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Marine ecosystem-based management: challenges remain, yet solutions exist, and progress is occurring

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Marine ecosystem-based management (EBM) is recognized as the best practice for managing multiple ocean-use sectors, explicitly addressing tradeoffs among them. However, implementation is perceived as challenging and often slow. A poll of over 150 international EBM experts revealed progress, challenges, and solutions in EBM implementation worldwide. Subsequent follow-up discussions with over 40 of these experts identified remaining impediments to further implementation of EBM: governance; stakeholder engagement; support; uncertainty about and understanding of EBM; technology and data; communication and marketing. EBM is often portrayed as too complex or too challenging to be fully implemented, but we report that identifiable and achievable solutions exist (e.g., political will, persistence, capacity building, changing incentives, and strategic marketing of EBM), for most of these challenges and some solutions can solve many impediments simultaneously. Furthermore, we are advancing in key components of EBM by practitioners who may not necessarily realize they are doing so under different paradigms. These findings indicate substantial progress on EBM, more than previously reported.

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INTRODUCTION

Marine ecosystems are facing more anthropogenic pressures than ever before, compromising the ecosystem services that these systems can deliver[1]. Species and habitat diversity are degrading, biomass is depleted, ocean chemistry is changing, waters are warming, pollution is increasing, species distributions are changing, and invasive species are increasing, while multiple ocean-use sectors are competing for the same space and resources[2–4]. Emerging industries such as deep-sea mining and offshore wind energy produce additional pressures on marine ecosystems and create further competition for resources and space, with implications for the patterns of benefits that are derived from the environment[5–7]. Addressing these challenges is key to achieving the Sustainable Development Goals of the United Nations 2030 agenda[8,9] and many related national priorities. Fortunately, there are ways to address many of these challenges that are an improvement over continuing with business-as-usual (BAU)[10–12]. Marine ecosystem-based management (EBM) is a multidisciplinary approach to management that accounts for interdependent components, structure, and functioning of ecosystems and human activities. EBM is recognized as the best practice for managing multiple ocean uses and their associated ocean-use sectors, explicitly addressing tradeoffs among them[13,14]. The current state of the world's ecosystems demonstrates that we cannot afford to keep waiting to implement EBM[15–17]. After decades of BAU, EBM has become something we "must do" instead of something that would be "nice to do." A key step in recognizing how to move forward with EBM is to evaluate the current state of global EBM progress and the common challenges that impede further implementation at a range of scales, in turn requiring an interdisciplinary global partnership.

In order to provide an updated evaluation of the global progress on EBM, the Marine Ecosystem-Based Management Progress Evaluation Group (MEBM-PEG), an international group of EBM experts (https://imber.info/science/endorsed-projects/marine-ecosystem-based-management-progress-evaluation-group-tracking-the-global-progress-of-ebm-mebm-peg/),

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Fig. 1 The global challenges, solutions, and progress for implementation of Ecosystem-Based Management (EBM) identified by the pre-workshop poll results and workshop results.

developed a poll consisting of 23 multiple-choice and open-ended questions (Supplementary Table 1). The preliminary poll results were used to guide discussions at an online workshop convened in late 2022. The workshop included over 40 invited EBM experts representing different countries and various ocean-use sectors (Supplementary Figs. S1-S9). The results represent a culmination of the poll, workshop discussions, and author expertise, supported by substantial literature where applicable. Based on this, the authors identified the global status of EBM, the top six challenges to EBM implementation, the solutions to overcome them (Fig. 1), and the probable direction of marine EBM in the coming years.

RESULTS

Impediments and solutions to implement EBM

#1 Governance. The results highlighted that the most commonly noted, obvious, and largest impediment to global EBM implementation is in the field of governance (Fig. 2). The perception is that there is little to no political will to implement EBM globally. Many politicians and resource managers are neither aware of EBM and its benefits nor how to implement it, and therefore, do not have EBM in their strategic agenda. Other decision-makers hold the assumption that EBM is too difficult and too expensive to implement. The associated challenge of bureaucratic inertia is evident in many places, despite commitments to EBM implementation on national and international levels[18]. In this surprisingly counterproductive way of ocean resource management, harmful inactions are often considered to be more acceptable than harmful actions[19]. The impacts of inertia are exacerbated by institutional silos that have narrow mandates which do not include ecosystem-scale actions; due to fixed bureaucratic processes, siloed institutions do not implement EBM unless required to. Furthermore, the workshop revealed that institutional overlap also creates inertia, as it is unclear who should do what or who has the ultimate authority to make decisions. Whether formal or not, a clear governance mandate for EBM seems to be lacking despite the growing calls to implement EBM[12,20–22]. Policies, legislation, and soft legislative mechanisms calling for EBM exist, but they are not being used to implement change[10]. Related impediments within governance structures include issues of scope and scale. Spatial and institutional scales differ within national and international jurisdictions, and the policies and legislation that managers work under lack coordination and are often too limited in spatial and temporal scale to implement EBM. Additionally, there are subnational jurisdictional challenges with local governance in coastal waters and national governance in offshore waters (e.g., state management in waters 0-3 nm and Federal management 3-200 nm in the U.S. and Australia). These governance impediments are closely interlinked, which means appropriate solutions can solve more than one impediment at a time. Rather than waiting on revolutionary changes to national and international governance structures[23], EBM implementation can move forward on an incremental and iterative basis.

The results from the poll and workshop found several solutions to the Governance impediments identified above. For example, better cross-sector decision-making can be developed through high-level leadership and political prioritization (i.e., leaders that understand the "triple-bottom-line" balancing environmental, social, and economic outcomes[24,25]). This necessitates making the business case for EBM (c.f., Impediment #6 below) to politicians, sectoral government officials, and leaders in organizations and private companies. Although significant action is needed from decision-makers through international agreements (e.g., through the United Nations) and local governance systems in collaboration with regional institutions, there should also be a

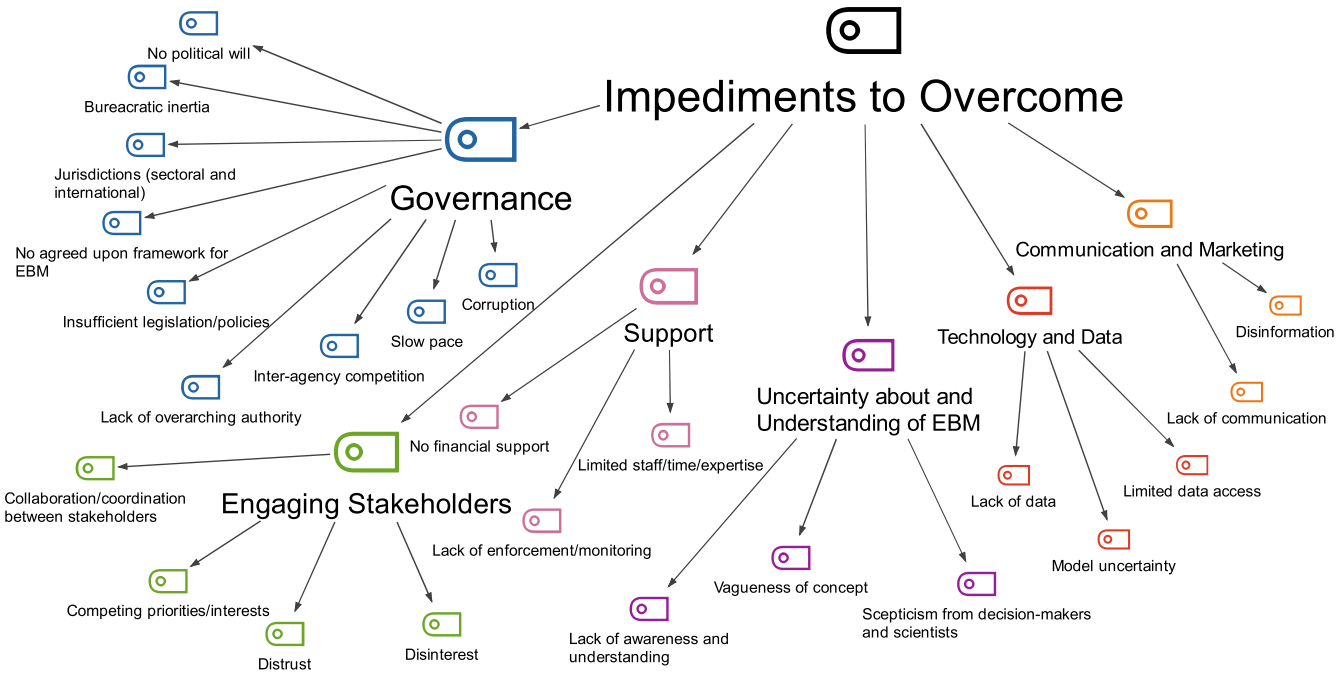

Fig. 2 The top six impediments (with subcategories) that obstruct Ecosystem-Based Management (EBM) implementation from the poll. Topic headlines 1–6 are scaled from biggest to smallest impediments to overcome based on the poll results.

bottom-up push for governance systems to change and mandate EBM[26,27]. Local bridging organizations and their role in polycentric governance structures are important[23,28], and bridges between the institutional silos are necessary and can be incentivized both at the level of individuals and institutions. For example, individual champions can build bridges across organizational elements; this can be encouraged and supported through incentives for organizations. Alternatively, coordinating governmental departments could progress EBM and efficiency in implementation by adopting and maintaining open, transparent, and participatory processes by working together to evaluate the impacts of and tradeoffs between different ocean use activities. The benefits of a coordinated approach extend beyond just cost savings from a streamlined process. For example, coordinating spatially explicit conversations with all affected stakeholders early on, including assessment of tradeoffs through cost-benefit analyses for each group, has improved cross-sectoral management in some locales[29–31]. For the purposes of this paper, the term "stakeholder" includes all relevant parties, including Indigenous Peoples and other rights holders. The workshop results indicate that bureaucratic inertia and siloed institutional management can be overcome by putting information into a currency that people, institutions, and departments care about (i.e., money, economic impacts, social impacts). Having open discussions and finding a balance between short- and long-term impacts (fundamental principles of EBM) can lead to more effective strategy development and actions, as this ultimately avoids shortsightedness and resulting larger problems (e.g., unexpected consequences) that are perpetuated by a lack of coordination and a failure to deal with tradeoffs explicitly.

Our results indicate that the key to overcoming the impediments associated with governance is to use an incremental approach to bring EBM into existing approaches. There also needs to be an exploration of current legislation and how it could be used to reduce barriers to implementing EBM[32]. We cannot let perfection be the enemy of progress; given the value of ocean ecosystems, we cannot continue with the status quo.

#2 Engaging stakeholders. Truly effective EBM requires the involvement of all stakeholders interested in ocean resources[33]. However, there is a notable power imbalance and inequality between stakeholders, and this affects their willingness to engage, how their objectives and desires are heard, and how these issues are addressed and prioritized via EBM. Our findings indicate that stakeholder inequality is problematic when there are competing interests because highly resourced stakeholder sectors (e.g., oil and gas, offshore wind, large-scale commercial fisheries, biomedical sectors, tourism, transportation, and shipping) are often able to outcompete poorly resourced or unorganized stakeholder groups (e.g., subsistence, some recreational and artisanal fisheries, Indigenous Peoples, biodiversity interests). Furthermore, there are currently few incentives for the highly resourced stakeholder groups to collaborate and coordinate for EBM purposes and few resources available to facilitate the participation of poorly resourced groups. Highly resourced groups often have established access to decision-makers, further empowering their role in the siloed, sectorial, status quo system. As a result, this undermines EBM since coordination across sectors is a key feature that differentiates the approach from the status quo, in which the tradeoffs across sectors are ignored. The results indicate that focus on a single sector inhibits EBM progress. Engaging only a subset of stakeholders can create or enhance distrust among stakeholders and widen the gap between stakeholders and decision-making organizations[13,34,35]. Furthermore, decision-makers are more likely to miss downstream effects or unintended consequences of different decisions when only views from some sectors are presented.

We identified two major solutions to ensure broader interest and participation from all ocean-use sectors: revising incentives and increasing stakeholder capacity. This means communicating information in terms that the different sectors care about (i.e., economics, good public relations, etc.) and using language that the stakeholders can understand (see Impediment #6 below). Information capturing the breadth of EBM must be disseminated through multiple channels using language and formats relatable to diverse stakeholders, including ecological, cultural, social,

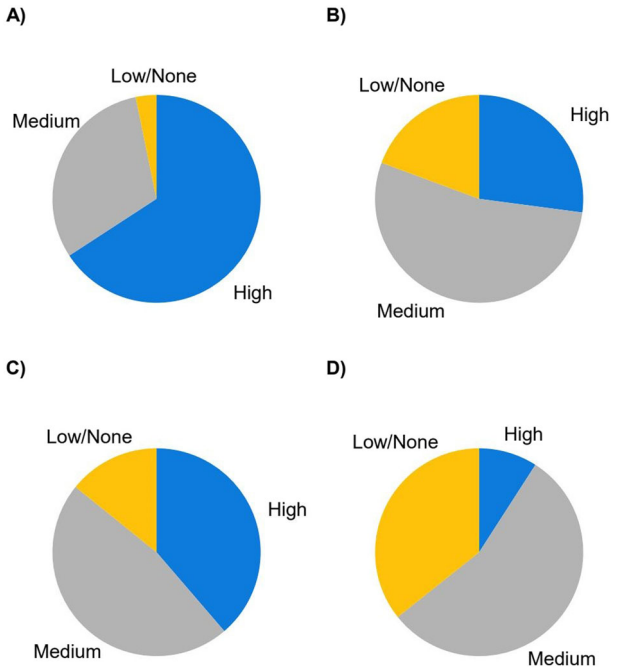

Fig. 3 The level of support (i.e., financial, staffing, or training resources, policies, mandates, etc., to employees, the public, other organizations, etc.) for Ecosystem-Based Management (EBM) from the poll varies between organizations/institutions and jurisdictions. A The level of verbal or written promised support ($n = 155$), and (**B**) the actual given support ($n = 155$) by an organization/institution for EBM. **C** The level of verbal or written promised support ($n = 155$), and (**D**) the actual given support ($n = 154$) by a jurisdiction for EBM.

economic, and governance dimensions[36], sometimes known as the "triple-bottom-line"[24]. Our workshop also highlighted the importance of providing ample opportunity for stakeholders to participate and be heard through various forums. However, meetings must be well organized with clear goals stemming from collaborative efforts to avoid stakeholder fatigue, show respect for participants' time, and consider accessibility options for those lacking the resources to attend discussions in person. Stipends could be used to ensure participation, but this requires the establishment of funding pools to facilitate attendance (additional governance consideration). The roles and responsibilities of all actors must be clear[37], and strategies to avoid perpetuating power imbalances are critical. Combining engagement efforts is a way to increase capacity for stakeholder participation. Key enablers of such change include capacity building in less organized sectors (e.g., providing training to developing proposal entities) combined with incentives for participation (e.g., data ownership, certifications, participation stipends) as potential mechanisms to help reduce impediments to stakeholder engagement in EBM.

#3 Support. There are large differences between promised and actual given support for EBM from organizations (e.g., institutes, non-government organizations, for-profit businesses, multilateral partnerships, etc.) and jurisdictions (i.e., national and local governmental institutions; Fig. 3). Organizations often say they support EBM at a high level, yet fall short of supporting financial, staffing, or training resources. Similarly, jurisdictional authorities indicate medium to high support for EBM but provide little to medium support for its implementation[38] (Fig. 3). While promises of increased support to EBM is a good first step, it needs to be followed with actual support (i.e., financial, staffing, or training resources). The lack of actual support for EBM is usually attributed to the lack of an overarching international, national, or local governance or funding body for EBM[39,40], or a lack of political will (Impediment #1) from government agencies. The workshop results identified several places where development for implementation of EBM is being executed primarily via research funding (e.g., in the European Union, New Zealand, as well as in the developing world)[34,41], through projects that are typically 2-5 years in duration. This makes establishing approaches problematic, along with presenting challenges for the continuity of implementation, monitoring of results and impacts of EBM, and retention of knowledge and skills, due to the lack of long-term funding, and hence limitations to established programs to meet EBM mandates. In order to advance EBM implementation, EBM needs to strive to be immune to changing political administrations.

The return on investment on such piecemeal EBM funding is sub-optimal. There is a large amount of research on EBM and a huge wealth of EBM knowledge, tools, and guidelines developed in research programs around the world[11,13,14,20,36,42–45]. However, the research, tools, and solutions are underutilized by decision-makers because they lack the necessary resources and support to identify or implement appropriate solutions. Alternatively, the tools are "delivered" by researchers rather than co-developed, thus making their incorporation into decision-making challenging[46]. Limited staff, time, and expertise for decision-making, monitoring, and finding relevant tools and approaches are challenging. As shown here, the issue is not always a lack of research and tools but rather a lack of support and commitment to implement them.

Sustained earmarked funding across departments, organizations, and jurisdictions for long-term EBM has historically been rare, but more stable support for EBM has become available in some regions (e.g., U.S., Canada, Australia, Norway) as EBM has become a higher priority in some organizations and jurisdictions in the last decade[18]. The results indicate that knowledge and resources for capacity building (e.g., staff, training, monitoring) are essential. Having people with EBM understanding - including knowledge of what is needed at different scales - and decision-making power when funds are allocated and distributed is key to appropriate financing. An overarching global funding body for EBM, perhaps situated under the U.N., can serve this purpose. For example, the Global Environmental Fund, the U.N. Environment Program Finance Initiative, the Global Commission on the Economy and Climate, or Regional Development Banks[39,47–49] could be engaged to develop EBM capacity more broadly (e.g., The Coral Triangle Initiative[50] and the African Banks' Integrated Safeguard System[51]).

Our results show that solving this capacity impediment is more nuanced than simply requesting more resources. The business case for EBM must be clearly articulated for organizations to back up their verbal support with actual resources (Fig. 3)[10,46]. The business case for EBM necessitates accounting for all the benefits and costs of business-as-usual policies relative to implementing EBM, inclusive of the full range of economic, cultural, social, environmental, and ancillary impacts on marine social-ecological ecosystems. This is more than just natural capital accounting[52] or attempting to place value on ecosystem goods and services[53]; it is also estimating opportunity costs and calculating the cost of damages[11] due to the lack of coordination across sectors as would occur in EBM. Preliminary calculations of holistic assessments universally demonstrate higher total costs and lower benefits of continuing with business-as-usual rather than implementing EBM[10,43,46].

#4 Uncertainty about and understanding of EBM. EBM is not a revolutionary concept and, in terms of principles and objectives, is closely linked to other paradigms, approaches, principles, and decision-making processes (e.g., Natural Capital Accounting,

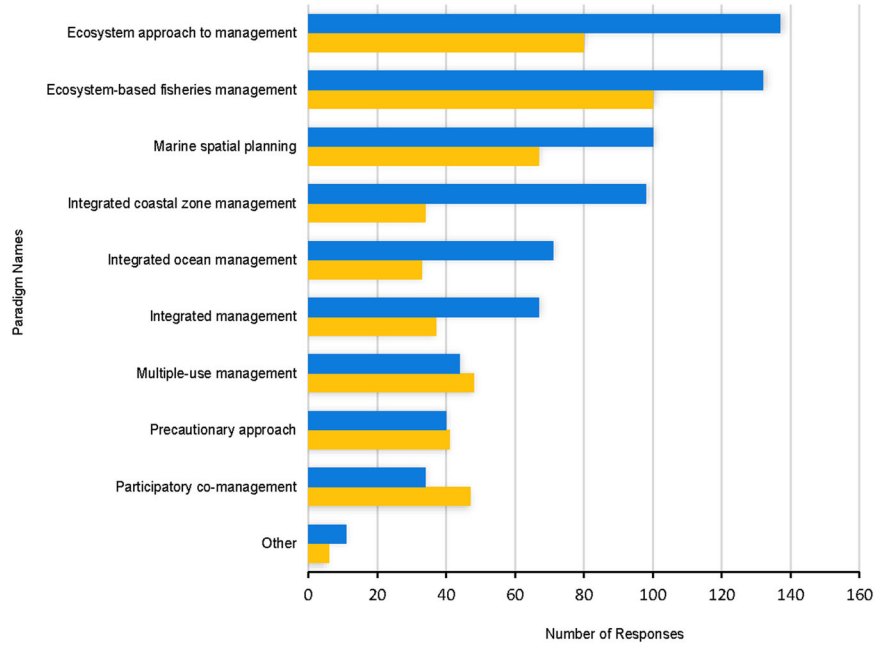

Fig. 4 Results from the poll where the participants were asked if they had heard Ecosystem-Based Management (EBM) called by other names or linked to other paradigms (top blue bar; $n = 153$) and if participants work on other EBM-related topics (bottom yellow bar; $n = 147$).

Ocean Accounts, holistic or systems-based approaches, Integrated Ecosystem Management, Social-Ecological Systems, Marine Governance, Horizontal Sectoral Integration, Strategic or Cumulative Effects Assessment, Vertical Marine Integration, Marine Spatial Planning, Ecosystem Approaches to Management, etc.[54] (Fig. 4)). A wide range of EBM-related terms and definitions have been similarly used more broadly[55–59]. The salient point about all these paradigms, approaches, and definitions is that they are all interrelated and generally espouse the same principles but emphasize different aspects particular to each of their specific contexts. (e.g., Marine Spatial Planning focuses on human activities' spatial and temporal distribution, while Natural Capital Accounting focuses on the condition and value of ecosystem services). These paradigms and principles can be largely circumscribed by merging two international treatments of the topic: the Convention on Biological Diversity (CBD) and Food and Agriculture Organization (FAO) conventions related to EBM[10,12,57,60]. Nevertheless, there have been many, often competing, frameworks and terminological discussions about EBM[57,58], which our results show has led to continued uncertainty and confusion about the concept. This uncertainty has resulted in skepticism and reservations about EBM from decision-makers, scientists, and stakeholders, including excuses such as *"EBM is too complex and too big of a task to do"* or *"I am not sure what it means."* EBM can be applied to a variety of management challenges at different spatial and temporal scales globally, but this lack of clarity or awareness about EBM means that 1) a universally accepted operational definition remains elusive; 2) benefits are going unfulfilled, 3) it is hard to ascertain the full implementation status of EBM; and 4) that many may be doing EBM under different paradigms and approaches without realizing it (Fig. 4). Nevertheless, it is good to remember that the goal of EBM lies in its principles and objectives, and not primarily in its definitions. In the end, it makes little difference what the name is as long as EBM is being done.

One solution that emerged from the workshop results was simply persistence. Continual communication to increase the understanding of EBM frameworks and clear and co-developed implementation plans are crucial to solving the impediments of uncertainty and understanding around EBM. Solutions already outlined for Impediments #1, #2, and #3 also help address this impediment of understanding - capacity building (called upon for impediments #2 and #3) raises awareness of EBM and its benefits while the concept of EBM marketing would help clarify the meaning and scope of EBM to the public and non-EBM practitioners. Noting that EBM terminology has remained relatively stable since first introduced via the Brundtland commission in the mid-1980s[57,61] and that it is written into treaties and legislation as a concept, should combat the skepticism that EBM is not worthy of being taken seriously.

The results from the poll and workshop discussions highlight the importance of not getting hung up on the terminology and definitions. Instead, we need to recognize and encourage communication of instances when common EBM principles are being employed under different paradigms, and more so, to begin to execute EBM and build up additional case studies of its success (Fig. 4)[56,62,63]. We identified several instances of successful EBM implementation that are geographically dispersed. For example, coordination between the shipping, oil and gas, fisheries, and environmental conservation sectors in the Barents Sea and the Norwegian Sea is being motivated by the desire to ensure the health, production, and function of the ecosystems while managing human activities and having a thriving economy[64–66]. In the Pacific Islands region, the desire to balance biodiversity conservation, sustainable development, and protection of cultural heritage and Indigenous Peoples rights have similarly driven the establishment of large-scale marine sanctuaries via bilateral agreements, learning exchanges, and collaboration on research, monitoring, and enforcement among stakeholders[67,68]. In Africa, the synergy between conservation and development thinking has resulted in environmental management frameworks to monitor activities, enhance better working conditions, and provision of social protection for communities displaced[51]. In the U.S., the shipping, gas, and conservation sectors worked together with government authorities to move shipping lanes to reduce strikes on whales[69], illustrating that two or more sectors agreeing to manage in an EBM-oriented manner continue to advance EBM implementation. These are just a few instances where multi-use

ocean sector management is being considered and implemented successfully – even if it may look different in each case and may not always be called EBM (i.e., a different paradigm).

#5 Technology and data. Lack of data is an impediment in some geographic regions but is also recognized as a myth that hinders the advancement of management[59,70]. The regions that have substantial data are not much further ahead in implementing EBM compared to places that do not have large quantities of data. Consequently, this implies that a lack of political will (#1) or support (#3) may be the true barrier to implementation rather than data availability. Instead, we need more *types* of data, not a higher *quantity* of data. For example, there is a lot of data within single sectors but limited access to data *across* sectors and departments globally.

Furthermore, there is a lack of transparency about data provision and access and how those data are used in decision-making processes. These challenges were described and addressed in the Aarhus Convention[71]. The lack of awareness about what data and tools are available often leads to duplication of effort (e.g., collection of data and development of tools that already exist). The solution is typically not to collect more data but to do more with existing data. Furthermore, we can expand on what we think of as acceptable data and knowledge for decision-making and recognize alternate, extant sources of data and knowledge (e.g., the use of local ecological knowledge to support data gaps). We can begin implementing EBM without having perfect information. EBM has been most successful in instances where it began with the data, expertize, and tools available[72]. An expert-based qualitative data process[73] is an achievable start in just about any situation, which can be built upon as more resources and support are available. Combining diverse forms of knowledge, including local and Indigenous knowledge, can substantially increase the available information for EBM[74]. Numerous online data repositories exist between disciplines, but these are rarely integrated/accessed by those outside of that discipline (e.g., satellite imagery syntheses, national economic reporting, etc.[75–78]), leading to siloed knowledge and understanding. Implementing clear data policies and licensing will maximize data availability to the community at large[79] and is more cost-effective than collecting new data that may duplicate what already exists. Two successful examples of this are the Ocean Reports tool developed to enable managers and stakeholders to access data relevant to ocean and coastal sectors[80], and the Marine Cadastre is a collaboration between two governing authorities, allowing stakeholders to work with the same data sets[81].

EBM tools and their utility can also be misunderstood. Capacity building (also a solution to Impediments #2, #4, and #6) is required to understand, interpret, and communicate EBM, its technology, methods, and results. One solution is to expand the training options and associated curricula available for EBM[82] and make them widely available. Learning from others is also important, for example, providing formal and informal venues for intentional and transdisciplinary decision-making involving multiple ocean users and researchers[83]. Furthermore, dedicated hubs for EBM learning and fora like the workshop that generated this manuscript are mutually and widely beneficial for capacity building among participants and sharing of resources and best practices for EBM. Taking advantage of building blocks inside current assessments and management processes (e.g., integrated ecosystem assessments, risk assessments, management strategy evaluation, etc.) is another way to build capacity and understand the tools in incremental steps[84,85].

#6 Communication and marketing. EBM is typically not communicated effectively, nor often, to the most appropriate audiences. Communication is directly related to impediments #2 on Engagement and #4 on Uncertainty in particular but also relates to all of the other impediments. Successful communication of complex issues in EBM is challenging and requires more effort and creativity than traditional scientific communication (e.g., scientific publishing, presentations, workshops, university, or agency press releases). The information must reach wider, to the decision-makers, stakeholders, and the public. Communicating about EBM in relatively small groups puts all the responsibility of seeking out EBM knowledge on the recipient (i.e., stakeholders, managers, and the public). The general public and some sectors do not yet understand the need for EBM nor how the lack of EBM can affect them.

Furthermore, people are less likely to consider EBM a solution if they are not familiar with the approach. In addition to the information not reaching the audience, the scientific community generally struggles to connect to the public[86]. EBM is often communicated through jargon and without consideration of the intended audience. EBM needs to be communicated in a manner that elicits staying and sustained interest, media responses, and presence among stakeholders and the public. There is currently little coherent or consistent messaging about EBM to stakeholders or the public at any scale, whether regionally, nationally, or globally. Additionally, disinformation about EBM exists in multiple channels and requires substantial efforts to combat[46].

One solution to this is strategic communications and focused EBM marketing campaigns. It seems wise to leverage more widely known paradigms (e.g., integrated management, the blue economy, marine spatial planning) to improve EBM marketing in multiple domains. The information must be multileveled for the public and specifically for various ocean-use stakeholders, e.g., using clear and appealing infographics and actively using social media to engage with the public. Science to support EBM must be shared early and in various formats to ensure this information is relevant and useful to managers, decision-makers, politicians, stakeholders, and the public[87]. This may require changing incentives for scientists and their institutions to emphasize not only scientific publications but also communication and management outcomes.

The workshop and poll results identified the introduction of certification incentives for EBM as another solution to elicit public competition from companies and stakeholders to show good EBM practices. Scoreboards similar to those linked to the United Nations' Sustainable Development Goals[88] that analyze the performance of companies and departments with EBM implementation can increase stakeholder awareness and incentivize companies to do EBM. For instance, there are no marketing campaigns for EBM, but several public marketing campaigns for single sectors or single issues in ocean sustainability have had significant success in recent years. Effective marketing to the public on the dangers of plastic straws to marine wildlife has resulted in plastic straw bans (i.e., change in legislation) and public outcry for alternatives[89]. The Marine Stewardship Council (MSC) ecolabeling certification program is intended to provide a market-based incentive for commercial fisheries to voluntarily improve their harvesting practices[90,91]. MSC certification can improve a fishery's reputation, resulting in economic and social benefits such as product longevity, lower risk of product withdrawal from stores, expanding or maintaining market share, and community empowerment in management decisions[90,92,93]. Another ecolabeling example is "Dolphin-safe tuna," which has become a requirement driven by the public, who do not wish to eat food that may have contributed to dolphin mortality[94,95]. These examples are not necessarily the most significant challenges facing our oceans but are excellent examples of effective marketing campaigns that have created legislative change and raised significant awareness about topics previously not on the agendas of politicians, funding agencies, private companies, or the public. Consumers have significant influence and are part of the solution to push EBM to

Table 1. The top six impediments and possible high-level solutions to Ecosystem-Based Management (EBM) implementation identified from the poll and workshop discussions.

Impediment \\ Solutions	#1 *Governance*	#2 *Engaging stakeholders*	#3 *Support*	#4 *Uncertainty about and understanding of EBM*	#5 *Technology and data*	#6 *Communication and marketing*
Increased political will (high-level leadership vs. bottom-up efforts)	✓		✓	✓		
Change incentives (albeit at different levels/areas)	✓	✓	✓			✓
Increase capacity (awareness, communications, technical skills, etc.)	✓	✓	✓	✓	✓	✓
Build a better business case	✓	✓	✓	✓	✓	✓
More resources, support	✓	✓	✓	✓	✓	✓
Persistence (i.e., just do it)	✓	✓	✓	✓	✓	✓
More types of data		✓			✓	
Dedicated training (sub of capacity)				✓	✓	
Marketing	✓	✓	✓	✓		✓
Certification (sub of changing incentives or business case)		✓	✓		✓	✓

the front of the agenda of politicians and decision-makers. It seems highly germane to start developing these kinds of marketing campaigns for EBM. Furthermore, this could be a way to allow the public to decide which companies they support, thereby ultimately changing the political will to implement EBM. Incentivizing EBM implementation using key metrics for specific assessment of EBM progress is a natural way of making a business case for EBM by creating positive public relations for companies participating in EBM.

One solution can solve multiple impediments

Though there are many challenges and impediments to implementing EBM, there are identified solutions to overcome them (Table 1; Fig. 1) that are being enacted to make progress toward EBM. Of particular interest identified in the workshop discussions are those solutions that have multiple benefits and address several impediments. Chief among these is EBM marketing, followed by capacity building, changing incentives, certification schemes, and making a stronger business case for EBM. The workshop results indicate that executing these solutions leads to follow-on solutions. For example, increased marketing has led to more awareness and capacity to consider EBM issues and increased calls for effective economic and environmental actions (e.g., certification), which has, in turn, led to increased political will and then, in some cases, more explicit mandates and requirements and ultimately support for EBM. We are not proposing that solutions be followed in a step-by-step manner, that any sequence will be preferable, or lead to any guaranteed results. Instead, we note that the solutions are often interconnected, and employing a couple of them seems prudent. For example, there are high-level feasible solutions, which can be well worth the resources spent as they address a number of the barriers to EBM implementation (Table 1). Furthermore, solutions can be addressed by high-level leadership (e.g., decision-makers) and by bottom-up efforts (e.g., individuals, small groups), noting that actions can be solutions, but not all solutions need to be clear-cut actions (i.e., political will, persistence).

Progress on implementing EBM

Our findings indicate substantial progress on global EBM implementation. For example, there is increased understanding, interdisciplinary collaboration, legislation, and stakeholder engagement as EBM work has become a higher priority and received broader focus as the work has become more operational than theoretical over the last decade (Figs. 5, 6, S7[14]). Some places are too early in the implementation process to determine success-level or if they are in status quo. More stakeholders than ever are participating and investing in EBM, which is laudable. However, our poll and workshop results showed there remain a few ocean-use sectors that are still not engaging in EBM as actively as needed, particularly oil and gas, tourism, shipping, and renewable energy, which have not been as engaged as the fisheries, conservation, aesthetics, biomedical, or aquaculture sectors (Fig. S9). In many instances, the tradeoffs across ocean-use sectors are increasing. For example, offshore wind, fishing, protected species, and shipping co-occur in the same ocean spaces, and thoughtful EBM strategies are needed to avoid and mitigate conflicts among these sectors[96–98]. The workshop and poll results found that in cases where EBM-oriented cross-sectoral communication and coordination has occurred, the resultant decisions have been more agreeable to all parties involved, minimizing regulatory, business, and social costs[11].

The results show that there is progress in implementing EBM as EBM is often done in many places under different paradigms[14,99]. As a result, a picture is emerging that shows some common EBM-oriented principles are being employed, and in many ways, we are doing EBM without calling it EBM (Fig. 4). Furthermore, we are

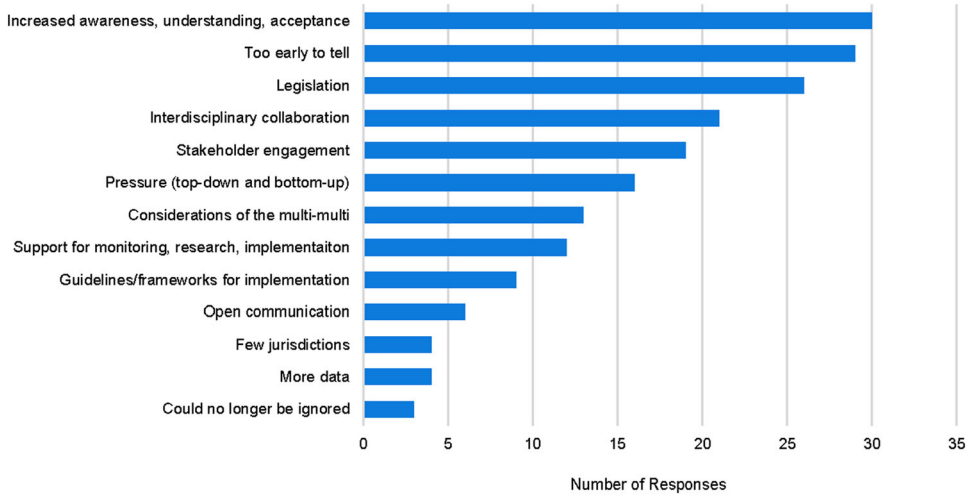

Fig. 5 Results from the poll where the participants were asked to name the top 3 reasons Ecosystem-Based Management (EBM) works ($n = 192$). *multi-multi referring to multiple sectors, multiple pressures, multiple objectives, etc.

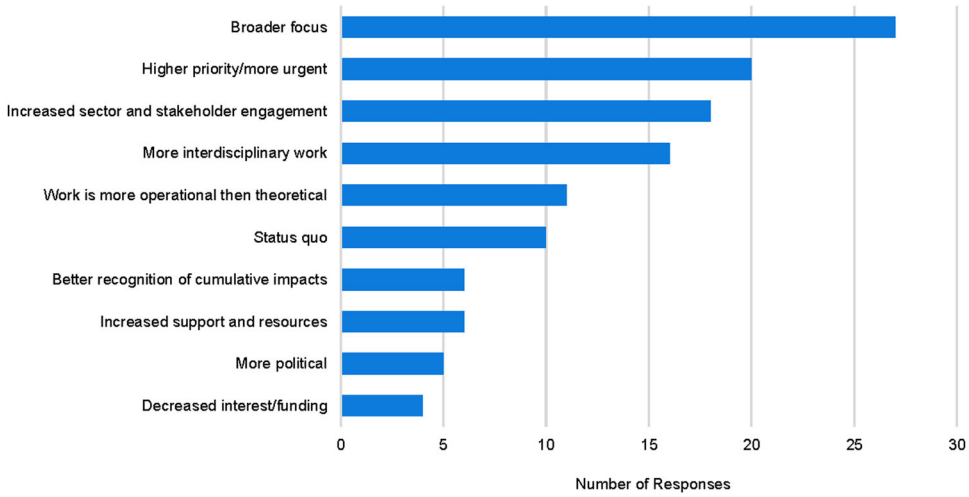

Fig. 6 Results from the poll where the participants were asked how their Ecosystem-Based Management (EBM) work has changed over the last ten years ($n = 123$).

doing EBM in international, national, sub-national, and local jurisdictions (Fig. S6), covering spatial extents from ocean basins to large marine ecosystems, major coastal areas, estuaries, bays, and harbors (Fig. S8). Given the method for distributing the poll, the results on progress are likely conservative as the full range of actors implementing EBM were not surveyed or did not respond. Unequivocally, there is success in implementing EBM in varying degrees, levels, and scales. In short, the global community of ocean-use managers and marine scientists is making progress on EBM worldwide – more than we give ourselves credit for.

DISCUSSION

The heightened awareness by stakeholders and decision-makers of sectoral tradeoffs and climate change engenders agreement on the urgency of EBM. Implementation of EBM needs a catalyst for change. These catalysts come in many forms but consistently galvanize public opinion and facilitate the political will, and leadership that is necessary to implement solutions. However, we note that waiting for a catalyst such as a social-ecological crisis, conflicts across sectors, or natural disaster events is not necessary nor desirable, as we have knowledge and solutions to act on EBM implementation now, avoiding the degradation that comes from being responsive rather than proactive[16]. We cannot afford to wait for another crisis to compel us to act, as inaction can result in severe consequences. The consensus on the urgency of EBM is a significant development, but it needs to be met with concrete actions. Critical solutions to address the impediments to implementation have been identified in this study (Table 1), and more importantly, these solutions are feasible. This means the knowledge to implement EBM exists; it simply requires political will, persistence, capacity building, dialog, education, changing incentives, and strategic marketing of EBM.

Calls for more resources, more data, increasing capacity, and stronger political will are not novel for EBM or science in general[30]. In contrast, building a better business case, certification schemes, and changing incentives are potentially under-utilized for EBM and are not widely noted in the literature[11]. We would argue that expanding these approaches warrants additional consideration, especially given the success of some marketing campaigns. In particular, EBM certification[100] seems worthy of further exploration.

There are social costs to not doing EBM. As resource managers, businesses, and the public become more aware of those costs, we anticipate that interest and action will follow. Admittedly, the EBM community has had limited success in communicating these costs[21]. Targeted, focused, and deliberate communication of these ideas can help to raise awareness and increase understanding. The outcome will be more sustainable use of shared ocean resources, ensuring an improved status of our marine ecosystems and promoting human health and well-being. Although successful outcomes are essential, success in the process should not be overlooked. As EBM is adaptive, participatory, dynamic, and iterative (i.e., there is no end-point to a process, but rather measurable outcomes), success occurs in varying degrees and levels. Currently, there is a gap between EBM theory and implementation, given the level of academic inputs and implementation progress. However, that gap is closing, and we can close it further both theoretically (e.g., development of frameworks, science, and research to advance the understanding of EBM) and in implementation (e.g., governance, increased support, marketing, and awareness). While challenges remain in EBM, many solutions exist, and significant progress is occurring.

METHODS

The poll

The Marine Ecosystem-Based Management Progress Evaluation Group (MEBM-PEG), an international group of EBM experts, was established to track progress on global EBM implementation in the marine environment, communicate the benefits of EBM, identify the remaining impediments to its use, and offer solutions to advance its implementation. The MEBM-PEG developed a poll with the objective of assessing the challenges, solutions, and progress of EBM implementation. To that goal, we developed 23 multiple-choice and open-ended questions. The poll was distributed using the snowball technique, where the authors asked their network of people working on EBM to fill out the poll and then send it to their network of experts. Additionally, we used the OCTO EBM email list to invite a known EBM community to answer the poll. The poll included an ethics statement stating that the information provided would be analyzed, published, and made public in aggregated form. By choosing to answer the poll, the respondents agreed to the terms. Identifiable information was not collected, and the respondents were asked only to fill it in once. Duplicate responses were removed from the analysis. The poll was open from June through October 2022 and was answered by 157 people, including the workshop participants.

Quantitative data analysis of the poll included summary statistics of the key demographic and multiple-choice questions (Supplementary Figs. S1-S9). Responses were quantified and, where appropriate, aggregated into common underlying or organizing themes (e.g., continents/countries, scientist/researcher, aesthetics/existence, etc.) and provided as frequencies of survey participants. This was done to capture the main distribution of the poll results and to help guide topics for discussion during the workshop. Although further statistics of the poll results are possible, the summary statistics, coupled with the qualitative data analysis (see below), were sufficient to identify major themes and patterns to identify the challenges, solutions, and progress of EBM implementation.

Qualitative data analysis of the poll results was executed with MAXQDA 2022[101]. Questions that were not answered were excluded from the analysis. In the open-ended questions (e.g., what are the top three major impediments to EBM?), some respondents provided only one answer, while others provided three answers as asked. The free answers were color-coded based on topic (e.g., support) and subcoded when the respondents provided more detail (e.g., support for funding and training staff). Due to the free-answer question layout, there was a possibility of all 157 respondents providing three answers, leading to 474 possible impediments to color-code, creating a higher response rate for those questions than the total number of people responding to the poll. The coded segments were used to build a hierarchical code-subcodes model displaying the connection between major impediments and related sub-impediments. The frequencies of the subcodes and parent code (i.e., major impediment) were aggregated to determine the size of the parent code. Codes whose frequencies were in the standard deviation range around the mean value are represented in an average size, and codes with more or less coded segments received a larger or smaller text size for the parent code name.

The workshop

The MEBM-PEG organized an online workshop from 11-14 October 2022 to evaluate the progress of global EBM implementation and identify the lessons learned regarding successful implementation strategies. Thirty-four invited experts, plus the nine experts from MEBM-PEG, who all worked in different countries and various ocean-use sectors, participated in the four-day workshop (demographics of poll participants, including workshop participants, are found in Supplementary Information). The workshop goals were to 1) Gauge who is doing EBM and identify successful EBM, 2) Document different disciplines and paradigms that are synonymous, similar, or contribute to EBM, 3) Describe the current impediments to EBM and solutions to them, and 4) Address how we can advance EBM further. The preliminary poll results were used to guide the discussions during the workshop. Each workshop day was structured with a starting plenary presenting the day's main topic, followed by discussions of the topic in breakout groups and a plenary summary at the end of each day. The experts were assigned to different breakout groups with respect to their field of expertize, country, career stage, and gender to allow for lively and varied discussions and to avoid one group where the majority of the participants worked in the same organization, region, etc. The breakout group summaries, which were presented to the plenary, were captured via recording of the workshop and notes from each breakout group session. The results from the breakout group discussions were collated and used by the authors to develop the major findings and status determination of global EBM progress.

DATA AVAILABILITY

The poll questions that generated the results in this study are available in Supplementary Information Table S1.

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AUTHOR CONTRIBUTIONS

J.B.H., J.S.L., K.C., A.B., M.D-C., H.M.L., J.H. and E.A.F. developed and distributed the poll and organized the workshop. J.B.H. and K.C. analyzed and interpreted the data. J.B.H. wrote the manuscript with substantial input from J.S.L. All authors participated in the workshop, provided edits, and reviewed the manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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