10 Managing sea space through dynamic boundaries

The evolution of Maritime Spatial Planning and the Italian experience

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Introduction

Maritime Spatial Planning (MSP) represents a transformative shift in the governance of marine spaces, moving from sectoral management to a multisectoral and integrated approach (Ehler & Douvere, 2009; Kidd & Shaw, 2014; Saunders et al., 2019). Traditionally, maritime governance operated within fragmented administrative frameworks, where different sectors – fisheries, energy, tourism, transport, and conservation – were managed independently, often leading to interactions among various anthropogenic activities, resulting in overlapping uses and spatial conflicts that adversely affected marine ecosystems (Ban et al., 2014; Roversi Monaco, 2018).

Over the years, two phenomena reinforced the urgency of advancing MSP. The first is the intensifying competition for marine space, given the growing spatial demand from emerging marine uses. The second is the need to expand conservation tools to safeguard marine biodiversity, guaranteeing a coherent ecosystem-based governance model (Walsh et al., 2022). The discipline thus faces the challenge of ensuring both development and conservation, but its role extends beyond ideally balancing them (Trouillet, 2020).

The formal institutionalisation of MSP occurred with Directive 2014/89/EU (MSPD), which required all coastal EU Member States to implement Maritime Spatial Plans (MS Plans) by 2021. Today, most European countries have completed their MSP processes and adopted their plans (Zaucha et al., 2025). The directive mandates that MS plans shall include land-sea interactions (LSIs), economic and environmental priorities, and stakeholder involvement, ensuring coherent spatial management across national and transboundary waters (2014/89/EC; Zaucha & Gee, 2019).

LSIs represent a fundamental interface to properly support and manage the coastal and MSP processes. It should be an approach contributing to dealing with the increasing pressure on both the sea and coastal areas by improving synergies and reducing conflicts (Bocci et al., 2024). At the same time, the issue of climate change is strictly connected with LSI because proper management and adaptive design of coastal areas can represent a crucial space to counteract local impacts (Innocenti & Musco, 2023).

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However, MSP presents unique challenges compared to terrestrial planning (Gazzola et al., 2015). As marine spaces operate under different conditions, the translation from land frameworks cannot be done without a conceptual shift (Jay, 2018). The emerging discipline must develop "softer" and flexible responsive practices that accommodate the dynamic and uncertain characteristics of the sea. Traditional spatial planning operates within relatively fixed and well-defined boundaries, whereas marine spaces are fluid, dynamic, and multidimensional (Collie et al., 2013; Gazzola et al., 2015; Trouillet, 2020). The concept of "soft space" offers a valuable opportunity for MSP to engage with critical planning theories and promote cross-pollination with terrestrial planning, better addressing complex and multidimensional challenges of dynamic spaces (Walsh et al., 2022).

Moreover, in an attempt not to flatten sea realities to benefit legibility, Couling and Hein (2020) propose "thicker" representations that encompass the sea's volumetric complexity, connectivity, temporal variability, and transboundary nature. Representation, often overlooked as a mere technical skill, plays a critical role in understanding the territory, and it is actively complicit in its production, serving as a tool for imagining alternative futures (Couling & Hein, 2020).

Building on this perspective, MSP operates within a context of complexity, uncertainty, and integration, leading numerous scholars to recognise it as a discipline inherently embedded in strategic planning practices (Ehler & Douvere, 2009; Kidd & Shaw, 2014; Papageorgiou & Kyvelou, 2018; Peel & Lloyd, 2004; Ramieri et al., 2024; Trouillet, 2020; Walsh et al., 2022; Zaucha et al., 2025).

This strategic orientation is particularly crucial given the rapid expansion of the blue economy. The concept of *Blue Growth*, introduced by the European Commission in 2012 (EC, 2012; Meiner, 2010; Schultz-Zehden et al., 2019), and later *Blue Acceleration* (Jouffray et al., 2020), have highlighted the increasing pressure on marine spaces due to competing economic interests, ranging from offshore energy production and aquaculture to tourism and maritime transport. As marine industries grow and intensify their operations, the spatial footprint of economic activities expands, increasing the risk of sectoral conflicts and environmental degradation (Couling & Hein, 2020).

Thus, MSP functions as both a governance mechanism and a mediation tool, structuring spatial functions while reconciling conservation priorities with economic interests (Ehler & Douvere, 2009; Rafael et al., 2024). By promoting a strategic, place-based, and adaptive framework, MSP ensures that socio-economic development progresses coherently with ecological sustainability, solidifying its role as a cornerstone of sustainable marine governance (Reimer et al., 2023a, 2023b). Given the dynamic nature of oceanographic conditions, shifting species distributions, and evolving human activities, MSP requires an adaptive planning approach, allowing for regular reassessment and flexible adjustment of spatial and temporal designations to respond effectively to environmental and socio-economic changes (Day, 2002; Jay, 2022).

To navigate these complexities, MSP institutional processes and initiatives have developed a set of spatial management techniques over the years, enabling planners to designate specific areas for different uses, regulate activity interactions,

and establish priority functions (Walsh et al., 2022; Zaucha et al., 2025; Zuercher et al., 2022). How to govern and manage marine space without imposing rigidity is a key challenge in MSP and the main objective of this chapter. Driven by the concept of dynamic boundaries and soft space (Allmendinger & Haughton, 2010; Jay, 2018) – offering an alternative to rigid, static zoning – this chapter investigates how different governance frameworks have sought to reconcile spatial organisation with the need for adaptability, highlighting the increasing flexibility in planning processes.

Planning techniques within the MSP domain should be oriented beyond conventional administrative and institutional boundaries, shaping new geographies tailored to specific objectives rather than being constrained by pre-existing governance structures (Allmendinger & Haughton, 2010). Thus, in looking to embrace different overlapping boundaries, and looking to plan with a greater connection to reality, the need to promote such soft spaces requires a fuzzying of boundaries, to recognise the dynamics inherent to marine space and all its different dimensions (Jay, 2018).

This chapter is structured into three main sections, to examine the extent to which dynamic boundary approaches facilitate integrated decision-making, enhance cross-sectoral coordination, and mitigate spatial conflicts: (i) the pre-MSPD period and the historical evolution of the two predominant integrated approaches that shaped and informed the foundation of early marine spatial planning practices; (ii) the post-MSPD period, providing a comprehensive assessment of the techniques and spatial governance strategies developed in both the academic literature and the officially approved MS plans across Europe; and (iii) the Italian MSP experience and how its approach integrates dynamic spatial distribution by analysing the role of Planning Units (PUs).

Pre-MSPD Era. Integrated approaches in early Marine Spatial Planning

By the late 20th century, the sea had become an increasingly urbanised space, not merely a vast and unregulated expanse but rather a territory subject to growing economic and governance pressures (Couling & Hein, 2020). As human activities expanded in scope and intensity, a new challenge emerged: the need to coordinate and regulate maritime uses more holistically to prevent spatial conflicts, ensure conservation values, and support economic growth (Ritchie & Ellis, 2010).

Early spatial management efforts in the sea date back to the conceptual developments of the 1980s, when two main approaches began to take shape in response to the growing complexity of governing marine spaces. These foundational perspectives shaped the initial environmental policy frameworks, and marine spatial governance, as well as MSP (Zaucha & Gee, 2019).

The first was the ecosystem-driven perspective, rooted in marine sciences, which promoted a holistic and adaptive form of governance focused on maintaining the biological integrity of marine ecosystems (Crowder & Norse, 2008; Day, 2002; Day et al., 2019). On the other hand, an evolutionary-territorial perspective

was influenced by established spatial planning theories, particularly those derived from land-use planning, which sought to structure marine activities based on functional zoning and economic rationales (Claydon, 2006; Jin-Kai et al., 2020). Both perspectives aimed to move beyond the fragmented, sectoral maritime space management and instead offer a more strategic and spatially coherent framework for governance.

Ecosystem-based zoning

A pioneering application of the ecosystem-based approach was implemented in Australia, establishing the Great Barrier Reef Marine Park (GBRMP) in 1975. This initiative marked one of the earliest attempts to combine conservation goals with regulated human use through the spatial zoning of marine environments (Kenchington & Day, 2011). By the 1980s, the GBRMP had introduced a zoning system that became a cornerstone of marine spatial governance, allocating distinct spatial areas for specific functions, such as conservation, tourism, fisheries, and other economic activities (Day et al., 2019; Kenchington, 2016).

In this context, zoning operates as a spatial management tool derived from terrestrial land-use planning. It allocates rights and responsibilities for different uses, aiming to minimise conflict, protect sensitive ecological areas, and regulate human interactions with the marine environment (Agardy, 2010). In the GBRMP, the zoning system is highly differentiated, comprising multiple zones that range from highly protected no-take areas to zones allowing extractive and commercial activities under regulated conditions. Each zone is assigned based on ecological suitability and management priorities, providing a robust structure for reconciling conservation with economic objectives (Day et al., 2019).

The comprehensive zoning model of the GBRMP has often been cited as one of the world's most sophisticated examples of large-scale marine spatial planning. Nevertheless, it presents limitations. Although comprehensive, the zoning system initially struggled to integrate with terrestrial planning frameworks fully, reducing its efficacy in managing LSIs and cumulative impacts from terrestrial activities (Day, 2002; Day et al., 2019). Furthermore, the GBRMP zoning approach remained largely conservation-oriented, and although it permitted multiple uses, it lacked a truly cross-sectoral integration of economic development planning within the marine realm (Kenchington & Day, 2011).

From a strategic planning standpoint, this raises questions about the rigidity and adaptability of zoning as a spatial instrument. While zoning undoubtedly helps structure spatial functions and reduce conflicts, its effectiveness hinges on how dynamically the zones can be redefined in response to changing ecological conditions, stakeholder demands, and policy objectives (Kenchington, 2016). In the GBRMP, zoning decisions are periodically reviewed and adjusted, a practice that aligns with the adaptive management principle and reflects the concept of dynamic boundaries, even if continuous financial support is required.

Within the GBRMP, zoning is supported by continuous monitoring, stakeholder engagement, and periodic reassessments, allowing the park authority to reallocate

spatial functions as ecological baselines shift or new socio-economic pressures arise (Crowder & Norse, 2008). This adaptability embodies the strategic and iterative nature of MSP as envisioned by Ehler & Douvere (2009), aligning with this chapter's broader aim of exploring governance mechanisms capable of integrating spatial organisation without rigidity.

Evolutionary-territorial zoning

In parallel with the emergence of the ecosystem-based approach, an evolutionary-territorial approach was also taking shape, grounded in land-use planning traditions. This perspective aimed to extend terrestrial planning principles to the marine domain, offering a regulatory and spatial framework that emphasised functionality, economic optimisation, and administrative clarity (Claydon, 2006). Unlike the ecosystemic focus on holistic environmental management, the evolutionary-territorial approach introduced a more technocratic zoning paradigm, using spatial designations as instruments to structure and allocate marine uses.

One of the earliest and most influential model implementations was China's Marine Functional Zoning (MFZ), initiated in the 1980s and formally institutionalised in 1988 (Fang et al., 2011; Jin-Kai et al., 2020). The MFZ system delineated China's vast maritime domain – encompassing internal waters, territorial seas, the Exclusive Economic Zone (EEZ), and continental shelf – into smaller administrative units, each with defined functional roles. This included designations for fishing, transport, conservation, tourism, and resource extraction, distributed across national, provincial, and municipal levels (Fang et al., 2011; Teng et al., 2021). Through this zoning structure, MFZ provided legal and institutional certainty over marine space, marking a pioneering moment in marine governance.

However, critical evaluations in recent years have identified substantial limitations in the MFZ model – particularly to the chapter's core concerns of adaptability, and conflict mitigation. Despite its spatial rigour, the MFZ process has been criticised for its rigidity and insufficient responsiveness to socio-ecological dynamics. The zoning schemes, typically developed on five-year cycles aligned with national economic planning, have often failed to accommodate emergent marine sectors – such as offshore wind and ocean energy – or to respond swiftly to shifting environmental baselines (Teng et al., 2021). This rigidity has been further compounded by complex revision procedures, requiring centralised approvals even for minor changes, thereby undermining adaptive management (Feng et al., 2016).

Moreover, MFZ has struggled to incorporate ecosystem-based principles into its regulatory dimension. Although marine environment protection is formally acknowledged, practical implementation has largely focused on managing user–user conflicts, with less emphasis on mitigating user–environment tensions (Teng et al., 2021). As a result, zoning decisions have often prioritised economic development over ecological sustainability, particularly in rapidly industrialising coastal provinces. Land-sea integration also remains a major weakness. Pollution and resource pressures from terrestrial areas have significantly impacted marine

ecosystems, yet MFZ has lacked the integrative tools necessary to address these upstream-downstream interactions (Feng et al., 2016; Jin-Kai et al., 2020).

Post-MSPD Era. Dynamic boundaries in the spatial and temporal marine dimension

The post-MSPD has seen 22 EU Member States intended to regulate activities within their jurisdiction, typically through zoning and designated uses, aiming to ensure compatibility among sectoral plans, promote integration, and strengthen stakeholder trust (Walsh et al., 2022). These national plans often establish long-term strategic visions, which promote integrative and cross-sectoral objectives and provide a policy framework for decision-makers for sustainable maritime management.

However, while the MSPD sets general goals, it leaves the means of achieving them open to interpretation, leading to different institutional arrangements and planning approaches across Member States (Zaucha et al., 2025). The challenge is ensuring coherence in spatial management across borders, particularly when the boundaries are not fixed, but dynamic and fluid. For instance, the plans do not adhere to a fixed zoning model but typically favour encouraging designations over prohibitions, establishing "priority areas" for specific sectors. The flexibility of these boundaries and the terminology used vary across different countries. In this context, questions arise about whether the evolution of MSP plans will draw fixed zones or propose more adaptable ones, with overlapping and negotiable edges (Jay, 2018).

Dynamic boundaries' spatial dimension

The sea is experienced by both human and non-human inhabitants, utilised across three dimensions: the space above the surface, throughout the water column, and under the seabed. Each dimension has distinct characteristics, such as light penetration, salinity, temperature, and ecology (Couling & Hein, 2020). While the EEZ is differentiated vertically, allowing free movement across the surface and ensuring nations' rights in the seabed, the MSP rarely dives into its depths.

Given the largely unknown nature of deep-sea ecosystems and the impacts of new offshore activities, planning must rely on assumptions and adopt a precautionary approach (Danovaro et al., 2024). It should remain flexible to accommodate future evaluations of area designations. For instance, Germany's MSP includes temporary priority and reservation areas for activities such as shipping and offshore wind farming. Shipping areas are designated for 15 years to refine traffic flow management, while offshore wind priority areas are set for 2026 and 2031, pending further evaluations (Gee et al., 2024).

As Jay (2018) suggests, one response to anticipated needs is to make the most efficient use of space, with the coexistence of uses being a strategy for spatial efficiency (Schultz-Zehden et al., 2019). Finland has employed this strategy by using overlapping areas to encourage dialogue between sectors and better coordinate activities in more detailed planning and permitting processes (Zaucha et al., 2025).

The country has also left some areas unplanned to ensure flexibility for future needs.

Poland's approach offers another example of spatial flexibility, with areas designated for future activities limited to mobile uses, preserving decision-making power for future generations (Zaucha et al., 2025). Similarly, Latvia, Sweden, and Belgium's MSP plans have incorporated "investigation areas" for environmental assessments, research, or feasibility studies to explore future marine activities (Zaucha et al., 2025). Spain's MSP plan identifies "High Potential Areas" for emerging sectors, such as offshore wind farms and aquaculture (Ministerio para la Transición Ecológica y el Reto Demográfico, 2023).

Such fluid boundaries in marine spaces present an opportunity for "scalar reinvention" (Jay, 2018). In an environment where national borders intersect with the interconnected nature of the marine ecosystem, EU-led initiatives can foster cooperation and strengthen territorial cohesion. However, despite the EU MSP Directive's requirement for coordinated plans across borders, many marine borders remain contested, particularly in environmentally sensitive areas (Ansong et al., 2023).

A contested marine border between the Republic of Ireland and Northern Ireland in Lough Foyle suffers environmental damage from unregulated oyster farming, while the lack of a clear transboundary policy hinders effective management (Ansong et al., 2023). Similarly, in the Pomeranian Bay, contested by Germany and Poland, decades of cooperation through institutions like HELCOM-VASAB have not led to a shared vision for the area. Germany prioritises environmental conservation, while Poland aims for port expansion. These examples highlight the challenges of managing fluid and contested maritime spaces, where geopolitical tensions and historical disputes often result in fragmented planning approaches (Figure 10.1). As Ansong (2025) argues, regardless of whether borders are defined or contested, an ecosystem-based approach is essential for MSP, fostering connectivity between ecosystems, users, and institutions.

Dynamic boundaries' temporal dimension

The marine environment is characterised by significant flux – fluctuating salinity, temperature, currents, tides, and the dynamic movement of sea ice, atmospheric conditions, and ecosystems (Couling & Hein, 2020). These natural processes, however, are strongly shaped by the influence of human activities, which also follow patterns that evolve over time, influenced by both technological advancements and policy shifts. For instance, Fishery Restricted Areas (FRAs) – zones where fishing is prohibited during certain times of the year to protect spawning populations but permitted when fish are not reproducing – demonstrate how human regulations can interact with ecological cycles. Given the emerging challenges posed by climate change and the need for energy transition, the planning of marine spaces must not only account for current conditions but also anticipate future needs and challenges.

Jay (2018) introduces the concept of "connectivity thinking", which promotes understanding the interrelationships between different system elements across

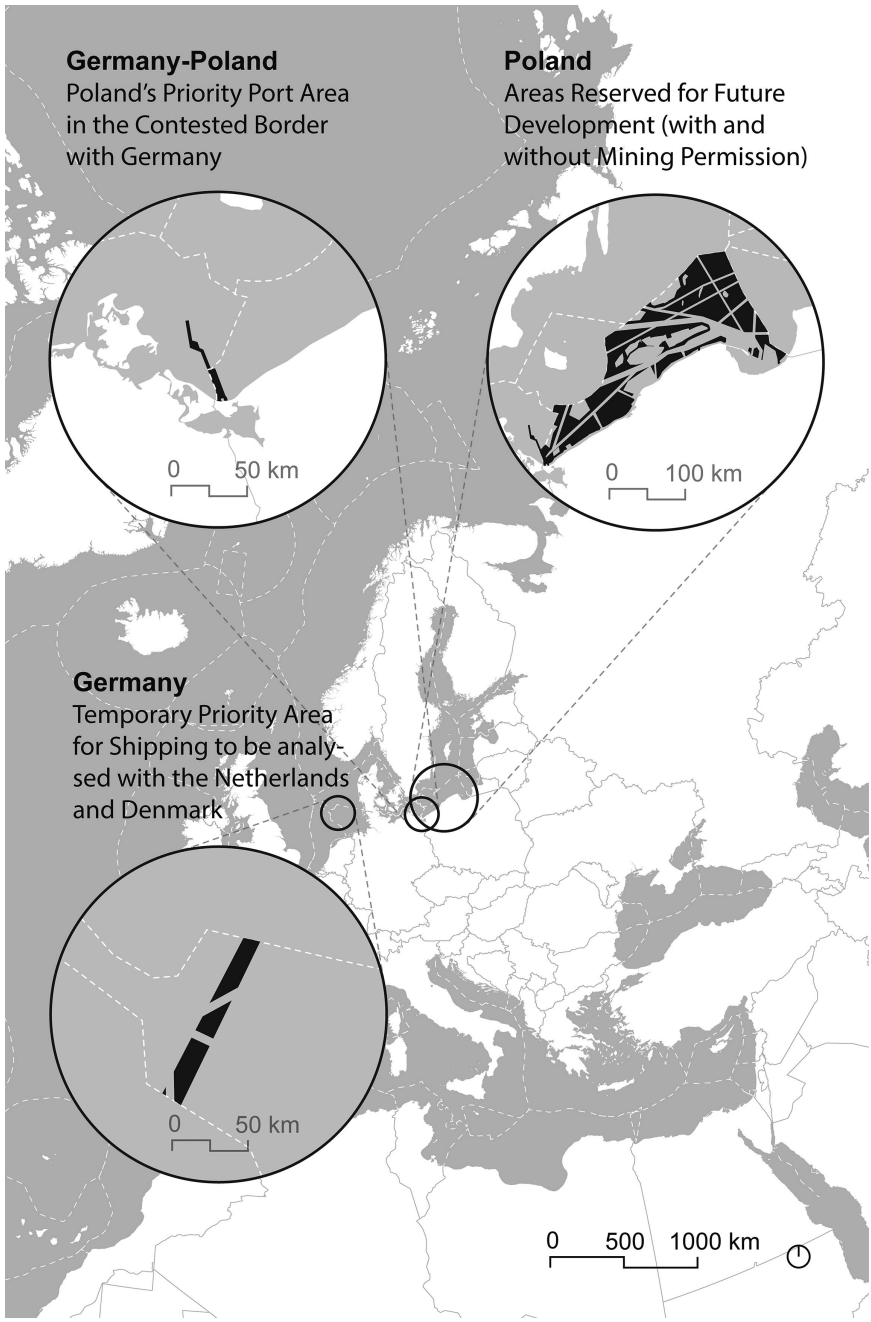

Figure 10.1 Insights of dynamic boundaries in the EU MSP context.

Source: EMODnet 2025; Fabio Carella; Alessandra Fudoli; Francesco Musco, 2025.

space and time. This approach encourages planners to adopt holistic and integrated strategies that consider long-term changes and the potential for unpredictable shifts in marine conditions. Being future-oriented requires flexibility in planning, allowing for "adaptive management" and "learning by doing" approaches to respond to changing circumstances (Jay, 2018). This dynamic and anticipatory planning is essential for addressing the evolving challenges of marine governance.

Dynamic Ocean Management (DOM) presents a promising framework for managing the temporal dimension of marine spaces. It integrates real-time data from multiple sources, including biological, oceanographic, social, and economic data, to continuously update and refine management zones and practices (Maxwell et al., 2015). By using advanced technologies such as data analytics and rapid data-sharing platforms, DOM allows for more responsive and adaptive management that balances ecological conservation with economic sustainability. This approach seeks to minimise unnecessary restrictions while effectively protecting marine species and habitats, thereby reducing conflicts between competing marine uses (Maxwell et al., 2015).

In this context, the concept of dynamic boundaries in MSP highlights the complexity of marine environments, requiring both spatial and temporal dimensions to be accounted for. The MSPD provides a valuable starting point, but the flexibility and adaptability of national plans will determine the extent to which dynamic boundaries can be effectively managed. As Zuercher et al. (2022) point out, the literature on the practical implementation of the MSP Plan's stated objectives remains underfunded and often under-prioritised. This gap in research highlights the need for further studies to assess the effectiveness of dynamic boundaries in delivering tangible environmental, social, and economic benefits.

The examples from Germany, Finland, and Spain demonstrate a variety of approaches for spatial flexibility, from overlapping designations to unplanned areas, while examples in Ireland and Poland highlight the challenges of contested borders. The temporal dimension, shaped by natural processes and human activities, requires strategies that integrate real-time data and adaptive management practices. Ultimately, dynamic boundaries offer an opportunity for more effective and responsive marine governance, but further research and implementation are needed to ensure the effective management of "thick" marine spaces.

Permeable geometries in the Italian MS Plans

Institutional framework and multi-scalar approach

In compliance with Directive 2014/89/EU, Italy formally adopted its Maritime Spatial Management Plans (MS Plans) on 25 September 2024 through Ministerial Decree No. 237 (Ministero delle Infrastrutture e dei Trasporti, 2024). The transposition of the MSP Directive into national legislation occurred in 2016 through Legislative Decree No. 201/2016 (Governo Italiano, 2016), which designated the Ministry of Infrastructure and Transport (MIT) as the Competent Authority

responsible for coordinating and overseeing the MSP process. An Interministerial Coordination Table (TIC) was established under Article 6 of the decree to ensure cross-sectoral alignment and integration. This coordination body, chaired by a Prime Minister's Office representative and composed of several national ministries with marine-related responsibilities, was tasked with elaborating the national MSP Guidelines (Presidenza del Consiglio dei Ministri, 2017).

These Guidelines (Presidenza del Consiglio dei Ministri, 2017), coherently with the Marine Strategy Framework Directive (2008/56/EC), divided the Italian Sea into three maritime areas: the Tyrrhenian–Western Mediterranean, the Adriatic Sea, and the Ionian–Central Mediterranean. A Technical Committee was also formed, including representatives from each Ministry responsible for maritime affairs and one representative from each of the 15 coastal regions, entrusted to elaborate the three MS Plans (one for each maritime area).

The Italian MS Plans are strategic legally binding plans, above all other sectoral instruments. To ensure uniformity across the three planning areas, a shared operational methodology was adopted, structured into six phases: (i) state-of-the-art and cognitive framework, (ii) analysis of sectoral interactions and environmental impacts, (iii) definition of strategic vision and objectives, (iv) planning phase and management measures, (v) monitoring programme, and (vi) implementation and revision processes.

Given the institutional fragmentation of marine governance in Italy, where responsibilities are distributed across government, regional, and in some cases municipal levels, the MS Plans have designed and employed a multi-scalar approach (Ramieri et al., 2024). The first result of this approach consists of dividing the three national maritime areas into sub-areas, 18 coastal and 9 offshore. In the case of coastal sub-areas, regional terrestrial administrative boundaries were extended up to 12 nautical miles, enabling the Regions to define their planning frameworks within their respective jurisdictions. This spatial configuration empowered regional authorities' role in managing marine resources (Roversi Monaco, 2018).

Offshore sub-areas, by contrast, were subject to a co-planning process centrally managed by the competent Ministry, ensuring a more coordinated approach to maritime areas beyond regional jurisdiction. As a second result of this approach, sub-areas were further subdivided into so-called PUs, each designed to prioritise specific marine uses and sectors over others. This approach made it possible to assign clear objectives to each sub-area, thereby optimising the use of marine space while aiming to reduce potential conflicts between sectors (Bocci et al., 2024; Ramieri et al., 2024).

This multi-layered structure enhances territorial ownership and strengthens both vertical integration between national and regional planning frameworks and horizontal coordination across the different sectors (Carella et al., 2024; Zaucha et al., 2025).

The recent formal adoption of the Italian MS Plans in 2024 (D.M. n. 237/2024), alongside the introduction of newly defined PUs, positions the Italian case as relevant to the discourse on dynamic boundaries. It also contributes broadly to the ongoing discussion of how MSP can address complexity and embed permeability within spatial planning frameworks.

Planning units with permeable boundaries

The multi-scalar approach employed within the Italian MS Plans lies in the spatial articulation of the PUs. These units might be considered a transformative shift from conventional zoning approaches, introducing a more flexible, permeable, adaptive, and context-sensitive mechanism to govern maritime soft space. As a core component of Italy's MSP architecture, PUs represent a functional response to organising marine uses without imposing static or rigid geometries, reflecting ecological, socio-economic, and institutional diversity.

Grounded in a set of interconnected criteria, the definition of PUs within each sub-area is informed by: (i) the existing marine uses and environmental components; (ii) trends in both ecological systems and socio-economic activities; (iii) future use developments aligned with the plan's overarching vision and strategic objectives; (iv) conservation imperatives and environmental enhancement goals; (v) institutional competences and governance frameworks; and (vi) existing regulatory instruments and spatial plans, particularly those concerning environmental protection, landscape conservation, and cultural heritage.

Each PU is classified according to its degree of use restriction and prioritisation into four typologies: generic, priority, limited, and reserved (Figure 10.2). Generic PUs allow most uses with specific regulatory mechanisms; priority PUs favour one or more functions while permitting compatible secondary uses; limited PUs are designated for a dominant activity with more stringent conditions on additional uses; and reserved PUs are allocated exclusively to a single-use, with access only permitted for supportive or instrumental activities.

Priority (P), Limited (L), and Reserved (R) PUs are assigned targeted guidance related to sectors and/or cross-cutting principles (natural resources or landscape and cultural heritage), which may apply either individually or jointly.

PUs are not confined to a single, fixed use; rather, each PU can accommodate a variety of uses based on the interlinked characteristics of the marine environment. This classification system allows PUs to be designated for specific functions or to prioritise certain activities – such as nature conservation – by assigning them a specific conservation status, either "priority" or "limited". For example, a PU may be classified as a "priority area" if it includes a protected site without an active management plan, or as a "limited area" if it encompasses a marine protected area with a defined management framework and regulatory measures in place. These configurations might be considered dynamic, responsive to evolving oceanographic conditions, shifting human uses, and the long-term impacts of climate change (Stelzenmüller et al., 2015).

Moreover, from this perspective, the strong interconnection between land-based vulnerabilities and territorial characteristics is a factor that triggers climatic impacts. An example is the interactions and temperature distributions between coastal infrastructure and the sea surface, and the related phenomenon of heating concerned rivers and infrastructure behaviour (Maragno et al., 2020).

This shift towards dynamic and permeable boundaries marks a departure from land-based zoning logic, where boundaries are largely stable and fixed. In the

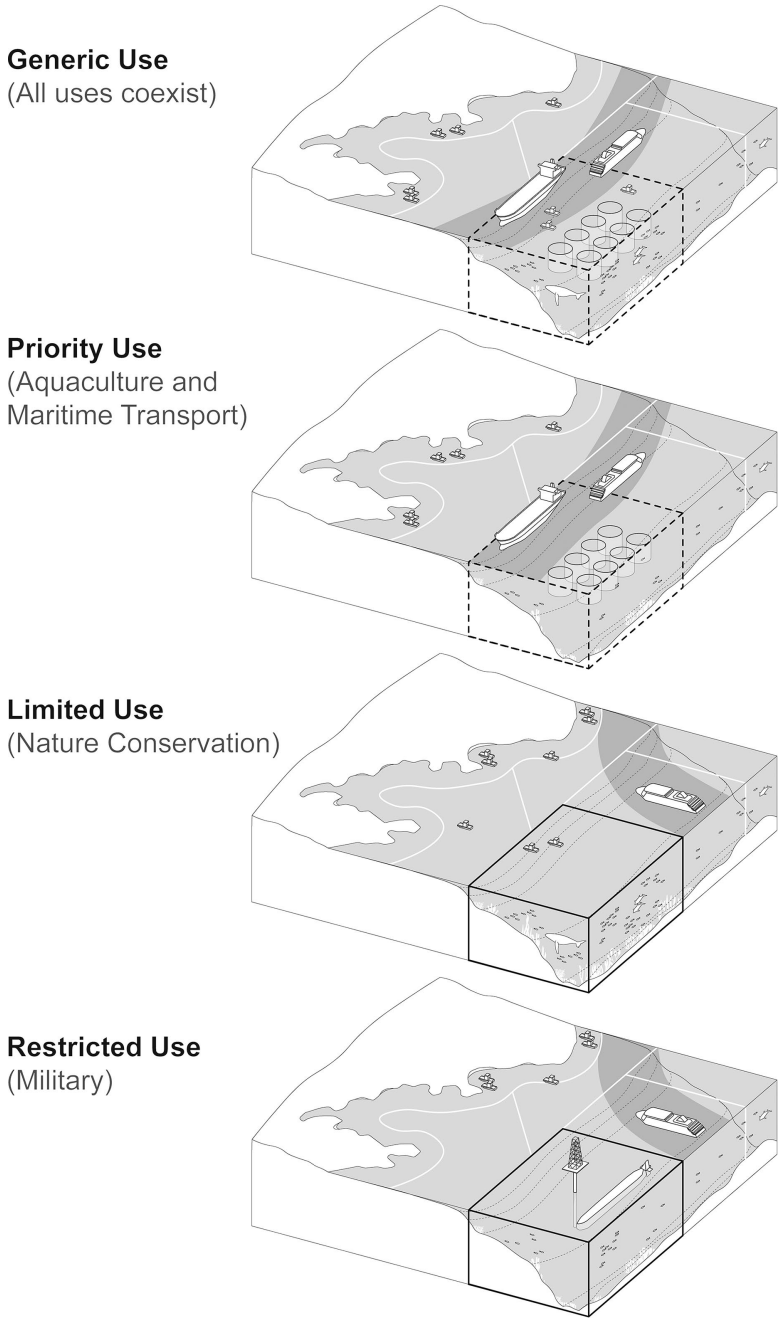

Figure 10.2 Mechanism of PUs classification.

Source: Fabio Carella; Alessandra Fudoli; Francesco Musco, 2025.

marine context, the Italian PU model embraces the need for revisability and strategic flexibility. As ecological conditions change – such as migratory routes, seasonal productivity, or seabed morphology – so too can the spatial designation of a PU (Maxwell et al., 2015). This responsiveness is built into the planning process through a feedback loop that includes scientific monitoring, institutional review, and stakeholder engagement (Stelzenmüller et al., 2015).

By identifying the conflictual interactions between maritime activities, as well as human uses and natural resources, the potential misalignments of interests among the various actors operating within marine space are also recognised. In this sense, PUs also provide a governance function, through which institutional coordination is operationalised. They act as platforms, enabling dialogue across national ministries, regional authorities, and sectoral stakeholders. This multi-level coordination ensures that planning remains coherent across scales while still allowing for differentiation based on local ecological and socio-economic conditions. As such, PUs are not merely spatial containers but institutional devices that facilitate adaptive governance (Ramieri et al., 2024).

As practical instruments through which national strategic objectives and PUs are realised, a tailored set of management measures – ranging across spatial, temporal, technical, regulatory, and economic dimensions – was listed. Depending on the PU's classification and function, they may include spatial restrictions, licensing systems, seasonal limits, or conservation incentives. The design of these measures is rooted in a place-based logic that allows regions to modulate the application of national strategies based on local priorities and constraints (Carella et al., 2024).

PUs offer a contextual and operational expression of dynamic boundaries in marine spatial planning. They respond directly to the central challenge of governing marine space without rigidity, aligning with broader discourses in MSP that advocate for soft, responsive, and strategic spatial governance (Allmendinger & Haughton, 2010; Jay, 2018). Through the PUs, Italy has institutionalised a flexible zoning system that treats space not as a static surface to be divided, but as a living and evolving domain that must be continually interpreted, managed, and revised.

Finally, the permeable geometries embodied in the Italian MS Plans reflect a conceptual evolution in marine spatial governance – from top-down regulation towards adaptive, multi-scalar, and place-based planning. The PU model demonstrates how spatial tools can be designed not only to organise space but to navigate complexity, embrace change, and support a more integrated and sustainable use of the sea.

Final consideration

The evolution from static, sectoral governance models to dynamic, adaptive frameworks marks a shift in marine space management. Central to this is the increasing tendency to employ flexible spatial tools that allow marine planning to respond to ecological variability, temporal fluctuations, and shifting socio-economic demands. Through the multi-scalar approach implementation and the

sequential PU design, the Italian experience illustrates how spatial flexibility can be institutionalised, offering a valuable model for iterative and context-sensitive marine governance.

However, despite conceptual and operational advances associated with dynamic boundaries, potential limitations and challenges persist. First, flexible zoning implementation often depends on robust institutional capacity and continuous political commitment. Adaptive planning, in contexts where administrative structures are fragmented or under-resourced, can be hindered by regulatory inertia. The iterative nature of dynamic MSP, which requires regular review, monitoring, and updating of plans, may face delays or disruptions without stable funding mechanisms and inter-institutional coordination.

Second, the flexibility of dynamic boundaries could lead to ambiguity or regulatory uncertainty. Without clear guidelines, overlapping uses and shifting designations may generate weak enforcement of environmental protections. As shown in transboundary contexts – such as the Pomeranian Bay or Lough Foyle – the absence of agreed-upon spatial definitions can exacerbate geopolitical disputes, undermine conservation efforts, and prevent effective cross-border cooperation. In such cases, dynamic approaches must be coupled with strong governance frameworks that clarify roles, responsibilities, and dispute-resolution mechanisms.

Third, the integration of temporal dynamics, such as seasonal closures or real-time management systems (e.g., Dynamic Ocean Management), requires high-quality, near-real-time data and digital infrastructure, which many countries still lack. Moreover, the legal and institutional frameworks needed to operationalise these dynamic tools often remain underdeveloped. As Zuercher et al. (2022) highlighted, the gap between aspirations and efficiency in MSP implementation remains a critical barrier.

Finally, dynamic boundaries challenge traditional planning paradigms by requiring planners to think beyond fixed geometries and instead engage with spatial fluidity, uncertainty, and negotiation. This conceptual shift demands new skills, interdisciplinary collaboration, and innovative planning practices – changes that cannot be achieved solely through policy mandates but require sustained capacity-building and epistemic evolution within planning institutions.

As such, while recognising that the dynamics of boundaries must be acknowledged for more effective planning, and that to do so there is a need to thicken the interpretation of a boundary, often fuzzying its edges to better absorb the reality of intertwining relationships of elements and sectors in these spaces, significant challenges remain, that ultimately requires a shift in thinking of planning marine spaces.

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