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*Total number of authors:*
14

*Published in:*
Journal of Fish Biology

*Link to article, DOI:*
10.1111/jfb.15168

*Publication date:*
2022

*Document Version*
Peer reviewed version

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**Abstract**

The USA, EU, and Canada established a trilateral working group on the ecosystem approach to ocean health and stressors, under the Atlantic Ocean Research Alliance. Recognizing the Atlantic Ocean as a shared resource and responsibility, the working group sought to advance understanding of the Atlantic Ocean and its dynamic systems to improve ocean health, enhance ocean stewardship, and

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/jfb.15168

promote the sustainable use and management of its resources. This included consideration of multiple ocean-use sectors such as fishing, shipping, tourism and offshore energy. The working group met for 4 years and worked through eight steps that covered the development of common language as a basis for collaboration, challenges of stakeholder engagement, review of the governance mandates, exploring the links between sectors and ecosystems effects, identifying gaps in knowledge and uptake of science, identification of tools for ecosystem based management, customary best practice for tool development and communication of key research priorities. The key findings were that ecosystem-based management enables new benefits and opportunities, and that we need to make the business case. That adequate mandates and effective tools exist for ecosystem-based management, and that ecosystem-based management urgently requires integration of human dimensions, so we must diversify the conversation. Also that stakeholders don't see their stake in ecosystem based management, so greater engagement with stakeholders and targeting of ocean literacy is required and that a sustainable future requires a sustained investment in ecosystem-based management, so long term commitment is key.

**Key words:** social-ecological, integrated management, trade-offs, marine

**Introduction**

The management of marine ecosystem use is transitioning towards implementation of ecosystem-based management (EBM), which offers a more systematic and integrated approach compared with conventional management. There are many definitions of EBM; as an example we provide the definition of Long *et al.* (2015), "*Ecosystem based management is an interdisciplinary approach that balances ecological, social and governance principles at appropriate temporal and spatial scales in a distinct geographical area to achieve sustainable resource use. ….. EBM recognizes coupled social-ecological systems with stakeholders involved in an integrated and adaptive management process where decisions reflect societal choice*". Stephenson *et al.* (2021), highlighted that EBM shares the overall objective of delivering ecologically sustainable development with several similar approaches (integrated ocean management, marine spatial planning, participatory co-management and others) but differs in that it has been written into many international agreements and treaties (Rudd *et al.,* 2018). Among the many such treaties, a notable example is the UN Convention on Biological Diversity Malawi principles (www.cbd.int/). Science informs ecosystem-based management, which includes key elements such as connections and linkages among and within ecosystems, as well as with social and economic systems. Ecosystem based fisheries management is EBM that is pertinent to the management of fisheries (EBFM, Link, 2002). Many organisations have published their own definition of EBM and/or roadmaps for action and implementation (e.g. Australian Ocean Policy, 1998; HELCOM OSPAR statement, 2003; Arctic Council, 2013; NOPP Implementing Ecosystem-Based Management Report to the U.S. National Ocean Council, 2013). Most recognise the management of human activities as central in the definition, but the social, economic, and institutional/governance objectives have not been as explicitly defined and explored as the ecological objectives (Singh *et al.,* 2021).

A wealth of literature describes processes and challenges for ecosystem-based management (e.g., Garcia and Cochrane, 2005; Jennings and Rice, 2011; Levin *et al.,* 2018), the importance of considering management objectives (e.g., Long *et al.,* 2015; Stephenson *et al.,* 2019), and the necessity to consider risk and maintain adaptive approaches (e.g., Dickey-Collas, 2014; Holsman *et al.,* 2017; Murphy *et al.*, 2021). The USA, EU, and Canada established in 2016 a trilateral working group on the ecosystem approach to ocean health and stressors, under the Atlantic Ocean Research

Alliance (AORA)[1] to investigate implementation of EBM in the North Atlantic, and describe commonalities across the three jurisdictions. Recognizing it as a shared resource and responsibility, the working group sought to advance understanding of the Atlantic Ocean and its dynamic systems to improve ocean health, enhance ocean stewardship, and promote the sustainable use and management of its resources. This included consideration of multiple ocean-use sectors such as fishing, shipping, tourism and offshore energy. The working group concluded in 2019, and this article summarises its findings.

The numerous international ongoing efforts to develop frameworks for potential implementation of EBM adds to the timeliness of the synthesis and recommendations of the working group. Global efforts include the UN Decade of Ocean Science for Sustainable Development (2021-2030); the Regular Process for Global Reporting and Assessment of the State of the Marine Environment (World Ocean Assessment); the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES); the UN Oceans Conference to support the implementation of Sustainable Development Goal 14; the post-2020 Biodiversity Framework (CBD 2050 Vision); Reviews of UN Resolutions (e.g. 61/105); OECD reviews; negotiations on a new international legally binding instrument for the conservation and sustainable use of biodiversity beyond national jurisdiction (BBNJ); the Intergovernmental Panel on Climate Change (IPCC) sixth assessment; development of International Seabed Authority exploitation regulations. These are supplemented by regional and national strategic plans for ocean management, including the Baltic Sea Action Plan, EU Marine Strategy Framework Directive, U.S. NOAA Fisheries Ecosystem-Based Fisheries Management Policy and Road Map 2018, the International Seabed Authority Regional Environmental Management Plan for the North Atlantic. All of these efforts explicitly highlight the value of ecosystem-based management or implicitly emphasize the many facets of ecosystem-based management, resulting in a strong drive for implementation (Cormier *et al.*, 2016).

This paper reports on the findings and recommendations of the trilateral working group on Ecosystem Approach to Ocean Health and Stressors. It increases our knowledge and understanding by reporting on an important example of international cooperation to assess the status of EBM concepts and implementation in the Atlantic. It also contributes to global efforts by outlining the work needed to improve the evidence base for management of human activities in the marine environment across local, regional and trans-Atlantic scales. **Methods**

Over a four-year period the working group developed an eight-step plan (Figure 1) which covered development of common language as a basis for collaboration, stakeholder engagement, review of governance mandates, linking industrial sectors and ecosystems effects, identifying gaps in knowledge and uptake of science, identification of tools for EBM, and communication of key research priorities.

[1] Atlantic Ocean Research Alliance was formed on the basis of the Galway Statement on Atlantic Ocean Cooperation (2013), https://ec.europa.eu/commission/presscorner/detail/en/IP_13_459

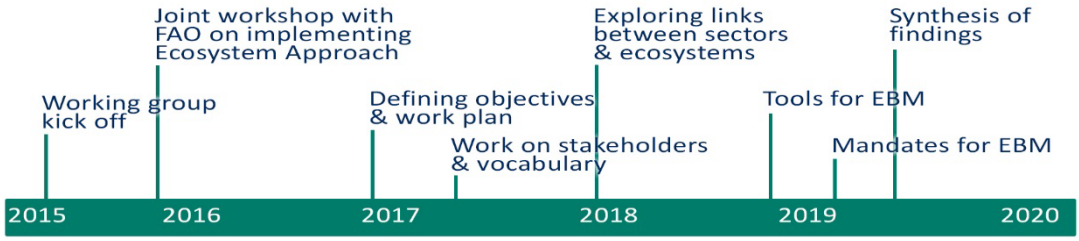


Figure 1. Time line of trilateral working group on the ecosystem approach to ocean health and stressors.

The working group was made up of experts from each of the jurisdictions, each with extensive experience of practical implementation of EBM, and EBFM. The working group surveyed researchers in the EBM field (see Marshak *et al.,* 2017 for methods and examples of EBM implementation) which acted as a resource to convene a joint workshop with the Food and Agriculture Organization of the United Nations on implementing the ecosystem approach in early 2016 (ICES, 2016). This discussion was continued at a smaller workshop in early 2017, that ultimately defined the objective and work plan for the working group (AORA, 2017). A series of workshops and analysis by correspondence then took place on legal mandates for EBM (AORA, 2018a), tools for EBM (AORA, 2018b) and ocean sectors linking to ecosystem components (AORA, 2019a). This exchange culminated in a synthesis workshop in 2019 (AORA, 2019b).

The majority of the working group participants were researchers, active as providers of the evidence base for EBM, and the activities of the working group helped us reflect and appreciate the obstacles and barriers to implementation that hinder action. The working group engaged with natural and social scientists, with lawyers and operational managers, with research funders and businesses from various ocean sectors across the North Atlantic.

## Key findings of the working group

### Yes, we can! Adequate mandates and effective tools exist for ecosystem-based management

The working group concluded that adequate, extant mandates exist to execute EBM (Link *et al.,* 2019; Rudd *et al.,* 2018). In all jurisdictions, nearly all ocean uses, goods and services, pressures, and stressors have some mandate coverage. The analysis included political mandates, legislative structures, and non-regulatory implementing policy. Even those ocean uses or pressures without direct mandate coverage have some form of overarching legislation or policy to address facets of cumulative effects, coordinated planning, and comprehensive, systematic consideration in all jurisdictions (see table 1, taken from Rudd *et al.,* 2018). No legal basis hinders EBM, and the potential benefits emphasize the urgency and need for greater implementation.

Notable commonalities span the mandates in the three jurisdictions of Canada, EU, and USA. Irrespective of the detailed requirements of these authorizations or the efficacy of their actual implementation, enabling legislation covers most major ocean uses and pressures associated with the ocean—e.g., water quality, fishing, shipping, offshore energy, mining, toxin and pollution mitigation, tourism.

Following this level of commonality, the mandates comprehensively cover facets of ocean uses, goods and services, as well as various ocean stressors and pressures, and enabling legislation covers

most aspects of ocean use and pressure. The risks and threats of a changing ocean are well described (IPCC, 2019). Gaps in mandate coverage persist for some ocean uses and pressures. For instance, some of the more recent technological developments in fields such as marine biotechnology, marine derivatives and bio-products, and marine bioprospecting lack many, if any, clear legislative mandated coverage across jurisdictions. This gap links to the management of genetic materials, which is similarly limited in mandate, as are geothermal uses. Sea level rise and destructive jellyfish blooms also exemplify issues lacking a directly associated mandate. Additionally, mandates address some ocean uses or stressors, but not all. For example, direct mandates address biodiversity, except in the US, although an endangered species act similar to other acts exists in that jurisdiction. Ocean acidification and considerations of heritage or special places also exemplify issues that legislation directly addresses, except in the EU.

Comprehensive, overarching laws or policies actually cover many gaps in direct mandate authority. Mandates in all jurisdictions address cumulative effects, and provisions of many sectoral-specific mandates consider other factors. Additionally, all jurisdictions have a mandate, or at least non-legislative policy, to consider an integrative, systemic look at ocean-use. Again, this approach does not speak to the interpretation or implementation or efficacy of these overarching (i.e., an umbrella) mandates but, theoretically, the ability to consider the majority of ocean uses and stressors exists. These observations represent the directly observable and obvious facets of legal mandates that cover ocean uses and stressors. The observed limited extent of EBM in practice therefore primarily results from lack of clear mandate implementation, political will, or tools for trade-off analysis. Lack of implementation appears to represent the major challenge across the three jurisdictions (CA/EU/US), but it is not due to lack of mandate. Part of the challenge of limited implementation lies with applying these trade-off tools but the venue of application of the tools is unspecified. That is, there is currently a governance gap, where venues for EBM decision-making, based on trade-off analyses between ocean uses and stressors, are not apparent.

Many stakeholders apparently perceive a paucity of tools for understanding and evaluating trade-offs in ecological, social, and institutional objectives, and this perception has constrained EBM advancement. The working group identified and reviewed a host of existing tools to support trade-off analysis in EBM. Managers use these tools to assess the state of the ecosystem and then explore the possible options and consequences of decision-making (Table 2). The provision of tools for societal decision-making requires that researchers operate beyond the traditional boundaries of their training (Cvitanovic et al., 2015). When developing tools that conform to best practice for use in the EBM arena, multiple challenges exist (including working across disciplines, combining evidence of differing veracities, co-production with stakeholders, transparency of information and assumptions, and simplification of complex processes when communicating outcomes), resulting in an often resource-intensive process.

The working group considered tools within the categories of conceptual modelling, static spatial planning and evaluation, models of intermediate complexity, strategic simulation models, Bayesian belief networks, and dynamic spatial models (Table 2, based on AORA, 2018b). It also considered frameworks for overarching approaches, such as risk assessment, management strategy evaluation, multi-criteria decision-making, ecosystem services framework, and strategic environmental assessment. Whilst many management challenges require EBM tools to address specific questions and evidence needs, the broad categories of tools highlighted here can guide researchers towards application. Despite substantial resource investment in developing tools for EBM across the jurisdictions of the North Atlantic, few examples of operational tool use exist, with even fewer examples of performance validation.

Table 2. Tools and wider framework available to define, present, evaluate trade-offs between management objectives for EBM.

| Tools | Frameworks |
|---|---|
| Conceptual modelling<br>Bayesian belief networks<br>Static spatial tools<br>Dynamic spatial tools<br>Models of intermediate complexity<br>Strategic simulation models | Strategic environmental assessment<br>Risk assessment<br>Structured multi-criteria decision making<br>Ecosystem services<br>Management strategy evaluation |

Trade-offs are defined as "A choice that involves losing one quality or service (of an ecosystem) in return for gaining another quality or service. Many decisions affecting ecosystems involve trade-offs, sometimes mainly in the long term." TEEB (2010). The working group considered the conceptual basis for customary best practice for tool development and application as:

- Construct the evidence using credible methods
- Document and peer review the process for evidence construction
- Address uncertainty with stakeholders
- Ensure realistic cost of tool development and application
- Develop the tool through co-creation/participatory processes
- Ensure legitimacy of the process of tool development because the outcomes are used in public decision-making
- Ensure quality control of the process for use of the tool, include training of users
- Ensure socially accepted treatment of data, data management, and decision- making
- Use methods and tools accepted in the wider independent scientific community
- Ideally, test the tool in a range of situations to ensure that it is robust and remains useful

Providing tools for the provision of evidence to inform trade-offs for EBM brings numerous challenges. Many resources are spent developing tools that are never utilized operationally (tactical or strategic). Customary best practice (described above) is rarely fully used. It is difficult to design a tool without understanding how that tool will be used. Most AORA jurisdictions lack any national or international arena or governance structure in which to use trade-off tools, especially cross jurisdictions or marine ocean use sectors.

Tools are used to assess the state and then explore the possible options and consequences of decision-making. The provision of tools for societal decision-making requires that researchers operate beyond the traditional boundaries of their training. When developing tools that conform to best practice, for use in the EBM arena, a number of challenges exist (including working across disciplines, combining evidence of differing veracities, co-production with stakeholders, transparency of information and assumptions, simplification of complex processes when communicating outcomes, and the process is often resource intensive. Whilst many management challenges require bespoke tools to address specific questions and evidence needs, the broad categories of tools highlighted here can be used to guide researchers towards application.

**Ecosystem-based management enables new benefits and opportunities; making the business case**

EBM challenges conventional approaches to ocean-related governance and management, and may even go beyond "environmental integration" challenges, given a basic notion to not only integrate "the environment" into other sector's activities, but to take a systematic approach that uses the

capacities and potentials of a social-ecological systems analysis as the basis for decision-making. This poses challenges for the variety of actors necessarily involved in EBM, which requires common understanding of EBM itself, its objectives, and its benchmarks. In return, EBM offers multiple societal and ecological benefits across ecosystem services that account for diverse social values.

The mis-perception that the raison d'etre of EBM resolves around protecting the marine environment and prevents stakeholders from engaging in ocean activities traditionally permitted by federal and national authorities creates a significant barrier to EBM. Although this concern generally lacks any foundation, this negative perception plays a significant role in opposition to EBM from many stakeholder groups. To mitigate this negative perception, managers may find utility in re-emphasising that EBM highlights its capacity to enable ocean stakeholders in better assessing potential effects both in sectoral and cumulative contexts, and to identify opportunities that solely sector-based approaches missed.

EBM can potentially improve long-term economic efficiency and outcomes as a result of:

- reducing costs to ocean industries, enhancing their long-run competitiveness;
- providing valuable social benefits, which financial assessments of ocean management options rarely consider;
- reducing the long-term transaction costs of governance by providing more coordinated and aligned management of ocean use across jurisdictions and industrial sectors.

Because EBM provides more systematic and integrated data and information, the perceived greater efficiency and lower costs of other regulatory mandates may increase reluctance to embrace EBM. Resources managed for multiple uses could provide higher total benefits than sectors managed individually. By re-emphasising that the goals of EBM focus not only on improving the health and stewardship of the oceans, but also streamlining and enhancing the effectiveness of the regulatory process and advancing business efficiency and opportunities, stakeholder perceptions may change and reduce barriers to EBM. Emphasizing enhanced sustainable growth for the blue economy could yield a subtle but important shift in perception to contextualize EBM and provide an important link to efforts such as marine spatial planning.

EBM recognizes the wide range of benefits that ecosystem goods and services that humanity derives from marine ecosystems (O'Higgins *et al.*, 2020). Natural capital (the endowment or stocks of environmental and ecological goods in the oceans, such as fish populations) supports human well-being in far more ways than simply providing economic profitability for firms, and it underpins thriving societies in many ways. While EBM will require substantial upfront investment (requiring integration of knowledge from the natural, social, economic and legal sciences), society must also consider the costs of not implementing EBM. Ocean's governance seeks to achieve two fundamental purposes: 1) to align the behaviour of societal actors (i.e., individuals, firms, organizations, etc.) with overall societal interests, and 2) to increase predictability concerning the causal chain linking human behaviour to risk factors to adverse social outcomes (Link *et al*., 2019; Rudd *et al.,* 2018). Acknowledging costs associated with further EBM implementation, an improved EBM regime also offers significant economic opportunities through coastal ecosystem restoration, carbon capture, and adaption through natural systems, among others.

EBM approaches will increase predictability as a result of improved coordination of processes and more compatible and accessible scientific data. Many ocean managers identify lack of predictability in permitting and administrative decision-making as the primary impediment to successfully investing in ocean activities. The predictability should increase on both the downside (risk and

adverse outcomes) and upside (increased ecosystem productivity, better human health, etc.). Unpredictable administrative outcomes also increases the level of costly litigation between stakeholders and governments. Moving away from sectoral approaches and toward more integrated EBM approaches will decrease the uncertainty and unpredictability that spurs legal disputes and litigation.

**Integration of human dimensions is essential for ecosystem-based management; diversify the conversation**

The persistent disconnect in communication among scientists, managers, and stakeholders results from them operating in different spheres of thought and understanding, impeding effective implementation of EBM. The plurality of knowledge, experience, and approaches creates an opportunity and a potential hindrance (Levin *et al.,* 2021). Each group often differs from one another, and even internally, in their expectations and priorities, and even their ability to understand different perspectives from other disciplines and sectors. Effective EBM requires complex and often difficult conversations. Scientists rarely couch their research results in a context accessible either to managers or to many stakeholders. As a result, managers may implement ineffective strategies, scientists become frustrated, and stakeholders fail to see the value of EBM and therefore disengage. Successful EBM requires that participants reconcile these differences and, if they can speak the same language, they may achieve common understanding of the definitions, approaches, and methods for understanding ecosystem processes, management instruments, and stakeholder ramifications. Only through such conversation can they appreciate the benefits and trade-offs each group must consider. Such conversations greatly increase the likelihood of achieving the consensus and support needed for successful EBM. Recognizing the differences in language between disciplines and jurisdictions, an iterative, living glossary/vocabulary was developed from this effort which can facilitate cross-disciplinary-sector conversations, especially when engaging newcomers (i.e., various ocean industry sectors, ICES, 2022).

**Stakeholders don't see their stake (in ecosystem-based management); engage and target ocean literacy to professionals**

The working group identified a key challenge with respect to engaging with stakeholders. The perception of the workshop participants was that stakeholders, particularly from some of the main ocean industry sectors (i.e., oil/gas, shipping), do not perceive their participation in EBM processes as essential. In addition, responses to an on-line questionnaire disseminated to ocean stakeholders in the EU, Canada, and USA confirmed this observation. The questionnaire explored ongoing EBM or EBM-like activities among targeted stakeholders. While the respondents supported EBM principles and offered examples of their EBM-like activities, they lacked a compelling reason to actively engage or promote EBM within their respective organizations. The respondents felt that they achieve success by largely focusing on operating within their various regulatory environments, which often vary in EBM consideration. This may be the case but it would likely be to the detriment of other sectors. They did not see the added benefit of EBM to their own sector or business. This is a failing of the EBM narrative. We recommend a targeted ocean literacy strategy and greater focus on the mechanisms for knowledge exchange, that engages with key stakeholders who are positioned to promote the benefits of EBM and foster greater engagement with EBM activities (Cvitanovic *et al.*, 2016). Until a compelling case to move from "business as usual" is made and routinely communicated, it is likely that different ocean-use sectors will continue to not see the benefits of a more integrated management of human activities. The history of integrated coastal management (ICM, Cicin-Sain and Knecht 1998; Christie, 2005) and ecosystem based fisheries management (Link, 2010) provide examples that likely explain this finding.

**A sustainable future requires a sustained investment in ecosystem-based management; commitment is key**

Implementing EBM to obtain its potential benefits and opportunities requires persistence in building tools, trust, experience, stakeholder engagement and governance venues. The tools used are often complex, with substantial initialization costs that increase efficiency of sustained operation. Ensuring integration of the human dimension and building trust requires dedicated, long-term collaboration, again requiring a maintained effort throughout the EBM process among participants of different sectors and disciplines (Cvitanovic *et al.,* 2021). Finally, the knowledge required to employ the detailed tools for EBM does not transfer easily among stakeholder groups, and requires sustained training of professional staff, particularly those involved in modelling. Hence, once experts are educated, efficiency requires ensuring that they remain within the field to avoid knowledge loss and perpetual investment in re-educating new staff. Without a persistent commitment from policy makers, managers, scientists and other stakeholders, management decisions will likely form a patchwork of largely inconsistent and ineffective measures, resulting in a net loss of potential opportunities and benefits to society.

**Recommendations**

From the combined efforts of the working group, a suite of five major recommendations emerged. The working group used a synthesis workshop to propose these recommendations which span the range of challenges noted. The recommendations were derived by assessing the existing literature, reviewing the findings of the workshops, and the combined experienced of the members of the working group. The five key recommendations::

1. Emphasize calls for future research on social-ecological systems that include:
    - Cumulative effects
    - Functioning and connectivity of systems
    - Ecosystem goods and services
    - Synthesis of empirical evidence with societal values for trade-off analysis
    - Implement cross-sectoral tools for Ecosystem-Based Management advice
    - Connections between management units, actions, and the dynamics of the ecosystem
2. To progress EBM requires establishment of enduring mechanisms for sustained engagement and capacity building for scientists, managers, and key ocean stakeholders in a way that brings a plethora of initiatives together towards a shared vision.
3. Funding mechanisms and timing must realign from a project-based approach to a more co-ordinated and sustained program for ecosystem-based management.
4. Re-emphasise that ecosystem-based management provides benefits and highlight the business case for EBM.
5. The barriers to implementation of ecosystem-based management need to be identified and overcome, with solutions that acknowledge the resource limitations, and the viable capacity building of the EBM system.

The working group acknowledged the risks of inaction and the opportunities offered by wider implementation of EBM. The recommendations require a shift away from business as usual. The consequences for recommendation 3 (a change in funding mechanisms) and 5 (identification of barriers) will necessarily be large and impact research, management and governance approaches. The costs and benefits of knowledge exchange efforts for EBM are often intangible, hard to measure, underappreciated and insufficiently budgeted for within research projects (Karcher *et al.,* 2022).The working group seeded a number of initiatives and as a component part of the Atlantic

Ocean Research Alliance, it was followed by the All Atlantic Ocean Research Alliance, stemming from the Belem Statement (Polejack *et al.*, 2021).

The key messages are:

1. Yes, we can! Adequate mandates and effective tools exist for ecosystem-based management
2. Ecosystem-based management enables new benefits and opportunities; making the business case
3. Integration of human dimensions is essential for ecosystem-based management; diversify the conversation
4. Stakeholders don't see their stake (in EBM); engage and target ocean literacy to professionals
5. A sustainable future requires a sustained investment in ecosystem-based management; commitment is key

Through a series of workshops, reviews, publications, and consultations, we identified the strengths and weaknesses in EBM implementation, progressed EBM implementation, developed the knowledge base, advanced the discipline, and strengthened understanding of EBM in the multi-disciplinary research network in the North Atlantic. However, significant challenges remain in integrating and prioritizing research/activities that will advance EBM implementation. Although the working group is now disestablished, we offer our expertise to advance our recommendations through involvement in an advisory capacity or through specific projects and initiatives. As leading experts within the EBM community in the North Atlantic, we remain active and committed to advancing EBM in the context of the Galway Statement on Atlantic Ocean Cooperation.

**Acknowledgements**

The Atlantic Ocean Research Alliance Coordination and Support Action (AORA-CSA) received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 652677. DJ and JMR received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 678760 (ATLAS). The USA's NOAA Fisheries and Canada's DFO also provided significant, in-kind resources. All of the participants in the working group workshops are thanked for their contributions. We would like to thanks Margaret Rae for her coordination and facilitation role throughout the working group's tenure.

**Significance Statement**

The AORA working group on the Ecosystem Approach to Ocean Health and Stressors is an important example of international cooperation to assess the status of EBM concepts, implementation, and outline further work needed towards improved management of human activities in the marine environment across local, regional and trans-Atlantic scales.

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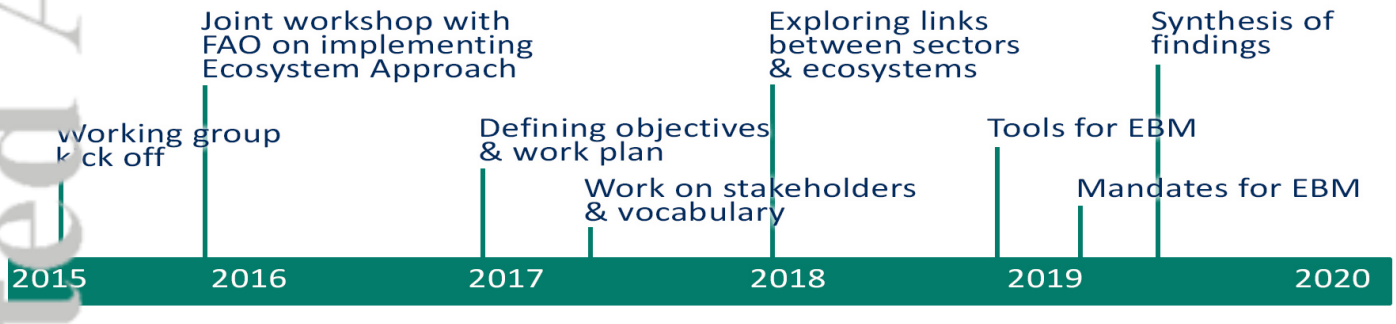


AORA EA2OHS time line.jpg

Table 1 Principles considered in comparing and contrasting EBM implementation across Canada, EU, US and ABNJ[a] jurisdictions, and expert opinion on realization level (Y, yes; N, no; ?, uncertain). Taken from Rudd *et al.,* (2018).

| EBM principle | Realization (Canada, EU, US, ABNJa) |
|---|---|
| 1. The objectives of management of land, water and living resources are a matter of societal choices | Y, Y, Y, Y |
| 2. Management should be decentralized[b] to the lowest appropriate level | Y, Y, Y, Y |
| 3. Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems | Y, N, N, ? |
| 4. Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context | Y, Y, Y, ? |
| 5. Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in a social context | N, N, N, ? (but emerging concept in Canada and EU) |
| 6. Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in a cultural context | N, N, N, ? (but emerging concept in Canada and EU) |
| 7. In order to maintain ecosystem services, the conservation of ecosystem structure and functioning should be an objective of the ecosystem approach | Y, Y, Y, Y |
| 8. Ecosystem must be managed within the limits of their functioning | N, N, N, ? |
| 9. The ecosystem approach should be undertaken at the appropriate spatial and temporal scales | Y, Y, Y, Y |
| 10. Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term | ?, ?, ?, ? (varies by legislative mandate) |
| 11. Management must recognize that change is inevitable | Y, Y, Y, Y |
| 12. The ecosystem approach should seek the appropriate trade-off (balance) between, and integration of, conservation and use of marine resources (e.g., biological diversity) | N, N, N, N |
| 13. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices | Y, N, ?, ? (varies by legislative mandate and region in and ABNJ) |
| 14. The ecosystem approach should involve all relevant sectors of society and scientific disciplines | N, ?, Y, ? (varies by legislative mandate and region in EU and ABNJ) |
| 15. The interdependence between human wellbeing and ecosystem well-being is recognized; | Y, Y, Y, ? |
| 16. An appropriate policy, legal, and institutional framework is adopted to support the sustainable and integrated use of the resources; | Y, Y, Y, ? |
| 17. An institutional framework is utilized; | Y, N, N, ? (but varies regionally in Canada) |
| 18. Objectives are reconciled through prioritization and making trade-offs; | Y, ?, Y, ? (but varies regionally in Canada and US) |
| 19. The need to maintain the productivity of ecosystems for present and future generations is recognized; | Y, Y, N, ? |
| 20. Efforts are made to establish and preserve equity in all its forms (intergenerational, intra-generational, cross-sectoral, cross-boundary and cross-cultural), with special attention given to rights of minorities. | N, N, N, ? (with exception of current reconciliation process in Canada) |

[a] ABNJ, areas beyond national jurisdiction.
[b] Unclear meaning of decentralized: could also mean devolved or subsidiary.

Table 2. Tools and wider framework available to define, present, evaluate trade-offs between management objectives for EBM.

| Tools | Frameworks |
|---|---|
| Conceptual modelling | Strategic environmental assessment |
| Bayesian belief networks | Risk assessment |
| Static spatial tools | Structured multi-criteria decision making |
| Dynamic spatial tools | Ecosystem services |
| Models of intermediate complexity | Management strategy evaluation |
| Strategic simulation models | |