asif *et al.*, 2015; Sharif *et al.*, 2015; Al-Asif and Habib, 2017; Mondal *et al.*, 2018a) (Figure 9).

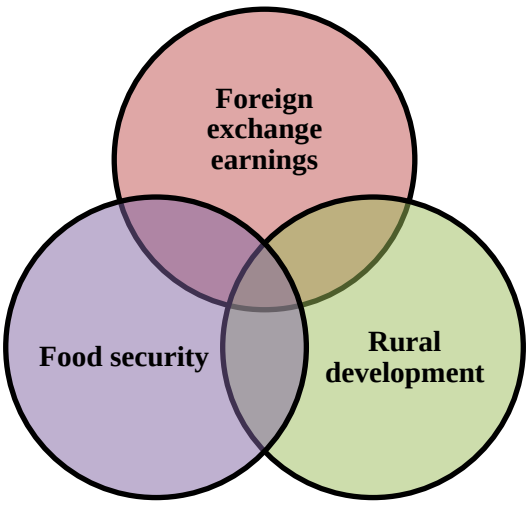

Figure 9. The impact of Blue Economy on national economy of Bangladesh.

3.1.4. Challenges and sustainability concerns

Overfishing: The historical reliance on traditional fishing methods has led to overfishing in certain areas, posing a threat to the sustainability of marine resources. Implementing effective fisheries management practices is imperative to prevent resource depletion (Mozumder *et al.*, 2023b; Sharwar *et al.*, 2023).

Environmental impact: Unregulated fishing practices and habitat destruction have resulted in environmental degradation. Sustainable practices and conservation measures are essential to mitigate the adverse environmental impacts of fisheries (Hasan *et al.*, 2018; Sarker *et al.*, 2019; Sharwar *et al.*, 2023).

Infrastructure gaps: Inadequate infrastructure, including storage and processing facilities, hinders the efficiency of the fisheries sector. Addressing these gaps is crucial for maximizing the economic potential of fisheries (Bhuyan *et al.*, 2022; Sharwar *et al.*, 2023) (Figure 10).

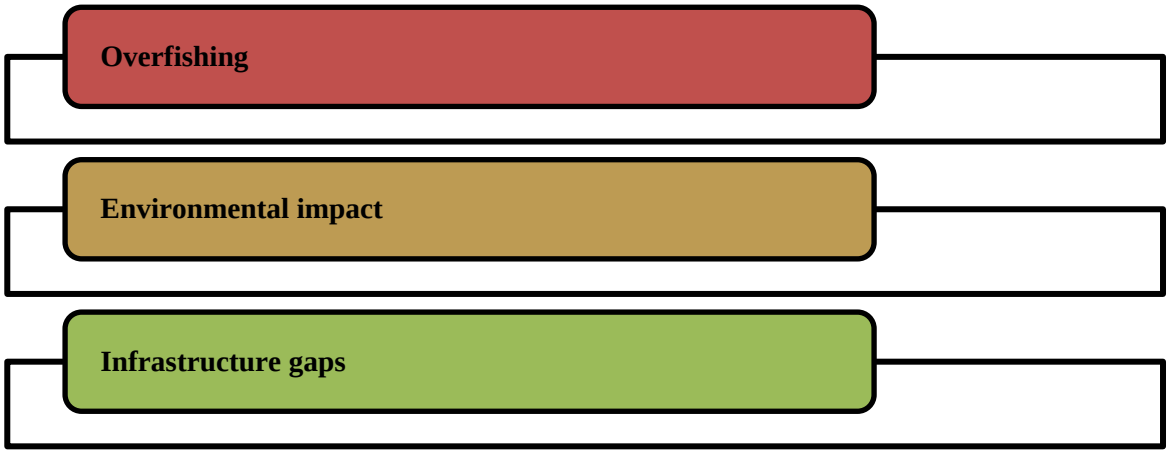

Figure 10. Major challenges and sustainability concerns for Blue Economy of Bangladesh.

4. Diversification beyond fisheries

As Bangladesh charts its course towards a diversified and resilient Blue Economy, the exploration extends beyond the traditional boundaries of fisheries. This section unravels the economic threads woven into the maritime fabric of the nation, delving into various facets that extend beyond fish and showcase the broad spectrum of opportunities within the Blue Economy.

4.1. Beyond fish: exploring other marine resources

Bountiful marine biodiversity: Bangladesh's maritime territory encompasses a wealth of diverse marine resources beyond fish. Exploration and sustainable utilization of non-fish resources such as crustaceans, mollusks, and seaweeds present untapped economic opportunities (Shamsuzzaman *et al.*, 2017a; Hussain *et al.*, 2019).

Bioactive compounds and pharmaceuticals: The marine ecosystem harbors bioactive compounds with pharmaceutical potential. Research and development initiatives focused on marine biotechnology can unlock economic value through the extraction and commercialization of these compounds, contributing to the pharmaceutical industry (Kiuru *et al.*, 2014; Hussain *et al.*, 2019; Sarker *et al.*, 2021).

Biotechnology and bioprospecting: The exploration of marine biotechnology opens avenues for bioprospecting and the development of biotechnological applications. From marine enzymes to biofuels, harnessing the potential of marine organisms presents novel economic prospects (Uddin and Islam, 2019; Askari *et al.*, 2021).

Eco-tourism and biodiversity conservation: The diverse marine ecosystems provide a foundation for eco-tourism initiatives, attracting enthusiasts seeking unique marine biodiversity experiences. The economic benefits of sustainable tourism extend beyond revenue generation to biodiversity conservation efforts (Bashar, 2018; Islam and Shamsuddoha, 2018; Shampa *et al.*, 2023)(Figure 11).

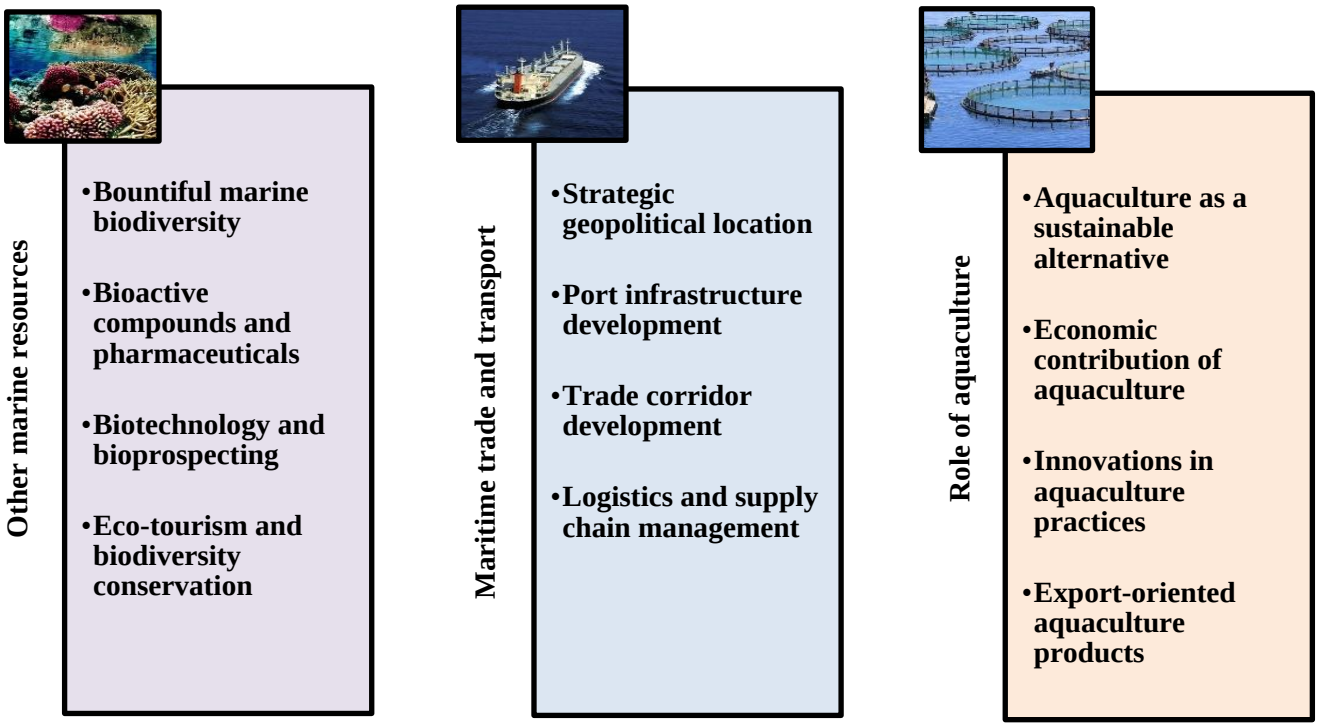

Figure 11. Diversification beyond fisheries in Blue Economy of Bangladesh.

4.2. Economic opportunities in maritime trade and transport

Strategic geopolitical location: Bangladesh's strategic location along the Bay of Bengal positions it as a key player in regional and international maritime trade. Leveraging this location can foster economic opportunities in shipping, logistics, and transshipment activities (Hussain *et al.*, 2019; Askari *et al.*, 2021; Sharwar *et al.*, 2023).

Port infrastructure development: Investing in port infrastructure, including modernization and expansion projects, enhances the country's capacity to handle increased maritime trade. Upgrading port facilities ensures efficiency in cargo handling and contributes to economic growth (Saha, 2017; Askari *et al.*, 2021; Iqbal, 2023).

Trade corridor development: Establishing and strengthening maritime trade corridors facilitates seamless connectivity with neighboring countries and global markets. Initiatives such as the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) play a pivotal role in regional economic integration (Biswas, 2020; Askari *et al.*, 2021).

Logistics and supply chain management: Efficient logistics and supply chain management are integral to optimizing the economic benefits of maritime trade. Developing robust logistics infrastructure and implementing modern supply chain practices contribute to economic competitiveness (Alamgir and Chowdhury, 2018; Askari *et al.*, 2021; Ibrahim and Xuefeng, 2023) (Figure 11).

4.3. Role of aquaculture in economic development

Aquaculture as a sustainable alternative: Recognizing the limitations of traditional fisheries, aquaculture emerges as a sustainable alternative. The controlled environment of aquaculture ponds allows for the cultivation of diverse aquatic species, meeting both domestic and international demand (Rahman *et al.*, 2018; Shamsuzzaman *et al.*, 2020; AftabUddin *et al.*, 2021; Hoque, 2021).

Economic contribution of aquaculture: The economic significance of aquaculture extends to employment generation, foreign exchange earnings, and rural development. As a thriving sector, aquaculture complements

traditional fisheries, mitigating pressures on natural marine resources (Islam *et al.*, 2016; Shamsuzzaman *et al.*, 2020; Azad and Azad, 2022; Hossain *et al.*, 2022).

Innovations in aquaculture practices: Continuous research and innovation in aquaculture practices enhance productivity and sustainability. From integrated multi-trophic aquaculture systems to the adoption of advanced technologies, innovations contribute to the economic resilience of the aquaculture sector (Ahmed and Glaser, 2016; Bunting *et al.*, 2023).

Export-oriented aquaculture products: The global demand for seafood presents opportunities for Bangladesh to position itself as a significant exporter of aquaculture products. Ensuring quality standards, value addition, and adherence to sustainable practices are essential in capitalizing on international markets (Mamun *et al.*, 2021; Hobbs *et al.*, 2023; Lahiri *et al.*, 2023)(Figure 11).
In navigating the expansive realms beyond fisheries, Bangladesh's Blue Economy unfolds as a tapestry of diverse opportunities. From the exploration of non-fish marine resources to the strategic development of maritime trade and the sustainable growth of aquaculture, this diversification reflects a comprehensive vision for economic prosperity rooted in the nation's rich maritime heritage.

5. Policy framework: navigating Bangladesh's Blue Economy development

In the intricate tapestry of Bangladesh's Blue Economy, the policy framework emerges as a guiding force, shaping the nation's vision for sustainable maritime development. We delves deeper into the multifaceted layers of the government's strategies, legal and regulatory landscape, and international collaborations, highlighting their collective role in navigating the trajectory of the Blue Economy (Islam and Mostaque, 2018; Failler *et al.*, 2019).

5.1. Government strategies for Blue Economy development

5.1.1. Holistic vision and strategic planning

Bangladesh's Blue Economy development is underpinned by a comprehensive vision outlined in strategic planning documents. The National Blue Economy Policy provides a foundational framework that integrates economic, social, and environmental considerations. This holistic approach recognizes the interconnected nature of maritime development and sets the stage for a balanced and sustainable future (Islam and Mostaque, 2018; Sarker *et al.*, 2019; Failler *et al.*, 2021).

5.1.2. Diversification and value addition

Government strategies extend beyond the conventional fisheries-centric model. There is a concerted effort to diversify economic activities within the Blue Economy. Exploration of non-fish marine resources, promotion of sustainable aquaculture, and value addition to marine products showcase a commitment to economic versatility and innovation (Failler *et al.*, 2021; Elegbede *et al.*, 2023; Sharwar *et al.*, 2023).

5.1.3. Integrated approach to development

Acknowledging the intricate web of socio-economic and environmental factors, the government adopts an integrated approach to Blue Economy development. Policies seek to strike a harmonious balance, ensuring that economic growth is not achieved at the expense of environmental degradation or social inequities. This integrated vision aims for a symbiotic relationship between economic prosperity and environmental stewardship (Wenhai *et al.*, 2019; Failler *et al.*, 2021; Sharwar *et al.*, 2023).

5.1.4. Community engagement and empowerment

Coastal communities are pivotal stakeholders in Bangladesh's Blue Economy, and government strategies reflect a commitment to their engagement and empowerment. Inclusive policies aim to uplift the socio-economic conditions of these communities, recognizing their role as custodians of marine resources. Community participation is not just a goal but an essential element in shaping and implementing Blue Economy policies (Islam and Mostaque, 2018; Failler *et al.*, 2019; Bax *et al.*, 2022; Bhuyan *et al.*, 2022) (Figure 12).

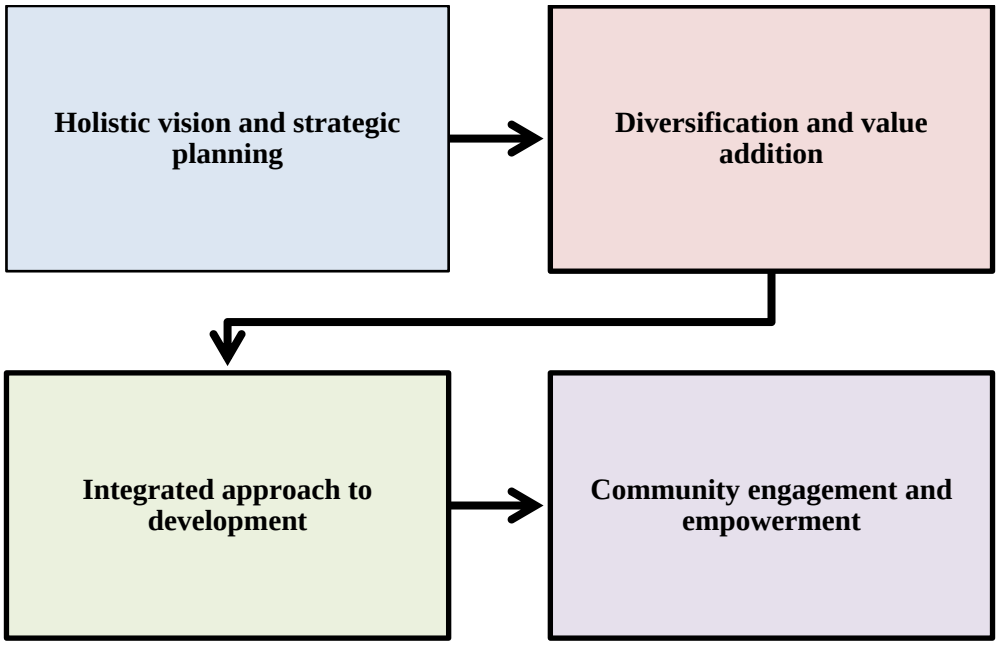

Figure 12. Government strategies for Blue Economy development in Bangladesh.

5.2. Legal and regulatory environment

5.2.1. Legislative framework for Blue Economy

The legal framework governing the Blue Economy in Bangladesh is underpinned by a series of legislative acts and regulations. Laws addressing fisheries management, marine resource conservation, environmental protection, and maritime trade are carefully crafted to provide a robust foundation for responsible economic activities. These laws undergo continuous review and adaptation to address emerging challenges (Islam and Mostaque, 2018; Failler *et al.*, 2019, 2021; Alam *et al.*, 2021; Sharwar *et al.*, 2023).

5.2.2. Licensing and permitting

Ensuring responsible and sustainable practices is integral to the legal and regulatory environment. Licensing and permitting mechanisms play a crucial role in monitoring and managing economic activities. Fishery licenses, aquaculture permits, and environmental clearances are not merely bureaucratic processes but essential tools for maintaining ecological integrity and responsible resource utilization (Shamsuzzaman and Islam, 2018; Rahman, 2021; Al Arif and Karim, 2022).

5.2.3. Environmental compliance

The legal framework prioritizes environmental sustainability. Regulations mandate strict compliance with environmental standards, reflecting the commitment to preserving marine ecosystems. Through these regulations, the government establishes a clear stance on the importance of balancing economic development with environmental conservation, emphasizing the need for businesses to operate responsibly (Bennett and Satterfield, 2018; Shayan *et al.*, 2022; Sharwar *et al.*, 2023).

5.2.4. Stakeholder accountability

Accountability is a cornerstone of the legal and regulatory environment. The legal framework outlines mechanisms to ensure stakeholder accountability, especially for corporations involved in maritime trade. This includes adherence to ethical business practices, safety standards, and social responsibility. The legal landscape thus acts as a safeguard, promoting responsible and ethical conduct within the Blue Economy (Failler *et al.*, 2019; Mannan *et al.*, 2020) (Figure 13).

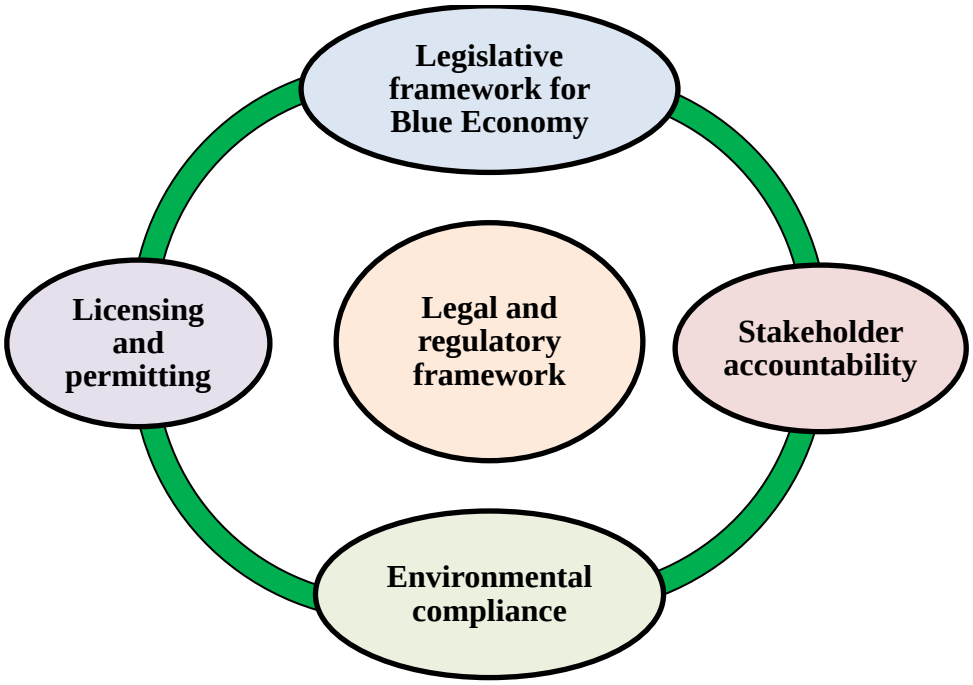

Figure 13. Legal and regulatory framework for Blue Economy in Bangladesh.

5.3. International collaborations and agreements

5.3.1. BIMSTEC and regional cooperation

Bangladesh's active engagement in regional collaborations, particularly through BIMSTEC, showcases a commitment to regional cooperation. The Bay of Bengal region is recognized as a hub for economic activities, and regional partnerships facilitate mutual benefits. Information exchange, technology transfer, and joint initiatives contribute to a shared vision of sustainable Blue Economy development (Rahman, 2017; Biswas, 2020).

5.3.2. Bilateral agreements

Bilateral agreements play a pivotal role in expanding Bangladesh's reach in the global Blue Economy landscape. Engaging with neighboring countries and international partners fosters collaboration in areas such as maritime trade, joint research, and technology transfer. These agreements not only open avenues for economic growth but also strengthen diplomatic ties and foster shared responsibility for sustainable development (Failler *et al.*, 2019; Haque, 2022; Sharwar *et al.*, 2023).

5.3.3. United Nations conventions

Bangladesh aligns its Blue Economy initiatives with international conventions endorsed by the United Nations. Adherence to conventions on the Law of the Sea, biodiversity conservation, and climate action underscores the nation's commitment to global sustainable development goals. By participating in these conventions, Bangladesh contributes to the collective effort to address transboundary challenges and ensures that its Blue Economy aligns with global best practices (Hasan *et al.*, 2018; Haque *et al.*, 2022).

5.3.4. Capacity building and knowledge exchange

International collaborations serve as conduits for capacity building and knowledge exchange. Bangladesh benefits from shared experiences, technological advancements, and best practices from its international partners. This collaborative learning enhances the effectiveness of Blue Economy policies and practices, fostering innovation and adaptability in the face of evolving challenges (Islam and Mostaque, 2018; Jafrin *et al.*, 2021; Sharwar *et al.*, 2023)(Figure 14).

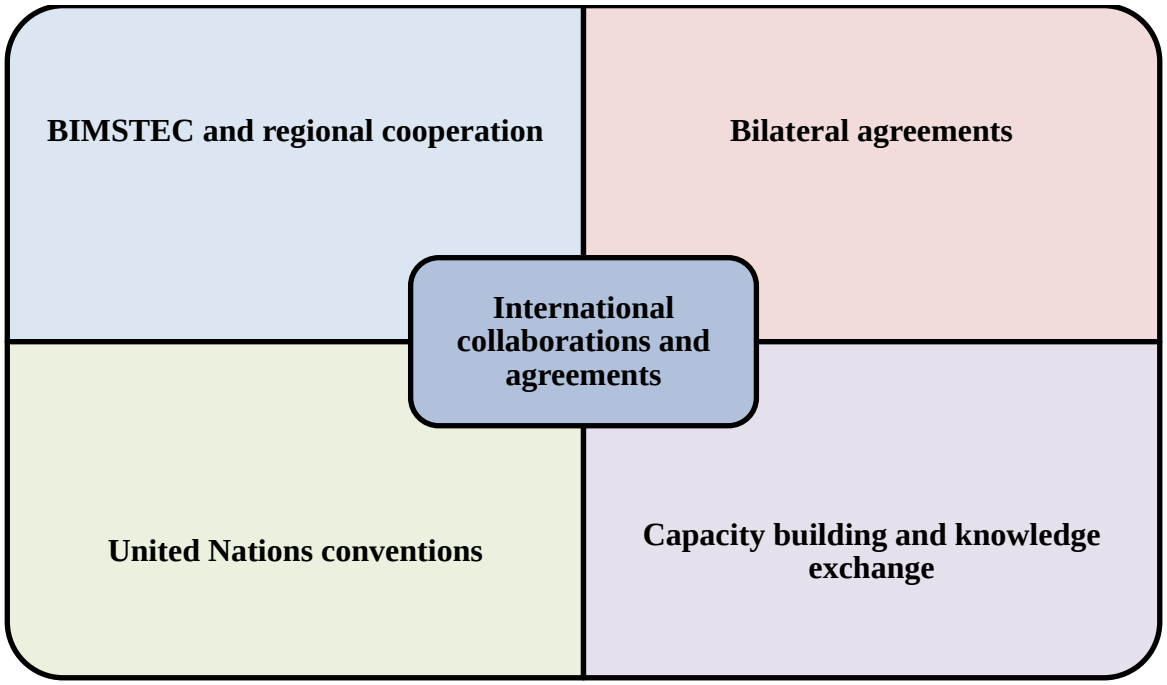

Figure 14. International collaborations and agreements for development and implementation of Blue Economy in Bangladesh.

6. Environmental sustainability: nurturing Bangladesh's Blue Economy for the future

As Bangladesh endeavors to foster a thriving Blue Economy, the critical imperative of environmental sustainability takes center stage. This section unravels the intricate relationship between Blue Economy activities and marine ecosystems, delving into conservation measures, sustainable practices, and the ongoing quest to strike a delicate balance between economic growth and environmental preservation (Islam and Mostaque, 2018; Failler *et al.*, 2021; Karim and Islam, 2022).

6.1. Impact of Blue Economy activities on marine ecosystems

Overfishing and resource depletion: Intensive fishing practices, a historical hallmark of maritime activities, have led to overfishing in certain regions. The overexploitation of fish stocks poses a threat to marine biodiversity and disrupts the delicate balance within ecosystems (Hussain *et al.*, 2018; Hossain and Hasan, 2021; Sultana *et al.*, 2022).

Habitat degradation: Unregulated development, including infrastructure projects and aquaculture expansion, may lead to habitat degradation. Destruction of mangroves, coastal areas, and breeding grounds negatively impacts the overall health of marine ecosystems (Sarker *et al.*, 2019; Islam *et al.*, 2020b; Akram *et al.*, 2023).

Pollution and contamination: Maritime trade, transport, and aquaculture activities contribute to pollution and contamination of marine environments. Discharges of pollutants, including chemicals and plastics, have far-reaching consequences for water quality and the health of marine flora and fauna (Hossain, 2019; Kumar *et al.*, 2021; Bhuyan *et al.*, 2022).

Climate change vulnerability: Bangladesh's marine ecosystems are vulnerable to the impacts of climate change. Rising sea levels, ocean acidification, and changes in temperature patterns pose additional stressors, affecting the distribution and abundance of marine species (Sarker *et al.*, 2019; Islam *et al.*, 2020a; Failler *et al.*, 2021) (Figure 15).

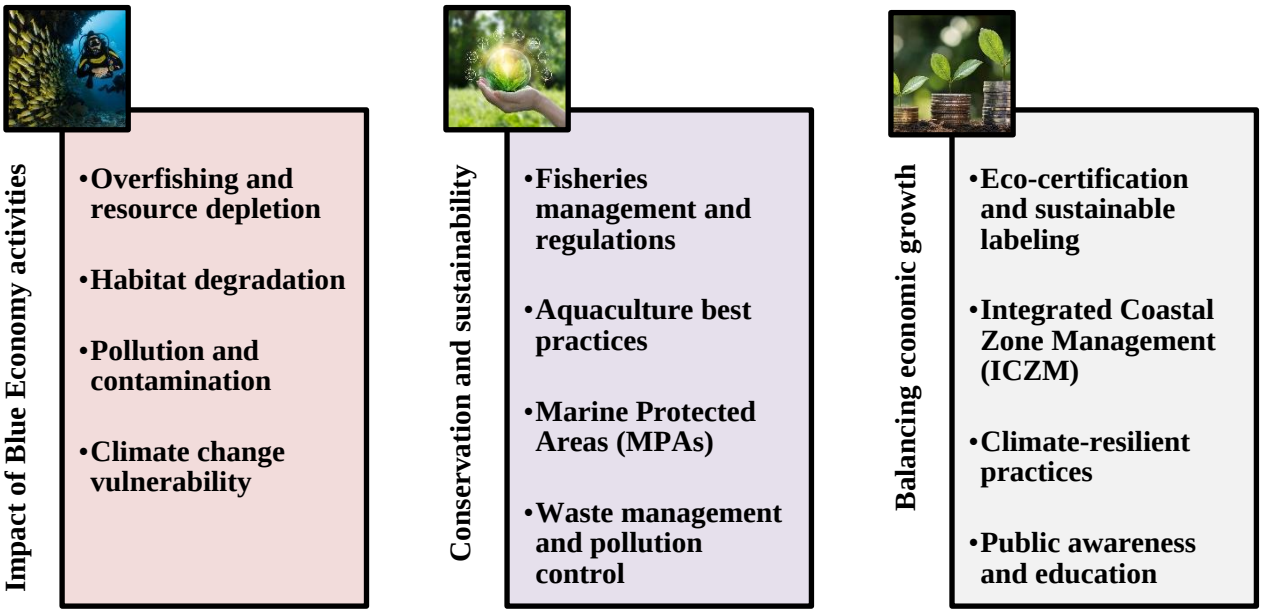

Figure 15. Environmental sustainability strategy for Blue Economy of Bangladesh.

6.2. Conservation measures and sustainable practices

Fisheries management and regulations: Implementing effective fisheries management practices is paramount to ensure sustainable exploitation of marine resources. This includes setting catch limits, regulating fishing gear, and establishing protected areas to allow fish stocks to replenish (Rahman *et al.*, 2018; Failler *et al.*, 2019; Shamsuzzaman *et al.*, 2022; Sharwar *et al.*, 2023).

Aquaculture best practices: In aquaculture, adopting best practices is crucial for minimizing environmental impact. Responsible farming methods, such as integrated multi-trophic aquaculture, reduce reliance on external inputs and mitigate the risk of habitat degradation (Wenhai *et al.*, 2019; Zhang *et al.*, 2019).

Marine Protected Areas (MPAs): Establishing Marine Protected Areas contributes to conservation efforts by safeguarding critical habitats and allowing marine ecosystems to recover. MPAs act as sanctuaries for marine life, supporting biodiversity and enhancing the resilience of ecosystems (Islam and Shamsuddoha, 2018; Iqbal, 2019).

Waste management and pollution control: Stringent waste management and pollution control measures are essential. Implementing technologies for wastewater treatment, regulating discharge norms, and promoting sustainable aquaculture practices help mitigate the impact of pollution on marine environments (Hasan *et al.*, 2018; Sarker *et al.*, 2019; Mubin *et al.*, 2023)(Figure 15).

6.3. Balancing economic growth with environmental concerns

Eco-certification and sustainable labeling: Embracing eco-certification and sustainable labeling for seafood products provides consumers with assurance about the environmental sustainability of the products. This incentivizes responsible practices within the fisheries and aquaculture sectors (Kaiser and Edwards-Jones, 2006; Wenhai *et al.*, 2019; Jafrin *et al.*, 2021).

Integrated Coastal Zone Management (ICZM): Integrated Coastal Zone Management strategies consider both economic development and environmental conservation. Balancing competing demands for coastal space involves zoning, spatial planning, and a holistic approach to manage human activities (Shampa *et al.*, 2023; Sharwar *et al.*, 2023).

Climate-resilient practices: Incorporating climate-resilient practices within Blue Economy activities is essential. This includes adapting to changing climate conditions, implementing strategies to mitigate climate impacts, and enhancing the overall resilience of coastal communities (Sarker *et al.*, 2019; Sharwar *et al.*, 2023).

Public awareness and education: Fostering public awareness and education is instrumental in promoting environmental stewardship. Engaging coastal communities, policymakers, and businesses in understanding the interconnectedness of economic activities and marine health encourages responsible practices (Islam and Mostaque, 2018; Failler *et al.*, 2019; Shayan *et al.*, 2022)(Figure 15).

As Bangladesh navigates the complex waters of Blue Economy development, the commitment to environmental sustainability stands as a guiding principle. Conservation measures, sustainable practices, and the conscientious pursuit of a delicate balance between economic aspirations and environmental concerns pave the way for a Blue Economy that thrives in harmony with nature.

7. Financial mechanisms and investments: sustaining Bangladesh's Blue Economy vision

The realization of Bangladesh's Blue Economy vision hinges on robust financial mechanisms and strategic investments. In this section, we explore the intricacies of financing Blue Economy projects, the role of both public and private sector investments, and the challenges inherent in attracting the necessary financial support (Huang *et al.*, 2022; Sharwar *et al.*, 2023).

7.1. Financing Blue Economy projects

Government budget allocations: Bangladesh demonstrates its commitment to the Blue Economy through budgetary allocations. Government funding serves as a primary source for initiating and sustaining Blue Economy projects, ranging from fisheries management initiatives to infrastructure development and environmental conservation efforts (Huang *et al.*, 2022; Nham and Ha, 2023).

International financial institutions: Collaboration with international financial institutions, such as the World Bank, Asian Development Bank, and the United Nations, plays a pivotal role in financing Blue Economy projects. These institutions provide financial assistance, technical expertise, and policy guidance to enhance the effectiveness of Bangladesh's maritime development initiatives (Failler *et al.*, 2019; Huang *et al.*, 2022; Loukoianova *et al.*, 2022).

Blue Economy funds and grants: Specialized funds and grants dedicated to Blue Economy projects contribute to financial sustainability. The establishment of Blue Economy funds, often supported by both domestic and international stakeholders, serves as a mechanism to pool resources for targeted projects that align with sustainable development goals (Tirumala and Tiwari, 2022; Nham and Ha, 2023).

Public-Private Partnerships (PPPs): Collaborative endeavors between the government and the private sector, known as public-private partnerships, provide an avenue for leveraging private capital for Blue Economy projects. These partnerships often involve joint investments in infrastructure, technology, and sustainable practices (Failler *et al.*, 2019; Haque *et al.*, 2020; Asian Development Bank, 2022; Loukoianova *et al.*, 2022) (Figure 16).

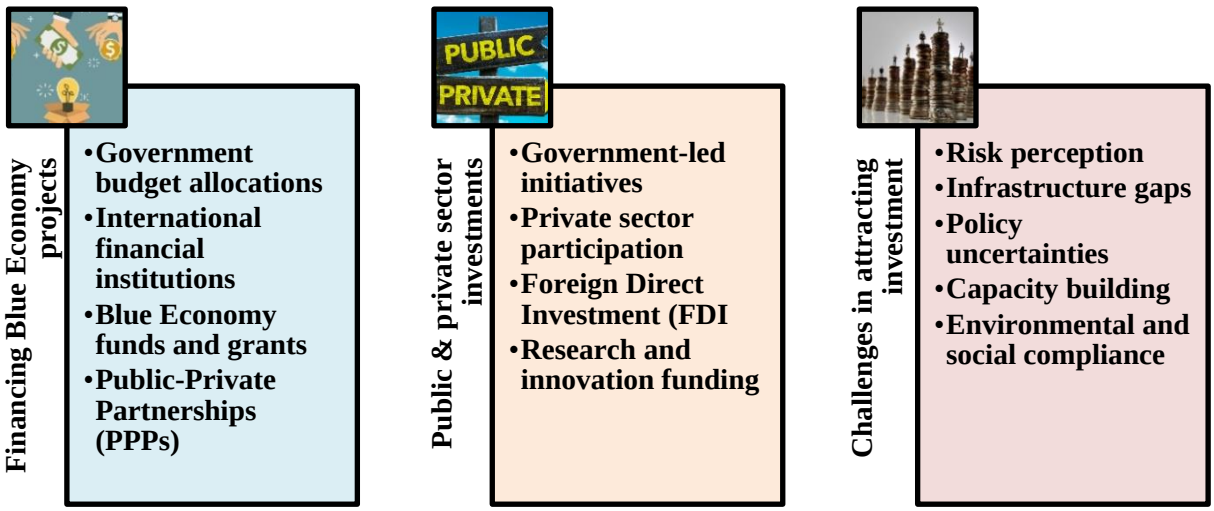

Figure 16. Financial mechanisms and investments in sustaining Blue Economy of Bangladesh.

7.2. Public and private sector investments

Government-led initiatives: The government takes a lead role in initiating and financing key Blue Economy projects. Investments in fisheries management, aquaculture development, maritime infrastructure, and research and development underscore the government's commitment to fostering sustainable economic growth in the maritime domain (Whisnant and Vandeweerd, 2019; Failler *et al.*, 2021; Sharwar *et al.*, 2023).

Private sector participation: The active involvement of the private sector is crucial for the diversification and expansion of the Blue Economy. Private investments in aquaculture ventures, seafood processing, marine transport, and eco-tourism contribute to economic dynamism and job creation within the maritime sector (Whisnant and Vandeweerd, 2019).

Foreign Direct Investment (FDI): Encouraging foreign direct investment is a strategic approach to infuse capital and expertise into Bangladesh's Blue Economy. Attracting FDI in sectors such as port development, fisheries technology, and marine research enhances the nation's economic capacity and strengthens its global standing in the Blue Economy arena (Sarker *et al.*, 2018; Mujeri, 2021; Huang *et al.*, 2022; Sharwar *et al.*, 2023).

Research and innovation funding: Investments in research and innovation are paramount for sustainable development. Financial support for scientific research, technology adoption, and innovation within the Blue Economy sphere ensures that Bangladesh remains at the forefront of advancements, enhancing the sector's economic viability (Whisnant and Vandeweerd, 2019; Tirumala and Tiwari, 2022) (Figure 16).

7.3. Challenges in attracting investment

Risk perception: The perceived risks associated with Blue Economy projects, including environmental uncertainties, market fluctuations, and geopolitical factors, may deter potential investors. Mitigating these risks through effective risk management strategies is imperative to attract sustainable investments (Bhuyan *et al.*, 2022; Huang *et al.*, 2022; Sharwar *et al.*, 2023).

Infrastructure gaps: Incomplete or inadequate maritime infrastructure poses a challenge in attracting private investments. The development of ports, cold storage facilities, processing units, and transport networks is pivotal for creating an investor-friendly environment and ensuring the efficient flow of goods and services (Whisnant and Vandeweerd, 2019; Bhuyan *et al.*, 2022; Sharwar *et al.*, 2023).

Policy uncertainties: Investors often face uncertainties related to regulatory frameworks and policy shifts. A stable and transparent policy environment, coupled with clear guidelines for Blue Economy activities, is essential to instill confidence and attract long-term investments (Martínez-Vázquez *et al.*, 2021; Niner *et al.*, 2022; Sharwar *et al.*, 2023).

Capacity building: The lack of skilled workforce and technical expertise within the Blue Economy sector may impede investor interest. Investment in capacity building initiatives, education, and skill development programs ensures a pool of trained professionals capable of driving the sector forward (Islam and Mostaque, 2018; Sharwar *et al.*, 2023).

Environmental and social compliance: Stringent environmental and social compliance requirements may pose challenges for investors. Striking a balance between economic development and environmental responsibility, coupled with transparent reporting and compliance mechanisms, is essential to address these concerns (Whisnant and Vandeweerd, 2019; Appiah *et al.*, 2023; Sharwar *et al.*, 2023) (Figure 16).

8. Case studies: Unveiling the tapestry of Bangladesh's Blue Economy journey

We delve into the rich tapestry of Bangladesh's Blue Economy through case studies that illuminate both successful projects and the valuable lessons gleaned from setbacks. These case studies provide a nuanced understanding of the complexities inherent in Blue Economy initiatives, offering insights into the triumphs, challenges, and best practices that shape the nation's maritime landscape (Wenhai *et al.*, 2019; Huang *et al.*, 2022).

8.1. Successful Blue Economy projects in Bangladesh

Shrimp aquaculture innovation: One notable success story in Bangladesh's Blue Economy is the innovative approach to shrimp aquaculture. Implementation of sustainable practices, including water management techniques and disease control measures, has propelled the shrimp industry to global prominence, contributing significantly to export earnings (Failler *et al.*, 2019; Wenhai *et al.*, 2019; Sarkar *et al.*, 2022; Nasreen *et al.*, 2023).

Community-based fisheries management: Successful community-based fisheries management initiatives empower local communities to actively participate in resource management. By establishing co-management structures, such as community fishing cooperatives, these projects enhance livelihoods, ensure sustainable practices, and foster a sense of ownership among coastal communities (Pomeroy *et al.*, 2001; Halls *et al.*, 2017; Mozumder *et al.*, 2018).

Mangrove restoration and eco-tourism: Integrating environmental conservation with economic development, projects focused on mangrove restoration and eco-tourism have flourished. The Sundarbans, the world's largest mangrove forest, exemplifies the synergy between preserving biodiversity, attracting tourists, and providing economic opportunities for local communities (Razzaque, 2017; Bashar, 2018; Islam and Bhuiyan, 2018; Huang *et al.*, 2022)(Figure 17).

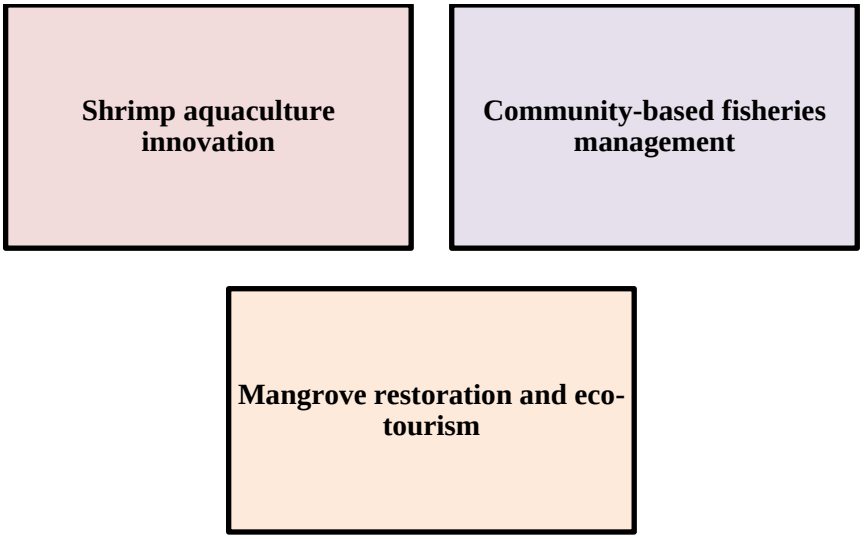

Figure 17. Some examples of successful Blue Economy projects in Bangladesh.

8.2. Lessons learned from failures and setbacks

Unintended environmental consequences of intensive aquaculture: Some Blue Economy initiatives, particularly intensive aquaculture practices, have faced challenges related to environmental degradation. Lessons learned include the need for careful environmental impact assessments, regulatory oversight, and sustainable aquaculture practices to prevent unintended consequences such as habitat destruction and pollution (Islam and Mostaque, 2018; Failler *et al.*, 2019; Huang *et al.*, 2022; Mizuta *et al.*, 2023; Troell *et al.*, 2023).

Inadequate infrastructure planning: Setbacks in maritime trade and transport projects have highlighted the importance of robust infrastructure planning. Instances of congestion, delays, and inefficiencies underscore the need for strategic investment in port facilities, transport networks, and logistics infrastructure to support the growing demands of Blue Economy activities (Munim and Schramm, 2018; Wagner *et al.*, 2022; Sharwar *et al.*, 2023).

Social equity concerns in eco-tourism: While eco-tourism initiatives have flourished, challenges related to social equity and community involvement have surfaced. Lessons learned emphasize the necessity of inclusive planning, benefit-sharing mechanisms, and community empowerment to ensure that the benefits of tourism activities are distributed equitably among local populations (Islam and Mostaque, 2018; Cisneros-Montemayor *et al.*, 2019; Martínez-Vázquez *et al.*, 2021) (Figure 18).

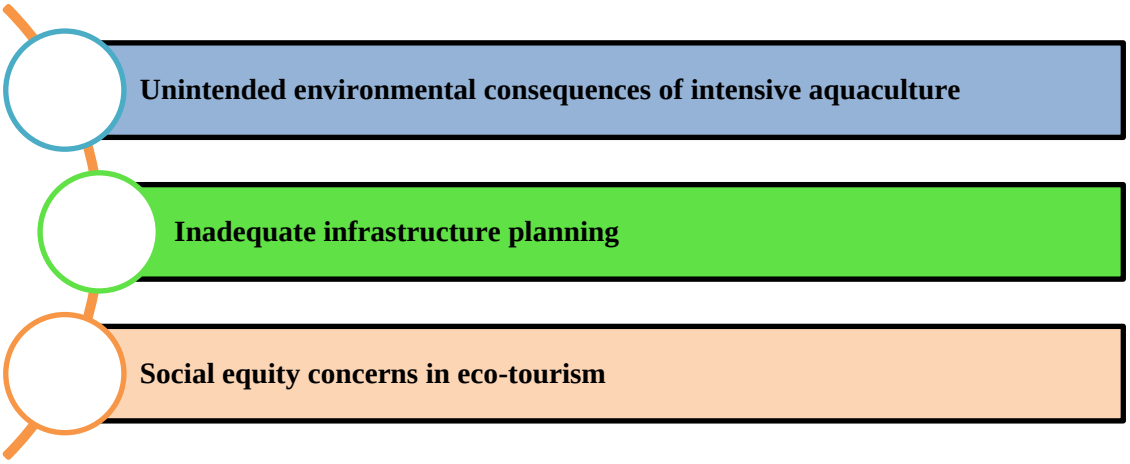

Figure 18. Lessons learned from failures and setbacks of Blue Economy development in Bangladesh.

8.3. Best practices for replication

Integrated Coastal Zone Management (ICZM): Successful case studies often feature Integrated Coastal Zone Management as a best practice. ICZM approaches, which incorporate ecological, social, and economic considerations, offer a holistic framework for managing coastal areas sustainably. This involves stakeholder engagement, spatial planning, and adaptive management practices (Islam *et al.*, 2009; Afroz and Alam, 2013).

Public-Private Partnerships (PPPs): Effective public-private partnerships emerge as a best practice, particularly in infrastructure development. Collaborative efforts between government bodies and private enterprises facilitate the mobilization of resources, technological expertise, and innovative solutions, contributing to the success of Blue Economy projects (Haque *et al.*, 2020; Asian Development Bank, 2022; Huang *et al.*, 2022; Loukoianova *et al.*, 2022).

Adaptive governance structures: Case studies highlight the importance of adaptive governance structures that can respond to dynamic challenges. Flexibility in policy frameworks, incorporating feedback from stakeholders, and continuous monitoring and evaluation contribute to the resilience and success of Blue Economy initiatives (Benzaken *et al.*, 2022; Huang *et al.*, 2022).

Investment in research and development: Successful projects emphasize the role of research and development in driving innovation and sustainability. Investing in scientific research, technological advancements, and capacity building enhances the ability to address challenges, optimize practices, and adapt to evolving conditions within the Blue Economy (Huang *et al.*, 2022; Agrawal *et al.*, 2023; Pace *et al.*, 2023b) (Figure 19).

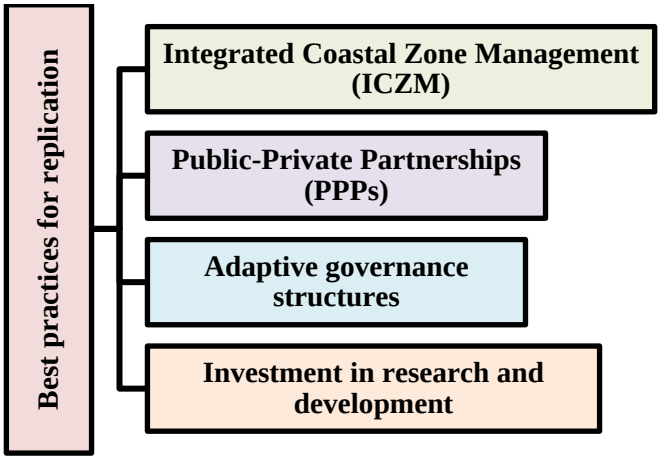

Figure 19. Best practices for replication for Blue Economy development in Bangladesh.

9. Future prospects

In envisioning the trajectory of Bangladesh's Blue Economy, this section explores the emerging trends, identifies opportunities for growth and expansion, and delves into strategies for addressing challenges. The dynamic nature of the maritime landscape requires a forward-looking approach that balances economic aspirations with sustainability and resilience (Failler *et al.*, 2021; Sharwar *et al.*, 2023).

9.1. Emerging trends in Bangladesh's Blue Economy

Technological integration: The integration of cutting-edge technologies is set to revolutionize Bangladesh's Blue Economy. From advanced fisheries monitoring systems to the application of artificial intelligence in aquaculture, technological innovations promise to enhance efficiency, reduce environmental impact, and optimize resource utilization (Moller *et al.*, 2023; Sharwar *et al.*, 2023; Capetillo-Contreras *et al.*, 2024).

Green shipping initiatives: As global concerns about environmental sustainability rise, green shipping initiatives are gaining momentum. Bangladesh's strategic location makes it a key player in regional shipping. Embracing eco-friendly practices, such as the use of cleaner fuels and energy-efficient vessels, positions the nation as a responsible player in international maritime trade (Alamoush *et al.*, 2021; Felício *et al.*, 2021; Sharwar *et al.*, 2023).

Circular economy in aquaculture: The adoption of circular economy principles in aquaculture is an emerging trend. This involves minimizing waste, recycling nutrients, and creating closed-loop systems that enhance the sustainability of aquaculture operations. Such practices not only reduce environmental impact but also contribute to the resilience of the sector (Kusumowardani and Tjahjono, 2020; Chary *et al.*, 2023; Sharwar *et al.*, 2023).

Blue biotechnology for pharmaceuticals: Blue biotechnology, focused on marine organisms, presents opportunities for pharmaceutical advancements. Research into marine-derived compounds for drug development and medical applications can open new frontiers, aligning economic growth with scientific innovation (Uddin and Islam, 2019; Bir *et al.*, 2020; Hossain, 2023; Pace *et al.*, 2023a) (Figure 20).

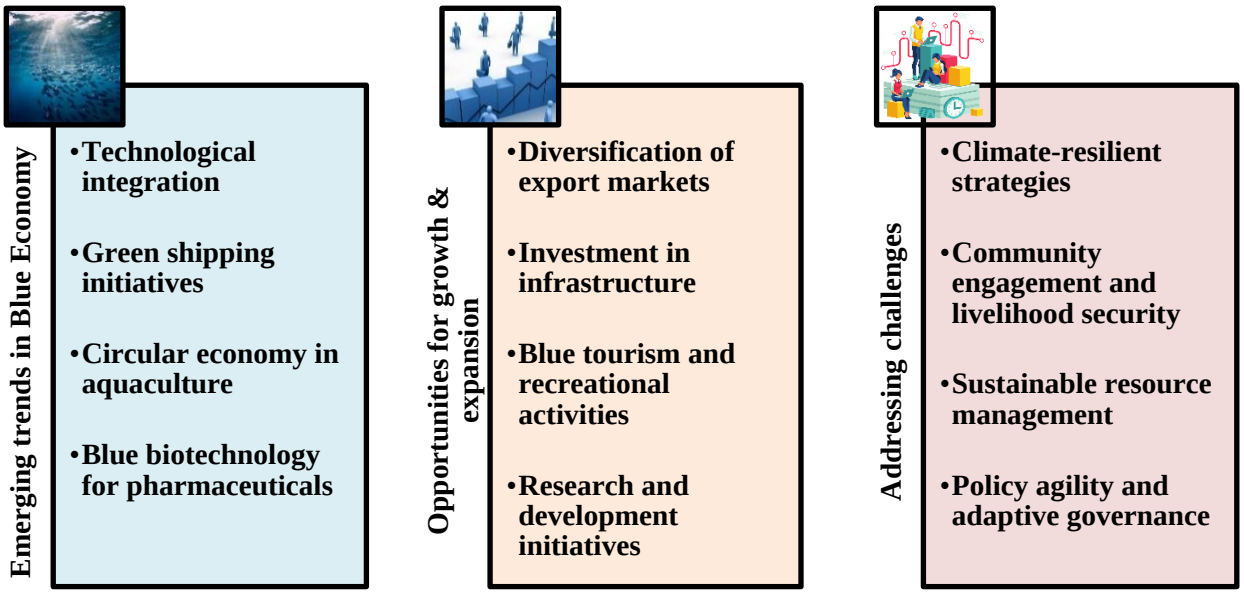

Figure 20. Future prospects of Blue Economy in Bangladesh.

9.2. Opportunities for growth and expansion

Diversification of export markets: Opportunities for growth lie in diversifying export markets for seafood products. Expanding trade partnerships and meeting the rising demand for sustainably sourced seafood present avenues for economic growth in the Blue Economy (Hussain *et al.*, 2018; Failler *et al.*, 2021; Huang *et al.*, 2022; Geng *et al.*, 2024).

Investment in infrastructure: Strategic investments in port infrastructure, cold storage facilities, and transportation networks are vital for the growth of maritime trade. Infrastructure development not only supports existing activities but also lays the foundation for future expansions in the Blue Economy (Hussain *et al.*, 2018; Huang *et al.*, 2022; Sharwar *et al.*, 2023).

Blue tourism and recreational activities: Leveraging the beauty of coastal areas for blue tourism and recreational activities presents significant economic potential. This includes eco-tourism initiatives, water sports, and the development of coastal resorts, contributing to job creation and revenue generation (Hussain *et al.*, 2018; Nur Nobi and Majumder, 2019; Bethel *et al.*, 2021; Failler *et al.*, 2021).

Research and development initiatives: Opportunities abound in research and development initiatives that enhance the sustainability and productivity of Blue Economy activities. From genetic improvements in aquaculture species to the development of eco-friendly fishing gear, investing in R&D ensures the resilience and competitiveness of the maritime sector (Hussain *et al.*, 2018; Failler *et al.*, 2021; Pace *et al.*, 2023b) (Figure 20).

9.3. Addressing challenges for a sustainable future

Climate-resilient strategies: Given the vulnerability of Bangladesh's coastal areas to climate change, implementing climate-resilient strategies is imperative. This involves adaptive measures in fisheries management, aquaculture practices, and infrastructure development to mitigate the impact of changing climate patterns (Sarker *et al.*, 2019; Smith *et al.*, 2021; Mozumder *et al.*, 2023a).

Community engagement and livelihood security: Proactive community engagement and measures to ensure livelihood security for coastal communities are critical. Empowering local populations through skill development, alternative income sources, and inclusive decision-making processes fosters social resilience within the Blue Economy framework (Hasan *et al.*, 2018; Chen *et al.*, 2020).

Sustainable resource management: Striking a balance between economic activities and resource conservation is foundational for a sustainable future. Implementing sustainable resource management practices, including responsible fisheries management and habitat conservation, ensures the longevity of Bangladesh's Blue Economy (Failler *et al.*, 2021; Sharwar *et al.*, 2023).

Policy agility and adaptive governance: The future requires policy frameworks which exhibit agility and adaptability. As challenges evolve, policies should be flexible enough to accommodate changes, incorporate new knowledge, and address emerging issues within the Blue Economy (Failler *et al.*, 2019; Bhuyan *et al.*, 2022; Huang *et al.*, 2022)(Figure 20).

In charting the future course of Bangladesh's Blue Economy, a strategic blend of innovation, responsible governance, and community-centric approaches will be pivotal. By seizing emerging opportunities, addressing challenges proactively, and staying attuned to global trends, Bangladesh can position itself as a beacon of sustainable and resilient maritime development (Failler *et al.*, 2021).

10. Conclusions

The exploration of Bangladesh's Blue Economy reveals a multifaceted narrative that intertwines economic prosperity, environmental sustainability, and social resilience. The holistic development paradigm, underpinned by robust policies and inclusive strategies, emphasizes the interconnectedness of these elements. Diversification beyond traditional fisheries emerges as a catalyst for sustained growth, reducing dependency on singular sectors. The empowerment of coastal communities and the assurance of livelihood security are crucial components of this narrative, fostering social resilience and equitable distribution of benefits. Environmental sustainability takes center stage as a non-negotiable imperative, calling for conservation measures, sustainable practices, and eco-friendly technologies to preserve marine ecosystems. Financial mechanisms and global collaborations, both public and private, play pivotal roles in catalyzing growth and fostering international partnerships. Lessons drawn from successes and setbacks, encapsulated in case studies, serve as guideposts for adaptive governance, sustainable practices, and continuous research and development. Charting a sustainable future for Bangladesh's Blue Economy involves navigating challenges, seizing emerging opportunities, and upholding a steadfast commitment to responsible development. Investments in infrastructure, research, and community well-being, coupled with adaptive policies, position Bangladesh to thrive economically while preserving its marine heritage and contributing to global best practices in Blue Economy development.

Data availability
Not applicable.

Conflict of interest
None to declare.

Authors' contribution
Conceptualization: Md. Atiqul Islam Mondal and Abdulla-Al-Asif; methodology: Abdulla-Al-Asif and Lirong Yu Abit; formal analysis: Md. Atiqul Islam Mondal, Lirong Yu Abit, Abdullah Al Mamun Siddiqui and Abdulla-Al-Asif; writing-original draft preparation: Abdulla-Al-Asif, Md. Atiqul Islam Mondal and Lirong Yu Abit; writing-review and editing: Lirong Yu Abit, Abdullah Al Mamun Siddiqui and Abdulla-Al-Asif. All authors have read and approved the final manuscript.

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