Framework for developing marine spatial plans for Indian regions: towards a resilient and inclusive blue economy

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Human activities in coastal and marine regions increasingly generate inter-sectoral conflicts, emphasizing the need of effective spatial planning. India's marine ecosystems, which sustain millions of livelihoods, are under mounting pressure from overexploitation, climate change and competing human uses. To address these challenges, developing a robust marine spatial planning framework is essential for both conservation and sustainable ocean use. Puducherry, with high recreational potential, serves as a pilot site for such an initiative, aiming to balancing stakeholder interests and needs, strengthening coastal resilience, and promoting a sustainable blue economy.

Ensuring sustainable ocean planning and management worldwide is imperative due to pervasive anthropogenic impacts that are adversely affecting a significant part of the ocean[1]. In such context, marine spatial planning (MSP) emerges as a crucial strategy to achieve sustainability departing from sectoral management approaches[2]. Widely acknowledged today, MSP is an integrated framework for ecosystem-based management, aiming to analyze and allocate marine spaces to achieve ecological, economic, and social objectives[3,4]. The ultimate goal of MSP is to organize and manage marine resource use while balancing environmental, economic, and social goals, minimizing conflicts and promoting compatibility between human activities and the environment[3]. Unlike traditional sector-by-sector designation, MSP offers a forward-looking approach to resolving disputes and fostering sustainable coexistence[5]. It is crucial to note that MSP can only regulate human uses, such as fisheries, aquaculture, shipping, offshore wind energy, tourism, and mining, among others, but not the marine ecosystem itself or its individual components[6].

While MSP has been widely used in European seas[7] and is gaining traction in Asian countries[8], it will continue to play a crucial role in achieving the objectives of a blue economy and biodiversity conservation globally[9,10]. The relationship between MSP and the blue economy is symbiotic, as MSP facilitates the growth of blue economy sectors and ensures responsible and sustainable ocean resource use, particularly in resolving conflicts between users and the ecosystem[11]. However, MSP is not without potential pitfalls and numerous studies have identified the importance of addressing social, political, ecological, economic, and governance challenges if MSP is to be sustainable and equitable[10,12–18]. This study aims to develop a strategic framework for implementing MSP across diverse coastal regions in India, emphasizing the advancement of ecological sustainability, resilience and inclusive economic growth by addressing climate related challenges. Through a comprehensive analysis, this study underscores the need for strategic MSP implementation in Indian marine regions to balance ecological conservation and socio-economic growth.

Rationale for MSP development in India

MSP in India is a strategic approach for managing ocean resources while ensuring ecological sustainability and economic growth. With a rapidly expanding blue economy, increasing human activities and mounting environmental pressures, there is an urgent need for integrated spatial management to minimize sectoral conflicts and safeguard marine biodiversity. MSP provides a systematic framework for coordinating diverse ocean-based industries while addressing challenges such as coastal degradation and climate-induced risks. By implementing MSP, India seeks to optimize resource allocation, enhance governance mechanisms, and build resilient coastal ecosystems that support long-term socio-economic development.

The Government of India has recognized the blue economy as a key driver of growth, with the Draft National Policy for India's Blue Economy-2021[19] identifying MSP as essential for unlocking this potential while ensuring sustainability. Since 2021, India has commenced MSP implementation for its ocean areas and coastal zones, conducting pilot studies in selected regions[20]. Puducherry was chosen as one of the pilot sites for developing MSP in India due to its environmental, social, economic and governance dynamics. The region experiences significant coastal erosion and increasing urbanization pressures, which affect its marine ecosystems and resource management[21]. Nestled along the southeastern shoreline, this Union Territory boasts a relatively compact coastal zone, which enables targeted policy interventions and effective stakeholder engagement. With a

growing tourism sector and traditional fishing livelihoods[22,23], MSP ensures resource management while preserving its biodiversity. Its relatively small coastal zone allows for targeted policy interventions and stakeholder engagement and also makes MSP implementation more manageable[24,25]. Existing environmental assessments such as the shoreline change studies[26] highlight its readiness for MSP, while climate-induced challenges like rising sea levels and habitat degradation underscore the need for proactive planning to balance ecological conservation and economic growth.

This initiative has been supported by a collaborative India–Norway MSP project organized under the umbrella of the 2020 "India-Norway Integrated Ocean Management and Research Initiative"[27]. Norway has over 20 years of experience with MSP, through the development of its Integrated Ocean Management Plans[28]. Such experience is particularly relevant for India, showing how human activities such as fisheries, oil exploitation, and shipping can be balanced with environmental conservation objectives[29,30]. This collaborative MSP project aims to develop a tailored framework that accommodates the unique environmental and socio-economic conditions of India's diverse coastal areas.

India's MSP framework

MSP is a multifaceted process that involves key steps and tasks as outlined in the UNESCO-IOC global guide on MSP[6]. India and Norway share common principles in MSP, such as an ecosystem-based approach, multi-sectoral integration and stakeholder-driven governance. Both countries aim to balance economic growth with marine conservation, ensuring sustainable ocean resource management. However, key differences arise due to geographical, socio-economic and governance contexts. Norway's MSP is deeply rooted in its long-standing maritime traditions, extensive exclusive economic zone (EEZ), and strong regulatory frameworks, whereas India's MSP is emerging within a rapidly expanding blue economy, addressing diverse coastal challenges like urbanization, fisheries management and climate resilience. While no universal MSP procedure exists, countries and regions can adapt the framework based on their specific needs and requirements. Based on such MSP global guidelines[6], the Indian Ministry of Earth Sciences (MoES) developed a seven-step framework tailored for the Indian EEZ (see Fig. 1).

As India stands at the crossroads of economic development and continues to develop its blue economy, the development of marine spatial plans is crucial for ensuring that such growth is sustainable, inclusive and equitable. However, developing MSP for Puducherry is a multifaceted endeavor that requires balancing ecological, economic, and social objectives. The development of MSP in Puducherry presents a transformative opportunity to foster a resilient and inclusive blue economy while addressing the ecological, economic, and social needs of the region. By prioritizing stakeholder engagement, the conservation of ecologically sensitive ecosystems (e.g., mangroves and corals), and the sustainable management of marine resources (e.g., optimizing sustainable fishing activities and unlocking sustainable economic opportunities in tourism and aquaculture), the implementation of MSP in Puducherry can serve as a model for a balanced development. Furthermore, by ensuring continued collaboration and adaptive management, it has the potential to contribute significantly to India's broader goals for sustainable ocean governance, setting a precedent for the Indian Ocean region and beyond.

The case of Puducherry MSP

The Puducherry MSP initiative aims to conserve ecologically important areas such as mangroves, coral reefs, and turtle nesting grounds while accommodating key human activities like fishing, tourism and port related activities[31]. The MSP management area covers the ocean from the shoreline all the way out to the limit of the country's EEZ. Protecting the existing ecosystems ensures environmental sustainability, supports coastal resilience, and fosters socio-economic benefits, making conservation an integral part of the marine spatial plan. The plan integrates areas for fishing activities, tourism, coral reef conservation and marine navigational pathways, therefore harmonizing economic development with environmental preservation within the boundaries of the marine management area (Fig. 2). Through meticulous zoning and regulation, the marine spatial plan for Puducherry seeks to optimize fishing while ensuring the long-term health of fish stocks. Additionally, it aims to ensure that economic activities such as aquaculture and tourism are compatible with conservation goals. Clear spatial limitations are established to prevent conflicts between different marine uses, while designated areas for cable protection safeguard vital communication infrastructure. Moreover, safe and efficient navigational pathways are delineated, promoting maritime safety and efficiency. Finally, by embracing stakeholder engagement, regulatory frameworks' development, capacity building, and adaptive management, the plan aspires to foster ecological resilience of marine ecosystems and support the sustainable development of Puducherry's coastal communities. In effect, the proper engagement of stakeholders has been essential in the Puducherry MSP process. The process has promoted the engagement of local communities, fishermen, tourism operators, and other key stakeholders to ensure their concerns and aspirations are properly considered, fostering collaboration through transparent decision-making aligned with the United Nations (UN) Sustainable Development Goal (SDG) 14 "Life Below Water"[17,18,32].

The MSP initiative for Puducherry began in October 2022, with the engagement of stakeholders and the establishment of goals and a vision for the future (steps 1 and 2, Fig. 1)[33]. These were followed by the launch of a spatial database in a geographical information system environment in February 2023 (step 3), which laid the groundwork to further analyzing impacts and interrelationships (step 4). During 2024, the process has progressed to the preparation of the plan (including zoning) and its implementation (steps 5, 6 and 7, Fig. 1). A Web GIS-based Dashboard named SAHAV was developed, providing decision-makers with comprehensive details and data related to various project aspects, progress, and underlying parameters. As of 2025, the MSP process has advanced with stakeholder meetings playing a crucial role in refining zoning strategies and implementation frameworks[33,34]. Additionally, benthic habitat workshops have been conducted to assess marine ecosystem health, integrating scientific findings into spatial planning efforts, which provided critical insights into habitat conservation priorities and sustainable development initiatives[35]. The ongoing monitoring and evaluation stage incorporates feedback from these engagements, ensuring that MSP remains adaptive and responsive to ecological and socio-economic dynamics. Furthermore, the SAHAV portal, has been officially recognized as a Digital Public Good (DPG) by the DPG alliance underscoring its role in promoting transparent, science-based ocean governance and supporting adaptive MSP frameworks.

Challenges, insights and future directions in MSP

Despite the fact that the Puducherry MSP initiative is still under development, it serves as a practical example or blueprint for guiding the implementation of marine area-based management approaches in other Indian regions. However, the applicability of MSP across India's diverse coastal jurisdictions presents unique challenges. Governance structures vary between coastal states and Union Territories, influencing policy enforcement and stakeholder participation. Additionally, environmental conditions differ widely, with some regions facing erosion and urbanization pressures while others contend with mangrove conservation, fisheries
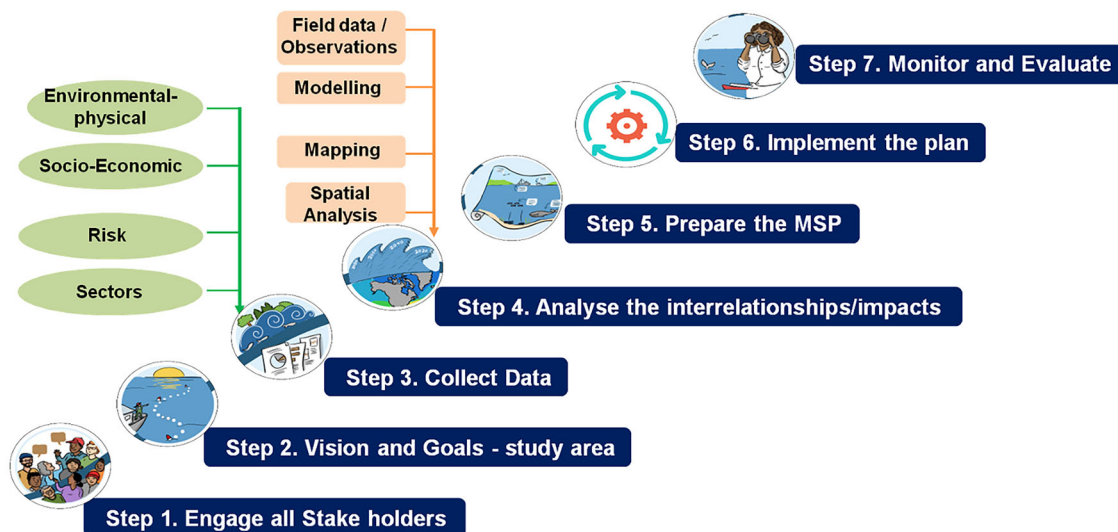
Step 1: **Stakeholder Engagement**: MSP initiates with a critical phase of stakeholder engagement to identify and involve relevant parties, forming an MSP team (Tailor et al., 2021). The aim is to ensure that the planning process is inclusive, transparent, and participatory.

Step 2: Identifying Visions and Goals: Formulating visions and goals for the study area, involving stakeholders and the MSP team, is a foundation for effective MSP (Tailor et al., 2021). Clear and consensus-driven visions and goals provide a roadmap for guiding decision-making, prioritizing actions, and evaluating progress.

Step 3: Collect Data: Spatial data plays a central role in decision-making for planning and management within a geographical framework. The Govt. of India has delineated three categories of parameters crucial for the preparation of a MSP : environmental-physical; socio-economic; risk and mitigation (MoEF & CC, 2022) .

Step 4: Analyze Interrelationships/Impacts: Defining and analyzing current and future conditions, considering ecological, socioeconomic, and political factors, and identifying conflicts and synergies. Alternative future scenarios are assessed before choosing a spatial vision for the future.

Step 5: Prepare the MSP: Defining spatially explicit management activities and creating an ocean zoning system to achieve the desired spatial vision (Agardy, 2010).

Step 6: Implement the Plan: Formal adoption and implementation is needed for the plan to take effect, focusing on two main tasks: 1) Establish a management structure for implementation that includes defining why-where-how-when-who. 2) the lead organizations should begin coordinating activities for implementation of the plan with the executing agency (MoEF&CC, 2022).

Step 7: Monitor and Evaluate: Establishing a performance monitoring and evaluation program involving the collection, assessment, examination, and reporting of relevant data (Ehler and Douvere, 2009). The results guide modifications to the planning process using an adaptive management approach, incorporating lessons learned (Douvere and Ehler, 2011; Santos et al., 2014).

Fig. 1 | Seven-step framework adopted for MSP development in India. The seven-step MSP framework illustrates the iterative process of stakeholder engagement, vision and goals establishment, data collection, analysis of interrelationships, preparation of the marine spatial plan, implementation, and monitoring and evaluation. Stakeholder engagement fosters collaboration and inclusivity, while defining a clear vision and goals ensures alignment with sustainable development objectives.

Comprehensive data collection enables informed decision-making, followed by thorough analysis of interrelationships among various factors. This informs the preparation of the MSP, which is then implemented, with ongoing monitoring and evaluation to adapt and refine the plan over time, ensuring its effectiveness and relevance in achieving desired outcomes for marine resource management.

Fig. 2 | Zoning scheme of the proposed marine spatial plan for Puducherry, India. The figure outlines key features and designations within the plan aimed at sustainable marine resource management and conservation. This plan includes proposed areas for various activities, delineated on the map. Coral conservation areas, fishing activity zones, cables corridors, vessel operation channels, port limits, and boat prohibited zones are depicted using distinct colors or symbols. These

designations reflect efforts to balance economic development with environmental protection, ensuring the long-term health and productivity of marine ecosystems in Puducherry. This map provides crucial spatial information for stakeholders, policymakers, and resource managers involved in the implementation of the Marine Spatial Plan, guiding decision-making processes for the sustainable use and conservation of marine resources.

management, or industrial expansion. Socio-economic factors also play a role, as coastal communities depend on marine resources for livelihoods, tourism, and industry, necessitating MSP frameworks that balance economic growth and ecological preservation. Further obstacles include multisectoral coordination, fragmented marine spatial data, and climate adaptation concerns such as rising sea levels and habitat degradation. It underscores the imperative for implementing ecosystem-based MSP with strong sustainability goals, prioritizing ocean health and resilience over blue growth objectives, aligned with the urgency to achieve UN SDG 14[17,18,32].

However, certain limitations were acknowledged. The development of MSP in Puducherry must navigate several challenges, including data scarcity,

stakeholder conflicts, and governance complexities. These require careful planning and alignment with national and international frameworks. Aligning MSP in Puducherry with national policies (such as the Draft National Policy for India's Blue Economy-2021), collaborating with international partners (as with the Indo-Norway International Ocean Management and Research Initiative), and benefiting from the support of the Government of Puducherry, is crucial to enhancing and advancing sustainable ocean management and governance[36]. India's collaboration with Norway on MSP provided insights into ecosystem-based management, scientific assessments and stakeholder coordination. However, Norway's strict zoning regulations and centralized governance were not fully

applicable to India's multi-level governance and livelihood-based marine sectors. This partnership helped India refine its adaptive MSP model, ensuring flexible zoning, community engagement and localized environmental strategies for sustainable ocean management. Additionally, the development of MSP in Puducherry highlights the importance of comprehensive data collection and active stakeholder participation (e.g., fishermen and tourism operators) to ensure effective MSP outcomes[13], balancing economic, social, and environmental objectives for long-term sustainability. In effect, MSP's failure to prioritize social well-being in some cases is a concern[37], especially for small-scale fishers and aquaculturists[38]. However, shared knowledge platforms (e.g., geographical information systems) can reduce conflicts and foster inclusive MSP development[39]. Also, international MSP practices, such as the Norwegian successful case study[40], show the value of transparent discussions about trade-offs in reducing conflicts.

Data availability

The datasets used and/or analyzed during the current study will be available from the corresponding author on reasonable request.

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M.A., R.M.M.V., T.U., D.S.K., E.O., and R.M. conceived and led the project. R.S.K., R.K., P.U.S., S.S., M.T., G.G., S.K.S., A.G., I.A., N.S.K., S.P.K., and V.B.P collected and contributed data. R.S.K., S.S., M.T., G.G., S.K.S., A.G., I.A., and N.S.K. processed and analyzed data. S.K.S, S.S., and G.G developed the SAHAV Portal. T.U., S.S., and E.O. drafted the manuscript. All authors edited and proof read the manuscript.

Competing interests
The authors declare no competing interests.

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