



An Ecosystem-Based Marine Spatial Planning Approach for Sustainable Natural Resources Management in the Bangladesh Delta

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Abstract: Despite the establishment of maritime boundaries with Myanmar (2012) and India (2014), which secured sovereign rights over approximately 118,813 km² of the Bay of Bengal, marine space is still managed on a sector-by-sector basis, and no marine spatial plan has been prepared. This study identifies significant ecological, economic, and cultural areas within Bangladesh's maritime zone, and proposes a framework for the blue economy and develops an ecosystem-based model of marine spatial planning (MSP). Secondary spatial and statistical data from government agencies, research institutions, and peer-reviewed literature were combined with NOAA-20 VIIRS ocean colour imagery in a GIS geodatabase. The ArcGIS-based AquaSpace tool then supported the identification of sites, scenario analysis, and conflict screening. The mapping covered marine protected areas, ecologically sensitive areas, fishing grounds, Hilsa sanctuaries, ports, shipping routes, ship-recycling yards and 26 offshore hydrocarbon blocks (15 in deep water and 11 in shallow water), as well as coastal tourism sites. Conflict hotspots arose between nearshore artisanal fishing and shipping and between offshore gas exploration and Hilsa sanctuaries and sensitive habitats. The proposed framework incorporates MSP into an Integrated Coast and Ocean Management policy and plan, while the spatial model allocates space for conservation, fisheries, mariculture, ports, energy, research and security. The reliance on secondary data and the absence of stakeholder validation limit the findings. However, the model offers a transparent starting point for Bangladesh's first national marine plan. As a general recommendation, planners and policymakers in coastal states with limited data should begin MSP by pooling existing sectoral data in a shared geodatabase, protecting ecologically sensitive areas first, separating conflicting uses in space, and refining the zones with stakeholders as new data emerge, so that blue growth is pursued within ecological limits.

Keywords: Marine Spatial Planning; Blue Economy; Ecosystem-Based Management; Bay of Bengal; Geographic Information System; Bangladesh

INTRODUCTION

The oceans and coasts provide humans with food, trade routes, energy and recreational opportunities. However, the ecosystem services upon which these benefits depend are eroded by eutrophication, overfishing and biodiversity loss (Millennium Ecosystem Assessment, 2005). As demand for ocean space intensifies, the separate management of fisheries, shipping, energy and conservation has struggled to anticipate cumulative effects or resolve conflicts among users (Curtin & Prellezo, 2010; Katsanevakis et al., 2011). Consequently, marine spatial planning (MSP) has emerged as a place-based process for analysing and allocating human activities in space and time, enabling the achievement of ecological, economic and social objectives (Ehler & Douvère, 2009). Since the early zoning schemes in places such as the Great Barrier Reef and China, and the adoption of the European Union's MSP Directive (European Parliament & Council, 2014), the field has expanded rapidly (Ehler, 2021). However, most documented case studies are still concentrated in Europe (Chalastani et al., 2021).

Bangladesh exemplifies the challenges and opportunities associated with the implementation of MSP in a developing coastal state. Two international legal decisions have resolved the country's maritime boundaries and established its sovereign rights over approximately 118,813 km² of the Bay of Bengal. These legal instruments include the judgment of the International Tribunal for the Law of the Sea (ITLOS) in the Bangladesh/Myanmar case in 2012 and the award of an Annex VII arbitral tribunal in the Bangladesh–India case in 2014 (ITLOS, 2012; PCA, 2014; Islam & Shamsuddoha, 2018). The Bay of Bengal supports diverse economic activities, including fisheries, shipping, and offshore gas development, in addition to serving as a habitat for significant ecological regions such as the Sundarbans mangroves and the Swatch of No Ground (SoNG) submarine canyon (Islam & Wahab, 2005; Islam & Shamsuddoha, 2018). The Seventh Five-Year Plan (2016–2020) identified MSP as a tool for ocean governance (General Economics Division [GED], 2015), and a Blue Economy Cell was established to coordinate policy (Islam & Shamsuddoha, 2018). However, the planning for the sea remains fragmented, with sectoral policies pursuing divergent objectives, and as of the time of this study, no marine spatial plan had been formulated.

Bangladeshi scholarship on MSP is in its infancy. Existing contributions have introduced MSP as a tool for achieving blue economy goals (Saha & Alam, 2018), examined the institutional arrangements needed to support it (Hassan & Alam, 2019) and, more recently, compiled spatial data on maritime activities and stakeholder views as a background for a plan, concluding that ecological data remain limited (Sarker & Failler, 2023). However, what is still missing is a spatially explicit, ecosystem-based allocation of marine space that links the distribution of key ecological, economic and cultural areas to a governance framework for the blue economy. The present paper aims to

address this gap by means of the following objectives: firstly, to identify and map significant ecological, economic and cultural areas in the Bangladesh maritime zone; secondly, to propose a framework for introducing blue growth through sustainable natural resource management; and thirdly, to develop an ecosystem-based model of MSP using a geospatial approach.

Ecosystem-based management and MSP

The concept of ecosystem-based management (EBM) emerged as a response to the shortcomings of sectoral resource management, which focused on individual industries and overlooked the cumulative pressures, such as eutrophication, pollution and habitat loss, that they collectively exerted on an ecosystem (Curtin & Prellezo, 2010). EBM is place-based in nature, taking an ecosystem, and the human activities affecting it, as the unit of management (Guerry, 2005), and it recognises interactions across spatial and temporal scales and between ecological and social systems (Leslie & McLeod, 2007). Sectoral approaches, in contrast, ignore interactions among ocean uses, their cumulative impacts, effects on ecosystem service provision and explicit trade-offs between activities (Katsanevakis et al., 2011; Lester et al., 2013). Despite the broad consensus on the necessity of EBM, examples of its implementation in marine settings remain few and have often centred on fisheries (Guerry, 2005; Tallis et al., 2010). Marine spatial planning (MSP) is increasingly regarded as a practical vehicle for EBM because it allocates space to uses and conservation within a single analytical framework (Gilliland & Laffoley, 2008; Katsanevakis et al., 2011).

The planning process

The UNESCO-IOC guide characterises MSP as a cyclical ten-step process that progresses from the establishment of needs and objectives, through the analysis of existing and future conditions, and the preparation of a spatial management plan, to the implementation, monitoring and adaptation of the plan, with stakeholder participation throughout (Ehler & Douvère, 2009; Pomeroy & Douvère, 2008). Monitoring and evaluation are considered essential so that plans can be revised as knowledge and conditions change (Douvère & Ehler, 2011). As information is usually incomplete, caution should be exercised in proportion to uncertainty: the more that is unknown about a system, the more cautious management decisions should be (McLeod et al., 2005). Early practice also demonstrates differences in purpose. Zoning of the Great Barrier Reef Marine Park was driven mainly by conservation, whereas China's marine functional zoning allocates space across ports, fisheries, mining, tourism, energy and protected areas in order to limit use conflicts (Fang et al., 2011), and European MSP has been shaped by the Integrated Maritime Policy and the 2014 Directive (Schaefer & Barale, 2011; European Parliament & Council, 2014).

Sustainability orientations

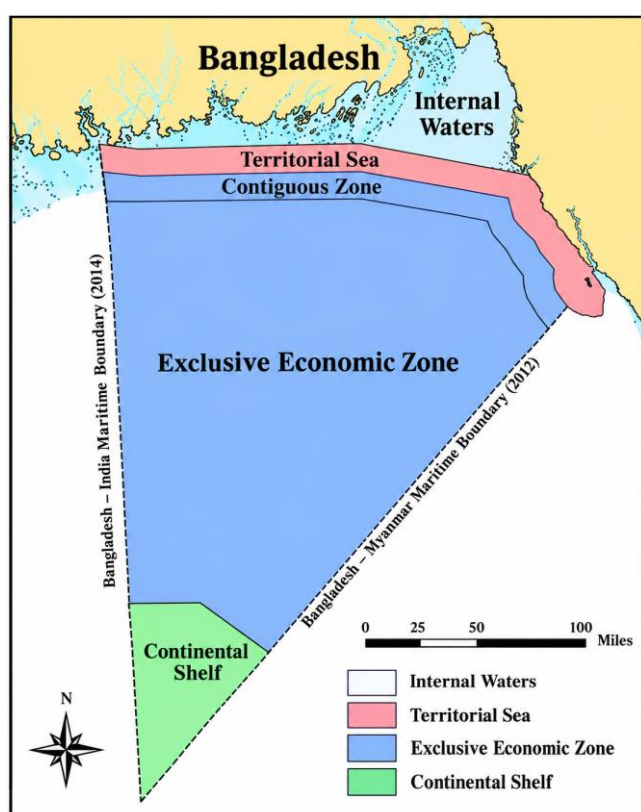
MSP can be conceptualised within the context of contrasting notions of sustainability. Strong (hard) sustainability is predicated on the premise that natural capital is to be maintained in a state of inviolate integrity, thus underpinning ecosystem-based MSP centred on ecosystem protection. Conversely, weak (soft) sustainability permits trade-offs among natural, manufactured and human capital, and is concomitant with integrated-use MSP oriented towards blue growth. The two positions converge as ecosystems approach tipping points of degradation (Qiu & Jones, 2013). The present study adopts an ecosystem-based, place-based orientation while acknowledging the blue growth objectives embedded in Bangladesh's policy agenda.

METHODOLOGY

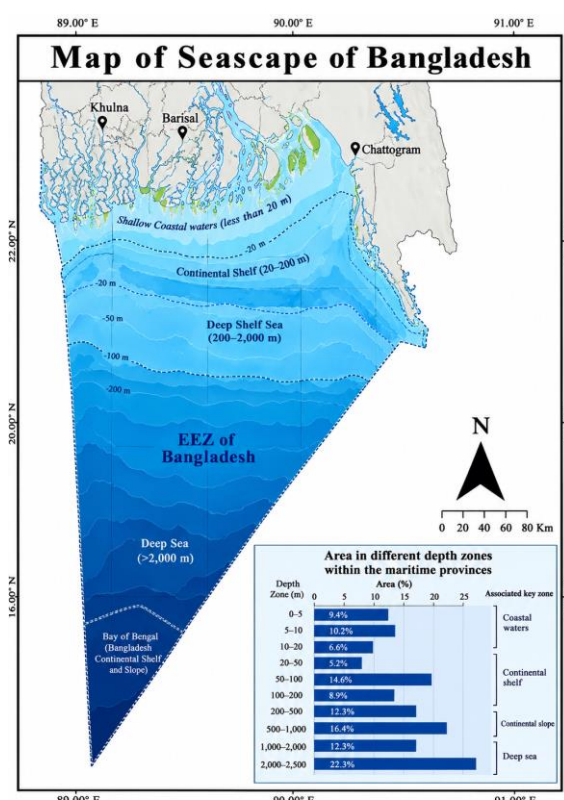
Study Area

Bangladesh is located at the head of the Bay of Bengal, and its markedly concave coastline exposes it to the risk of being enclosed by the maritime claims of its neighbours (Bissinger, 2010). Claims made in the 1970s were contested

by both India and Myanmar (Bissinger, 2010). The International Tribunal for the Law of the Sea (ITLOS) delivered its judgment on 14 March 2012, allocating approximately 111,631 km² of the area in dispute to Bangladesh (ITLOS, 2012), and the arbitral tribunal issued its award on 7 July 2014, granting Bangladesh 19,467 km² of the 25,602 km² disputed with India (PCA, 2014). The maritime zone is commonly reported as approximately 118,813 km², comprising a territorial sea of up to 12 nautical miles, an exclusive economic zone (EEZ) of up to 200 nautical miles and the continental shelf (Islam & Shamsuddoha, 2018; Figure 1a). The EEZ was therefore selected as the target region for planning. Based on geomorphology, the coast was divided into eastern, central and western regions, represented by Cox's Bazar, Kuakata and the Sundarbans respectively; these locations were regarded as the most important spaces for planning future blue economy zones. The seascape comprises shallow coastal waters (0–10 m), an inner shelf (10–80 m), an outer shelf (80–200 m) and a deep sea reaching about 2,200 m (Figure 1b).



(a) Maritime zones



(b) Seascape, depth zones and offshore blocks

Figure 1. Study area: (a) maritime zones of Bangladesh in the Bay of Bengal and (b) seascape of Bangladesh with depth zones, offshore gas blocks, major ports and the Swatch of No Ground MPA and marine reserve (author's compilation)

Research design

The study was meticulously designed and implemented across five distinct stages. These stages encompassed a systematic sequence of activities, including problem analysis, extensive literature review, collection of pertinent

secondary data, spatial analysis and modelling, and final reporting. The analysis was methodically structured around three overarching objectives. It was organised in accordance with the sequence of data acquisition, data-gap

identification, and geodatabase creation and modelling, as outlined below.

Data

The present study made use of a substantial amount of secondary data from a variety of sources, including the Intergovernmental Oceanographic Commission (IOC), the Bangladesh Oceanographic Research Institute (BORI), the Bangladesh Meteorological Department (BMD), various line departments and ministries, as well as a range of peer-reviewed and grey literature, such as journal articles, reports, books and newspapers. The data were meticulously edited, cross-checked and reviewed against the study's objectives to minimise contradictions and inaccuracies. The scarcity of topic-specific books, reports and articles represented the primary challenge during the data collection process. Table

1 provides a comprehensive overview of the sectoral data layers and their probable sources.

The satellite data utilised in this study was obtained from the USGS EarthExplorer portal and comprised NOAA-20 Visible Infrared Imaging Radiometer Suite (VIIRS) ocean-colour bands M1–M5. The following link provides access to the EARTH EXPLORER website: <https://earthexplorer.usgs.gov/> to collect necessary open-access data. The objective of the study was to depict coastal coverage, ocean colour, depth zones and sensitive areas. To this end, scenes with zero per cent cloud cover, acquired in winter and during daytime, were selected to minimise interference from cloud, haze and water vapour. Atmospheric correction and image enhancement were then carried out in a GIS/remote-sensing environment (ArcGIS 10.8.2).

Table 1. Sectors, data variables and probable data sources used to design the MSP (author's compilation).

Sector	Data variables	Probable sources
Shipping	Ports of Chattogram, Mongla and Payra; planned shipping routes; channel depth and navigability	Department of Shipping; port authorities
Fisheries and aquaculture	Fish habitats; aquaculture and mariculture sites; fishing and shrimping areas; hatcheries; marine fishing range; protected areas	Department of Fisheries; fisheries research institutes
Energy, mining and communication	Leasing blocks; gas fields; oil and gas wells; offshore platforms; pipelines; potential wind-farm sites; submarine cables and landing stations	Department of Energy; PetroBangla; research articles
Environment and conservation	Marine protected areas; Hilsa sanctuaries; ecologically critical areas; ship-breaking sites; blue-carbon sites	Department of Environment
Forest	Mangrove forests (Sundarbans); afforestation sites	Department of Forest
Geomorphology	Potential land-reclamation sites; security zones	Water resources agencies
Oceanography	Marine geological research; coral-reef research and transects; bottom-mounted instruments	Universities; research literature
Tourism	Coastal tourism zones; marine cruise routes; marine sports and recreation sites	Department of Tourism

Geodatabase

Tabular data in Excel and CSV formats were converted to SQL tables and managed in a relational database (Microsoft SQL Server), which was linked to the spatial layers.

Spatial modelling

The AquaSpace GIS tool (Gimpel et al., 2018), an ArcGIS add-in originally developed to assess spatial planning trade-offs for aquaculture, was utilised for site identification, scenario analysis and the identification of conflicting issues and future opportunities (Gilliland & Laffoley, 2008). It supported the re-allocation of space for shrimping, security zones, coral-reef research, ports, marine geological research, land-reclamation sites, Hilsa breeding sites, ecologically critical areas and aquaculture, following a place-based approach intended to reduce conflicts among ocean uses while sustaining natural resources. The spatial model is shown in Figure 3.

RESULTS

Significant ecological, economic and cultural areas

Marine protected and ecologically sensitive areas: The first marine protected area (MPA) in Bangladesh, the Swatch of No Ground (SoNG), was declared in 2014 and covers approximately 1,738 km² of a submarine canyon that is more than 900 m deep (WCS Bangladesh, 2014). The canyon cuts into the shelf off the Ganges delta, providing feeding and breeding habitat for whales, dolphins, sharks and porpoises (Islam & Shamsuddoha, 2018). Two ecologically sensitive areas were also mapped. The Sundarbans, a UNESCO World Heritage Site, is the world's largest single-tract mangrove forest (Islam & Wahab, 2005), and St Martin's Island, a fragile coral-associated ecosystem at the south-eastern tip of the country, shelters and provides breeding habitat for juvenile fish, turtles and crabs (Islam & Shamsuddoha, 2018). The inventory in Figure 3 reflects the protected areas available during data compilation; later declarations, such as the Nijhum Dwip marine reserve in 2019 (The Daily Star, 2019), should be added in future iterations.

Fishing areas: Fishing can be categorised into two distinct types: industrial and artisanal (Islam et al., 2017). Artisanal fishers utilise small wooden boats, which can navigate only a limited distance from the coast, approximately 20–30 km (DoF, 2018). This practice results in the concentration of effort and fishing villages along the shoreline (Shamsuzzoha and Ahamed, 2023; 2024; Shamsuzzoha et al., 2026), thereby exerting significant pressure on coastal ecosystems and giving rise to conflicts with shipping, tourism and gas exploration (DoF, 2018). During the study period, a 65-day seasonal ban (20 May–23 July) was implemented for the purpose of sustainable fisheries management, and affected households received rice assistance (DoF, 2018; Shamsuzzaman & Islam, 2018). The Meghna estuary serves as a crucial breeding and nursery ground for Hilsa (*Tenualosa ilisha*) and Vetki (*Lates calcarifer*) and encompasses Hilsa sanctuaries designated by the Department of Fisheries (Islam et al., 2016).

Ports, shipping and ship recycling: Maritime trade is expanding rapidly. The value of import and export trade was estimated at approximately USD 80 billion, with an annual growth rate of 10–15% (Bari, 2017). Most of this trade is handled by the ports of Chattogram and Mongla, and new capacity is being developed at Payra, Matarbari and the Kutubdia LPG/LNG terminal (Figure 3). Apart from trade with India, coastal shipping is almost non-existent (Padmaja, 2016). Ship recycling is concentrated at Sitakunda near Chattogram, which is one of the world's largest ship-breaking locations. It supplies a significant proportion of domestic steel but has been a major polluter of the coastal environment. Each yard is now required to obtain clearance from the Department of Environment before recycling a vessel (Rabbi & Rahman, 2017).

Oil and gas: Bangladesh has 26 offshore blocks in the Bay of Bengal, 15 of which are in deep water and 11 in shallow water (see Figure 1b; Bari, 2017). The country has been producing gas from offshore Block 16 since 1998 (Hussain et al., 2018). However, as several blocks lie near the Hilsa sanctuary and other environmentally sensitive areas, further exploration is likely to generate new conflicts with fisheries and conservation (Islam & Shamsuddoha, 2018).

Tourism: Cox's Bazar, which is the longest natural sea beach, in conjunction with Kuakata, St Martin's Island and the Sundarbans, provides Bangladesh with considerable potential as a coastal and marine tourism destination (Hossain et al., 2017). It is estimated that Cox's Bazar alone has approximately 100 hotels and motels, which collectively employ over 10,000 people (Bari, 2017). However, as visitors continue to rise, there is a risk of overuse, littering

and pollution of coral and coastal waters. Therefore, the incorporation of ecotourism routes within the model is imperative to mitigate these issues.

Framework for the blue economy

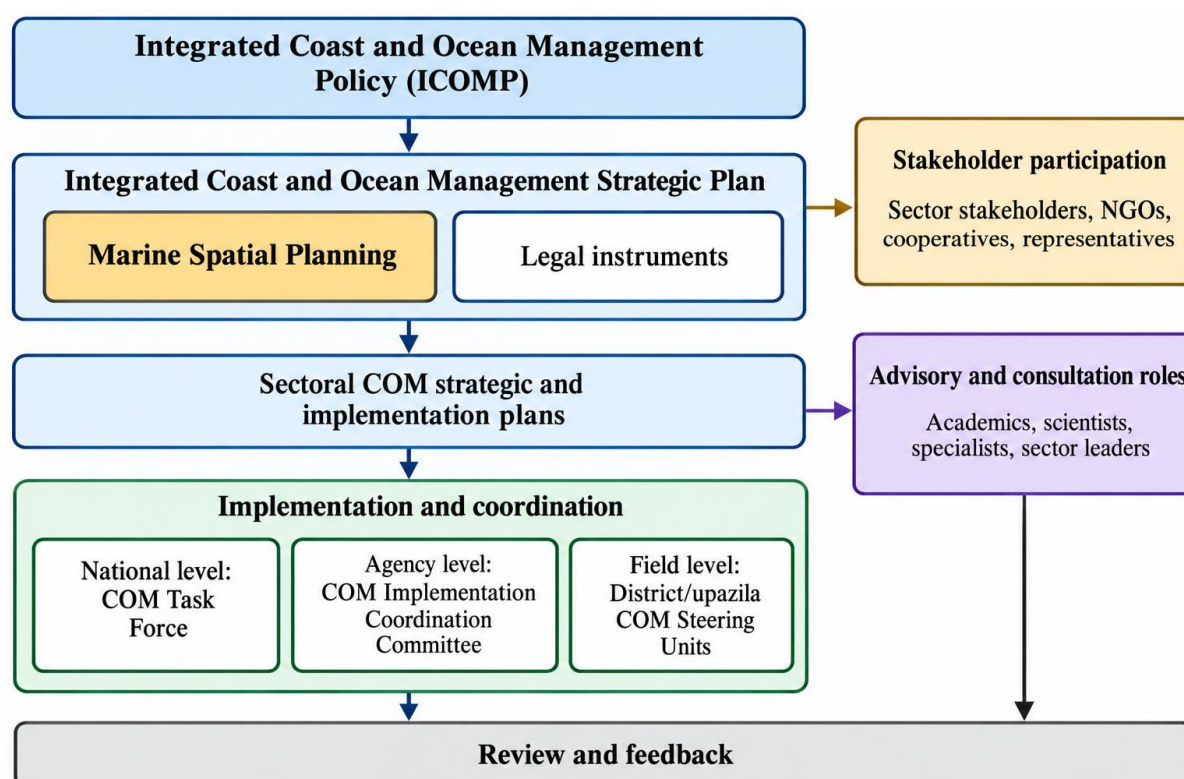
A total of eight productive sectors has been identified for the purpose of utilising ocean resources within the current maritime boundary. These sectors include, but are not limited to, marine fisheries and aquaculture; cultivation of non-traditional marine species; marine biotechnology; blue carbon sequestration; oil, gas and mineral mining; marine renewable energy; sea-salt production; and trade, shipping and maritime transport (Hossain et al., 2014). In conjunction with tourism, maritime research and surveillance, these sectors form the resource base that is summarised in Table 2. If ocean space is subject to proper planning, the establishment of cross-sector coordination, public–private partnerships and investment become a possibility within a single ecosystem-based management framework.

Marine activity in Bangladesh is intricate, with numerous interacting elements comprising its complex nature. The country's abundant natural capital and ecosystem services, its growing business sector, and the multiple stakeholders involved, along with the various local, national, regional, and global agencies that influence its regulatory framework, are but a few of the interacting elements (Hossain et al., 2014). The management of such complexity necessitates an integrated approach encompassing five distinct dimensions: across sectors, levels of government, the land–water interface, disciplines, and countries. This integrated management approach requires a comprehensive knowledge base that incorporates the practical knowledge of resource users and managers with scientific information, verified through approaches such as data triangulation (Hossain et al., 2014).

The proposed framework (Figure 2) has been modified after Hossain et al. (2014). The Integrated Coast and Ocean Management Policy (ICOMP) is situated at the top of the framework and establishes duties and objectives that result in an Integrated Coast and Ocean Management Strategic Plan, with the MSP at its centre. The strategic plan is supported by legal instruments, with existing legislation able to guide strategic planning in many sectors with minor adjustments. The subsequent sectoral coast and ocean management (COM) strategic and implementation plans are then followed by implementation, which is coordinated through a National COM Task Force, an agency-level COM Implementation Coordination Committee and District/Upazila COM Steering Units. Sector stakeholders, NGOs and cooperatives participate throughout, academics and specialists advise, and a review-and-feedback loop supports adaptive management.

Table 2. Marine economic sectors, status during the study period and spatial planning considerations (status modified after Anon., 2016).

Sector	Status during the study period	Spatial planning consideration
Marine fisheries and aquaculture	Fishing on shallow and shelf grounds; extensive shrimp farming improved; soft-shell crab culture limited	Zone artisanal and industrial fishing separately; protect Hilsa sanctuaries; reserve mariculture and aquaculture sites
Non-traditional species and marine biotechnology	Seaweed and algae culture is no longer practised; no marine oyster, mussel or sea-cucumber culture; biotechnology is not applied to marine resources	Reserve suitable shallow sites for pilot mariculture; support research
Blue carbon	Sequestration in estuarine and coastal habitats is not yet accurately estimated; mangrove deforestation	Protect and restore mangroves (Sundarbans, Meghna delta)
Oil, gas and minerals	Partial exploration and extraction; coastal sand mining and dredging	Buffer exploration blocks from sanctuaries and sensitive habitats
Sea salt	Traditional solar evaporation	Safeguard coastal salt-farming areas; strengthen cooperatives and credit
Marine renewable energy	Solar, wave and wind energy of limited use	Assess the offshore resource; reserve corridors once assessed
Trade, shipping and transport	Port shipping and transport limited	Designate approach routes to ports; separate them from fishing grounds
Tourism	Coastal tourism limited	Ecotourism routes; carrying capacity limits at popular sites
Maritime research and surveillance	Research and human-resource development limited; Navy and Coast Guard surveillance	Research and security zones

**Figure 2.** Proposed framework of the blue economy for Bangladesh (modified after Hossain et al., 2014).

Ecosystem-based model of marine spatial planning

The spatial model integrates the layers described above (see Figure 3). It follows place-based logic, in which ecologically sensitive areas are set aside for conservation, uses that conflict are separated spatially, and compatible uses

are placed together (cf. Gilliland & Laffoley, 2008). In the west, the Sundarbans mangrove forest and Hilsa breeding sites are allocated to conservation, with Mongla Port and a marine geological research area offshore. Payra Port and its approaches lie in the central estuarine zone, alongside a security zone, and land-reclamation sites are identified in the

Meghna estuary; Chattogram Port occupies the north-east. Nearshore waters are zoned for shrimping and marine fishing, while the shelf carries mariculture and aquaculture farms, a general fishing area and hatchery fishing. St Martin's Island is reserved for coral-reef research and tourism. Submarine cables, oil and gas lines, planned lines and wind-power lines are shown as marine lines that cross these zones, and the deep southern waters are designated as a proposed ecologically critical area.

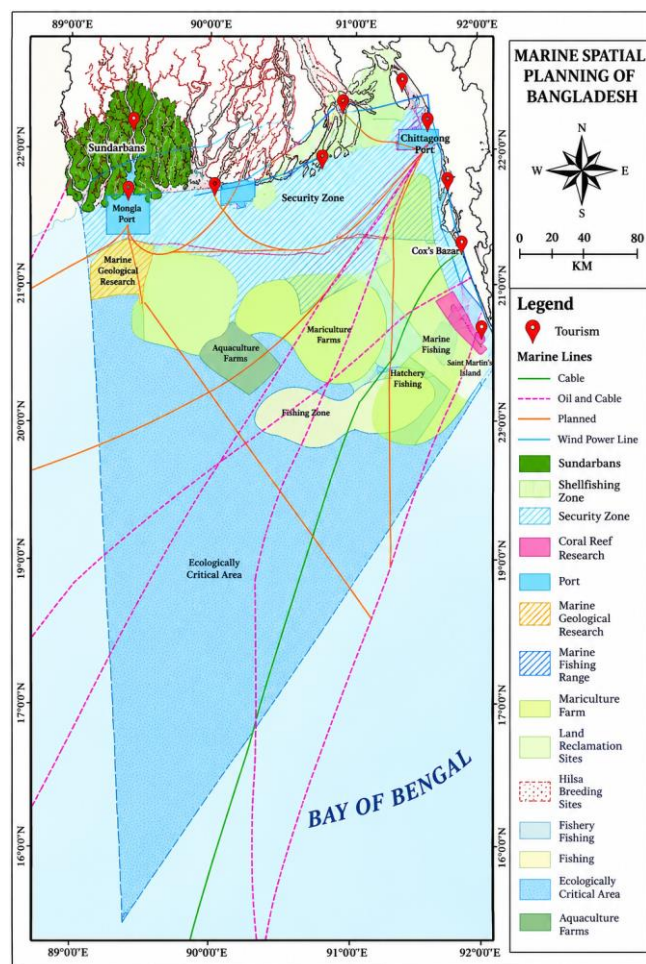


Figure 3. Ecosystem-based model of marine spatial planning for Bangladesh (Author generated).

It is evident that several sectors require place-specific measures that the model accommodates (see Table 2). Solar salt production, which is concentrated along the Cox's Bazar coast and dependent on the dry season, could be strengthened through community-based land leasing, access to credit, mechanisation and producer cooperatives. Marine and coastal ecotourism is contingent on a healthy marine environment and the definition of routes and carrying-capacity limits to prevent the overuse and pollution that ultimately undermines tourism itself (Hossain et al., 2017). With regard to energy, the national assessment by the National Renewable Energy Laboratory (NREL, 2018) estimated more than 20,000 km² of land with wind speeds of 5.75–7.75 m/s and a gross potential above 30,000 MW; this is an onshore resource, so an offshore assessment is necessary before wind corridors can be allocated at sea.

Potential land-reclamation sites identified in the Bangladesh Delta Plan 2100 (Bangladesh Planning Commission, 2018) can be coordinated with living-shoreline and mangrove afforestation measures that combine erosion control with ecosystem enhancement. Locally, the priorities are as follows: coral conservation at St Martin's Island, shellfish-reef living shorelines at Moheshkhali and Kutubdia, and mangrove afforestation in the Meghna delta.

DISCUSSION

The analysis demonstrates that Bangladesh's marine space is characterised by a high concentration of uses in the nearshore area, including artisanal fisheries, ports, ship recycling and tourism. In contrast, the offshore domain is significantly larger and comparatively underutilised. As capacity increases, the offshore domain is expected to become more active, with activities such as hydrocarbon exploration, mariculture and conservation. MSP is anticipated to add value by integrating the geography, environment and current and future uses of a sea area into a unified analytical framework. This approach enables the anticipation of potential conflicts rather than their resolution after the fact (Ehler & Douvère, 2009). The identified hotspots, including small-boat fisheries located close to the shore, alongside shipping lanes and tourism areas, and offshore gas blocks in proximity to the Hilsa sanctuary and other sensitive habitats (DoF, 2018; Islam & Shamsuddoha, 2018), highlight the interactions and trade-offs that are not addressed by sectoral management (Lester et al., 2013).

The primary mechanism by which the model mitigates conflict among fisheries, salt production, ports and terminals, and conservation is the delineation of territories for each sector through zoning. Zoning of this nature has been central to China's marine functional zoning (Fang et al., 2011). This paper will discuss two implications for Bangladesh. Firstly, recommended approach routes to Chattogram, Mongla and Payra should be designated and kept distinct from fishing grounds. Secondly, exploration blocks near Hilsa sanctuaries and sensitive habitats require buffers and careful sequencing, so that gas development does not undermine fisheries and conservation values.

Bangladesh's policy discourse places significant emphasis on blue growth, yet the planning model presented here is deliberately ecosystem-based. In the typology proposed by Qiu and Jones (2013), an integrated-use, growth-oriented plan involves the acceptance of trade-offs among natural and man-made capital. Conversely, an ecosystem-based plan prioritises the maintenance of natural capital as a fundamental prerequisite. Considering the dearth of ecological knowledge concerning Bangladeshi waters (Sarker & Failler, 2023), a precautionary stance, characterised by heightened caution in areas of knowledge deficit (McLeod et al., 2005), is deemed appropriate. This approach should be accompanied by systematic monitoring and evaluation, ensuring that zoning can be continually revised as data accumulates (Douvère & Ehler, 2011).

The proposed framework places MSP within an integrated coast and ocean management policy and plan, with coordinating bodies at national, agency and field levels.

This response is in accordance with the literature, which has already identified institutional weaknesses (Hassan & Alam, 2019). It is evident from experience elsewhere that stakeholder engagement is central to legitimacy and implementation (Pomeroy & Douvere, 2008). This is why the framework assigns formal roles to sector stakeholders, NGOs, cooperatives and academic advisers. Marine species and ecological processes ignore administrative boundaries, and therefore ecological principles such as connectivity argue for coordination across jurisdictions (Foley et al., 2010), implying transboundary cooperation with India and Myanmar. Climate change adds further uncertainty for the low-lying Bangladesh coast, and integrating climate considerations into ocean planning (Frazão Santos et al., 2020; Shamsuzzoha et al., 2026) would make the plan more robust. For example, mangroves and other protected habitats could be treated as natural coastal defences.

The findings of this study are subject to several limitations. Most of the spatial data were of secondary nature and were characterised by heterogeneity in terms of date, scale and quality. It should be noted that certain layers reflect the inventory available during the data compilation process. Protected area declarations made after the study, such as the Nijhum Dwip marine reserve (The Daily Star, 2019), should be incorporated. The model was not validated through stakeholder consultation, and it does not include quantitative cumulative-impact or ecosystem-service trade-off analysis (Lester et al., 2013) or an assessment of offshore renewable energy. It is therefore recommended that future work update and standardise the geodatabase, co-produce zoning with stakeholders (particularly small-scale fishing communities), quantify cumulative impacts and trade-offs, and assess offshore wind and other emerging uses. Recent Bangladeshi work reaches similar conclusions on data and stakeholder needs (Sarker & Failler, 2023).

CONCLUSIONS AND RECOMMENDATIONS

This study mapped the principal ecological, economic and cultural areas of the Bangladesh maritime zone. It also proposed a framework that nests MSP within integrated coast and ocean management and developed an ecosystem-based spatial model that allocates space to conservation and to fisheries, mariculture, ports, energy, research and security uses. By making conflicts among nearshore fisheries, shipping, offshore gas development and conservation areas explicit, the study demonstrates why a coordinated plan is needed to pursue blue growth within ecological limits. The model is a conceptual and data-limited first step rather than a statutory plan. To move towards implementation, the study recommends that:

- i. The Government of Bangladesh is to establish an authorised body under the Prime Minister's Office to lead the adoption of MSP.
- ii. The establishment of a national data-management policy and a central marine geodatabase is imperative. In addition, there is a necessity to collect data systematically on all existing and emerging maritime sectors.

- iii. Thirdly, to mitigate the potential for conflict between fishing and shipping activities, it is recommended that designated approach routes be established for Chattogram, Mongla and Payra.
- iv. Fourthly, policy should be explicit in its commitment to achieving a balance between environmental conservation and economic growth. This is because user-environment conflicts represent the most common problem in Bangladesh's marine area.
- v. The fifth point for consideration is the validation of the proposed zoning through participatory processes with stakeholders, with subsequent updating as new data and protected areas emerge.
- vi. Sixthly, it is recommended that maritime and marine-planning topics be incorporated into academic curricula with a view to enhancing national capacity.

Beyond Bangladesh, these findings support a general recommendation for planners, policymakers and researchers in coastal states where marine data are limited: MSP need not wait for complete information. A practical first step is to pool existing sectoral data in a shared geodatabase, set aside ecologically sensitive areas on a precautionary basis, separate conflicting uses in space, and then refine the zones with stakeholders as new data become available.

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Informed Consent Statement

Not applicable.

Data availability Statement

The spatial layers compiled for this study are derived from secondary sources cited in the text and are available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors declare no competing interests.

Use of AI and AI-Assisted Technologies

The authors used DeepL to correct sentences and remove grammatical mistakes. All content was reviewed and approved by the corresponding author using a licensed Microsoft 365 subscription product.

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