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The opportunity for climate action through climate-smart Marine Spatial Planning

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Despite global climate-driven change in marine ecosystems and associated economic sectors, climate-smart Marine Spatial Planning (CSMSP) implementation remains limited. This joint perspective from across the climate research and Marine Spatial Planning policy interface discusses reasons for CSMSP's slow pace (blockers) and shares operational examples about how CSMSP is working around the world (enablers). Learning from national CSMSP contexts can help deliver needed and faster international collaboration on climate action.

The human-driven alteration of the global climate system is expressed in the ocean in many ways that include, amongst others, warming and changes in regional temperature patterns, acidification, deoxygenation, extreme events, changes in productivity and salinity, and circulation patterns[1]. This represents an immediate challenge to the sustainable management of ocean ecosystems, and to the maintenance of primary ocean processes and attributes that enable life on earth, including oxygen and nutrient cycling, carbon storage, climate regulation, and the sustenance of biodiversity[2]. Such changes will impact a wealth of other ocean ecosystem services and goods and benefits for human populations, directly and indirectly, through ocean-based food security, cultural values, health benefits: the foundation of the world's 7th largest economy, the "blue economy"[3,4]. Limiting and responding to those challenges (i.e. climate change mitigation and adaptation, respectively) will alter the global economy in the long term. The Joint Declaration on Ocean and Climate Action (Dubai, 2023), which emerged from the 28th Conference of Parties to the United Nations Framework Convention on Climate Change, highlighted that key to overcoming these challenges is the delivery of sustainable means to manage marine space[5]. The importance of managing marine space is further highlighted in other UN initiatives, including the United Nations Decade of Ocean Science for Sustainable Development framework (Challenge 6, Vision 2030 Working Group 6), within the Kunming-Montreal Framework for Biodiversity of the United Nations Convention on Biological Diversity (Target 1[6]), and in the Agreement on the conservation and sustainable use of marine biological diversity of Areas Beyond National Jurisdiction (ABNJ)—the "BBNJ Agreement"[7].

Marine Spatial Planning (or Maritime Spatial Planning, "MSP") is the public process of analysing, recording and allocating the spatial and temporal distribution of marine space uses to achieve ecological, economic and social objectives overarched by political processes, and has emerged as a key approach to deliver Ecosystem-Based Management EBM[8]. Resulting marine spatial plans (hereafter, "plans") present a unique opportunity to deliver ocean-climate action[9]. Namely, through : (1) advice to, or regulation of, the sharing of marine space by different maritime activities; (2) setting out of priorities in space use; and (3) by encouraging the protection of natural capital, ecosystem services, and societal goods and benefits, in harmony with

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diverse policies and broader development and environmental goals. Indeed, delivering climate-resilience is a key step towards achieving EBM, a core principle of MSP[8,10]. This is recognised in plans and policies both within national[11,12] and international contexts[13]. Inherent to the delivery of that ambition is the adoption of a long-term perspective that links MSP to both policies addressing climate change mitigation (i.e. those tackling the cause of climate change) such as National Energy and Climate planning and Renewable Energy Directive EU/2018/2001; and to policies and mechanisms supporting adaptation (i.e. addressing the effects of climate change)[10,14]. The former has become somewhat commonplace, with plans often including actions that prioritise areas for the marine renewable energy sector towards a transition to a fossil-fuel free global economy, and for the protection of natural carbon sinks[15]. However, a more holistic approach to the delivery of climate-action through MSP, explicitly incorporating adaptation as well as mitigation mechanisms (i.e. "climate-smart MSP"), is often lacking[16].

However, whilst climate objectives have been included in plans of some regions for some time, the delivery of broad climate goals through planning has been slow. In this paper, we move beyond recent, comprehensive reviews on climate-smart MSP[16–18] to provide a joint perspective from marine and climate change researchers and MSP practitioners. The bridging of these perspectives was seen as necessary to advance planning practice and to ensure that climate-smart MSP research and practice become better aligned. Indeed, non-alignment between research and practice has been proposed as contributing to delayed progress on climate-smart MSP delivery[19].

We discuss current, real-life climate-smart MSP implementation, leveraging the knowledge and experiences of MSP practitioners and marine and climate change researchers, shared as part of an International Council for the Exploration of the Sea's Workshop "Climate change considerations in Marine Spatial Planning"[20] (please see Supplementary Information for detail). Specifically, we address three key research questions: I: How does climate change affect MSP?; (II) How are climate change adaptation and mitigation actions being implemented through national and sub-national marine plans?; and (III) How can marine spatial planning provide an opportunity to deliver international goals on climate change? We document practical solutions which the two communities have been co-developing to deliver climate goals through planning. We further highlight areas where the two communities identified a need for further development, including improving how MSP can help accelerate the delivery of international climate goals. Through this knowledge co-production exercise, recommendations made are intended to help identify strategies to overcome perceived barriers to the delivery of climate-smart plans. We discuss where and how success is already occurring, to help others now beginning to tackle the challenge of designing and implementing climate-smart plans. We focus specifically on MSP and plans as multi-sectoral instruments, and not on other associated single-sector area-based management tools, such as the design of marine protected areas, or fisheries management plans. The perspectives presented here advance the literature by focusing on real-life best-practice co-development, bringing researchers and practitioners together. And whilst we aimed to collect examples from a range of backgrounds and contexts around the world, many examples presented are still focused on Europe and North America, given the membership of the workshop (Supplementary Information). Replicating this effort to join up perspectives across the globe will be particularly important into the future.

How does climate change affect MSP?

Climate change evidence and MSP development

The perceived lag in the inclusion of climate action within plans (especially for adaptation) often stems from limited integration between climate-policies within plans and broader international, national and subnational climate change policy; as well as from perceived competing sectoral goals Fig. 1[21];. Instead of complementary, different within-plan policies are also at times perceived as contradictory (such as expanding offshore renewables and biodiversity restoration), delaying progress.

In practical terms for planners, the development of climate actions through planning may also be hindered by limited allocation of dedicated human resources and financing to increase the capacity to adequately

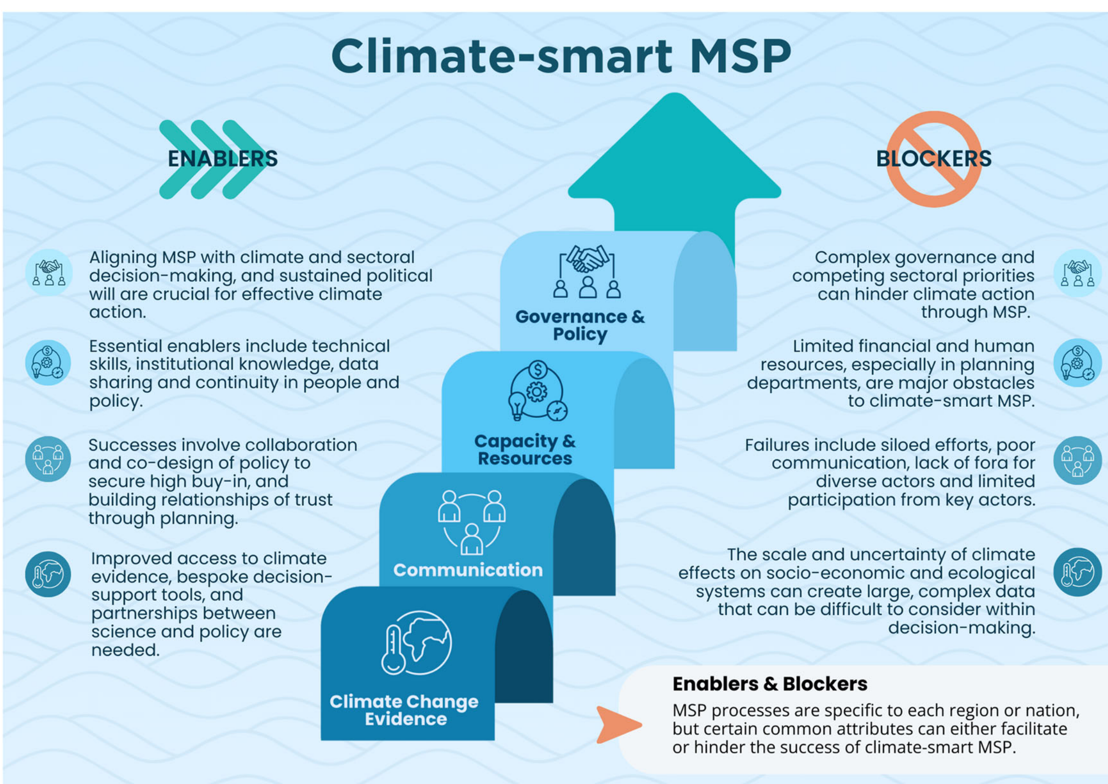

Fig. 1 | Enablers and blockers of climate-smart Marine Spatial Planning (MSP).

provide a policy response to changing conditions[16]. Such resources are not always available, but are necessary to deliver the additional assessment of climate evidence, engagement with the required stakeholders and broader policies, and the development of climate-smart strategies for MSP (Fig. 1). Indeed, climate-smart MSP requires the collation of data and expertise from a wide range of disciplines (e.g. natural and social sciences, modelling, economics, policy) and institutions (e.g. government, industry, research, finance and society). The inclusion of climate action within plans, amongst other policy priorities, is therefore a stakeholder-heavy process, not only to ensure data acquisition, but also to ensure coordination and communication of priorities between stakeholder groups, and into the planning process. Such communication relies on trust between different stakeholders and planners. However, focus work with planners and stakeholders has occasionally highlighted existing scepticism about climate modelling evidence and its uncertainty[22], perhaps due to lower levels of familiarity with this type of evidence. This scepticism is especially present when climate change goals are considered alongside with sectoral needs, as also found with other marine stakeholders[23]. This scepticism may ultimately lead to slow uptake on planning policies that deliver climate action[24,25]; Hence, dedicated engagement is necessary to improve social license for such actions (Fig. 1). Nevertheless, as the marine social-ecological systems are altered in step with climate change, failing to address resulting climate impacts may lead not only to the non-delivery of goals set out in MSP, but also to unsustainable use of the marine environment, and ineffective conservation measures[17]. Failure to address climate change may also exacerbate existing management challenges on a local scale, through unsustainable use of resources, and thus affect the relationship between stakeholders and planners, lowering support for planning measures into the future Fig. 1[26];. A supporting institutional and governance environment is ultimately required, that acknowledges the need for plans to be adaptive, being able respond to the short- and long-term challenges resulting from climate change (Fig. 1).

Adequate engagement at the science and policy interface can help fill climate change data gaps within the MSP process. However, when we explored perspectives of MSP practitioners and researchers on what data are needed to further support the development of climate-smart MSP, some divergence emerged (Fig. 2). Whilst some topical areas were seen particularly important by both practitioners and researchers, many were not, demonstrating a gap between data needs and provision (practice and research). This gap may partially explain some of the slower progress in some aspects of climate-smart MSP development. Key areas, identified by both practitioners and researchers, where essential data gaps remain include (Fig. 2): (1) assessments of the economic, environmental and social impacts of climate change on a planning area, including cumulative impact assessments to support climate change adaptation; (2) clearer definitions of priority needs for conservation within planning areas (e.g. biodiversity, carbon sequestration, fish stocks); and (3) a better understanding and modelling of the displacement of existing human activities within the planning area, resulting from climate change. Greater efforts in these key areas may help to accelerate the delivery of climate actions through MSP, especially on adaptation. Dedicated assessments of this type (Fig. 2) elucidating potential discrepancies between data requirements and provision could help align research efforts with marine planning needs in individual nations and regions, and in this way too, help accelerate climate-smart MSP delivery.

Beyond issues of scale and usability of climate change evidence in climate-smart planning[14,21,27], a key aspect that may affect the uptake of climate change evidence into the MSP process is how inherent modelling uncertainty is communicated[28] Fig. 1. The development of better media to facilitate that communication[29], as well as the establishment of dedicated bodies to help communicate climate change evidence at the science-policy interface (e.g. the UK's Marine Climate Change Impacts Partnership, MCCIP) have been identified as important vehicles to help close climate evidence gaps within MSP, especially during evidence gathering and plan preparation. For instance, MCCIP brings together scientific experts to work with planners, ministers, and those responsible for policy implementation on marine planning - communicating complex issues such as uncertainty and spatial and temporal variation in a way that allows information to be incorporated into decision making[23]. Strong connection and communication at the science-policy interface is particularly important when making policy decisions in response to current (climate) events, necessitating an urgency in the use of scientific models and data which does not fit with the traditional ways that scientific information is disseminated (e.g. scientific peer review), which tends to take more time. Such collaborative forums established at the science-policy interface may become increasingly important to ensure MSP and plans remain effective, in a time of an increasingly complex and relatively unknown ocean environment, as climate change unfolds.

Lastly, local communities, including Indigenous Peoples, are often found to be underrepresented in stakeholder engagement underpinning MSP development, although the marine environment is fundamental to their way of life[17]. These very groups hold essential knowledge that can inform on how plans can address (or how effectively plans are addressing) climate change[26,30]. Local communities and Indigenous Peoples often notice the effects of climate change before scientific evidence is collected and made available; for example, declines in populations, distributional changes, or altered behavioural patterns of marine species in their area[31]. Harnessing that knowledge as evidence within planning provides a means to enrich the database available to build climate-smart MSP and monitor its effectiveness (Fig. 1). Such approaches may be especially important in developing nations, where the impacts of climate change are often strongest and more immediate, and where governance may be less established[32]. In such nations and regions, supporting climate change adaptation and mitigation now through climate-smart MSP may have immediate and needed effects for people and nature. Foundational approaches for engagement with local communities and Indigenous People can already be found in the literature[33] and in emerging MSP practices on the ground[34]. For instance: co-delivered research in Finland on the interaction between planners and local fishers is informing planning to account for the impacts of climate change on professional fishing[35]; and Indigenous People's knowledge and western science were brought together to inform the design of Marine Spatial Plans in Canada's Northern Shelf Bioregion[26].

At which stage of the planning process do climate change considerations come into focus?

Although planning cycles vary between countries and regions, generic design-implement-review cycles predominantly apply in MSP[9]. Some nations have already undertaken more than one MSP cycle (e.g. England, the Netherlands, Belgium, Germany, Sweden); whilst other nations are now developing MSP for the first time (e.g. Spain, Italy). Consensus amongst practitioners attending the workshop was that climate change considerations should be considered at all stages of MSP. Broadly, the early stages of planning include the identification of planning themes, issues, and opportunities, gathering evidence for analysing the planning context, and outlining a scope and objectives[9]. Evidence sits at the centre of an MSP process. Consideration of climate change evidence as a starting point, thus enables climate change to be a consistent theme across the plan and throughout the planning process (Fig. 1, "enablers"). Such evidence may include anticipating climate-driven changes in marine biodiversity, resources and ecosystems, changes in ecosystem services and associated goods and benefits to people, changes in maritime activities (and/or their location), and associated socio-economic and cultural impacts due to a changing climate. Evidence should be at the appropriate scale and resolution to ensure that it is useful to planners ("Climate change evidence and MSP development", Fig. 2).

At the design stage, there is also an opportunity to determine the extent to which climate change is taken into account within legislation underpinning MSP (and the previous plan, if there have been previous iterations of the design-implement-review planning cycle). It is also necessary to identify any links between planning and broader, high-level policies designed to address climate change adaptation and mitigation at the appropriate level (sub-national, national). To an extent, these links will

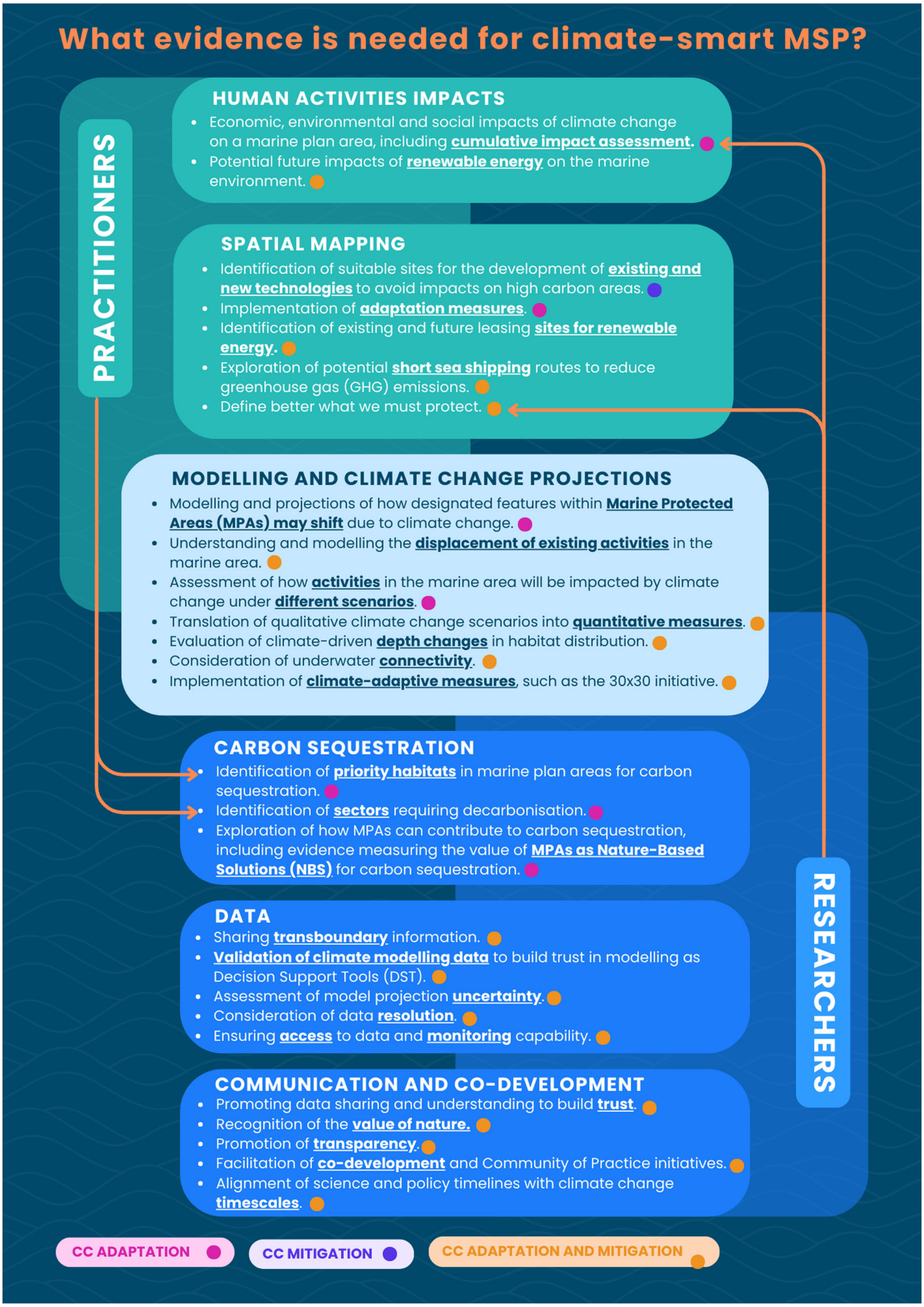

Fig. 2 | What evidence is needed to support climate-smart Marine Spatial Planning (MSP)?. Workshop discussion focused specifically on exploring the perspectives of practitioners and researchers on what data are needed to further support the development of climate-smart MSP, through science-policy collaboration. It emerged that while some types of data appeared to be relevant from both lenses, many did not. The diagram identifies key gaps between the data needs of practitioners and data provision by researchers. Such disconnect may explain some of the slower progress in aspects of climate-smart MSP development. Key areas identified by both practitioners and researchers as areas where essential data gaps remain included: (1) Assessments of the economic, environmental and social impacts of climate change; (2) clearer definitions of priority needs for conservation in planning areas (e.g. biodiversity, carbon sequestration, fish stocks, etc.), and (3) a better understanding and modelling the displacement of existing human activities resulting from climate change and their ecosystem effects. Greater efforts in science-policy collaborations in these key areas may thus help accelerate the delivery of climate actions through MSP, especially in support of adaptation.

determine the scope for a plan to deliver climate action. Good cohesion between the legislation and governance structures underpinning MSP and climate change policy is thus seen to enable effective climate-smart MSP (Fig. 1), as noted by others[18]. However, in practice, it is still more common for MSP to incorporate climate change considerations into the earlier stages of planning, rather than during implementation, monitoring or evaluation. Incorporating climate change evidence into the MSP monitoring, evaluation and adaptation stages (e.g. to track progress on climate action introduced through MSP) is seen as more challenging and remains as a stumbling block (Fig. 1).

Depending on a nation's (or region's) MSP process, it may be possible to continue gathering evidence into the final MSP plan preparation stages. Further or newer evidence on climate change may be incorporated into the plan's objectives, its zoning scheme, and management actions, for instance, to assess the potential impacts on net greenhouse gas emissions of draft planning decisions[36]. However, the earlier that evidence is collected, the more thoroughly it can be integrated to inform plan design. Workshop participants agreed that acting on climate change evidence will always need to be considered alongside other environmental or sectoral goals (e.g. for fisheries, navigation, recreation, etc.) included in plans, as well as national and regional interests. Providing evidence about how climate action may help to support other marine planning goals e.g. promoting access to climate change refugia for the fishing sector through the spatial management of other sectors in refugia areas[21,37–39], could thus be key to promote climate action through MSP.

Once a plan is adopted, climate change considerations should continue to be incorporated into the planning cycle through the dynamic and flexible process of adaptive management and well connected to relevant sector governance. The monitoring, evaluation, and adaptation stages of MSP are essential for determining the effectiveness of a plan and the impact of its measures and objectives. These stages could therefore be used to help track whether climate action is being delivered through that specific MSP process, via the use of indicators. Indicator schemes that include at least some aspect of climate action have been proposed to help governments, planners, and other actors track how plans may be leading to the implementation and monitoring of climate targets[10]. Such schemes could highlight where further development of climate-smart implementation mechanisms is needed, as found for other elements of MSP[27]. However, at present, there is no general working framework to track whether a plan delivers on climate change adaptation and mitigation. For instance, a recent analysis of existing MSP guides[40] produced an index to help practitioners score the extent to which the fundamental principles of MSP have been put into practice. The index includes the means to assess whether the MSP addresses and considers climate change, but it does not provide a measure of whether the plan is effective in delivering on that aim[40]. Providing evidence that a specific plan policy is delivering climate action may require analyses over multiple MSP cycles, given the time that is required to assess the effectiveness of some interventions e.g. minimising disturbance of seabed area to enhance carbon sequestration[11]. Finally, delivering climate action through planning for one sector may, in turn, impede adaptation options in other sectors. For example, dedicating large exclusive areas to renewables, may reduce the adaptive capacity of small-scale fishers in the face of shifting resource distributions[41]. Balancing climate change objectives together with other sectoral objectives included in plans, and understanding trade-offs and options for co-existence or multi-use through consideration of appropriate evidence (Fig. 2), is a key step in enabling an informed delivery of climate action through MSP.

How are climate change adaptation and mitigation actions being implemented through national and sub-national marine plans?

What type of climate change adaptation and mitigation measures are already being implemented as part of MSP?

The rapid increase in the development of MSP around the world has provided examples of how climate action (i.e. implementation c.f. aspiration) is being promoted within MSP processes and addressed within plans[42]. Examples demonstrating the value of MSP as a tool that is supporting the delivery of climate goals are shown in Table 1. In practical terms, planning policies, strategies and measures being implemented differ depending on the specific MSP processes, and national and regional contexts. A key aspect leading to those differences is the legislative basis varying among countries and determining the degree to which a given Marine Spatial Plan is used in the decision-making arena (rather than as an advisory process). The capacity to deliver climate action through MSP will depend upon the decision-making capability of government bodies involved in planning. In some cases, MSP may not be able to deliver on climate action without support from ancillary legislation, which may be the responsibility of separate bodies from those designing MSP. Understanding the context, specific to each nation and region for which a plan is drafted, is key to understanding how climate action can be promoted through MSP.

Climate change mitigation. Examples of climate actions being enacted through marine plans frequently focus on mitigation(Table 1). The most striking example of these are plan policies that promote the growth of the offshore renewable energy sector, the momentum for which has been seen by some as an important driver of operational MSP[43]. By and large, these initiatives have focused on offshore wind sector development, but some have focused on other forms of offshore renewables, such as wave and tidal energies, as well as floating solar[44]. The European Union is a strong driver of deployment of offshore renewables, and its recent communication on the topic (European Commission 2023) gives MSP a central role in expediting renewable deployment. Recent work has highlighted how partnerships between policy, communities, industry and academia can further the growth of this sector as part of a transition to a net zero blue economy[45], such as partnerships between NGOs and the offshore renewable energy sector Belgian Offshore Platform et al., 2021, Offshore Coalition for Energy and Nature, 2022[46],. Ambitious targets for the growth of the sector are therefore part of many national and regional MSP[47], sometimes with opposition from local communities (Figure 1 Todt, et al.[48]). While in many countries the development of offshore renewables is therefore a clear political priority[49], there is the need to ensure that the expansion of renewables is appropriately informed by public consultation during MSP. The expansion of renewables should align with other targets for conservation, coastal communities, and other uses such as fisheries, to enable a fair transition[41,45,50–52]. Moreover, future accounting for the overall life cycle analysis of emissions attributable to different sectors (e.g. wind farms, aquaculture facilities, new harbours) could enable more informed decision making with regard to the long-term climate effects of activities, to ensure that future planning and licensing decisions more closely meet climate policies set out by governments[53]. Similarly, the analysis of the impact of different human activities on marine carbon storage and flows could help inform future climate-smart planning decisions, including zoning (as in the Belgian North Sea).

Other major spatial measures now frequently included within plans to support climate change mitigation include the establishment of Marine Protected Areas, Ecologically and/or Biologically Sensitive Areas, and Other Effective Area-based Conservation Measures as tools for protecting marine habitats playing a vital role in ocean carbon sequestration and storage. For example, the Irish National Marine Planning Framework includes specific spatial advice on the location and regulation of uses of marine areas where the seafloor has high natural carbon content[11]. The protection of these and other types of blue carbon habitats (e.g. coastal wetlands, seagrasses, the seafloor[54] is being explored by nations and regions, as their understanding grows and the (currently limited) evidence for the location of such sites beyond the coast becomes more widely available[55,56].

Lastly, shipping route optimisation (i.e. short sea shipping) and near real time forecasting tools to ensure less time at sea already exist with a view to reduce emissions[57]. These measures are also seen as important steps to help limit climate change, which are not yet but could be supported through

Table 1 | Examples of Marine Spatial Plans which are being used to support the delivery of climate action

Nation, Region	Marine Spatial Plan	Climate Action	Detail
Germany	Spatial Planfor the German Exclusive Economic Zone in the North Sea and in the Baltic Sea	Mitigation	The plan designates priority and reservation areas for offshore wind in line with the federal government's expansion targets for offshore wind.
Ireland	National Marine Planning Framework (Irish Government 2022)	Mitigation	Advice on location and regulation of uses of areas of seafloor with naturally high carbon uptake rates.
Netherlands	North Sea Program 2022–2027 (Dutch MSP, Government of the Netherlands 2022)	Adaptation	Sand extraction is strategically regulated to ensure provision to coastal areas to limit impacts of sea-level rise, and to limit potential to enhance coastal erosion.
Northern Ireland	Draft Marine Plan for Northern Ireland	Adaptation Mitigation	Climate change is a core policy within the plan, requiring public authorities to consider and take measures on greenhouse gas emissions and climate adaptation.
Norway	Integrated ocean management plans for the Barents Sea–Lofoten area; the Norwegian Sea; and the North Sea and Skagerrak (Norwegian Ministry of Climate and Environment, 2015)	Adaptation Mitigation	Lays out the government's ambitions for knowledge gathering in relation to marine climate change and strategies for a green transition in marine industries (e.g. petroleum, Offshore Renewables).
Seychelles	Seychelles Marine Spatial Plan	Adaptation Mitigation	Zoning for biodiversity protection includes analysis of sea surface temperature (refuges). Seagrass habitats are also protected to support mitigation.
Sweden	Marine Spatial Plans for the Gulf of Bothnia, Baltic Sea and Skagerrak/Kattegat(Swedish Agency for Marine and Water Management 2022)	Adaptation Mitigation	Support for four-fold growth of the offshore renewable wind sector. Consideration of the location of climate change refuges (temperature) for particular species in the characterisation of areas within the plan and proposing priority areas for nature.
Scotland, Orkney Islands	Orkney Islands Regional Marine Plan (Consultation Draft, Orkney Islands Council 2023)	Mitigation	Policy identifies areas to grow the renewable sector, to meet net zero targets and minimise impacts on nature.
United States of America, Rhode Island	Rhode Island Ocean Special Area Management Plan (Fugate 2012, Olsen, McCann and Fugate 2014)	Mitigation	Identifies priority areas for the offshore wind sector resulting in the successful implementation of the first offshore wind farm in the United states.
England, SW of England	South West Inshore and Offshore Marine Plan (Department for the Environment Food and Rural Affairs 2021)	Adaptation Mitigation	Climate change is a strategic theme within the plan, which incorporates three specific climate change adaptation policies focused on flood and erosion defence, carbon sequestration, enhancing climate change resilience of activities and ecosystems.

Please note that in all nations and regions listed, the Marine Spatial Plan is the policy instrument, but in some cases (e.g. nations of the United Kingdom) the plan can include additional governance instruments on specific themes, such as climate change, which are also termed "policies".

MSP. These may be easy wins for MSP to deliver climate action, building on existing decision support tools.

Climate change adaptation. Climate-adaptive MSP approaches that aim to improve the ability of species, habitats, and sectors to adapt to climate change (and minimise impacts) are beginning to be implemented (Table 1). Typical examples include the common requirements of taking into account climate change impacts (e.g. sea level rise, increased storm surges and flooding) in marine and coastal infrastructure or extraction projects[58]. The responsibility for such actions sometimes lies with licensing processes or, in coastal areas, with land-use planners, underlining that climate-smartness is another area of planning where improvement is needed to better address land-sea interactions in MSP[59]. The drive to apply such approaches is, on the one hand, frequently linked to the broader policy landscape within which a specific MSP process sits and, on the other hand, to climate change, biodiversity, or sectoral goals that a plan is designed to help meet. In practice, these approaches rely on the use of tools that provide information (i.e. projections) on how the distribution of species, habitats, and other resources (e.g. wind) of conservation and commercial value may change due to climate change, potentially causing shifts in the activity of various economic sectors, and the ecological and socio-economic impacts of such shifts (e.g. on coastal communities).

Modelling-based decision support tools[60] may help determine areas where climate change impacts may be more or less severe, where potential hazards, risks or impacts requiring management action may emerge, and where measures may be required to ensure a fair and just transition. Those analyses can feed into the design of potential management scenarios contrasting different alternative futures with regard to priority setting, space occupied by different sectors, trade-offs and synergies[8,61]. Different scenarios may then be the object of consultation, leading to specific zoning and/or spatial policy design and helping to set priorities within plans. For example, Symphony is a decision support tool applied in the ecosystem-based MSP in Sweden[62] and later adapted to support MSP in the Western Indian Ocean region[63]. Symphony is used for a spatial cumulative pressures assessment that includes some (limited) climate change evidence that can be used to identify the location of climate refugia for conservation consideration during planning. The potential identification of climate refugia in support of climate-smart MSP goes beyond conservation targets, and also include sectors such as fisheries, aquaculture and aggregate extraction. In the United Kingdom, scientific research co-delivered with policy makers and industry is promoting the use of information on the location of climate refugia for conservation, fisheries and aquaculture, identified using climate modelling analyses, towards the design of climate-smart marine plans that are also socially acceptable and economically viable[21].

More often than not, however, the designation of Marine Protected Areas and Other Effective Area-based Conservation Measures is the responsibility of separate governmental bodies and does not involve planners (e.g. Finland, United Kingdom; Trouillet and Jay 2021). This disconnection between designation and MSP may limit how much planning can promote climate-adaptive conservation objectives. However, in those cases, MSP (and subsequently, sector plans and licensing) can be used as a vehicle to help manage other sectors to avoid or limit adverse impacts on biologically or ecologically important areas that emerge as a result of shifting habitat distributions under climate change[21,64].

Lastly, there remains a perception that incorporating climate change adaptation actions within plans has been delayed by how MSP, as a framework, emerged historically without full reference to climate change. Zoning elements of MSP, and big infrastructure projects supported by MSP such as the offshore renewable energy sector, may be static or difficult to alter, legally and practically. Such elements may hinder the delivery of more dynamic approaches proposed for MSP, to help society and ecosystems adapt to climate change[65]. In modern MSP, the need for climate-adaptive measures is being brought to the fore, and additional flexibility is being built into the planning process to help promote adaptation[66], such as by allowing for the consideration of new or up-to-date climate change evidence throughout the MSP cycle (2.2)[67]. Perhaps one of the greatest challenges to delivering adaptation through MSP is that, at present, MSP is performed in its vast majority of instances within nation states, with only emerging coordination between states. As such, "regional seas MSP" does not yet exist formally, although some Regional Seas Conventions aim to promote it, and new initiatives are emerging[68]. Coherence and equivalence between member states MSP thus becomes even more important[69], as species and habitats move in response to climate change, necessitating more flexible, dynamic or anticipatory approaches to the spatial management of marine sectors[16].

How can marine spatial planning provide an opportunity to deliver international goals on climate change?

How to link climate actions delivered through planning with climate actions in broader ocean governance and sector policies?

International climate change commitments as well as national policies and legislation are beginning to recognise the role of MSP as a central part in enabling climate change adaptation and mitigation. However, addressing climate change from a cross-border or sea-basin perspective may require work with processes and consensus where regulatory action is not yet easily available. In this regard, MSP is, and should continue to be, co-developed with stakeholders at multiple levels, from local authorities, communities and sectors, NGOs, national ministries (e.g. environment, fisheries, transport, energy), and to supra-national and international policy bodies (e.g. DG MARE, OSPAR, IOC-UNESCO, FAO, IMO). Such work, inclusive of diverse voices, ensures good links between the development of climate-smart MSP with the governance and policies for climate, maritime sectors and the needs of adjacent communities, and may also help revise sectoral policies to ensure they too are climate-resilient (Fig. 1). Such a co-development approach also potentially ensures that there may be greater incentives for compliance with a potentially transformative policy landscape. (driven by climate pressures and the aim to curb climate change) developed from the early stages of climate-smart planning, through a sense of joint ownership of policy direction that may in this way be more agile, dynamic, and just[70].

Strong, pre-existing links between national climate ambitions and sectoral policy for monitoring, reporting and evaluation in MSP may be a key facilitator of this process (Fig. 1), which can be further stimulated at the international level. For example, European Union Member States have to indicate in their National Climate and Energy Plans how much energy they will produce from renewables. Renewable expansion is a key policy target for MSP in the European Union, recognised in the European Maritime Spatial Planning Directive (Directive 2014/8), which sets the legal framework for the development of MSP in member countries. This is an example of how early linkage between MSP and broader sectoral policy helps promote cohesion in the delivery of action, that is supported across the legislative and governance structure underpinning MSP, and guiding any subsequent need for additional structures, fora and procedures. In this case, the link between MSP and energy, which in turn is linked to national commitments to net-zero, stimulated internationally (e.g. by the UNFCCC). Furthermore, alignment of objectives that are often perceived as contradictory, such as expanding offshore renewables while also achieving biodiversity conservation, could also be accelerated through a focus on climate action. Indeed, licensing for many marine activities, including renewables, now requires mitigation and even compensation, such as biodiversity offsets to account for local loss of habitats, which come with additional costs and, at times, untested benefits. With climate change adaptation measures often requiring some degree of relocation of uses (as species, habitats and other marine resources redistribute under climate change), an opportunity emerges to potentially reset and readdress sectorial conflicts by ensuring the use of space meets multiple objectives which are resilient into the future. Using climate change impacts as a common driver, developing constructive and practical multi-use options for maritime space could thus be accelerated, focusing on opportunities as well as impacts[14,21,71,72].

Finally, the implementation of monitoring processes, and the necessarily accompanying indicators, that explicitly consider climate and sectoral objectives, and that inform meaningful evaluation of plans, will be needed to ensure plans deliver climate change action in addition to other objectives. Those indicators could form the basis of international agreements on the delivery of climate-smart MSP, with existing guidance on the attributes of effective indicators for policy[27].

Success stories about how planning has been used to stimulate climate action across borders

A key area where MSP is being seen to stimulate international climate action is through the growth of renewable energy[45]. The effective and sustainable growth of the offshore renewable sector also necessitates that an optimisation of marine spatial uses is coordinated across boundaries[69]. In Europe, the Netherlands, Denmark and Germany are aligning spatial management of activities to pave the way for offshore renewable wind expansion. An important, additional climate effect of this initiative, is the resulting alignment of shipping routes, creating more effective routes for shipping across those nations' waters whilst opening more areas for renewable energy. The effect of shipping emissions on climate is complex[73], but it is thought that, in the long-term, reductions in shipping emissions would decrease global warming, with the short-term effect of reduced aerosol emissions being outweighed by others[74]. The way through which MSP is helping to advance renewable energy development in Europe may therefore, additionally, have positive effects on climate change that result not only from lower reliance on fossil fuels, but also from lower shipping emissions[75]. The delivery of these outcomes may be further stimulated by the Greater North Sea Basin Initiative[68], which is providing a collaborative framework between nine North Sea countries to promote better international transboundary integration of uses and better alignment of MSP to tackle issues such as climate change. Similar approaches are not yet known in other areas of the world, with much opportunity for development.

What'smore, the delivery of needed international climate action for biodiversity[2] through MSP is not yet rich in success stories. But a key milestone has been recently reached in the international arena that may help deliver those in the near future. Specifically, the recognition within the United Nations Convention on Biological Diversity's Kunming-Montreal Global Biodiversity Framework[6], of Target 1 on the need to: "Plan and Manage all Areas To Reduce Biodiversity Loss". Target 1 is a central focal point for current work under the Convention, setting an intention for the 196 party nations to deliver planning as an instrument to protect biodiversity. Additionally, Target 8 requires parties to "Minimise the Impacts of Climate Change on Biodiversity and Build Resilience". Nations' commitments to deliver the GBF by 2030 are thus an incentive to use climate-smart MSP to deliver immediate outcomes for biodiversity conservation. This ambition may yet be realised this decade, and is a cause for optimism.

However, in the absence of official policy instruments to help deliver coordinated international climate action through MSP[76], multi-stakeholder platforms and networks[77] are seen as key facilitators of progress toward joint goals. The works of several such networks are recognised as important focal points in this area, including: the Baltic Planners Forum (supported by Capacity4MSP); the International Council for the Exploration of Sea (ICES) Working Group on Marine Planning and Coastal Zone Management; OSPAR; HELCOM; eMSP NSBR; MED-MSP-CoP; 30 by 30 / the America the Beautiful Act; and the UNESCO-IOC/EU program MSP Global. The upcoming United Nations Decade of Ocean Science for Sustainable Development's Sustainable Ocean Planning programme may too become a central mechanism to focus and advance this momentum (Ocean Decade Programme on Sustainable Ocean Planning (SOP Programme) - Ocean Decade).

Can planning help address broader challenges in international waters, into the future?

In addition to challenges between in coordinating MSP between nations, there is also no clear international arrangement or legal source to engage MSP with the spatial management of areas beyond national jurisdiction in a coordinated way, across sectors[76]. International waters therefore still present an untapped opportunity for the development of international collaboration to deliver on climate through planning. For instance, the recent Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (the "BBNJ agreement" United Nations[7]), is seeking to deliver effective and sustainable spatial management of areas beyond the 200 nm limit and which cover 60% of the global ocean[78]. Whilst calling for a general approach to deliver on its objectives that includes improving ecosystem resilience to climate change (i.e. adaptation), as well as recognising the vital role the ocean plays in global carbon cycling and in regulating the global climate system (i.e. mitigation), the BBNJ could therefore also be instrumental in delivering climate goals though spatial planning[79]. How area-based management tools (ABMTs)– one of the key pillars of the BBNJ agreement – will be defined, and whether they will include climate-change considerations may be a key step towards that delivery.

MSP practitioners, researchers and marine stakeholders hold much of the knowledge and tools regarding effective and sustainable ecosystem-based management that could help achieve that climate action in international waters, but there is yet no mechanism to enable this knowledge sharing. A new, dedicated multi-stakeholder networks focused on sharing knowledge from the MSP process with the BBNJ could, therefore, help to harness the strengths of MSP in the High Seas. It could also help address overlooked hurdles to the implementation of climate action in the BBNJ, as learned from national contexts around the world, as well as promote sharing of climate data, knowledge and tools to facilitate the design of ABMTs, to help deliver on the BBNJs core mission. Better engagement between the BBNJ agreement and MSP could help facilitate successful engagement of multiple actors and the design of multi-sectoral and multiple objective policies for the high seas (as done within Nations for MSP), and help outline a roadmap to implement climate action through conservation. Technical advice to the scientific advisory body that will be established for this treaty, as exists for other UN Conventions, could therefore become an important route to facilitate that knowledge and data sharing. This may, too, become a cause for optimism in the management of the global ocean beyond EEZs in the immediate future.

Closing remarks: The path toward increasingly climate-smart MSP

Views explored together here, across the science-policy interface, highlight how climate-smart MSP is already taking shape in many countries and regions and what key challenges remain. While advances have been made, our collective experiences indicate that there is an opportunity to: improve the coordination of research and policy development; create dedicated decision-support and communication tools to improve stakeholder literacy, trust and engagement with climate change evidence; improve resourcing (staff and financing) to enable climate change evidence consideration during MSP; and for better integration of MSP policy and the broader policy landscape on climate action (both on mitigation and adaptation). There are still, however, important gaps in the path to climate-smart MSP. Specifically, more engagement is needed to help harness the fundamental knowledge held by local communities and Indigenous Peoples about a changing ocean. More work is needed to help develop trust and facilitate the use of climate modelling and scenario approaches as evidence in MSP decision-making to support, especially, the co-development of needed climate change adaptation actions. Furthermore, a bigger drive, and an easier structure, will be needed to facilitate transboundary alignment of MSP action on climate across borders and, vitally, to facilitate the deliver of this action in the high seas, especially to support nature. International cooperation across and beyond borders is key to climate action, and there are already good examples highlighting this can be achieved through MSP[68]. MSP as a framework[9,80] has much to offer in terms of lessons learned about how that cooperation can be facilitated, and this will be essential to deliver climate action in the ABNJ, where 60% of the ocean lies. We are only now setting the foundations for the delivery of climate action in the ABNJ[7]. Let us ensure MSP can help guide that process too. Planners and associated governance structures will need appropriate resources, literacy, and tools to meet these challenges.

Finally, because we cannot manage what we do not measure, improving the efficacy of MSP policies in delivering climate action will require that suitable indicator frameworks are deployed, in line with other aspects of MSP[27]. Closing these gaps will be essential to capitalise on the momentum of MSP around the world, and to deliver necessary and urgent change in ocean practices that help prepare for, adapt to, and ultimately curb climate change.

There is no single solution to accelerate climate-smart MSP as processes are unique to each region and nation, and MSP interacts with multiple sectors. The examples and knowledge shared here, which outline what is working and where key challenges remain, may help to focus efforts, and to provide practical guidance for those starting on an MSP journey. With greenhouse gas emissions peaking once more in 2024, and unprecedented planetary boundaries being crossed through climate change, it is time that we manage ocean space for what it is: our largest CO_2 reservoir and home to unique biodiversity in our planet.

Data availability

No datasets were generated or analysed during the current study.

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Author contributions

A.M.Q. and C.N.A. conceptualised the manuscript. A.M.Q., C.N.A., and T.tB. led the workshop that requested inputs from all authors for this manuscript. All authors contributed to discussions during the workshop that led to inputs to the first draft skeleton, written by A.M.Q. A.M.Q., C.N.A., J.A.F.S., S.D.S., C.P., C.L., E.T., S.M., M.B., C.S., M.E., R.S., and P.B.S. wrote the first draft. E.G. and IW contributed additional, valuable inputs to the manuscript. A.M.Q. led the draft development. All authors, including H.E., R.V.V., E.A.V., K.Y., A.M., M.F., M.C., and K.G. contributed comments to, and reviewed, the final version.

Competing interests

C.F.S. is an Editor-in-Chief (co) and E.G. and R.V. are Guest Editors of npj Ocean Sustainability but were not involved in the peer-review process or decision-making for this manuscript. The authors declare no other conflicts of interest.

Additional information

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